BIC Meeting of June 20, 2012

Agenda Item #7

City and County of San Francisco
Department of Building Inspection

Edwin M. Lee, Mayor
Vivian L. Day, C.B.O., Director

June 14, 2012

Building Inspection Commission
1660 Mission Street
San Francisco, CA 94103

RE: CAPSS Implementation Team Proposed Administrative Bulletins AB-098, AB-099, AB-100

Honorable Members of the Commission:

At the regular meeting of June 13, 2012 the full Code Advisory Committee (CAC) deliberated on the revised versions of the following CAPSS Implementation Team proposed new Administrative Bulletins:

a. AB-098 (Draft 6) *Post-Earthquake Repair and Retrofit Requirements for Wood-Frame Residential Buildings with Three or More Dwelling Units*
b. AB-099 (Draft 8) *Post-Earthquake Repair and Retrofit Requirements for Concrete Buildings*
c. AB-100 (Draft 6) *Post-Earthquake Repair and Retrofit Requirements for One- and Two-Family* Dwellings

The CAC duly forwards a recommendation of approval for these three bulletins as written to the Building Inspection Commission for their further action.

Respectfully submitted,

Kirk Means
DBI Technical Services Division
Secretary to the Code Advisory Committee

cc: Vivian L. Day, C.B.O., Director
Tom Hui, Deputy Director
David Leung, Manager
Richard Halloran, Supervisor
Ned Fennie, Jr., Chair, Code Advisory Committee
William Strawn, Legislative Affairs

Attach: AB-098
AB-099
AB-100

ADMINISTRATIVE BULLETIN

DRAFT #6 (6/4/2012)

NO. AB-100

DATE :

SUBJECT : Permit Review and Operation

TITLE : Post-Earthquake Repair and Retrofit Requirements for One- and Two-Family Dwellings

PURPOSE : The purpose of this Bulletin is to establish policy for interpreting the San Francisco Building Code regarding post-earthquake damage retrofit triggers for one- and two-family dwellings of wood-frame construction and to detail the scope and criteria for such triggered retrofits. The Bulletin also provides guidance on the scope of required building repair if retrofits are not triggered.

REFERENCE :

2010 San Francisco Building Code
- Section 3401.8, Lateral force design requirements for existing buildings
- Section 3402, Definition of Disproportionate Damage [pending code revision]
- Section 3402, Definition of Substantial Structural Damage
- Section 3405, Repairs

2010 California Historical Building Code, CCR Title Part 8

2012 International Existing Building Code, Appendix Chapter A4, or 2009 International Existing Building Code, Appendix Chapter A4 with NCSEA/SEAOC amendments

ASCE/SEI Standard 31-03, 2003, Seismic Evaluation of Existing Buildings

ASCE/SEI Standard 41-06, 2007, Seismic Rehabilitation of Existing Buildings, with Supplement 1

California Health and Safety Code, Section 17920.3

CAPSS Report, *Here Today—Here Tomorrow: The Road to Earthquake Resilience in San Francisco, Post-Earthquake Repair and Retrofit Requirements* (ATC-52-4 Report), http://www.sfcapss.org/PDFs/PostQuakeRepair.pdf

CUREE EDA-2: General Guidelines for the Assessment and Repair of Earthquake Damage in Residential Woodframe Buildings, (CUREE, 2010)

FEMA 306: Evaluation of Earthquake Damaged Concrete and Masonry Wall Buildings: Basic Procedures Manual (FEMA, 1999)

DISCUSSION : San Francisco Building Code, Section 3405.2 triggers seismic evaluation, and possibly retrofit of buildings, when earthquake-related damage reaches the level of "substantial structural damage to vertical elements of the lateral-force-resisting system." Substantial structural damage is defined in San Francisco Building Code, Section 3402 as, in essence, a loss of lateral capacity of 20 percent or more in any horizontal direction. The code does not give specific rules for identifying a 20-percent capacity loss nor guidance as to how to calculate capacity loss, so implementation of these code provisions relies on interpretation by the Department of Building Inspection. This Bulletin presents the Department's interpretation of a 20-percent lateral capacity loss based on visual indicators of such damage, and details the evaluation procedure and retrofit scope for buildings that exhibit earthquake-induced substantial structural damage. The Bulletin also provides guidance on the scope of required repair of building components or assemblies if such retrofits are not triggered.

In addition to substantial structural damage, San Francisco Building Code, Section 3405.4 triggers structural evaluation and possibly retrofit when earthquake-related damage reaches the level of disproportionate damage, which is defined in San Francisco Building Code, Section 3402 as, in essence, a lateral capacity loss of 10 percent or more in an earthquake of limited intensity. This Bulletin presents the Department of Building Inspection's interpretation of a 10 percent capacity loss based on visual indicators of such damage and provides evaluation procedures and retrofit scope for buildings with such earthquake induced disproportionate damage. [*provisional, pending San Francisco Building Code adoption of provisions for Disproportionate Damage.*]

Residential buildings that incur substantial structural damage or disproportionate damage as detailed in this Bulletin are considered to be "substandard" per California Health and Safety Code Section 17920.3 (b) Structural hazards and (o) Inadequate structural resistance to horizontal forces.

APPLICABILITY

A building is eligible to apply the interpretations and provisions of this Bulletin if all of the following criteria are met:

A. The building includes at least one story in which the seismic force-resisting system consists of a wood light-frame system in at least one direction, and

B. The building has only wood floor and roof diaphragms, and

C. The building ~~is assigned to~~ ***contains a*** residential occupancy group R-3 as defined in San Francisco Building Code, Section 310. At the discretion of the Department of Building Inspection, a building in this group may be evaluated and repaired or retrofitted using the criteria for a residential building with three or more units under AB-098 if the building is structurally and architecturally similar to that group of buildings.

Buildings of other construction types and occupancies may also apply the provisions of this Bulletin on a case-by-case basis when approved by the Department of Building Inspection. Other methods of determining capacity loss based on analysis, testing, or other objective data may also be allowed at the discretion of the Department.

Qualified buildings may be permitted to be evaluated or retrofitted using the provisions in the California Historical Building Code provided that such provisions do not result in seismic performance that is less than the evaluation and retrofit engineering provisions detailed in this Bulletin.

EVALUATION PRODECURES AND RETROFIT SCOPE

For the purpose of determining if a building has incurred substantial structural damage or disproportionate damage per San Francisco Building Code, visual observation and classification of damage and severity may be used in lieu of a calculation of percentage loss of capacity. All determinations of substantial structural damage or disproportionate damage, including visual observation and classification of damage and severity, shall be made by a licensed design professional, and evaluation shall be submitted in accordance with San Francisco Building Code, Section 3405.2.1. For damage not deemed to be either substantial structural damage or disproportionate damage, repairs shall restore the building to its original strength or condition by methods acceptable to the Department of Building Inspection.

Buildings with Substantial Structural Damage

Earthquake-induced substantial structural damage to elements of lateral force-resisting system of a building shall be deemed to exist when any of the components and conditions is observed to reach the severity of "triggering damage" given in Table 1. For buildings with such substantial structural damage, evaluation and retrofit, where required, shall proceed in accordance with the "Action Required" column shown in Table 1 and the "Further Evaluation and

Retrofit Engineering Criteria" section.

Buildings with Disproportionate Damage

Disproportionate damage to elements of the lateral force-resisting system of a building shall be deemed to exist when any of the components and conditions is observed to reach the severity of "triggering damage" given in Table 1. For buildings with such disproportionate damage, evaluation and retrofit, where required, shall proceed in accordance with the "Action Required" column shown in Table 1 and the "Further Evaluation and Retrofit Engineering Criteria" section.

Table 1: Substantial and Disproportionate Damage Triggers for Repair and Retrofit of One and Two-Family Dwellings

Components and Damage Condition	Triggering Damage		Action Required
	Substantial Structural Damage	Disproportionate Damage	
Stone or masonry veneer, incidental URM wall (non-chimney)	• Appearance similar to "Heavy Damage" as described in Section 7.5 of FEMA 306 [Attachment B], or • Failure of anchorage to backing in over 20% of the wall area	• Appearance similar to "Moderate Damage" as described in Section 7.5 of FEMA 306 [Attachment B], or • Visible failure of anchorage to backing anywhere	Remove and replace damaged elements.
• URM foundation piers • Continuous footings with crawl space or under-floor area	• "Moderate Damage" as described in Section 7.5 of FEMA 306 [Attachment B], or • Visible relative movement of supported joist or beams on support of 1″ or more, or • Permanent movement that results in inadequate bearing of supported member		Retrofit crawl space or under-floor area.
Cracks in continuous footings without visible related soil failure or movement	Crack width of less than 0.25″		No retrofit required. Repair to original strength in accordance with Section 4A.3 of CUREE EDA-2.
	Crack width or offset of greater than 0.25″		No retrofit required. Obtain design professional guidance for repair.

Components and Damage Condition	Triggering Damage		Action Required
	Substantial Structural Damage	Disproportionate Damage	
Cracks in continuous footings with visible related soil failure or movement	Cracks and visible related soil failure or movement		• Obtain design professional guidance for mitigation of soil movement and repair of footing, and • Mitigate any soil issues as recommended by design professional.
• Post-and-beam crawl space or under-floor area • Cripple wall with stud height not exceeding 4 feet	• Permanent lateral displacement of 2″ anywhere, or • Visible relative movement of 1″ or more between supported joists or beams and their supports, or • Permanent movement that results in inadequate bearing of over 50% of the supported members	• Permanent lateral displacement of 1″ anywhere, or • Visible relative movement for more than 50% of the supported joists or beams and their supports	Retrofit crawl space or under-floor area in accordance with IEBC Chapter A3.
Anchorage of floor/wall framing to foundations	Permanent movement of 1" anywhere		Retrofit crawl space or under-floor area in accordance with IEBC Chapter A3 [Attachment A].
• Hillside structure where height of supports from foundation to the point of bearing for the floor assembly above exceeds 4 feet • Cripple wall with stud height exceeding 4 feet	• Permanent lateral displacement of 2″ or 2% drift, whichever is greater, at downhill cripple wall stud in any direction, or • Failure of connections in downhill supports if post-and-beam braced frame or moment frame, or • Separation of uphill framing from foundation support or indication of relative movement during shaking of 1″ or more in the direction parallel to the slope	• Permanent lateral displacement of 1″ or 1% drift, whichever is greater, at downhill cripple wall stud in any direction, or • Signs of movement that could lead to failure of the downhill supports, or • Visible relative movement of the uphill support in the direction parallel to the slope	Retrofit from the foundation level to a level above with a full-plate diaphragm, specifically addressing the torsion created by walls of varying height, supports, or other causes.
	• Permanent lateral displacement of 2″ or more, or		Retrofit soft story and any

Components and Damage Condition	Triggering Damage		Action Required
	Substantial Structural Damage	Disproportionate Damage	
Weak Story: when any story has less than 80% of the strength of the story above in either direction	• Indication of any lateral movement in story of 4″ or more during shaking in any direction		support system below.
Stories other than weak stories	• Permanent lateral displacement of 2″ or more anywhere in any direction, or • Permanent lateral displacement of 1″ anywhere if torsional displacement is observed, or • Indications of excessive response such as severe cracking of brittle walls nail fracture or pullout in wood, multiple jammed doors, and/or broken windows		• Retrofit from damaged story down to the foundation, and • Repair walls not part of the designated lateral force-resisting system in accordance with Section 5.8 of CUREE EDA-2.
Connection between two parts of a structure including wings, split levels, porches, and beam to post connections	• Permanent separation or sliding at joint of 1″ or more, or • Permanent movement that results in inadequate bearing of a supported member		Provide structural separation with independent gravity support for each structure or a seismic tie that will transfer 20% of the weight of the lighter portion across the joint.
Unreinforced masonry chimneys	Damage patterns described in Chapter 7 of CUREE EDA-2 that require replacement of any chimney bricks or flue tiles or substantial extent of mortar	Earthquake caused horizontal cracking at roof line or at the top of fire box	Minimum retrofit/ replacement according to Appendix 7A of Chapter 7 of CUREE EDA-2.

Components and Damage Condition	Triggering Damage		Action Required
	Substantial Structural Damage	Disproportionate Damage	
Any chimney	• Earthquake induced separation of chimney from the surrounding or adjacent wood framing, or • Clear movement from a hand pushed "rock test" as described in Section 7.7.3 of CUREE EDA-2.		**For Substantial Structural Damage:** Repair/replace attic ties if present. If no tie to wood framing is evident, provide new engineered tie or replace chimney according to Appendix 7A of CUREE EDA-2
			For Disproportionate Damage: Repair/replace chimney according to Appendix 7A of CUREE EDA-2.
Ceiling plaster	Falling or delaminated ceiling plaster greater than 10% of area within any room.		Determine extent of delamination or deteriorated plaster and replace.
Ceiling material	Cracks in ceiling material indicating permanent movement or local crushing of ceiling material at crack.		If cracks are caused by movement of joists at their supports, provide tie across area of slippage. Otherwise, repair.
Roof tiles	Damage to anchorage of roof tiles, unanchored or slipped tiles.		Determine extent of missing or deteriorated anchorage and replace damaged tiles.

FURTHER EVALUATION AND RETROFIT ENGINEERING CRITERIA:

If, after an evaluation per San Francisco Building Code, Section 3405.2, the pre-earthquake building is determined to satisfy the criteria, then the building need not be retrofitted, but shall be restored to its pre-earthquake capacity. When retrofit is triggered by earthquake damage at any level, the engineering criteria for retrofit shall be permitted to use earthquake loads that are 75 percent of those prescribed by the San Francisco Building Code for new construction, in accordance with San Francisco Building Code, Section 3405.2.

Alternatively, any of the following codes, standards, or guidelines may be used as alternative evaluation or retrofit criteria for qualifying buildings:

A. Meets the requirements of ASCE 31-03 for the Life Safety Performance Level, or

B. Meets the requirements of ASCE 41-06 for the Life Safety Performance Level (S-3) in a BSE-1 earthquake hazard level, or

C. Meets the requirements of 2012 IEBC Appendix Chapter A4 or 2009 IEBC Appendix Chapter A4 with NCSEA/SEAOC amendments, or

D. Meets the 2010 San Francisco Building Code, Sections 3415-3420.

Signed by:

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Vivian L. Day, C.B.O. Date
Director
Department of Building Inspection

Approved by the Building Inspection Commission on _____

Attachment A	Excerpt from 2012 International Code for Existing Buildings, Appendix Chapters A3 & A4
Attachment B	Excerpt from FEMA 306: Evaluation of Earthquake Damaged Concrete and Masonry Wall Buildings: Basic Procedures Manual, Chapter 7, Section 5
Attachment C	Excerpts from CUREE Publication No. EDA-02: General Guidelines for the Assessment and Repair of Earthquake Damage in Residential Woodframe Buildings

Chapter A3 - Prescriptive Provisions for Seismic Strengthening of Cripple Walls and Sill Plate Anchorage of Light Wood-Frame Residential Buildings

SECTION A301 GENERAL

A301.1 Purpose.
The provisions of this chapter are intended to promote public safety and welfare by reducing the risk of earthquake-induced damage to existing wood-frame residential buildings. The requirements contained in this chapter are prescriptive minimum standards intended to improve the seismic performance of residential buildings; however, they will not necessarily prevent earthquake damage.

This chapter sets standards for strengthening that may be approved by the *code official* without requiring plans or calculations prepared by a registered design professional. The provisions of this chapter are not intended to prevent the use of any material or method of construction not prescribed herein. The *code official* may require that construction documents for strengthening using alternative materials or methods be prepared by a registered design professional.

A301.2 Scope.
The provisions of this chapter apply to residential buildings of light-frame wood construction containing one or more of the structural weaknesses specified in Section A303.

Exception: The provisions of this chapter do not apply to the buildings, or elements thereof, listed below. These buildings or elements require analysis by a registered design professional in accordance with Section A301.3 to determine appropriate strengthening:

1. Group R-1, R-2 or R-4 occupancies with more than four dwelling units.
2. Buildings with a lateral force-resisting system using poles or columns embedded in the ground.
3. Cripple walls that exceed 4 feet (1219 mm) in height.
4. Buildings exceeding three stories in height and any three-story building with cripple wall studs exceeding 14 inches (356 mm) in height.
5. Buildings where the *code official* determines that conditions exist that are beyond the scope of the prescriptive requirements of this chapter.
6. Buildings or portions thereof constructed on concrete slabs on grade.

A301.3 Alternative design procedures.
The details and prescriptive provisions herein are not intended to be the only acceptable strengthening methods permitted. Alternative details and methods may be used where designed by a registered design professional and approved by the *code official.* Approval of alternatives shall be based on a demonstration that the method or material used is at least equivalent in terms

of strength, deflection and capacity to that provided by the prescriptive methods and materials.

Where analysis by a registered design professional is required, such analysis shall be in accordance with all requirements of the building code, except that the seismic forces may be taken as 75 percent of those specified in the building code.

SECTION A302 DEFINITIONS

For the purpose of this chapter, in addition to the applicable definitions in the building code, certain additional terms are defined as follows:

COMPOSITE PANEL. A wood structural panel product composed of a combination of wood veneer and wood-based material, and bonded with waterproof adhesive.

CRIPPLE WALL. A wood-frame stud wall extending from the top of the foundation to the underside of the lowest floor framing.

EXPANSION ANCHOR. An approved post-installed anchor, inserted into a pre-drilled hole in existing concrete or masonry, that transfers loads to or from the concrete or masonry by direct bearing or friction or both.

ORIENTED STRAND BOARD (OSB). A mat-formed wood structural panel product composed of thin rectangular wood strands or wafers arranged in oriented layers and bonded with waterproof adhesive.

PERIMETER FOUNDATION. A foundation system that is located under the exterior walls of a building.

PLYWOOD. A wood structural panel product composed of sheets of wood veneer bonded together with the grain of adjacent layers oriented at right angles to one another.

SNUG-TIGHT. As tight as an individual can torque a nut on a bolt by hand, using a wrench with a 10-inch-long (254 mm) handle, and the point at which the full surface of the plate washer is contacting the wood member and slightly indenting the wood surface.

WAFERBOARD. A mat-formed wood structural panel product composed of thin rectangular wood wafers arranged in random layers and bonded with waterproof adhesive.

WOOD STRUCTURAL PANEL. A structural panel product composed primarily of wood and

meeting the requirements of United States Voluntary Product Standard PS 1 and United States Voluntary Product Standard PS 2. Wood structural panels include all-veneer plywood, composite panels containing a combination of veneer and wood-based material, and mat-formed panels such as oriented strand board and waferboard.

SECTION A303 STRUCTURAL WEAKNESSES

A303.1 General.

For the purpose of this chapter, structural weaknesses shall be as specified below.

1. Sill plates or floor framing that are supported directly on the ground without a foundation system that conforms to the building code.

2. A perimeter foundation system that is constructed only of wood posts supported on isolated pad footings.

3. Perimeter foundation systems that are not continuous.

Exceptions:

1. Existing single-story exterior walls not exceeding 10 feet (3048 mm) in length, forming an extension of floor area beyond the line of an existing continuous perimeter foundation.
2. Porches, storage rooms and similar spaces not containing fuel-burning appliances.

4. A perimeter foundation system that is constructed of unreinforced masonry or stone.

5. Sill plates that are not connected to the foundation or that are connected with less than what is required by the building code.

Exception: Where approved by the *code official,* connections of a sill plate to the foundation made with other than sill bolts may be accepted if the capacity of the connection is equivalent to that required by the building code.

6. Cripple walls that are not braced in accordance with the requirements of Section A304.4 and Table A3-A, or cripple walls not braced with diagonal sheathing or wood structural panels in accordance with the building code.

SECTION A304 STRENGTHENING REQUIREMENTS

A304.1 General.

A304.1.1 Scope.
The structural weaknesses noted in Section A303 shall be strengthened in accordance with the requirements of this section. Strengthening work may include both new construction and alteration of existing construction. Except as provided herein, all strengthening work and materials shall comply with the applicable provisions of the building code.

A304.1.2 Condition of existing wood materials.
All existing wood materials that will be a part of the strengthening work (sills, studs, sheathing, etc.) shall be in a sound condition and free from defects that substantially reduce the capacity of the member. Any wood material found to contain fungus infection shall be removed and replaced with new material. Any wood material found to be infested with insects or to have been infested with insects shall be strengthened or replaced with new materials to provide a net dimension of sound wood at least equal to its undamaged original dimension.

A304.1.3 Floor joists not parallel to foundations.
Floor joists framed perpendicular or at an angle to perimeter foundations shall be restrained either by an existing nominal 2-inch-wide (51 mm) continuous rim joist or by a nominal 2-inch-wide (51 mm) full-depth block between alternate joists in one-and two-story buildings, and between each joist in three-story buildings. Existing blocking for multistory buildings must occur at each joist space above a braced cripple wall panel.

Existing connections at the top and bottom edges of an existing rim joist or blocking need not be verified in one-story buildings. In multistory buildings, the existing top edge connection need not be verified; however, the bottom edge connection to either the foundation sill plate or the top plate of a cripple wall shall be verified. The minimum existing bottom edge connection shall consist of 8d toenails spaced 6 inches (152 mm) apart for a continuous rim joist, or three 8d toenails per block. When this minimum bottom edge-connection is not present or cannot be verified, a supplemental connection installed as shown in Figure A3-8A or A3-8C shall be provided.

Where an existing continuous rim joist or the minimum existing blocking does not occur, new $^{3}/_{4}$-inch (19 mm) or $^{23}/_{32}$-inch (18 mm) wood structural panel blocking installed tightly between floor joists and nailed as shown in Figure A3-9 shall be provided at the inside face of the cripple wall. In lieu of wood structural panel blocking, tight fitting, full-depth 2-inch (51 mm) blocking may be used. New blocking may be omitted where it will interfere with vents or plumbing that penetrates the wall.

A304.1.4 Floor joists parallel to foundations.
Where existing floor joists are parallel to the perimeter foundations, the end joist shall be located over the foundation and, except for required ventilation openings, shall be continuous and in continuous contact with the foundation sill plate or the top plate of the cripple wall. Existing connections at the top and bottom edges of the end joist need not be verified in one-story buildings. In multistory buildings, the existing top edge connection of the end joist need not be verified; however, the bottom edge connection to either the

foundation sill plate or the top plate of a cripple wall shall be verified. The minimum bottom edge connection shall be 8d toenails spaced 6 inches (152 mm) apart. If this minimum bottom edge connection is not present or cannot be verified, a supplemental connection installed as shown in Figure A3-8B, A3-8C or A3-9 shall be provided.

A304.2 Foundations.

A304.2.1 New perimeter foundations.
New perimeter foundations shall be provided for structures with the structural weaknesses noted in Items 1 and 2 of Section A303. Soil investigations or geotechnical studies are not required for this work unless the building is located in a special study zone as designated by the *code official* or other authority having jurisdiction.

A304.3 Foundation sill plate anchorage.

A304.3.1 Existing perimeter foundations.
Where the building has an existing continuous perimeter foundation, all perimeter wall sill plates shall be anchored to the foundation with adhesive anchors or expansion anchors in accordance with Table A3-A.

Anchors shall be installed in accordance with Figure A3-3, with the plate washer installed between the nut and the sill plate. The nut shall be tightened to a snug-tight condition after curing is complete for adhesive anchors and after expansion wedge engagement for expansion anchors. All anchors shall be installed in accordance with manufacturer's recommendations. Where existing conditions prevent anchor installations through the sill plate, this connection may be made in accordance with Figure A3-4A, A3-4B, or A3-4C. The spacing of these alternate connections shall comply with the maximum spacing requirements of Table A3-A. Expansion anchors shall not be used where the installation causes surface cracking of the foundation wall at the locations of the bolt.

A304.4 Cripple wall bracing.

A304.4.1 General.
Exterior cripple walls not exceeding 4 feet (1219 mm) in height shall be permitted to be specified by the prescriptive bracing method in Section A304.4. Cripple walls over 4 feet (1219 mm) in height require analysis by a registered design professional in accordance with Section A301.3.

A304.5 Quality control.
All work shall be subject to inspection by the *code official* including, but not limited to:

1. Placement and installation of new adhesive or expansion anchors installed in existing foundations. Special inspection is not required for adhesive anchors installed in existing foundations regulated by the prescriptive provisions of this chapter.
2. Installation and nailing of new cripple wall bracing.
3. Any work may be subject to special inspection when required by the *code official* in accordance with the building code.

Chapter A4 - Earthquake Risk Reduction in Wood-Frame Residential Buildings with Soft, Weak or Open Front Walls

SECTION A401 GENERAL

A401.1 Purpose.

The purpose of this chapter is to promote public welfare and safety by reducing the risk of death or injury that may result from the effects of earthquakes on existing wood-frame, multiunit residential buildings. The ground motions of past earthquakes have caused the loss of human life, personal injury and property damage in these types of buildings. This chapter creates minimum standards to strengthen the more vulnerable portions of these structures. When fully followed, these minimum standards will improve the performance of these buildings but will not necessarily prevent all earthquake-related damage.

A401.2 Scope.

The provisions of this chapter shall apply to all existing Occupancy Group R-1 and R-2 buildings of wood construction or portions thereof where the structure has a soft, weak, or open-front wall line, and there exists one or more stories above.

SECTION A402 DEFINITIONS

Notwithstanding the applicable definitions, symbols and notations in the building code, the following definitions shall apply for the purposes of this chapter:

GROUND FLOOR. Any floor whose elevation is immediately accessible from an adjacent grade by vehicles or pedestrians. The ground floor portion of the structure does not include any floor that is completely below adjacent grades.

NONCONFORMING STRUCTURAL MATERIALS. Wall bracing materials other than wood structural panels or diagonal sheathing.

OPEN-FRONT WALL LINE. An exterior wall line, without vertical elements of the lateral force-resisting system, that requires tributary seismic forces to be resisted by diaphragm rotation or excessive cantilever beyond parallel lines of shear walls. Diaphragms that cantilever more than 25 percent of the distance between lines of lateral force-resisting elements from which the diaphragm cantilevers shall be considered excessive. Exterior exit balconies of 6 feet (1829 mm) or less in width shall not be considered excessive cantilevers.

RETROFIT. An improvement of the lateral force-resisting system by *alteration* of existing structural elements or *addition* of new structural elements.

SOFT WALL LINE. A wall line whose lateral stiffness is less than that required by story drift limitations or deformation compatibility requirements of this chapter. In lieu of analysis, a soft wall line may be defined as a wall line in a story where the story stiffness is less than 70 percent of the story above for the direction under consideration.

STORY. A story as defined by the building code, including any basement or underfloor space of a building with cripple walls exceeding 4 feet (1219 mm) in height.

STORY STRENGTH. The total strength of all seismic-resisting elements sharing the same story shear in the direction under consideration.

WALL LINE. Any length of wall along a principal axis of the building used to provide resistance to lateral loads. Parallel wall lines separated by less than 4 feet (1219 mm) shall be considered one wall line for the distribution of loads.

WEAK WALL LINE. A wall line in a story where the story strength is less than 80 percent of the story above in the direction under consideration.

SECTION A403 ANALYSIS AND DESIGN

A403.1 General.

All modifications required by the provisions in this chapter shall be designed in accordance with the *International Building Code* provisions for new construction, except as modified by this chapter.

Exception: Buildings for which the prescriptive measures provided in Section A404 apply and are used.

No *alteration* of the existing lateral force-resisting system or vertical load-carrying system shall reduce the strength or stiffness of the existing structure, unless the altered structure would remain in conformance to the building code and this chapter.

A403.2 Scope of analysis.

This chapter requires the *alteration, repair,* replacement or *addition* of structural elements and their connections to meet the strength and stiffness requirements herein. The lateral-load-path analysis shall include the resisting elements and connections from the wood diaphragm

immediately above any soft, weak or open-front wall lines to the foundation soil interface or to the uppermost story of a podium structure comprised of steel, masonry, or concrete structural systems that supports the upper, wood-framed structure. Stories above the uppermost story with a soft, weak, or open-front wall line shall be considered in the analysis but need not be modified. The lateral-load-path analysis for added structural elements shall also include evaluation of the allowable soil-bearing and lateral pressures in accordance with the building code. Where any portion of a building within the scope of this chapter is constructed on or into a slope steeper than one unit vertical in three units horizontal (33-percent slope), the lateral force-resisting system at and below the base level diaphragm shall be analyzed for the effects of concentrated lateral forces at the base caused by this hillside condition.

Exception: When an open-front, weak or soft wall line exists because of parking at the ground floor of a two-story building and the parking area is less than 20 percent of the ground floor area, then only the wall lines in the open, weak or soft directions of the enclosed parking area need comply with the provisions of this chapter.

A403.3 Design base shear and design parameters.
The design base shear in a given direction shall be permitted to be 75 percent of the value required for similar new construction in accordance with the building code. The value of R used in the design of the strengthening of any story shall not exceed the lowest value of R used in the same direction at any story above. The system overstrength factor, Ω_0, and the deflection amplification factor, C_d, shall not be less than the largest respective value corresponding to the R factor being used in the direction under consideration.

Exceptions:

1. For structures assigned to Seismic Design Category B, values of R, Ω_0 and C_d shall be permitted to be based on the seismic force-resisting system being used to achieve the required strengthening.

2. For structures assigned to Seismic Design Category C or D, values of R, Ω_0 and C_d shall be permitted to be based on the seismic force-resisting system being used to achieve the required strengthening, provided that when the strengthening is complete, the strengthened structure will not have an extreme weak story irregularity defined as Type 5b in ASCE 7 Table 12.3-2.

3. For structures assigned to Seismic Design Category E, values of R, Ω_0 and C_d shall be permitted to be based on the seismic force-resisting system being used to achieve the required strengthening, provided that when the strengthening is complete, the strengthened structure will not have an extreme soft story, a weak story, or an extreme weak story irregularity defined, respectively, as Types 1b, 5a and 5b in ASCE 7 Table 12.3-2.

A403.4 Story drift limitations.
The calculated story drift for each retrofitted story shall not exceed the allowable deformation compatible with all vertical load-resisting elements and 0.025 times the story height. The calculated story drift shall not be reduced by the effects of horizontal diaphragm stiffness but shall be increased when these effects produce rotation. Drift calculations shall be in accordance with the building code.

A403.5 P Δ effects.
The requirements of the building code shall apply, except as modified herein. All structural framing elements and their connections not required by design to be part of the lateral force-resisting system shall be designed and/or detailed to be adequate to maintain support of design dead plus live loads when subjected to the expected deformations caused by seismic forces. The stress analysis of cantilever columns shall use a buckling factor of 2.1 for the direction normal to the axis of the beam.

A403.6 Ties and continuity.
All parts of the structure included in the scope of Section A403.2 shall be interconnected as required by the building code.

A403.7 Collector elements.
Collector elements shall be provided that can transfer the seismic forces originating in other portions of the building to the elements within the scope of Section A403.2 that provide resistance to those forces.

A403.8 Horizontal diaphragms.
The strength of an existing horizontal diaphragm sheathed with wood structural panels or diagonal sheathing need not be investigated unless the diaphragm is required to transfer lateral forces from vertical elements of the seismic force-resisting system above the diaphragm to elements below the diaphragm because of an offset in placement of the elements.

Wood diaphragms with stories above shall not be allowed to transmit lateral forces by rotation or cantilever except as allowed by the building code; however, rotational effects shall be accounted for when unsymmetric wall stiffness increases shear demands.

Exception: Diaphragms that cantilever 25 percent or less of the distance between lines of lateral load-resisting elements from which the diaphragm cantilevers may transmit their shears by cantilever, provided that rotational effects on shear walls parallel and perpendicular to the load are taken into account.

A403.9 Wood-framed shear walls.
Wood-framed shear walls shall have strength and stiffness sufficient to resist the seismic loads and shall conform to the requirements of this section.

SECTION A404 PRESCRIPTIVE MEASURES FOR WEAK STORY

A404.1 Limitation.

These prescriptive measures shall apply only to two-story buildings and only when deemed appropriate by the *code official.* These prescriptive measures rely on rotation of the second floor diaphragm to distribute the seismic load between the side and rear walls of the ground floor open area. In the absence of an existing floor diaphragm of wood structural panel or diagonal sheathing, a new wood structural panel diaphragm of minimum thickness of $^3/_4$ inch (19 mm) and with 10d common nails at 6 inches (152 mm) on center shall be applied.

A404.2 Minimum required retrofit.

A404.2.1 Anchor size and spacing.

The anchor size and spacing shall be a minimum of $^3/_4$ inch (19 mm) in diameter at 32 inches (813 mm) on center. Where existing anchors are inadequate, supplemental or alternative approved connectors (such as new steel plates bolted to the side of the foundation and nailed to the sill) shall be used.

SECTION A405 MATERIALS OF CONSTRUCTION

A405.1 New materials.

New materials shall meet the requirements of the *International Building Code,* except where allowed by this chapter.

A405.2 Allowable foundation and lateral pressures.

The use of default values from the building code for continuous and isolated concrete spread footings shall be permitted. For soil that supports embedded vertical elements, Section A403.6 shall apply.

A405.3 Existing materials.

The physical condition, strengths, and stiffnesses of existing building materials shall be taken into account in any analysis required by this chapter. The verification of existing materials conditions and their conformance to these requirements shall be made by physical observation, material testing or record drawings as determined by the registered design professional subject to the approval of the *code official.*

SECTION A406 INFORMATION REQUIRED TO BE ON THE PLANS

A406.1 General.

The plans shall show all information necessary for plan review and for construction and shall

accurately reflect the results of the engineering investigation and design. The plans shall contain a note that states that this retrofit was designed in compliance with the criteria of this chapter.

A406.2 Existing construction.
The plans shall show existing diaphragm and shear wall sheathing and framing materials; fastener type and spacing; diaphragm and shear wall connections; continuity ties; and collector elements. The plans shall also show the portion of the existing materials that needs verification during construction.

A406.3 New construction.

A406.3.1 Foundation plan elements.
The foundation plan shall include the size, type, location and spacing of all anchor bolts with the required depth of embedment, edge and end distance; the location and size of all shear walls and all columns for braced frames or moment frames; referenced details for the connection of shear walls, braced frames or moment-resisting frames to their footing; and referenced sections for any grade beams and footings.

SECTION A407 QUALITY CONTROL

A407.1 Structural observation, testing and inspection.
Structural observation, in accordance with Section 1709 of the *International Building Code,* shall be required for all structures in which seismic retrofit is being performed in accordance with this chapter. Structural observation shall include visual observation of work for conformance to the approved construction documents and confirmation of existing conditions assumed during design.

Structural testing and inspection for new construction materials shall be in accordance with the building code, except as modified by this chapter.

7.5 Unreinforced Masonry Component Guides

The following Component Damage Classification Guides contain details of the behavior modes for unreinforced masonry components. Included are the distinguishing characteristics of the specific behavior mode, the description of damage at various levels of severity, and performance restoration measures. Information may not be included in the Component Damage Classification Guides for certain damage severity levels; in these instances, for the behavior mode under consideration, it is not possible to make refined distinctions with regard to severity of damage. See also Section 3.5 for general discussion of the use of the Component Guides and Section 4.4.3 for information on the modeling and acceptability criteria for components.

URM1F	COMPONENT DAMAGE CLASSIFICATION GUIDE	System:	**URM**
		Component Type:	**Solid Wall**
		Behavior Mode:	**Flexural Cracking/ Toe Crushing/Bed Joint Sliding**

How to distinguish behavior mode:

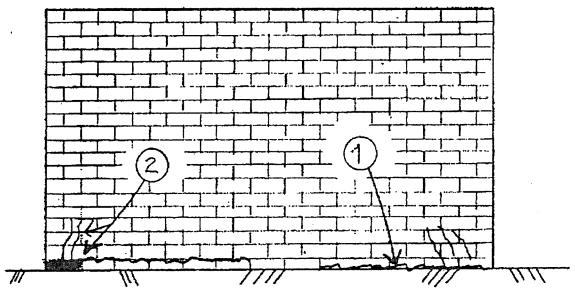
By observation:
This type of moderately ductile behavior has been experimentally observed in walls with $L/h_{eff} \approx 1.7$ in which bed joint sliding and toe crushing strength capacities are similar. Damage occurs in the following sequence. First, flexural cracking occurs at the heel of the wall. Then diagonally-oriented cracks appear at the toe of the wall, typically accompanied by spalling and crushing of the units. In some cases, toe crushing is immediately followed by a steep inclined crack propagating upward from the toe. Next, sliding occurs along a horizontal bed joint near the base of the wall, accompanied in some cases by stair-stepped bed joint sliding at upper portions of the wall. With repeated cycles of loading, diagonal cracks increase. Eventually, crushing of the toes or excessive sliding leads to failure.

By analysis:
At higher damage levels, cracking may be similar to URM1H; however, in URM1F, the bed joint sliding will occur at the base of the wall, in addition to the center of the wall. Confirm by analysis that bed joint sliding capacities are sufficiently low to trigger URM1F.

Caution: At low damage levels, flexural cracking may be similar to cracking that occurs in other modes.

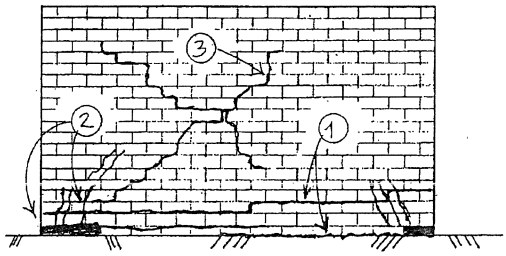
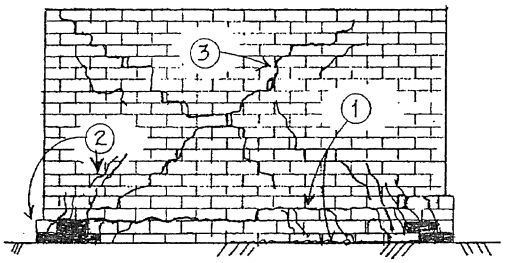
Refer to Evaluation Procedures for:

- In-plane wall behavior: See Section 7.3.2

Level	Description of Damage	Typical Performance Restoration Measures
Insignificant $\lambda_K = 1.0$ $\lambda_Q = 1.0$ $\lambda_D = 1.0$ $\mu_\Delta \leq 1.5$	*Criteria:* 1. Horizontal hairline cracks in bed joints at the heel of the wall. 2. Possibly diagonally-oriented cracks and minor spalling at the toe of the wall. *Typical Appearance:*  	Not necessary for restoration of structural performance. (Measures may be necessary for restoration of nonstructural characteristics.)
Slight	Not used	

COMPONENT DAMAGE CLASSIFICATION GUIDE **continued**

URM1F

Level	Description of Damage	Typical Performance Restoration Measures
Moderate $\lambda_K = 0.9$ $\lambda_Q = 0.6^1$ $\lambda_D = 0.9$ 1. As an alternative, calculate as V_{bjs2}/V_{tc} $\Delta/h_{eff} \leq 0.8\%$	*Criteria:* 1. Horizontal cracks/spalled mortar at bed joints at or near the base of the wall indicating that in-plane offset along the crack has occurred up to approximately 1/4". 2. Possibly diagonally-oriented cracks and spalling at the toe of the wall. Cracks extend upward several courses. 3. Possibly diagonally-oriented cracks at upper portions of the wall which may be in the units. *Typical Appearance:*  	• Replace/drypack damaged units. • Repoint spalled mortar and open head joints. • Inject cracks and open head joints. • Install pins and drilled dowels in toe regions. $\lambda_K^* = 1.0^1$ $\lambda_Q^* = 1.0^1$ $\lambda_D^* = 1.0^1$ 1. In some cases, grout injection may actually increase strength, but decrease deformation capacity, by changing behavior from bed joint sliding to a less ductile behavior mode (see FEMA 307, Section 4.1.3).
Heavy $\lambda_K = 0.8$ $\lambda_Q = 0.6^1$ $\lambda_D = 0.9$ 1. As an alternative, calculate as V_{bjs2}/V_{tc} $\Delta/h_{eff} \leq 1.2\%$	*Criteria:* 1. Horizontal bed joint cracks near the base of the wall similar to Moderate, except width is up to approximately 1/2". 2 Possibly extensive diagonally-oriented cracks and spalling at the toe of the wall. Cracks extend upward several courses. 3 Possibly diagonally-oriented cracks up to 1/2" at upper portions of the wall. *Typical Appearance:*  	• Replace/drypack damaged units. • Repoint spalled mortar and open head joints. • Inject cracks and open head joints. • Install pins and drilled dowels in toe regions. $\lambda_K^* = 1.0^1$ $\lambda_Q^* = 1.0^1$ $\lambda_D^* = 1.0^1$ 1. In some cases, grout injection may actually increase strength, but decrease deformation capacity, by changing behavior from bed joint sliding to a less ductile behavior mode (see FEMA 307, Section 4.1.3).
Extreme	*Criteria:* • Vertical load-carrying ability is threatened *Typical Indications* • Stair-stepped movement is so significant that upper bricks have slid off their supporting brick. • Toes have begun to disintegrate. • Residual set is so significant that portions of masonry at the edges of the pier have begun or are about to fall.	• Replacement or enhancement required.

URM1H	DAMAGE CLASSIFICATION AND REPAIR GUIDE	System:	**URM**
		Component Type:	**Solid Wall**
		Behavior Mode:	**Flexural Cracking/ Toe Crushing**

How to distinguish behavior mode:

By observation:

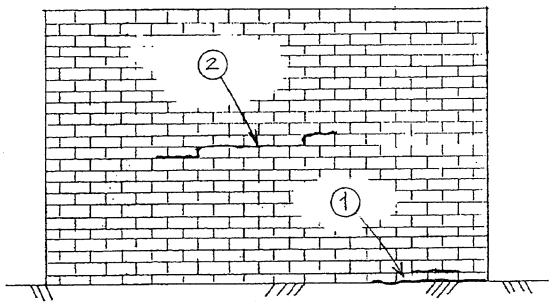
This type of behavior typically occurs in stockier walls with $L/h_{eff} > 1.25$. Based on laboratory testing, four steps can usually be identified. First, flexural cracking happens at the base of the wall, but it does not propagate all the way across the wall. This can also cause a series of horizontal cracks to form above the heel. Second, sliding occurs on bed joints in the central portion of the pier. Third, diagonal cracks form at the toe of the wall. Finally, large cracks form at the upper corners of the wall. Failure occurs when the triangular portion of wall above the crack rotates off the crack or the toe crushes so significantly that vertical load is compromised. Note that, for simplicity, the figures below only show a single crack, but under cyclic loading, multiple cracks stepping in each direction are possible.

By analysis:

Stair-stepped cracking may resemble a form of bed joint sliding; confirm by analysis that toe crushing governs over bed joint sliding.

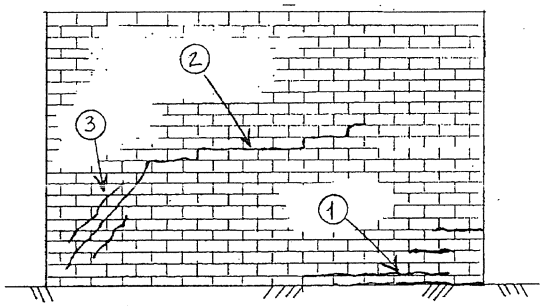
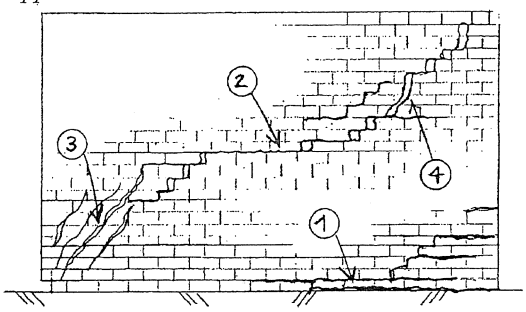
Refer to Evaluation Procedures for:

- In-plane wall behavior: See Section 7.3.2

Level	Description of Damage	Typical Performance Restoration Measures
Insignificant $\lambda_K = 0.9$ $\lambda_Q = 1.0$ $\lambda_D = 1.0$ $\mu_\Delta \leq 1.5$	*Criteria:* 1. Horizontal hairline cracks in bed joints at the heel of the wall. 2. Horizontal cracking on 1-3 cracks in the central portion of the wall. No offset along the crack has occurred and the crack plane is not continuous across the pier. 3 No cracks in masonry units. *Typical Appearance:*  	Not necessary for restoration of structural performance. (Measures may be necessary for restoration of nonstructural characteristics.)
Slight	Not used	
Moderate	Not used	

COMPONENT DAMAGE
CLASSIFICATION GUIDE **continued**

URM1H

Level	Description of Damage	Typical Performance Restoration Measures
Heavy $\lambda_K = 0.8$ $\lambda_Q = 0.8$ $\lambda_D = 1.0$ $\Delta/h_{eff} \leq 0.3\%$	*Criteria:* 1. Horizontal hairline cracks in bed joints at the heel of the wall. 2. Horizontal cracking on 1-3 cracks in the central portion of the wall. Some offset along the crack may have occurred. 3. Diagonal cracking at the toe of the wall, likely to be through the units, and some of units may be spalled. *Typical Appearance:*  	Replacement or enhancement is required for full restoration of seismic performance. For <u>partial</u> restoration of performance: • Repoint spalled mortar. • Inject cracks. $\lambda_K^* = 0.9$ $\lambda_Q^* = 0.9$ $\lambda_D^* = 1.0$
Extreme $\lambda_K = 0.6$ $\lambda_Q = 0.6$ $\lambda_D = 0.9$ $\Delta/h_{eff} \leq 0.9\%$	*Criteria:* 1. Horizontal hairline cracks in bed joints at the heel of the wall. 2 Horizontal cracking on 1 or more cracks in the central portion of the wall. Offset along the crack will have occurred. 3 Diagonal cracking at the toe of the wall, likely to be through the units, and some of units may be spalled. 4 Large cracks have formed at upper portions of the wall. In walls with aspect ratios of $L/h_{eff} > 1.5$, these cracks will be diagonally oriented; for more slender piers, cracks will be more vertical and will go through units. *Typical Appearance:*  	Replacement or enhancement is required for full restoration of seismic performance. For <u>partial</u> restoration of performance: • Replace/drypack damaged units. • Repoint spalled mortar. • Inject cracks. • Install pins and drilled dowels in toe regions. $\lambda_K^* = 0.9$ $\lambda_Q^* = 0.8$ $\lambda_D^* = 1.0$

URM1M	COMPONENT DAMAGE CLASSIFICATION GUIDE	System:	**URM**
		Component Type:	**Solid Wall**
		Behavior Mode:	**Out-of-Plane Flexural Response**

How to distinguish behavior mode:

By observation:

Out-of-plane failures are common in URM buildings. Usually they occur due to the lack of adequate wall ties, as discussed in Table 7-1. When ties are adequate, the wall may fail due to out-of-plane bending between floor levels. One mode of failure observed in experiments is rigid-body rocking motion occurring on three cracks: one at the top of the wall, one at the bottom, and one at midheight. As rocking increases, the mortar and masonry units at the crack locations can be degraded, and residual offsets can occur at the crack planes. The ultimate limit state is that the walls rock too far and overturn. Important variables are the vertical stress on the wall and the height-to-thickness ratio of the wall. Thus, walls at the top of buildings and slender walls are more likely to suffer damage.

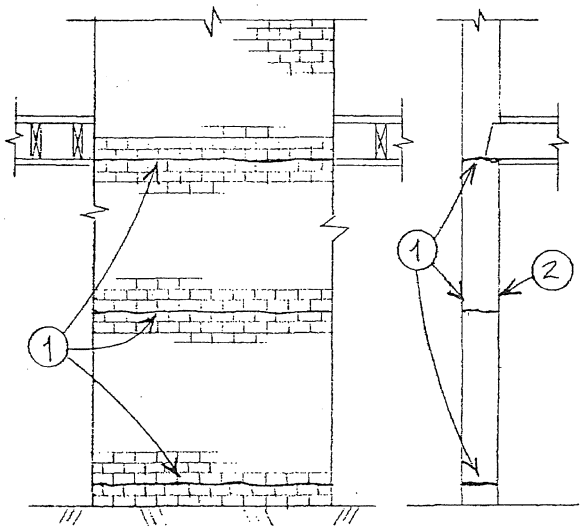
By analysis:

None required.

Caution:

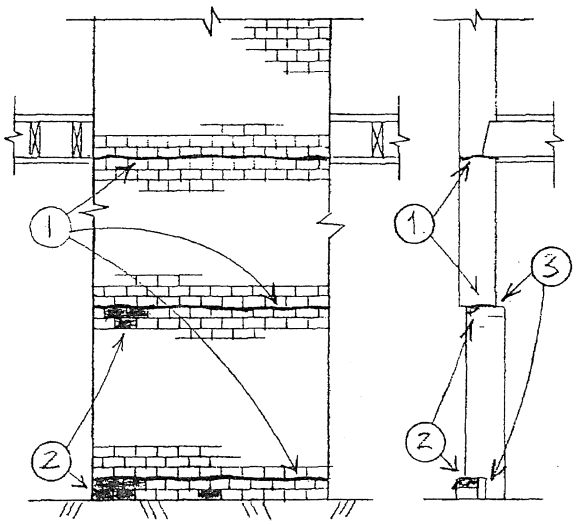
If horizontal cracks are located directly below wall-diaphragm ties, damage may be due to bed joint sliding associated with tie damage. For piers, if horizontal cracks are observed at the top and bottom of the pier but not at midheight, see URM2A. Confirm whether the face brick is unbonded to the backing brick. If so, the thickness in the *h/t* requirement is reduced to the thickness of the backing wythes.

Refer to Evaluation Procedures for: Out-of-plane wall behavior: See Section 7.3.5.

Level	Description of Damage	Typical Performance Restoration Measures
Insignificant For out-of-plane loads: $\lambda_{h/t}$= 1.0 For in-plane modes given previously, assume out-of-plane damage leads to Moderate damage for URM2B and Insignificant damage for all other modes.	*Criteria:* 1. Hairline cracks at floor/roof lines and midheight of stories. 2. No out-of-plane offset or spalling of mortar along cracks. *Typical Appearance:* 	Not necessary for restoration of structural performance. (Measures may be necessary for restoration of nonstructural characteristics.)

COMPONENT DAMAGE CLASSIFICATION GUIDE **continued**

URM1M

Level	Description of Damage	Typical Performance Restoration Measures
Slight	Not used.	
Moderate For out-of-plane loads: $\lambda_{h/t}$= 0.9 For in-plane modes, see Insignificant damage	*Criteria:* 1. Cracks at floor/roof lines and midheight of stories may have mortar spalls up to full depth of joint and possibly: 2. Out-of-plane offsets along cracks of up to 1/8". *Typical Appearance:* See Insignificant damage above.	• Repoint spalled mortar: • For out-of-plane loads: $\lambda_{h/t}$= 1.0 • For in-plane loads: use Moderate for URM2B and Insignificant for all other modes.
Heavy For out-of-plane loads: $\lambda_{h/t}$= 0.6 For in-plane modes given previously, assume out-of-plane damage leads to *Heavy* for all other modes.	*Criteria:* 1 Cracks at floor/roof lines and midheight of stories may have mortar spalls up to full depth of joint. 2 Spalling and rounding at edges of units along crack plane. 3 Out-of-plane offsets along cracks of up to 1/2". *Typical Appearance:*  	Replacement or enhancement is required for full restoration of seismic performance. For partial restoration of out-of-plane performance: • Replace/drypack damaged units • Repoint spalled mortar $\lambda_{h/t}$= 0.8
Extreme	*Criteria:* • Vertical-load-carrying ability is threatened *Typical Indications* • Significant out-of-plane or in-plane movement at top and bottom of piers ("walking"). • Significant crushing/spalling of bricks at crack locations.	• Replacement or enhancement required.

URM2A	COMPONENT DAMAGE CLASSIFICATION GUIDE	System: **URM**
		Component Type: **Weaker Pier**
		Behavior Mode: **Wall-Pier Rocking**

How to distinguish behavior mode:

By observation:

Rocking-critical piers form horizontal flexural cracks at the top and bottom of piers. Because the cracks typically close as the pier comes back to rest at the end of ground shaking, these cracks can be quite subtle when only a few cycles of rocking have occurred and when pier drift ratios during shaking were small. As damage increases, softening of the pier can occur due to cracking, and the pier may begin to "walk" out-of-plane at the top and bottom. At the highest damage levels, crushing of units at the corners can occur.

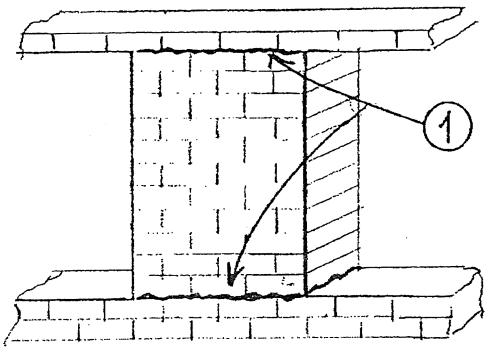
By analysis:

As damage increases to the Moderate level and beyond, some small cracking within the pier may occur. Confirm by analysis that rocking governs over diagonal tension and bed joint sliding.

Caution: If horizontal cracks are located directly below wall-diaphragm ties, damage may be due to bed joint sliding associated with tie damage. If a horizontal crack is observed at midheight of the pier, see URM1M.

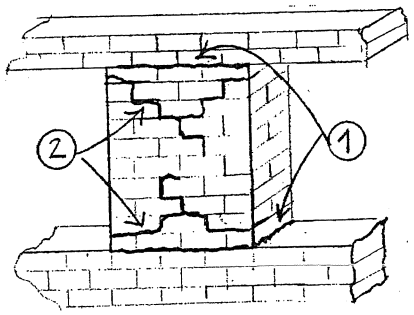
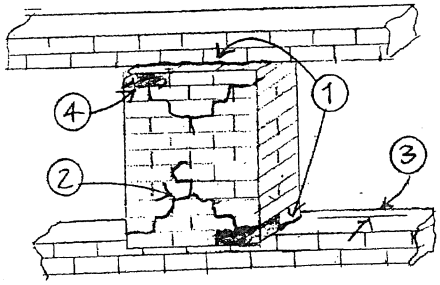
Refer to Evaluation Procedures for:

- In-plane wall behavior: See Section 7.3.2.

Level	Description of Damage	Typical Performance Restoration Measures
Insignificant $\lambda_K = 0.8$ $\lambda_Q = 1.0$ $\lambda_D = 1.0$ $\mu_\Delta \leq 1.5$	*Criteria:* • Hairline cracks/spalled mortar in bed joints at top and bottom of pier. *Typical Appearance:*  	Not necessary for restoration of structural performance. (Measures may be necessary for restoration of nonstructural characteristics.)

COMPONENT DAMAGE CLASSIFICATION GUIDE **continued**

URM2A

Level	Description of Damage	Typical Performance Restoration Measures
Slight	Not used.	
Moderate $\lambda_K = 0.6$ $\lambda_Q = 0.9$ $\lambda_D = 1.0$ $\Delta/h_{eff} \leq h_{eff}/L_{eff}$* 0.4%	*Criteria:* 1. Hairline cracks/spalled mortar in bed joints at top and bottom of pier. 2. Possible hairline cracking/spalled mortar in bed joints within piers. *Typical Appearance:*  	Replacement or enhancement is required for full restoration of seismic performance. For partial restoration of performance: • Repoint spalled mortar. λ_K* = 0.8 λ_Q* = 0.9 λ_D* = 1.0
Heavy $\lambda_K = 0.4$ $\lambda_Q = 0.8$ $\lambda_D = 0.7$ $\Delta/h_{eff} \leq h_{eff}/L_{eff}$* 0.8%	*Criteria:* 1. Hairline cracks/spalled mortar in bed joints at top and bottom of pier, plus one or more of: 2. Hairline cracking/spalled mortar in bed joints within piers, but bed joints typically do not open. 3. Possible out-of-plane or in-plane movement at top and bottom of piers ("walking"). 4. Crushed/spalled bricks at corners of piers. *Typical Appearance:*  	Replacement or enhancement is required for full restoration of seismic performance. For partial restoration of performance: • Replace/drypack damaged units • Repoint spalled mortar • Inject cracks λ_K* = 0.8 λ_Q* = 0.9 λ_D* = 1.0
Extreme	*Criteria:* • Vertical load-carrying ability is threatened. *Typical Indications* • Significant out-of-plane or in-plane movement at top and bottom of piers ("walking"). • Significant crushing/spalling of bricks at corners of piers.	• Replacement or enhancement required.

URM2B	COMPONENT DAMAGE CLASSIFICATION GUIDE	System: **URM**
		Component Type: **Weaker Pier**
		Behavior Mode: **Bed Joint Sliding**

How to distinguish behavior mode:

By observation:

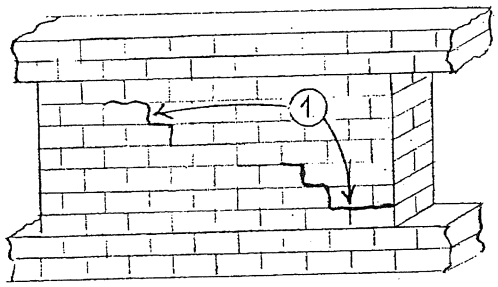
In this type of behavior, sliding occurs on bed joints. Commonly observed both in the field and in experimental tests, there are two basic forms: sliding on a horizontal plane, and a stair-stepped diagonal crack where the head joints open and close to allow for movement on the bed joint. Note that, for simplicity, the figures below only show a single crack, but under cyclic loading, multiple cracks stepping in each direction are possible. Pure bed joint sliding is a ductile mode with significant hysteretic energy absorption capability. If sliding continues without leading to a more brittle mode such as toe crushing, then gradual degradation of the cracking region occurs until instability is reached. Theoretically possible, but not widely reported, is the case of stair-stepped cracking when sliding goes so far that an upper brick slides off a lower unit.

By analysis:

Stair-stepped cracking may resemble a form of diagonal tension cracking; confirm by analysis that bed joint sliding governs over diagonal tension.

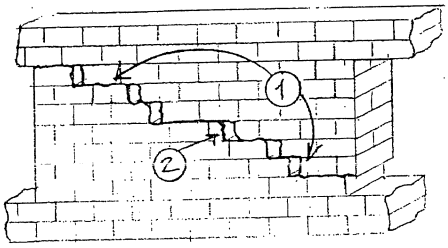
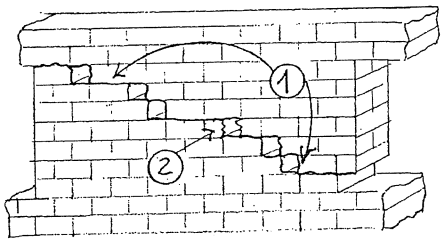
Refer to Evaluation Procedures for:

- In-plane wall behavior: See Section 7.3.2.

Level	Description of Damage	Typical Performance Restoration Measures
Insignificant	*Criteria:* 1. Hairline cracks/spalled mortar in head and bed joints either on a horizontal plane or in a stair-stepped fashion have been initiated, but no offset along the crack has occurred and the crack plane or stair-stepping is not continuous across the pier. 2. No cracks in masonry units.	Not necessary for restoration of structural performance. (Measures may be necessary for restoration of nonstructural characteristics.)
$\lambda_K = 0.9$ $\lambda_Q = 0.9$ $\lambda_D = 1.0$	*Typical Appearance:* 	
$\mu_\Delta \leq 1.5$		

COMPONENT DAMAGE CLASSIFICATION GUIDE **continued**

URM2B

Level	Description of Damage	Typical Performance Restoration Measures
Slight	Not used.	
Moderate $\lambda_K = 0.8$ $\lambda_Q = 0.6^*$ $\lambda_D = 1.0$ *As an alternative, calculate as V_{bjs2}/V_{bjs1} $\Delta/h_{eff} \leq 0.4\%$	*Criteria:* 1. Horizontal cracks/spalled mortar at bed joints indicating that in-plane offset along the crack has occurred and/or opening of the head joints up to approximately 1/4", creating a stair-stepped crack pattern. 2. 5% of courses or fewer have cracks in masonry units. *Typical Appearance:*  	Replacement or enhancement is required for full restoration of seismic performance. For partial restoration of performance: • Repoint spalled mortar and open head joints. • Inject cracks and open head joints $\lambda_K^* = 0.8$ $\lambda_Q^* = 0.8^*$ $\lambda_D^* = 1.0^*$ *In some cases, grout injection may actually increase strength, but decrease deformation capacity, by changing behavior from bed joint sliding to a less ductile behavior mode (see FEMA 307, Section 4.1.3).
Heavy $\lambda_K = 0.6$ $\lambda_Q = 0.6^*$ $\lambda_D = 0.9$ *As an alternative, calculate as V_{bjs2}/V_{bjs1} $\Delta/h_{eff} \leq 0.8\%$	*Criteria:* 1. Horizontal cracks/spalled mortar on bed joints indicating that in-plane offset along the crack has occurred and/or opening of the head joints up to approximately 1/2", creating a stair-stepped crack pattern. 2. 5% of courses or fewer have cracks in masonry units. *Typical Appearance:*  	Replacement or enhancement is required for full restoration of seismic performance. For partial restoration of performance: • Repoint spalled mortar and open head joints. • Inject cracks and open head joints. $\lambda_K^* = 0.8$ $\lambda_Q^* = 0.8^*$ $\lambda_D^* = 1.0^*$ *In some cases, grout injection may actually increase strength, but decrease deformation capacity, by changing behavior from bed joint sliding to a less ductile behavior mode (see FEMA 307, Section 4.1.3).
Extreme	*Criteria:* • Vertical load-carrying ability is threatened. *Typical Indications* • Stair-stepped movement is so significant that upper bricks have slid off their supporting brick. • Cracks have propagated into a significant number of courses of units. • Residual set is so significant that portions of masonry at the edges of the pier have begun or are about to fall.	• Replacement or enhancement required.

URM2K	COMPONENT DAMAGE CLASSIFICATION GUIDE	System: **URM**
		Component Type: **Weaker Pier**
		Behavior Mode: **Diagonal Tension**

How to distinguish behavior mode:

By observation:

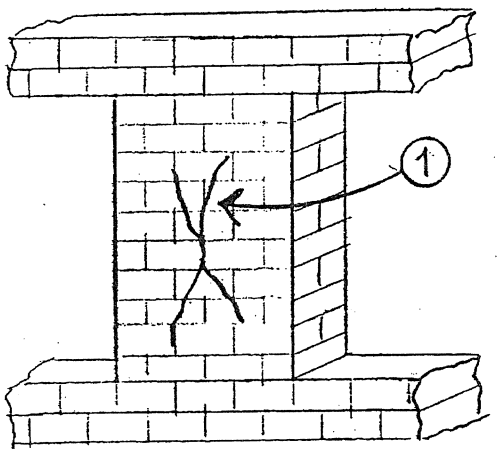
Typical diagonal tension cracking—resulting from strong mortar, weak units, and high compressive stress—can be identified by diagonal cracks ("X" cracks) that propagate through the units. In many cases, the cracking is sudden, brittle, and vertical load capacity drops quickly. The cracks may then extend to the toe and the triangles above and below the crack separate. In a few cases, the load drop may be more gradual with cracks increasing in size and extent with each cycle. A second form of diagonal tension cracking also has been experimentally observed with weak mortar, strong units and low compressive stress where the cracks propagate in a stair-stepped manner in head and bed joints. The first (typical) case is shown below.

By analysis:

Since the stair-stepping form of cracking would appear similar to the early levels of stair-stepped bed joint sliding, confirm by analysis that diagonal tension governs over bed joint sliding. Since deterioration at the corners in the Heavy damage level may resemble toe crushing, also confirm that diagonal tension governs over toe crushing.

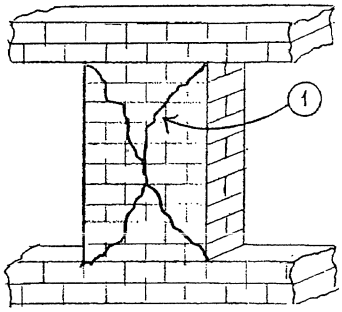
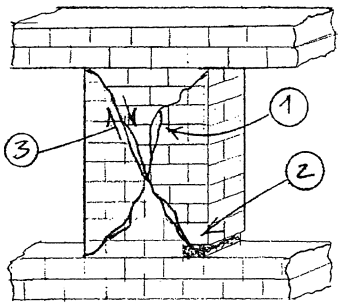
Refer to Evaluation Procedures for:

- In-plane wall behavior: See Section 7.3.2.

Level	Description of Damage	Typical Performance Restoration Measures
Insignificant λ_K=1.0 λ_Q = 1.0 λ_D = 1.0 $\mu_\Delta \leq 1$	*Criteria:* 1. Hairline diagonal cracks in masonry units in fewer than 5% of courses. *Typical Appearance:*  	Not necessary for restoration of structural performance. (Measures may be necessary for restoration of nonstructural characteristics.)

COMPONENT DAMAGE
CLASSIFICATION GUIDE **continued**

URM2K

Level	Description of Damage	Typical Performance Restoration Measures
Slight	Not used.	
Moderate λ_K=0.8 λ_Q = 0.9 λ_D = 1.0 $\mu_\Delta \approx$1-1.5	*Criteria:* 1. Diagonal cracks in pier, many of which go through masonry units, with crack widths below 1/4". 2. Diagonal cracks reach or nearly reach corners. 3. No crushing/spalling of pier corners. *Typical Appearance:*  	• Repoint spalled mortar. • Inject cracks. λ_K* = 0.8 λ_Q* = 1.0 λ_D* = 1.0
Heavy λ_K = 0.4 λ_Q = 0.8 λ_D = 0.7 μ_Δ >1.5	*Criteria:* 1. Diagonal cracks in pier, many of which go through masonry units, with crack widths over 1/4". Damage may also include: 2. Some minor crushing/spalling of pier corners and/or 3. Minor movement along or across crack plane. *Typical Appearance:*  	Replacement or enhancement is required for full restoration of seismic performance. For <u>partial</u> restoration of performance: • Replace/drypack damaged units. • Repoint spalled mortar. • Inject cracks. λ_K* = 0.8 λ_Q* = 0.8 λ_D* = 1.0
Extreme	*Criteria:* • Vertical load-carrying ability is threatened *Typical Indications* • Significant movement or rotation along crack plane. • Residual set is so significant that portions of masonry at the edges of the pier have begun or are about to fall.	• Replacement or enhancement required.