

PARAMETRIC STUDY OF MULTI-STOREY RC BUILDING WITH PLAN IRREGULARITY

Harpal Singh¹, Akash Aneja²

1. Guru Nanak Dev Engineering College, Ludhiana
2. Guru Nanak Dev Engineering College, Ludhiana

ABSTRACT. The parametric study to evaluate irregular structures in plan L-shape, H-shape and U-shape has been carried out. Lateral length ratio is varied for each shape plan configuration and the assessment of each plan is done on the basis lateral length ratio. Buildings are analysed for Dead loads, Live loads, Wind loads and Earthquake load taken as per the relevant Indian Standard codes. Each building is 11 storeys high having 4m X 4m bays, the height of each storey is taken as 3m and bottom storey height taken is 4m, making the total height of the structure 34m. 3D Modelling and analysis of the structure has been carried out using “ETABS” software. Response quantities such as storey shear, internal forces, storey drift, and storey displacement are considered for the assessment. Based on the results, graphs are plotted for design eccentricity, storey shear, internal forces, storey drift, and storey displacement versus lateral length ratios for different shapes; conclusion for the most stable structure is drawn.

Keywords: RC building, Plan irregularity, 3D modelling, Earthquake load.

Dr. Harpal Singh is a Professor in Civil Engineering, Guru Nanak Dev Engineering College, Ludhiana, India. He is working in the structural modelling.

Akash Aneja is Post Graduate student, Guru Nanak Dev Engineering College, Ludhiana, India

INTRODUCTION

A Masi et al. (2012) carried out non-linear static analyses were performed on 3D models considering the presence of staircase structure and of masonry infills as per the Italian seismic code performed. The results shows a significant role of in-plan irregularity and of masonry infills on the earthquake performance of existing buildings. Wakchaure M.R. (2012) carried out the seismic analysis of G+9 storey building for bared frame and infilled frames and found that due to infill walls in building the base shear is increased and storey drift decreased. Sachin G. et al. (2013) compared the torsional behaviour of two asymmetric building without considering any torsion and considering torsion. The second case was found to be critical. Sundareson A et al. (2014) studied a normal structure is compared to shear wall, brick infill and strong column structures with same configuration considered. From the study, it was concluded that due to presence of shear wall, strong column and brick infill, the stiffness of building was increased, story displacement was decreased whereas the maximum base shear force was increased. Guleria A. (-2014) studied structural analysis of a multi-storeyed building using ETABS for different plan configurations, In this study, the results of analysis of the multi-storey structure shows that the storey overturning moment was decreasing with increase in story height. And almost a similar response was observed in L-shape, I-shape type buildings against the overturning moment. Storey drift was increased with storey height up to 6th storey reached to a maximum value and then started decreasing with increase in story height. Sakshi A. et al. (2014) studied the analysis of multi-storeyed building (upto14 story) subjected to earthquake force was carried. Effect of column stiffness, effect of number of bays, and building height etc. was studied using SAP. Mahesh S. et al. (2014) performed analysis and design of regular and irregular configuration of residential G+11 multi-storey building in various seismic zones and various types of soils using ETABS and STAAD Pro V8i. The design area of steel in columns using the two software's was found to vary from 5% and 10%.

STRUCTURAL MODELLING

In the present study, three cases are adopted by assuming the horizontal plan configuration in different shapes keeping the area of construction same for all the structures for the respective shapes. The different shapes in plan studied are: a) L-shape Plan b) H-shape Plan c) U-shape Plan as shown in Figure 1. Each building is 11 storeys high having 4m X 4m bays, the height of each storey is taken as 3m and bottom storey height taken is 4m, making the total height of the structure 34m.

L-Shape Plans In the present thesis report, typical floor plans are studied for different shapes of horizontal irregular buildings and for assessing the most stable structure, the lateral length ratio $L1/L2$ of L-shape plan is varied from 0 to 2.5. The plan different dimensions taken were 20/36m, 24/32m, 28/28m, 40/16m. A typical plan has been shown in Figure 2

H- Shape Plans For the assessment of the more stable structure, the lateral length ratios $L1/L2$ for H-shape plans are varied from 0.75 to 1.5. The different plan dimensions taken were 34/28m, 32/32m, 30/36m, 28/40m. A typical plan has been shown in Figure 3.

U-Shape Plans For the assessment of the more stable structure, the lateral length ratio for H-shape plans are varied from 0.5 to 1.5. The different plan dimensions taken were 24/36m, 26/32m, 28/28m, 30/24m. A typical plan has been shown in Figure 4.

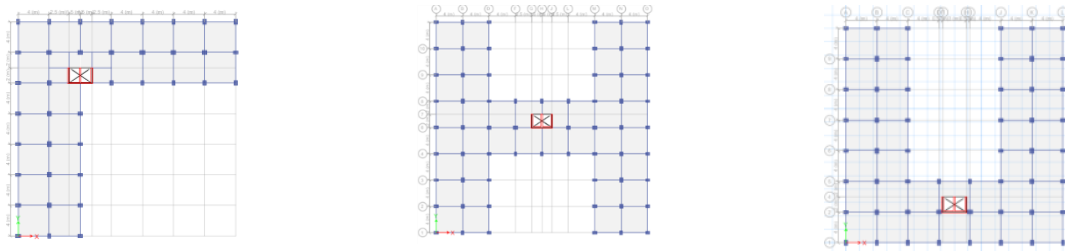


Figure 1. (a) L-Shaped, (b) H-Shaped, (c) U-Shaped

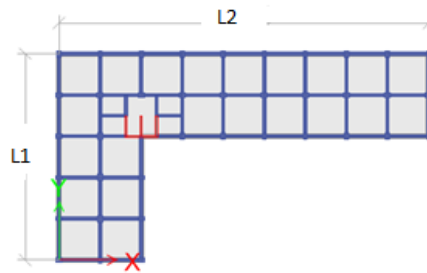


Figure 2 L Shaped Plan with $LL=0.556, 0.75, 1, 2.5$

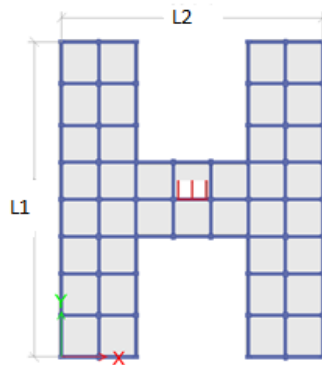


Figure 3 $LL=0.82, LL=1, LL=1.2, LL=1.42$

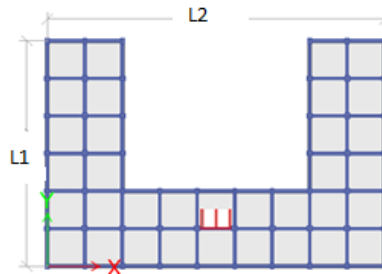


Figure 4 $LL=0.667, LL=0.81, LL=1, LL=1.25$

BUILDING DESCRIPTION

Each building is 11 storeys high having 4m X 4m bays, the height of each storey is taken as 3m and bottom storey height taken is 4m, making the total height of the structure 34m. Building Description has been given in Table 1 and Material Specifications in Table 2. The Seismic Properties are given in Table 3. 3D-models of the buildings are shown in the following Figure 5.

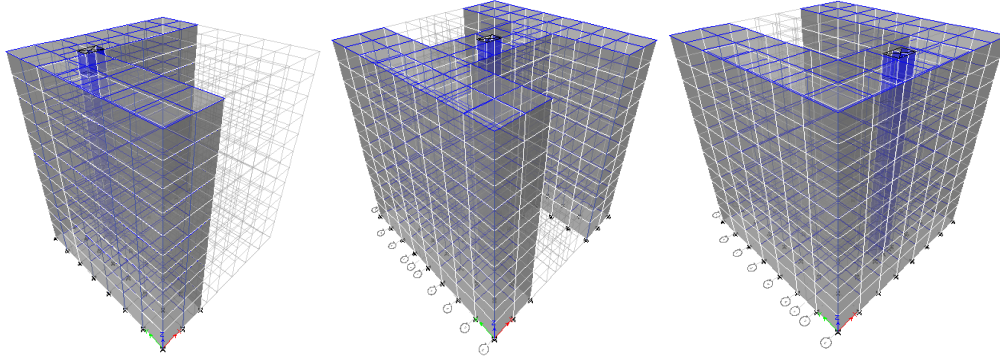


Figure 5 3D-models of the buildings L, H, U shaped

Table 1 Building Description

BUILDING DESCRIPTION	
Type of structure	Multi-storey rigid jointed frame (special RC moment resisting frame)
Number of stories	11(G+10)
Storey height	3m
Bottom storey height	4m
Beam dimensions	450x350
External column dimensions	400x600
Internal column dimensions	500x600
Slab thickness	150mm
Thickness of main wall	230mm
Thickness of partition wall	115mm
Height of parapet wall	0.90m
Thickness of parapet wall	115mm
Support conditions	Fixed

Table 2 Material Specifications

MATERIAL SPECIFICATIONS	
Grade of concrete, M30	$f_{ck} = 30\text{N/mm}^2$
Grade of steel	$f_y = 415\text{N/mm}^2$
Density of concrete	$\gamma_c = 25\text{KN/m}^3$
Density of Brick walls considered	$\gamma_{\text{Brick}} = 20\text{KN/m}^3$

LOADS CONSIDERED

Loads acting on the structure are live load (LD), dead load (DL), seismic load (Eqx & Eqy) and wind loads (WL).

Self-weight comprises of the weight of beams, columns and slab of the building.

Dead load: Wall load, Parapet load and floor load (IS: 875(Part1))

Wall load(due to main wall) = (unit weight x wall thickness x wall height) =

a) $20 \frac{\text{kN}}{\text{m}^3} \times 0.230\text{m} \times 3\text{m} = 13.8 \frac{\text{kN}}{\text{m}}$ (acting on the beam)

Wall load(due to parapet wall) = (unit weight x wall thickness x wall height) =

b) $20 \frac{\text{kN}}{\text{m}^3} \times 0.230\text{m} \times 0.90\text{m} = 2.07 \frac{\text{kN}}{\text{m}}$ (acting on the beam)

Wall load(due to partition wall) = (unit weight x wall thickness x wall height) =

c) $20 \frac{\text{kN}}{\text{m}^3} \times 0.115\text{m} \times 3\text{m} = 6.9 \frac{\text{kN}}{\text{m}}$ (acting on the beam)

Live load: Floor load: 3kN/m^2 and Roof load: 1.5kN/m^2 taken from (IS 875 (Part 2) acting on beams.

Seismic Load: Here Seismic load is considered along two directions, Eqx along length and Eqy along width. IS 1893(Part-1):2002 is followed. The seismic properties are defined in the following table:

Table 3 Seismic Properties

SEISMIC PROPERTIES	
Importance Factor(I)	1
Earthquake Zone	IV
Earthquake Zone Factor	0.24
Damping Ratio	5%
Response reduction factor, R	5
Site type	II

Wind load The parameters required to compute the maximum probable wind intensities on a structure are defined in the Table 4

Load Combination A load combinations as per Indian standards have been used.

Seismic Analysis

The seismic analysis using response spectrum analysis based on Indian standard 1893:2002 (Part-1) has been carried out using ETABS software. According to IS-1893 (Part-1):2002, the design eccentricity e_{di} to be used at the floor i shall be taken as:

$$e_{di} = \begin{cases} 1.5e_{si} + 0.05b_i \\ \text{or } e_{si} - 0.05b_i \end{cases}$$

Table 4 Wind Parameters

WIND PARAMETERS	
Wind Speed (V_b)	47m/sec
Terrain Category	2
Structure Class	B
Risk Coefficient (k_1 Factor)	1
Topography (k_3 Factor)	1

Whichever of these gives the more severe effect in the shear of any frame, where e_{di} = static eccentricity at floor i defined as the distance between the centre of mass and centre of rigidity.

b_i = Floor plan dimension of floor i , perpendicular to the direction of force.
The buildings are analysed considering design eccentricity in both the directions.

RESULTS AND DISCUSSIONS

Lateral length ratio is varied for every shape. Response quantities such as internal forces, Storey shear, Storey displacement and storey drift are considered for the assessment.

Results Obtained for L-Shape Buildings

Storey Displacement

The storey drifts for the different lateral length ratios has been shown in Figure 6. The plan with lateral length ratio 1 is gives the minimum lateral displacement of the 11th storey in x and y direction i.e. 16.4 and 26.7 mm respectively, of all other plans with different lateral length ratios whereas the plan with lateral length ratio 0.556 is showing maximum lateral displacement of the 11th storey in x and y directions i.e. 18.4 and 37.4 mm respectively. And the buildings with lateral length ratios 0.75 and 2.5 are showing top storey displacement of 31.1, 32.7 mm in y direction, respectively.

Storey Shear

The Figure 7. shows the storey shears of the 1st, 5th, 8th and 11th storey for the buildings with different lateral length ratios and the graph clearly shows that the storey shears of all the 4

storeys in the building with lateral length ratio 1 is coming out to be the minimum of all with the base shear of 1715 kN whereas the buildings with lateral length ratio 0.556, 0.75 and 2.5 are showing larger storey shears.

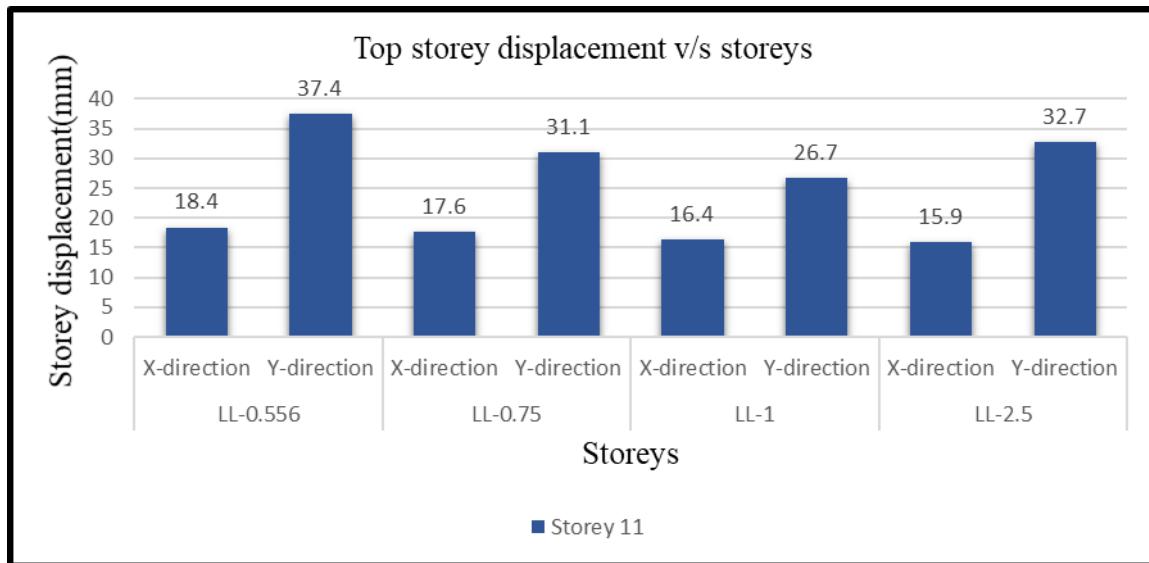


Figure 6 Storey Displacement v/s storeys for different lateral length ratios

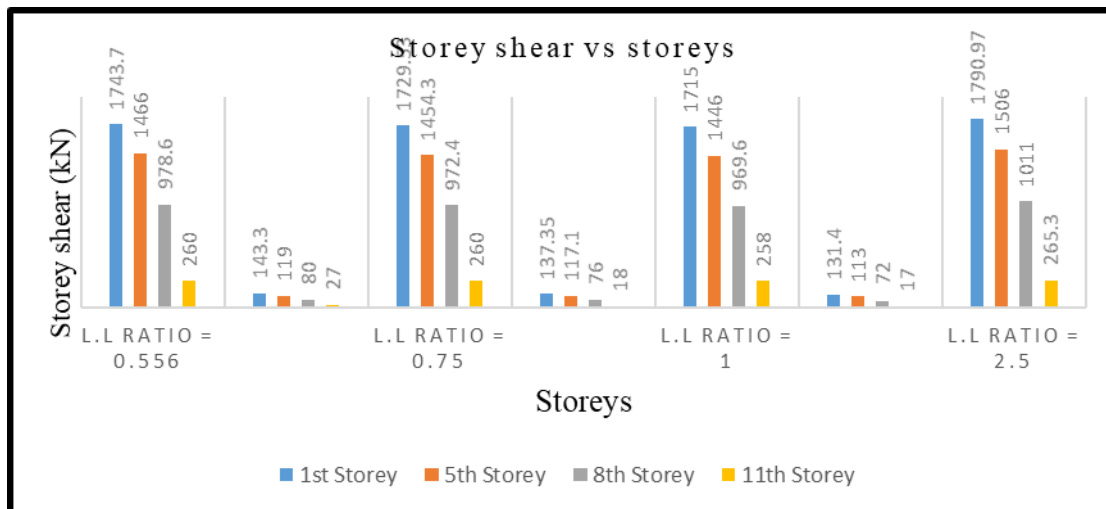


Figure 7 Storey shear v/s Lateral length ratio

Bending Moment of the sample column

The bending moments of the particular column (shown in Figure 8, marked in red circle) of all the columns of the ground storey of all the buildings with different lateral length ratios are checked and the following Figure 9 represents the variation of the bending moment M_x or M_z , v/s lateral length ratio.

From the graph it is clear that the bending moment of a sample column of the ground storey of the building with lateral length ratio 1 is coming out to be the minimum i.e. 99.5 kN-m,

whereas, the other buildings with lateral length ratios 0.556, 0.75 and 2.5 showing higher bending moments such as 133.5, 117.5 and 150.76 kN-m respectively.

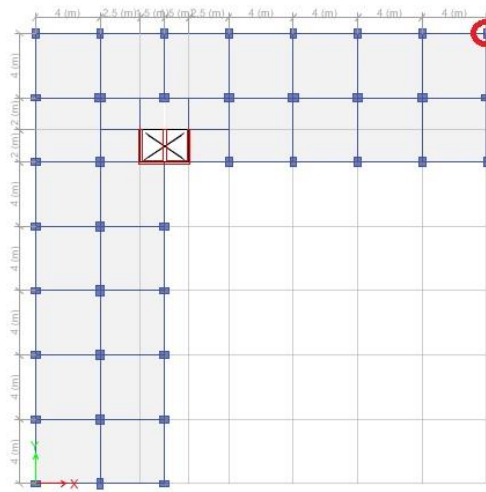


Figure 8 Ground Storey Column marked in red circle

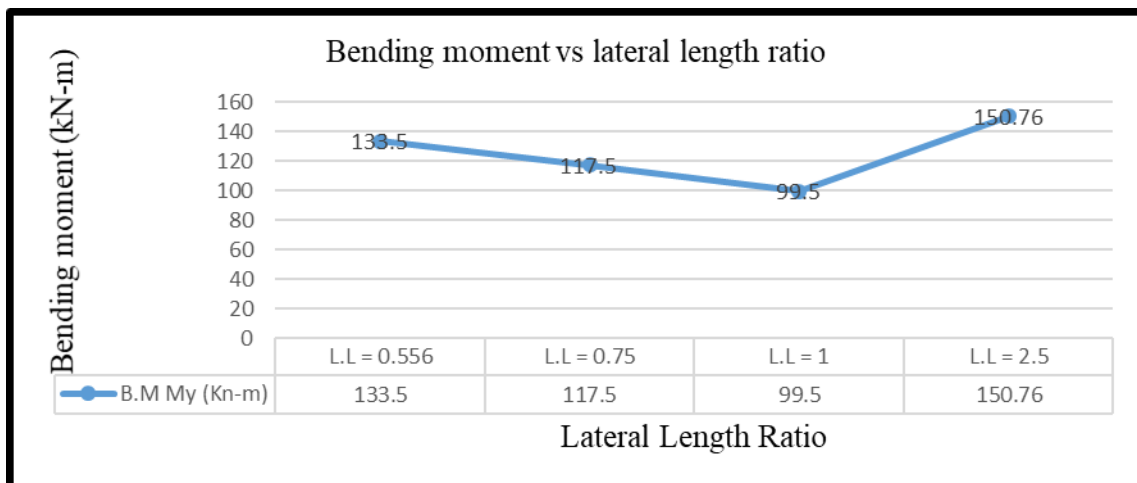


Figure 9 Bending moment v/s lateral length ratio

Story Drift

It is defined as the difference in lateral deflection between two adjacent stories. During an earthquake, large lateral forces can be imposed on structures; Lateral deflection and drift have three primary effects on a structure; the movement can affect the structural elements (such as beams and columns); the movements can affect non-structural elements (such as the windows and cladding); and the movements can affect adjacent structures. Without proper consideration during the design process, large deflections and drifts can have adverse effects on structural elements, non-structural elements, and adjacent structures.

The storey drift of the 11 storeys are shown in the following table and graph of storey drift v/s Storeys for all L-shaped buildings of different lateral length for the worst combination in y-direction:

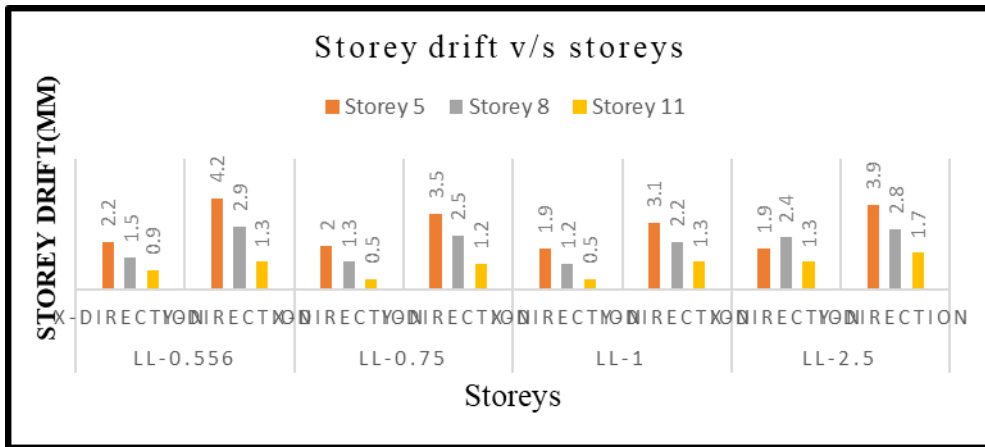


Figure 10 Storey drift v/s Storeys

The Figure 10 between storey drift v/s Storeys for buildings with different lateral length ratios clearly shows that the Storey drift in buildings with lateral length ratio 1 is coming out to be the minimum of all with the maximum value in x and y directions i.e 1.9 and 3.1 mm respectively, whereas the buildings with lateral length ratios 0.556, 0.75 and 2.5 are showing higher values such as 4.2, 3.5 and 3.9 mm in y direction respectively.

Results Obtained for H - Shaped Buildings

Lateral Displacement

The lateral storey displacements of the 11 storeys are shown in the following Figure 11 and graph is plotted for top storey displacement v/s Lateral length ratio for all H - shaped buildings of different lateral length for the worst combination in x and y direction:

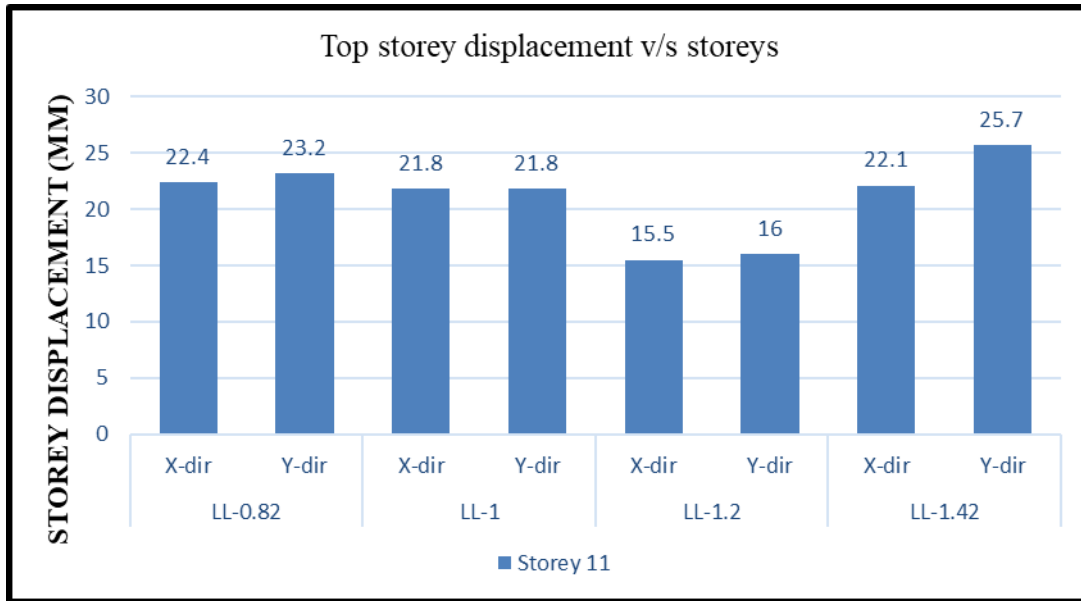


Figure 11 Storey Displacement v/s Storeys

And from the graph it is clear that plan with lateral length ratio 1.2 is showing the minimum lateral displacement of the 11th storey in x and y directions i.e. 15.5 and 16 mm respectively, of all other plans, whereas the plan with lateral length ratio 0.82, 1 and 1.42 are showing maximum lateral displacement of the 11th storey i.e. 23.2, 21.8 and 25.7 mm in y direction respectively.

Storey Drift

The storey drift of the 11 storeys are shown in the following graph of storey drift v/s Storeys for all H-shaped buildings of different lateral length for the worst combination in x and y direction:

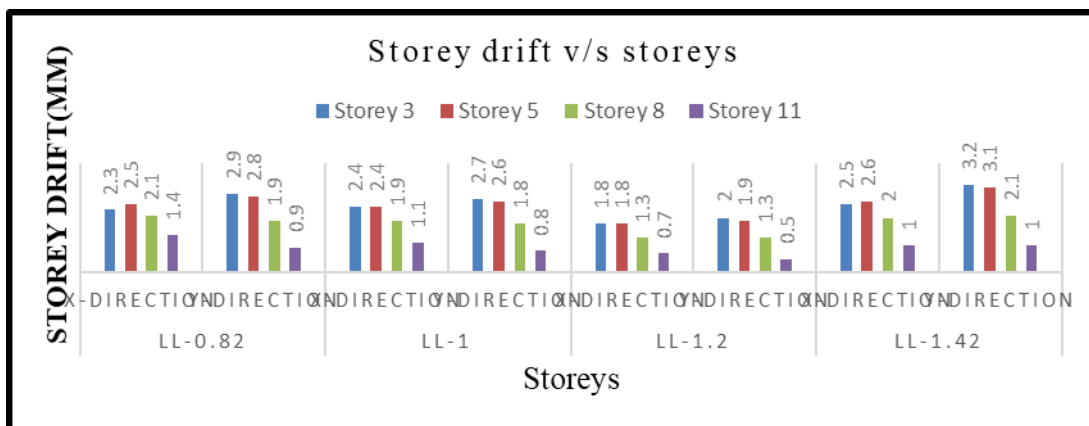


Figure 12 Storey Drift v/s Storeys

The Figure 12 between storey drift v/s Storeys for buildings with different lateral length ratios clearly shows that the Storey drift in buildings with lateral length ratios 1.2 is coming out to be the minimum of all with the maximum values in both the directions i.e 1.8 and 2

mm respectively, whereas the buildings with lateral length ratios 0.82, 1 and 1.42 are showing higher values of 2.9, 2.7 and 3.1 mm in y direction, respectively.

Bending Moment of the Sample Column

The bending moments of the particular column (shown in Figure 13 marked with red circle) of all the columns of the ground storey of all the buildings with different lateral length ratios are checked and the Figure 14 represents the variation of the bending moment M_x or M_z , v/s lateral length ratio.

From the graph it is clear that the bending moment of a sample column of the ground storey of the building with lateral length ratio 1.2 are coming out to be the minimum i.e. 82.25 kN-m respectively, whereas, the other buildings with lateral length ratios 0.82, 1 and 1.42 are showing higher bending moments such as 90, 85.2 and 88 KN-m respectively.

Storey Shear

The storey shear of the 11 storeys are represented in the Figure 15 of Storey shear v/s Storeys for all H-shaped buildings of different lateral length for the worst combination in x and y direction:

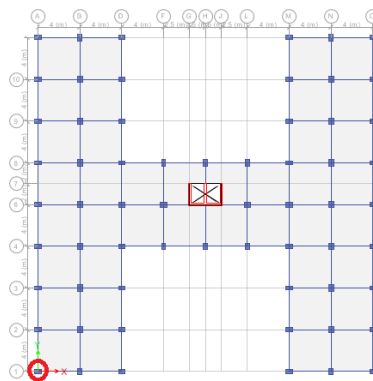


Figure 13 Ground Storey Column Marked in Red Circle

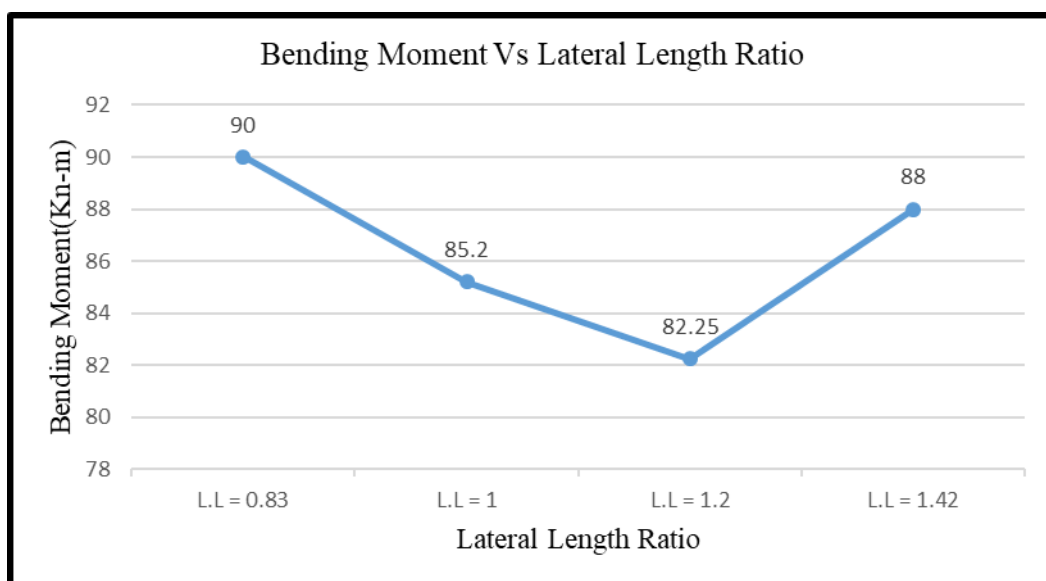


Figure 14 Bending Moment V/s Lateral Length Ratio

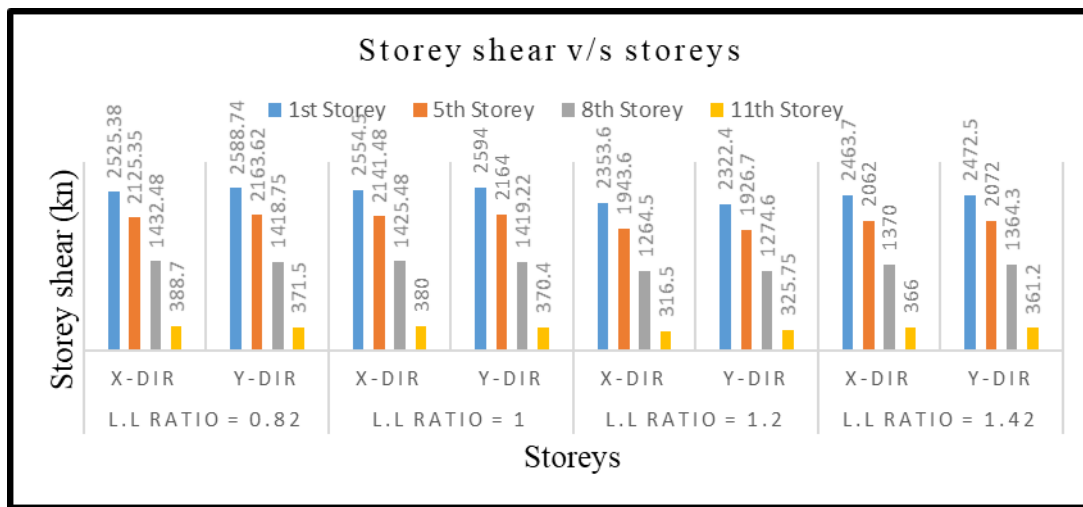


Figure 15 Storey Shear v/s Storeys

The bar graph showing the storey shears of the 1st, 5th, 8th and 11th storey for the buildings with different lateral length ratios and the graph clearly shows that the storey shears of all the 4 storeys in the building with lateral length ratio 1.2 is coming out to be the minimum of all with the base shear of 2322.4 kN in y direction whereas the buildings with lateral length ratio 0.82, 1 and 1.42 are showing base shears of 2588.74, 2594 and 2472.5 kN in y direction, respectively.

Results Obtained U - Shaped Buildings

Lateral Displacement

The lateral storey displacements of the 11 storeys are shown Figure 16 is plotted Top storey displacements v/s lateral length ratio for all U - shaped buildings of different lateral length for the worst combination in y-direction:

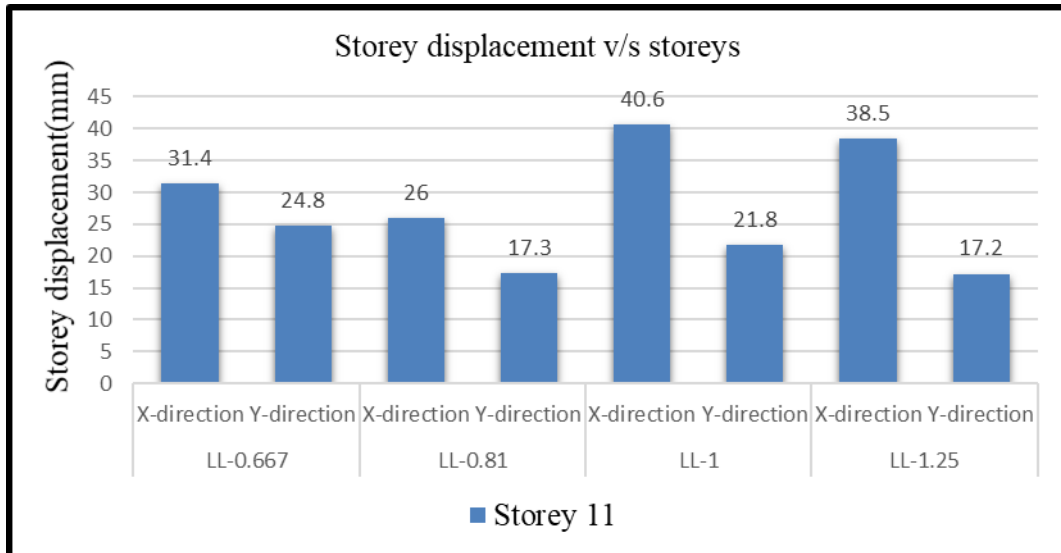


Figure 16 Storey Displacement v/s Storeys

And from the graph it is clear that plan with lateral length ratio 0.81 is showing the minimum lateral displacement of the 11th storey in x and y directions i.e. 26 and 17.3 mm respectively, of all other plans with different lateral length ratios whereas the plan with lateral length ratio 1 is showing maximum lateral displacement of the 11th storey in x and y direction i.e. 40.6 and 21.8 mm. And the building with lateral length ratios 0.667 and 1.25 are showing storey displacement of 31.4 and 40.6 mm respectively.

Storey Drift

The storey drift of the 11 storeys is shown in the Figure 17 of storey drift v/s Storeys for all U-shaped buildings of different lateral length for the worst combination in y-direction. The graph 13 between storey drift v/s Storeys for buildings with different lateral length ratios clearly shows that the Storey drift in buildings with lateral length ratio 0.81 is coming out to be the minimum of all with the maximum values of 3 and 2.1 mm in x and y direction respectively, whereas the buildings with lateral length ratios 0.667, 1 and 1.25 are showing higher values such as 10, 4.6, and 4.6 mm in x-direction, respectively.

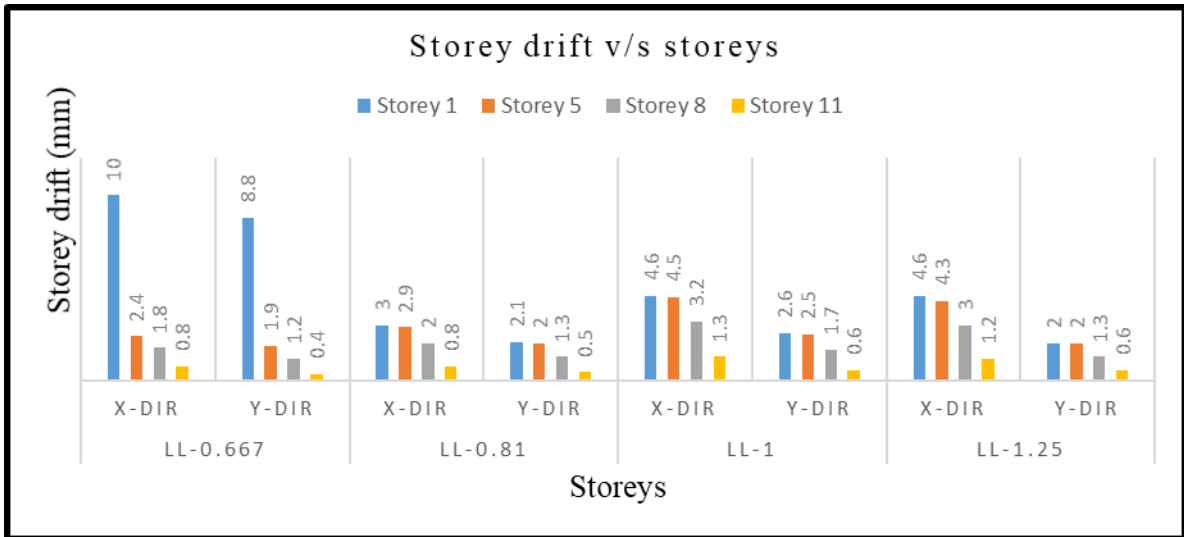


Figure 17 Storey Drift v/s Storeys

Bending Moment of the Sample Column

The bending moments of the particular column(shown in Figure 18 marked in red circle) of all the columns of the ground storey of all the buildings with different lateral length ratios are checked and the Figure 19 represents the variation of the bending moment M_x or M_z , v/s lateral length ratio.

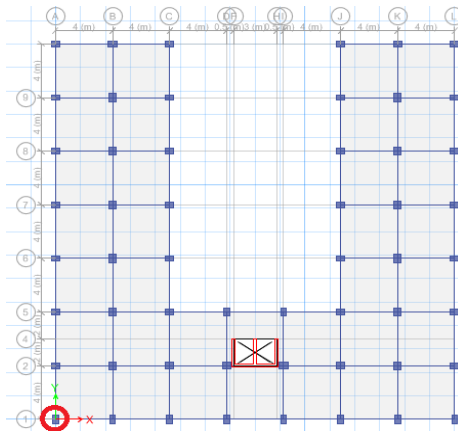


Figure 18 Ground storey column marked in red circle

From the graph it is clear that the bending moment of a sample column of the ground storey of the building with lateral length ratio 0.81 is coming out to be the minimum i.e. 71.76 kN-m, whereas, the other buildings with lateral length ratios 0.556, 1 and 1.25 are showing higher bending moments such as 73.10, 89.2 and 117.4 kN-m respectively.

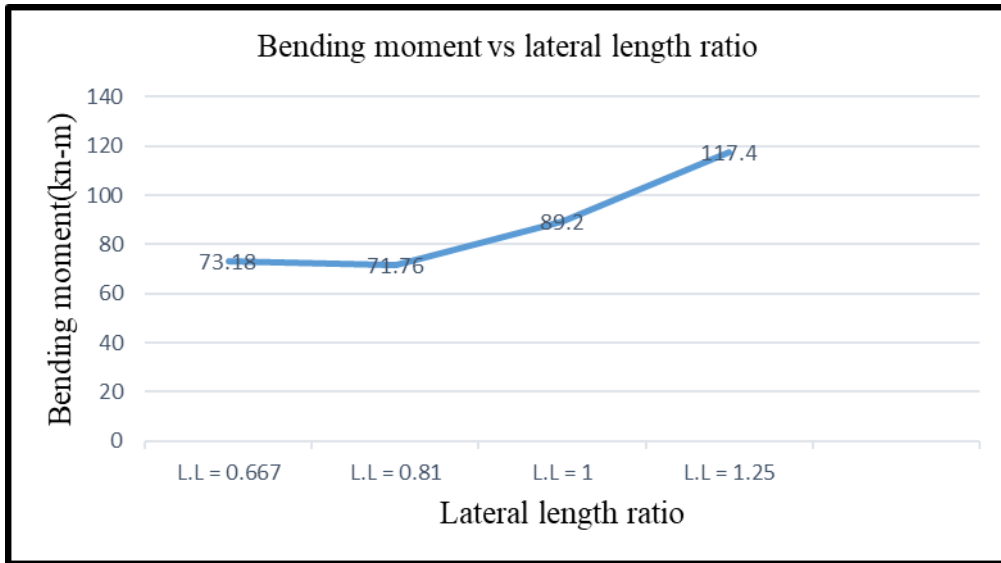


Figure 19 Bending Moment V/s Lateral Length Ratio

Storey Shear

The storey shear of the 11 storeys are represented in the Figure 20 of Storey shear v/s Storeys for all U-shaped buildings of different lateral length for the worst combination in x and y direction:

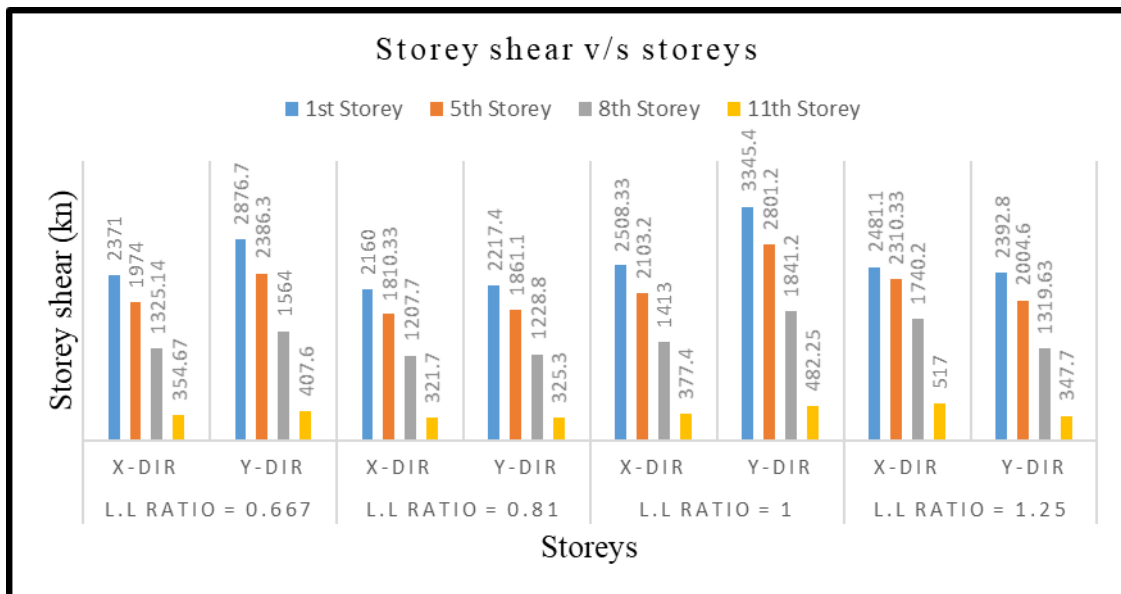


Figure 20 Storey Shear v/s Storeys

The bar graph showing the storey shears of the 1st, 5th, 8th and 11th storey for the buildings with different lateral length ratios and the graph clearly shows that the storey shears of all the 4 storeys in the building with lateral length ratio 0.81 is coming out to be the minimum of all with the base shear of 2217.4 kN in y-direction, whereas the buildings with lateral length ratio 0.667, 1 and 1.25 are showing base shears of 2876.7, 3345.4 and 2329.8 kN respectively.

CONCLUDING REMARKS

For L-shape plans, based on the results obtained, it is observed that the building with lateral length ratio – 1 is showing minimum values for the parameters such as lateral displacements, storey drift, storey shear and the bending moment of the sample column of the ground storey. Hence, it can be concluded that the L-shape building plan with lateral length ratio -1 is the most suitable structure among all the plans.

While assessing the stability of the H-shape buildings, it can be observed that the building plan with lateral length ratio 1.2 is showing the minimum lateral displacement, storey drift and bending moment of the sample column of the ground storey but whereas it is showing the maximum value for the storey shear, hence, it can be concluded that U shape building plan with lateral length ratio 1.2 is the most suitable structure among all plans.

For U-shape plans, the building plan with lateral length ratio – 0.81 is showing the minimum lateral displacement, minimum storey drift, storey shears and minimum bending moment of the sample column of the ground storey plan. Hence, it can be stated that the U-shape building plan ratio – 0.81 is the most suitable structure among for all U-shape plans.

REFERENCES

1. A Masi, V Manfredi, A Digrisolo, (2012): Seismic Assessment of RC Existing Irregular Buildings, 15th World Conference of Earthquake Engineering, LISBOA, Sept.
2. Wakchaure M.R, (2012) : Earthquake Analysis of High Rise Building with and Without In filled Walls, International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 2, August
3. Sachin G. Maske, Dr. P. S. Pajgade (2013): Torsional behaviour of asymmetric building, International Journal of Modern Engineering Research (IJMER) www.ijmer.com, Vol.3, Issue.2, March-April. pp-1146-1149, ISSN: 2249-6645.
4. Sundareson A, Ganesh Baravkar and Vijaya Sarathy (2014): Parametric study of response of an asymmetric building for various earthquake resistance factors, IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308, April.
5. Abhay Guleria (2014) structural analysis of a multi-storeyed building using ETABS for different plan configurations, International Journal of Engineering Research & Technology (IJERT). ISSN: 2278-0181, IJERTV3IS051552, www.ijert.org, Vol. 3 Issue 5, May
6. Sakshi A. Manchalwar, Priyadarshini's J.L. (2014) Seismic Analysis of RC Frame – A Parametric Study, International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, IJERTV3IS091143, www.ijert.org, (This work is licensed under a Creative Commons Attribution 4.0 International License.), Vol. 3 Issue 9, September- 2014.
7. S.Mahesh, B.Panduranga Rao (2014), Comparison of analysis and design of regular and irregular configuration of multi Story building in various seismic zones and various types of soils using ETABS and STAAD, IOSR Journal of Mechanical and

Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 11, Issue 6 Ver. I (Nov- Dec. 2014), PP 45-52 www.iosrjournals.org

8. BIS (1987), IS 875 (Part 2)-1987, Indian standard Code of practice for design load (other than earthquake) for buildings and structures, Bureau of Indian Standard, New Delhi.
9. BIS (2002), IS 1893 (Part 1)-2002, Indian Standard Criteria for Earthquake Resistant Design of Structures, Part 1 – General Provisions and Buildings, Bureau of Indian Standards, New Delhi.
10. BIS (1987), IS 875 (Part 3) – 1987, Indian Standard code of practice for design loads (other than earthquake) for buildings and structures, Bureau of Indian Standard, New Delhi.
11. BIS (1987), IS 875 (Part 5) – 1987, Indian Standard code of practice for design loads (other than earthquake) for buildings and structures, Bureau of Indian Standard, New Delhi
12. BIS (2000), IS: 456 – 2000, Standard plan and reinforced concrete- code of practice, Bureau of Indian Standard, New Delhi.