BEHAVIOUR OF ARCHITECTURALLY IRREGULAR BUILDING

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ABSTRACT:

Architecturally Irregular buildings like setback buildings are characterized by staggered abrupt reductions in floor area along the height of the building, with consequent drops in mass, strength and stiffness. Height-wise changes in stiffness and mass render the dynamic characteristics of these buildings different from the 'regular' building. The increasing number of damage after seismic ground motion has provided strong evidence that setback buildings exhibit inadequate behavior though they were designed according to the current seismic codes. Many investigations have been performed to understand the behavior of irregular structures as well as setback structures and to ascertain method of improving their performance. So, there is a need to study the seismic performance of setback structures designed by recent codes the adequacy of current seismic design requirements for setback buildings, and new design methods to improve the seismic response of setback buildings. It is possible to evaluate the seismic performance of setback building accurately using STAAD. Pro. Software. It is instructive to study the performance of static equivalent analysis methodology as well as other alternative methodologies for setback buildings and to suggest improvements suitable for setback buildings. After study all models in details it is concluded that consideration of the revised seismic codes provisions for geometric vertical irregularities seems to be essential to stipulate more restrictive limits or apply more accurate analytical procedures to predict the seismic performance of setback structures under the seismic excitations, especially for structures with critical setback ratios.

Keywords: Architecturally Irregular structure, vertical irregularity, setback.

INTRODUCTION

A common type of vertical geometrical irregularity in building structures, needed from various functional and aesthetic architecture requirements, is the presence of setbacks i.e. the presence of abrupt reduction of the lateral dimension of the building at specific levels of the elevation. This building category belongs under setback building. In particular, such a setback form provides adequate daylight and ventilation for the lower storey in an urban locality with closely spaced tall buildings. This type of building form also provides for compliance with building bye-law restrictions related to 'floor area ratio' (practice in India).

Setback buildings are characterized by staggered abrupt reductions in floor area along the height of the building, with consequent drops in mass, strength and stiffness. Height-wise changes in stiffness and mass render the dynamic characteristics of these buildings different from the 'regular' building. The increasing number of damage after seismic ground motion has provided strong evidence that setback buildings exhibit inadequate behavior though they were designed according to the current seismic codes. This inferior seismic performance has been attributed to the combined action of structural irregularities i.e. to the combined non-uniform distribution of mass, stiffness, and strength along the height of setback frames, and to concentration of inelastic action at setback level.

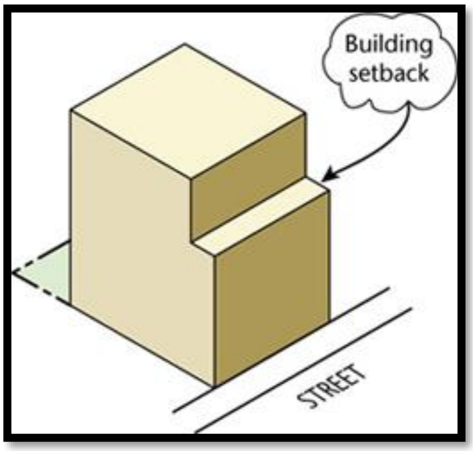


Figure 1.: Typical view of Setback Building

LITERATURE REVIEW

Earthquakes present one of the most devastating hazards on the planet. They threaten the safety of civilians in seismically active regions, and are of extreme concern in applications that demand a high level of safety, i. e. the nuclear industry. However, in nearly all cases, the fatalities that occur are because of the collapse of man-made structures. Hence the problems facing Civil Engineers who are concerned with seismic mitigation is evident.

Many of the researchers have adopted different method for design and analysis earthquake resisting structure of setback buildings. Some of which is presented under,

1) ***H. Shakib and M. Pirizade—***

Seismic analysis of setback building by using probabilistic approach method-(ASCE)ST.1943-

They modelled one side setback building, which is investigated by probabilistic approach and also observed effect of two orthogonal ground motion with different setback ratio are assessed by studying. They applying Limit state capacities, mean annual frequencies of exceeding performances levels and confidence levels in meeting performance objectives.

They conclude that Elasticity to global instability and assessment of code design setback structure by incremental dynamic analysis demonstrates the poorer performance of these tortionally coupled structure relative to regular structure depending upon the setback ratio values. Therefore revision of seismic code.

2) **Jack P. Moehle,1 A. M. ASCE - Seismic response of vertical irregular structure-Journal of Structural Engineering, Vol. 110, No. 9, September, 1984.**

They modelled four irregular reinforced concrete test structures and interpreted it. They taken two different combination 1) frame wall combination 2) Discontinuing the structural walls at various levels. They found that standard limit analysis and static inelastic analysis provides good measures of strength and deformation characteristics under strong earthquake motion.

3) **Jack P. Moehle, A. M. ASCE and Luis F. Alarcon- Seismic analysis of irregular building –Journal of Structural Engineering, Vol. 112, No. 1, January, 1986.**

They perform combined experimental of two frame wall structure Using various method or analysis. They collect result on that, elastic static and dynamic method were superior to the elastic method in interpreting effects of the structural discontinuities. Vertical irregular building, Seismic response & Design of setback building. Experimental – Ductile moment resting reinforced concrete test structure. – A static lateral – load design method to improve performance is proposed.

4) **Sharon L, Wood,1 Associate Member, ASCE- Seismic response for R.C. Frames with irregular Profiles. Journal of Structural Engineering, Vol. 118, No. 2, February, 1992. ©ASCE**

They modelled the various symmetrical & unsymmetrical arrangement of setback in building. Over that they observed that Setback frame are not observed to be more susceptible to damage or more susceptible to higher mode effect than the frames with uniform profiles.

5) **Juan C. De la Llera,t Associate Member, ASCE, and Anil K. Chopra/ Member, ASCE - Inelastic behaviour of asymmetric multi-storey building. Journal of Structural Engineering, Vol. 122, No.6, June, 1996. c>ASCE**

They studied the inelastic seismic behavior and design of asymmetric multistory buildings emphasizing, primarily, the use of story shear and torque histories. The following six different structural characteristics and their effect on the torsional response of buildings are analyzed. Finally, they concluded that the use of the story shear and response histories in conjunction with the corresponding story yield surfaces is a powerful tool for conceptual understanding of the earthquake behavior of asymmetric structures.

METHODOLOGY

During an earthquake, ground motions occur in random fashion, both horizontally and vertically, in all directions radiating from the epicenter. These ground motions cause structures to vibrate and induce inertial forces on them. Hence, structure in such locations need to be suitably designed and detailed to ensure stability, strength, and serviceability with acceptable levels of safety under seismic effects. These requirements take into consideration the characteristics and probability of occurrence of earthquake.

a) The methodology adopted to perform the seismic evaluation of the building requires an understanding of equivalent lateral force procedure also recognized as equivalent static procedure in literature.

b) In deep, knowledge of STAAD Pro software is required as the building was modeled in STAAD Pro and post analysis data obtained from it will be used in the design of the structure.

c) The seismic stability of the structure under the various load combinations in accordance with IS 1893-2016 (part 1)

DETAILS OF BUILDING:

The study is based on frames which are plane and orthogonal with storey heights and bay widths. Different building geometries were taken for the study. These building geometries represent varying degree of irregularity or amount of setback. Nine different categories of setback buildings, ranging from 4 to 4 bays (in X and Z direction) with a bay width of 4mX3m and 11 bays in Y direction were considered for this study.

It should be noted that bay width of 4m – 6m is the usual case, especially in Indian and European practice. Similarly, same height categories were considered for the study, G+10, with a uniform storey height of 3m. Altogether 10 building frames with different amount of setback irregularities due to the successive reduction of Ra = 25% for (S1) buildings, Ra = 50% for (S2)) buildings and Ra = 75% for (S3)) buildings were selected. The regular frame (R), without any setback, is also studied. The structures are modelled by using computer software STAAD. Pro.

The earthquake ground motion is defined by the equivalent static analysis available in the software. The column sections defined for the frames satisfy both the requirements for strength and stiffness. All the selected models were designed with M-20 grade of concrete and Fe-415 grade of reinforcing steel as per Indian Standards.

Table No. 1 Building description:

Sr. No.	DISCRIPTION	SPECIFICATION
1	Building Type	Reinforced concrete frame
2	Usage	Institutional Building
3	Number of stories	G+10
4	Plan dimension	16m X 12m
5	Building height	33m
6	Number of bay in X- Direction	4 Bay
7	Number of bay in Z- Direction	4 Bay
8	Number of bay in Y- Direction	11 Bay
9	Size of Beam	0.45m X 0.3m
10	Size of Column	0.45m X 0.45m

Table No. 2 Grade of Material:

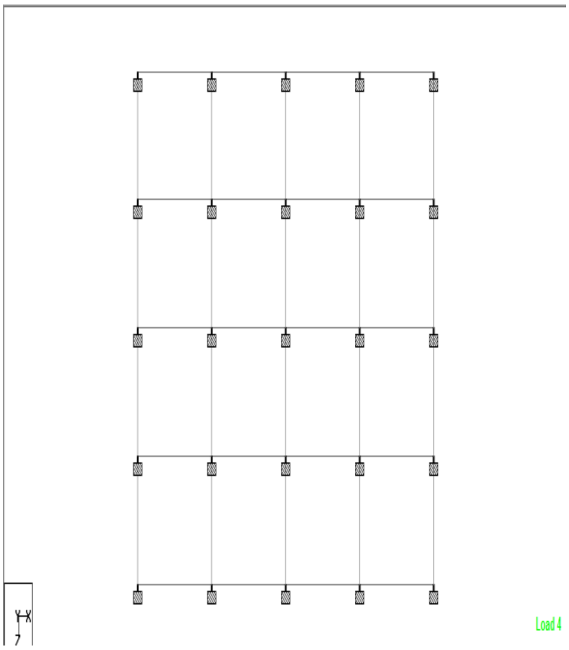
Sr. No.	DISCRIPTION	SPECIFICATION
1	Concrete	M20
2	Reinforcing Steel	Fe415

Modeling in STAAD Pro:

Table No. 3 Details of reference structure:

Sr. No.	Description	Dimension
1	Plan area	16m X 12m
2	Height of building	33m
3	No. of bay in X	4 Bay
4	No. of bay in Z	4 Bay
5	Length	16m
6	Width	12m
7	Height	33m

1)



2)

Figure 2: Plan of Reference BuildingSetback Critical Ratios

1) **Reference Building (R1).**

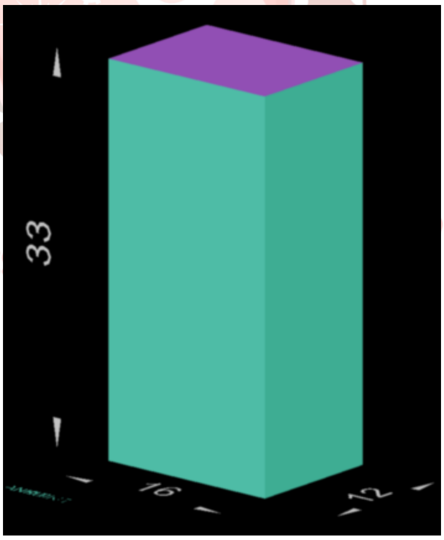


Figure 3 : Dimension of building is 16mX12m in plan and 33m Height.

Table No. 4-Setback Critical Ratios S1

Sr. No.	Along plan area-RA	Along height-RH
1	RA=0.25	RH=3/8
		RH=6/5
		RH=9/2

2) Setback building of type (S1).

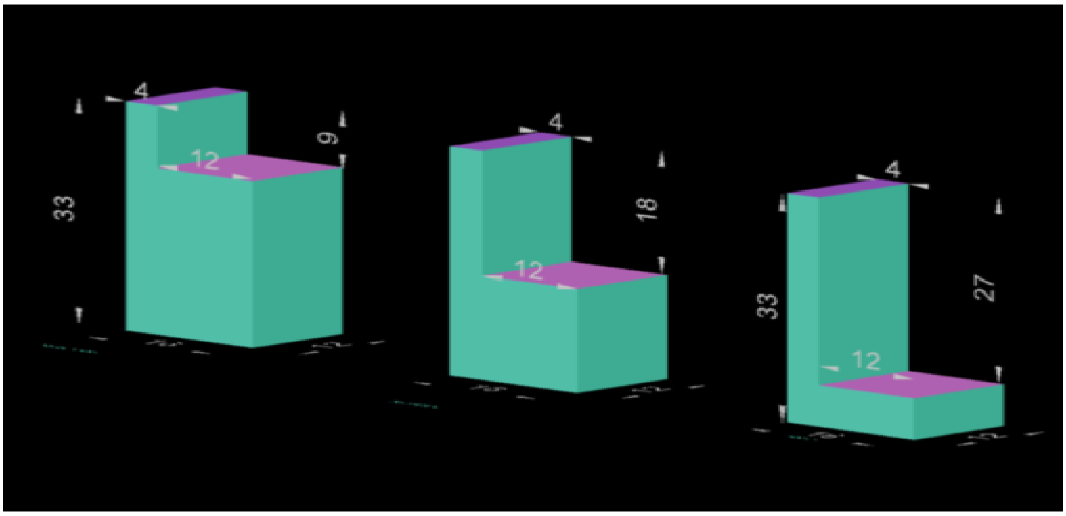


Figure 4: Irregularities in height i.e. RA=0.25 and RH=3/8, RH=6/5, RH=9/2.

Table No. 5-Setback Critical Ratios S2

Sr. No.	Along plan area-RA	Along height-RH
1	RA=0.50	RH=3/8
		RH=6/5
		RH=9/2

3) Setback building type (S2).

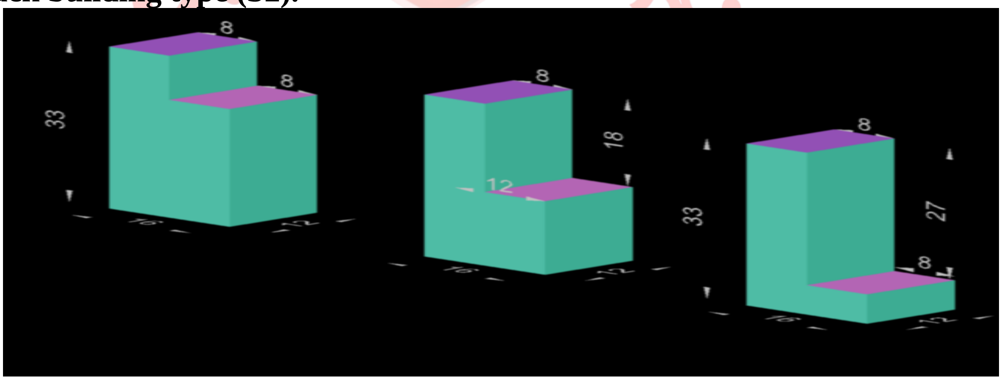


Figure 5: Irregularities in height i.e. RA=0.50 and RH=3/8, RH=6/5, RH=9/2.

Table No. 3.6-Setback Critical Ratios S3

Sr. No.	Along plan area-RA	Along height-RH
3	RA= 0.75	RH=3/8
		RH=6/5
		RH=9/2

4) Setback building of type (S3).

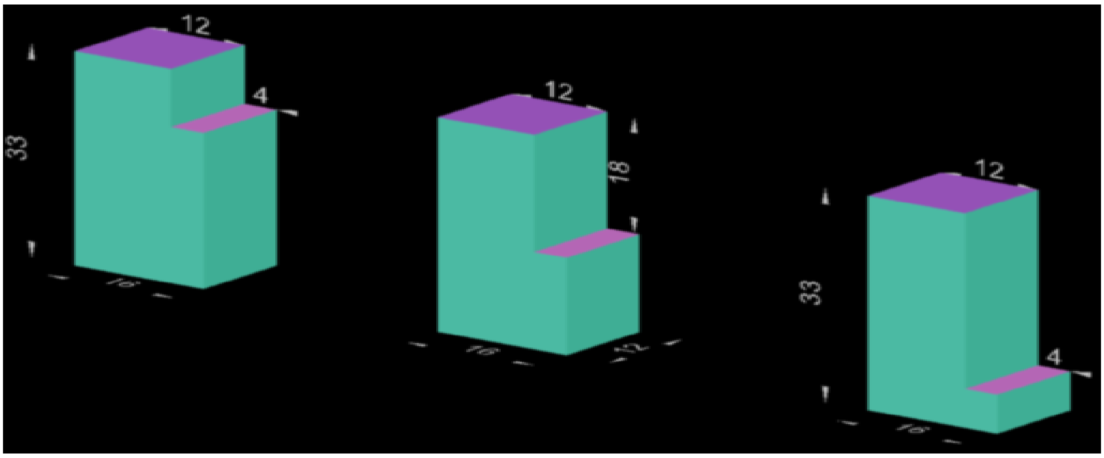
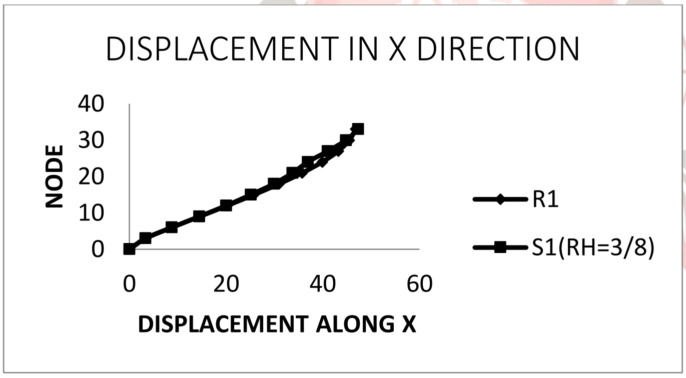


Figure 6 Irregularities in height i.e. RA=0.75 and RH=3/8, RH=6/5, RH=9/2.

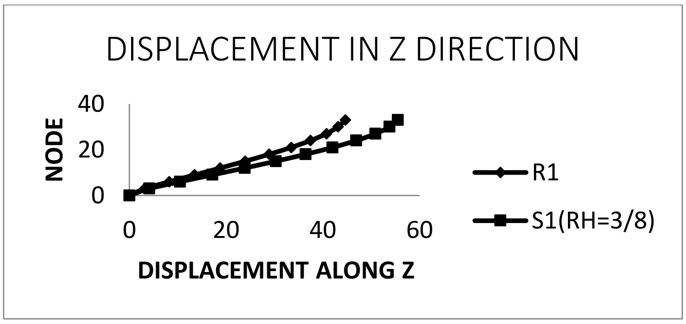
RESULTS AND DISCUSSION

To study the behaviour of architecturally irregular structure nine different model considered with one reference regular model and results and discussions carried out accordingly.

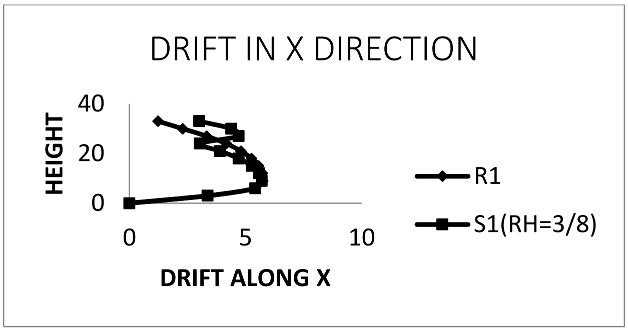
Analysis Result of Critical Setback Ratio- RH=3/8 & RA=0.25 (S1)



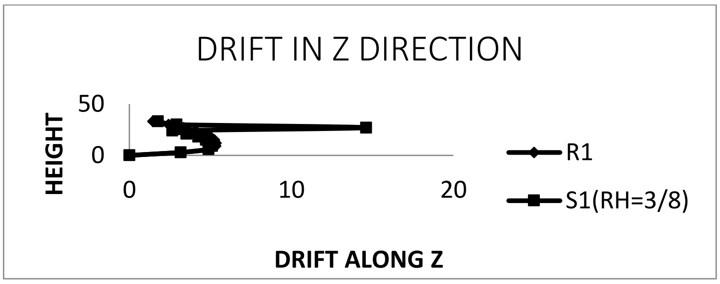
Graph No 7 Graph Showing Displacement in X direction for RA=0.25 and RH=3/8



Graph No 8 Graph Showing Displacement in Z direction for RA=0.25 and RH=3/8

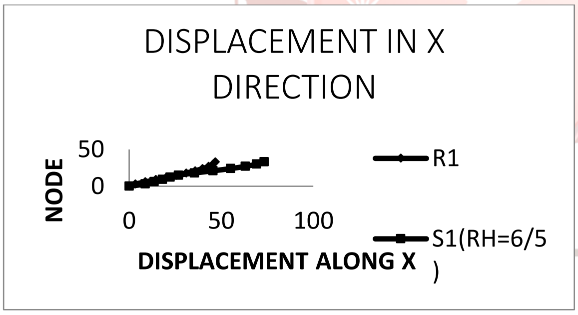


Graph No 9 Graph Showing Storey Drift in X & Z direction for RA=0.25 and RH=3/8

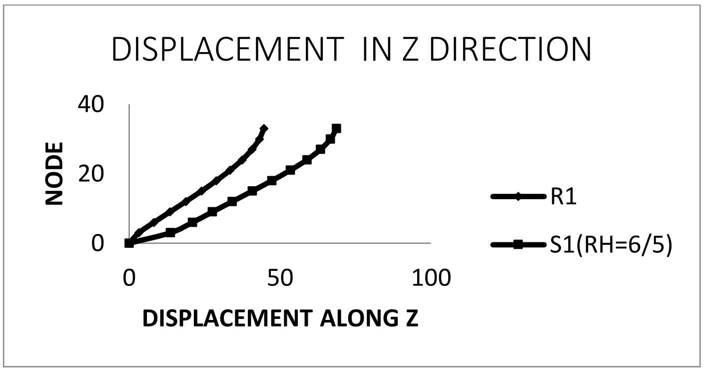


Graph No: 10: Graph Showing Storey Drift in Z direction for RA=0.25 and RH=3/8

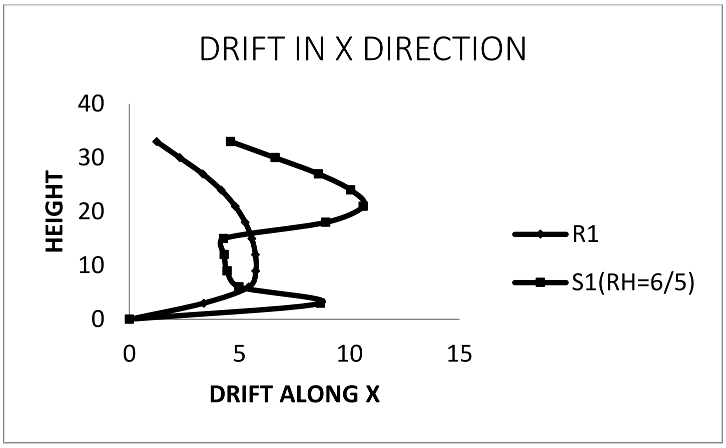
Analysis Result of Critical Setback Ratio- RH=6/5 & RA=0.25 (S1)



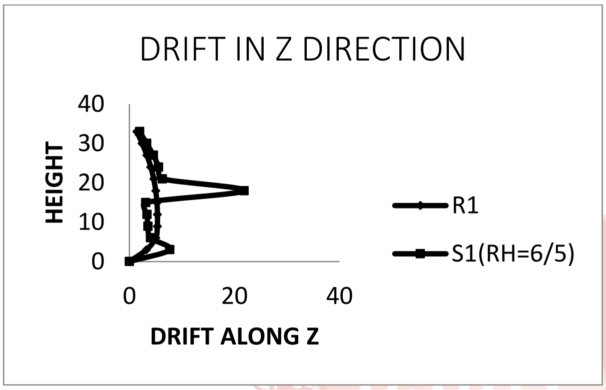
Graph No: 11: Graph Showing Displacement in X direction for RA=0.25 and RH=6/5



Graph No: 12 Graph Showing Displacement in Z direction for RA=0.25 and RH=6/5

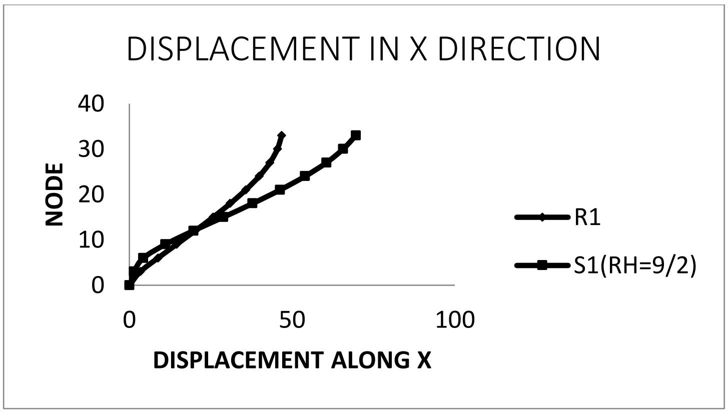


Graph No: 13: Graph Showing Storey Drift in X direction for RA=0.25and RH=6/5

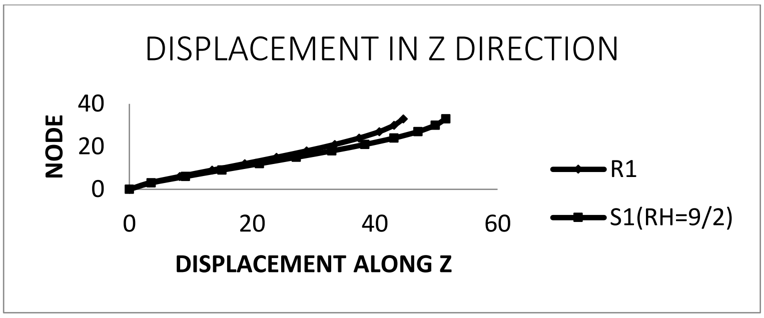


Graph No: 14: Graph Showing Storey Drift in Z direction for RA=0.25and RH=6/5

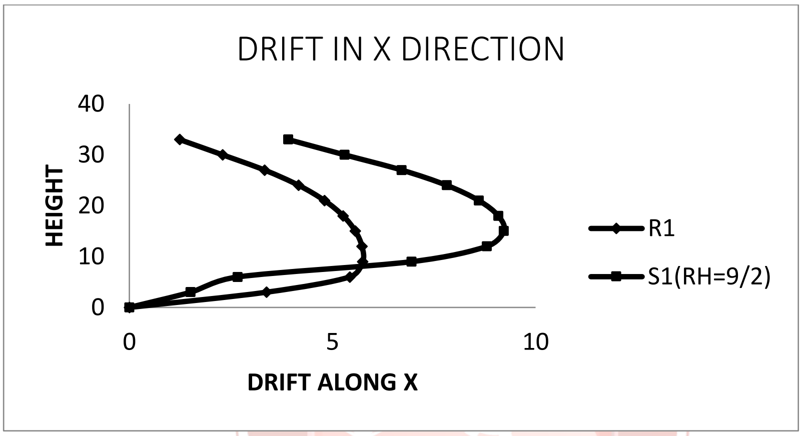
Analysis Result of Critical Setback Ratio- RH=9/2 & RA=0.25 (S1)



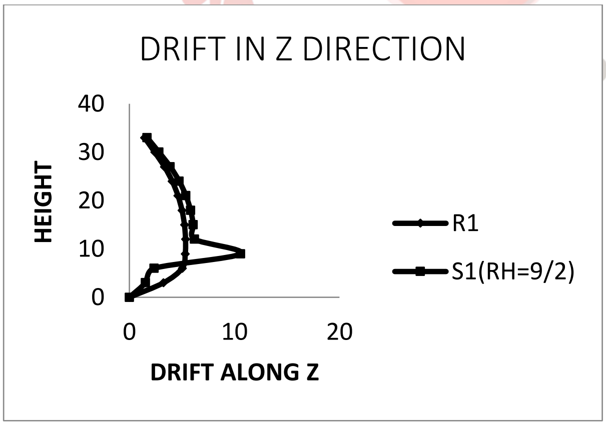
Graph No: 15: Graph Showing Displacement in X direction for RA=0.25 and RH=9/2



Graph No: 16: Graph Showing Displacement in Z direction for RA=0.25 and RH=9/2

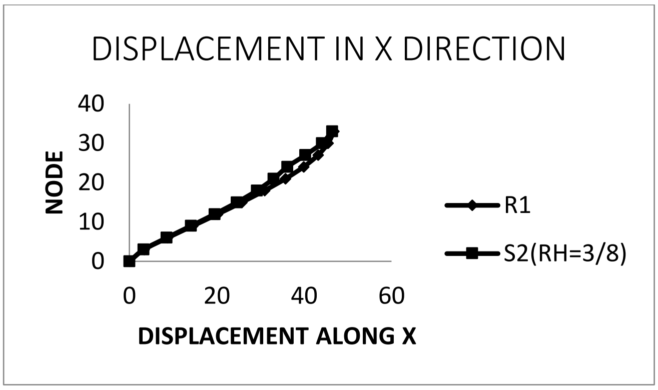


Graph No: 17 Graph Showing Storey Drift in X direction for RA=0.25 and RH=9/2

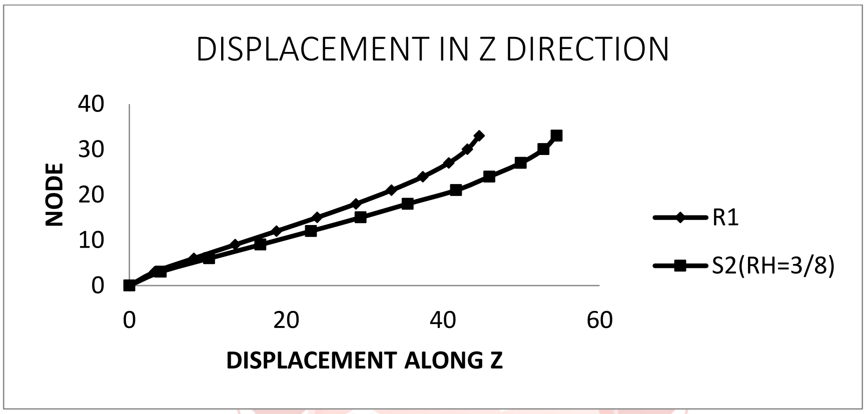


Graph No: 18 Graph Showing Storey Drift in Z direction for RA=0.25 and RH=9/2

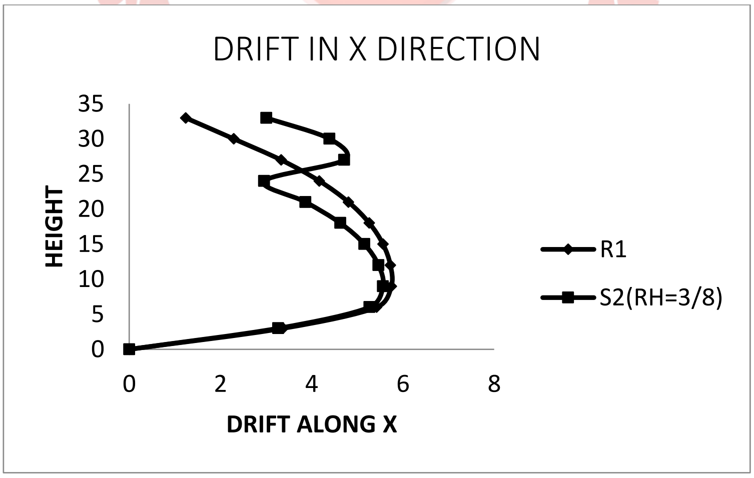
Analysis Result of Critical Setback Ratio- RH=3/8 & RA=0.5 (S2)



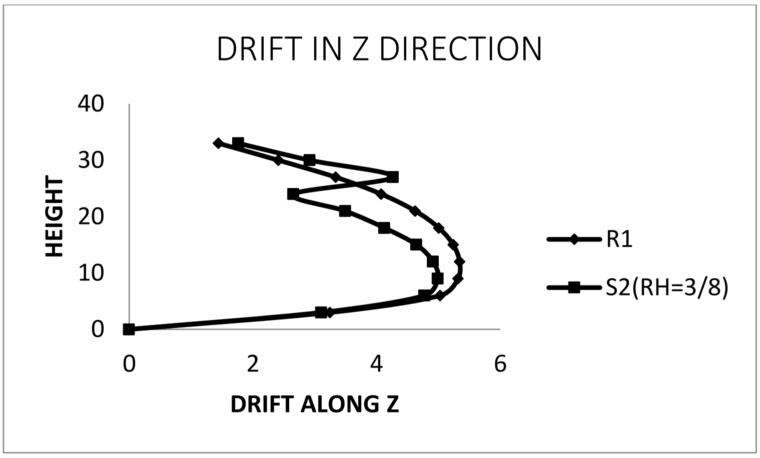
Graph No: 19 Graph Showing Displacement in X direction for RA=0.5 and RH=3/8



Graph No: 20 Graph Showing Displacement in Z direction for RA=0.5 and RH=3/8

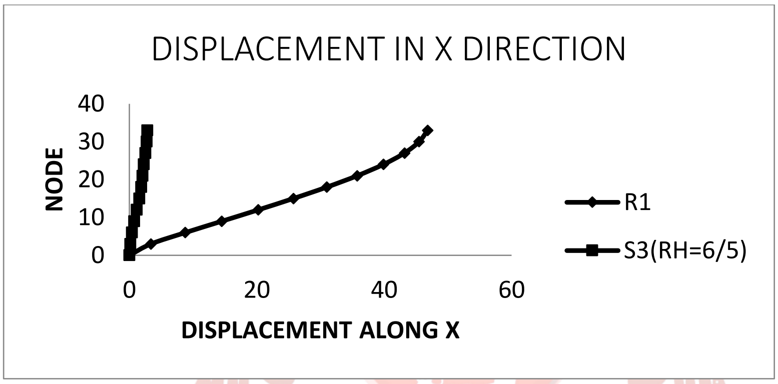


Graph No: 21 Graph Showing Storey Drift in X direction for RA=0.5 and RH=3/8

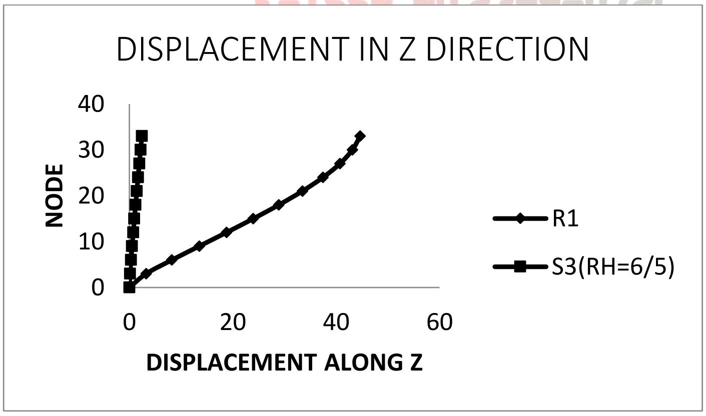


Graph No: 22 Graph Showing Storey Drift in Z direction for RA=0.5 and RH=3/8

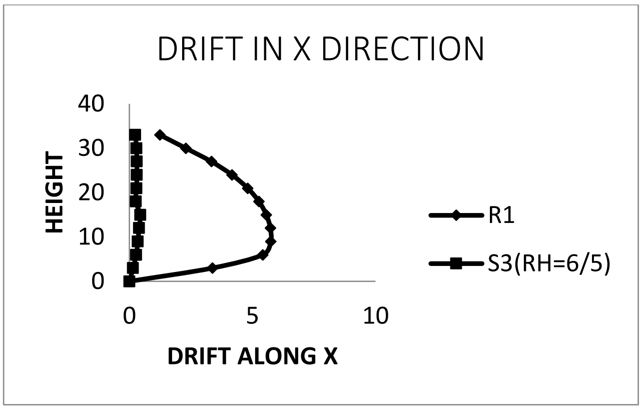
Analysis Result of Critical Setback Ratio- RH=6/5 & RA=0.75 (S3)



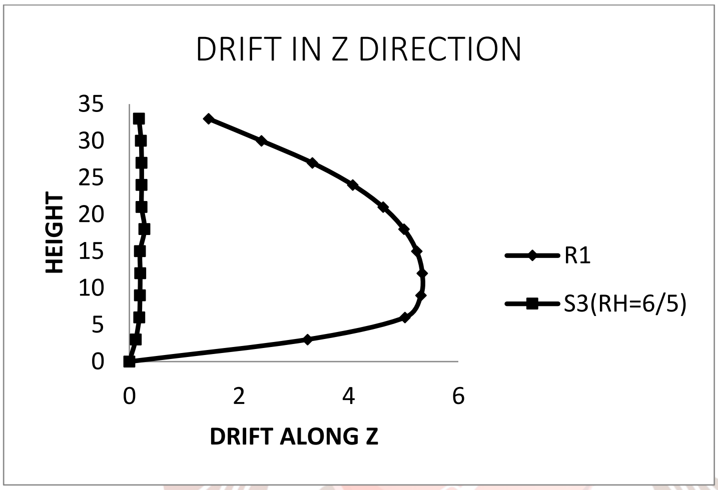
Graph No: 23 Graph Showing Displacement in X direction for RA=0.75 and RH=6/5



Graph No: 24: Graph Showing Displacement in Z direction for RA=0.75 and RH=6/5

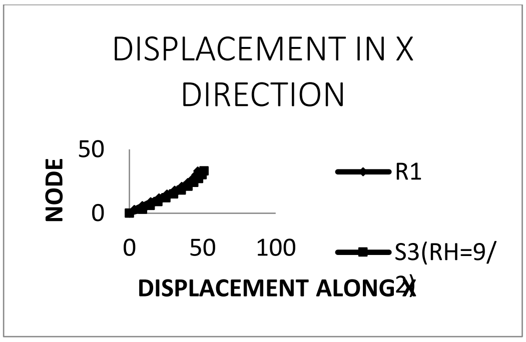


Graph No: 25 Graph Showing Storey Drift in X direction for RA=0.75 and RH=6/5

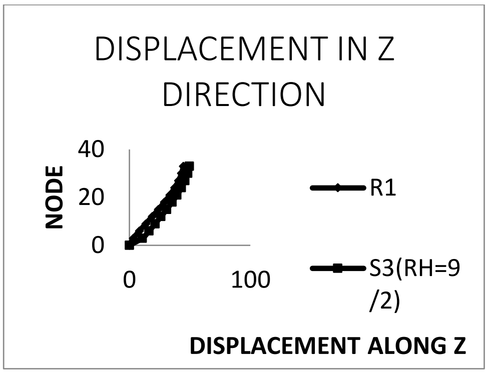


Graph No: 26 Graph Showing Storey Drift in Z direction for RA=0.75 and RH=6/ **Analysis**

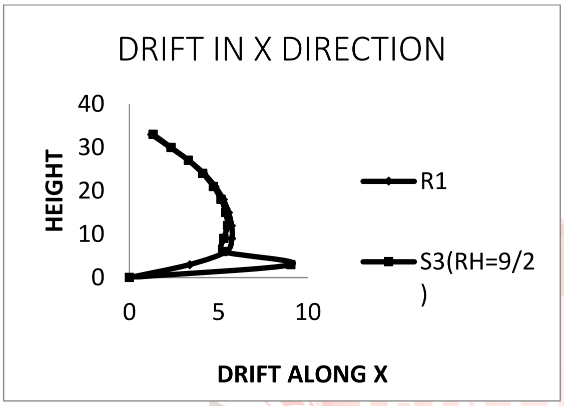
Result of Critical Setback Ratio- RH=9/2 & RA=0.75 (S3)



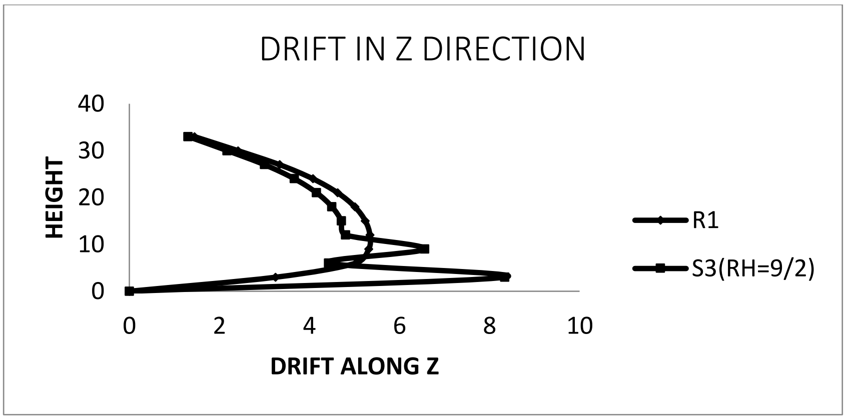
Graph No: 27 Graph Showing Displacement in X direction for RA=0.75 and RH=9/2



Graph No: 28 Graph Showing Displacement in Z direction for RA=0.75 and RH=9/2



Graph No: 29 Graph Showing Storey Drift in X direction for RA=0.75 and RH=9/2



Graph No: 30 Graph Showing Storey Drift in Z direction for RA=0.75 and RH=9/2

CONCLUSIONS

Depending on result obtain from analysis of model using different permutation and combinations of architecturally irregular structures and its variations in nodal displacement and story drift are presented in results and discussion chapter. Following conclusion can be draw from the obtaining result,

1) Critical setback ratio RA=0.25 and RH=6/5 shows the variation in story drift which signifies the jumping of the forces due to unequal distribution of mass along the plan as well as along the height.
2) The optimum value of critical setback ratios mainly RA and RH comes out to be RA=0.75 and RH=6/5. Above value complies with the criteria given in IS 1893 2016 for considering the structure to be irregular.
3) From the obtained results it may be concluded that the irregular structures must be treated with proper understanding and by following the codal provisions given in the code.
4) It may also be concluded that the revision of seismic codes provisions for geometric vertical irregularities seems to be essential to stipulate more restrictive limits or apply more accurate analytical procedures to predict the seismic performance of setback structures under the seismic excitations, especially for structures with critical setback ratios.

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