ARTICLE 5
PROCEDURES FOR SHEAR WALLS

5.0 INTRODUCTION

Shear walls have two aspects--carrying in-plane shear when the earthquake direction under consideration is parallel to the wall and resisting out-of-plane forces when the earthquake direction under consideration is perpendicular to the wall. The in-plane effects are covered in this article. Out-of-plane effects are covered in Article 8, "Procedures for Connections". All walls not structurally isolated are assumed to act as shear walls that will participate in resisting lateral forces up to their capacity.

5.1 CONCRETE SHEAR WALLS

5.1.1 SHEARING STRESS CHECK: The building satisfies the quick check of the shearing stress in the shear walls.

For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. Generate the lateral loads using the quick check procedure of Sec. 2.4.7.3. If v_{avg} is greater than 50 psi (or square root of f'_c if f'_c is known), a more detailed evaluation of the structure shall be performed. This evaluation shall employ a more accurate estimation of the level and distribution of the lateral loads; using the analysis procedures in Article 2.

5.1.2 OVERTURNING: All shear walls have h_w/l_w ratios less than 4 to 1.

For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the required resistance to overturning moments. Calculate the resistance to the required overturning moments. The overturning resistance shall include the resistance contributed by wall flanges, friction on piling, earth over foundations, and floor and roof weights supported by the wall. The calculated resistance shall be greater than 0.75 times the base moment of the shear wall. The overturning resistance moment may be taken as the righting moment about an edge of the footing or the wall flexural capacity, whichever is less.

5.1.3 COUPLING BEAMS: The stirrups in all coupling beams are spaced at d/2 or less and are anchored into the core with hooks of 135 degrees or more.

For buildings designed and constructed in accordance with the 1989 or later editions of Part 2, Title 24, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the strength of the coupling beams. Assume that the beams yield. Calculate their end-moment capacity based either on flexural yield or shear capacity, whichever is lower. The coupling beam moment capacity should include the contribution of a reasonable portion of the adjacent floor slab reinforcement when this reinforcement is in tension. Analyze the walls as independent walls with these restoring moments or shears helping to stabilize the walls. Check the stability of the wall and the stresses in the vertical boundaries. Conforming buildings which fail this check shall be placed in SPC 4, and no calculations are necessary.

5.1.4 COLUMN SPLICES: Steel column splice details in shear wall boundary elements can develop the tensile strength of the column.

For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the strength of the splice in the boundary column. Determine the maximum tensile column load in each case and verify the adequacy of the splice to resist this load, including gravity loads. Check the adequacy of the splice connection for all gravity and seismic loads. Amplify the seismic load for partial-penetration welded splices by the factor $C_d/2$, but not less than 1.5, when the seismic load produces tension at the splice.

5.1.5 WALL CONNECTIONS: There is positive connection between the shear walls and the steel beams and columns.

For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the adequacy of the connections between the shear wall and the beams and columns that are its boundary elements. Calculate the effective overturning demand for the walls and check the adequacy of the shear transfer to the steel

elements. A value for shear friction between steel and concrete shall be included only if the steel element is completely encased with reinforced concrete.

5.1.6 CONFINEMENT REINFORCING: For shear walls with h_w/l_w greater than 2.0, the boundary elements are confined with spirals or ties with spacing less then 8 d_b.
For buildings designed and constructed in accordance with the 1989 or later editions of Part 2, Title 24, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the ductility of the vertical boundary elements that are required to resist large axial forces. Check the need for boundary elements, per ACI 318. Where boundary elements are required but not provided, amplify the seismic forces for the entire structure by the factor 1.25 (and use 0.8 C_d for drift calculation). Conforming buildings which fail this evaluation statement shall be placed in SPC 4, and no calculations are necessary.

5.1.7 REINFORCING STEEL: The total reinforcing steel for concrete walls is greater than 0.0025 times the gross area of the wall along both the longitudinal and transverse axes and the maximum spacing of reinforcing steel is 18 inches.
For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the quantity of reinforcing in the wall. Calculate the capacity of the walls with the reinforcing that is provided but amplify the seismic forces by the factor 1.25 (and use $0.8C_d$ for drift calculation). Where the reinforcing in the wall is less than 0.0015 times the gross area of the wall along the longitudinal or transverse axis, or if the reinforcing steel spacing exceeds 18 inches, the contribution of the wall to lateral strength and stiffness of the building shall be ignored, and, if it is a bearing wall, the building shall be placed in SPC "1".

5.1.8 REINFORCING AT OPENINGS: There is special wall reinforcement around all openings.
For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the reinforcing in the piers and spandrels. Determine the capacity of the spandrels and piers considering all available reinforcing steel that crosses the critical sections.

5.2 PRECAST CONCRETE SHEAR WALLS

Shear walls of precast concrete are in segments that are tied together, but the connections may be of a brittle type. Connections adequate for design level forces may not be capable of developing the yield level capacity of the panels. The effects of the precast panel connections on the other evaluation statements concerned with wall elements shall be considered. The deficiency is in the quality and ductility of the connections.

5.2.1 PANEL-TO-PANEL CONNECTIONS: Adjacent wall panels are not connected by welded steel inserts.
For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the strength of the inserts. Check the welded inserts. Determine where connection failures would be brittle (e.g., pull-out of an embedded item would occur before yield of a mild steel element). Analyze structure for stability assuming that these brittle connections have failed or are not capable of transmitting forces or check such connections for seismic force amplified by the factor $C_d/2$, but not less than 1.5.

5.2.2 WALL OPENINGS: Openings constitute less than 75 percent of the length of any perimeter wall with the wall piers having h_w/l_w ratios of less than 2.0.
For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency may be in the strength of the panel connections or may be that the reinforced concrete elements actually behave like a moment frame and should be evaluated as such. Check the elements in the precast shear wall system. When large open areas exist, check the transfer of shear between the diaphragm and the wall. Compare the lateral displacements of the wall due to shear and flexure. If more than 50 percent of the total lateral displacement is due to flexure, or if the width of the wall piers is less than 5 times the thickness, analyze the wall as a moment frame.

5.2.3 COLLECTORS: Wall elements with openings larger than a typical panel at a building corner are connected to the remainder of the wall with collector reinforcing.
For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the configuration of the wall or the diaphragm. Find an adequately strong path of forces; if none is found, report this as a deficiency.

5.3 REINFORCED MASONRY SHEAR WALLS

5.3.1 SHEARING STRESS CHECK: The building satisfies the Quick Check of the shearing stress in the reinforced masonry shear walls.
For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. Generate the lateral loads using the Quick Check procedure of Sec. 2.4.7.3. If v_{avg} is greater than the 15 psi, a more detailed evaluation of the structure shall be performed. This evaluation shall employ a more accurate estimation of the level and distribution of the lateral loads; using the analysis procedures in Article 2.

5.3.2 REINFORCING: The total vertical and horizontal reinforcing steel in reinforced masonry walls is 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 is less than 48 inches; and all vertical bars extend to the top of the walls.
For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. If the quantity of wall reinforcing is less than the specified amounts, report this condition as a deficiency.

5.3.3 REINFORCING AT OPENINGS: All wall openings that interrupt rebar have trim reinforcing on all sides.
For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the lack of reinforcing at the end of wall elements adjacent to openings and at the corners of walls. Check the wall using only the length of piers between reinforcing steel.

5.4 UNREINFORCED MASONRY SHEAR WALLS

Unreinforced masonry bearing wall buildings are automatically classified as SPC 1. The following provisions apply to unreinforced masonry shear wall structures that also possess a complete vertical load-carrying space frame.

5.4.1 SHEARING STRESS CHECK: The building satisfies the Quick Check of the shearing stress in the unreinforced masonry shear walls.
Generate the lateral loads using the Quick Check procedure of Sec. 2.4.7.3. The allowable stress (on the gross area) for solid brick masonry is 10 psi; for hollow unit masonry, 6 psi; and for grouted block masonry, 12.5 psi. If v_{avg} is greater than the allowable stress, an Advanced Analysis of the structure shall be performed, or the building shall be placed in SPC 1.

5.4.2 MASONRY LAY-UP: Filled collar joints of multiwythe masonry walls have negligible voids.
The deficiency is in the lay-up of the wall that left voids between the wythes. Investigate the lay-up. This can be done when masonry units are removed for strength tests. If voids are present, report this condition as a deficiency.

5.5 UNREINFORCED MASONRY INFILL WALLS IN FRAMES

5.5.1 PROPORTIONS: The height/thickness ratio of the wall panels is as follows:

One-story building	$h_w/t < 14$
Multistory building	
Top story	$h_w/t < 9$
Other stories	$h_w/t < 20$

The deficiency is in the out-of-plane strength of the wall. Check the out-of-plane demand using the procedure for parts and portions of a building given in Sec. 2.4.6.

5.5.2 SOLID WALLS: The infill walls are not of cavity construction.
The deficiency is in the out-of-plane strength of the wall. If infill walls are of cavity construction, report this as a deficiency.

5.5.3 INFILL WALLS: The infill walls are continuous to the soffits of the frame beams.
For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the strength of the columns. Check the shear capacity of the columns to develop opposing yield moments at top and bottom of the short free height or to resist required force amplified by the factor $C_d/2$, but not less than 1.5.

5.5.4 WALL CONNECTIONS: All infill panels are constructed to encompass the frames around their entire perimeter.
For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the connection of the infill panel to the frame. Determine the panel edge condition from available drawings or from field investigation. If the panels are not properly connected to the frame, report this condition as a deficiency.

5.6 WALLS IN WOOD FRAME BUILDINGS

5.6.1 SHEARING STRESS CHECK: The building satisfies the Quick Check of the shearing stress in wood shear walls.
For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. Generate the lateral loads using the Quick Check procedure of Section 2.4.7.3 and compare to 400 pounds per foot of plywood wall or 50 pounds per foot of walls composed of gypsum board or other materials. If v_{avg} is greater than these values, a more detailed evaluation of the structure shall be performed. This evaluation shall employ a more accurate estimation of the level and distribution of the lateral loads using the analysis procedures in Article 2.

5.6.2 OPENINGS: Walls with garage doors or other large openings are braced with plywood shear walls or are supported by adjacent construction through substantial positive ties.
For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the strength of the lateral force resisting system. Check the ability of the walls and diaphragms to control, through torsional capacity, displacements at walls with large openings. Check that the diaphragm is a complete system with chords and collectors provided to deliver the lateral loads as required.

5.6.3 WALL REQUIREMENTS: All walls supporting tributary area of 24 to 100 square feet per foot of wall are plywood sheathed with proper nailing or rod braced and have a height-to-depth (H/D) ratio of 1 to 1 or less or have properly detailed and constructed hold downs.
For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the strength of the wall and/or in hold-downs to resist overturning forces. Check the walls using floor areas tributary to the walls. Check all portions of the load path to ensure proper force transfer.

5.6.4 CRIPPLE WALLS: All exterior cripple walls below the first floor level are braced to the foundation with shear elements.
For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the shear strength of the cripple walls. Check all exterior cripple walls below the first floor level to ensure that they are braced to the foundation with shear elements.

5.6.5 NARROW SHEAR WALLS: Narrow wood shear walls with an aspect ratio greater than 2 to 1 do not resist forces developed in the building.
For conforming buildings, the evaluator may consider this condition as mitigated, and no calculations are necessary. The deficiency is in the strength of the narrow walls. Determine the shear capacity of the wall and related overturning demand. This shear capacity and related overturning must be transferred to the foundation within allowable stresses.

5.6.6 STUCCO (EXTERIOR PLASTER) SHEAR WALLS: Multi-story buildings do not rely on exterior stucco walls as the primary lateral-force-resisting system.
The deficiency is in the strength of the stucco walls. Inspect stucco clad buildings to determine if there is a lateral system such as plywood or diagonal sheathing at all but the top floor. Where exterior plaster is present, verify that the wire reinforcing is attached directly to the wall framing and the wire is completely embedded into the plaster material. Conforming buildings which fail this check shall be placed into SPC 4.

5.6.7 PLASTER OR GYPSUM WALLBOARD SHEAR WALLS: Interior plaster or gypsum wallboard is not being used for shear walls in buildings over one story in height.
The deficiency is in the strength of the walls. Determine if there is a lateral system such as plywood or diagonal sheathing at all but the top floor. Multi-story buildings shall not rely on interior plaster or gypsum wallboard walls as the primary lateral-force-resisting-system. Conforming buildings which fail this check shall be placed into SPC 4.