Equivalent Static Load Method

Equivalent Static Force Method

- There are two commonly used methods for specifying seismic design forces:
  1. Equivalent Static Force Method
  2. Dynamic Analysis

- In the equivalent static force method, the inertial forces are specified as static forces using empirical formulas. The empirical formulas do not explicitly account for the "dynamic characteristics" of the particular structure being designed or analyzed.

- The formulas were, however, developed to adequately represent the dynamic behavior of what are called "regular" structures, which have a reasonably uniform distribution of mass and stiffness. For such structures, the equivalent static force method is most often adequate.

Equivalent Static Force Method

The concept employed in *equivalent static lateral method* is to place static loads on a structure with magnitudes and direction that closely approximate the effects of dynamic loading caused by earthquakes.

Concentrated lateral forces due to dynamic loading tend to occur at floor and ceiling/roof levels in buildings, where concentration of mass is the highest.

Furthermore, concentrated lateral forces tend to be larger at higher elevations in a structure.

Thus, the greatest lateral displacements and the largest lateral forces often occur at the top level of a structure (particularly for tall buildings). These effects are modeled in *equivalent static lateral force* procedures of the IBC and UBC by placing a force at each story level in a structure

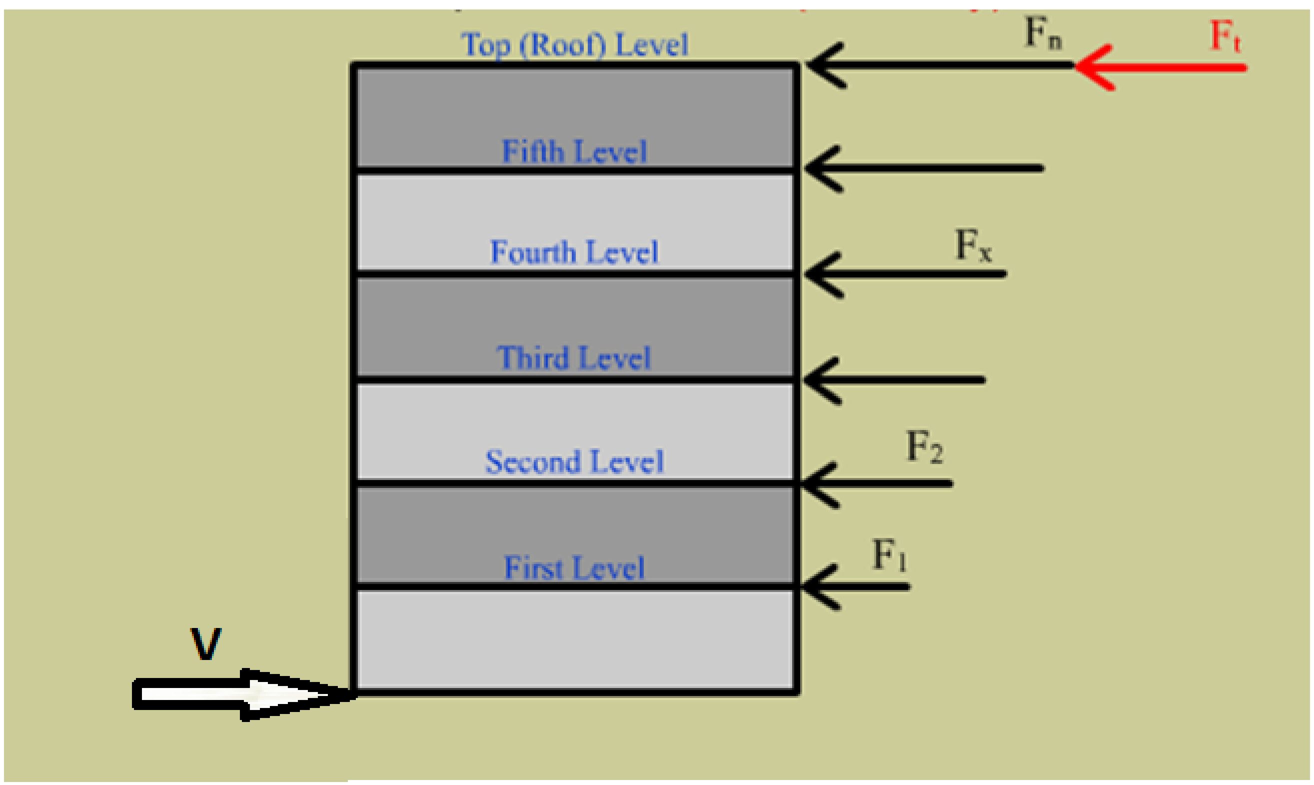
Equivalent Static Force Method

In general, the distribution of lateral story forces is associated with the first (fundamental) mode of vibration of a cantilevered structure. (In this case, a typical structure is idealized as a vertical cantilever rigidly attached to the ground.)

The effects of higher modes of vibration are approximated in the UBC by considering an additional lateral force, $\mathbf{F_t}$, applied to the top level of a structure.

The summation of the lateral story forces (plus the additional lateral force at the top, Ft, in the UBC) must be equivalent to the base shear (V) force applied to the structure due to seismic ground motion.

Equivalent Static Force Method



where

V = base shear force associated with ground motion at the base of the structure

F_x = lateral story force applied at each story level of the structure

F_t = additional lateral force applied at the top level of the structure (per the UBC)

Equivalent Static Force Method

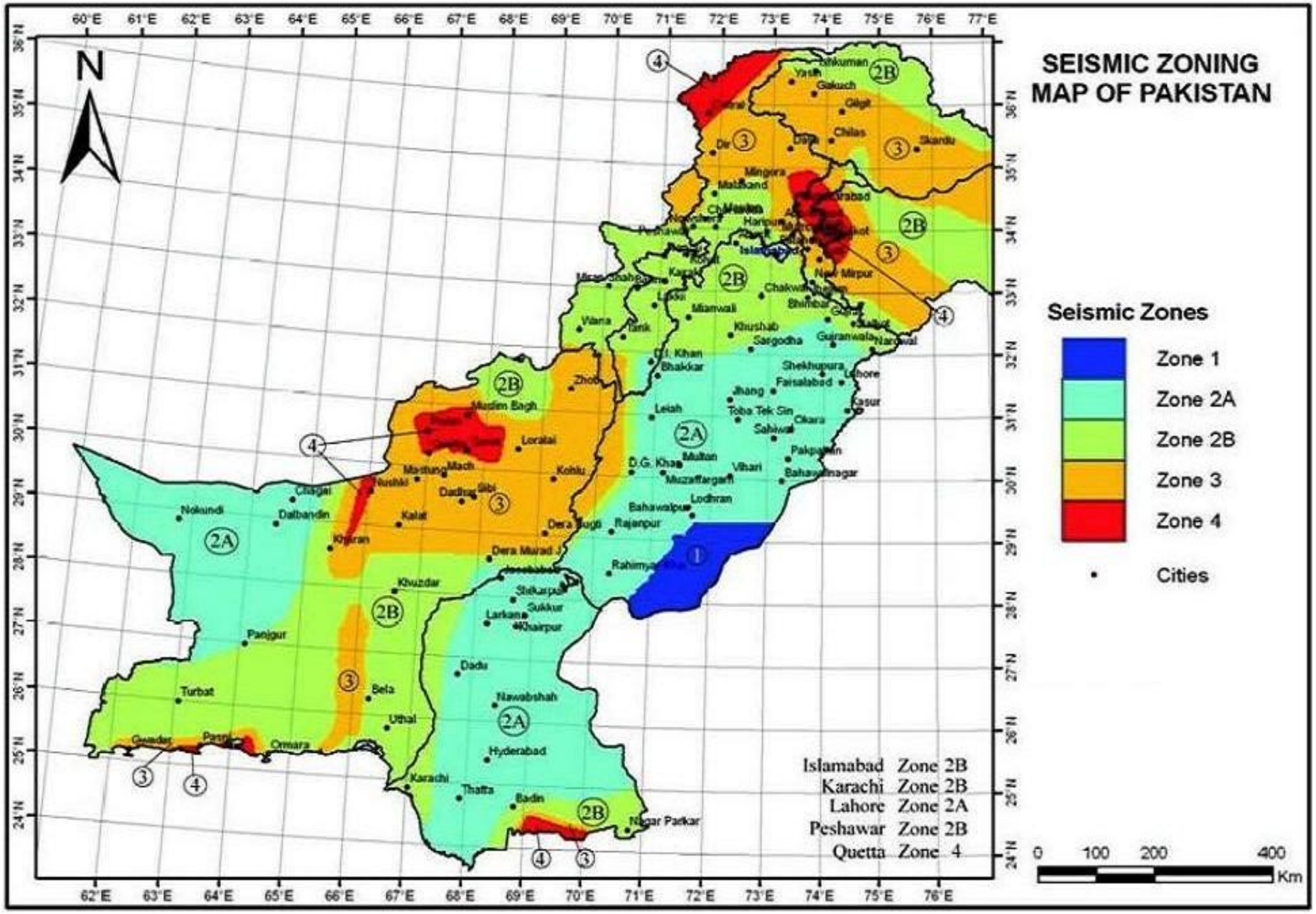
Base Shear

Base shear is an estimate of the **maximum expected lateral force** that will occur due to seismic ground motion at the base of a structure. Calculations of base shear (**V**) depend on:

- soil conditions at the site
- proximity to potential sources of seismic activity (such as geological faults)
- probability of significant seismic ground motion
- the level of ductility and overstrength associated with various structural configurations and the total weight of the structure
- the fundamental (natural) period of vibration of the structure when subjected to dynamic loading

Equivalent Static Force Method: Seismic Zones

The UBC addresses the probability of significant seismic activity in various locations by categorizing geographic regions of the into Seismic Zones 1 through 4. Seismic Zone 1 indicates a geographic location where least seismic activity is expected to occur. Seismic Zone 4 indicates a geographic location with a high probability of significant seismic activity.



Equivalent Static Force Method: Design Base Shear UBC-97

- The total design base shear in a given direction shall be determined from the following formula:

$$V = \frac{C_v I}{RT} W \qquad UBC97 \quad 30-4$$

- The total design base shear need not exceed the following:

$$V = \frac{2.5 C_a I}{R} W \qquad UBC97 \quad 30-5$$

- The total design base shear shall not be less than the following:

$$V = 0.11 C_a I W \qquad UBC97 \quad 30-6$$

- In addition, for seismic zone 4, the total base shear shall also be not less than the following:

$$V = \frac{0.8 Z N_v I}{R} W \qquad UBC97 \quad 30-7$$

Equivalent Static Force Method: Design Base Shear UBC-97

Where:

- Z= seismic zone factor, **Table 16-I.**
- I= importance factor, **Table 16K.**
- R= numerical coefficient representative of the inherent over strength and global ductility capacity of lateral- force- resisting systems, **Table 16-N.**
- C_a=acceleration seismic coefficient, **Table 16-Q.**
- C_v= velocity seismic coefficient, **Table 16-R.**
- N_v= near source factor, **Table 16-T.**

- **Seismic Dead Load (*W*)**

The seismic dead load (*W*) consists of the following:

- Dead load of the structure.
- **25 percent** of the floor live load for storage and warehouses.
- A minimum allowance of **50 kg/m²** for movable partitions.
- The total weight of permanent equipment and fittings.

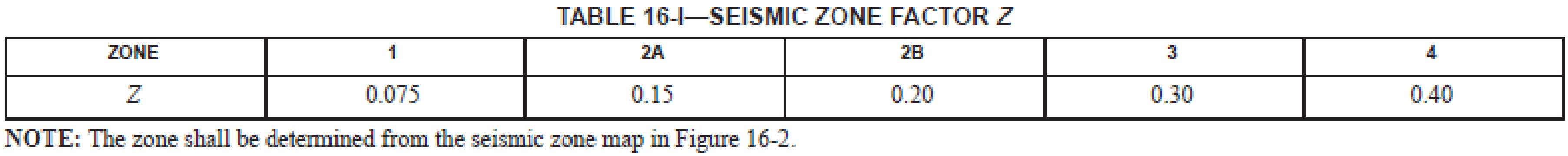


TABLE 16-I—SEISMIC ZONE FACTOR *Z*

ZONE	1	2A	2B	3	4
Z	0.075	0.15	0.20	0.30	0.40

NOTE: The zone shall be determined from the seismic zone map in Figure 16-2.

Equivalent Static Force Method: Design Base Shear UBC-97

- I= importance factor, **Table 16K.**

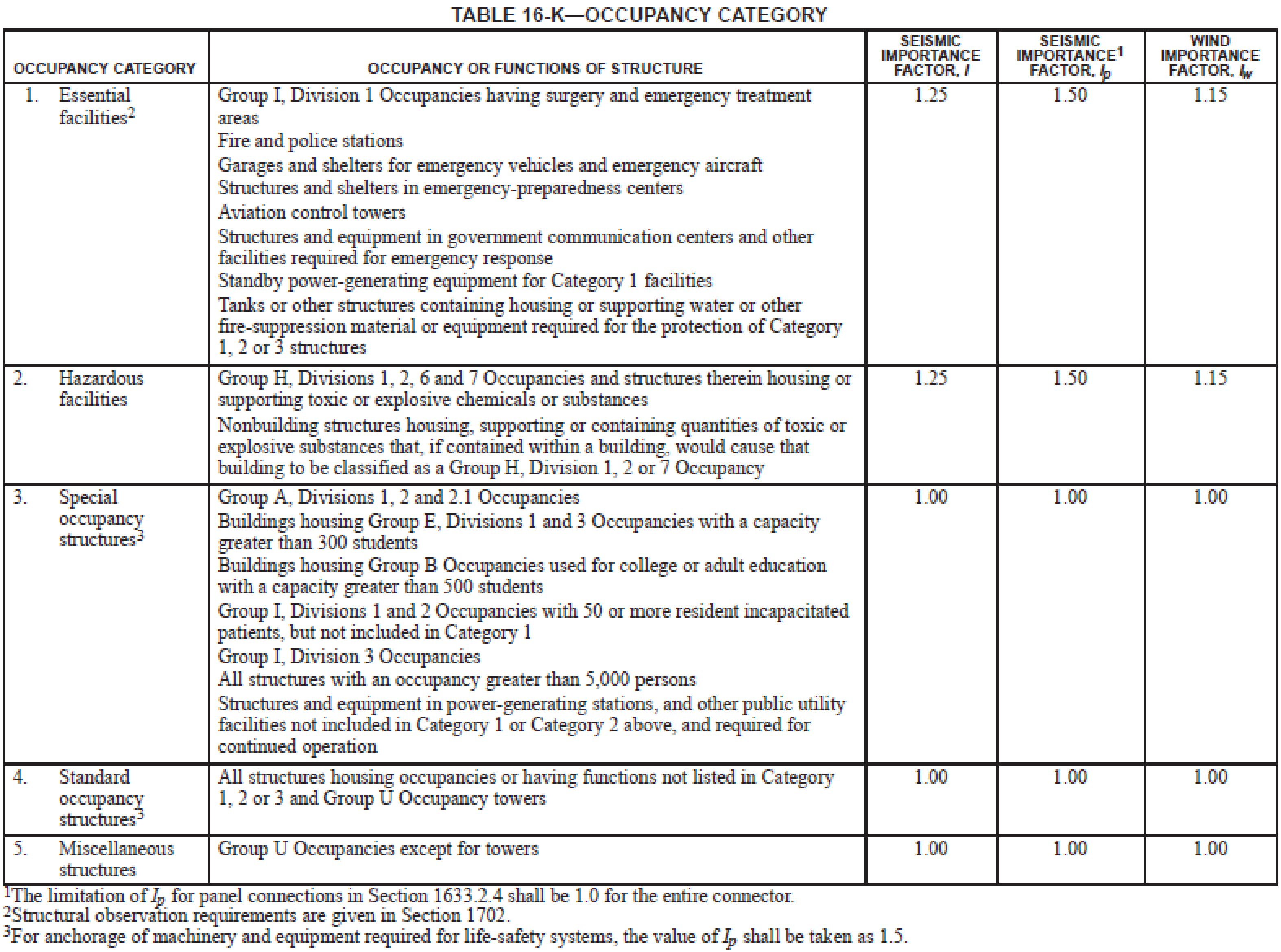


TABLE 16-K—OCCUPANCY CATEGORY

OCCUPANCY CATEGORY	OCCUPANCY OR FUNCTIONS OF STRUCTURE	SEISMIC IMPORTANCE FACTOR, I	SEISMIC IMPORTANCE[1] FACTOR, I_p	WIND IMPORTANCE FACTOR, I_w
1. Essential facilities[2]	Group I, Division 1 Occupancies having surgery and emergency treatment areas Fire and police stations Garages and shelters for emergency vehicles and emergency aircraft Structures and shelters in emergency-preparedness centers Aviation control towers Structures and equipment in government communication centers and other facilities required for emergency response Standby power-generating equipment for Category 1 facilities Tanks or other structures containing housing or supporting water or other fire-suppression material or equipment required for the protection of Category 1, 2 or 3 structures	1.25	1.50	1.15
2. Hazardous facilities	Group H, Divisions 1, 2, 6 and 7 Occupancies and structures therein housing or supporting toxic or explosive chemicals or substances Nonbuilding structures housing, supporting or containing quantities of toxic or explosive substances that, if contained within a building, would cause that building to be classified as a Group H, Division 1, 2 or 7 Occupancy	1.25	1.50	1.15
3. Special occupancy structures[3]	Group A, Divisions 1, 2 and 2.1 Occupancies Buildings housing Group E, Divisions 1 and 3 Occupancies with a capacity greater than 300 students Buildings housing Group B Occupancies used for college or adult education with a capacity greater than 500 students Group I, Divisions 1 and 2 Occupancies with 50 or more resident incapacitated patients, but not included in Category 1 Group I, Division 3 Occupancies All structures with an occupancy greater than 5,000 persons Structures and equipment in power-generating stations, and other public utility facilities not included in Category 1 or Category 2 above, and required for continued operation	1.00	1.00	1.00
4. Standard occupancy structures[3]	All structures housing occupancies or having functions not listed in Category 1, 2 or 3 and Group U Occupancy towers	1.00	1.00	1.00
5. Miscellaneous structures	Group U Occupancies except for towers	1.00	1.00	1.00

[1] The limitation of I_p for panel connections in Section 1633.2.4 shall be 1.0 for the entire connector.

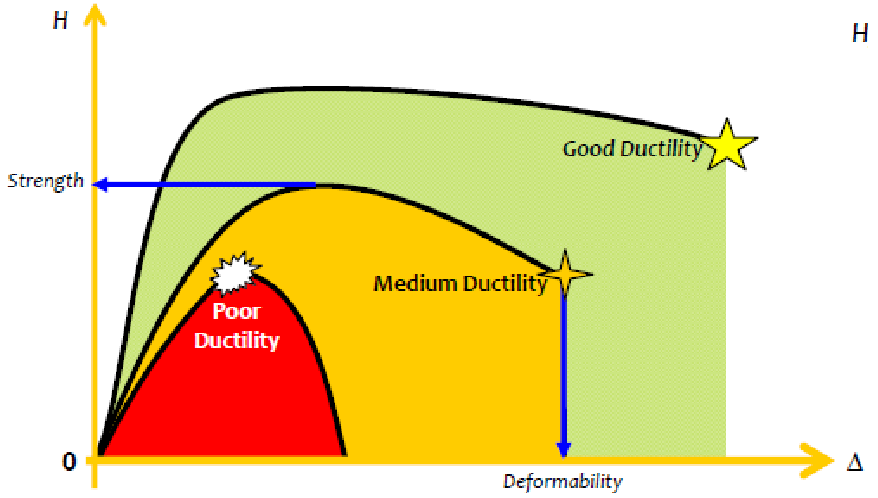
[2] Structural observation requirements are given in Section 1702.

[3] For anchorage of machinery and equipment required for life-safety systems, the value of I_p shall be taken as 1.5.

Equivalent Static Force Method: Design Base Shear UBC-97

Ductility

- **Ductility** of an element shows its capacity to deform in the inelastic range without collapse.



Response Modification Factor (R)

- The value of the response modification factor (R) is determined from consideration of a structure's over-strength capacity beyond the point at which the elastic response of the structure is exceeded.

- This reduced force level is made possible by the energy absorption and dissipation capacity of the structure at displacements in excess of initial yield.

Equivalent Static Force Method: Design Base Shear UBC-97

R= Response modification factor, numerical coefficient representative of the inherent over strength and global ductility capacity of lateral-force- resisting systems, **Table 16-N.**

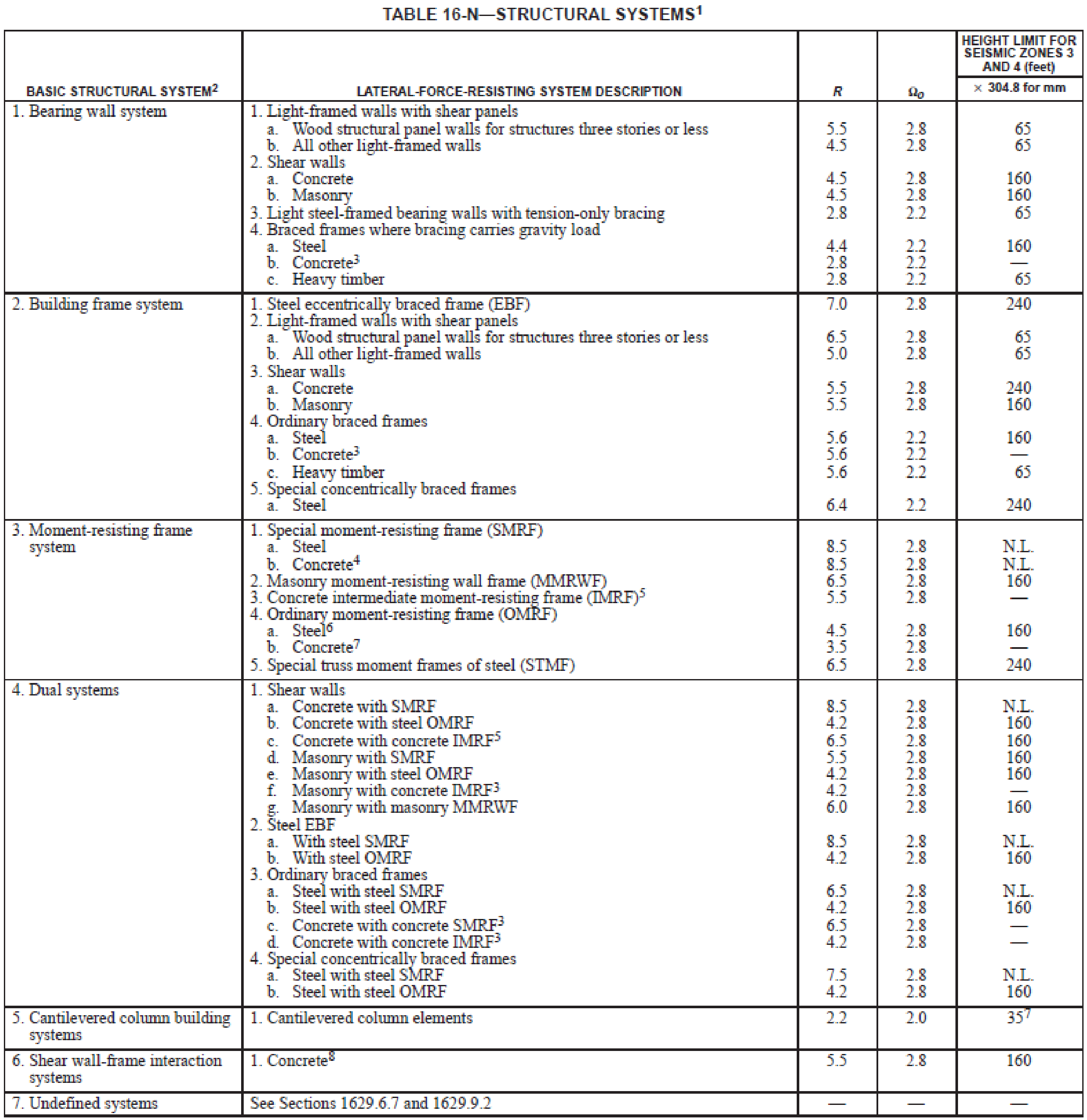


TABLE 16-N—STRUCTURAL SYSTEMS[1]

BASIC STRUCTURAL SYSTEM[2]	LATERAL-FORCE-RESISTING SYSTEM DESCRIPTION	R	Ω_o	HEIGHT LIMIT FOR SEISMIC ZONES 3 AND 4 (feet) × 304.8 for mm
1. Bearing wall system	1. Light-framed walls with shear panels			
	a. Wood structural panel walls for structures three stories or less	5.5	2.8	65
	b. All other light-framed walls	4.5	2.8	65
	2. Shear walls			
	a. Concrete	4.5	2.8	160
	b. Masonry	4.5	2.8	160
	3. Light steel-framed bearing walls with tension-only bracing	2.8	2.2	65
	4. Braced frames where bracing carries gravity load			
	a. Steel	4.4	2.2	160
	b. Concrete[3]	2.8	2.2	—
	c. Heavy timber	2.8	2.2	65
2. Building frame system	1. Steel eccentrically braced frame (EBF)	7.0	2.8	240
	2. Light-framed walls with shear panels			
	a. Wood structural panel walls for structures three stories or less	6.5	2.8	65
	b. All other light-framed walls	5.0	2.8	65
	3. Shear walls			
	a. Concrete	5.5	2.8	240
	b. Masonry	5.5	2.8	160
	4. Ordinary braced frames			
	a. Steel	5.6	2.2	160
	b. Concrete[3]	5.6	2.2	—
	c. Heavy timber	5.6	2.2	65
	5. Special concentrically braced frames			
	a. Steel	6.4	2.2	240
3. Moment-resisting frame system	1. Special moment-resisting frame (SMRF)			
	a. Steel	8.5	2.8	N.L.
	b. Concrete[4]	8.5	2.8	N.L.
	2. Masonry moment-resisting wall frame (MMRWF)	6.5	2.8	160
	3. Concrete intermediate moment-resisting frame (IMRF)[5]	5.5	2.8	—
	4. Ordinary moment-resisting frame (OMRF)			
	a. Steel[6]	4.5	2.8	160
	b. Concrete[7]	3.5	2.8	—
	5. Special truss moment frames of steel (STMF)	6.5	2.8	240
4. Dual systems	1. Shear walls			
	a. Concrete with SMRF	8.5	2.8	N.L.
	b. Concrete with steel OMRF	4.2	2.8	160
	c. Concrete with concrete IMRF[5]	6.5	2.8	160
	d. Masonry with SMRF	5.5	2.8	160
	e. Masonry with steel OMRF	4.2	2.8	160
	f. Masonry with concrete IMRF[3]	4.2	2.8	—
	g. Masonry with masonry MMRWF	6.0	2.8	160
	2. Steel EBF			
	a. With steel SMRF	8.5	2.8	N.L.
	b. With steel OMRF	4.2	2.8	160
	3. Ordinary braced frames			
	a. Steel with steel SMRF	6.5	2.8	N.L.
	b. Steel with steel OMRF	4.2	2.8	160
	c. Concrete with concrete SMRF[3]	6.5	2.8	—
	d. Concrete with concrete IMRF[3]	4.2	2.8	—
	4. Special concentrically braced frames			
	a. Steel with steel SMRF	7.5	2.8	N.L.
	b. Steel with steel OMRF	4.2	2.8	160
5. Cantilevered column building systems	1. Cantilevered column elements	2.2	2.0	35[7]
6. Shear wall-frame interaction systems	1. Concrete[8]	5.5	2.8	160
7. Undefined systems	See Sections 1629.6.7 and 1629.9.2	—	—	—

Equivalent Static Force Method: Design Base Shear UBC-97

C_a=acceleration seismic coefficient, **Table 16-Q.**

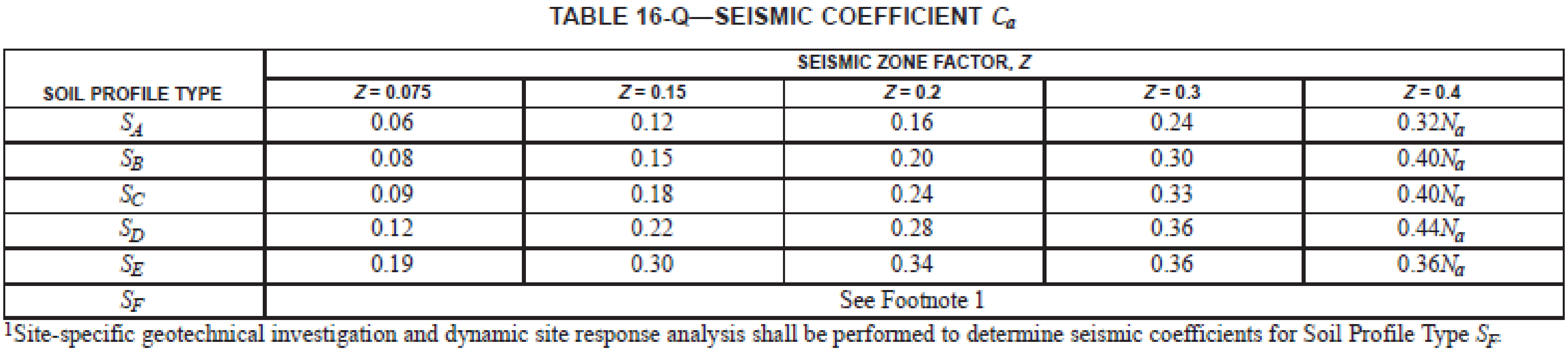


TABLE 16-Q—SEISMIC COEFFICIENT C_a

SOIL PROFILE TYPE	SEISMIC ZONE FACTOR, Z				
	$Z = 0.075$	$Z = 0.15$	$Z = 0.2$	$Z = 0.3$	$Z = 0.4$
S_A	0.06	0.12	0.16	0.24	$0.32N_a$
S_B	0.08	0.15	0.20	0.30	$0.40N_a$
S_C	0.09	0.18	0.24	0.33	$0.40N_a$
S_D	0.12	0.22	0.28	0.36	$0.44N_a$
S_E	0.19	0.30	0.34	0.36	$0.36N_a$
S_F	See Footnote 1				

[1] Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficients for Soil Profile Type S_F.

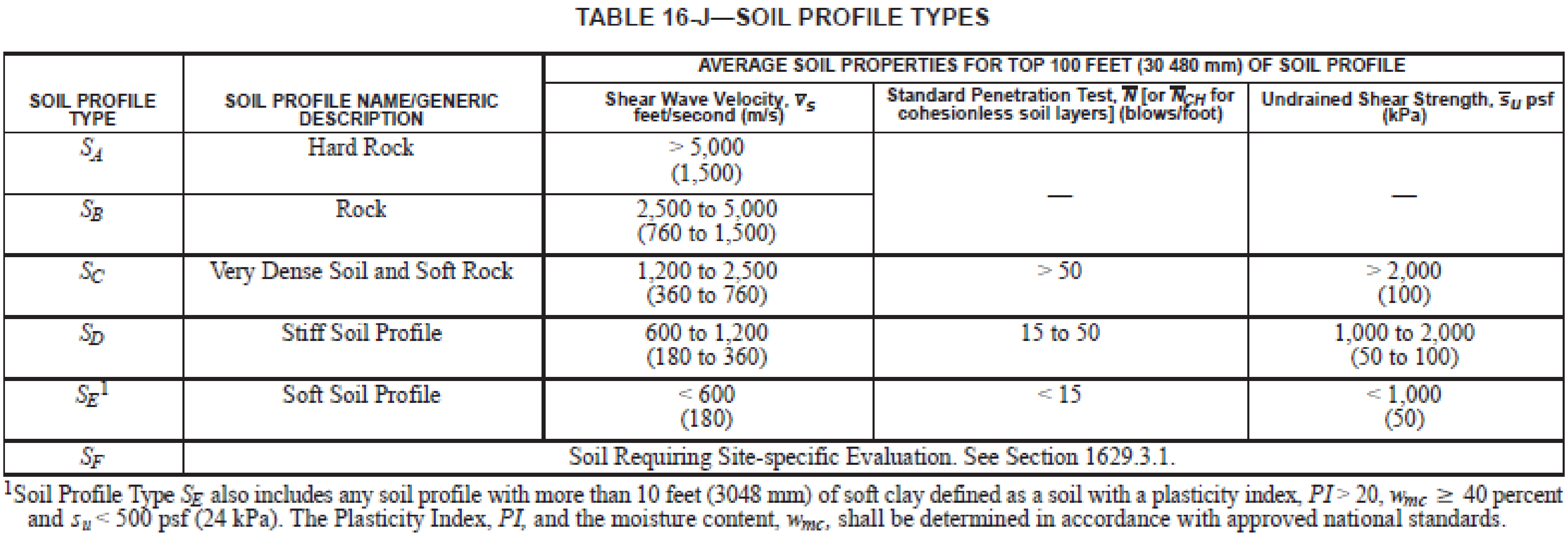


TABLE 16-J—SOIL PROFILE TYPES

SOIL PROFILE TYPE	SOIL PROFILE NAME/GENERIC DESCRIPTION	AVERAGE SOIL PROPERTIES FOR TOP 100 FEET (30 480 mm) OF SOIL PROFILE		
		Shear Wave Velocity, $\bar{v}_s$ feet/second (m/s)	Standard Penetration Test, $\bar{N}$ [or $\bar{N}_{CH}$ for cohesionless soil layers] (blows/foot)	Undrained Shear Strength, $\bar{s}_u$ psf (kPa)
S_A	Hard Rock	> 5,000 (1,500)	—	—
S_B	Rock	2,500 to 5,000 (760 to 1,500)		
S_C	Very Dense Soil and Soft Rock	1,200 to 2,500 (360 to 760)	> 50	> 2,000 (100)
S_D	Stiff Soil Profile	600 to 1,200 (180 to 360)	15 to 50	1,000 to 2,000 (50 to 100)
S_E[1]	Soft Soil Profile	< 600 (180)	< 15	< 1,000 (50)
S_F	Soil Requiring Site-specific Evaluation. See Section 1629.3.1.			

[1] Soil Profile Type S_E also includes any soil profile with more than 10 feet (3048 mm) of soft clay defined as a soil with a plasticity index, $PI > 20$, $w_{mc} \geq 40$ percent and $s_u < 500$ psf (24 kPa). The Plasticity Index, PI, and the moisture content, w_{mc}, shall be determined in accordance with approved national standards.

Equivalent Static Force Method: Design Base Shear UBC-97

C_v= velocity seismic coefficient, **Table 16-R.**

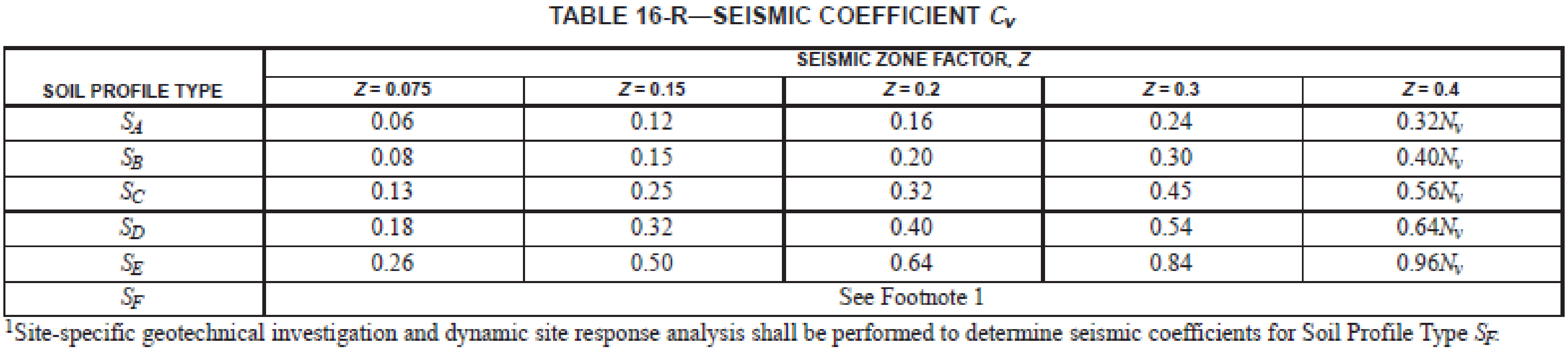


TABLE 16-R—SEISMIC COEFFICIENT C_v

SOIL PROFILE TYPE	SEISMIC ZONE FACTOR, Z				
	$Z = 0.075$	$Z = 0.15$	$Z = 0.2$	$Z = 0.3$	$Z = 0.4$
S_A	0.06	0.12	0.16	0.24	$0.32N_v$
S_B	0.08	0.15	0.20	0.30	$0.40N_v$
S_C	0.13	0.25	0.32	0.45	$0.56N_v$
S_D	0.18	0.32	0.40	0.54	$0.64N_v$
S_E	0.26	0.50	0.64	0.84	$0.96N_v$
S_F	See Footnote 1				

[1] Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficients for Soil Profile Type S_F.

N_v= near source factor, **Table 16-T.**

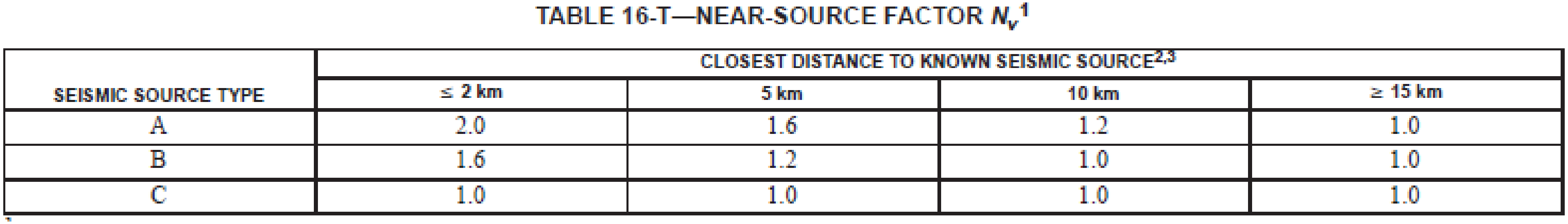


TABLE 16-T—NEAR-SOURCE FACTOR N_v[1]

SEISMIC SOURCE TYPE	CLOSEST DISTANCE TO KNOWN SEISMIC SOURCE[2,3]			
	≤ 2 km	5 km	10 km	≥ 15 km
A	2.0	1.6	1.2	1.0
B	1.6	1.2	1.0	1.0
C	1.0	1.0	1.0	1.0

Equivalent Static Force Method: Fundamental Time Period of a Structure

- The time period of a structure may exactly be calculated by performing free vibration analysis of the structure, which involves lengthy calculations
- Following empirical methods are also available to reasonably guess the fundamental time period of a structure:
    - **Approximate method**
    - Fundamental time period,

$$T = \frac{\text{number of stories}}{10} \text{ sec}$$

Equivalent Static Force Method: Fundamental Time Period of a Structure

- **Method A of UBC**

$$T_A = C_t(h_n)^{3/4}$$

- where
- h_n = height of the roof above the base in meters, not including the height of parapets.
- C_t = 0.085 for steel moment resisting frames

  = 0.073 for reinforced concrete moment resisting frames and eccentric braced steel frames

  = 0.050 for all other buildings

Equivalent Static Force Method: Fundamental Time Period of a Structure

- **Method B of UBC**

$$T_B = 2\pi\sqrt{\frac{\sum W_i \delta_i^{\,2}}{g\sum f_i \delta_i}} \quad \leq 1.4 T_A \text{ for Zones 1,2 and 3}$$

$$\leq 1.3\ T_A \text{ for Zones 4}$$

- where

δ_i = static elastic deflection at level "*i*" due to the forces applied at all levels, increasing in a linear way with height. The value of deflection must be with respect to the base in mm.

$$= \frac{\text{total lateral force at } i \text{ - th floor}}{k_i} + \delta_{i-1}$$

k_i = shear stiffness of columns under floor "*i*"

f_i = lateral force at level "*i*", N

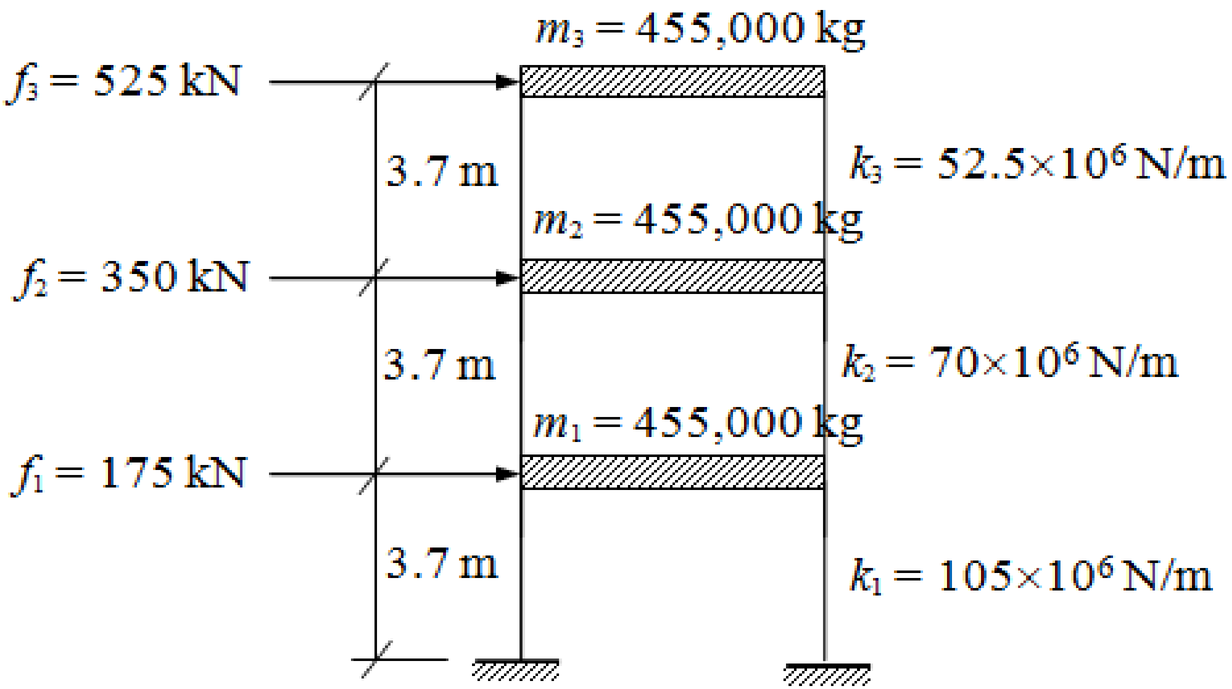
w_i= dead load located at level "*i*", N

g = acceleration due to gravity

= 9810 mm/sec

Example

- Calculate the empirical time period for the steel moment resisting frame, shown in Fig. , located on a site in zone-3



Example

Solution:

1. Approximate Method:

T = number of stories / 10 = **0.3 sec**

2. Method A:

$h_n = 3 \times 3.7 = 11.1 \text{ m}$

$T_A = C_t (h_n)^{3/4} = 0.085(11.1)^{3/4} = \mathbf{0.517\ sec}$

3. Method B:

$k_1 = 105000 \text{ N/mm}$, $k_2 = 70000 \text{ N/mm}$ and $k_3 = 52500 \text{ N/mm}$

$$\begin{aligned}\delta_1 &= (f_3 + f_2 + f_1) / k_1 \\ &= (525 + 350 + 175)(1000) / 105000 \\ &= 10 \text{ mm}\end{aligned}$$

$$\begin{aligned}\delta_2 &= (f_3 + f_2) / k_2 + \delta_1 \\ &= (525 + 350)(1000) / 70000 + 10 \\ &= 22.5 \text{ mm}\end{aligned}$$

$$\begin{aligned}\delta_3 &= f_3 / k_3 + \delta_2 \\ &= 525000 / 52500 + 22.5 \\ &= 32.5 \text{ mm}\end{aligned}$$

Example

$$\sum W_i\delta_i^{\,2} = (455000\times10^2 + 455000\times22.5^2 + 455000\times32.5^2)\times9.81$$

$$= 7.421\times10^9 \text{ N-mm}^2$$

$$\sum f_i\delta_i = 175000\times10 + 350000\times22.5 + 525000\times32.5$$

$$= 2.669\times10^7 \text{ N-mm}^2$$

$$T_B = 2\pi\sqrt{\frac{\sum W_i\delta_i^{\,2}}{g\sum f_i\delta_i}} \leq 1.4T_A \text{ for Zones 1,2 and 3}$$

$$= 2\pi\sqrt{\frac{7.421\times10^9}{9810\times2.669\times10^7}} \leq 1.4\times0.517$$

$$= 1.058 \qquad\qquad \leq 0.724$$

$$= \mathbf{0.724\ sec}$$

Example

$$
\begin{aligned}
\sum W_i\delta_i^{\,2} &= (455000\times10^2 + 455000\times22.5^2 + 455000\times32.5^2)\times9.81 \\
&= 7.421\times10^9 \text{ N-mm}^2 \\
\sum f_i\delta_i &= 175000\times10 + 350000\times22.5 + 525000\times32.5 \\
&= 2.669\times10^7 \text{ N-mm}^2
\end{aligned}
$$

$$
\begin{aligned}
T_B &= 2\pi\sqrt{\frac{\sum W_i\delta_i^{\,2}}{g\sum f_i\delta_i}} && \le 1.4T_A \text{ for Zones 1,2 and 3} \\
&= 2\pi\sqrt{\frac{7.421\times10^9}{9810\times2.669\times10^7}} && \le 1.4\times0.517 \\
&= 1.058 && \le 0.724 \\
&= \mathbf{0.724\ sec}
\end{aligned}
$$

Vertical Distribution of Forces

A concentrated force F_t that shall be applied at the top of the structure as part of the base shear shall be determined from the following formula:

$$F_t = 0.07TV \le 0.25V \; for\, T > 0.7 \; seconds$$

And

$$F_t = 0.0 \; for\, T \le 0.7 \; seconds$$

So,

The total base shear, V will be:

$$V = F_t + \sum_{i=1}^{n} F_i$$

$$F_x = \frac{(V - F_t)w_x h_x}{\sum_{i=1}^{n} w_i h_i}$$

Vertical Distribution of Forces

$$F_x = \frac{(V - F_t)w_x h_x}{\sum_{i=1}^{n} w_i h_i}$$

Where:

- F_x= design seismic force applied to level x,
- W_x= that portion of weight, W located at or assigned to level x
- W_i= that portion of weight, w located to or assigned to level i
- h_x, h_i= height in meters above the base to level x or i, respectively

Horizontal Distribution of Forces

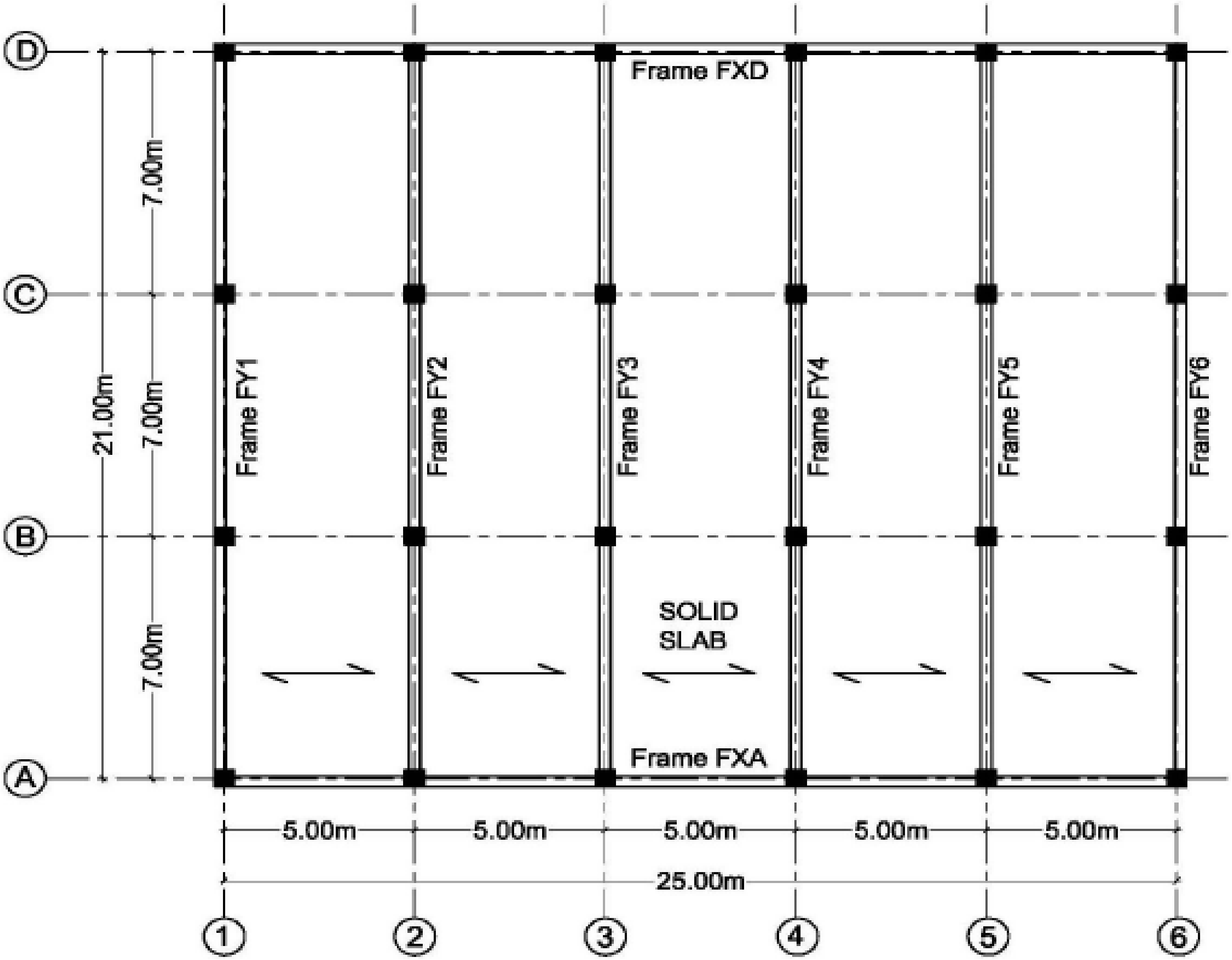
$$V_{yi} = \frac{K_{yi}}{\sum K_{yi}} V_y \mp \frac{K_{yi} X_i}{K_t} V_y e$$

$$K_t = \sum K_{yi} X_i{}^2 + \sum K_{xi} Y_i{}^2$$

Where:

- V_{yi}= shear force to frame i
- V_y= shear force
- K_{yi}= stiffness of frame i
- X_i= distance from frame i to center of stiffness of the floor in x-direction
- Y_i= distance from frame i to center of stiffness of the floor in y-direction
- e= eccentricity
- K_t= torsional stiffness of resisting frames

Example : Intermediate Moment Resisting Frames Lateral Force Resisting System



Example : Intermediate Moment Resisting Frames Lateral Force Resisting System

- Number of stories = five
- Story height= 3.5m
- Concrete cylinder compressive strength at 28 days, f’c= 28MPa
- Steel yield strength, fy= 420MPa
- All columns are square with side length equals to 500mm
- All beams are 300mm section width and 600mm total thickness
- The slab is one way solid slab of 200mm thickness .

Example : Intermediate Moment Resisting Frames Lateral Force Resisting System

- The live load is $3kN/m^2$
- The superimposed dead load is $4kN/m^2$
- The perimeter wall weight is 3kN/m
- Importance factor =1
- Soil: soft rock, Sc type in accordance with UBC 97 provisions.
- Zone 2B , Zone Factor factor: Z=0.2 (Table 16-I)
- Ca= 0.24 (Table 16-Q)
- Cv= 0.32 (Table 16-R)

Example : Intermediate Moment Resisting Frames Lateral Force Resisting System

- ***Step 1: weight of the building***

Solid slab own weight= slab thickness x unit weight of concrete

$W_D = 0.20 \times 25 = 5kN/m^2$

$W_{slab} = 25 \times 21 \times 5 = 2625kN$

Beams weight= length of beams x cross section area x unit weight of concrete

$W_{beams} = (21 \times 6 + 25 \times 2)(0.30 \times 0.40 \times 25) = 528kN$

It shall be noted that the beam depth below slab is used which is 0.60-0.20= 0.40m

Example : Intermediate Moment Resisting Frames Lateral Force Resisting System

- ***Step 1: weight of the building***

Columns weight= length of columns x cross section area x unit weight of concrete

$W_{columns} = 2.9 \times 24 \times 0.50 \times 0.50 \times 25 = 435kN$

Perimeter wall weight= length of wall x weight of wall/m

$$W_{walls} = (25 \times 2 + 21 \times 2)(3) = 276kN$$

Superimposed dead load on slab= area of slab x superimposed dead load/m^2

$W_{superimposed} = 25 \times 21 \times 4 = 2100kN$

Total weight of one story= 5964kN

Total weight of building= 5964 x 5= 29820kN

Example : Intermediate Moment Resisting Frames Lateral Force Resisting System

- ***Step 2: base shear***

Building period:

$$T = C_t(h_n)^{\frac{3}{4}}$$

$$h_n = 5\ floors\ \times\ 3.5 = 17.5m$$

$$C_t = 0.0731$$

$$T = 0.0731(17.5)^{\frac{3}{4}}\ = 0.625\ seconds$$

Example : Intermediate Moment Resisting Frames Lateral Force Resisting System

- ***Step 2: base shear***

Notice that the stiffness, k, which is the force divided by the lateral deformation, varies in each direction. But, in this example use this period, T, in both directions.

The base shear, V, is computed as follows:

R= 5.5 from **Table16-N** (intermediate moment resisting frame)

$$V = \frac{C_v I}{RT} W \qquad V = \frac{0.32 \times 1}{5.5 \times 0.625} W = 0.093W$$

Example : Intermediate Moment Resisting Frames Lateral Force Resisting System

- ***Step 2: base shear***

The base shear, V, need not exceed

$$V = \frac{2.5C_aI}{R}W$$

$$V = \frac{2.5 \times 0.24 \times 1}{5.5}W = 0.109W > 0.093W$$

The base shear shall not be less than

$$V = 0.11C_aIW$$

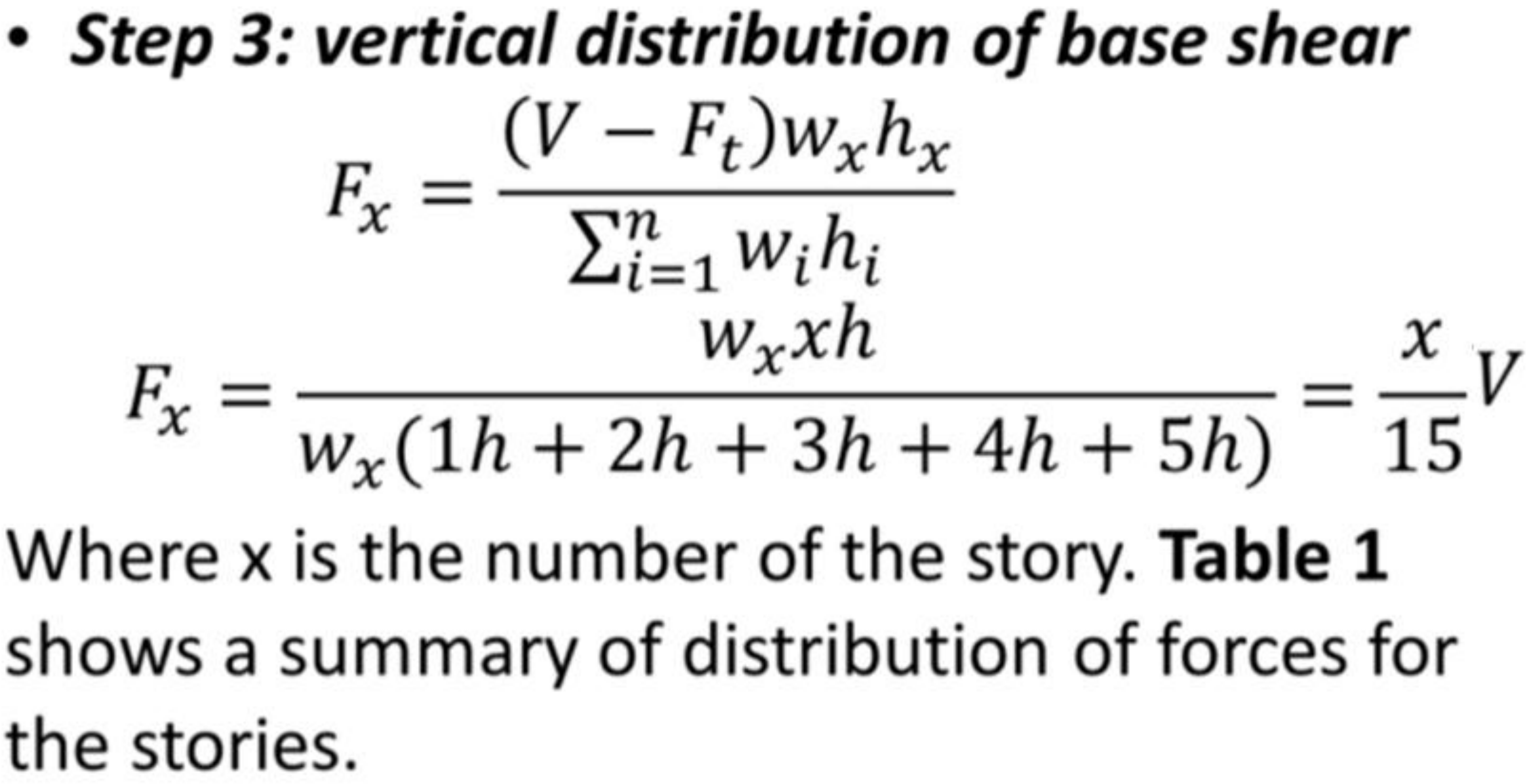
$$V = 0.11 \times 0.24 \times 1 \times W = 0.026W \quad < 0.093W$$

So, total base shear will be

$V = 0.093 \times 29820 = 2773kN$

Since, T <0.7 seconds, F_t=0.0 kN

Example : Intermediate Moment Resisting Frames Lateral Force Resisting System



- ***Step 3: vertical distribution of base shear***

$$F_x = \frac{(V - F_t) w_x h_x}{\sum_{i=1}^{n} w_i h_i}$$

$$F_x = \frac{w_x x h}{w_x (1h + 2h + 3h + 4h + 5h)} = \frac{x}{15} V$$

Where x is the number of the story. **Table 1** shows a summary of distribution of forces for the stories.

Example : Intermediate Moment Resisting Frames Lateral Force Resisting System

Table 1: Distribution of forces to stories

Story	w_x (kN)	h_x (m)	$w_x h_x$ (kN.m)	F_x (kN)
5	5964	17.5	104370	(5/15) V= 924
4	5964	14	83496	(4/15) V= 739
3	5964	10.5	62622	(3/15) V= 555
2	5964	7	41748	(2/15) V= 370
1	5964	3.5	20874	(1/15) V= 185
0	0	0	0	0
			313110 kN.m	2773 kN

Example : Intermediate Moment Resisting Frames Lateral Force Resisting System

- ***Step 4: horizontal distribution of story shear to frames***

The force in each frame of y- direction is

$$\frac{V}{6} = \frac{2773}{6} = 462kN$$

The force in each frame of x- direction is

$$\frac{V}{2} = \frac{2773}{2} = 1387kN$$

Example : Intermediate Moment Resisting Frames Lateral Force Resisting System

Story	h_x (m)	Forces to frames in y direction FY1 to FY6 V/6	Forces to frames in X direction FXA , FXD V/2
5	17.5	154	462
4	14	123	370
3	10.5	93	278
2	7	62	185
1	3.5	31	93
0	0	0	0
sum		463kN	1388kN

Example : Intermediate Moment Resisting Frames Lateral Force Resisting System

If 5% eccentricity is assumed to base shear in y-direction; parallel to frames FY1 to FY6, then, for y-direction

Let the stiffness of each frame be K, so

$$\sum K_{yi} = 6K$$

$$e = 0.05 \times 25 = 1.25m$$

$$K_t = 2(K(2.5)^2 + K(7.5)^2 + K(12.5)^2) = 437.5K$$

So, for frame FY1 or FY6

$$V_{y1,6} = \frac{K}{6K} V_y + \frac{K(12.5)}{437.5K} V_y(1.25) = 0.167V_y + 0.036V_y$$

$$= 0.203V_y$$

$$0.203V_y = 0.203(2773) = 563kN$$

It should be noted that the force is increased on the frame by

$$\frac{563}{462} = 1.22 \qquad 22\% \qquad \mathit{increase}$$