Comparative Analysis of Regular and Irregular Multi Storey Building for Different Soil Types in Seismic Zone

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Abstract - *As new emerging urban Nation we have ever-growing requirement for building but space for so is limited that's why we are making multistoried buildings for the purpose. And RCC building structures are most suitable and common building type for urban India. But they also subjected to several types of Forces during their service life such as dead load live load as static loads and dynamic loading due to earthquake. This paper presents a work on multi storey buildings for earthquake analysis. Its focus is on regular multistoried buildings for different soil types in seismic zone.*

***Key Words*:** RCC Structure, Multi Storey, Dynamic Analysis, Seismic loading.

1. INTRODUCTION

Earthquakes are themselves not fatal but the building in which people are living or working and building is weak structurally. This can prove to be fatal. Earthquakes are unpredictable thus making the aftermath dangerous. Earthquakes are juggernauts as they cannot be stopped. IS codes have already clarified in ANNEXE E of IS code 1893(part 1):2016, all the cities with population of over three lakh and the zones in which the cities lie.

Based on the occurrence of earthquakes in the past around India, the country is divided into four Seismic Zones, namely zones II, III, IV and V, where II is the least severe and V is the most severe. Based on this zoning, about 60% of India's land area is under moderate seismic threat or more, i.e., under seismic zone III or above in fact, the Gujarat, Latur earthquake which were fatal.

Even now amongst our four mega-cities, Delhi is in seismic zone IV, which Mumbai, Calcutta and Chennai are in seismic zone III. Despite this level of seismic hazard, little is being done, particularly in these cities, to make the development akin to earthquake shaking. The quality of both design engineering and construction is way behind the expected seismic standards. The experience of severe earthquake has shown that when structures were built in accordance with seismic codes, the consequences of earthquakes were least severe.

We know that different type of vertical irregularities buildings are used in modern infrastructure. During an earthquake, the building tends to collapse. This is mainly due to discontinuity in geometry, mass and stiffness. This discontinuity is termed as Irregular structures. So vertical irregularities are one of the major reasons of failures of structures during earthquakes. In planning stage of vertical irregularity due to some architectural and functional reasons. During an earthquake, failure of structure starts at points of weakness. This weakness arises due to discontinuity in mass, stiffness and geometry of structure. The structures having this discontinuity are termed as Irregular structures. But nowadays need and demand of the latest generation and growing population has made the architects or engineers inevitable towards planning of irregular configurations. Hence earthquake engineering has developed the key issues in understanding the role of building configurations. The major factor is the asymmetry of the building the asymmetry contributes significantly for translational torsional coupling in the seismic responses which can lead to lateral deformation of the building. Buildings with asymmetric distribution of stiffness and strength in plan undergo coupled lateral and torsional motions during earthquake. In many of cases the center of resistances dose not coincide with the center of mass.

Buildings are the complex system and multiple items have to be considered at the moment of designing them. Hence at the planning stage itself, architects and structural engineers must work together to ensure that the unfavorable features are avoided and good building configuration is chosen.

During Earthquake, failure of structure starts at points of weakness. There are basically two types of irregularities in building,

1. Plan irregularity

2. Vertical irregularity

Irregular Structures and Their Collapse:

Real structures are almost always irregular, as perfect regularity is an idealization that very rarely occurs. Structural irregularities may vary dramatically in their nature and in principle, are very difficult to define regarding buildings, for practical purposes, major seismic codes distinguish between irregularity in plan and in elevation, but it must be realized that quite often structural.

Irregularity is the result of a combination of both. In order to identify the torsionally irregular structures, IS: 1893(Part-1)-2002 has given the clear definitions of irregular buildings in Clause 7.1.

An expression for the design eccentricity, which is very much needed for the analysis of torsionally unbalanced structures, is given in Clause 7.9 of the same. According to Clause 7.8.1, the method of analysis to be used for a structure depends on its irregularity, in addition to the total height of the structure and the seismic zone where it is situated.

To understand the importance of codal provisions, which are especially meant for irregular buildings, an attempt is made in the present study considering various parameters, which are contributing to torsional irregularity.

Objective:

The following objectives were identified based on these parameters:

1. The objective of this project is to do comparative study of the regular and plane irregular building under earthquake forces.
2. To study the effect of irregular distribution of mass in plan on the seismic response of structures.
3. To study the influence of asymmetric distribution of stiffness on the structural responses.
4. To study the performance level of the structure.
5. To study the effect of irregular distribution of mass, asymmetric distribution of stiffness and irregular plan configurations and compare it with the seismic response of a regular structure

2. LITERATURE REVIEW

Paper [1] aims to the seismic response of various vertical irregularity structures. The project is done by Response spectrum analysis (RSA) of vertically irregular RC building. This study includes the modelling of regular and H-shape plan irregular building having area of 25X25m and height of 3.5 m from each G+10 storey. The performance of this framed building during study earthquake motions depends on the distribution of stiffness, strength, and mass in both the horizontal and vertical planes of the building. The main aim of this work is comparative study of the stiffness of the structure by considering the three models in Regular Structure and three models in Plan irregular structure with different Vertical irregular structure. All models are analysed with dynamic earthquake loading for the Zones V. Result found from the response spectrum analysis that in irregular shaped building displacements are more than that of regular shaped building. All building frames are modelled & analysed in software Staad.Pro V8i. Various seismic responses like base shear, frequency, node displacement, etc. are obtained. The overall performance of regular building is found better than irregular building. The seismic performance of multistory regular building is determined by Response Spectrum analysis in STAAD Pro. Software.

The Paper [2] shows foundation of a building is the substructure through which the loads of the whole structure are transmitted to the soil. There are various types of soil present in India. The types of soil play a major role while designing a structure. Here the analysis and design of building is done by varying the type of soil. The difference in analysis of structure is studied. After that the seismic analysis for various zones are carried out for the same soil conditions and also by changing the model of building, the same are done. And the difference is studied. From model analysis the time period obtained from all zones are same and its same for all soil conditions as in table 2. By static earthquake analysis the base shear obtained is maximum for fixed support conditions and for hard soil conditions then the base shear is decreasing to medium soil and then to soft soil. When comparing the zones in static earthquake analysis zone I have lowest base shear then its increases by zone II, zone III and zone IV as shown in table 3. But in case of story displacement Zone I have lowest displacement. Then Zone II have comparatively 7-8 % increase than zone I. when going to zone III and zone IV an average of 7-8% increase in story displacement .By Time History analysis (Elcentro) the base shear and story displacement obtained during analysis is comparatively lesser than Static earthquake analysis. Due to this the steel required is comparatively lesser than static earthquake analysis.

Paper [3] presents a review of the comparison of static and dynamic analysis multistoried building. Design parameters such as Displacement, bending moment, Base shear, Storey drift, Torsion, Axial Force were the focus of the study. It was found that, The difference of values of displacement between static and dynamic analysis is insignificant for lower stories but the difference is increased in higher stories and static analysis gives higher values than dynamic analysis. Static analysis is not sufficient for high rise buildings and it's necessary to provide dynamic analysis. Building with re-entrant corners experienced more lateral drift and reduction in base shear capacity compared to regular building When compared to irregular configuration the story drift value is more in the regular configuration. Story drift is increased as height of building increased. Base shear value is more in the zone 5 and that in the soft soil in irregular configuration. Irregular shapes are severely affected during earthquakes especially in high seismic zones. The irregular shape building undergoes more deformation and hence regular shape building must be preferred. The results of equivalent static analysis are approximately uneconomical because values of displacement are higher than dynamic analysis.

Paper [4] deals with the comparison between equivalent static technique &response spectrum technique. The earthquake effect lead to the damage the property and many people loss of life. So we have to know the structural performance under seismic load before construction. Method of analysis: Adopt the equivalent static and response spectrum techniques to analyze the model for the present study and observe the lateral displacement of the structure in a regular and irregular structure in various zones. Finding: The major parameters considered in this study to observe the seismic conduct of various zones i.e. ZONE-II, Zone-III, ZONE-IV&ZONE-V and the base shear, lateral displacements in various levels. According to IS-1893- 2002 seismic loads are calculated. The lateral forces are calculated by using the STAAD Pro and the results are compared between two Zones in both response spectrum and seismic coefficient technique. Applications: To analyze the building as per code IS 1893-2002 part I criteria for earthquake resistant structure. Dynamic analysis of the building using response spectrum method. Building with different lateral stiffness systems. To get economical and efficient lateral stiffness system.

The main aim of the paper [5] is comparative study of the stiffness of the structure by considering the three models that is Regular Structure, Plan irregular structure and Vertical irregular structure. All these three models are analyzed with static and dynamic earthquake loading for the Zones II, III, IV & V. The results are tabulated and graphs are plotted for displacement, drift, base shear and time period. Based on the results and discussion the structural behavior and stiffness is concluded for regular and irregular structures, among these structures regular structure shown maximum displacement and drift for all the zones in both static and dynamic analysis.

The paper [6] shows national building code of India (NBC) 2015 was released by bureau of Indian standards during December 2016/january2017. The various sections of this NBC have undergone changes as per latest technologies and user requirements. It is necessary to identify the performance of the structures to withstand against disaster for both new and existing one. The paper discusses the performance evaluation of RC (Reinforced Concrete) Buildings with plan irregularity.

Structural irregularities are important factors which decrease the seismic performance of the structures. This study as a whole makes an effort to evaluate the effect of plan irregularity on RC buildings using IS 1893:2002 and IS 1893:2016 in terms of dynamic characteristics.

Paper [7] is concerned with the study of seismic analysis and design of high-rise building. The structural analysis of high rise multistory storey reinforced concrete symmetrical and asymmetrical frame building is done with the help of SAP software. In the present study, The Response spectrum analysis (RSA) of regular RC building frames is compare with Response spectrum analysis of regular building and carry out the ductility-based design. As per IS 1893:2002 and IS 1893:2016.

Paper [8] shows an analytical description of the damages caused by different plan irregularities, during seismic events of different magnitudes. Although these effects of architectonic and/or structural configuration have been identified like not adapted in previous damages, have come maintaining their presence in constructions anywhere in the world. The effects of commented irregularities were studied with qualitative analyses of important and recent investigations, as much in Mexico as abroad. The work describes to the geometric forms that are repeated more in the urban areas in México (squared, rectangular, section U, section L and section T), as well as its variations from plants observed with extracted aerial photography of Google Earth. These architectonic plants were modeled in SAP2000 considering one, two and four levels to determine the effect of the geometric form in the seismic behavior of structures with elastic analyses. Also, effects of the extension in rectangular plants and the inclusion of projections in sections with architectonic plants U, L and T were studied. In all the studied systems, effects of different irregularities are analyzed based on the variation of displacements, with respect to regular systems.

In paper [9], the seismic behavior of three intermediate moment-resisting concrete space frames with unsymmetrical plan in five, seven and ten stories are evaluated by using pushover analysis. In each of these frames, both projections of the structure beyond a reentrant corner are greater than 33 percent of the plan dimension of the structure in the given direction. The performance of these buildings has been investigated using the pushover analysis. Results have been compared with those obtained from non-linear dynamic analysis.

In paper [10], the torsional response of plan asymmetric RC building structures for predicting the seismic responses were investigated. The linear dynamic response of plan asymmetric with different eccentricities were initially compared, in order to evaluate the effects of the torsional response.

The behaviour [11] of building during earthquake depends critically on its overall shape, size and geometry. Building with simple geometry in plan have performed well during strong past earthquake but building with u, v, H & + shaped in plan have sustained significant damage. So the proposed project attempts to evaluate the effect of plan configurations on the response of structure by RSM (response spectrum method).

Paper [12] represent the seismic load assessment for multistory building as per IS: 1893-2002 and IS: 1893-2016 recommendations. Considering and analyzing the four storey RC framed multistorey building. It is concluded that such study is done on individual RC framed building structure which is designed using earlier code. To predict the seismic vulnerability of building structure and to check due to revisions and changes in the IS codal provisions the structure is safe or unsafe. As the analysis of the building structure is carried out from both IS codes to inspect the changes done in latest IS code for calculating lateral force of the multistorey building. The strong and ductile structure is designed as per seismic design approach of both IS codes.

Paper [13] performance of R.C framed structure with and without considering plan irregularities was investigated using the non-linear static analysis. Following were the major conclusions drawn from the study. Regular building model collapse after all building model. It means regular building resist earth quake forces longer time and withstand for longer time. Irregular building model shape-H having less resistance to earth quake forces. And it will collapse before regular building and O shape building.

Irregular building model shape-L having very less resistance to earth quake forces compared with other all building models. And it will collapse before all other models. Irregular building model shape-O having less resistance to earth quake forces only compare to regular building. And it will collapse after H and L shape building and before regular building model. Therefore, if there is an increase in the irregularity of a building having the same volume then buildings performance will decrease.

Paper [14] shows the Static pushover analysis is an attempt by the structural engineers to evaluate the real strength of the structure. This method of analysis promises to be a useful and effective tool for performance based design of structure. Four residential buildings with different plan aspect ratio have been analyzed by this method and results have been compared in terms of base shear, displacement and, plastic hinge pattern. From this study, following conclusions can be drawn. Pushover analysis has been found relatively simple and evaluates the performance of the building close to more realistic behaviour.

In paper [15] drift point of view, in zone II, zone III and zone IV all the frames are within permissible limits hence there is no requirement of shear wall in these zones. In zone V only building 4, i.e., C shape building exceeds permissible limits and requires shear wall throughout the height.

Paper [16] shows the absolute displacements obtained geometry irregular building at respective nodes were found to be greater than that in case of regular building for upper stories but gradually as we move to lower stories displacements in both structures tended to converge. This is because in geometry irregular structure upper stories have lower stiffness than the lower stories. Lower stiffness results in higher displacements of upper stories.

As Paper [17] shows the irregularity of the structure increases, storey displacement increases and maximum displacement will be at places where storey stiffness is less. It has been observed that L shape model has displaced more compared to C, T, Z and regular buildings. Column shear and moment at the re-entrant corner of the structure is almost 40 to 50 percentage more than the shear force and moment at other areas of the irregular building. Hence re-entrant corners have to be strong enough to withstand the moment and shear.

Paper [18] shows for all vertical irregular frames with setback considered, displacement value for IR1, IR2, IR3,IR4, IR5, IR6, IR7, IR8 and IR9 at the level of setback increases, and the result shows that the top node displacement in case of irregular frames in more that of the RB, except for IR5, IR6, IR7, IR8 and IR9. In case of setback irregular frames, a sudden extreme change in story drift due to setback has been observed, it indicates that in setback floor the story drift value extremely goes higher, while story drift for RB is normal.

3. METHODOLOGY

1. IS Codal provisions such as IS 456:2000, IS 1893 (Part I):2016, IS 875 (Part 1):1987 and IS 875 (Part II):1987 for the need of project has been studied to carry out work.
2. Modeling of G+11 building will be analyzed for the parameters that are mentioned in the objectives of this project.
3. Three different Model of G+11 Building will be designed with the standard data and keeping loads and design parameters constant for all the three structures.
4. At the end the results will be compared and the building which will give best and efficient results in terms of mentioned parameters will be considered as the suitable one for the given condition.

Structural Plan of G+11 Building Model (Regular):

The model has grid size of 24 m × 24m. The Centre to Centre spacing between columns is taken as 4m. Six shear walls on the longer side of the building and four shear walls on the shorter dimension of the building. The model dimension and size with the properties is taken same for seismic loadings.

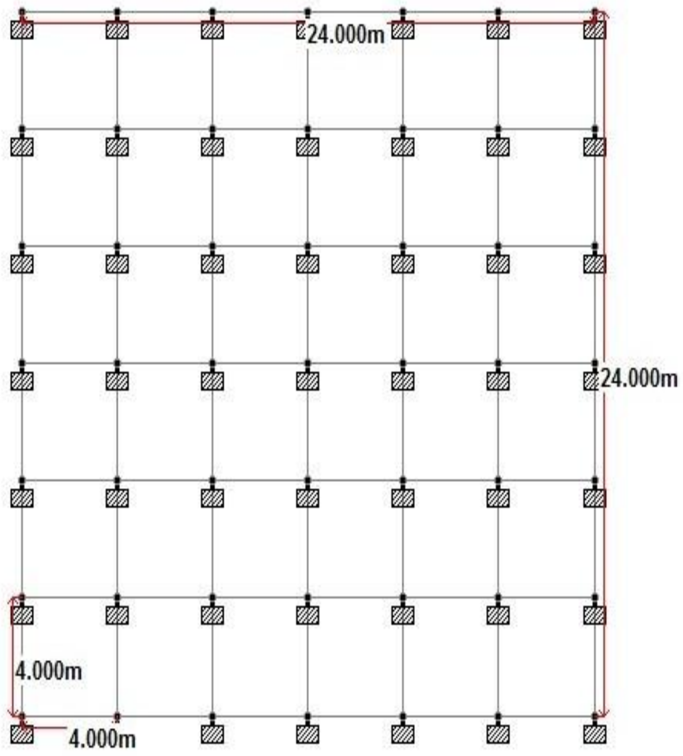

Fig. 3.1 Top View of Plan with Plan Dimension

- **Detail of Building**

1. Model: G +11 Building Design

1. Number of bays in X direction and its width= 6 bays of 4 m each
2. Number of bays in Z direction and its width = 6 bays of 4 m each
3. Story height = 3 m each
4. Spacing between frames = 4 m
5. Column size = 600 mm x 400 mm
6. Beam size = 400 mm x 300 mm
7. Thickness of Slab =100 mm
8. Wall load = 5 KN/m
9. Density of concrete = 25 KN/m3
10. Live load on roof = 1.5 KN/m2
11. Live load on floors = 2 KN/m2
12. Floor finish = 1.25 KN/m2
13. Brick wall on peripheral beams = 230 mm
14. Density of AAC wall =6.78 KN/m3
15. Grade of Concrete = M30
16. Grade of Steel = Fe500
17. Clear Cover of Column = 40mm
18. Clear Cover of Beam = 25mm

2. Model: G +11 Building Design with same area(L2 & T2)

1. Number of bays in X direction and its width= 7 bays of 4 m each
2. Number of bays in Z direction and its width = 8 bays of 4 m each

For the this project we call building with same perimeter as L1 & T1 (As per their shape) For Building with same area we call them as L2 & T2(As per their shape)

4. RESULT AND ANALYSIS

Nodal Displacement in the Storey for X-Direction of the Regular and Irregular Building:

Elements or members of building should be designed and constructed to resist the effects of design lateral force. STADDPro gives the lateral force distribution at various levels and at each storey level. Lateral force of earthquake is predominant force which needs to be resisted for any structure to be earthquake resistant. The equivalent static method and response spectrum method have been used to find the nodal displacement in the storey for X direction of the regular and irregular building in STADDPro.

Table.1 Maximum Displacement along X- Direction by Equivalent Static Method

Type of Building	Hard soil	Medium soil	Soft soil
	X(in mm)	X(in mm)	X(in mm)
Regular	95.351	129.628	157.479
L1	95.306	129.676	157.601
T1	98.483	133.925	162.721
L2	107.377	146.043	164.441
T2	108.042	146.914	165.351

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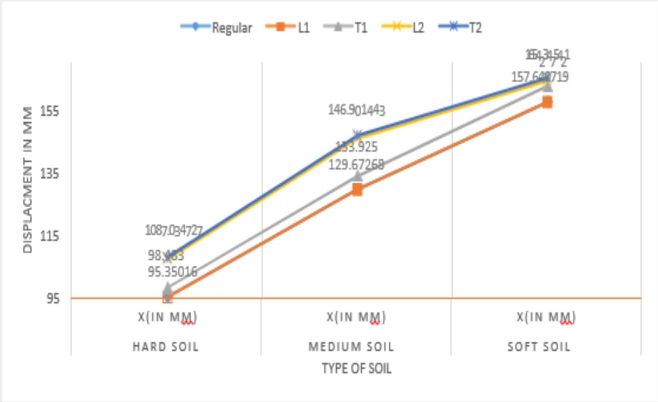

Fig. 4.1 Displacement in different Soil Type along X- Direction

The Nodal displacement for (G+11) building model has been evaluated for regular, T Shape, & L Shape for Different soil types. The displacement on average in soft soil is 65% more and in Medium soil is 36% more as compare to hard soil when perimeter is same and when area is same for soft soil is 53% more and for medium soil is 36% more as compare to hard soil. When comparing between building in same soil in soft soil difference in displacement is negligible between all Buildings but in Hard and Medium soil difference in displacement is negligible in Regular, L1, & T1 building but it is 12.60% more in L2 and 13.30% more in T2 as compare to regular building in X direction.

Table.2 Peak story shear in Soft Soil along X-direction

STOREY	LEVEL IN METER	PEAK STORY SHEAR IN KN				
		Regular	L1	T1	L2	T2
		X	X	X	X	X
12	36	553.36	431.05	388.46	679.27	558.44
11	33	1237.04	959.33	863.09	1332.12	1241.02
10	30	1763.48	1362.13	1223.21	1825.01	1760.27
9	27	2170	1671.59	1498.5	2203.63	2158.59
8	24	2491.34	1916.04	1715.23	2501.75	2472.44
7	21	2752.79	2114.84	1891.27	2744.68	2726.86
6	18	2991.36	2296.85	2052.84	2971.06	2960.2
5	15	3229.94	2479.75	2215.87	3201.86	3195.71
4	12	3465.66	2660.82	2377.95	3432.28	3429.34
3	9	3690.08	2833.81	2533.51	3654.32	3653.17
2	6	3869.24	2972.57	2658.67	3833.25	3833.49
1	3	3946.98	3032.85	2713.05	3911	3912.06
BASE	0	3946.98	3032.85	2713.05	3911	3912.06

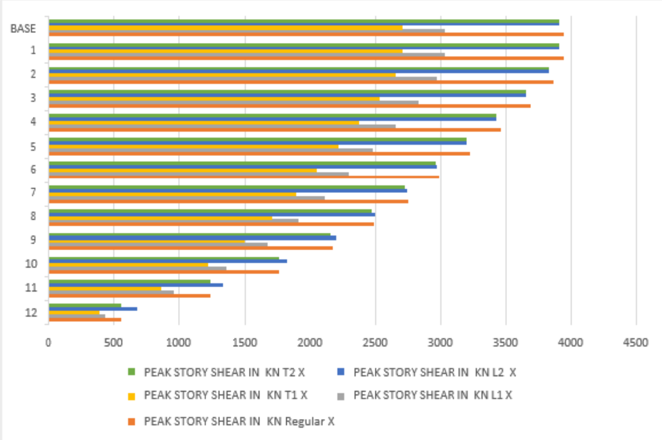

Fig. 4.2 Peak story shear in Soft soil along X-direction throughout the height.

The Peak Story Shear for G+11 Building Models has been evaluated for Regular, L shape & T shape Building. As per the above table and graph lateral force decreases as floor increases and As per the above table and graph lateral force decreases as floor increases in X direction as shows in fig. 4.2

5. CONCLUSION

The analytical study is carried out in order to compare the behavior of Regular, and Irregular building types i.e. L Shape and T Shape. The structure subjected to equivalent static method and dynamic analysis [Response Spectrum Analysis] Seismic loading for Zone III in 3 soil types i.e. Soft, Medium, Hard Soil, from the Study the following conclusions are obtained. This Comparative Study presented the seismic load effects on Regular, and Irregular Buildings By observing the overall analysis of results and graphs the following conclusions are as follows:

- The displacement on average in soft soil is 65% more and in Medium soil is 36% more as compare to hard soil when perimeter is same and when area is same for soft soil is 53% more and for medium soil is 36% more as compare to hard soil.
- When comparing between building in same soil in soft soil difference in displacement is negligible between all Buildings but in Hard and Medium soil difference in displacement is negligible in Regular, L1, & T1 building but it is 12.60% more in L2 and 13.30% more in T2 as compare to regular building in X direction.
- The displacement on average in soft soil is 65% more and in Medium soil is 36% more as compare to hard soil when perimeter is same and when area is same for soft soil is 43% more and for medium soil is 36% more as compare to hard soil.
- When comparing between building in same soil in soft soil difference in displacement is negligible between all Buildings but in Hard and Medium soil difference in displacement is negligible in Regular, L1, & T1

building but it is 15.20% more in L2 and 11.50% more in T2 as compare to regular building in Z direction

- The maximum bending moment on average in soft soil is 65% more and in Medium soil is 35.50% more as compare to hard soil when perimeter is same and when area is same for soft soil is 52.50% more and for medium soil is 35.60% more as compare to hard soil.
- When comparing between building in same soil in soft soil difference in maximum bending moment is negligible between all Buildings but in Hard and Medium soil difference in bending moment is negligible in Regular, L1, & T1 building but it is 8.60% more in L2 and 8.60% more in T2 as compare to regular building in Z direction.
- The displacement on average in soft soil is 69.56% more and in Medium soil is 38% more as compare to hard soil when perimeter is same and when area is same for soft soil is 56.51% more and for medium soil is 38% more as compare to hard soil.
- When comparing between building in all soil as compare to regular building on average L1 has 5% more , T1 has 10.20% more, L2 has 21.36% more, and T2 has 20.14% more displacement in X direction.
- The displacement on average in soft soil is 69.47% and in Medium soil is 37.80% as compare to hard soil when perimeter is same and when area is same for soft soil is 47.31% and for medium soil is 37.86% as compare to hard soil.
- When comparing between building in all soil as compare to regular building on average L1 has negligible , T1 has 8.6% more, L2 has 17.5% more, and T2 has 24.11% more displacement in Z direction
- The Shear force on average in soft soil is 69.70% and in Medium soil is 38% as compare to hard soil when perimeter is same and when area is same for soft soil is 52% and for medium soil is 37.95% as compare to hard soil.
- When comparing between building in all soil as compare to regular building on average L1 has 4.86% more , T1 has 8.25% more, L2 has 22.84% more, and T2 has 22.81% more shear force in X direction
- The maximum bending moment on average in soft soil is 65% more and in Medium soil is 36.40% more as compare to hard soil when perimeter is same and when area is same for soft soil is 52.36% more and for medium soil is 36.21% more as compare to hard soil.
- When comparing between building in all soil as compare to regular building on average L1 has 3.47% less , T1 has 5.54% less, L2 has 10.26% more, and T2 has 9.21% more bending moment in X direction
- The Peak Story Shear for G+11 Building Models has been evaluated for Regular, L shape & T shape Building. As per the above table and graph lateral force decreases as floor increases and As per the above table and graph lateral force decreases as floor increases in X and Z direction

FUTURE SCOPE:

1. The Building results can be analyzed by using Pushover Analysis Method with torsion
2. The Building results can be analyzed in different seismic zones i.e. zone II, IV& V.
3. The Building results can be analyzed with more irregular building Shape and Type.
4. The Building Results can be analyzed with Soil Structure interaction.

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