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STUDY OF RESPONSE OF VERTICALLY IRREGULAR BUILDINGS TO SEISMIC EXCITATIONS KEEPING FLOOR AREA CONSTANT

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ABSTRACT

*Consideration of seismic load is one of the important factor in designing of high rise symmetrical and asymmetrical buildings to minimize damage in earthquake zones. Generally structures hold irregularities in plan and elevation due to architectural requirement which is difficult with regular shapes buildings but irregular distribution of mass, stiffness and strength make structure weak and structure may collapse due to unanticipated dynamic loads. This paper does comparative study between 3D asymmetrical frames(in two directions) with 3D asymmetrical (In one direction) frame keeping floor area constant in all buildings . All frames are of 9*9 bays and 9 storeys. Response spectrum method is employed for seismic analysis of buildings. Responses of building frame are obtained using STAAD.Pro V8i. Responses like Horizontal Displacement, Torsion and Drift of buildings are compared altogether. It is concluded that performance of structures increases in symmetrical building then asymmetrical buildings.*

Keywords:- Asymmetric Structure, Response Spectrum Analysis, Seismic Performance, STAAD. Pro V8i

I INTRODUCTION

A building is said to be regular when it is symmetric about all axis and building is called irregular when it having asymmetry about any axis in geometry, stiffness or mass. Irregular structures are a major part of urban infrastructure. During an earthquake, failure of structure begins at a point of weakness. This weakness arises due to discontinuity in mass, stiffness and geometry of structure. So behaviour of irregular structure is very different then regular structure. The IS-1893:2002(Part-I) has given an explanation about configuration system of reinforced cement concrete building for better performance during earthquake. Two types of irregularities have also been described in IS code. One is horizontal irregularity and second is vertical irregularity. Horizontal Irregularities include asymmetrical plan shapes or discontinuities in horizontal resisting elements such as re-entrant corners, large openings and cut outs etc. Vertical Irregularities include sudden change of stiffness, strength, mass and geometry of structure in elevation.

The IS 1893(part1): 2002 lists various types of vertical irregularity as follows:

1a) Stiffness Irregularity- Soft story is defined to exist when there is a story in which the lateral stiffness is less

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than 70% of that in the story above or less than 80% of the average stiffness of the three stories above.

1b) Stiffness Irregularity- Extreme soft story is defined to exist when there is a story in which the lateral stiffness is less than 60% of that in the story above or less than 70% of the average stiffness of the three stories above.

Mass Irregularity- It is defined to exist where the effective mass of any story is more than 150% of the effective mass of an adjacent story. A roof that is lighter than the floor below, need not be considered.

Vertical geometric irregularity- It can be defined to exist where the horizontal dimension of the lateral force resisting system in any story is more than 130% of that in an adjacent story.

In-plane discontinuity in vertical lateral force resisting elements is defined to exist where an in plane offset of the lateral force resisting elements is greater than the length of those elements or there is a reduction in stiffness of the resisting element in the story below.

Discontinuity in capacity- Weak story is one in which the story lateral strength is less than 80% of that in the story above. The total lateral strength of all seismic resisting elements bearing the story shear, for the direction under consideration, is called story lateral strength.

It is concluded by most of the literatures that irregular buildings are not suitable in seismic zone. According to Ramesh Konakalla [1], there is no torsional effect in symmetrical frame but vertical irregular frame is subjected to torsion. It is concluded by Himanshu Bansal [2] that mass irregular buildings experience large base shear than similar regular buildings.

The main purpose of this paper is to find best possible irregular shape of building which can show better performance in seismic zone in comparison of the other vertical irregular buildings having floor area constant.

II MODELING OF STRUCTURE

2.1 General

In this paper three dimensional vertical irregular reinforced concrete buildings frame of 9*9 bays with 9 stories is studied. The structures are modeled using STAAD.PRO V8i and analyzed by response spectrum method. The following parameters have been taken for all building frames considered in study:-

2.2 General Properties of Models

Structure type: Special Moment Resisting Reinforced Concrete Frame

Type of building use: Residential Building

Foundation type: Isolated footing

All building frames have 2 m foundation. Height of each story is 3.2 m, so overall height of building frames is 30.8 m. Width of each bay is 5 m, so overall length of building frames is 45 m respectively. Width of building frames is same as their length in plan.

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2.3 Support Information

The frames are assumed to be firmly fixed at bottom and soil-structure interaction has been neglected.

2.4 Material Properties

Building frame is considered as Reinforced Concrete Building. Its design is as per provisions of IS 456 (2000), IS 13920 (1993).

Modulus of Elasticity of Concrete (Ec)	:	28,500MPa
Modulus of Elasticity of Masonry (Eb)	:	3,500MPa
Poisson's ratio	:	0.2
Unit Weight of Concrete	:	25kN/m3
Unit Weight of Masonry	:	20kN/m3s

2.5 Member Properties/Element Sections

Thickness of slab	:	150 mm
Beam size	:	300 mm x 600 mm
Column size	:	300 mm x 700 mm
Thickness of brick masonry partition wall	:	230 mm
Height of parapet wall	:	1 m.

2.6 Load Information

Analysis of frame has been carried out for combination of gravity loads (vertical loads) and lateral loads. In lateral load earthquake loads have been considered .

2.6.1 Vertical Loads

For all building vertical loads are taken as

Dead load on floors (including floor finish 1 KN/m2)	:	4.75 KN/m^2
Dead load on roof (including weathering course 2 KN/m2)	:	5.75 KN/m^2
Live load on floors	:	4 KN/m^2
Live load on roof	:	2 KN/m^2
Uniform distributed load on floor beams	:	13.4 KN/m
Uniform distributed load on roof beams	:	4.6 KN/m

2.6.2 Lateral Load (Seismic Load)

As per IS Code: 1893-2002

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Seismic Details

1) Zone	:	III
2) Response Reduction Factor	:	5 (Special moment-resisting RC frame)
3) Importance Factor	:	1
4) Type of soil	:	Hard soil
5) Damping	:	5%

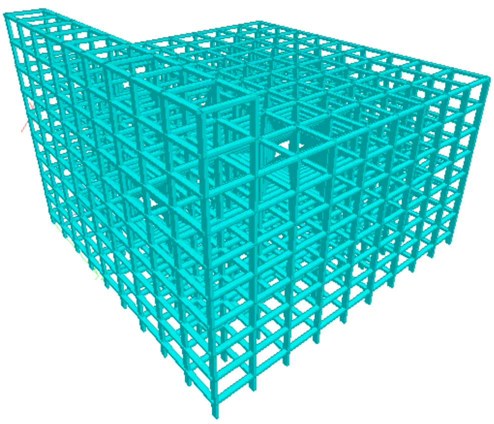
2.7 Method of Analysis

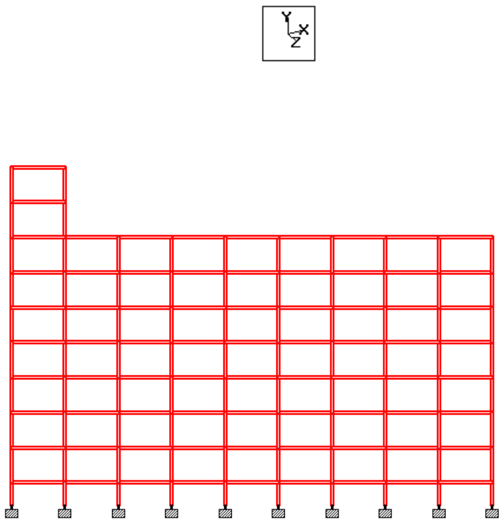
Structure response of earthquake is dynamic phenomenon that depends on dynamic characteristics of structure and intensity, duration and the frequency content of exciting ground motion. Structure vibrates and deforms during high seismic movement of the ground. Here the response spectrum analysis is used for analysis of irregular structure.

2.8 Model Information

Irregular building with changing position of top two floors in X direction keeping floor area constant

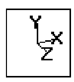
Model-A1- Building having top two floors (1*9 bay) situated extreme left in X direction.





3-D view 2-D view

Model-A2- Building having top two floors (1*9 bay) situated 1 unit (5 meters) away from extreme left in X direction.



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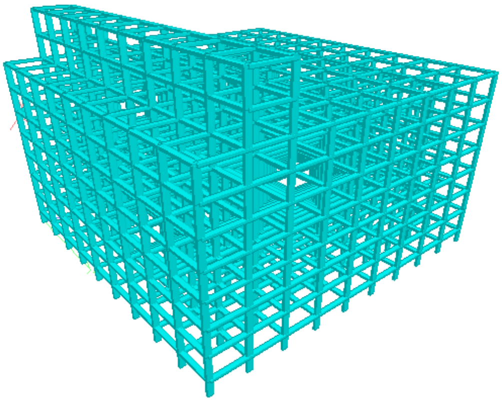
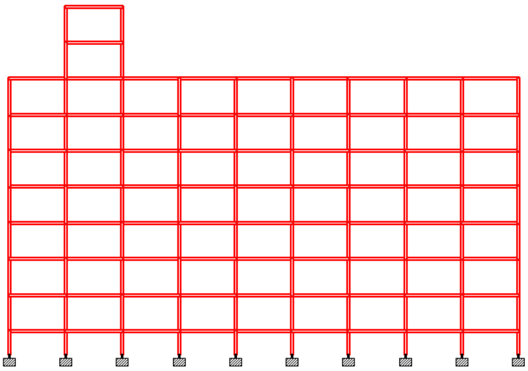
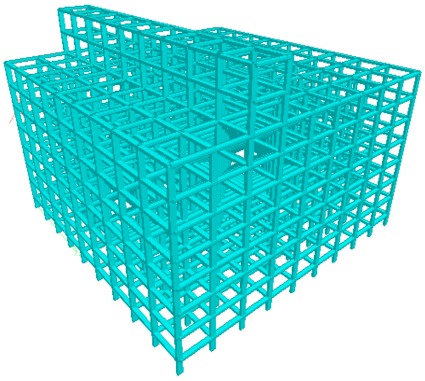
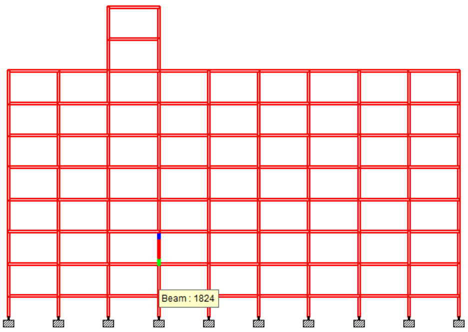




3-D view 2-D view

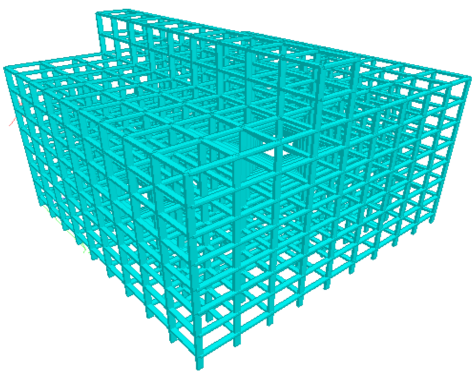
Model-A3- Building having top two floors (1*9 bay) situated 2 unit (10 meters) away from extreme left in X direction.

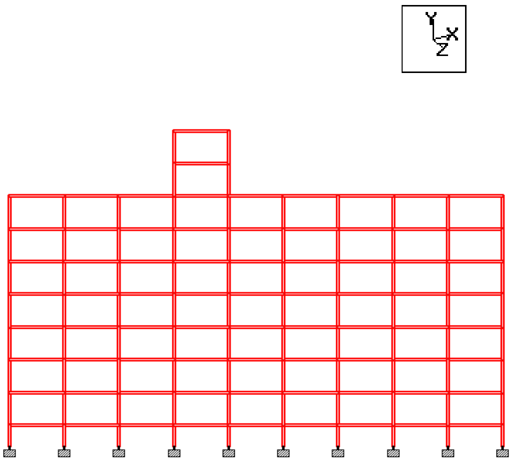




3-D view 2-D view

Model-A4 Building having top two floors (1*9 bay) situated 3 unit (15 meters) away from extreme left in X direction.





3-D view 2-D view

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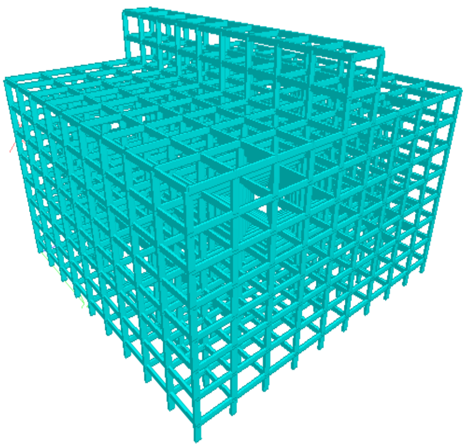
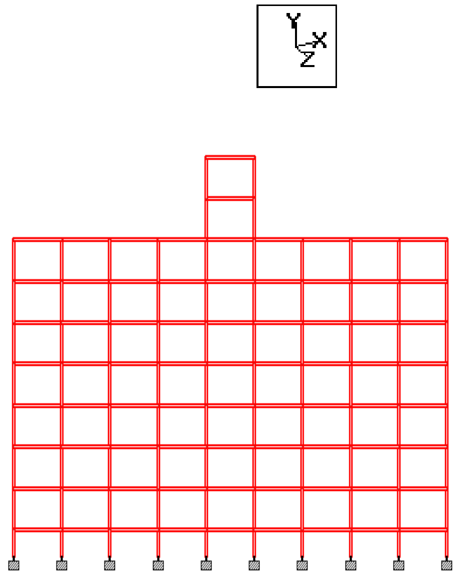
Model-A5 Building having top two floors (1*9 bay) situated 4 unit (20 meters) away from extreme left in X direction i.e. at the center of the building.



3-D view



2-D view

III RESULT AND DISCUSSION OF RESULT

STAAD.Pro V8i software which has capabilities of performing analysis and design of R.C.C. structure has been used here. The frame members have been defined as members having rigid end zone. The dynamic analysis performed on the models of the building frames considered in this study is the response spectrum analysis as per the guidelines of IS 1893(Part I):2002.

3.1 Results

Response Structure analysis is performed on various irregular buildings using STAAD Pro V8i. The horizontal displacement and story drift are calculated on each floor. The base shear and torsion are also calculated for each case and graphs are plotted for each structure. In this 9*9 bays with height of 30.8 mt building is used with different vertical configuration. To compare the behavior of irregular building frame, four parameters have been obtained from STAAD results. These are as follows:

Horizontal displacement of each floor, inter-story drift for each story, base shear of each irregular building and torsion of each irregular building are calculated and graph has been plotted among all models.

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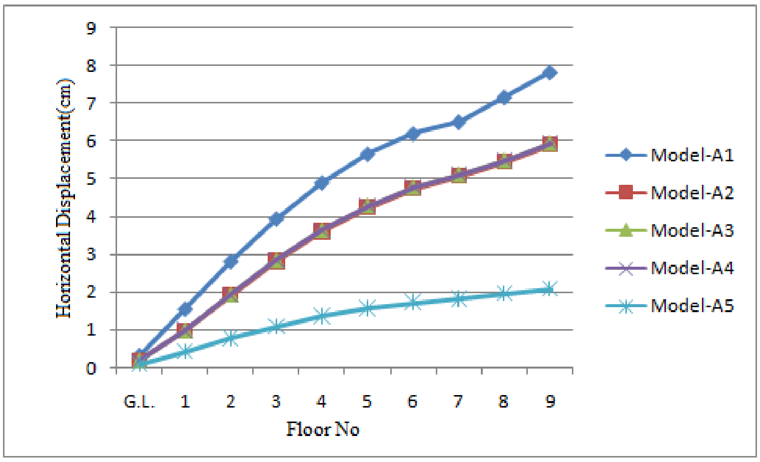
TABLE -1 Horizontal Displacement on each floor

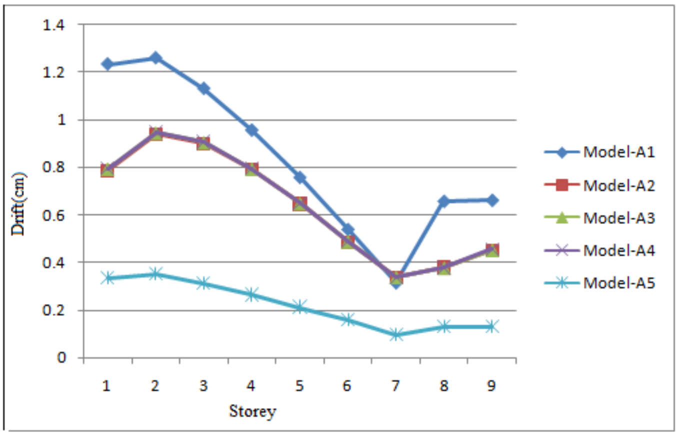
Horizontal Displacement in X Direction (cm)					
Floors	Model-A1	Model-A2	Model-A3	Model-A4	Model-A5
G.L.	0.3305	0.1956	0.1975	0.1982	0.0913
1	1.564	0.9825	0.9913	0.9948	0.4257
2	2.8237	1.9221	1.9369	1.9434	0.7752
3	3.9548	2.8233	2.842	2.8511	1.0861
4	4.9105	3.615	3.6361	3.6472	1.3485
5	5.6669	4.2617	4.2846	4.2969	1.5598
6	6.2047	4.7473	4.771	4.7838	1.7155
7	6.518	5.0835	5.1069	5.1198	1.8113
8	7.1741	5.4619	5.4817	5.4971	1.9398
9	7.8344	5.9124	5.9325	5.9512	2.0671



Graph-1 Variation of Horizontal Displacement among models

TABLE -2 Drift on each story

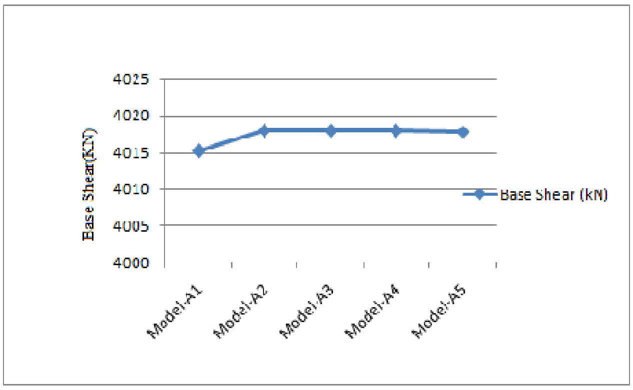
Drift in X Direction in cm					
story	Model-A1	Model-A2	Model-A3	Model-A4	Model-A5
1	1.2335	0.7869	0.7938	0.7966	0.3344
2	1.2597	0.9395	0.9456	0.9486	0.3495
3	1.131	0.9012	0.9051	0.9077	0.3109
4	0.9557	0.7918	0.7941	0.7961	0.2624
5	0.7564	0.6467	0.6484	0.6497	0.2113
6	0.5378	0.4856	0.4864	0.4869	0.1557
7	0.3134	0.3362	0.3359	0.336	0.0958
8	0.6561	0.3784	0.3748	0.3773	0.1285
9	0.6603	0.4505	0.4509	0.4541	0.1273



Graph-2 Variation of Drift among models

TABLE-3 Base Shear

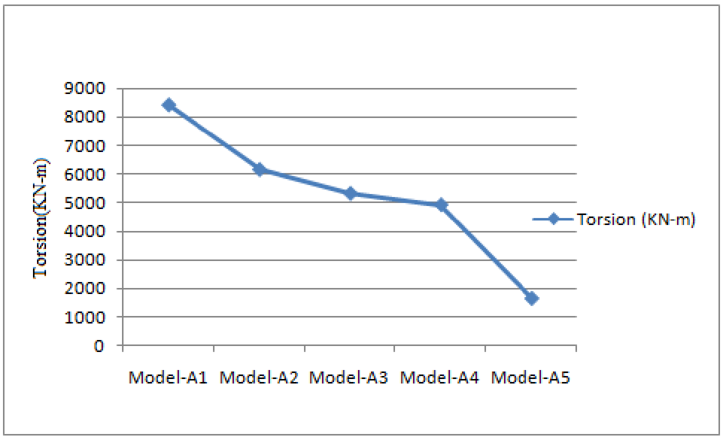
Models	Base Shear (KN)
Model-A1	4015.15
Model-A2	4017.86
Model-A3	4017.85
Model-A4	4017.84
Model-A5	4017.83



Graph-3 Variation of Base Shear among models

TABLE-4 Torsion

Models	Torsion (KN-m)
Model-A1	8403.29
Model-A2	6149.93
Model-A3	5322.14
Model-A4	4931.49
Model-A5	1669.11



Graph-4 Variation of Torsion among models

Based on above figures, graphs and tables, following conclusions can be obtained.

(1) From Table-1 and Graph-1, it has been observed that magnitude of horizontal displacement increases from lower story to upper story of building in all models i.e. horizontal displacement is higher on upper floors.

It can be noticed that slope of the graph of Model-A5 is less than slope of other models. There is large difference in the slope of Model-A1 in comparison to Model-A5.

While comparing models A1 to A5, it can be noticed that magnitude of top floor displacement decreases from 7.8344 cm (in Model-A1) to 2.0671 cm (in Model-A5) i.e. there is maximum reduction of 73.61% in horizontal displacement values. Therefore, it may be concluded that horizontal displacement increases in case of asymmetrical building in comparison of less asymmetrical building. As the asymmetry is increased, the top floor displacement is increased.

(2) As far as drift is concerned, a sharp change is seen at different locations in the drift-story graph, as shown in Graph-2 , sudden increment and decrement of drift is observed at various story levels in different models. It is observed that magnitude of story drift is more in the lower stories than the higher stories.

From Table-2, it can be seen that there is a sudden jump of drift from 7th to 8th story because of abrupt reduction in stiffness and mass at the eight story.

Considering all models from A1 to A5, there is reduction in magnitude of top story drift from 0.6603 cm (in model-A1) to 0.1273 cm (in model-A5) i.e. there is maximum reduction of 80.72% in drift values. Therefore, it may be concluded that drift is more in case of asymmetrical buildings as compared to less asymmetrical building.

(3) From Table-3and Graph-,3, it has been observed that base shear is almost same in all models of case A, negligible difference is observed in the values of base shear.

(4) From Table-4 and Graph-4, it may be concluded that less asymmetrical structure (Model-A5) is subjected to least torsion in comparison to other models and value of torsion decreases from Model-A1 to Model-A5. As the difference between center of mass and center of rigidity of building reduces, torsion decreases. There is reduction in magnitude of torsion from 8403.29 KN-m (in Model-A1) to 1669.11 KN-m (in Model-A5) i.e. there is maximum reduction of 80.13% in torsion values. Therefore, it may be concluded that torsion is more in case of asymmetrical building as compared to less asymmetrical building.

IV CONCLUSION

It is concluded that each floor of asymmetrical building (asymmetrical in more than one direction) is subjected to higher horizontal displacement in comparison of each floor of building having asymmetry in only one direction.

It is also observed that, the storey drift values in the building is high in bottom floors than top floors as shear is dominating then the bending. In case of higher asymmetrical building, drift values are comparatively higher then drift values in less asymmetrical building. In case of reduction in stiffness or mass in a building, a sudden jump can be observed in drift values.

It is also concluded that higher asymmetrical building is subjected to more torsion then less asymmetrical building.

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