ALTERNATE DESIGN METHODOLOGY FOR UNREINFORCED MASONRY BUILDINGS

I. GENERAL

This bulletin provides an alternate method of design for the structural upgrading of buildings which fall within the scope of Division 88. All design parameters of Division 88 not specifically incorporated into this bulletin, shall remain applicable.

II. LIMITATIONS

A. The building's horizontal diaphragm system must be of wood construction and must meet the basic criteria under which the plot of demand/capacity ratio (DCR) was developed. The criteria used for development of the demand/capacity ratio, is described in item A under Part III References.

B. Where applicable, the effects of adjacent structures shall be considered in the analysis of the diaphragm for the determination of the allowable height/thickness ratios of the URM walls.

C. Horizontal diaphragms shall not be considered to transmit lateral forces by rotation. A minimum of two lateral load resisting elements shall be parallel to each axis of the building.

D. This analysis shall not be applicable to buildings in Rating Class I.

E. Existing anchors, installed under previous permits, shall meet or be upgraded to meet the requirements of this bulletin.

F. Buildings where uses dictate a variation in dead load (i.e. partition or storage loads) must be investigated for the limiting condition.

G. Existing crosswalls need not be continuous below a wood diaphragm at/or near grade, provided:

1. Shear connections and anchorage requirements of Section 8808.2 and 8808.3 are satisfied at all edges of the diaphragm.

2. Crosswalls with total capacity of 0.07 ΣW_d interconnect the diaphragm to the foundation.

3. The demand/capacity ratio of the diaphragm between the crosswalls that are continuous to their foundations shall be calculated as $[0.33W_d + V_{ca}] / 2v_uD$ and shall not exceed 2.5.

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III. REFERENCES

A. Basic design concepts utilized in the bulletin were derived from "The Methodology for Mitigation of Seismic Hazards in Existing Unreinforced Masonry Buildings," by ABK, A Joint Venture, under National Science Foundation contract number NSF-C-PFR 78-19200. The loads and shear values that are used in the bulletin were factored to working stress values from those used in the Methodology.

B. Notes prepared by the Ad Hoc Hazardous Building Committee of the SEASOC for the October 1986 seminars.

C. "Code" shall mean the Los Angeles City Building Code, current edition.

IV. DEFINITIONS

Definitions in the code shall be applicable, except as modified herein:

A. Crosswall:

A wood-framed wall sheathed with any of the materials described in Tables B and C. Other systems, such as moment frames, may be used as crosswalls provided that the yield deflection does not exceed one inch in each story height. Crosswalls shall have a strength of 30% of the diaphragm strength in the direction of consideration within any 40 foot length measured on the diaphragm span.

B. Diaphragm Edge:

The intersection of the horizontal diaphragm and a shear wall.

C. Lateral Load Resisting System:

The interconnected building elements (including horizontal diaphragms, shear walls and crosswalls) that form a path for the required seismic forces from each building level to the building base.

D. Open Front:

An exterior building wall plane without a shear wall adequate to resist the required lateral forces.

E. Shear Wall:

A wall utilized to resist the required seismic forces (not including crosswalls). All reinforced or unreinforced masonry or concrete walls shall be considered shear walls. Braced frames shall be considered as shear walls. Moment frames may be designed as crosswalls or shear walls.

F. Yield Deflection:
The deflection at which yield stress is first developed in a frame member.

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G. Symbols:

A = Area of unreinforced masonry pier in square inches.

D = In-plane width dimension of pier in inches, or depth of diaphragm in feet.

h/t = Height/thickness ratio of URM wall. Height is measured between wall anchorage levels.

H = Least clear height of opening on either side of pier, in inches.

L = Span from shear wall to open front or span of diaphragm between shear walls.

Lc = Length of crosswall in feet.

L1 = Effective Span = $2[(W_w/W_d) \times L + L]$.

P = Axial dead load on pier in pounds.

v_c = Maximum shear strength in pounds per foot for a crosswall sheathed with any of the materials given in Tables B or C.

v_u = Maximum shear strength in pounds per foot for a diaphragm sheathed with any of the materials given in Tables B or C.

v_a = Allowable shear in pounds per square inch for unreinforced masonry.

V_A = Allowable shear in pounds in any URM pier, based on the allowable in-plane shear value.

V_c = Total shear capacity of crosswalls in the direction of analysis immediately below the diaphragm level being investigated.

V_{ca} = Total shear capacity of crosswalls in the direction of analysis immediately above the diaphragm level being investigated.

V_R = Allowable restoring shear in pounds of any URM pier, based on the cracked pier analysis.

W_d = Total of the dead load that is tributary to a diaphragm level.

$\sum W_d$ = Total of the dead load that is tributary to all of the diaphragms.

W_w = Total dead load of an unreinforced masonry shear wall above the level under consideration or above an open front of a building.

V. REQUIRED ANALYSIS AND DESIGN

A. General:

Except as modified herein, the analysis and design for the seismic upgrading of existing structures

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shall be in accordance with Division 88 of the LA Building Code.

B. Lateral Forces on Elements of Structures:

1. Lateral forces on parts or portions of structures shall be as per Section 8808.2

   EXCEPTIONS:

   a. For determination of the strength of shear connections at diaphragm edges, the values of ICp as set forth in Table A shall be used. However, the strength of the shear connections need not exceed the strength of the diaphragm as given in Tables B and C.

   b. The strength of a shear wall at any level need not exceed the value of $IKCSW_w$ plus the sum of the diaphragms' strength.

2. Anchorage and interconnection of parts, portions and elements of the structure shall be analyzed and designed for lateral forces in accordance with Equation 8-2 of Chapter 88. Anchorage of masonry walls to each floor or roof shall resist a minimum force of 200 lbs/ft acting normal to the wall, at the level of the floor or roof.

C. Analysis/Design:

1. **General:**

   Stresses in materials and existing construction utilized to transfer seismic forces from the ground to parts or portions of the structure shall conform to those permitted by the Code and those materials and types of construction specified in Tables B, C, Figure 1, and as modified below.

2. **Unreinforced Masonry Walls:**

   a. Allowable Shear Value: The allowable shear shall be as specified in Table 88-J of the Code, except that the allowable shear may be increased by adding 15% of the axial stress due to the weight of the wall directly above.

   b. Where walls exceed the h/t as allowed in Table 88-G of the Code, the walls shall be braced for the Cp forces given in Chapter 88, except that flexible vertical bracing members shall be designed for two-thirds of the loads specified above.

   c. In-Plane Loads: Shear strength of an URM pier shall be calculated utilizing Figure 2 and the following equations:
      i. $V_A = v_a \times A$
      ii. $V_R = 0.5\ P \times D/H$
      iii. Figure 2

3. **Crosswalls:**

   a. Existing and new wall materials and values given in Tables B and C may be utilized in crosswalls.

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b. A moment resisting frame may be utilized as a crosswall, provided that its yield deflection is less than 1" in each story height.

c. Spacing of crosswalls shall not exceed 40'-0" O.C. in the direction of consideration.

4. **Shear Walls/Frames:**

a. Existing and new shear wall materials and values given in Tables B and C may be utilized in combination.

b. Other shear resisting elements which meet the requirements of Division 88 may be utilized.

c. The maximum deflection of laterals load resisting frames shall be limited to the lesser of the following:

i. 0.005 times the story height; or

ii. The requirements for crosswalls.

d. In-plane forces shall be distributed to resisting vertical elements in accordance with their rigidity.

e. The seismic force distributed to the shear wall at any diaphragm level shall be the lesser value calculated as:

i. For buildings without crosswalls, $IKCSW_d / 2$.

ii. For buildings with crosswalls in all levels:
$v_u \times D \times \Sigma IKCSW_d / [\Sigma(2 v_u \times D) + V_c]$
where:
$\Sigma IKCSW_d$ = total seismic forces of all diaphragms.
$\Sigma (2 v_u \times D)$ = total strength of both ends of all diaphragms.
$v_u \times D$ = Strength of the end of the diaphragm under consideration at the shear wall.
V_c = The capacity of the crosswalls in the lowest story.

iii. $v_u \times D$.

5. **Diaphragms:**

a. Diaphragms shall be constructed of materials described in Tables B and C and shall be analyzed to meet the requirements of Figure 1.

b. Wood diaphragms to control displacements of open front buildings shall be analyzed by the following procedure:

i. Calculate L_1, diaphragm span in feet, for use in Figure 1 as:
L_1 = Effective span = $2[(W_w/W_d) \times L + L]$

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W_w = Total dead load of URM wall above the open front.
L = Span from shear wall to open front or span of diaphragm beyond crosswall.

ii. Calculate demand/capacity ratio as:
$0.33(W_d + W_w)/(v_u \times D)$

iii. If crosswalls are used to limit displacement at open front, calculate demand/capacity ratio as:

$0.33(W_d + W_w)/[(v_u \times D) + V_c]$

iv. A supplemental support system in conformance to 8810.2.3 shall be provided at lintels bearing on unreinforced masonry piers at the open front.

6. **Information Required on Plans:**

a. The use of this bulletin shall be noted on the plans.

b. The plans shall indicate all existing crosswalls and their materials of construction. The location of the crosswalls shall be fully dimensioned and drawn to scale on the plans.

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TABLE A

Configuration of Materials	ICp
Roofs with straight or diagonal sheathing and roofing applied directly to the sheathing and floors with straight tongue and groove sheathing.	0.2
Double or multiple layers of boards with edges offset and blocked plywood systems.	0.3

TABLE B – VALUES FOR EXISTING MATERIALS

Existing Materials or Configurations of Materials[1]			Allowable Values
1.	Existing Diaphragms		
	a.	Roofs with straight sheathing and roofing applied directly to the sheathing.	100 lbs. per foot for seismic shear.
	b.	Roofs with diagonal sheathing and roofing applied directly to the sheathing.	250 lbs. per foot for seismic shear.
	c.	Floors with straight tongue-and-groove sheathing.	100 lbs. per foot for seismic shear.
	d.	Floors with straight sheathing and finished wood flooring with board edges offset or perpendicular.	500 lbs. per foot for seismic shear.
	e.	Floors with diagonal sheathing and finished wood flooring.	600 lbs. per foot for seismic shear.
2.	Crosswalls [2]		
	a.	Plaster on wood or metal lath	per side: 200 lbs. per foot for seismic shear.
	b.	Plaster on gypsum lath	175 lbs. per foot for seismic shear.
	c.	Gypsum wall board, unblocked edges	75 lbs. per foot for seismic shear.
	d.	Gypsum wall board, blocked edges	125 lbs. per foot for seismic shear.
3.	Existing Footings, Wood Framing, Structural Steel and Reinforcing Steel		
	a.	Plain concrete footings	f'c = 1500 psi unless otherwise shown by tests.
	b.	Douglas fir wood	Allowable stress same as No. 1 D.F.
	c.	Reinforcing steel	f_t = 18,000 lbs. per square inch maximum.
	d.	Structural steel	f_t = 20,000 lbs. per square inch maximum[3].

1 Material must be sound and in good condition.

2 For crosswalls, values of all materials may be combined, except the total combined value shall not exceed 300 lbs. per foot for seismic shear.

3 Stresses given may be increased for combination of loads as specified in Section 8808.7.

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TABLE C - ALLOWABLE VALUES OF NEW MATERIALS USED IN CONJUNCTION WITH EXISTING CONSTRUCTION

New Materials or Configuration of Materials[1]		
1. Horizontal Diaphragms		
	Plywood sheathing applied directly over existing straight sheathing with ends of plywood sheets bearing on joists or rafters and edges of plywood located on center of individual sheathing boards.	225lbs. foot for seismic shear.
2. Crosswalls		
a.	Plywood sheathing applied directly over existing wood studs. No value shall be given to plywood applied over existing plaster or wood sheathing	1.33 times the values specified in Table 2306.3 (2) of the LABC for shear walls.
b.	Drywall or plaster applied directly over existing wood studs. Per Section 2513 (includes 1:1 height to length ratio for seismic.	100% of the values specified in Table No.2306.7 of the LABC.
3.	Shear Bolts - Shear bolts and shear dowels embedded a minimum of eight inches into unreinforced masonry walls. Bolt centered in 2-1/2-inch-diameter hole with dry-pack or non-shrink grout around circumference of bolt or dowel.[1,3]	100% of the values for plain masonry specified in Table No. 88-M of the LABC. No values larger than those given for 3/4-inch bolts shall be used.
4.	Tension Bolts - Tension bolts and tension dowels extending entirely through unreinforced masonry walls secured with bearing plate side of a 3 wythe minimum wall with at least 30 square inches of area.[2,3]	1800 lbs. per bolt or dowel. 900 lbs. for 2 wythe walls.
5. Wall Anchors [8810.2.1]		
a.	Bolts extending to the exterior face of the wall with a 2 1/2-inch round plate under the head. Install as specified for shear bolts. Spaced not closer than 12 inches on centers.[1,2,3]	600 lbs. per bolt.
b.	Bolts or dowels extending to the exterior face of the wall with a 2 1/2-inch round plate under the head and drill at an angle of 22 1/2 degrees to the horizontal. Installed as specified for shear bolts.[1,2,3]	1200 lbs. per bolt or dowel.
6.	Infield Walls - Reinforced masonry infilled openings in existing unreinforced masonry walls. Provide keys or dowels to match reinforcing.	Same as values specified for unreinforced masonry walls.
7.	Reinforced Masonry - Masonry piers and walls reinforced per Section 2106 or 2107 (working strength).	Same as values specified in 2106 of the LABC.
8.	Reinforced Concrete - Concrete footings, walls and piers reinforced as specified in Division 19 and design for tributary loads.	Same as values specified in Division 19 of this Code.
9.	Existing Foundation Loads - Foundation loads for structures exhibiting no evidence of settlement	Calculated existing foundation load may be increased 25% for dead load, and may be increased 50% for dead load plus seismic load required by this Division.

[1] Bolts and dowels to be tested as specified in Section 8809.6.
[2] Bolts and dowels to be 1/2-inch minimum in diameter.
[3] Drilling for bolts and dowels shall be done with an electric rotary drill. Impact tools shall not be used for drilling holes or tightening anchors and shear bolt nuts.

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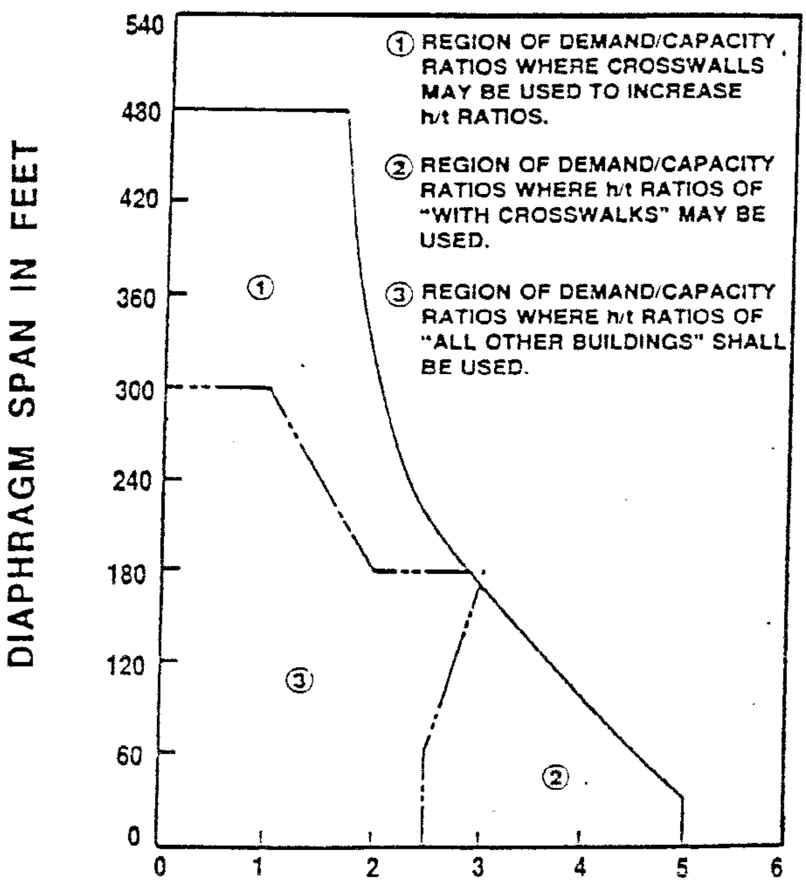
Figure 1. ACCEPTABLE SPAN FOR DIAPHRAGMS (BASED ON DISPLACEMENT CONTROL CONCEPTS)



DEMAND CAPACITY RATIO, $0.33W_d/(2v_uD)$ OR $0.33W_d/(2v_uD + V_c)$

For multistory buildings with crosswalls in all levels above the diaphragm level under consideration, the demand-capacity shall be calculated as: $0.33\ \Sigma W_d/2\ \Sigma v_uD$ or $0.33\ \Sigma W_d/(2\ \Sigma v_uD + V_c)$

where ΣW_d = total of the tributary dead load of all diaphragms at and above the level of consideration.

Σv_uD = total strength of the diaphragms at and above the level of consideration.

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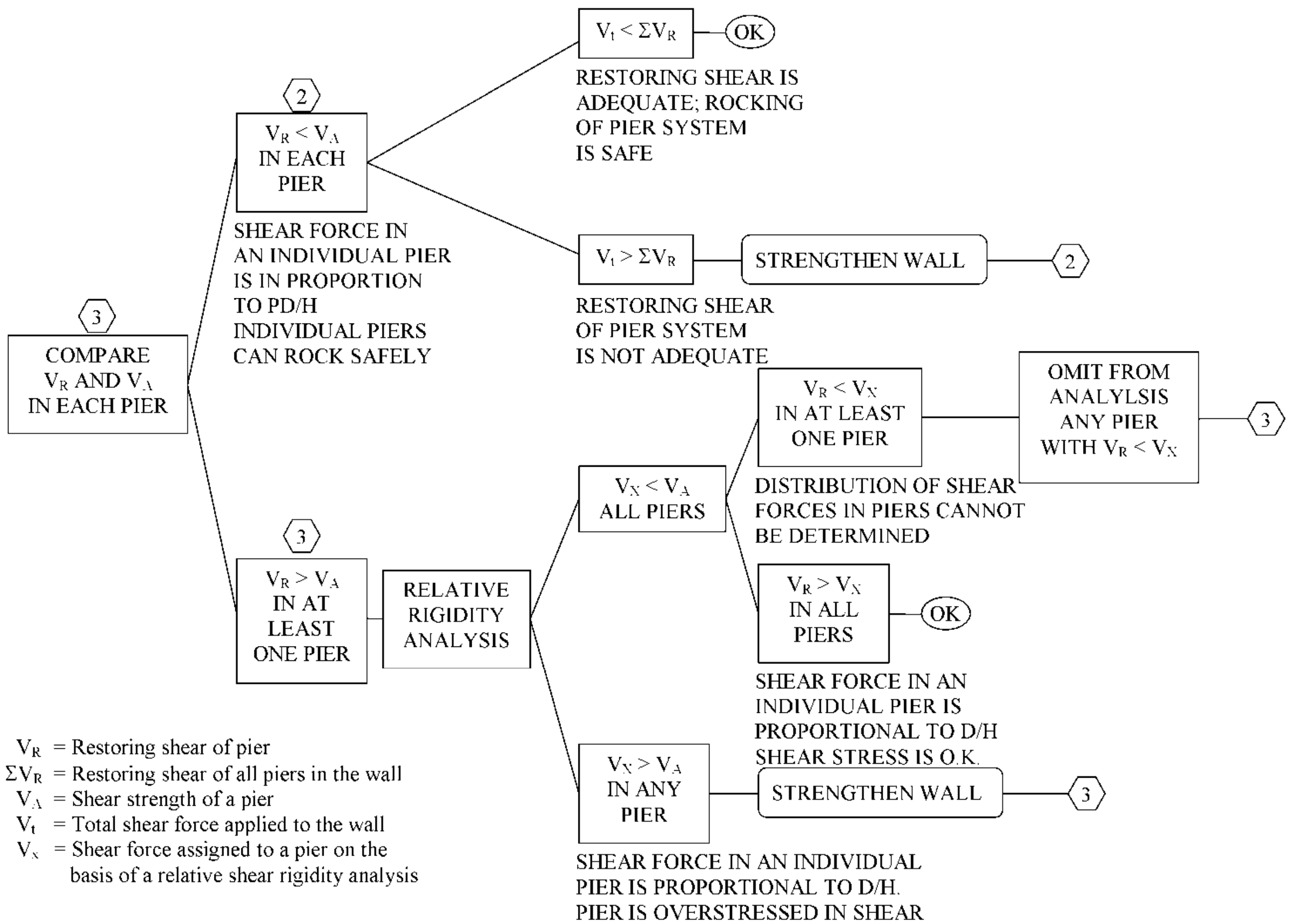

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