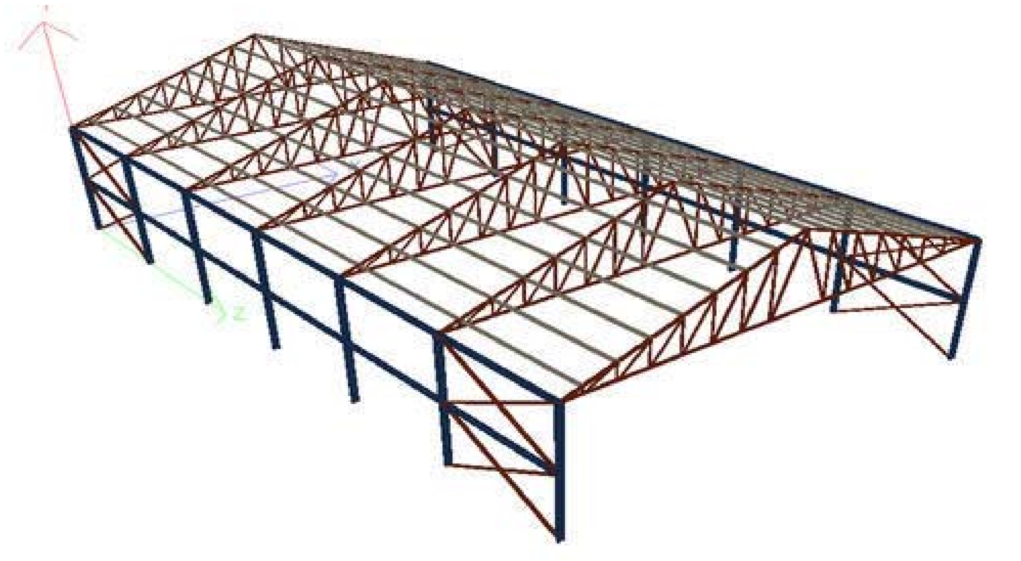
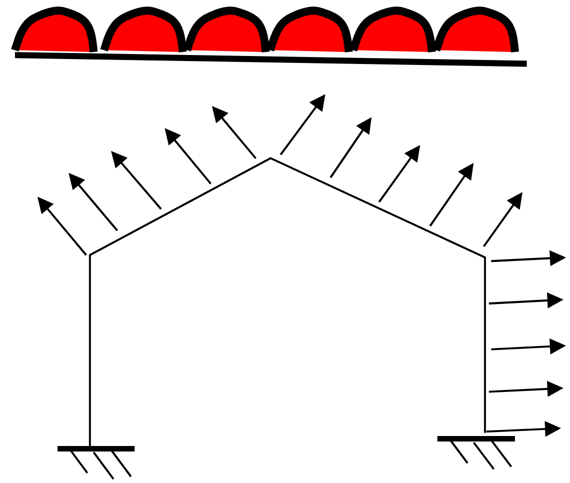
STRUCTURAL DESIGN AND DETAILING

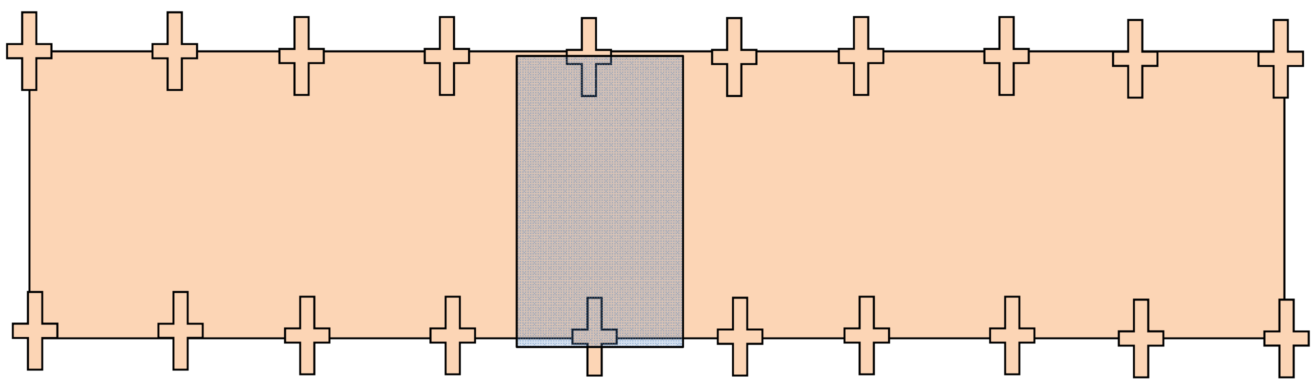
CVP 441

INTERACTIVE SESSION AND GUIDELINES ON CONCEIVING AND ANALSYSIS FOR RC STRUCTURE

In exercise one, we had done very simplified plane frame analysis taking advantage of the repetitive nature of the structural system. This will not be case in Exercise 2







PROBLEM STATEMENT

Figures 1 to 5 show the general architectural floor plan of a three storeyed RC office building of a start-up company.

The floor to floor height is 3.5 m for all storeys.

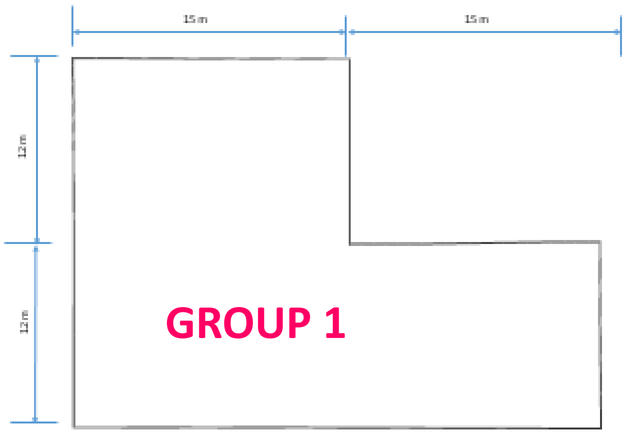
Finished ground floor level is 450 mm above the finished ground level (FGL), which is in turn 800 mm above the natural ground level (NGL).

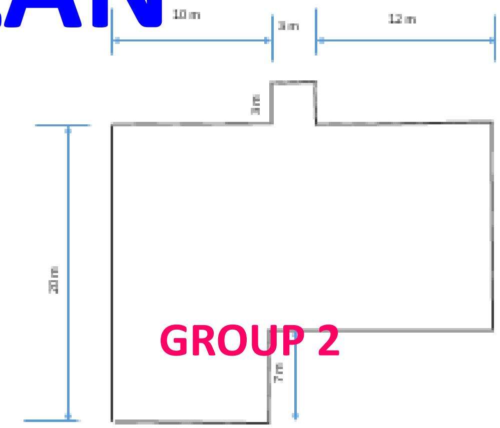
The geotechnical investigation report recommends isolated footings under the columns, to be placed 1.5 m below NGL, with the allowable net bearing pressure equal to 180 kN/m^2 being recommended by the Geotechnical expert.

All external walls are 230 mm thick. In absence of exact details of partitions, an equivalent UDL of 1 kN/m^2 may be assumed.

BUILDING PLAN

CVP 441 Structural Design and Detailing





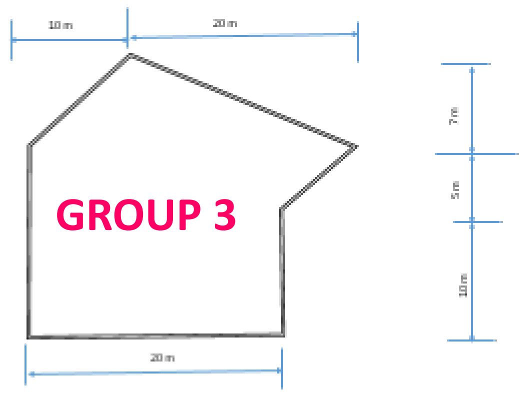
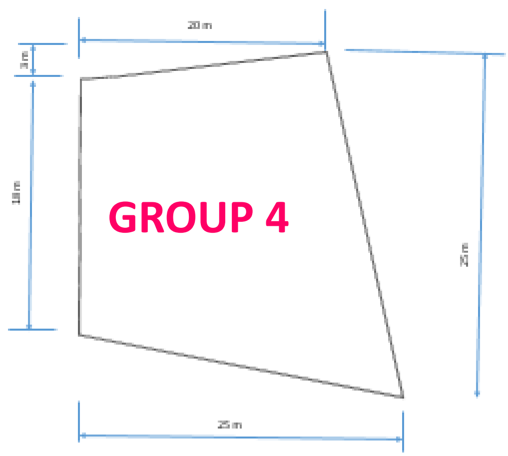


Figure 4 Building plan for Group 4 (minor details may be assumed)



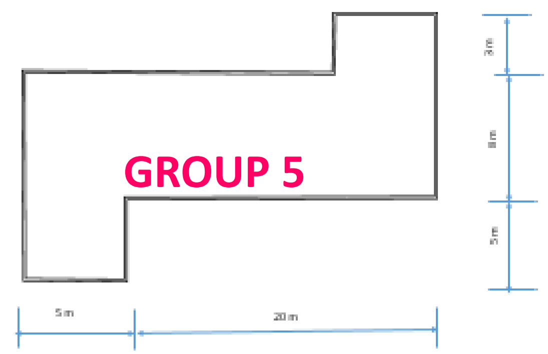
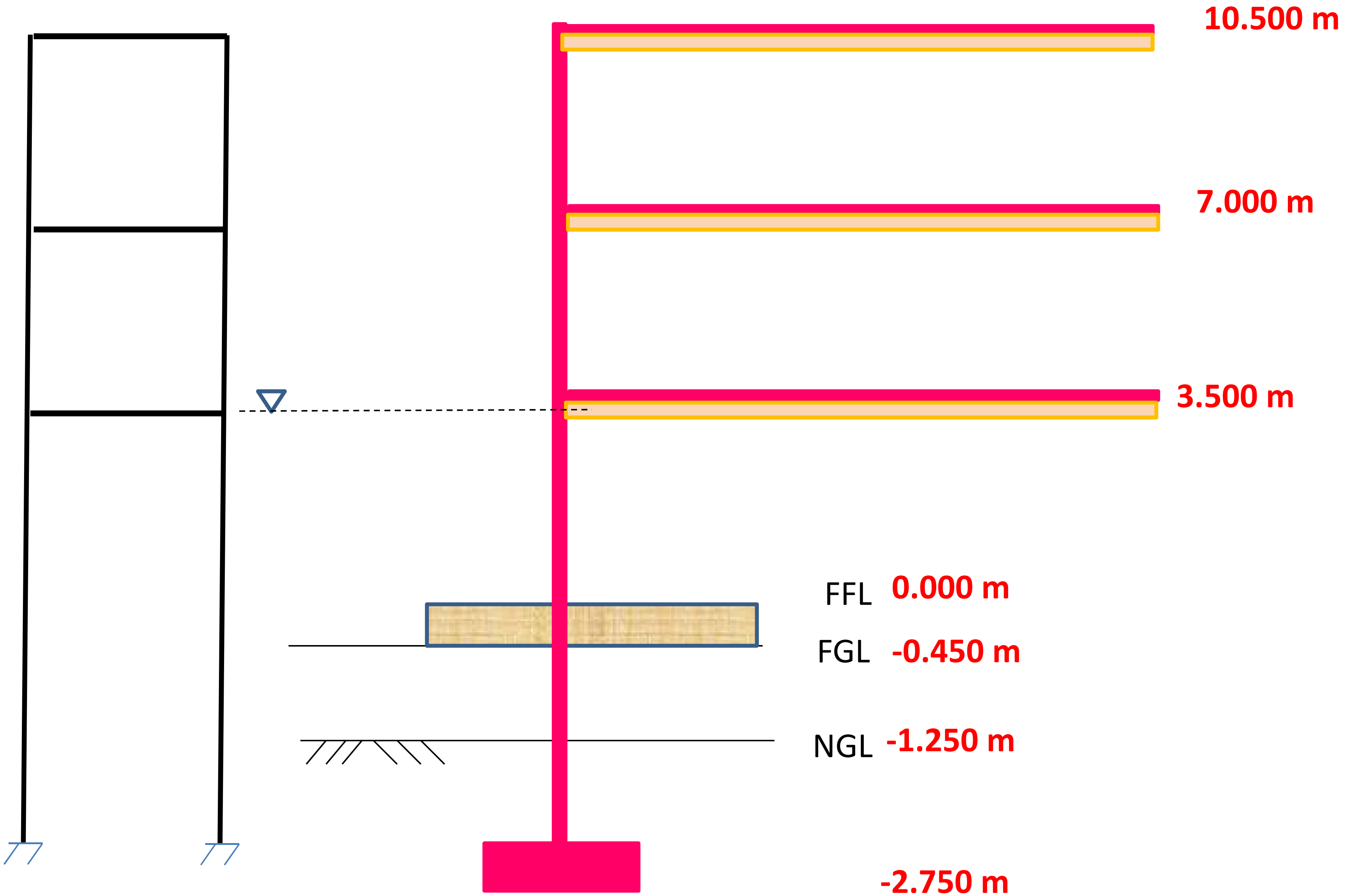


Figure 5 Building plan for Group 5 (minor details may be assumed)

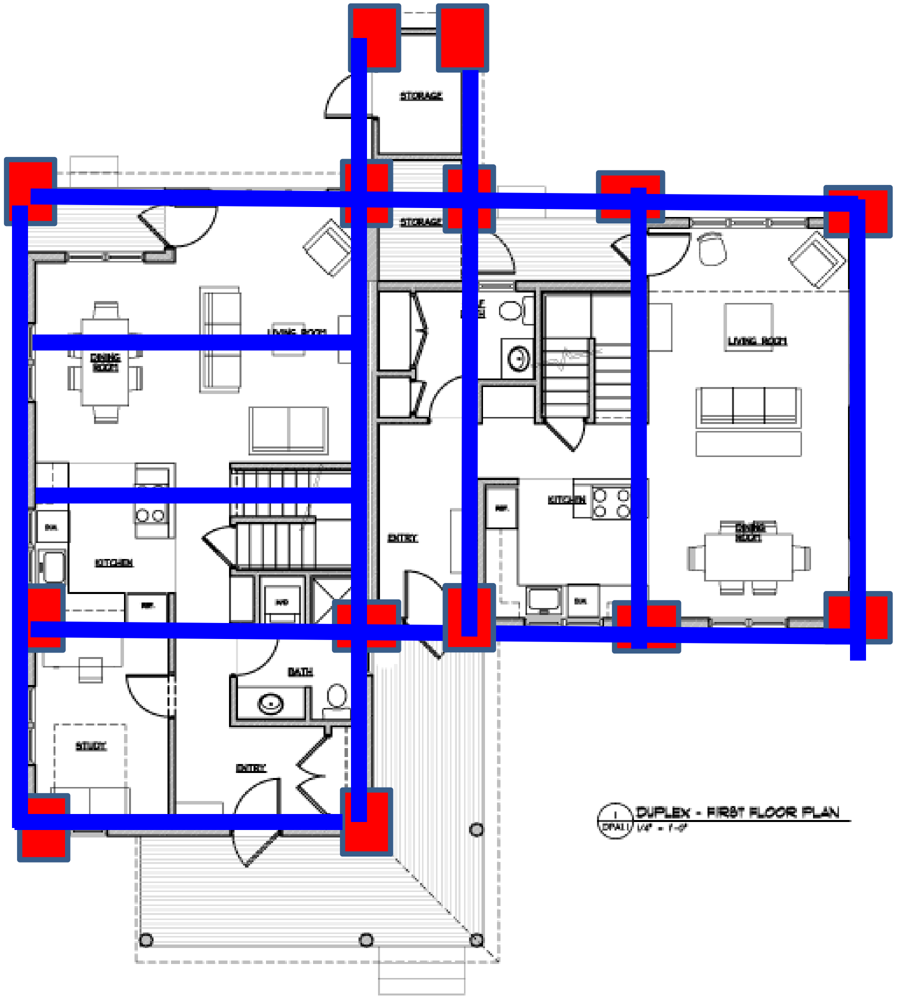
BUILDING ELEVATION



SOLUTION STEPS

1. Formulate structural system
2. Assume member sizes
3. Determine dead, imposed, wind and earthquake loads (apply higher of wind/ earthquake)
4. Model in STAAD, apply loads and analyze
5. Interpret and summarize analysis results and keep them ready for Exercise 3

Formulate structural system



GUIDELINES

Spans 6 to 12 m

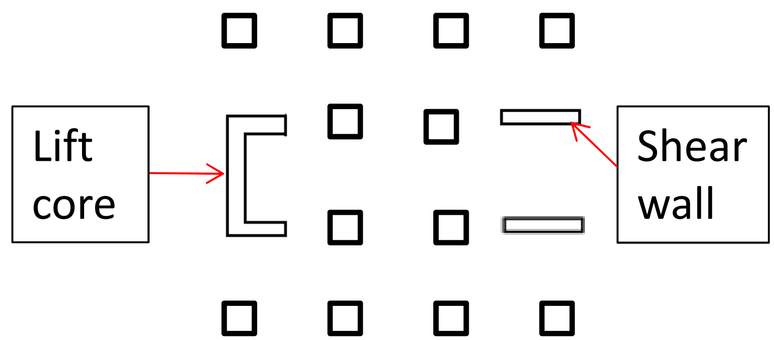
Beam sizes:
Width 250/300mm, depth: 500/600mm

Column sizes:
300 to 500 mm
Orient in both directions for economical design

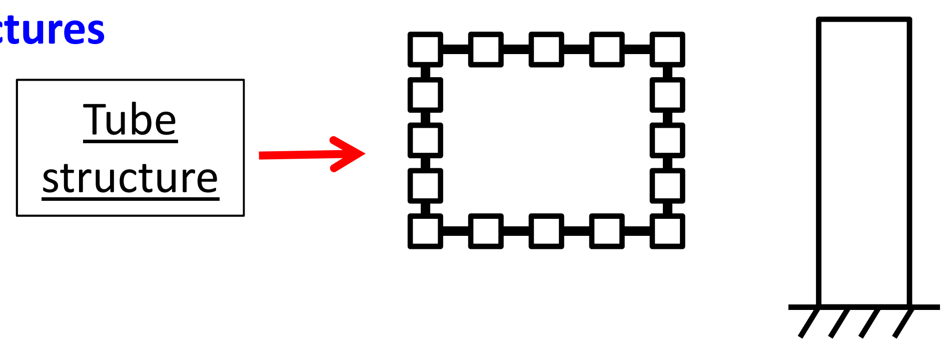
ANALYSIS OF BUILDING FRAMES

1) **<8-10 storeys** : Simple frames (gravity + lateral loads)

2) **8-10 storeys onwards (upto 20 storeys)** : Frames + Shear walls (Lift core)

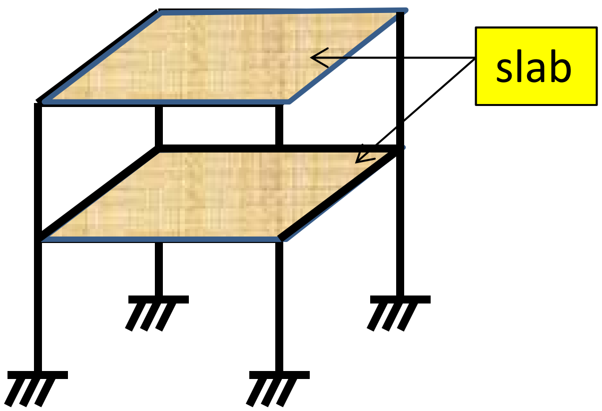


3) **Very tall structures**

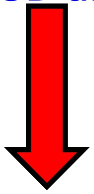


GENERAL 3D ANALYSIS

1) Distribution of vertical and lateral loads is automatically taken care of.
2) Rigorous
3) Output very compact



Usual 3D analysis



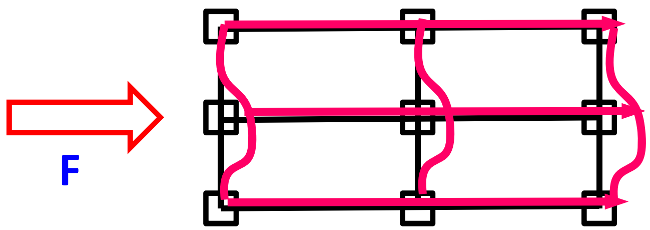
Ignores presence of slab

Structural functions of floor system

1) Distribution of vertical loads to beams through bending.

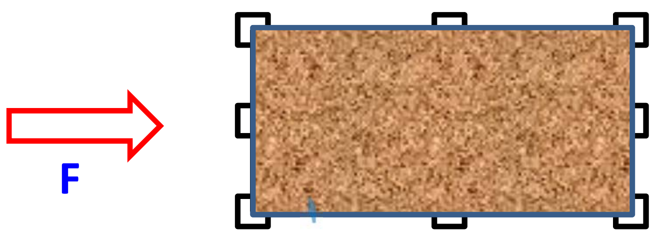
2) Distribution of lateral loads by in plane action.

HOW DOES THE PRESENCE OR ABSENCE OF SLAB AFFECT THE VERTICAL AND LATERAL LOAD ANALYSIS??



Symmetrical Building without slab

- ✓Under vertical loads
- ✓Under horizontal loads



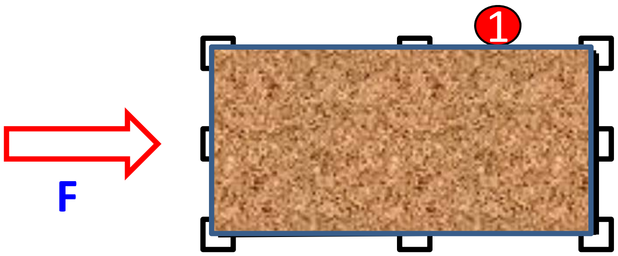
Symmetrical Building with slab

- ✓Uniform translation
- ✓No rotation of floor

✓Forces will be distributed in proportion to stiffness of frames

What will happen in above two cases if the force "F" were acting unsymmetrically

SYMMETRICAL BUILDING UNDER :
(a) SYMMETRICAL LOADS (b) UNSYMMERICAL LOADS

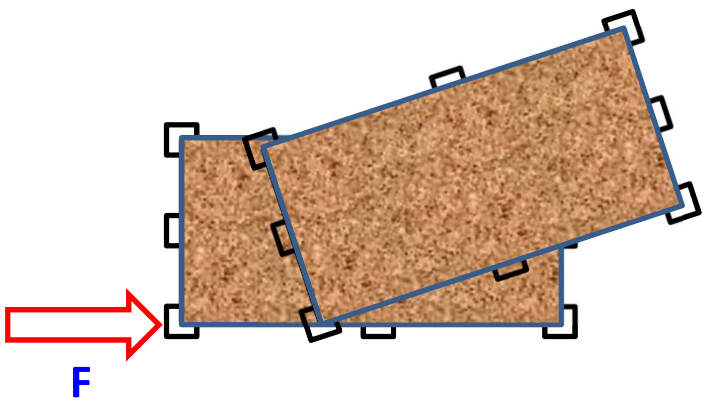


Symmetrical Building

- ✓**Uniform translation**
- ✓**No rotation of floor**

Here plane frame analysis can be carried out

- ✓Forces will be distributed in proportion to stiffness of frames

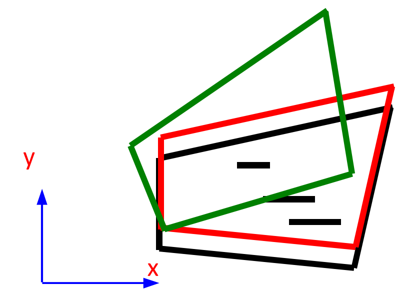


- ✓**Translation + rotation of floor**

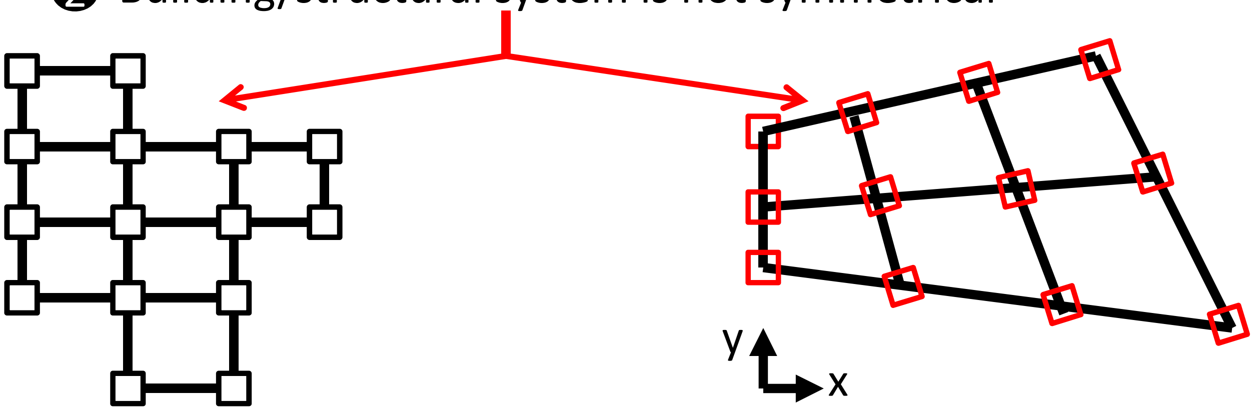
Here plane frame analysis will not be valid

WHEN BUILDING IS UNSYMMERICAL OR SYMMETRICAL BUILDING UNDER UNSYMMETRICAL LATERL LOADS

❶ Unsymmetrical lateral loading (Torsion)



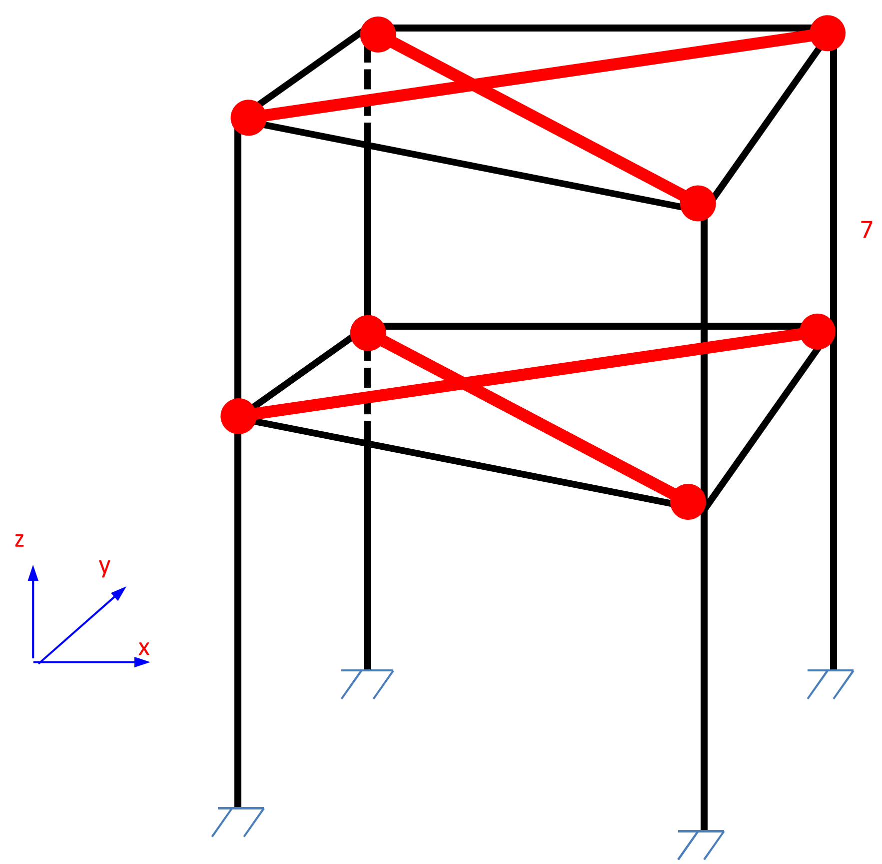
❷ Building/structural system is not symmetrical



Only full 3D analysis considering the effect of floor slab will yield correct results for lateral load analsysis

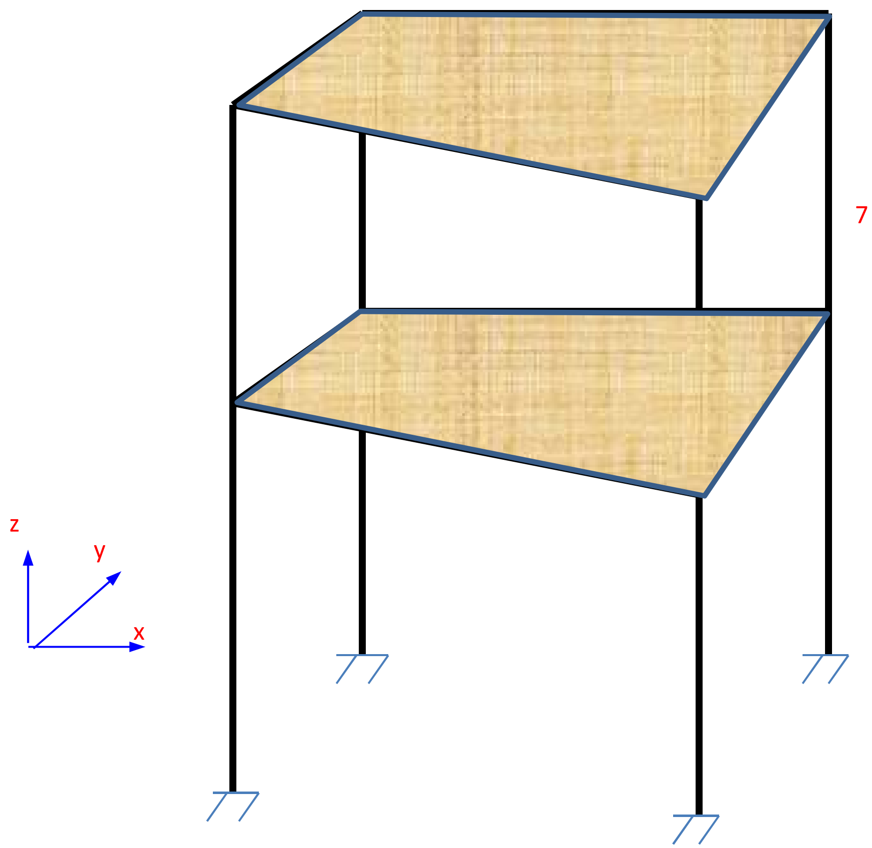
USE OF STANDARD SOFTWARE TO RIGOROUSLY CONSIDER SLAB ACTION

OPTION 1: ADD LINK ELEMENTS AS HORIZONTAL BRACES IN ALL BAYS (ASSIGN HIGH STIFFNESS)



USE OF STANDARD SOFTWARE TO RIGOROUSLY CONSIDER SLAB ACTION

OPTION 2: INCLUDE PLATE ELEMENT IN ANALYSIS



LOAD COMPUTATION

DEAD LOADS : IS 875 (I)

IMPOSED LOADS : IS 875 (II)

WIND LOADS : IS 875 (III)
(Already familiar after Exercise 1)

EARTHQUAKE LOADS : IS 1893 (I)
(More rigorous calculations needed than Exercise 1)

Compute both wind and earthquake loads and apply the higher of the two on the structure

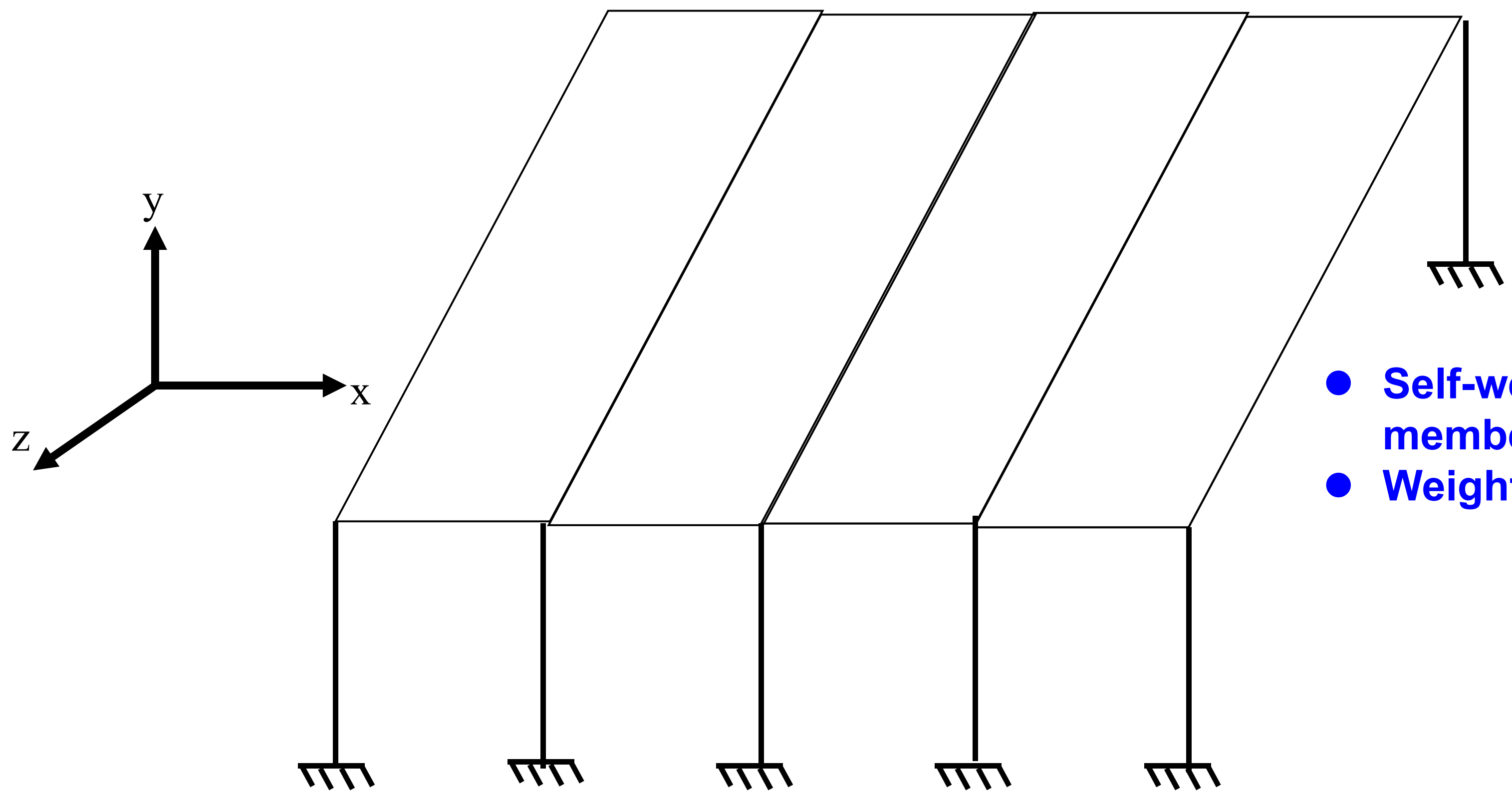
DEAD/IMPOSED LOADS

Assume suitable material densities as per IS 875 (I). All peripheral walls are single brick thick (9 inches or 230 mm)

Assume suitable slab thickness and floor finishes. Apply equivalent UDL for interior partitions.

Apply suitable imposed loads on various floors as per IS 875 (II).

DISTRIBUTION OF DEAL AND IMPOSED LOADS



- Self-weight of members
- Weight from floor

Can be done automatically in STAAD.

EARTHQUAKE FORCE IS 1893(I)
(Assume building located in Delhi)

6.4 Design Spectrum

6.4.1 For the purpose of determining seismic forces, the country is classified into four seismic zones as shown in Fig. 1.

6.4.2 The design horizontal seismic coefficient A_h for a structure shall be determined by the following expression:

$$A_h = \frac{Z\,I\,S_a}{2\,R\,g}$$

Provided that for any structure with $T \leq 0.1$ s, the value of A_h will not be taken less than $Z/2$ whatever be the value of I/R

7.5.3 *Design Seismic Base Shear*

The total design lateral force or design seismic base shear (V_B) along any principal direction shall be determined by the following expression:

$$V_B = A_h W$$

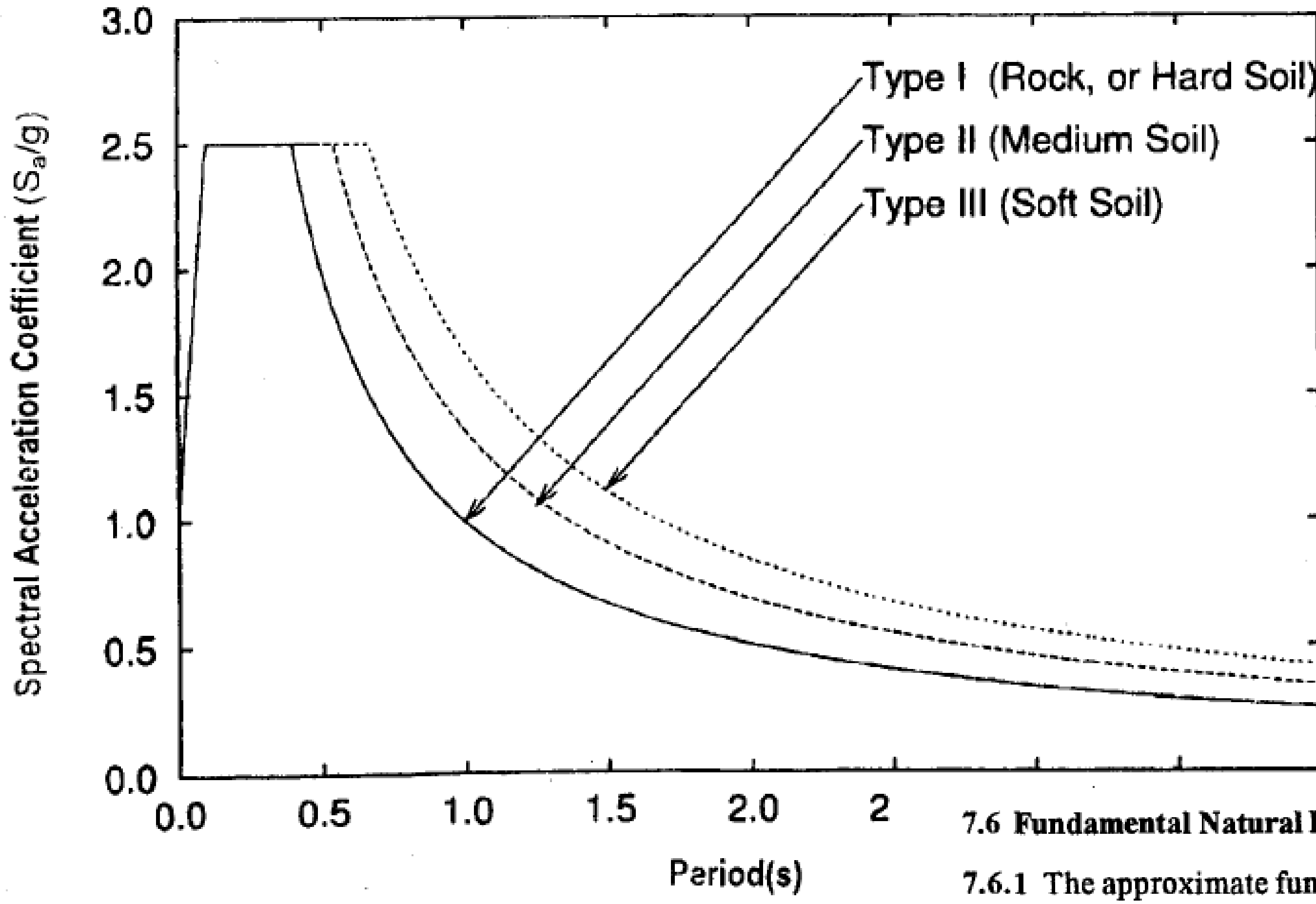
3.29 Seismic Weight (*W*)

It is the total dead load plus appropriate amounts of specified imposed load.

Table 8 Percentage of Imposed Load to be Considered in Seismic Weight Calculation

(*Clause* 7.3.1)

Imposed Uniformity Distributed Floor Loads (kN/m^2)	Percentage of Imposed Load
(1)	(2)
Upto and including 3.0	25
Above 3.0	50



$$A_h = \frac{Z\,I\,S_a}{2\,R\,g}$$

Provided that for any structure with $T \leq 0.1$ s, the value of A_h will not be taken less than $Z/2$ whatever be the value of I/R

7.6 Fundamental Natural Period

7.6.1 The approximate fundamental natural period of vibration (T_a), in seconds, of a moment-resisting frame building without brick infil panels may be estimated by the empirical expression:

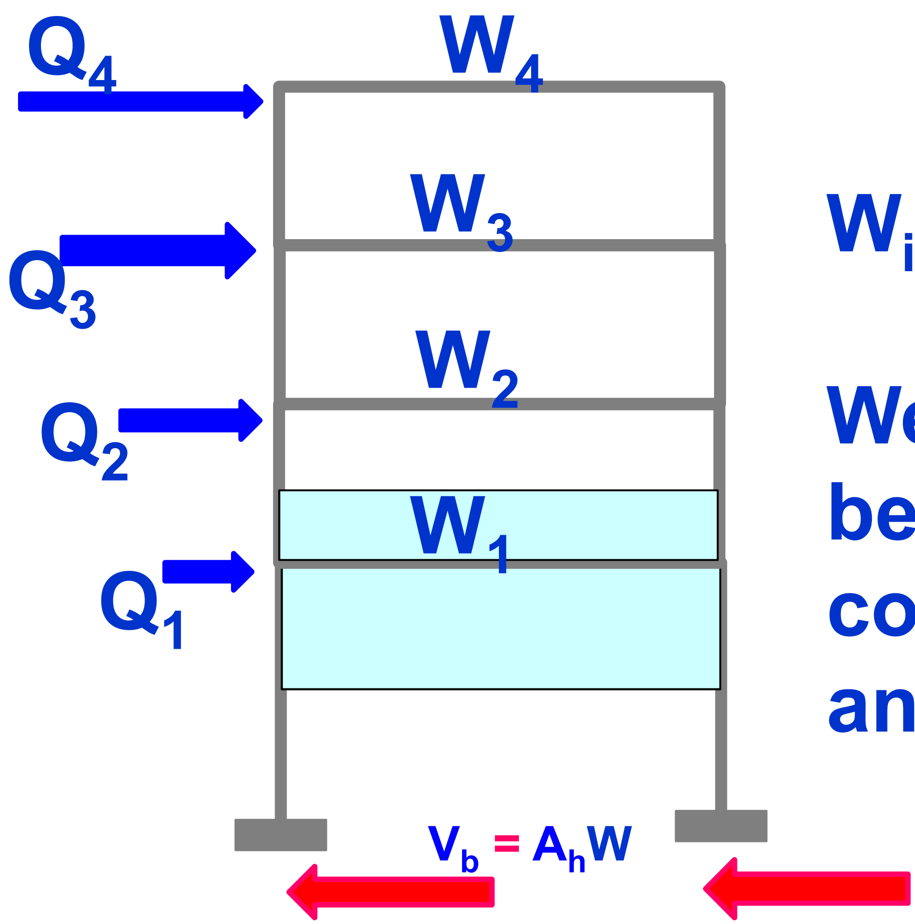
$T_a = 0.075\,h^{0.75}$ for RC frame building

$= 0.085\,h^{0.75}$ for steel frame building

where

h = Height of building, in m. This excludes the basement storeys, where basement walls

WEIGHT LUMPED AT VARIOUS FLOOR LEVELS



W_i =

Weight contributed floor, beams, half height of columns/ walls above and below

$W = W_1+W_2+W_3+W_4$

Total earthquake base shear $V_b = A_h W$

SEISMIC WEIGHT LUMPED AT ANY FLOOR

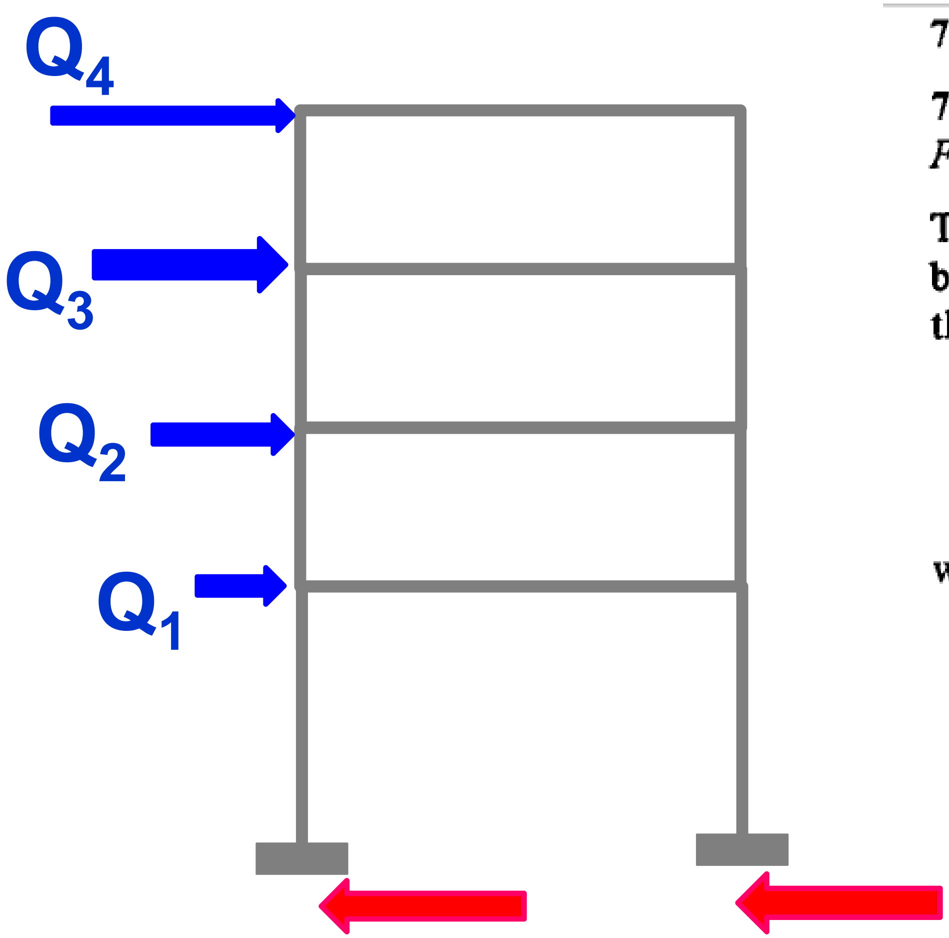
Slab weight along with finishes

All beams at that level

Half height of walls and columns from storeys above and below the floor considered

Consider all external walls as one brick thick (230mm). Internal partitions can be considered half brick thick....or an appropriate equivalent UDL may be considered for internal walls.

DISTRIBUTION OF EARTHQUAKE FORCES AT VARIOUS FLOOR LEVELS



$V_b = A_h W$

7.7 Distribution of Design Force

7.7.1 *Vertical Distribution of Base Shear to Different Floor Levels*

The design base shear (V_B) computed in **7.5.3** shall be distributed along the height of the building as per the following expression:

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2}$$

where

Q_i = Design lateral force at floor i,

W_i = Seismic weight of floor i,

h_i = Height of floor i measured from base, and

n = Number of storeys in the building is the number of levels at which the masses are located.

Q_i to be applied at each floor level equally distributed among all joints

7.12.2.2 *Horizontal projection*

All horizontal projections like cornices and balconies shall be designed and checked for stability for five times the design vertical coefficient specified in **6.4.5** (that is = 10/3 A_h).

LOAD COMBINATIONS (IS 456)

Table 18 Values of Partial Safety Factor γ_f for Loads

(*Clauses* 18.2.3.1, 36.4.1 *and* B-4.3)

Load Combination	Limit State of Collapse			Limit States of Serviceability		
	DL	*IL*	*WL*	*DL*	*IL*	*WL*
(1)	(2)	(3)	(4)	(5)	(6)	(7)
DL + *IL*	1.5		1.0	1.0	1.0	–
DL + *WL*	1.5 or 0.9[1)]	–	1.5	1.0	–	1.0
DL + *IL* + *WL*	1.2			1.0	0.8	0.8

NOTES

1 While considering earthquake effects, substitute *EL* for *WL*.

2 For the limit states of serviceability, the values of γ_f given in this table are applicable for short term effects. While assessing the long term effects due to creep the dead load and that part of the live load likely to be permanent may only be considered.

[1)] This value is to be considered when stability against overturning or stress reversal is critical.

Provide inputs in STAAD for both factored and unfactored load combinations

REPORT/ SUBMISSION

Prepare an ANALYSIS REPORT (typed) in following format.

1. Sketch showing building plan and elevation
2. 2D model of typical frame showing main dimensions
3. Summary of main loadings (dead, imposed, earthquake and wind)-max 3 pages, reference to codes where necessary)
4. Input text file (compact-max two pages, truncate if necessary)
5. Output file (compact-max three pages, truncate if necessary, showing typical outputs, if necessary, only of the members you have chosen in next step).
6. Tables of critical/ governing load combinations for foundation and column design in following format.

From STAAD analysis, find out the worst/ governing load combinations for:

- **(a) One corner footing of your choice**
- **(b) Column stemming out from the footing above up to first floor**
- **(c) Any roof beam from one end of the building to other end**

Table 1: Critical load combinations for foundation design (show the node considered in 3D model of the building) (Add more rows if necessary)

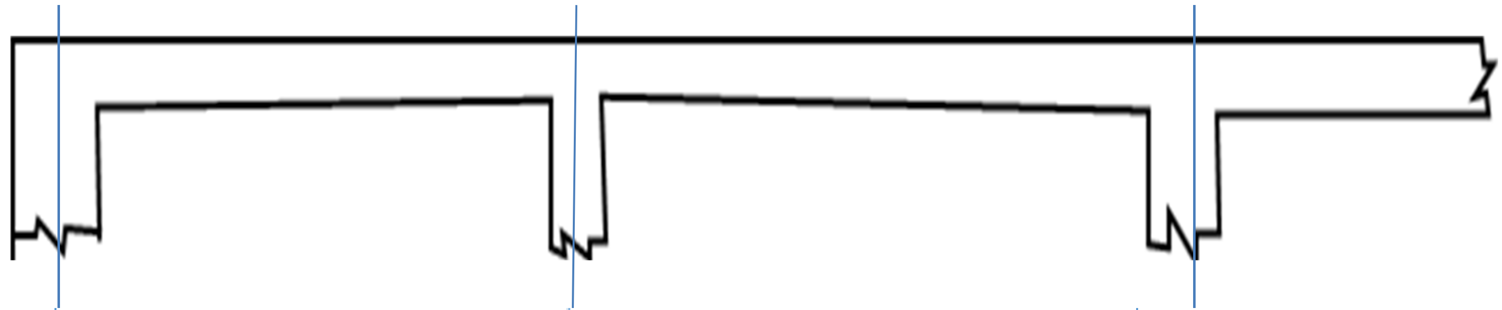
UNFACTORED LOAD COMBINATIONS (SUPPORT REACTIONS)

S. No.	Load combination	Vertical force (kN)	Horizontal force (kN)	Bending moment (kN-m)

Table 2: Critical load combinations for column design (show the member considered in 3D model of the building) (Add more rows if necessary) **FACTORED MEMBER END FORCES**

S. No.	Location (bottom/ top node)	Load combination	Axial force (kN)	Shear force (kN)	Bending moment (kN-m)

Table 3: Critical load combinations for beam design (show the member considered in 3D model of the building) FACTORED



Max negative bending moment (kNm) and corresponding load combination	-350 1.5(D+Ex)	-450 1.2(D+I+Ex)	-350 1.2(D+L+Ex)	-280 1.2(D+I+Ex)	-370 1.5(D+Ex)
Max positive bending moment (kNm) and corresponding load combination	+400 1.5(D+L)		+350 1.5(D+L)		+400 1.5(D+L)
Max shear force and corresponding load combination	230	300	400	350	400

NOTES:

Values filled here are for example, replace with your own analysis results.

The above forces/ moments may be computed at the point other than ther node for economy

THANK YOU

ANY QUERIES???