Structural Design Basis- Basic Requirements

- The building structure shall include complete lateral and vertical force resisting system capable of providing adequate strength, stiffness, and energy dissipation capacity to withstand the design ground motions within the prescribe limits of deformation and strength demand.
- The design ground motions shall be assumed to occur along any horizontal direction of a building structure.

Structural Design Basis- Basic Requirements

- The design seismic forces and their distribution over the height of the building structure, shall be established in accordance with procedure specified in section 12.6 and the corresponding internal forces and deformations in the members of the structure shall be determined.
- Individual members, including those not part of the seismic force resisting system shall be provided with adequate strength to resist the shears, axial forces and moments .

Structural Design Basis- Basic Requirements

- The deformation the structure shall not exceed the prescribed limits where the structure is subjected to design seismic forces.
- A continuous load path or paths with adequate strength and stiffness shall be provided to transfer all forces from the point of application to the final point of resistance.
- A connection for resisting a horizontal force acting parallel to the member shall be provided for each beam, girder or truss.

Structural Design Basis- Basic Requirements

- The foundations shall be designed to resist the forces developed and accommodate the movements imparted to the structure by the design ground motions.
- Structural elements including the foundations shall conform the material design and detailing requirements.

Structural System Selection

- The basis lateral and vertical seismic force resisting system shall conform to one of the types indicated in Table 12.2-1. For e.g.
  - Bearing wall system
  - Moment resisting frame
  - Dual systems etc.
- Each type in 12.2-1 is subdivided by the types of vertical elements used to resist lateral seismic forces and three values are mentioned i.e. Response Modification factor "R", Over-strength Factor, " Ω_o" and deflection amplification Factor C_d

Seismic response coefficient

TABLE 12.2-1 DESIGN COEFFICIENTS AND FACTORS FOR SEISMIC FORCE–RESISTING SYSTEMS

Seismic Force–Resisting System	ASCE 7 Section where Detailing Requirements are Specified	Response Modification Coefficient, R^a	System Overstrength Factor, $\Omega_0{}^g$	Deflection Amplification Factor, $C_d{}^b$	Structural System Limitations and Building Height (ft) Limit[c]				
					Seismic Design Category				
					B	C	D[d]	E[d]	F[e]
C. MOMENT-RESISTING FRAME SYSTEMS									
1. Special steel moment frames	14.1 and 12.2.5.5	8	3	5½	NL	NL	NL	NL	NL
2. Special steel truss moment frames	14.1	7	3	5½	NL	NL	160	100	NP
3. Intermediate steel moment frames	12.2.5.6, 12.2.5.7, 12.2.5.8, 12.2.5.9, and 14.1	4.5	3	4	NL	NL	35[h,i]	NP[h]	NP[i]
4. Ordinary steel moment frames	12.2.5.6, 12.2.5.7, 12.2.5.8, and 14.1	3.5	3	3	NL	NL	NP[h]	NP[h]	NP[i]
5. Special reinforced concrete moment frames	12.2.5.5 and 14.2	8	3	5½	NL	NL	NL	NL	NL
6. Intermediate reinforced concrete moment frames	14.2	5	3	4½	NL	NL	NP	NP	NP
7. Ordinary reinforced concrete moment frames	14.2	3	3	2½	NL	NP	NP	NP	NP
8. Special composite steel and concrete moment frames	12.2.5.5 and 14.3	8	3	5½	NL	NL	NL	NL	NL
9. Intermediate composite moment frames	14.3	5	3	4½	NL	NL	NP	NP	NP
10. Composite partially restrained moment frames	14.3	6	3	5½	160	160	100	NP	NP
11. Ordinary composite moment frames	14.3	3	3	2½	NL	NP	NP	NP	NP

Structural System Selection

- The selected seismic force resisting system shall be designed and detailed in accordance with specific requirements for the system defined in codes.
- Different seismic force resisting systems are permitted to be used to resist seismic forces along each of the two orthogonal axis of the structure.
- When a combination of any system to be used then least "R" value will be selected however, C_d and Ω_o factors considered are the maximum.

Structural System Selection-Types-Dual

- For a dual system, the moment frames shall be capable of resisting 25% of the design seismic forces. The total seismic force resistance is to be provided by the combination of the moment frames and the shear walls or braced frames in proportion to their rigidities.

Structural System Sélection-Types- Spécial Moment Resisting Frames

- For structures assigned to SDC D,E or F, a special moment frame is used.
- A special moment resisting frame shall not be discontinuous.
- The frame shall be continuous up to the foundation.

Structural System Selection-Types- Int./Ordinary Moment Resisting Frames

- An Intermediate / Ordinary moment resisting frame shall not be discontinuous.
- They have lower values of “R”, resulting in higher base shear.
- The energy dissipation is less in comparison to SMRF system.
- The frame shall be continuous up to the foundation.

Analysis procédure

- During the earthquake motions, the structure is subjected to the deformations that produces internal forces and stresses.
- Earthquake Engineering philosophy is to relate earthquake dynamic forces to the equivalent static forces, and then using static analysis of the structure, determine deformations, internal forces and stresses in the structure.

Analysis procédure

- IBC describes two analysis procedures to determine the equivalent static forces that will simulate an earthquake action on the structure.
  - The equivalent lateral force procedure (used for SDC B,C,D,E & F)
  - The simplified analysis (used for SDC, B,C,D,E&F and for constructions limited to two stories in height and three stories for light construction.

Analysis procédure

- For structures in SDC "A" neither the simplified analysis not the equivalent lateral force procedure can be utilized.
- This type of structure should be designed so that the lateral resisting force system can resist the minimum design lateral force, F_x, applied at each floor level. (ASCE 7-05, Section 11.7.2). The design lateral force and be determined for this type of structure using the following equation.

Analysis procédure

- $F_x = 0.01\ w_x$
- Where w_x is dead wt. of the str. Assigned to level x.

Equivalent Lateral

- This procedure describes how to calculate the seismic base shear and lateral seismic forces. (ASCE 7-05, Section 12.8)
  - $V = C_s W$
- Where Cs= Seismic response coefficient
- W = the effective weight of the structure including the total dead load and other load as below.
  - In areas used for storage, a minimum 25% of the reduced floor live load (floor live load in public garage and open parking areas need not to be included.

Equivalent Lateral

- In areas used for storage, a minimum 25% of the reduced floor live load (floor live load in public garage and open parking areas need not to be included.
- Partition load if it is equal to more than 10 psf
- Total weight of permanent operating equipment.
- 20% of flat roof snow load where flat snow load exceeds 30 psf.

Seismic response coefficient

- The seismic response coefficient, Cs, shall determined from:
  - $$Cs = \frac{S_{DS}}{\left(\frac{R}{I_E}\right)}$$
- Where "R" is response modification factor as per Section 12.2.1
- I_E is occupancy importance factor determined from Table 11.5-1 ASCE 7-05

Seismic response coefficient

TABLE 12.2-1 DESIGN COEFFICIENTS AND FACTORS FOR SEISMIC FORCE–RESISTING SYSTEMS

Seismic Force–Resisting System	ASCE 7 Section where Detailing Requirements are Specified	Response Modification Coefficient, R^a	System Overstrength Factor, $\Omega_0{}^g$	Deflection Amplification Factor, $C_d{}^b$	Structural System Limitations and Building Height (ft) Limit[c] — Seismic Design Category: B	C	D^d	E^d	F^e
C. MOMENT-RESISTING FRAME SYSTEMS									
1. Special steel moment frames	14.1 and 12.2.5.5	8	3	5½	NL	NL	NL	NL	NL
2. Special steel truss moment frames	14.1	7	3	5½	NL	NL	160	100	NP
3. Intermediate steel moment frames	12.2.5.6, 12.2.5.7, 12.2.5.8, 12.2.5.9, and 14.1	4.5	3	4	NL	NL	$35^{h,i}$	NP^h	NP^i
4. Ordinary steel moment frames	12.2.5.6, 12.2.5.7, 12.2.5.8, and 14.1	3.5	3	3	NL	NL	NP^h	NP^h	NP^i
5. Special reinforced concrete moment frames	12.2.5.5 and 14.2	8	3	5½	NL	NL	NL	NL	NL
6. Intermediate reinforced concrete moment frames	14.2	5	3	4½	NL	NL	NP	NP	NP
7. Ordinary reinforced concrete moment frames	14.2	3	3	2½	NL	NP	NP	NP	NP
8. Special composite steel and concrete moment frames	12.2.5.5 and 14.3	8	3	5½	NL	NL	NL	NL	NL
9. Intermediate composite moment frames	14.3	5	3	4½	NL	NL	NP	NP	NP
10. Composite partially restrained moment frames	14.3	6	3	5½	160	160	100	NP	NP
11. Ordinary composite moment frames	14.3	3	3	2½	NL	NP	NP	NP	NP

Seismic response coefficient

TABLE 11.5-1 IMPORTANCE FACTORS

Occupancy Category	*I*
I or II	1.0
III	1.25
IV	1.5

Seismic response coefficient

- The value of C_s should not exceed :
  - $Cs = \frac{S_{D1}}{T\left(\frac{R}{I_E}\right)}$ For ($T \leq T_L$)
- Where "T" is the fundamental time period of the structure.
- T_L is long period transition period determined from Figure 22-15 ASCE 7-05.
- Also C_s shall not be less than the following.

Seismic response coefficient

- For buildings and structures in seismic design categories A, B, C and D and in buildings and structures for which 1-second spectral response acceleration, S1 is less than 0.6g, the value of the seismic coefficient, Cs, should not be taken less than
  - $C_{s(min)} = 0.01$
- For buildings and structures in seismic design categories "E" and "F" and in buildings and structures for which the 1-sec spectral response

Seismic response coefficient

- Acceleration, S1, is equal to or greater than 0.6g, the value of the seismic coefficient, Cs, should not be taken less than
    - $C_s = \frac{0.5S_1}{\left(\frac{R}{I_E}\right)}$
- The response modification factor, R, is a function of several factors. Some of them are ductility capacity and inelastic performance of structural materials and systems during past earthquakes.

Fundamental period (T)

- Elastic fundamental period, T, is a function of the mass and the stiffness of the structure.
- If the building is not designed, the period, T cannot be precisely determined.
- On the other hand, to design a building, the period of vibration should be known and included in the equations for design.
- That is why building codes provide equations for calculation of approximate periods of vibrations, Ta.

Fundamental period (T)

- Calculated approximate periods are shorter than the real periods of the structure, which leads to the higher base shear and safe design.
  - $T_a = C_t\, h_n^x$ Hn is total height of building
- Where "h_n" is the height in feet above the base to the highest level of the structure and the coefficient "Ct" and "x" are determined from Table 12.8-2.

Fundamental period (T)

TABLE 12.8-2 VALUES OF APPROXIMATE PERIOD PARAMETERS C_t AND x

Structure Type	C_t	x
Moment-resisting frame systems in which the frames resist 100% of the required seismic force and are not enclosed or adjoined by components that are more rigid and will prevent the frames from deflecting where subjected to seismic forces:		
Steel moment-resisting frames	0.028 (0.0724)[a]	0.8
Concrete moment-resisting frames	0.016 (0.0466)[a]	0.9
Eccentrically braced steel frames	0.03 (0.0731)[a]	0.75
All other structural systems	0.02 (0.0488)[a]	0.75

[a] Metric equivalents are shown in parentheses.

Fundamental period (T)

- For concrete moment resisting frame buildings that do not exceed 12 stories in height and have a minimum story height of 10 feet, the approximate period of vibration, T, can be determined using the following equations:
  - $T_a = 0.1\,N$
  - Where "N" is the number of stories in the building.

Lateral Seismic Force Calculation

- Vertical distribution of the base shear force produces seismic lateral forces, F_x, at any floor level.
- Seismic lateral forces act at the floor levels because mass is concentrated at the floor level.
- It is known that force is produced of mass and acceleration. ($F = m\ a$)
- E.Q motions produce accelerations of the structures and induce forces at the places of mass concentrations. (i.e. floor levels)

Lateral Seismic Force Calcualation

- The lateral forces that will be applied to level “x” of the structure, F_x, can be determined from the following equation:
  - $F_x = C_{vx} V$
  - $C_{vx} = \dfrac{W x h_x^k}{\sum_{i=1}^{n} w_i h_i^k}$
- C_{vx} = vertical distribution factor.
- K = distribution exponent related to the building period, it is “1” when T ≤ 0.5 sec.
- =2 for building have period T≥ 2.5 sec

Lateral Seismic Force Calculation

- = 2 or linear interpolation between 1 and 2, for building having a period of 0.5sec ≤ T ≥ 2.5 sec
- h_i, h_x = height from the base to the level "i "and x"
- w_i, w_x = portion of "W" assigned to the level "i "and x"

Summary: Eqv. Lateral Procedure

- Determine seismic design category and choose appropriate "I_E" value.
- Choose "R" value.
- Determine "T" i.e. Time period.
- Calculate "Cs" and check it against minimum and maximum values.
- Calculate total gravity Load.
- Calculate seismic base shear.
- Calculate seismic lateral load for every level of structure.

The simplified analysis

- The simplified analysis procedure for seismic design is used as per ASCE 7-05 section 12.14.8.1 and is applicable to any structure that satisfies the following limitations and conditions:
  - Seismic design category B, C, D, E or F.
  - Light frame construction not exceeding three stories in height, excluding basement or any construction.

The simplified analysis

- The seismic base shear and lateral seismic forces are calculated as follows:

12.14.8.1 Seismic Base Shear. The seismic base shear, V, in a given direction shall be determined in accordance with Eq. 12.14-9:

$$V = \frac{F S_{DS}}{R} W \qquad (12.14\text{-}11)$$

where

$$S_{DS} = \frac{2}{3} F_a S_s$$

The simplified analysis

where F_a is permitted to be taken as 1.0 for rock sites, 1.4 for soil sites, or determined in accordance with Section 11.4.3. For the purpose of this section, sites are permitted to be considered to be rock if there is no more than 10 ft (3 m) of soil between the rock surface and the bottom of spread footing or mat foundation. In calculating S_{DS}, S_s shall be in accordance with Section 11.4.1, but need not be taken larger than 1.5. Ss

F = 1.0 for one-story buildings
F = 1.1 for two-story buildings
F = 1.2 for three-story buildings
R = the response modification factor from Table 12.14-1

The simplified analysis

W = effective seismic weight of structure that shall include the total dead load and other loads listed in the following text

1. In areas used for storage, a minimum of 25 percent of the floor live load (floor live load in public garages and open parking structures need not be included).
2. Where provision for partitions is required by Section 4.2.2 in the floor load design, the actual partition weight, or a minimum weight of 10 psf (0.48 kN/m^2) of floor area, whichever is greater.
3. Total operating weight of permanent equipment.
4. Where the flat roof snow load, P_f, exceeds 30 psf (1.44 kN/m^2), 20 percent of the uniform design snow load, regardless of actual roof slope.

The simplified analysis

12.14.8.2 Vertical Distribution. The forces at each level shall be calculated using the following equation:

$$F_x = \frac{w_x}{W} V \qquad (12.14\text{-}12)$$

where w_x = the portion of the effective seismic weight of the structure, W, at level x.

The simplified analysis: Procedure

- Check whether the structure satisfies the three conditions given in code.
- Determine the value of SDS .
- Choose appropriate R value.
- Determine the total gravity load W, of the structure.
- Calculate the seismic base shear "V"
- Determine the seismic lateral forces acting on the structure.

Design Storey Shear

- The seismic lateral forces will produce seismic design story shear, V_x, at any story “x” that can be determined from the following equation.
  - $V_x = \sum_{i=1}^{n} F_i$
- F_i is portion of seismic base shear assigned to level “i” and “n” is no. of stories.
- The seismic story shear in any story “x” should be collected and transferred to the story below by vertical elements of lateral force resisting system (walls).

Design Storey Shear

- The distribution of story shear on vertical elements depends on flexibility of the diaphragm, which those elements (walls) support.
- There are two types of diaphragms:
- Flexible and Rigid
  - Diaphragm is flexible when the lateral deformation of diaphragm is more than two times the average story drift of the story that supports diaphragm. Lateral deformation of diaphragm is maximum in plane deflection of

Design Storey Shear

  - the diaphragm under lateral load and the story drift is the difference b/w the deflection of the COM at the top and bottom of the story being considered.
  - A diaphragm that is not flexible the above definition is a rigid diaphragm.
- For flexible diaphragms, the seismic story shear, V_x, is distributed to vertical elements in the story "x" based on the area of the diaphragm tributary to each line of resistance.

Design Storey Shear

- The vertical elements of the seismic force resisting system may be considered to be in the same line of resistance if the maximum out of plane offset b/w such elements is less than 5% of the building dimension perpendicular to the direction of the lateral force.
- For rigid diaphragms, V_x, is distributed to the vertical elements in the story "x" based on the relative lateral stiffness of the vertical resisting elements and the diaphragm.

Torsional Effects

- For rigid diaphragm the eccentricity between COM and COR can occur.
- The lateral shear force is applied to the COM.
- Distribution of "V_x" to the vertical elements can be determined when the shear force acts to the COR.
- When the shear force moves from the COM to the COR it produces torsional moment .
- Effect of torsion will increase horizontal forces on vertical elements.

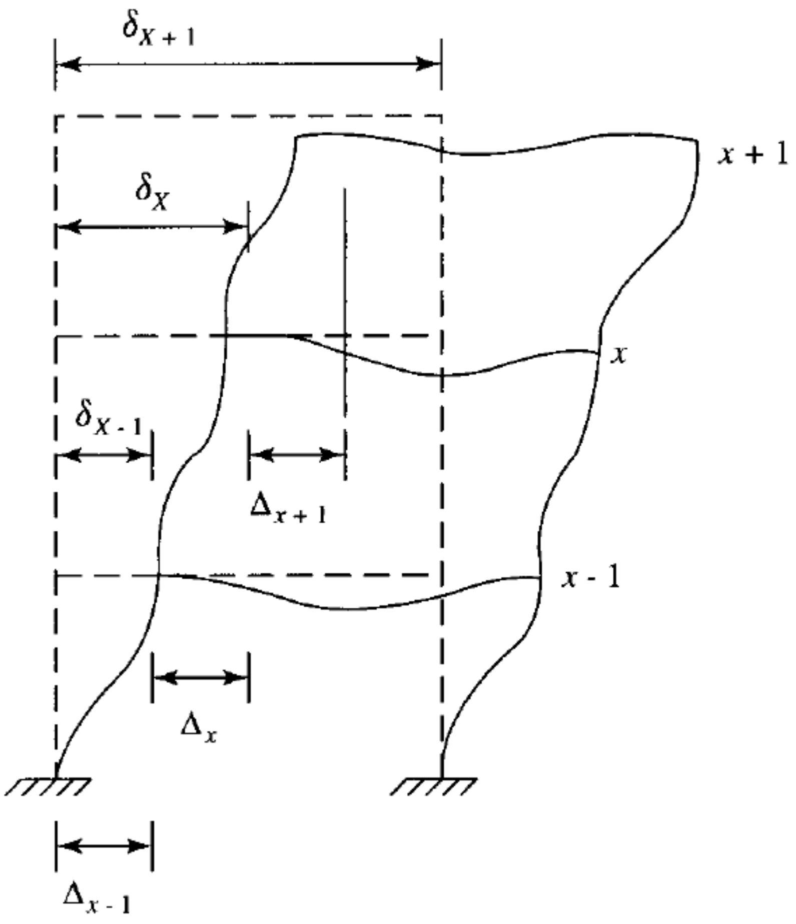
Torsional Effects

- Forces will not decrease due to torsional effects
  - $T = V_x * e$
  - Where "e" is eccentricity between COM and COR. It may occur in both "x" and "y" direction.

Overturning Moment

- The lateral seismic force produces the overturning moments. Overturning moment "M_x" should be calculated using the following equation:
  - $Mx = \tau \sum_{i=1}^{n} F_i(hi - hx)$
- F_i = portion of the SBS, V, at level "i".
- h_i, h_x = height from the base to level "i" and "x"
- τ = Overturning moment reduction factor
- = 1.0 for top 10 stories, 0.8 for the 20th story from top and below and permitted to be taken 1.0 for full height of the structure.

Lateral Deformation of Structure



Latéral Déformation of Structure

- The seismic lateral forces should be used in calculating the deformations of the structure.
- The value that is of interest for engineers is story drift.
- The value of story drift under seismic forces is important from different perspectives:
  - stability of the structure
  - Potential damage to non-structural elements
  - Human comfort

Lateral Deformation of Structure

- The allowable values for story drift are given in Table 12.12-1 ASCE 7-05

TABLE 12.12-1 ALLOWABLE STORY DRIFT, Δ_a[a,b]

Structure	Occupancy Category		
	I or II	III	IV
Structures, other than masonry shear wall structures, 4 stories or less with interior walls, partitions, ceilings and exterior wall systems that have been designed to accommodate the story drifts.	$0.025h_{sx}$[c]	$0.020h_{sx}$	$0.015h_{sx}$
Masonry cantilever shear wall structures [d]	$0.010h_{sx}$	$0.010h_{sx}$	$0.010h_{sx}$
Other masonry shear wall structures	$0.007h_{sx}$	$0.007h_{sx}$	$0.007h_{sx}$
All other structures	$0.020h_{sx}$	$0.015h_{sx}$	$0.010h_{sx}$

[a] h_{sx} is the story height below Level x.

[b] For seismic force–resisting systems comprised solely of moment frames in Seismic Design Categories D, E, and F, the allowable story drift shall comply with the requirements of Section 12.12.1.1.

[c] There shall be no drift limit for single-story structures with interior walls, partitions, ceilings, and exterior wall systems that have been designed to accommodate the story drifts. The structure separation requirement of Section 12.12.3 is not waived.

[d] Structures in which the basic structural system consists of masonry shear walls designed as vertical elements cantilevered from their base or foundation support which are so constructed that moment transfer between shear walls (coupling) is negligible.

Lateral Deformation of Structure

12.12.1.1 Moment Frames in Structures Assigned to Seismic Design Categories D through F. For seismic force–resisting systems comprised solely of moment frames in structures assigned to Seismic Design Categories D, E, or F, the design story drift (Δ) shall not exceed Δ_a/ρ for any story. ρ shall be determined in accordance with Section 12.3.4.2.

Lateral Deformation of Structure

12.3.4.2 Redundancy Factor, ρ, for Seismic Design Categories D through F. For structures assigned to Seismic Design Category D, E, or F, ρ shall equal 1.3 unless one of the following two conditions is met, whereby ρ is permitted to be taken as 1.0:

a. Each story resisting more than 35 percent of the base shear in the direction of interest shall comply with Table 12.3-3.

b. Structures that are regular in plan at all levels provided that the seismic force–resisting systems consist of at least two bays of seismic force–resisting perimeter framing on each side of the structure in each orthogonal direction at each story resisting more than 35 percent of the base shear. The number of bays for a shear wall shall be calculated as the length of shear wall divided by the story height or two times the length of shear wall divided by the story height for light-framed construction.

Lateral Deformation of Structure

TABLE 12.3-3 REQUIREMENTS FOR EACH STORY RESISTING MORE THAN 35% OF THE BASE SHEAR

Lateral Force-Resisting Element	Requirement
Braced Frames	Removal of an individual brace, or connection thereto, would not result in more than a 33% reduction in story strength, nor does the resulting system have an extreme torsional irregularity (horizontal structural irregularity Type 1b).
Moment Frames	Loss of moment resistance at the beam-to-column connections at both ends of a single beam would not result in more than a 33% reduction in story strength, nor does the resulting system have an extreme torsional irregularity (horizontal structural irregularity Type 1b).
Shear Walls or Wall Pier with a height-to-length ratio of greater than 1.0	Removal of a shear wall or wall pier with a height-to-length ratio greater than 1.0 within any story, or collector connections thereto, would not result in more than a 33% reduction in story strength, nor does the resulting system have an extreme torsional irregularity (horizontal structural irregularity Type 1b).
Cantilever Columns	Loss of moment resistance at the base connections of any single cantilever column would not result in more than a 33% reduction in story strength, nor does the resulting system have an extreme torsional irregularity (horizontal structural irregularity Type 1b).
Other	No requirements

Lateral Deformation of Structure

- For structures that can be designed based on simplified analysis procedure, the drift can be taken as 1% of the story height unless more eaxct analysis is provided.
    - $\Delta = 0.01hx$
- The value of the design story drift should be less than or equal to the value of allowable story drift given in Table 12.12-1.

Lateral Deformation of Structure

- For all other structures that cannot be analyzed using the simplified analysis procedure the drift should be determined as follows:
- 1. Calculate the deflection, δ_x , at level "x" from the following equation.
  - $\delta_x = \frac{C_d \delta_{xe}}{I_E}$
- C_d = Deflection amplification factor (Table 12.2-1)
- 2. The design story drift shall be determined from the difference b/w deflections of COM of any two adjacent stories.

Lateral Deformation of Structure

- 3. Check for P-Delta effect and check for magnification if needed.

P-Delta Effect

- An accurate estimate of story drift can be obtained by the P-Delta analysis. In first order structural analysis the equilibrium equations are formulated for the un-deformed shape of the structure.
- When deformations are significant the second order analysis must be applied and the P-Delta effect must be considered in determining the overall stability of the structure.

P-Delta Effect

- The P-Delta effect does not need to be applied when the ratio of secondary to primary moment, θ, does not exceed 0.1. This ratio is given by the following equations:

P-Delta Effect

$$\theta = \frac{P_x \Delta}{V_x h_{sx} C_d} \qquad (12.8\text{-}16)$$

where

P_x = the total vertical design load at and above Level x (kip or kN); where computing P_x, no individual load factor need exceed 1.0

Δ = the design story drift as defined in Section 12.8.6 occurring simultaneously with V_x (in. or mm)

V_x = the seismic shear force acting between Levels x and $x - 1$ (kip or kN)

h_{sx} = the story height below Level x (in. or mm)

C_d = the deflection amplification factor in Table 12.2-1

The stability coefficient (θ) shall not exceed θ_{max} determined as follows:

$$\theta_{max} = \frac{0.5}{\beta C_d} \leq 0.25 \qquad (12.8\text{-}17)$$

P-Delta Effect

where β is the ratio of shear demand to shear capacity for the story between Levels x and $x - 1$. This ratio is permitted to be conservatively taken as 1.0.

Where the stability coefficient (θ) is greater than 0.10 but less than or equal to θ_{max}, the incremental factor related to P-delta effects on displacements and member forces shall be determined by rational analysis. Alternatively, it is permitted to multiply displacements and member forces by $1.0/(1 - \theta)$.

Where θ is greater than θ_{max}, the structure is potentially unstable and shall be redesigned.

Where the P-delta effect is included in an automated analysis, Eq. 12.8-17 shall still be satisfied, however, the value of θ computed from Eq. 12.8-16 using the results of the P-delta analysis is permitted to be divided by $(1 + \theta)$ before checking Eq. 12.8-17.

Lateral Deformation of Structure:Summary

Step 1. If the structure satisfies the limitations for the simplified analysis procedure listed in Section 20.3.3, use Eq. 20.24 to determine the story drift.

Step 2. For structures that do not satisfy the limitations for the simplified analysis procedure listed in Section 20.3.3, use Eqs. 20.24, 20.25, 20.26,and 20.27 to calculate δ_x, δ_{x-1}, Δ, θ, and $\theta_{\max}$. Check whether the P-delta effect must be considered and adjust Δ to Δ_p using Eq. 20.29.

Step 3. Determine allowable drift from Table 20.9 and compare with the calculated design drift. If calculated drift exceeds the allowable drift, redesign the structure.

Structural Modelling

12.7.1 Foundation Modeling. For purposes of determining seismic loads, it is permitted to consider the structure to be fixed at the base. Alternatively, where foundation flexibility is considered, it shall be in accordance with Section 12.13.3 or Chapter 19.

12.13.3 Foundation Load-Deformation Characteristics.

Where foundation flexibility is included for the linear analysis procedures in Chapters 12 and 16, the load-deformation characteristics of the foundation-soil system (foundation stiffness) shall be modeled in accordance with the requirements of this section. The linear load-deformation behavior of foundations shall be represented by an equivalent linear stiffness using soil properties that are compatible with the soil strain levels associated with the design earthquake motion.

Structural Modelling

12.7.2 Effective Seismic Weight. The effective seismic weight, W, of a structure shall include the total dead load and other loads listed below:

1. In areas used for storage, a minimum of 25 percent of the floor live load (floor live load in public garages and open parking structures need not be included).
2. Where provision for partitions is required by Section 4.2.2 in the floor load design, the actual partition weight or a minimum weight of 10 psf (0.48 kN/m^2) of floor area, whichever is greater.
3. Total operating weight of permanent equipment.
4. Where the flat roof snow load, P_f, exceeds 30 psf (1.44 kN/m^2), 20 percent of the uniform design snow load, regardless of actual roof slope.

Structural Modelling

TABLE 12.6-1 PERMITTED ANALYTICAL PROCEDURES

Seismic Design Category	Structural Characteristics	Equivalent Lateral Force Analysis Section 12.8	Modal Response Spectrum Analysis Section 12.9	Seismic Response History Procedures Chapter 16
B, C	Occupancy Category I or II buildings of light-framed construction not exceeding 3 stories in height	P	P	P
	Other Occupancy Category I or II buildings not exceeding 2 stories in height	P	P	P
	All other structures	P	P	P
D, E, F	Occupancy Category I or II buildings of light-framed construction not exceeding 3 stories in height	P	P	P
	Other Occupancy Category I or II buildings not exceeding 2 stories in height	P	P	P
	Regular structures with $T < 3.5T_s$ and all structures of light frame construction	P	P	P
	Irregular structures with $T < 3.5T_s$ and having only horizontal irregularities Type 2, 3, 4, or 5 of Table 12.2-1 or vertical irregularities Type 4, 5a, or 5b of Table 12.3-1	P	P	P
	All other structures	NP	P	P

NOTE: P: Permitted; NP: Not Permitted

Structural Modelling

12.7.3 Structural Modeling. A mathematical model of the structure shall be constructed for the purpose of determining member forces and structure displacements resulting from applied loads and any imposed displacements or P-Delta effects. The model shall include the stiffness and strength of elements that are significant to the distribution of forces and deformations in the structure and represent the spatial distribution of mass and stiffness throughout the structure.

Structural Modelling

Structures that have horizontal structural irregularity Type 1a, 1b, 4, or 5 of Table 12.3-1 shall be analyzed using a 3-D representation. Where a 3-D model is used, a minimum of three dynamic degrees of freedom consisting of translation in two orthogonal plan directions and torsional rotation about the vertical axis shall be included at each level of the structure. Where the diaphragms have not been classified as rigid or flexible in accordance with Section 12.3.1, the model shall include representation of the diaphragm's stiffness characteristics and such additional dynamic degrees of freedom as are required to account for the participation of the diaphragm in the structure's dynamic response. In addition, the model shall comply with the following:

a. Stiffness properties of concrete and masonry elements shall consider the effects of cracked sections.

b. For steel moment frame systems, the contribution of panel zone deformations to overall story drift shall be included.