Analysis of Multi-Storey RCC Frames of Regular and Irregular Plan Configuration using Response Spectrum Method

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Abstract

This research paper focuses on the structural behaviour of multi-storey building for different plan configuration such as regular building along with L- shape and I- shape in accordance with the seismic provisions suggested in IS: 1893-2002 to analyze the performance of existing buildings if exposed to seismic loads. In this modelling of G+25 storeys RCC framed building is studied for earthquake load using STAAD- PRO V8i. Assuming that material property is linear static and dynamic analysis is performed. These analyses are carried out by considering different seismic zones (IV and V) and for each zone the behaviour is assessed by taking three different types of soils namely Hard, Medium and Soft. Post analysis of the structure, lateral displacements, story drift, base shear, maximum bending moment and design results are also computed and compared for all the cases.

Keywords – *Structural Analysis and Design, High Rise Building, Response Spectrum, Plan Irregularity, STAAD-Pro V8i.*

I. INTRODUCTION

This research paper studies the introduction of plan irregularity which is harmful to the structure as it increases the torsion irregularity, shear force, bending moment and other earthquake parameters. So, the chances of failure of these structures are more predominant than the regular structure constructed using same design parameters. The design is focused so that the structure constructed using irregularities can safely withstand the unpredictable seismic ground motion.

A. Methods used for the Analysis of Structure

1) Equivalent Static Analysis

The equivalent static analysis defines a series of forces to study the effect of earthquake ground motion on a building, defined by a seismic design response spectrum. It this method the building responds in its fundamental mode of vibration. To obtain the above condition, the structure must be low-rise and must not twist when the earth moves.

2) Linear Dynamic Analysis

In the linear dynamic procedure, the modelling of structure is done as a multi-degree-of-freedom (MDOF) system with a linear elastic stiffness matrix along with an equivalent viscous damping matrix. The seismic data is modelled using either time history analysis or response spectral analysis but in both the cases, the internal forces and displacements in the structure are obtained using linear dynamic analysis. Therefore, for tall buildings a dynamic procedure is required for the buildings with torsional irregularities, or non-orthogonal systems.

Methods used for linear dynamic analysis-

a) Response Spectrum Analysis

In this method graph between maximum spectral acceleration and various time period of structure is prepared for some ground acceleration and structures response at every instance of time is not calculated. This method involves the calculation of only the maximum values of displacements and member forces in each mode of vibration.

b) Time History Analysis

This method calculates response of structure subjected to earthquake excitation at every instant of time. Various seismic data are necessary to carry out the seismic analysis i.e. acceleration, velocity, displacement data etc., which can be easily procured from seismograph data's analysis for any particular earthquake.

Comparison of Response Spectrum Method with Time History Analysis Method

The size of the problem is reduced to finding only the maximum response of a limited number of modes of the structure, rather than calculating the entire time history of responses during the earthquake. This makes the problem much more tractable in terms both of processing time and (equally significant) size of computer output and allows a clear understanding of the contributions of different modes of vibration.

3) Non Linear Static Analysis

The linear procedures are applicable when the structure is expected to remain elastic for the level of ground motion but when the design results in nearly uniform distribution of nonlinear response throughout the structure then non linear static analysis is performed. As the performance of the structure involves greater inelastic demands, the uncertainty with linear procedures increases to a point that requires a high level of conservatism in demand.

4) *Non linear dynamic analysis*

Nonlinear dynamic analysis method uses combination of seismic records with detailed modelling of the building and therefore is capable of generating results with relatively low uncertainty. In this analysis, when the model of the structure is subjected to seismic ground-motion, it produces estimates of component deformations for each degree of freedom in the model to obtain the modal responses.

B. *Criteria for Performing Dynamic Analysis*

Equivalent static analysis is performed for low- to medium-rise buildings, in which only the first mode in each direction is of significance without significant coupled lateral-torsional modes but for tall buildings (over, say, 75 m), where second and higher modes can be important, or buildings with torsional effects require more complex methods to be used such as Linear dynamic analysis.

As recommended in IS-1893:2002, Dynamic analysis shall be performed to obtain the design seismic force, and its distribution to different levels along the height of the building and to the various lateral load resisting elements, for the following buildings:

For regular buildings those greater than 40 m in height in Zones IV and V and those greater than 90 m in height in Zones II and III. Modeling as per 7.8.4.5 can be used and for irregular buildings all framed buildings higher than 12m in Zones IV and V and those greater than 40m in height in Zones II and III.

C. *Objective*

Objective of this research is to study the effect of plan irregularity on the seismic behavior of the building. In this, modeling of G+25 storeys RCC frame building is analysed using Staad-Pro V8i software. . To study various effects of plan irregularity in the structure various parameters such as lateral displacement, inter-storey drift, base shear etc, are studied. These parameters are studied so that the structure constructed can safely withstand the earthquake shocks and the associated unpredictable ground motion. This analysis also explains the effect of plan irregularity on the cost of the structure, as the increase in cost makes the structure uneconomical.

II. MODELING OF STRUCTURE AND LOADING CONDITIONS

A. *Modelling of Building Frames*

An RCC Structure is mainly an assembly of Beams, Columns, Slabs and foundation inter-connected to each other as a single unit. Generally the transfer of load in these structures is from slab to beam, from beam to column and finally column to foundation which in turn transfers the entire load to the soil. In this study, we have adopted three cases by assuming different shapes for the structure modelled using STAAD-Pro. We have adopted three cases by assuming different plan shapes such as Rectangular Shape shown in Figure 1 and 2, L-Shape shown in figure 3 and 4 and I-Shape shown in figure 5 and 6.

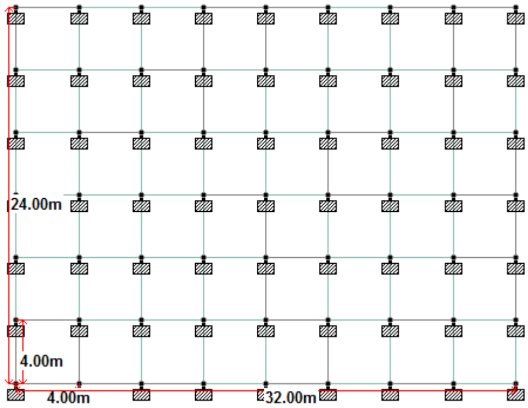

Figure 1: Plan of Rectangular Building

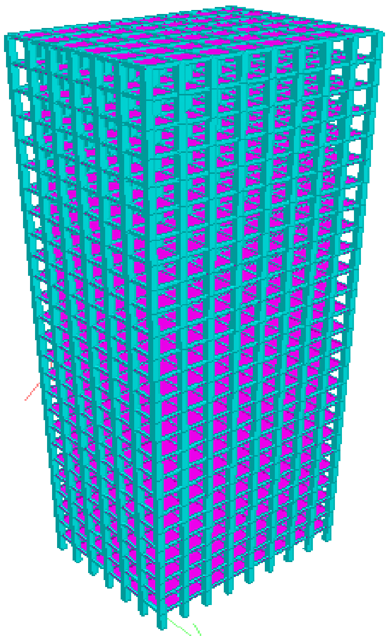

Figure 2: 3-D View of Rectangular Building

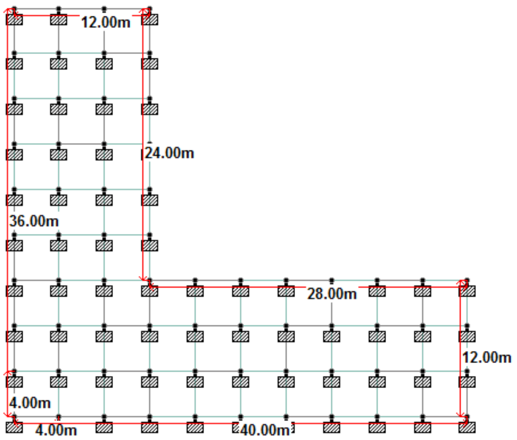

Figure 3: Plan of L-Shape building

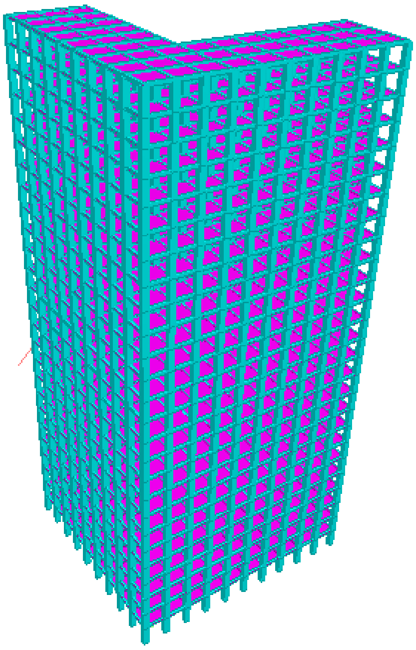

Figure 4: 3-D view of L-Shape Building

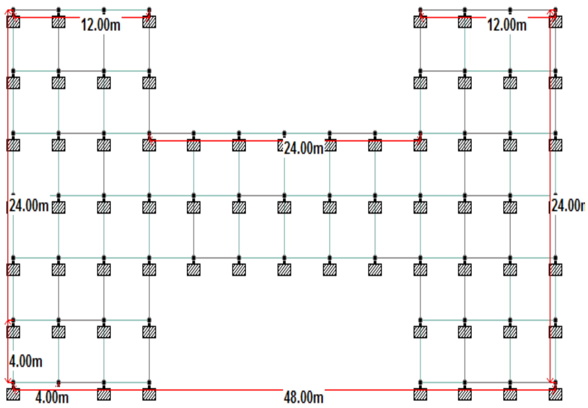

Figure 5: Plan of I-Shape Building

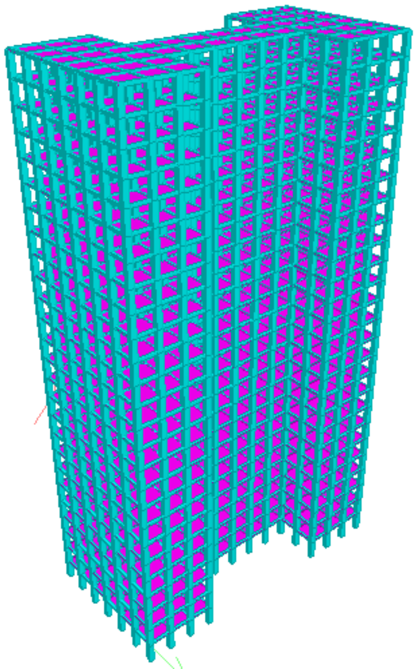

Figure 6: 3-D View of I-Shape building

B. Method of Analysis

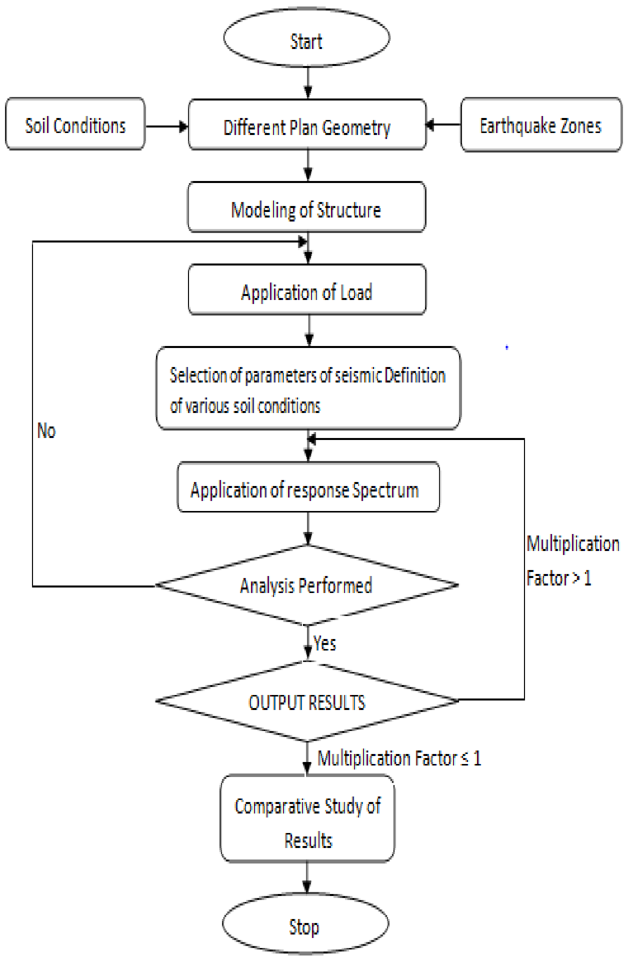

Figure 7: Flow Chart Showing the Analysis Process

C. Material Properties and Method of Analysis

S.No.	Building Description and Material Specification	
1.	Plan Area	$768m^2$
2.	X-Y Direction Grid Spacing	4m x 4m
3.	Storey Height	3.5m
4.	Number of storey	25
5.	Beam Dimension	300mm x 500mm
6.	Column Dimension	800mm x 800mm
7.	Slab Thickness	175mm
8.	Thickness of main wall	250mm
9.	Thickness of parapet wall	125mm
10.	Height of parapet wall	1000 mm
11.	Bottom Support Condition	Fixed
12.	Grade of Concrete, M-30	f_{ck} = 30N/mm^2
13.	Grade of Steel, Fe-415	f_y = 415N/mm^2
14.	Density of Concrete	γ_c = 25KN/m^3
15.	Density of Brick wall	γ_{brick} =20KN/m^3
16.	Cost of Steel bars	Rs 38 per Kg
17.	Cost of Concrete	Rs 4000 per m^3

Table 1: Building Description and material specification

D. Loading Condition

Sr. No.	Load Type	Intensity of load
1.	Dead load	Wall Load - 17.5KN/m
		Floor load - 6KN/ m^2
2.	Live load	Floor load - 4KN/ m^2
3.	Earthquake Load	Floor load - 8KN/ m^2

Table 2: Loadings are Adopted in the Analysis

Seismic Definition
Earthquake zone – V (Z=0.36), IV (Z=0.24)
Response reduction factor – 5
Importance Factor – 1
Damping - 5%
Soil Type: Hard, Medium, Soft soil

III. RESULTS AND INFERENCES

A. Results

1) Maximum Displacement

Maximum displacement in X and Z-Direction in zone V is shown in figure8 and figure9 and maximum displacement in X and Z- Direction in zone IV is shown in figure10 and figure11.

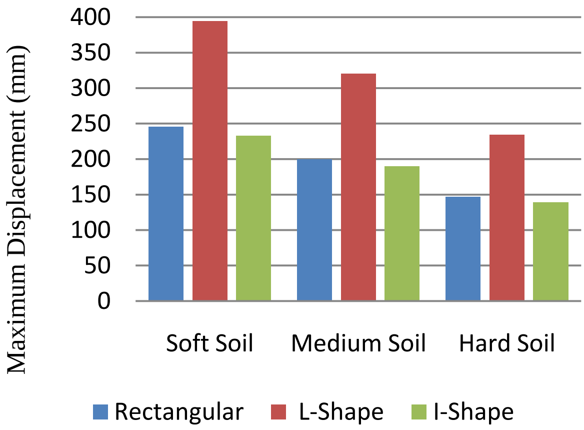

Figure 8: Maximum Displacements in X-Direction in Seismic Zone-V

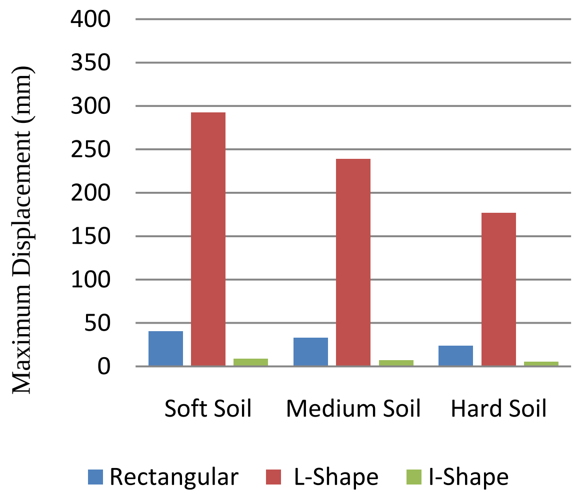

Figure 9: Maximum Displacements in Z-Direction in Seismic Zone-V

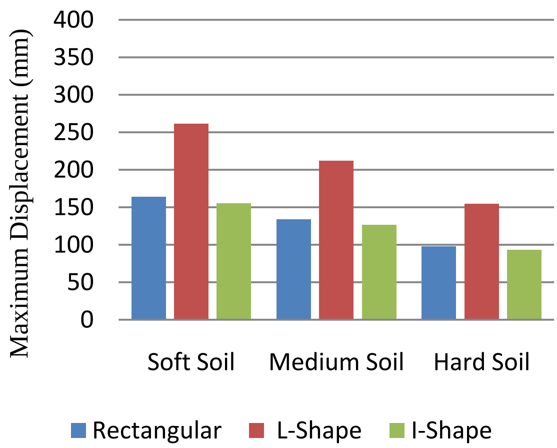

Figure 10: Maximum Displacements in X-Direction in Seismic Zone-IV

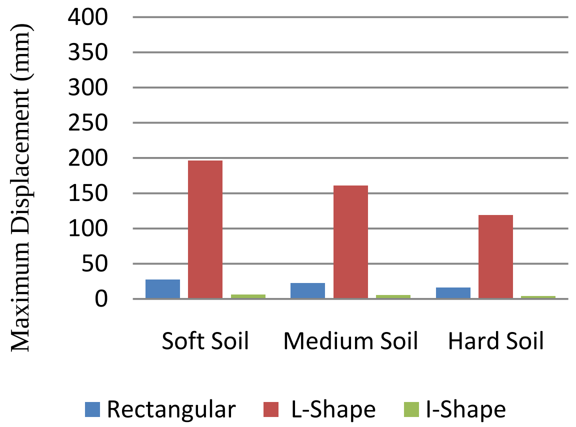

Figure 11: Maximum Displacements in Z-Direction in Seismic Zone-IV

2) Maximum Bending Moment

Maximum bending moment in X and Z-Direction in zone V is shown in figure12 and figure13 and maximum bending moment in X and Z-Direction in zone IV is shown in figure14 and figure15.

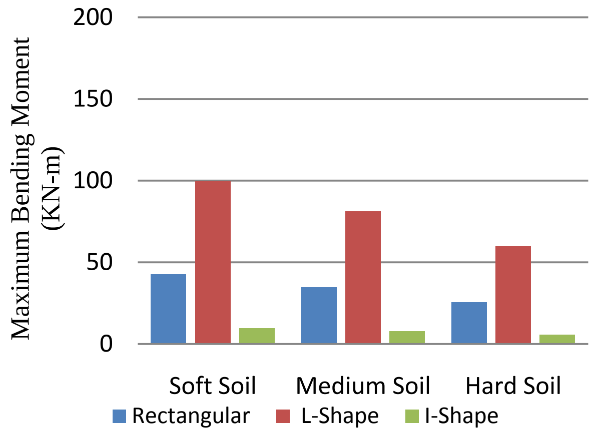

Figure 12: Maximum Bending Moment in X-Direction in Seismic Zone-V

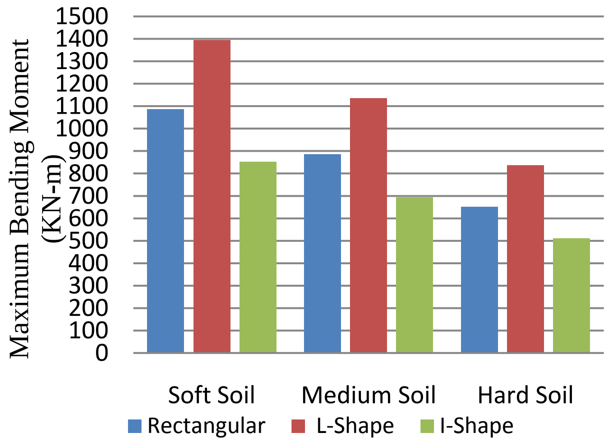

Figure 13: Maximum Bending Moment in Z-Direction in Seismic Zone-V

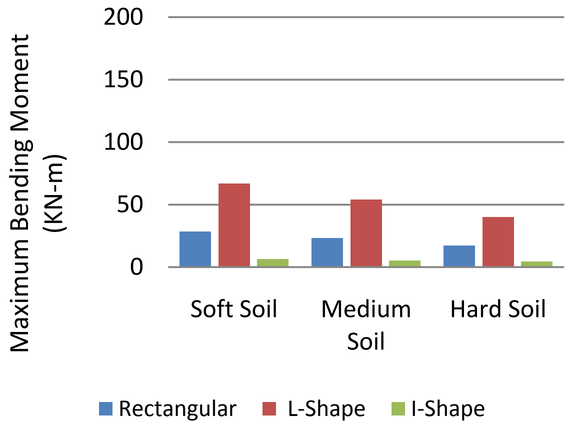

Figure 14: Maximum Bending Moment in X-Direction in Seismic Zone-IV

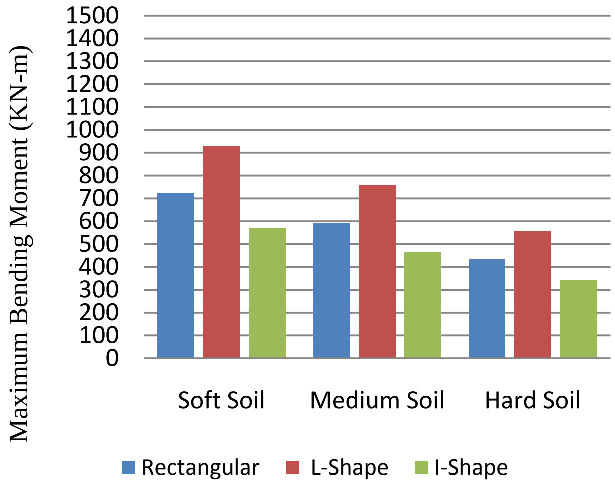

Figure 15: Maximum Bending Moment in Z-direction in seismic Zone-IV

3) Base Shear

Base shear in seismic zone V is shown in figure16 and base shear in seismic zone IV is shown in figure 17.

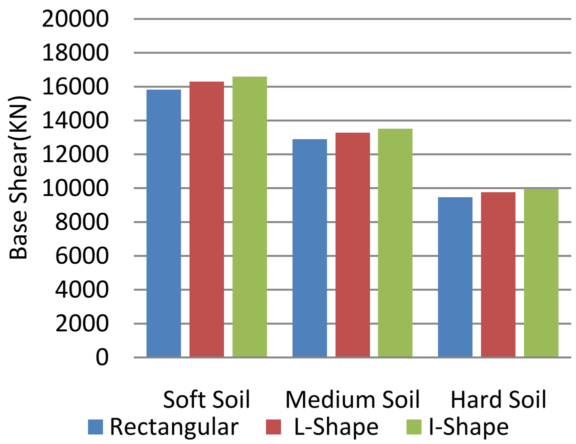

Figure 16: Base Shear in Seismic Zone-V

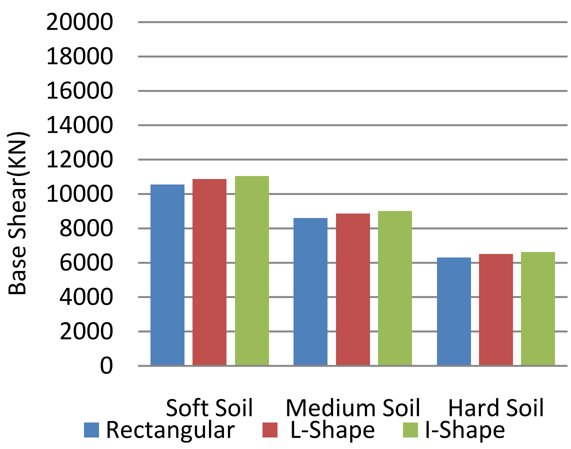

Figure 17: Base Shear in Seismic Zone-IV

*4) **Lateral Displacement***

Average Lateral Displacement in X and Z-Direction in zone V is shown in figure18 and figure19 and average Lateral Displacement in X and Z- Direction in zone IV is shown in figure20 and figure21.

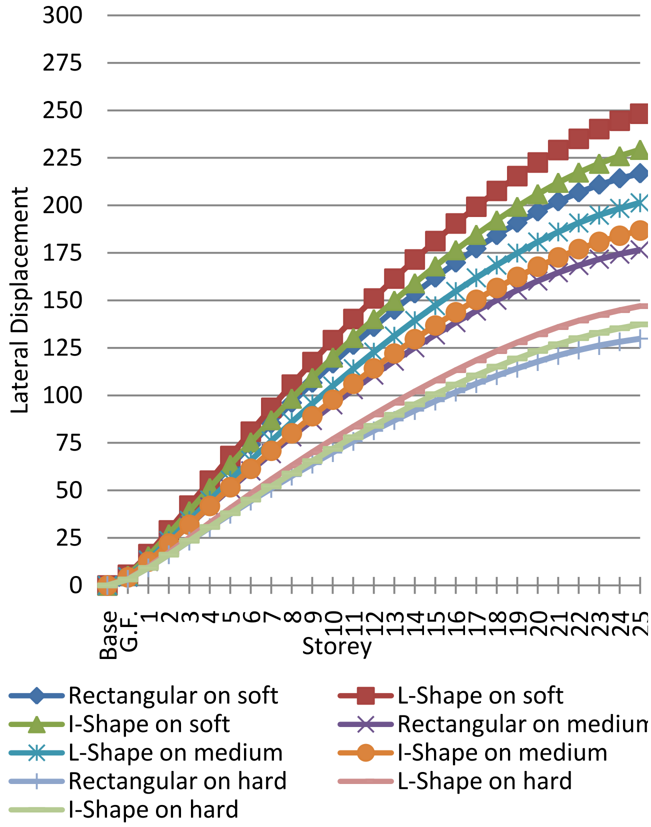

Figure 18: Average Lateral Displacement in X-direction in Seismic zone-V

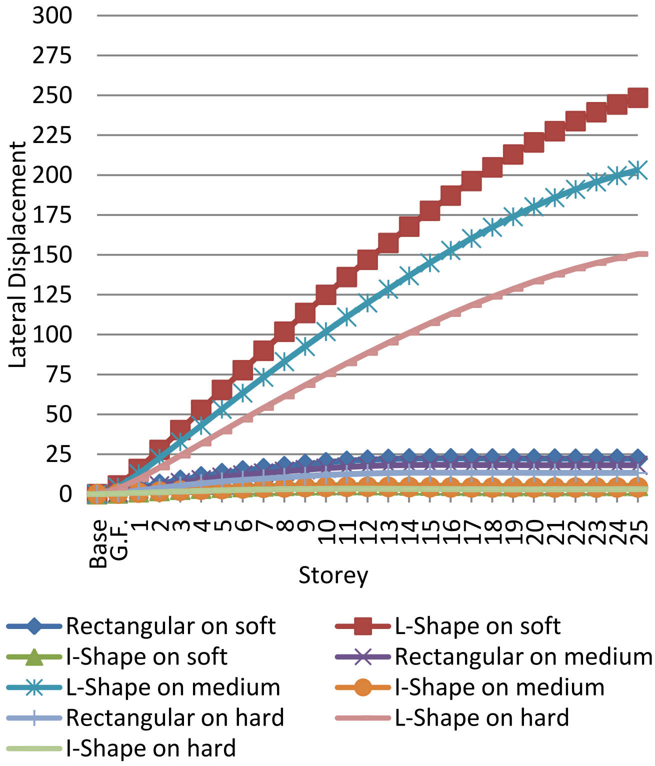

Figure 19: Average Lateral Displacement in Z-direction in Seismic zone-V

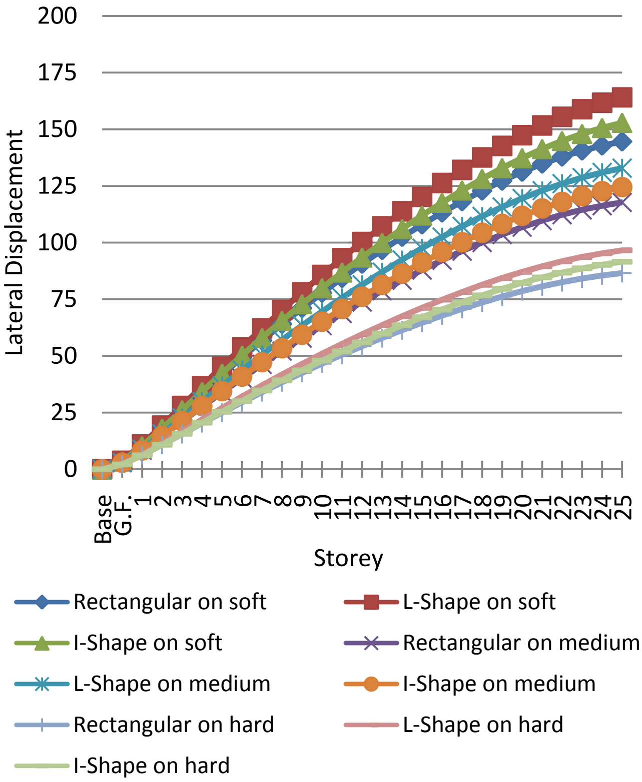

Figure 20: Average Lateral Displacement in X-Direction in Seismic zone-IV

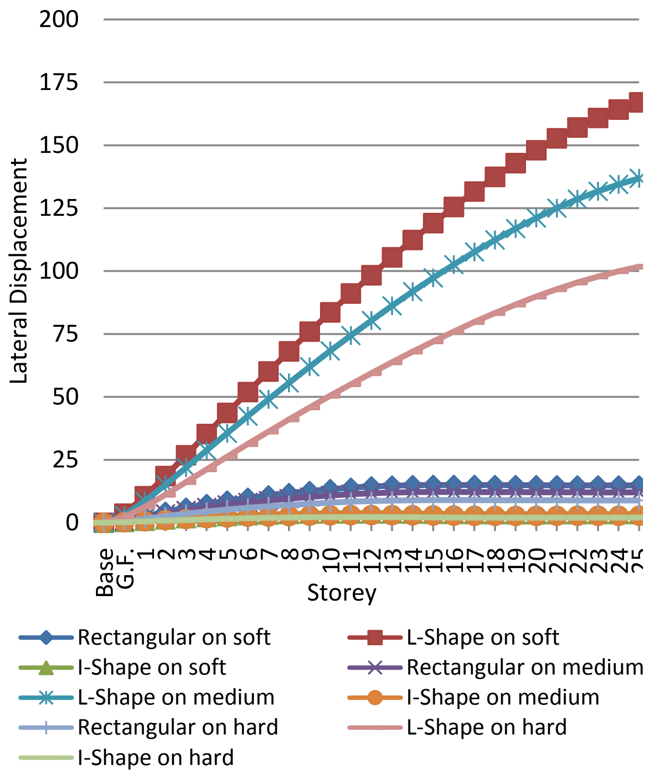

Figure 21: Average Lateral Displacement in Z-direction in seismic zone-IV

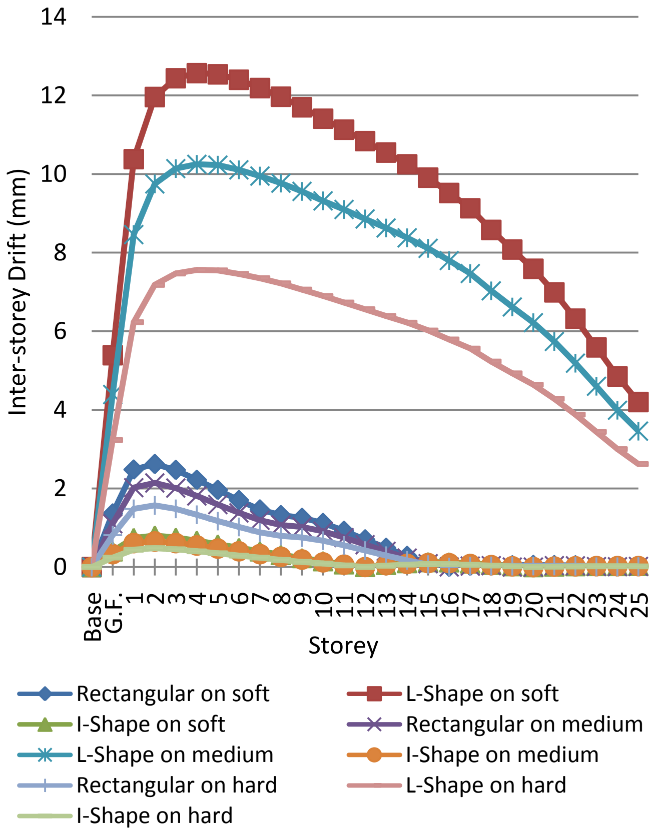

Figure 23: Inter-Storey Drift in Z-direction in Seismic Zone-V

5) Inter-Storey Drift

Inter-Storey Drift in X and Z- Direction in zone V is shown in figure22 and figure23 and inter-Storey Drift in X and Z- Direction in zone IV is shown in figure24 and figure25.

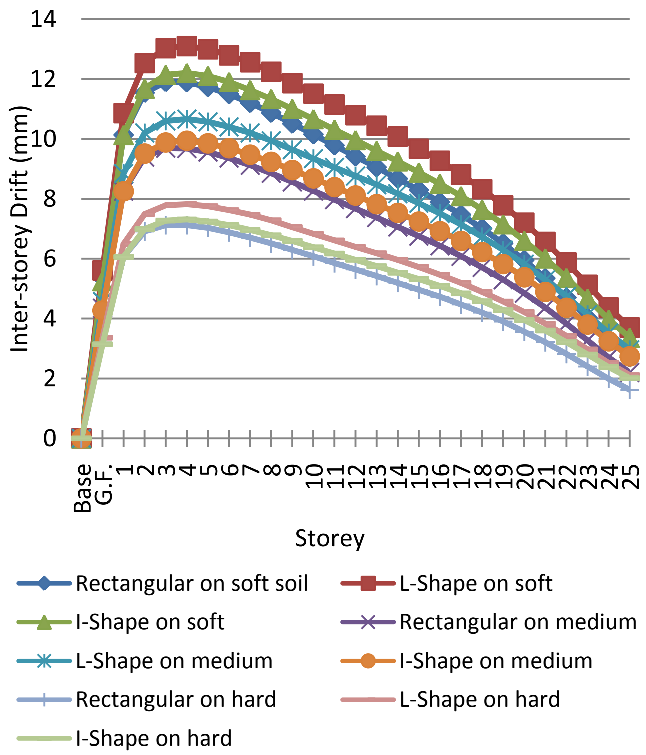

Figure 22: Inter-Storey Drift in X-Direction in Seismic Zone-V

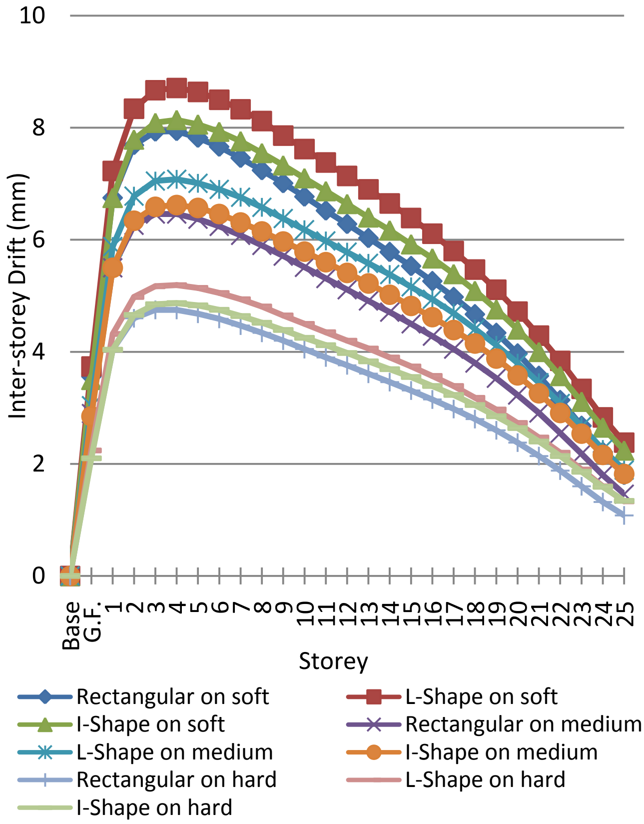

Figure 24: Inter-Storey Drift in X-direction in Seismic Zone-IV

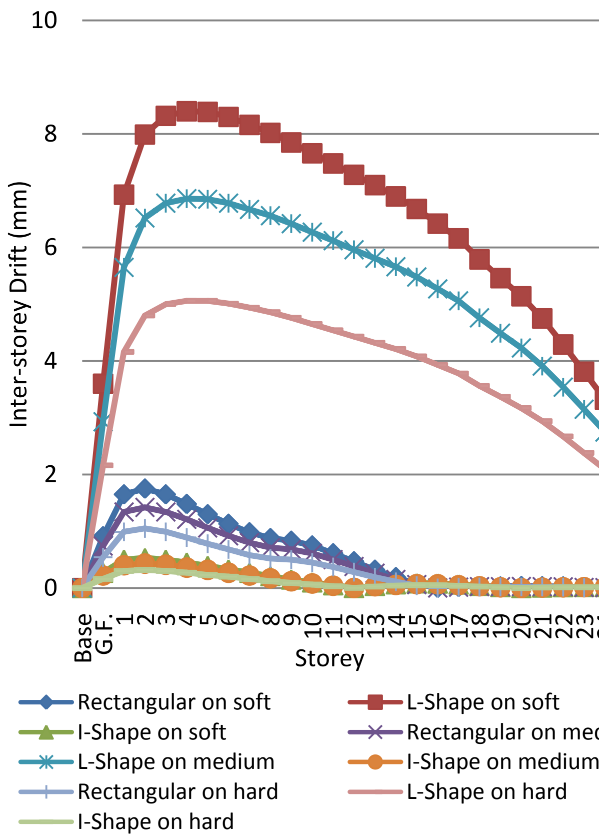

Figure 25: Inter-Storey Drift in Z-direction in seismic zone-IV

6) *Quantity of Concrete*

Total Quantity of concrete in shown in Figure 26

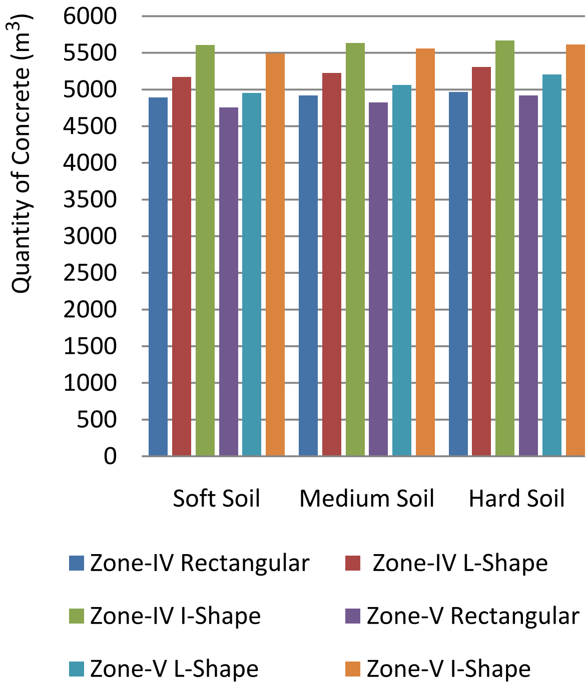

Figure 26: Quantity of Concrete

7) *Quantity of Steel*

Total Quantity of concrete in shown in Figure 27

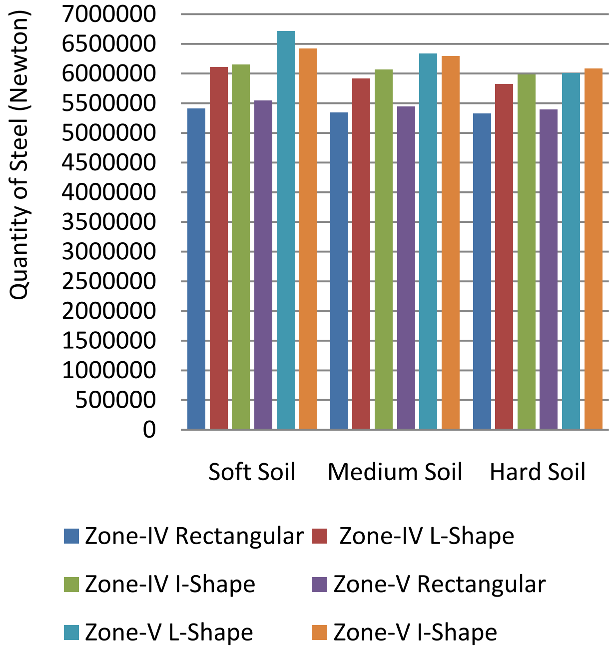

Figure 27: Quantity of Steel

8) *Overall Cost of the Structure*

Overall cost of the structure in shown in figure 28

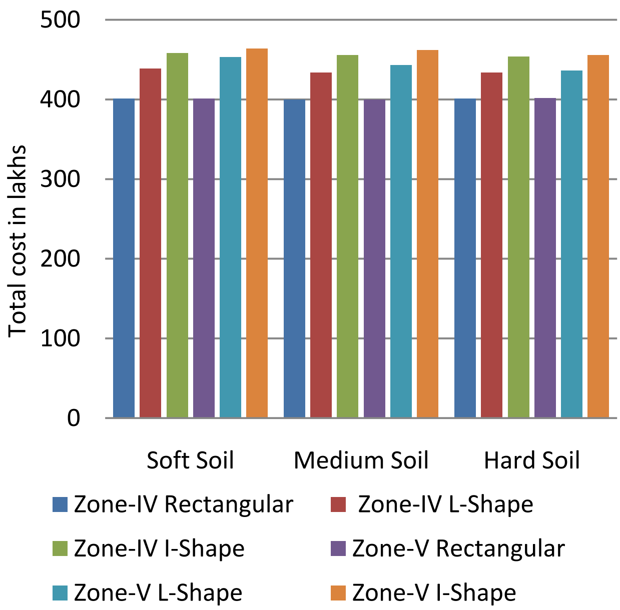

Figure 28: Overall Cost of the Structure

B. *Discussion and Inferences*

The analysis of multi-storeyed building reflects the following points:

1) The value of both maximum bending moment and maximum displacement is maximum in L-shape which shows torsion irregularity in the

plan geometry whereas, the Rectangular and I-Shape shows similar results. But when we talk about Z-direction the minimum value is obtained for I-Shape followed by rectangular section and L-Shape section has maximum value.

2) It is clear from the above results that the value of base shear acts at the base of the building is always minimum for the Rectangular section for both the zones on different type of soils.
3) While considering the effect of lateral displacement on different shapes of the building of the structure it has been observed that, asymmetrical shape such as L-shape shows higher value which means building is displaced more in both directions as compare to regular shape.
4) It is clearly visible that the inter-storey drift increases with storey height up to 4^{th} storey reaches the maximum value and then started decreasing. The inter-storey drift value is maximum for L-shape whereas the rectangular shape gives the best results in X-direction while in Z-direction rectangular and I-shape type of buildings gives almost similar results.
5) It is also clear that the response of the building towards the earthquake decreases as the base width increases. So increase in the base width of the structure lesser its chances of failure during earthquake.
6) Design results shows than the overall cost of irregular structure is much higher due to torsion and high shear force the amount of steel and concrete required is more as compared to regular structure which shows less requirement of concrete and steel.
7) From the above results it is obtained that the trend of graphs in both the zones is similar only the intensity of loading is decreases from zone-V to zone-IV due to decrease in zone factor value which reduces from 0.36 to 0.24.

IV. CONCLUSION

Considering above Inferences made on analysis of Regular and Irregular structures, it is conclude that regular geometry shows less force and perform well during the effect of earthquake. The analysis proves that irregularities are harmful for the structures and it is important to have regular shapes of frames as well as uniform load distribution around the building. Since the regular shape building shows more safety, serviceability and is economic then irregular building when constructed in the earthquake prone zones. Therefore, as far as possible irregularities in a building must be avoided.

REFERANCES

[1] De Stefano, M. and Pintucchi, B., 2008. A review of research on seismic behaviour of irregular building structures since 2002. *Bulletin of Earthquake Engineering*, *6*(2), pp.285-308.

[2] Herrera, R.G. and Soberon, C.G., 2008, October. Influence of plan irregularity of buildings. In *The 14th World Conference on Earthquake Engineering*.

[3] Ravikumar, C.M., KS, B.N., Sujith, B.V. and Reddy, V., 2012. Effect of irregular configurations on seismic vulnerability of RC buildings. *Architecture Research*, *2*(3), pp.20-26.

[4] Guleria, A., 2014. Structural Analysis of a Multi-Storeyed Building using ETABS for different Plan Configurations. *international journal of engineering research (IJERTI)" ISSN*, pp.2278-0181.

[5] Smith, B.S., Coull, A. and Stafford-Smith, B.S., 1991. *Tall building structures: analysis and design* (Vol. 5). New York: Wiley.

[6] Taranath, B.S., 2016. *Structural analysis and design of tall buildings: steel and composite construction*. CRC press.

[7] Indian Standard, I.S., 2002. 1893: 2002 (Part-III). *Earthquake Resistant Design of Structure.*

[8] Indian Standard, I.S., 2000. 456: 2000. *Plain and Reinforced Concrete Code of Practice*.

[9] Indian Standard, I.S., 1987. 875: 1987 (Part-I). *Dead Loads - Unit Weights of Building Materials and Stored Materials.*

[10] Indian Standard, I.S., 1987. 875: 1987 (Part-II). *Imposed Load.*