Earthquake Load

Some Basic Definitions:

☐***Base***: The level at which the earthquake motions are considered to be imparted to the structures or the level at which the structure as a dynamic vibrator is supported.

☐***Base Shear***: Total design lateral force or shear at the base of a structure.

☐***Building Frame System***: A structural system with an essentially complete space frame providing support for gravity loads. Resistance to lateral loads is provided by shear walls or braced frames separately.

☐***Moment Resisting Frame***: A structural system with an essentially complete space frame providing support for gravity loads. Moment resisting frames also provide resistance to lateral load primarily by flexural action of members.

→ *Ordinary Moment Resisting Frame*: A moment resisting frame not meeting special detailing requirements for ductile behavior.

→ *Intermediate Moment Resisting Frame*: A concrete or steel frame designed in accordance with sec 8.3 or 10.5.17 stated in BNBC 93

→ *Special Moment Resisting Frame*: A moment resisting frame specially detailed to provide ductile behavior complying with the seismic requirements provided in BNBC 93 (Ch-8 & 10)

☐***Dual System***: A combination of a special or intermediate moment resisting frame and shear wall etc.

☐***Shear Wall***: A wall designed to resist lateral forces parallel to the plane of the wall.

☐ ***Soft Storey***: Storey in which the lateral stiffness is less than 70 percent of the stiffness of the story above.

Seismic Zoning Map:

The seismic zoning map of Bangladesh is provided in the following figure: (BNBC:6-52) based on the severity of the probable intensity of seismic ground motion and damages, Bangladesh has been divided into three seismic zones, i.e. ***zone 1, zone 2 and zone 3.***

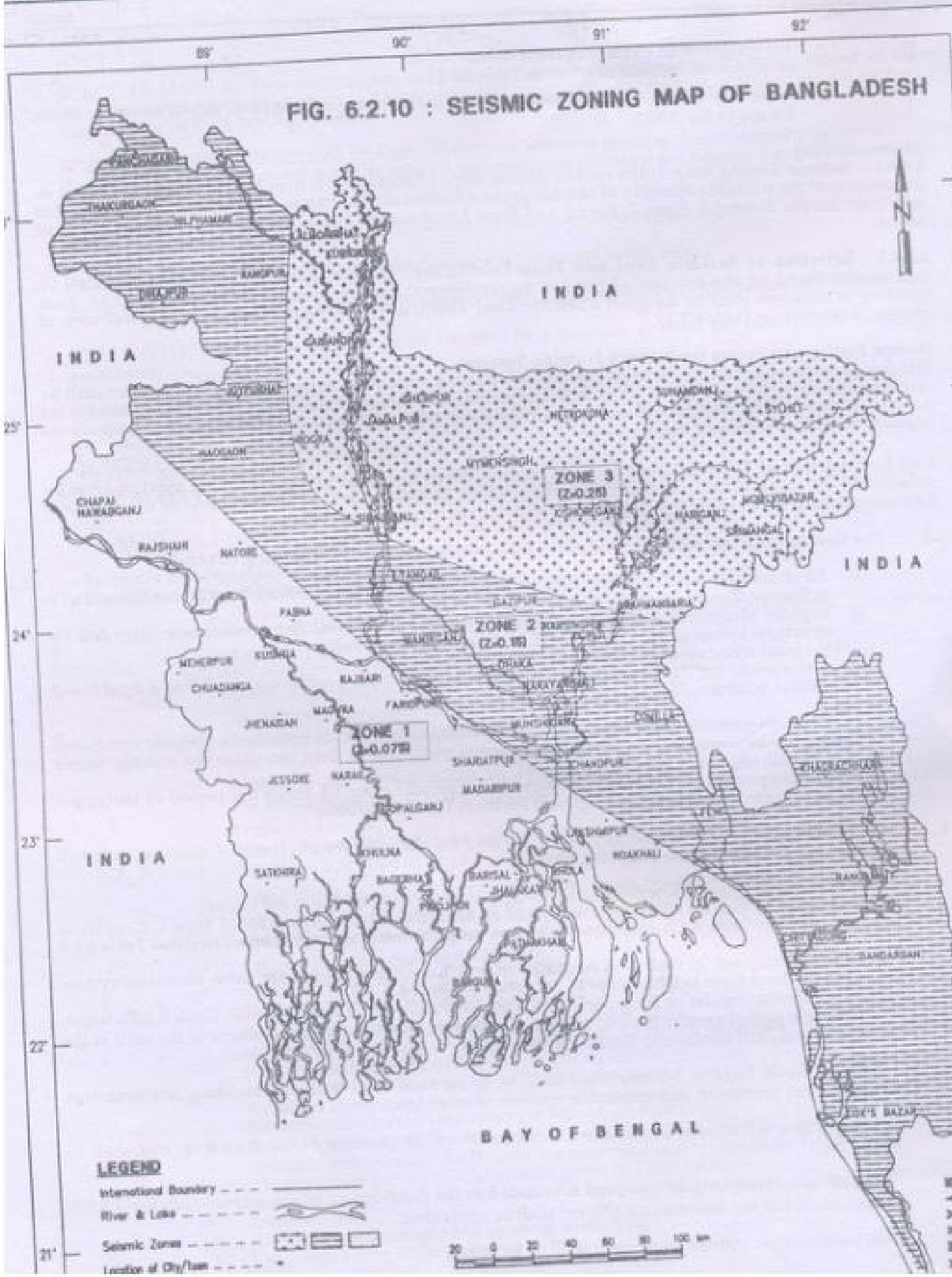


FIG. 6.2.10 : SEISMIC ZONING MAP OF BANGLADESH

Design Earthquake Forces:

Seismic lateral forces on primary framing systems shall be determined using two methods.

- **Equivalent Static Force Method**
- **Dynamic Response Method**

** *In our undergraduate course system, we can calculate the seismic forces by Equivalent Static Force Method.*

Seismic Dead Load:

Seismic Dead Load, W, is the total load of a building or a structure, including permanent partitions and applicable portions of other loads listed below:

- In storage and warehouse occupancies, a minimum of 25 percent of the floor live load shall be applicable.
- Where an allowance for partition load is included in the floor design, all such loads but not less than 0.6 KN/m^2 shall be applicable.
- Total weight of permanent equipment shall be included.

Equivalent Static Force Method

Design Base Shear:

$$V = \frac{ZIC}{R} W$$

Where,

Z = Seismic zone coefficient given in the table
I = Structue importance coefficient
R = Response modification coefficient for structural system
W = The total seismic dead load
C = Numerical coefficient

$$C = \frac{1.25S}{T^{2/3}}$$

S = Site coefficient for soil characterstics
T = Fundamental period of vibration in seconds, of the structure for the direction under consideration

$$T = C_t h_n^{2/3}$$

C_t = ***0.083*** for steel moment resisting frame
= ***0.073*** for reinforced concrete moment resisting frames, and eccentric braced steel frames.
= ***0.049*** for all other structural systems

h_n = Height in metres above the base to level n

Seismic Zone	Zone Coefficient
1	0.075
2	0.15
3	0.25

Structural importance catagory	Structural importance coefficient
1. Essential facilities	1.25
2. Hazardous facilities	1.25
3. Special occupancy structures	1.00
4. Standard occupancy structures	1.00
5. Low risk structures	0.80

Type	Description	Coefficient, S
S_1	A soil profile with either: a) A rock like material characterized by a shear wave velocity greater than 762 m/sec or by other suitable means of classifications, or b) Stiff or dense soil condition where the soil depth is less than 61 metres.	1.0
S_2	A soil profile with dense or stiff soil conditions, where the soil depth exceeds 61m	1.2
S_3	A soil profile 21m or more in depth and containing more than 6m of soft to medium stiff clay but not more than 12m of soft clay	1.5
S_4	A soil profile containing more than 12m of soft clay characterized by a shear wave velocity less than 152 m/s	2.0
The site coefficient shall be established from properly substantiated geotechnical data. In locations where the soil properties are not known in sufficient detail to determine the soil profile type, soil profile S_3 shall be used.		

Basic Structural System	Description of lateral force resisting system	R
Bearing wall system	Light framed walls with shear panels	
	a) Plywood walls for structures, 3 storey or less	
	b) All other light framed walls	8
	Shear walls	6
	a) Concrete	6
	b) Masonry	6
	Light steel framed bearing walls with tension only bracing	4
	Braced frames where bracing carries gravity loads	6
	a) Steel	4
	b) Concrete	4
	c) Heavy timber	
Building frame system	Steel eccentric braced frame (EBF)	
	Light framed walls with shear panels	10
	a) Plywood walls for structures 3 storey or less	9
	b) All other light framed walls	7
	Shear walls	8
	a) Concrete	8
	b) Masonry	8
	Concentric braced frames (CBF)	8
	a) Steel	8
	b) Concrete	
	c) Heavy timber	
Moment resisting frame system	Special moment resisting frames (SMRF)	
	a) Steel	12
	b) Concrete	12
	Intermediate moment resisting frames (IMRF), concrete	8
	Ordinary moment resisting frames (OMRF)	8
	Steel	8
	Concrete	
Dual system	Shear walls	
	a) Concrete with steel or concrete SMRF	
	b) Concrete with steel OMRF	12
	c) Concrete with IMRF	6
	d) Masonry with steel or concrete	9
	e) Masonry with steel	8
	f) Masonry with concrete	6
	Steel EBF	7
	a) With steel SMRF	12
	b) With steel OMRF	6
	Concentric braced frame (CBF)	10
	a) Steel with steel SMRF	6
	b) Steel with steel OMRF	9
	c) Concrete with concrete SMRF	6
	d) Concrete with concrete IMRF	

Vertical Distribution of Lateral Forces:

The total base shear, V shall be distributed along the height of the structure in accordance with the following equations:

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

Where,

F_i = Lateral force applied at storey level – i

F_t = Concentrated lateral force considered at the top of the building in addition to the force F_n

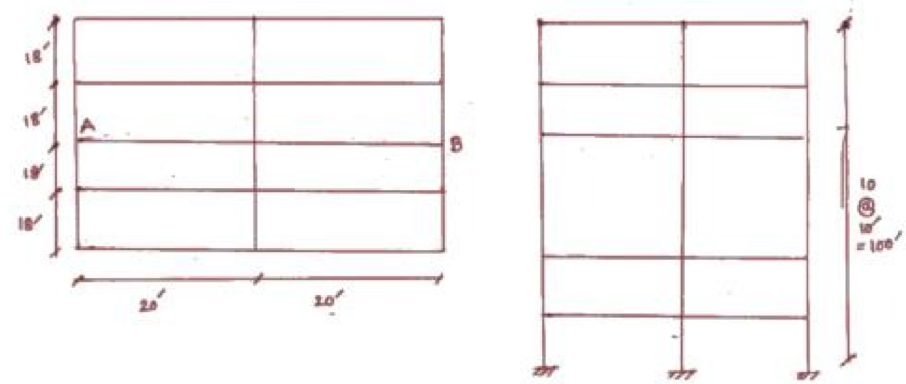
$F_t = 0.07TV \leq 0.25V$ when T> 0.7 second

$= 0.0$ when T≤ 0.7 second

The remaining portion fo the base shear (V- F_t), shall be distributed over the height of the building including level-n, according to the relation:

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

Q. Calculate the earthquake force for an interior frame AB of the structure shown in the figure. The structure is to be used as a hospital building located at sylhet. the soil is medium stiff clay. the building system shall be a special moment resisting frame in concrete. the slab is 6" thick. Partition and floor finish loads have been estimated to be 50 psf.



Solution:

Hospital Building; Essential facilities, $I = 1.25$

Location: sylhet, $Z = 0.25$

Medium stiff clay, $S = 1.5$

$$C = \frac{1.25S}{T^{2/3}}$$

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

$$= 0.073 * \left(\frac{100}{3.28}\right)^{3/4}$$

$$= 0.947$$

$$C = \frac{1.25 * 1.5}{(0.947)^{2/3}} = 1.944$$

special moment resisting frame, $R = 12$

weight of slab $= \frac{6}{12} \times 150 = 75$ psf $= 3.59$ KN/m²

Partition wall and Floor finish $= 50$ psf $= 2.39$ KN/m²

Total Dead load $= (3.59 + 2.39)$ KN/m² $= 5.98$ KN/m²

Partition wall load $\rightarrow 2.39$ KN/m² > 0.6 KN/m².

Total seismic dead load, $W = 5.98 * (40 \times 18) * \frac{1}{(3.28)^2}$ KN/Floor

$= 400.2$ KN/Floor.

$= (400.2 * 10)$ KN

$= 4002$ KN.

$$V = \frac{ZIC}{R} * W$$

$$= \frac{0.25 * 1.25 * 1.944}{12} * 4002$$

$$= 202.6 \text{ KN}.$$

$T = 0.947 > 0.7$ sec.

$F_t = 0.07 TV$

$= (0.07 * 0.947 * 202.6)$

$= 13.43$.

Check:

$0.25V$

$= 50.65$

$\therefore F_t < 0.25V$

$\therefore F_t = 13.43$ KN.

Now, $F_x = \frac{(V - F_t) w_x h_x}{\sum w_i h_i}$

$w_x = 400.2$ KN

$\sum w_i h_i = 400.2 * (3 + 6 + 9 + 12 + \cdots 30.48)$

$\therefore w_x = w_i$

$$F_x = \frac{(202.6 - 13.43) * \cancel{w_x} h_x}{\cancel{w_x} * (3+6+9+12+15+18+21+24+27+30)} = 1.15\, h_x .$$