SEISMIC ANALYSIS F0R STANDARD AND VERTICALLY IRREGULAR RCC FRAME BUILDING WITH S0FT ST0REY AT VARI0US LEVELS

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Abstract - "Soft story" and "weak story" are irregular building configurati0ns that are significant source of serious earthquake damage. These configurations that are essentially originated due to architectural decisions have long been recognized by earthquake engineering as seismically vulnerable. In terms 0f seismic regulations their irregular condition requires the application of special considerations in their structural design and analysis

The present study to understanding the behavior of regular and irregular shape of RC structure subjected to seismic forces and the analysis are carried out for different load combination as per IS codal provisions. A G+14 structure is considered with regular and vertically irregular structure. However in the present study s0me important parameters are studied, like storey displacement, inter storey drift, Top storey displacement, Base shear and Time period.

Key Words: **Soft storey, Irregular structure, Seismic regulation, ETABS, Structural analysis, Storey displacement, Storey drift, Time period.**

1. INTRODUCTION

Building is a structure that people use it as a place to live, work, or store their belongings. There is already a scarcity of land for the construction of new buildings. Vertical development allows for faster growth in both residential and industrial areas. Tall Buildings are being constructed on a wide scale due to their importance. Some irregular shape structures are used for architectural appearance, ventilation purpose etc. The tall buildings require a realistic method of transporting people vertically and economical method of Construction. The development of elevators and modern metal frame constructions removed the limitation on the height of the building. Today with the advantage of computers, new structural systems are conceivable and applied to extremely tall buildings allowing the engineer to evaluate the new configurati0n for economical aspects.

A structure must fulfill a variety of functions. Among these are the building's usefulness for its intended usage and occupancy, structural protection, fire safety, and hygienic, ventilation, and daylight standards enforcement.

In urban India, reinforced concrete (RC) frame buildings are becoming more common. Because of the scarcity of land, many such buildings built recently have a unique feature: the ground storey is left open for parking as shown in Fig 1.1, i.e. columns in the ground storey do not have any partition walls (either masonry or RC) between them. These structures are known as open ground storey (OGS) structures. For most urban multistory buildings, open storey is now an inevitable characteristic for car parking, stores, and other uses. Since the first storey are made up of only columns and the upper storey's are separated by solid walls, the open storey becomes soft and frail in comparison to the other upper storey's.

Figure 1.1: An example of an open Ground Storey structure.

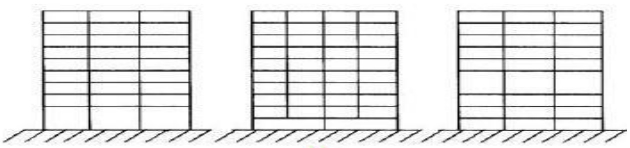
1.1 VERTICAL IRREGULARITIES IN BUILDING

Buildings with vertical irregularities are a common feature in urban areas. Buildings become vertically irregular in most cases during the planning stage for architectural and functional purposes. Many studies in the deterministic domain have been conducted in this field. As a result, the current research focuses on evaluating the relative outputs of traditional vertically irregular buildings in a probabilistic domain. This form of irregularity develops as a result of a sudden loss of stiffness or strength in a particular storey.

1.2 IS 1893 DEFINITION OF VERTICALLY IRREGULAR STRUCTURES

The irregularity of structural system may be because of inconsistent mass, weight, and stiffness distributions along the building's height. When these structures are built in high seismic zones, study and design of the structure become more difficult.

The types of irregularities for buildings are listed below, according to IS 1893



(a)

Figure 1.2 (a) Stiffness/strength irregularity

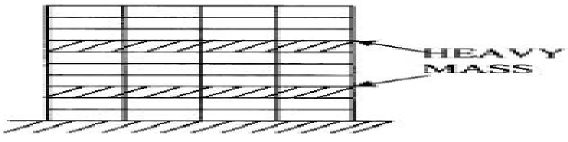


Figure 1.2(b) Mass irregularity

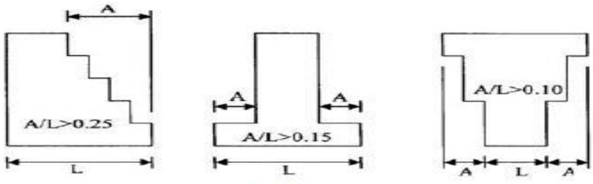


Figure 1.2 (c) Vertical ge0metric irregularity 0r set-back

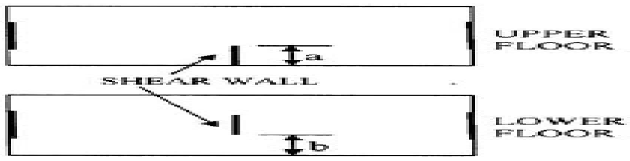


Figure 1.2 (d) In-plane discontinuities in lateral-force-resisting vertical elements when b > a: plan view (after BIS, 2002).

1.3 BARE FRAME BUILDING

According to the Indian standard code for earthquake resistance system design, the contribution of infill is ignored when constructing a structure. The structures are constructed as a bare frame, with only the arrangement of columns and beams taken into account. This is the worst case in terms of seismic vulnerability as opposed to other building styles where the vulnerability is more against lateral loads due to the lack of infill.

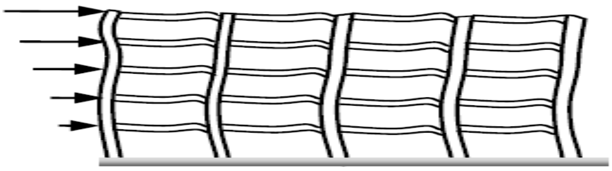


Fig 1.3: Bare Frame Compatibility with lateral load

1.4 INFILL MASONRY BUILDING

Standard infill masonry buildings are common structures with infill walls spread uniformly across the framework to raise its strength and stiffness. Infill walls are considered a non-structural element in the convenience of design practice, according to the IS code. In reality, however, the presence of infill walls induces a strut compressive action acting diagonally in the opposite direction of the lateral force application, which can attempt to combat the lateral force that causes fewer deflections. The only way for bending moments and shear forces to grow in various beams and columns in a bare frame is via rigid jointed moti0n of the beam-column joints. However, in an infill structure, strut movement results in reduced bending moments but increased axial forces in the beams and columns, resulting in reduced bending moments but increased axial forces in the beams and columns.

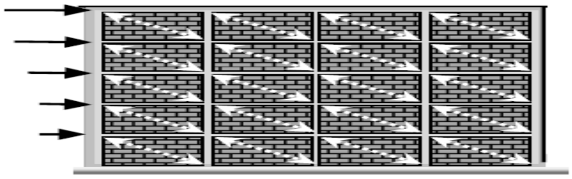


Fig 1.4: Behavior of fully frame under lateral load

1.5 OPEN GROUND STOREY BUILDING

The stiffness abruptly decreases due to the absence of infill walls at the ground storey and the presence of infill walls at all storeys above, which is referred to as stiffness irregularity. The ground storey columns register the base shear. Increased shear force leads to increased bending moment and, as a result, higher curvature, which can lead to higher inter-storey drift formation at the ground storey, which is aided by the P-effect, resulting in the formation of plastic hinges. The upper store will be moved in one piece. Soft storey collapse is the name given to this form of collapse.

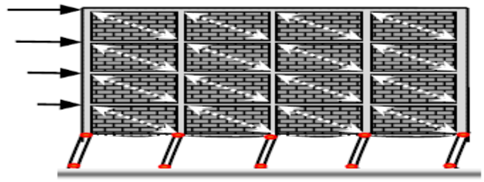


Fig 1.5: Behavior 0f OGS frame under lateral load

1.6 STEPPED BUILDING

The term "stepped house" refers to a reduction in the lateral dimension of a structure along its height. These styles of buildings are preferred in modern multi-story building design due to their functional and aesthetic architecture. The main key features of structure are that it offers excellent ventilation and adequate sunshine to the lower storey's, as well as compliance with building bye-law floor area ratio restrictions. Stepped structures are used to raise the heights of masonry structures by distributing the gravity loads produced by building materials like brick, stone, and other materials.

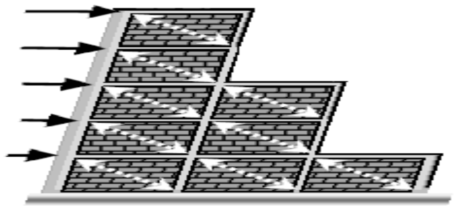


Fig 1.6: Behavior of stepped building under lateral load

1.7 ADVANTAGES OF SOFT STOREY AND STEPPED BUILDING

- Mainly for the Parking purpose.
- Astonishing view, because of aesthetic architectural design.
- Stepped building provides good ventilation and sun lights to the lower storeys.

- Stepped building reduces, gravity loads such as dead load of the materials used in the upper storeys.

1.8 DISADVANTAGES OF SOFT STOREY AND STEPPED BUILDING

- Soft storeys will posses less stiffness and rigidity.
- In soft storey columns, core concrete is crushed, lateral bonds break, and longitudinal support bars buckle.
- Easy in damage and collapse of building under lateral loads.
- The soft storey's displacement, or storey drift, is significantly higher than the infill storey's.

1.9 OBJECTIVES OF THE WORK

The aim of this research is to better understand the behavior of normal and irregular shapes of RC structures when subjected to seismic forces, and to conduct analyses for various load combinations in accordance with IS codal provisions. However, in this analysis, some main parameters are investigated. Based on these parameters that shape the present analysis, the following objectives were established.

- To examine three structural irregularities: mass, stiffness, and vertical irregularities.
- To understand the behaviour of the building model when accounting for the impact of the soft storey in seismic zone V.
- T0 identify the most vulnerable model considered in sever seismic zone V.
- Considering the impact of soft storey, among the considered irregular shape of model which is more suitable.

1.10 LIMITATIONS OF THE STUDY

- Only RC structures are taken into account.
- The column was designed to be fixed to the ground.
- Masonry infill is introduced only for the Periphery walls.
- In this analysis, only one earth quake zone, namely zone V, is taken into account.

2. M0DELING

2.1 GENERAL DETAILS 0F BUILDING

In this analysis, the ETABS software is used to examine two separate buildings, a normal and a vertically irregular building, in which soft st0reys were supported at different levels. The properties of the building configuration considered in this study are stated below. It is assumed that the structural material is isotropic and homogeneous. Masonry infill wall was used to model the joint between the building elements (beam and columns). Masonry infill is only used on the periphery wall.

Table 2.1: Specifications of Building

Modelling details of building			
PLAN DIMENSION			50 x 30m
SPACING B/W FRAME			5 m in all directions
N0. OF STOREY			Ground+14
STOREY HEIGHT	Ground storey		3.5 m
	Upper storey		3.5 m
BUILDING FRAME SYSTEM			ORDINARY MOMENT RESISTING FRAME (OMRF)
BUILDING USE			COMMERCIAL
FOUNDATION TYPE			FIXED
SEISMIC ZONE			ZONE-V
SOIL TYPE			MEDIUM SOIL
IMPORTANCE FACTOR (I)			1
RESPONCE REDUCTION FACTOR (R)			3
DAMPING RATIO			5%
MATERIAL PROPERTIES			
CONCRETE GRADE			M20
			M25
			M30
STEEL GRADE			Fe-415
GRADE OF CONCRETE WITH ITS YOUNG'S MODULUS (E)		M20	22.36×10^6 KN/m^2
		M25	25×10^6 KN/m^2
		M30	27.38×10^6KN/m^2
DENSITY OF CONCRETE			25 kN/m^3
POISSI0N'S RATIO OF CONCTERE			0.20
MODULUS OF ELESTICITY OF INFILL			4675×10^3 kN/m^2
COMPRESSIVE STRENGTH OF INFILL			1.9kN/m^2
DENSITY OF INFILL			19kN/m^3
P0ISSI0N'SRATI0OF INFILL			0.15
STRUCTURAL MEMBERS			
SLAB THICKNESS			150 mm (M20c0ncrete)
WALL THICKNESS			200mm
C0LUMN SIZE IN DIFFERENT ST0REY'S	St0rey 1-5	M30	0.75m×0.4m
	St0rey 6-10	M25	0.75m×0.3m
	St0rey 11-15	M20	0.6m×0.25m
BEAM SIZE IN DIFFERENT ST0REY'S	St0rey 1-5	M30	0.6m×0.4m
	St0rey 6-10	M25	0.6m×0.3m
	St0rey 11-15	M20	0.5m×0.25m
ASSUMED DEAD L0AD INTENSITIES			
R00F			2.0 KN/m^2
FL00R			2.0 KN/m^2
LIVE L0AD INTENSITIES			
R00F			1.5 KN/m^2

FL0OR	4.0 KN/m^2
EARTHHQUAKE & RESP0NCE SPECTRUM L0ADS	
EARTHQUAKE	As per c0de IS 1893(Part-1):2002
RESP0NCE SPECTRA	As per c0de IS 1893(Part-1):2002

2.2 M0DELS C0NSIDERED F0R ANALYSIS

For the purpose of the analysis in this article, two different styles of buildings are considered.
Type 1 - Regular building
Type 2 - Vertically irregular building (Stepped building)

2.2.1 Type-1: Regular Building

Model-1: Bare Frame

This model consists of only frame structure, infill walls are absent for the entire storey in the building.

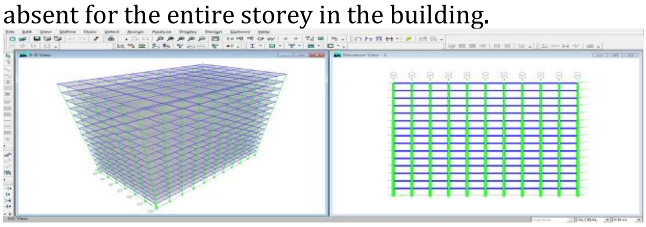


Fig 2.1: ETABS Model Screen short of regular building Model-1

Model-2: Infill Frame

The modification made in this model with respect to Model-1 is infill walls are introduced for the entire storey in the building.

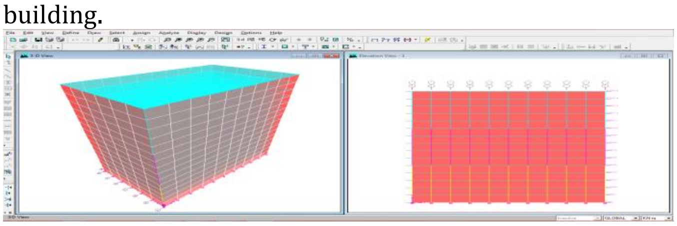


Fig 2.2: ETABS model screen short of regular building Model-2

Model-3: Ground Floor Soft Storey

The modification made in this model with respect to Model-2 is ground floor (first storey) is made as soft storey, that is infill walls are absent in the first storey of the building.

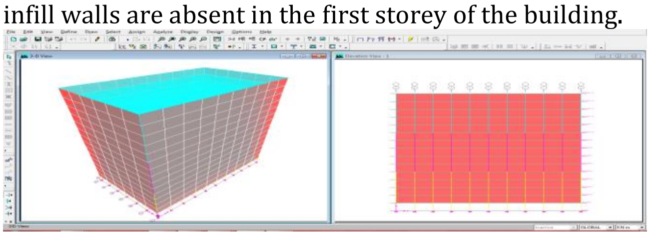


Fig 2.3: ETABS Model screen sh0rt0f regular building Model-3

Model- 4: First Floor soft storey

The modificati0n made in this model with respect to Model-2 is first floor (second storey) is made as soft storey, that is infill walls are absent in the second storey of the building.

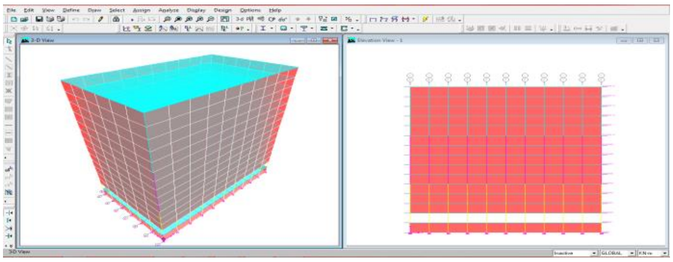


Fig 2.4: ETABS model screen sh0rt0f regular building Model-4

Model- 5: Fourth Floor soft storey

The modification made in this model with respect to Model-2 is fourth floor (fifth storey) is made as soft storey, that is infill walls are absent in the fifth storey of the building.

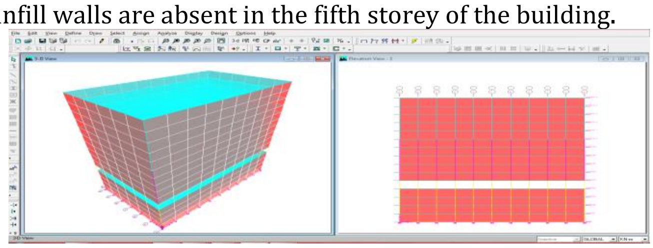


Fig 2.5: ETABS model screen sh0rt0f regular building Model-5

Model- 6: Ninth Floor soft storey

The modification made in this model with respect to Model-2 is ninth floor (tenth storey) is made as soft storey, that is infill walls are absent in the tenth storey of the building.

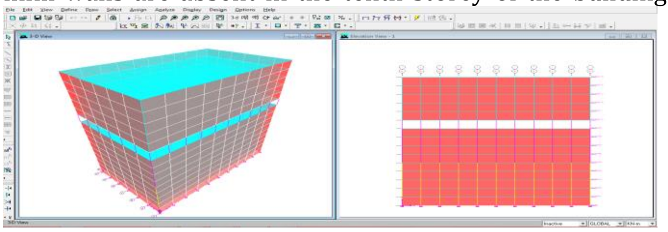


Fig 2.6: ETABS model screen short of regular building Model-6

Model- 7: Fourteenth Floor soft storey

The modification made in this model with respect to Model-2 is fourteenth floor (fifteenth storey) is made as soft storey, that is infill walls are absent in the fifteenth storey of the building.

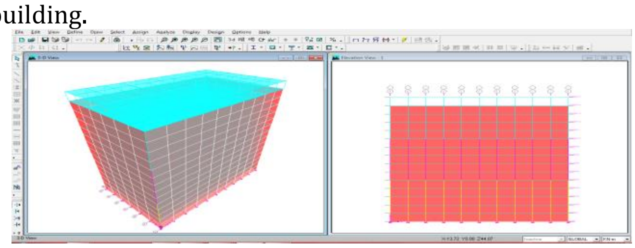


Fig 2.7: ETABS model screen sh0rt0f regular building Model-7

2.2.2 Type - 2: Vertically Irregular Building (Stepped Building)

The modification made in this model with respect to Model-1 is setbacks are provided in 5th and 10th st0rey of the building.

Model-8: Bare Frame

In this model infill walls are absent for the entire storey in the building.

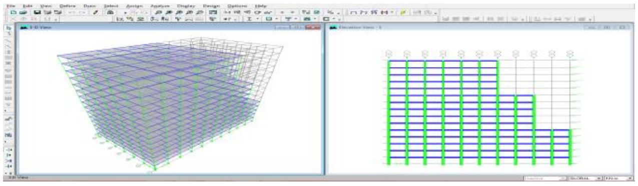


Fig 2.8: ETABS model of an irregular structure Model-8

Model-9: Infill Frame

The modification made in this model with respect to Model-8 is infill walls are introduced for the entire storey in the building.

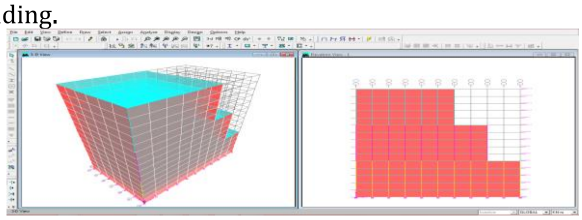


Fig 2.9: ETABS model of an irregular structure Model-9

Model-10: Ground Floor soft storey

The modification made in this model with respect to Model-9 is ground floor (first storey) is made as soft storey, that is infill walls are absent in the first storey of the building.

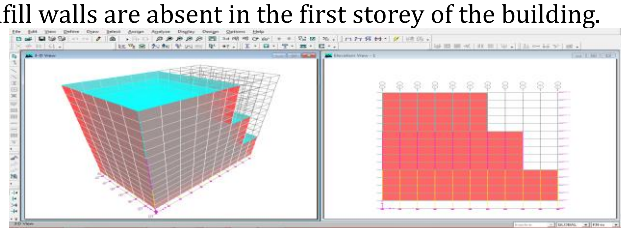


Fig 2.10: ETABS model of an irregular structure Model-10

M0del-11: First Floor soft storey

The modification made in this model with respect to Model-9 is first floor (second storey) is made as soft storey, that is infill walls are absent in the second storey of the building.

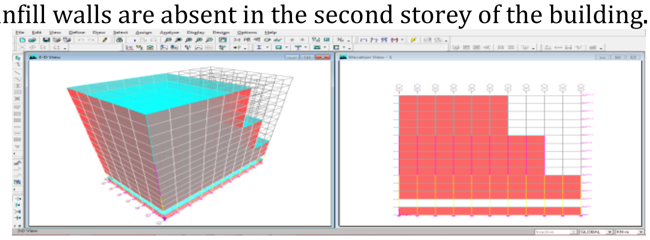


Fig 2.11: ETABS model 0f an irregular structure Model-11

Model-12: Fourth Floor soft storey

The modification made in this model with respect to Model-9 is fourth floor (fifth storey) is made as soft storey, that is infill walls are absent in the fifth storey of the building.

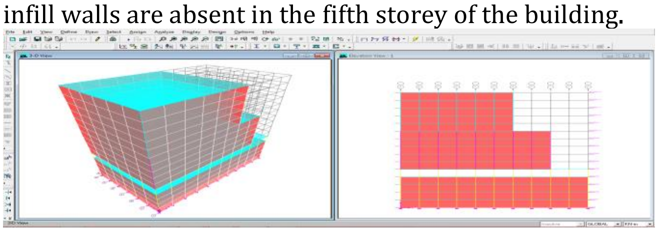


Fig 2.12: ETABS model of an irregular structure Model-12

Model-13: Ninth Floor soft storey

The modification made in this model with respect to Model-9 is ninth floor (tenth storey) is made as soft storey, that is infill walls are absent in the tenth storey of the building.

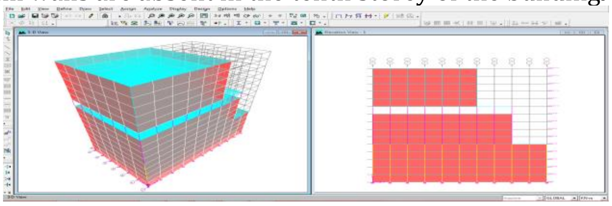


Fig 2.13: ETABS model of an irregular structure Model-13

Model-14: Fourteenth Floor soft storey

The modification made in this model with respect to Model-9 is fourteenth floor (fifteenth storey) is made as soft storey, that is infill walls are absent in the fifteenth storey of the building.

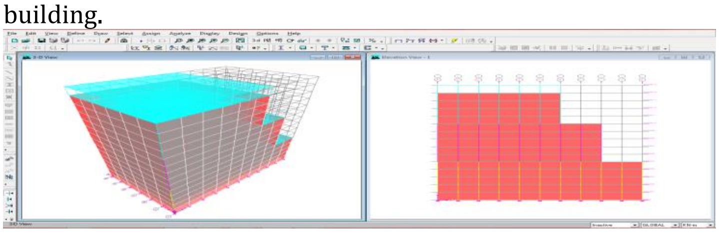


Fig 2.14: ETABS model of an irregular structure Model-14

3. RESULTS AND DISCUSSI0NS

3.1 GENERAL

The outcomes of each building model are discussed in this chapter. The study's findings are obtained using similar static analysis and response spectrum analysis for both typical and vertical abnormal buildings. All models are shown with the results of lateral displacement at the roof, inter storey drift, base shear, and fundamental time span at the first mode. In this analysis, normal and irregular buildings in seismic zone V are compared.

3.2 STOREY DISPLACEMENT AND INTER STOREY DRIFT FOR COMBINATION-1

The results of storey displacement and inter storey drift at various levels for considered models as shown using table and graphs.

3.2.1 Storey Displacement for Type-1 regular Building for Combination-1

The resultant storey displacement at various storey levels for considered models is as indicated in the Table 3.1, and the combined graph is as shown in Fig 3.1 and Fig 3.2. The maximum displacement for the building is obtained in the top storey. From the table we can observe that the Model-1 is having the maximum storey displacement of 95.108mm. The reduction in storey displacement is observed in Model-2 that is 30.085mm. The storey displacement with various location of the soft storey provided (Model-3 to Model-7) in the building are nearly 31.182mm to 34.539mm which are almost nearer values and are slightly higher than that 0f

Model-2. The storey displacement for the Model-2 is lesser than the other models.

Table 3.1:Storey displacement for Type-1 Building

STOREY	Model -1	Model -2	Model -3	Model -4	Model -5	Model -6	Model -7
15	95.10	30.08	31.182	31.595	32.262	34.539	33.517
14	91.882	29.117	30.286	30.750	31.396	33.627	28.908
13	86.303	27.812	29.094	29.623	30.239	32.402	27.551
12	78.523	26.206	27.636	28.245	28.822	30.896	25.988
11	69.110	24.347	25.956	26.656	27.186	29.183	24.161
10	60.000	22.287	24.099	24.898	25.375	27.014	22.131
9	53.637	20.150	22.174	23.077	23.497	18.772	20.020
8	46.919	17.877	20.129	21.142	21.501	16.331	17.770
7	39.839	15.523	18.011	19.138	19.430	14.202	15.435
6	32.574	13.122	15.852	17.095	17.349	12.001	13.053
5	25.692	10.720	13.690	15.050	14.877	9.803	10.666
4	19.827	8.404	11.603	13.072	7.648	7.684	8.363
3	14.019	6.115	9.536	11.148	5.256	5.590	6.087
2	8.310	3.894	7.554	8.840	3.365	3.560	3.877
1	3.067	1.747	5.269	1.897	1.508	1.597	1.739

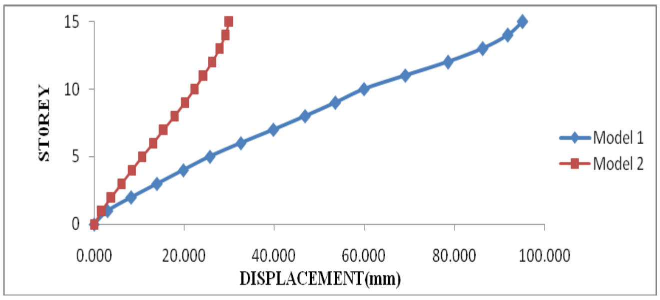


Fig 3.1: Graph of Displacement vs Storey for building Type-1 of Bare and Infill Frame for Combination-1

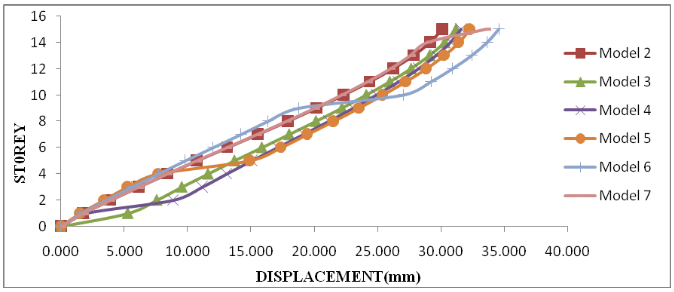


Fig 3.2: Graph of Displacement vs Storey for building Type-1 for Combination-1

Table 3.2 – Inter-storey drift for Type-1 Building

STOREY	Model -1	Model -2	Model -3	Model-4	Model-5	Model-6	Model-7
15	3.227	0.968	0.896	0.846	0.865	0.913	4.609
14	5.578	1.305	1.193	1.127	1.157	1.224	1.357
13	7.781	1.606	1.457	1.378	1.417	1.506	1.563
12	9.412	1.859	1.680	1.589	1.636	1.714	1.827
11	9.111	2.060	1.857	1.757	1.811	2.169	2.030
10	6.363	2.137	1.925	1.821	1.878	8.241	2.111
9	6.718	2.273	2.045	1.935	1.996	2.442	2.250
8	7.080	2.355	2.118	2.004	2.071	2.129	2.334
7	7.265	2.401	2.159	2.043	2.080	2.201	2.383
6	6.882	2.402	2.162	2.045	2.473	2.198	2.387
5	5.865	2.316	2.087	1.978	7.229	2.119	2.303
4	5.808	2.289	2.067	1.924	2.392	2.093	2.276
3	5.709	2.221	1.983	2.307	1.891	2.031	2.210
2	5.243	2.147	2.284	6.943	1.857	1.963	2.138
1	3.067	1.747	5.269	1.897	1.508	1.597	1.739

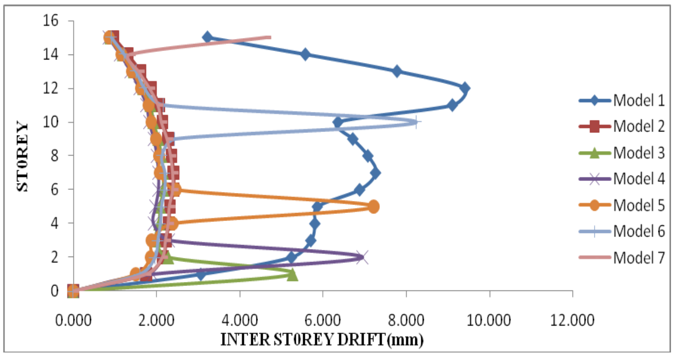


Fig 3.3: Graph of Inter-storey drift vs storey for building Type-1 for Combination-1

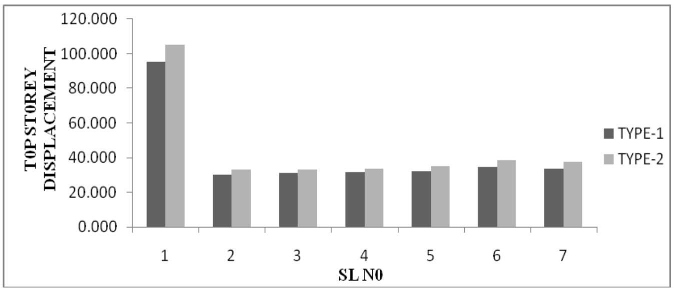


Fig 3.4: Graph of top storey displacement for comparison of Type1 and Type2 building for Combination-1

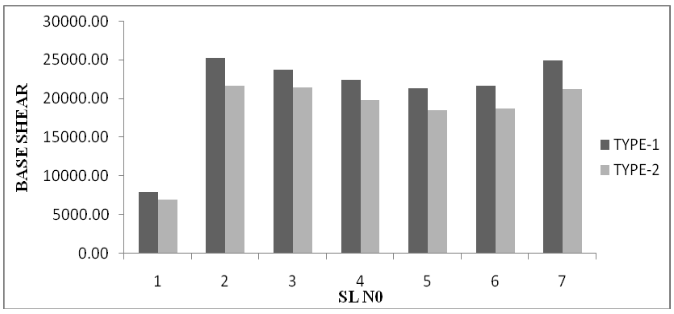


Fig 3.5: Graph of base shear for comparison of Type-I and Type-II building for Combination-3

4. CONCLUSIONS

From the present research comparative research is done for the structure (g+14 Storey's) with and without vertical irregularity, also the behavior is studied for the effects of soft storey in the structure at different levels and analysis is performed for static and dynamic earthquake loadings. The conclusions of the present thesis are listed as below.

1. In Dynamic & Static loading for both vertically standard and irregular buildings, the bare frame structure possess the highest displacements, while on other side structure with total infill possess the least displacements.
2. The provision of soft storey at different levels in the building reduces the stiffness of the building and increases its displacement of about 5% t0 13% when compared with the fully infill model.
3. According to the analysis, the displacement of a vertically irregular building is nearly 2% to 20%

higher than that of a regular building for all 0f the models considered.

4. For frames with full infill, the base shear values appear to be higher, as these models offer more stiffness with the addition of infill wall but the bare frame models, on the other hand, show the comparative less value of base shear, from analysis, the base shear of the soft storey provided models is almost 2% to 13% less when compared with infill model.
5. From analysis, the base shears of the vertically irregular building is almost 5% to 15% less when compared with regular building for all the considered models.
6. According to data analysis, the natural cycle decreases as the stiffness of the building increases, resulting in an increase in base shear, the time period of soft storey provided models is almost 2% to 11% more when compared with infill model, this shows that the performance of soft storey building is more vulnerable.
7. From analysis, the time period of the vertically irregular building is almost 7% to 16% less when compared with regular building for all the considered models.
8. It can be validate that providing soft-storey leads to higher drift values in the upper floors due to the variation in the mass and stiffness.
9. The structure with vertical irregularity will be having maximum inter storey drift as the structure stiffness will be reduced due to the reduced plan area and also due to the effect of soft storey, Model 13 shows the large drift values in comparison with all other models.
10. For both vertically standard and irregular buildings with soft storey provided at different location the maximum displacement and the drift values are observed in the 10th floor soft storey model, hence provision for the soft storey above 10th st0rey level shall be avoided.
11. As a result, it can be validate that buildings with full infill shows least displacement, inter-storey drift, and time period as compared to bare frame and all other soft storey models.
12. From the study it is concluded that the irregular building is more vulnerable than regular building during the earthquake.

4.1 SCOPE FOR FUTURE WORK

1. The analysis can be further c0ntinued by applying different time history and the behavior of the structure can be studied in comparison with the equivalent static and response spectrum method.
2. The study can be made by comparing the structure with infill walls and the shear walls with soft storey at different levels.
3. The soil structure interaction study can be made on the structure for different type's of sub soil strata.
4. The base isolation technique can be applied and the behavior of the structure for dynamic loadings can be performed.

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