Building Seismic Checks: ASCE 7-22

1. Torsion (12.8.4.2, 12.8.4.3, Table 12.3-1) — rigid diaphragm, one story at a time

Lateral elements: X elements (stiffness k_i) along lines $y = y_i$; Y elements (k_j) along lines $x = x_j$.

$$K_x = \sum k_i, \quad y_R = \frac{\sum k_i\, y_i}{K_x}, \qquad K_y = \sum k_j, \quad x_R = \frac{\sum k_j\, x_j}{K_y}, \qquad J = \sum k_i (y_i - y_R)^2 + \sum k_j (x_j - x_R)^2$$

Story shear V acts at the center of mass c shifted by the accidental eccentricity $e = \pm\, 0.05\, A_x\, L$,
L = plan dimension perpendicular to V. R = center of rigidity coordinate in the same direction as c.

$$\delta(z) = \frac{V}{K} + \frac{V\,(c + e - R)\,(z - R)}{J} \qquad \text{story drift at plan position } z \text{ (edges } z = 0, L)$$

$\delta_{max}/\delta_{avg} > 1.2$: Type 1a; > 1.4: Type 1b extreme (with $A_x = 1$; not for flexible diaphragms).

$$A_x = \left(\frac{\delta_{max}}{1.2\, \delta_{avg}} \right)^2, \qquad 1 \le A_x \le 3.0 \qquad \text{(SDC C to F, Type 1a or 1b)}$$

Element force: $F = k\,\delta$ at the element line, with rotation $\theta = V(c + e - R)/J$; the larger of $\pm e$ is reported.

2. Vertical irregularity (Table 12.3-2, 12.3.3.1)

1a soft story: $K_i < 0.70\, K_{i+1}$ or $K_i < 0.80\, \bar{K}_{i+1..i+3}$ 1b extreme soft: $< 0.60\, K_{i+1}$ or $< 0.70\, \bar{K}$

2 weight (mass): $W_i > 1.5\, W$ of an adjacent story (a roof lighter than the floor below is not considered)

3 vertical geometric: SFRS plan width $> 1.3\times$ that of an adjacent story (one-story penthouses excluded)

5a weak story: lateral strength $< 0.80\times$ story above 5b extreme weak: $< 0.65\times$ story above

Exception 1: Types 1a, 1b and 2 do not apply where no story drift ratio exceeds 130 % of the story above (the top two stories are not evaluated).

12.3.3.1: SDC E, F: Types 1b, 5a, 5b not permitted. SDC D: Type 5b not permitted (see 12.3.3.2).

3. Redundancy factor ρ (12.3.4)

SDC B and C: $\rho = 1.0$ (12.3.4.1, which also lists other cases with $\rho = 1.0$).

SDC D to F, each direction: $\rho = 1.0$ if (a) or (b) holds for every story resisting more than 35 % of the base shear; otherwise $\rho = 1.3$.

(a) removing one element (Table 12.3-3) does not cut the story strength by more than 33 % nor create an extreme torsional irregularity (Type 1b).

(b) the structure is regular in plan at all levels and has at least two bays of perimeter framing on each side of the story. Shear walls: bays = wall length / h_{sx} (two times for light-frame construction).

Units: English: in, kip, kip/in. metric: mm, kN, kN/mm. Ratios, ρ, A_x dimensionless.

4. Modal response spectrum scaling (12.9.1)

Modes: cumulative modal mass in each direction ≥ 0.90 (12.9.1.1).

$V_t < V$: forces $\times \dfrac{V}{V_t}$ (12.9.1.4.1; V = ELF base shear with $T \leq C_u T_a$; 100 % of V)

$V_t < C_s W$: drifts $\times \dfrac{C_s W}{V_t}$ (12.9.1.4.2; C_s from the minimum-C_s equation)

$C_{s,min} = \max(0.044\, S_{DS}\, I_e,\ 0.01)$; and where $S_1 \geq 0.6g$: $C_{s,min} \geq 0.5\, S_1/(R/I_e)$

Enter the combined (CQC or SRSS) MRSA story shears and drifts at strength level (spectrum $\times\ I_e/R$).

5. Direction of loading, orthogonal effects (12.5)

$E_1 = |E_X| + 0.3\,|E_Y|$, $E_2 = 0.3\,|E_X| + |E_Y|$, $E = \max(E_1, E_2)$ (100 % + 30 % procedure)

SDC B (12.5.2): loads applied independently in each of two orthogonal directions; $E = \max(|E_X|, |E_Y|)$.

SDC C (12.5.3): as SDC B, but structures with horizontal irregularity Type 5 (nonparallel systems) use the 100 % + 30 % combination (or simultaneous orthogonal ground motions in a response history analysis).

SDC D to F (12.5.4): as SDC C, and also each column or wall forming part of two or more intersecting seismic force-resisting systems whose seismic axial load from either direction is at least 20 % of its axial design strength.

Example (Load Example button, English units, SDC D)

Torsion: plan 1200 in $\times$ 720 in, center of mass (600, 360).

X frames: $k = 250$ kip/in at $y = 0$, 50 at $y = 720$; Y frames: 100 kip/in at $x = 0$ and $x = 1200$.

$y_R = 50(720)/300 = 120$ in, $J = 250(120)^2 + 50(600)^2 + 2(100)(600)^2 = 9.36 \times 10^7$ kip-in. Story 1: $V_x = 300$ kip, $e = 36$ in.

$\delta(0) = 1 - 300(276)(120)/J = 0.8938$ in, $\delta(720) = 1 + 300(276)(600)/J = 1.5308$ in,

ratio $= 1.5308/1.2123 = 1.2627 > 1.2$: Type 1a, $A_x = (1.2627/1.2)^2 = 1.107$.

Vertical: story 1 stiffness 300 vs 600 above ($0.50 < 0.60$): Type 1b. Strength 400 vs 600 (0.667): Type 5a.

Story 3 SFRS width 1200 in vs 900 in above (1.33): Type 3.

MRSA, X: $V = 400$, $V_t = 200$ kip: forces $\times$ 2.0. $C_{s,min} = 0.044$, $C_s W = 220$ kip $> V_t$: drifts $\times$ 1.1. 90 % mass at mode 3.

Orthogonal: column C1, $E_X = 120$, $E_Y = 40$, axial ratio 0.25, intersecting: $E = 120 + 0.3(40) = 132$.

Reference

ASCE/SEI 7-22, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, Sections 12.3, 12.5, 12.8.4, 12.9.1.

Section numbers as in ASCE 7-16 and 7-22; check them against your copy of the standard.