DEPARTMENT OF BUILDING AND SAFETY

Supplemental Plan Check List for Concrete Special Moment Resisting Frame

Plan Check / PCIS Application Number: _____

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* Special Concrete Moment Frame assigned to Seismic Category D, E, or F only (ASCE 7-05, Table 12.2-1) ; References are based on ACI 318-08 ; Special Moment Frame – A cast in place frame complying with requirements of 21.1.2 through 21.1.8, 21.5 through 21.8, 21.11 through 21.13, and Chapter 1 through 16, ACI 318-08.

PLAN DETAILS

Flexural Members (with factored axial compressive force # $A_g f_c'$ /10)

1. For flexural members of frames, provide details as follows:
   a) Clear span for the members shall not be less than four times its effective depth (21.5.1.2)
   b) The width of member shall not be less than smaller of 0.3h (h=overall thickness of member) or 10 in. (21.5.1.3)
   c) Width of member shall not exceed the width of its supporting member plus a distance on each side of supporting member equal to the smaller of (1) width of supporting member, c2, and (2) 0.75 of the overall dimension of supporting member, c1. (21.5.1.4)

2. For longitudinal reinforcement, splices, provide details as follows: (21.5.2)
   a) Provide hoop or spiral reinforcement over lap length of flexural reinforcement (21.5.2.3).
   b) Spacing of the transverse reinforcement enclosing the lap-spliced bars shall not exceed d/4 or 4 in.
   c) Longitudinal bar lap splices shall not be used at following locations: (21.5.2.3)
      i) Within the joints,
      ii) Within a distance of twice the member depth from the face of the joint.
      iii) Where an analysis indicates flexural yielding is caused by inelastic lateral displacement of the frame.

3. Welded splices shall conform to 21.1.7 and mechanical splices shall conform to 21.1.6. (21.5.2.4)

4. For transverse reinforcement of the flexural frame member, provide details as follows:
   a) Hoops shall be provided in the following regions of frame members: (21.5.3.1)
      i) Over a length equal to 2 times the member depth measured from the face of the supporting member toward midspan, at both ends of the flexural member;
      ii) Over lengths equal to 2 times the member depth on both sides of a section where flexural yielding may occur in connection with inelastic lateral displacements of the frames.

b) The first hoop shall be located not more than 2" from the face of a supporting member. (21.5.3.2)

c) The spacing of the hoops shall not exceed the smallest of following:

(i) d/4,

(ii) 8 times the diameter of smallest longitudinal bars,

(iii) 24 times of the hoop bars, and

(iv) 12".

d) Where hoops are not required, stirrups with seismic hooks at both ends shall be placed at a distance no more than d/2 throughout the length of the member. (21.5.3.4)

e) Where hoops are required, longitudinal bars on the perimeter shall have lateral support conforming to Sec. 7.10.5.3. (21.5.3.3)

f) Stirrups ot ties required to resist shear shall be hoops over lengths of members in Sec. 21.5.3.1. (21.5.3.5)

g) Hoops in flexural members shall be permitted to be made up of two pieces of reinforcement as specified in Sec. 21.5.3.6.

Columns of the Frame (with factored axial compressive force > $A_g f_c'$ /10)

1. For members of concrete special moment resisting frame resisting earthquake-induced forces subject to combined bending and axial loads, size of the frame member shall comply with:

   a) The shortest cross sectional dimension to the measured on a straight line passing through the geometric centroid, shall not be less than 12 in. (21.6.1.1)

   b) The ratio of the shortest cross-sectional dimension to the perpendicular dimension shall not be less than 0.4. (21.6.1.2)

2. Lap splices are permitted only within the center half of the column height and must be designed as tension splice. (21.6.3.2) Mechanical splices shall conform to Section 21.1.6 and welded splices shall conform to 21.1.7.

3. Flexural strengths of columns shall satisfy Eq. (21-1) , $\mathbf{\Sigma M_{nc} \geq (6/5) \Sigma M_{nb}}$. (21.6.2.2)

4. If Sec. 21.6.2.2 is not satisfied at a joint, the lateral strength and stiffness of the columns framing into that joint shall be ignored when determining the calculated strength and stiffness of the structure. (21.6.2.3)

5. Area of longitudinal reinforcement, A_{st}, shall not be less than $0.01A_g$ or more than $0.06A_g$. (21.6.3.1).

6. Tie shall be arranged such that every corner and alternate longitudinal bar shall have lateral support provided by the corner of a tie with an included angle not more than 135 deg and no bar shall be farther 6 in. clear on each side along the tie from such a laterally supported bar. Where longitudinal bars are located around perimeter of a circle, a complete circular tie shall be permitted. (7.10.5.3)

7. For transverse reinforcement (confinement), provide details as follows:

   a) The spacing of transverse reinforcement shall not exceed the smallest of following: (21.6.4.3)

   (i) 1/4 of minimum member dimension,

   (ii) six times the diameter of the longitudinal reinforcement,

   (iii) $S_o=4+(14-h_x)/3$. The value of S_o shall not exceed 6" and need not be taken less than 4".

b) Horizontal spacing of crossties or legs of rectilinear hoops, h_x, shall not exceed 14" on center. (21.6.4.2)

c) Transverse reinforcement as specified in 21.6.4.2 through 21.6.4.4 shall be provided over a length (l_o) from each joint face and on both sides of any section where flexural yielding is likely to occur as a result of inelastic lateral displacements of the frame. Length (l_o) shall not be less than the largest of (1) the depth of the member at the joint face or at the section where flexural yielding likely to occur; (2) one-sixth of the clear span of the member; and (3) 18". (21.6.4.1)

d) Beyond the length l_o specified in 21.6.4.1 the column shall contain spiral or hoop reinforcement with center-to-center spacing not exceeding the smaller of 6 times the diameter of the smallest longitudinal column bars and 6". (21.6.4.5)

e) Columns supporting reactions from discontinuous stiff members, such as walls, shall be provided with transverse reinforcements as required in 21.6.4.2 through 21.6.4.4 over their full height at all levels beneath the discontinuity if the factored axial compressive force in these members, related to earthquake effect, exceeds $A_g f_c'/10$. Where design forces have been magnified to account for the overstrength of the vertical elements of the seismic-force-resisting system, the limit of $A_g f_c'/10$ shall be increased to $A_g f_c'/4$. (21.6.4.6(a))

f) Transverse reinforcement as required in 21.6.4.2 through 21.6.4.4 shall extend into the discontinued member at least l_d of the largest longitudinal column bar, where l_d is determined in accordance of 21.7.5. Where the lower end of the column terminates on a wall, the required transverse reinforcement shall extend into the wall at least ld of the largest longitudinal column bar at the point of termination. If column terminates on a footing or mat, the required transverse reinforcement shall extend at least 12" into the footing or mat. (21.6.4.6 (b))

Joints of Frames

1. At joints of frames, provide details as follows:

   a) Beam longitudinal reinforcement terminated in a column shall be extended to the far face of the confined column core and anchored in tension according to 21.7.5 and in compression according to Chapter 12. (21.7.2.2)

   b) Where longitudinal reinforcement extends through a joint, the column dimension parallel to the beam reinforcement shall not be less than 20 times the diameter of the largest longitudinal bar for normal weight concrete. For lightweight aggregate concrete, the dimension shall not be less than 26 times the bar diameter. (21.7.2.3)

   c) The joint transverse reinforcement shall satisfy 21.6.4.4, and shall also satisfy 21.6.4.2, 21.6.4.3, and 21.6.4.7, unless the joint is confined by structural members per Sec. 21.7.3.2. (21.7.3.1).

   d) Where members frame into all four sides of the joint and each member width is at least 3/4 the column width, the transverse reinforcement specified in 21.6.4.4 shall be permitted to be reduced by half, and the spacing required in 21.6.4.3 shall be permitted to be increased to 6" within the overall depth **h** of the shallowest framing member. (21.7.3.2)

CALCULATIONS

Strength and Serviceability Requirements

1. For members in concrete special moment resisting frame resisting earthquake-induced forces: (9.2.1)
   U= 1.4D
   U= 1.2D+1.6L+ 0.5Lr
   U= 1.2D+1.6Lr +f_1L

U= 1.2D+ f_1L+1.0E
U= 0.9D+1.0E

2. Strength Reduction Factor - Strength reduction factor used to calculate the design strength shall be follows: (9.3.2)
   - ϕ = 0.75 shear
   - ϕ = 0.90 flexure without axial load
   - ϕ = 0.75* axial compression load (members with spiral reinforcing)
   - ϕ = 0.65* axial compression load (members with other reinforced members)

   (* *Variation of ϕ with net tensile strain in extreme tension steel for Grade 60 reinforcement shall be permitted to be increased linearly per Sec. 9.3.2.2)*.

Flexural Members (with factored axial compressive force # $A_g f_c$' /10)

1. For flexural member, provide the following:
   a) Minimum longitudinal reinforcement (top & bottom)$ 200b_wd /f_y (21.5.2.1)
   b) Reinforcement ratio, shall not exceed 0.025 (21.5.2.1)
   c) At least 2-bars shall be provided continuously at both top and bottom. (21.5.2.1)
   d) Positive moment strength at joint shall not be less than ½ the negative moment provided at the face of the joint. At every section, the positive and negative moment capacity shall not be less than 1/4 the maximum moment capacity provided at the face of either joint. (21.5.2.2)
   e) The design shear force shall be assumed that moments of opposite sign corresponding to probable flexural moment strength, M_{pr}, act at the joint faces and that the member is loaded with the factored tributary gravity load along its span. (21.5.4.1)
   f) Assume V_c = 0 when both of the following conditions occur: (21.5.4.2)
      (i) The earthquake-Induced shear force calculated in accordance with section 21.5.3.1 represents one-half or more of the maximum required shear strength within the lengths;
      (ii) The factored axial compressive force including earthquake effects is less than $A_g f_c$' /20.

Columns of the Frame (with factored axial compressive force > $A_g f_c$' /10)

1. For the columns of frames, provide the following requirements:
   a) Flexural strengths of columns shall satisfy Eq. (21-1): (21.6.2.2)

      $\Sigma M_{nc} \geq (6/5)\Sigma M_{nb}$

      Otherwise, the lateral strength and stiffness of the columns framing into that joint shall be ignored when determining the calculated strength and stiffness of the structure. (21.6.2.3)

   b) Total cross-sectional area of rectangular hoop reinforcement shall not be less that the following formulas: (21.6.4.4)

      $A_{sh} = 0.3(s*b_c f'_c / f_{yt})[(A_g / A_{ch})-1]$ (21-4)
      $A_{sh} = 0.09\ (s*b_c*f'_c / f_{yt})$ (21-5)

   c) Volumetric ratio of spiral or circular hoop reinforcement shall not be less that the following formulas: (21.6.4.3(a))

      $\rho_s = 0.12$ (fc'/fyt) (21-3)

      $\rho_s = 0.45$ (Ag/Ach-1) f''c/fyt (10-5)

If the thickness of the concrete cover outside the confining transverse reinforcement exceeds 4 in., additional transverse reinforcement shall be provided at a spacing not exceeding 12 in. Concrete over on additional reinforcement shall not exceed 4 in. (21.6.4.7)

d) Assume $V_c = 0$ for transverse reinforcement over the length l_o (21.6.4.1) when both of the following conditions occur:

i) The earthquake-induced shear force calculated per section 21.6.5.1 represents one-half or more of the maximum required shear strength within l_o.

ii) The factored axial compression force including earthquake effects is less than $A_g f_c'/20$.

Joints of Frames

1. At joints of frames, comply with the following requirements: (21.7.2)

a) In determining shear forces in the joints, forces in the longitudinal beam reinforcement at the joint face shall be determined by assuming that the stress in the flexural tensile reinforcement is 1.25 f_y. (21.7.2.1)

b) For lightweight aggregate concrete, the nominal shear strength of the joint shall not exceed 3/4 of the limits for normal-weight aggregate concrete given in section 21.7.4.1. (21.7.4.2)

c) For structures that rely on special moment frames to resist earthquake effects, E, ϕ for shear shall be 0.6 if the nominal shear strength of the member is less than the shear corresponding to the development of the nominal flexural strength of the member. (9.3.4 (a))

d) The nominal shear strength of the joint shall not be greater than the forces below for normal-weight aggregate concrete. (21.7.4.1)

*For the joints Confined on all four faces:	20	$f'_c A_j$
*For the joints Confined on 3-faces or on two opposite faces;	15	$f'_c A_j$
*All Others	12	$f'_c A_j$

A joint is considered to be confined if confining members frame into all faces of the joint. A member that frames into a face is considered to provide confinement at the joint if at least 3/4 of the face of the joint is covered by the framing member. (21.7.4.1)

Aj is the effective cross sectional area within a joint computed from joint depth times effective joint width. Joint depth shall be the overall depth of the column. Effective joint width shall be the overall width of the column, except where the beam frames into a wider column. The effective joint width shall not exceed the smaller of (a) and (b): (21.7.4.1)

a) beam width plus joint depth

b) twice the smaller perpendicular distance from longitudinal axis of beam to column side.

NOTES ON PLANS

1. For concrete in members resisting earthquake-induced forces, the minimum compressive strength of concrete shall be: (21.1.4.2, 21.1.4.3)

a) 3,000 psi minimum for normal weight concretes.

b) 3,000 psi minimum and 5,000 psi maximum for light weight concrete.

2. For reinforcement in members resisting earthquake-induced forces, the reinforcement shall comply with the following: (21.1.5)

a) All reinforcement shall comply with ASTM A706.

b) A 615 Grades 40 and 60 reinforcement may be used provided: F_y (mill test) - F_y (design) < 18.0 ksi (No retests shall be permitted)

c) Actual tensile strength / actual yield strength < 1.25

d) No plain reinforcement allowed.

e) The value of f_{yt} used to compute the amount of confinement reinforcement shall not exceed 100,000 psi. (21.1.5.4)

ADDITIONAL CORRECTIONS	**Code Sec. No.**