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STUDY OF SEISMIC BEHAVIOR OF IRREGULAR BUILDING IN COMPARISON WITH REGULAR BUILDING USING ETABS SOFTWARE

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***Abstract—* This Structures with easy and same configurations are subjected to much less damage during earthquake .Many buildings in the current state have abnormal configurations. This may subject to damaging earthquake in destiny. To examine which is most unfavourable case, A seismic evaluation is done on Irregular building and are compared with the regular buildings The building is analysed d by Etabs software. Comparative evaluation on maximum displacement, storey drift and storey shear of different buildings has been explored.**

***Keywords—* Base shear, Storey shear, Storey displacement, plan irregularities, vertical Irregularities ,storey drift**

I. INTRODUCTION

This Architecture which evolved centuries back has got the same importance till today, since then the people had a fantasy of building the structures with the better architecture, with pleasing aesthetic looks depicting their community or religion etc. This is where the structural engineering comes into picture in designing the structurally stable and aesthetically beautiful structure. In the growing urbanization the irregular buildings are dominating because of their aesthetic view. The irregular configurations make the building more vulnerable during the natural disasters such as earthquake.

Our world is facing threat of natural disasters now and then because of which different parts of world have faced terrible losses (loss of lives and property). Earthquake is one such disaster which is most unpredictable and devasting of all, and hence results in tremendous loss of lives and property. So it becomes a duty of a structural engineer to build the structures to resist the earthquake forces. If a structure has to perform well during an earthquake then it should possess certain attributes such as 1) Simple and regular structural configuration, 2) At least a minimum initial lateral stiffness, 3) At least a minimum lateral strength, and 4) Adequate ductility.

But the building with irregular configuration does not possess these qualities hence are prone to damage. In this present study an effort is made to know the seismic behaviour of RC frame buildings with irregular configurations.

A Influence of building configuration on seismic response

At certain times the seismic design will have an equal importance as structural analysis depending on the building configuration

a. Buildings with simple and regular plan are preferred, and the buildings having plans in the shape of L Y or T etc. are to be avoided if not should be divided into two or more regular shapes.

b. As far as possible plan should be selected such that it is symmetric, if not it may result in torsion

c. All the vertical structural elements should be tied together to ensure continuous load path for the better performance of the structure.

d. The structure should be in such a way that, it should possess regularity in both plan and elevation, also there should not be much difference in the storey stiffness.

B Regular and Irregular Building Structures

Because of the considerations of the magnitude and pattern of the building's structural elements and their arrangements the building structure are referred as regular and irregular building structures.

The IS1893 (part 1)2002 has recommended building configuration system in section 7 for the better performance of RC buildings during earthquake. The building configuration has been described as regular or irregular in terms of size and shape of the building, arrangement of structural elements and mass.

Regular building configurations are almost symmetrical in plan and elevation about the axis and have uniform distribution of the lateral force resisting structure such that it provides continuous load path for both gravity and lateral loads

A building that lacks symmetry and has discontinuity in geometry, mass or load resisting elements is called irregular. These irregularities may cause interruption of force flow and stress concentrations. Asymmetrical arrangement of mass and stiffness of elements may cause large torsional force (where the centre of mass does not coincide with centre of rigidity)

II. PROBLEM DISCRIPTION

A. Scope

The seismic behaviour of the RC building with irregular configurations in the upper stories and having same and regular configurations at bottom stories has been studied. Different irregular configurations has been considered and each model is studied individually considering the effects and significance of different parameters in earthquake analysis. Seismic analysis has been carried out as per IS 1893:20029(part 1) using ETABS 2016. Models has been analysed using equivalent static method, response spectrum method and time history method and results are compared to know the actual behaviour of the structures and efficiency of the structures with irregular configurations

B.Objectives

1. To study the behaviour of RC building having geometrical irregularities in the upper floors and have the symmetry and regular configurations at the bottom stories
2. To study the response of the structure by analysing the RC frame using a. Equivalent static method b. Response spectrum method c. Time history method
3. To study the behaviour under seismic loading considering the following parameters
 a. Storey shear b. Storey displacement c. Max. storey drift of all models d. Time period

III. METHODOLOGY

A. Model considered for the analysis

The model consists of G+14 floors, bottom floors up to 5 stories are of equal area and the floors above 5 stories have lower area i.e., only centre core of the building is raised leaving 2bays on all the sides. The bottom floors have the area of 1600m2 and the upper floors have the area equal to 400m2. In the first model both the upper and lower part of the structure remain square in shape and symmetrical along both the axis, and this model is considered as the regular one and the all other model results are compared with respect to this model.

In addition to these 5 more models are considered and each model has different irregularities in the upper floors. The bottom structure remains same for all the models. The behaviour of models are studied by carrying out static and dynamic analysis. Each model has different irregularity, one model has the vertical irregularity along with the symmetry along both the axis and the other model is symmetric about x axis and asymmetric about y axis. The remaining three models are not symmetric about any of the axis, one of them has a plan irregularity and the other two have both plan and vertical irregularity. The configuration of each model is explained in the subsequent sections.

Model 1: Regular structure

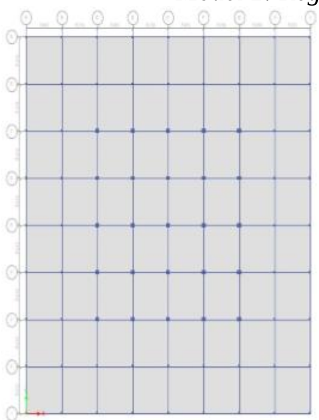


Fig 1: Plan view of Model

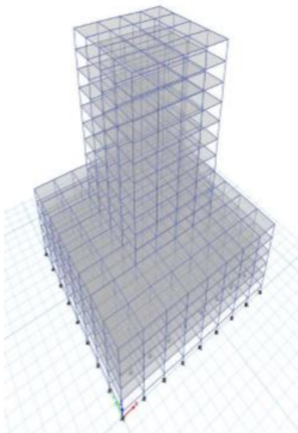


Fig 2: 3D view of model

Details:

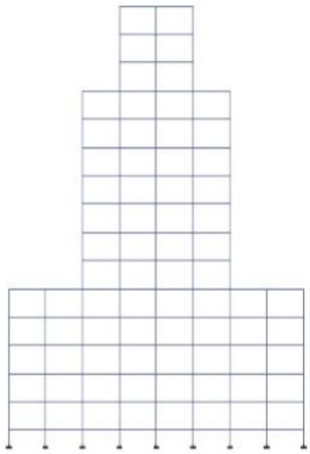
a. Model is regular no irregularities are provided

b. b. Bottom part of the structure has a floor area of 1600m2

c. From the 6th storey only the centre core of the building has been raised

d. Both the bottom base of the structure and the raised centre core are in square in plan and no vertical irregularity is provided.

Model 2 : Vertical geometrical irregularity on either side



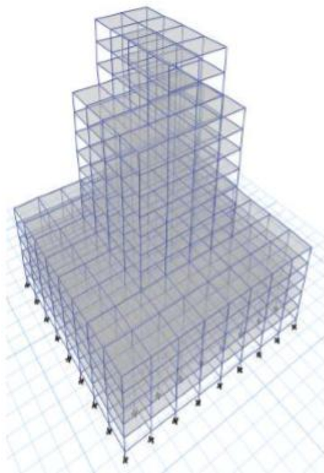
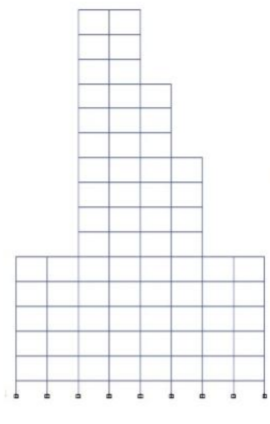


Fig 3: Elevation of Model 2 Fig 4: 3D view of Model 2

Details:
a. The model has vertical geometrical irregularity in the upper storeys.
b. The irregularity is of 25% above the 13th storey i.e., A/L = 0.25
c. The irregularity is provided on either side.
d. The building is symmetric about x and y axis

Model 3: Vertical geometrical irregularity on one side



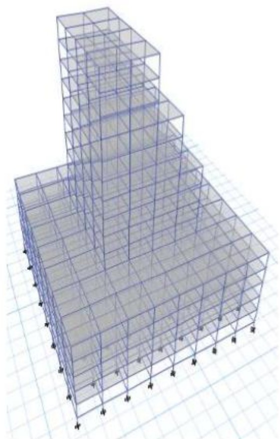


Fig 5: Elevation of Model 3 Fig 6: 3D view of Model 3

Details:
a. The model has vertical geometrical irregularity in the upper storeys.
b. The irregularty is of 50% above the 12th storey i.e., A/L = 0.5
c. The irregularty is of 25% above the 9th storey i.e., A/L = 0.25
d. The irregularity is provided on one side only.
e. The building is symmetric about x axis.
f. The building is not symmetric about y axis.

Model 4: Plan irregularity (L shape)

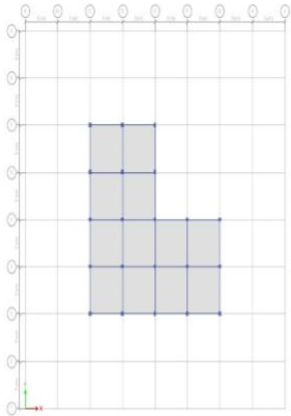
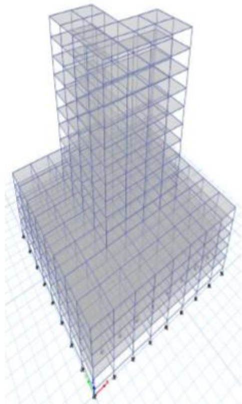



Fig 7 :Top view of Model 4 Fig 8: 3D view of Model 4

Details:

a. The model has plan irregularity in the upper storeys, i.e., upper structure is of L shape.
b. There is no additional vertical irregularity provided.
c. This results in re-entrant corner with 50% projections on both X and Y direction.
d. The building is not symmetric about both x and y axis.

Model 5: Plan irregularity and vertical irregularity in both directions

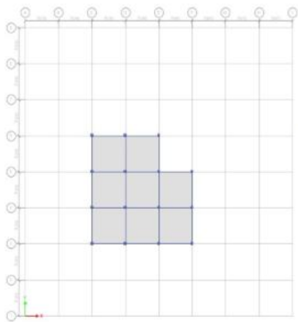
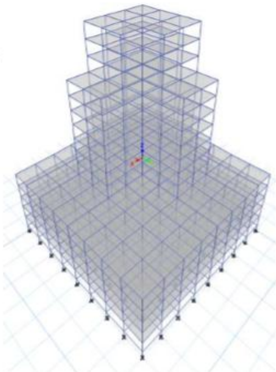



Fig 9: Top view of Model Fig 10: 3D view of Model 5

Details :

a. The model has plan irregularity in the upper stories, i.e., upper structure is of L shape.
b. There is additional vertical geometrical irregularity provided above 12th floor.
c. The irregularity is of 25% above the 12th storey i.e., A/L = 0.25
d. The vertical geometric irregularity is provided on both the directions.
e. The building is not symmetric about both x and y axis.

Model 6 : Plan irregularity and vertical irregularity in X direction

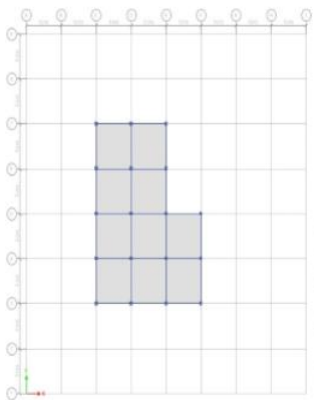
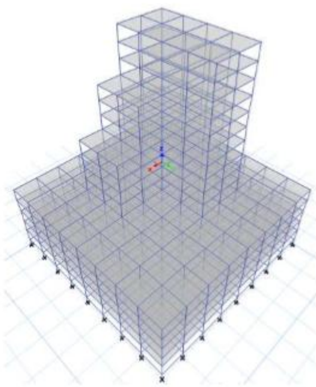



Fig 11:Top view of Model 6 Fig 12: 3D view of Model 6:

Details:

a. The model has plan irregularity in the upper stories, i.e., upper structure is of L shape.
b. There is additional vertical geometrical irregularity provided above 9th floor.
c. The irregularity is of 50% above the 12th storey i.e., A/L = 0.5
d. The irregularity is of 25% above the 9th storey i.e., A/L = 0.25
e. The vertical geometric irregularity is provided in the x direction.
f. The building is not symmetric about both x and y axis

B Parameters considered for the design

Table I: Parameters considered for the design

Parameter	**Type/Value**
Structure Type	RC frame structure
Number of Stories	G+14
Storey Height	3m
Area of Structure	1600m^2
Bay Width in both direction	5m
Beam Size	300mmX450mm
Column Size	300mm X 300mm, 450mmX 450mm, 450mm X 600mm
Grade of Concrete	M30
Grade of Concrete	Fe500
Live Load	3kN/m^2
SIDL (wall of thickness 150mm, only weight is considered, and modelling is not done)	10kN/m
Seismic Zone	V
Importance Factor	1
Response Reduction Factor	5
Soil Type	II
Type of structure	SMRF(Special Moment Resisting Frame)
Damping	5%
Time history (ground motion)	Elcentro Earthquake

C Methodology

According to IS1893:2002(part 1) the structures can be analyzed using static or dynamic analysis. The code also specifies certain conditions for choosing the method of analysis i.e., equivalent static method is applicable to (i) building with regular configuration and height of building is less than 48m (ii) building with regular configuration having height greater than 48m and fundamental translational natural period less than 3.5sec. If not it is recommended to use dynamic analysis

Linear dynamic analysis shall be performed for the,

a. Regular buildings: taller than 48m in zone III,IV,V and taller than 70m in zone II
b. Irregular building: having irregularities as per table 4 and 5 IS 1893:2002, taller than 12m in zones III,IV,V and taller than 48m in zone II

The code also suggests to carry out dynamic analysis for buildings with irregular configurations even with the lower heights, therefore in the present study both static and dynamic analysis is carried out.

In the linear approach, it is assumed that the force is constant with time. This approach is again sub-classified into linear static and linear dynamic approach as discussed belo

A *Linear static approach*

Most of the design codes prescribes this approach for building structures with smaller storey height. According to this approach, the seismic response can be computed by applying set of lateral forces to the structure. The linear static approach is a force based and the design parameters mainly depend on computation of base shear which in turn depends upon fundamental time period and seismic weight. The factor 'R' is the response reduction factor and it intends to account for both damping and ductility element in the structural system at yield and ultimate displacement. Therefore, for a system with light damping made of brittle material, the parameter R would be closer to unity, and for a heavily damped ductile frame it would range from 2 to 5 (UBC 1997). However, the parameter R assumes the value of 3 and 5 for OMRF and SMRF frames (IS 1893:2002). Likewise, different seismic design codes prescribe different value of parameter 'R'.

Nevertheless, the importance factor I depends on the required seismic performance of the structure, and assumes different values as per different seismic design codes. The fundamental time period is estimated by code expressions which are slightly different from each other. These equations are derived based on Rayleigh's method.

B Linear dynamic approach

The linear dynamic approach is similar to the linear static approach and uses the structural model linearly elastic in nature. However, this analysis adopts the dynamic forces contrary to the linear static approach which employs the static forces. The dynamic forces in this method are applied in the form of the code specified response spectrum to the structure. Therefore, it provides a greater insight into the structural response as compared to the linear static approach. Furthermore, the representative ground motion is not reduced by the response modification factor R.

This method requires an Eigen-value analysis of the building analytical model to determine the natural frequencies and the mode shapes. By use of the mathematical procedures and a response spectrum corresponding to the specified damping, the modal frequencies and shapes are further used to compute the spectral demands. These spectral demands are used to calculate the member forces, displacements, storey shears, base reactions etc. These modal forces are then combined using an established rule (SRSS, ABS, CQC) to calculate the total response quantity to achieve better accuracy

C Time history method

Time-History analysis is a step-by-step procedure where the loading and the response history are evaluated at successive time increments. During each step the response is evaluated from the initial conditions existing at the beginning of the step (displacements and velocities and the loading history in the interval). In this method, the non-linear behaviour may be easily considered by changing the structural properties (e.g. stiffness, k) from one step to the other. Therefore, this method is very effective to determine the non-linear response. However, in linear time history analysis, the structural properties are assumed to remain constant and a linear behaviour of structure is assumed during the entire loading history

IV. RESULTS AND DISCUSSIONS

As mentioned, the parameters considered for the study are time period, storey shear, inter storey drift, and displacement and the same are discussed in detail for all the models in different method of analysis in this chapter.

The first parameter is time period which depends on building flexibility and mass, so any changes done to the building will alter the values of time period of the building. The storey shear is obtained by the static analysis of the structure for the lateral forces acting on it, and the IS codes specify the lateral force in terms of base shear which in turn depends on seismic weight of the building. Inter storey drift is the difference between the roof and floor displacements of the storey under consideration as the building sways during the earthquake, normalized by the storey height. And the displacement is the horizontal movement of the building with respect to the ground.

A *comparison of Results from Static Analysis and Dynamic Analysis*

A. Base shear from ELF and RSM.

Table II: Base shear values

Model No.	EQ X(kN)	SPEC X(kN)	% Variation
1	3160	2744	13.17
2	3342	2722	18.55
3	3363	2668	20.65
4	3023	2463	18.53
5	3147	2532	19.53
6	3154	2037	35.41

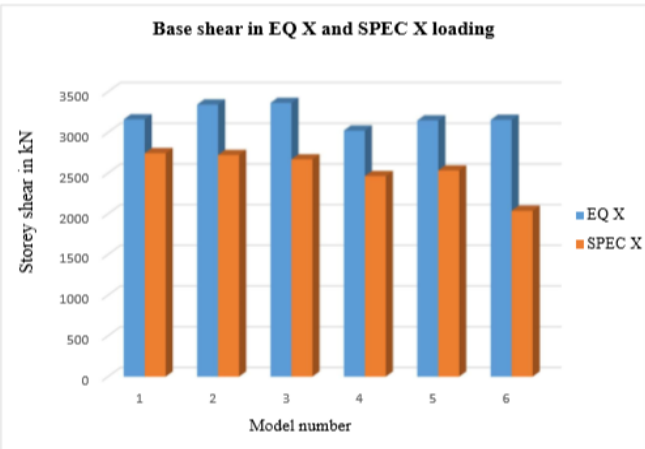


Fig 13 : Base shear values of all the Models

It is clear from table II and fig 13 that base shear of all models are higher in static method in comparison to response spectrum method. The maximum variation is seen in Model 6 with both vertical and horizontal irregularity. In this static value is 35.41% higher than RSM value. Model 1 which has regular configuration has the least difference i.e., RSM value is 13% lesser than that of static value. Static method overestimates the base shear especially for the buildings with the irregular configuration.

B Base shear values of all the Models

TableIII: Base shear values of all the Models

Model No.	EQ Y(kN)	SPEC Y(kN)	% Variation
1	3111	2669	14.21
2	3277	2674	18.42
3	3217	2169	32.57
4	2982	2388	19.9
5	3100	2465	20.47
6	3054	2065	32.39

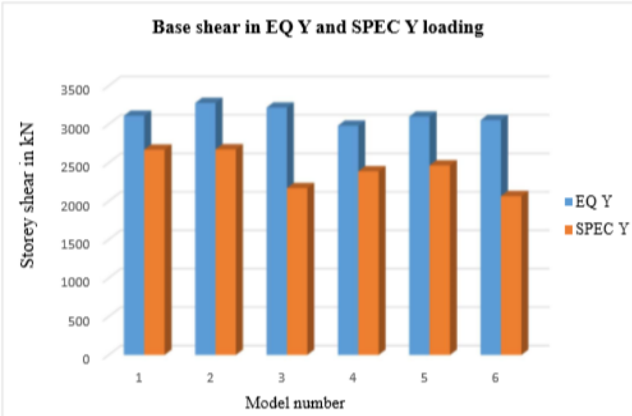


Fig 14: Graph showing Base shear values of all the Models

It is clear from table III and fig 14 known that base shear values are lower in RSM and the difference in variation depends on the building configuration. Model 3 with vertical irregularity and lacking symmetry in y direction has the difference of 33% from static method also Model 6 with both vertical and horizontal irregularity has the difference of 32%. But Model 1 with regular configuration has the least difference i.e, 14% almost half of what Model 3 and Model 6 have. It is clear that dynamic analysis gives better results for buildings with irregular configuration

C.Displacement from ELF and RSM

Table IV : Displacement values of all the Models

Model No.	EQ X(mm)	SPEC X(mm)	% variation
1	103.861	56.027	46.05
2	102.2	59.498	41.78
3	109.484	63.433	42.06
4	118.057	61.792	47.66
5	118.143	65.804	44.3
6	133.023	74.561	43.95

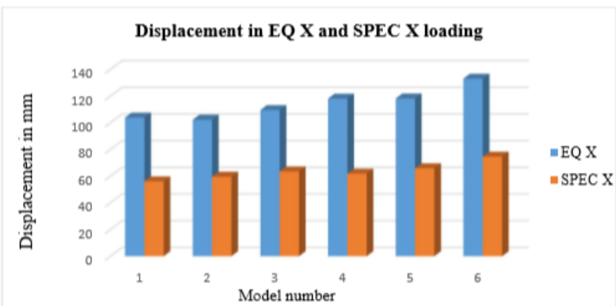


Fig: 15Graph showing the comparison of displacement values

D. Displacement values of all the Models

Table V: Displacement values of all the Models

Model No.	EQ Y(mm)	SPEC Y(mm)	% Variation
1	104.034	57.614	44.6
2	102.233	60.467	40.85
3	120.595	84.501	29.9
4	117.974	63.469	46.2
5	118.093	67.907	42.5
6	126.765	74.965	40.8

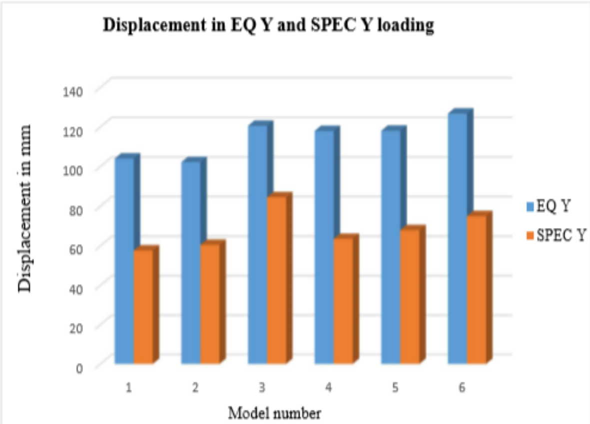


Fig 16: Graph showing displacement in EQ Y and SPEC Y loading

From table V and fig 16 , it is clear that Displacement is dependent on the lateral force acting on the building and the code specifies the lateral force in terms of base shear. Therefore higher the base shear higher the values of displacement, hence the static method gives higher values of displacement compared to dynamic analysis results. The values differ by almost 40% in all the models and the difference is higher in case of Model 4 which has horizontal irregularity.

V Conclusion

1. The results from response spectrum analysis and time history analysis indicated that displacement of the buildings is much lower when compared to static analysis
2. The results from all the three methods conclude that the Model 1 with regular configuration performs better during earthquake, since the drift values are within the limits and the displacement values are lower than irregular models in both the static and dynamic analysis.
3. Model 2 with vertical irregularity but symmetrical about both x and y axis performs almost as good as Model 1 and when storey drift values are considered the Model 2 results are almost closer (sometimes lower than) to Model 1
4. Model 3 with vertical irregularity provided on only one side and which is symmetrical only about x axis will give lower displacements values when the lateral load is acting along x direction in comparison to the results when load is acting on the other direction, which results in higher values of displacement (46%>M1)
5. Model 6 with both horizontal and vertical irregularity is the most vulnerable structure during seismic event, as the maximum storey drift value exceeds the safe storey drift limitation in static analysis. Also has 33% higher values of displacement compared to regular model in dynamic analysis
6. Considering the maximum storey drift values all the models meet the safe storey drift limitation specified by IS 1893:2002 in dynamic analysis, but the Model 5 and Model 6 cross the safe storey drift limitation in linear static analysis.

REFERENCES

[1].Pradip Sarkal , A meher Prasad Devdas Menon , "*Vertical Geometrical Irregularity in stepped building frames* " Engineering structures 32

[2].C J Athanassiadou ," *Seismic performance of RC plane frame irregular in elevation Engineering structures 30*"

[3].Eggert V, Valmundsson and James M Nau, "*Seismic Response of building frames with vertical structural Irregularities* " Journal of structural Engineering ASCE

[4]. Pankaj Agarwal and Manish Srikande Earthwuake Resistant design of Structures

[5].Geoge Georgoussis, Achilleas Tsopanos and triantafyllos Makarios," *Approximate Seismic Analysis of Multi storey building with mass and stiffeness irregularities* "

[6].H Gokdemir,H ozbasaran M dogan , E unluoghu U. Albaryrak ," *Effect of torsional irregularity to structures"*