Analytical Study on Horizontal Irregularities in Buildings under Seismic Load with and without Shear Wall

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ABSTRACT

Majority of buildings collapse under the action of dynamic loads which includes earthquake and wind loads. The greatest challenge to any structural engineer in present scenario is designing of seismic resistant irregular structures. Irregular buildings are those devoid of symmetry with discontinuity in geometry, mass or load resisting elements. Irregularities in construction of buildings are unavoidable and they constitute a large portion of modern urban infrastructure. In this present study, the behavior of three G+10 storied buildings with differing plans have been considered; one square shaped regular model and other two H shaped and hexagonal shaped models with horizontal irregularities. The total built-up area is 605.10 m^2. All the models are located in Bangalore region with a seismic Zone factor 0.1(zone –II). Analysis of all the models was carried out using ETABS 2016.0.3 software. Linear static analysis method was used for the study of different parameters like storey drift, storey displacement, storey shear, shear force and bending moment with and without shear wall. Comparison between three models with these parameters were done and it was found that the H-shaped model with shear wall gave better resistant to seismic load compared to other models and hence was chosen as the best frame.

Keywords: Earthquake, Seismic Behavior, Shear Wall, Horizontal Irregularity, Linear Static Analysis, Storey Drift, Storey Displacement, Storey Shear, Bending Moment, Shear Force.

1. INTRODUCTION

The shaking of the earth's surface resulting from the sudden release of energy in the earth's lithosphere which creates seismic waves is called an earthquake. Earthquakes occur along the cracks in the earth's surface called fault lines and can be felt over large areas, although they normally last for less than one minute. Most of the time damage to buildings due to earthquake is initiated at a storey which has less column or greater height or heavy mass compared to an adjacent storey. The primary objective in designing an earthquake resistant structure is to ensure that the building has enough ductility to withstand the earthquake load.

The behavior of a building during an earthquake is affected by stiffness, adequate lateral strength, and ductility, simple and regular configurations. Buildings with regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation are damaged to lesser extent compared to irregular configurations. But nowadays need and demand of the latest generation and increasing population has made the architects or engineers inevitable towards planning of irregular structures.

1.1 Irregular Structure

Buildings are described as regular or irregular in terms of their size and shape, arrangements of structural elements and mass. Regular building are almost symmetrical (in plan and elevation) about the axis and have uniform distribution of lateral force –resisting structure such that it provides a continuous load path for both gravity and lateral loads.

A building that lacks symmetry having discontinuity in geometry, mass or load resisting element is called irregular building. These irregularities may cause interruption of force flow and concentration of stresses.

Types of irregularities:

a) Vertical irregularities referring to sudden change in strength, stiffness, geometry and mass results in irregular distribution of forces or deformation over the height of the structure.

b) Plan/Horizontal irregularities which refer to asymmetrical plan shape (L, T, U, F) or discontinuous in horizontal resisting elements (diaphragms) such as cut-outs, large openings, re-entrant corners etc resulting in torsion, diaphragm deformation and stress concentration.

The main aim of this present work is to study the response of horizontally irregular structures under seismic load. For this, three RC building frames; a symmetrical plan configuration of square shape, and unsymmetrical H shaped and hexagonal shaped are chosen ,drafted in Auto CAD 2013 software and ETABS 2016.0.3 software is proposed for the analysis. Suitable Load combinations were selected to get comparative results of the parameters like storey drift, storey shear, storey displacement, shear force and bending moment for these models.

1.2 Shear Wall

A shear wall is a structural system composed of shear panels to counter the effects of lateral loads such as wind and seismic loads acting on a structure. Due to high in-plane strength and stiffness these walls can be used simultaneously for resisting large horizontal and gravity loads. Shear walls are most efficient when they align vertically and are supported on foundation walls or footings. Shear walls transfer the horizontal forces to the next element in the load path below them such as other shear walls, floors, foundation walls, slabs or footing

2. Description of Models

Table 1. Geometric, Structural, Seismic, Loading and Material data for all models

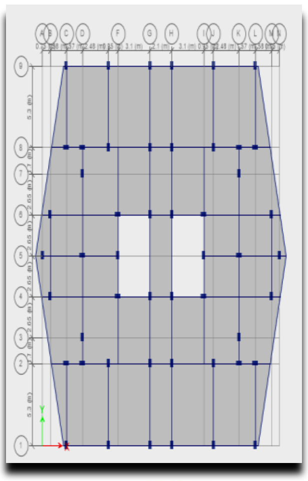
Specifications	**Models-1,2 &3**
Type of structure	SMRF(Special RC Moment Resisting Frame)
Seismic zone	II
Seismic Zone factor,F_o	0.1
Importance factor	1
Type of soil	Medium, Type 2
Number of storey	G+10
Dimensions of building	24.6mX24.6m
Height of Building	30.5m
Built up area(m^2)	605.10
Floor height (typical) (m)	3
Base floor height (m)	3.5
Imposed load (kN/m^2)	2
Floor finish(kN/m^2)	1
Total load on slab(kN/m^2)	10.5

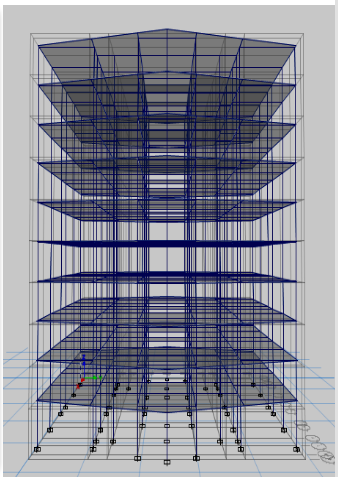
UDL(concrete block masonry wall)	
a) For 3m height wall,300m thick with 20mm plaster on both sides	17.1kN/m
b) Parapet wall considering 1m height	5.7kN/m
Materials	M30&M35 concrete and Fe 415 steel
Size of column	300mmX550mm
Size of beam	300mmX550mm
Depth of slab (mm)	150
Sp. weight of RCC (kN/m^3)	25
Safe bearing capacity,SBC(kN/m^2)	180
Wall thickness	Outer300mm,partition-200mm &150mm

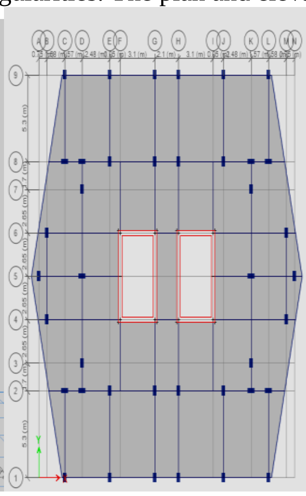
Table 2: Different Load Combinations

1.5(DL)	1.5(DL+LL)	1.2(DL+LL+EQX)	1.2(DL+LL-EQX)	1.2(DL+LL+EQY)
1.2(DL+LL-EQY)	1.5(DL+EQX)	1.5(DL-EQX)	1.5(DL+EQY)	1.5(DL-EQY)
0.9DL+1.5EQX	0.9(DL)-1.5EQX	0.9(DL)+1.5EQY	0.9(DL)-1.5(EQY)	1.2(DL+LL+W)
1.2(DL+LL-W)	1.5(DL+W)	1.5(DL-W)	0.9(DL)+1.5(W)	0.9(DL)-1.5(W)

Analysis portion is done adopting Linear Static Analysis method. A set of three different models with and without shear wall are prepared for the analysis out of which the first model is symmetric with square shape, the remaining two H shaped and Hexagonal shaped models have horizontal irregularities. The plan and elevation of the buildings are sbelow.







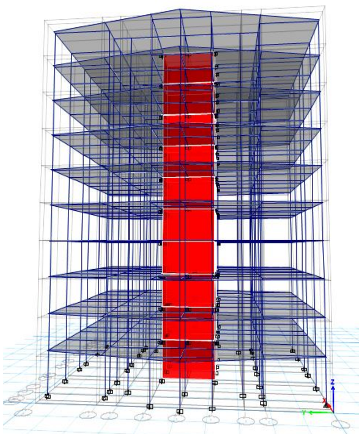


Figure-1: Model A(Hexagonal without shear wall) Figure-2: Model A′ (Hexagonal with shear wall)

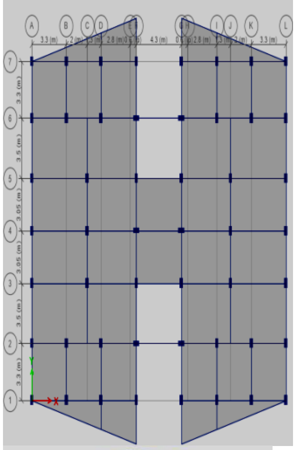
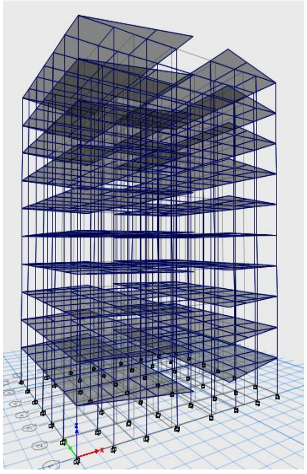
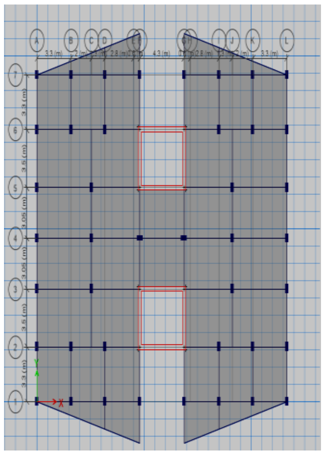
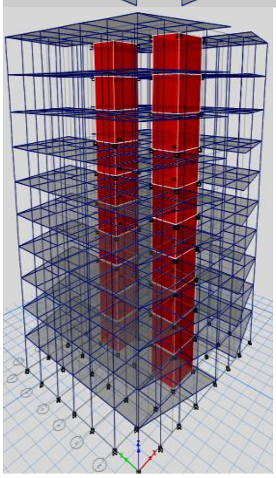





Figure-3:Model B(H shaped without shear wall) Figure-4: Model B′ (H shaped with shear wall)

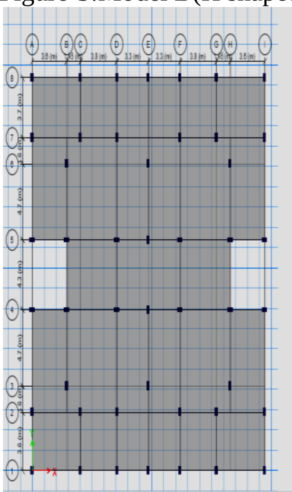
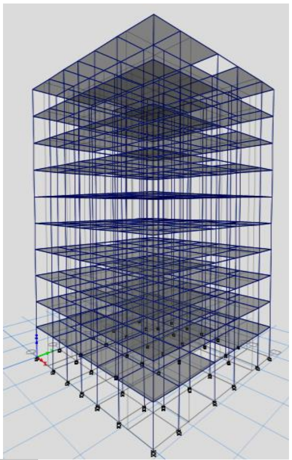
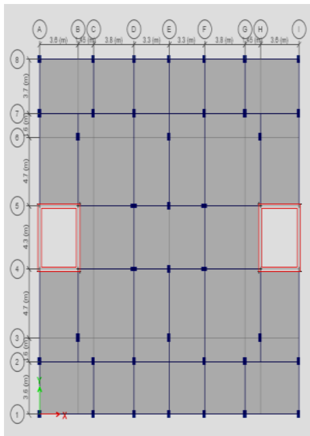
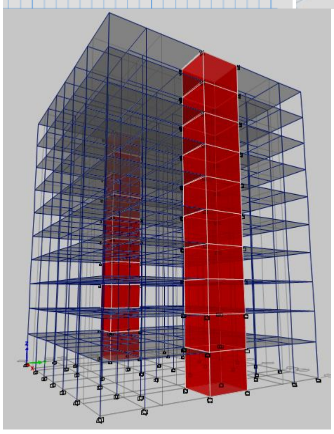





Figure-5: Model C (square without shear wall) Figure-6: Model C′ (square with shear wall)

3. RESULTS AND DISCUSSIONS

Table 3:Storey Drift(mm)

	Without shear wall			With shear wall		
Storey	Model A	Model B	Model C	Model A′	Model B′	Model C′
Base	0	0	0	0	0	0
Story1	0.000363	0.000264	0.000381	0	0	0
Story2	0.000418	0.000333	0.000433	4.70E-05	2.75E-05	3.90E-05
Story3	0.000432	0.000343	0.000431	7.10E-05	4.30E-05	5.80E-05
Story4	0.000438	0.000345	0.000425	9.10E-05	5.60E-05	7.30E-05
Story5	0.000432	0.000338	0.00041	0.000107	6.80E-05	8.60E-05
Story6	0.000414	0.000323	0.000383	0.000118	8.22E-05	9.60E-05
Story7	0.000383	0.000296	0.000344	0.000126	0.000098	0.000102
Story8	0.000338	0.000258	0.000229	0.000131	0.000093	0.000105
Story9	0.000278	0.000207	0.000250	0.000132	0.000099	0.000106
Story10	0.000209	0.000152	0.000137	0.000132	0.000102	0.000106

3.1 Storey Drift

From table 3 it is observed that the storey drift values without shear wall of H-shaped model @storey 2 was 27% less compared to model A and 23 % less than model C. It was also seen that with the use of shear wall the drift value of this model was 41% less compared to Model A′ and 29% less compared to model C′.

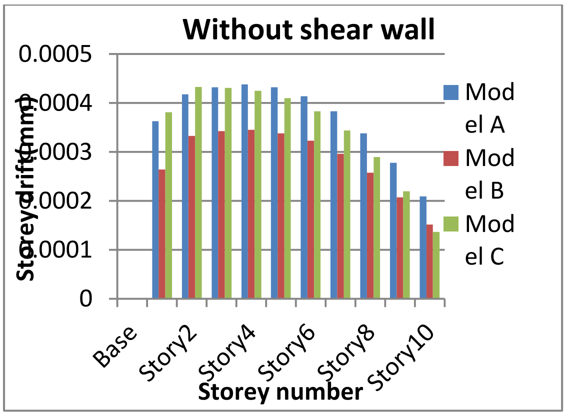


Figure-7: Storey Drift without shear wall

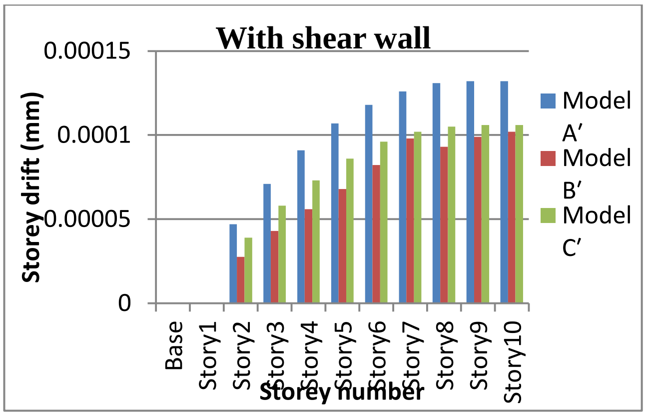


Figure-8: Storey Drift with shear wall

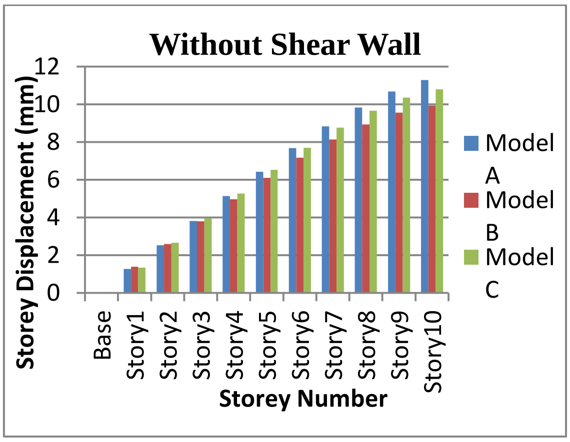
Table 4:Storey Displacement

	Without shear wall			With shear wall		
Storey	Model A	Model B	Model C	Model A′	Model B′	Model C′
Base	0	0	0	0	0	0
Story1	1.271	1.382	1.344	0	0	0
Story2	2.524	2.592	2.658	0.142	0.132	0.118
Story3	3.82	3.789	3.971	0.35	0.279	0.285
Story4	5.134	4.97	5.268	0.621	0.492	0.503
Story5	6.431	6.108	6.523	0.939	0.653	0.76
Story6	7.674	7.174	7.701	1.293	0.896	1.044
Story7	8.824	8.132	8.764	1.67	1.028	1.348

Story8	9.838	8.941	9.666	2.06	1.488	1.661
Story9	10.672	9.555	10.357	2.454	1.625	1.979
Story10	11.296	9.933	10.797	2.848	2.532	2.795

3.2 Storey Displacement

From table 4 it is observed that the model B has least story displacement than the other 2 models. The successive storey displacement values between storey 9 &10 of H-shaped model was 68% less compared to successive storey displacement values between storey 1 &2.



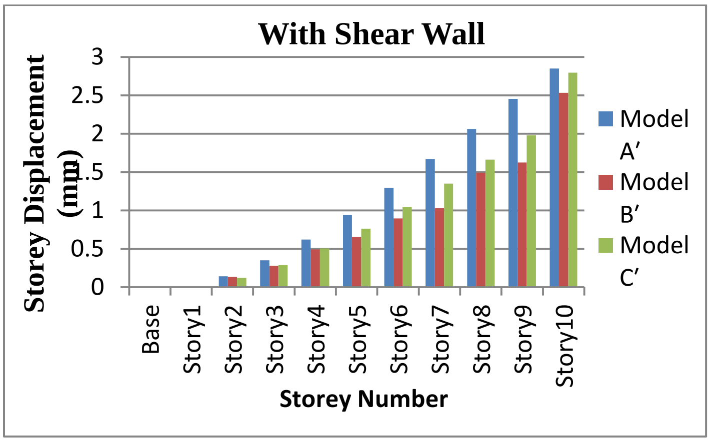


Figure-9: Storey Displacement without shear wall **Figure-10: Storey Displacement with shear wall**

Table 5: Storey Shear

	Without shear wall			With shear wall		
Storey	Model A	Model B	Model C	Model A′	Model B′	Model C′
Base	0	0	0	0	0	0
Story1	721.398	679.0025	665.2167	614.0163	420.177	160.577
Story2	718.8851	676.6297	662.9016	238.754	237.888	237.6147
Story3	710.3218	668.5589	655.0148	241.3706	238.235	234.4677
Story4	692.0298	651.3189	638.1677	234.7394	229.238	227.8941
Story5	660.3608	621.4713	609.0003	215.3531	215.889	216.3326
Story6	611.6665	575.5777	564.1525	195.4179	197.239	198.4492
Story7	542.2987	510.1995	500.2642	167.2106	169.456	172.8917
Story8	448.6091	421.8983	413.9753	129.5909	135.963	138.3051
Story9	326.9494	307.2357	301.9258	81.3771	86.965	93.4083
Story10	173.6714	162.7733	160.7556	16.2213	26.759	36.0094

3.3 Storey shear

All the storey shear values are found to be higher at lower stories and least at the top stories, which is satisfactory. Model B with shear wall showed the lesser storey shear at the top in comparison to all models analyzed.

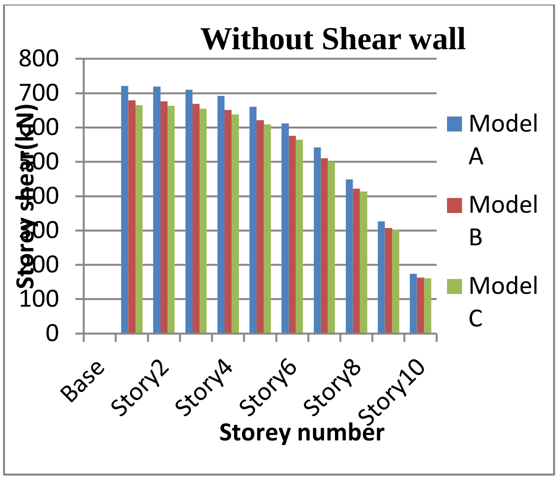


Figure-11: Storey Shear without shear wall

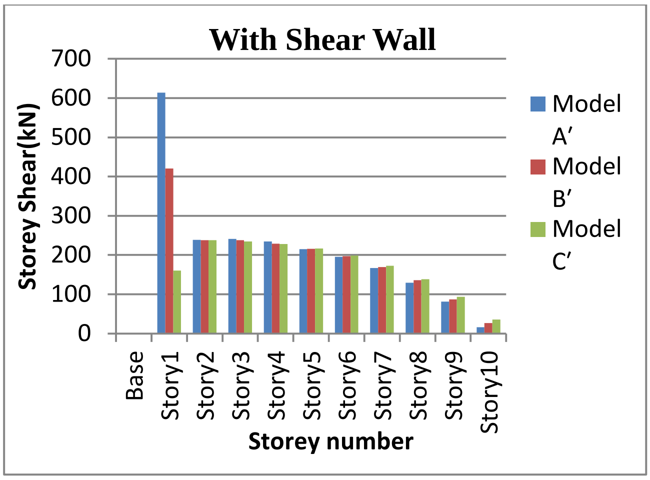


Figure-12: Storey Shear with shear wall

3.4 Shear Force

Table 6:Shear Force						
	Without shear wall			With shear wall		
Column	Model A	Model B	Model C	Model A′	Model B′	Model C′
C-37(storey 1)	14.0937kN	15.3031kN	24.3059kN	4.9829kN	5.2857kN	6.987kN

Shear force for model B with shear wall was found to be 65% less than without shear wall.

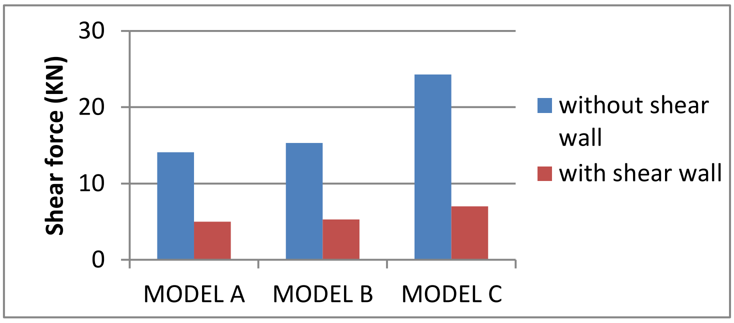


Figure-13: Shear Force of models with & without shear wall

3.5 Bending Moment

Table 7:Bending Moment						
	Without shear wall			With shear wall		
Column	Model A	Model B	Model C	Model A′	Model B′	Model C′
C-37(storey 1)	5.339kN-m	9.424kN-m	20.8337kN-m	4.6483kN-m	6.8369kN-m	11.6764kN-m

Bending moment for H-shaped model with shear wall was found to be 27% less than without shear wall.

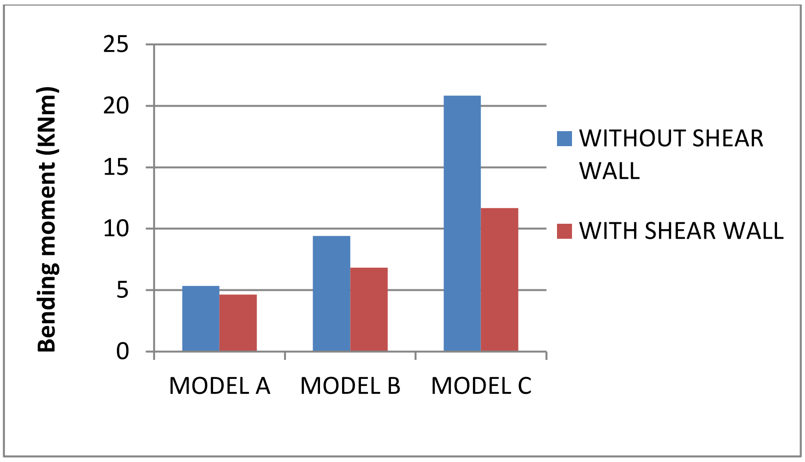


Figure-14: Bending Moment of models with & without shear wall

4. CONCLUSIONS

The following conclusions were made from the obtained results.

1) Out of the different models analyzed, horizontally irregular H-shaped models was found to be better in resisting seismic load.
2) Horizontally irregular H-shaped model with shear wall is an efficient structure than without shear wall.
3) The storey drift of H shaped model at the 10th storey without shear wall was found to be 33% more compared to H-shaped model with shear wall.
4) The inter-storey displacement values between storey 9 &10 of H-shaped model with shear wall was found to be 68% less compared to successive storey displacement values between storey 1 &2.
5) The storey shear value for H shaped model with shear wall between two successive storey's 1 & 2 was reduced to 43% in comparison to that without shear wall where there was only 3% reduction.
6) With the introduction of shear wall, load on column of H-shaped model was reduced by 65%.
7) Bending moment for H-shaped model with shear wall was found to be 27% less than without shear wall. This shows that 27% of load is carried by the shear wall.

5. Future scope of Work

a) Analysis can be carried out on different shapes of horizontal irregularity, vertical irregularity and combinations of both vertical and horizontal irregularity.
b) Analysis can also be done for other types of building such as industrial, commercial etc as per IS-875:1987(part-1).
c) Nonlinear dynamic analysis study is required in order to understand the complete behavior of irregular structure from linear stage to the collapse stage. This is possible only by performing the simulation using Applied Element Method [5] coding or Finite Element Method.
d) Analysis can also be carried out by considering other different soil type like hard soil, soft clay soil and hard rocky soil.
e) Present work can also be carried out by considering the different earthquake zone like zone III, zone IV and zone V as per IS-1893:2002.

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