Applied Technology Council
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Advancing Engineering Applications for Hazard Mitigation
California ▪ Virginia

201 REDWOOD SHORES PARKWAY, SUITE 240 REDWOOD CITY, CALIFORNIA 94065
PHONE 650/595-1542 FAX 650/593-2320 WEB SITE www.atcouncil.org

Subject Guidance for the implementation of FEMA P-2018, *Seismic Evaluation of Older Concrete Buildings for Collapse Potential*

Date February 19, 2021

Authors William Holmes, Abbie Liel, Jack Moehle

Purpose This document provides clarifications to FEMA P-2018, *Seismic Evaluation of Older Concrete Buildings for Collapse Potential* (Publication date: December 2018). It is intended to provide an engineer who is implementing FEMA P-2018 with additional guidance that is not included in the published document.

CLARIFICATIONS

1. Buildings with wood diaphragms
Page 2-1 Section 2.1.1

The FEMA P-2018 methodology is, in general, limited to buildings with concrete diaphragms due to assumptions made in the mechanism analysis (Section 5.5.1) and torsional analysis (Section 7.6.2). These assumptions will not be significantly affected in structures with wood diaphragms that have a regular pattern of frames with identical or similar design and with little or no torsion and, for such cases, the methodology can therefore be applied. The FEMA P-2018 methodology should not be used for frame-wall or bearing wall structures with wood diaphragms.

2. Buildings with setbacks in upper levels
Page 2-8, Section 2.3, Page 6-6, Section 6.6.2, and Page 7-7, Section 7.6.2

Buildings with setbacks in upper levels may develop plastic mechanisms influenced by the setback. For example, Mechanism 4 (Figure 5-5) may dominate in a setback building. Presence of the setback may also cause twisting effects on the plastic mechanism that should be considered.

Buildings with setbacks in upper levels also may be susceptible to torsion warranting application of the torsional amplification factor of Section 7.6.2. For this purpose, the plastic shear V_{px} is determined for critical story x and is positioned in the floor plan at the centroid of lateral forces considering the lateral forces from level x to the roof. The torsion demand, T_{Dx}, at story x is then determined using Equation 7-8. Torsion demand T_{Dx} is directional and must be calculated for each direction of earthquake loading.

Note: Buildings with minor setbacks, for example, a building with a penthouse setback, need not consider the torsional amplification factor.

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3. Use of Alternative Analysis Methods
Page 2-8, Section 2.3, Bulleted items

- **Effective Fundamental Period.** An accepted analysis procedure should be used that recognizes the reduction of effective stiffness due to nonlinear behavior of the components, such as the Nonlinear Static Procedure in ASCE/SEI 41-17, Section 7.4.3. Effective fundamental period T_e obtained by that alternative procedure may be used directly in Equation 5-2 but not subjected to the limitations of Section 5.4.2; and may be used directly as the value for T_e elsewhere throughout the methodology.

  Linear dynamic analysis can be useful in helping to understand the vibration characteristics of complex building structures, for example, buildings with plan torsion. However, vibration periods obtained from such analysis depend on the member effective stiffness values assumed, which are affected by member dimensions, reinforcement ratio, slip of reinforcement from adjacent anchorage zones, and stiffness degradation. The effective stiffness models from ASCE/SEI 41-17 Section 10.3.1.2 only partially account for these effects. Consequently, such methods should not be used for direct determination of T_e in this methodology. Similarly, it is not generally acceptable to use the approximate period formulas of ASCE/SEI 41-17 or ASCE/SEI 7.

- **Effective Yield Strength**. The preferred alternative is to use an accepted analysis procedure that recognizes the stepwise development of an inelastic mechanism under increasing lateral forces, such as the Nonlinear Static Procedure in ASCE/SEI 41-17 Section 7.4.3. Alternatively, a plastic mechanism analysis can be performed by assuming rigid-perfectly-plastic component behavior with different mechanisms explored to find the mechanism corresponding to minimum lateral force. The resulting base-shear strengths, calculated along each principal direction of the building, may be used to define the effective yield strength of the structure, V_y, as defined in Section 5.5 and used in subsequent portions of the methodology. The resulting yield mechanisms, one along each principal direction, might not exactly match any of the primary mechanisms identified in Chapter 5, Section 5.5. Therefore, exercise judgment to interpret the mechanisms obtained. If the yield mechanism is concentrated in the lower third of the building height, then it may be appropriate to apply procedures associated with Mechanism 1. If the yield mechanism extends from the base to the upper third of the building, then it may be appropriate to apply procedures associated with Mechanism 2, and so on.

- **Story Drift Demand**. In this methodology, story drift demand and drift demands on critical components will be calculated in accordance with procedures such as those in Sections 6.5 and 6.6, or 7.5 and 7.6. As an alternative, it can be acceptable to use the results of an accepted nonlinear dynamic analysis procedure, such as the Nonlinear Dynamic Procedure of ASCE/SEI 41-17 Section 7.4.4, to calculate the story drift demands (e.g., Section 6.6, 7.6) directly. To be consistent with this methodology, the component of drift in each vertical element in two orthogonal directions shall be taken as input to determine ratings. Linear procedures of ASCE/SEI 41-17 are not acceptable for estimating story drifts for use in the FEMA P-2018 methodology. The nonlinear static procedure of ASCE/SEI 41-17 also may not provide reliable results and is thus not recommended for estimating story drifts for use in the FEMA P-2018 methodology.

4. Use of Alternative Analysis Methods
Page 2-8, Section 2.3, Last paragraph

It is reasonable to assume that traditional analysis, although more time consuming, will better estimate drifts, and therefore ratings, than the approximate tools of this methodology. Therefore, for complicated or highly torsional structures for which the mechanism analysis of Section 5.5 would be indeterminate, it is permissible to obtain a rating using input from alternative analysis. However, in general, for decision making at the public policy level, and implementation in mandatory evaluation and retrofit programs, it is recommended that the complete methodology be used whenever possible.

5. Undefined structural systems or framing, including ramps in parking structures
Page 5-3, Section 5.3

FEMA P-2018 requires the classification of buildings into structural systems of similar seismic response characteristics. Sections 5.3.1 through 5.3.4 define characteristics of frame systems, frame-wall systems, bearing wall systems, and infilled frame systems, respectively. Generally, some engineering judgment will be required to determine whether a building fits sufficiently within one of these structural system classifications. For example, a building used as a parking structure may be primarily a frame building, but ramps rising through the height of the building may change the behavior of the structure, because the ramps may create diagonal bracing action and the intersections between ramps and columns may produce captive columns, both of which were not anticipated in developing the provisions for frames. Where such conditions occur, a structural analysis of the building using more sophisticated modeling may be necessary to understand the expected behavior under lateral loads (See Section 2.3). On the other hand, if parking ramps occur only in subterranean levels where the building is already braced by stiff basement walls, then it may be acceptable to use the provisions of FEMA P-2018 without modification.

6. Classification of Building Systems
Page 5-3. Section 5.3

The classification of structures into the systems described, particularly frames and wall frames, is important in this methodology because the system chosen determines which approximate vibration period equation is used (Equation 5-18 vs. Equation 5-19) and also which lateral deformation profile is used (α factors in Table 6-1 vs. Table 7-1). Back-up studies to determine α factors (Appendix H) indicated that a relatively small amount of wall — where the ratio of the area of wall divided by the sum of area of all the supported levels, A_w/A_{fl}, was equal or greater than 0.0003 — would be sufficient to force frame-wall-type deformations. However, those studies used only one or two walls to make up the wall area, and the walls extended to the top level. Neither the wall-area criterion nor the requirement for full height walls was included in the definition of frame-wall systems (Section 5.3.2).

In addition, the suggested limit on column dimensions in Section 5.2.1 ($h_{max}/h_{min} \leq 2.5$), derived primarily from the column test data, will in some buildings lead the evaluator to classify vertical elements slightly over this limit as walls. For example, this can occur in pier-spandrel type exterior walls—with or without pilasters—where the piers do not meet the horizontal length requirement of one-third the bay width (See Section 5.3.2). The sum of the area of these small walls might well be over the 0.0003 ratio described above, but in structures with many interior frame lines, the overall lateral deformation pattern will more closely be aligned with the frame pattern (Table 6-1) rather than the wall-frame pattern (Table 7-1).

Therefore, judgement is required to determine the classification of frame-type buildings with a small amount of walls. As a guide to identify frame-walls for the purpose of calculating the period and determining the appropriate alpha table, the $A_w/A_{fl} \geq 0.0003$ can be used, but near the limit, this area should be concentrated in only a few walls. At least one substantial wall should extend to at least 0.7 of the building height. However, in no case should the period from the wall equation (5-19) be taken longer than that from the frame equation (5-18). Frame-type structures with walls that do not meet these criteria should be evaluated as a frame, including the period. However, walls in these structures should be considered in strength calculations related to the mechanism analysis. For the building rating, drift capacity of these walls can be determined from Chapter 7.

7. **Configuration of Bearing Wall Buildings**
   Page 5-4, Section 5.3.3

   Bearing wall buildings are typically residential occupancies with transverse demising walls of concrete and longitudinal corridor walls of concrete. Columns are only occasionally used to make selected rooms bigger. The 25% rule included here is only guidance and should not be used as a cut-off criterion.

8. **Limitation of use of Equation 5-3**
   Page 5-6, Section 5.4.2

   The period Equation 5-3 applies <u>only</u> when calculating the Wall Strength Index.

9. **Buildings with plan torsion**
   Page 5-18, Section 5.5.4

   Section 7.6.2 addresses a drift amplification factor to be applied to buildings with plan torsion. The procedures of that section can be used for analysis of buildings as required in Section 5.5.4. Specifically, calculate a plastic mechanism strength V_{px} for the critical story as the sum of the plastic capacities of each of the individual frames in each principal horizontal direction for that story. Then, calculate the torsional ratio TR per Equation 7-7. If $TR > 1.5$, then the building is considered to have too much torsion to be able to use V_{px} and the procedures of Chapter 5, and, therefore, in accordance with Chapter 7, classify the building as an exceptionally high seismic risk building. If $TR \leq 1.5$, then the building is not exceptionally high risk on the basis on torsion alone and further analysis is needed. To proceed, it is acceptable to use the calculated plastic mechanism strength V_{px} along with the various other procedures of FEMA P-2018. See also Section 2.3.

10. **Period equations for frame-wall systems and bearing wall systems**
    Page 5-20, Section 5.6.1, Equations 5-19 and 5-20

    Although the heading for the section containing Equations 5-19 and 5-20 reads "Frame-Wall Systems," this section and those equations are intended to apply to both frame-wall systems and bearing wall systems.

    Equations 5-19 and 5-20 are nearly identical to the similar period equations for shear wall structures that appear in Chapter 12 of ASCE/SEI 7-16. There are, however, two exceptions. One exception is the use of the coefficient 0.0026 in Equation 5-10 of FEMA P-2018 rather than the coefficient 0.0019 in ASCE/SEI 7-16. The larger coefficient in FEMA P-2018, which is consistent with the upper bound to the measured wall periods in Goel and Chopra (1998), is intended to reflect increased period due to more extensive concrete cracking. Another difference is that FEMA P-2018 uses the ratio h_{wi}/l_{wi} in the denominator of Equation 5-20 rather than the ratio h_n/l_{wi} used in ASCE 7-16. The FEMA P-2018 ratio is more consistent with the original recommendation of Goel and Chopra (1998).

11. Clarification of corner beam-column connections
Page 6-3, Section 6.3.3, and Page 7-4, Section 7.3.4

Beam-column corner connections are defined as beam-column connections in which two or more adjacent vertical joint faces are not confined by beams or beam stubs framing into that face.

12. Load combination for determination of slab critical section shear
Page 6-9, Section 6.7.2 and Page 7-11, Section 7.7.2

In evaluating the gravity shear ratio V_g/V_c, V_g is the gravity shear acting on the slab critical section for two-way shear considering expected gravity loads, as defined by the load combination $1.0D + 0.25L$, where D is dead load and L is the unreduced live load, consistent with the load combination specified in Section 4.2.1.

13. Components of Equation 6-7
Page 6-7, Section 6.7.1

The term 0.01 in Equation 6-7 is a simplification for the elastic component of the drift ratio of a fixed-fixed column. Although it would be possible to calculate a different coefficient for different boundary conditions, doing so would result in an inconsistency with the alpha factors in Chapters 6 and 7. Therefore, modification of the coefficient is not allowed in FEMA P-2018.

14. Tightly confined masonry infill
Page 5-4 and 5-5, Section 5.3.4

It is generally assumed that infill is tightly confined (meaning it has no gap or a small gap < ¼ inch between beams/columns and the infill wall). In the case that infill is not tightly confined, and the infill classification is very weak, weak, or strong in Table 5-1, the building should be assessed with and without the relevant infill panels, and the building rating determined by the worst case. If the infill is not tightly confined and it is classified as ineffective in Table 5-1, the infill can be ignored.

15. Frame-wall systems with infills
Page 5-5, Section 5.3.4

It is possible for a frame-wall system to have infill panels and to be evaluated according to this methodology. In this case, follow the procedures for calculating the period of a frame-wall system (Equation 5-20). Infill walls should be considered as a wall in Equation 5-20, taking A_{wi} as 0.25 x wall's plan area. Then, proceed to Chapter 9 to evaluate the building (including the effects of infill). Wall ratings can be determined according to 7.7.4.

16. Calculation of wall ratings
Page 7-12, Section 7.7.4

Drift capacities of critical walls and vertical wall segments are provided in Section 7.7.4. In Table 7-6 and Table 7-7 and Equations 7-15 and 7-16, drift capacities are given in units of percent drift. For comparison with drift demands and calculation of wall ratings, these need to be converted to units of displacement, by multiplying by h_{sx}.

CORRECTIONS

17. Reference to equation for period of frame systems
Page 5-21, Section 5.6.1, last sentence

The effective fundamental period for frame systems is given by Equation 5-18 rather than Equation 5-20.