Soil–Structure Interaction Effect on Seismic Response of Different Shapes of Plan Asymmetric Buildings

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Abstract— Earthquake has always been a threat to human civilization from the day of its existence, devastating human lives, property, and man-made structures. The very recent earthquake that we faced in our neighbouring country Nepal has again shown nature's fury, causing such a massive destruction to the country and its people. It is such an unpredictable calamity that it is very necessary for survival to ensure the strength of the structures against seismic forces. Therefore, there is continuous research work going on around the globe, revolving around development of new and better techniques that can be incorporated in structures for better seismic performance. Obviously, buildings designed with special techniques to resist damages during seismic activity have much higher cost of construction than normal buildings, but for safety against failures under seismic forces it is a prerequisite. In this study, we did comparative study on the effect of earthquake on a tall structure to determine its negative impact to enhance our structures resistivity and comparing the variation in forces in irregular shape frame under the effect of seismic forces with different zones and soil types. For this study we are considering a G+24 structure providing loadings as per Indian provisions and seismic zone III & V with soft, medium and hard type soil as per I.S. 1893 part-1 for modelling and analysis we are using analysis tool/software STAAD.Pro V8i.

Keywords: Plan Irregularity, Seismic Analysis, Staad Pro

I. INTRODUCTION

Horizontal irregularities refer to asymmetrical plan shapes such as L-shape, T-shape, U-shape, E-shape etc. or discontinuities in the horizontal resisting elements (diaphragms) such as cut-outs, large openings, re-entrant corners and other abrupt changes resulting in torsion, diaphragm deformations and stress concentration. To perform well in an earthquake a building should possess four main attributes namely simple and regular configuration, ductility and stiffness and adequate lateral Strength. Buildings having simple regular geometry and uniformly distributed mass and stiffness in plan as well as elevation, suffer much less damage to earthquake than buildings with irregular configuration.

A. Plan irregularity

1) Torsion Irregularity

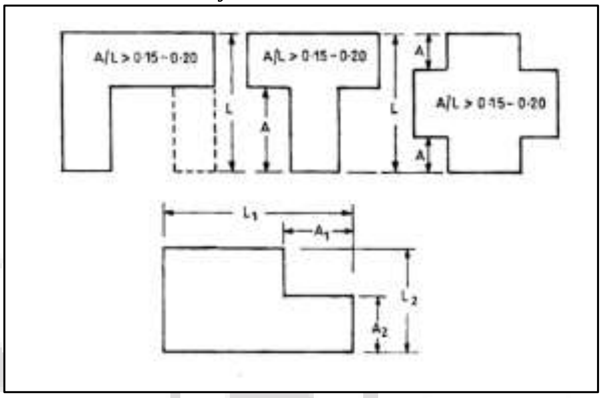
To be considered when floor diaphragms are rigid in their own plan in relation to the vertical structural elements that resist the lateral forces. Torsional irregularity to be considered to exist when the maximum storey drift, computed with design eccentricity, at one end of the structures transverse to an axis is more than 1.2 times the average of the storey drifts at the two ends of the structure

2) Re-entrant Corners

Plan configurations of a structure and its lateral force resisting system contain re-entrant corners, where both projections of the structure beyond the re-entrant corner are greater than 15 percent of its plan dimension in the given direction.

3) Diaphragm Discontinuity

Diaphragms with abrupt discontinuities or variations in stiffness, including those having cut-out or open areas greater than 50 percent of the gross enclosed diaphragm area, or changes in effective diaphragm stiffness of more than 50 percent from one storey to the next.



4) Out-of-Plane Offsets

Discontinuities in a lateral force resistance path, such as out-of-plane offsets of vertical elements.

5) Non-parallel Systems

The vertical elements resisting the lateral force are not parallel to or symmetric about the major orthogonal axes or the lateral force resisting elements.

To perform well in an earthquake a building should follow certain rules shown below: -

- The configuration of the building (Plan and elevation) should be as simple as possible.
- The formation should generally be based on hard and uniform ground.
- The members resisting horizontal forces should be arranged so that torsional deformation is not produced.
- The structure of the building should be dynamically simple and definite.
- The frame of the building structure should have adequate ductility in addition to required strength.
- Deformations produced in a building should be held to values, which will not provide obstacles to safety use of building.

II. OBJECTIVE OF STUDY

Objective of this research is to study the effect of plan irregularity on the seismic behaviour of the building. In this, modelling of G+24 stories RCC frame building is analyzed 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.
- To evaluate the effect of plan irregularity on comparative cost of structure.
- To study the effect of Mode shapes that is generated from dynamic analysis on design of structure.
- To obtain and compare results based on parameters i.e., displacement, drift, base shear, and different stresses beam & column.

III. METHODOLOGIES

The growth in computer processing power has made possible a continuous drive towards increasingly accurate but at the same time more complex analysis method. Thus, the state of the art has progressively moved from elastic static analysis to dynamic elastic, nonlinear static and finally nonlinear dynamic analysis.

In the present scenario, because of the wide range of plans possible, the accumulated understanding is still limited, thus there is need of an attempt to investigate the behaviour of irregular plans in RCC building frame. This thesis includes comparative study of structural behaviour different plan irregularities in different zones considering different soil condition in done using STAAD-Pro V8i software. A comparison in analysis results is done on certain important parameters such as displacement, moment, storey drift, base shear, peak storey shear etc. Detailed configuration and material specification of the building are shown in Table-

1.	Plan Area	768m2
2.	X-Y Direction Grid Spacing	4m x 4m
3.	Storey Height	3.5m
4.	Number of storeys	20
5.	Beam Dimension	350mm x 450mm
6.	Column Dimension	600mm x 600mm
7.	Slab Thickness	150mm
8.	Thickness of main wall	200mm
9.	Thickness of parapet wall	125mm
10.	Height of parapet wall	1000 mm
11.	Bottom Support Condition	Fixed

Table 1:

A. *Response Spectrum Method*

The representation of the most response of idealized single degree freedom system having certain period and damping, throughout earthquake ground motions. The maximum response plotted in against two of un-damped natural period and for various damping values and may be expressed in terms of maximum absolute acceleration, most relative velocity or maximum relative displacement. For this motive response spectrum case of analysis have been executed in line with IS 1893.

Response Spectrum Analysis (RSA) is linear Dynamic Method. RSA is followed by the Free Vibration (un-damped) analysis of structure by using methods of structural dynamics. Free Vibration analysis gives fundamental time periods and the mode shape coefficients of the structure. The time period of the structure gives the spectral acceleration coefficient, Sa/g from Response Spectra given in IS 1893 (Part 1): 2002.

The approximate time period is obtained by,

$$T_a = \frac{0.09\,h}{\sqrt{d}}$$

Where h = Height of building in m,
d= Base dimension of the building at the plinth level in m, along the considered direction of the lateral force.
Design Horizontal Seismic Coefficient, *Ah*

$$A_h = \frac{Z}{2} \cdot \frac{I}{R} \cdot (S_a/g)$$

Design Base shear is given by

$$\bar{V}B = A_h . W$$

Distribution of Base Shear along height of building is given by,

$$Q_i = \bar{V}B \frac{w_i h_i^2}{\sum_{j=1}^{n} w_j h_j^2}$$

Thereafter the modal mass, Mk for the mode k is calculated as,

$$M_k = \frac{\left[\sum_{i=1}^{n} W_i \Phi_{ik}\right]^2}{g \sum_{i=1}^{n} W_i (\Phi_{ik})^2}$$

Then, the modal participation factor, Pk is calculated as,

$$P_k = \frac{\left[\sum_{i=1}^{n} W_i \Phi_{ik}\right]}{\sum_{i=1}^{n} W_i (\Phi_{ik})^2}$$

The Design lateral force at each floor in each mode is given by,

$$Q_{ik} = A_k \Phi_{ik} P_k W_i$$

The peak shear force acting on the storey i in the particular mode k is given by

$$V_{ik} = \sum_{j=i+1}^{n} Q_{ik}$$

In this manner the lateral forces for all the storeys are determined in all the modes of the building.

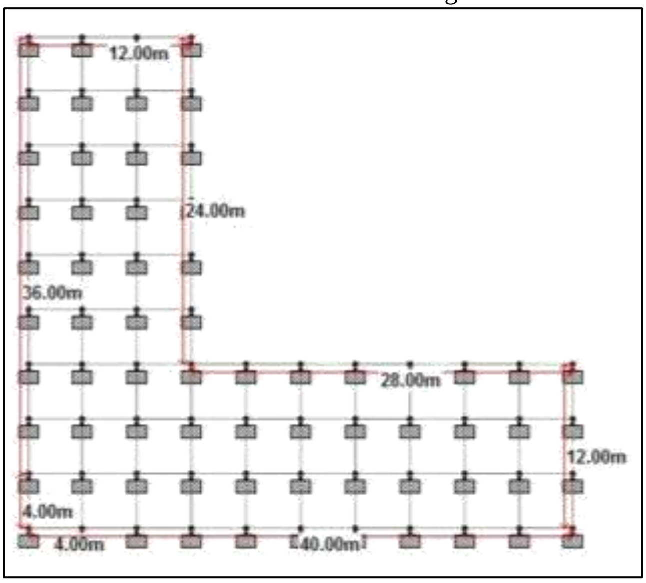


Fig. 1: L-Shaped Building

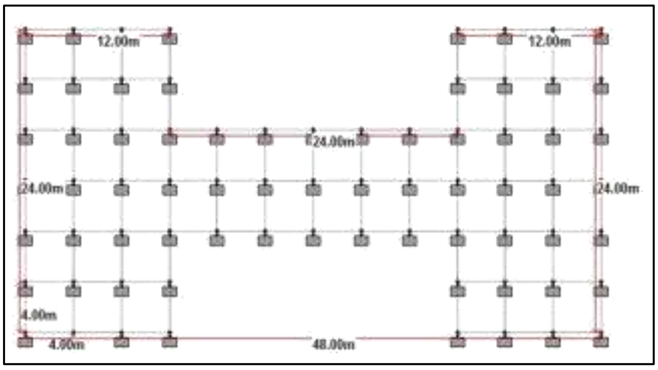
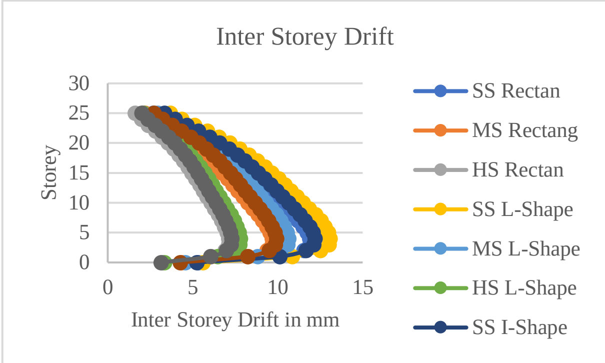
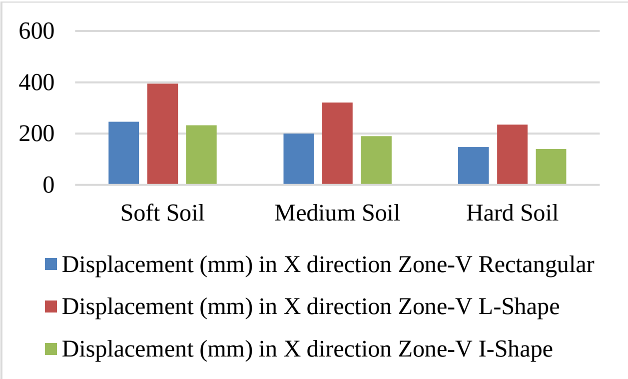


Fig. 2: I- Shaped Building

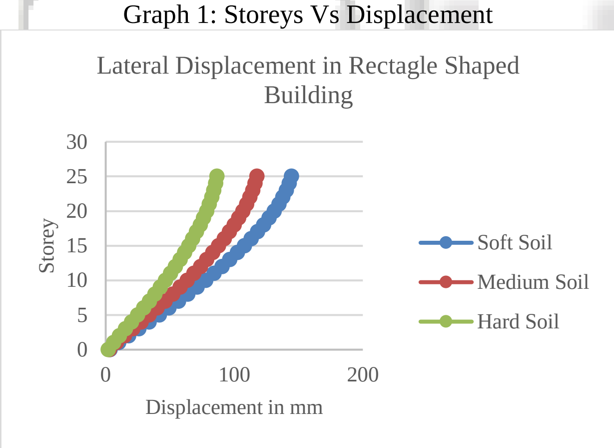


Graph 4: Inter storey Drift

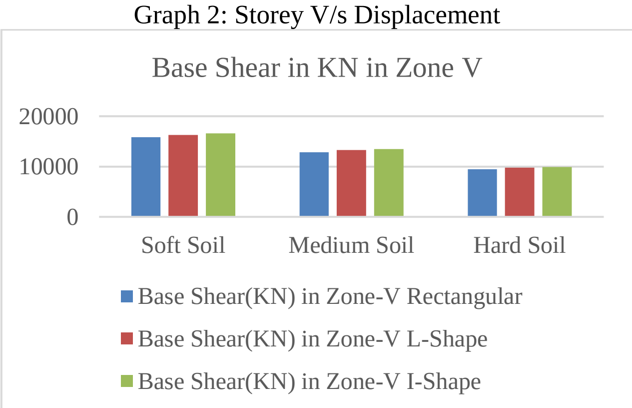
IV. Results



Graph 1: Storeys Vs Displacement



Graph 2: Storey V/s Displacement



Graph 3: Base Shear V/s Different Soil Condition

V. Conclusion

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.

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 compared to regular shape.

It is clearly visible that the inter-storey drift increases with storey height up to 4th 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.

The analysis proves that irregularities are harmful for the structures, and it is important to have simpler and 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. But, if irregularities must be introduced for any reason, they must be analyzed and designed properly following the conditions of IS 1893-part-1: 2002 and IS456: 2000, and joints should be made ductile as per IS 13920:1993.

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