

FEMA-310

Handbook for the Seismic Evaluation of Buildings, 1998

Introduction

The American Society of Civil Engineers (ASCE) contracted with the Federal Emergency Management Agency (FEMA) to convert FEMA 178, *NEHRP Handbook for the Seismic Evaluation of Existing Buildings* into a prestandard. The development of the prestandard was the first step in turning FEMA 178 into an American National Standards Institute (ANSI) approved national consensus standard. The document was completed in January 1998 and is published as FEMA 310, *Handbook for the Seismic Evaluation of Buildings--A Prestandard*.

Notice

American Society of Civil Engineers (ASCE) has completed its effort to turn FEMA 310 into a national consensus-based standard. The document is now known as ASCE 31-02 and supercedes FEMA 310. Therefore, the document on this page is for information purposes only. For more information on obtaining a copy of ASCE 31-02, please contact ASCE at www.asce.org

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Due to electronic incompatibilities, the entire FEMA 310 electronic version is not available. Also, the format may not be exactly as shown in the published version. However, the content is the same as the published version.

1.0 General Provisions

1.1 Scope

This Handbook provides a three-tiered process for seismic evaluation of existing buildings in any region of seismicity. Buildings are evaluated to either the Life Safety or Immediate Occupancy Performance Level.

Use of this Handbook and mitigation of deficiencies identified using this Handbook are voluntary or as required by the authority having jurisdiction. The design of mitigation measures is not addressed in this Handbook.

This Handbook does not preclude a building from being evaluated by other well-established procedures based on rational methods of analysis in accordance with principles of mechanics and approved by the authority having jurisdiction.

Commentary:

This Handbook provides a process for seismic evaluation of existing buildings. A major portion is dedicated to instructing the evaluating design professional on how to determine if a building is adequately designed and constructed to resist seismic forces. All aspects of building performance are considered and defined in terms of structural, nonstructural and foundation/geologic hazard issues.

Prior to using this Handbook, a rapid visual screening of the building may be performed to determine if an evaluation is needed using the following document:

- *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook* (FEMA 154 and 155).

Mitigation strategies for rehabilitating buildings found to be deficient are not included in this Handbook; additional resources should be consulted for information regarding mitigation strategies.

Handbook Basis

This Handbook is based on the *NEHRP Handbook for Seismic Evaluation of Existing Buildings* (FEMA 178). This Handbook was written to:

- reflect advancements in technology,
- incorporate design professional experience,
- incorporate lessons learned during recent earthquakes,
- be nationally applicable, and
- provide evaluation techniques for varying levels of building performance.

Since the development and publication of FEMA 178, numerous significant earthquakes have occurred: the 1985 Michoacan Earthquakes that affected the Mexico City area, the 1989 Loma Prieta Earthquake in the San Francisco Bay Area, the 1994 Northridge Earthquake in the Los Angeles area, and the 1995 Hyokogen-Nanbu Earthquake in the Kobe area. While each earthquake validated the fundamental assumptions underlying the procedures presented in FEMA 178, each also offered new insights into the potential weaknesses in certain systems that should be mitigated. (It should be noted that while the publication of FEMA 178 occurred after the Mexico City and Loma Prieta Earthquakes, data and lessons learned from them were unable to be incorporated into the document prior to publication.)

Extent of Application

Model building codes typically exempt certain classes of buildings from seismic requirements pertaining to new construction. This is most often done because the building is unoccupied or it is of a style of construction that is naturally earthquake resistant. It is reasonable to expect that these classes of buildings may be exempt from the requirements of this Handbook as well.

No buildings are automatically exempt from the evaluation provisions of this Handbook; exemptions

exemptions should be defined by public policy. However, based on the exemption contained in the codes for new buildings, jurisdictions may exempt the following classes of construction:

- Detached one- and two-family dwellings located where the design short-period spectral response acceleration parameter, S_{DS} , is less than 0.4g.
- Detached one- and two-family wood frame dwellings located where the design short-period response acceleration parameter, S_{DS} , is equal to or greater than 0.4g that satisfy the light-frame construction requirements of the *1997 NEHRP Recommended Provisions for Seismic Regulations for New Buildings*; and
- Agricultural storage structures that are intended only for incidental human occupancy.

Application to Historic Buildings

Although the principles for evaluating historic structures are similar to those for other buildings, special conditions and considerations may exist of which the design professional should be aware.

Historic structures often include archaic materials, systems, and details. It may be necessary to look at handbooks and building codes from the year of construction to determine details and material properties.

Another unique aspect of historic building evaluation is the need to consider architectural elements or finishes. Testing that damages the historic character of the building generally is not acceptable.

In addition, an appropriate level of performance for historic structures needs to be chosen that is acceptable to the local jurisdiction. Some feel that historic buildings should meet the safety levels of other buildings since they are a subset of the general seismic safety needs. Others feel that historic structures, because of their value to society, should meet a higher level of performance. And in some cases a reduced level of performance has

some cases a reduced level of performance has been allowed to avoid damaging historic fabric.

The following resources may be useful when evaluating historic structures:

- *Secretary of the Interior's Standards for the Treatment of Historic Properties*, and
- *National Park Service Catalog of Historical Preservation Publications*.

Alternative Methods

Alternative documents that may be used to evaluate existing buildings include:

- *Uniform Code for Building Conservation (UCBC, 1997)*,
- *Los Angeles Division 91*, *Los Angeles Division 95*, and
- *Seismic Evaluation and Retrofit of Concrete Buildings*.

Some users have based the seismic evaluation of buildings on the provisions of new buildings. While this may seem appropriate, it must be done with full knowledge of the inherent assumptions. Codes for new buildings contain three basic types of requirements including strength, stiffness, and detailing. The strength and stiffness requirements are easily transferred to existing buildings; the detailing provisions are not. If the lateral-force-resisting elements of an existing building do not have the proper details of construction, the basic expectations of the other strength and stiffness provisions will not be met. Lateral-force-resisting elements that are not properly detailed should be omitted during an evaluation using a code for new buildings.

ATC-14 offered the first technique for adjusting the evaluation for the lack of proper detailing by using a three-level acceptance criteria, FEMA 178 used reduced R-factors to accomplish the same thing. FEMA 273 contains the most comprehensive procedure with its element-based approach. This Handbook follows the lead of FEMA 273 with a new style of analysis procedure tailored to the Tier 1 and Tier 2 evaluation levels.

Mitigation Strategies

Potential seismic deficiencies in existing buildings may be identified using this Handbook. If the evaluation is voluntary, the owner may choose to accept the risk of damage from future earthquakes rather than upgrade, or demolish the building. If the evaluation is required by a local ordinance for a hazard-reduction program, the owner may have to choose between rehabilitation, demolition, or other options.

The following documents may be useful in determining appropriate rehabilitation or mitigation strategies:

- *NEHRP Handbook of Techniques for the Seismic Rehabilitation of Existing Buildings* (FEMA 172),
- *NEHRP Benefit-Cost Model for the Seismic Rehabilitation of Buildings* (FEMA 227 and 228),
- *NEHRP Typical Costs for Seismic Rehabilitation of Existing Buildings* (FEMA 156 and 157), and
- *NEHRP Guidelines and Commentary for the Seismic Rehabilitation of Buildings* (FEMA 273 and 274).

Requirements

Prior to conducting the seismic evaluation, the evaluation requirements of Chapter 2 shall be met.

A Tier 1 evaluation shall be conducted for all buildings in accordance with the requirements of Chapter 3. Checklists, as applicable, of compliant/non-compliant statements related to structural, nonstructural and foundation conditions, shall be selected and completed in accordance with the requirements of Section 3.3 for a Tier 1 Evaluation. Potential deficiencies shall be summarized upon completion of the Tier 1 evaluation.

Structural Tier 1 checklists are not provided for unreinforced masonry bearing wall buildings with flexible diaphragms. The structural evaluation of unreinforced masonry bearing wall buildings with flexible diaphragms shall be completed using the Tier 2 Special Procedure of Section 4.2.6; a Tier 1 Evaluation for foundations and non-structural elements remains applicable for this type of building.

For those buildings identified in Section 3.4, a Full-Building Tier 2 Evaluation or a Tier 3 Evaluation shall be performed upon completion of the Tier 1 Evaluation.

For those buildings not identified in Section 3.4 as requiring a Full Building Tier 2 Evaluation or a Tier 3 Evaluation, but for which potential deficiencies were identified in Tier 1, a Deficiency-Only Tier 2 Evaluation may be performed. For a Deficiency-Only Tier 2 Evaluation, only the procedures associated with non-compliant checklist statements need be completed. Potential deficiencies shall be summarized upon completion of the Tier 2 Evaluation. Alternatively, the design professional may choose to end the investigation and report the deficiencies in accordance with Chapter 1.

A Tier 3 evaluation shall be performed in accordance with the requirements of Chapter 5 for buildings identified in Section 3.4 or when the design professional chooses to further evaluate buildings for which potential deficiencies were identified in Tier 1 or Tier 2. Potential deficiencies shall be summarized upon completion of the Tier 3 Evaluation.

After a seismic evaluation has been performed, a final report shall be prepared. As a minimum, the report shall identify: the building and its character, the tier(s) of evaluation used, and the findings.

The three-tiered process for seismic evaluation of buildings is depicted in Figure 1-1.

Commentary:

Prior to conducting the seismic evaluation based on this Handbook, the design professional should understand the evaluation process and the basic requirements specified in this section.

The evaluation process consists of the following three tiers, which are shown in Figure 1-1: Screening Phase (Tier 1), Evaluation Phase (Tier 2), and Detailed Evaluation Phase (Tier 3). As indicated in Figure 1-1, the design professional may choose to (i) report deficiencies and screening

recommend mitigation or (ii) conduct further evaluation, after any tier of the evaluation process.

The screening phase, Tier 1, consists of 3 sets of checklists that allow a rapid evaluation of the structural, nonstructural and foundation/geologic hazard elements of the building and site conditions. It shall be completed for all building evaluations conducted in accordance with this Handbook. The purpose of a Tier 1 evaluation is to screen out buildings that comply with the provisions of this Handbook or quickly identify potential deficiencies. In some cases "Quick Checks" may be required during a Tier 1 evaluation, however, the level of analysis necessary is minimal. If deficiencies are identified for a building using the checklists, the design professional may proceed to Tier 2 and conduct a more detailed evaluation of the building or conclude the evaluation and state that potential deficiencies were identified. In some cases a Tier 2 or Tier 3 evaluation may be required.

Based on the ABK research (ABK, 1984), unreinforced masonry buildings with flexible diaphragms were shown to behave in a unique manner. Special analysis procedures provided in Section 4.2.6 were developed to predict the behavior. Since this special procedure does not lend itself to the checklist format of Tier 1, no Structural Checklists are provided. The design professional must perform the Tier 2 Special Procedure as the first step of the evaluation. The Special Procedure only applies to the structural aspects of the building; Tier 1 Checklists provided for the nonstructural elements and for the foundation and geologic hazards issues still apply.

For Tier 2, a complete analysis of the building that addresses all of the deficiencies identified in Tier 1 shall be performed. Analysis in Tier 2 is limited to simplified linear analysis methods. As in Tier 1, evaluation in Tier 2 is intended to identify buildings not requiring rehabilitation. If deficiencies are identified during a Tier 2 evaluation, the design professional may choose to either conclude the evaluation and report the deficiencies or proceed to Tier 3 and conduct a detailed seismic evaluation.

Available methods and references for conducting a Tier 3 detailed evaluation are described in Chapter 5 of this Handbook. Recent research has shown that certain types of complex structures can be shown to be adequate using nonlinear analysis procedures even though other common procedures do not. While these procedures are complex and expensive to carry out, they often result in construction savings equal to many times their cost. The use of Tier 3 procedures must be limited to appropriate cases.

The final report serves to communicate the results to the owner and record the process and assumptions used to complete the evaluation. Each section should be carefully written in a manner that is understandable to its intended audience. The extent of the final report may range from a letter to a detailed document. The final report should include at least the following items:

- 1) Scope and Intent: a list of the tier(s) followed and level of investigation conducted;
- 2) Site and Building Data:
 - General building description (number of stories and dimensions),
 - Structural system description (framing, lateral load resisting system, floor and roof diaphragm construction, basement, and foundation system),
 - Nonstructural element description (nonstructural elements that could interact with the structure and affect seismic performance)
 - Building type,
 - Performance Level,
 - Region of Seismicity,
 - Soil Type,
 - Building Occupancy, and
 - Historic Significance;
- 3) List of Assumptions: material properties, site soil conditions;
- 4) Findings: list of deficiencies;
- 5) Recommendations: mitigation schemes or further evaluation;
- 6) Appendix: references, preliminary calculations.

Chapter 1.0 - General Provisions

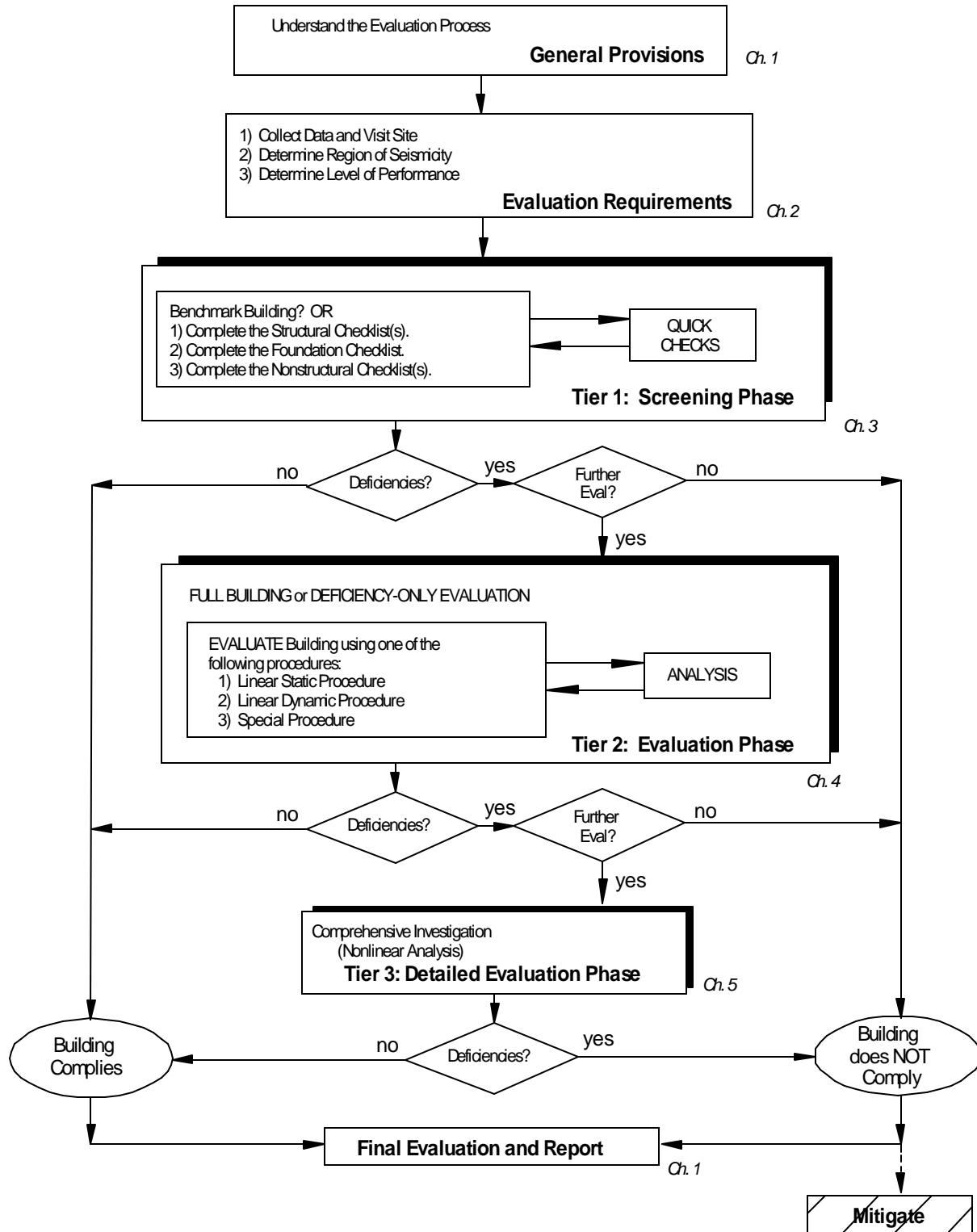


Figure 1-1. Evaluation Process

Judgment by the Design Professional

While this Handbook provides very prescriptive direction for the evaluation of existing buildings, it is not to be taken as the only direction. This Handbook provides direction for common details, deficiencies and behavior observed in past earthquakes that are found in common building types. However, every structure is unique and may contain features and details not covered by this Handbook. It is important that the design professional use judgment when applying the provisions of this Handbook. The design professional should always be looking for uncommon details and behavior about the structure not covered by this Handbook that may have the potential for damage or collapse.

1.3 Definitions

ACTION: Forces or moments that cause displacements and deformations.

ASPECT RATIO: Ratio of full height to length for shear walls; ratio of span to depth for horizontal diaphragms.

BASIC NONSTRUCTURAL CHECKLIST: Set of evaluation statements that shall be completed as part of the Tier 1 Evaluation. Each statement represents a potential nonstructural deficiency based on performance in past earthquakes.

BASIC STRUCTURAL CHECKLIST: Sets of evaluation statements that shall be completed as part of the Tier 1 Evaluation. Each statement represents a potential structural deficiency based on performance in past earthquakes.

BENCHMARK BUILDING: A building designed and constructed or evaluated to a specific performance level using an acceptable code or standard listed in Table 3-1.

BUILDING TYPE: A building classification defined in Section 2.6, that groups buildings with common lateral-force-resisting systems and performance characteristics in past earthquakes.

CAPACITY: The permissible strength or deformation for a component action.

COLLECTOR: A member that transfers lateral forces from the diaphragm of the structure to vertical elements of the lateral-force resisting system.

CROSS WALL: A wood-framed wall sheathed with lumber, structural panels, or gypsum wallboard.

DEFICIENCY-ONLY TIER 2 EVALUATION: An evaluation, beyond the Tier 1 Evaluation, that investigates only the non-compliant checklist evaluation statements.

DESIGN EARTHQUAKE: See Maximum Considered Earthquake.

DIAPHRAGM: A horizontal structural system that serves to interconnect the building and acts to transmit lateral forces to the vertical resisting elements.

DIAPHRAGM EDGE: The intersection of the horizontal diaphragm and a shear wall.

DISPLACEMENT-CONTROLLED ACTION: An action that has an associated deformation that is allowed to exceed the yield value of the element being evaluated. The extent of permissible deformation beyond yield is based on component modification factors (m-factors).

EXPECTED STRENGTH: The actual strength of a material, not the specified minimum or nominal strength. For purposes of an evaluation using this Handbook, the expected strength shall be taken equal to the nominal strength multiplied by 1.25. Alternatively, actual statistically based test data may be used.

FLEXIBLE DIAPHRAGM: A diaphragm where the maximum lateral deformation along its length is more than twice the average inter-story drift.

FORCE-CONTROLLED ACTION: An action that has an associated deformation that is not allowed to exceed the yield value of the element being evaluated. The action is not directly related to the pseudo seismic forces used in the evaluation, rather it is based on the maximum action that can be delivered to the element by the yielding structural system.

FULL-BUILDING TIER 2 EVALUATION: An evaluation beyond a Tier 1 Evaluation that involves a complete analysis of the entire lateral-force-resisting system of the building using the Tier 2 analysis procedures defined in Section 4.2. While special attention should be given to the potential deficiencies identified in the Tier 1 evaluation, all lateral force resisting elements must be evaluated. This evaluation is required when triggered by Table 3-3.

GEOLOGIC SITE HAZARDS AND FOUNDATIONS CHECKLIST: Set of evaluation statements that shall be completed as part of the Tier 1 Evaluation. Each statement represents a potential foundation or site deficiency based on the performance of buildings in past earthquakes.

IMMEDIATE OCCUPANCY PERFORMANCE LEVEL: Building performance that includes very limited damage to both structural and nonstructural components during the design earthquake. The basic vertical and lateral-force-resisting systems retain nearly all of their pre-earthquake strength and stiffness. The level of risk for life-threatening injury as a result of damage is very low. Although some minor repairs may be necessary, the building is fully habitable after a design earthquake, and the needed repairs may be completed while the building is occupied.

LATERAL FORCE RESISTING SYSTEM: The collection of frames, shear walls, bearing walls, braced frames and interconnecting horizontal diaphragms that provides earthquake resistance to a building.

LIFE SAFETY PERFORMANCE LEVEL: Building performance that includes significant damage to both structural and nonstructural components during a design earthquake, though at least some margin against either partial or total structural collapse remains. Injuries may occur, but the level of risk for life-threatening injury and entrapment is low.

LINEAR DYNAMIC PROCEDURE (LDP): A Tier 2 response spectrum based modal analysis procedure shall be used for buildings taller than 100 feet, buildings with vertical or geometric irregularities, and buildings where the distribution of the lateral forces departs from that assumed for the Linear Static Procedure.

LINEAR STATIC PROCEDURE (LSP): A Tier 2 lateral force analysis procedure where the pseudo lateral force is equal to the force required to impose the expected actual deformation of the structure in its yielded state when subjected to the design earthquake motions. It shall be used for buildings for which the Linear Dynamic or the Special Procedure is not required.

MAXIMUM CONSIDERED EARTHQUAKE: An earthquake with a 2% probability of exceedance in 50 years with deterministic-based maximum values near known fault sources.

MOMENT-RESISTING FRAME (MRF): A frame capable of resisting horizontal forces because the members (beams and columns) and joints are capable of resisting forces primarily by flexure.

PRIMARY COMPONENT: A part of the lateral-force-resisting system capable of resisting seismic forces.

PSEUDO LATERAL FORCE (V): The calculated lateral force used for the Tier 1 Quick Checks and for the Tier 2 Linear Static Procedure. The pseudo lateral force represents the force required, in a linear analysis, to impose the expected actual deformation of the structure in its yielded state when subjected to the design earthquake motions. It does not represent an actual lateral force that the building must resist in traditional code design.

QUICK CHECK: Analysis procedure used in Tier 1 Evaluations to determine if the lateral-force-resisting system has sufficient strength and/or stiffness.

REGION OF LOW SEISMICITY CHECKLIST: Set of evaluation statements that shall be completed as part of the Tier 1 Evaluation for buildings in regions of low seismicity being evaluated to the Life Safety Performance Level.

REGION OF SEISMICITY: An area with similar expected earthquake hazard. For this Handbook, all regions are categorized as low, moderate, or high, based on mapped acceleration values and site amplification factors as defined in Section 2.5.

RIGID DIAPHRAGM: A diaphragm where the maximum lateral deformation is less than half the average inter-story drift associated with the story.

SECONDARY COMPONENT: An element that is capable of resisting gravity loads, but is not able to resist seismic forces it attracts, though is not needed to achieve the designated performance level.

SITE CLASS: Groups of soil conditions that affect the site seismicity in a common manner. The soil types used are defined in Section 3.5.2.3.1; designated as A, B, C, D, E, or F.

SPECIAL PROCEDURE: Analysis procedure, used for unreinforced masonry bearing wall buildings with flexible diaphragms, that properly characterizes the diaphragm motion, strength and damping.

SPECIAL PROCEDURE TIER 2

EVALUATION: An evaluation procedure specifically written for unreinforced masonry bearing wall buildings with flexible diaphragms using the special procedure.

STIFF DIAPHRAGM: A diaphragm that is not classified as either flexible or rigid.

STORY SHEAR FORCE: Portion of the pseudo lateral force carried by each story of the building.

SUPPLEMENTAL NONSTRUCTURAL

CHECKLIST: Set of nonstructural evaluation statements that shall be completed as part of the Tier 1 Evaluation for buildings in regions of moderate or high seismicity being evaluated to the Immediate Occupancy Performance Level.

SUPPLEMENTAL STRUCTURAL

CHECKLIST: Set of evaluation statements that shall be completed as part of the Tier 1 Evaluation for buildings in regions of moderate seismicity being evaluated to the Immediate Occupancy Performance Level, and for buildings in regions of high seismicity.

TIER 1 EVALUATION: Completion of checklists of evaluation statements that identifies potential deficiencies in a building based on performance in past earthquakes.

TIER 2 EVALUATION: The specific evaluation of potential deficiencies to determine if they represent actual deficiencies that may require mitigation. Depending on the building type, this evaluation may be a Full-Building Tier 2 Evaluation, Deficiency-Only Tier 2 Evaluation, or a Special Procedure Tier 2 Evaluation.

TIER 3 EVALUATION: A comprehensive building evaluation implicitly or explicitly recognizing nonlinear response.

1.4 Notation

a_p	Component amplification factor,
A_{br}	Average cross-sectional area of the diagonal brace,
A_c	Summation of the cross-sectional area of all columns in the story under consideration,
A_n	Area of net mortared/grouted section (in ²),
A_w	Summation of the horizontal cross-sectional area of all shear walls in the direction of loading,
A_x	Amplification factor to account for accidental torsion,
C	Modification factor to relate expected maximum inelastic displacements calculated for linear elastic response,
C	Compliant,
C_p	Horizontal force factor,
C_t	Modification factor, based on earthquake records, used to adjust the building period to account for the characteristics of the building system,
C_{vx}	Vertical distribution factor, based on story weights and heights, that defines a triangular loading pattern,

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D	In-plane width dimension of masonry (in.) or depth of diaphragm (ft.),	n, N	number of stories above ground,
		N/A	Not Applicable,
DCR	Demand-capacity ratio,	N_{br}	Number of diagonal braces in tension and compression if the braces are designed for compression; Number of diagonal braces in tension if the braces are designed for tension only,
D_p	Relative displacement,		
DR, D_r	Drift ratio,		
E	Modulus of Elasticity;		
F_a	Site Coefficient defined in Table 3-6,	n_c	Total number of columns,
f_{br}	Average axial stress in diagonal bracing elements,	n_f	Total number of frames,
		NC	Non-Compliant,
F_i	Lateral force applied at floor level i,	NL	No Limit,
F_{px}	Total diaphragm force at level x,	P_{CE}	Expected gravity compressive force applied to a wall or pier component stress,
F_v	Site Coefficient defined in Table 3-5,	P_D	Superimposed dead load at the top of the pier under consideration (lb.),
F_{wx}	Force applied to a wall at level x (lb.),	P_w	Weight of wall (lb.),
F_x	Total story force at level x,	Q_{CE}	Expected strength,
F_y	Yield Stress,	Q_D	Actions due to effective dead load,
h	Story height,	Q_E	Actions due to earthquake loads,
h_i, h_x	Height (ft.) from the base to floor level i or x,	Q_G	Actions due to effective gravity load,
h_n	Height (in feet) above the base to the roof level,	Q_L	Actions due to effective live load,
H	Least clear height of opening on either side of pier (in.),	Q_S	Actions due to effective snow load,
I	Moment of Inertia,	Q_{UD}	Deformation-controlled design actions,
IO	Immediate Occupancy Performance Level,	Q_{UF}	Force-controlled design actions,
		R_p	Component response modification factor,
j	number of story level under consideration,	s	Average span length of braced spans (ft.),
J	Force-delivery reduction factor,	S_a	Response spectral acceleration,
k	Exponent related to the building period,	S_{DS}	Design short-period spectral response acceleration parameter,
k_b	Stiffness of a representative beam (I/L);	S_{D1}	Design spectral response acceleration parameter at a one-second period,
k_c	Stiffness of a representative column (I/h);	S_S	Short-period spectral response acceleration parameter,
L	Length;	S₁	Spectral response acceleration parameter at a one-second period,
L_{br}	Average length of the diagonal brace,		
LS	Life-Safety Performance Level,		
m	Component modification factor,	t	Thickness of wall (in.)
M_g	Moment in girder (k-ft),		

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T	Fundamental period of vibration of the building,	W_w	Total dead load of an unreinforced masonry wall above the level under consideration or above an open front of a building,
T1	Tier 1 Evaluation,		
T2	Tier 2 Evaluation,		
T3	Tier 3 Evaluation,	W_{wx}	Dead load of an unreinforced masonry wall assigned to level x halfway above and below the level under consideration (lb.),
v_{avg}	Average shear stress,	x	Height in structure of highest point of attachment of component,
v_{me}	Expected masonry shear strength (psi),	X,Y	Height of lower support attachment at level x or y as measured from grade,
v_u	Unit shear strength for a diaphragm (lb./ft.),	D_d	Diaphragm displacement,
v_{te}	Average bed-joint shear strength (psi), not to exceed 100 psi,	D_w	In-plane wall displacement,
V	Pseudo lateral force,	d_{avg}	the maximum displacement at any point of diaphragm at level x,
V_a	Shear strength of an unreinforced masonry pier (lb.),	d_{max}	the algebraic average of displacements at the extreme points of the diaphragm at level x,
V_c	Column shear force,	d_{xA}, d_{yA}	Deflection at building level x or y of building A,
V_{ca}	Total shear capacity of cross walls in the direction of analysis immediately above the diaphragm level being investigated (lb.),	d_{xB}	Deflection at building level x of building B,
V_{cb}	Total shear capacity of cross walls in the direction of analysis immediately below the diaphragm level being investigated (lb.),	r''	Volumetric ratio of horizontal confinement reinforcement in a joint.
V_d	Diaphragm shear (lb.),		
V_j	Story shear force,		
V_p	Shear force on an unreinforced masonry wall pier (lb.),		
V_r	Pier rocking shear capacity of an unreinforced masonry wall or wall pier (lb.),		
V_{wx}	Total shear force resisted by a shear wall at the level under consideration (lb.),		
w_i, w_x	Portion of the total building weight assigned to floor level i or x,		
W	Total seismic weight,		
W_d	Total dead load tributary to a diaphragm (lb.),		
W_j	Total seismic weight of all stories above level j,		
W_p	Component operating weight,		

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2.0 Evaluation Requirements

2.1 General

Prior to conducting a seismic evaluation, the evaluation requirements of this Chapter shall be met.

2.2 Level of Investigation Required

Prior to conducting a Tier 1 Evaluation, all available documents shall be collected and reviewed. A complete examination of all available documents pertaining to the design and construction of the building shall be conducted. If construction documents are available, the examination shall include verification that the building was constructed in accordance with the documents. All alterations and deviations shall be noted. The information collected shall be sufficient to define the level of performance desired in accordance with Section 2.4, the region of seismicity in accordance with Section 2.5, and the building type in accordance with Section 2.6. In addition, the level of investigation shall be sufficient to complete the Tier 1 Checklists. Destructive examination shall be conducted as required to complete the Checklists for buildings being evaluated to the Immediate Occupancy Performance Level; judgment shall be used regarding the need for destructive evaluation for buildings being evaluated to the Life-Safety Performance Level. Non-destructive examination of connections and conditions, shall be performed for all Tier 1 Evaluations. Default values may be used for material properties for a Tier 1 Evaluation.

In addition to the information required for a Tier 1 Evaluation, sufficient information shall be collected for a Tier 2 Evaluation to complete the required Tier 2 Procedures. Destructive examination shall be conducted as required to complete the Procedures for buildings being evaluated to the Immediate Occupancy Performance Level and for buildings in regions of high seismicity as defined in Table 2-1. Non-destructive examination of connections and conditions shall be performed for all Tier 2 Evaluations. While material testing is not required for a Tier 2 Evaluation, default

values for material properties shall not be used. Material property data shall be obtained from building codes from the year of construction of the building being evaluated, from as-built plans, or from physical tests.

Exception: Unreinforced masonry bearing wall buildings with flexible diaphragms using the Tier 2 Special Procedure of Section 4.2.6 shall have destructive tests conducted to determine the average bed-joint shear strength, v_{te} , and the strength of the anchors.

Detailed information about the building is required for a Tier 3 Evaluation. If no documents are available, an as-built set of drawings shall be created indicating the existing lateral-force-resisting system. Non-destructive and destructive examination and testing shall be conducted for a Tier 3 Evaluation to establish:

- the expected strength of all materials that participate in the lateral-force-resisting system of the building; deterioration shall be taken into account;
- the composition and configuration of all primary components and conditions in the lateral-force-resisting system.

Commentary:

Building evaluation involves many substantial difficulties. One is the matter of uncovering the structure since plans and calculations often are not available. In many buildings the structure is concealed by architectural finishes, and the design professional will have to get into attics, crawl spaces, and plenums to investigate. Some intrusive testing may be necessary to determine material quality and allowable stresses. If reinforcing plans are available, some exposure of critical reinforcement may be necessary to verify conformance with the plans. The extent of investigation required depends on the level of

evaluation because the conservatism inherent in both the Tier 1 and Tier 2 analysis covers the lack of detailed information in most cases. The evaluating design professional is encouraged to balance the investigation with the sophistication of the evaluation technique.

The design professional in responsible charge should be consulted if possible. In addition, the evaluating design professional may find it helpful to do some research on historical building systems, consult old handbooks and building codes, and perhaps consult with older engineers who have knowledge of early structural work in the community or region.

The evaluation should be based on facts, as opposed to assumptions, to the greatest extent possible.

One of the more important factors in any evaluation is the material properties and strengths. For a Tier 1 Evaluation, the following default values may be assumed: f'_c of 3000 psi for concrete, F_y of 40 ksi for reinforcing steel, F_y of 36 ksi for structural steel, f'_m of 1500 psi for masonry. For a Tier 2 Evaluation, the material strengths can be determined by existing documentation or material testing. For a Tier 3 Evaluation, material testing is required to verify the existing documentation or establish the strengths if existing documentation is not available.

Prior to evaluating a building using this handbook, the design professional should:

- Look for an existing geotechnical report on site soil conditions;
- Establish site and soil parameters;
- Assemble building design data including contract drawings, specifications, and calculations;
- Look for other data such as assessments of the building performance during past earthquakes; and
- Select and review the appropriate sets of evaluation statements included in Chapter 3.

Testing of Masonry

Different types of masonry require different tests to determine the shear capacity. The design professional should use the following as a general guide for selecting the correct test method:

- Multi-wythe masonry laid with headers should use the in-place shear push test;
- For modern masonry, the design professional should consider using a core tested as prescribed in ASTM C 496-90 to determine the tensile-splitting stress. The tensile-splitting stress is the same as the horizontal shear stress. The mortar joints should be at 45° to the load. This should be modified for axial stress by Mohr's procedures;
- Another method is to use a square prism extracted from the wall that is tested as prescribed in ASTM E 519-74 to determine the tensile-splitting stress. The method of relating the test to tensile-splitting in ASTM E 519-74 requires verification. The effect of axial loading on the tensile-splitting stress must be added for the expected horizontal shear stress;
- Use a prism extracted from the wall to determine f'_m . Then use f'_m in empirical formulas to determine the expected shear strength;
- Trace the source of the masonry units for the unit compressive strength. Then use the unit compressive strength with the mortar class on the available construction documents to determine f'_m .

2.3 Site Visit

A site visit shall be conducted by the evaluating design professional to verify existing data or collect additional data, determine the general condition of the building, and verify or assess the site conditions.

Commentary:

Relevant building data that should be determined through a site visit includes:

- General building description - number of stories, year(s) of construction, and dimensions.
- Structural system description - framing, lateral-force-resisting system(s), floor and roof diaphragm construction, basement, and foundation system.
- Nonstructural element description - nonstructural elements that could interact with the structure and affect seismic performance.
- Building type(s) - Categorize the building as one or more of the Common Building Types, if possible.
- Performance Level - Note the performance level required in the evaluation.
- Region of Seismicity - Identify the seismicity of the site to be used for the evaluation.
- Soil type - Note the soil type.
- Building Occupancy - The occupancy of the building should be noted.
- Historic Significance - Identify any historic elements in the building. Any impacts or areas of the building affected by the evaluation should be noted.

A first assessment of the evaluation statements may indicate a need for more information about the building. The design professional may need to re-visit the site to do the following:

1. Verify existing data;
2. Develop other required data;
3. Verify the vertical and lateral-force-resisting systems;
4. Check the condition of the building;
5. Look for special conditions and anomalies;
6. Address the evaluation statements again while in the field; and
7. Perform material tests, as necessary.

Commentary:

FEMA 178 addressed only the Life Safety Performance Level for buildings. This Handbook addresses both the Life Safety and Immediate Occupancy Performance Levels.

The seismic analysis and design of buildings has traditionally focused on one performance level; reducing the risk to life loss in the largest expected earthquake. Building codes for new buildings and the wide variety of evaluation guidelines developed in the last 30 years have based their provisions on the historic performance of buildings and the deficiencies that caused life safety concerns to develop. Beginning with the damage to hospitals in the 1971 San Fernando earthquake, there has been a growing desire to design and construct certain “essential facilities” that are needed immediately after an earthquake. In addition, there has been a growing recognition that new buildings should have some measure of damaged resistance built in while existing buildings need to be held only to a minimum safety standard. During this time, a new style of design guidelines began appearing that promised a variety of performance levels. At one extreme, the ABK Methodology was developed to better understand when URM buildings needed to be strengthened to achieve a minimum level of safety. At the other extreme, the California Building Code for Hospital Design and Construction set the

Construction set the criteria for buildings that need to remain operational.

The extensive and expensive, non-life threatening damage that occurred in the Northridge Earthquake brought these various performance levels to the point of formalization. Performance Based Engineering was rigorously described by the Structural Engineers Association of California in their Vision 2000 document. At the same time, the Earthquake Engineering Research Center published a research and development plan for the development of Performance Based Engineering Guidelines and Standards. The first formal application in published guidelines occurred in FEMA 273, where the range of possible performance levels and hazard levels were combined to define specific performance objectives to be used to rehabilitate buildings.

This Handbook defines and uses performance levels in a manner consistent with FEMA 273. The Life Safety and Immediate Occupancy Performance Levels are the same as defined in FEMA 273. The hazard level used is the third in a series of four levels defined in FEMA 273. The level chosen is consistent with the hazard traditionally used for seismic analysis and similar to that used in FEMA 178. For other performance levels and/or hazard levels, the design professional should perform a Tier 3 analysis.

The process for defining the appropriate level of performance is the responsibility of the design professional or the authority having jurisdiction. Considerations in choosing an appropriate level of performance should include achieving basic safety, a cost-benefit analysis, the building occupancy type, economic constraints, etc.

In general, buildings classified as essential facilities should be evaluated to the Immediate Occupancy Performance Level. The *1997 NEHRP Recommended Provisions for Seismic Regulations for New Buildings* categorizes the following buildings as essential facilities "...required for post-earthquake recovery":

- Fire or rescue and police stations,

- Hospitals or other medical facilities having surgery or emergency treatment facilities,
- Emergency preparedness centers including the equipment therein,
- Power generating stations or other utilities required as emergency back-up facilities for other facilities listed here,
- Emergency vehicle garages,
- Communication centers, and
- Buildings containing sufficient quantities of toxic or explosive substances deemed to be dangerous to the public if released.

2.4 Level of Performance

A desired level of performance shall be defined prior to conducting a seismic evaluation using this Handbook. The level of performance shall be determined by the design professional and by the authority having jurisdiction. The following two performance levels for both structural and nonstructural components are defined in Section 1.3 of this handbook: Life Safety (LS) and Immediate Occupancy (IO). For both performance levels, the seismic demand is based on Maximum Considered Earthquake (MCE) spectral response acceleration values. Buildings complying with the criteria of this Handbook shall be deemed to meet the specified performance level.

2.5 Region of Seismicity

The region of seismicity of the building shall be defined as low, moderate, or high in accordance with Table

Commentary:

The successful performance of buildings in areas of high seismicity depends on a combination of strength, ductility (manifested in the details of construction) and the presence of a fully interconnected, balanced, and complete lateral-force-resisting system. As these fundamentals are applied in regions of lower seismicity, the need for strength and ductility reduces substantially and, in fact, strength can substitute for a lack of ductility. Very brittle lateral-force-resisting systems can be excellent performers as long as they are never pushed beyond their elastic strength.

ATC-14, the first generation version of FEMA 178 recognized this fact and defined separate provisions for regions of low and high seismicity. Based in part on work sponsored by the Nation Center for Earthquake Engineering Research (NCEER, 1987) FEMA 178 eliminated the separate provisions and elected to permit the lateral force calculations to determine when there was sufficient strength to make up for a lack of detailing and ductility.

The collective experience of the engineers using FEMA 178 is that the requirements too often require calculations for deficiencies that are never a problem because of the low lateral forces. This Handbook took this experience and has develop three separate Tier 1 procedures for the three fundamental regions of seismicity. The regions are defined in terms of the expected spectral response for the site under consideration. Thus the criteria for an area depends both on the expected MCE accelerations and on the site adjustment factors. This will cause area in the transition zone between regions to have sub-areas that are in one region immediately adjacent to a sub-area in another region. This is an intentional result and the

experience at the Marina District in the Loma Prieta Earthquake is ample evidence of its credibility.

2-1. Regions of seismicity are defined in terms of mapped response acceleration values and site amplification factors.

Table 2-1. Regions of Seismicity Definitions

Region of Seismicity ¹	S _{DS}	S _{D1}
Low	< 0.167g	< 0.067g
Moderate	< 0.500g	< 0.200g
	> 0.167g	> 0.067g

Commentary:

Fundamental to the Tier 1 analysis of buildings is the grouping of buildings into sets that have similar behavioral characteristics. These groups of “building types” were first defined in ATC-14 and have been used in most of the FEMA guideline documents since. During the development of FEMA 273, it was determined that a number of additional types of buildings were needed to cover all common styles of construction. These were fully developed and presented in that document. The added building types included a Northridge-style apartment building, and a number of variations on diaphragm type for the basic building systems. The new types are included as subtypes to the original fifteen, so there remains fifteen model building types.

The common building types are defined in Table 2-2. Because most structures are unique in some fashion, judgment should be used when selecting the building type, with the focus on the lateral-force-resisting system and elements.

Separate checklists for each of the Common Building Types are included in this Handbook as well as General Structural Checklists for buildings that may not be classified as one of the Common Building Types. Procedures for using the General Checklists are provided in Section 3.3.

where: $S_{DS} = \frac{2}{3}F_a S_s$
 = design short-period spectral response

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Table 2-2. Common Building Types

Building Type 1 : Wood Light Frames	
W1	These buildings are single or multiple family dwellings of one or more stories in height. Building loads are light and the framing spans are short. Floor and roof framing consists of closely spaced wood joists or rafters on wood studs. The first floor framing is supported directly on the foundation, or is raised up on cripple studs and post and beam supports. The foundation consists of spread footings constructed of concrete, concrete masonry block, or brick masonry in older construction. Chimneys, when present, consist of solid brick masonry, masonry veneer, or wood frame with internal metal flues. Lateral forces are resisted by wood frame diaphragms and shear walls. Floor and roof diaphragms consist of straight or diagonal wood sheathing, tongue and groove planks, or plywood. Shear walls consist of straight or diagonal wood sheathing, plank siding, plywood, stucco, gypsum board, particle board, or fiberboard. Interior partitions are sheathed with plaster or gypsum board.
W1A	These buildings are multi-story, multi-unit residences similar in construction to W1 buildings, but with open front garages at the first story. The first story consists of wood floor framing on wood stud walls and steel pipe columns, or a concrete slab on concrete or concrete masonry block walls.
Building Type 2: Wood Frames, Commercial and Industrial	
W2	These buildings are commercial or industrial buildings with a floor area of 5,000 square feet or more. Building loads are heavier than light frame construction, and framing spans are long. There are few, if any, interior walls. The floor and roof framing consists of wood or steel trusses, glulam or steel beams, and wood posts or steel columns. Lateral forces are resisted by wood diaphragms and exterior stud walls sheathed with plywood, stucco, plaster, straight or diagonal wood sheathing, or braced with rod bracing. Large openings for storefronts and garages, when present, are framed by post-and-beam framing. Lateral force resistance around openings is provided by steel rigid frames or diagonal bracing.
Building Type 3 : Steel Moment Frame s	
S1	These buildings consist of a frame assembly of steel beams and steel columns. Floor and roof framing consists of cast-in-place concrete slabs or metal deck with concrete fill supported on steel beams, open web joists or steel trusses. Lateral forces are resisted by steel moment frames that develop their stiffness through rigid or semi-rigid beam-column connections. When all connections are moment resisting connections, the entire frame participates in lateral force resistance. When only selected connections are moment resisting connections, resistance is provided along discrete frame lines. Columns are oriented so that each principal direction of the building has columns resisting forces in strong axis bending. Diaphragms consist of concrete or metal deck with concrete fill and are stiff relative to the frames. When the exterior of the structure is concealed, walls consist of metal panel curtain walls, glazing, brick masonry, or precast concrete panels. When the interior of the structure is finished, frames are concealed by ceilings, partition walls and architectural column furring. Foundations consist of concrete spread footings or deep pile foundations.
S1A	These buildings are similar to S1 buildings, except that diaphragms consist of wood framing or untopped metal deck, and are flexible relative to the frames.

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Table 2-2. Common Building Types (cont'd)

Building Type 4 : Steel Braced Frame s	
S2	These buildings consist of a frame assembly of steel beams and steel columns. Floor and roof framing consists of cast-in-place concrete slabs or metal deck with concrete fill supported on steel beams, open web joists or steel trusses. Lateral forces are resisted by tension and compression forces in diagonal steel members. When diagonal brace connections are concentric to beam column joints, all member stresses are primarily axial. When diagonal brace connections are eccentric to the joints, members are subjected to bending and axial stresses. Diaphragms consist of concrete or metal deck with concrete fill and are stiff relative to the frames. When the exterior of the structure is concealed, walls consist of metal panel curtain walls, glazing, brick masonry, or precast concrete panels. When the interior of the structure is finished, frames are concealed by ceilings, partition walls and architectural furring. Foundations consist of concrete spread footings or deep pile foundations.
S2A	These buildings are similar to S2 buildings, except that diaphragms consist of wood framing or untopped metal deck, and are flexible relative to the frames.
Building Type 5: Steel Light Frame s	
S3	These buildings are pre-engineered and prefabricated with transverse rigid steel frames. They are one-story in height. The roof and walls consist of lightweight metal, fiberglass or cementitious panels. The frames are designed for maximum efficiency and the beams and columns consist of tapered, built-up sections with thin plates. The frames are built in segments and assembled in the field with bolted or welded joints. Lateral forces in the transverse direction are resisted by the rigid frames. Lateral forces in the longitudinal direction are resisted by wall panel shear elements or rod bracing. Diaphragm forces are resisted by untopped metal deck, roof panel shear elements, or a system of tension-only rod bracing.
Building Type 6: Steel Frames with Concrete Shear Walls	
S4	These buildings consist of a frame assembly of steel beams and steel columns. The floors and roof consist of cast-in-place concrete slabs or metal deck with or without concrete fill. Framing consists of steel beams, open web joists or steel trusses. Lateral forces are resisted by cast-in-place concrete shear walls. These walls are bearing walls when the steel frame does not provide a complete vertical support system. In older construction the steel frame is designed for vertical loads only. In modern dual systems, the steel moment frames are designed to work together with the concrete shear walls in proportion to their relative rigidity. In the case of a dual system, the walls shall be evaluated under this building type and the frames shall be evaluated under S1 or S1A, Steel Moment Frames. Diaphragms consist of concrete or metal deck with or without concrete fill. The steel frame may provide a secondary lateral-force-resisting system depending on the stiffness of the frame and the moment capacity of the beam-column connections.

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acceleration parameter;

Table 2-2. Common Building Types (cont'd)

Building Type 7 : Steel Frames with Infill Masonry Shear Walls	
S5	This is an older type of building construction that consists of a frame assembly of steel beams and steel columns. The floors and roof consist of cast-in-place concrete slabs or metal deck with concrete fill. Framing consists of steel beams, open web joists or steel trusses. Walls consist of infill panels constructed of solid clay brick, concrete block, or hollow clay tile masonry. Infill walls may completely encase the frame members, and present a smooth masonry exterior with no indication of the frame. The seismic performance of this type of construction depends on the interaction between the frame and infill panels. The combined behavior is more like a shear wall structure than a frame structure. Solidly infilled masonry panels form diagonal compression struts between the intersections of the frame members. If the walls are offset from the frame and do not fully engage the frame members, the diagonal compression struts will not develop. The strength of the infill panel is limited by the shear capacity of the masonry bed joint or the compression capacity of the strut. The post-cracking strength is determined by an analysis of a moment frame that is partially restrained by the cracked infill. The diaphragms consist of concrete floors and are stiff relative to the walls.
S5A	These buildings are similar to S5 buildings, except that diaphragms consist of wood sheathing or untopped metal deck, or have large aspect ratios and are flexible relative to the walls.
Building Type 8: Concrete Moment Frame s	
C1	These buildings consist of a frame assembly of cast-in-place concrete beams and columns. Floor and roof framing consists of cast-in-place concrete slabs, concrete beams, one-way joists, two-way waffle joists, or flat slabs. Lateral forces are resisted by concrete moment frames that develop their stiffness through monolithic beam-column connections. In older construction, or in regions of low seismicity, the moment frames may consist of the column strips of two-way flat slab systems. Modern frames in regions of high seismicity have joint reinforcing, closely spaced ties, and special detailing to provide ductile performance. This detailing is not present in older construction. Foundations consist of concrete spread footings or deep pile foundations.
Building Type 9 : Concrete Shear Wall Buildings	
C2	These buildings have floor and roof framing that consists of cast-in-place concrete slabs, concrete beams, one-way joists, two-way waffle joists, or flat slabs. Floors are supported on concrete columns or bearing walls. Lateral forces are resisted by cast-in-place concrete shear walls. In older construction, shear walls are lightly reinforced, but often extend throughout the building. In more recent construction, shear walls occur in isolated locations and are more heavily reinforced with boundary elements and closely spaced ties to provide ductile performance. The diaphragms consist of concrete slabs and are stiff relative to the walls. Foundations consist of concrete spread footings or deep pile foundations.
C2A	These buildings are similar to C2 buildings, except that diaphragms consist of wood sheathing, or have large aspect ratios, and are flexible relative to the walls.

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Table 2-2. Common Building Types (cont'd)

Building Type 10: Concrete Frames with Infill Masonry Shear Walls	
C3	This is an older type of building construction that consists of a frame assembly of cast-in-place concrete beams and columns. The floors and roof consist of cast-in-place concrete slabs. Walls consist of infill panels constructed of solid clay brick, concrete block, or hollow clay tile masonry. The seismic performance of this type of construction depends on the interaction between the frame and infill panels. The combined behavior is more like a shear wall structure than a frame structure. Solidly infilled masonry panels form diagonal compression struts between the intersections of the frame members. If the walls are offset from the frame and do not fully engage the frame members, the diagonal compression struts will not develop. The strength of the infill panel is limited by the shear capacity of the masonry bed joint or the compression capacity of the strut. The post-cracking strength is determined by an analysis of a moment frame that is partially restrained by the cracked infill. The shear strength of the concrete columns, after cracking of the infill, may limit the semiductile behavior of the system. The diaphragms consist of concrete floors and are stiff relative to the walls.
C3A	These buildings are similar to C3 buildings, except that diaphragms consists of wood sheathing, or have large aspect ratios, and are flexible relative to the walls.
Building Type 11 : Precast/Tilt-up Concrete Shear Wall Buildings	
PC1	These buildings are one or more stories in height and have precast concrete perimeter wall panels that are cast on site and tilted into place. Floor and roof framing consists of wood joists, glulam beams, steel beams or open web joists. Framing is supported on interior steel columns and perimeter concrete bearing walls. The floors and roof consist of wood sheathing or untopped metal deck. Lateral forces are resisted by the precast concrete perimeter wall panels. Wall panels may be solid, or have large window and door openings which cause the panels to behave more as frames than as shear walls. In older construction, wood framing is attached to the walls with wood ledgers. Foundations consist of concrete spread footings or deep pile foundations.
PC1A	These buildings are similar to PC1 buildings, except that diaphragms consist of precast elements, cast-in-place concrete, or metal deck with concrete fill, and are stiff relative to the walls.
Building Type 12 : Precast Concrete Frame s	
PC2	These buildings consist of a frame assembly of precast concrete girders and columns with the presence of shear walls. Floor and roof framing consists of precast concrete planks, tees or double-tees supported on precast concrete girders and columns. Lateral forces are resisted by precast or cast-in-place concrete shear walls. Diaphragms consist of precast elements interconnected with welded inserts, cast-in-place closure strips, or reinforced concrete topping slabs.
PC2A	These buildings are similar to PC2 buildings, except that concrete shear walls are not present. Lateral forces are resisted by precast concrete moment frames that develop their stiffness through beam-column joints rigidly connected by welded inserts or cast-in-place concrete closures. Diaphragms consist of precast elements interconnected with welded inserts, cast-in-place closure strips, or reinforced concrete topping slabs. This type of construction is not permitted in regions of high seismicity for new construction.

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Table 2-2. Common Building Types (cont'd)

Building Type 13: Reinforced Masonry Bearing Wall Buildings with Flexible Diaphragms	
RM1	These buildings have bearing walls that consist of reinforced brick or concrete block masonry. Wood floor and roof framing consists of wood joists, glulam beams and wood posts or small steel columns. Steel floor and roof framing consists of steel beams or open web joists, steel girders and steel columns. Lateral forces are resisted by the reinforced brick or concrete block masonry shear walls. Diaphragms consist of straight or diagonal wood sheathing, plywood, or untopped metal deck, and are flexible relative to the walls. Foundations consist of brick or concrete spread footings.
Building Type 14: Reinforced Masonry Bearing Wall Buildings with Stiff Diaphragms	
RM2	These buildings are similar to RM1 buildings, except the diaphragms consist of metal deck with concrete fill, precast concrete planks, tees, or double-tees, with or without a cast-in-place concrete topping slab, and are stiff relative to the walls. The floor and roof framing is supported on interior steel or concrete frames or interior reinforced masonry walls.
Building Type 15 : Unreinforced Masonry Bearing Wall Buildings	
URM	These buildings have perimeter bearing walls that consist of unreinforced clay brick masonry. Interior bearing walls, when present, also consist of unreinforced clay brick masonry. In older construction floor and roof framing consists of straight or diagonal lumber sheathing supported by wood joists, on posts and timbers. In more recent construction floors consist of structural panel or plywood sheathing rather than lumber sheathing. The diaphragms are flexible relative to the walls. When they exist, ties between the walls and diaphragms consist of bent steel plates or government anchors embedded in the mortar joints and attached to framing. Foundations consist of brick or concrete spread footings.
URMA	These buildings are similar to URM buildings, except that the diaphragms are stiff relative to the unreinforced masonry walls and interior framing. In older construction or large, multistory buildings, diaphragms consist of cast-in-place concrete. In regions of low seismicity, more recent construction consists of metal deck and concrete fill supported on steel framing.

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$S_{D1} = \frac{2}{3}F_v S_1$
= design spectral response acceleration parameter at a one second period;

F_v, F_a = site coefficients defined in Tables 3-5 and 3-6, respectively;

S_s = short-period spectral response acceleration parameter (Sec. 3.5.2.3.1);

S_1 = spectral response acceleration parameter at a one second period (Sec. 3.5.2.3.1).

2.6 Building Type

The building being evaluated shall be classified as one or more of the building types listed in Table 2-2 based on the lateral force-resisting system(s) and the diaphragm type. Two separate building types shall be used for buildings with different lateral-force-resisting systems in each of the two orthogonal directions.

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3.0 Screening Phase (Tier 1)

3.1 General

A Tier 1 Evaluation shall be conducted for all buildings after the evaluation requirements of Chapter 2 have been completed. Tier 1 of the evaluation process is shown schematically in Figure 3-1.

Initially, the design professional shall determine whether the building meets the benchmark building criteria of Section 3.2. If the building meets the benchmark building criteria, it shall be deemed to meet the structural requirements of this Handbook for the specified level of performance; a Tier 1 Evaluation for foundations and nonstructural elements remains applicable.

If the building is not a benchmark building, the design professional shall select and complete the appropriate checklists in accordance with Section 3.3.

Structural checklists are not used for unreinforced masonry bearing wall buildings with flexible diaphragms. The structural evaluation of this type of building shall be completed using the Tier 2 Special Procedure of Section 4.2.6; a Tier 1 Evaluation for foundations and nonstructural elements remains applicable for this type of building.

A list of deficiencies identified by evaluation statements for which the building was found to be non-compliant shall be compiled upon completion of the Tier 1 Checklists.

Further evaluation requirements shall be determined in accordance with Section 3.4 once the checklists have been completed.

Commentary:

The purpose of the screening phase of the evaluation process is to identify quickly buildings that comply with the provisions of this handbook. A Tier 1 Evaluation also familiarizes the design professional

professional with the building, its potential deficiencies and its potential behavior.

A Tier 1 Evaluation is required for all buildings so that potential deficiencies may be quickly identified. Further evaluation using a Tier 2 or Tier 3 Evaluation will then focus, as a minimum, on the potential deficiencies identified in Tier 1.

3.2 Benchmark Buildings

A structural seismic evaluation using this Handbook need not be performed for buildings designed and constructed or evaluated in accordance with the benchmark documents listed in Table 3-1; an evaluation for foundations and nonstructural elements remains applicable. Table 3-1 identifies documents whose seismic design, construction or evaluation provisions are acceptable for certain building types so that further evaluation is not required. If the seismicity of a region has changed since the benchmark dates listed in Table 3-1, a building must have been designed and constructed or evaluated in accordance with the current seismicity of the region to be compliant with this section. The design professional shall document in the final report the evidence used to determine that the building is designed and constructed or evaluated in accordance with the documents listed in Table 3-1 and current seismicity of the region.

The applicable level of performance is indicated in Table 3-1 for each document as a superscript.

Commentary:

While benchmark buildings need not proceed with further evaluation, it should be noted that they are not simply exempt from the criteria of this Handbook. The design professional must clearly demonstrate the building is compliant with the

Chapter 3.0 - Screening Phase (Tier 1)

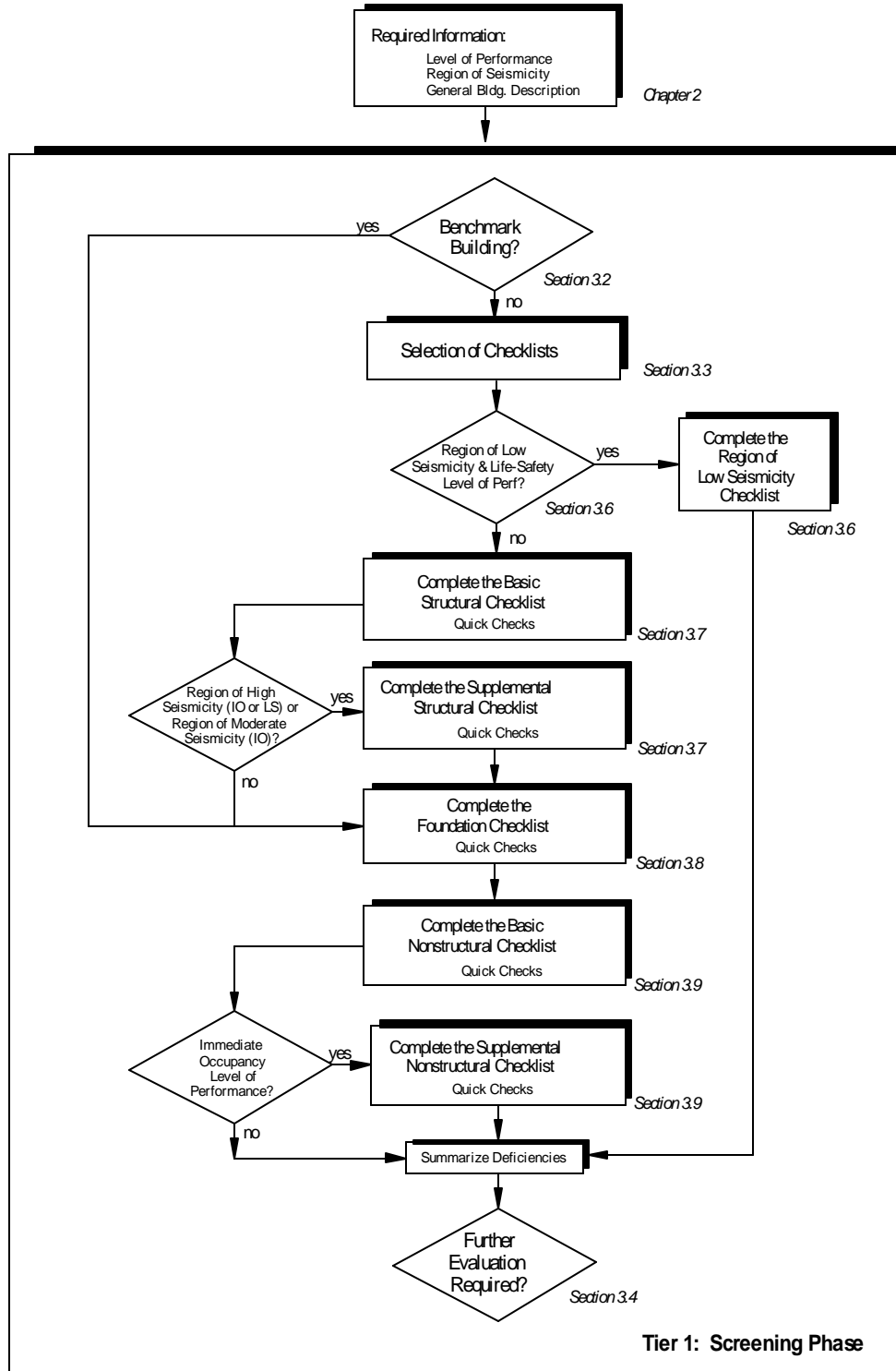


Figure 3-1. Tier 1 Evaluation Process

Chapter 3.0 - Screening Phase (Tier 1)

Table 3-1. Benchmark Buildings

Building Type ¹	Model Building Seismic Design Provisions				FEMA 178 ^{ls}	CBC ^{io}
	BOCA ¹ _s	SBCC ^{ls}	UBC ^{ls}	NEHRP ^{ls}		
Wood Frame, Wood Shear Panels (Type W1 & W2) ²	1992	1993	1976	1985	*	1973
Wood Frame, Wood Shear Panels (Type W1A)	1992	1993	1976	1985	*	1973
Steel Moment Resisting Frame (Type S1 & S1A)	**	**	1994 ⁴	**	*	1995
Steel Braced Frame (Type S2 & S2A)	1992	1993	1988	1991	1992	1973
Light Metal Frame (Type S3)	*	*	*	*	1992	1973
Steel Frame w/ Concrete Shear Walls (Type S4)	1992	1993	1976	1985	1992	1973
Reinforced Concrete Moment Resisting Frame (Type C1) ³	1992	1993	1976	1985	*	1973
Reinforced Concrete Shear Walls (Type C2 & C2A)	1992	1993	1976	1985	*	1973
Steel Frame with URM Infill (Type S5, S5A)	*	*	*	*	*	*
Concrete Frame with URM Infill (Type C3 & C3A)	*	*	*	*	*	*
Tilt-up Concrete (Type PC1 & PC1A)	*	*	1997	*	*	*
Precast Concrete Frame (Type PC2 & PC2A)	*	*	*	*	1992	1973
Reinforced Masonry (Type RM1)	*	*	1997	*	*	*
Reinforced Masonry (Type RM2)	1992	1993	1976	1985	*	*
Unreinforced Masonry (Type URM) ⁵	*	*	1991 ⁶	*	1992	*
Unreinforced Masonry (Type URMA)	*	*	*	*	*	*

¹Building Type refers to one of the Common Building Types defined in Table 2-2.

²Buildings on hillside sites shall not be considered Benchmark Buildings.

³Flat Slab Buildings shall not be considered Benchmark Buildings.

⁴Steel Moment-Resisting Frames shall comply with the 1994 UBC Emergency Provisions.

⁵URM buildings evaluated using the ABK Methodology (ABK, 1984) may be considered benchmark buildings.

⁶Refers to the UCBC Section of the UBC.

^{ls}Only buildings designed and constructed or evaluated in accordance with these documents and being evaluated to the Life-Safety Performance Level may be considered Benchmark Buildings.

^{io}Buildings designed and constructed or evaluated in accordance with these documents and being evaluated to either the Life-Safety or Immediate Occupancy Performance Level may be considered Benchmark Buildings.

*No benchmark year; buildings shall be evaluated using this handbook.

**Local provisions shall be compared with the UBC.

BOCA - Building Officials and Code Administrators, *National Building Code*.

SBCC - Southern Building Code Congress, *Standard Building Code*

UBC - International Conference of Building Officials, *Uniform Building Code*

NEHRP - Federal Emergency Management Agency, *NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings*

CBC - California Building Standards Commission, *California Building Code*

benchmark document. Knowledge that a code was in effect at the time of construction is not sufficient. A statement on the drawings simply stating that it was designed to the benchmark document will not suffice. Sometimes, details in the existing building will not correspond to the construction documents. Sometimes, the building is not properly detailed to meet the benchmark document. This may occur due to renovations or poor construction management. Only through a site visit, an examination of existing documentation, and other requirements of Chapter 2 will the design professional be able to determine whether the structure being evaluated complies with this section.

3.3 Selection and Use of Checklists

Required checklists, as a function of region of seismicity and level of performance, are listed in Table 3-2. Each of the required checklists designated in Table 3-2 shall be completed for a Tier 1 Evaluation. Each of the evaluation statements on the checklists shall be marked "compliant" (C), "noncompliant" (NC), or "not applicable" (N/A). Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated.

Quick Checks for Tier 1 shall be performed in accordance with Section 3.5 when necessary to complete an evaluation statement.

The Region of Low Seismicity Checklist, located in Section 3.6, shall be completed for buildings in regions of low seismicity being evaluated to the Life Safety Performance Level. For buildings in regions of low seismicity being evaluated to the Immediate Occupancy Performance Level and buildings in regions of moderate or high seismicity, the appropriate Structural, Geologic Site Hazards, and Nonstructural Checklists shall be completed in accordance with Table 3-2.

The appropriate Structural Checklists shall be selected based on the Common Building Types defined in Table 2-2. The General Structural Checklists shall be used for buildings that cannot be classified as one of the Common Building Types defined in Table 2-2.

A building with a different lateral-force-resisting system in each principal direction shall use two sets of structural checklists, one for each direction. A building with more than one type of lateral-force-resisting system along a single axis of the building shall be classified as a mixed system. The General Structural Checklists shall be used for this type of building.

Two separate Structural Checklists are provided for each building type: a Basic Structural Checklist and a Supplemental Structural Checklist. As shown in Table 3-2, the Basic Structural Checklist shall be completed for buildings in regions of low seismicity being evaluated to the Immediate Occupancy Performance Level and buildings in regions of moderate and high seismicity. The Supplemental Structural Checklist shall be completed in addition to the Basic Structural Checklist for buildings in regions of moderate seismicity being evaluated to the Immediate Occupancy Performance Level and buildings in regions of high seismicity.

The Geologic Site Hazards and Foundations Checklist shall be completed for all buildings except those in regions of low seismicity being evaluated to the Life Safety Performance Level.

Two separate Nonstructural Checklists also are provided: a Basic and Supplemental Nonstructural Checklist. As shown in Table 3-2, the Basic Nonstructural Checklist shall be completed for all buildings except those in regions of low seismicity being evaluated to the Life Safety Performance Level. The Supplemental Nonstructural Checklists shall be completed in addition to the Basic Nonstructural Checklist for buildings in regions of moderate or high seismicity being evaluated to the Immediate Occupancy Performance Level.

Commentary:

The evaluation statements provided in the checklists form the core of the Tier 1 Evaluation Methodology. These evaluation statements are based on observed earthquake structural damage during actual

during actual earthquakes. The checklists do not necessarily identify the response of the structure to ground motion; rather, the design professional obtains a general sense of the structure's deficiencies and potential behavior during an earthquake. By quickly identifying the potential deficiencies in the structure, the design professional has a better idea of what to examine and analyze in a Tier 2 or Tier 3 Evaluation.

The General Structural Checklists are a complete listing of all evaluation statements used in Tier 1 Evaluations. They should be used for buildings with structural systems that do not match the common building types. While the general purpose of the Tier 1 Checklists is to identify potential weak-links in structures that have been observed in past significant earthquakes, the General Checklists, by virtue of their design, do not accomplish this. They only represent a listing of all possible deficiencies. The design professional must consider first the applicability of the potential deficiency to the building system being considered. Generally, only the deficiencies that participate in the yielding elements of the building need be considered.

While the section numbers in parentheses following each evaluation statement correspond to Tier 2 Evaluation procedures, they also correspond to commentary in Chapter 4 regarding the statement's purpose. If the design professional requires additional information on particular evaluation statements, please refer to the commentary associated with the Tier 2 procedure for that evaluation statement..

3.4 Further Evaluation Requirements

Upon completion of the Tier 1 Evaluation, further evaluation shall be conducted in accordance with Table 3-3.

A Full-Building Tier 2 Evaluation shall be completed for buildings with more than the number of stories listed in Table 3-3. 'NL' designates No Limit on the number of stories.

A Full-Building Tier 2 Evaluation also is required for buildings designated in Table 3-3 by 'T2'. A Tier 3 Evaluation shall be required for buildings designated by 'T3' in Table 3-3.

For buildings not requiring a Full-Building Tier 2 Evaluation or a Tier 3 Evaluation, a Deficiency-Only Tier 2 Evaluation may be conducted if potential deficiencies are identified by the Tier 1 Evaluation. Alternatively, the design professional may choose to end the investigation and report the deficiencies in accordance with Chapter 1.

Commentary:

In most cases, the Tier 1 identification of potential deficiencies leads to further evaluation of only these deficiencies. As defined in Chapter 4, the required analysis may be localized to the specific deficiencies or it may involve a global analysis to evaluate the specific deficiency. Each checklist evaluation statement concludes with a reference to the applicable section in Chapter 4; the Tier 2 procedures as well as commentary on the statements' purpose.

The 'NL' designation for most buildings being evaluated to the Life Safety Performance Level is consistent with FEMA 178, which had no restriction on the use of the checklists. The 'SP' designation for unreinforced masonry bearing wall buildings with flexible diaphragms also is consistent with FEMA 178.

The 'T2,' 'T3,' and number of story designations in the Immediate Occupancy Performance Level category indicates that the building cannot be deemed to meet the requirements of this Handbook without a full evaluation of the building. Based on past performance of these types of buildings in earthquakes, the behavior of the structure must be examined and understood. However, the Tier 1 Checklists will provide insight and information about the structure prior to a Tier 2 or Tier 3 Evaluation.

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Table 3-2. Checklists Required for a Tier 1 Evaluation

Region of Seismicity	Level of Performance ²	Required Checklists ¹					
		Region of Low Seismicity (Sec. 3.6)	Basic Structural (Sec. 3.7)	Supplemental Structural (Sec. 3.7)	Geologic Site Hazard and Foundation (Sec. 3.8)	Basic Nonstructural (Sec. 3.9.1)	Supplemental Nonstructural (Sec. 3.9.2)
Low	LS	√					
	IO		√		√	√	
Moderate	LS		√		√	√	
	IO		√	√	√	√	√
High	LS		√	√	√	√	
	IO		√	√	√	√	√

¹A checkmark (√) designates that the checklist that must be completed for a Tier 1 evaluation as a function of the region of seismicity and level of performance.

²LS = Life-Safety; IO = Immediate Occupancy; defined in Section 2.3.

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Table 3-3. Further Evaluation Requirements¹

Model Building Type	Number of Stories beyond which a Full-Building Tier 2 Evaluation is Required					
	Low		Moderate		High	
	LS	IO	LS	IO	LS	IO
Wood Frames						
Light (W1)	NL	2	NL	2	NL	2
Multistory, Multi-Unit Residential (W1A)	NL	3	NL	2	NL	2
Commercial and Industrial (W2)	NL	2	NL	2	NL	2
Steel Moment Frames						
Rigid Diaphragm (S1)	NL	3	NL	T2	NL	T2
Flexible Diaphragm (S1A)	NL	3	NL	T2	NL	T2
Steel Braced Frames						
Rigid Diaphragm (S2)	NL	3	NL	2	NL	2
Flexible Diaphragm (S2A)	NL	3	NL	2	NL	2
Steel Light Frames (S3)	NL	1	NL	1	NL	1
Steel Frame with Concrete Shear Walls (S4)	NL	4	NL	4	NL	3
Steel Frame with Infill Masonry Shear Walls						
Rigid Diaphragm (S5)	NL	2	NL	T2	NL	T2
Flexible Diaphragm (S5A)	NL	2	NL	T2	NL	T2
Concrete Moment Frames (C1)	NL	2	NL	T2	NL	T2
Concrete Shear Walls						
Rigid Diaphragm (C2)	NL	4	NL	4	NL	3
Flexible Diaphragm (C2A)	NL	4	NL	4	NL	3
Concrete Frame with Infill Masonry Shear Walls						
Rigid Diaphragm (C3)	NL	2	NL	T2	NL	T2
Flexible Diaphragm (C3A)	NL	2	NL	T2	NL	T2
Precast/Tilt-up Concrete Shear Walls						
Flexible Diaphragm (PC1)	NL	1	NL	T2	NL	T2
Rigid Diaphragm (PC1A)	NL	1	NL	T2	NL	T2
Precast Concrete Frames						
With Shear Walls (PC2)	NL	4	NL	4	NL	3
Without Shear Walls (PC2A)	NL	T2	NL	T2	NL	T2
Reinforced Masonry Bearing Walls						
Flexible Diaphragm (RM1)	NL	3	NL	T2	NL	T2
Rigid Diaphragm (RM2)	NL	3	NL	3	NL	2
Unreinforced Masonry Bearing Walls						
Flexible Diaphragm (URM)	NL	T3	SP	T3	SP	T3
Rigid Diaphragm (URMA)	NL	1	NL	T3	NL	T3
Mixed Systems	NL	2	NL	T2	NL	T2

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¹A Full-Building Tier 2 or Tier 3 Evaluation shall be completed for buildings with more than the number of stories listed herein .

SP - Special Procedure (A Tier 2 Evaluation is required using the Special Procedure defined in Section 4.2.6; the Geologic Site Hazards and Foundations Checklist and the Nonstructural Checklist shall be completed prior to performing the Special Procedure Analysis) .

NL - No Limit (No limit on the number of stories).

T2 - Tier 2 (A Full-Building Tier 2 Evaluation is required; proceed to Chapter 4).

T3 - Tier 3 (A Tier 3 Evaluation is required; proceed to Chapter 5).

3.5 Tier 1 Analysis

$$V = 0.75W \quad (3-2)$$

3.5.1 Overview

Analyses performed as part of Tier 1 of the Evaluation Process are limited to Quick Checks. Quick Checks shall be used to calculate the stiffness and strength of certain building components to determine whether the building complies with certain evaluation criterion. Quick Checks shall be performed in accordance with Section 3.5.3 when triggered by evaluation statements from the Checklists of Section 3.7. Seismic shear forces for use in the Quick Checks shall be computed in accordance with Section 3.5.2.

If Equation (3-2) is used, an *m*-factor of 1.0 shall be used to compute the component forces and stresses for the Quick Checks of Section 3.5.3 and acceptance criteria of Section 4.2.4.

3.5.2 Seismic Shear Forces

Table 3-4. Modification Factor, C

3.5.2.1 Pseudo Lateral Force

The pseudo lateral force, in a given horizontal direction of a building, shall be calculated in accordance with Equations (3-1) and (3-2).

$$V = C S_a W \quad (3-1)$$

where:

- V = Pseudo lateral force;
- C = Modification factor to relate expected maximum inelastic displacements to displacements calculated for linear elastic response; C shall be taken from Table 3-4;
- S_a = Response spectral acceleration at the fundamental period of the building in the direction under consideration. The value of S_a shall be calculated in accordance with the procedures in Section 3.5.2.3.
- W = Total dead load and anticipated live load as follows:
 - In storage and warehouse occupancies, a minimum of 25% of the floor live load; The actual partition weight or minimum weight of 10 psf of floor area, whichever is greater;
 - The applicable snow load;
 - The total weight of permanent equipment and furnishings.

Alternatively, for buildings with shallow foundations and without basements being evaluated for the Life Safety Performance Level, Equation (3-2) may be used to compute the pseudo lateral force:

Building Type ¹	Number of Stories			
	1	2	3	≥ 4
Wood (W1, W1A, W2) Moment Frame (S1, S3, C1, PC2A)	1.3	1.1	1.0	1.0
Shear Wall (S4, S5, C2, C3, PC1A, PC2, RM2, URMA) Braced Frame (S2)	1.4	1.2	1.1	1.0
Unreinforced Masonry (URM) Flexible Diaphragms (S1A, S2A, S5A, C2A, C3A, PC1, RM1)	1.0	1.0	1.0	1.0

¹Defined in Table 2-2.

Commentary:

The seismic evaluation procedure of this Handbook, as well as the *NEHRP Recommended Provisions for Seismic Regulations for New Buildings* and the *Uniform Building Code*, is based on a widely-accepted philosophy that permits nonlinear response of a building when subjected to a ground motion that is representative of the design earthquake. The *NEHRP Recommended Provisions for Seismic Regulations for New Buildings*, the *Uniform Building Code* and FEMA 178 account for nonlinear seismic response in a linear static analysis procedure by including a response modification factor, R, in calculating a reduced equivalent base shear to produce a rough approximation of the internal forces during a design earthquake. In other words, the base shear is equivalent to what the building is expected to resist strength-wise, but the building displacement using this base shear are significantly less than the displacements the building will actually experience during a design earthquake. Thus, this approach

increases the base shear by another factor (C_d , $.7R$, etc.) when checking drift and ductility requirements. In summary, this procedure is based on equivalent lateral forces and pseudo displacements.

The linear static analysis procedure in this Handbook, as well as in FEMA 273, takes a different approach to account for the nonlinear seismic response. Pseudo static lateral forces are applied to the structure to obtain "actual" displacements during a design earthquake. The pseudo lateral force of Equation (3-1) represents the force required, in a linear static analysis, to impose the expected actual deformation of the structure in its yielded state when subjected to the design earthquake motions.

It does not represent an actual lateral force that the building must resist in traditional design codes or FEMA 178. In summary, this procedure is based on equivalent displacements and pseudo lateral forces. For additional commentary regarding this linear static analysis approach, please refer to the commentary for Section 4.2.2.1 and FEMA 273 and 274.

Instead of applying a ductility related response reduction factor, R , to the applied loads, this Handbook uses ductility related m -factors in the acceptability checks of each component. Thus, instead of using a single R -value for the entire structure, different m -factors are used depending on the ductility of the component being evaluated. The m -factors specified for each Tier of analysis shall not be used for other Tiers of analysis (i.e., Tier 3 values of m may not be used when a Tier 1 or Tier 2 analysis is performed).

For short and stiff buildings with low ductility located in regions of high seismicity, the required building strength in accordance with Equation (3-1) may exceed the force required to cause sliding at the foundation level. The strength of the structure, however, does not need to exceed the strength of the ground. Thus, when Equation (3-2) is applied to these buildings, the required strength of structural components need not exceed $0.75W$.

3.5.2.2 Story Shear Forces

For multi-story buildings, the pseudo lateral force computed in accordance with Section 3.5.2.1 shall be distributed vertically in accordance with Equation (3-3).

$$V_j = \left(\frac{n+j}{n+1} \right) \left(\frac{W_j}{W} \right) V \quad (3-3)$$

where:

- V_j = Story shear at story level j ,
- n = Total number of stories above ground level,
- j = Number of story level under consideration,
- W_j = Total seismic weight of all stories above level j ,
- W = Total seismic weight per Section 3.5.2.1,
- V = Pseudo lateral force from Equation (3-1) or (3-2).

For buildings with flexible diaphragms (Types S1A, S2A, S5A, C2A, C3A, PC1, RM1, URM), story shear shall be calculated separately for each line of lateral resistance. This value shall be calculated using Equation (3-3) with W_j defined as the seismic weight of all stories above level j tributary to the line of resistance under consideration.

3.5.2.3 Spectral Acceleration

Spectral acceleration for use in computing the pseudo lateral force shall be computed in accordance with this section. Spectral acceleration shall be based on mapped spectral accelerations, defined in Section 3.5.2.3.1, for the site of the building being evaluated. Alternatively, a site specific response spectrum may be developed according to Section 3.5.2.3.2.

3.5.2.3.1 Mapped Spectral Acceleration

The mapped spectral acceleration, S_a , shall be computed in accordance with Equation (3-4).

$$S_a = \frac{S_{D1}}{T}, \text{ but} \quad (3-4)$$

$$S_a \text{ shall not exceed } S_{DS};$$

where:

$$S_{D1} = \frac{2}{3} F_v S_I \quad (3-5)$$

$$S_{DS} = \frac{2}{3} F_a S_s \quad (3-6)$$

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T = Fundamental period of vibration of the building calculated in accordance with Section 3.5.2.4.

S_s and S_1 are short period response acceleration and spectral response acceleration at a one second period parameters, respectively, for the Maximum Considered Earthquake (MCE). S_s and S_1 shall be obtained from the *Seismic Map Package*. F_v and F_a are site coefficients and shall be determined from Tables 3-5 and 3-6, respectively, based on the site class and the values of the response acceleration parameters S_s and S_1 . The site class of the building shall be defined as one of the following:

- **Class A:** Hard rock with measured shear wave velocity, $\bar{v}_s > 5,000$ ft/sec;
- **Class B:** Rock with $2,500$ ft/sec $\leq \bar{v}_s \leq 5,000$ ft/sec.
- **Class C:** Very dense soil and soft rock with $1,200$ ft/sec $< \bar{v}_s \leq 2,500$ ft/sec or with either standard blow count $\bar{N} > 50$ or undrained shear strength $\bar{s}_u > 2,000$ psf.
- **Class D:** Stiff soil with 600 ft/sec $< \bar{v}_s \leq 1,200$ ft/sec or with $15 < \bar{N} \leq 50$ or $1,000$ psf $\leq \bar{s}_u < 2000$ psf.
- **Class E:** Any profile with more than 10 feet of soft clay defined as soil with plasticity index $PI > 20$, or water content $w > 40$ percent, and $\bar{s}_u < 500$ psf or a soil profile with $\bar{v}_s < 600$ ft/sec.
- **Class F:** Soils requiring a site-specific geotechnical investigation and dynamic site response analyses:
 - Soils vulnerable to potential failure or collapse under seismic loading, such as liquefiable soils, quick and highly-sensitive clays, collapsible weakly-cemented soils;
 - Peats and/or highly organic clays ($H > 10$ feet of peat and/or highly organic clay; where H = thickness of soil);
 - Very high plasticity clays ($H > 25$ feet with $PI > 75$ percent);
 - Very thick soft/medium stiff clays ($H > 120$ feet).

For a soil profile classified as Class F, a Class E soil profile may be assumed for a Tier 1 Evaluation. If sufficient data is not available to classify a soil profile, a

Class E profile shall be assumed. For one- and two-story buildings with a roof height equal to or less than 25 feet, a Class D soil profile may be assumed if site conditions are not known.

Table 3-5. Values of F_v as a Function of Site Class and Mapped Spectral Acceleration at a One Second Period, S_1

Site Class	Mapped Spectral Acceleration at One Second Period ¹				
	$S_1 \leq 0.1$	$S_1 = 0.2$	$S_1 = 0.3$	$S_1 = 0.4$	$S_1 \geq 0.5$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.4	2.8	2.4	2.2
F	*	*	*	*	*

¹Note: Use straight-line interpolation for intermediate values of S_1 .

* See Class F soil profile.

Table 3-6. Values of F_a as a Function of Site Class and Mapped Short-Period Spectral Acceleration, S_s

Site Class	Mapped Spectral Acceleration at Short Periods ¹				
	$S_s \leq 0.25$	$S_s = 0.50$	$S_s = 0.75$	$S_s = 1.00$	$S_s \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	*	*	*	*	*

¹NOTE: Use straight-line interpolation for intermediate values of S_s .

*See Class F soil profile.

Commentary:

The short period response acceleration and spectral response acceleration at a one second period parameters, S_s and S_1 , are provided in the *Seismic Map Package*. The values of S_s and S_1 represent an earthquake with a 2% probability of exceedance in 50 years with deterministic-based maximum values near known fault sources. For information on obtaining a copy of the *Seismic Map Package*, please contact the FEMA Distribution Facility at 1-800-480-2520.

- = 0.030 for eccentrically-braced steel frames (Building Types S2 and S2A);
- = 0.020 for all other framing systems;
- h_n = height (in feet) above the base to the roof level.

Alternatively, for steel or reinforced-concrete moment frames of 12 stories or less the fundamental period of the building may be calculated as follows:

$$T=0.10N \quad (3-8)$$

where:

N = number of stories above the base.

3.5.2.3.2 Site-Specific Spectral Acceleration

Development of site-specific response spectra shall be based on the geologic, seismological, and soil characteristics associated with the specific site of the building being evaluated. Site-specific response spectra shall be based on input ground motions with a 2% probability of exceedance in 50 years (2500 year return interval) and developed for an equivalent viscous damping ratio of 5%. The site specific response spectra need not exceed the mean deterministic spectra for faults with known slip rates. When the 5% damped site specific spectrum has spectral amplitudes in the period range of greatest significance to the structural response that are less than 70% of the mapped spectral amplitudes, an independent third-party review of the spectrum shall be made by an individual with expertise in the evaluation of ground motion.

3.5.2.4 Period

The fundamental period of a building, in the direction under consideration, shall be calculated in accordance with Equation (3-7).

$$T = C_t h_n^{3/4} \quad (3-7)$$

where:

- T = Fundamental period (in seconds) in the direction under consideration;
- C_t = 0.060 for wood buildings (Building Types W1, W1A, and W2);
- = 0.035 for moment-resisting frame systems of steel (Building Types S1 and S1A);
- = 0.030 for moment-resisting frames of reinforced concrete (Building Type C1);

3.5.3 Quick Checks for Strength and Stiffness

Quick Checks shall be used to compute the stiffness and strength of building components. Quick Checks are triggered by evaluation statements in the Checklists of Section 3.7 and are required to determine the compliance of certain building components. The seismic shear forces used in the Quick Checks shall be calculated in accordance with Section 3.5.2.

Commentary:

The quick check equations used here are essentially the same as those used in FEMA 178, modified for use with the pseudo lateral forces and the appropriate material m -factors.

3.5.3.1 Story Drift for Moment Frames

Equation (3-9) shall be used to calculate the drift ratios of regular, multistory, multibay moment frames with columns continuous above and below the story under consideration. The drift ratio is based on the deflection due to flexural displacement of a representative column, including the effect of end rotation due to bending of the representative girder.

$$DR = \left(\frac{k_b + k_c}{k_b \cdot k_c} \right) \left(\frac{h}{12E} \right) V_c \quad (3-9)$$

where:

- DR = Drift Ratio = Interstory displacement divided by story height,
- k_b = I/L for the representative beam,
- k_c = I/h for the representative column,
- h = Story height (in.),
- I = Moment of inertia (in⁴),

- L = Center to center length of columns (in.),
- E = Modulus of elasticity (ksi),
- V_c = Shear in the column (kips).

The column shear forces shall be taken as a portion of the story shear forces, computed in accordance with Section 3.5.2.2. For reinforced concrete frames, an equivalent cracked section moment of inertia equal to one half of gross value shall be used.

Equation (3-9) may also be used for the first floor of the frame if columns are fixed against rotation at the bottom. However, if columns are pinned at the bottom, an equivalent story height equal to twice the actual story height shall be used in calculating the value of k_c.

For other configurations of frames, the quick check need not be performed as a Full-Building Tier 2 Evaluation including calculation of the drift ratio shall be completed based on principles of structural mechanics.

3.5.3.2 Shear Stress in Concrete Frame Columns

The average shear stress, v_{avg}, in the columns of concrete frames shall be computed in accordance with Equation (3-10).

$$v_{avg} = \frac{1}{m} \left(\frac{n_c}{n_c - n_f} \right) \left(\frac{V_j}{A_c} \right) \quad (3-10)$$

where:

- n_c = Total number of columns;
- n_f = Total number of frames in the direction of loading;
- A_c = Summation of the cross sectional area of all columns in the story under consideration; and
- V_j = Story shear computed in accordance with Section 3.5.2.2.
- m = component modification factor; m shall be taken equal to 2.0 for buildings being evaluated to the Life Safety Performance Level and 1.3 for buildings being evaluated to the Immediate Occupancy Performance Level.

Commentary:

Equation (3-10) assumes that all of the columns in the frame have similar stiffness.

3.5.3.3 Shear Stress in Shear Walls

The average shear stress in shear walls, v_{avg}, shall be calculated in accordance with Equation (3-11).

$$v_{avg} = \frac{1}{m} \left(\frac{V_j}{A_w} \right) \quad (3-11)$$

where:

- V_j = Story shear at level j computed in accordance with Section 3.5.2.2;
- A_w = Summation of the horizontal cross sectional area of all shear walls in the direction of loading. Openings shall be taken into consideration when computing A_w. For masonry walls, the net area shall be used. For wood framed walls, the length shall be used rather than the area.
- m = component modification factor; m shall be taken from Table 3-7.

Table 3-7. m-factors for Shear Walls

Wall Type	Level of Performance ¹	
	LS	IO
Reinforced Concrete, Precast Concrete, and Wood	4.0	2.0
Reinforced Masonry	3.0	1.5
Unreinforced Masonry	1.5	N/A

¹Defined in Section 2.4.

3.5.3.4 Diagonal Bracing

The average axial stress in diagonal bracing elements, f_{br}, shall be calculated in accordance with Equation (3-12).

$$f_{br} = \frac{1}{m} \left(\frac{V_j}{sN_{br}} \right) \left(\frac{L_{br}}{A_{br}} \right) \quad (3-12)$$

where:

- L_{br} = Average length of the braces (ft);
- N_{br} = Number of braces in tension and compression if the braces are designed for compression; if not, use the number of braces in tension, if the braces are not designed for compression;
- s = Average span length of braced spans (ft);
- A_{br} = Average area of a diagonal brace (in²);

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V_j = Maximum story shear at each level (kips);
 m = component modification factor; m shall be taken from Table 3-8.

Table 3-8. m -factors for Diagonal Braces

Brace Type	(d/t) *	Level of Performance ¹	
		LS	IO
Tube	$\leq 90/(F_{ye})^{1/2}$	6.0	2.5
	$> 190/(F_{ye})^{1/2}$	3.0	1.5
Pipe	$\leq 1500/F_{ye}$	6.0	2.5
	$> 6000/F_{ye}$	3.0	1.5
Tension-only		3.0	1.5
All others		6.0	2.5

¹Defined in Section 2.4.

*Interpolation permitted.

$F_{ye} = 1.25F_y$; expected yield stress as defined by Section 4.2.4.4.

3.5.3.5 Precast Connections

The precast connection in precast concrete moment frames shall be able to develop the moment in the girder, M_g , calculated in accordance with Equation (3-13).

$$M_g = \frac{V_j}{m} \left(\frac{n_c}{n_c - n_f} \right) \left(\frac{h}{2} \right) \quad (3-13)$$

where:

- n_c = Total number of columns;
- n_f = Total number of frames in the direction of loading;
- V_j = Story shear at the level directly below the connection under consideration;
- h = Typical column story height;
- m = Component modification factor taken equal to 2.0 for buildings being evaluated to the Life Safety Performance Level and 1.3 for buildings being evaluated to the Immediate Occupancy Performance Level.

3.5.3.6 Axial Stress Due to Overturning

The axial stress of columns subjected to overturning forces, p_{ot} , shall be calculated in accordance with Equation (3-14).

$$p_{ot} = \frac{1}{m} \left(\frac{2}{3} \right) \left(\frac{Vh_n}{Ln_f} \right) \quad (3-14)$$

where:

- n_f = Total number of frames in the direction of loading;
- V = Pseudo lateral force;
- h_n = height (in feet) above the base to the roof level.
- L = Total length of the frame (in feet);
- m = Component modification factor taken equal to 2.0 for buildings being evaluated to the Life Safety Performance Level and 1.3 for buildings being evaluated to the Immediate Occupancy Performance Level.

3.6 Region Of Low Seismicity Checklist

This Region of Low Seismicity Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Structural Components

- | | | | |
|---|----|-----|---|
| C | NC | N/A | LOAD PATH: The structure shall contain one complete load path for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1) |
| C | NC | N/A | WALL ANCHORAGE: Exterior concrete or masonry walls shall be anchored for out-of-plane forces at each diaphragm level with steel anchors or straps that are developed into the diaphragm. (Tier 2: Sec. 4.6.1.1) |

Geologic Site and Foundation Components

- | | | | |
|---|----|-----|--|
| C | NC | N/A | FOUNDATION PERFORMANCE: There shall be no evidence of excessive foundation movement such as settlement or heave that would affect the integrity or strength of the structure. (Tier 2: Sec. 4.7.2.1) |
|---|----|-----|--|

Nonstructural Components

- | | | | |
|---|----|-----|---|
| C | NC | N/A | EMERGENCY LIGHTING: Emergency lighting equipment shall be anchored to prevent falling or swaying during an earthquake. (Tier 2: Sec. 4.8.3.2) |
| C | NC | N/A | CLADDING ANCHORS: Cladding components weighing more than 10 psf shall be anchored to the exterior wall framing at a spacing equal to or less than 6 ft. (Tier 2: Sec. 4.8.4.1) |
| C | NC | N/A | GLAZING: Glazing in curtain walls and individual panes over 16 square feet in area, located up to a height of 10 feet above an exterior walking surface, shall be laminated annealed or heat strengthened safety glass that will remain in the frame when cracked. (Tier 2: Sec. 4.8.4.9) |
| C | NC | N/A | PARAPETS: There shall be no laterally unsupported unreinforced masonry parapets or cornices above the highest anchorage level with height-to-thickness ratios greater than 2.5. (Tier 2: Sec. 4.8.8.1) |
| C | NC | N/A | CANOPIES: Canopies located at building exits shall be anchored at a spacing of 10 ft. (Tier 2: Sec. 4.8.8.2) |
| C | NC | N/A | STAIRS: Walls around stair enclosures shall not consist of unbraced hollow clay tile or unreinforced masonry. (Tier 2: Sec. 4.8.10.1) |
| C | NC | N/A | EMERGENCY POWER: Equipment used as part of an emergency power system shall be anchored. (Tier 2: Sec. 4.8.12.1) |

3.7 Structural Checklists

This section provides Basic and Supplemental Structural Checklists for the following building types:

- W1: Wood Light Frames
- W1A: Multi-Story, Multi-Unit Residential Wood Frames
- W2: Wood Frames, Commercial and Industrial
- S1: Steel Moment Frames with Stiff Diaphragms
- S1A: Steel Moment Frames with Flexible Diaphragms
- S2: Steel Braced Frames with Stiff Diaphragms
- S2A: Steel Braced Frames with Flexible Diaphragms
- S3: Steel Light Frames
- S4: Steel Frames with Concrete Shear Walls
- S5: Steel Frames with Infill Masonry Shear Walls and Stiff Diaphragms
- S5A: Steel Frames with Infill Masonry Shear Walls and Flexible Diaphragms
- C1: Concrete Moment Frames
- C2: Concrete Shear Wall Buildings with Stiff Diaphragms
- C2A: Concrete Shear Wall Buildings with Flexible Diaphragms
- C3: Concrete Frames with Infill Masonry Shear Walls and Stiff Diaphragms
- C3A: Concrete Frames with Infill Masonry Shear Walls and Flexible Diaphragms
- PC1: Precast/Tilt-up Concrete Shear Wall Buildings with Flexible Diaphragms
- PC1A: Precast/Tilt-up Concrete Shear Wall Buildings with Stiff Diaphragms
- PC2: Precast Concrete Frames with Shear Walls
- PC2A: Precast Concrete Frames without Shear Walls
- RM1: Reinforced Masonry Bearing Wall Buildings with Flexible Diaphragms
- RM2: Reinforced Masonry Bearing Wall Buildings with Stiff Diaphragms
- URMA: Unreinforced Masonry Bearing Wall Buildings with Stiff Diaphragms

General Basic Structural Checklist

General Supplemental Structural Checklist

For a description of the specific building types listed above, refer to Table 2-2.

The appropriate Basic Structural Checklist shall be completed when required by Table 3-2.

The appropriate Supplemental Structural Checklist shall be completed when required by Table 3-2. The appropriate Basic Structural Checklist shall be completed prior to completing the appropriate Supplemental Structural Checklist.

3.7.1 Basic Structural Checklist for Building Type W1: Wood Light Frames

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

These buildings are single or multiple family dwellings of one or more stories in height. Building loads are light and the framing spans are short. Floor and roof framing consists of closely spaced wood joists or rafters on wood studs. The first floor framing is supported directly on the foundation, or is raised up on cripple studs and post and beam supports. The foundation consists of spread footings constructed of concrete, concrete masonry block, or brick masonry in older construction. Chimneys, when present, consist of solid brick masonry, masonry veneer, or wood frame with internal metal flues. Lateral forces are resisted by wood frame diaphragms and shear walls. Floor and roof diaphragms consist of straight or diagonal wood sheathing, tongue and groove planks, or plywood. Shear walls consist of straight or diagonal wood sheathing, plank siding, plywood, stucco, gypsum board, particle board, or fiberboard. Interior partitions are sheathed with plaster or gypsum board.

Building System

- C NC N/A LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1)
- C NC N/A VERTICAL DISCONTINUITIES: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4)
- C NC N/A DETERIORATION OF WOOD: There shall be no signs of decay, shrinkage, splitting, fire damage, or sagging in any of the wood members and none of the metal accessories shall be deteriorated, broken, or loose. (Tier 2: Sec. 4.3.3.1)
- C NC N/A OVERDRIVEN FASTENERS: There shall be no evidence of overdriven fasteners in the shear walls. (Tier 2: Sec. 4.3.3.2)

Lateral Force Resisting System

- C NC N/A REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.1.1)

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- | | | | | | | | | | | | |
|-----------------------------|----------|-----|---|-----------------------------|----------|---------------------|---------|---------------------|--------|-----------------------|---------|
| C | NC | N/A | <p>SHEAR STRESS CHECK The shear stress in the shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than the following values for Life Safety and Immediate Occupancy (Tier 2: Sec. 4.4.2.7.1)</p> <table border="0" style="margin-left: 40px;"> <tr> <td>Structural panel sheathing:</td> <td style="padding-left: 20px;">1000 plf</td> </tr> <tr> <td>Diagonal sheathing:</td> <td style="padding-left: 20px;">700 plf</td> </tr> <tr> <td>Straight sheathing:</td> <td style="padding-left: 20px;">80 plf</td> </tr> <tr> <td>All other conditions:</td> <td style="padding-left: 20px;">100 plf</td> </tr> </table> | Structural panel sheathing: | 1000 plf | Diagonal sheathing: | 700 plf | Straight sheathing: | 80 plf | All other conditions: | 100 plf |
| Structural panel sheathing: | 1000 plf | | | | | | | | | | |
| Diagonal sheathing: | 700 plf | | | | | | | | | | |
| Straight sheathing: | 80 plf | | | | | | | | | | |
| All other conditions: | 100 plf | | | | | | | | | | |
| C | NC | N/A | <p>STUCCO (EXTERIOR PLASTER) SHEAR WALLS: Multistory buildings shall not rely on exterior stucco walls as the primary lateral-force-resisting system. (Tier 2: Sec. 4.4.2.7.2)</p> | | | | | | | | |
| C | NC | N/A | <p>GYPSUM WALLBOARD OR PLASTER SHEAR WALLS: Interior plaster or gypsum wallboard shall not be used as shear walls on buildings over one story in height. (Tier 2: Sec. 4.4.2.7.3)</p> | | | | | | | | |
| C | NC | N/A | <p>NARROW WOOD SHEAR WALLS: Narrow wood shear walls with an aspect ratio greater than 2 to 1 for Life Safety and 1.5 to 1 for Immediate Occupancy shall not be used to resist lateral forces developed in the building. (Tier 2: Sec. 4.4.2.7.4)</p> | | | | | | | | |
| C | NC | N/A | <p>WALLS CONNECTED THROUGH FLOORS: Shear walls shall have interconnection between stories to transfer overturning and shear forces through the floor. (Tier 2: Sec. 4.4.2.7.5)</p> | | | | | | | | |
| C | NC | N/A | <p>HILLSIDE SITE: For a sloping site greater than one-half story, all shear walls on the downhill slope shall have an aspect ratio less than 1 to 1 for Life-Safety and 1 to 2 for Immediate Occupancy. (Tier 2: Sec. 4.4.2.7.6)</p> | | | | | | | | |
| C | NC | N/A | <p>CRIPPLE WALLS All cripple walls below first floor level shear walls shall be braced to the foundation with shear elements. (Tier 2: Sec. 4.4.2.7.7)</p> | | | | | | | | |

Connections

- | | | | |
|---|----|-----|---|
| C | NC | N/A | <p>WOOD POSTS: There shall be a positive connection of wood posts to the foundation. (Tier 2: Sec. 4.6.3.3)</p> |
| C | NC | N/A | <p>WOOD SILLS All wood sill s shall be bolted to the foundation. (Tier 2: Sec. 4.6.3.4)</p> |
| C | NC | N/A | <p>GIRDER/COLUMN CONNECTION: There shall be a positive connection between the girder and the column support. (Tier 2: Sec. 4.6.4.1)</p> |

3.7.1S Supplemental Structural Checklist For Building Type W1: Wood Light Frames

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

- C NC N/A OPENINGS: Walls with garage doors or other large openings shall be braced with plywood shear walls or shall be supported by adjacent construction through substantial positive ties. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec 4.4.2.7.8)
- C NC N/A HOLD-DOWN ANCHORS: All walls shall have properly constructed hold-down anchors. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec 4.4.2.7.9)

Diaphragms

- C NC N/A DIAPHRAGM CONTINUITY: The diaphragms shall not be composed of split-level floors. In wood buildings, the diaphragms shall not have expansion joints. (Tier 2: Sec. 4.5.1.1)
- C NC N/A ROOF CHORD CONTINUITY: All chord elements shall be continuous, regardless of changes in roof elevation. (Tier 2: Sec. 4.5.1.3)
- C NC N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)
- C NC N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8)
- C NC N/A STRAIGHT SHEATHING: All straight sheathed diaphragms shall have aspect ratios less than 2 to 1 for Life Safety and 1 to 1 for Immediate Occupancy in the direction being considered. (Tier 2: Sec. 4.5.2.1)
- C NC N/A SPANS: All wood diaphragms with spans greater than 24 ft. for Life Safety and 12 ft. for Immediate Occupancy shall consist of wood structural panels or diagonal sheathing. Wood commercial and industrial buildings may have rod-braced systems. (Tier 2: Sec. 4.5.2.2)
- C NC N/A UNBLOCKED DIAPHRAGMS: All unblocked wood structural panel diaphragms shall have horizontal spans less than 40 ft. for Life Safety and 25 ft. for Immediate Occupancy and shall have aspect ratios less than or equal to 4 to 1 for Life Safety and 3 to 1 for Immediate Occupancy. (Tier 2: Sec. 4.5.2.3)
- C NC N/A OTHER DIAPHRAGMS: The diaphragm shall not consist of a system other than those described in Section 4.5. (Tier 2: Sec. 4.5.7.1)

Connections

- C NC N/A WOOD SILL BOLTS: Sill bolts shall be spaced at 6 ft. or less for Life Safety and 4 ft. or less for Immediate Occupancy, with proper edge distance provided for wood and concrete. (Tier 2: Sec. 4.6.3.9)

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3.7.1A Basic Structural Checklist For Building Type W1A: Multi-Story, Multi-Unit Residential Wood Frames

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

These buildings are single or multiple family dwellings of one or more stories in height with open front garages at the first story. Building loads are light and the framing spans are short. Floor and roof framing consists of closely spaced wood joists or rafters on wood studs. The first story consists of wood floor framing on wood stud walls and steel pipe columns, or a concrete slab on concrete or concrete masonry block walls. The foundation consists of spread footings constructed of concrete, concrete masonry block, or brick masonry in older construction. Chimneys, when present, consist of solid brick masonry, masonry veneer, or wood frame with internal metal flues. Lateral forces are resisted by wood frame diaphragms and shear walls. Floor and roof diaphragms consist of straight or diagonal wood sheathing, tongue and groove planks, or plywood. Shear walls consist of straight or diagonal wood sheathing, plank siding, plywood, stucco, gypsum board, particle board, or fiberboard. Interior partitions are sheathed with plaster or gypsum board.

Building System

- | | | | |
|---|----|-----|--|
| C | NC | N/A | LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1) |
| C | NC | N/A | WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1) |
| C | NC | N/A | SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2) |
| C | NC | N/A | VERTICAL DISCONTINUITIES: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |
| C | NC | N/A | DETERIORATION OF WOOD: There shall be no signs of decay, shrinkage, splitting, fire damage, or sagging in any of the wood members and none of the metal accessories shall be deteriorated, broken, or loose. (Tier 2: Sec. 4.3.3.1) |

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- C NC N/A OVERDRIVEN FASTENERS There shall be no evidence of overdriven fasteners in the shear walls. (Tier 2: Sec. 4.3.3.2)

Lateral Force Resisting System

- C NC N/A REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.1.1)
- C NC N/A SHEAR STRESS CHECK The shear stress in the shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than the following values for Life Safety and Immediate Occupancy (Tier 2: Sec. 4.4.2.7.1)

Structural panel sheathing:	1000 plf
Diagonal sheathing:	700 plf
Straight sheathing:	80 plf
All other conditions:	100 plf

- C NC N/A STUCCO (EXTERIOR PLASTER) SHEAR WALLS: Multistory buildings shall not rely on exterior stucco walls as the primary lateral-force-resisting system. (Tier 2: Sec. 4.4.2.7.2)
- C NC N/A GYPSUM WALLBOARD OR PLASTER SHEAR WALLS: Interior plaster or gypsum wallboard shall not be used as shear walls on buildings over one story in height. (Tier 2: Sec. 4.4.2.7.3)
- C NC N/A NARROW WOOD SHEAR WALLS: Narrow wood shear walls with an aspect ratio greater than 2 to 1 for Life Safety and 1.5 to 1 for Immediate Occupancy shall not be used to resist lateral forces developed in the building. (Tier 2: Sec. 4.4.2.7.4)
- C NC N/A WALLS CONNECTED THROUGH FLOORS: Shear walls shall have interconnection between stories to transfer overturning and shear forces through the floor. (Tier 2: Sec. 4.4.2.7.5)
- C NC N/A HILLSIDE SITE: For a sloping site greater than one-half story, all shear walls on the downhill slope shall have an aspect ratio less than 1 to 1 for Life-Safety and 1 to 2 for Immediate Occupancy. (Tier 2: Sec. 4.4.2.7.6)
- C NC N/A CRIPPLE WALLS All cripple walls below first floor level shear walls shall be braced to the foundation with shear elements. (Tier 2: Sec. 4.4.2.7.7)

Connections

- C NC N/A WOOD POSTS: There shall be a positive connection of wood posts to the foundation. (Tier 2: Sec. 4.6.3.3)
- C NC N/A WOOD SILLS All wood sill s shall be bolted to the foundation. (Tier 2: Sec. 4.6.3.4)
- C NC N/A GIRDER/COLUMN CONNECTION: There shall be a positive connection between the girder and the column support. (Tier 2: Sec. 4.6.4.1)

3.7.1AS Supplemental Structural Checklist For Building Type W1A: Multi-Story, Multi-Unit Residential Wood Frames

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

- C NC N/A OPENINGS: Walls with garage doors or other large openings shall be braced with plywood shear walls or shall be supported by adjacent construction through substantial positive ties. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec 4.4.2.7.8)
- C NC N/A HOLD-DOWN ANCHORS: All walls shall have properly constructed hold-down anchors. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec 4.4.2.7.9)

Diaphragms

- C NC N/A DIAPHRAGM CONTINUITY: The diaphragms shall not be composed of split-level floors. In wood buildings, the diaphragms shall not have expansion joints. (Tier 2: Sec. 4.5.1.1)
- C NC N/A ROOF CHORD CONTINUITY: All chord elements shall be continuous, regardless of changes in roof elevation. (Tier 2: Sec. 4.5.1.3)
- C NC N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)
- C NC N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8)
- C NC N/A STRAIGHT SHEATHING: All straight sheathed diaphragms shall have aspect ratios less than 2 to 1 for Life Safety and 1 to 1 for Immediate Occupancy in the direction being considered. (Tier 2: Sec. 4.5.2.1)
- C NC N/A SPANS: All wood diaphragms with spans greater than 24 ft. for Life Safety and 12 ft. for Immediate Occupancy shall consist of wood structural panels or diagonal sheathing. Wood commercial and industrial buildings may have rod-braced systems. (Tier 2: Sec. 4.5.2.2)
- C NC N/A UNBLOCKED DIAPHRAGMS: All unblocked wood structural panel diaphragms shall have horizontal spans less than 40 ft. for Life Safety and 25 ft. for Immediate Occupancy and shall have aspect ratios less than or equal to 4 to 1 for Life Safety and 3 to 1 for Immediate Occupancy. (Tier 2: Sec. 4.5.2.3)
- C NC N/A OTHER DIAPHRAGMS: The diaphragm shall not consist of a system other than those described in Section 4.5. (Tier 2: Sec. 4.5.7.1)

Connections

- C NC N/A WOOD SILL BOLTS: Sill bolts shall be spaced at 6 ft. or less for Life Safety and 4 ft. or less for Immediate Occupancy, with proper edge distance provided for wood and concrete. (Tier 2: Sec. 4.6.3.9)

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3.7.2 Basic Structural Checklist For Building Type W2: Wood Frames, Commercial And Industrial

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

These buildings are commercial or industrial buildings with a floor area of 5,000 square feet or more. Building loads are heavier than light frame construction, and framing spans are long. There are few, if any, interior walls. The floor and roof framing consists of wood or steel trusses, glulam or steel beams, and wood posts or steel columns. Lateral forces are resisted by wood diaphragms and exterior stud walls sheathed with plywood, stucco, plaster, straight or diagonal wood sheathing, or braced with rod bracing. Large openings for storefronts and garages, when present, are framed by post-and-beam framing. Lateral force resistance around openings is provided by steel rigid frames or diagonal bracing.

Building System

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|---|----|-----|--|
| C | NC | N/A | LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1) |
| C | NC | N/A | MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3) |
| C | NC | N/A | WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1) |
| C | NC | N/A | SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2) |
| C | NC | N/A | GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3) |
| C | NC | N/A | VERTICAL DISCONTINUITIES: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |

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|---|----|-----|---|
| C | NC | N/A | MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5) |
| C | NC | N/A | DETERIORATION OF WOOD: There shall be no signs of decay, shrinkage, splitting, fire damage, or sagging in any of the wood members and none of the metal accessories shall be deteriorated, broken, or loose. (Tier 2: Sec. 4.3.3.1) |
| C | NC | N/A | OVERDRIVEN FASTENERS There shall be no evidence of overdriven fasteners in the shear walls (Tier 2: Sec. 4.3.3.2) |

Lateral Force Resisting System

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|---|----|-----|---|
| C | NC | N/A | REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.1.1) |
| C | NC | N/A | SHEAR STRESS CHECK The shear stress in the shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than the following values for Life Safety and Immediate Occupancy (Tier 2: Sec. 4.4.2.7.1) |
| | | | Structural panel sheathing: 1000 plf |
| | | | Diagonal sheathing: 700 plf |
| | | | Straight sheathing: 80 plf |
| | | | All other conditions: 100 plf |
| C | NC | N/A | STUCCO (EXTERIOR PLASTER) SHEAR WALLS: Multistory buildings shall not rely on exterior stucco walls as the primary lateral-force-resisting system. (Tier 2: Sec. 4.4.2.7.2) |
| C | NC | N/A | GYPHUM WALLBOARD OR PLASTER SHEAR WALLS: Interior plaster or gypsum wallboard shall not be used as shear walls on buildings over one story in height. (Tier 2: Sec. 4.4.2.7.3) |
| C | NC | N/A | NARROW WOOD SHEAR WALLS: Narrow wood shear walls with an aspect ratio greater than 2 to 1 for Life Safety and 1.5 to 1 for Immediate Occupancy shall not be used to resist lateral forces developed in the building. (Tier 2: Sec. 4.4.2.7.4) |
| C | NC | N/A | WALLS CONNECTED THROUGH FLOORS: Shear walls shall have interconnection between stories to transfer overturning and shear forces through the floor. (Tier 2: Sec. 4.4.2.7.5) |
| C | NC | N/A | HILLSIDE SITE: For a sloping site greater than one-half story, all shear walls on the downhill slope shall have an aspect ratio less than 1 to 1 for Life-Safety and 1 to 2 for Immediate Occupancy. (Tier 2: Sec. 4.4.2.7.6) |
| C | NC | N/A | CRIPPLE WALLS All cripple walls below first floor level shear walls shall be braced to the foundation with shear elements. (Tier 2: Sec. 4.4.2.7.7) |

Connections

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| C | NC | N/A | WOOD POSTS: There shall be a positive connection of wood posts to the foundation. (Tier 2: Sec. 4.6.3.3) |
| C | NC | N/A | WOOD SILLS All wood sills shall be bolted to the foundation. (Tier 2: Sec. 4.6.3.4) |
| C | NC | N/A | GIRDER/COLUMN CONNECTION: There shall be a positive connection between the girder and the column support. (Tier 2: Sec. 4.6.4.1) |

3.7.2S Supplemental Structural Checklist For Building Type W2: Wood Frames, Commercial And Industrial

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

- C NC N/A OPENINGS: Walls with garage doors or other large openings shall be braced with plywood shear walls or shall be supported by adjacent construction through substantial positive ties. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec 4.4.2.7.8)
- C NC N/A HOLD-DOWN ANCHORS: All walls shall have properly constructed hold-down anchors. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec 4.4.2.7.9)

Diaphragms

- C NC N/A DIAPHRAGM CONTINUITY: The diaphragms shall not be composed of split-level floors. In wood buildings, the diaphragms shall not have expansion joints. (Tier 2: Sec. 4.5.1.1)
- C NC N/A ROOF CHORD CONTINUITY: All chord elements shall be continuous, regardless of changes in roof elevation. (Tier 2: Sec. 4.5.1.3)
- C NC N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)
- C NC N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8)
- C NC N/A STRAIGHT SHEATHING: All straight sheathed diaphragms shall have aspect ratios less than 2 to 1 for Life Safety and 1 to 1 for Immediate Occupancy in the direction being considered. (Tier 2: Sec. 4.5.2.1)
- C NC N/A SPANS: All wood diaphragms with spans greater than 24 ft. for Life Safety and 12 ft. for Immediate Occupancy shall consist of wood structural panels or diagonal sheathing. Wood commercial and industrial buildings may have rod-braced systems. (Tier 2: Sec. 4.5.2.2)
- C NC N/A UNBLOCKED DIAPHRAGMS: All unblocked wood structural panel diaphragms shall have horizontal spans less than 40 ft. for Life Safety and 25 ft. for Immediate Occupancy and shall have aspect ratios less than or equal to 4 to 1 for Life Safety and 3 to 1 for Immediate Occupancy. (Tier 2: Sec. 4.5.2.3)
- C NC N/A OTHER DIAPHRAGMS: The diaphragm shall not consist of a system other than those described in Section 4.5. (Tier 2: Sec. 4.5.7.1)

Connections

- C NC N/A WOOD SILL BOLTS: Sill bolts shall be spaced at 6 ft. or less for Life Safety and 4 ft. or less for Immediate Occupancy, with proper edge distance provided for wood and concrete. (Tier 2: Sec. 4.6.3.9)

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3.7.3 Basic Structural Checklist For Building Type S1: Steel Moment Frames With Stiff Diaphragms

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

These buildings consist of a frame assembly of steel beams and steel columns. Floor and roof framing consists of cast-in-place concrete slabs or metal deck with concrete fill supported on steel beams, open web joists or steel trusses. Lateral forces are resisted by steel moment frames that develop their stiffness through rigid or semi-rigid beam-column connections. When all connections are moment resisting connections the entire frame participates in lateral force resistance. When only selected connections are moment resisting connections, resistance is provided along discrete frame lines. Columns are oriented so that each principal direction of the building has columns resisting forces in strong axis bending. Diaphragms consist of concrete or metal deck with concrete fill and are stiff relative to the frames. When the exterior of the structure is concealed, walls consist of metal panel curtain walls, glazing, brick masonry, or precast concrete panels. When the interior of the structure is finished, frames are concealed by ceilings, partition walls and architectural column furring. Foundations consist of concrete spread footings or deep pile foundations.

Building System

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| C | NC | N/A | LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1) |
| C | NC | N/A | ADJACENT BUILDINGS: An adjacent building shall not be located next to the structure being evaluated closer than 4% of the height for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.1.3) |
| C | NC | N/A | MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3) |
| C | NC | N/A | WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1) |

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2) |
| C | NC | N/A | GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3) |
| C | NC | N/A | VERTICAL DISCONTINUITIES All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |
| C | NC | N/A | MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5) |
| C | NC | N/A | TORSION: The distance between the story center of mass and the story center of rigidity shall be less than 20% of the building width in either plan dimension for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.6) |
| C | NC | N/A | DETERIORATION OF STEEL: There shall be no visible rusting, corrosion, cracking or other deterioration in any of the steel elements or connections in the vertical- or lateral-force-resisting systems. (Tier 2: Sec. 4.3.3.3) |
| C | NC | N/A | DETERIORATION OF CONCRETE: There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements. (Tier 2: Sec. 4.3.3.4) |

Lateral Force Resisting System

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| C | NC | N/A | REDUNDANCY: The number of lines of moment frames in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. The number of bays of moment frames in each line shall be greater than or equal to 2 for Life Safety and 3 for Immediate Occupancy. (Tier 2: Sec. 4.4.1.1.1) |
| C | NC | N/A | INTERFERING WALLS: All infill walls placed in moment frames shall be isolated from structural elements. (Tier 2: Sec. 4.4.1.2.1) |
| C | NC | N/A | DRIFT CHECK: The drift ratio of the steel moment frames, calculated using the Quick Check procedure of Section 3.5.3.1, shall be less than 0.025 for Life Safety and 0.015 for Immediate Occupancy. (Tier 2: Sec. 4.4.1.3.1) |
| C | NC | N/A | AXIAL STRESS CHECK: The axial stress due to gravity loads in columns subjected to overturning forces shall be less than $0.10F_y$ for Life Safety and Immediate Occupancy. Alternatively, the axial stress due to overturning forces alone, calculated using the Quick Check Procedure of Section 3.5.3.6, shall be less than $0.30F_y$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.1.3.2) |

Connections

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| C | NC | N/A | TRANSFER TO STEEL FRAMES: Diaphragms shall be connected for transfer of loads to the steel frames for Life Safety and the connections shall be able to develop the shear strength of the frames for Immediate Occupancy. (Tier 2: Sec. 4.6.2.2) |
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Chapter 3.0 - Screening Phase (Tier 1)

C **NC** **N/A** STEEL COLUMNS: The columns in lateral-force-resisting frames shall be anchored to the building foundation for Life Safety and the anchorage shall be able to develop the tensile capacity of the foundation for Immediate Occupancy. (Tier 2: Sec. 4.6.3.1)

3.7.3S Supplemental Structural Checklist For Building Type S1: Steel Moment Frames With Stiff Diaphragms

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

- C NC N/A MOMENT-RESISTING CONNECTIONS: All moment connections shall be able to develop the strength of the adjoining members or panel zones. (Tier 2: Sec. 4.4.1.3.3)
- C NC N/A PANEL ZONES: All panel zones shall have the shear capacity to resist the shear demand required to develop $0.8\Sigma M_p$ of the girders framing in at the face of the column. (Tier 2: Sec. 4.4.1.3.4)
- C NC N/A COLUMN SPLICES: All column splice details located in moment resisting frames shall include connection of both flanges and the web for Life Safety and the splice shall develop the strength of the column for Immediate Occupancy. (Tier 2: Sec. 4.4.1.3.5)
- C NC N/A STRONG COLUMN/WEAK BEAM: The percent of strong column/weak beam joints in each story of each line of moment resisting frames shall be greater than 50% for Life Safety and 75% for Immediate Occupancy. (Tier 2: Sec. 4.4.1.3.6)
- C NC N/A COMPACT MEMBERS: All moment frame elements shall meet compact section requirements set forth by the *Load and Resistance Factor Design Specification for Structural Steel Buildings* (AISC, 1993). This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.7)
- C NC N/A BEAM PENETRATIONS: All openings in frame-beam webs shall be less than 1/4 of the beam depth and shall be located in the center half of the beams. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.8)
- C NC N/A GIRDER FLANGE CONTINUITY PLATES: There shall be girder flange continuity plates at all moment-resisting frame joints. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.9)
- C NC N/A OUT-OF-PLANE BRACING: Beam-column joints shall be braced out-of-plane. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.10)
- C NC N/A BOTTOM FLANGE BRACING: The bottom flange of beams shall be braced out-of-plane. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.11)

Diaphragms

- C NC N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)
- C NC N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8)

Chapter 3.0 - Screening Phase (Tier 1)

Connections

C	NC	N/A	LATERAL LOAD AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for Life Safety, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for Immediate Occupancy. (Tier 2: Sec. 4.6.3.10)
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3.7.3A Basic Structural Checklist For Building Type S1A: Steel Moment Frames With Flexible Diaphragms

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

These buildings consist of a frame assembly of steel beams and steel columns. Floor and roof framing consists of wood framing or untopped metal deck supported on steel beams, open web joists or steel trusses. Lateral forces are resisted by steel moment frames that develop their stiffness through rigid or semi-rigid beam-column connections. When all connections are moment resisting connections the entire frame participates in lateral force resistance. When only selected connections are moment resisting connections, resistance is provided along discrete frame lines. Columns are oriented so that each principal direction of the building has columns resisting forces in strong axis bending. Diaphragms consist of wood sheathing or untopped metal deck, and are flexible relative to the frames. When the exterior of the structure is concealed, walls consist of metal panel curtain walls, glazing, brick masonry, or precast concrete panels. When the interior of the structure is finished, frames are concealed by ceilings, partition walls and architectural column furring. Foundations consist of concrete spread footings or deep pile foundations.

Building System

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| C | NC | N/A | LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1) |
| C | NC | N/A | ADJACENT BUILDINGS: An adjacent building shall not be located next to the structure being evaluated closer than 4% of the height for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.1.3) |
| C | NC | N/A | MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.2) |
| C | NC | N/A | WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1) |
| C | NC | N/A | SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2) |

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3) |
| C | NC | N/A | VERTICAL DISCONTINUITIES All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |
| C | NC | N/A | MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5) |
| C | NC | N/A | DETERIORATION OF WOOD: There shall be no signs of decay, shrinkage, splitting, fire damage, or sagging in any of the wood members and none of the metal accessories shall be deteriorated, broken, or loose. (Tier 2: Sec. 4.3.3.1) |
| C | NC | N/A | DETERIORATION OF STEEL: There shall be no visible rusting, corrosion, cracking or other deterioration in any of the steel elements or connections in the vertical- or lateral-force-resisting systems. (Tier 2: Sec. 4.3.3.3) |

Lateral Force Resisting System

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| C | NC | N/A | REDUNDANCY: The number of lines of moment frames in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. The number of bays of moment frames in each line shall be greater than or equal to 2 for Life Safety and 3 for Immediate Occupancy. (Tier 2: Sec. 4.4.1.1.1) |
| C | NC | N/A | INTERFERING WALLS: All infill walls placed in moment frames shall be isolated from structural elements. (Tier 2: Sec. 4.4.1.2.1) |
| C | NC | N/A | DRIFT CHECK: The drift ratio of the steel moment frames, calculated using the Quick Check procedure of Section 3.5.3.1, shall be less than 0.025 for Life Safety and 0.015 for Immediate Occupancy. (Tier 2: Sec. 4.4.1.3.1) |
| C | NC | N/A | AXIAL STRESS CHECK: The axial stress due to gravity loads in columns subjected to overturning forces shall be less than $0.10F_y$ for Life Safety and Immediate Occupancy. Alternatively, the axial stresses due to overturning forces alone, calculated using the Quick Check Procedure of Section 3.5.3.6, shall be less than $0.30F_y$ for Life Safety and Immediate Occupancy. (Tier2: Sec. 4.4.1.3.2) |

Connections

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| C | NC | N/A | TRANSFER TO STEEL FRAMES: Diaphragms shall be connected for transfer of loads to the steel frames for Life Safety and the connections shall be able to develop the shear strength of the frames for Immediate Occupancy. (Tier 2: Sec. 4.6.2.2) |
| C | NC | N/A | STEEL COLUMNS: The columns in lateral-force-resisting frames shall be anchored to the building foundation for Life Safety and the anchorage shall be able to develop the tensile capacity of the foundation for Immediate Occupancy. (Tier 2: Sec. 4.6.3.1) |

3.7.3AS Supplemental Structural Checklist For Building Type S1A: Steel Moment Frames With Flexible Diaphragms

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

- C NC N/A MOMENT-RESISTING CONNECTIONS: All moment connections shall be able to develop the strength of the adjoining members or panel zones. (Tier 2: Sec. 4.4.1.3.3)
- C NC N/A PANEL ZONES: All panel zones shall have the shear capacity to resist the shear demand required to develop $0.8\Sigma M_p$ of the girders framing in at the face of the column. (Tier 2: Sec. 4.4.1.3.4)
- C NC N/A COLUMN SPLICES: All column splice details located in moment resisting frames shall include connection of both flanges and the web for Life Safety and the splice shall develop the strength of the column for Immediate Occupancy. (Tier 2: Sec. 4.4.1.3.5)
- C NC N/A STRONG COLUMN/WEAK BEAM: The percent of strong column/weak beam joints in each story of each line of moment resisting frames shall be greater than 50% for Life Safety and 75% for Immediate Occupancy. (Tier 2: Sec. 4.4.1.3.6)
- C NC N/A COMPACT MEMBERS: All moment frame elements shall meet compact section requirements set forth by the *Load and Resistance Factor Design Specification for Structural Steel Buildings* (AISC, 1993). This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.7)
- C NC N/A BEAM PENETRATIONS: All openings in frame-beam webs shall be less than 1/4 of the beam depth and shall be located in the center half of the beams. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.8)
- C NC N/A GIRDER FLANGE CONTINUITY PLATES: There shall be girder flange continuity plates at all moment-resisting frame joints. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.9)
- C NC N/A OUT-OF-PLANE BRACING: Beam-column joints shall be braced out-of-plane. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.10)
- C NC N/A BOTTOM FLANGE BRACING: The bottom flange of beams shall be braced out-of-plane. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.11)

Diaphragms

- C NC N/A CROSS TIES: There shall be continuous cross ties between diaphragm chords. (Tier 2: Sec. 4.5.1.2)
- C NC N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension . This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8) |
| C | NC | N/A | STRAIGHT SHEATHING: All straight sheathed diaphragms shall have aspect ratios less than 2 to 1 for Life Safety and 1 to 1 for Immediate Occupancy in the direction being considered. (Tier 2: Sec. 4.5.2.1) |
| C | NC | N/A | SPANS: All wood diaphragms with spans greater than 24 ft. for Life Safety and 12 ft. for Immediate Occupancy shall consist of wood structural panels or diagonal sheathing. Wood commercial and industrial buildings may have rod-braced systems. (Tier 2: Sec. 4.5.2.2) |
| C | NC | N/A | UNBLOCKED DIAPHRAGMS: All unblocked wood structural panel diaphragms shall have horizontal spans less than 40 ft. for Life Safety and 25 ft. for Immediate Occupancy and shall have aspect ratios less than or equal to 4 to 1 for Life Safety and 3 to 1 for Immediate Occupancy. (Tier 2: Sec. 4.5.2.3) |
| C | NC | N/A | NON-CONCRETE DIAPHRAGMS: Untopped metal deck diaphragms or metal deck diaphragms with fill other than concrete shall consist of horizontal spans of less than 40 ft. and shall have aspect ratios less than 4 to 1. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.3.1) |
| C | NC | N/A | OTHER DIAPHRAGMS: The diaphragm shall not consist of a system other than those described in Section 4.5. (Tier 2: Sec. 4.5.7.1) |

Connections

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| C | NC | N/A | LATERAL LOAD AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for Life Safety, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for Immediate Occupancy. (Tier 2: Sec. 4.6.3.10) |
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3.7.4 Basic Structural Checklist For Building Type S2: Steel Braced Frames With Stiff Diaphragms

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

These buildings consist of a frame assembly of steel beams and steel columns. Floor and roof framing consists of cast-in-place concrete slabs or metal deck with concrete fill supported on steel beams, open web joists or steel trusses. Lateral forces are resisted by tension and compression forces in diagonal steel members. When diagonal brace connections are concentric to beam column joints, all member stresses are primarily axial. When diagonal brace connections are eccentric to the joints, members are subjected to bending and axial stresses. Diaphragms consist of concrete or metal deck with concrete fill and are stiff relative to the frames. When the exterior of the structure is concealed, walls consist of metal panel curtain walls, glazing, brick masonry, or precast concrete panels. When the interior of the structure is finished, frames are concealed by ceilings, partition walls and architectural furring. Foundations consist of concrete spread footings or deep pile foundations.

Building System

C	NC	N/A	LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1)
C	NC	N/A	MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3)
C	NC	N/A	WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1)
C	NC	N/A	SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2)
C	NC	N/A	GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3)

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | VERTICAL DISCONTINUITIES All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |
| C | NC | N/A | MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5) |
| C | NC | N/A | TORSION: The distance between the story center of mass and the story center of rigidity shall be less than 20% of the building width in either plan dimension for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.6) |
| C | NC | N/A | DETERIORATION OF STEEL: There shall be no visible rusting, corrosion, cracking or other deterioration in any of the steel elements or connections in the vertical- or lateral-force-resisting systems. (Tier 2: Sec. 4.3.3.3) |
| C | NC | N/A | DETERIORATION OF CONCRETE: There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements. (Tier 2: Sec. 4.3.3.4) |

Lateral Force Resisting System

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| C | NC | N/A | AXIAL STRESS CHECK: The axial stress due to gravity loads in columns subjected to overturning forces shall be less than $0.10F_y$ for Life Safety and Immediate Occupancy. Alternatively, the axial stress due to overturning forces alone, calculated using the Quick Check Procedure of Section 3.5.3.6, shall be less than $0.30F_y$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.1.3.2) |
| C | NC | N/A | REDUNDANCY: The number of lines of braced frames in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. The number of braced bays in each line shall be greater than 2 for Life Safety and 3 for Immediate Occupancy. (Tier 2: Sec. 4.4.3.1.1) |
| C | NC | N/A | AXIAL STRESS CHECK: The axial stress in the diagonals, calculated using the Quick Check procedure of Section 3.5.3.4, shall be less than 18 ksi or $0.50F_y$ for Life Safety and for Immediate Occupancy. (Tier 2: Sec. 4.4.3.1.2) |
| C | NC | N/A | COLUMN SPLICES: All column splice details located in braced frames shall develop the tensile strength of the column. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.3.1.5) |

Connections

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| C | NC | N/A | TRANSFER TO STEEL FRAMES: Diaphragms shall be connected for transfer of loads to the steel frames for Life Safety and the connections shall be able to develop the shear strength of the frames for Immediate Occupancy. (Tier 2: Sec. 4.6.2.2) |
| C | NC | N/A | STEEL COLUMNS: The columns in lateral-force-resisting frames shall be anchored to the building foundation for Life Safety and the anchorage shall be able to develop the tensile capacity of the foundation for Immediate Occupancy. (Tier 2: Sec. 4.6.3.1) |

3.7.4S Supplemental Structural Checklist For Building Type S2: Steel Braced Frames With Stiff Diaphragms

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

- C NC N/A MOMENT-RESISTING CONNECTIONS: All moment connections shall be able to develop the strength of the adjoining members or panel zones. (Tier 2: Sec. 4.4.1.3.3)
- C NC N/A COMPACT MEMBERS: All moment frame elements shall meet compact section requirements set forth by the *Load and Resistance Factor Design Specification for Structural Steel Buildings* (AISC, 1993). This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.7)
- C NC N/A STIFFNESS OF DIAGONALS: All diagonal elements required to carry compression shall have KI/r ratios less than 120. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.3.1.3)
- C NC N/A CONNECTION STRENGTH: All the brace connections shall develop the yield capacity of the diagonals. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.3.1.4)
- C NC N/A OUT-OF-PLANE BRACING: Braced frame connections attached to beam bottom flanges located away from beam-column joints shall be braced out-of-plane at the bottom flange of the beams. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.3.1.6)
- C NC N/A K-BRACING: The bracing system shall not include K-braced bays. (Tier 2: Sec. 4.4.3.2.1)
- C NC N/A TENSION-ONLY BRACES: Tension-only braces shall not comprise more than 70% of the total lateral-force-resisting capacity in structures over two stories in height. (Tier 2: Sec. 4.4.3.2.2)
- C NC N/A CHEVRON BRACING: The bracing system shall not include chevron, or V-braced bays. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.3.2.3)
- C NC N/A CONCENTRIC JOINTS: All the diagonal braces shall frame into the beam-column joints concentrically. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.3.2.4)

Diaphragms

- C NC N/A OPENINGS AT BRACED FRAMES: Diaphragm openings immediately adjacent to the braced frames shall extend less than 25% of the frame length for Life Safety and 15% of the frame length for Immediate Occupancy. (Tier 2: Sec. 4.5.1.5)
- C NC N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)

Chapter 3.0 - Screening Phase (Tier 1)

C NC N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension . This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8)

Connections

C NC N/A LATERAL LOAD AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for Life Safety, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for Immediate Occupancy . (Tier 2: Sec. 4.6.3.10)

3.7.4A Basic Structural Checklist For Building Type S2A: Steel Braced Frames With Flexible Diaphragms

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

These buildings consist of a frame assembly of steel beams and steel columns. Floor and roof framing consists of wood framing or untopped metal deck supported on steel beams, open web joists or steel trusses. Lateral forces are resisted by tension and compression forces in diagonal steel members. When diagonal brace connections are concentric to beam column joints, all member stresses are primarily axial. When diagonal brace connections are eccentric to the joints, members are subjected to bending and axial stresses. Diaphragms consist of wood sheathing or untopped metal deck and are flexible relative to the frames. When the exterior of the structure is concealed, walls consist of metal panel curtain walls, glazing, brick masonry, or precast concrete panels. When the interior of the structure is finished, frames are concealed by ceilings, partition walls and architectural furring. Foundations consist of concrete spread

Building System

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| C | NC | N/A | LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1) |
| C | NC | N/A | ADJACENT BUILDINGS: An adjacent building shall not be located next to the structure being evaluated closer than 4% of the height for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.1.2) |
| C | NC | N/A | MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3) |
| C | NC | N/A | WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1) |
| C | NC | N/A | SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2) |

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3) |
| C | NC | N/A | VERTICAL DISCONTINUITIES All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |
| C | NC | N/A | MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5) |
| C | NC | N/A | DETERIORATION OF WOOD: There shall be no signs of decay, shrinkage, splitting, fire damage, or sagging in any of the wood members and none of the metal accessories shall be deteriorated, broken, or loose. (Tier 2: Sec. 4.3.3.1) |
| C | NC | N/A | DETERIORATION OF STEEL: There shall be no visible rusting, corrosion, cracking or other deterioration in any of the steel elements or connections in the vertical- or lateral-force-resisting systems. (Tier 2: Sec. 4.3.3.3) |

Lateral Force Resisting System

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| C | NC | N/A | AXIAL STRESS CHECK: The axial stress due to gravity loads in columns subjected to overturning forces shall be less than $0.10F_y$ for Life Safety and Immediate Occupancy. Alternatively, the axial stress due to overturning forces alone, calculated using the Quick Check Procedure of Section 3.5.3.6, shall be less than $0.30F_y$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.1.3.2) |
| C | NC | N/A | REDUNDANCY: The number of lines of braced frames in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. The number of braced bays in each line shall be greater than 2 for Life Safety and 3 for Immediate Occupancy. (Tier 2: Sec. 4.4.3.1.1) |
| C | NC | N/A | AXIAL STRESS CHECK: The axial stress in the diagonals, calculated using the Quick Check procedure of Section 3.5.3.4, shall be less than 18 ksi or $0.50F_y$ for Life Safety and for Immediate Occupancy. (Tier 2: Sec. 4.4.3.1.2) |
| C | NC | N/A | COLUMN SPLICES: All column splice details located in braced frames shall develop the tensile strength of the column. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.3.1.5) |

Connections

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| C | NC | N/A | TRANSFER TO STEEL FRAMES: Diaphragms shall be connected for transfer of loads to the steel frames for Life Safety and the connections shall be able to develop the shear strength of the frames for Immediate Occupancy. (Tier 2: Sec. 4.6.2.2) |
| C | NC | N/A | STEEL COLUMNS: The columns in lateral-force-resisting frames shall be anchored to the building foundation for Life Safety and the anchorage shall be able to develop the tensile capacity of the foundation for Immediate Occupancy. (Tier 2: Sec. 4.6.3.1) |

3.7.4AS Supplemental Structural Checklist For Building Type S2A: Steel Braced Frames With Flexible Diaphragms

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

- C NC N/A MOMENT-RESISTING CONNECTIONS: All moment connections shall be able to develop the strength of the adjoining members or panel zones. (Tier 2: Sec. 4.4.1.3.3)
- C NC N/A COMPACT MEMBERS: All moment frame elements shall meet compact section requirements set forth by the *Load and Resistance Factor Design Specification for Structural Steel Buildings* (AISC, 1993). This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.7)
- C NC N/A STIFFNESS OF DIAGONALS: All diagonal elements required to carry compression shall have KI/r ratios less than 120. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.3.1.3)
- C NC N/A CONNECTION STRENGTH: All the brace connections shall develop the yield capacity of the diagonals. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.3.1.4)
- C NC N/A OUT-OF-PLANE BRACING: Braced frame connections attached to beam bottom flanges located away from beam-column joints shall be braced out-of-plane at the bottom flange of the beams. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.3.1.6)
- C NC N/A K-BRACING: The bracing system shall not include K-braced bays. (Tier 2: Sec. 4.4.3.2.1)
- C NC N/A TENSION-ONLY BRACES: Tension-only braces shall not comprise more than 70% of the total lateral-force-resisting capacity in structures over two stories in height. (Tier 2: Sec. 4.4.3.2.2)
- C NC N/A CHEVRON BRACING: The bracing system shall not include chevron, or V-braced bays. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.3.2.3)
- C NC N/A CONCENTRIC JOINTS: All the diagonal braces shall frame into the beam-column joints concentrically. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.3.2.4)

Diaphragms

- C NC N/A CROSS TIES: There shall be continuous cross ties between diaphragm chords. (Tier 2: Sec. 4.5.1.2)
- C NC N/A OPENINGS AT BRACED FRAMES: Diaphragm openings immediately adjacent to the braced frames shall extend less than 25% of the frame length for Life Safety and 15% of the frame length for Immediate Occupancy. (Tier 2: Sec. 4.5.1.5)
- C NC N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension . This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8) |
| C | NC | N/A | STRAIGHT SHEATHING: All straight sheathed diaphragms shall have aspect ratios less than 2 to 1 for Life Safety and 1 to 1 for Immediate Occupancy in the direction being considered. (Tier 2: Sec. 4.5.2.1) |
| C | NC | N/A | SPANS: All wood diaphragms with spans greater than 24 ft. for Life Safety and 12 ft. for Immediate Occupancy shall consist of wood structural panels or diagonal sheathing. Wood commercial and industrial buildings may have rod-braced systems. (Tier 2: Sec. 4.5.2.2) |
| C | NC | N/A | UNBLOCKED DIAPHRAGMS: All unblocked wood structural panel diaphragms shall have horizontal spans less than 40 ft. for Life Safety and 25 ft. for Immediate Occupancy and shall have aspect ratios less than or equal to 4 to 1 for Life Safety and 3 to 1 for Immediate Occupancy. (Tier 2: Sec. 4.5.2.3) |
| C | NC | N/A | NON-CONCRETE DIAPHRAGMS: Untopped metal deck diaphragms or metal deck diaphragms with fill other than concrete shall consist of horizontal spans of less than 40 ft. and shall have aspect ratios less than 4 to 1. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.3.1) |

Connections

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| C | NC | N/A | LATERAL LOAD AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for Life Safety, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for Immediate Occupancy . (Tier 2: Sec. 4.6.3.10) |
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3.7.5 Basic Structural Checklist For Building Type S3: Steel Light Frames

This Basic Structural Checklist shall be completed when required by Table 3-2. This Basic Structural Checklist shall not be used for a structure with a roof dead load greater than 25 psf or a building area greater than 20,000 ft. When either limit is exceeded, a Steel Moment Frame Basic Structural Checklist (Type S1 or S1A) shall be used.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

These buildings are pre-engineered and prefabricated with transverse rigid steel frames. They are one-story in height. The roof and walls consist of lightweight metal, fiberglass or cementitious panels. The frames are designed for maximum efficiency and the beams and columns consist of tapered, built-up sections with thin plates. The frames are built in segments and assembled in the field with bolted or welded joints. Lateral forces in the transverse direction are resisted by the rigid frames. Lateral forces in the longitudinal direction are resisted by wall panel shear elements or rod bracing. Diaphragm forces are resisted by untopped metal deck, roof panel shear elements, or a system of tension-only rod bracing.

Building System

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| C | NC | N/A | LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1) |
| C | NC | N/A | MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3) |
| C | NC | N/A | VERTICAL DISCONTINUITIES: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |
| C | NC | N/A | TORSION: The distance between the story center of mass and the story center of rigidity shall be less than 20% of the building width in either plan dimension for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.6) |
| C | NC | N/A | DETERIORATION OF STEEL: There shall be no visible rusting, corrosion, cracking or other deterioration in any of the steel elements or connections in the vertical- or lateral-force-resisting systems. (Tier 2: Sec. 4.3.3.3) |

Chapter 3.0 - Screening Phase (Tier 1)

Lateral Force Resisting System

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| C | NC | N/A | AXIAL STRESS CHECK: The axial stress in the diagonals, calculated using the Quick Check procedure of Section 3.5.3.4, shall be less than 18 ksi or $0.50F_y$ for Life Safety and for Immediate Occupancy. (Tier 2: Sec. 4.4.3.1.2) |
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Connections

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| C | NC | N/A | TRANSFER TO STEEL FRAMES: Diaphragms shall be connected for transfer of loads to the steel frames for Life Safety and the connections shall be able to develop the shear strength of the frames for Immediate Occupancy. (Tier 2: Sec. 4.6.2.2) |
| C | NC | N/A | STEEL COLUMNS: The columns in lateral-force-resisting frames shall be anchored to the building foundation for Life Safety and the anchorage shall be able to develop the tensile capacity of the foundation for Immediate Occupancy. (Tier 2: Sec. 4.6.3.1) |
| C | NC | N/A | WALL PANELS Metal, fiberglass or cementitious wall panels shall be positively attached to the foundation for Life Safety and the attachment shall be able to develop the shear capacity of the panels for Immediate Occupancy. (Tier 2: Sec. 4.6.3.8) |
| C | NC | N/A | ROOF PANELS: Metal, plastic, or cementitious roof panels shall be positively attached to the roof framing to resist seismic forces for Life Safety and the attachment shall be able to develop the strength of the panels for Immediate Occupancy. (Tier 2: Sec. 4.6.5.1) |
| C | NC | N/A | WALL PANELS Metal, fiberglass or cementitious wall panels shall be positively attached to the framing to resist seismic forces or Life Safety and the attachment shall be able to develop the strength of the panels for Immediate Occupancy. (Tier 2: Sec. 4.6.5.2) |

3.7.5S Supplemental Structural Checklist For Building Type S3: Steel Light Frames

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist. This Supplemental Structural Checklist shall not be used for a structure with a roof dead load greater than 25 psf or a building area greater than 20,000 ft. When either limit is exceeded, a Steel Moment Frame Supplemental Structural Checklist (Type S1 or S1A) shall be used.

Lateral Force Resisting System

- C NC N/A MOMENT-RESISTING CONNECTIONS: All moment connections shall be able to develop the strength of the adjoining members or panel zones. (Tier 2: Sec. 4.4.1.3.3)
- C NC N/A BEAM PENETRATIONS: All openings in frame-beam webs shall be less than 1/4 of the beam depth and shall be located in the center half of the beams. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.8)
- C NC N/A COMPACT MEMBERS: All moment frame elements shall meet compact section requirements set forth by the *Load and Resistance Factor Design Specification for Structural Steel Buildings* (AISC, 1993). This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.7)
- C NC N/A OUT-OF-PLANE BRACING: Beam-column joints shall be braced out-of-plane. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.10)
- C NC N/A BOTTOM FLANGE BRACING: The bottom flange of beams shall be braced out-of-plane. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.11)

Diaphragms

- C NC N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)
- C NC N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragm openings larger than 50% of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8)
- C NC N/A OTHER DIAPHRAGMS: The diaphragm shall not consist of a system other than those described in Section 4.5. (Tier 2: Sec. 4.5.7.1)

Connections

- C NC N/A LATERAL LOAD AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for Life Safety, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for Immediate Occupancy. (Tier 2: Sec. 4.6.3.10)

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3.7.6 Basic Structural Checklist For Building Type S4: Steel Frames With Concrete Shear Walls

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

These buildings consist of a frame assembly of steel beams and steel columns. The floors and roof consist of cast-in-place concrete slabs or metal deck with or without concrete fill. Framing consists of steel beams, open web joists or steel trusses. Lateral forces are resisted by cast-in-place concrete shear walls. These walls are bearing walls when the steel frame does not provide a complete vertical support system. In older construction the steel frame is designed for vertical loads only. In modern dual systems, the steel moment frames are designed to work together with the concrete shear walls in proportion to their relative rigidity. In the case of a dual system, the walls shall be evaluated under this building type and the frames shall be evaluated under S1 or S1A, Steel Moment Frames. Diaphragms consist of concrete or metal deck with or without concrete fill. The steel frame may provide a secondary lateral-force-resisting system depending on the stiffness of the frame and the moment capacity of the beam-column connections.

Building System

C	NC	N/A	LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1)
C	NC	N/A	MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3)
C	NC	N/A	WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1)
C	NC	N/A	SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2)
C	NC	N/A	GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3)

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | VERTICAL DISCONTINUITIES All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |
| C | NC | N/A | MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5) |
| C | NC | N/A | TORSION: The distance between the story center of mass and the story center of rigidity shall be less than 20% of the building width in either plan dimension for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.6) |
| C | NC | N/A | DETERIORATION OF STEEL: There shall be no visible rusting, corrosion, cracking or other deterioration in any of the steel elements or connections in the vertical- or lateral-force-resisting systems. (Tier 2: Sec. 4.3.3.3) |
| C | NC | N/A | DETERIORATION OF CONCRETE: There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements. (Tier 2: Sec. 4.3.3.4) |
| C | NC | N/A | CONCRETE WALL CRACKS All existing diagonal cracks in wall elements shall be less than 1/8" for Life Safety and 1/16" for Immediate Occupancy, shall not be concentrated in one location, and shall not form an X pattern. (Tier 2: Sec. 4.3.3.9) |

Lateral Force Resisting System

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| C | NC | N/A | COMPLETE FRAMES: Steel or concrete frames classified as secondary components shall form a complete vertical load carrying system. (Tier 2: Sec. 4.4.1.6.1) |
| C | NC | N/A | REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.1.1) |
| C | NC | N/A | SHEAR STRESS CHECK: The shear stress in the concrete shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 100 psi or $2\sqrt{f'_c}$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.1) |
| C | NC | N/A | REINFORCING STEEL: The ratio of reinforcing steel area to gross concrete area shall be greater than 0.0015 in the vertical direction and 0.0025 in the horizontal direction for Life Safety and Immediate Occupancy. The spacing of reinforcing steel shall be equal to or less than 18" for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.2) |
| C | NC | N/A | COLUMN SPLICES: Steel columns encased in shear wall boundary elements shall have splices that develop the tensile strength of the column. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.9) |

Chapter 3.0 - Screening Phase (Tier 1)

Connections

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| C | NC | N/A | TRANSFER TO SHEAR WALLS Diaphragms shall be reinforced and connected for transfer of loads to the shear walls for Life Safety and the connections shall be able to develop the shear strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.2.1) |
| C | NC | N/A | WALL REINFORCING: Walls shall be doweled into the foundation for Life Safety and the dowels shall be able to develop the strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.3.5) |
| C | NC | N/A | SHEAR-WALL-BOUNDARY COLUMNS The shear wall boundary columns shall be anchored to the building foundation for Life Safety and the anchorage shall be able to develop the tensile capacity of the column for Immediate Occupancy. (Tier 2: Sec. 4.6.3.6) |

3.7.6S Supplemental Structural Checklist For Building Type S4: Steel Frames With Concrete Shear Walls

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

- C NC N/A COUPLING BEAMS: The stirrups in all coupling beams over means of egress shall be spaced at or less than $d/2$ and shall be anchored into the core with hooks of 135° or more for Life Safety and Immediate Occupancy. In addition, the beams shall have the capacity in shear to develop the uplift capacity of the adjacent wall for Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.3)
- C NC N/A OVERTURNING: All shear walls shall have aspect ratios less than 4 to 1. Wall piers need not be considered. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.4)
- C NC N/A CONFINEMENT REINFORCING: For shear walls with aspect ratios greater than 2.0, the boundary elements shall be confined with spirals or ties with spacing less than $8d_b$. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.5)
- C NC N/A REINFORCING AT OPENINGS: There shall be added trim reinforcement around all wall openings. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.6)
- C NC N/A WALL THICKNESS: Thickness of bearing walls shall not be less than $1/25$ the minimum unsupported height or length, nor less than 4". This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.7)
- C NC N/A WALL CONNECTIONS: There shall be a positive connection between the shear walls and the steel beams and columns for Life Safety and the connection shall be able to develop the strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.8)

Diaphragms

- C NC N/A OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls shall be less than 25% of the wall length for Life Safety and 15% of the wall length for Immediate Occupancy. (Tier 2: Sec. 4.5.1.4)
- C NC N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)
- C NC N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragm openings larger than 50% of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8)

Connections

- C NC N/A LATERAL LOAD AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for Life Safety, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for Immediate Occupancy. (Tier 2: Sec. 4.6.3.10)

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3.7.7 Basic Structural Checklist For Building Type S5: Steel Frames With Infill Masonry Shear Walls And Stiff Diaphragms

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the user may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

This is an older type of building construction that consists of a frame assembly of steel beams and steel columns. The floors and roof consist of cast-in-place concrete slabs or metal deck with concrete fill. Framing consists of steel beams, open web joists or steel trusses. Walls consist of infill panels constructed of solid clay brick, concrete block, or hollow clay tile masonry. Infill walls may completely encase the frame members, and present a smooth masonry exterior with no indication of the frame. The seismic performance of this type of construction depends on the interaction between the frame and infill panels. The combined behavior is more like a shear wall structure than a frame structure. Solidly infilled masonry panels form diagonal compression struts between the intersections of the frame members. If the walls are offset from the frame and do not fully engage the frame members, the diagonal compression struts will not develop. The strength of the infill panel is limited by the shear capacity of the masonry bed joint or the compression capacity of the strut. The post-cracking strength is determined by an analysis of a moment frame that is partially restrained by the cracked infill. The diaphragms consist of concrete floors and are stiff relative to the walls.

Building System

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| C | NC | N/A | LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1) |
| C | NC | N/A | MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3) |
| C | NC | N/A | WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1) |
| C | NC | N/A | SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2) |

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3) |
| C | NC | N/A | VERTICAL DISCONTINUITIES All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |
| C | NC | N/A | MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5) |
| C | NC | N/A | TORSION: The distance between the story center of mass and the story center of rigidity shall be less than 20% of the building width in either plan dimension for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.6) |
| C | NC | N/A | DETERIORATION OF STEEL: There shall be no visible rusting, corrosion, cracking or other deterioration in any of the steel elements or connections in the vertical- or lateral-force-resisting systems. (Tier 2: Sec. 4.3.3.3) |
| C | NC | N/A | DETERIORATION OF CONCRETE: There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements. (Tier 2: Sec. 4.3.3.4) |
| C | NC | N/A | MASONRY UNITS: There shall be no visible deterioration of masonry units. (Tier 2: Sec. 4.3.3.7) |
| C | NC | N/A | MASONRY JOINTS: The mortar shall not be easily scraped away from the joints by hand with a metal tool, and there shall be no areas of eroded mortar. (Tier 2: Sec.4.3.3.8) |
| C | NC | N/A | CRACKS IN INFILL WALLS: There shall be no existing diagonal cracks in infill walls that extend throughout a panel , are greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy, or have out-of-plane offsets in the bed joint greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy. (Tier 2: Sec. 4.3.3.12) |

Lateral Force Resisting System

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| C | NC | N/A | REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.1.1) |
| C | NC | N/A | SHEAR STRESS CHECK The shear stress in the reinforced masonry shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 50 psi for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.4.1) |
| C | NC | N/A | SHEAR STRESS CHECK: The shear stress in the unreinforced masonry shear walls calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 15 psi for clay units and 30 psi for concrete units for Life Safety and Immediate Occupancy (Tier 2: Sec. 4.4.2.5.1) |
| C | NC | N/A | WALL CONNECTIONS All infill walls shall have a positive connection to the frame to resist out-of-plane forces for Life Safety and the connection shall be able to develop the out-of-plane strength of the wall for Immediate Occupancy. (Tier 2: Sec. 4.4.2.6.1) |

Chapter 3.0 - Screening Phase (Tier 1)

Connections

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| C | NC | N/A | TRANSFER TO SHEAR WALLS Diaphragms shall be reinforced and connected for transfer of loads to the shear walls for Life Safety and the connections shall be able to develop the shear strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.2.1) |
| C | NC | N/A | STEEL COLUMNS: The columns in lateral-force-resisting frames shall be anchored to the building foundation for Life Safety and the anchorage shall be able to develop the tensile capacity of the foundation for Immediate Occupancy. (Tier 2: Sec. 4.6.3.1) |

3.7.7S Supplemental Structural Checklist For Building Type S5: Steel Frames With Infill Masonry Shear Walls And Stiff Diaphragms

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

- C NC N/A REINFORCING AT OPENINGS: All wall openings that interrupt rebar shall have trim reinforcing on all sides. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.4.3)
- C NC N/A PROPORTIONS: The height-to-thickness ratio of the shear walls at each story shall be less than 30. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.4.4)
- C NC N/A SOLID WALLS: The infill walls shall not be of cavity construction. (Tier 2: Sec. 4.4.2.6.3)

Diaphragms

- C NC N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)
- C NC N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8)

Connections

- C NC N/A ANCHOR SPACING: Exterior masonry walls shall be anchored to the floor and roof systems at a spacing of 4 ft. or less for Life Safety and 3 ft. or less for Immediate Occupancy. (Tier 2: Sec. 4.6.1.3)
- C NC N/A LATERAL LOAD AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for Life Safety, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for Immediate Occupancy. (Tier 2: Sec. 4.6.3.10)

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3.7.7A Basic Structural Checklist For Building Type S5A: Steel Frames With Infill Masonry Shear Walls And Flexible Diaphragms

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

This is an older type of building construction that consists of a frame assembly of steel beams and steel columns. The floors and roof consist of untopped metal deck or wood framing between the steel beams and are flexible relative to the walls. Framing consists of steel beams, open web joists or steel trusses. Walls consist of infill panels constructed of solid clay brick, concrete block, or hollow clay tile masonry. Infill walls may completely encase the frame members, and present a smooth masonry exterior with no indication of the frame. The seismic performance of this type of construction depends on the interaction between the frame and infill panels. The combined behavior is more like a shear wall structure than a frame structure. Solidly infilled masonry panels form diagonal compression struts between the intersections of the frame members. If the walls are offset from the frame and do not fully engage the frame members, the diagonal compression struts will not develop. The strength of the infill panel is limited by the shear capacity of the masonry bed joint or the compression capacity of the strut. The post-cracking strength is determined by an analysis of a moment frame that is partially restrained by the

Building System

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| C | NC | N/A | LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1) |
| C | NC | N/A | MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3) |
| C | NC | N/A | ADJACENT BUILDINGS: An adjacent building shall not be located next to the structure being evaluated closer than 4% of the height for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.1.2) |
| C | NC | N/A | WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1) |

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2) |
| C | NC | N/A | GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3) |
| C | NC | N/A | VERTICAL DISCONTINUITIES All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |
| C | NC | N/A | MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5) |
| C | NC | N/A | DETERIORATION OF WOOD: There shall be no signs of decay, shrinkage, splitting, fire damage, or sagging in any of the wood members and none of the metal accessories shall be deteriorated, broken, or loose. (Tier 2: Sec. 4.3.3.1) |
| C | NC | N/A | DETERIORATION OF STEEL: There shall be no visible rusting, corrosion, cracking or other deterioration in any of the steel elements or connections in the vertical- or lateral-force-resisting systems. (Tier 2: Sec. 4.3.3.3) |
| C | NC | N/A | MASONRY UNITS: There shall be no visible deterioration of masonry units. (Tier 2: Sec. 4.3.3.7) |
| C | NC | N/A | MASONRY JOINTS: The mortar shall not be easily scraped away from the joints by hand with a metal tool, and there shall be no areas of eroded mortar. (Tier 2: Sec. 4.3.3.8) |
| C | NC | N/A | CRACKS IN INFILL WALLS: There shall be no existing diagonal cracks in infill walls that extend throughout a panel, are greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy, or have out-of-plane offsets in the bed joint greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy. (Tier 2: Sec. 4.3.3.12) |

Lateral Force Resisting System

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| C | NC | N/A | REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.1.1) |
| C | NC | N/A | SHEAR STRESS CHECK The shear stress in the reinforced masonry shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 50 psi for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.4.1) |
| C | NC | N/A | SHEAR STRESS CHECK: The shear stress in the unreinforced masonry shear walls calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 15 psi for clay units and 30 psi for concrete units for Life Safety and Immediate Occupancy (Tier 2: Sec. 4.4.2.5.1) |
| C | NC | N/A | WALL CONNECTIONS All infill walls shall have a positive connection to the frame to resist out-of-plane forces for Life Safety and the connection shall be able to develop the out-of-plane strength of the wall for Immediate Occupancy. (Tier 2: Sec. 4.4.2.6.1) |

Chapter 3.0 - Screening Phase (Tier 1)

Connections

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| C | NC | N/A | TRANSFER TO SHEAR WALLS Diaphragms shall be reinforced and connected for transfer of loads to the shear walls for Life Safety and the connections shall be able to develop the shear strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.2.1) |
| C | NC | N/A | STEEL COLUMNS: The columns in lateral-force-resisting frames shall be anchored to the building foundation for Life Safety and the anchorage shall be able to develop the tensile capacity of the foundation for Immediate Occupancy. (Tier 2: Sec. 4.6.3.1) |

3.7.7AS Supplemental Structural Checklist For Building Type S5A: Steel Frames With Infill Masonry Shear Walls And Flexible Diaphragms

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

- C NC N/A REINFORCING AT OPENINGS: All wall openings that interrupt rebar shall have trim reinforcing on all sides. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.4.3)
- C NC N/A PROPORTIONS: The height-to-thickness ratio of the infill walls at each story shall be less than 9 for Life Safety in regions of high seismicity, 13 for Immediate Occupancy in regions of moderate seismicity, and 8 for Immediate Occupancy in regions of high seismicity. (Tier 2: Sec. 4.4.2.6.2)
- C NC N/A SOLID WALLS: The infill walls shall not be of cavity construction. (Tier 2: Sec. 4.4.2.6.3)

Diaphragms

- C NC N/A CROSS TIES: There shall be continuous cross ties between diaphragm chords. (Tier 2: Sec. 4.5.1.2)
- C NC N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)
- C NC N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8)
- C NC N/A STRAIGHT SHEATHING: All straight sheathed diaphragms shall have aspect ratios less than 2 to 1 for Life Safety and 1 to 1 for Immediate Occupancy in the direction being considered. (Tier 2: Sec. 4.5.2.1)
- C NC N/A SPANS: All wood diaphragms with spans greater than 24 ft. for Life Safety and 12 ft. for Immediate Occupancy shall consist of wood structural panels or diagonal sheathing. Wood commercial and industrial buildings may have rod-braced systems. (Tier 2: Sec. 4.5.2.2)
- C NC N/A UNBLOCKED DIAPHRAGMS: All unblocked wood structural panel diaphragms shall have horizontal spans less than 40 ft. for Life Safety and 25 ft. for Immediate Occupancy and shall have aspect ratios less than or equal to 4 to 1 for Life Safety and 3 to 1 for Immediate Occupancy. (Tier 2: Sec. 4.5.2.3)
- C NC N/A ASPECT RATIO: All wood diaphragms with an aspect ratio greater than 3 to 1 for Life Safety and 2 to 1 for Immediate Occupancy shall have nonstructural walls connected to all diaphragm levels at a spacing less than 40 ft. for Life Safety and 25 ft. for Immediate Occupancy. (Tier 2: Sec. 4.5.2.4)
- C NC N/A NON-CONCRETE DIAPHRAGMS: Untopped metal deck diaphragms or metal deck diaphragms with fill other than concrete shall consist of horizontal spans of less than 40 ft. and shall have aspect ratios less than 4 to 1. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.3.1)

Chapter 3.0 - Screening Phase (Tier 1)

C NC N/A OTHER DIAPHRAGMS: The diaphragm shall not consist of a system other than those described in Section 4.5. (Tier 2: Sec. 4.5.7.1)

Connections

C NC N/A ANCHOR SPACING: Exterior masonry walls shall be anchored to the floor and roof systems at a spacing of 4 ft. or less for Life Safety and 3 ft. or less for Immediate Occupancy (Tier 2: Sec. 4.6.1.3)

C NC N/A STIFFNESS OF WALL ANCHORS: Anchors of concrete or masonry walls to wood structural elements shall be installed taut and shall be stiff enough to prevent movement between the wall and the diaphragm. If bolts are present, the size of the bolt holes in both the connector and framing shall be a maximum of 1/16" larger than the bolt diameter. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.6.1.5)

C NC N/A LATERAL LOAD AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for Life Safety, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for Immediate Occupancy. (Tier 2: Sec. 4.6.3.10)

3.7.8 Basic Structural Checklist For Building Type C1: Concrete Moment Frames

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

These buildings consist of a frame assembly of cast-in-place concrete beams and columns. Floor and roof framing consists of cast-in-place concrete slabs, concrete beams, one-way joists, two-way waffle joists, or flat slabs. Lateral forces are resisted by concrete moment frames that develop their stiffness through monolithic beam-column connections. In older construction, or in regions of low seismicity, the the moment frames may consist of the column strips of two-way flat slab systems. Modern frames in regions of high seismicity have joint reinforcing, closely spaced ties, and special detailing to provide ductile performance. This detailing is not present in older construction. Foundations consist of concrete spread footings or deep pile foundations.

Building System

- C NC N/A LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1)
- C NC N/A ADJACENT BUILDINGS: An adjacent building shall not be located next to the structure being evaluated closer than 4% of the height for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.1.2)
- C NC N/A MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3)
- C NC N/A WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1)
- C NC N/A SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2)
- C NC N/A GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3)

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | VERTICAL DISCONTINUITIES All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |
| C | NC | N/A | MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5) |
| C | NC | N/A | TORSION: The distance between the story center of mass and the story center of rigidity shall be less than 20% of the building width in either plan dimension for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.6) |
| C | NC | N/A | DETERIORATION OF CONCRETE: There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements. (Tier 2: Sec. 4.3.3.4) |
| C | NC | N/A | POST-TENSIONING ANCHORS: There shall be no evidence of corrosion or spalling in the vicinity of post-tensioning or end fittings. Coil anchors shall not have been used. (Tier 2: Sec. 4.3.3.5) |

Lateral Force Resisting System

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| C | NC | N/A | REDUNDANCY: The number of lines of moment frames in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. The number of bays of moment frames in each line shall be greater than or equal to 2 for Life Safety and 3 for Immediate Occupancy. (Tier 2: Sec. 4.4.1.1.1) |
| C | NC | N/A | INTERFERING WALLS: All infill walls placed in moment frames shall be isolated from structural elements. (Tier 2: Sec. 4.4.1.2.1) |
| C | NC | N/A | SHEAR STRESS CHECK The shear stress in the concrete columns, calculated using the Quick Check procedure of Section 3.5.3.2, shall be less than 100 psi or $2\sqrt{f'_c}$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.1.4.1) |
| C | NC | N/A | AXIAL STRESS CHECK: The axial stress due to gravity loads in columns subjected to overturning forces shall be less than $0.10f'_c$ for Life Safety and Immediate Occupancy. Alternatively, the axial stresses due to overturning forces alone, calculated using the Quick Check Procedure of Section 3.5.3.6, shall be less than $0.30f'_c$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.1.4.2) |

Connections

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| C | NC | N/A | CONCRETE COLUMNS: All concrete columns shall be doweled into the foundation for Life Safety and the dowels shall be able to develop the tensile capacity of the column for Immediate Occupancy. (Tier 2: Sec. 4.6.3.2) |
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3.7.8S Supplemental Structural Checklist For Building Type C1: Concrete Moment Frames

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

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| C | NC | N/A | FLAT SLAB FRAMES: The lateral-force-resisting system shall not be a frame consisting of columns and a flat slab/plate without beams. (Tier 2: Sec. 4.4.1.4.3) |
| C | NC | N/A | PRESTRESSED FRAME ELEMENTS: The lateral-load-resisting frames shall not include any prestressed or post-tensioned elements. (Tier 2: Sec. 4.4.1.4.4) |
| C | NC | N/A | SHORT CAPTIVE COLUMNS: There shall be no columns at a level with height/depth ratios less than 50% of the nominal height/depth ratio of the typical columns at that level for Life Safety and 75% for Immediate Occupancy. (Tier 2: Sec. 4.4.1.4.5) |
| C | NC | N/A | NO SHEAR FAILURES: The shear capacity of frame members shall be able to develop the moment capacity at the top and bottom of the columns. (Tier 2: Sec. 4.4.1.4.6) |
| C | NC | N/A | STRONG COLUMN/WEAK BEAM: The sum of the moment capacity of the columns shall be 20% greater than that of the beams at frame joints. (Tier 2: Sec. 4.4.1.4.7) |
| C | NC | N/A | BEAM BARS: At least two longitudinal top and two longitudinal bottom bars shall extend continuously throughout the length of each frame beam. At least 25% of the longitudinal bars provided at the joints for either positive or negative moment shall be continuous throughout the length of the members for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.1.4.8) |
| C | NC | N/A | COLUMN-BAR SPLICES: All column bar lap splice lengths shall be greater than $35 d_b$ for Life Safety and $50 d_b$ for Immediate Occupancy and shall be enclosed by ties spaced at or less than $8 d_b$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.1.4.9) |
| C | NC | N/A | BEAM-BAR SPLICES: The lap splices for longitudinal beam reinforcing shall not be located within $l_b/4$ of the joints and shall not be located within the vicinity of potential plastic hinge locations. (Tier 2: Sec. 4.4.1.4.10) |
| C | NC | N/A | COLUMN-TIE SPACING: Frame columns shall have ties spaced at or less than $d/4$ for Life Safety and Immediate Occupancy throughout their length and at or less than $8 d_b$ for Life Safety and Immediate Occupancy at all potential plastic hinge locations. (Tier 2: Sec. 4.4.1.4.11) |
| C | NC | N/A | STIRRUP SPACING: All beams shall have stirrups spaced at or less than $d/2$ for Life Safety and Immediate Occupancy throughout their length. At potential plastic hinge locations stirrups shall be spaced at or less than the minimum of $8 d_b$ or $d/4$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.1.4.12) |
| C | NC | N/A | JOINT REINFORCING: Beam-column joints shall have ties spaced at or less than $8d_b$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.1.4.13) |
| C | NC | N/A | JOINT ECCENTRICITY: There shall be no eccentricities larger than 20% of the smallest column plan dimension between girder and column centerlines. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.4.14) |

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | STIRRUP AND TIE HOOKS: The beam stirrups and column ties shall be anchored into the member cores with hooks of 135° or more. This statement shall apply to the Immediate Occupancy Performance Level only.(Tier 2: Sec. 4.4.1.4.15) |
| C | NC | N/A | DEFLECTION COMPATIBILITY: Secondary components shall have the shear capacity to develop the flexural strength of the elements for Life Safety and shall have ductile detailing for Immediate Occupancy. (Tier 2: Sec. 4.4.1.6.2) |
| C | NC | N/A | FLAT SLABS: Flat slabs/plates classified as secondary components shall have continuous bottom steel through the column joints for Life Safety. Flat slabs/plates shall not be permitted for the Immediate Occupancy Performance Level. Tier 2: Sec. 4.4.1.6.3) |

Diaphragms

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| C | NC | N/A | DIAPHRAGM CONTINUITY: The diaphragms shall not be composed of split-level floors. In wood buildings, the diaphragms shall not have expansion joints. (Tier 2: Sec. 4.5.1.1) |
| C | NC | N/A | PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only.(Tier 2: Sec. 4.5.1.7) |
| C | NC | N/A | DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension . This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8) |

Connections

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|---|----|-----|---|
| C | NC | N/A | LATERAL LOAD AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for Life Safety, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for Immediate Occupancy. (Tier 2: Sec. 4.6.3.10) |
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3.7.9 Basic Structural Checklist For Building Type C2: Concrete Shear Wall Buildings With Stiff Diaphragms

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

These buildings have floor and roof framing that consists of cast-in-place concrete slabs, concrete beams, one-way joists, two-way waffle joists, or flat slabs. Floors are supported on concrete columns or bearing walls. Lateral forces are resisted by cast-in-place concrete shear walls. In older construction, shear walls are lightly reinforced, but often extend throughout the building. In more recent construction, shear walls occur in isolated locations and are more heavily reinforced with boundary elements and closely spaced ties to provide ductile performance. The diaphragms consist of concrete slabs and are stiff relative to the walls. Foundations consist of concrete spread footings or deep pile foundations.

Building System

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| C | NC | N/A | LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1) |
| C | NC | N/A | MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3) |
| C | NC | N/A | WEAK STORY: The strength of the lateral-force-resisting-system in any story shall not be less than 80% of the strength in an adjacent story, above or below, for Life Safety and Immediate Occupancy (Tier 2: Sec. 4.3.2.1) |
| C | NC | N/A | SOFT STORY: The stiffness of the lateral-force-resisting-system in any story shall not be less than 70% of the stiffness in an adjacent story above or below, or less than 80% of the average stiffness of the three stories above or below for Life Safety and Immediate Occupancy. |
| C | NC | N/A | GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3) |
| C | NC | N/A | VERTICAL DISCONTINUITIES: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5) |
| C | NC | N/A | TORSION: The distance between the story center of mass and the story center of rigidity shall be less than 20% of the building width in either plan dimension for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.6) |
| C | NC | N/A | DETERIORATION OF CONCRETE: There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements. (Tier 2: Sec. 4.3.3.4) |
| C | NC | N/A | POST-TENSIONING ANCHORS: There shall be no evidence of corrosion or spalling in the vicinity of post-tensioning or end fittings. Coil anchors shall not have been used. (Tier 2: Sec. 4.3.3.5) |
| C | NC | N/A | CONCRETE WALL CRACKS All existing diagonal cracks in wall elements shall be less than 1/8" for Life Safety and 1/16" for Immediate Occupancy, shall not be concentrated in one location, and shall not form an X pattern. (Tier 2: Sec. 4.3.3.9) |

Lateral Force Resisting System

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| C | NC | N/A | COMPLETE FRAMES: Steel or concrete frames classified as secondary components shall form a complete vertical load carrying system. (Tier 2: Sec. 4.4.1.6.1) |
| C | NC | N/A | REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.1.1) |
| C | NC | N/A | SHEAR STRESS CHECK: The shear stress in the concrete shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 100 psi or $2\sqrt{f'_c}$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.1) |
| C | NC | N/A | REINFORCING STEEL: The ratio of reinforcing steel area to gross concrete area shall be greater than 0.0015 in the vertical direction and 0.0025 in the horizontal direction for Life Safety and Immediate Occupancy. The spacing of reinforcing steel shall be equal to or less than 18" for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.2) |

Connections

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| C | NC | N/A | TRANSFER TO SHEAR WALLS Diaphragms shall be reinforced and connected for transfer of loads to the shear walls for Life Safety and the connections shall be able to develop the shear strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.2.1) |
| C | NC | N/A | WALL REINFORCING: Walls shall be doweled into the foundation for Life Safety and the dowels shall be able to develop the strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.3.5) |

3.7.9S Supplemental Structural Checklist For Building Type C2: Concrete Shear Wall Buildings With Stiff Diaphragms

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

- C NC N/A DEFLECTION COMPATIBILITY: Secondary components shall have the shear capacity to develop the flexural strength of the elements for Life Safety and shall have ductile detailing for Immediate Occupancy. (Tier 2: Sec. 4.4.1.6.2)
- C NC N/A FLAT SLABS: Flat slabs/plates classified as secondary components shall have continuous bottom steel through the column joints for Life Safety. Flat slabs/plates shall not be permitted for the Immediate Occupancy Performance Level. (Tier 2: Sec. 4.4.1.6.3)
- C NC N/A COUPLING BEAMS: The stirrups in all coupling beams over means of egress shall be spaced at or less than $d/2$ and shall be anchored into the core with hooks of 135° or more for Life Safety and Immediate Occupancy. In addition, the beams shall have the capacity in shear to develop the uplift capacity of the adjacent wall for Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.3)
- C NC N/A OVERTURNING: All shear walls shall have aspect ratios less than 4 to 1. Wall piers need not be considered. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.4)
- C NC N/A CONFINEMENT REINFORCING: For shear walls with aspect ratios greater than 2.0, the boundary elements shall be confined with spirals or ties with spacing less than $8 d_b$. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.5)
- C NC N/A REINFORCING AT OPENINGS: There shall be added trim reinforcement around all wall openings. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.6)
- C NC N/A WALL THICKNESS: Thickness of bearing walls shall not be less than $1/25$ the minimum unsupported height or length, nor less than 4". This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.7)

Diaphragms

- C NC N/A DIAPHRAGM CONTINUITY: The diaphragms shall not be composed of split-level floors. In wood buildings, the diaphragms shall not have expansion joints. (Tier 2: Sec. 4.5.1.1)
- C NC N/A OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls shall be less than 25% of the wall length for Life Safety and 15% of the wall length for Immediate Occupancy. (Tier 2: Sec. 4.5.1.4)
- C NC N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)

Chapter 3.0 - Screening Phase (Tier 1)

C NC N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension . This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8)

Connections

C NC N/A LATERAL LOAD AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for Life Safety, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for Immediate Occupancy . (Tier 2: Sec. 4.6.3.10)

3.7.9A Basic Structural Checklist For Building Type C2A: Concrete Shear Wall Buildings With Flexible Diaphragms

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

These buildings have floor and roof framing that consists of wood sheathing on wood framing and concrete beams. Floors are supported on concrete columns or bearing walls. Lateral forces are resisted by cast-in-place concrete shear walls. In older construction, shear walls are lightly reinforced, but often extend throughout the building. In more recent construction, shear walls occur in isolated locations and are more heavily reinforced with boundary elements and closely spaced ties to provide ductile performance. The diaphragms consist of wood sheathing or have large aspect ratios and are flexible relative to the walls. Foundations consist of concrete spread footings or deep pile foundations.

Building System

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| C | NC | N/A | LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1) |
| C | NC | N/A | ADJACENT BUILDINGS: An adjacent building shall not be located next to the structure being evaluated closer than 4% of the height for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.1.2) |
| C | NC | N/A | MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3) |
| C | NC | N/A | WEAK STORY: The strength of the lateral-force-resisting-system in any story shall not be less than 80% of the strength in an adjacent story, above or below, for Life Safety and Immediate Occupancy (Tier 2: Sec. 4.3.2.1) |
| C | NC | N/A | SOFT STORY: The stiffness of the lateral-force-resisting-system in any story shall not be less than 70% of the stiffness in an adjacent story above or below, or less than 80% of the average stiffness of the three stories above or below for Life Safety and Immediate Occupancy. |
| C | NC | N/A | GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3) |

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | VERTICAL DISCONTINUITIES All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |
| C | NC | N/A | MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5) |
| C | NC | N/A | DETERIORATION OF WOOD: There shall be no signs of decay, shrinkage, splitting, fire damage, or sagging in any of the wood members and none of the metal accessories shall be deteriorated, broken, or loose. (Tier 2: Sec. 4.3.3.1) |
| C | NC | N/A | DETERIORATION OF CONCRETE: There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements. (Tier 2: Sec. 4.3.3.4) |
| C | NC | N/A | POST-TENSIONING ANCHORS: There shall be no evidence of corrosion or spalling in the vicinity of post-tensioning or end fittings. Coil anchors shall not have been used. (Tier 2: Sec. 4.3.3.5) |
| C | NC | N/A | CONCRETE WALL CRACKS All existing diagonal cracks in wall elements shall be less than 1/8" for Life Safety and 1/16" for Immediate Occupancy, shall not be concentrated in one location, and shall not form an X pattern. (Tier 2: Sec. 4.3.3.9) |

Lateral Force Resisting System

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|---|----|-----|--|
| C | NC | N/A | REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.1.1) |
| C | NC | N/A | SHEAR STRESS CHECK: The shear stress in the concrete shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 100 psi or $2\sqrt{f'_c}$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.1) |
| C | NC | N/A | REINFORCING STEEL: The ratio of reinforcing steel area to gross concrete area shall be greater than 0.0015 in the vertical direction and 0.0025 in the horizontal direction for Life Safety and Immediate Occupancy. The spacing of reinforcing steel shall be equal to or less than 18" for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.2) |

Connections

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|---|----|-----|--|
| C | NC | N/A | WALL ANCHORAGE: Exterior concrete or masonry walls shall be anchored for out-of-plane forces at each diaphragm level with steel anchors or straps that are developed into the diaphragm (Tier 2: Sec. 4.6.1.1) |
| C | NC | N/A | TRANSFER TO SHEAR WALLS Diaphragms shall be reinforced and connected for transfer of loads to the shear walls for Life Safety and the connections shall be able to develop the shear strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.2.1) |
| C | NC | N/A | WALL REINFORCING: Walls shall be doweled into the foundation for Life Safety and the dowels shall be able to develop the strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.3.5) |

3.7.9AS Supplemental Structural Checklist For Building Type C2A: Concrete Shear Wall Buildings With Flexible Diaphragms

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

- C NC N/A COUPLING BEAMS: The stirrups in all coupling beams over means of egress shall be spaced at or less than $d/2$ and shall be anchored into the core with hooks of 135° or more for Life Safety and Immediate Occupancy. In addition, the beams shall have the capacity in shear to develop the uplift capacity of the adjacent wall for Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.3)
- C NC N/A OVERTURNING: All shear walls shall have aspect ratios less than 4 to 1. Wall piers need not be considered. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.4)
- C NC N/A CONFINEMENT REINFORCING: For shear walls with aspect ratios greater than 2.0, the boundary elements shall be confined with spirals or ties with spacing less than $8d_b$. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.5)
- C NC N/A REINFORCING AT OPENINGS: There shall be added trim reinforcement around all wall openings. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.6)
- C NC N/A WALL THICKNESS: Thickness of bearing walls shall not be less than $1/25$ the minimum unsupported height or length, nor less than 4". This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.7)

Diaphragms

- C NC N/A DIAPHRAGM CONTINUITY: The diaphragms shall not be composed of split-level floors. In wood buildings, the diaphragms shall not have expansion joints. (Tier 2: Sec. 4.5.1.1)
- C NC N/A CROSS TIES: There shall be continuous cross ties between diaphragm chords. (Tier 2: Sec. 4.5.1.2)
- C NC N/A OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls shall be less than 25% of the wall length for Life Safety and 15% of the wall length for Immediate Occupancy. (Tier 2: Sec. 4.5.1.4)
- C NC N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)
- C NC N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8)
- C NC N/A STRAIGHT SHEATHING: All straight sheathed diaphragms shall have aspect ratios less than 2 to 1 for Life Safety and 1 to 1 for Immediate Occupancy in the direction being considered. (Tier 2: Sec. 4.5.2.1)

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | SPANS: All wood diaphragms with spans greater than 24 ft. for Life Safety and 12 ft. for Immediate Occupancy shall consist of wood structural panels or diagonal sheathing. Wood commercial and industrial buildings may have rod-braced systems. (Tier 2: Sec. 4.5.2.2) |
| C | NC | N/A | UNBLOCKED DIAPHRAGMS: All unblocked wood structural panel diaphragms shall have horizontal spans less than 40 ft. for Life Safety and 25 ft. for Immediate Occupancy and shall have aspect ratios less than or equal to 4 to 1 for Life Safety and 3 to 1 for Immediate Occupancy. (Tier 2: Sec. 4.5.2.3) |
| C | NC | N/A | NON-CONCRETE DIAPHRAGMS: Untopped metal deck diaphragms or metal deck diaphragms with fill other than concrete shall consist of horizontal spans of less than 40 ft. and shall have aspect ratios less than 4 to 1. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.3.1) |
| C | NC | N/A | OTHER DIAPHRAGMS: The diaphragm shall not consist of a system other than those described in Section 4.5. (Tier 2: Sec. 4.5.7.1) |

Connections

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|---|----|-----|---|
| C | NC | N/A | LATERAL LOAD AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for Life Safety, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for Immediate Occupancy. (Tier 2: Sec. 4.6.3.10) |
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3.7.10 Basic Structural Checklist For Building Type C3: Concrete Frames With Infill Masonry Shear Walls And Stiff Diaphragms

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

This is an older type of building construction that consists of a frame assembly of cast-in-place concrete beams and columns. The floors and roof consist of cast-in-place concrete slabs. Walls consist of infill panels constructed of solid clay brick, concrete block, or hollow clay tile masonry. The seismic performance of this type of construction depends on the interaction between the frame and infill panels. The combined behavior is more like a shear wall structure than a frame structure. Solidly infilled masonry panels form diagonal compression struts between the intersections of the frame members. If the walls are offset from the frame and do not fully engage the frame members, the diagonal compression struts will not develop. The strength of the infill panel is limited by the shear capacity of the masonry bed joint or the compression capacity of the strut. The post-cracking strength is determined by an analysis of a moment frame that is partially restrained by the cracked infill. The shear strength of the concrete columns, after cracking of the infill, may limit the semiductile behavior of the system. The diaphragms consist of concrete floors and are stiff relative to the walls.

Building System

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|---|----|-----|--|
| C | NC | N/A | LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1) |
| C | NC | N/A | MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3) |
| C | NC | N/A | WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1) |
| C | NC | N/A | SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2) |
| C | NC | N/A | GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3) |

Chapter 3.0 - Screening Phase (Tier 1)

C	NC	N/A	VERTICAL DISCONTINUITIES All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4)
C	NC	N/A	MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5)
C	NC	N/A	TORSION: The distance between the story center of mass and the story center of rigidity shall be less than 20% of the building width in either plan dimension for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.6)
C	NC	N/A	DETERIORATION OF CONCRETE: There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements. (Tier 2: Sec. 4.3.3.4)
C	NC	N/A	MASONRY UNITS: There shall be no visible deterioration of masonry units. (Tier 2: Sec. 4.3.3.7)
C	NC	N/A	MASONRY JOINTS: The mortar shall not be easily scraped away from the joints by hand with a metal tool, and there shall be no areas of eroded mortar. (Tier 2: Sec. 4.3.3.8)
C	NC	N/A	CRACKS IN INFILL WALLS: There shall be no existing diagonal cracks in infill walls that extend throughout a panel , are greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy, or have out-of-plane offsets in the bed joint greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy. (Tier 2: Sec. 4.3.3.12)
C	NC	N/A	CRACKS IN BOUNDARY COLUMNS: There shall be no existing diagonal cracks wider than 1/8" for Life Safety and 1/16" for Immediate Occupancy in concrete columns that encase masonry infills. (Tier 2: Sec. 4.3.3.13)

Lateral Force Resisting System

C	NC	N/A	REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.1.1)
C	NC	N/A	SHEAR STRESS CHECK The shear stress in the reinforced masonry shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 50 psi for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.4.1)
C	NC	N/A	SHEAR STRESS CHECK: The shear stress in the unreinforced masonry shear walls calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 15 psi for clay units and 30 psi for concrete units for Life Safety and Immediate Occupancy (Tier 2: Sec. 4.4.2.5.1)
C	NC	N/A	WALL CONNECTIONS: All infill walls shall have a positive connection to the frame to resist out-of-plane forces for Life Safety and the connection shall be able to develop the out-of-plane strength of the wall for Immediate Occupancy. (Tier 2: Sec. 4.4.2.6.1)

Connections

C	NC	N/A	TRANSFER TO SHEAR WALLS Diaphragms shall be reinforced and connected for transfer of loads to the shear walls for Life Safety and the connections shall be able to develop the shear strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.2.1)
C	NC	N/A	CONCRETE COLUMNS: All concrete columns shall be doweled into the foundation for Life Safety and the dowels shall be able to develop the tensile capacity of the column for Immediate Occupancy. (Tier 2: Sec. 4.6.3.2)

3.7.10S Supplemental Structural Checklist For Building Type C3: Concrete Frames With Infill Masonry Shear Walls And Stiff Diaphragms

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

- C NC N/A DEFLECTION COMPATIBILITY: Secondary components shall have the shear capacity to develop the flexural strength of the elements for Life Safety and shall have ductile detailing for Immediate Occupancy. (Tier 2: Sec. 4.4.1.6.2)
- C NC N/A FLAT SLABS: Flat slabs/plates classified as secondary components shall have continuous bottom steel through the column joints for Life Safety. Flat slabs/plates shall not be permitted for the Immediate Occupancy Performance Level. (Tier 2: Sec. 4.4.1.6.3)
- C NC N/A REINFORCING AT OPENINGS: All wall openings that interrupt rebar shall have trim reinforcing on all sides. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.4.3)
- C NC N/A PROPORTIONS: The height-to-thickness ratio of the infill walls at each story shall be less than 9 for Life Safety in regions of high seismicity, 13 for Immediate Occupancy in regions of moderate seismicity, and 8 for Immediate Occupancy in regions of high seismicity. (Tier 2: Sec. 4.4.2.6.2)
- C NC N/A SOLID WALLS: The infill walls shall not be of cavity construction. (Tier 2: Sec. 4.4.2.6.3)
- C NC N/A INFILL WALLS: The infill walls shall be continuous to the soffits of the frame beams. (Tier 2: Sec. 4.4.2.6.4)

Diaphragms

- C NC N/A DIAPHRAGM CONTINUITY: The diaphragms shall not be composed of split-level floors. In wood buildings, the diaphragms shall not have expansion joints. (Tier 2: Sec. 4.5.1.1)
- C NC N/A OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls shall be less than 25% of the wall length for Life Safety and 15% of the wall length for Immediate Occupancy. (Tier 2: Sec. 4.5.1.4)
- C NC N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)
- C NC N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8)

Connections

- C NC N/A LATERAL LOAD AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for Life Safety, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for Immediate Occupancy. (Tier 2: Sec. 4.6.3.10)

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3.7.10A Basic Structural Checklist For Building Type C3A: Concrete Frames With Infill Masonry Shear Walls And Flexible Diaphragms

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

This is an older type of building construction that consists of a frame assembly of cast-in-place concrete beams and columns. The floors and roof consist of wood sheathing on wood framing between concrete beams. Walls consist of infill panels constructed of solid clay brick, concrete block, or hollow clay tile masonry. The seismic performance of this type of construction depends on the interaction between the frame and infill panels. The combined behavior is more like a shear wall structure than a frame structure. Solidly infilled masonry panels form diagonal compression struts between the intersections of the frame members. If the walls are offset from the frame and do not fully engage the frame members, the diagonal compression struts will not develop. The strength of the infill panel is limited by the shear capacity of the masonry bed joint or the compression capacity of the strut. The post-cracking strength is determined by an analysis of a moment frame that is partially restrained by the cracked infill. The shear strength of the concrete columns, after cracking of the infill, may limit the semiductile behavior of the system. Diaphragms consist of wood sheathing, or have large aspect ratios and are flexible relative to the walls.

Building System

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| C | NC | N/A | LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1) |
| C | NC | N/A | ADJACENT BUILDINGS: An adjacent building shall not be located next to the structure being evaluated closer than 4% of the height for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.1.2) |
| C | NC | N/A | MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3) |
| C | NC | N/A | WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1) |

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2) |
| C | NC | N/A | GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3) |
| C | NC | N/A | VERTICAL DISCONTINUITIES All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |
| C | NC | N/A | MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5) |
| C | NC | N/A | DETERIORATION OF WOOD: There shall be no signs of decay, shrinkage, splitting, fire damage, or sagging in any of the wood members and none of the metal accessories shall be deteriorated, broken, or loose. (Tier 2: Sec. 4.3.3.1) |
| C | NC | N/A | DETERIORATION OF CONCRETE: There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements. (Tier 2: Sec. 4.3.3.4) |
| C | NC | N/A | MASONRY UNITS: There shall be no visible deterioration of masonry units. (Tier 2: Sec. 4.3.3.7) |
| C | NC | N/A | MASONRY JOINTS: The mortar shall not be easily scraped away from the joints by hand with a metal tool, and there shall be no areas of eroded mortar. (Tier 2: Sec. 4.3.3.8) |
| C | NC | N/A | CRACKS IN INFILL WALLS: There shall be no existing diagonal cracks in infill walls that extend throughout a panel, are greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy, or have out-of-plane offsets in the bed joint greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy. (Tier 2: Sec. 4.3.3.12) |
| C | NC | N/A | CRACKS IN BOUNDARY COLUMNS: There shall be no existing diagonal cracks wider than 1/8" for Life Safety and 1/16" for Immediate Occupancy in concrete columns that encase masonry infills. (Tier 2: Sec. 4.3.3.13) |

Lateral Force Resisting System

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| C | NC | N/A | REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.1.1) |
| C | NC | N/A | SHEAR STRESS CHECK The shear stress in the reinforced masonry shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 50 psi for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.4.1) |
| C | NC | N/A | SHEAR STRESS CHECK: The shear stress in the unreinforced masonry shear walls calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 15 psi for clay units and 30 psi for concrete units for Life Safety and Immediate Occupancy (Tier 2: Sec. 4.4.2.5.1) |
| C | NC | N/A | WALL CONNECTIONS: All infill walls shall have a positive connection to the frame to resist out-of-plane forces for Life Safety and the connection shall be able to develop the out-of-plane strength of the wall for Immediate Occupancy. (Tier 2: Sec. 4.4.2.6.1) |

Chapter 3.0 - Screening Phase (Tier 1)

Connections

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| C | NC | N/A | TRANSFER TO SHEAR WALLS Diaphragms shall be reinforced and connected for transfer of loads to the shear walls for Life Safety and the connections shall be able to develop the shear strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.2.1) |
| C | NC | N/A | CONCRETE COLUMNS: All concrete columns shall be doweled into the foundation for Life Safety and the dowels shall be able to develop the tensile capacity of the column for Immediate Occupancy. (Tier 2: Sec. 4.6.3.2) |

**3.7.10AS Supplemental Structural Checklist For Building Type C3A:
Concrete Frames With Infill Masonry Shear Walls And Flexible Diaphragms**

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

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| C | NC | N/A | REINFORCING AT OPENINGS: All wall openings that interrupt rebar shall have trim reinforcing on all sides. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.4.3) |
| C | NC | N/A | PROPORTIONS: The height-to-thickness ratio of the infill walls at each story shall be less than 9 for Life Safety in regions of high seismicity, 13 for Immediate Occupancy in regions of moderate seismicity, and 8 for Immediate Occupancy in regions of high seismicity. (Tier 2: Sec. 4.4.2.6.2) |
| C | NC | N/A | SOLID WALLS: The infill walls shall not be of cavity construction. (Tier 2: Sec. 4.4.2.6.3) |
| C | NC | N/A | INFILL WALLS: The infill walls shall be continuous to the soffits of the frame beams. (Tier 2: Sec. 4.4.2.6.4) |

Diaphragms

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| C | NC | N/A | DIAPHRAGM CONTINUITY: The diaphragms shall not be composed of split-level floors. In wood buildings, the diaphragms shall not have expansion joints. (Tier 2: Sec. 4.5.1.1) |
| C | NC | N/A | CROSS TIES: There shall be continuous cross ties between diaphragm chords. (Tier 2: Sec. 4.5.1.2) |
| C | NC | N/A | OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls shall be less than 25% of the wall length for Life Safety and 15% of the wall length for Immediate Occupancy. (Tier 2: Sec. 4.5.1.4) |
| C | NC | N/A | PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7) |
| C | NC | N/A | DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8) |
| C | NC | N/A | STRAIGHT SHEATHING: All straight sheathed diaphragms shall have aspect ratios less than 2 to 1 for Life Safety and 1 to 1 for Immediate Occupancy in the direction being considered. (Tier 2: Sec. 4.5.2.1) |
| C | NC | N/A | SPANS: All wood diaphragms with spans greater than 24 ft. for Life Safety and 12 ft. for Immediate Occupancy shall consist of wood structural panels or diagonal sheathing. Wood commercial and industrial buildings may have rod-braced systems. (Tier 2: Sec. 4.5.2.2) |

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | UNBLOCKED DIAPHRAGMS: All unblocked wood structural panel diaphragms shall have horizontal spans less than 40 ft. for Life Safety and 25 ft. for Immediate Occupancy and shall have aspect ratios less than or equal to 4 to 1 for Life Safety and 3 to 1 for Immediate Occupancy. (Tier 2: Sec. 4.5.2.3) |
| C | NC | N/A | NON-CONCRETE DIAPHRAGMS: Untopped metal deck diaphragms or metal deck diaphragms with fill other than concrete shall consist of horizontal spans of less than 40 ft. and shall have aspect ratios less than 4 to 1. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.3.1) |
| C | NC | N/A | OTHER DIAPHRAGMS: The diaphragm shall not consist of a system other than those described in Section 4.5. (Tier 2: Sec. 4.5.7.1) |

Connections

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| C | NC | N/A | ANCHOR SPACING: Exterior masonry walls shall be anchored to the floor and roof systems at a spacing of 4 ft. or less for Life Safety and 3 ft. or less for Immediate Occupancy (Tier 2: Sec. 4.6.1.3) |
| C | NC | N/A | STIFFNESS OF WALL ANCHORS: Anchors of concrete or masonry walls to wood structural elements shall be installed taut and shall be stiff enough to prevent movement between the wall and the diaphragm. If bolts are present, the size of the bolt holes in both the connector and framing shall be a maximum of 1/16" larger than the bolt diameter. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.6.1.5) |
| C | NC | N/A | LATERAL LOAD AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for Life Safety, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for Immediate Occupancy. (Tier 2: Sec. 4.6.3.10) |

**3.7.11 Basic Structural Checklist For Building Type
PC1: Precast/Tilt-Up Concrete Shear Wall Buildings With Flexible Diaphragms**

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

These buildings are one or more stories in height and have precast concrete perimeter wall panels that are cast on site and tilted into place. Floor and roof framing consists of wood joists, glulam beams, steel beams or open web joists. Framing is supported on interior steel or concrete columns and perimeter concrete bearing walls. The floors and roof consist of wood sheathing or untopped metal deck. Lateral forces are resisted by the precast concrete perimeter wall panels. Wall panels may be solid, or have large window and door openings which cause the panels to behave more as frames than as shear walls. In older construction, wood framing is attached to the walls with wood ledgers. Foundations consist of concrete spread footings or deep pile foundations.

Building System

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| C | NC | N/A | LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1) |
| C | NC | N/A | ADJACENT BUILDINGS: An adjacent building shall not be located next to the structure being evaluated closer than 4% of the height for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.1.2) |
| C | NC | N/A | MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3) |
| C | NC | N/A | WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1) |
| C | NC | N/A | SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2) |
| C | NC | N/A | GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3) |

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | VERTICAL DISCONTINUITIES All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |
| C | NC | N/A | MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5) |
| C | NC | N/A | DETERIORATION OF WOOD: There shall be no signs of decay, shrinkage, splitting, fire damage, or sagging in any of the wood members and none of the metal accessories shall be deteriorated, broken, or loose. (Tier 2: Sec. 4.3.3.1) |
| C | NC | N/A | PRECAST CONCRETE WALLS: There shall be no visible deterioration of concrete or reinforcing steel or evidence of distress, especially at the connections. (Tier 2: Sec. 4.3.3.6) |

Lateral Force Resisting System

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| C | NC | N/A | REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.1.1) |
| C | NC | N/A | SHEAR STRESS CHECK The shear stress in the precast panels, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 100 psi or $2\sqrt{f'_c}$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.3.1) |
| C | NC | N/A | REINFORCING STEEL: The ratio of reinforcing steel area to gross concrete area shall be greater than 0.0015 in the vertical direction and 0.0025 in the horizontal direction for Life Safety and Immediate Occupancy. The spacing of reinforcing steel shall be equal to or less than 18" for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.3.2) |

Connections

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| C | NC | N/A | WALL ANCHORAGE: Exterior concrete or masonry walls shall be anchored for out-of-plane forces at each diaphragm level with steel anchors or straps that are developed into the diaphragm. (Tier 2: Sec. 4.6.1.1) |
| C | NC | N/A | PRECAST WALL PANELS Precast wall panels shall be doweled into the foundation for Life Safety and the dowels shall be able to develop the strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.3.7) |
| C | NC | N/A | GIRDER/COLUMN CONNECTION: There shall be a positive connection between the girder and the column support. (Tier 2: Sec. 4.6.4.1) |

**3.7.11S Supplemental Structural Checklist For Building Type
PCI: Precast/Tilt-Up Concrete Shear Wall Buildings With Flexible Diaphragms**

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

- C NC N/A COUPLING BEAMS: The stirrups in all coupling beams over means of egress shall be spaced at or less than $d/2$ and shall be anchored into the core with hooks of 135° or more for Life Safety and Immediate Occupancy. In addition, the beams shall have the capacity in shear to develop the uplift capacity of the adjacent wall for Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.3)
- C NC N/A WALL OPENINGS: Openings shall constitute less than 75% of the length of any perimeter wall for Life Safety and 50% for Immediate Occupancy with the wall piers having aspect ratios of less than 2. (Tier 2: Sec. 4.4.2.3.3)
- C NC N/A CORNER OPENINGS: Walls with openings at a building corner larger than the width of a typical panel shall be connected to the remainder of the wall with collector reinforcing. (Tier 2: Sec. 4.4.2.3.4)
- C NC N/A PANEL-TO-PANEL CONNECTIONS: Adjacent wall panels shall be interconnected to transfer overturning forces between panels by methods other than welded steel inserts. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.3.5)
- C NC N/A WALL THICKNESS: Thickness of bearing walls shall not be less than $1/25$ the minimum unsupported height or length, nor less than 4". This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.3.6)

Diaphragms

- C NC N/A CROSS TIES: There shall be continuous cross ties between diaphragm chords. (Tier 2: Sec. 4.5.1.2)
- C NC N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)
- C NC N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8)
- C NC N/A STRAIGHT SHEATHING: All straight sheathed diaphragms shall have aspect ratios less than 2 to 1 for Life Safety and 1 to 1 for Immediate Occupancy in the direction being considered. (Tier 2: Sec. 4.5.2.1)
- C NC N/A SPANS: All wood diaphragms with spans greater than 24 ft. for Life Safety and 12 ft. for Immediate Occupancy shall consist of wood structural panels or diagonal sheathing. Wood commercial and industrial buildings may have rod-braced systems. (Tier 2: Sec. 4.5.2.2)

Chapter 3.0 - Screening Phase (Tier 1)

C NC N/A UNBLOCKED DIAPHRAGMS: All unblocked wood structural panel diaphragms shall have horizontal spans less than 40 ft. for Life Safety and 25 ft. for Immediate Occupancy and shall have aspect ratios less than or equal to 4 to 1 for Life Safety and 3 to 1 for Immediate Occupancy. (Tier 2: Sec. 4.5.2.3)

C NC N/A OTHER DIAPHRAGMS: The diaphragm shall not consist of a system other than those described in Section 4.5. (Tier 2: Sec. 4.5.7.1)

Connections

C NC N/A WOOD LEDGERS: The connection between the wall panels and the diaphragm shall not induce cross-grain bending or tension in the wood ledgers. (Tier 2: Sec. 4.6.1.2)

C NC N/A PRECAST PANEL CONNECTIONS: There shall be at least two anchors from each precast wall panel into the diaphragm elements for Life Safety and the anchors shall be able to develop the strength of the panels for Immediate Occupancy. (Tier 2: Sec. 4.6.1.4)

C NC N/A LATERAL LOAD AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for Life Safety, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for Immediate Occupancy. (Tier 2: Sec. 4.6.3.10)

C NC N/A GIRDERS: Girders supported by walls or pilasters shall have at least two additional ties to secure the anchor bolts for Life Safety and Immediate Occupancy (Tier 2: Sec. 4.6.4.2)

**3.7.11A Basic Structural Checklist For Building Type
PC1A: Precast/Tilt-Up Concrete Shear Wall Buildings With Stiff Diaphragms**

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

These buildings are one or more stories in height and have precast concrete perimeter wall panels that are cast on site and tilted into place. The floors and roof consist precast elements, cast-in-place concrete, or metal deck with concrete fill, and are stiff relative to the walls. Framing is supported on interior steel or concrete columns and perimeter concrete bearing walls. Lateral forces are resisted by the precast concrete perimeter wall panels. Wall panels may be solid, or have large window and door openings which cause the panels to behave more as frames than as shear walls. Foundations consist of concrete spread footings or deep pile foundations.

Building System

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| C | NC | N/A | LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1) |
| C | NC | N/A | MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3) |
| C | NC | N/A | WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1) |
| C | NC | N/A | SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2) |
| C | NC | N/A | GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3) |
| C | NC | N/A | VERTICAL DISCONTINUITIES: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5) |
| C | NC | N/A | TORSION: The distance between the story center of mass and the story center of rigidity shall be less than 20% of the building width in either plan dimension for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.6) |
| C | NC | N/A | POST-TENSIONING ANCHORS: There shall be no evidence of corrosion or spalling in the vicinity of post-tensioning or end fittings. Coil anchors shall not have been used. (Tier 2: Sec. 4.3.3.5) |
| C | NC | N/A | PRECAST CONCRETE WALLS: There shall be no visible deterioration of concrete or reinforcing steel or evidence of distress, especially at the connections. (Tier 2: Sec. 4.3.3.6) |

Lateral Force Resisting System

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| C | NC | N/A | REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.1.1) |
| C | NC | N/A | SHEAR STRESS CHECK The shear stress in the precast panels, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 100 psi or $2\sqrt{f'_c}$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.3.1) |
| C | NC | N/A | REINFORCING STEEL: The ratio of reinforcing steel area to gross concrete area shall be greater than 0.0015 in the vertical direction and 0.0025 in the horizontal direction for Life Safety and Immediate Occupancy. The spacing of reinforcing steel shall be equal to or less than 18" for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.3.2) |

Diaphragms

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| C | NC | N/A | TOPPING SLAB: Precast concrete diaphragm elements shall be interconnected by a continuous reinforced concrete topping slab. (Tier 2: Sec. 4.5.5.1) |
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Connections

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|---|----|-----|--|
| C | NC | N/A | WALL ANCHORAGE: Exterior concrete or masonry walls shall be anchored for out-of-plane forces at each diaphragm level with steel anchors or straps that are developed into the diaphragm. (Tier 2: Sec. 4.6.1.1) |
| C | NC | N/A | TRANSFER TO SHEAR WALLS Diaphragms shall be reinforced and connected for transfer of loads to the shear walls for Life Safety and the connections shall be able to develop the shear strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.2.1) |
| C | NC | N/A | TOPPING SLAB TO WALLS OR FRAMES Reinforced concrete topping slabs that interconnect the precast concrete diaphragm elements shall be doweled into the shear wall or frame elements for Life Safety and the dowels shall be able to develop the shear strength of the walls or frames for Immediate Occupancy. (Tier 2: Sec. 4.6.2.3) |

Chapter 3.0 - Screening Phase (Tier 1)

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|---|----|-----|--|
| C | NC | N/A | PRECAST WALL PANELS Precast wall panels shall be doweled into the foundation for Life Safety and the dowels shall be able to develop the strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.3.7) |
| C | NC | N/A | GIRDER/COLUMN CONNECTION: There shall be a positive connection between the girder and the column support. (Tier 2: Sec. 4.6.4.1) |

**3.7.11AS Supplemental Structural Checklist For Building Type
PC1A: Precast Tilt-Up Concrete Shear Wall Buildings With Stiff Diaphragms**

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

- C NC N/A DEFLECTION COMPATIBILITY: Secondary components shall have the shear capacity to develop the flexural strength of the elements for Life Safety and shall have ductile detailing for Immediate Occupancy. (Tier 2: Sec. 4.4.1.6.2)
- C NC N/A COUPLING BEAMS: The stirrups in all coupling beams over means of egress shall be spaced at or less than $d/2$ and shall be anchored into the core with hooks of 135° or more for Life Safety and Immediate Occupancy. In addition, the beams shall have the capacity in shear to develop the uplift capacity of the adjacent wall for Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.3)
- C NC N/A WALL OPENINGS: Openings shall constitute less than 75% of the length of any perimeter wall for Life Safety and 50% for Immediate Occupancy with the wall piers having aspect ratios of less than 2. (Tier 2: Sec. 4.4.2.3.3)
- C NC N/A CORNER OPENINGS: Walls with openings at a building corner larger than the width of a typical panel shall be connected to the remainder of the wall with collector reinforcing. (Tier 2: Sec. 4.4.2.3.4)
- C NC N/A PANEL-TO-PANEL CONNECTIONS: Adjacent wall panels shall be interconnected to transfer overturning forces between panels by methods other than welded steel inserts. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.3.5)
- C NC N/A WALL THICKNESS: Thickness of bearing walls shall not be less than $1/25$ the minimum unsupported height or length, nor less than 4". This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.3.6)

Diaphragms

- C NC N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)
- C NC N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8)

Connections

- C NC N/A PRECAST PANEL CONNECTIONS: There shall be at least two anchors from each precast wall panel into the diaphragm elements for Life Safety and the anchors shall be able to develop the strength of the panels for Immediate Occupancy. (Tier 2: Sec. 4.6.1.4)
- C NC N/A LATERAL LOAD AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for Life Safety, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for Immediate Occupancy. (Tier 2: Sec. 4.6.3.10)

Chapter 3.0 - Screening Phase (Tier 1)

C	NC	N/A	GIRDERS: Girders supported by walls or pilasters shall have at least two additional ties to secure the anchor bolts for Life Safety and Immediate Occupancy (Tier 2: Sec. 4.6.4.2)
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**3.7.12 Basic Structural Checklist For Building Type
PC2: Precast Concrete Frames With Shear Walls**

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

These buildings consist of a frame assembly of precast concrete girders and columns with the presence of shear walls. Floor and roof framing consists of precast concrete planks, tees or double-tees supported on precast concrete girders and columns. Lateral forces are resisted by precast or cast-in-place concrete shear walls. Diaphragms consist of precast elements interconnected with welded inserts, cast-in-place closure strips, or reinforced concrete topping slabs.

Building System

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| C | NC | N/A | LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1) |
| C | NC | N/A | MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3) |
| C | NC | N/A | WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1) |
| C | NC | N/A | SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2) |
| C | NC | N/A | GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3) |
| C | NC | N/A | VERTICAL DISCONTINUITIES: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |
| C | NC | N/A | MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5) |

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | TORSION: The distance between the story center of mass and the story center of rigidity shall be less than 20% of the building width in either plan dimension for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.6) |
| C | NC | N/A | DETERIORATION OF CONCRETE: There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements. (Tier 2: Sec. 4.3.3.4) |
| C | NC | N/A | POST-TENSIONING ANCHORS: There shall be no evidence of corrosion or spalling in the vicinity of post-tensioning or end fittings. Coil anchors shall not have been used. (Tier 2: Sec. 4.3.3.5) |
| C | NC | N/A | CONCRETE WALL CRACKS All existing diagonal cracks in wall elements shall be less than 1/8" for Life Safety and 1/16" for Immediate Occupancy, shall not be concentrated in one location, and shall not form an X pattern. (Tier 2: Sec. 4.3.3.9) |

Lateral Force Resisting System

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| C | NC | N/A | COMPLETE FRAMES: Steel or concrete frames classified as secondary components shall form a complete vertical load carrying system. (Tier 2: Sec. 4.4.1.6.1) |
| C | NC | N/A | REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.1.1) |
| C | NC | N/A | SHEAR STRESS CHECK: The shear stress in the concrete shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 100 psi or $2\sqrt{f'_c}$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.1) |
| C | NC | N/A | REINFORCING STEEL: The ratio of reinforcing steel area to gross concrete area shall be greater than 0.0015 in the vertical direction and 0.0025 in the horizontal direction for Life Safety and Immediate Occupancy. The spacing of reinforcing steel shall be equal to or less than 18" for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.2) |

Diaphragms

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|---|----|-----|--|
| C | NC | N/A | TOPPING SLAB: Precast concrete diaphragm elements shall be interconnected by a continuous reinforced concrete topping slab. (Tier 2: Sec. 4.5.5.1) |
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Connections

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|---|----|-----|--|
| C | NC | N/A | WALL ANCHORAGE: Exterior concrete or masonry walls shall be anchored for out-of-plane forces at each diaphragm level with steel anchors or straps that are developed into the diaphragm. (Tier 2: Sec. 4.6.1.1) |
| C | NC | N/A | TRANSFER TO SHEAR WALLS Diaphragms shall be reinforced and connected for transfer of loads to the shear walls for Life Safety and the connections shall be able to develop the shear strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.2.1) |

Chapter 3.0 - Screening Phase (Tier 1)

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|---|----|-----|---|
| C | NC | N/A | TOPPING SLAB TO WALLS OR FRAMES: Reinforced concrete topping slabs that interconnect the precast concrete diaphragm elements shall be doweled into the shear wall or frame elements for Life Safety and the dowels shall be able to develop the shear strength of the walls or frames for Immediate Occupancy. (Tier 2: Sec. 4.6.2.3) |
| C | NC | N/A | WALL REINFORCING: Walls shall be doweled into the foundation for Life Safety and the dowels shall be able to develop the strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.3.5) |
| C | NC | N/A | GIRDER/COLUMN CONNECTION: There shall be a positive connection between the girder and the column support. (Tier 2: Sec. 4.6.4.1) |

**3.7.12S Supplemental Structural Checklist For Building Type
PC2: Precast Concrete Frames With Shear Walls**

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

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|---|----|-----|--|
| C | NC | N/A | PRECAST FRAMES: For buildings with concrete shear walls, lateral forces shall not be resisted by precast concrete frame elements. (Tier 2: Sec. 4.4.1.5.2) |
| C | NC | N/A | PRECAST CONNECTIONS: For buildings with concrete shear walls, the connection between precast frame elements such as chords, ties, and collectors in the lateral-force-resisting system shall develop the capacity of the connected members. (Tier 2: Sec. 4.4.1.5.3) |
| C | NC | N/A | DEFLECTION COMPATIBILITY: Secondary components shall have the shear capacity to develop the flexural strength of the elements for Life Safety and shall have ductile detailing for Immediate Occupancy. (Tier 2: Sec. 4.4.1.6.2) |
| C | NC | N/A | COUPLING BEAMS: The stirrups in all coupling beams over means of egress shall be spaced at or less than $d/2$ and shall be anchored into the core with hooks of 135° or more for Life Safety and Immediate Occupancy. In addition, the beams shall have the capacity in shear to develop the uplift capacity of the adjacent wall for Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.3) |
| C | NC | N/A | OVERTURNING: All shear walls shall have aspect ratios less than 4 to 1. Wall piers need not be considered. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.4) |
| C | NC | N/A | CONFINEMENT REINFORCING: For shear walls with aspect ratios greater than 2.0, the boundary elements shall be confined with spirals or ties with spacing less than $8d_b$. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.5) |
| C | NC | N/A | REINFORCING AT OPENINGS: There shall be added trim reinforcement around all wall openings. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.6) |
| C | NC | N/A | WALL THICKNESS: Thickness of bearing walls shall not be less than $1/25$ the minimum unsupported height or length, nor less than 4". This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.7) |

Diaphragms

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|---|----|-----|---|
| C | NC | N/A | OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls shall be less than 25% of the wall length for Life Safety and 15% of the wall length for Immediate Occupancy. (Tier 2: Sec. 4.5.1.4) |
| C | NC | N/A | PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7) |

Chapter 3.0 - Screening Phase (Tier 1)

C NC N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension . This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8)

Connections

C NC N/A LATERAL LOAD AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for Life Safety, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for Immediate Occupancy . (Tier 2: Sec. 4.6.3.10)

C NC N/A CORBEL BEARING: If the frame girders bear on column corbels, the length of bearing shall be greater than 3" for Life Safety and Immediate Occupancy (Tier 2: Sec. 4.6.4.3)

C NC N/A CORBEL CONNECTIONS: The frame girders shall not be connected to corbels with welded elements. (Tier 2: Sec. 4.6.4.4)

**3.7.12A Basic Structural Checklist For Building Type
PC2A: Precast Concrete Frames Without Shear Walls**

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

These buildings consist of a frame assembly of precast concrete girders and columns without the presence of concrete shear walls. Lateral forces are resisted by precast concrete moment frames that develop their stiffness through beam-column joints rigidly connected by welded inserts or cast-in-place concrete closures. Diaphragms consist of precast elements interconnected with welded inserts, cast-in-place closure strips, or reinforced concrete topping slabs. This type of construction is not permitted in regions of high seismicity for new construction.

Building System

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| C | NC | N/A | LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1) |
| C | NC | N/A | ADJACENT BUILDINGS: An adjacent building shall not be located next to the structure being evaluated closer than 4% of the height for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.1.2) |
| C | NC | N/A | MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3) |
| C | NC | N/A | WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1) |
| C | NC | N/A | SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2) |
| C | NC | N/A | GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3) |

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | VERTICAL DISCONTINUITIES All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |
| C | NC | N/A | MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5) |
| C | NC | N/A | TORSION: The distance between the story center of mass and the story center of rigidity shall be less than 20% of the building width in either plan dimension for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.6) |
| C | NC | N/A | DETERIORATION OF CONCRETE: There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements. (Tier 2: Sec. 4.3.3.4) |
| C | NC | N/A | POST-TENSIONING ANCHORS: There shall be no evidence of corrosion or spalling in the vicinity of post-tensioning or end fittings. Coil anchors shall not have been used. (Tier 2: Sec. 4.3.3.5) |

Lateral Force Resisting System

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| C | NC | N/A | REDUNDANCY: The number of lines of moment frames in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. The number of bays of moment frames in each line shall be greater than or equal to 2 for Life Safety and 3 for Immediate Occupancy. (Tier 2: Sec. 4.4.1.1.1) |
| C | NC | N/A | SHEAR STRESS CHECK The shear stress in the concrete columns, calculated using the Quick Check procedure of Section 3.5.3.2, shall be less than 100 psi or $2\sqrt{f'_c}$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.1.4.1) |
| C | NC | N/A | AXIAL STRESS CHECK: The axial stress due to gravity loads in columns subjected to overturning forces shall be less than $0.10f'_c$ for Life Safety and Immediate Occupancy. Alternatively, the axial stresses due to overturning forces alone, calculated using the Quick Check Procedure of Section 3.5.3.6, shall be less than $0.30f'_c$ for Life Safety and Immediate Occupancy. (Tier2: Sec. 4.4.1.4.2) |
| C | NC | N/A | PRECAST CONNECTION CHECK: The precast connections at frame joints shall have the capacity to resist the shear and moment demands calculated using the Quick Procedure of Section 3.5.3.5(Tier 2: Sec. 4.4.1.5.1) |

Diaphragms

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| C | NC | N/A | TOPPING SLAB: Precast concrete diaphragm elements shall be interconnected by a continuous reinforced concrete topping slab. (Tier 2: Sec. 4.5.5.1) |
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Connections

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|---|----|-----|---|
| C | NC | N/A | TOPPING SLAB TO WALLS OR FRAMES: Reinforced concrete topping slabs that interconnect the precast concrete diaphragm elements shall be doweled into the shear wall or frame elements for Life Safety and the dowels shall be able to develop the shear strength of the walls or frames for Immediate Occupancy. (Tier 2: Sec. 4.6.2.3) |
| C | NC | N/A | GIRDER/COLUMN CONNECTION: There shall be a positive connection between the girder and the column support. (Tier 2: Sec. 4.6.4.1) |

**3.7.12AS Supplemental Structural Checklist For Building Type
PC2A: Precast Concrete Frames Without Shear Walls**

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

- C NC N/A PRESTRESSED FRAME ELEMENTS: The lateral-load-resisting frames shall not include any prestressed or post-tensioned elements. (Tier 2: Sec. 4.4.1.4.4)
- C NC N/A SHORT CAPTIVE COLUMNS: There shall be no columns at a level with height/depth ratios less than 50% of the nominal height/depth ratio of the typical columns at that level for Life Safety and 75% for Immediate Occupancy. (Tier 2: Sec. 4.4.1.4.5)
- C NC N/A JOINT REINFORCING: Column ties shall extend at their typical spacing through all beam-column joints at exterior columns. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.4.13)
- C NC N/A DEFLECTION COMPATIBILITY: Secondary components shall have the shear capacity to develop the flexural strength of the elements for Life Safety and shall have ductile detailing for Immediate Occupancy. (Tier 2: Sec. 4.4.1.6.2)

Diaphragms

- C NC N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)
- C NC N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragm openings larger than 50% of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8)

Connections

- C NC N/A LATERAL LOAD AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for Life Safety, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for Immediate Occupancy. (Tier 2: Sec. 4.6.3.10)
- C NC N/A GIRDERS: Girders supported by walls or pilasters shall have at least two additional ties to secure the anchor bolts for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.6.4.2)
- C NC N/A CORBEL BEARING: If the frame girders bear on column corbels, the length of bearing shall be greater than 3" for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.6.4.3)
- C NC N/A CORBEL CONNECTIONS: The frame girders shall not be connected to corbels with welded elements. (Tier 2: Sec. 4.6.4.4)

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**3.7.13 Basic Structural Checklist For Building Type
RM1: Reinforced Masonry Bearing Wall Buildings With Flexible Diaphragms**

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

These buildings have bearing walls that consist of reinforced brick or concrete block masonry. Wood floor and roof framing consists of wood joists, glulam beams and wood posts or small steel columns. Steel floor and roof framing consists of steel beams or open web joists, steel girders and steel columns. Lateral forces are resisted by the reinforced brick or concrete block masonry shear walls. Diaphragms consist of straight or diagonal wood sheathing, plywood, or untopped metal deck, and are flexible relative to the walls. Foundations consist of brick or concrete spread footings.

Building System

C	NC	N/A	LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1)
C	NC	N/A	ADJACENT BUILDINGS: An adjacent building shall not be located next to the structure being evaluated closer than 4% of the height for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.1.2)
C	NC	N/A	MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3)
C	NC	N/A	WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1)
C	NC	N/A	SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2)
C	NC	N/A	GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3)

Chapter 3.0 - Screening Phase (Tier 1)

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|---|----|-----|--|
| C | NC | N/A | VERTICAL DISCONTINUITIES All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |
| C | NC | N/A | MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5) |
| C | NC | N/A | DETERIORATION OF WOOD: There shall be no signs of decay, shrinkage, splitting, fire damage, or sagging in any of the wood members and none of the metal accessories shall be deteriorated, broken, or loose. (Tier 2: Sec. 4.3.3.1) |
| C | NC | N/A | MASONRY UNITS: There shall be no visible deterioration of masonry units. (Tier 2: Sec. 4.3.3.7) |
| C | NC | N/A | MASONRY JOINTS: The mortar shall not be easily scraped away from the joints by hand with a metal tool, and there shall be no areas of eroded mortar. (Tier 2: Sec. 4.3.3.8) |
| C | NC | N/A | REINFORCED MASONRY WALL CRACKS All existing diagonal cracks in wall elements shall be less than 1/8" for Life Safety and 1/16" for Immediate Occupancy, shall not be concentrated in one location, and shall not form an X pattern. (Tier 2: Sec. 4.3.3.10) |

Lateral Force Resisting System

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|---|----|-----|--|
| C | NC | N/A | REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.1.1) |
| C | NC | N/A | SHEAR STRESS CHECK The shear stress in the reinforced masonry shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 50 psi for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.4.1) |
| C | NC | N/A | REINFORCING STEEL: The total vertical and horizontal reinforcing steel ratio in reinforced masonry walls shall be greater than 0.002 for Life Safety and 0.003 for Immediate Occupancy of the wall with the minimum of 0.0007 for Life Safety and 0.001 for Immediate Occupancy in either of the two directions; the spacing of reinforcing steel shall be less than 48" for Life Safety and 24" for Immediate Occupancy; and all vertical bars shall extend to the top of the walls. (Tier 2: Sec. 4.4.2.4.2) |

Connections

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|---|----|-----|--|
| C | NC | N/A | WALL ANCHORAGE: Exterior concrete or masonry walls shall be anchored for out-of-plane forces at each diaphragm level with steel anchors or straps that are developed into the diaphragm. (Tier 2: Sec. 4.6.1.1) |
| C | NC | N/A | TRANSFER TO SHEAR WALLS Diaphragms shall be reinforced and connected for transfer of loads to the shear walls for Life Safety and the connections shall be able to develop the shear strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.2.1) |
| C | NC | N/A | WALL REINFORCING: Walls shall be doweled into the foundation for Life Safety and the dowels shall be able to develop the strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.3.5) |
| C | NC | N/A | GIRDER/COLUMN CONNECTION: There shall be a positive connection between the girder and the column support. (Tier 2: Sec. 4.6.4.1) |

**3.7.13S Supplemental Structural Checklist For Building Type
RM1: Reinforced Masonry Bearing Wall Buildings With Flexible Diaphragms**

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

- C NC N/A REINFORCING AT OPENINGS: All wall openings that interrupt rebar shall have trim reinforcing on all sides. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.4.3)
- C NC N/A PROPORTIONS: The height-to-thickness ratio of the shear walls at each story shall be less than 30. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.4.4)

Diaphragms

- C NC N/A CROSS TIES: There shall be continuous cross ties between diaphragm chords. (Tier 2: Sec. 4.5.1.2)
- C NC N/A OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls shall be less than 25% of the wall length for Life Safety and 15% of the wall length for Immediate Occupancy. (Tier 2: Sec. 4.5.1.4)
- C NC N/A OPENINGS AT EXTERIOR MASONRY SHEAR WALLS: Diaphragm openings immediately adjacent to exterior masonry shear walls shall not be greater than 8 feet long for Life Safety and 4 ft. long for Immediate Occupancy. (Tier 2: Sec. 4.5.1.6)
- C NC N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)
- C NC N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8)
- C NC N/A STRAIGHT SHEATHING: All straight sheathed diaphragms shall have aspect ratios less than 2 to 1 for Life Safety and 1 to 1 for Immediate Occupancy in the direction being considered. (Tier 2: Sec. 4.5.2.1)
- C NC N/A SPANS: All wood diaphragms with spans greater than 24 ft. for Life Safety and 12 ft. for Immediate Occupancy shall consist of wood structural panels or diagonal sheathing. Wood commercial and industrial buildings may have rod-braced systems. (Tier 2: Sec. 4.5.2.2)
- C NC N/A UNBLOCKED DIAPHRAGMS: All unblocked wood structural panel diaphragms shall have horizontal spans less than 40 ft. for Life Safety and 25 ft. for Immediate Occupancy and shall have aspect ratios less than or equal to 4 to 1 for Life Safety and 3 to 1 for Immediate Occupancy. (Tier 2: Sec. 4.5.2.3)

Chapter 3.0 - Screening Phase (Tier 1)

C NC N/A NON-CONCRETE DIAPHRAGMS: Untopped metal deck diaphragms or metal deck diaphragms with fill other than concrete shall consist of horizontal spans of less than 40 ft. and shall have aspect ratios less than 4 to 1. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.3.1)

C NC N/A OTHER DIAPHRAGMS: The diaphragm shall not consist of a system other than those described in Section 4.5. (Tier 2: Sec. 4.5.7.1)

Connections

C NC N/A WOOD LEDGERS: The connection between the wall panels and the diaphragm shall not induce cross-grain bending or tension in the wood ledgers. (Tier 2: Sec. 4.6.1.2)

C NC N/A ANCHOR SPACING: Exterior masonry walls shall be anchored to the floor and roof systems at a spacing of 4 ft. or less for Life Safety and 3 ft. or less for Immediate Occupancy (Tier 2: Sec. 4.6.1.3)

C NC N/A STIFFNESS OF WALL ANCHORS: Anchors of concrete or masonry walls to wood structural elements shall be installed taut and shall be stiff enough to prevent movement between the wall and the diaphragm. If bolts are present, the size of the bolt holes in both the connector and framing shall be a maximum of 1/16" larger than the bolt diameter. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.6.1.5)

**3.7.14 Basic Structural Checklist For Building Type
RM2: Reinforced Masonry Bearing Wall Buildings With Stiff Diaphragms**

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

These buildings have bearing walls that consist of reinforced brick or concrete block masonry. Diaphragms consist of metal deck with concrete fill, precast concrete planks, tees, or double-tees, with or without a cast-in-place concrete topping slab, and are stiff relative to the walls. The floor and roof framing is supported on interior steel or concrete frames or interior reinforced masonry walls.

Building System

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|---|----|-----|--|
| C | NC | N/A | LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1) |
| C | NC | N/A | MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3) |
| C | NC | N/A | WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1) |
| C | NC | N/A | SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2) |
| C | NC | N/A | GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3) |
| C | NC | N/A | VERTICAL DISCONTINUITIES: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |
| C | NC | N/A | MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5) |

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | TORSION: The distance between the story center of mass and the story center of rigidity shall be less than 20% of the building width in either plan dimension for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.6) |
| C | NC | N/A | DETERIORATION OF CONCRETE: There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements. (Tier 2: Sec. 4.3.3.4) |
| C | NC | N/A | MASONRY UNITS: There shall be no visible deterioration of masonry units. (Tier 2: Sec. 4.3.3.7) |
| C | NC | N/A | MASONRY JOINTS: The mortar shall not be easily scraped away from the joints by hand with a metal tool, and there shall be no areas of eroded mortar. (Tier 2: Sec. 4.3.3.8) |
| C | NC | N/A | REINFORCED MASONRY WALL CRACKS: All existing diagonal cracks in wall elements shall be less than 1/8" for Life Safety and 1/16" for Immediate Occupancy, shall not be concentrated in one location, and shall not form an X pattern. (Tier 2: Sec. 4.3.3.10) |

Lateral Force Resisting System

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|---|----|-----|--|
| C | NC | N/A | REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.1.1) |
| C | NC | N/A | SHEAR STRESS CHECK: The shear stress in the reinforced masonry shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 50 psi for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.4.1) |
| C | NC | N/A | REINFORCING STEEL: The total vertical and horizontal reinforcing steel ratio in reinforced masonry walls shall be greater than 0.002 for Life Safety and 0.003 for Immediate Occupancy of the wall with the minimum of 0.0007 for Life Safety and 0.001 for Immediate Occupancy in either of the two directions; the spacing of reinforcing steel shall be less than 48" for Life Safety and 24" for Immediate Occupancy; and all vertical bars shall extend to the top of the walls. (Tier 2: Sec. 4.4.2.4.2) |

Diaphragms

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| C | NC | N/A | TOPPING SLAB: Precast concrete diaphragm elements shall be interconnected by a continuous reinforced concrete topping slab. (Tier 2: Sec. 4.5.5.1) |
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Connections

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| C | NC | N/A | WALL ANCHORAGE: Exterior concrete or masonry walls shall be anchored for out-of-plane forces at each diaphragm level with steel anchors or straps that are developed into the diaphragm. (Tier 2: Sec. 4.6.1.1) |
| C | NC | N/A | TRANSFER TO SHEAR WALLS: Diaphragms shall be reinforced and connected for transfer of loads to the shear walls for Life Safety and the connections shall be able to develop the shear strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.2.1) |
| C | NC | N/A | TOPPING SLAB TO WALLS OR FRAMES: Reinforced concrete topping slabs that interconnect the precast concrete diaphragm elements shall be doweled into the shear wall or frame elements for Life Safety and the dowels shall be able to develop the shear strength of the walls or frames for Immediate Occupancy. (Tier 2: Sec. 4.6.2.3) |

Chapter 3.0 - Screening Phase (Tier 1)

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|---|----|-----|--|
| C | NC | N/A | WALL REINFORCING: Walls shall be doveled into the foundation for Life Safety and the dowels shall be able to develop the strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.3.5) |
| C | NC | N/A | GIRDER/COLUMN CONNECTION: There shall be a positive connection between the girder and the column support. (Tier 2: Sec. 4.6.4.1) |

**3.7.14S Supplemental Structural Checklist For Building Type
RM2: Reinforced Masonry Bearing Wall Buildings With Stiff Diaphragms**

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

- C NC N/A REINFORCING AT OPENINGS: There shall be added trim reinforcement around all wall openings. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.6)
- C NC N/A PROPORTIONS: The height-to-thickness ratio of the shear walls at each story shall be less than 30. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.4.4)

Diaphragms

- C NC N/A OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls shall be less than 25% of the wall length for Life Safety and 15% of the wall length for Immediate Occupancy. (Tier 2: Sec. 4.5.1.4)
- C NC N/A OPENINGS AT EXTERIOR MASONRY SHEAR WALLS: Diaphragm openings immediately adjacent to exterior masonry shear walls shall not be greater than 8 feet long for Life Safety and 4 ft. long for Immediate Occupancy. (Tier 2: Sec. 4.5.1.6)
- C NC N/A PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)
- C NC N/A DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8)

Connections

- C NC N/A ANCHOR SPACING: Exterior masonry walls shall be anchored to the floor and roof systems at a spacing of 4 ft. or less for Life Safety and 3 ft. or less for Immediate Occupancy. (Tier 2: Sec. 4.6.1.3)

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**3.7.15A Basic Structural Checklist For Building Type
URMA: Unreinforced Masonry Bearing Wall Buildings With Stiff Diaphragms**

This Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Commentary:

These buildings have perimeter bearing walls that consist of unreinforced clay brick masonry. Interior bearing walls, when present, also consist of unreinforced clay brick masonry. Diaphragms are stiff relative to the unreinforced masonry walls and interior framing. In older construction or large, multistory buildings, diaphragms consist of cast-in-place concrete. In regions of low seismicity, more recent construction consists of metal deck and concrete fill supported on steel framing.

Building System

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|---|----|-----|--|
| C | NC | N/A | LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1) |
| C | NC | N/A | MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3) |
| C | NC | N/A | WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1) |
| C | NC | N/A | SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2) |
| C | NC | N/A | GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3) |
| C | NC | N/A | VERTICAL DISCONTINUITIES: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4) |
| C | NC | N/A | MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5) |

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | TORSION: The distance between the story center of mass and the story center of rigidity shall be less than 20% of the building width in either plan dimension for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.6) |
| C | NC | N/A | DETERIORATION OF CONCRETE: There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements. (Tier 2: Sec. 4.3.3.4) |
| C | NC | N/A | MASONRY UNITS: There shall be no visible deterioration of masonry units. (Tier 2: Sec. 4.3.3.7) |
| C | NC | N/A | MASONRY JOINTS: The mortar shall not be easily scraped away from the joints by hand with a metal tool, and there shall be no areas of eroded mortar. (Tier 2: Sec. 4.3.3.8) |
| C | NC | N/A | UNREINFORCED MASONRY WALL CRACKS There shall be no existing diagonal cracks in wall elements greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy or out-of-plane offsets in the bed joint greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy. (Tier 2: Sec. 4.3.3.11) |

Lateral Force Resisting System

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|---|----|-----|---|
| C | NC | N/A | REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.1.1) |
| C | NC | N/A | SHEAR STRESS CHECK: The shear stress in the unreinforced masonry shear walls calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 15 psi for clay units and 30 psi for concrete units for Life Safety and Immediate Occupancy (Tier 2: Sec. 4.4.2.5.1) |

Connections

- | | | | |
|---|----|-----|--|
| C | NC | N/A | WALL ANCHORAGE: Exterior concrete or masonry walls shall be anchored for out-of-plane forces at each diaphragm level with steel anchors or straps that are developed into the diaphragm. (Tier 2: Sec. 4.6.1.1) |
| C | NC | N/A | TRANSFER TO SHEAR WALLS Diaphragms shall be reinforced and connected for transfer of loads to the shear walls for Life Safety and the connections shall be able to develop the shear strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.2.1) |
| C | NC | N/A | GIRDER/COLUMN CONNECTION: There shall be a positive connection between the girder and the column support. (Tier 2: Sec. 4.6.4.1) |

**3.7.15AS Supplemental Structural Checklist For Building Type
URMA: Unreinforced Masonry Bearing Wall Buildings With Stiff Diaphragms**

This Supplemental Structural Checklist shall be completed when required by Table 3-2. The Basic Structural Checklist shall be completed prior to completing this Supplemental Structural Checklist.

Lateral Force Resisting System

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|--------------------------------------|----|-----|--|------------------------------------|---|--------------------------------------|----|-----------------------|----|
| C | NC | N/A | <p>PROPORTIONS: The height-to-thickness ratio of the shear walls at each story shall be less than the following for Life Safety and Immediate Occupancy (Tier 2: Sec. 4.4.2.5.2):</p> <table border="0" style="margin-left: 20px;"> <tr> <td>Top story of multi-story building:</td> <td style="text-align: right;">9</td> </tr> <tr> <td>First story of multi-story building:</td> <td style="text-align: right;">15</td> </tr> <tr> <td>All other conditions:</td> <td style="text-align: right;">13</td> </tr> </table> | Top story of multi-story building: | 9 | First story of multi-story building: | 15 | All other conditions: | 13 |
| Top story of multi-story building: | 9 | | | | | | | | |
| First story of multi-story building: | 15 | | | | | | | | |
| All other conditions: | 13 | | | | | | | | |
| C | NC | N/A | <p>MASONRY LAY-UP: Filled collar joints of multiwythe masonry walls shall have negligible voids. (Tier 2: Sec. 4.4.2.5.3)</p> | | | | | | |

Diaphragms

General

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|---|----|-----|--|
| C | NC | N/A | <p>OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls shall be less than 25% of the wall length for Life Safety and 15% of the wall length for Immediate Occupancy. (Tier 2: Sec. 4.5.1.4)</p> |
| C | NC | N/A | <p>OPENINGS AT EXTERIOR MASONRY SHEAR WALLS: Diaphragm openings immediately adjacent to exterior masonry shear walls shall not be greater than 8 feet long for Life Safety and 4 ft. long for Immediate Occupancy. (Tier 2: Sec. 4.5.1.6)</p> |
| C | NC | N/A | <p>PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7)</p> |
| C | NC | N/A | <p>DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8)</p> |

Connections

- | | | | |
|---|----|-----|---|
| C | NC | N/A | <p>ANCHOR SPACING: Exterior masonry walls shall be anchored to the floor and roof systems at a spacing of 4 ft. or less for Life Safety and 3 ft. or less for Immediate Occupancy. (Tier 2: Sec. 4.6.1.3)</p> |
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3.7.16 General Basic Structural Checklist

This General Basic Structural Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

BUILDING SYSTEM

General

- C NC N/A LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation. (Tier 2: Sec. 4.3.1.1)
- C NC N/A ADJACENT BUILDINGS: An adjacent building shall not be located next to the structure being evaluated closer than 4% of the height for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.1.2)
- C NC N/A MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure. (Tier 2: Sec. 4.3.1.3)

Configuration

- C NC N/A WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80% of the strength in an adjacent story above, or below, for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.1)
- C NC N/A SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70% of the stiffness in an adjacent story above or below or less than 80% of the average stiffness of the three stories above or below for Life-Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.2)
- C NC N/A GEOMETRY: There shall be no changes in horizontal dimension of the lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses. (Tier 2: Sec. 4.3.2.3)
- C NC N/A VERTICAL DISCONTINUITIES: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4)
- C NC N/A MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.5)
- C NC N/A TORSION: The distance between the story center of mass and the story center of rigidity shall be less than 20% of the building width in either plan dimension for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.3.2.6)

Chapter 3.0 - Screening Phase (Tier 1)

Condition of Materials

C	NC	N/A	DETERIORATION OF WOOD: There shall be no signs of decay, shrinkage, splitting, fire damage, or sagging in any of the wood members and none of the metal accessories shall be deteriorated, broken, or loose. (Tier 2: Sec. 4.3.3.1)
C	NC	N/A	OVERDRIVEN FASTENERS There shall be no evidence of overdriven fasteners in the shear walls (Tier 2: Sec. 4.3.3.2)
C	NC	N/A	DETERIORATION OF STEEL: There shall be no visible rusting, corrosion, cracking or other deterioration in any of the steel elements or connections in the vertical- or lateral-force-resisting systems. (Tier 2: Sec. 4.3.3.3)
C	NC	N/A	DETERIORATION OF CONCRETE: There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements. (Tier 2: Sec. 4.3.3.4)
C	NC	N/A	POST-TENSIONING ANCHORS: There shall be no evidence of corrosion or spalling in the vicinity of post-tensioning or end fittings. Coil anchors shall not have been used. (Tier 2: Sec. 4.3.3.5)
C	NC	N/A	PRECAST CONCRETE WALLS: There shall be no visible deterioration of concrete or reinforcing steel or evidence of distress, especially at the connections. (Tier 2: Sec. 4.3.3.6)
C	NC	N/A	MASONRY UNITS: There shall be no visible deterioration of masonry units. (Tier 2: Sec. 4.3.3.7)
C	NC	N/A	MASONRY JOINTS: The mortar shall not be easily scraped away from the joints by hand with a metal tool, and there shall be no areas of eroded mortar. (Tier 2: Sec. 4.3.3.8)
C	NC	N/A	CONCRETE WALL CRACKS All existing diagonal cracks in wall elements shall be less than 1/8" for Life Safety and 1/16" for Immediate Occupancy, shall not be concentrated in one location, and shall not form an X pattern. (Tier 2: Sec. 4.3.3.9)
C	NC	N/A	REINFORCED MASONRY WALL CRACKS All existing diagonal cracks in wall elements shall be less than 1/8" for Life Safety and 1/16" for Immediate Occupancy, shall not be concentrated in one location, and shall not form an X pattern. (Tier 2: Sec. 4.3.3.10)
C	NC	N/A	UNREINFORCED MASONRY WALL CRACKS There shall be no existing diagonal cracks in wall elements greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy or out-of-plane offsets in the bed joint greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy. (Tier 2: Sec. 4.3.3.11)
C	NC	N/A	CRACKS IN INFILL WALLS: There shall be no existing diagonal cracks in infill walls that extend throughout a panel, are greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy, or have out-of-plane offsets in the bed joint greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy. (Tier 2: Sec. 4.3.3.12)
C	NC	N/A	CRACKS IN BOUNDARY COLUMNS There shall be no existing diagonal cracks wider than 1/8" for Life Safety and 1/16" for Immediate Occupancy in concrete columns that encase masonry infills. (Tier 2: Sec. 4.3.3.13)

LATERAL FORCE RESISTING SYSTEM

Moment Frames

General

- C NC N/A REDUNDANCY: The number of lines of moment frames in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. The number of bays of moment frames in each line shall be greater than or equal to 2 for Life Safety and 3 for Immediate Occupancy. (Tier 2: Sec. 4.4.1.1.1)

Moment Frames with Infill Walls

- C NC N/A INTERFERING WALLS: All infill walls placed in moment frames shall be isolated from structural elements. (Tier 2: Sec. 4.4.1.2.1)

Steel Moment Frames

- C NC N/A DRIFT CHECK: The drift ratio of the steel moment frames, calculated using the Quick Check procedure of Section 3.5.3.1, shall be less than 0.025 for Life Safety and 0.015 for Immediate Occupancy. (Tier 2: Sec. 4.4.1.3.1)

- C NC N/A AXIAL STRESS CHECK: The axial stress due to gravity loads in columns subjected to overturning forces shall be less than $0.10F_y$ for Life Safety and Immediate Occupancy. Alternatively, the axial stress due to overturning forces alone, calculated using the Quick Check Procedure of Section 3.5.3.6, shall be less than $0.30F_y$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.1.3.2)

Concrete Moment Frames

- C NC N/A SHEAR STRESS CHECK The shear stress in the concrete columns, calculated using the Quick Check procedure of Section 3.5.3.2, shall be less than 100 psi or $2\sqrt{f'_c}$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.1.4.1)

- C NC N/A AXIAL STRESS CHECK: The axial stress due to gravity loads in columns subjected to overturning forces shall be less than $0.10f'_c$ for Life Safety and Immediate Occupancy. Alternatively, the axial stresses due to overturning forces alone, calculated using the Quick Check Procedure of Section 3.5.3.6, shall be less than $0.30f'_c$ for Life Safety and Immediate Occupancy. (Tier2: Sec. 4.4.1.4.2)

Precast Concrete Moment Frames

- C NC N/A PRECAST CONNECTION CHECK: The precast connections at frame joints shall have the capacity to resist the shear and moment demands calculated using the Quick Procedure of Section 3.5.3.5(Tier 2: Sec. 4.4.1.5.1)

Frames Not Part of the Lateral-Force-Resisting System

- C NC N/A COMPLETE FRAMES: Steel or concrete frames classified as secondary components shall form a complete vertical load carrying system. (Tier 2: Sec. 4.4.1.6.1)

Chapter 3.0 - Screening Phase (Tier 1)

Shear Walls

General

- C NC N/A REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.1.1)

Concrete Shear Walls

- C NC N/A SHEAR STRESS CHECK: The shear stress in the concrete shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 100 psi or $2\sqrt{f'_c}$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.1)
- C NC N/A REINFORCING STEEL: The ratio of reinforcing steel area to gross concrete area shall be greater than 0.0015 in the vertical direction and 0.0025 in the horizontal direction for Life Safety and Immediate Occupancy. The spacing of reinforcing steel shall be equal to or less than 18" for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.2)
- C NC N/A COLUMN SPLICES: Steel columns encased in shear wall boundary elements shall have splices that develop the tensile strength of the column. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.9)

Precast Concrete Shear Walls

- C NC N/A SHEAR STRESS CHECK: The shear stress in the precast panels, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 100 psi or $2\sqrt{f'_c}$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.3.1)
- C NC N/A REINFORCING STEEL: The ratio of reinforcing steel area to gross concrete area shall be greater than 0.0015 in the vertical direction and 0.0025 in the horizontal direction for Life Safety and Immediate Occupancy. The spacing of reinforcing steel shall be equal to or less than 18" for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.3.2)

Reinforced Masonry Shear Walls

- C NC N/A SHEAR STRESS CHECK: The shear stress in the reinforced masonry shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 50 psi for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.2.4.1)
- C NC N/A REINFORCING STEEL: The total vertical and horizontal reinforcing steel ratio in reinforced masonry walls shall be greater than 0.002 for Life Safety and 0.003 for Immediate Occupancy of the wall with the minimum of 0.0007 for Life Safety and 0.001 for Immediate Occupancy in either of the two directions; the spacing of reinforcing steel shall be less than 48" for Life Safety and 24" for Immediate Occupancy; and all vertical bars shall extend to the top of the walls. (Tier 2: Sec. 4.4.2.4.2)

Chapter 3.0 - Screening Phase (Tier 1)

Unreinforced Masonry Shear Walls

- C NC N/A SHEAR STRESS CHECK: The shear stress in the unreinforced masonry shear walls calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 15 psi for clay units and 30 psi for concrete units for Life Safety and Immediate Occupancy (Tier 2: Sec. 4.4.2.5.1)

Infill Walls in Frames

- C NC N/A WALL CONNECTIONS: All infill walls shall have a positive connection to the frame to resist out-of-plane forces for Life Safety and the connection shall be able to develop the out-of-plane strength of the wall for Immediate Occupancy. (Tier 2: Sec. 4.4.2.6.1)

Walls in Wood-Frame Buildings

- C NC N/A SHEAR STRESS CHECK The shear stress in the shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than the following values for Life Safety and Immediate Occupancy (Tier 2: Sec. 4.4.2.7.1)

Structural panel sheathing:	1000 plf
Diagonal sheathing:	700 plf
Straight sheathing:	80 plf
All other conditions:	100 plf

- C NC N/A STUCCO (EXTERIOR PLASTER) SHEAR WALLS: Multistory buildings shall not rely on exterior stucco walls as the primary lateral-force-resisting system. (Tier 2: Sec. 4.4.2.7.2)
- C NC N/A GYPSUM WALLBOARD OR PLASTER SHEAR WALLS: Interior plaster or gypsum wallboard shall not be used as shear walls on buildings over one story in height. (Tier 2: Sec. 4.4.2.7.3)
- C NC N/A NARROW WOOD SHEAR WALLS: Narrow wood shear walls with an aspect ratio greater than 2 to 1 for Life Safety and 1.5 to 1 for Immediate Occupancy shall not be used to resist lateral forces developed in the building. (Tier 2: Sec. 4.4.2.7.4)
- C NC N/A WALLS CONNECTED THROUGH FLOORS: Shear walls shall have interconnection between stories to transfer overturning and shear forces through the floor. (Tier 2: Sec. 4.4.2.7.5)
- C NC N/A HILLSIDE SITE: For a sloping site greater than one-half story, all shear walls on the downhill slope shall have an aspect ratio less than 1 to 1 for Life-Safety and 1 to 2 for Immediate Occupancy. (Tier 2: Sec. 4.4.2.7.6)
- C NC N/A CRIPPLE WALLS All cripple walls below first floor level shear walls shall be braced to the foundation with shear elements. (Tier 2: Sec. 4.4.2.7.7)

Chapter 3.0 - Screening Phase (Tier 1)

Braced Frames

General

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|---|----|-----|--|
| C | NC | N/A | REDUNDANCY: The number of lines of braced frames in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. The number of braced bays in each line shall be greater than 2 for Life Safety and 3 for Immediate Occupancy. (Tier 2: Sec. 4.4.3.1.1) |
| C | NC | N/A | AXIAL STRESS CHECK: The axial stress in the diagonals, calculated using the Quick Check procedure of Section 3.5.3.4, shall be less than 18 ksi or $0.50F_y$ for Life Safety and for Immediate Occupancy. (Tier 2: Sec. 4.4.3.1.2) |
| C | NC | N/A | COLUMN SPLICES: All column splice details located in braced frames shall develop the tensile strength of the column. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.3.1.5) |

DIAPHRAGMS

Precast Concrete Diaphragms

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| C | NC | N/A | TOPPING SLAB: Precast concrete diaphragm elements shall be interconnected by a continuous reinforced concrete topping slab. (Tier 2: Sec. 4.5.5.1) |
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CONNECTIONS

Anchorage for Normal Forces

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|---|----|-----|---|
| C | NC | N/A | WALL ANCHORAGE: Exterior concrete or masonry walls shall be anchored for out-of-plane forces at each diaphragm level with steel anchors or straps that are developed into the diaphragm. (Tier 2: Sec. 4.6.1.1) |
|---|----|-----|---|

Shear Transfer

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|---|----|-----|---|
| C | NC | N/A | TRANSFER TO SHEAR WALLS: Diaphragms shall be reinforced and connected for transfer of loads to the shear walls for Life Safety and the connections shall be able to develop the shear strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.2.1) |
| C | NC | N/A | TRANSFER TO STEEL FRAMES: Diaphragms shall be connected for transfer of loads to the steel frames for Life Safety and the connections shall be able to develop the shear strength of the frames for Immediate Occupancy. (Tier 2: Sec. 4.6.2.2) |
| C | NC | N/A | TOPPING SLAB TO WALLS OR FRAMES: Reinforced concrete topping slabs that interconnect the precast concrete diaphragm elements shall be doweled into the shear wall or frame elements for Life Safety and the dowels shall be able to develop the shear strength of the walls or frames for Immediate Occupancy. (Tier 2: Sec. 4.6.2.3) |

Chapter 3.0 - Screening Phase (Tier 1)

Vertical Components

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|---|----|-----|---|
| C | NC | N/A | STEEL COLUMNS: The columns in lateral-force-resisting frames shall be anchored to the building foundation for Life Safety and the anchorage shall be able to develop the tensile capacity of the foundation for Immediate Occupancy. (Tier 2: Sec. 4.6.3.1) |
| C | NC | N/A | CONCRETE COLUMNS: All concrete columns shall be doweled into the foundation for Life Safety and the dowels shall be able to develop the tensile capacity of the column for Immediate Occupancy. (Tier 2: Sec. 4.6.3.2) |
| C | NC | N/A | WOOD POSTS: There shall be a positive connection of wood posts to the foundation. (Tier 2: Sec. 4.6.3.3) |
| C | NC | N/A | WOOD SILLS All wood sill s shall be bolted to the foundation. (Tier 2: Sec. 4.6.3.4) |
| C | NC | N/A | WALL REINFORCING: Walls shall be doweled into the foundation for Life Safety and the dowels shall be able to develop the strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.3.5) |
| C | NC | N/A | SHEAR-WALL-BOUNDARY COLUMNS The shear wall boundary columns shall be anchored to the building foundation for Life Safety and the anchorage shall be able to develop the tensile capacity of the column for Immediate Occupancy. (Tier 2: Sec. 4.6.3.6) |
| C | NC | N/A | PRECAST WALL PANELS Precast wall panels shall be doweled into the foundation for Life Safety and the dowels shall be able to develop the strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.6.3.7) |
| C | NC | N/A | WALL PANELS Metal, fiberglass or cementitious wall panels shall be positively attached to the foundation for Life Safety and the attachment shall be able to develop the shear capacity of the panels for Immediate Occupancy. (Tier 2: Sec. 4.6.3.8) |

Interconnection of Elements

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|---|----|-----|---|
| C | NC | N/A | GIRDER/COLUMN CONNECTION: There shall be a positive connection between the girder and the column support. (Tier 2: Sec. 4.6.4.1) |
|---|----|-----|---|

Panel Connections

- | | | | |
|---|----|-----|---|
| C | NC | N/A | ROOF PANELS: Metal, plastic, or cementitious roof panels shall be positively attached to the roof framing to resist seismic forces for Life Safety and the attachment shall be able to develop the strength of the panels for Immediate Occupancy. (Tier 2: Sec. 4.6.5.1) |
| C | NC | N/A | WALL PANELS Metal, fiberglass or cementitious wall panels shall be positively attached to the framing to resist seismic forces or Life Safety and the attachment shall be able to develop the strength of the panels for Immediate Occupancy. (Tier 2: Sec. 4.6.5.2) |

3.7.16S General Supplemental Structural Checklist

This General Supplemental Structural Checklist shall be completed when required by Table 3-2. The General Basic Structural Checklist shall be completed prior to completing this General Supplemental Structural Checklist.

LATERAL FORCE RESISTING SYSTEM

Moment Frames

Steel Moment Frames

- C NC N/A MOMENT-RESISTING CONNECTIONS: All moment connections shall be able to develop the strength of the adjoining members or panel zones. (Tier 2: Sec. 4.4.1.3.3)
- C NC N/A PANEL ZONES: All panel zones shall have the shear capacity to resist the shear demand required to develop $0.8\Sigma M_p$ of the girders framing in at the face of the column. (Tier 2: Sec. 4.4.1.3.4)
- C NC N/A COLUMN SPLICES: All column splice details located in moment resisting frames shall include connection of both flanges and the web for Life Safety and the splice shall develop the strength of the column for Immediate Occupancy. (Tier 2: Sec. 4.4.1.3.5)
- C NC N/A STRONG COLUMN/WEAK BEAM: The percent of strong column/weak beam joints in each story of each line of moment resisting frames shall be greater than 50% for Life Safety and 75% for Immediate Occupancy. (Tier 2: Sec. 4.4.1.3.6)
- C NC N/A COMPACT MEMBERS: All moment frame elements shall meet compact section requirements set forth by the *Load and Resistance Factor Design Specification for Structural Steel Buildings* (AISC, 1993). This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.7)
- C NC N/A BEAM PENETRATIONS: All openings in frame-beam webs shall be less than 1/4 of the beam depth and shall be located in the center half of the beams. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.8)
- C NC N/A GIRDER FLANGE CONTINUITY PLATES: There shall be girder flange continuity plates at all moment-resisting frame joints. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.9)
- C NC N/A OUT-OF-PLANE BRACING: Beam-column joints shall be braced out-of-plane. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.10)
- C NC N/A BOTTOM FLANGE BRACING: The bottom flange of beams shall be braced out-of-plane. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.3.11)

Concrete Moment Frames

- C NC N/A FLAT SLAB FRAMES: The lateral-force-resisting system shall not be a frame consisting of columns and a flat slab/plate without beams. (Tier 2: Sec. 4.4.1.4.3)
- C NC N/A PRESTRESSED FRAME ELEMENTS: The lateral-load-resisting frames shall not include any prestressed or post-tensioned elements. (Tier 2: Sec. 4.4.1.4.4)

Chapter 3.0 - Screening Phase (Tier 1)

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| C | NC | N/A | SHORT CAPTIVE COLUMNS: There shall be no columns at a level with height/depth ratios less than 50% of the nominal height/depth ratio of the typical columns at that level for Life Safety and 75% for Immediate Occupancy. (Tier 2: Sec. 4.4.1.4.5) |
| C | NC | N/A | NO SHEAR FAILURES: The shear capacity of frame members shall be able to develop the moment capacity at the top and bottom of the columns. (Tier 2: Sec. 4.4.1.4.6) |
| C | NC | N/A | STRONG COLUMN/WEAK BEAM: The sum of the moment capacity of the columns shall be 20% greater than that of the beams at frame joints (Tier 2: Sec. 4.4.1.4.7) |
| C | NC | N/A | BEAM BARS: At least two longitudinal top and two longitudinal bottom bars shall extend continuously throughout the length of each frame beam. At least 25% of the longitudinal bars provided at the joints for either positive or negative moment shall be continuous throughout the length of the members for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.1.4.8) |
| C | NC | N/A | COLUMN-BAR SPLICES: All column bar lap splice lengths shall be greater than $35 d_b$ for Life Safety and $50 d_b$ for Immediate Occupancy and shall be enclosed by ties spaced at or less than $8 d_b$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.1.4.9) |
| C | NC | N/A | BEAM-BAR SPLICES: The lap splices for longitudinal beam reinforcing shall not be located within $l_b/4$ of the joints and shall not be located within the vicinity of potential plastic hinge locations. (Tier 2: Sec. 4.4.1.4.10) |
| C | NC | N/A | COLUMN-TIE SPACING: Frame columns shall have ties spaced at or less than $d/4$ for Life Safety and Immediate Occupancy throughout their length and at or less than $8 d_b$ for Life Safety and Immediate Occupancy at all potential plastic hinge locations. (Tier 2: Sec. 4.4.1.4.11) |
| C | NC | N/A | STIRRUP SPACING: All beams shall have stirrups spaced at or less than $d/2$ for Life Safety and Immediate Occupancy throughout their length. At potential plastic hinge locations stirrups shall be spaced at or less than the minimum of $8 d_b$ or $d/4$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.1.4.12) |
| C | NC | N/A | JOINT REINFORCING: Beam-column joints shall have ties spaced at or less than $8 d_b$ for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.4.1.4.13) |
| C | NC | N/A | JOINT ECCENTRICITY: There shall be no eccentricities larger than 20% of the smallest column plan dimension between girder and column centerlines This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.4.14) |
| C | NC | N/A | STIRRUP AND TIE HOOKS: The beam stirrups and column ties shall be anchored into the member cores with hooks of 135° or more. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.1.4.15) |

Chapter 3.0 - Screening Phase (Tier 1)

Precast Concrete Moment Frames

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|---|----|-----|--|
| C | NC | N/A | PRECAST FRAMES: For buildings with concrete shear walls, lateral forces shall not be resisted by precast concrete frame elements. (Tier 2: Sec. 4.4.1.5.2) |
| C | NC | N/A | PRECAST CONNECTIONS: For buildings with concrete shear walls, the connection between precast frame elements such as chords, ties, and collectors in the lateral-force-resisting system shall develop the capacity of the connected members. (Tier 2: Sec. 4.4.1.5.3) |

Frames Not Part of the Lateral-Force-Resisting System

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|---|----|-----|---|
| C | NC | N/A | DEFLECTION COMPATIBILITY: Secondary components shall have the shear capacity to develop the flexural strength of the elements for Life Safety and shall have ductile detailing for Immediate Occupancy. (Tier 2: Sec. 4.4.1.6.2) |
| C | NC | N/A | FLAT SLABS: Flat slabs/plates classified as secondary components shall have continuous bottom steel through the column joints for Life Safety. Flat slabs/plates shall not be permitted for the Immediate Occupancy Performance Level. (Tier 2: Sec. 4.4.1.6.3) |

Shear Walls

Concrete Shear Walls

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|---|----|-----|--|
| C | NC | N/A | COUPLING BEAMS: The stirrups in all coupling beams over means of egress shall be spaced at or less than $d/2$ and shall be anchored into the core with hooks of 135° or more for Life Safety and Immediate Occupancy. In addition, the beams have the capacity in shear to develop the uplift capacity of the adjacent wall for Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.3) |
| C | NC | N/A | OVERTURNING: All shear walls shall have aspect ratios less than 4 to 1. Wall piers need not be considered. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.4) |
| C | NC | N/A | CONFINEMENT REINFORCING: For shear walls with aspect ratios greater than 2.0, the boundary elements shall be confined with spirals or ties with spacing less than $8 d_b$. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.5) |
| C | NC | N/A | REINFORCING AT OPENINGS: There shall be added trim reinforcement around all wall openings. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.6) |
| C | NC | N/A | WALL THICKNESS: Thickness of bearing walls shall not be less than $1/25$ the minimum unsupported height or length, nor less than 4". This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.2.7) |
| C | NC | N/A | WALL CONNECTIONS: There shall be a positive connection between the shear walls and the steel beams and columns for Life Safety and the connection shall be able to develop the strength of the walls for Immediate Occupancy. (Tier 2: Sec. 4.4.2.2.8) |

Chapter 3.0 - Screening Phase (Tier 1)

Precast Concrete Shear Walls

- C NC N/A WALL OPENINGS: Openings shall constitute less than 75% of the length of any perimeter wall for Life Safety and 50% for Immediate Occupancy with the wall piers having aspect ratios of less than 2. (Tier 2: Sec. 4.4.2.3.3)
- C NC N/A CORNER OPENINGS: Walls with openings at a building corner larger than the width of a typical panel shall be connected to the remainder of the wall with collector reinforcing (Tier 2: Sec. 4.4.2.3.4)
- C NC N/A PANEL-TO-PANEL CONNECTIONS: Adjacent wall panels shall be interconnected to transfer overturning forces between panels by methods other than welded steel inserts. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.3.5)
- C NC N/A WALL THICKNESS: Thickness of bearing walls shall not be less than 1/25 the minimum unsupported height or length, nor less than 4". This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.3.6)

Reinforced Masonry Shear Walls

- C NC N/A REINFORCING AT OPENINGS: All wall openings that interrupt rebar shall have trim reinforcing on all sides. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.2.4.3)
- C NC N/A PROPORTIONS: The height-to-thickness ratio of the shear walls at each story shall be less than 30. This statement shall apply to the immediate occupancy performance level only. (Tier 2: sec. 4.4.2.4.4)

Unreinforced Masonry Shear Walls

- C NC N/A PROPORTIONS: The height-to-thickness ratio of the shear walls at each story shall be less than the following for Life Safety and Immediate Occupancy (Tier 2: Sec. 4.4.2.5.2)
- | | |
|--------------------------------------|----|
| Top story of multi-story building: | 9 |
| First story of multi-story building: | 15 |
| All other conditions: | 13 |
- C NC N/A MASONRY LAY-UP: Filled collar joints of multiwythe masonry walls shall have negligible voids. (Tier 2: Sec. 4.4.2.5.3)

Chapter 3.0 - Screening Phase (Tier 1)

Infill Walls in Frames

- | | | | |
|---|----|-----|--|
| C | NC | N/A | PROPORTIONS: The height-to-thickness ratio of the infill walls at each story shall be less than 9 for Life Safety in regions of high seismicity, 13 for Immediate Occupancy in regions of moderate seismicity, and 8 for Immediate Occupancy in regions of high seismicity. (Tier 2: Sec. 4.4.2.6.2) |
| C | NC | N/A | SOLID WALLS The infill walls shall not be of cavity construction. (Tier 2: Sec. 4.4.2.6.3) |
| C | NC | N/A | INFILL WALLS The infill walls shall be continuous to the soffits of the frame beams. (Tier 2: Sec. 4.4.2.6.4) |

Walls in Wood-Frame Buildings

- | | | | |
|---|----|-----|--|
| C | NC | N/A | OPENINGS: Walls with garage doors or other large openings shall be braced with plywood shear walls or shall be supported by adjacent construction through substantial positive ties. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec 4.4.2.7.8) |
| C | NC | N/A | HOLD-DOWN ANCHORS: All walls shall have properly constructed hold-down anchors. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec 4.4.2.7.9) |

Braced Frames

General

- | | | | |
|---|----|-----|--|
| C | NC | N/A | STIFFNESS OF DIAGONALS: All diagonal elements required to carry compression shall have K/r ratios less than 120. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.3.1.3) |
| C | NC | N/A | CONNECTION STRENGTH: All the brace connections shall develop the yield capacity of the diagonals. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.3.1.4) |
| C | NC | N/A | OUT-OF-PLANE BRACING: Braced frame connections attached to beam bottom flanges located away from beam-column joints shall be braced out-of-plane at the bottom flange of the beams. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.3.1.6) |

Centrally Braced Frames

- | | | | |
|---|----|-----|---|
| C | NC | N/A | K-BRACING: The bracing system shall not include K-braced bays. (Tier 2: Sec. 4.4.3.2.1) |
| C | NC | N/A | TENSION-ONLY BRACES: Tension-only braces shall not comprise more than 70% of the total lateral-force-resisting capacity in structures over two stories in height. (Tier 2: Sec. 4.4.3.2.2) |
| C | NC | N/A | CHEVRON BRACING The bracing system shall not include chevron, or V-braced bays. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.3.2.3) |
| C | NC | N/A | CONCENTRIC JOINTS: All the diagonal braces shall frame into the beam-column joints concentrically. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.4.3.2.4) |

Chapter 3.0 - Screening Phase (Tier 1)

Diaphragms

General

- | | | | |
|---|----|-----|---|
| C | NC | N/A | DIAPHRAGM CONTINUITY: The diaphragms shall not be composed of split-level floors. In wood buildings, the diaphragms shall not have expansion joints. (Tier 2: Sec. 4.5.1.1) |
| C | NC | N/A | CROSS TIES: There shall be continuous cross ties between diaphragm chords. (Tier 2: Sec. 4.5.1.2) |
| C | NC | N/A | ROOF CHORD CONTINUITY: All chord elements shall be continuous, regardless of changes in roof elevation. (Tier 2: Sec. 4.5.1.3) |
| C | NC | N/A | OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls shall be less than 25% of the wall length for Life Safety and 15% of the wall length for Immediate Occupancy. (Tier 2: Sec. 4.5.1.4) |
| C | NC | N/A | OPENINGS AT BRACED FRAMES: Diaphragm openings immediately adjacent to the braced frames shall extend less than 25% of the frame length for Life Safety and 15% of the frame length for Immediate Occupancy. (Tier 2: Sec. 4.5.1.5) |
| C | NC | N/A | OPENINGS AT EXTERIOR MASONRY SHEAR WALLS: Diaphragm openings immediately adjacent to exterior masonry shear walls shall not be greater than 8 feet long for Life Safety and 4 ft. long for Immediate Occupancy. (Tier 2: Sec. 4.5.1.6) |
| C | NC | N/A | PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.7) |
| C | NC | N/A | DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.1.8) |

Wood Diaphragms

- | | | | |
|---|----|-----|---|
| C | NC | N/A | STRAIGHT SHEATHING: All straight sheathed diaphragms shall have aspect ratios less than 2 to 1 for Life Safety and 1 to 1 for Immediate Occupancy in the direction being considered. (Tier 2: Sec. 4.5.2.1) |
| C | NC | N/A | SPANS: All wood diaphragms with spans greater than 24 ft. for Life Safety and 12 ft. for Immediate Occupancy shall consist of wood structural panels or diagonal sheathing. Wood commercial and industrial buildings may have rod-braced systems. (Tier 2: Sec. 4.5.2.2) |
| C | NC | N/A | UNBLOCKED DIAPHRAGMS: All unblocked wood structural panel diaphragms shall have horizontal spans less than 40 ft. for Life Safety and 25 ft. for Immediate Occupancy and shall have aspect ratios less than or equal to 4 to 1 for Life Safety and 3 to 1 for Immediate Occupancy. (Tier 2: Sec. 4.5.2.3) |
| C | NC | N/A | ASPECT RATIO: All wood diaphragms with an aspect ratio greater than 3 to 1 for Life Safety and 2 to 1 for Immediate Occupancy shall have nonstructural walls connected to all diaphragm levels at a spacing less than 40 ft. for Life Safety and 25 ft. for Immediate Occupancy (Tier 2: Sec. 4.5.2.4) |

Chapter 3.0 - Screening Phase (Tier 1)

Metal Deck Diaphragms

- C NC N/A NON-CONCRETE DIAPHRAGMS: Untopped metal deck diaphragms or metal deck diaphragms with fill other than concrete shall consist of horizontal spans of less than 40 ft. and shall have aspect ratios less than 4 to 1. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.5.3.1)

Other Diaphragms

- C NC N/A OTHER DIAPHRAGMS: The diaphragm shall not consist of a system other than those described in Section 4.5. (Tier 2: Sec. 4.5.7.1)

CONNECTIONS

Anchorage for Normal Forces

- C NC N/A WOOD LEDGERS: The connection between the wall panels and the diaphragm shall not induce cross-grain bending or tension in the wood ledgers. (Tier 2: Sec. 4.6.1.2)
- C NC N/A ANCHOR SPACING: Exterior masonry walls shall be anchored to the floor and roof systems at a spacing of 4 ft. or less for Life Safety and 3 ft. or less for Immediate Occupancy (Tier 2: Sec. 4.6.1.3)
- C NC N/A PRECAST PANEL CONNECTIONS: There shall be at least two anchors from each precast wall panel into the diaphragm elements for Life Safety and the anchors shall be able to develop the strength of the panels for Immediate Occupancy. (Tier 2: Sec. 4.6.1.4)
- C NC N/A STIFFNESS OF WALL ANCHORS: Anchors of concrete or masonry walls to wood structural elements shall be installed taut and shall be stiff enough to prevent movement between the wall and the diaphragm. If bolts are present, the size of the bolt holes in both the connector and framing shall be a maximum of 1/16" larger than the bolt diameter. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.6.1.5)

Vertical Components

- C NC N/A WOOD SILL BOLTS: Sill bolts shall be spaced at 6 ft. or less for Life Safety and 4 ft. or less for Immediate Occupancy, with proper edge distance provided for wood and concrete. (Tier 2: Sec. 4.6.3.9)
- C NC N/A LATERAL LOAD AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for Life Safety, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for Immediate Occupancy. (Tier 2: Sec. 4.6.3.10)

Chapter 3.0 - Screening Phase (Tier 1)

Interconnection of Elements

- | | | | |
|---|----|-----|---|
| C | NC | N/A | GIRDERS: Girders supported by walls or pilasters shall have at least two additional ties to secure the anchor bolts for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.6.4.2) |
| C | NC | N/A | CORBEL BEARING: If the frame girders bear on column corbels, the length of bearing shall be greater than 3" for Life Safety and Immediate Occupancy (Tier 2: Sec. 4.6.4.3) |
| C | NC | N/A | CORBEL CONNECTIONS: The frame girders shall not be connected to corbels with welded elements. (Tier 2: Sec. 4.6.4.4) |

Panel Connections

- | | | | |
|---|----|-----|---|
| C | NC | N/A | ROOF PANEL CONNECTIONS: Roof panel connections shall be spaced at or less than 12" for Life Safety and 8" for Immediate Occupancy. (Tier 2: Sec. 4.6.5.3) |
|---|----|-----|---|

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Chapter 3.0 - Screening Phase (Tier 1)

3.8 Geologic Site Hazards And Foundations Checklist

This Geologic Site Hazards and Foundations Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Geologic Site Hazards

The following statements shall be completed for buildings in regions of high or moderate seismicity.

- C NC N/A LIQUEFACTION: Liquefaction susceptible, saturated, loose granular soils that could jeopardize the building's seismic performance shall not exist in the foundation soils at depths within 50 feet under the building for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.7.1.1)
- C NC N/A SLOPE FAILURE: The building site shall be sufficiently remote from potential earthquake-induced slope failures or rockfalls to be unaffected by such failures or shall be capable of accommodating any predicted movements without failure. (Tier 2: Sec. 4.7.1.2)
- C NC N/A SURFACE FAULT RUPTURE: Surface fault rupture and surface displacement at the building site is not anticipated. (Tier 2: Sec. 4.7.1.3)

Condition of Foundations

The following statement shall be completed for all Tier 1 building evaluations.

- C NC N/A FOUNDATION PERFORMANCE: There shall be no evidence of excessive foundation movement such as settlement or heave that would affect the integrity or strength of the structure. (Tier 2: Sec. 4.7.2.1)

The following statement shall be completed for buildings in regions of high or moderate seismicity being evaluated to the Immediate Occupancy Performance Level.

- C NC N/A DETERIORATION: There shall not be evidence that foundation elements have deteriorated due to corrosion, sulfate attack, material breakdown, or other reasons in a manner that would affect the integrity or strength of the structure. (Tier 2: Sec. 4.7.2.2)

Capacity of Foundations

The following statement shall be completed for all Tier 1 building evaluations.

- C NC N/A POLE FOUNDATIONS: Pole foundations shall have a minimum embedment depth of 4 ft. for Life Safety and Immediate Occupancy. (Tier 2: Sec. 4.7.3.1)

Chapter 3.0 - Screening Phase (Tier 1)

The following statements shall be completed for buildings in regions of high seismicity and for buildings in regions of moderate seismicity being evaluated to the Immediate Occupancy Performance Level.

- | | | | |
|---|----|-----|--|
| C | NC | N/A | OVERTURNING: The ratio of the effective horizontal dimension, at the foundation level of the lateral-force-resisting system, to the building height (base/height) shall be greater than $0.6S_a$. (Tier 2: Sec. 4.7.3.2) |
| C | NC | N/A | TIES BETWEEN FOUNDATION ELEMENTS: The foundation shall have ties adequate to resist seismic forces where footings, piles, and piers are not restrained by beams, slabs, or soils classified as Class A, B, or C. (Tier 2: Sec. 4.7.3.3) |
| C | NC | N/A | DEEP FOUNDATIONS: Piles and piers shall be capable of transferring the lateral forces between the structure and the soil. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.7.3.4) |
| C | NC | N/A | SLOPING SITES: The grade difference from one side of the building to another shall not exceed one-half the story height at the location of embedment. This statement shall apply to the Immediate Occupancy Performance Level only. (Tier 2: Sec. 4.7.3.5) |

3.9 Nonstructural Checklists

The following checklists are included in this Section:

- Basic Nonstructural Component Checklist, and
- Supplemental Nonstructural Component Checklist.

These checklists shall be completed when required by Table 3-2. The Basic Nonstructural Component Checklist shall be completed prior to completing the Supplemental Nonstructural Component Checklist.

3.9.1 Basic Nonstructural Component Checklist

This Basic Nonstructural Component Checklist shall be completed when required by Table 3-2.

Each of the evaluation statements on this checklist shall be marked compliant (C), non-compliant (NC), or not applicable (N/A) for a Tier 1 Evaluation. Compliant statements identify issues that are acceptable according to the criteria of this Handbook, while non-compliant statements identify issues that require further investigation. Certain statements may not apply to the buildings being evaluated. For non-compliant evaluation statements, the design professional may choose to conduct further investigation using the corresponding Tier 2 evaluation procedure; the section numbers in parentheses following each evaluation statement correspond to Tier 2 evaluation procedures.

Partitions

- | | | | |
|---|----|-----|--|
| C | NC | N/A | UNREINFORCED MASONRY: Unreinforced masonry or hollow clay tile partitions shall be braced at a spacing of equal to or less than 10 feet in regions of low and moderate seismicity and 6 feet in regions of high seismicity. (Tier 2: Sec. 4.8.1.1) |
|---|----|-----|--|

Ceiling Systems

- | | | | |
|---|----|-----|--|
| C | NC | N/A | INTEGRATED CEILINGS: Integrated suspended ceilings at exits and corridors or weighing more than 2 lb/ft ² shall be laterally restrained with a minimum of 4 diagonal wires or rigid members attached to the structure above at a spacing of equal to or less than 12 ft. (Tier 2: Sec. 4.8.2.1) |
| C | NC | N/A | LAY-IN TILES: Lay-in tiles used in ceiling panels located at exitways and corridors shall be secured with clips. (Tier 2: Sec. 4.8.2.2) |
| C | NC | N/A | SUPPORT: The integrated suspended ceiling system shall not be used to laterally support the tops of gypsum board, masonry, or hollow clay tile partitions. (Tier 2: Sec. 4.8.2.3) |
| C | NC | N/A | SUSPENDED LATH AND PLASTER: Ceilings consisting of suspended lath and plaster or gypsum board shall be attached for each 10 square feet of area. (Tier 2: Sec. 4.8.2.4) |

Light Fixtures

- | | | | |
|---|----|-----|---|
| C | NC | N/A | INDEPENDENT SUPPORT: Light fixtures in suspended grid ceilings shall be supported independently of the ceiling suspension system by a minimum of two wires at diagonally opposite corners of the fixtures. (Tier 2: Sec. 4.8.3.1) |
| C | NC | N/A | EMERGENCY LIGHTING: Emergency lighting shall be anchored or braced to prevent falling or swaying during an earthquake. (Tier 2: Sec. 4.8.3.2) |

Cladding and Glazing

- | | | | |
|---|----|-----|---|
| C | NC | N/A | CLADDING ANCHORS: Cladding components weighing more than 10 psf shall be anchored to the exterior wall framing at a spacing equal to or less than 6 ft. for Life Safety and 4 ft. for Immediate Occupancy. (Tier 2: Sec. 4.8.4.1) |
| C | NC | N/A | CLADDING ISOLATION: For moment frame buildings of steel or concrete, panel connections shall be detailed to accommodate a drift ratio of 0.02 for Life Safety and 0.01 for Immediate Occupancy. (Tier 2: Sec. 4.8.4.2) |

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- | | | | |
|---|----|-----|--|
| C | NC | N/A | MULTISTORY PANELS: For multistory panels attached at each floor level, the panels and connections shall be able to accommodate a drift ratio of 0.02 for Life Safety and 0.01 for Immediate Occupancy. (Tier 2: Sec. 4.8.4.3) |
| C | NC | N/A | BEARING CONNECTIONS: Where bearing connections are required, there shall be a minimum of two bearing connections for each wall panel.(Tier 2: Sec. 4.8.4.4) |
| C | NC | N/A | INSERTS: Where inserts are used in concrete connections, the inserts shall be anchored to reinforcing steel. (Tier 2: Sec. 4.8.4.5) |
| C | NC | N/A | PANEL CONNECTIONS: Exterior cladding panels shall be anchored with a minimum of 2 connections for each wall panel for Life Safety and 4 connections for Immediate Occupancy. (Tier 2: Sec. 4.8.4.6) |
| C | NC | N/A | DETERIORATION: There shall be no evidence of deterioration or corroding in any of the connection elements. (Tier 2: Sec. 4.8.4.7) |
| C | NC | N/A | DAMAGE: There shall be no damage to exterior wall cladding. (Tier 2: Sec. 4.8.4.8) |
| C | NC | N/A | GLAZING: Glazing in curtain walls and individual panes over 16 square feet in area, located up to a height of 10 feet above an exterior walking surface, shall be laminated annealed or heat strengthened safety glass that will remain in the frame when cracked.(Tier 2: Sec. 4.8.4.9) |

Masonry Veneer

- | | | | |
|---|----|-----|--|
| C | NC | N/A | SHELF ANGLES: Masonry veneer shall be supported by shelf angles or other elements at each floor above the first floor. (Tier 2: Sec. 4.8.5.1) |
| C | NC | N/A | TIES: Masonry veneer shall be connected to the back-up with corrosion-resistant ties. The ties shall have a spacing of equal to or less than 36" for Life Safety and 24" for Immediate Occupancy with a minimum of one tie for every 2-2/3 square feet. (Tier 2: Sec. 4.8.5.2) |
| C | NC | N/A | WEAKENED PLANES: Masonry veneer shall be anchored to the back-up at locations of flashing. (Tier 2: Sec. 4.8.5.3) |

Parapets, Cornices, Ornamentation and Appendages

- | | | | |
|---|----|-----|---|
| C | NC | N/A | URM PARAPETS: There shall be no laterally unsupported unreinforced masonry parapets or cornices above the highest anchorage level with height-to-thickness ratios greater than 1.5 in regions of high seismicity and 2.5 in regions of moderate or low seismicity. (Tier 2: Sec. 4.8.8.1) |
| C | NC | N/A | CANOPIES: Canopies located at building exits shall be anchored at a spacing 10 feet for Life Safety and 6 feet for Immediate Occupancy. (Tier 2: Sec. 4.8.8.2) |

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Masonry Chimneys

- | | | | |
|---|----|-----|---|
| C | NC | N/A | URM: No unreinforced masonry chimney shall extend above the roof surface more than twice the least dimension of the chimney. (Tier 2: Sec. 4.8.9.1) |
| C | NC | N/A | MASONRY: Masonry chimneys shall be anchored to the floor and roof. (Tier 2: Sec. 4.8.9.2) |

Stairs

- | | | | |
|---|----|-----|---|
| C | NC | N/A | URM WALLS: Walls around stair enclosures shall not consist of unbraced hollow clay tile or unreinforced masonry. (Tier 2: Sec. 4.8.10.1) |
| C | NC | N/A | STAIR DETAILS: In moment frame structures, the connection between the stairs and the structure shall not rely on shallow anchors in concrete. Alternatively, the stair details shall be capable of accommodating the drift calculated using the Quick Check Procedure of Section 3.5.3.1 without inducing tension in the anchors. (Tier 2: Sec. 4.8.10.2) |

Building Contents and Furnishing

- | | | | |
|---|----|-----|---|
| C | NC | N/A | TALL NARROW CONTENTS: Contents with a height-to-depth ratio greater than 3 for Immediate Occupancy and 4 for Life Safety shall be anchored to the floor slab or adjacent walls. (Tier 2: Sec. 4.8.11.1) |
|---|----|-----|---|

Mechanical and Electrical Equipment

- | | | | |
|---|----|-----|--|
| C | NC | N/A | EMERGENCY POWER: Equipment used as part of an emergency power system shall be mounted to maintain continued operation after an earthquake. (Tier 2: Sec. 4.8.12.1) |
| C | NC | N/A | HEAVY EQUIPMENT: Equipment weighing over 20 lb that is attached to ceilings, walls, or other supports 4 ft. above the floor level shall be braced. (Tier 2: Sec. 4.8.12.2) |

Piping

- | | | | |
|---|----|-----|--|
| C | NC | N/A | FIRE SUPPRESSION PIPING: Fire suppression piping shall be anchored and braced in accordance with <i>NFPA-13</i> (NFPA, 1996). This statement need not be evaluated for buildings in regions of moderate seismicity being evaluated to the Life Safety Performance Level(Tier 2: Sec. 4.8.13.1) |
| C | NC | N/A | FLEXIBLE COUPLINGS: Fluid, gas and fire suppression piping shall have flexible couplings. This statement need not be evaluated for buildings in regions of moderate seismicity being evaluated to the Life Safety Performance Level(Tier 2: Sec. 4.8.13.2) |

Hazardous Materials Storage and Distribution

- | | | | |
|---|----|-----|---|
| C | NC | N/A | TOXIC SUBSTANCES: Toxic and hazardous substances stored in breakable containers shall be restrained from falling by latched doors, shelf lips, wires, or other methods. (Tier 2: Sec. 4.8.15.1) |
|---|----|-----|---|

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3.9.1S Supplemental Nonstructural Component Checklist

This Supplemental Nonstructural Component Checklist shall be completed when required by Table 3-2. The Basic Nonstructural Component Checklist shall be completed prior to completing this Supplemental Nonstructural Component Checklist.

Partitions

- | | | | |
|---|----|-----|---|
| C | NC | N/A | DRIFT: The drift ratio for masonry partitions shall be limited to 0.005. (Tier 2: Sec. 4.8.1.2) |
| C | NC | N/A | STRUCTURAL SEPARATIONS: Partitions at structural separations shall have seismic or control joints. (Tier 2: Sec. 4.8.1.3) |
| C | NC | N/A | TOPS: The tops of framed or panelized partitions that only extend to the ceiling line shall have lateral bracing to the building structure at a spacing of equal to or less than 6 feet. (Tier 2: Sec. 4.8.1.4) |

Ceiling Systems

- | | | | |
|---|----|-----|--|
| C | NC | N/A | EDGES: The edges of integrated suspended ceilings shall be separated from enclosing walls by a minimum of 1/2". (Tier 2: Sec. 4.8.2.5) |
| C | NC | N/A | SEISMIC JOINT: The ceiling system shall not extend continuously across any seismic joint. (Tier 2: Sec. 4.8.2.6) |

Light Fixtures

- | | | | |
|---|----|-----|--|
| C | NC | N/A | PENDANT SUPPORTS: Light fixtures on pendant supports shall be attached at a spacing of equal to or less than 6 ft. and, if rigidly supported, shall be free to move without damaging adjoining materials. (Tier 2: Sec. 4.8.3.3) |
| C | NC | N/A | LENS COVERS: Lens covers on fluorescent light fixtures shall be attached or supplied with safety devices. (Tier 2: Sec. 4.8.3.4) |

Masonry Veneer

- | | | | |
|---|----|-----|--|
| C | NC | N/A | MORTAR: The mortar in masonry veneer shall not be easily scraped away from the joints by hand with a metal tool, and there shall not be significant areas of eroded mortar. (Tier 2: Sec. 4.8.5.4) |
| C | NC | N/A | WEEP HOLES: Weep holes shall be present and base flashing shall be installed. (Tier 2: Sec. 4.8.5.5) |
| C | NC | N/A | CORROSION: Corrosion of veneer ties, tie screws, studs, and stud tracks shall be minimal. (Tier 2: Sec. 4.8.5.6) |
| C | NC | N/A | STONE PANELS: Stone panels less than 2 inches nominal thickness shall be anchored every 2 square feet of area. (Tier 2: Sec. 4.8.5.7) |
| C | NC | N/A | CRACKS: There shall no be visible cracks or weak veins in the stone. (Tier 2: Sec. 4.8.5.8) |

Chapter 3.0 - Screening Phase (Tier 1)

Metal Stud Back-Up Systems

- C NC N/A STUD TRACKS: Stud tracks shall be fastened to structural walls or floors at a spacing of equal to or less than 24 inches. (Tier 2: Sec. 4.8.6.1)
- C NC N/A OPENINGS: Additional steel studs shall frame window and door openings. (Tier 2: Sec. 4.8.6.2)

Concrete Block and Masonry Back-Up Systems

- C NC N/A CONCRETE BLOCK: Concrete block shall qualify as reinforced masonry. (Tier 2: Sec. 4.8.7.1)
- C NC N/A BACK-UP: Concrete block back-up shall be anchored to the structural frame at a spacing of equal to or less than 4 feet along the floors and roof. (Tier 2: Sec. 4.8.7.2)
- C NC N/A URM BACK-UP: There shall not be any unreinforced masonry back-up. (Tier 2: Sec. 4.8.7.3)

Parapets, Cornices, Ornamentation and Appendages

- C NC N/A CONCRETE PARAPETS: Concrete parapets with height-to-thickness ratios greater than 2.5 shall have vertical reinforcement. (Tier 2: Sec. 4.8.8.3)
- C NC N/A APPENDAGES: Cornices, parapets, signs, and other appendages that extend above the highest anchorage level or cantilever from exterior wall faces and other exterior wall ornamentation shall be reinforced and anchored to the structural system at a spacing of equal to or less than 10 ft. for Life Safety and 6 ft. for Immediate Occupancy. (Tier 2: Sec. 4.8.8.4)

Building Contents and Furnishing

- C NC N/A FILE CABINETS: File cabinets arranged in groups shall be attached to one another (Tier 2: Sec. 4.8.11.2)
- C NC N/A DRAWERS: Cabinet drawers shall have latches to keep them closed during an earthquake. (Tier 2: Sec. 4.8.11.3)
- C NC N/A COMPUTER ACCESS FLOORS: Computer access floors shall be braced (Tier 2: Sec. 4.8.11.4)
- C NC N/A ACCESS FLOORS: Equipment supported on access floor systems shall be either attached to the structure or fastened to a laterally braced floor system. (Tier 2: Sec. 4.8.11.5)

Mechanical and Electrical Equipment

- C NC N/A HEAVY EQUIPMENT: Equipment weighing over 100 lb. shall be anchored to the structure or foundation. (Tier 2: Sec. 4.8.12.3)
- C NC N/A VIBRATION ISOLATORS: Equipment mounted on vibration isolators shall be equipped with restraints or snubbers. (Tier 2: Sec. 4.8.12.4)
- C NC N/A ELECTRICAL EQUIPMENT: Electrical equipment shall be attached to the structural system. (Tier 2: Sec. 4.8.12.5)

Chapter 3.0 - Screening Phase (Tier 1)

Piping

- | | | | |
|---|----|-----|--|
| C | NC | N/A | FLUID AND GAS PIPING: Fluid and gas piping shall be anchored and braced to the structure in accordance with SP-58 (MSS, 1993). (Tier 2: Sec. 4.8.13.3) |
| C | NC | N/A | SHUT-OFF VALVES: Shut-off devices shall be present at building utility interfaces to shut off the flow of gas and high temperature energy in the event of earthquake-induced failure (Tier 2: Sec. 4.8.13.4) |
| C | NC | N/A | C-CLAMPS: One-sided C-clamps that support major piping shall not be unrestrained. (Tier 2: Sec. 4.8.13.5) |

Ducts

- | | | | |
|---|----|-----|--|
| C | NC | N/A | DUCT BRACING: Rectangular ductwork exceeding 6 square feet in cross-sectional area, and round ducts exceeding 28" in diameter shall be braced. Maximum transverse bracing shall not exceed 40 feet for Life Safety and 30 feet for Immediate Occupancy. Maximum longitudinal bracing shall not exceed 80 feet for Life Safety and 60 feet for Immediate Occupancy. Intermediate supports shall not be considered part of the lateral-force-resisting system. (Tier 2: Sec. 4.8.14.1) |
| C | NC | N/A | STAIR AND SMOKE DUCTS: Stair pressurization and smoke flow of gas and high temperature energy in the event of earthquake-induced failure. (Tier 2: Sec. 4.8.13.4) |
| C | NC | N/A | DUCT SUPPORT: Ducts shall not be supported by piping or other nonstructural elements. (Tier 2: Sec. 4.8.14.3) |

Hazardous Materials Storage and Distribution

- | | | | |
|---|----|-----|--|
| C | NC | N/A | GAS CYLINDERS: Compressed gas cylinders shall be restrained. (Tier 2: Sec. 4.8.15.2) |
| C | NC | N/A | HAZARDOUS MATERIALS: Piping containing hazardous materials shall have shut-off valves or other devices to prevent major spills or leaks. (Tier 2: Sec. 4.8.15.3) |

Chapter 3.0 - Screening Phase (Tier 1)

Elevators

- | | | | |
|---|----|-----|---|
| C | NC | N/A | SUPPORT SYSTEM: All elements of the elevator system shall be anchored (Tier 2: Sec. 4.8.16.1) |
| C | NC | N/A | SEISMIC SWITCH: All elevators shall be equipped with seismic switches that will terminate operations when the ground motion exceeds 0.10g. (Tier 2: Sec. 4.8.16.2) |
| C | NC | N/A | SHAFT WALLS: All elevator shaft walls shall be anchored and reinforced to prevent toppling into the shaft during strong shaking. (Tier 2: Sec. 4.8.16.3) |
| C | NC | N/A | RETAINER GUARDS: Cable retainer guards on sheaves and drums shall be present to inhibit the displacement of cables. (Tier 2: Sec. 4.8.16.4) |
| C | NC | N/A | RETAINER PLATE: A retainer plate shall be present at the top and bottom of both car and counterweight. (Tier 2: Sec. 4.8.16.5) |
| C | NC | N/A | COUNTERWEIGHT RAILS: All counterweight rails shall be sized to current industry standards and shall be larger than eight-pound rails. (Tier 2: Sec. 4.8.16.6) |
| C | NC | N/A | BRACKETS: The brackets that tie the counterweight rail to the building structure shall be sized to meet industry standards and shall have a spacing of 8 feet or less (Tier 2: Sec. 4.8.16.7) |
| C | NC | N/A | SPREADER BRACKET: Spreader brackets shall not be used to resist seismic forces (Tier 2: Sec. 4.8.16.8) |

4.0 Evaluation Phase (Tier 2)

4.1 General

A Tier 1 Evaluation shall be completed for all buildings prior to performing a Tier 2 Evaluation. A Full-Building Tier 2 analysis and evaluation of the adequacy of the lateral-force-resisting system shall be performed for all buildings designated as "T2" in Table 3-3. For all other buildings, the design professional may choose to perform a Deficiency-Only Tier 2 evaluation that addresses only the deficiencies identified in Tier 1. Tier 2 procedures for further evaluation of Tier 1 deficiencies are identified by a section number in parentheses after each Tier 1 checklist evaluation statement.

A Tier 2 Evaluation shall include an analysis using one of the following linear methods: Linear Static Procedure, Linear Dynamic Procedure, or Special Procedure. Analysis procedures and component acceptance criteria are specified in Section 4.2. Unless otherwise designated in Table 3-3, the analysis as a minimum, shall address all of the potential deficiencies identified in Tier 1, using procedures specified in Sections 4.3 to 4.8.

If deficiencies are identified in a Tier 2 Evaluation, the design professional may perform a Tier 3 Evaluation in accordance with the requirements of Chapter 5. Alternatively, the design professional may choose to end the investigation and report the deficiencies in accordance with Chapter 1.

design and capacity over demand ratios that accounted for the lack of modern detailing.

FEMA 178 used an analysis procedure based on the *1988 NEHRP Provisions'* equivalent lateral force procedure using R factors and ultimate strength design. Nonconforming structural systems that did not have proper detailing were assigned lower R factors to account for their lack of ductility.

This Handbook uses a displacement-based lateral force procedure and m-factors on an element by element basis. It represents the most direct method for considering nonconforming systems. The lateral forces related to each of these approaches is radically different and cannot be directly compared.

Commentary:

The procedures for evaluating potential deficiencies have been completely revised from FEMA 178. The new procedures represent the most current available techniques and are consistent with procedures used in FEMA 273.

The original evaluation process defined in ATC-14 was based on the Uniform Building Code's equivalent lateral force procedure; a working stress based process using R_w factors, allowable stress

4.2 Tier 2 Analysis

4.2.1 General

Four analysis procedures are provided in this section:

- Linear Static Procedure (LSP),
- Linear Dynamic Procedure (LDP),
- Special Procedure, and
- Procedure for Nonstructural Components.

All building structures, except unreinforced masonry (URM) bearing wall buildings with flexible diaphragms, shall be evaluated by either the Linear Static Procedure (LSP) of Section 4.2.2.1 or the Linear Dynamic Procedure (LDP) of Section 4.2.2.2. The acceptability criteria for both the LSP and LDP are provided in Section 4.2.4. Out-of-plane forces on walls shall be calculated in accordance with Section 4.2.5.

If original design calculations are available, the results may be used; an appropriate scaling factor, however, to relate the original design base shear to the pseudo lateral force of this Handbook shall be applied.

Unreinforced masonry (URM) bearing wall buildings with flexible diaphragms shall be evaluated in accordance with the requirements of the Special Procedure defined in Section 4.2.6 directly.

The demands on nonstructural components shall be calculated in accordance with Section 4.2.7. These demands shall be compared with the acceptance criteria included in the Procedures for Nonstructural Components in Section 4.8.

4.2.2 Analysis Procedures for LSP & LDP

The Linear Static or Linear Dynamic Procedure shall be performed as required by the Procedures of Section 4.3 through 4.6.

The Linear Dynamic Procedure shall be used for:

- buildings taller than 100 ft,
- buildings with mass, stiffness, or geometric irregularities as specified in Sections 4.3.2.2, 4.3.2.3, and 4.3.2.5.

4.2.2.1 Linear Static Procedure (LSP)

The Linear Static Procedure shall be performed as follows:

- A mathematical building model shall be developed in accordance with Section 4.2.3;
- The pseudo lateral force shall be calculated in accordance with Section 4.2.2.1.1;
- The lateral forces shall be distributed vertically in accordance with Section 4.2.2.1.2;
- The building or component forces and displacements using linear, elastic analysis methods shall be calculated;
- Diaphragm forces shall be calculated in accordance with Section 4.2.2.1.3, if required.
- The component actions shall be compared with the acceptance criteria of Section 4.2.4.5.

Commentary:

In the Linear Static Procedure, the building is modeled with linearly-elastic stiffness and equivalent viscous damping that approximate values expected for loading to near the yield point. Design earthquake demands for the Linear Static Procedure are represented by static lateral forces whose sum is equal to the pseudo lateral force defined by Equation (3-1). The magnitude of the pseudo lateral force has been selected with the intention that when it is applied to the linearly elastic model of the building it will result in design displacement amplitudes approximating maximum displacements that are expected during the design earthquake. If the building responds essentially elastically to the design earthquake, the calculated internal forces will be reasonable approximations to those expected during the design earthquake. If the building responds inelastically to the design earthquake, as will commonly be the case, the calculated internal forces will exceed those that would develop in the yielding building.

The component forces in yielding structures calculated from linear analysis represent the total (linear and nonlinear) deformation of the component. The acceptability criteria reconciles the calculated forces with component capacities using component ductility related factors, m . The linear procedures

linear procedures represent a rough approximation of the non-linear behavior of the actual structure and ignores redistribution of forces and other non-linear effects. In certain cases alternative acceptable approaches are presented that may provide wide variation in the results. This is expected, considering the limitations of the linear analysis procedures.

4.2.2.1.1 Pseudo Lateral Force

The pseudo lateral force applied in a Linear Static Procedure shall be calculated in accordance with Section 3.5.2.1.

The fundamental period of vibration of the building for use in Equation (3-1) shall be calculated as follows:

- For a one-story building with a single span flexible diaphragm, in accordance with Equation (4-1).

$$T = (0.1\Delta_w + 0.078\Delta_d)^{0.5} \quad (4-1)$$

where:

Δ_w and Δ_d are in-plane wall and diaphragm displacements in inches due to a lateral force equal to the weight tributary to diaphragm in the direction under consideration, or

- For multiple-span diaphragms, a lateral force equal to the weight tributary to the diaphragm span under consideration shall be applied to each span of the diaphragm to calculate a separate period for each diaphragm span. The period that maximizes the pseudo lateral force shall be used for design of all walls and diaphragm spans in the building, or
- Based on an eigenvalue (dynamic) analysis of the mathematical model of the building, or
- In accordance with Section 3.5.2.4.

4.2.2.1.2 Vertical Distribution of Seismic Forces

The pseudo lateral force calculated in accordance with Section 4.2.2.1.1 shall be distributed vertically in accordance with Equations (4-2) and (4-3).

$$F_x = C_{vx} V \quad (4-2)$$

$$C_{vx} = \frac{w_x h_x^k}{\sum_{i=1}^n w_i h_i^k} \quad (4-3)$$

where:

$k = 1.0$ for $T \leq 0.5$ second,

$= 2.0$ for $T > 2.5$ seconds,

Linear interpolation shall be used for intermediate values of k ;

C_{vx} = Vertical distribution factor,

V = Pseudo lateral force (Section 4.2.2.1.1),

w_i = Portion of the total building weight W located on or assigned to floor level i ,

w_x = Portion of the total building weight W located on or assigned to floor level x ,

h_i = Height (ft) from the base to floor level i ,

h_x = Height (ft) from the base to floor level x .

4.2.2.1.3 Floor Diaphragms

The effects of inertial forces, calculated in accordance with Equation (4-4), developed at the level under consideration and horizontal forces resulting from offsets in, or changes in stiffness of, the vertical lateral-force-resisting elements above and below the diaphragm shall be considered in the analyses. Forces resulting from offsets in, or changes in stiffness of, the vertical lateral-force-resisting elements shall be equal to the elastic forces without reduction, unless smaller forces can be justified by rational analysis.

$$F_{px} = \frac{1}{C} F_i \frac{w_x}{\sum_{i=1}^n w_i} \quad (4-4)$$

where:

F_{px} = Total diaphragm force at level x ,

F_i = Lateral load applied at floor level i defined by Equation (4-2),

w_i = Portion of the total building weight W located or assigned to floor level i ,

w_x = Portion of the total building weight W located or assigned to floor level x ,

C = Modification Factor defined in Table 3-4.

The lateral forces on flexible diaphragms shall be distributed along the span of the diaphragm, based on the distribution of mass and displaced shape of the diaphragm.

4.2.2.1.4 Determination of Deformations

Structural deformations and story drifts shall be calculated using lateral forces in accordance with Equations (3-1), (4-2) and (4-4).

4.2.2.2 Linear Dynamic Procedure (LDP)

The Linear Dynamic Procedure shall be performed as follows:

- Develop a mathematical building model in accordance with Section 4.2.3;
- Develop a response spectrum for the site in accordance with Section 4.2.2.2.2;
- Perform a response spectrum analysis of the building;
- Modify the actions and deformations in accordance with Section 4.2.2.2.3;
- Compute diaphragm forces in accordance with Section 4.2.2.2.4, if required;
- Compute the component actions in accordance with Section 4.2.4.3;
- Compare the component actions with the acceptance criteria of Section 4.2.4.5.

Modal responses shall be combined using the SRSS (square root sum of the squares) or CQC (complete quadratic combination) method to estimate the response quantities. The CQC shall be used when modal periods associated with motion in a given direction are within 25%. The number of modes considered in the response spectrum analysis shall be sufficient to capture at least 90% of the participating mass of the building in each of the building's principal horizontal axes.

Multidirectional excitation effects shall be considered in accordance with Section 4.2.3.5. Alternatively, the SRSS method may be used to combine multidirectional effects. The CQC method shall not be used for combination of multidirectional effects.

4.2.2.2.2 Ground Motion Characterization

The seismic ground motions shall be characterized for use in the LDP by developing:

- A mapped response spectrum in accordance with Section 3.5.2.3.1, or
- A site-specific response spectrum in accordance with Section 3.5.2.3.2.

4.2.2.2.3 Modification of Demands

With the exception of diaphragm actions and deformations, all actions and deformations calculated using the Linear Dynamic Procedure shall be multiplied by the modification factor, C , defined in Table 3-4.

Commentary:

Note that, in contrast to NEHRP and the UBC, the results of the response spectrum analysis are not scaled to the pseudo lateral force of the LSP. Such scaling is unnecessary since the LSP is based on the use of actual spectral acceleration values from proper response spectra and is not reduced by R values used in traditional code design.

4.2.2.2.4 Floor Diaphragms

Floor diaphragms shall be analyzed for (1) the seismic forces calculated by dynamic analysis, and (2) the horizontal forces resulting from offsets in, or changes in stiffness of, the vertical seismic framing elements above and below the diaphragm. The seismic forces calculated by dynamic analysis shall not be less than 85% of the forces calculated using Equation (4-4). Forces resulting from offsets in, or changes in stiffness of, the vertical lateral-force-resisting elements shall be taken to be equal to the elastic forces without reduction, unless smaller forces can be justified by rational analysis.

4.2.3 Mathematical Model for LSP & LDP

4.2.3.1 Basic Assumptions

Buildings with stiff or rigid diaphragms shall be modeled two-dimensionally if torsional effects are either sufficiently small to be ignored or indirectly captured; alternatively, a three-dimensional model may be developed. If torsional effects are not sufficiently small to be ignored or indirectly captured, a three-dimensional model of the building shall be developed.

Lateral-force-resisting frames in buildings with flexible diaphragms shall be modeled and analyzed as two-dimensional assemblies of components; alternatively, a three-dimensional model shall be used with the diaphragms modeled as flexible elements.

4.2.3.2 Horizontal Torsion

The effects of horizontal torsion shall be considered in a Tier 2 analysis. The total torsional moment at a given floor level shall be equal to the sum of the following two torsional moments:

- Actual torsion resulting from the eccentricity between the centers of mass and the centers of rigidity of all floors above and including the given floor, and
- Accidental torsion produced by horizontal offset in the centers of mass, at all floors above and including the given floor, equal to a minimum of 5% of the horizontal dimension at the given floor level measured perpendicular to the direction of the applied load.

The effects of accidental torsion shall not be used to reduce force and deformation demands on building components.

A building is considered torsionally irregular if the building has stiff or rigid diaphragms and the ratio $\delta_{\max}/\delta_{\text{avg}}$ due to total torsional moment exceeds 1.2. In torsionally irregular buildings, the effect of accidental torsion shall be amplified by the factor, A_x , given in Equation (4-5).

$$A_x = \left(\frac{\delta_{\max}}{1.2\delta_{\text{avg}}} \right)^2 \quad (4-5)$$

where:

δ_{\max} = the maximum displacement at any point of diaphragm at level x;

δ_{avg} = the algebraic average of displacements at the extreme points of the diaphragm at level x;

A_x = shall be greater than or equal to 1.0 and need not exceed 3.0.

If the ratio, η , of the maximum displacement at any point on any floor diaphragm (including torsional amplification), to the average displacement, exceeds 1.50, a three-dimensional model shall be developed for a Tier 2 analysis. When $\eta < 1.5$, the forces and displacements calculated using two-dimensional models shall be increased by the maximum value of η calculated for the building.

4.2.3.3 Primary and Secondary Components

Components shall be classified as either primary or secondary in accordance with Section 1.3.

Only the stiffness of primary components need be included in the mathematical building model. If secondary components are modeled, the total stiffness of the secondary components shall be no greater than 25% of the total stiffness of the primary components calculated at each level of the building.

Commentary:

The classification of components and elements should not result in a change in the regularity of a building. That is, components and elements should not be selectively assigned as either primary or secondary to change the configuration of a building from irregular to regular.

4.2.3.4 Diaphragms

Diaphragm deformations shall be estimated using the seismic forces computed in this Section. Mathematical models of buildings with stiff diaphragms shall explicitly include diaphragm flexibility. Mathematical models of buildings with rigid diaphragms shall explicitly account for the rigidity of the diaphragms. For buildings with flexible diaphragms at each floor level, the vertical

lines of seismic framing may be considered independently, with seismic masses assigned on the basis of tributary area.

The in-plane deflection of the diaphragm shall be calculated for an in-plane distribution of lateral force consistent with the distribution of mass, as well as all in-plane lateral forces associated with offsets in the vertical seismic framing.

4.2.3.5 Multidirectional Excitation Effects

Buildings shall be analyzed for seismic forces in any horizontal direction. Seismic displacements and forces shall be assumed to act nonconcurrently in the direction of each principal axis of a building, unless the building is torsionally irregular as defined in Section 4.2.3.2 or one or more components form part of two or more intersecting elements, in which case multidirectional excitation effects shall be considered.

Multidirectional (orthogonal) excitation shall be evaluated by applying 100% of the seismic forces in one horizontal direction plus 30% of the seismic forces in the perpendicular horizontal direction.

4.2.3.6 Vertical Acceleration

The effects of vertical excitation on horizontal cantilevers and prestressed elements shall be considered using static or dynamic analysis methods. Vertical earthquake motions shall be characterized by a spectrum with ordinates equal to 67% of those of the horizontal spectrum in Section 3.5.2.3.1. Alternatively, vertical response spectra are developed using site-specific analysis may be used.

4.2.4 Acceptance Criteria for LSP & LDP

4.2.4.1 General Requirements

Component actions shall be computed according to Section 4.2.4.3; gravity loads as well as seismic forces shall be considered. Component strengths shall be computed in accordance with Section 4.2.4.4. Component actions and strengths then shall be compared with the acceptance criteria in Section 4.2.4.5.

4.2.4.2 Component Gravity Loads

Component gravity forces shall be calculated in accordance with Equation (4-6) and (4-7).

$$Q_G = 1.1(Q_D + Q_L + Q_S) \quad (4-6)$$

$$Q_G = 0.9 Q_D \quad (4-7)$$

where:

Q_D = Dead load,

Q_L = Effective live load, equal to 25% of the unreduced design live load but not less than the measured live load,

Q_S = Effective snow load, equal to either 70% of the full design snow load or, where conditions warrant and approved by the regulatory agency, not less than 20% of the full design snow load, except that where the design snow load is 30 pounds per square foot or less, $Q_S = 0.0$.

4.2.4.3 Component Actions

Actions shall be classified as either deformation-controlled or force-controlled. A deformation-controlled action shall be defined as an action that has an associated deformation that is allowed to exceed the yield value; the maximum associated deformation is limited by the ductility capacity of the component. A force-controlled action shall be defined as an action that has an associated deformation that is not allowed to exceed the yield value; actions with limited ductility shall be considered force-controlled.

Commentary:

Global deformation of a structure is primarily due to the elastic and inelastic deformations associated with the deformation-controlled actions. The maximum force in force-controlled components are governed by the capacity of deformation-controlled components.

Consider actions in beams and columns of a reinforced concrete moment frame. Flexural moment are typically a deformation-controlled action. Shear forces in beams and axial forces in columns are force-controlled actions. The yielding of deformation-controlled actions (beam moment in this example), controls the forces that can be

delivered to the force-controlled actions (beam shear & column axial force in this example).

Consider a braced frame structure. The axial force in the diagonal braces are deformation-controlled actions. The force in brace connections and axial force in columns are force-controlled actions. Yielding and buckling of braces control the maximum force that can be delivered to the connections and columns.

Typical deformation- and force-controlled actions are listed below where 'M' designates moment, 'V' designates shear force, and 'P' designates axial load.

	Deformation-Controlled	Force-Controlled
Moment Frames		
Beams	M	V
Columns	M	P, V
Joints	--	V
Shear Walls	M, V	P
Braced Frames		
Braces	P	--
Beams	--	P
Columns	--	P
Shear Link	V	P, M

4.2.4.3.1 Deformation-Controlled Actions

Deformation-controlled design actions, Q_{UD} , shall be calculated according to Equation (4-8).

$$Q_{UD} = Q_G \pm Q_E \quad (4-8)$$

where:

- Q_{UD} = Action due to gravity loads and earthquake forces,
- Q_G = Action due to gravity forces as defined in Section 4.2.4.2,
- Q_E = Action due to earthquake forces calculated using forces and analysis models described in either Section 4.2.2.1 or Section 4.2.2.2.

4.2.4.3.2 Force-Controlled Actions

Method 1

Force-controlled actions, Q_{UF} shall be calculated as the sum of forces due to gravity and the maximum force that can be delivered by deformation-controlled actions.

Method 2

Alternatively, force-controlled actions may be calculated according to Equation (4-9) or Equation (4-10). Equation (4-9) shall be used when the forces contributing to Q_{UF} are delivered by yielding components of the seismic framing system. Equation (4-10) shall be used for all other evaluations.

$$Q_{UF} = Q_G \pm \frac{Q_E}{C_I} \quad (4-9)$$

$$Q_{UF} = Q_G \pm \frac{Q_E}{C} \quad (4-10)$$

where:

- Q_{UF} = Actions due to gravity loads and earthquake forces,
- C = Modification Factor defined in Table 3-4,
- J = a force-delivery reduction factor given by Equation (4-11) and shall not exceed 2.5 for buildings being evaluated to the Life Safety Performance Level and 2.0 for buildings being evaluated to the Immediate Occupancy Performance Level.

$$J = 1.5 + S_{DS} \quad (4-11)$$

where:

- S_{DS} = Design short-period spectral acceleration parameter, calculated in accordance with Section 3.5.2.3.1.

Method 3

For the evaluation of buildings analyzed using pseudo lateral force of Equation (3-2), Equation (4-10), with $C=1.0$, shall be used.

Commentary:

Force-controlled actions are those actions that provide little deformation to the entire building through inelastic behavior. Because of the limited ductility associated with force-controlled actions, inelastic action in these elements may cause a sudden partial or total collapse of the structure.

There are three methods for determining force-controlled actions. The first method is the sum of forces due to gravity and the maximum force that can be delivered by deformation-controlled actions. Q_{UF} for a brace connection would be equal to the axial force capacity of the brace member. Q_{UF} for shear in a beam would be equal to gravity shear plus the shear force associated with development of flexural moment capacity at the ends of the beam. Q_{UF} for axial force in a moment frame column would be equal to the sum of maximum shear forces that can be developed in the beams supported by the columns. If it can be shown that the deformation-controlled action can be developed before the failure of the associated force-controlled action, then the failure will not occur due to the fact the yielding of the deformation-controlled components will limit the demand on the force-controlled component. This method is recommended as the method to use in evaluating force-controlled components.

The second and third methods provide conservative estimates of force-controlled actions due to a design earthquake. Equation (4-9) may be used if other yielding elements in the building will limit the amount of force that can be delivered to the force-controlled component. Equation (4-10) is used if the force-controlled component is the "weak link" and, thus, must be evaluated for full earthquake force. Equation (4-10) must also be used if foundation sliding controls the behavior of the building as assumed by Equation (3-2).

4.2.4.3.3 Connections

Connections shall be evaluated as force-controlled actions. Alternatively, hold-down anchors used to resist overturning forces in wood shear wall buildings may be evaluated as deformation-controlled actions using the appropriate m-factors specified in Table 4-6.

4.2.4.3.4 Foundation/Soil Interface

Actions at the soil-foundation interface shall be considered force-controlled as defined in Section 4.2.4.3.2. The value of the earthquake force in Section 4.2.4.3.2 may be multiplied by a factor of 2/3 for buildings being evaluated for the Immediate Occupancy Performance Level and 1/3 for the Life Safety Performance Level.

Commentary:

This criteria allows the earthquake component of the total force at soil foundations interface to be reduced, because limited uplifting of the foundation is permitted. Foundation compressive loads can also be calculated using the reduced earthquake loads. Alternatively, the compressive soil pressure can be calculated by considering the equilibrium of forces with the foundations in uplifted condition.

4.2.4.4 Component Strength

Component strength for all actions shall be taken as the expected strength, Q_{CE} . Unless calculated otherwise, the expected strength shall be assumed equal to the nominal strength multiplied by 1.25. Alternatively, if allowable stresses are used, nominal strengths shall be taken as the allowable values multiplied by the following values:

Steel	1.7
Masonry	2.5
Wood	2.0

Except for wood diaphragms and wood and masonry shear walls, the allowable values shall not include a one-third increase for short term loading.

When calculating capacities of deteriorated elements, the evaluating design professional shall make

reductions in the material strength, section properties, and other parameters as approved by the authority having jurisdiction to account for the deterioration.

Commentary:

The 1997 NEHRP Recommended Provisions for Seismic Regulations of New Buildings and Other Structures provides component capacities for use in strength design or load and resistance factor design. These include nominal strength for wood, concrete, masonry and steel. Note that the resistance factors (ϕ), which are used in ultimate strength code design, are not used in calculating capacities of members when the LSP or LDP is used.

Commentary:

The m -factors in Tables 4-3 to 4-6 were developed using the values in FEMA 273 as a starting point, and modified so that this document provides comparable results to FEMA 178 for life safety performance level. Considering the effect of factor C (for short period structures) and different capacities used in the two documents, it can be shown that, for equivalent results with FEMA 178, the value of m for life safety level of performance should be in the range of 0.7 to 0.9 times the value of R .

Note that the acceptability criteria and use of m -factors is applicable to the LSP and LDP only. m -factors are not used in conjunction with evaluating walls for out-of-plane forces or nonstructural elements or when using the Special Procedures for unreinforced masonry bearing walls with flexible diaphragms.

4.2.4.5 Acceptance Criteria for the LSP & LDP

4.2.4.5.1 Deformation-Controlled Actions

The acceptability of deformation-controlled primary and secondary components shall be determined in accordance with Equation (4-12).

$$Q_{CE} \geq \frac{Q_{UD}}{m} \quad (4-12)$$

where:

Q_{UD} = Action due to gravity and earthquake loading per Section 4.2.4.3.1.

m = Component demand modifier to account for the expected ductility of the component; the appropriate m -factor shall be chosen from Tables 4-3 to 4-6 based on the level of performance and component characteristics; Interpolation shall be permitted in Tables 4-3 to 4-6; $m = 1.0$ for all components in buildings analyzed using Equation (3-2).

Q_{CE} = Expected strength of the component at the deformation level under consideration. Q_{CE} shall be calculated in accordance with Section 4.2.4.4 considering all co-existing actions due to gravity and earthquake loads.

4.2.4.5.2 Force-Controlled Actions

The acceptability of force-controlled primary and secondary components shall be determined in accordance with Equation (4-13).

$$Q_{CE} \geq Q_{UF} \quad (4-13)$$

where:

Q_{UF} = Action due to gravity and earthquake loading; Q_{UF} shall be calculated in accordance with Section 4.2.4.3.2.

Q_{CE} = Expected strength of the component at the deformation level under consideration Q_{CE} shall be calculated in accordance with Section 4.2.4.4 considering all co-existing actions due to gravity and earthquake loads.

4.2.5 Out-of-plane Wall Forces

Out-of-plane wall forces shall be computed in accordance with this section when triggered by the Procedures of Section 4.3 through 4.6.

Walls shall be anchored to each diaphragm for a minimum force of:

- $400S_{DS}$ pounds per foot of wall or
- χS_{DS} times the unit weight of the wall where χ shall be taken as 0.4 for Life Safety and 0.6 for Immediate Occupancy.

Forces shall be developed into the diaphragm. For flexible diaphragms, the anchorage forces shall be taken as 2 times those specified above and shall be developed into the diaphragm by continuous diaphragm cross ties. Diaphragms may be partitioned into a series of subdiaphragms. Each subdiaphragm shall be capable of transmitting the shear forces due to wall anchorage to a continuous diaphragm tie.

Subdiaphragms shall have aspect ratios of 3 or less. Where wall panels are stiffened for out-of-plane behavior by pilasters and similar stiffening elements, anchors shall be provided at each such element and the distribution of out-of-plane forces to wall anchors and diaphragm ties shall consider the stiffening effect.

A wall shall have adequate strength to span between locations of out-of-plane support when subjected to out-of-plane forces equal to $0.4S_{DS}$ times the unit weight of the wall, over its area.

Strength of members and connections shall be taken as ϕ times the nominal strength.

Commentary:

Values of ϕ and nominal strengths may be obtained from *1997 NEHRP Recommended Provisions for Seismic Regulations for New Buildings*.

4.2.6 Special Procedure

4.2.6.1 General

Unreinforced masonry bearing wall buildings with flexible diaphragms being evaluated to the Life Safety Performance Level shall be evaluated in accordance with the requirements of this section.

The evaluation requirements of Chapter 2 shall be met prior to conducting this special procedure.

This special procedure shall apply to unreinforced masonry bearing wall buildings with the following characteristics:

- Flexible diaphragms at all levels above the base of the structure;
- A minimum of two lines of walls in each principal direction, except for single-story buildings with an open front on one side.

A Tier 3 evaluation shall be conducted for buildings not meeting the requirements of this section.

4.2.6.2 Cross Walls

4.2.6.2.1 General

Cross walls shall not be spaced more than 40 feet on center measured perpendicular to the direction under consideration and should be present in each story of the building. Cross walls shall extend the full story height between diaphragms.

Exceptions:

- Cross walls need not be present at all levels in accordance with Section 4.2.6.3.1, Equation (4-18),
- Cross walls that meet the following requirements need not be continuous:
 - Shear connections and anchorage at all edges of the diaphragm shall meet the requirements of Section 4.2.6.3.6;
 - Cross walls shall have a shear capacity of $0.6S_{D1} \Sigma W_d$ and shall interconnect the diaphragm to the foundation;

- Diaphragms spanning between cross walls that are continuous shall comply with the following equation:

$$\frac{2.5S_{D1}W_d+V_{ca}}{2v_uD} \leq 2.5 \quad (4-14)$$

4.2.6.2.2 Shear Capacity

Within any 40 feet measured along the span of the diaphragm, the sum of the cross wall shear capacities shall greater than or equal to 30% of the diaphragm shear capacity of the strongest diaphragm at or above the level under consideration.

4.2.6.2.3 Aspect Ratio

Cross walls shall have a length-to-height ratio between openings equal to or greater than 1.5.

4.2.6.3 Diaphragms

4.2.6.3.1 Demand-Capacity Ratios

Demand-capacity ratios shall be calculated for a diaphragm at any level in accordance with the following equations:

Diaphragms without cross walls at levels immediately above or below:

$$DCR = \frac{2.5S_{D1}W_d}{\sum v_uD} \quad (4-15)$$

Diaphragms in a one-story building with cross walls:

$$DCR = \frac{2.5S_{D1}W_d}{\sum v_uD+V_{cb}} \quad (4-16)$$

Diaphragms in a multi-story building with cross walls at all levels:

$$DCR = \frac{2.5S_{D1}\sum W_d}{\sum(\sum v_uD+V_{cb})} \quad (4-17)$$

Roof diaphragms and the diaphragms directly below if coupled by cross walls:

$$DCR = \frac{2.5S_{D1}\sum W_d}{\sum(\sum v_uD)} \quad (4-18)$$

where:

v_u = unit shear strength of the diaphragm calculated in accordance with Section 4.2.4.4.

4.2.6.3.2 Acceptability Criteria

The intersection of diaphragm span between walls, L, and the demand-capacity ratio, DCR, shall be located within Region 1, 2, or 3 on Figure 4-1.

4.2.6.3.3 Chords

An analysis for diaphragm flexure need not be made and chords need not be provided.

4.2.6.3.4 Collectors

Where walls do not extend the length of the diaphragm, collectors shall be provided. The collectors shall be able to the transfer diaphragm shears calculated in accordance with Section 4.2.6.3.6 into the shear walls.

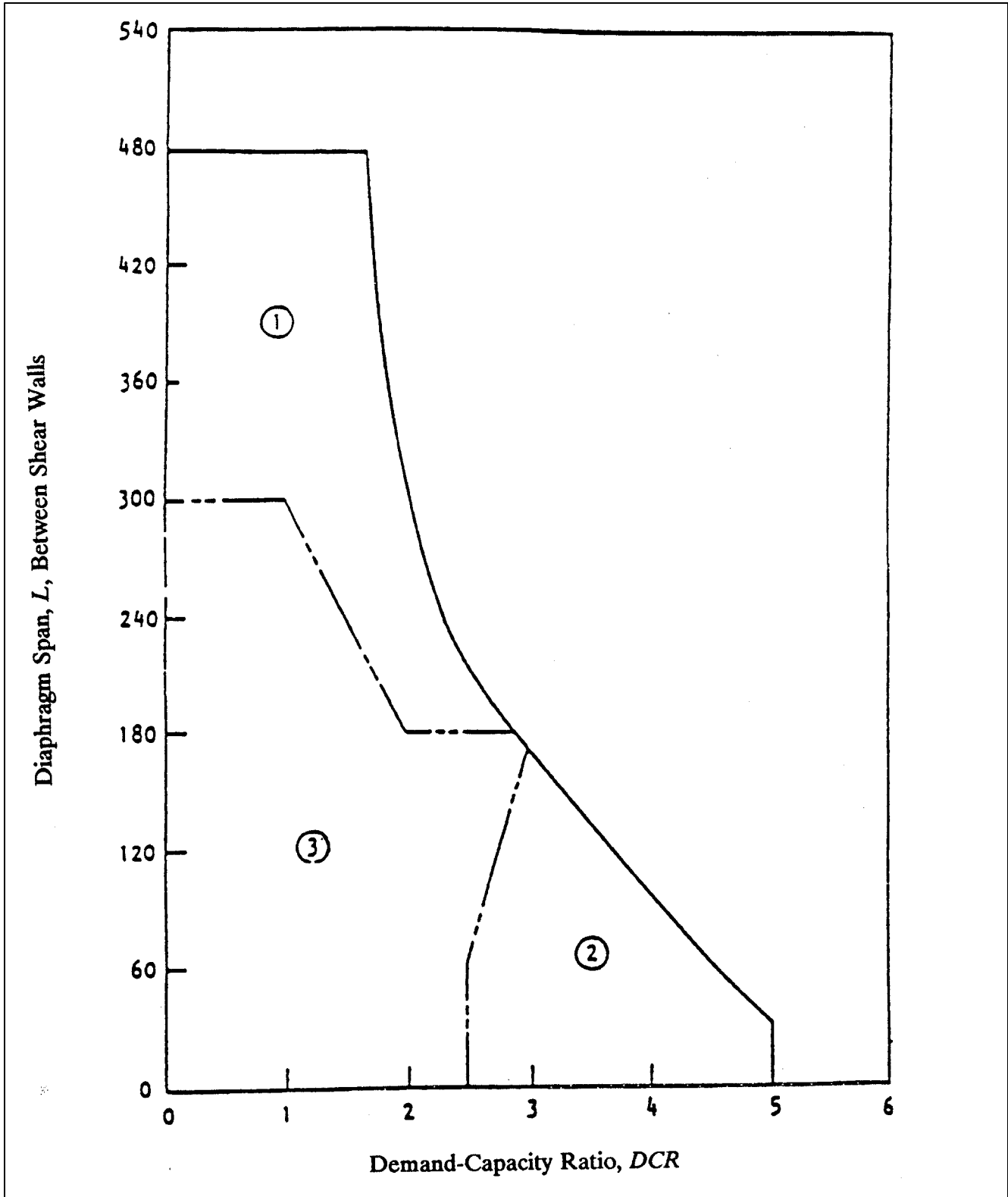
4.2.6.3.5 Diaphragm Openings

Diaphragm forces at corners at openings shall be investigated.

The diaphragm shall have the tensile capacity to develop the strength of the diaphragm at opening corners.

The demand-capacity ratio shall be calculated and evaluated in accordance with Sections 4.2.6.3.1 and 4.2.6.3.2 for the portion of the diaphragm adjacent to an opening using the opening dimension as the diaphragm span.

The demand-capacity ratio shall be calculated and evaluated in accordance with Sections 4.2.6.3.1 and 4.2.6.3.2 for openings occurring in the end quarter of the diaphragm span. The diaphragm capacity, v_uD , shall be based on the net depth of the diaphragm.



4.2.6.3.6 Diaphragm Shear Transfer

Figure 4-1. Diaphragm Span, L , Between Shear Walls (ft)

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Diaphragms shall be connected to shear walls at each end and shall be able to develop the minimum of the forces calculated in accordance with Equations (4-19) and (4-20).

$$V_d = 1.5S_{D1} C_p W_d \quad (4-19)$$

$$V_d = v_u D \quad (4-20)$$

Table 4-1 Horizontal Force Factor, C_p

Configuration of Materials	C_p
Roofs with straight or diagonal sheathing and roofing applied directly to the sheathing, or floors with straight tongue-and-groove sheathing	0.50
Diaphragm with double or multiple layers of boards with edges offset, and blocked structural panel systems.	0.75

4.2.6.4 Shear Walls

4.2.6.4.1 Shear Wall Actions

The walls story force distributed to a shear wall at any diaphragm level shall be determined in accordance with the following equations:

For buildings without cross walls:

$$F_{wx} = S_{D1} (W_{wx} + 0.5W_d) \quad (4-21)$$

but not exceed,

$$F_{wx} = S_{D1} W_{wx} + v_u D \quad (4-22)$$

For buildings with cross walls in all levels:

$$F_{wx} = 0.75S_{D1} (W_{wx} + 0.5W_d) \quad (4-23)$$

but need not exceed,

$$F_{wx} = 0.75S_{D1} (W_{wx} + \sum W_d (\frac{v_u D}{\sum v_u D})) \quad (4-24)$$

and need not exceed,

$$F_{wx} = 0.75S_{D1} W_{wx} + v_u D \quad (4-25)$$

The wall story shear shall be calculated in accordance with Equation (4-26).

$$V_{wx} = \sum F_{wx} \quad (4-26)$$

4.2.6.4.2 Shear Wall Strengths

The shear wall strength shall be calculated in accordance with Equation (4-27).

$$V_a = 0.67v_{me}Dt \quad (4-27)$$

where:

- D = In-plane width dimension of masonry (in.),
- t = Thickness of wall (in.),
- v_{me} = expected masonry shear strength (psi) given by Equation (4-28),

$$v_{me} = \frac{0.75 \left(0.75v_{te} + \frac{P_{CE}}{A_n} \right)}{1.5} \quad (4-28)$$

where:

- v_{te} = Average bed-joint shear strength (psi) determined in accordance with Section 2.2 and not to exceed 100 psi;
- P_{CE} = Expected gravity compressive force applied to a wall or pier component stress;
- A_n = Area of net mortared/grouted section (in²).

The rocking shear strength shall be calculated in accordance with Equations (4-29) and (4-30)

For walls without openings:

$$V_r = 0.9(P_D + 0.5P_W) \frac{D}{H} \quad (4-29)$$

For walls with openings:

$$V_r = 0.9P_D \frac{D}{H} \quad (4-30)$$

4.2.6.4.3 Shear Wall Acceptance Criteria

The acceptability of unreinforced masonry shear walls shall be determined in accordance with Equations (4-31), (4-32), and (4-33).

When $V_r < V_a$,

$$0.6V_{wx} < \Sigma V_r \quad (4-31)$$

When $V_a < V_r$, V_{wx} shall be distributed to the individual wall piers, V_p , in proportion to D/H and equation (4-32) and (4-33) shall be met.

$$V_p < V_a \quad (4-32)$$

$$V_p < V_r \quad (4-33)$$

If $V_p < V_a$ and $V_p > V_r$ for any pier, the pier shall be omitted from the analysis and the procedure repeated.

4.2.6.5 Out-of-Plane Demands

The unreinforced masonry wall height-to-thickness ratios shall be less than those set forth in Table 4-2.

The following limitations shall apply to Table 4-2:

- For buildings within Region 1 of Figure 4-1 as defined in Section 4.2.6.3.2, height to thickness ratios in column A of Table 4-2 may be used if cross walls comply with the requirements of Section 4.2.6.2 are present in all stories.
- For buildings within Region 2 of Figure 4-1 as defined in Section 4.2.6.3.2, height-to-thickness ratios in column A may be used.
- For buildings within Region 3 of Figure 4-1 as defined in Section 4.2.6.3.2, height-to-thickness in column B may be used.

Table 4-2. Allowable Height-to-Thickness Ratios of Unreinforced Masonry Walls

Wall Type	Regions of Moderate Seismicity	Regions of High Seismicity	
		A	B
Top story of multi-story building	14	14	9
First story of multi-story building	18	16	15
All other conditions	16	16	13

4.2.6.6 Wall Anchorage

Anchors shall be capable of developing the maximum of:

- $2.5S_{D1}$ times the weight of the wall, or
- 200 pounds per lineal foot, acting normal to the wall at the level of the floor or roof.

Walls shall be anchored at the roof and all floor levels at a spacing of equal to or less than 6 feet on center.

At the roof and all floor levels, anchors shall be provided within 2 feet horizontally from the inside corners of the wall.

The connection between the walls and the diaphragm shall not induce cross-grain bending or tension in the wood ledgers.

4.2.6.7 Buildings with Open Fronts

Single-story buildings with an open front on one side shall have cross walls parallel to the open front. The effective diaphragm span, L_i , for use in Figure 4-1, shall be calculated in accordance with Equation (4-34).

$$L_i = 2L \left(\frac{W_w}{W_d} + 1 \right) \quad (4-34)$$

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The diaphragm demand-capacity ratio shall be calculated in accordance with Equation (4-35).

$$DCR = \frac{2.5S_{D1}(W_d+W_u)}{(V_u D+V_c)} \quad (4-35)$$

4.2.7 Demands on Nonstructural Components

The seismic forces on nonstructural components shall be calculated in accordance with Equations (4-36), (4-37) and (4-38) when triggered by the Procedures in Section 4.8.

$$F_p = 0.4a_p S_{DS} W_p (1 + 2x/h)/R_p \quad (4-36)$$

F_p shall not be greater than:

$$F_p = 1.6S_{DS} W_p \quad (4-37)$$

and F_p shall not be taken as less than:

$$F_p = 0.3S_{DS} W_p \quad (4-38)$$

where:

- F_p = Seismic design force centered at the component's center of gravity and distributed relative to the component's mass distribution,
- S_{DS} = Design short-period spectral acceleration, as determined from Section 3.5.2.3.1,
- a_p = Component amplification factor from Table 4-7,
- W_p = Component operating weight,
- R_p = Component response modification factor, that varies from 1.0 to 6.0 (select appropriate value from Table 4-7),
- x = Height in structure of highest point of attachment of component. For components at or below grade x shall be taken as 0,
- h = Average roof height of structure relative to grade.

The force (F_p) shall be applied independently, longitudinally, and laterally in combination with service loads associated with the component. When positive and negative wind loads exceed F_p for nonstructural exterior walls, these wind loads shall govern the analysis. Similarly, when the building code horizontal loads exceed F_p for interior partitions, these building code loads shall govern the analysis.

Drift ratios (D) shall be determined in accordance with the following Equations (4-39) or (4-40).

For two connecting points on the same building or structural system:

$$D_r = (d_{xA} - d_{yA})/(X - Y) \quad (4-39)$$

For two connection points on separate buildings or structural systems:

$$D_p = d_{xA} + d_{xB} \quad (4-40)$$

where:

- D_p = Relative displacement,
- D_r = Drift ratio,
- X = Height of upper support attachment at level x as measured from grade,
- Y = Height of lower support attachment at level y as measured from grade,
- δ_{xA} = Deflection at building level x of building A, determined by elastic analysis,
- δ_{yA} = Deflection at building level y of Building A, determined by elastic analysis,
- δ_{xB} = Deflection at building level x of building B, determined by elastic analysis.

The effects of seismic displacements shall be considered in combination with displacements caused by other loads, as appropriate.

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Table 4-3. m-factors for Steel Components

Component/Conditions	Primary		Secondary	
	LS	IO	LS	IO
Fully restrained moment frames				
<u>Beams</u>				
$\frac{b}{2t_f} < \frac{52}{\sqrt{F_{ye}}}$	8	3	13	3
$\frac{b}{2t_f} > \frac{95}{\sqrt{F_{ye}}}$	3	2	4	2
<u>Columns (P < 0.2P_y)</u>				
$\frac{b}{2t_f} < \frac{52}{\sqrt{F_{ye}}}$	8	3	13	3
$\frac{b}{2t_f} > \frac{95}{\sqrt{F_{ye}}}$	2	2	3	2
<u>Columns (0.2P_y < P < 0.5P_y)</u>				
$\frac{b}{2t_f} < \frac{52}{\sqrt{F_{ye}}}$	(1)	2	(2)	2
$\frac{b}{2t_f} > \frac{95}{\sqrt{F_{ye}}}$	2	2	3	2
<u>Panel Zones</u>				
	10	3	14	3
<u>Welded Moment Connections</u> ⁽⁵⁾				
	2	1	2	1
Partially restrained moment connections				
<u>Bolts or Welds in Tension</u>				
	2.5	1.5	3.5	1.5
<u>Other</u>				
	4	2	6	2
Braced Frames				
<u>Columns</u> ⁽³⁾				
<u>Eccentric Braced Frames</u>				
Link Beam				
Brace and Column ⁽³⁾				
Same as beams in fully restrained frames.				
<u>Braces in Compression</u>				
Tubes: $\frac{d}{t} \leq \frac{90}{\sqrt{F_{ye}}}$; Pipes: $\frac{d}{t} \leq \frac{1500}{\sqrt{F_{ye}}}$	6	2.5	9	2.5
Tubes: $\frac{d}{t} \leq \frac{190}{\sqrt{F_{ye}}}$; Pipes: $\frac{d}{t} \leq \frac{6000}{\sqrt{F_{ye}}}$	3	1.5	3	1.5
Other shapes				
	6	2.5	9	2.5
<u>Braces in Tension</u>				
Tension-compression brace				
	6	2.5	11	3
Tension-only brace				
	3	1.5	11	3
Metal Deck				
	4	2	--	--

$F_{ye} = 1.25F_y$, Expected yield stress;

⁽¹⁾m=12(1.7P/P_y);

⁽²⁾m=20(1.7P/P_y);

⁽³⁾Force-controlled;

⁽⁴⁾Axial load due to gravity and earthquake calculated as force-controlled action per Section 4.2.4.3.2.

⁽⁵⁾Alternatively, these connections may be considered force-controlled if connections and joint web shear can be shown to develop the capacity of the beam.

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Table 4-4. m-factors for Concrete Components

Component/Conditions	Primary		Secondary	
	LS	IO	LS	IO
Beams, flexure				
<u>Ductile</u> ⁽¹⁾				
$v \leq 3\sqrt{f'_c}$	8	3	8	3
$v \geq 6\sqrt{f'_c}$	4	2.5	4	2.5
<u>Non-Ductile</u>	2.5	1.5	3	1.5
Columns, flexure				
<u>Ductile</u> ⁽¹⁾				
$\frac{P}{A_g f'_c} \leq 0.1$	5	3	5	3
$\frac{P}{A_g f'_c} \geq 0.4$	2	1.5	2	1.5
<u>Non-Ductile</u>	2.5	1.5	3	2
$\frac{P}{A_e f'_c} \leq 0.1$	1.5	1.5	1.5	1.5
$\frac{P}{A_e f'_c} \geq 0.4$				
Beams controlled by shear	2	1.5	3.5	2.5
Beam-Column Joints	(2)	(2)	(2)	(2)
Slab-Column Systems ⁽⁵⁾				
$\frac{V_s}{V_c} \leq 0.1$	3	3	3	3
$\frac{V_s}{V_c} \geq 0.4$	1.5	1.5	1.5	1.5
Infilled Frame Columns Modeled as Chords				
<u>Confined along entire length</u>	4	1.5	5	1.5
<u>Not confined</u>	1.5	1.5	1.5	1.5
Shear Walls Controlled by Flexure				
<u>With confined boundary</u>				
$a \leq 0.1$ ⁽³⁾	5	3	6	3
$a \geq 0.25$	3	1.5	4	1.5
<u>Without confined boundary</u>				
$a \leq 0.1$	3	2	4	2
$a \geq 0.25$	2	1.5	2.5	1.5
Coupling Beams	2.5	1.5	4	2
Shear Walls Controlled by Shear	2.5	1.5	3	2

⁽¹⁾Ductile beams and columns shall conform to the following requirements: (a) Within the plastic region, closed stirrups shall be spaced at $< d/3$, (b) Strength provided by stirrups shall be at least 3/4 of the design shear, (c) Longitudinal reinforcement shall not be lapped within the plastic hinge region, (d) $(\rho - \rho')/\rho_{bal} < 0.5$, (e) Column flexural capacity exceeds beam flexural capacity.

⁽²⁾These joints shall be considered force-controlled.

⁽³⁾ $a = [(A_s - A_s')f_y + P]/A_w f'_c$.

⁽⁴⁾ P = Axial load due to gravity and earthquake calculated as a force-controlled action per Section 4.2.4.3.2.

⁽⁵⁾ V_g = gravity shear; V_o = punching shear capacity.

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Table 4-5. m-factors for Masonry Components

Component/Conditions	Primary		Secondary	
	LS	IO	LS	IO
Unreinforced Masonry ⁽¹⁾	1.5	1	3	1
Reinforced Masonry in Flexure ⁽²⁾				
$f_a \leq 0.04f_m$				
$\rho f_y / f'_c = 0.01$ ⁽³⁾	6	3	8	3
$\rho f_y / f'_c = 0.05$	4.5	2.5	7	2.5
$\rho f_y / f'_c = 0.20$	2.5	1.5	4	1.5
$f_a \leq 0.075f_m$				
$\rho f_y / f'_c = 0.01$	4	2.5	7	2.5
$\rho f_y / f'_c = 0.05$	3	2	6	2
$\rho f_y / f'_c = 0.20$	2.5	1.5	4	1.5
Reinforced Masonry in Shear	2.5	1	4	1.5
Masonry Infill ⁽⁴⁾	3	1	--	--

⁽¹⁾ Applicable to building with rigid diaphragms; for flexible diaphragms see Special Procedure.

⁽²⁾ f_a = axial stress due to gravity loads per Equation (4-11).

⁽³⁾ ρ = percentage of total vertical reinforcement including boundary elements, if any.

⁽⁴⁾ Capacity based on bed joint shear strength for zero vertical compressive stress.

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Table 4-6. m-factors for Wood Components

Component/Conditions	Primary		Secondary	
	LS	IO	LS	IO
Straight Sheathing, Diagonal Sheathing, and Double Diagonal Sheathing ⁽¹⁾	3	1.5	4	1.5
Gypsum Sheathing/Wallboard ⁽¹⁾	4	2	5	2
Plywood Sheathing				
<u>Shear Walls</u>				
$h/L \leq 1.0$	4.5	2	5.5	2
$3.5 \geq h/L \geq 2.0$ ⁽²⁾	3.5	1.7	4.5	1.7
<u>Diaphragms</u>	3.5	2	4	2
Hold-down anchors	3.5	2	No limit	No limit

⁽¹⁾For $h/L \geq 2.0$, the component shall not be considered effective as a primary component.

⁽²⁾For $h/L \geq 3.5$, the component shall not be considered effective as a primary component.

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Table 4-7. Nonstructural Component Amplification and Response Modification Factors

Component	$a_p^{(1)}$	$R_p^{(2)}$
A. ARCHITECTURAL		
1. Exterior Skin		
Adhered Veneer	1	4
Anchored Veneer	1	3 ⁽³⁾
Glass Block	1	2
Prefabricated Panels	1	3 ⁽³⁾
Glazing Systems	1	2
2. Partitions		
Heavy	1	1.5
Light	1	3
3. Interior Veneers		
Stone, Including Marble	1	1.5
Ceramic Tile	1	1.5
4. Ceilings		
Directly Applied to Structure	1	1.5
Dropped, Furred Gypsum Board	1	1.5
Suspended Lath and Plaster	1	1.5
Suspended Integrated Ceiling	1	1.5
5. Parapets, Cornices, Ornamentation and Appendages	2.5	1.25
6. Canopies and Marquees	2.5	1.5
7. Chimneys and Stacks	2.5	1.25
8. Stairs	1	3
B. MECHANICAL EQUIPMENT		
1. Mechanical Equipment		
Boilers and Furnaces	1	3
General Mfg. and Process Machinery	1	3
HVAC Equipment, Vibration Isolated	2.5	3
HVAC Equipment, Nonvibration Isolated	1	3
HVAC Equipment, mounted in-line	1	3
2. Storage Vessels and Water-heaters		
Vessels on Legs	2.5	1.5
Flat Bottom Vessels	2.5	3
3. High-Pressure Piping	2.5	4
4. Fire-Suppression Piping	2.5	4
5. Fluid piping, not Fire Suppression		
Hazardous Materials	2.5	1
Nonhazardous Materials	2.5	4
6. Ductwork	1	3

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Table 4-7. Nonstructural Component Amplification and Response Modification Factors (cont'd.)

Component		$a_p^{(1)}$	$R_p^{(2)}$
C. ELECTRICAL AND COMMUNICATIONS EQUIPMENT			
1.	Electrical and Communications Equipment	1	3
2.	Electrical and Communications Distribution Equipment	2.5	5
3.	Light Fixtures		
	Recessed	1	1.5
	Surface Mounted	1	1.5
	Integrated Ceiling	1	1.5
	Pendant	1	1.5
D. FURNISHINGS AND INTERIOR EQUIPMENT			
1.	Storage Racks	2.5	4
2.	Bookcases	1	3
3.	Computer Access Floors	1	3
4.	Hazardous Materials Storage	2.5	1
5.	Computer and Communications Racks	2.5	6
6.	Elevators	1	3
7.	Conveyors	2.5	3

⁽¹⁾ A lower value for a_p may be justified by detailed dynamic analysis. The value for a_p is for equipment generally regarded as rigid and rigidly attached. The value of $a_p=2.5$ is for equipment generally regarded as flexible and flexibly mounted. Refer to the definitions for explanations of "Component, Flexible" and "Component, Rigid." Where flexible diaphragms provide lateral support for walls and partitions, the value of a_p shall be increased to 2.0 for the center one-half of the span.

⁽²⁾ $R_p=1.5$ for anchorage design when component anchorage is provided by expansion bolts, shallow chemical anchors, or shallow (nonductile) cast-in-place anchors or when the component is constructed of nonductile materials. Shallow anchors are those with an embedment length-to-bolt diameter ratio of less than 8.

⁽³⁾ Applies when attachment is ductile material and design, otherwise $R_p=1.5$.

4.3 Procedures for Building Systems

This section provides Tier 2 evaluation procedures that apply to all building systems: general, configuration and condition of the materials.

4.3.1 General

4.3.1.1 LOAD PATH: The structure shall contain one complete load path for Life Safety and Immediate Occupancy for seismic force effects from any horizontal direction that serves to transfer the inertial forces from the mass to the foundation.

Commentary:

There must be a complete lateral-force-resisting system that forms a continuous load path between the foundation, all diaphragm levels, and all portions of the building for proper seismic performance. The general load path is as follows: seismic forces originating throughout the building are delivered through structural connections to horizontal diaphragms; the diaphragms distribute these forces to vertical lateral-force-resisting elements such as shear walls and frames; the vertical elements transfer the forces into the foundation; and the foundation transfers the forces into the supporting soil.

If there is a discontinuity in the load path, the building is unable to resist seismic forces regardless of the strength of the existing elements. Mitigation with elements or connections needed to complete the load path is necessary to achieve the selected performance level. The design professional should be watchful for gaps in the load path. Examples would include a shear wall that does not extend to the foundation, a missing shear transfer connection between a diaphragm and vertical element, a discontinuous chord at a diaphragm notch, or a missing collector.

In cases where there is a structural discontinuity, a load path may exist but it may be a very undesirable one. At a discontinuous shear walls, for example, the diaphragm may transfer the forces to frames not intended to be part of the lateral-force-resisting system. While not ideal, it may be possible to show that the load path is acceptable.

A complete load path is a basic requirement for all buildings. The remaining evaluation statements in this handbook target specific components of the load path and are intended to assist the design professional in locating potential gaps in the load path. While non-compliant statements further along in the procedure might indicate a potential discontinuity or inadequacy in the load path, the identification of a complete load path is a necessary first step before continuing with the

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for load paths in non-compliance.

4.3.1.2 ADJACENT BUILDINGS: An adjacent building shall not be located next to the structure being evaluated closer than 4% of the height for Life Safety and Immediate Occupancy.

Tier 2 Evaluation Procedure: The drifts in the structure being evaluated shall be calculated using the Linear Static Procedure in Section 4.2. The drifts in the adjacent building shall be estimated using available information and the procedures of this Handbook. The SRSS combination of both building drifts shall be less than the total separation at each level. Alternatively, if no information is available on the adjacent building, the drifts in the adjacent building shall be assumed to equal three-quarters of the available separation. The SRSS combination of this assumed drift and the calculated drift of the structure being evaluated shall be less than the total separation at each level. In addition, the design professional shall render a judgment on the potential seismic performance of the adjacent building and any potential hazard to the structure being evaluated.

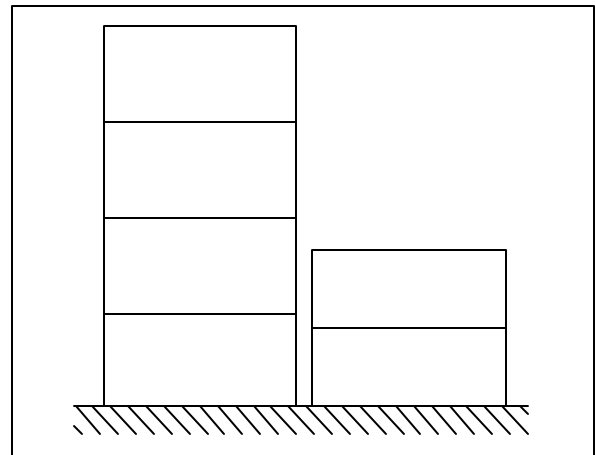
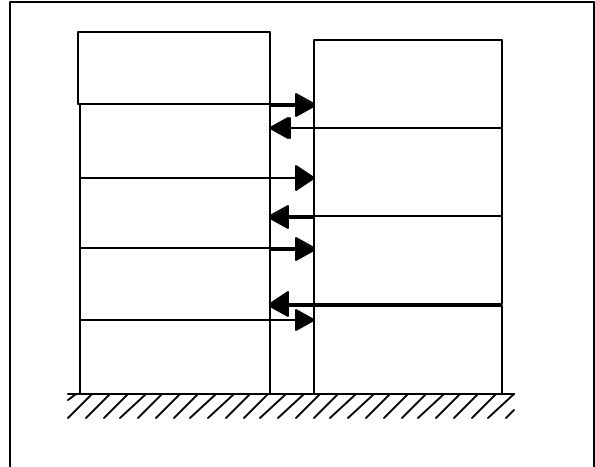
Commentary:

Buildings often are built right up to property lines in order to make maximum use of space, and historically buildings have been designed as if the adjacent buildings do not exist. As a result, the buildings may impact each other, or pound, during an earthquake. Building pounding can alter the dynamic response of both buildings, and impart additional inertial loads on both structures.

Buildings that are the same height and have matching floors will exhibit similar dynamic behavior. If the buildings pound, floors will impact other floors, so damage due to pounding usually will be limited to nonstructural components. When the floors of adjacent buildings are at different elevations, floors will impact the columns of the adjacent building and can cause structural damage (see Figure 4-2). When the buildings are of different heights, the shorter building can act as a buttress for the taller building. The shorter building receives an unexpected load while the taller building suffers from a major stiffness discontinuity that alters its dynamic response (see Figure 4-3). Since neither building is designed for these conditions, there is a potential for extensive damage and possible collapse.

Buildings that are the same height and have matching floor levels need not comply with this statement. Non-compliant separations between buildings that do not have matching floors must be checked using calculated drifts for both buildings. The SRSS combination is used because of the low probability that maximum drifts in both buildings will occur simultaneously and out of phase. When information on the adjacent building is not available, conservative assumptions for drift are made in the procedure.

The potential hazard of the adjacent building must also be evaluated. If a neighbor is a potential collapse hazard, this must be noted.



Commentary:

It is very common for mezzanines to lack a lateral-force-resisting system. Often mezzanines are added on by the building owner. Unbraced mezzanines can be a potential collapse hazard, and should be checked for stability.

Lateral-force-resisting elements must be present in both directions to provide bracing. When the mezzanine is attached to the main structure, the supporting elements of the main structure should be evaluated considering both the magnitude and location of the additional forces imparted by the mezzanine.

If the load path is incomplete or non-existent, mitigation with elements or connections needed to complete the load path is necessary to achieve the selected performance level.

Figure 4-2. Unmatching Floors

One of the basic goals in seismic design is to distribute yielding throughout the structure.

Distributed yielding dissipates more energy and helps prevent the premature failure of any one element or groups of elements. For example, in moment frames (as discussed in Section 4.4) it is desirable to have strong columns relative to the beams to help distribute the formation of plastic hinges throughout the building and prevent the formation of a story mechanism. Code provisions regarding vertical irregularities are intended to achieve this result. Significant irregularities that cause damage to be concentrated in certain areas require special treatment.

Horizontal irregularities involve the horizontal distribution of lateral forces to the resisting frames or shear walls. Irregularities in the diaphragm itself (i.e., diaphragms that have projecting wings or re-entrant corners) are discussed in Section 4.5.

Figure 4-3. Buildings of Different Height

Commentary:

Good details and construction quality are of secondary value if a building has an odd shape that was not properly considered in the design. Although a building with an irregular configuration may be designed to meet all code requirements, irregular buildings generally do not perform as well as regular buildings in an earthquake. Typical building configuration deficiencies include an irregular geometry, a weakness in a given story, a concentration of mass, or a discontinuity in the lateral force resisting system.

Vertical irregularities are defined in terms of strength, stiffness, geometry, and mass. These quantities are evaluated separately, but are related and may occur simultaneously. For example, the frame in Figure 4-4 has a tall first story. It can be a weak story, a soft story, or both depending on the relative strength and stiffness of this story and the stories above.

4.3.1.3 MEZZANINES: Interior mezzanine levels shall be braced independently from the main structure, or shall be anchored to the lateral-force-resisting elements of the main structure.

Tier 2 Evaluation Procedure: The load path from the mezzanine to the main structure shall be identified. The adequacy of the load path shall be evaluated for the forces in Section 4.2 considering the effect of the magnitude and location of any forces imparted by the mezzanine on the main structure.

Commentary:

The story strength is the total strength of all the lateral force resisting elements in a given story for the direction under consideration. It is the shear capacity of columns or shear walls, or the horizontal component of the capacity of diagonal braces. If the columns are flexural controlled, the shear strength is the shear corresponding to the flexural strength. Weak stories are usually found where vertical discontinuities exist, or where

member size or reinforcement has been reduced. It is necessary to calculate the story strengths and compare them. The result of a weak story is a concentration of inelastic activity that may result in the partial or total collapse of the story.

An examination of recent earthquake damage revealed a number of buildings that suffered mid-height collapses. It appears that this situation occurred most often in the near field area of major earthquakes and only affected mid-rise buildings between five and fifteen stories tall. These types of buildings are typically designed for primary mode effects, with strength and stiffness reductions up the height of the structure. This reduction in strength and stiffness coupled with unexpected higher mode effects may have been the potential cause of the mid-height collapses.

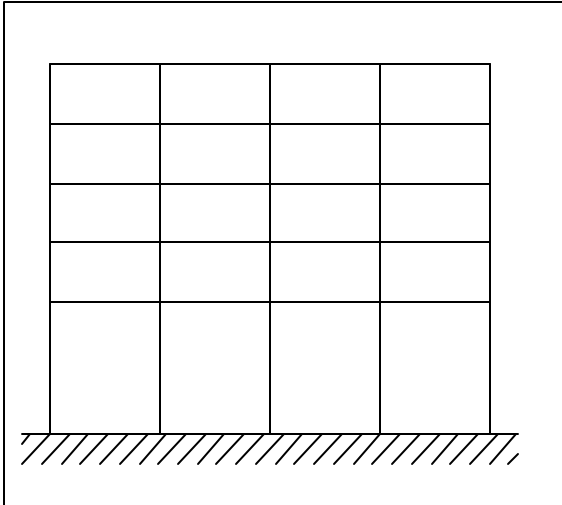
A dynamic analysis could be performed to determine if there are unexpectedly high seismic demands at locations of strength discontinuities. Compliance can be achieved if the elements of the weak story can be shown to have adequate capacity near elastic levels.

Commentary:

This condition commonly occurs in commercial buildings with open fronts at ground-floor storefronts, and hotels or office buildings with particularly tall first stories. Figure 4-4 (see following page) shows an example of a tall story. Such cases are not *necessarily* soft stories because the tall columns may have been designed with appropriate stiffness, but they are *likely* to be soft stories if they have been designed without consideration for interstory drift. Soft stories usually are revealed by an abrupt change in interstory drift. Although a comparison of the stiffnesses in adjacent stories is the direct approach, a simple first step might be to plot and compare the interstory drifts as indicated in Figure 4-5 (see following page) if analysis results happen to be available.

The difference between "soft" and "weak" stories is the difference between stiffness and strength. A column may be limber but strong, or stiff but weak. A change in column size can affect strength and stiffness, and both need to be considered.

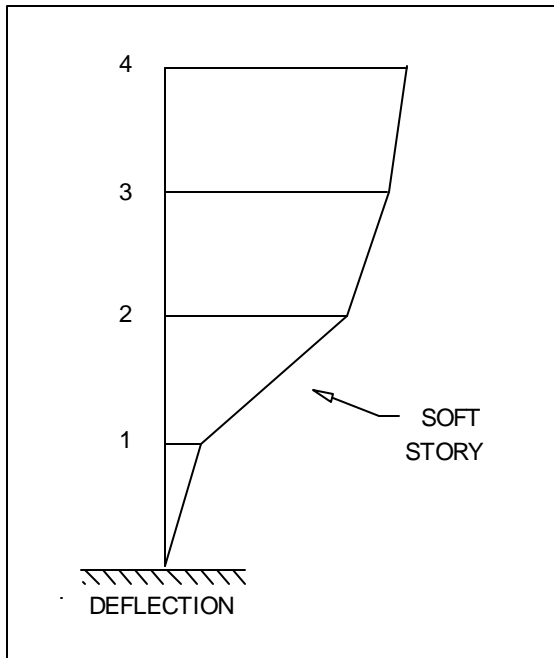
An examination of recent earthquake damage revealed a number of buildings that suffered mid-height collapses. It appears that this situation occurs most often in the near field area of major earthquakes and only affects mid-rise buildings between five and fifteen stories tall. These types of buildings are typically designed for primary mode effects and reduce in strength and/or stiffness up the height of the structure. This reduction in strength and/or stiffness coupled with unexpected higher mode effects may have the potential to cause mid-height collapses. A dynamic analysis should be performed to determine if there are unexpectedly high seismic demands at locations of stiffness discontinuities.



capacity to resist one half the total pseudo lateral force.

4.3.2.2 SOFT STORY The stiffness of the lateral-force-resisting-system in any story shall not be less than 70% of the stiffness in an adjacent story above or below, or less than 80% of the average stiffness of the three stories above or below for Life Safety and Immediate Occupancy.

4.3.2 Configuration



4.3.2.1 WEAK STORY The strength of the lateral-force-resisting-system in any story shall not be less than 80% of the strength in an adjacent story, above or below, for Life Safety and Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with the procedures in Section 4.2 shall be performed. The story strength shall be calculated, and the adequacy of the lateral-force-resisting elements in the non-compliant story shall be checked for the

Commentary:

Geometric irregularities are usually detected in an examination of the story-to-story variation in the dimensions of the lateral-force-resisting system (see Figure 4-6, following page). A building with upper stories set back from a broader base structure is a common example. Another example is a story in a high-rise that is set back for architectural reasons. It should be noted that the irregularity of concern is in the dimensions of the lateral-force-resisting system, not the dimensions of the envelope of the building, and, as such, it may not be obvious.

Geometric irregularities affect the dynamic response of the structure, and may lead to unexpected higher mode effects and concentrations of demand. A dynamic analysis is required to more accurately calculate the distribution of seismic forces. One story penthouses need not be considered.

Tier 2 Evaluation Procedure: An analysis in accordance with the Linear Dynamic Procedure of Section 4.2 shall be performed. The adequacy of the elements in the lateral-force-resisting system shall be evaluated.

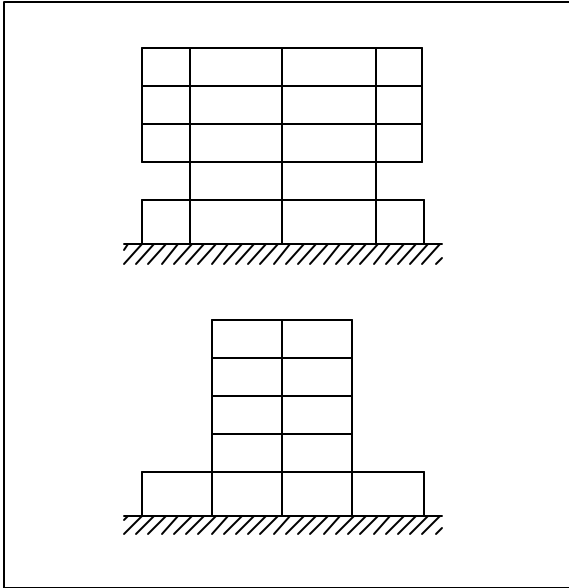


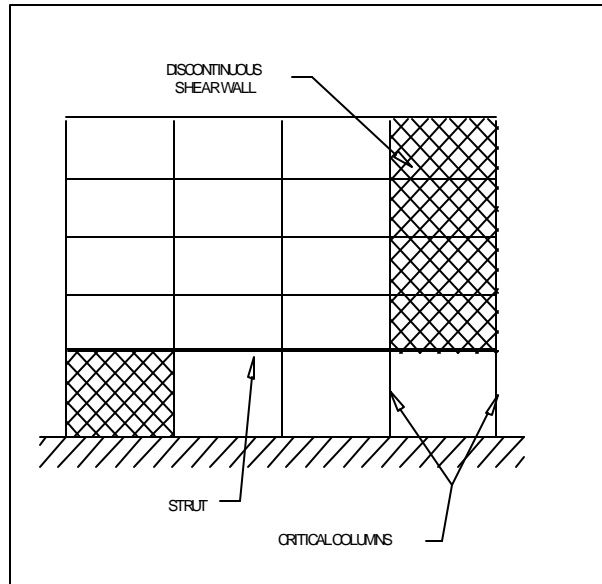
Figure 4-4. Tall Story

Figure 4-5. Soft Story

This issue is a local strength and ductility problem below the discontinuous element, not a global story strength or stiffness irregularity. The concern is that the wall or braced frame may have more shear capacity than considered in the design. These capacities impose overturning forces that could overwhelm the columns. While the strut or connecting diaphragm may be adequate to transfer the shear forces to adjacent elements, the columns which support vertical loads are the most critical. It should be noted that moment frames can have the same kind of discontinuity.

Compliance can be achieved if an adequate load path to transfer seismic forces exists, and the supporting columns can be demonstrated to have adequate capacity to resist the overturning forces generated by the shear capacity of the discontinuous elements.

4.3.2.3 GEOMETRY: There shall be no change in horizontal dimension of the



lateral-force-resisting system of more than 30% in a story relative to adjacent stories for Life Safety and Immediate Occupancy, excluding one-story penthouses.

Tier 2 Evaluation Procedure: An analysis in accordance with the Linear Dynamic Procedure of Section 4.2 shall be performed. The adequacy of the lateral-force-resisting elements shall be evaluated.

Commentary:
Vertical discontinuities are usually detected by visual observation. The most common example is a discontinuous shear wall or braced frame. The element is not continuous to the foundation but stops at an upper level. The shear at this level is transferred through the diaphragm to other resisting elements below. This force transfer can be accomplished either through a strut if the elements are in the same plane (see Figure 4-7) or through a connecting diaphragm if the elements are not in the same plane (see Figure 4-8, on following page). In either case, the overturning forces that develop in the element continue down through the supporting columns.

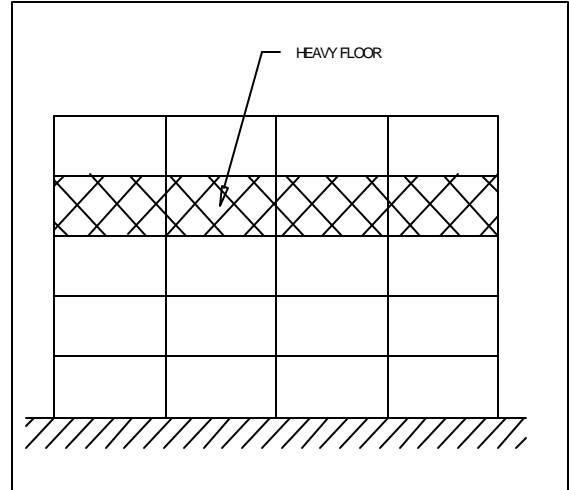
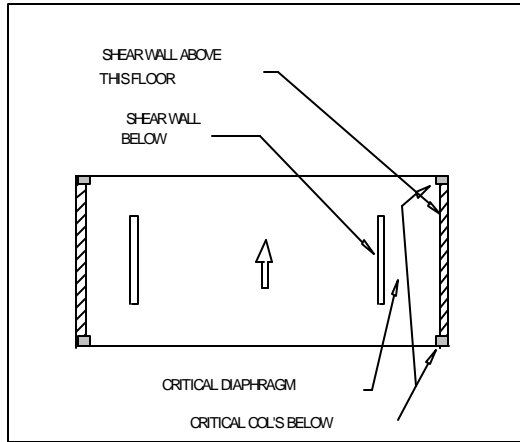


Figure 4-6. Geometric Irregularities

4.3.2.4 VERTICAL DISCONTINUITIES: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation.

Tier 2 Evaluation Procedure: The adequacy of elements below vertical discontinuities shall be evaluated to support gravity forces and overturning forces generated by the capacity of the discontinuous elements above. The adequacy of struts and diaphragms to transfer load from discontinuous elements to adjacent elements shall be evaluated.

Figure 4-7. Vertical Discontinuity In-Plane

Commentary:

Mass irregularities can be detected by comparison of the story weights (see Figure 4-9). The effective mass consists of the dead load of the structure tributary to each level, plus the actual weights of partitions and permanent equipment at each floor. Buildings are typically designed for primary mode effects. The validity of this approximation is dependent upon the vertical distribution of mass and stiffness in the building. Mass irregularities affect the dynamic response of the structure, and may lead to unexpected higher mode effects and concentrations of demand.

A dynamic analysis is required to more accurately calculate the distribution of seismic forces. Light roofs and penthouses need not be considered.

Commentary:

Whenever there is significant torsion in a building, the concern is for additional seismic demands and lateral drifts imposed on the vertical elements by rotation of the diaphragm. Buildings can be designed to meet code forces including torsion, but buildings with severe torsion are less likely to perform well in earthquakes. It is best to provide a balanced system at the start, rather than design torsion into the system.

One concern is for columns that support the diaphragm, especially if the columns are not intended to be part of the lateral-force-resisting system. The columns are forced to drift laterally

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with the diaphragm which induces lateral forces and p-delta effects. Such columns often have not been designed to resist these movements.

Another concern is the strength of the vertical elements of the lateral force resisting system that will experience additional seismic demands due to torsion.

In the Case A building shown in Figure 4-10, the center of gravity is near the center of the diaphragm while the center of rigidity is also near the centerline but close to wall A. Under longitudinal loading, the eccentricity, e_1 , between the center of gravity (center of earthquake load) and the center of rigidity (center of resistance) causes a torsional moment. The entire earthquake force is resisted directly by wall A and the torsional moment is resisted by a couple consisting of equal and opposite forces in walls B and C. These two walls have displacements in opposite directions and the diaphragm rotates.

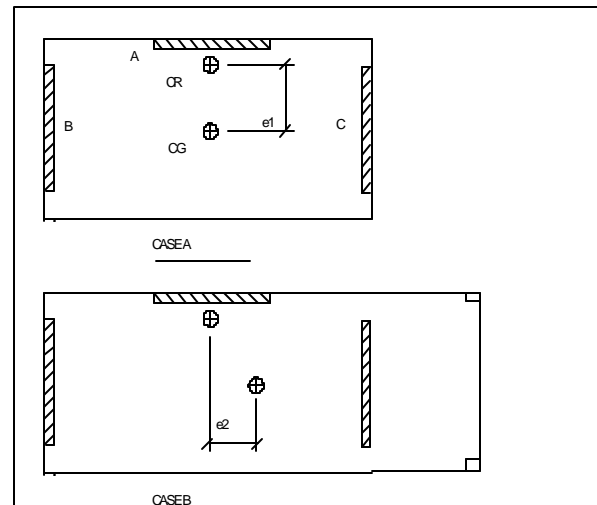
These are very simple cases for analysis and design and if the systems are designed and detailed properly, they should perform well. With the ample proportions suggested by the length of the walls in Figure 4-10, stresses will be low and there will be little rotation of the diaphragm. The hazard appears when the diaphragm, and consequently the diaphragm stresses, become large; when the stiffness of the walls is reduced; or when the walls have substantial differences in stiffnesses.

The Case C building shown in Figure 4-11 (see following page) has a more serious torsional condition than the ones in Figure 4-10. Wall A has much greater rigidity than wall D as indicated by their relative lengths.

For transverse loading, the center of rigidity is close to wall A and there is a significant torsional moment. All four walls are involved in the resistance to the torsional moment. Walls B, C, and D, although strong enough for design forces, have little rigidity and that allows substantial rotation of the diaphragm. There are two concerns here. First,

displacement at E and F, that induces sidesway moments in the columns that may not have been recognized in the design. Their failure could lead to a collapse. Second, the stability of the building under transverse loading depends on wall D. The Case D building shown in Figure 4-11 is shown with wall D failed. The remaining walls, A, B, and C, are in the configuration of Figure 4-10 and now there is a very large eccentricity that may cause walls B and C to fail. Note that this is an example of a building that lacks redundancy.

Figure 4-8. Vertical Discontinuity Out-of-Plane



4.3.2.5 MASS: There shall be no change in effective mass more than 50% from one story to the next for Life Safety and for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with the Linear Dynamic Procedure of Section 4.2 shall be performed. The adequacy of the lateral-force-resisting elements shall be evaluated.

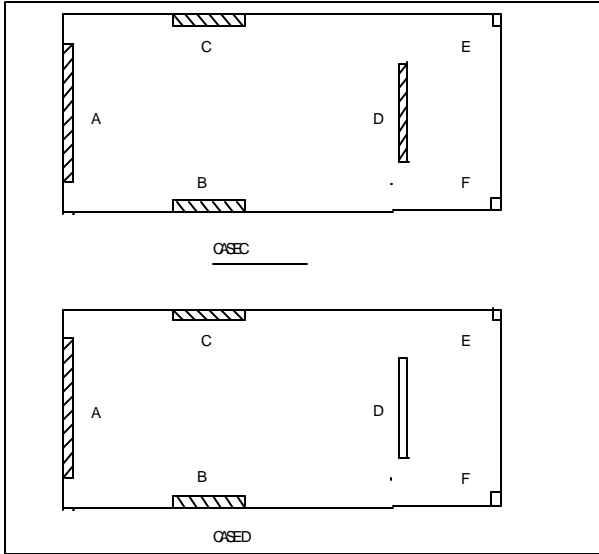


Figure 4-9. Heavy Floor

4.3.2.6 TORSION: The distance between the story center of mass and the story center of

Commentary:

Deteriorated structural materials may jeopardize the capacity of the vertical- and lateral-force-resisting systems. The most common type of deterioration is caused by the intrusion of water. Stains may be a clue to water-caused deterioration where the structure is visible on the exterior, but the deterioration may be hidden where the structure is concealed by finishes. In the latter case, the design professional may have to find a way into attics, plenums, and crawl spaces in order to assess the structural systems and their condition.

The design professional should be careful when dealing with a building that appears to be in good condition and is known to have been subjected to earthquakes in the past. One is tempted to say that the building has "withstood the test of time"; however, the earthquakes the building was subjected to may not have been significant or the good appearance may only be a good cosmetic repair that hides damage that was not repaired. Examples of problems include cracked concrete walls and frames, torn steel connections, bent fasteners or torn plywood in diaphragms and walls,

rigidity is less than 20% of the building width in either plan dimension for Life Safety and Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with the procedures in Section 4.2 shall be performed. The adequacy of the lateral-force-resisting system including torsional demands shall be evaluated. The maximum story drift including the additional displacement due to torsion shall be calculated. The adequacy of the vertical-load-carrying elements under the calculated drift, including P-delta effects, shall be evaluated.

Commentary:

The condition of the wood in a structure has a direct relationship as to its performance in a seismic event. Wood that is split, rotten, or has insect damage may have a very low capacity to resist loads imposed by earthquakes. Structures with wood elements depend to a large extent on the connections between members. If the wood at a bolted connection is split, the connection will possess only a fraction of the capacity of a similar connection in undamaged wood.

Figure 4-10. Torsion: Cases A and B

Commentary:

Fasteners connecting structural panels to the framing are supposed to be driven flush with, but should not penetrate the surface of the sheathing. This effectively reduces the shear capacity of the fastener and increases the potential for the fastener to fail by pulling through the sheathing.

For structures built prior to the wide use of nailing guns (pre-1970), the problem is generally not present. More recent projects are often constructed with alternate fasteners, such as staples, T-nails, clipped head nails, or cooler nails, installed with pneumatic nail guns and often overdriven, completely penetrating one or more

Figure 4-11. Torsion: Cases C and D

4.3.3 Condition of Materials

4.3.3.1 DETERIORATION OF WOOD There shall be no signs of decay, shrinkage, splitting, fire damage, or sagging in any of the wood members, and none of the metal accessories shall be deteriorated, broken, or loose.

Tier 2 Evaluation Procedure:The cause and extent of damage shall be identified. The consequences of this damage to the lateral-force-resisting system shall be determined. The adequacy of damaged lateral-force-resisting elements shall be evaluated considering the extent of the

Commentary:
 Environmental effects over prolonged periods of time may lead to deterioration of steel elements. Significant rusting or corrosion, can substantially reduce the member cross sections, with a corresponding reduction in capacity.

 Often steel elements have surface corrosion which looks worse than it is, and is likely not a concern. When corrosion is present, care should be taken to determine the actual loss in cross section. Such deterioration must be considered in the evaluation when it occurs at critical locations in the lateral force resisting system.

damage and impact on the capacity of each damaged element.

4.3.3.2 OVERDRIVEN FASTENERS There shall be no evidence of overdriven fasteners in the shear walls

Tier 2 Evaluation Procedure:The extent of overdriven fasteners shall be identified. The consequences of overdriven fasteners to the lateral-force-resisting system shall be determined. The adequacy these shear walls shall be evaluated considering the extent of overdriven fasteners and impact on the capacity.

4.3.3.3 DETERIORATION OF STEEL There shall be no visible rusting, corrosion, cracking or other deterioration in any of the steel elements or connections in the vertical- or

Commentary:
 Deteriorated concrete and reinforcing steel can significantly reduce the strength of concrete elements. This statement is concerned with deterioration such as spalled concrete associated with rebar corrosion and water intrusion. Cracks in concrete are covered elsewhere in this Handbook. Spalled concrete over reinforcing bars reduces the available surface for bond between the concrete and steel. Bar corrosion may significantly reduce the cross section of the bar.

 Deterioration is a concern when the concrete cover has begun to spall, and there is evidence of rusting at critical locations.

lateral-force-resisting systems.

Tier 2 Evaluation Procedure:The cause and extent of damage shall be identified. The consequences of this damage to the lateral-force-resisting system shall be determined. The adequacy of damaged lateral-force-resisting elements shall be evaluated considering the extent of the damage and impact on the capacity of each damaged element.

Commentary:
 Corrosion in post-tensioning anchors can lead to failure of the gravity load system if ground motion causes a release or slip of prestressing strands.

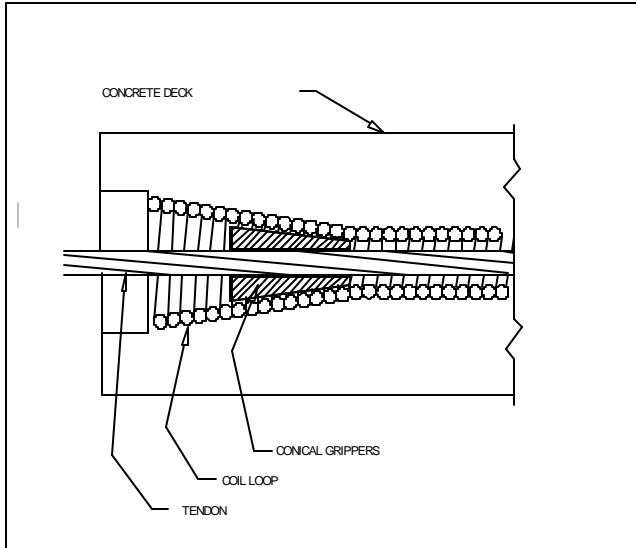
anchors (see Figure 4-12), with or without corrosion, have performed poorly under cyclic loads.

The performance of precast concrete wall systems is completely dependent on the condition of the connections.

4.3.3.4 DETERIORATION OF CONCRETE:

4.3.3.5 POST-TENSIONING ANCHORS:

There shall be no evidence of corrosion or spalling in the vicinity of post-tensioning or end fittings. Coil anchors shall not have been used.



Tier 2 Evaluation Procedure: The cause and extent of damage shall be identified. The consequences of this damage to the lateral-force-resisting system shall be determined. The adequacy of damaged lateral-force-resisting elements shall be evaluated considering the extent of the

There shall be no visible deterioration of concrete or reinforcing steel in any of the vertical- or lateral- force-resisting elements.

Commentary:

Deteriorated or poor quality masonry elements can result in significant reductions in the strength of structural elements. Damaged or deteriorated masonry may not be readily observable.

Tier 2 Evaluation Procedure: The cause and extent of damage shall be identified. The consequences of this damage to the lateral-force-resisting system shall be determined. The adequacy of damaged lateral-force-resisting elements shall be evaluated considering the extent of the damage and impact on the capacity of each damaged element.

damage and impact on the capacity of each damaged element.

Figure 4-12. Coil Anchor

4.3.3.6 PRECAST CONCRETE WALLS: There shall be no visible deterioration of concrete or reinforcing steel or evidence of distress, especially at the connections.

Tier 2 Evaluation Procedure: The cause and extent of damage shall be identified. The consequences of this damage to the

Commentary:

Precast concrete elements are sometimes only nominally interconnected and may be subject to shrinkage, creep, or temperature stresses that were not adequately considered in design. Distress caused by these factors could directly affect the lateral strength of the building. The most common damage is cracking and spalling at embedded connections between panels. This includes both the nominal connections along the vertical edges and the chord connections at the level of the

Commentary:

Older buildings constructed with lime mortar may have surface repointing but still have deteriorated mortar in the main part of the joint. One test is to tap a small hole with a nail in the repointing and, if it breaks through, powdery lime mortar shows on the nail. If it does not break through after aggressive blows, the wall probably is repointed full depth. This also can be seen by looking behind exterior trim or

trim or wall fixtures where the new repointing never reached. Mortar that is severely eroded or can easily be scraped away has been found to have low shear strength, which results in low wall strength. Destructive or in-plane shear tests are required to measure the strength of the bond between the brick and mortar in order to determine the shear capacity of the walls.

lateral-force-resisting system shall be determined. The adequacy of damaged walls shall be evaluated considering the extent of the damage and impact on the capacity of each damaged wall.

4.3.3.7 MASONRY UNITS: There shall be no visible deterioration of masonry units.

Tier 2 Evaluation Procedure: The cause and extent of damage shall be identified. The consequences of this damage to the lateral-force-resisting system shall be determined. The adequacy of damaged lateral-force-resisting elements shall be evaluated considering the extent of the

Commentary:

Small cracks in concrete elements have little effect on strength. A significant reduction in strength is usually the result of large displacements or crushing of concrete. Only when the cracks are large enough to prevent aggregate interlock or have the potential for buckling of the reinforcing steel does the adequacy of the concrete capacity become a concern.

Crack width is commonly used as a convenient indicator of damage to a wall, but it should be noted that recent studies (ATC 43 - *Evaluation and Repair of Earthquake Damaged Concrete and Masonry Wall Buildings*) list other factors, such as location, orientation, number, distribution and pattern of the cracks to be equally important in measuring the extent of damage present in the shear walls. All these factors should be considered when evaluating the reduced capacity of a cracked element.

damage and impact on the capacity of each damaged element.

4.3.3.8 MASONRY JOINTS: The mortar shall not be easily scraped away from the joints by hand with a metal tool, and there shall be no areas of eroded mortar.

Tier 2 Evaluation Procedure: The extent of loose or eroded mortar shall be identified. Walls with loose mortar shall be omitted from the analysis, and the adequacy of the lateral-force-resisting system shall be evaluated. Alternatively, the adequacy of the walls may be evaluated with shear strength determined by testing.

Commentary:

Diagonal wall cracks, especially along the masonry joints, may affect the interaction of the masonry units, leading to a reduction of strength and stiffness. The cracks may indicate distress in the wall from past seismic events, foundation settlement, or other causes.

Crack width is commonly used as a convenient indicator of damage to a wall, but it should be noted that recent studies (ATC 43 - *Evaluation and Repair of Earthquake Damaged Concrete and Masonry Wall Buildings*) list other factors, such as location, orientation, number, distribution and pattern of the cracks to be equally important in measuring the extent of damage present in the shear walls. All these factors should be considered when evaluating the reduced capacity of a cracked element.

4.3.3.9 CONCRETE WALL CRACKS: All existing diagonal cracks in the wall elements shall be less than 1/8" for Life Safety and 1/16" for Immediate Occupancy, shall not be concentrated in one location, and shall not form an X pattern.

Tier 2 Evaluation Procedure: The cause and extent of damage shall be identified. The consequences of the damage to the lateral-force-resisting system shall be determined. The adequacy of damaged walls shall be evaluated

considering the extent of the damage and impact on the capacity of each damaged wall.

4.3.3.10 REINFORCED MASONRY WALL CRACKS: All existing diagonal cracks in the wall elements shall be less than 1/8" for Life Safety and 1/16" for Immediate Occupancy, shall not be concentrated one location, and shall not form an X pattern.

Tier 2 Evaluation Procedure: The cause and extent of damage shall be identified. The consequences of the damage to the lateral-force-resisting system shall be

Commentary:

Diagonal wall cracks, especially along the masonry joints, may affect the interaction of the masonry units, leading to a reduction of strength and stiffness. The cracks may indicate distress in the wall from past seismic events, foundation settlement, or other causes.

Crack width is commonly used as a convenient indicator of damage to a wall, but it should be noted that recent studies (ATC 43 - *Evaluation and Repair of Earthquake Damaged Concrete and Masonry Wall Buildings*) list other factors, such as location, orientation, number, distribution and pattern of the cracks to be equally important in measuring the extent of damage present in the shear walls. All these factors should be considered when evaluating the reduced capacity of a cracked element.

determined. The adequacy of damaged lateral-force-resisting elements shall be evaluated considering the extent of the damage and impact on the capacity of each damaged element.

Commentary:

Diagonal wall cracks, especially along the masonry joints, may affect the interaction of the masonry units, leading to a reduction of strength and stiffness. The cracks may indicate distress in the wall from past seismic events, foundation settlement, or other causes.

Offsets in the bed joint along the masonry joints may affect the interaction of the masonry units in resisting out-of-plane forces. The offsets may indicate distress in the wall from past seismic events, or just poor construction.

Crack width is commonly used as a convenient indicator of damage to a wall, but it should be noted that recent studies (ATC 43 - *Evaluation and Repair of Earthquake Damaged Concrete and Masonry Wall Buildings*) list other factors, such as location, orientation, number, distribution and pattern of the cracks to be equally important in measuring the extent of damage present in the shear walls. All these factors should be considered when evaluating the reduced capacity of a cracked element.

4.3.3.11 UNREINFORCED MASONRY WALL CRACKS: There shall be no existing diagonal cracks in the wall elements greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy, or out-of-plane offsets in the bed joint greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy.

Tier 2 Evaluation Procedure: The cause and extent of damage shall be identified. Damaged walls or portions of walls shall be omitted from the analysis, and the adequacy of the lateral-force-resisting system shall be evaluated.

Commentary:

Small cracks in concrete elements have little effect on strength. A significant reduction in strength is usually the result of large displacements or crushing of concrete. Only when the cracks are large enough to prevent aggregate interlock or have the potential for buckling of the reinforcing steel does the adequacy of the concrete element capacity become a concern.

Columns are required to resist diagonal compression strut forces that develop in infill wall panels. Vertical components induce axial forces in the columns. The eccentricity between horizontal components and the beams is resisted by the columns. Extensive cracking in the columns may indicate locations of possible weakness. Such columns may not be able to function in conjunction with the infill panel as expected.

4.3.3.12 CRACKS IN INFILL WALLS: There shall be no existing diagonal cracks in the infilled walls that extend throughout a panel, are greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy, or out-of-plane offsets in the bed joint greater than 1/8" for Life Safety and 1/16" for Immediate Occupancy.

Tier 2 Evaluation Procedure: The cause and extent of damage shall be identified. The consequences of the damage to the lateral-force-resisting system shall be determined. The adequacy of damaged lateral-force-resisting elements shall be evaluated considering the extent of the damage and impact on the capacity of each damaged element.

4.3.3.13 CRACKS IN BOUNDARY

COLUMNS : There shall be no existing diagonal cracks wider than 1/8" for Life Safety and 1/16" for Immediate Occupancy in concrete columns that encase masonry infills.

Tier 2 Evaluation Procedure: The cause and extent of damage shall be identified. The consequences of the damage to the lateral-force-resisting system shall be determined. The adequacy of damaged lateral-force-resisting elements shall be evaluated considering the extent of the damage and impact on the capacity of each damaged element.

4.4 Procedures for Lateral-Force-Resisting Systems

This section provides Tier 2 evaluation procedures that apply to lateral force resisting systems: moment frames, shear walls and braced frames.

4.4.1 Moment Frames

Commentary:

Moment frames develop their resistance to lateral forces through the flexural strength and continuity of beam and column elements.

In an earthquake, a frame with suitable proportions and details can develop plastic hinges that will absorb energy and allow the frame to survive actual displacements that are larger than calculated in an elastic-based design.

In modern moment frames, the ends of beams and columns, being the locations of maximum seismic moment, are designed to sustain inelastic behavior associated with plastic hinging over many cycles and load reversals. Frames that are designed and detailed for this ductile behavior are called "special" moment frames.

Frames without special seismic detailing depend on the reserve strength inherent in the design of the members. The basis of this reserve strength is the load factors in strength design or the factors of safety in working-stress design. Such frames are called "ordinary" moment frames. For ordinary moment frames, failure usually occurs due to a sudden brittle mechanism, such as shear failure in concrete members.

For evaluations using this Handbook, it is not necessary to determine the type of frame in the building. The performance issue is addressed by appropriate acceptance criteria in the specified procedures. The fundamental requirements for all ductile moment frames are that:

1. They have sufficient strength to resist seismic demands,

2. They have sufficient stiffness to limit interstory drift,
3. Beam-column joints have the ductility to sustain the rotations they are subjected to,
4. Elements can form plastic hinges, and
5. Beams will develop hinges before the columns at locations distributed throughout the structure (the strong column/weak beam concept).

These items are covered in more detail in the evaluation statements that follow.

It is expected that the combined action of gravity loads and seismic forces will cause the formation of plastic hinges in the structure. However, a concentration of plastic hinge formation at undesirable locations can severely undermine the stability of the structure. For example, in a weak column situation (see Figure 4-13 next page), hinges can form at the tops and bottoms of all the columns in a particular story, and a story mechanism develops. This condition results in a concentration of ductility demand and displacement in a single story that can lead to collapse.

In a strong column situation (see Figure 4-13 next page) the beams hinge first, yielding is distributed throughout the structure, and the ductility demand is more dispersed.

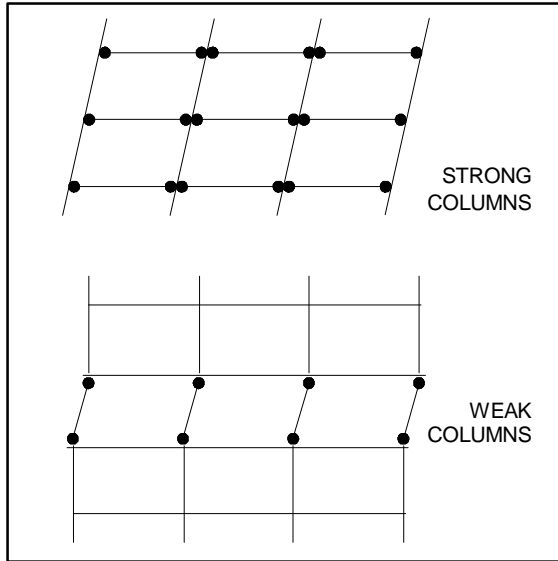


Figure 4-13. Plastic Hinge Formation

4.4.1.1 General

4.4.1.1.1 REDUNDANCY: The number of lines of moment frames in each direction shall be greater than equal to 2 for Life Safety and for Immediate Occupancy. The number of bays of moment frames in each line shall be greater than or equal to 2 for Life Safety and 3 for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with the procedures in Section 4.2 shall be performed. The adequacy of all elements and connections in the frames shall be evaluated.

Commentary:

Redundancy is a fundamental characteristic of lateral force resisting systems with superior seismic performance. Redundancy in the structure will ensure that if an element in the lateral force resisting system fails for any reason, there is another element present that can provide lateral force resistance. Redundancy also provides multiple locations for potential yielding, distributing inelastic activity throughout the structure and improving ductility and energy dissipation. Typical characteristics of redundancy include multiple lines of resistance to distribute the lateral forces uniformly throughout the structure, and multiple bays in each line of resistance to reduce the shear and axial demands on any one element (see Figure 4-14).

A distinction should be made between redundancy and adequacy. For the purpose of this Handbook, redundancy is intended to mean simply "more than one." That is not to say that for large buildings two elements is adequate, or for small buildings one is not enough. Separate evaluation statements are present in the Handbook to determine the adequacy of the elements provided.

When redundancy is not present in the structure, an analysis which demonstrates the adequacy of the lateral force elements is required.

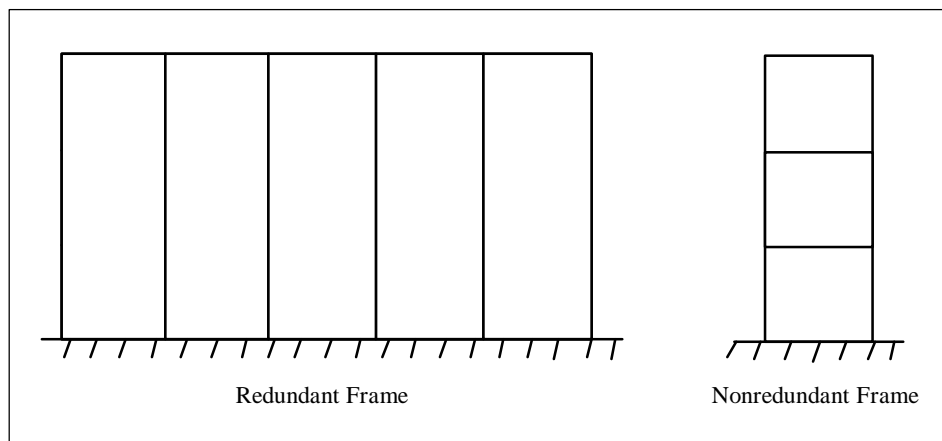


Figure 4-14. Redundancy Along a Line of Moment Frame

4.4.1.2 Moment Frames with Infill Walls

Commentary:

Infill walls used for partitions, cladding or shaft walls that enclose stairs and elevators should be isolated from the frames. If not isolated, they will alter the response of the frames and change the behavior of the entire structural system. Lateral drifts of the frame will induce forces on walls that interfere with this movement. Cladding connections must allow for this relative movement. Stiff infill walls confined by the frame will develop compression struts that will impart loads to the frame and cause damage to the walls. This is particularly important around stairs or other means of egress from the building.

4.4.1.2.1 INTERFERING WALLS: All infill walls placed in moment frames shall be isolated from structural elements.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The demands imparted by the structure to the interfering walls, and the demands induced on frame shall be calculated. The adequacy of the interfering walls and the frame to resist the induced forces shall be evaluated.

4.4.1.3 Steel Moment Frames

Commentary:

When an infill wall interferes with the moment frame, the wall becomes an unintended part of the lateral-force-resisting system. Typically these walls are not designed and detailed to participate in the lateral-force-resisting system and may be subject to significant damage.

Interfering walls should be checked for forces induced by the frame, particularly when damage to these walls can lead to falling hazards near means of egress. The frames should be checked for forces induced by contact with the walls, particularly if the walls are not full height, or do not completely infill the bay.

Commentary:

The following are characteristics of steel moment frames that have demonstrated acceptable seismic performance:

1. The beam end connections develop the plastic moment capacity of the beam or panel zone,
2. There is a high level of redundancy in the number of moment connections,
3. The column web has sufficient strength to sustain the stresses in the beam-column joint,
4. The lower flanges have lateral bracing sufficient to maintain stability of the frame, and
5. There is flange continuity through the column.

Prior to the 1994 Northridge earthquake, steel moment-resisting frame connections generally consisted of complete penetration flange welds and a bolted or welded shear tab connection at the web. This type of connection, which was an industry standard from 1970 to 1995, was thought to be ductile and capable of developing the full capacity of the beam sections. However, over 200 buildings experienced extensive brittle damage to this type of connection during the Northridge earthquake. As a result, an emergency code change was made to the *1994 UBC* (ICBO, 1994) removing the prequalification of this type of connection. The reasons for this unexpected performance are still under investigation. A full discussion of the various fractures mechanisms and ways of preventing or repairing them is given in *FEMA 267* (SAC, 1995) and *FEMA 267A* (SAC, 1997).

4.4.1.3.1 DRIFT CHECK: The drift ratio of the steel moment frames, calculated using the Quick Check Procedure of Section 3.5.3.1, shall be less than the 0.025 for Life Safety and 0.015 for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the beams and columns, including P- Δ effects, shall be evaluated using the m -factors in Table 4-3.

Commentary:

Moment-resisting frames are more flexible than shear wall or braced frame structures. This flexibility can lead to large interstory drifts that may potentially cause extensive structural and nonstructural damage to welded beam-column connections, partitions, and cladding. Drifts may also induce large P- Δ demands, and pounding when adjacent buildings are present.

An analysis of non-compliant frames is required to demonstrate the adequacy of frame elements subjected to excessive lateral drifts.

4.4.1.3.2 AXIAL STRESS CHECK: The axial stress due to gravity loads in columns subjected to overturning forces shall be less than $0.10F_y$ for Life Safety and Immediate Occupancy. Alternatively, the axial stress due to overturning forces alone, calculated using the Quick Check Procedure of Section 3.5.3.6, shall be less than $0.30F_y$ for Life Safety and Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The gravity and overturning demands for non-compliant columns shall be calculated and the adequacy of the columns to resist overturning forces shall be evaluated using the m -factors in Table 4-3.

Commentary:

Columns that carry a substantial amount of gravity load may have limited additional capacity to resist seismic forces. When axial forces due to seismic overturning moments are added, the columns may buckle in a nonductile manner due to excessive axial compression.

The alternative calculation of overturning stresses due to seismic forces alone is intended to provide a means of screening out frames with high gravity loads, but are known to have small seismic overturning forces.

When both demands are large, the combined effect of gravity and seismic forces must be calculated to demonstrate compliance.

4.4.1.3.3 MOMENT-RESISTING CONNECTIONS: All moment connections shall be able to develop the strength of the adjoining members or panel zones.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the members and connections shall be evaluated using the m -factors in Table 4-3.

Commentary:

Prior to the 1994 Northridge earthquake, steel moment-resisting frame connections generally consisted of full penetration flange welds and a bolted or welded shear tab connection at the web. This type of connection, (see Figure 4-15 on the following page) which was an industry standard from 1970 to 1995, was thought to be ductile and capable of developing the full capacity of the beam sections. However, over 200 buildings experienced extensive brittle damage to this type of connection during the Northridge earthquake. As a result, an emergency code change was made to the 1994 UBC (ICBO, 1994) removing the prequalification of this type of connection. The reasons for this

unexpected performance are still under investigation. A full discussion various fracture mechanisms and ways of preventing or repairing them is given in *FEMA 267* (SAC, 1995) and *FEMA 267A* (SAC, 1997).

For this Handbook, the Tier 1 evaluation statement is considered non-compliant for full penetration flange welds and a more detailed analysis is required to determine the adequacy of these moment-resisting connections.

Commentary:

Panel zones with thin webs may yield or buckle before developing the capacity of the adjoining members, reducing the inelastic performance and ductility of the moment frames.

When panel zones cannot develop the strength of the beams, compliance can be demonstrated by checking the panel zones for actual shear demands.

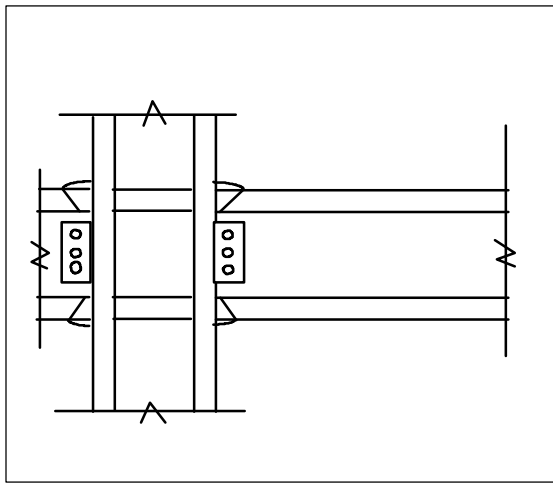


Figure 4-15. Northridge-Type Connection

4.4.1.3.4 PANEL ZONES: All panel zones shall have the shear capacity to resist the shear demand required to develop $0.8SM_p$ of the girders framing in at the face of the column.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The demands in non-compliant joints shall be calculated and the adequacy of the panel zones for web shear shall be evaluated using the *m*-factors in Table 4-3.

4.4.1.3.5 COLUMN SPLICES: All column splice details located in moment resisting frames shall include connection of both flanges and the web for Life Safety, and the splice shall develop the strength of the column for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The gravity and seismic demands shall be calculated and the adequacy of the splice connection shall be evaluated.

Commentary:

The lack of a substantial connection at the splice location may lead to separation of the spliced sections and misalignment of the columns resulting in loss of vertical support and partial or total collapse of the building. Tests on partial-penetration weld splices have shown limited ductility.

An inadequate connection also reduces the effective capacity of the column. Splices are checked against calculated demands to demonstrate compliance.

4.4.1.3.6 STRONG COLUMN/WEAK BEAM: The percent of strong column/weak beam joints in each story of each line of moment resisting frames shall be greater than 50% for Life Safety and 75% for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the columns to resist calculated demands shall be evaluated using an m -factor equal to 2.5. Alternatively, the story strength shall be calculated, and checked for the capacity to resist one half the total pseudo lateral force.

Commentary:

When columns are not strong enough to force hinging in the beams, column hinging can lead to story mechanisms and a concentration of inelastic activity at a single level. Excessive story drifts may result in an instability of the frame due to P- Δ effects. Good post-elastic behavior consists of yielding distributed throughout the frame. A story mechanism will limit forces in the levels above, preventing the upper levels from yielding. Joints at the roof level need not be considered.

If it can be demonstrated that non-compliant columns are strong enough to resist calculated demands with sufficient overstrength, acceptable behavior can be expected.

The alternative procedure checks for the formation of a story mechanism. The story strength is the sum of the shear capacities of all the columns as limited by the controlling action. If the columns are shear critical, a shear mechanism forms at the shear capacity of the columns. If the columns are controlled by flexure, a flexural mechanism forms at a shear corresponding to the flexural capacity.

Should additional study be required, a Tier 3 evaluation would include a non-linear pushover analysis. The formation of a story mechanism would be acceptable, provided the target displacement is met .

4.4.1.3.7 COMPACT MEMBERS: All moment frame elements shall meet compact section requirements set forth by the *Load and Resistance Factor Design Specification For Structural Steel Buildings* (AISC, 1993). This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of non-compliant beams and columns shall be evaluated using the m -factors in Table 4-3.

Commentary:

Noncompact frame elements may experience premature local buckling prior to development of their full moment capacities. This can lead to poor inelastic behavior and ductility.

The adequacy of the frame elements can be demonstrated using reduced m -factors in consideration of reduced capacities for noncompact sections.

4.4.1.3.8 BEAM PENETRATIONS: All openings in frame-beam webs shall be less than 1/4 of the beam depth and shall be located in the center half of the beams. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The shear and flexural demands on non-compliant beams shall be calculated. The adequacy of the beams considering the strength around the penetrations shall be evaluated.

Commentary:

Members with large beam penetrations may fail in shear prior to the development of their full moment capacity, resulting in poor inelastic behavior and ductility.

The critical section is at the penetration with the highest shear demand. Shear transfer across the web opening will induce secondary moments in the beam sections above and below the opening that must be considered in the analysis.

4.4.1.3.9 GIRDER FLANGE CONTINUITY PLATES: There shall be girder flange continuity plates at all moment resisting frame joints. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: The adequacy of the column flange to transfer girder flange forces to the panel zone without continuity plates shall be evaluated.

Commentary:

The lack of girder flange continuity plates may lead to a premature failure at the column web or flange at the joint. Beam flange forces are transferred to the column web through the column flange, resulting in a high stress concentration at the base of the column web. The presence of continuity plates, on the other hand, transfers the beam flange forces along the entire length of the column web.

Adequate force transfer without continuity plates will depend on the strength and stiffness of the column flange in weak-way bending.

4.4.1.3.10 OUT-OF-PLANE BRACING: Beam-column joints shall be braced out-of-plane. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The axial demands on non-compliant columns shall be calculated and the adequacy of the column to resist buckling between points of lateral support shall be evaluated considering a horizontal out-of-plane force equal to 6% of the critical column flange compression force acting concurrently at the non-compliant joint.

Commentary:

Joints without proper bracing may buckle prematurely out-of-plane before the strength of the joint can be developed. This will limit the ability of the frame to resist seismic forces.

The combination of axial load and moment on the columns will result in higher compression forces in one of the column flanges. The tendency for highly loaded joints to twist out-of-plane is due to compression buckling of the critical column compression flange.

Compliance can be demonstrated if the column section can provide adequate lateral restraint for the joint between points of lateral support.

4.4.1.3.11 BOTTOM FLANGE BRACING: The bottom flange of beams shall be braced out-of-plane. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the beams shall be evaluated considering the potential for lateral torsional buckling of the bottom flange between points of lateral support.

Commentary:

Beams flanges in compression require out-of-plane bracing to prevent lateral torsional buckling. Buckling will occur before the full strength of the beam is developed, and the ability of the frame to resist lateral forces will be limited.

Top flanges are typically braced by connection to the diaphragm. Bottom flange bracing occurs at discrete locations, such as at connection points for supported beams. The spacing of bottom flange bracing may not be close enough to prevent premature lateral torsional buckling when seismic loads induce large compression forces in the bottom flange.

Note that this condition is not considered a life-safety concern, and need only be examined for the Immediate Occupancy Performance Level.

4.4.1.4 Concrete Moment Frames

Commentary:

Concrete moment frame buildings typically are more flexible than shear wall buildings. This flexibility can result in large interstory drifts that may lead to extensive nonstructural damage and P-delta effects. If a concrete column has a capacity in shear that is less than the shear associated with the flexural capacity of the column, brittle column shear failure may occur and result in collapse. This condition is common in buildings in zones of moderate seismicity and in older buildings in zones of high seismicity. The columns in these buildings often have ties at standard spacing equal to the depth of the column, whereas current code maximum spacing for shear reinforcing is $d/2$. The following are the characteristics of concrete moment frames that have demonstrated acceptable seismic performance:

1. Brittle failure is prevented by providing a sufficient number of beam stirrups, column ties, and joint ties to ensure that the shear

capacity of all elements exceeds the shear associated with flexural capacity,

2. Concrete confinement is provided by beam stirrups and column ties in the form of closed hoops with 135-degree hooks at locations where plastic hinges will occur.
3. Overall performance is enhanced by long lap splices that are restricted to favorable locations and protected with additional transverse reinforcement.
4. The strong column/weak beam requirement is achieved by suitable proportioning of the members and their longitudinal reinforcing.

Older frame systems that are lightly reinforced, precast concrete frames, and flat slab frames usually do not meet the detail requirements for ductile behavior.

4.4.1.4.1 SHEAR STRESS CHECK: The shear stress in the concrete columns, calculated using the Quick Check Procedure of Section 3.5.3.2, shall be less than 100 psi or $2\sqrt{f'c}$ or Life Safety and Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the concrete frame elements shall be evaluated using the m -factors in Table 4-4.

Commentary:

The shear stress check provides a quick assessment of the overall level of demand on the structure. The concern is the overall strength of the building.

4.4.1.4.2 AXIAL STRESS CHECK: The axial stress due to gravity loads in columns subjected to overturning forces shall be less than $0.10f'_c$ for Life Safety and Immediate Occupancy. Alternatively, the axial stress due to overturning forces alone, calculated using the Quick Check Procedure of Section 3.5.3.6, shall be less than $0.30f'_c$ for Life Safety and Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The gravity and overturning demands for non-compliant columns shall be calculated and the adequacy of the columns to resist overturning forces shall be evaluated using the m -factors in Table 4-4.

Commentary:

Columns that carry a substantial amount of gravity load may have limited additional capacity to resist seismic forces. When axial forces due to seismic overturning moments are added, the columns may crush in a nonductile manner due to excessive axial compression.

The alternative calculation of overturning stresses due to seismic forces alone is intended to provide a means of screening out frames with high gravity loads, but are known to have small seismic overturning forces.

When both demands are large, the combined effect of gravity and seismic forces must be calculated to demonstrate compliance.

4.4.1.4.3 FLAT SLAB FRAMES: The lateral-force-resisting system shall not be a frame consisting of columns and a flat slab/plate without beams.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the slab-column system for resisting seismic forces and punching shear shall be evaluated using the m -factors in Table 4-4.

Commentary:

The concern is the transfer of the shear and bending forces between the slab and column, which could result in a punching shear failure and partial collapse. The flexibility of the lateral-force-resisting system will increase as the slab cracks.

Continuity of some bottom reinforcement through the column joint will assist in the transfer of forces and provide some resistance to collapse by catenary action in the event of a punching shear failure.

4.4.1.4.4 PRESTRESSED FRAME ELEMENTS: The lateral-load-resisting frames shall not include any prestressed or post-tensioned elements.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the concrete frame including prestressed elements shall be evaluated using the m -factors in Table 4.4.

Commentary:

Frame elements that are prestressed or post-tensioned may not behave in a ductile manner. The concern is the inelastic behavior of prestressed elements.

4.4.1.4.5 SHORT CAPTIVE COLUMNS: There shall be no columns at a level with height/depth ratios less than 50% of the nominal height/depth ratio of the typical columns at that level for Life Safety and 75% for Immediate Occupancy.

Tier 2 Evaluation Procedure: The adequacy of the columns for the shear force required to develop the moment capacity at the top and bottom of the clear height of the columns shall be evaluated. Alternatively, evaluate the columns as force controlled elements in accordance with the alternative equations in Section 4.2.4.3.2.

Commentary:

Short captive columns tend to attract seismic forces because of high stiffness relative to other columns in a story. Significant damage has been observed in parking structure columns adjacent to ramping slabs, even in structures with shear walls. Captive column behavior may also occur in buildings with clerestory windows, or in buildings with partial height masonry infill panels.

If not adequately detailed, the columns may suffer a non-ductile shear failure which may result in partial collapse of the structure.

A captive column that can develop the shear capacity to develop the flexural strength over the clear height will have some ductility to prevent sudden non-ductile failure of the vertical support system.

4.4.1.4.6 NO SHEAR FAILURES: The shear capacity of frame members shall be able to develop the moment capacity at the top and bottom of the columns.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The shear demands shall be calculated for non-compliant columns and the adequacy of the columns for shear shall be evaluated.

Commentary:

If the shear capacity of a column is reached before the moment capacity, there is a potential for a sudden non-ductile failure of the column, leading to collapse.

Columns that cannot develop the flexural capacity in shear should be checked for adequacy against calculated shear demands. Note that the shear capacity is affected by the axial loads on the column and should be based on the most critical combination of axial load and shear.

4.4.1.4.7 STRONG COLUMN/WEAK BEAM: The sum of the moment capacity of the columns shall be 20% greater than that of the beams at frame joints.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the columns to resist calculated demands shall be evaluated using an *m*-factor equal to 2.0. Alternatively, the story strength shall be calculated, and checked for the capacity to resist one half the total pseudo lateral force.

Commentary:

When columns are not strong enough to force hinging in the beams, column hinging can lead to story mechanisms and a concentration of inelastic activity at a single level. Excessive story drifts may result in an instability of the frame due to P- Δ effects. Good post-elastic behavior consists of yielding distributed throughout the frame. A story mechanism will limit forces in the levels above, preventing the upper levels from yielding. Joints at the roof level need not be considered.

If it can be demonstrated that non-compliant columns are strong enough to resist calculated demands with sufficient overstrength, acceptable behavior can be expected. Reduced *m*-factors are used to check the columns at near elastic levels.

The alternative procedure checks for the formation of a story mechanism. The story strength is the sum of the shear capacities of all the columns as limited by the controlling action. If the columns are shear critical, a shear mechanism forms at the shear capacity of the columns. If the columns are controlled by flexure, a flexural mechanism forms at a shear corresponding to the flexural capacity.

4.4.1.4.8 BEAM BARS: At least two longitudinal top and two longitudinal bottom bars shall extend continuously throughout the length of each frame beam. At least 25% of the longitudinal bars provided at the joints for either positive or negative moment, shall be continuous throughout the length of the members for Life Safety and Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The flexural demand at several sections along the length of the non-compliant beams shall be calculated, and the adequacy of the beams shall be evaluated using an *m*-factor equal to 1.0.

Commentary:

The requirement for two continuous bars is a collapse prevention measure. In the event of complete beam failure, continuous bars will prevent total collapse of the supported floor, holding the beam in place by catenary action.

Previous construction techniques used bent up longitudinal bars as reinforcement. These bars transitioned from bottom to top reinforcement at the gravity load inflection point. Some amount of continuous top and bottom reinforcement is desired because moments due to seismic forces can shift the location of the inflection point.

Because non-compliant beams are vulnerable to collapse, the beams are required to resist demands at an elastic level. Continuous slab reinforcement adjacent to the beam may be considered as continuous top reinforcement.

4.4.1.4.9 COLUMN-BAR SPLICES: All column bar lap splice lengths shall be greater than $35 d_b$ for Life Safety and $50 d_b$ for Immediate Occupancy, and shall be enclosed by ties spaced at or less than $8 d_b$ for Life Safety and Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The flexural demands at non-compliant column splices shall be calculated and the adequacy of the columns shall be evaluated using the *m*-factors in Table 4-4.

Commentary:

Located just above the floor level, column bar splices are typically located in regions of potential plastic hinge formation. Short splices are subject to sudden loss of bond. Widely spaced ties can result in a spalling of the concrete cover and loss of bond. Splice failures are sudden and non-ductile.

Columns with non-compliant lap splices are checked using reduced *m*-factors to account for this potential lack of ductility. If the members have sufficient capacity, the demands on the splices are less likely to exceed the capacity of the bond.

4.4.1.4.10 BEAM-BAR SPLICES: The lap splices for longitudinal beam reinforcing shall not be located within $l_b/4$ of the joints and shall not be located in the vicinity of potential plastic hinge locations.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The flexural demands in non-compliant beams shall be calculated and the adequacy of the beams shall be evaluated using the *m*-factors for non-ductile beams in Table 4-4.

Commentary:

Lap splices located at the end of beams and in vicinity of potential plastic hinges may not be able

to develop the full moment capacity of the beam as the concrete degrades during multiple cycles.

Beams with non-compliant lap splices are checked using reduced m -factors to account for this potential lack of ductility. If the members have sufficient capacity, the demands are less likely to cause degradation and loss of bond between concrete and the reinforcing steel.

4.4.1.4.11 COLUMN-TIE SPACING: Frame columns shall have ties spaced at or less than $d/4$ for Life Safety and Immediate Occupancy throughout their length and at or less than $8 d_b$ for Life Safety and Immediate Occupancy at all potential plastic hinge locations

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The flexural demand in non-compliant columns shall be calculated and the adequacy of the columns shall be evaluate using the m -factors in Table 4-4.

Commentary:

Widely spaced ties will reduce the ductility of the column, and it may not be able to maintain full moment capacity through several cycles. Columns with widely spaced ties have limited shear capacity and non-ductile shear failures may result.

Elements with non-compliant confinement are checked using reduced m -factors to account for this potential lack of ductility.

4.4.1.4.12 STIRRUP SPACING: All beams shall have stirrups spaced at or less than $d/2$ for Life Safety and Immediate Occupancy throughout their length. At potential plastic hinge locations stirrups shall be spaced at or less than the minimum of $8 d_b$ or $d/4$ for Life Safety and Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The flexural demand in non-compliant beams shall be calculated and the adequacy of the beams shall be evaluate using the m -factors in Table 4-4.

Commentary:

Widely spaced ties will reduce the ductility of the column, and it may not be able to maintain full moment capacity through several cycles. Columns with widely spaced ties have limited shear capacity and non-ductile shear failures may result.

Elements with non-compliant confinement are checked using reduced m -factors to account for this potential lack of ductility.

4.4.1.4.13 JOINT REINFORCING: Beam-column joints shall have ties spaced at or less than $8d_b$ for Life Safety and Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The joint shear demands shall be calculated and the adequacy of the joint to develop the adjoining members forces shall be evaluated.

Commentary:

Beam-column joints without shear reinforcement may not be able to develop the strength of the connected members, leading to a non-ductile failure of the joint. Perimeter columns are especially vulnerable because the confinement of joint is limited to three sides (along the exterior) or two sides (at a corner).

The shear capacity of the joint may be calculated as follows:

$$Q_{ci} = \lambda \gamma A_j (f'_c)^{1/2} \text{ psi, where } \gamma \text{ is:}$$

$$\rho' < 0.003 \quad \rho' \geq 0.003$$

Int. joints w/ transverse beams	12	20
Int. joints w/o transverse beams	10	15
Ext. joints w/ transverse beams	8	15
Ext. joints w/o transverse beams	6	12
Corner joints	4	8

$\lambda = 0.75$ for lightweight concrete

A_j = joint cross-sectional area

4.4.1.4.14 JOINT ECCENTRICITY: There shall be no eccentricities larger than 20% of the smallest column plan dimension between girder and column centerlines for Immediate Occupancy. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The joint shear demands including additional shear stresses from joint torsion shall be calculated and the adequacy of the beam-column joints shall be evaluated.

Commentary:

Joint eccentricities can result in high torsional demands on the joint area, which will result in higher shear stresses.

4.4.1.4.15 STIRRUP AND TIE HOOKS: The beam stirrups and column ties shall be anchored into the member cores with hooks of 135° or more. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The shear and axial demands in non-compliant members shall be calculated and the adequacy of the beams and columns shall be evaluated using the *m*-factors in Table 4-4.

Commentary:

To be fully effective, stirrups and ties must be anchored into the confined core of the member. 90° hooks that are anchored within the concrete cover are unreliable if the cover spalls during plastic hinging. The amount of shear resistance and confinement will be reduced if the stirrups and ties are not well anchored.

Elements with non-compliant confinement are checked using reduced *m*-factors to account for this potential lack of ductility.

4.4.1.5 Precast Concrete Moment Frames

4.4.1.5.1 PRECAST CONNECTION CHECK:

The precast connections at frame joints shall have the capacity to resist the shear and moment demands calculated using the QuickCheck Procedure of Section 3.5.3.5.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the precast connections shall be evaluated as force controlled elements using the procedures in Section 4.2.4.3.2.

Commentary:

Precast frame elements may have sufficient strength to meet lateral force requirements, but connections often cannot develop the strength of the members, and may be subject to premature non-ductile failures. Failure mechanisms may include fractures in the welded connections between inserts, pull out of embeds, and spalling of concrete.

Since full member capacities cannot be realized, the behavior of this system is entirely dependent on the performance of the connections.

4.4.1.5.2 PRECAST FRAMES: For buildings with concrete shear walls, lateral forces shall not be resisted by precast concrete frame elements.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the precast frame elements shall be evaluated as force controlled elements using the procedures in Section 4.2.4.3.2.

Commentary:

Precast frame elements may have sufficient strength to meet lateral force requirements, but connections often cannot develop the strength of the members, and may be subject to premature non-ductile failures. Failure mechanisms may include fractures in the welded connections between inserts, pull out of embeds, and spalling of concrete.

Since full member capacities cannot be realized, the behavior of this system is entirely dependent on the performance of the connections.

4.4.1.5.3 PRECAST CONNECTIONS: For buildings with concrete shear walls, the connection between precast frame elements such as chords, ties, and collectors in the lateral-force-resisting system shall develop the capacity of the connected members.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the connections for seismic forces shall be evaluated as force controlled elements using the procedures in Section 4.2.4.3.2.

Commentary:

Precast frame elements may have sufficient strength to meet lateral force requirements, but connections often cannot develop the strength of the members, and may be subject to premature non-ductile failures. Failure mechanisms may include fractures in the welded connections between

between inserts, pull out of embeds, and spalling of concrete.

Since full member capacities cannot be realized, the behavior of this system is entirely dependent on the performance of the connections.

4.4.1.6 Frames Not Part of the Lateral-Force-Resisting System

Commentary:

This section deals with secondary components consisting of frames that were not designed to be part of the lateral-force-resisting system. These are basic structural frames of steel or concrete that are designed for gravity loads only. Shear walls or other vertical elements provide the resistance to lateral forces. In actuality, however, all frames act as part of the lateral-force-resisting system. Lateral drifts of the building will induce forces in the beams and columns of the secondary frames. Furthermore, in the event that the primary elements fail, the secondary frames become the primary lateral force resisting components of the building.

If the walls are concrete (infilled in steel frames or monolithic in concrete frames), the building should be treated as a concrete shear wall building (Types C2 or C2A) with the frame columns as boundary elements. If the walls are masonry infills, the frames should be treated as steel or concrete frames with infill walls of masonry (Types S5, S5A, C3 or C3A). Research is continuing on the behavior of infill frames. Lateral forces are resisted by compression struts that develop in the masonry infill and induce forces on the frame elements eccentric to the joints.

The concern for secondary frames is the potential loss of vertical-load-carrying capacity due to excessive deformations and p-delta effects.

4.4.1.6.1 COMPLETE FRAMES: Steel or concrete frames classified as secondary components shall form a complete vertical load carrying system.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The gravity and seismic demands for the shear walls shall be calculated and the adequacy of the shear walls shall be evaluated.

Commentary:

If the frame does not form a complete vertical load carrying system, the walls will be required to provide vertical support as bearing walls. (see Figure 4-16). A frame is incomplete if there are no columns cast into the wall, there are no columns adjacent to the wall, and beams frame into the wall, supported solely by the wall.

During an earthquake, shear walls might become damaged by seismic forces, limiting their ability to support vertical loads. Loss of vertical support may lead to partial collapse.

Compliance can be demonstrated if the wall is judged adequate for combined vertical and seismic forces.

4.4.1.6.2 DEFLECTION COMPATIBILITY: Secondary components shall have the shear capacity to develop the flexural strength of the elements for Life Safety and shall have ductile detailing for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The flexural and shear demands at maximum interstory drifts for non-compliant elements shall be calculated and the adequacy of the elements shall be evaluated.

Commentary:

Frame components, especially columns, that are not specifically designed to participate in the lateral-force-resisting system will still undergo displacements associated with overall seismic interstory drifts. If the columns are located some distance away from the lateral-force-resisting elements, the added deflections due to semi-rigid floor diaphragms will increase the drifts. Stiff columns, designed for potentially high gravity loads, may develop significant bending moments due to the imposed drifts. The moment-axial force interaction may lead to a nonductile failure of the columns and a collapse of the building.

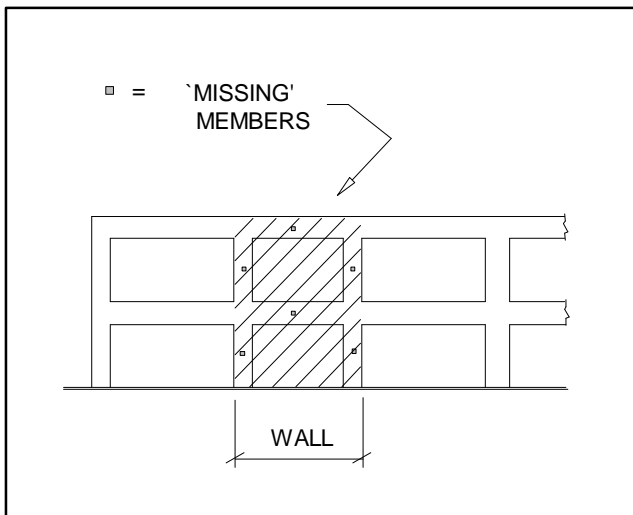


Figure 4-16. Incomplete Frame

4.4.1.6.3 FLAT SLABS: Flat slab/plates classified as secondary components shall have continuous bottom steel through the column joints for Life Safety. Flat slabs/plates shall not be permitted for the Immediate Occupancy Performance Level.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the joint for punching shear for all gravity and seismic demands, and shear transfer due to seismic moments, shall be evaluated.

Commentary:

Flat slabs not designed to participate in the lateral-force-resisting system may still experience seismic forces due to displacements associated with

overall building drift. The concern is the transfer of the shear and bending forces between the slab and column, which could result in a punching shear failure.

Continuity of some bottom reinforcement through the column joint will assist in the transfer of forces and provide some resistance to collapse by catenary action in the event of a punching shear failure (see Figure 4-17). Bars can be considered continuous if they have proper lap splices, mechanical couplers, or are developed beyond the support.

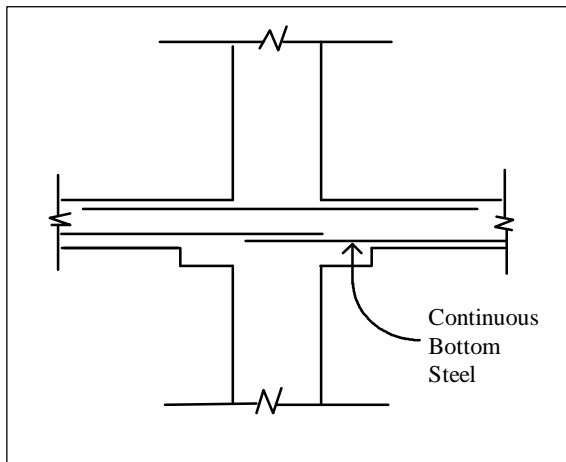


Figure 4-17. Continuous Bottom Steel

usually dominated by flexural behavior, and may require substantial boundary elements at each end.

It is a good idea to sketch a complete free-body diagram of the wall (as indicated in Figure 4-18) so that no forces are inadvertently neglected. An error often made in the design of wood shear walls is to treat the walls one story at a time, considering only the shear force in the wall and overlooking the accumulation of overturning forces from the stories above.

When the earthquake direction being considered is parallel to a shear wall, the wall develops in-plane shear and flexural forces as described above.

When the earthquake direction is perpendicular to a shear wall, the wall contributes little to the lateral force resistance of the building and the wall is subjected to out-of-plane forces tending to separate it from the rest of the structure. This section addresses the in-plane behavior of shear walls.

Out-of-plane strength and anchorage of shear walls to the structure is addressed in Section 4.5.

Solid shear walls usually have sufficient strength, though they may be lightly reinforced. Problems with shear wall systems arise when walls are not continuous to the foundation, or when numerous openings break the walls up into small piers with limited shear and flexural capacity.

4.4.2 Shear Walls

4.4.2.1 General

Commentary:

Shear walls, as the name implies, resist lateral forces primarily in shear. In the analysis of shear walls, it is customary to consider the shear taken by the length of the wall and the flexure taken by vertical reinforcement added at each end, much as flexure in diaphragms is designed to be taken by chords at the edges. Squat walls that are long compared to their height, are dominated by shearing behavior. Flexural forces require only a slight local reinforcement at each end. Slender walls that are tall compared to their length are

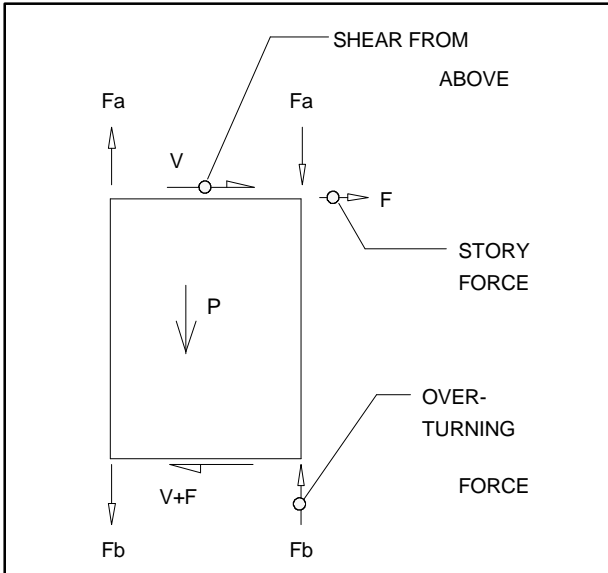


Figure 4-18. Wall Free-Body Diagram.

4.4.2.1.1 REDUNDANCY: The number of lines of shear walls in each direction shall be greater than or equal to 2 for Life Safety and for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with the procedures in Section 4.2 shall be performed. The adequacy of all walls and connections shall be evaluated.

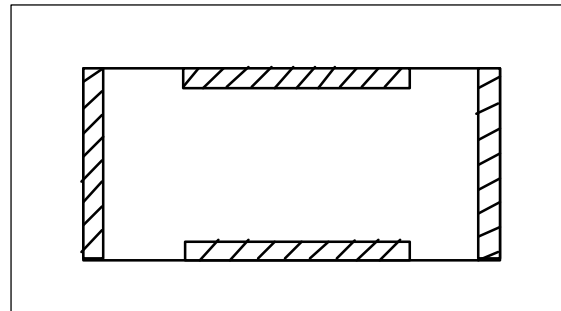
Commentary:

Redundancy is a fundamental characteristic of lateral force resisting systems with superior seismic performance. Redundancy in the structure will ensure that if an element in the lateral force resisting system fails for any reason, there is another element present that can provide lateral force resistance. Redundancy also provides multiple locations for potential yielding, distributing inelastic activity throughout the structure and improving ductility and energy absorption. Typical characteristics of redundancy include multiple lines of resistance to distribute the lateral forces uniformly throughout the structure, (see Figure 4-19) and multiple bays in each line of resistance to reduce the shear and axial demands on any one element.

A distinction should be made between redundancy and adequacy. For the purpose of this Handbook, redundancy is intended to mean simply "more than one". That is not to say that for large buildings two elements is adequate, or for small buildings one is not enough. Separate evaluation statements are present in the Handbook to determine the adequacy of the elements provided.

When redundancy is not present in the structure, an analysis which demonstrates the adequacy of the lateral force elements is required.

Figure 4-19. Redundancy in Shear Walls



4.4.2.2 Concrete Shear Walls

Commentary:

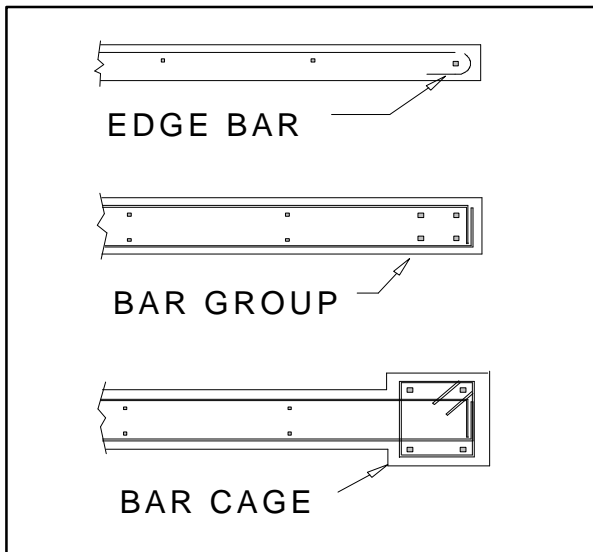
In highly redundant buildings with many long walls, stresses in concrete shear walls are usually low. In less redundant buildings with large openings and slender walls, the stresses can be high. In the ultimate state, when overturning forces are at their highest, a thin wall may fail in buckling along the compression edge, or it may fail in tension along the tension edge. Tension failures may consist of slippage in bar lap splices, or bar yield and fracture if adequate lap splices have been provided.

In the past, designs have been based on liberal assumptions about compression capacity, and have simply packed vertical rebar into the ends of the walls to resist the tensile forces. Recent codes, recognizing the importance of boundary members,

have special requirements for proportions, bar splices, and transverse reinforcement. Examples of boundary members with varying amounts of reinforcing are shown in Figure 4-20. Existing buildings often do not have these elements, and the acceptance criteria are designed to allow for this.

Another development in recent codes is the requirement to provide shear strength compatible with the flexural capacity of the wall to ensure ductile flexural yielding prior to brittle shear failure. Long continuous walls and walls with embedded steel or large boundary elements can have high flexural capacities with the potential to induce correspondingly high shear demands that are over and above the minimum design shear demands.

Figure 4-20. Boundary Elements.



4.4.2.2.1 SHEAR STRESS CHECK: The shear stress in the concrete shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 100 psi or $2\sqrt{f'_c}$ for Life Safety and Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the concrete shear wall elements shall be evaluated using the *m*-factors in Table 4-4.

Commentary:

The shear stress check provides a quick assessment of the overall level of demand on the structure. The concern is the overall strength of the building.

4.4.2.2.2 REINFORCING STEEL: The ratio of reinforcing steel area to gross concrete area shall be greater than 0.0015 in the vertical direction and 0.0025 in the horizontal direction for Life Safety and Immediate Occupancy. The spacing of reinforcing steel shall be equal to or less than 18" for Life Safety and for Immediate Occupancy

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the concrete shear wall elements shall be evaluated using the *m*-factors in Table 4-4.

Commentary:

If the walls do not have sufficient reinforcing steel, they will have limited capacity in resisting seismic forces. The wall will also behave in a nonductile manner for inelastic forces.

4.4.2.2.3 COUPLING BEAMS: The stirrups in all coupling beams over means of egress shall be spaced at or less than $d/2$ and shall be anchored into the core with hooks of 135° or more for Life Safety and Immediate Occupancy. In addition, the beams shall have the capacity in shear to develop the uplift capacity of the adjacent wall for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The shear and flexural demands on non-compliant coupling beams shall be calculated and the adequacy of the coupling beams shall be evaluated. If the coupling beams are inadequate, the adequacy of the coupled walls shall be evaluated as if they were independent.

Commentary:

Coupling beams with sufficient strength and stiffness can increase the lateral stiffness of the system significantly beyond the stiffnesses of the independent walls. When the walls deflect laterally, large moments and shears are induced in the coupling beams as they resist the imposed deformations. Coupling beams also link the coupled walls for overturning resistance (see Figure 4-21).

Coupling beam reinforcement is often inadequate for the demands that can be induced by the movement of the coupled walls. Seismic forces may damage and degrade the beams so severely that the system degenerates into a pair of independent walls. This changes the distribution of overturning forces which may result in potential stability problems for the independent walls. The boundary reinforcement may also be inadequate for flexural demands if the walls act independently.

If the beams are lightly reinforced, their degradation could result in falling debris that is a potential life-safety hazard, especially at locations of egress.

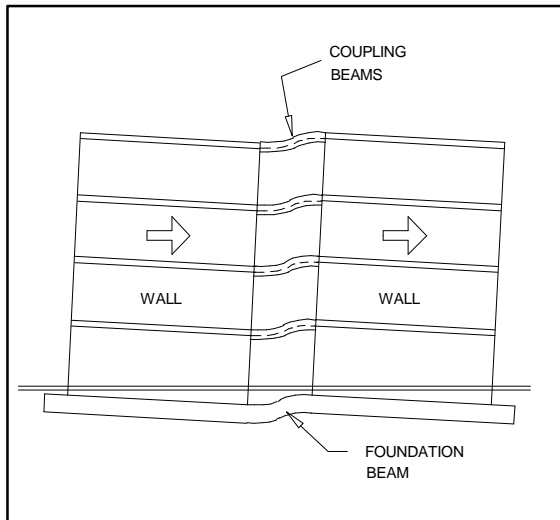


Figure 4-21. Coupled Walls.

4.4.2.2.4 OVERTURNING: All shear walls shall have aspect ratios less than 4 to 1. Wall piers need not be considered. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The overturning demands for non-compliant walls shall be calculated and the adequacy of the shear walls shall be evaluated.

Commentary:

Tall, slender shear walls may have limited overturning resistance. Displacements at the top of the building will be greater than anticipated if overturning forces are not properly resisted.

Often sufficient resistance can be found in immediately adjacent bays, if a load path is present to activate the adjacent column dead loads.

4.4.2.2.5 CONFINEMENT REINFORCING: For shear walls with aspect ratios greater than 2.0, the boundary elements shall be confined with spirals or ties with spacing less than $8 d_v$. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The shear and flexural demands on the non-compliant walls shall be calculated and the adequacy of the shear walls shall be evaluated.

Commentary:

Fully effective shear walls require boundary elements to be properly confined with closely spaced ties (see Figure 4-20). Degradation of the concrete in the vicinity of the boundary elements can result in buckling of rebar in compression and failure of lap splices in tension. Non-ductile failure of the boundary elements will lead to reduced capacity to resist overturning forces.

4.4.2.2.6 REINFORCING AT OPENINGS: There shall be added trim reinforcement around all

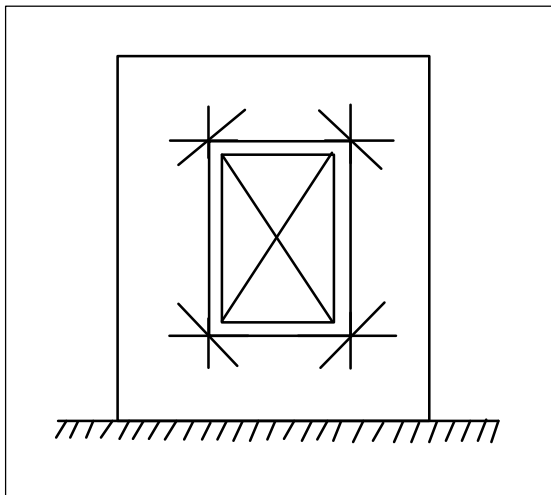
openings. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The flexural and shear demands around the openings shall be calculated and the adequacy of the piers and spandrels shall be evaluated.

Figure 4-22. Conventional Trim Steel

Commentary:

Conventional trim steel is adequate only for small openings (see Figure 4-22). Large openings will cause significant shear and flexural stresses in the adjacent piers and spandrels. Inadequate reinforcing steel around these openings will lead to strength deficiencies, nonductile performance and degradation of the wall.



4.4.2.2.7 WALL THICKNESS: Thickness of bearing walls shall not be less than 1/25 the minimum unsupported height or length, nor less than 4". This statement shall apply to the Immediate Occupancy Performance Level only

Tier 2 Evaluation Procedure: The adequacy of the walls to resist out-of-plane forces in combination with vertical loads shall be evaluated.

Commentary:

Slender bearing walls may have limited capacity for vertical loads and higher potential for damage due to out-of-plane forces and magnified moments. Note that this condition is not considered a life-safety concern and need only be examined for the Immediate Occupancy performance level.

4.4.2.2.8 WALL CONNECTIONS: There shall be a positive connection between the shear walls and the steel beams and columns for Life Safety, and the connection shall be able to develop the strength of the walls for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The shear and flexural demands on the shear walls shall be calculated and the adequacy of the connection to transfer shear between the walls and the steel frame shall be evaluated.

Commentary:

Insufficient shear transfer between the steel and concrete elements will limit the ability of the steel to contribute to the performance of the shear walls. The connections to the column are especially important as the columns will develop a portion of the shear wall overturning moment. The connections should include welded studs, welded reinforcing steel, or fully encased steel elements with longitudinal reinforcing and ties.

Shear friction between the concrete and steel should only be used when the steel is completely encased in the concrete.

4.4.2.2.9 COLUMN SPLICES: Steel columns encased in shear wall boundary elements shall have splices that develop the tensile strength of the column. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The tension demands due to overturning forces on non-compliant columns shall be calculated and the adequacy of the splice connections shall be evaluated.

Commentary:

Columns encased in shear wall boundary elements may be subjected to high tensile forces due to shear wall overturning moments. If the splice cannot develop the strength of the column, the ability of the column to contribute to overturning resistance will be limited.

The presence of axial loads may reduce the net tensile demand on the boundary element columns to a level below the capacity of the splice.

4.4.2.3 Precast Concrete Shear Walls

Commentary:

Precast concrete shear walls are constructed in segments that are usually interconnected by embedded steel elements. These connections usually possess little ductility, but are important to the overall behavior of the wall assembly. Interconnection between panels increases the overturning capacity by transferring overturning demands to end panels. Panel connections at the diaphragm are often used to provide continuous diaphragm chords. Failure of these connections will reduce the capacity of the system.

4.4.2.3.1 SHEAR STRESS CHECK: The shear stress in the precast panels, calculated using the Quick Check Procedure of Section 3.5.3.3, shall be less than 100 psi or $2\sqrt{f'_c}$ for Life Safety and Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the concrete shear wall elements shall be evaluated using the *m*-factors in Table 4-4.

Commentary:

The shear stress check provides a quick assessment of the overall level of demand on the structure. The concern is the overall strength of the building.

4.4.2.3.2 REINFORCING STEEL: The ratio of reinforcing steel area to gross concrete area shall be greater than 0.0015 in the vertical direction and 0.0025 in the horizontal direction for Life Safety and Immediate Occupancy. The spacing of reinforcing steel shall be equal to or less than 18" for Life Safety and Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the concrete shear wall elements shall be evaluated using the *m*-factors in Table 4-4.

Commentary:

If the walls do not have sufficient reinforcing steel, they will have limited capacity in resisting seismic forces. The wall will also behave in a nonductile manner for inelastic forces.

4.4.2.3.3 WALL OPENINGS: Openings shall constitute less than 75% of the length of any perimeter wall for Life Safety and 50% for Immediate Occupancy with the wall piers having aspect ratios of less than 2.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the remaining wall shall be evaluated for shear and overturning resistance, and the adequacy of the shear transfer connection between the diaphragm and the wall shall be evaluated. The adequacy of the connection between any collector elements and the wall shall also be evaluated.

Commentary:

In tilt-up construction, typical wall panels are often of sufficient length that special detailing for collector elements, shear transfer, and overturning resistance is not provided. Perimeter walls that are substantially open, such as at loading docks, have limited wall length to resist seismic forces, and may be subject to overturning or shear transfer problems that were not accounted for in the original design.

Walls will be compliant if an adequate load path for shear transfer, collector forces and overturning resistance can be demonstrated.

4.4.2.3.4 CORNER OPENINGS: Walls with openings at a building corner larger than the width of a typical panel shall be connected to the remainder of the wall with collector reinforcing.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the diaphragm to transfer shear and spandrel panel forces to the remainder of the wall beyond the opening shall be evaluated.

Commentary:

Open corners often are designed as entrances with the typical wall panel replaced by a spandrel panel and a glass curtain wall. Seismic forces in these elements are resisted by adjacent panels and, therefore, must be delivered through collectors.

If the spandrel and other wall elements are adequately tied to the diaphragm, panel forces can be transferred back to adjacent wall panels through collector elements in the diaphragm.

4.4.2.3.5 PANEL-TO-PANEL CONNECTIONS: Adjacent wall panels shall be interconnected to transfer overturning forces between panels by methods other than steel welded inserts. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The overturning demands shall be calculated and the adequacy of the welded inserts to transfer overturning forces shall be evaluated as force controlled elements in accordance with Section 4.2.4.3.2.

Commentary:

Welded steel inserts can be brittle and may not be able to transfer the overturning forces between panels. Latent stresses may be present due to shrinkage and temperature effects. Brittle failure may include weld fracture, pull-out of the embedded anchors, or spalling of the concrete.

Failure of these connections will result in separation of the wall panels, and a reduction in overturning resistance.

4.4.2.3.6 WALL THICKNESS: Thickness of bearing walls shall not be less than 1/25 the minimum unsupported height or length, nor less than 4". This statement shall apply to the Immediate Occupancy Performance Level only

Tier 2 Evaluation Procedure: The adequacy of the walls to resist out-of-plane forces shall be evaluated.

Commentary:

Slender bearing walls may have limited capacity for vertical loads and higher potential for damage due to out-of-plane forces and magnified moments. Note that this condition is not considered a life-safety concern and only needs to be examined for the Immediate Occupancy performance level.

4.4.2.4 Reinforced Masonry Shear Walls

4.4.2.4.1 SHEAR STRESS CHECK: The shear stress in the reinforced masonry shear walls, calculated using the Quick Check Procedure of Section 3.5.3.3, shall be less than 50 psi for Life Safety and Immediate Occupancy

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the reinforced masonry shear wall elements shall be evaluated using the *m*-factors in Table 4-5.

Commentary:

The shear stress check provides a quick assessment of the overall level of demand on the structure. The concern is the overall strength of the building.

4.4.2.4.2 REINFORCING STEEL: The total vertical and horizontal reinforcing steel ratio in reinforced masonry walls shall be greater than 0.002 for Life Safety and 0.003 for Immediate Occupancy with the minimum of 0.0007 for Life Safety and 0.001 for Immediate Occupancy in either of the two directions; the spacing of reinforcing steel shall be less than 48" for Life Safety and 24" for Immediate Occupancy, and all vertical bars shall extend to the top of the walls.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the reinforced masonry shear wall elements shall be evaluated using the *m*-factors in Table 4-5.

Commentary:

If the walls do not have sufficient reinforcing steel, they will have limited capacity in resisting seismic forces. The wall will also behave in a nonductile manner for inelastic forces.

4.4.2.4.3 REINFORCING AT OPENINGS: All wall openings that interrupt rebar shall have trim reinforcing on all sides. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The flexural and shear demands around the openings shall be calculated and the adequacy of the walls shall be evaluated using only the length of the piers between reinforcing steel.

Commentary:

Conventional trim steel is adequate only for small openings. Large openings will cause significant shearing and flexural stresses in the adjacent piers and spandrels. Inadequate reinforcing steel around these openings will lead to strength deficiencies, non-ductile performance and degradation of the wall.

4.4.2.4.4 PROPORTIONS: The height-to-thickness ratio of the shear walls at each story shall be less than 30. This statement shall apply to the Immediate Occupancy Performance Level only

Tier 2 Evaluation Procedure: The adequacy of the walls to resist out-of-plane forces in combination with vertical loads shall be evaluated.

Commentary:

Slender bearing walls may have limited capacity for vertical loads and higher potential for damage due to out-of-plane forces and magnified moments. Note that this condition is not considered a life-safety concern and need only be examined for the Immediate Occupancy performance level.

4.4.2.5 Unreinforced Masonry Shear Walls

4.4.2.5.1 SHEAR STRESS CHECK: The shear stress in the unreinforced masonry shear walls, calculated using the Quick Check Procedure of Section 3.5.3.3, shall be less than 15 psi for clay units and 30 psi for concrete units for Life Safety and Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the unreinforced masonry shear wall elements shall be evaluated using the *m*-factors in Table 4-5.

Commentary:

The shear stress check provides a quick assessment of the overall level of demand on the structure. The concern is the overall strength of the building.

4.4.2.5.2 PROPORTIONS: The height-to-thickness ratio of the shear walls at each story shall be less than the following for Life Safety and for Immediate Occupancy:

Top story of multi-story building:	9
First story of multi-story building:	15
All other conditions:	13

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unreinforced masonry shear wall proportions in non-compliance. A Tier 3 evaluation is necessary to achieve the selected performance level.

Commentary:

Slender unreinforced masonry bearing walls with large height-to-thickness ratios have a potential for damage due to out-of-plane forces which may result in falling hazards and potential collapse of the structure.

4.4.2.5.3 MASONRY LAY-UP: Filled collar joints of multiwythe masonry walls shall have negligible voids.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unreinforced masonry shear wall proportions in non-compliance. A Tier 3 evaluation is necessary to achieve the selected performance level.

Commentary:

When walls have poor collar joints, the inner and outer wythes will act independently. The walls may be inadequate to resist out-of-plane forces due to a lack of composite action between the inner and outer wythes.

Mitigation to provide out-of-plane stability and anchorage of the wythes may be necessary to achieve the selected performance level.

4.4.2.6 Infill Walls in Frames

4.4.2.6.1 WALL CONNECTIONS: All infill walls shall have a positive connection to the frame to resist out-of-plane forces for Life Safety, and the connection shall be able to develop the out-of-plane strength of the wall for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The out-of-plane demands on the wall shall be calculated and the adequacy of the connection to the frame shall be evaluated.

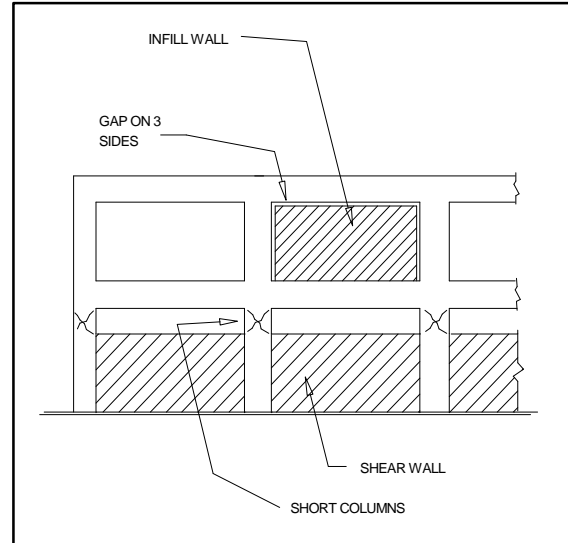


Figure 4-23. Infill Wall

4.4.2.6.2 PROPORTIONS: The height-to-thickness ratio of the infill walls at each story shall be less than 9 for Life Safety in regions of high seismicity, 13 for Immediate Occupancy in regions of moderate seismicity, and 8 for Immediate Occupancy in regions of high seismicity.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unreinforced masonry shear wall proportions in non-compliance. A Tier 3 evaluation is necessary to demonstrate compliance with the selected performance level.

Commentary:

Performance of frame buildings with masonry infill walls is dependent upon the interaction between the frame and infill panels. In-plane lateral force resistance is provided by a compression strut developing in the infill panel that extends diagonally between corners of the frame. If gaps exist between the frame and infill, this strut cannot be developed (see Figure 4-23). If the infill panels separate from the frame due to out-of-plane forces, the strength and stiffness of the system will be determined by the properties of the bare frame, which may not be detailed to resist seismic forces. Severe damage or partial collapse due to excessive drift and p-delta effects may occur.

A positive connection is needed to anchor the infill panel for out-of-plane forces. In this case, a positive connection can consist of a fully grouted bed joint in full contact with the frame, or complete encasement of the frame by the brick masonry. The mechanism for out-of-plane resistance of infill panels is discussed in the commentary to Section 4.4.2.6.2.

If the connection is non-existent, mitigation with adequate connection to the frame is necessary to achieve the selected performance level.

Commentary:

Slender masonry infill walls with large height-to-thickness ratios have a potential for damage due to out-of-plane forces. Failure of these walls out-of-plane will result in falling hazards and degradation of the strength and stiffness of the lateral force resisting system.

The out-of-plane stability of infill walls is dependent on many factors including flexural strength of the wall and confinement provided by the surrounding frame. If the infill is unreinforced, the flexural strength is limited by the flexural tension capacity of the material. The surrounding frame will provide confinement, induce infill thrust forces and develop arching action against

out-of-plane forces. The height-to-thickness limits in the evaluation statement are based on arching action models that will exceed any plausible acceleration levels in various seismic zones.

Further investigation of non-compliant infill panels requires a Tier 3 level analysis.

4.4.2.6.3 SOLID WALLS: The infill walls shall not be of cavity construction.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for infill walls in non-compliance.

Commentary:

When the infill walls are of cavity construction, the inner and outer wythes will act independently. due to a lack of composite action, increasing the potential for damage from out-of-plane forces. Failure of these walls out-of-plane will result in falling hazards and degradation of the strength and stiffness of the lateral force resisting system.

Mitigation to provide out-of-plane stability and anchorage of the wythes is necessary to achieve the selected performance level.

4.4.2.6.4 INFILL WALLS: The infill walls shall be continuous to the soffits of the frame beams.

Tier 2 Evaluation Procedure: The adequacy of the columns adjacent to non-conforming infill walls shall be evaluated for the shear force required to develop the flexural capacity of the column over the clear height above the infill.

Commentary:

Discontinuous infill walls occur when full bay windows or ventilation openings are provided between the top of the infill and bottom soffit of the frame beams. The portion of the column above the

infill is a short captive column which may attract large shear forces due to increased stiffness relative to other columns (see Figure 4-24). Partial infill walls will also develop compression struts with horizontal components that are highly eccentric to the beam column joints. If not adequately detailed, concrete columns may suffer a non-ductile shear failure which may result in partial collapse of the structure. Because steel columns are not subject to the same kind of brittle failure, this is not generally considered a concern in steel frame infill buildings.

A column that can develop the shear capacity to develop the flexural strength over the clear height above the infill will have some ductility to prevent sudden catastrophic failure of the vertical support system.

4.4.2.7 Walls in Wood-Frame Buildings

4.4.2.7.1 SHEAR STRESS CHECK: The shear stress in the shear walls, calculated using the Quick Check Procedure of 3.5.3.3, shall be less than the following values for Life Safety and Immediate Occupancy:

Structural panel sheathing:	1000 plf
Diagonal sheathing:	700 plf
Straight sheathing:	80 plf
All other conditions:	100 plf

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the wood shear wall elements shall be evaluated using the *m*-factors in Table 4-6.

Commentary:

The shear stress check provides a quick assessment of the overall level of demand on the structure. The concern is the overall strength of the building.

4.4.2.7.2 STUCCO (EXTERIOR PLASTER)

SHEAR WALLS: Multistory buildings shall not rely on exterior stucco walls as the primary lateral-force-resisting system.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The overturning and shear demands for non-compliant walls shall be calculated and the adequacy of the stucco shear walls shall be evaluated using the *m*-factors in Table 4-6.

Commentary:

Exterior stucco walls are often used (intentionally and unintentionally) for resisting seismic forces. Stucco is relatively stiff, but brittle, and the shear capacity is limited. Building movements due to differential settlement, temperature changes and earthquake or wind forces can cause cracking in the stucco and loss of lateral strength. Lateral force resistance is unreliable because sometimes the stucco will delaminate from the framing and the system is lost. Multistory buildings should not rely on stucco walls as the primary lateral-force-resisting system.

4.4.2.7.3 GYPSUM WALLBOARD OR PLASTER SHEAR WALLS: Interior plaster or gypsum wallboard shall not be used as shear walls on buildings over one story in height.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The overturning and shear demands for non-compliant walls shall be calculated and the adequacy of the gypsum wallboard or plaster shear walls shall be evaluated using the *m*-factors in Table 4-6.

Commentary:

Gypsum wallboard or gypsum plaster sheathing tends to be easily damaged by differential foundation movement or earthquake shaking.

Though the capacity of these walls is low, most residential buildings have numerous walls constructed with plaster or gypsum wallboard. As a result, plaster and gypsum wallboard walls may provide adequate resistance to moderate earthquake shaking.

One problem that can occur is incompatibility with other lateral-forcing-resisting elements. For example, narrow plywood shear walls are more flexible than long stiff plaster walls; as a result, the plaster or gypsum walls will take all the load until they fail and then the plywood walls will start to resist the lateral loads. In multistory buildings, plaster or gypsum wallboard walls should not be used for shear walls except in the top story.

4.4.2.7.4 NARROW WOOD SHEAR WALLS: Narrow wood shear walls with an aspect ratio greater than 2 to 1 for Life Safety and 1.5 to 1 for Immediate Occupancy shall not be used to resist lateral forces developed in the building.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The overturning and shear demands for non-compliant walls shall be calculated and the adequacy of the narrow shear walls shall be evaluated using the *m*-factors in Table 4-6.

Commentary:

Narrow shear walls are highly stressed and subject to severe deformations that will damage the capacity of the walls. Most of the damage occurs at the base, and consists of sliding of the sill plate and deformation of hold-down anchors when present. As the deformation continues, the plywood pulls up on the sill plate causing splitting. Splitting of the end studs at the bolted attachment of hold down anchors is also common.

4.4.2.7.5 WALLS CONNECTED THROUGH FLOORS: Shear walls shall have interconnection between stories to transfer overturning and shear forces through the floor.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for walls in non-compliance.

Commentary:

In platform construction, wall framing is discontinuous at floor levels. The concern is that this discontinuity will prevent shear and overturning forces from being transferred between shear walls in adjacent stories.

Mitigation with elements or connections needed to complete the load path is necessary to achieve the selected performance level.

4.4.2.7.6 HILLSIDE SITE: For a sloping site greater than one-half story, all shear walls on the downhill slope shall have an aspect ratio less than 1 to 1 for Life Safety and 1 to 2 for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The shear and overturning demands on the downhill slope walls shall be calculated including the torsional effects of the hillside. The adequacy of the shear walls on the downhill slope shall be evaluated.

Commentary:

Buildings on a sloping site will experience significant torsion during an earthquake. Taller walls on the downhill slope are more flexible than the supports on the uphill slope. Therefore, significant displacement and racking of the shear walls on the downhill slope will occur. If the walls are narrow, significant damage or collapse may occur.

4.4.2.7.7 CRIPPLE WALLS: All cripple walls below first floor level shear walls shall be braced to the foundation with shear elements.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for cripple walls in non-compliance.

Commentary:

Cripple walls are short stud walls that enclose a crawl space between the first floor and the ground. Often there are no other walls at this level, and these walls have no stiffening elements other than architectural finishes. If this sheathing fails, the building will experience significant damage and, in the extreme case, may fall off its foundation. To be effective, all exterior cripple walls below the first floor level should have adequate shear strength, stiffness, and proper connection to the floor and foundation. Cripple walls that change height along their length, such as along sloping walls on hillside sites, will not have a uniform distribution of shear along the length of the wall, due to the varying stiffness. These walls may be subject to additional damage on the uphill side due to concentration of shear demand.

Mitigation with shear elements needed to complete the load path is necessary to achieve the selected performance level.

4.4.2.7.8 OPENINGS: Walls with garage doors or other large openings shall be braced with plywood shear walls or shall be supported by adjacent construction through substantial positive ties. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The overturning and shear demands on non-compliant walls shall be calculated and the adequacy of the shear walls shall be evaluated using the *m*-factors in Table 4-6

Commentary:

Walls with large openings may have little or no resistance to shear and overturning forces. They must be specially detailed to resist these forces, or braced to other parts of the structure with collectors. Special detailing and collectors are not part of conventional construction procedures. Lack of this bracing can lead to collapse of the wall.

4.4.2.7.9 HOLD-DOWN ANCHORS: All walls shall have properly constructed hold-down anchors. This statement shall apply to the Immediate Occupancy Performance Level only

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The overturning and shear demands for non-compliant walls shall be calculated and the adequacy of the shear walls shall be evaluated using the *m*-factors in Table 4-6.

Commentary:

Buildings without hold-down anchors may be subject to significant damage due to uplift and racking of the shear walls. Note that this condition is not considered a life-safety concern and only needs to be examined for the Immediate Occupancy performance level.

4.4.3 Braced Frames

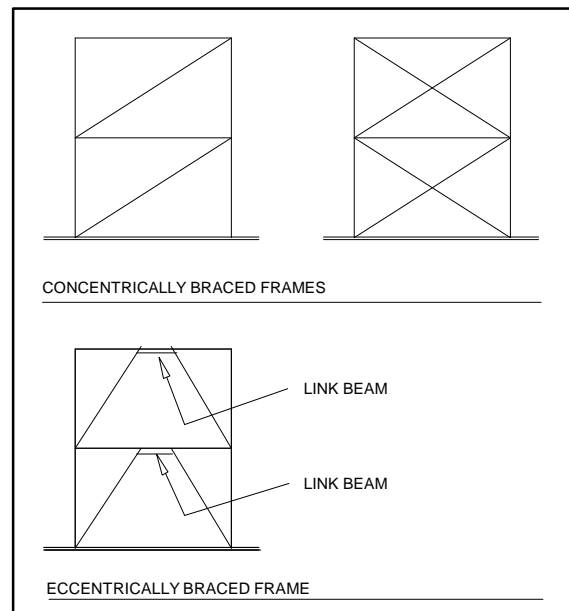
Commentary:

Braced frames develop their lateral force resistance through axial forces developed in the diagonal bracing members. The braces induce forces in the associated beams and columns, and all are subjected to stresses that are primarily axial. When the braces are eccentric to beam/column joints, members are subjected to shear and flexure in

addition to axial forces. A portal frame with knee braces near the frame joints is one example.

Braced frames are classified as either concentrically braced frames or eccentrically braced frames (see Figure 4-24). Concentrically braced frames have braces that frame into beam/column joints or concentric connections with other braces. Minor connection eccentricities may be present and are accounted for in the design. Eccentrically braced frames have braces that are purposely located away from joints, and connections that are intended to induce shear and flexure demands on the members. The eccentricity is intended to force a concentration of inelastic activity at a predetermined location that will control the behavior of the system. Modern eccentrically braced frames are designed with strict controls on member proportions and special out-of-plane bracing at the connections to ensure the frame behaves as intended.

Figure 4-24. Braced Frames



4.4.3.1 General

4.4.3.1.1 REDUNDANCY: The number of lines of braced frames in each principal direction shall be greater than or equal to 2 for Life Safety and Immediate Occupancy. The number of braced bays in each line shall be greater than 2 for Life Safety and 3 for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with the procedures in Section 4.2 shall be performed. The adequacy of all elements and connections in the braced frames shall be evaluated.

Commentary:

Redundancy is a fundamental characteristic of lateral force resisting systems with superior seismic performance. Redundancy in the structure will ensure that if an element in the lateral force resisting system fails for any reason, there is another element present that can provide lateral force resistance. Redundancy also provides multiple locations for potential yielding, distributing inelastic activity throughout the structure and improving ductility and energy absorption. Typical characteristics of redundancy include multiple lines of resistance to distribute the lateral forces uniformly throughout the structure, and multiple bays in each line of resistance to reduce the shear and axial demands on any one element.

A distinction should be made between redundancy and adequacy. For the purpose of this Handbook, redundancy is intended to mean simply "more than one". That is not to say that for large buildings two elements is adequate, or for small buildings one is not enough. Separate evaluation statements are present in the Handbook to determine the adequacy of the elements provided.

When redundancy is not present in the structure, an analysis which demonstrates the adequacy of the lateral force elements is required.

4.4.3.1.2 AXIAL STRESS CHECK: The axial stress in the diagonals, calculated using the Quick

Check Procedure of Section 3.5.3.4, shall be less than 18 ksi or $0.50F_y$ for Life Safety and Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the braced frame elements shall be evaluated using the m -factors in Table 4-3.

4.4.3.1.3 STIFFNESS OF DIAGONALS: All

Commentary:

The axial stress check provides a quick assessment of the overall level of demand on the structure. The concern is the overall strength of the building.

diagonal elements required to carry compression shall have Kl/r ratios less than 120. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The compression demands in non-compliant braces shall be calculated and the adequacy of the braces shall be evaluated for buckling.

Commentary:

Code design requirements have allowed compression diagonal braces to have Kl/r ratios of up to 200. Cyclic test have demonstrated that elements with high Kl/r ratios are subjected to large buckling deformations resulting in brace or connection fractures. They cannot be expected to provide adequate performance. Limited energy dissipation and premature buckling can significantly reduce strength, increase the building displacements and jeopardize the performance of the framing system.

4.4.3.1.4 CONNECTION STRENGTH: All the brace connections shall develop the yield capacity of the diagonals. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The demands on the non-compliant connections shall be calculated and the adequacy of the brace connections shall be evaluated.

4.4.3.1.5 COLUMN SPLICES: All column splice details located in braced frames shall develop the tensile strength of the column. This statement shall

Commentary:

Since connection failures are usually nonductile in nature, it is more desirable to have inelastic behavior in the members.

apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The tension demands on non-compliant columns shall be calculated and the adequacy of the splice connections shall be evaluated.

Commentary:

Columns in braced frames may be subject to large tensile forces. A connection that is unable to resist this tension may limit the ability of the frame to resist lateral forces. Columns may uplift and slide off bearing supports, resulting in a loss of vertical support and partial collapse.

4.4.3.1.6 OUT-OF-PLANE BRACING: Braced frame connections attached to beam bottom flanges located away from beam-column joints shall be braced out-of-plane at the bottom flange of the beams. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The demands shall be calculated and the adequacy of the beam shall be evaluated considering a horizontal out-of-plane force equal to 2% of the brace compression force acting concurrently at the bottom flange of the beam.

Commentary:

Brace connections at beam bottom flanges that do not have proper bracing may have limited ability to resist seismic forces. Out-of-plane buckling may occur before the strength of the brace is developed. Connections to beam top flanges are braced by the diaphragm, so V-bracing need not be considered.

This statement is intended to target chevron type bracing, where braces intersect the beam from below at a location well away from a column. Here only the beam can provide out-of-plane stability for the connection. At beam/column joints, the continuity of the column will provide stability for the connection.

To demonstrate compliance, the beam is checked for the strength required to provide out-of-plane stability using the 2% rule.

4.4.3.2 Concentrically Braced Frames

Commentary:

Common types of concentrically braced frames are shown in Figure 4-25.

Braces can consist of light tension-only rod bracing, double angles, pipes, tubes or heavy wide-flange sections.

Concrete braced frames are rare and are not permitted in some jurisdictions because it is difficult to detail the joints with the kind of reinforcing that is required for ductile behavior.

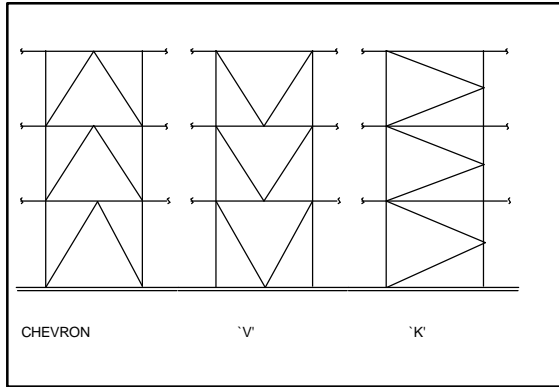


Figure 4-25. Bracing Types

4.4.3.2.1 K-BRACING: The bracing system shall not include K-braced bays.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the columns shall be evaluated for all demands including concurrent application of the unbalanced force that can be applied to the column by the braces. The unbalanced force shall be taken as the horizontal component of the tensile capacity of one brace, assuming the other brace has buckled in compression. The *m*-factors in Table 4-3 shall be used.

Commentary:

In K-brace configurations, diagonal braces intersect the column between floor levels (see Figure 4-25). When the compression brace buckles, the column will be loaded with the horizontal component of the adjacent tension brace. This will induce large midheight demands that can jeopardize the stability of the column and vertical support of the building.

In most cases, columns have not been designed to resist this force. The risk to the vertical support system makes this an undesirable bracing configuration.

4.4.3.2.2 TENSION-ONLY BRACES:

Tension-only braces shall not comprise more than 70% of the total lateral-force-resisting capacity in structures over two stories in height. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the tension-only braces shall be evaluated using the *m*-factors in Table 4-3.

Commentary:

Tension-only brace systems may allow the brace to deform with large velocities during cyclic response after tension yielding cycles have occurred. Limited energy dissipation and premature fracture can significantly reduce the strength, increase the building displacements and jeopardize the performance of the framing system.

4.4.3.2.3 CHEVRON BRACING: The bracing system shall not include chevron-, or V-braced bays. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the beams shall be evaluated for all demands including concurrent application of the unbalanced force that can be applied to the beams by the braces. The unbalanced force shall be taken as the vertical component of the tensile capacity of one brace, assuming the other brace has buckled in compression. The *m*-factors in Table 4-3 shall be used.

Commentary:

In chevron and V-brace configurations, diagonal braces intersect the beam between columns (see Figure 4-25). When the compression brace buckles, the beam will be loaded with the vertical component of the adjacent tension brace. This will induce large midspan demands on the beam that can jeopardize the support of the floor.

In most cases, beams have not been designed to resist this force. The risk to the vertical support system makes chevron and V-bracing undesirable bracing configurations.

4.4.3.2.4 CONCENTRIC JOINTS: All the diagonal braces shall frame into the beam-column joints concentrically. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The axial, flexural, and shear demands including the demands due to eccentricity of the braces shall be calculated. The adequacy of the joints shall be evaluated.

Commentary:

Frames that have been designed as concentrically braced frames may have local eccentricities within the joint. A local eccentricity is where the lines of action of the bracing members do not intersect the centerline of the connecting members. These eccentricities induce additional flexural and shear stresses in the members that may not have been accounted for in the design. Excessive eccentricity can cause premature yielding of the connecting members or failures in the connections, thereby reducing the strength of the frames.

4.4.3.3 Eccentrically Braced Frames

No evaluation statements or Tier 2 procedures have been provided specifically for eccentrically braced frames. Eccentrically braced frames shall be checked for the general braced frame evaluation statements and Tier 2 procedures in Section 4.4.3.1.

Commentary:

Eccentrically braced frames have braces that are purposely located away from joints, and connections that are intended to induce shear and

flexure demands on the members. The eccentricity is intended to force a concentration of inelastic activity at a predetermined location that will control the behavior of the system. Modern eccentrically braced frames are designed with strict controls on member proportions and special out-of-plane bracing at the connections to ensure the frame behaves as intended.

The eccentrically braced frame is a relatively new type of frame that is recognizable by a diagonal with one end significantly offset from the joints (Figure 4-26). As with any braced frame, the function of the diagonal is to provide stiffness and transmit lateral forces from the upper to the lower level. The unique feature of eccentrically braced frames is an offset zone in the beam, called the "link". The link is specially detailed for controlled yielding. This detailing is subject to very specific requirements, so an ordinary braced frame that happens to have an offset zone that looks like a link may not necessarily behave like an eccentrically braced frame.

An eccentrically braced frame has the following essential features:

1. There is a link beam at one end of each brace.
2. The length of the link beam is limited to control shear deformations and rotations due to flexural yielding at the ends of the link.
3. The brace and the connections are designed to develop forces consistent with the strength of the link.
4. When one end of a link beam is connected to a column, the connection is a full moment connection.
5. Lateral bracing is provided to prevent out-of-plane beam displacements that would compromise the intended action.

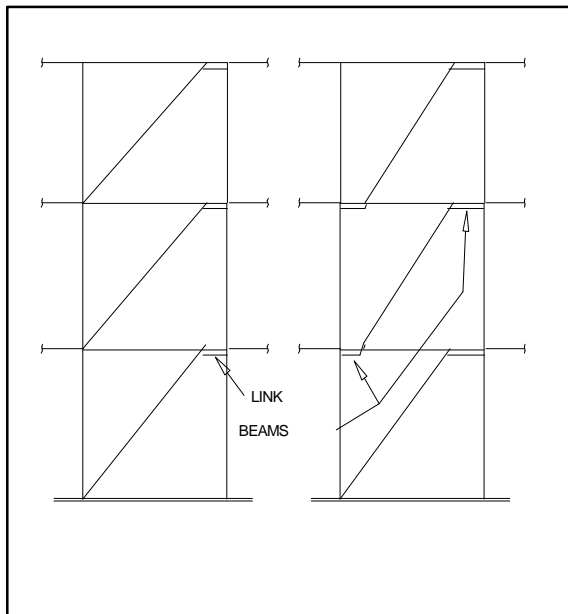
In most cases where eccentrically braced frames are used, the frames comprise the entire lateral force resisting system. In some tall buildings, eccentrically braced frames have been added as

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stiffening elements to help control drift in moment resisting steel frames.

There are no evaluation statements for eccentrically braced frames because their history is so short, but the engineer is alerted to their possible presence in a building. For guidance in dealing with eccentrically braced frames, the evaluating engineer is referred to the Recommended Lateral Force Requirements and Commentary (SEAOC, 1996). It should be noted that some engineers who were familiar with current research, designed eccentrically braced frames before the SEAOC provisions were developed. These frames may not satisfy all of the detailing requirements present in the current code. Any frame that was clearly designed to function as proper eccentrically braced frame should be recognized and evaluated with due regard for any possible shortcomings that will affect the intended behavior.

Figure 4-26. Eccentrically Braced Frames



4.5 Procedures for Diaphragms

This section provides Tier 2 evaluation procedures that apply to diaphragms: general, wood, metal deck, concrete, precast concrete, horizontal bracing, and other diaphragms.

Commentary:

Diaphragms are horizontal elements that distribute seismic forces to vertical lateral force resisting elements. They also provide lateral support for walls and parapets. Diaphragm forces are derived from the self weight of the diaphragm and the weight of the elements and components that depend on the diaphragm for lateral support. Any roof, floor, or ceiling can participate in the distribution of lateral forces to vertical elements up to the limit of its strength. The degree to which it participates depends on relative stiffness and on connections. In order to function as a diaphragm, horizontal elements must be interconnected to transfer shear, with connections that have some degree of stiffness. An array of loose elements such as ceiling tiles, or metal-deck panels attached to beams with wind clips does not qualify.

4.5.1 General

Commentary:

It is customary to analyze diaphragms using a beam analogy. The floor, which is analogous to the web of a wide-flange beam, is assumed to carry the shear. The edge of the floor, which could be a spandrel or wall, is analogous to the flange, and is assumed to carry the flexural stress. A free-body diagram of these elements is shown in Figure 4-27. The diaphragm chord can be a line of edge beams that is connected to the floor, or reinforcing in the edge of a slab or in a spandrel. Examples of chords are shown in Figure 4-28.

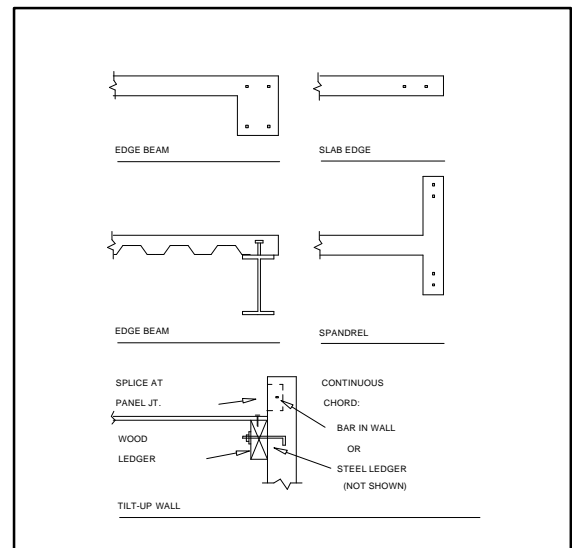
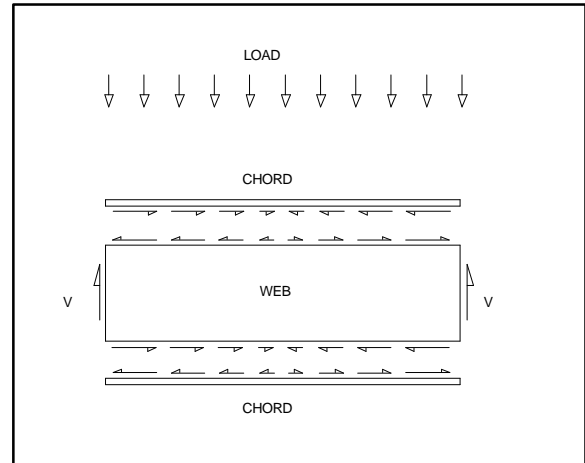


Figure 4-27. Diaphragm as a Beam

Figure 4-28. Chord Sections

Two essential requirements for the chord are continuity and connection with the slab. Almost any building with an edge beam has a potential diaphragm chord. Even if designed for vertical loads only, the beam end connections probably have some capacity to develop horizontal forces through the column.

The force in the chord is customarily determined by dividing the moment in the diaphragm by the depth of the diaphragm. This yields an upper bound on the chord force since it assumes elastic beam

behavior in the diaphragm and neglects bending resistance provided by any other components of the diaphragm. A lack of diaphragm damage in post-earthquake observations provides some evidence that certain diaphragms may not require specific chords as determined by the beam analogy. For the purpose of this Handbook, the absence of chords is regarded as a deficiency that warrants further evaluation. Consideration may be given to the available evidence regarding the suitability of the beam analogy and the need for defined chords in the building being evaluated.

Consistent with the beam analogy, a stair or skylight opening may weaken the diaphragm just as a web opening for a pipe may weaken a beam. An opening at the edge of a floor may weaken the diaphragm just as a notch in a flange weakens a beam.

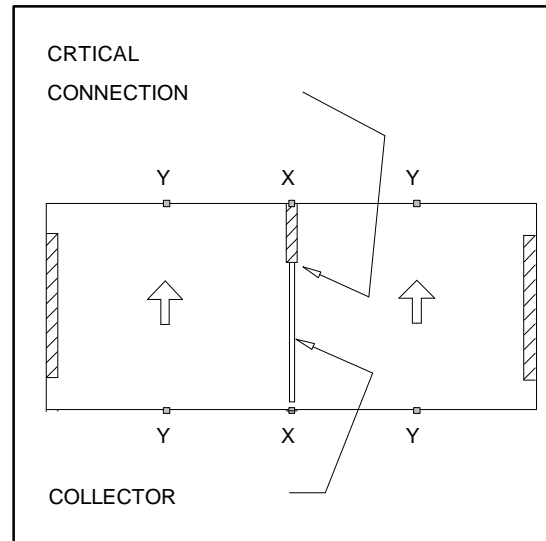


Figure 4-29. Rigid and Flexible Diaphragms

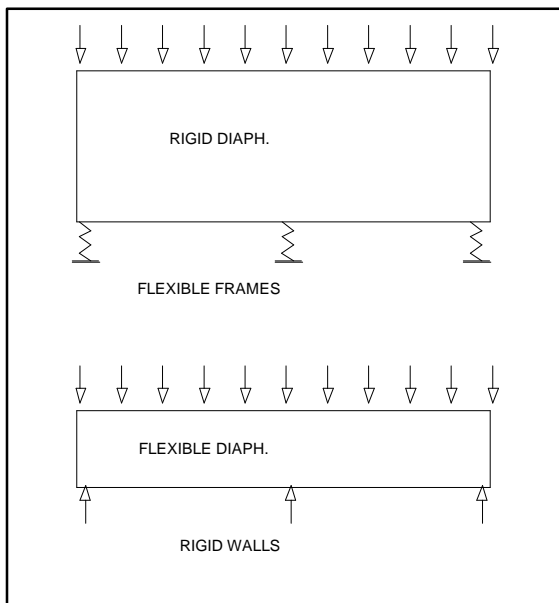


Figure 4-30. Collector

4.5.1.1 DIAPHRAGM CONTINUITY: The

An important characteristic of diaphragms is flexibility, or its opposite, rigidity. In seismic design, rigidity means relative rigidity. Of importance is the in-plane rigidity of the diaphragm relative to the walls or frame elements that transmit the lateral forces to the ground (Figure 4-29). A concrete floor is relatively rigid compared to steel moment frames, whereas a metal deck roof is relatively flexible compared to concrete or masonry walls. Wood diaphragms are generally treated as flexible, but consideration must be given to rigidity of the vertical elements. Wood diaphragms may not be flexible compared to wood shear wall panels in a given building.

Another consideration is continuity over intermediate supports. In a three-bay building, for example, the diaphragm has three spans and four supports. If the diaphragm is relatively rigid, the chords should be continuous over the supports like flanges of a continuous beam over intermediate supports. If the diaphragm is flexible, it may be designed as a simple beam spanning between walls without consideration of continuity of the chords. In the latter case, the design professional should remember that the diaphragm is really continuous, and that this continuity is simply being neglected.

diaphragms shall not be composed of split-level

Figure 4-30 (on previous page) shows a diaphragm of two spans that may or may not be continuous over the intermediate support. If chord continuity is developed at the points marked X, these will be the locations of maximum chord force. If chord continuity is not provided at X, the spans will act as two simple beams. The maximum chord force will occur at the middle of each span, at the points marked Y. The end rotations of the two spans may cause local damage at points X.

Finally, there must be an adequate mechanism for the transfer of diaphragm shear forces to the vertical elements. This topic is addressed in detail in Section 4.6. An important element related to diaphragm force transfer is the collector, or drag strut. In Figure 4-31, a member is added to collect the diaphragm shear and drag it into the short intermediate shear wall. The presence of a collector avoids a concentration of stress in the diaphragm at the short shear wall. Collectors must be continuous across any interrupting elements such as perpendicular beams, and must be adequately connected to the shear wall to deliver forces into the wall.

In buildings of more than one story, the design professional must consider the effect of flexible diaphragms on walls perpendicular to the direction of seismic force under consideration.

floors. In wood buildings, the diaphragms shall not have expansion joints.

Tier 2 Evaluation Procedure: The load path around the discontinuity shall be identified. The diaphragm shall be analyzed for the forces in Section 4.2 and the adequacy of the elements in the load path shall be evaluated.

4.5.1.2 CROSS TIES: There shall be continuous cross ties between diaphragm chords.

Commentary:

Split level floors and roofs, or diaphragms interrupted by expansion joints, create discontinuities in the diaphragm. This condition is common in ramped parking structures. It is a problem unless special details are used, or lateral-force-resisting elements are provided at the vertical offset of the diaphragm or on both sides of the expansion joint. Such a discontinuity may cause the diaphragm to function as a cantilever element or three-sided diaphragm. If the diaphragm is not supported on at least three sides by lateral-force-resisting elements, torsional forces in the diaphragm may cause it to become unstable. In both the cantilever and three-sided cases, increased lateral deflection in the discontinuous diaphragm may cause increased damage to, or collapse of, the supporting elements.

If the load path is incomplete, mitigation with elements or connections required to complete the load path is necessary to achieve the selected performance level.

Tier 2 Evaluation Procedure: Out-of-plane forces in accordance with Section 4.2 shall be calculated. The adequacy of the existing connections, including development of the forces into the diaphragm, shall be evaluated.

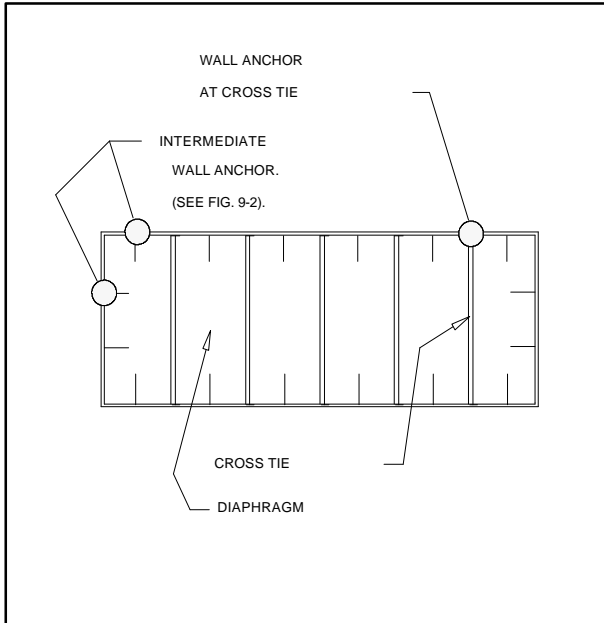
Figure 4-31. Cross Ties

Commentary:

Continuous crossties between diaphragm chords are needed to develop out-of-plane wall forces into the diaphragm (see Figure 4-31). The crossties should have a positive and direct connection to the walls to keep the walls from separating from the building. The connection of the crosstie to the wall, and connections within the crosstie, must be detailed so that cross-grain bending or cross-grain tension does not occur in any wood member (see Section 4.6.1.2).

Sub-diaphragms may be used between continuous cross-ties to reduce the required number of full length cross-ties.

4.5.1.3 ROOF CHORD CONTINUITY: All chord



elements shall be continuous, regardless of changes in roof elevation.

Tier 2 Evaluation Procedure: The load path around the discontinuity shall be identified. The diaphragm shall be analyzed for the forces in Section 4.2 and the adequacy of the elements in the load path shall be evaluated.

Figure 4-32. Roof Chord Continuity

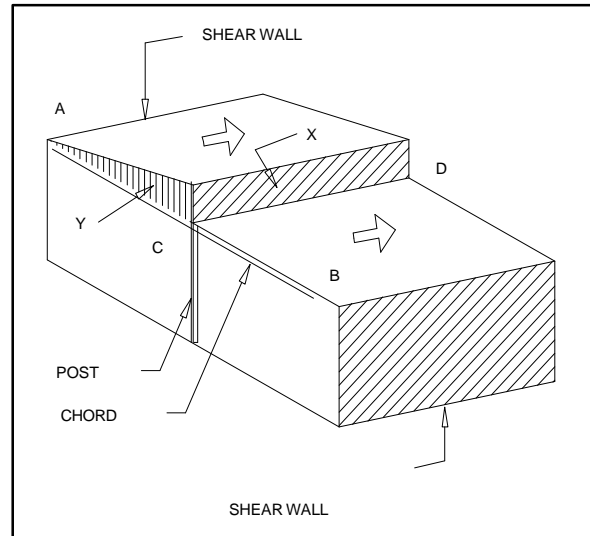
Commentary:

Diaphragms with discontinuous chords will be more flexible and will experience more damage around the perimeter than properly detailed diaphragms. Vertical offsets or elevation changes in a diaphragm often cause a chord discontinuity (see Figure 4-32). To provide continuity the following elements are required: a continuous chord element; plane X to connect the offset portions of the diaphragm; plane Y to develop the sloping diaphragm into the chord; and vertical

supports (posts) to resist overturning forces generated by plane X.

If the load path is incomplete, mitigation with elements or connections required to complete the load path is necessary to achieve the selected performance level.

4.5.1.4 OPENINGS AT SHEAR WALLS:



Diaphragm openings immediately adjacent to the shear walls shall be less than 25% of the wall length for Life Safety and 15% of the wall length for Immediate Occupancy.

Tier 2 Evaluation Procedure: The in-plane shear transfer demand at the wall shall be calculated. The adequacy of the diaphragm to transfer loads to the wall shall be evaluated considering the available length and the presence of any drag struts. The adequacy of the walls to span out-of-plane between points of anchorage shall be evaluated and the adequacy of the diaphragm connections to resist wall out-of-plane forces shall be evaluated.

Figure 4-33. Opening at Exterior Wall

Commentary:

Large openings at shear walls significantly limit the ability of the diaphragm to transfer lateral forces to the wall (see Figure 4-33). This can have a compounding effect if the opening is near one end of the wall and divides the diaphragm into small segments with limited stiffness that are ineffective in transferring shear to the wall. This might have the net effect of a much larger opening. Large openings may also limit the ability of the diaphragm to provide out-of-plane support for the wall.

The presence of drag struts developed into the diaphragm beyond the wall will help mitigate this effect.

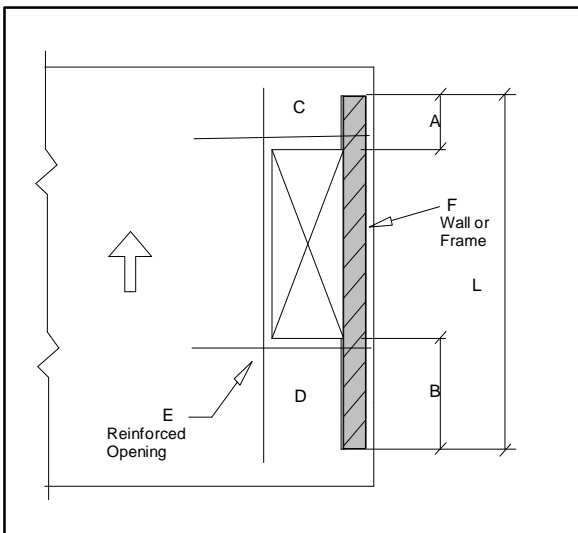
Commentary:

Large openings at braced frames significantly limit the ability of the diaphragm to transfer lateral forces to the frame. This can have a compounding effect if the opening is near one end of the frame and divides the diaphragm into small segments with limited stiffness that are ineffective in transferring shear to the frame. This might have the net effect of a much larger opening.

The presence of drag struts developed into the diaphragm beyond the frame will help mitigate this effect.

not be greater than 8 ft. long for Life Safety and 4 ft. long for Immediate Occupancy.

4.5.1.5 OPENINGS AT BRACED FRAMES:



Diaphragm openings immediately adjacent to the braced frames shall extend less than 25% of the frame length for Life Safety and 15% of the frame length for Immediate Occupancy.

Tier 2 Evaluation Procedure: The in-plane shear transfer demand at the frame shall be calculated. The adequacy of the diaphragm to transfer loads to the frame shall be evaluated considering the available length and the presence of any drag struts.

4.5.1.6 OPENINGS AT EXTERIOR MASONRY SHEAR WALLS: Diaphragm openings immediately adjacent to exterior masonry walls shall

Tier 2 Evaluation Procedure: The in-plane shear transfer demand at the wall shall be calculated. The adequacy of the diaphragm to transfer loads to the wall shall be evaluated considering the available length and the presence of any drag struts. The adequacy of the walls to span out-of-plane between points of anchorage shall be evaluated and the adequacy of the diaphragm connections to resist wall out-of-plane forces shall be evaluated.

Commentary:

Large openings at shear walls significantly limit the ability of the diaphragm to transfer lateral forces to the wall (see Figure 4-33). This can have a compounding effect if the opening is near one end of the wall and divides the diaphragm into small segments with limited stiffness that are ineffective in transferring shear to the wall. This might have the net effect of a much larger opening. Large openings may also limit the ability of the diaphragm to provide out-of-plane support for the wall.

The presence of drag struts developed into the diaphragm beyond the wall will help mitigate this effect.

4.5.1.7 PLAN IRREGULARITIES: There shall be tensile capacity to develop the strength of the diaphragm at re-entrant corners or other locations of plan irregularities. This statement shall apply to the Immediate Occupancy performance level only.

Tier 2 Evaluation Procedure: The chord and collector demands at locations of plan irregularities shall be calculated by analyzing the diaphragm for the forces in Section 4.2. Relative movement of the projecting wings of the structure shall be considered by applying the static base shear assuming each wing moves in the same direction, or each wing moves in opposing directions, whichever is more severe. The adequacy of all elements that can contribute to the tensile capacity at the location of the irregularity shall be evaluated.

Commentary:

Diaphragms with plan irregularities such as extending wings, plan insets, or E-, T-, X-, L-, or C-shaped configurations have re-entrant corners where large tensile and compressive forces can develop (see Figure 4-34). The diaphragm may not have sufficient strength at these re-entrant corners to resist these tensile forces. Local damage may occur (see Figure 4-35).

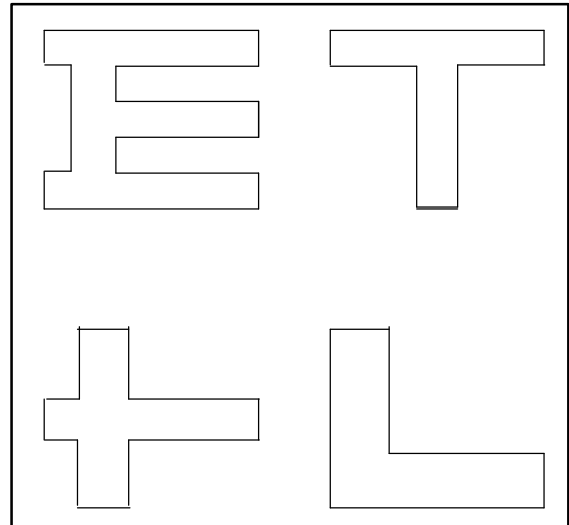


Figure 4-34. Plan Irregularities

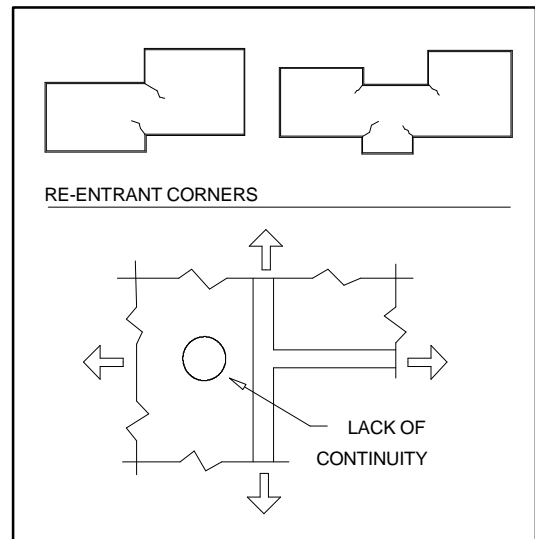


Figure 4-35. Re-entrant Corners

4.5.1.8 DIAPHRAGM REINFORCEMENT AT OPENINGS: There shall be reinforcing around all diaphragms openings larger than 50% of the building width in either major plan dimension. This statement shall apply to the Immediate Occupancy performance level only.

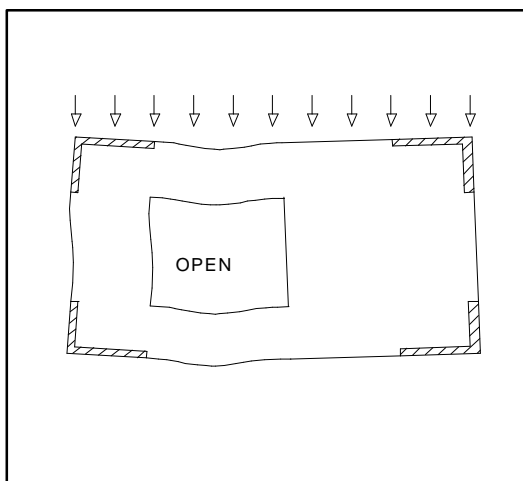
Tier 2 Evaluation Procedure: The diaphragm shall be analyzed for the forces in Section 4.2. The shear and flexural demands at major openings shall be calculated and the resulting chord forces shall be determined. The adequacy of the diaphragm elements to transfer forces around the opening shall be evaluated.

Figure 4-36. Diaphragm Opening

Commentary:

Openings in diaphragms increase shear stresses and induce secondary moments in the diaphragm segments adjacent to the opening. Tension and compression forces are generated along the edges of these segments by the secondary moments, and must be resisted by chord elements in the subdiaphragms around the openings.

Openings that are small relative to the diaphragm dimensions may have only a negligible impact. Openings that are large relative to the diaphragm dimensions can substantially reduce the stiffness of the diaphragm and induce large forces around the openings (see Figure 4-36).



4.5.2 Wood Diaphragms

4.5.2.1 STRAIGHT SHEATHING: All straight sheathed diaphragms shall have aspect ratios less than 2 to 1 for Life Safety and 1 to 1 for Immediate Occupancy in the direction being considered

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the shear capacity of non-compliant diaphragms shall be evaluated.

Commentary:

Straight-sheathed diaphragms are flexible and weak relative to other types of wood diaphragms. Shear capacity is provided by a force couple between nails in the individual boards of the diaphragm and the supporting framing. Because of the limited strength and stiffness of these diaphragms, they are most suitable in applications with limited demand, such as in regions of low seismicity.

In regions of moderate and high seismicity, the span and aspect ratio of straight-sheathed diaphragms are limited to minimize shear demands. The aspect ratio (span/depth) must be calculated for the direction being considered.

Compliance can be achieved if the diaphragm has adequate capacity for the demands in the building being evaluated.

4.5.2.2 SPANS: All wood diaphragms with spans greater than 24 ft. for Life Safety and 12 ft. for Immediate Occupancy shall consist of wood structural panels or diagonal sheathing. Wood commercial and industrial buildings may have rod-braced systems.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the shear capacity of non-compliant diaphragms shall be evaluated. The diaphragm deflection shall be calculated, and the adequacy of the vertical-load carrying elements shall be evaluated at maximum diaphragm deflection, including p-delta effects.

Commentary:

Long span diaphragms will often experience large lateral deflections and diaphragm shear demands. Large deflections in the diaphragm can result in increased damage or collapse of elements laterally supported by the diaphragm. Excessive diaphragm shear demands will cause damage and reduced stiffness in the diaphragm.

Compliance can be demonstrated if the diaphragm and vertical load carrying elements can be shown to have adequate capacity at maximum deflection.

Wood commercial and industrial buildings may have rod-braced systems, in lieu of wood structural panels, and can be considered compliant.

4.5.2.3 UNBLOCKED DIAPHRAGMS: All unblocked wood panel diaphragms shall have horizontal spans less than 40 ft. for Life Safety and 25 ft. for Immediate Occupancy and shall have aspect ratios less than or equal to 4 to 1 for Life Safety and 3 to 1 for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The adequacy of the shear capacity of non-compliant diaphragms shall be evaluated.

Commentary:

Wood structural panel diaphragms may not have blocking below unsupported panel edges. The shear capacity of unblocked diaphragms is less than that of fully blocked diaphragms, due to the limited ability for direct shear transfer at unsupported panel edges. The span and aspect ratio of unblocked diaphragms are limited to minimize shear demands. The aspect ratio (span/depth) must be calculated for the direction being evaluated.

Compliance can be demonstrated if the unblocked diaphragm can be shown to have adequate capacity for the demands in the building being evaluated.

4.5.3 Metal Deck Diaphragms

Commentary:

Bare metal deck can be used as a roof diaphragm when the individual panels are adequately fastened to the supporting framing. The strength of the diaphragm depends on the profile and gage of the deck and the layout and size of the welds or fasteners. Allowable shear capacities for metal deck diaphragms are usually obtained from approved test data and analytical work developed by the industry.

Metal decks used in floors generally have concrete fill. In cases with structural concrete fill, the metal deck is considered to be a concrete form, and the diaphragm is treated as a reinforced concrete diaphragm. In some cases, however, the concrete fill is not structural. It may be a topping slab or an insulating layer that is used to encase conduits or provide a level wearing surface. This type of construction is considered to be an untopped metal deck diaphragm with a capacity determined by the metal deck alone. Non-structural topping, however, is somewhat beneficial and has a stiffening effect on the metal deck.

Metal deck diaphragm behavior is limited by buckling of the deck and by the attachment to the framing. Weld quality can be an issue because welding of light gage material requires special consideration. Care must be taken during construction to ensure the weld has proper fusion to the framing, but did not burn through the deck material.

Concrete-filled metal decks generally make excellent diaphragms and usually are not a problem as long as the basic requirements for

chords, collectors, and reinforcement around openings are met. However, the evaluating engineer should look for conditions that can weaken the diaphragm such as troughs, gutters, and slab depressions that can have the effect of short circuiting the system or of reducing the system to the bare deck.

4.5.3.1 NON-CONCRETE DIAPHRAGMS: Untopped metal deck diaphragms or metal deck diaphragms with fill other than concrete shall consist of horizontal spans of less than 40 ft. and shall have span/depth ratios less than 4 to 1. This statement shall apply to the Immediate Occupancy performance level only.

Tier 2 Evaluation Procedure: Non-compliant diaphragms shall be evaluated for the forces in Section 4.2. The adequacy of the shear capacity of the metal deck diaphragm shall be evaluated.

Commentary:

Untopped metal deck diaphragms have limited strength and stiffness. Long span diaphragms with large aspect ratios will often experience large lateral deflections and high diaphragm shear demands. This is especially true for aspect ratios greater than 4 to 1.

In regions of moderate and high seismicity, the span and aspect ratio of untopped metal deck diaphragms are limited to minimize shear demands. The aspect ratio (span/depth) must be calculated for the direction being considered.

Compliance can be achieved if the diaphragm has adequate capacity for the demands in the building being evaluated.

No evaluation statements or Tier 2 procedures specific to cast-in-place concrete diaphragms are included in this Handbook. Concrete diaphragms shall be evaluated for the general diaphragm evaluation statements and Tier 2 procedures in Section 4.5.1.

4.5.5 Precast Concrete Diaphragms

Commentary:

Concrete slab diaphragm systems have demonstrated good performance in past earthquakes. Building damage is rarely attributed to a failure of the concrete diaphragm itself, but rather failure in related elements in the load path such as collectors or connections between diaphragms and vertical elements. These issues are addressed elsewhere in this Handbook. The design professional should assess concrete diaphragms for general evaluation statements that will address configuration, irregularities, openings and load path. The design professional should also carefully assess pan joist systems and other systems that have thin slabs.

4.5.5.1 TOPPING SLAB: Precast concrete diaphragm elements shall be interconnected by a continuous reinforced concrete topping slab.

Commentary:

Precast concrete diaphragms consist of horizontal precast elements which may or may not have a cast-in-place topping slab. Precast elements may be precast planks laid on top of framing, or precast T-sections which consist of both the framing and the diaphragm surface cast in one piece.

Because of the brittle nature of the connections between precast elements, special attention should be paid to eccentricities, adequacy of welds, and length of embedded bars. If a topping slab is provided, it should be capable of taking all of the shear. Welded steel connections between precast elements, with low rigidity relative to the concrete topping, will not contribute significantly to the strength of the diaphragm when a topping slab is present.

4.5.4 Concrete Diaphragms

Tier 2 Evaluation Procedure: Non-compliant diaphragms shall be evaluated for the forces in Section 4.2. The adequacy of the slab element interconnection shall be evaluated. The adequacy of the shear capacity of the diaphragm shall be evaluated.

4.5.6 Horizontal Bracing

Commentary:

Precast concrete diaphragm elements may be interconnected with welded steel inserts. These connections are susceptible to sudden failure such as weld fracture, pull-out of the embedment, or spalling of the concrete. Precast concrete diaphragms without topping slabs may be susceptible to damage unless they were specifically detailed with connections capable of yielding or of developing the strength of the connected elements.

In precast construction, topping slabs may have been poured between elements without consideration for providing continuity. The topping slab may not be fully effective if it is interrupted at interior walls. The presence of dowels or continuous reinforcement is needed to provide continuity.

When the topping slab is not continuous, an evaluation considering the discontinuity is required to ensure a complete load path for shear transfer, collectors and chords.

No evaluation statements or Tier 2 procedures have been provided for horizontal bracing. Horizontal bracing shall be evaluated for the general diaphragm evaluation statements and Tier 2 procedures in Section 4.5.1.

4.5.7 Other Diaphragms

Commentary:

Horizontal bracing usually is found in industrial buildings. These buildings often have very little mass so that wind considerations govern over seismic considerations. The wind design is probably adequate if the building shows no signs of distress. If bracing is present, the design professional should look for a complete load path with the ability to collect all tributary forces and deliver them to the walls or frames.

4.5.7.1 OTHER DIAPHRAGMS: The diaphragm shall not consist of a system other than those described in Section 4.5.

Tier 2 Evaluation Procedure: Non-compliant diaphragms shall be evaluated for the forces in Section 4.2. The adequacy of the non-compliant diaphragms shall be evaluated using available reference standards for the capacity of diaphragms not covered by this Handbook.

Commentary:

In some codes and standards there are procedures and allowable diaphragm shear capacities for diaphragms not covered by this Handbook. Examples include thin planks and gypsum toppings, but these systems are brittle and have limited strength. As such, they may not be desirable elements in the lateral force resisting system.

The design professional should be watchful for systems that look like diaphragms but may not have the strength, stiffness, or interconnection between elements necessary to perform the intended function.

4.6 Procedures for Connections

This section provides Tier 2 evaluation procedures that apply to structural connections: anchorage for normal forces, shear transfer, vertical components, interconnection of elements and panel connections.

4.6.1 Anchorage for Normal Forces

Commentary:

Bearing walls that are not positively anchored to the diaphragms may separate from the structure. This may result in a loss of bearing support and partial collapse of the floors and roof. Non-bearing walls which separate from the structure may represent a significant falling hazard. The hazard increases with the height above the building base as the building response amplifies the ground motion. Amplification of the ground motion used to estimate the wall anchorage forces depends on the type and configuration of both the walls and the diaphragms as well as the type of soil.

4.6.1.1 WALL ANCHORAGE: Exterior concrete or masonry walls shall be anchored for out-of-plane forces at each diaphragm level with steel anchors or straps that are developed into the diaphragm.

Tier 2 Evaluation Procedure: The adequacy of the walls to span between points of anchorage shall be evaluated. The adequacy of the existing connections for the wall forces in Section 4.2 shall be evaluated.

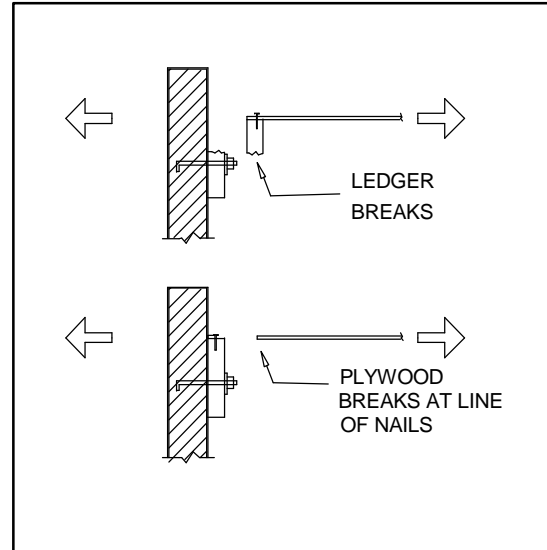
Commentary:

Bearing walls that are not positively anchored to the diaphragms may separate from the structure causing partial collapse of the floors and roof. Non-bearing walls which separate from the structure may represent a significant falling hazard. The hazard amplifies with the height above the building base. Anchorage forces must be fully developed into the diaphragm to prevent pull out failure of the anchor or local failure of the

diaphragm (see Figure 4-38, following page).

If the anchorage is non-existent, mitigation with elements or connections needed to anchor the walls to the diaphragms is necessary to achieve the selected performance level.

Figure 4-37. Wood Ledgers



4.6.1.2 WOOD LEDGERS: The connection between the wall panels and the diaphragm shall not induce cross-grain bending or tension in the wood ledgers.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available to demonstrate compliance of wood ledgers loaded in cross-grain bending.

Commentary:

Wood members in general have very little resistance to tension applied perpendicular to grain. Connections that rely on cross-grain bending in wood ledgers induce tension perpendicular to grain (see Figure 4-37). Failure of such connections is sudden and non-ductile, and can result in loss of bearing support and partial collapse of the floors and roof.

Mitigation with elements or connections needed to provide wall anchorage without inducing cross-grain bending is necessary to achieve the selected performance level.

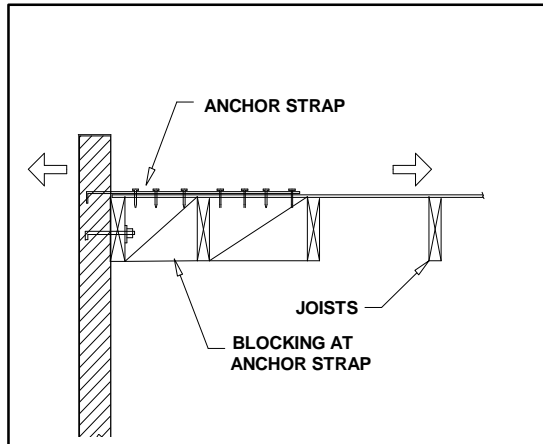


Figure 4-38. Wall Anchorage

4.6.1.3 ANCHOR SPACING: Exterior masonry walls shall be anchored to the floor and roof systems at a spacing of 4 ft. or less for Life Safety and 3 ft. or less for Immediate Occupancy.

Tier 2 Evaluation Procedure: The adequacy of the walls to span between points of anchorage shall be evaluated. The adequacy of the existing connections for the forces in Section 4.2 shall be evaluated.

Commentary:

A sufficient number of anchors should be provided to limit the demand on any one anchor and to adequately prevent the walls from separating from the structure.

4.6.1.4 PRECAST PANEL CONNECTIONS:

There shall be at least two anchors from each precast wall panel into the diaphragm elements for Life Safety and the anchors shall be able to develop the strength of the panels for Immediate Occupancy.

Tier 2 Evaluation Procedure: The stability of the wall panels for the out-of-plane forces in Section 4.2 shall be evaluated. The adequacy of the existing connections to deliver all forces into the diaphragm, including moments due to eccentricities between the panel center of mass and points of anchorage, shall be evaluated.

Commentary:

At least two connections between each panel and the diaphragm are required for basic stability of the wall panel for out-of-plane forces. Many connection configurations are possible, including one anchor supporting two adjacent panels.

A single anchor, or line of anchors, near the panel center of mass should be evaluated for an accidental eccentricity of 5% of the critical panel dimension, as a minimum.

4.6.1.5 STIFFNESS OF WALL ANCHORS:

Anchors of heavy concrete or masonry walls to wood structural elements shall be installed taut and shall be stiff enough to prevent movement between the wall and diaphragm. If bolts are present, the size of the bolt holes in both the connector and framing shall be a maximum of 1/16" larger than the bolt diameter. This statement shall apply to the Immediate Occupancy performance level only.

Tier 2 Evaluation Procedure: The amount of relative movement possible given the existing connection configuration shall be determined. The impact of this movement shall be evaluated by analyzing the elements of the connection for forces induced by the maximum potential movement.

Commentary:

The concern is that flexibility or slip in wall anchorage connections requires relative movement between the wall and structure before the anchor is engaged. This relative movement can induce forces in elements not intended to be part of the load path for out-of-plane forces. It can be enough to cause a loss of bearing at vertical supports, or can induce cross-grain bending in wood ledger connections.

Compliance can be demonstrated if the movement has no detrimental affect on the connections. Forces generated by any additional eccentricity at bearing supports should be considered.

Commentary:

The floor or roof diaphragms must be connected to the shear walls to provide a complete load path for the transfer of diaphragm shear forces to the walls. Where the wall does not extend the full depth of the diaphragm, this connection may include collectors or drag struts. Collectors and drag struts must be continuous across intersecting framing members, and must be adequately connected to the wall to deliver high tension and compression forces at a concentrated location.

In the case of frame buildings with infill walls (building types S5, S5A, C3, C3A) the seismic performance is dependent upon the interaction between the frame and infill, and the behavior is more like that of a shear wall building. The load path between the diaphragms and the infill panels is most likely through the frame elements, which may also act as drag struts and collectors. In this case the evaluation statement is addressing the connection between the diaphragm and the frame elements.

If the connection is non-existent, mitigation with elements or connections needed to transfer diaphragm shear to the shear walls is necessary to achieve the selected performance level.

4.6.2 Shear Transfer

Commentary:

The transfer of diaphragm shears into shear walls and frames is a critical element in the load path for lateral force resistance. If the connection is inadequate, or non-existent, the ability of the walls and frames to receive lateral forces will be limited, and the overall lateral force resistance of the building will be reduced.

4.6.2.1 TRANSFER TO SHEAR WALLS: Diaphragms shall be reinforced and connected for transfer of loads to the shear walls for Life Safety and shall be able to develop the shear strength of the walls for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The diaphragm and wall demands shall be calculated, and the adequacy of the connection to transfer the demands to the shear walls shall be evaluated.

4.6.2.2 TRANSFER TO STEEL FRAMES: Diaphragms shall be connected for transfer of loads to the steel frames for Life Safety and the connection shall be able to develop the strength of the frames for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The diaphragm and frame demands shall be calculated, and the adequacy of the connection to transfer the demands to the steel frames shall be evaluated.

Commentary:

The floor and roof diaphragms must be adequately connected to the steel frames to provide a complete load path for shear transfer between the

diaphragms and the frames. This connection may consist of shear studs or welds between the metal deck and steel framing. In older construction, steel framing may be encased in concrete. Direct force transfer between concrete and steel members by shear friction concepts should not be used unless the members are completely encased in concrete.

If the connection is non-existent, mitigation with elements or connections needed to transfer diaphragm shear to the steel frames is necessary to achieve the selected performance level.

4.6.2.3 TOPPING SLAB TO WALLS OR FRAMES: Reinforced concrete topping slabs that interconnect the precast concrete diaphragm elements shall be doweled into the shear wall or frame elements for Life Safety and shall be able to develop the shear strength of the walls or frames for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The diaphragm and wall demands shall be calculated, and the adequacy of the connection to transfer the demands to the vertical elements shall be evaluated.

Commentary:

The topping slabs at each floor or roof must be connected to the shear walls or frame elements to provide a complete load path for the transfer of diaphragm shear forces to the vertical elements. Welded inserts between precast floor or roof elements are susceptible to weld fracture and spalling, and are likely not adequate to transfer these forces alone.

If a direct topping slab connection is non-existent, mitigation with elements or connections needed to transfer diaphragm shear to the vertical elements is necessary to achieve the selected performance level.

Commentary:

The following statements reflect a number of common concerns related to inadequate connections between elements. For example, members may be incapable of transferring forces into the foundation or may be displaced when uplifted, resulting in reduced support for vertical loads. A potential deficiency common to all of the following statements would be a non-existent connection.

4.6.3.1 STEEL COLUMNS: The columns in lateral-force-resisting frames shall be anchored to the building foundation for Life Safety and the anchorage shall be able to develop the tensile capacity of the foundation for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The column demands including axial load due to overturning shall be calculated, and the adequacy of the connections to transfer the demands to the foundation shall be evaluated.

Commentary:

Steel columns that are part of the lateral-force-resisting system must be connected for the transfer of uplift and shear forces at the foundation (see Figure 4-39). The absence of a substantial connection between the columns and the foundation may allow the column to uplift or slide off of bearing supports which may limit the ability of the columns to support vertical loads or resist lateral forces.

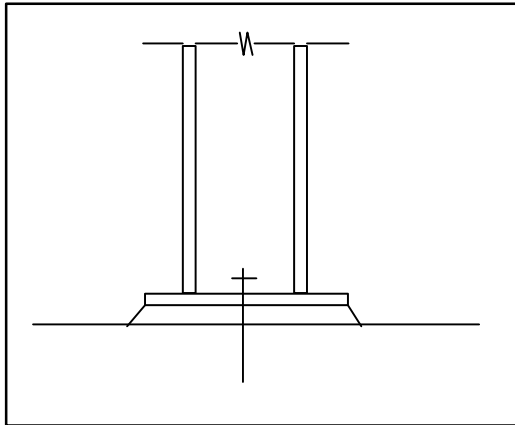
As an upper bound limit for the Immediate Occupancy performance level, the connection is checked for the tensile capacity of the foundation, which is the weak link in the load path between the superstructure and the supporting soil. It could be the uplift capacity of the pile, the connection

4.6.3 Vertical Components

between the pile and the cap, or the foundation dead load that can be activated by the column.

If the connection is non-existent, mitigation with elements or connections needed to anchor the vertical elements to the foundation is necessary to achieve the selected performance level.

Figure 4-39. Steel Column Connection



4.6.3.2 CONCRETE COLUMNS: All concrete columns shall be doweled into the foundation for Life Safety and the dowels shall be able to develop the tensile capacity of the column for Immediate Occupancy.

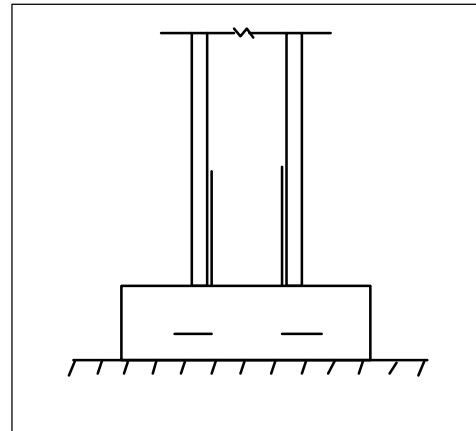
Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The column demands shall be calculated and the adequacy of the connection to transfer the demands to the foundation shall be evaluated.

Commentary:

Concrete columns that are part of the lateral-force-resisting system must be connected for the transfer of uplift and shear forces to the foundation (see Figure 4-40). The absence of a substantial connection between the columns and the foundation may allow the column to uplift or slide off of bearing supports which will limit the ability of the columns to support vertical loads or resist lateral forces.

If the connection is non-existent, mitigation with elements or connections needed to anchor the vertical elements to the foundation is necessary to achieve the selected performance level.

Figure 4-40. Column Doweled into Foundation



4.6.3.3 WOOD POSTS: There shall be a positive connection of wood posts to the foundation.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for connections in non-compliance.

4.6.3.4 WOOD SILLS: All wood sills shall be

Commentary:

The absence of a substantial connection between the wood posts and the foundation may allow the posts to slide off of bearing supports as the structure drifts in an earthquake.

Mitigation with elements or connections needed to anchor the posts to the foundation is necessary to achieve the selected performance level.

bolted to the foundation.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for connections in non-compliance.

Commentary:

The absence of a connection between the wood sills and the foundation is a gap in the load path that will limit the ability of the shear walls to resist lateral forces. Structures may potentially slide off foundation supports

Mitigation with elements or connections needed to anchor the sills to the foundation is necessary to achieve the selected performance level.

4.6.3.5 WALL REINFORCING: Walls shall be doweled to the foundation for Life Safety and the dowels shall be able to develop the strength of the walls for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The wall demands shall be calculated and the adequacy of the connection to transfer the demands to the foundation shall be evaluated.

Commentary:

The absence of an adequate connection between the shear walls and the foundation is a gap in the load path that will limit the ability of the shear walls to resist lateral forces.

If the connection is non-existent, mitigation with elements or connections needed to anchor the walls to the foundation is necessary to achieve the selected performance level.

4.6.3.6 SHEAR-WALL-BOUNDARY COLUMNS: The shear wall boundary columns shall be anchored to the building foundation for Life Safety and the anchorage shall be able to develop the tensile capacity of the column for Immediate Occupancy

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The overturning resistance of the shear wall considering the dead load above the foundation and the portion of the foundation dead load that can be activated by the boundary column anchorage connection shall be evaluated.

Commentary:

Shear wall boundary column anchorage is necessary for overturning resistance of the shear walls. Boundary columns which are not substantially anchored to the foundation may not be able to activate foundation dead loads for overturning resistance.

4.6.3.7 PRECAST WALL PANELS: Precast wall panels shall be doweled to the foundation for Life Safety and the dowels shall be able to develop the strength of the walls for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The wall panel demands shall be calculated and the adequacy of the connection to transfer the demands to the foundation shall be evaluated.

Commentary:

The absence of an adequate connection between the precast wall panels and the foundation is a gap in the load path that will limit the ability of the panels to resist lateral forces.

If the connection is non-existent, mitigation with elements or connections needed to anchor the precast walls to the foundation is necessary to achieve the selected performance level.

4.6.3.8 WALL PANELS: Metal, fiberglass or cementitious wall panels shall be positively attached to the foundation for Life Safety and the attachment shall be able to develop the shear capacity of the panels for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The wall panel demands shall be calculated and the adequacy of the connection to transfer the demands to the foundation shall be evaluated.

Commentary:

The absence of a shear transfer connection between metal, fiberglass or cementitious panel shear walls and the foundation is a gap in the load path that will limit the ability of the walls to resist lateral forces.

In some cases, these panels are not intended to be part of the lateral force resisting system. In this case the evaluation should be limited to the anchorage forces and connections for the panels to prevent falling hazards. Consideration should be given to the ability of the connections to resist the deformations imposed by building movements.

If the connection is non-existent, mitigation with elements or connections needed to anchor the vertical elements to the foundation is necessary to achieve the selected performance level.

4.6.3.9 WOOD SILL BOLTS: Sill bolts shall be spaced at 6 ft. or less for Life Safety and 4 ft. or less for Immediate Occupancy, with proper edge distance provided for wood and concrete.

Tier 2 Evaluation Procedure: The adequacy of the existing bolts for the lateral forces in Section 4.2 shall be evaluated. Reduced capacities shall be used when proper edge distance has not been provided.

Commentary:

The absence of an adequate connection between the wood sills and the foundation is a gap in the load path that will limit the ability of the shear walls to resist lateral forces. Structures may slide off foundation supports.

Sill bolt spacing has been limited in moderate and high seismic zones to limit the demand on individual bolts. Compliance can be demonstrated if the existing bolts are adequate to resist the demands in the building being evaluated.

4.6.3.10 LATERAL LOAD PATH AT PILE CAPS: Pile caps shall have top reinforcement and piles shall be anchored to the pile caps for Life Safety, and the pile cap reinforcement and pile anchorage shall be able to develop the tensile capacity of the piles for Immediate Occupancy.

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The axial forces due to overturning and shear demands at the pile cap shall be calculated and the adequacy of the pile cap reinforcement and pile connections to transfer uplift forces to the piles shall be evaluated.

Commentary:

Pile foundations may have been designed considering downward gravity loads only. A potential problem is a lack of top reinforcement in the pile cap and a lack of a positive connection between the piles and the pile cap. The piles may be socketed into the cap without any connection to resist tension.

Seismic forces may induce uplift at the foundation which must be delivered into the piles for overturning stability. The absence of top reinforcement means the pile cap cannot distribute the uplift forces to the piles. The absence of pile tension connections means that the forces cannot be transferred to the piles.

4.6.4 Interconnection of Elements

4.6.4.1 GIRDER/COLUMN CONNECTION:

There shall be a positive connection between the girder and the column support.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for connections in non-compliance.

Commentary:

The absence of a substantial connection between the girders and supporting columns may allow the girders to slide off of bearing supports as the structure drifts in an earthquake.

Mitigation with elements or connections needed to connect the girders and columns is necessary to achieve the selected performance level.

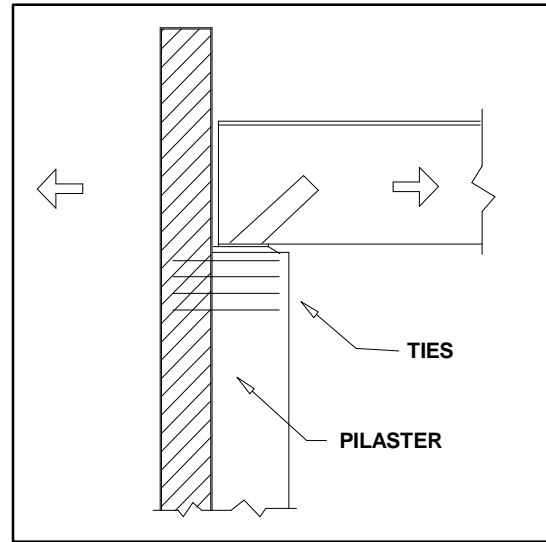


Figure 4-41. Girder Anchorage

4.6.4.3 CORBEL BEARING: If the frame girders bear on column corbels, the length of bearing shall be greater than 3" for Life Safety and for Immediate Occupancy.

Tier 2 Evaluation Procedure: The interstory drift shall be calculated using the procedures in Section 4.2. The bearing length shall be sufficient to provide support for the girders at maximum drift. The adequacy of the bearing support for all loads, including any additional eccentricity at maximum drift, shall be evaluated.

Commentary:

If drifts are sufficiently large, girders can slide off bearing supports without adequate length. At maximum drift, the bearing support may experience additional eccentricity not considered in the design. The support should be evaluated for strength at this extreme condition.

4.6.4.2 GIRDERS: Girders supported by walls or pilasters shall have at least two additional ties to secure the anchor bolts for Life Safety and Immediate Occupancy.

Tier 2 Evaluation Procedure: A determination shall be made as to whether or not the girder connection at the pilaster will be required to resist wall out-of-plane forces. The adequacy of the connection to resist the forces in Section 4.2 without damage shall be evaluated.

Commentary:

Girders supported on wall pilasters may be required to resist wall out-of-plane forces. Without adequate confinement, anchor bolts may pull out of the pilaster (see Figure 4-41). The potential for the pilaster to spall can lead to reduced bearing area or loss of bearing support for the girder.

4.6.4.4 CORBEL CONNECTIONS: The frame girders shall not be connected to corbels with welded elements.

Tier 2 Evaluation Procedure: The force in the welded connections induced by interstory drift shall be calculated. The adequacy of the connections to resist these forces shall be evaluated. Calculated overstresses in these connections shall not jeopardize the vertical support of the girders or the lateral-force-resisting system.

Commentary:

Precast elements that are interconnected at the supports may develop unintended frame action and attract seismic forces. The concern is that the welded connections are unable to develop the strength of the members and will be subject to sudden non-ductile failure, possibly leading to partial collapse of the floor or roof.

Connections may be in compliance if failure of the connection will not jeopardize the vertical support of the girder.

Panels not intended to be a part of the diaphragm represent a potential falling hazard if not positively attached to the framing. In this case the evaluation should be limited to the anchorage forces and connections of the panels. Consideration should be given to the ability of the connections to resist the deformations imposed by building movements.

If the connection is non-existent, mitigation with elements or connections needed to attach the roof panels is necessary to achieve the selected performance level.

4.6.5.2 WALL PANELS: Metal, fiberglass or cementitious wall panels shall be positively attached to the framing to resist seismic forces for Life Safety and the attachment shall be able to develop the strength of the panels for Immediate Occupancy

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The wall panel demands shall be calculated and the adequacy of the wall panels to transfer the demands to the framing shall be evaluated.

4.6.5 Panel Connections

4.6.5.1 ROOF PANELS: Metal, plastic, or cementitious roof panels shall be positively attached to the roof framing to resist seismic forces for Life Safety and the attachment shall be able to develop the strength of the panels for Immediate Occupancy

Tier 2 Evaluation Procedure: An analysis in accordance with Section 4.2 shall be performed. The roof panel demands shall be calculated and the adequacy of the wall panels to transfer the demands to the roof framing shall be evaluated.

Commentary:

The absence of a positive connection between metal, fiberglass or cementitious panels and the roof framing is a gap in the load path that will limit the ability of the panels to act as a diaphragm.

Commentary:

The absence of a positive connection between metal, fiberglass or cementitious panels and the framing is a gap in the load path that will limit the ability of the panels to resist seismic forces.

Panels not intended to be a part of the lateral force resisting system represent a potential falling hazard if not positively attached to the framing. In this case the evaluation should be limited to the anchorage forces and connections of the panels. Consideration should be given to the ability of the connections to resist the deformations imposed by building movements.

If the connection is non-existent, mitigation with elements or connections needed to attach the panels is necessary to achieve the selected performance level.

4.6.5.3 ROOF PANEL CONNECTIONS: Roof panel connections shall be spaced at or less than 12" for Life Safety and 8" for Immediate Occupancy

Tier 2 Evaluation Procedure: The adequacy of the existing connections for the lateral forces in Section 4.2 shall be evaluated.

Commentary:

An insufficient number of connections between the panels and the framing will reduce the capacity of the panels to act as a diaphragm.

4.7 Procedures for Geologic Site Hazards and Foundations

This section provides Tier 2 evaluation procedures that apply to foundations and supporting soils: geologic site hazards, condition of foundations and capacity of foundations.

Commentary:

A thorough seismic evaluation of an existing building should include an examination of the foundation, an assessment of the capability of the soil beneath the foundation to withstand the forces applied during an earthquake, and consideration of nearby geologic hazards that may affect the stability of the building during an earthquake.

To fully assess the potential hazard presented by local geologic site conditions, and to establish soil engineering parameters required for analysis of these hazards, it may be necessary to consult with a geotechnical design professional. The evaluating design professional is strongly urged to seek consultation with appropriate professionals whenever site conditions are beyond the experience or expertise of the design professional.

4.7.1 Geologic Site Hazards

Commentary:

Certain geologic and local site conditions can lead to structural damage in the event of an earthquake. Large foundation movements due to any number of causes can severely damage otherwise seismic resistant building. Potential causes of significant foundation movement include settlement or lateral spreading due to liquefaction, slope failure, or surface ruptures. An evaluation of the building should include consideration for these effects and the impact they might have on the superstructure.

4.7.1.1 LIQUEFACTION: Liquefaction susceptible, saturated, loose granular soils that could jeopardize the building's seismic performance shall not exist in the foundation soils at depths within 50 feet under the building for Life Safety and Immediate Occupancy.

Tier 2 Evaluation Procedure: The potential for liquefaction and magnitude of differential settlement shall be evaluated. An analysis of the building in accordance with the procedures in Section 4.2 shall be performed. The adequacy of the structure shall be evaluated for all gravity and seismic forces in combination with the forces induced by the potential differential movement in the foundation.

Commentary:

Soils susceptible to liquefaction may lose all vertical load bearing capacity during an earthquake. Loss of vertical support for the foundation will cause large differential settlements and induce large forces in the building superstructure.

These forces will be concurrent with all existing gravity loads and seismic forces during the earthquake.

4.7.1.2 SLOPE FAILURE: The building site shall be sufficiently remote from potential earthquake-induced slope failures or rockfalls to be unaffected by such failures or shall be capable of accommodating any predicted movements without failure.

Tier 2 Evaluation Procedure: The potential magnitude of differential movement in the foundation shall be evaluated. An analysis of the building in accordance with the procedures in Section 4.2 shall be performed. The adequacy of the structure shall be evaluated for all gravity and seismic forces in combination with the forces induced by the potential differential movement in the foundation.

Commentary:

Steep slopes are susceptible to slides during an earthquake. Slope failures are possible in rock or other on non-liquefiable soils on slopes that normally exceed 6 percent. Slopes that exhibit signs of prior landslides require the most attention.

The concern for buildings on the uphill side of slopes is lateral spreading of the downhill footings. The concern for buildings on the downhill side is impact by sliding soil and debris.

4.7.1.3 SURFACE FAULT RUPTURE: Surface fault rupture and surface displacement at the building site is not anticipated.

Tier 2 Evaluation Procedure: The proximity of the building to known active faults shall be determined. The potential for surface fault rupture and magnitude of rupture shall be determined. An analysis of the building in accordance with the procedures in Section 4.2 shall be performed. The adequacy of the structure shall be evaluated for all gravity and seismic forces in combination with the forces induced by the potential

Commentary:

In the near field of active faults there is a potential for large fissures and differential movement to occur in the surface soils. Foundations of buildings located above these ruptures will be subjected to large differential movements that will induce large forces in the building superstructure.

These forces will be concurrent with all existing gravity loads and seismic forces during the earthquake.

differential movement in the foundation.

4.7.2 Conditions of Foundations

Commentary:

Foundation elements are usually below grade and concealed from view. Evaluations, however, should still include consideration of the foundation and the condition of the elements. Often signs of foundation performance are visible on the surface in the form of existing differential settlement, sloping floors, out-of-plumb walls, and cracking or distress in visible portions of the footings.

4.7.2.1 FOUNDATION PERFORMANCE: There shall be no evidence of excessive foundation movement such as settlement or heave that would affect the integrity or strength of the structure.

Tier 2 Evaluation Procedure: The magnitude of differential movement in the foundation shall be evaluated. An analysis of the building in accordance with the procedures in Section 4.2 shall be performed. The adequacy of the structure shall be evaluated for all gravity and seismic forces in combination with the forces induced by the potential differential movement in the foundation.

Commentary:

The integrity and strength of foundation elements may be reduced by cracking, yielding, tipping, or buckling of the foundation. Such weakening may be critical in the event of an earthquake.

Lower level walls, partitions, grade beams, visible footings, pile caps, and similar elements shall be visually examined for cracking, yielding, buckling, and out-of-level conditions. Any such signs should be identified and further evaluated.

4.7.2.2 DETERIORATION: There shall not be evidence that foundation elements have deteriorated due to corrosion, sulphate attack, material breakdown, or other reasons in a manner that would affect the integrity or strength of the structure.

Tier 2 Evaluation Procedure: The cause and extent of deterioration shall be identified. The consequences of this damage to the lateral-force-resisting system shall be determined. The adequacy of damaged lateral-force-resisting elements shall be evaluated considering the extent of the damage and impact on the capacity of each damaged element.

Commentary:

Deterioration can cause weakening of the foundation elements, limiting their ability to support the building. Historical records of foundation performance in the local area may help assess the possibility of deterioration in the foundation of the building being evaluated.

4.7.3 Capacity of Foundations

Commentary:

Building foundation elements normally have a capacity at least two times the gravity loads. If there are no signs of foundation distress due to settlement, erosion, corrosion or other reasons, the foundations are likely to have adequate vertical capacity if the total gravity and seismic overturning loads do not exceed the allowable static capacity by more than a factor of two.

Foundations are considered to have adequate lateral capacity for seismic resistance if the allowable horizontal capacity of the foundation system exceeds the calculated seismic base shear of the buildings.

When the evaluation of foundation elements indicates significant problems, the evaluating design professional should consult with a qualified geotechnical design professional to establish rational criteria for foundation analysis and mitigation of unsatisfactory conditions.

4.7.3.1 POLE FOUNDATIONS: Pole foundations shall have minimum embedment of 4 ft. for Life Safety and Immediate Occupancy.

Tier 2 Evaluation Procedure: The lateral force resistance of embedded poles shall be checked using conventional procedures; the lateral force resistance shall be compared with conventional allowable pressures times 1.5.

Commentary:

Pole buildings are structures supported by poles or posts, usually found on rocky and hillside sites. Seismic resistance for a pole structure depends on the embedment depth of the poles and the resistance to active and passive soil pressures.

4.7.3.2 OVERTURNING: The ratio of the effective horizontal dimension, at the foundation level of the lateral-force-resisting system, to the building height (base/height) shall be greater than $0.6S_a$.

Tier 2 Evaluation Procedure: An analysis in accordance with the procedures in Section 4.2 shall be performed. The adequacy of the foundation including all gravity and seismic overturning forces shall be evaluated.

Commentary:

The concentration of seismic overturning forces in foundation elements may exceed the capacity of the soil, the foundation structure, or both.

For shallow foundations, the shear and moment capacity of the foundation elements should be evaluated for adequacy to resist calculated seismic forces. The vertical bearing pressure of the soil under seismic loading conditions due to the total gravity and overturning loads should be calculated and compared to two times the allowable static bearing pressure. For deep foundations, the ultimate vertical capacity of the pile or pier under seismic loads should be determined. The foundation capacity shall then be compared to the demands due to gravity loads plus overturning.

4.7.3.3 TIES BETWEEN FOUNDATION

ELEMENTS: The foundation shall have ties adequate to resist seismic forces where footings, piles, and piers are not restrained by beams, slabs, or soils classified as Class A, B, or C.

Tier 2 Evaluation Procedure: The magnitude of differential movement in the foundation shall be determined. An analysis of the building in accordance with the procedures in Section 4.2 shall be performed. The adequacy of the structure shall be evaluated for all gravity and seismic forces in combination with the forces induced by the potential differential movement in the foundation.

Commentary:

Ties between discrete foundation elements, such as pile caps and pole footings, are required when the seismic ground motions are likely to cause significant lateral spreading of the foundations. Ties may consist of tie beams, grade beams or slabs. If the foundations are restrained laterally by competent soils or rock, ties are not required.

4.7.3.4 DEEP FOUNDATIONS: Piles and piers shall be capable of transferring the lateral forces between the structure and the soil. This statement shall apply to the Immediate Occupancy Performance Level Only. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: The lateral capacity of the piles, as governed by the soil or pile construction, shall be determined. An analysis of the building in accordance with the procedures in Section 4.2 shall be performed. The adequacy of the piles shall be evaluated for all gravity and seismic forces.

Commentary:

Common problems include flexural strength and ductility of the upper portions of piles or piers, or at the connection to the cap. Distinct changes in soil stiffness can create high bending stresses along the length of the pile.

For concrete piles, the design professional should check for a minimal amount of longitudinal reinforcement in the upper portion of piles or piers, and for hoops or ties immediately beneath the caps. The design professional should also check for confining transverse reinforcement wherever bending moments might be high along the length of the pile, including changes in soil stiffness.

4.7.3.5 SLOPING SITES: The grade difference from one side of the building to another shall not exceed one-half the story height at the location of embedment. This statement shall apply to the Immediate Occupancy Performance Level Only.

Tier 2 Evaluation Procedure: An analysis of the building in accordance with the procedures in Section 4.2 shall be performed. The adequacy of the foundation to resist sliding shall be evaluated including the horizontal force due to the grade difference.

Commentary:

The transfer of seismic force is more difficult when a permanent horizontal force is present.

4.8 Procedures for Nonstructural Components

This section provides Tier 2 Evaluation Procedures that apply to nonstructural components.

Commentary:

Nonstructural Components

"Nonstructural" is the name given by design professionals to those architectural, mechanical and electrical components that are delineated on the construction documents, and where additional guidance may be requested from another design professional with expertise in the design of structural components.

Investigation of nonstructural components can be very time consuming because they usually are not well detailed on plans and because they often are concealed. It is essential, however, to investigate these items because their seismic support may have been given little attention in the past and they are potentially dangerous. Of particular importance in nonstructural component evaluation efforts are site visits to identify the present status of nonstructural items.

For nonstructural component evaluation in general, the key issue is generally whether the component or piece of equipment is braced or anchored. This is generally immediately visible, and is part of the Tier 1 evaluation. If the component is braced or anchored a Tier 2 evaluation may be necessary (based on the design professional's judgment) to establish the capacity of the components. Evaluation of cladding, exterior veneers, back-up materials and glazing requires more careful investigation, because the critical components, such as connections and framing, will often be concealed. In some cases it will be necessary to remove materials in order to conduct the evaluation. In addition, some calculations may be necessary to establish capacity to accommodate estimated seismic forces.

Several different types of deficiencies may be identified by the design professional in the Tier 1

evaluation. Some of these, such as the non existence of anchorage or bracing are clearly non-complying and any further evaluation is not necessary. In other cases, where some bracing or anchorage is provided, or material is deteriorated or corroded, further evaluation and judgment is necessary to ascertain the extent of the deficiency and the consequences of failure. Some simple calculations of weights, dimensional ratios and forces are used in this Tier of evaluation. A few critical components, such as heavy cladding, may justify a complete analysis (a Tier 3 evaluation) for ability to withstand forces and drifts and achievement of the desired performance level

Hazards

Nonstructural elements can pose significant hazards to life safety under certain circumstances. In addition, certain types of building contents can pose hazards (e.g., toxic chemicals) and should be given attention during the evaluation. Special consideration also is warranted for nonstructural elements in essential facilities (e.g., hospitals, police and fire stations) and other facilities that must remain operational after an earthquake.

Unintended Structural Effects

Any element with rigidity will be a part of the lateral-force resisting system until it fails. All walls have some rigidity, and they will participate in resisting lateral forces in proportion to their relative rigidity. Walls of gypsum board or plaster have considerable rigidity. If connected at top and bottom, they can take a significant portion of the lateral load at low force levels; at some higher level they crack and lose strength and the main system then takes all of the lateral load.

4.8.1 Partitions

4.8.1.1 UNREINFORCED MASONRY:

Unreinforced masonry or hollow clay tile partitions shall be braced at a spacing of equal to or less than 10 feet in regions of low and moderate seismicity and 6 feet in regions of high seismicity.

Tier 2 Evaluation Procedure: The adequacy of the bracing to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Hollow clay tile units are brittle and subject to shattering. Unreinforced masonry units may have cracks, loose blocks, or weak mortar. Bracing is needed to prevent portions of the unreinforced masonry from dislodging due to out-of-plane seismic forces. Door openings often create localized weaknesses due to inadequate support for the block masonry or clay tile at the head and at the sides of the opening.

If bracing is non-existent, mitigation with elements or connections needed to brace the partitions is necessary to achieve the selected performance level.

4.8.1.2 DRIFT: The drift ratio for masonry partitions shall be limited to 0.005.

Second Tier 2 Evaluation Procedure: The adequacy of masonry partitions to resist expected levels of drift calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Full-height partitions may fail due to lack of provision for building drift. Masonry partitions should be detailed to provide adequate space for the structure to drift without racking the masonry walls, while retaining out-of-plane support. In addition, if not separated from the structure at the top and sides, the masonry walls may alter the response of the building.

4.8.1.3 STRUCTURAL SEPARATIONS:

Partitions at structural separations shall have seismic or control joints.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for partitions at structural separations without seismic or control joints.

Commentary:

Seismic and control joints are necessary to permit differential structural movement at building separations. If localized cracking of the partition will not lead to out-of-plane failure of the wall, the costs of a difficult rehabilitation process may not be justified.

4.8.1.4 TOPS: The tops of framed or panelized partitions that extend only to the ceiling line shall have lateral bracing to the building structure at a spacing of equal to or less than 6 feet.

Tier 2 Evaluation Procedure: The adequacy of the lateral bracing to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Partitions extending only to suspended ceilings may fall out-of-plane due to lack of bracing. Movement of the partition may damage the ceiling. Crosswalls that may frame into the wall will have a beneficial impact on preventing excessive out-of-plane movement and should be considered in the evaluation process.

If lateral bracing is non-existent, mitigation with elements or connections needed to brace the partitions is necessary to achieve the selected performance level.

4.8.2 Ceiling Systems

4.8.2.1 INTEGRATED CEILINGS: Integrated suspended ceilings at exitways and corridors or weighing more than 2 lb/ft² shall be laterally restrained with a minimum of 4 diagonal wires or rigid members attached to the structure above at a spacing of equal to or less than 12 ft.

Tier 2 Evaluation Procedure: The adequacy of the bracing to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Without bracing, integrated ceiling systems are susceptible to vertical and lateral movement which can damage fire sprinkler piping and other elements that penetrate the ceiling grid. Lightweight suspended ceilings may not pose a life safety hazard unless special conditions apply in the judgment of the design professional, such as a large area of ceiling, poor quality construction, vulnerable occupancy, or egress route.

If bracing is non-existent, mitigation with elements or connections needed to brace the ceilings is necessary to achieve the selected performance level.

4.8.2.2 LAY-IN TILES: Lay-in tiles used in ceiling panels located at exitways and corridors shall be secured with clips.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for non-compliant lay-in tiles.

Commentary:

Lay-in board or tile ceilings may drop out of the grid and depending on their location and weight could cause injury. In egress areas, falling tile represents a hazard because it may pile up on the floor and slow evacuations. Clips can reduce the likelihood of tiles falling, but depending on the type of ceiling, the likelihood of failure may vary; the design professional should use judgment in assessing the risk.

4.8.2.3 SUPPORT: The integrated suspended ceiling system shall not be used to laterally support the tops of gypsum board, masonry, or hollow clay tile partitions.

Tier 2 Evaluation Procedure: The adequacy of integrated ceiling systems used to laterally support the tops of gypsum board, masonry, or hollow clay tile partitions to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Integrated suspended ceilings braced with diagonal wires will move laterally when subjected to seismic forces. The ability of the gypsum board, masonry or hollow clay tile partitions to accommodate such movement without collapse should be considered by the design professional.

4.8.2.4 SUSPENDED LATH AND PLASTER: Ceilings consisting of suspended lath and plaster shall be anchored for every 10 square feet of area.

Tier 2 Evaluation Procedure: The adequacy of the anchorage to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Suspended plaster ceilings may behave like structural diaphragms and resist in-plane seismic forces. If the strength of the plaster is exceeded, cracking and spalling of portions of the ceiling are possible. Large areas of suspended plaster may separate from the suspension system and fall if not properly fastened. The interconnection of the plaster to the lath and lath to the support framing should also be specifically assessed.

If anchorage is non-existent, mitigation with elements or connections needed to brace the ceilings is necessary to achieve the selected performance level.

4.8.2.5 EDGES: The edges of integrated suspended ceilings shall be separated from enclosing walls by a minimum of 1/2 inch.

Tier 2 Evaluation Procedure: The adequacy of integrated suspended ceilings to resist expected levels of drift calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

This provision relates especially to large suspended grid ceilings, but may also apply to other forms of hung ceilings. The intent is to ensure that the ceiling is sufficiently detached from the surrounding structural walls that it can tolerate out-of-plane drift without suffering distortion and damage.

4.8.2.6 SEISMIC JOINT: The ceiling system shall not extend continuously across any seismic joint.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for ceiling systems that extend continuously across any seismic joint.

Commentary:

Localized damage to ceilings is expected where seismic separations are not provided in the ceiling framing. Seismic or control joints should be provided based on a consideration of the consequences of local ceiling damage. If the damage is unlikely to create a falling hazard or prevent safe egress, the costs of a difficult rehabilitation process may not be justified.

4.8.3 Light Fixtures

4.8.3.1 INDEPENDENT SUPPORT: Light fixtures in suspended grid ceilings shall be supported independently of the ceiling suspension system by a minimum of two wires at diagonally opposite corners of the fixtures.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for light fixtures not independently supported.

Commentary:

With lay-in fluorescent lighting systems, ceiling movement can cause fixtures to separate and fall from suspension systems. These fixtures perform satisfactorily when they are supported separately from the ceiling system or have back-up support that is independent of the ceiling system. If the fixtures are independently supported by methods other than that described, design professional should exercise judgment as to its efficacy.

If independent support is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.3.2 EMERGENCY LIGHTING: Emergency lighting shall be anchored or braced to prevent falling or swaying during an earthquake.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for emergency lighting that is not braced or anchored.

Commentary:

Emergency lighting should be provided with positive anchorage and/or bracing to prevent falling hazards and to enhance the reliability of post-earthquake performance.

If bracing or anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.3.3 PENDANT SUPPORTS: Light fixtures on pendant supports shall be attached at a spacing of equal to or less than 6 ft. and, if rigidly supported, shall be free to move without damaging adjoining materials.

Tier 2 Evaluation Procedure: The adequacy of the anchorage to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

With stem-hung incandescent or fluorescent fixtures, the fixtures are usually suspended from stems or chains that allow them to sway. This swaying may cause the light and/or fixture to break after encountering other building components. The stem or chain connection may fail. Long rows of fluorescent fixtures placed end to end have sometimes fallen due to poor support, and their weight makes them hazardous. Long-stem fixtures, which may swing considerably, tend to suffer more damage than short-stem items.

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.3.4 LENS COVERS: Lens covers on fluorescent light fixtures shall be attached or shall be supplied with safety devices.

Tier 2 Evaluation Procedure: The adequacy of lens covers on fluorescent light fixtures to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Devices or detailing to prevent lens covers from falling from the fixture are a necessary safety feature.

4.8.4 Cladding and Glazing

4.8.4.1 CLADDING ANCHORS: Cladding components weighing more than 10 psf shall be anchored to the exterior wall framing at a spacing equal to or less than 6 ft. for Life Safety and 4 ft. for Immediate Occupancy.

Tier 2 Evaluation Procedure: The adequacy of the anchorage to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated. The adequacy of cladding components to resist expected levels of drift calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Exterior cladding components, which are often heavy, can fail if their connections to the building frames have insufficient strength and/or ductility. The design professional should assess the consequences of failure, in particular the location of the panels in relation to building occupants and passers-by.

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.4.2 CLADDING ISOLATION: For moment frame buildings of steel or concrete, panel connections shall be detailed to accommodate a drift ratio of 0.02 for Life Safety and 0.01 for Immediate Occupancy.

Tier 2 Evaluation Procedure: The adequacy of panel connections to resist expected levels of drift calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

High levels of drift and deformation may occur in moment frames. If cladding connections are not detailed to accommodate the drift, failure of connections can result and panels can become dislodged.

4.8.4.3 MULTISTORY PANELS: For multistory panels attached at each floor level, the panels and connections shall be able to accommodate a drift ratio of 0.02 for Life Safety and 0.01 for Immediate Occupancy.

Tier 2 Evaluation Procedure: The adequacy of the panels and connections to resist expected levels of drift calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

The design professional should determine whether the panels themselves and/or their connections to the structure will deform to accommodate the interstory drift. If the connectors are expected to deform, they should be capable of doing so without loss of structural support for the panel. If the panels are expected to rack, they should be capable of deforming without becoming unstable and without loss of support for other interconnected systems such as glazing.

4.8.4.4 BEARING CONNECTIONS: Where bearing connections are required, there shall be a minimum of two bearing connections for each wall panel.

Tier 2 Evaluation Procedure: The adequacy of the connection to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

A single bearing connection can result in a dangerous lack of redundancy. The adequacy of single point bearing connections should be evaluated for resistance to in-plane overturning forces including all eccentricities. Small panels such as some column covers may have a single bearing connection, and still provide adequate safety against failure.

If connections are non-existent, mitigation is necessary to achieve the selected performance level.

4.8.4.5 INSERTS: Where inserts are used in concrete connections, the inserts shall be anchored to reinforcing steel.

Tier 2 Evaluation Procedure: The adequacy of inserts used in concrete connections to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Out-of-plane panel connections which do not engage panel reinforcement are susceptible to pulling out when subjected to seismic forces.

4.8.4.6 PANEL CONNECTIONS: Exterior cladding panels shall be anchored out-of-plane with a minimum of 2 connections for each wall panel for Life Safety and 4 connections for Immediate Occupancy.

Tier 2 Evaluation Procedure: The adequacy of the connections to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

A minimum of two connections are generally required for stability in resisting out-of-plane earthquake forces. Evaluation of connection adequacy should include consideration of all connection eccentricities.

If connections are non-existent, mitigation is necessary to achieve the selected performance level.

4.8.4.7 DETERIORATION: There shall be no evidence of deterioration or corroding in any of the connection elements.

Tier 2 Evaluation Procedure: The adequacy of the remaining undeteriorated or undamaged connections to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Corrosion can reduce the strength of connections and lead to deterioration of the adjoining materials. The extent of corrosion and its impact on the wall cladding and structure should be considered in the evaluation.

4.8.4.8 DAMAGE: There shall be no damage to exterior wall cladding.

Tier 2 Evaluation Procedure: The extent and consequences of damage to exterior wall cladding shall be evaluated.

Commentary:

Water leakage into and through exterior walls is a common building problem. Damage due to corrosion, rotting, freezing, or erosion can be concealed in wall spaces. Substantial deterioration can lead to loss of cladding elements or panels.

Exterior walls should be checked for deterioration. Probe into wall spaces if necessary and look for signs of water leakage at vulnerable locations (e.g., at windows and at floor areas). Pay particular attention to element that tie cladding to the back-up structure and that tie the back-up structure to the floor and roof slabs.

Extremes of temperature can cause substantial structural damage to exterior walls. The resulting weakness may be brought out in a seismic event. Check exterior walls for cracking due to thermal movements.

4.8.4.9 GLAZING: Glazing in curtain walls and individual panes over 16 square feet in area, located up to a height of 10 feet above an exterior walking surface, shall be laminated annealed or heat strengthened safety glass that will remain in the frame when cracked.

Tier 2 Evaluation Procedure: Glazing in curtain walls and individual panes over 16 square feet in area shall be shown by analysis or dynamic racking testing to be detailed to accommodate expected levels of drift calculated in accordance with Section 4.2.7.

Commentary:

Glazing may shatter and fall due to lack of provision for building drift or racking. If it is safety glazing with racking capability it may shatter or crack in a manner that is unlikely to cause injury, and it may remain in the frame to provide a temporary weather barrier. Glass generally fails in earthquakes because of deformation of the frame and lack of space between the glass and frame to allow for independent movement. Special attention should be given to glazing over or close to entrance and exitways.

4.8.5 Masonry Veneer

4.8.5.1 SHELF ANGLES: Masonry veneer shall be supported by shelf angles or other elements at each floor above the first floor.

Tier 2 Evaluation Procedure: The adequacy of masonry veneer anchors to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Inadequately fastened masonry veneer can pose a falling hazard if it peels away from its backing. Judgment may be needed to assess the adequacy of various attachments that may be used.

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.5.2 TIES: Masonry veneer shall be connected to the back-up with corrosion-resistant ties. The ties shall have a spacing of equal to or less than 36" for Life Safety and 24" for Immediate Occupancy with a minimum of one tie for every 2-2/3 square feet

Tier 2 Evaluation Procedure: The adequacy of the masonry veneer ties to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

4.8.5.3 WEAKENED PLANES: Masonry veneer

Commentary:

Inadequately fastened masonry veneer can pose a falling hazard if it peels away from its backing. Judgment may be needed to assess the adequacy of various attachments that may be used.

If ties are non-existent, mitigation is necessary to achieve the selected performance level.

shall be anchored to the back-up at weakened planes such as at the locations of flashing.

Tier 2 Evaluation Procedure: The adequacy of masonry veneer anchors at weakened planes created by flashing or other discontinuities shall be evaluated. Anchors shall be evaluated for resistance to seismic forces calculated in accordance with Section 4.2.7.

Commentary:

Inadequate attachment at locations of wall discontinuities is a potential source of weakness. Such discontinuities can be created by base flashing or architectural reveals. In areas of high seismicity, masonry veneer should be anchored to the back-up system immediately above the weakened plane..

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.5.4 MORTAR: The mortar in masonry veneer shall not be easily scraped away from the joints by hand with a metal tool, and there shall not be significant areas of eroded mortar.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for non-compliant mortar.

Commentary:

Inadequate mortar will affect the veneer's ability to withstand seismic motions and maintain attachment to the back-up system.

If mortar is non-compliant, mitigation is necessary to achieve the selected performance level.

4.8.5.5 WEEP HOLES: Weep holes shall be present and base flashing shall be installed.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for non-compliant weep holes.

Commentary:

Absence of weep holes and flashing indicates an inadequately detailed veneer. Water intrusion can lead to deterioration of the veneer and/or substrate. Destructive investigation may be needed to evaluate whether deterioration has taken place and mitigation is necessary.

If weep holes are non-compliant, mitigation is necessary to achieve the selected performance level.

4.8.5.6 CORROSION: Corrosion of veneer ties, tie screws, studs, and stud tracks shall be minimal.

Tier 2 Evaluation Procedure: The calculated tensile stresses in the veneer shall not exceed the allowable stresses for unreinforced brick as defined by ACI 530. Seismic forces shall be calculated in accordance with Section 4.2.7.

Commentary:

Corroded connections are a both a general and a seismic hazard that can cause veneer to become dislodged.

4.8.5.7 STONE PANELS: Stone panels less than 2 inches nominal thickness shall be anchored every 2 square feet of area.

Tier 2 Evaluation Procedure: The adequacy of stone panel anchors to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Stone panels are relatively heavy and may become dislodged during an earthquake if not adequately anchored.

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.5.8 CRACKS: There shall be no visible cracks or weak veins in the stone.

Tier 2 Evaluation Procedure: The extent and consequences of visible cracking shall be evaluated.

Commentary:

Cracking in the panel, depending on the material, may be due to weathering, or to stresses imposed by movement of the structure or connection system. Severely cracked panels will probably require replacement.

4.8.6 Metal Stud Back-up Systems

4.8.6.1 STUD TRACKS: Stud tracks shall be fastened to the structural frame at a spacing of equal to or less than 24 inches on center.

Tier 2 Evaluation Procedure: The adequacy of stud track fasteners to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Without proper anchorage at top and bottom tracks, metal stud back-up systems are susceptible to excessive movement during an earthquake.

If fasteners are non-existent, mitigation is necessary to achieve the selected performance level.

4.8.6.2 OPENINGS: Additional steel studs shall frame window and door openings.

Tier 2 Evaluation Procedure: The adequacy of window and door framing shall be evaluated.

Commentary:

This issue is primarily one of the general framing system of the building. Absence of adequate framing around openings indicates a possible out-of-plane weakness in the framing system.

4.8.7 Concrete Block and Masonry Back-up Systems

4.8.7.1 CONCRETE BLOCK: Concrete block back-up shall qualify as reinforced masonry.

Tier 2 Evaluation Procedure: The ability of concrete block back-up that does not qualify as reinforced masonry to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

To qualify as reinforced masonry, the reinforcing steel shall be greater than 0.002 times the gross area of the wall with a minimum of 0.0007 in either of the two directions; the spacing of reinforcing steel shall be less than 48 inches; and all vertical bars shall extend to the top of the back-up walls.

Judgment by the design professional must be used to evaluate the adequacy of concrete block walls not classified as "reinforced". Concrete block walls lacking the minimum reinforcement may be susceptible to excessive in-plane cracking under seismic loads and portions of the wall may become dislodged.

4.8.7.2 BACK-UP: Concrete block back-up shall be anchored to the structural frame at a spacing of equal to or less than 4 feet along the floors and roof.

Tier 2 Evaluation Procedure: The adequacy of the concrete block back-up to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

4.8.7.3 URM BACK-UP: There shall not be any

Commentary:

Inadequate anchorage of the back-up wall may affect the whole assembly's ability to withstand seismic motions and maintain attachment to back-up.

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

unreinforced masonry back-up.

Tier 2 Evaluation Procedure: The adequacy of unreinforced masonry to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Unreinforced masonry back-up is common in early steel framed buildings with cut stone exteriors. The design professional should use judgment in evaluating the condition and integrity of the back-up and necessary remedial measures.

Complete replacement of back-up is extremely expensive: depending on the state of the installation and the facing materials; alternative methods may be possible.

4.8.8 Parapets, Cornices, Ornamentation and Appendages

4.8.8.1 URM PARAPETS: There shall be no laterally unsupported unreinforced masonry parapets or cornices above the highest anchorage level with height-to-thickness ratios greater than 1.5 in regions of high seismicity and 2.5 in regions of low or moderate seismicity.

Tier 2 Evaluation Procedure: The adequacy of the anchorage to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

URM parapets present a major falling hazard and potential life-safety threat.

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.8.2 CANOPIES: Canopies located at building exits shall be anchored at a spacing of 10 feet for Life Safety and 6 feet for Immediate Occupancy.

Tier 2 Evaluation Procedure: The adequacy of the anchorage to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Inadequately supported canopies present a life safety hazard. A common form of failure is pullout of shallow anchors from building walls.

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.8.3 CONCRETE PARAPETS: Concrete parapets with height-to-thickness ratios greater than 2.5 shall have vertical reinforcement.

Tier 2 Evaluation Procedure: The adequacy of the anchorage to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Inadequately reinforced parapets can be severely damaged during an earthquake.

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.8.4 APPENDAGES: Cornices, parapets, signs, and other appendages that extend above the highest anchorage level or cantilever from exterior wall faces and other exterior wall ornamentation shall be reinforced and anchored to the structural system at a spacing of equal to or less than 10 ft. for Life Safety and 6 ft. for Immediate Occupancy

Tier 2 Evaluation Procedure: The adequacy of the anchorages to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

The above components may vary greatly in size, location and attachment; the design professional should use judgment in their assessment. If any of these items are of insufficient strength and/or are not securely attached to the structural elements, they may break off and fall onto storefronts, streets, sidewalks, or adjacent property and become significant life-safety hazards.

If anchorages are non-existent, mitigation is necessary to achieve the selected performance level.

4.8.9 Masonry Chimneys

4.8.9.1 URM: No unreinforced masonry chimney shall extend above the roof surface more than twice the least dimension of the chimney.

Tier 2 Evaluation Procedure: The adequacy of the chimney anchorage to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Unreinforced masonry chimneys are highly vulnerable to damage in earthquakes. Typically, chimneys extending above the roof more than twice the least dimension of the chimney crack just above the roof line and become dislodged. Chimneys may fall through the roof or on a public or private walkway creating a life-safety hazard. Experience has shown that the costs of rehabilitating masonry chimneys can sometimes exceed the costs of damage repair.

4.8.9.2 MASONRY: Masonry chimneys shall be anchored to the floor and roof.

Tier 2 Evaluation Procedure: The adequacy of the anchorage to resist seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Refer to commentary associated with Section 4.8.9.1.

4.8.10 Stairs

4.8.10.1 URM WALLS: Walls around stair enclosures shall not consist of unbraced hollow clay tile or unreinforced masonry.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unbraced hollow clay tile or unreinforced masonry around stair enclosures.

Commentary:

Hollow tile or unreinforced masonry walls may fail and block stairs and corridors. Post-earthquake evacuation efforts can be severely hampered as a result.

If bracing is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.10.2 STAIR DETAILS: In moment frame structures, the connection between the stairs and the structure shall not rely on shallow anchors in concrete. Alternatively, the stair details shall be capable of accommodating the drift calculated using the Quick Check Procedure of Section 3.5.3.1 without inducing tension in the anchors.

Tier 2 Evaluation Procedure: The adequacy of stair connections shall be evaluated when subjected to interstory drifts calculated in accordance with Section 4.2.

Commentary:

If stairs are not specially detailed to accommodate interstory drift they can modify structural response by acting as struts attracting seismic force. The connection of the stair to the structure must be capable of resisting the imposed forces without loss of gravity support for the stair.

4.8.11 Building Contents and Furnishing

4.8.11.1 TALL NARROW CONTENTS: Contents with a height-to-depth ratio greater than 3 for Immediate Occupancy and 4 for Life Safety shall be anchored to the floor slab or adjacent walls.

Tier 2 Evaluation Procedure: The adequacy of tall, narrow contents to resist overturning due to seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

Tall, narrow storage or file cabinets or racks can tip over if they are not anchored to resist overturning forces.

4.8.11.2 FILE CABINETS: File cabinets arranged in groups shall be attached to one another.

Tier 2 Evaluation Procedure: The adequacy of file cabinets to resist overturning due to seismic forces calculated in accordance with Section 4.2.7 shall be evaluated.

Commentary:

File cabinets that are grouped together and attached can virtually eliminate the possibility of overturning; the attachment of these file cabinets to the floor then may not be necessary.

4.8.11.3 DRAWERS: Cabinet drawers shall have latches to keep them closed during an earthquake.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for non-compliant cabinet drawers.

Commentary:

Breakable items stored on shelves should be restrained from falling by latched doors, shelf lips, wires, or other methods. It may not be necessary for every drawer to have a safety latch.

4.8.11.4 COMPUTER ACCESS FLOORS:

Computer access floors shall be braced.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unbraced computer access floors.

Commentary:

Unbraced computer access floors can collapse onto the structural slab. Small areas of unbraced floors "captured" on all sides within full-height walls may be acceptable, however, the impact of ramps and or other access openings should be considered in evaluating the adequacy of such unbraced access floors.

If bracing is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.11.5 ACCESS FLOORS: Equipment supported on access floor systems shall be either attached to the structure or fastened to a laterally braced floor system.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unattached equipment supported on access floor systems.

Commentary:

Tall, narrow computers and communications equipment can overturn if not properly anchored. Where overturning is not a concern due to the aspect ratio of the equipment and it is desirable to provide some isolation between the equipment and the structure, it may be acceptable to support the equipment on a raised floor without positive restraint. In this case the consequences of equipment movement should be considered. Tethering or some other form of restraint may be appropriate for limiting the range of movement.

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.12 Mechanical and Electrical Equipment

4.8.12.1 EMERGENCY POWER: Equipment used as part of an emergency power system shall be anchored to maintain continued operation following an earthquake.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unanchored equipment used as part of an emergency power system.

Commentary:

Protection of the emergency power system is critical to post-earthquake recovery, and proper mounting of the components of the system is needed for reliable performance.

If anchorage is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.12.2 ATTACHED EQUIPMENT: Equipment weighing over 20 pounds that is attached to ceiling, wall, or other support more than 4 feet above the floor shall be braced.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unbraced equipment weighing over 20 pounds.

Commentary:

Equipment located more than 4 feet above the floor poses a falling hazard unless properly anchored and braced. Suspended equipment is more susceptible to damage than floor-, roof-, or wall-mounted equipment. Unbraced suspended equipment can sway during an earthquake causing damage upon impact with other adjacent items.

If bracing is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.12.3 HEAVY EQUIPMENT: Equipment weighing over 100 pounds shall be anchored to the structure or foundation.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unbraced equipment weighing over 100 pounds.

Commentary:

For rigidly mounted large equipment (e.g., boilers, chillers, tanks, generators), inadequate anchorage can lead to horizontal movement. Unanchored equipment, particularly equipment with high aspect ratios such as all tanks, may overturn and/or move and damage utility connections. Performance generally is good when positive attachment to the structure is provided.

If bracing is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.12.4 VIBRATION ISOLATORS: Equipment mounted on vibration isolators shall be equipped with restraints or snubbers.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for non-compliant equipment mounted on vibration isolators.

Commentary:

Many isolation devices for vibration isolated equipment (e.g., fans, pumps,) offer no restraint against lateral movement. As a result, earthquake forces can cause the equipment to fall off its isolators, usually damaging interconnected piping. Snubbers or other restraining devices are needed to prevent horizontal movement in all directions.

If restraints and snubbers are non-existent, mitigation is necessary to achieve the selected performance level.

4.8.12.5 ELECTRICAL EQUIPMENT: Electrical equipment shall be attached to the structural system.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unattached electrical equipment.

4.8.13 Piping

4.8.13.1 FIRE SUPPRESSION PIPING: Fire suppression piping shall be anchored and braced in accordance with NFPA-13 (NFPA, 1996).

Commentary:

Without proper connection to the structure electrical equipment can move horizontally and/or overturn. The movement can damage the equipment and may create a hazardous condition. Equipment may be mounted to the primary structural system or on walls or ceilings that are capable of resisting the applied loads. Distribution lines that cross structural separations should be investigated. If relative movement of two adjacent buildings can be accommodated by "slack" in the distribution lines, the condition may be acceptable.

If attachment is non-existent, mitigation is necessary to achieve the selected performance level.

Commentary:

Fire sprinkler piping has performed poorly in past earthquakes rendering systems unusable when most needed. Causes of fire sprinkler piping failure included: inadequate lateral bracing of sprinkler mains and cross-mains, inadequate flexibility and clearance around sprinkler piping, and impact between sprinkler pipes and other unbraced nonstructural elements. Proper pipe bracing is needed for reliable performance of the system.

NFPA-13 is intended to provide a life-safety level of performance. Where a higher performance is desired, careful design and detailing of all components of the system are needed.

If anchorage and bracing are non-existent, mitigation is necessary to achieve the selected performance level.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unbraced and unanchored fire suppression piping.

Commentary:

Failures may occur in pipes that cross seismic joints due to differential movement of the two adjacent structures. Special detailing is required to accommodate the movement. Flexibility can be provided by a variety of means including special couplings and pipe bends. Flexible couplings should be evaluated for their ability to accommodate expected seismic movements in *all* directions.

If flexible couplings are non-existent, mitigation is necessary to achieve the selected performance level.

Commentary:

Piping can fail at elbows, tees, and connections to supported equipment. The potential for failure is dependent upon the rigidity, ductility, and expansion or movement capability of the piping system. Joints may separate and hangers may fail. Hanger failures can cause progressive failure of other hangers or supports. Smaller diameter pipes, which generally have greater flexibility, often perform better than larger diameter pipes but they are still subject to damage at the joints. Piping in vertical runs typically performs better than in horizontal runs if it is regularly connected to a vertical shaft.

If anchorage and bracing are non-existent, mitigation is necessary to achieve the selected performance level.

4.8.13.2 FLEXIBLE COUPLINGS: Fluid, gas and fire suppression piping shall have flexible couplings to allow for building movement at seismic separations.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for fluid, gas and fire suppression piping without flexible couplings.

Commentary:

Post earthquake recovery efforts have been severely hampered in cases where damaged utility lines could not be expediently isolated from main distribution systems. Shut-off valves are needed to allow for isolation of a building or portions of a building. The valves should be easily accessible and training should be provided for reliable post-earthquake response.

If shut-off devices are non-existent, mitigation is necessary to achieve the selected performance level. The need for and location of shut-off devices should be established in cooperation with local utility companies. Utility companies vary in their policies regarding the installation of shut-off devices.

4.8.13.3 FLUID AND GAS PIPING: Fluid and gas piping shall be anchored and braced to the building structure in accordance with SP-58 (MSS, 1993).

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unbraced and unanchored fluid and gas piping.

Commentary:

C-clamps have proven to be unreliable during an earthquake. Pipe movement can cause the C-clamp to work itself off its support causing local loss of gravity support for the pipe. The loss of a single C-clamp can lead to progressive collapse of other supports.

If C-clamps are non-compliant, mitigation is necessary to achieve the selected performance level.

Commentary:

Large duct installations are heavy and can cause damage to other materials and may pose a hazard to occupants. Failures may occur in long runs due to large amplitude swaying. Failure usually consists of leakage rather than collapse.

When evaluating the ductwork, the function of the duct system, proximity to occupants, and other materials likely to be damaged should be considered.

If bracing is non-existent, mitigation is necessary to achieve the selected performance level.

4.8.13.4 SHUT-OFF VALVES: Shut-off devices shall be present at building utility interfaces to shut off the flow of gas and high temperature energy in the event of earthquake-induced failure.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for non-compliant shut-off devices.

Commentary:

Since these ducts are part of the fire protection system they are more critical than normal air conditioning ducts. Depending on the duct layout and function of the building, however, the hazard may vary greatly and judgment should be exercised during the evaluation.

If bracing or flexible connections are non-existent, mitigation is necessary to achieve the selected performance level.

Commentary:

Though generally undesirable, this condition is only serious when large ducts are supported by other elements that are poorly supported and braced.

4.8.13.5 C-CLAMPS: One-sided C-clamps that support major piping shall not be unrestrained.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for non-compliant C-clamps.

4.8.14 Ducts

4.8.14.1 DUCT BRACING: Rectangular ductwork exceeding 6 square feet in cross-sectional area, and round ducts exceeding 28" in diameter shall be

Commentary:

Unrestrained containers are susceptible to overturning and falling resulting in release of materials. Storage conditions should be evaluated in relation to the proximity to occupants, the nature of the substances involved and the possibility of a toxic condition.

If restraints are non-existent, mitigation is necessary to achieve the selected performance level.

braced. Maximum transverse bracing shall not exceed 40 feet for Life Safety and 30 feet for Immediate Occupancy. Maximum longitudinal bracing shall not exceed 80 feet for Life Safety and 60 feet for Immediate Occupancy. Intermediate supports shall not be considered part of the

Commentary:

Unrestrained gas cylinders are highly susceptible to overturning. Release and/or ignition of gas may result. Cylinders should be prevented from overturning by positive means.

If restraints are non-existent, mitigation is necessary to achieve the selected performance level.

lateral-force-resisting system.

Commentary:

Post-earthquake recovery efforts will be hampered if toxic releases can not be promptly stopped. Shut-off valves should be accessible and training should be provided to enhance the reliability of post-earthquake recovery efforts. The specifics of the materials and systems vary greatly. Federal, state and local codes will govern regarding the installation of shut-off devices.

If shut-off devices are non-existent, mitigation is necessary to achieve the selected performance level. The need for and location of shut-off devices should be established in cooperation with local utility companies. Utility companies vary in their policies regarding the installation of shut-off devices.

Tier 2 Evaluation Procedure: The adequacy of the bracing to resist seismic forces calculated in accordance with Section 4.2.7 in ductwork exceeding 28" in diameter shall be evaluated.

Commentary:

The successful performance of an elevator system requires that the various elements of the system remain in place, undamaged and capable of operating after inspection. As a minimum, all equipment, including hoistway doors, brackets, controllers, and motors must be anchored.

4.8.14.2 STAIR AND SMOKE DUCTS: Stair pressurization and smoke control ducts shall be braced and shall have flexible connections at seismic joints.

Commentary:

Traction elevators, unless carefully designed and constructed, are highly vulnerable to damage during strong shaking. It is very common for the counter-weights to swing out of their rails and collide with the car. Current industry practice and most elevator regulations assure that the elevator occupants will remain safe by installing seismic switches that sense when strong shaking has begun and automatically shut the system down. Seismic switches are generally located in the elevator machine room and connected directly to the controller. The design professional should verify that the switch is operational as they are often disabled due to malfunctioning.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for stair pressurization and smoke control ducts without bracing or flexible connections at seismic joints.

Commentary:

Elevator shaft walls are often unreinforced masonry construction using hollow clay tile or concrete masonry block. In the event of strong shaking, these walls may experience significant damage due to in-plane forces and fall into the shaft.

4.8.14.3 DUCT SUPPORT: Ducts shall not be supported by piping or other nonstructural elements.

Commentary:

Strong earthquake motions causes the elevator hoist way cables to whip around and often misalign on the sheaves and drums. Retainer guards are effective at reducing the number of misalignments and improving the possibility that the elevator can continue in service after inspection.

Tier 2 Evaluation Procedure: The adequacy of piping or other nonstructural elements to resist seismic forces calculated in accordance with Section 4.2.7 and

Commentary:

Retainer plates are installed just above or below all roller guides and serve to prevent derailment. They are U-shaped, firmly attached to the roller guides and run not more than 3/4" from the rail.

gravity forces shall be evaluated.

4.8.15 Hazardous Materials

4.8.15.1 TOXIC SUBSTANCES: Toxic and

Commentary:

The typically poor performance of counterweights is due to the size of the rails and that spacing of the rail brackets. Eight-pound rails have routinely shown to be insufficient and are best replaced by fifteen-pound rails as a minimum.

hazardous substances stored in breakable containers shall be restrained from falling by latched doors, shelf lips, wires, or other methods.

Tier 2 Evaluation Procedure: No Tier 2 evaluation

Commentary:

The brackets that support the rails must be properly spaced and designed to be effective. It is common for brackets to be properly spaced but improperly designed. The design professional should be particularly aware of the eccentricities that often occur within the standard bracket systems most commonly used.

procedure is available for toxic and hazardous substances stored in unrestrained breakable containers.

4.8.15.2 GAS CYLINDERS: Compressed gas cylinders shall be restrained.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for unrestrained compressed gas cylinders.

4.8.15.3 HAZARDOUS MATERIALS: Piping containing hazardous materials shall have shut-off

Commentary:

Spreader brackets are a useful element to maintain alignment of counterweight rails between supporting brackets. They have worked very successfully under normal daily operating loads. However, they do not offer any protection to the rails under seismic loading because of the large eccentricities inherent in their shape.

4.8.16.6 COUNTERWEIGHT RAILS: All counterweight rails shall be sized to meet current industry standards and shall be larger than eight-pound rails.

4.8.16.7 BRACKETS: The brackets that tie the counterweight rail to the building structure shall be sized to meet industry standards and shall have a spacing of 8 feet or less.

valves or other devices to prevent major spills or leaks.

Tier 2 Evaluation Procedure: No Tier 2 evaluation procedure is available for non-compliant shut-off devices.

4.8.16 Elevators

Tier 2 Evaluation Procedure: To evaluate all the items specified below, the elevator installation shall be reviewed by the design professional and an elevator consultant or representative of the elevator manufacturer familiar with elevator seismic requirements. Seismic forces and expected levels of interstory drift shall be calculated in accordance with Section 4.2.7..

4.8.16.1 SUPPORT SYSTEM: All elements of the elevator system shall be anchored

4.8.16.2 SEISMIC SWITCH: All elevators shall be equipped with seismic switches that will terminate operations when the ground motion exceeds 0.10g.

4.8.16.3 SHAFT WALLS: All elevator shaft walls shall be anchored and reinforced to prevent toppling into the shaft during strong shaking

4.8.16.4 RETAINER GUARDS: Cable retainer guards on sheaves and drums shall be present to inhibit the displacement of cables.

4.8.16.5 RETAINER PLATE: A retainer plate shall be present at the top and bottom of both car and counterweight.

4.8.16.8 SPREADER BRACKET: Spreader brackets shall not be used to resist seismic forces

5.0 Detailed Evaluation Phase (Tier 3)

5.1 General

For buildings requiring further investigation, a Tier 3 Evaluation shall be completed in accordance with this Chapter. A Tier 3 Evaluation shall be performed either for the entire building after the requirements of Chapter 2 have been met or for those elements identified to be deficient in a Tier 1 and/or Tier 2 Evaluation.

Commentary:

Tier 1 and Tier 2 evaluations have the potential for being conservative because of the simplifying assumptions involved in their application. More detailed and presumably more accurate evaluations may employ less conservatism and may therefore reveal that buildings or building components identified by Tier 1 and/or Tier 2 evaluations as having seismic deficiencies are satisfactory to resist seismic forces.

The decision as to whether to employ a Tier 3 evaluation requires judgment regarding the likelihood of finding that Tier 1 and/or Tier 2 evaluations are too conservative and whether there would be a significant economic or other advantage to a more detailed evaluation.

No evaluation procedures more detailed than the Tier 1 and Tier 2 are presently available. Therefore, in order to make more detailed evaluations, it is necessary to adapt procedures intended for design.

Provisions intended for design may be used for evaluation by inserting existing conditions in the analysis procedures intended for design. Expected performance of existing components can be evaluated by comparing calculated demands on the components with their capacities.

5.2 Available Procedures

A Tier 3 Evaluation shall be performed using one of the two following procedures:

5.2.1 Provisions for Seismic Rehabilitation Design

A component-based evaluation procedure developed for seismic rehabilitation of existing buildings shall be used for a Tier 3 Evaluation. Acceptable analysis procedures for such a detailed evaluation include linear and nonlinear methods for static or dynamic analysis of buildings. Acceptance criteria for such detailed evaluations for various performance levels are based on stiffness, strength, and ductility characteristics of elements and components derived from laboratory tests and analytical studies. The more accurate analysis method and more realistic acceptance criteria developed specifically for rehabilitation of existing buildings shall constitute the detailed evaluation phase. Such a component-based detailed evaluation procedure shall be used in accordance with the authority having jurisdiction.

Force levels used for analysis in provisions for seismic rehabilitation of existing buildings shall be multiplied by 0.75 when used in a Tier 3 Evaluation. If a linear analysis method is selected, the analysis shall implicitly or explicitly recognize nonlinear response.

Commentary:

The only nationally applicable provisions for seismic rehabilitation of existing buildings are the *NEHRP Guidelines and Commentary for the Seismic Rehabilitation of Buildings* (FEMA 273 and 274). Regionally applicable provisions may be available such as *Seismic Evaluation and Retrofit of Concrete Buildings* (SSC 96-01) and *Division 95 of the City of Los Angeles Code*, both of which were developed specifically for use with reinforced concrete buildings in California. Several procedures for nonlinear static analysis and nonlinear dynamic

nonlinear dynamic analysis have been developed which also could be used for Tier 3 Evaluations with the approval of the authority having jurisdiction.

The *NEHRP Guidelines and Commentary for the Seismic Rehabilitation of Buildings* is the recommended design procedure for adaptation to evaluation. All analysis procedures described in the *Guidelines* except for the Simplified Procedure may be used as permitted by the *Guidelines*.

The 0.75 reduction factor can be applied to seismic forces because the force levels in these documents are intended for rehabilitation design. For evaluation of existing buildings, the 0.75 reduction factor provides a "break" due to expected component capacities rather than design capacities. Note that the 0.75 factor applies to the evaluation of the building only. Any mitigation or rehabilitation as a result of the evaluation must use the full seismic force level for design.

5.2.2 Provisions for Design of New Buildings

Well-established provisions for the design of new buildings approved by the authority having jurisdiction shall be used to perform a Tier 3 Evaluation of an existing building. Acceptable provisions for such a detailed evaluation include Section 9, Earthquake Loads, *Minimum Design Loads for Buildings and Other Structures (ASCE 7-95)*. Such a detailed evaluation shall be performed in accordance with the authority having jurisdiction.

Force levels used for analysis in provisions for seismic design of new buildings shall be multiplied by 0.75 when used in a Tier 3 Evaluation. If a linear analysis method is selected, the analysis shall implicitly or explicitly recognize nonlinear response.

Commentary:

Provisions for design of new buildings may not be well suited for evaluation of existing buildings because they are based on construction details and building configurations meeting specific standards which may not describe the construction details and configurations or the archaic materials of

construction frequently found in existing buildings.

The 0.75 reduction factor can be applied to seismic forces because the force levels in these documents are intended for new design. For evaluation of existing buildings, the 0.75 reduction factor provides a "break" due to expected component capacities rather than design capacities. Note that the 0.75 factor applies to the evaluation of the building only. Any mitigation or rehabilitation as a result of the evaluation must use the full seismic force level for design.

5.3 Selection of Detailed Procedures

Buildings with one or more of the following characteristics shall be evaluated using linear dynamic or nonlinear static or dynamic analysis methods:

- Height exceeds 100 feet;
- The ratio of the building's horizontal dimension at any story exceeds 1.4 times the horizontal dimension at an adjacent story (excluding penthouses);
- The calculated drift along the side of any story, where the diaphragm above is not flexible, is more than 150% of the average story drift (torsional stiffness irregularity);
- The average drift in any story (excluding penthouses) is more than 150% of the drift of the story above or below (vertical stiffness irregularity);
- The lateral-force-resisting system is non-orthogonal.

Commentary:

The procedure selected should be based on the judgment as to which procedure is most applicable to the building being evaluated and is likely to yield the most useful data.

Because procedures that explicitly recognize the nonlinear response of building components in earthquakes are likely to yield the most accurate results, nonlinear analysis methods should be selected for complex or irregular buildings and for higher performance levels.