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"BEHAVIORAL STUDY OF IRREGULAR STRUCTURE BY ALTERING THE POSITION OF SHEAR WALL"

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ABSTRACT—

In the current context, the majority of RC buildings have irregular layouts, either in plan or elevation, which may be vulnerable to destructive earthquakes. In the event that it is necessary to determine the performance of structures to bear lateral loading, both new and existing ones. This research is concerned with architectural imperfections and the effects of lateral load resistance at various locations on a structure's seismic response. To avoid failure and reduce the susceptibility of irregular buildings subjected to lateral stresses, their responses must be thoroughly investigated. In this work, the responses of irregular structures are analysed using the RSA approach and compared to those of regular buildings with the same plinth area. To improve the study, the stiffness of the staircase is taken into consideration using an actual FEM model, and the optimal position of the shear wall for irregular buildings has been identified. The models were analysed in accordance with IS 1893 (Part 1):2016 codal rules. The characteristics studied in this work are primary mode shapes, mass participation ratios, natural time period, storey displacement, storey drift, and base shear. The resulting results are compared to those of a regular structure using the analytical tool Etabs.

Keywords – Torsional Irregularity, Plan Irregularity, Sesimic analysis, Base Shear, Drift, Displacement, IS 1893 – 2016, ETABS 2018.

1. Introduction –

In present scenario, voluminous building involves irregularities that cannot be avoided. However, the behaviour of structures with these anomalies during earthquakes needs to be investigated. The primary goal of Earthquake Engineering is to design and build a structure in such a way that damage to the structure and its structural components is minimized during an earthquake. Seismic excitations can cause a variety of damage to structures. Despite having the same structural configuration, locale, and earthquake, the system's damages are not comparable or homogeneous. So, various aspects influence the seismic behaviour of a structure, including the structural system, earthquake characteristics, construction quality, soil location, and maintenance. However, based on previous and current earthquakes, the majority of the damage is caused by architectural and structural configurations in plan and elevation, as well as site ground impacts. Irregular buildings make up a substantial percentage of modern urban infrastructure. Adequate measures should be adopted. A thorough examination of the structural behavior of structures with irregularities is required for earthquake design and behavior. As a result, the structural engineer must have a good understanding of how irregular structures respond seismically. Several related researches have focused on assessing the reaction of "Regular Structures." Irregularities in seismic demand of building structures are often required.

According to IS 1893, the irregularities in the construction have been roughly divided into the following categories:

a. **Plan Irregularities:** According to Clause 7.1 of the Sixth edition of IS 1893-2016 (Part 1). Torsion irregularity, re-entrant corners, floor slabs with excessive cut-outs or apertures, out-of-plane offsets in vertical parts, and a non-parallel lateral force system are all examples of plan abnormalities.
b. **Torsion Irregularity:** A building is said to be torsion ally irregular when the maximum horizontal displacement of any level in the direction of the lateral force at one of the floors exceeds 1.5 times the minimum horizontal displacement at the far end in that direction.
c. **Vertical Irregularities:** According to Clause 7.1 of the Sixth revision of IS 1893-2016 (Part 1). Vertical irregularities are divided into four types: mass irregularity, vertical geometrical irregularity, stiffness irregularity, and in-plane discontinuity in vertical elements resisting lateral force.
d. **Mass irregularity** shall be regarded to exist when the seismic weight of any floor exceeds 150 percent of that of its surrounding floors. This requirement of 150 percent may be lowered in the case of roofing.
e. **Vertical Geometric Irregularity:** Vertical geometric irregularity is regarded to exist when the horizontal dimension of the lateral force resisting system in any storey exceeds 125 percent of that in its neighboring level.

The goal of this hypothetical study is to investigate how abnormalities in buildings induce eccentricity between the building mass and stiffness centers, resulting in a negative effect on the building. Furthermore, designing and analyzing an irregular building necessitates a large amount of engineering and designer effort, whereas a regular building is simply evaluated and designed.

2. OBJECTIVES OF THE STUDY

- The main goal of this work is to analyse the behaviour of irregular structures and implement a technique.
- Investigating torsion behaviour during earthquakes in buildings with irregular plans.
- Study storey displacement parameters and maximum drift for all models under lateral loading.
- Analyse time periods and mass participation percentages across modes.
- Evaluate the impact of shear walls on irregular structures.
- Study the behaviour of structures with varying stiffness of stairs based on actual conditions.
- Improve the structural system to account for Torsion Seismic behaviour.
- Analyse the data to determine the optimal building arrangement.

3. METHODOLOGY –

The tenacity of the carrying out the analysis method of determining the seismic behaviour by finding the several parameters which comprises the force, the deformation, and the capacities of each of the components in the building structure. These analysis methodologies are listed in a hierarchical order as follows:
Linear static analysis (Equivalent Static Analysis)
Linear dynamic analysis (Response Spectrum Analysis)
Non linear dynamic analysis (Time History Analysis)

LINEAR STATIC ANALYSIS (Equivalent Static Method) - This is one of the simplest analytical processes, making it easier for the structural designer to perform and complete the design process. This analytical method is also required in practically all cod-al formats used for seismological analysis, and it is mostly utilized for buildings with some regular component parameters for design purposes. This method is also known as the lateral forces method because the effects of seismic motion are thought to be similar to those caused by static transverse stresses. The various cod-al provisions provide their own ways for obtaining and distributing static forces in order to assess the impact of seismic ground motion on structural frames. Generally, the phrase is first defined to specify a value for the minimal lateral seismic force, also known as the base shear force. The single basic general requirement for the building structure in relation to the implementation of this approach is that the natural vibration period of the building structure be reduced to a maximum value, which will undoubtedly result in minimal values of frequency or stiffness. This is due to the fact that many reactions are essentially determined by their initial modes of vibration. As a result of the low frequency values, the contribution of higher modes can be largely ignored.

LINEAR DYNAMIC ANALYSIS (Response Spectrum Analysis) - The linear dynamic method of analysis has been proven to be one of the most efficient ever design approaches, and it is almost exclusively utilized and recommended by structural designers for the purpose of analyzing and designing RC framed structures and its components. When conducting a dynamic study, the inelastic response is empirically examined as the nonlinear behavioral aspects of the buildings that only determine the design under strong ground motion. Because of these factors, the designers recommend and prefer the simplex methodology for doing the study using elastic dynamic analysis methodologies. The evaluation of each mode's modal contributions is a critical parameter in multi-story constructions. Every single mode has a unique distortion. Several major features of building structures rely only on the contributions of these vibration modes. The modal contributions arising from higher modes are smaller for the seismic response of a short to medium-rise building since the basic mode's influencing property is much larger, ranging between 70 and 90%. In this procedure, it is very crucial to address vibrations in the early stages so that we can obtain results in virtually perfect conditions.

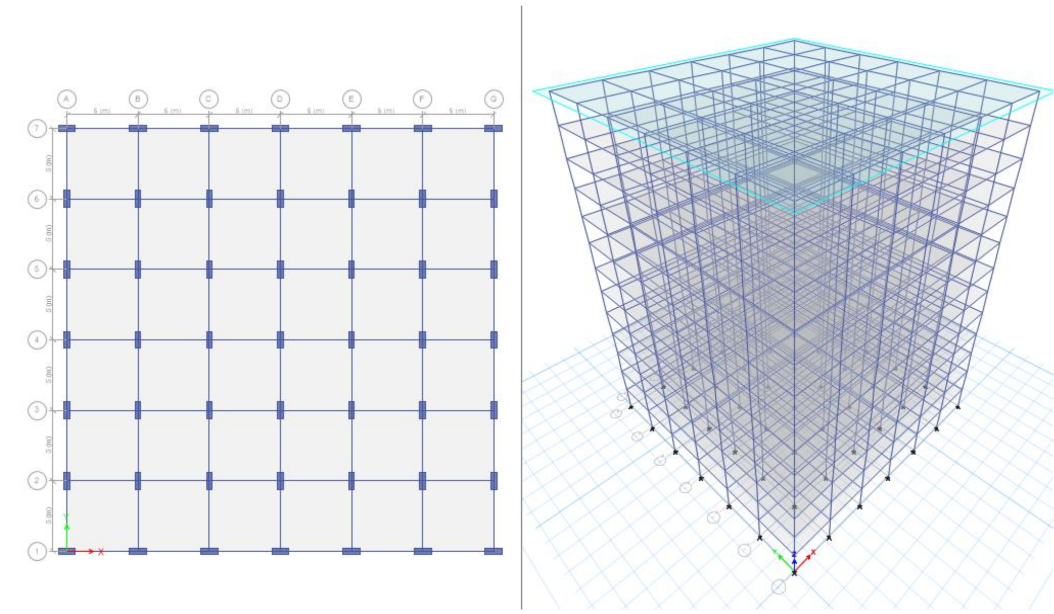
Modelling Details -
Various variants for the irregular L-shaped G+12 storey building has been prepared with varied placements of shear walls, and their impacts will be compared to the regular structure of the same plinth area.
Model 1 – Regular Moment Resisting Framed RC Building
Model 2 – Plan Irregular L shaped RC building
Model 3 – Plan Irregular L shaped RC building with the introduction of definite stiffness of stair case
Model 4 – Plan Irregular L shaped RC building with the provision of shear wall at corners of the structure.
Model – 5 - Plan Irregular L shaped RC building with the provision of shear wall at central portion of the perimeter of the structure.
Model – 6 - Plan Irregular L shaped RC building with the provision of shear wall at internal central core portion of the structure.
The dimensions of beams, columns, and slab are listed below, and additional data utilized for analysis has been extracted from IS 1893:2016.

General Properties	
No. of storeys	G+12
Typical Storey Height	3.6 m.
Size of Column	600 mm x 1200 mm
Size of Beam	400 mm x 600 mm
Thickness of Slab	150 mm.

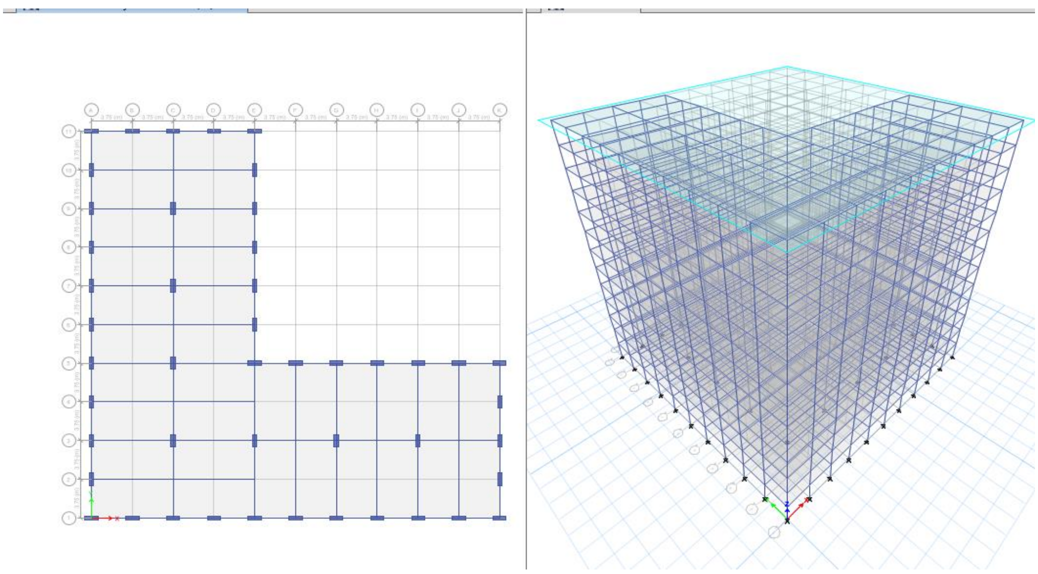
Thickness of Wall	230 mm.
Material Properties	
Grade of Concrete	M 35
Grade of Steel Rebar	Fe 500
Type of Loading	
Wall Load	13.5 KN/m
Live Load	2 KN/m^2
Floor Finishing	1.5 KN/m^2
Seismic Details (IS 1893:2016)	
Seismic Zone	V
Zone Factor	0.36
Importance Factor	1
Type of Soil	II - Medium
Building Type (R)	5 (SMRF)

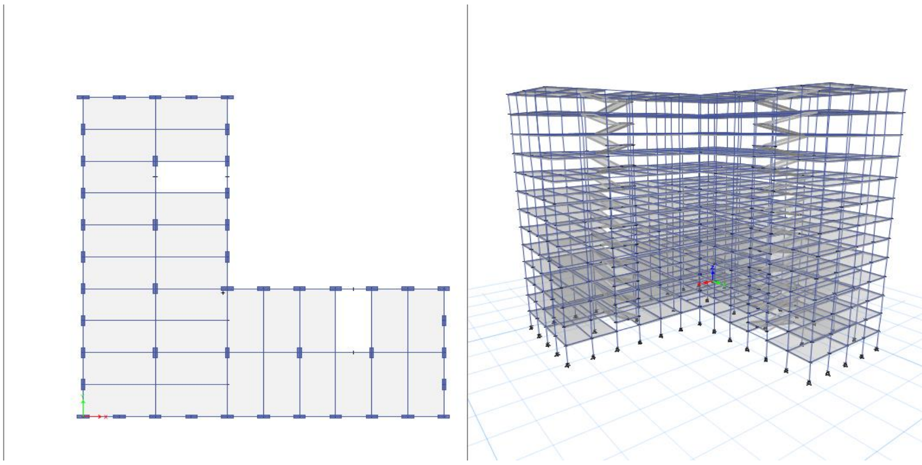
DETAILS OF THE MODEL –

MODEL 1

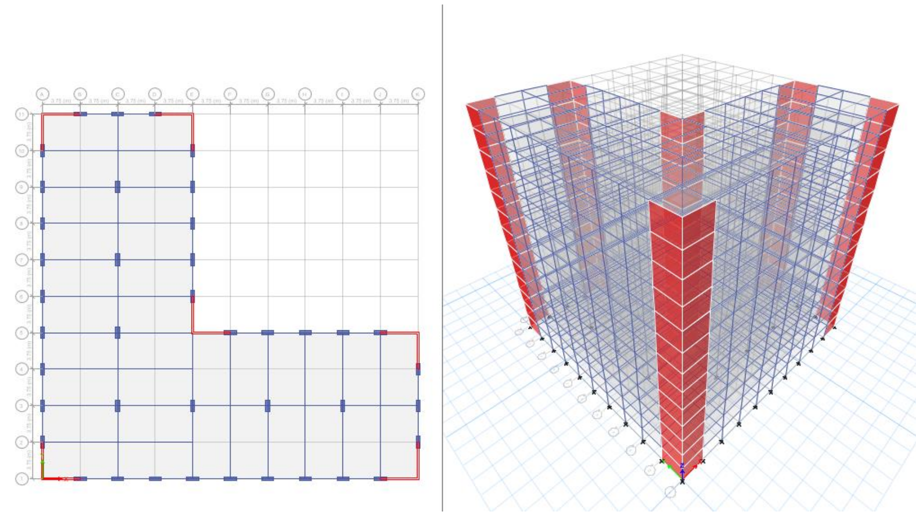


MODEL 2

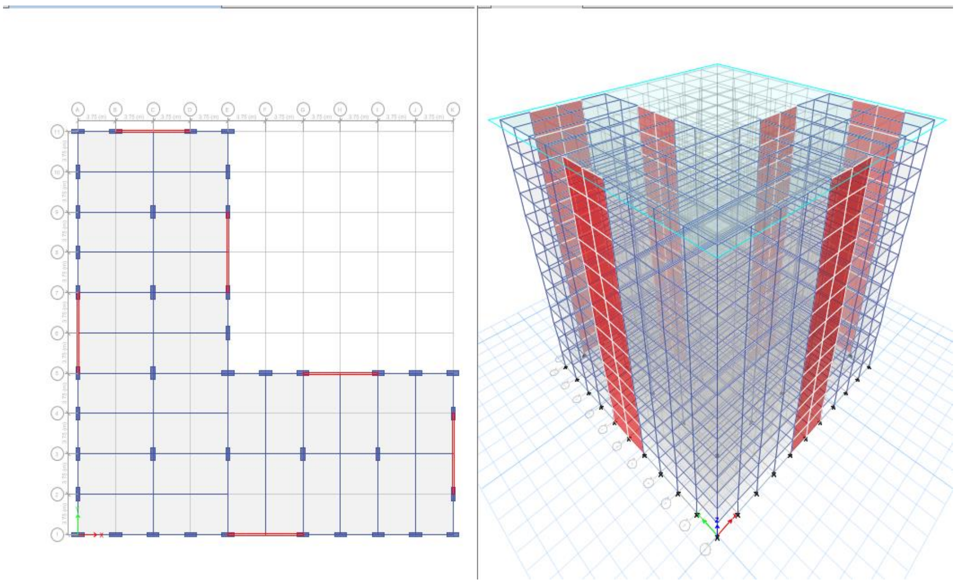




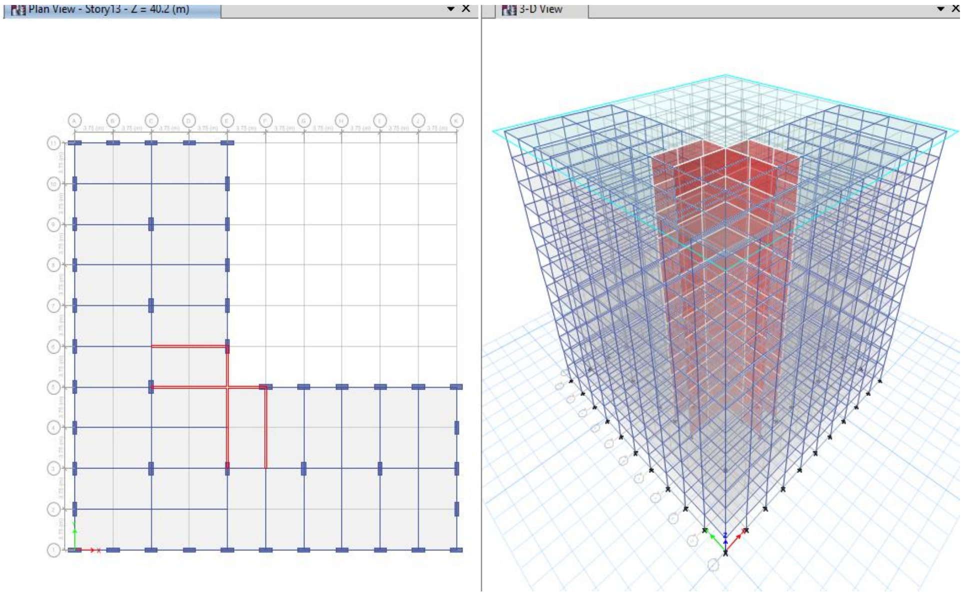
MODEL 3



Model 4



Model 5

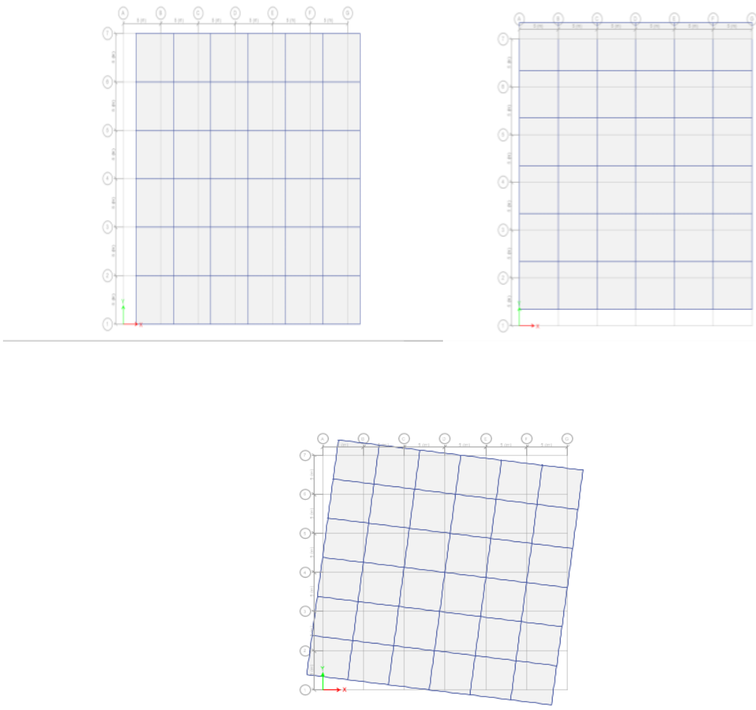


Model 6

4. RESULTS –

The findings from these building models are presented here. The analysis used is Response Spectrum (Linear Dynamic) analysis.
Deformed structural forms for the first three basic modes:

Model 1

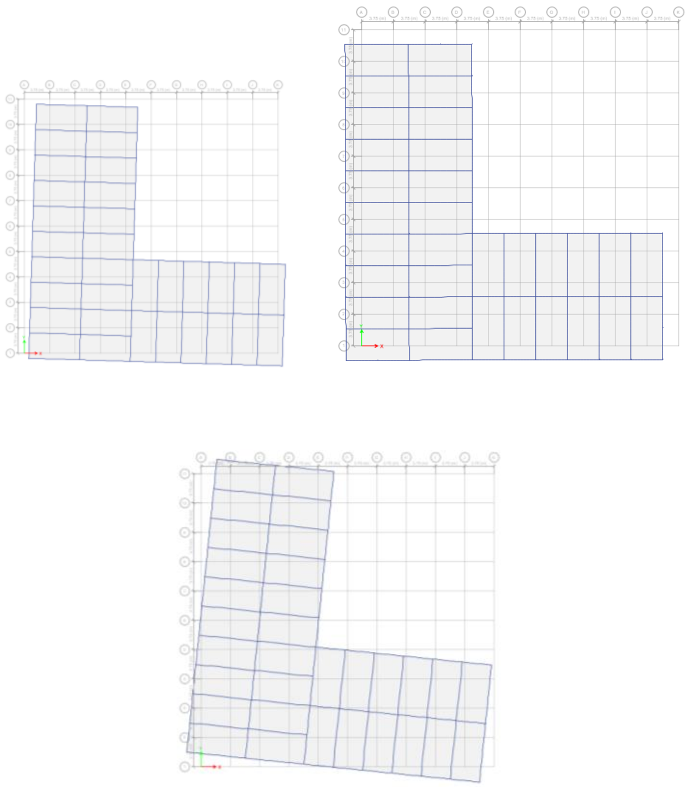


Deformed shape for Model 1 for first three primary modes
Modal Participating Mass Ratios

Mode Shape	Time Period	Ux	Uy	Rx	Ry	Rz	Sum Ux	Sum Uy	Sum Rz

Mode 1	4.339	2.33E-05	0.6931	0.2235	1.81E-05	0.0658	2.33E-05	0.6931	0.0658
Mode 2	3.714	0.2094	0.0488	0.0133	0.0679	0.5135	0.2094	0.7419	0.5793
Mode 3	3.397	0.5613	0.0213	0.0046	0.1638	0.1991	0.7707	0.7632	0.7784
Mode 4	1.369	2.57E-05	0.1222	0.4344	0	0.0104	0.7707	0.8853	0.7888
Mode 5	1.194	0.0225	0.0063	0.0302	0.0753	0.0862	0.7932	0.8916	0.875
Mode 6	1.102	0.09	0.0011	0.0074	0.3927	0.0154	0.8832	0.8927	0.8904
Mode 7	0.747	9.23E-07	0.0351	0.0717	9.51E-07	0.0018	0.8832	0.9279	0.8922
Mode 8	0.672	0.0017	0.0015	0.0027	0.0036	0.0326	0.8849	0.9294	0.9248
Mode 9	0.622	0.0347	4.22E-05	4.38E-05	0.0615	0.0013	0.9196	0.9294	0.9262
Mode 10	0.52	0	0.018	0.06	4.60E-06	0.0007	0.9196	0.9474	0.9269
Mode 11	0.467	0.0004	0.0006	0.0022	0.001	0.0175	0.92	0.948	0.9444
Mode 12	0.426	0.019	7.93E-06	0.0001	0.0641	0.0003	0.939	0.948	0.9447

Model 2

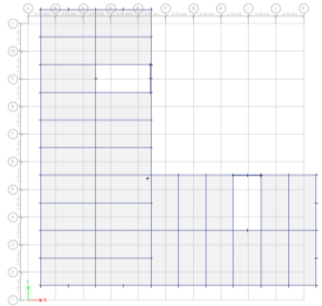


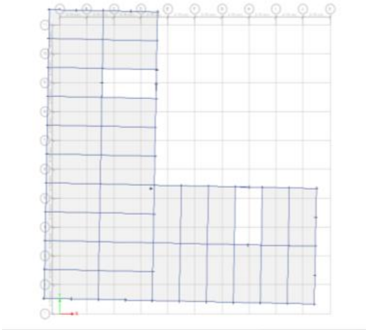
Deformed shape for Model 2 for first three primary modes

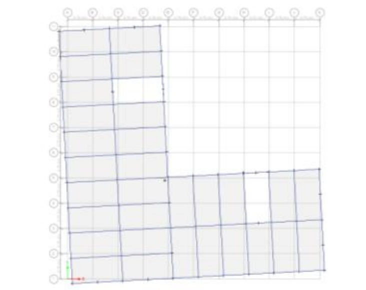
Modal Participating Mass Ratios

Mode Shape	Time Period	Ux	Uy	Rx	Ry	Rz	Sum Ux	Sum Uy	Sum Rz
Mode 1	4.083	0.0004	0.6096	0.2168	0.0001	0.1321	0.0004	0.6096	0.1321
Mode 2	3.854	0.7064	0.0166	0.0059	0.1986	0.0564	0.7068	0.6262	0.1885
Mode 3	3.433	0.0786	0.1203	0.0357	0.0179	0.5796	0.7854	0.7465	0.768
Mode 4	1.255	0.0345	0.0642	0.2014	0.1577	0.0295	0.8199	0.8107	0.7975
Mode 5	1.248	0.0715	0.05	0.1507	0.3197	0.0006	0.8914	0.8607	0.7981
Mode 6	1.111	0.0044	0.0189	0.0802	0.0275	0.0855	0.8958	0.8796	0.8837
Mode 7	0.709	0.0347	4.021E-06	0	0.0649	0.0006	0.9305	0.8796	0.8842
Mode 8	0.666	0.0001	0.0307	0.0608	0.0003	0.0078	0.9306	0.9103	0.892
Mode 9	0.625	0.0003	0.0074	0.0134	0.0004	0.0284	0.9309	0.9178	0.9204
Mode 10	0.497	0.0179	0	2.873E-06	0.0651	0.0002	0.9488	0.9178	0.9206
Mode 11	0.451	2.763E-05	0.0158	0.0474	0.0001	0.0045	0.9488	0.9336	0.9251
Mode 12	0.429	0.0001	0.0044	0.0145	0.0004	0.0148	0.9489	0.9379	0.9398

Model 3





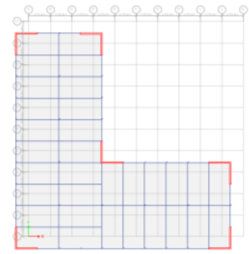


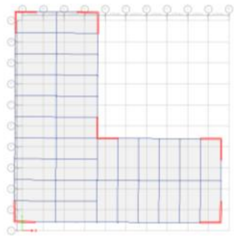
Deformed shape for Model 3 for first three primary modes
Modal Participating Mass Ratios

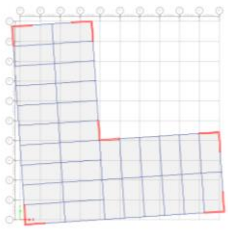
Mode Shape	Time Period	Ux	Uy	Rx	Ry	Rz	Sum Ux	Sum Uy	Sum Rz
Mode 1	4.221	5.418E-07	0.6528	0.2236	9.478E-07	0.0954	5.418E-07	0.6528	0.0954
Mode 2	3.728	0.5007	0.0345	0.0107	0.1503	0.2343	0.5007	0.6873	0.3297
Mode 3	3.451	0.2768	0.0656	0.0175	0.0744	0.4419	0.7775	0.7528	0.7716
Mode 4	1.31	0	0.1178	0.388	4.746E-05	0.0163	0.7775	0.8706	0.7878
Mode 5	1.196	0.0813	0.0046	0.0173	0.3352	0.0315	0.8588	0.8752	0.8194
Mode 6	1.125	0.0301	0.0082	0.0402	0.1494	0.0662	0.8889	0.8834	0.8856
Mode 7	0.704	0.0001	0.0341	0.0672	0.0001	0.0038	0.889	0.9175	0.8894
Mode 8	0.666	0.0303	0.0009	0.0019	0.056	0.0049	0.9193	0.9184	0.8943
Mode 9	0.641	0.0053	0.0025	0.0043	0.0089	0.0277	0.9246	0.9209	0.922
Mode 10	0.481	3.68E-05	0.0181	0.0568	0.0002	0.0016	0.9246	0.939	0.9236
Mode 11	0.461	0.0169	0.0003	0.001	0.0584	0.0016	0.9415	0.9394	0.9252
Mode 12	0.443	0.0017	0.0012	0.0043	0.0066	0.0159	0.9433	0.9405	0.9411

Deformed shapes of structure for first three primary modes:

Model 4





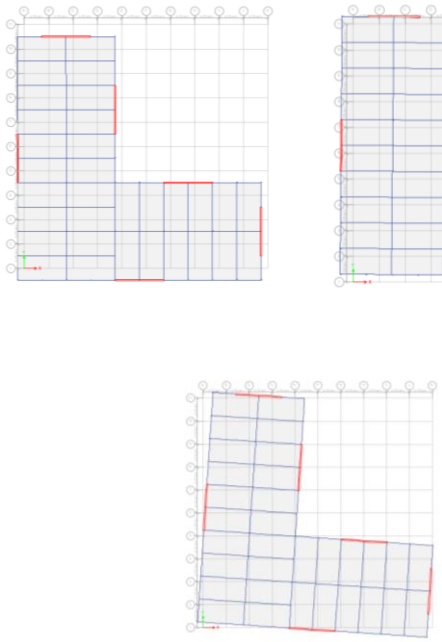


Deformed shape for Model 4 for first three primary modes

Modal Participating Mass Ratios

Mode Shape	Time Period	Ux	Uy	Rx	Ry	Rz	Sum Ux	Sum Uy	Sum Rz
Mode 1	4.173	1.502E-05	0.6519	0.2219	8.995E-07	0.0978	1.502E-05	0.6519	0.0978
Mode 2	3.733	0.5062	0.0351	0.011	0.1536	0.2273	0.5063	0.687	0.325
Mode 3	3.448	0.2694	0.0669	0.018	0.073	0.4493	0.7756	0.7539	0.7743
Mode 4	1.298	6.064E-06	0.1179	0.3885	0.0001	0.0172	0.7756	0.8718	0.7915
Mode 5	1.196	0.0789	0.0055	0.0207	0.3204	0.0329	0.8545	0.8773	0.8245
Mode 6	1.125	0.0324	0.0083	0.0408	0.1589	0.0633	0.8869	0.8856	0.8877
Mode 7	0.699	0.0001	0.0332	0.0666	0.0001	0.0045	0.887	0.9188	0.8922
Mode 8	0.665	0.0278	0.0015	0.0031	0.0511	0.0071	0.9148	0.9204	0.8993
Mode 9	0.644	0.008	0.0026	0.0045	0.0136	0.0246	0.9228	0.923	0.9239
Mode 10	0.48	3.195E-05	0.0175	0.0552	0.0001	0.002	0.9228	0.9404	0.9259
Mode 11	0.458	0.0149	0.0006	0.002	0.0505	0.0036	0.9377	0.9411	0.9294
Mode 12	0.447	0.004	0.0012	0.0046	0.0146	0.0133	0.9417	0.9423	0.9427

Model 5

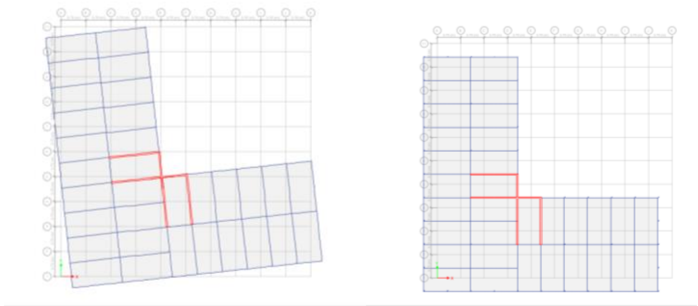


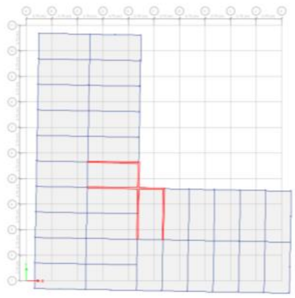
Deformed shape for Model 5 for first three primary modes

Modal Participating Mass Ratios

Mode Shape	Time Period	Ux	Uy	Rx	Ry	Rz	Sum Ux	Sum Uy	Sum Rz
Mode 1	6.875	0.0063	0.8411	0.1046	0.0009	0.0411	0.0063	0.8411	0.0411
Mode 2	5.783	0.5292	0.0058	0.0004	0.0402	0.3927	0.5355	0.8469	0.4338
Mode 3	5.351	0.4029	0.0462	0.0017	0.0195	0.5031	0.9384	0.8931	0.9369
Mode 4	2.03	0.0009	0.0973	0.8045	0.0051	0.0055	0.9393	0.9904	0.9424
Mode 5	1.742	0.0349	0.0006	0.0079	0.4647	0.0308	0.9742	0.991	0.9732
Mode 6	1.587	0.0208	0.0015	0.0403	0.437	0.0205	0.995	0.9925	0.9937
Mode 7	0.923	9.457E-07	0.0052	0.0228	5.29E-07	0.0005	0.995	0.9977	0.9942
Mode 8	0.833	0.0006	0.0002	0.0008	0.0027	0.0037	0.9956	0.9979	0.9979
Mode 9	0.784	0.0031	1.341E-05	2.356E-05	0.0124	0.0003	0.9986	0.9979	0.9982
Mode 10	0.615	0	0.0012	0.0114	1.982E-05	0.0001	0.9986	0.9991	0.9983
Mode 11	0.553	0.0001	2.834E-05	0.0006	0.0005	0.0009	0.9987	0.9991	0.9992
Mode 12	0.517	0.0008	1.037E-06	0.0001	0.0132	3.71E-05	0.9995	0.9991	0.9993

Model 6



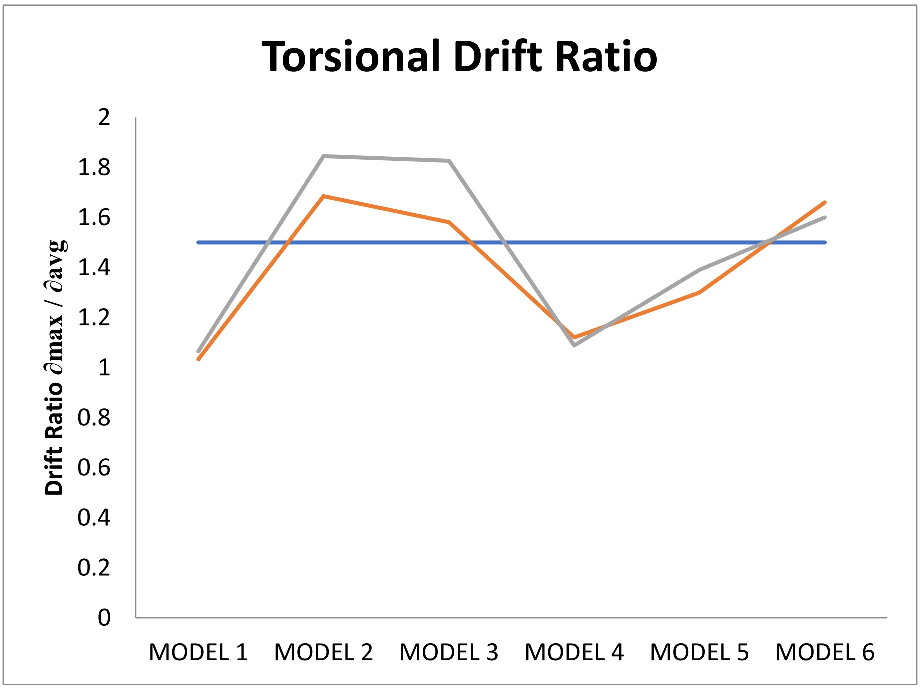


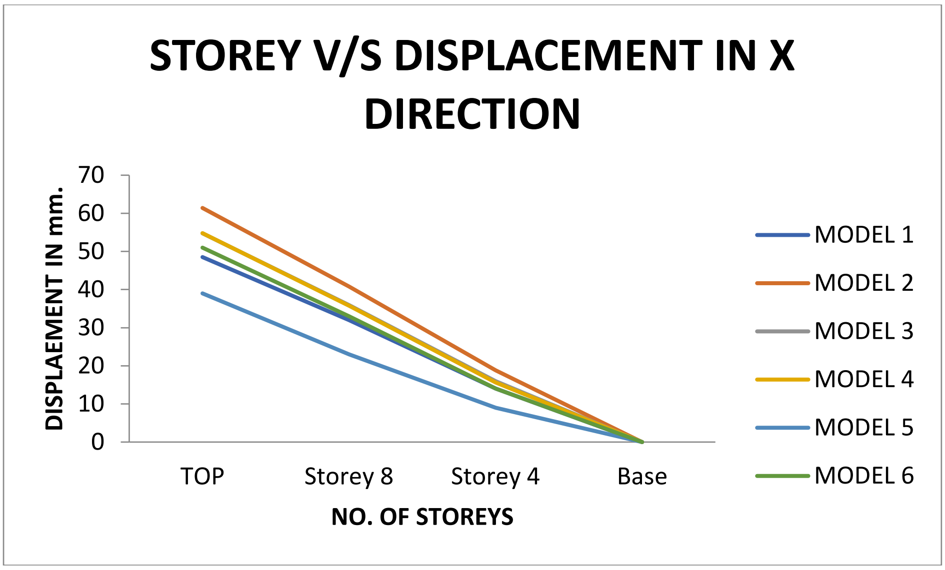
Deformed shape for Model 6 for first three primary modes

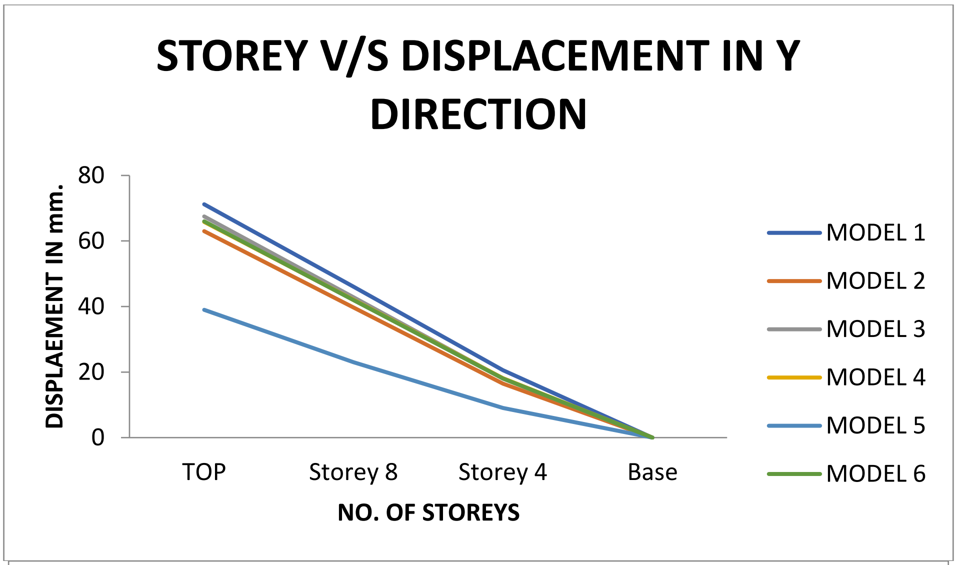
Modal Participating Mass Ratios

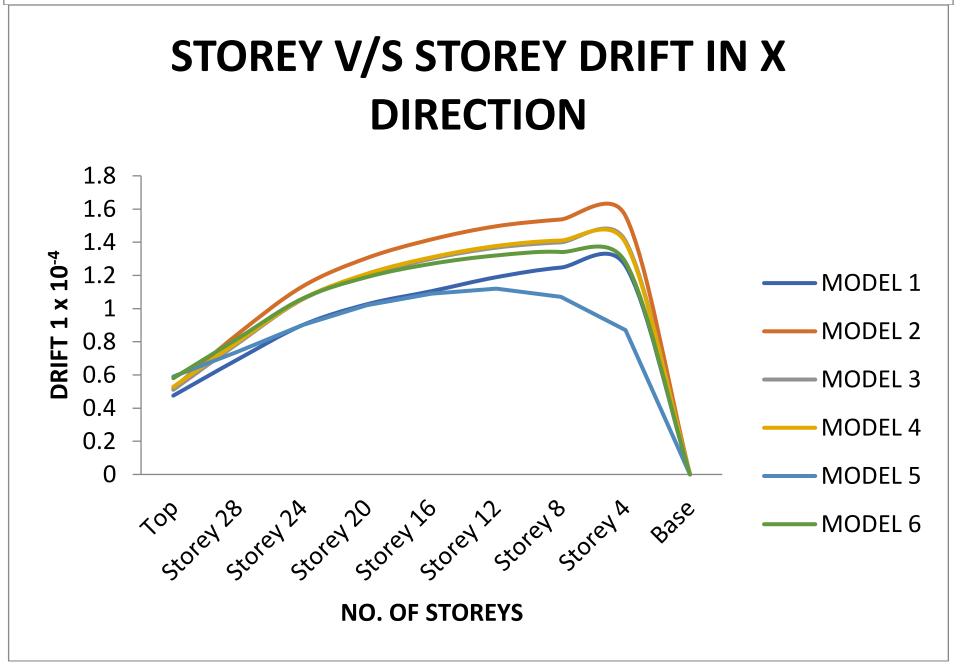
Mode Shape	Time Period	Ux	Uy	Rx	Ry	Rz	Sum Ux	Sum Uy	Sum Rz
Mode 1	3.769	0.0669	0.6556	0.256	0.0249	0.0024	0.0669	0.6556	0.0024
Mode 2	3.06	0.661	0.0605	0.0231	0.2314	0.0198	0.728	0.7161	0.0222
Mode 3	2.747	0.0168	0.0095	0.0023	0.0044	0.7023	0.7448	0.7256	0.7245
Mode 4	1.103	0.0162	0.1265	0.3402	0.0511	0.0003	0.761	0.8521	0.7247
Mode 5	0.927	0.1071	0.0165	0.0507	0.3636	0.0002	0.8681	0.8686	0.7249
Mode 6	0.797	4.951E-05	1.123E-05	0.0005	3.085E-05	0.1362	0.8682	0.8686	0.8611
Mode 7	0.562	0.007	0.039	0.0757	0.0128	6.697E-06	0.8752	0.9075	0.8611
Mode 8	0.487	0.0373	0.0081	0.015	0.0662	0.0002	0.9125	0.9156	0.8613
Mode 9	0.398	0.0003	0.0001	0.0001	0.0005	0.0518	0.9128	0.9157	0.9131
Mode 10	0.365	0.0042	0.0206	0.0573	0.012	0	0.917	0.9362	0.9131
Mode 11	0.316	0.0198	0.0047	0.0134	0.0581	0.0002	0.9368	0.9409	0.9133
Mode 12	0.263	0.0026	0.0124	0.0311	0.0062	5.79E-06	0.9394	0.9533	0.9133

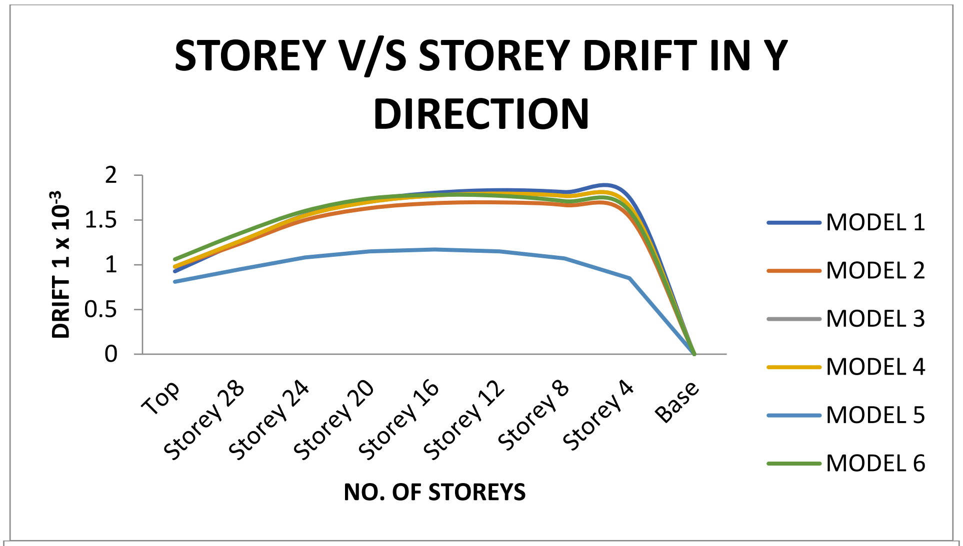
TORSIONAL VALUE -

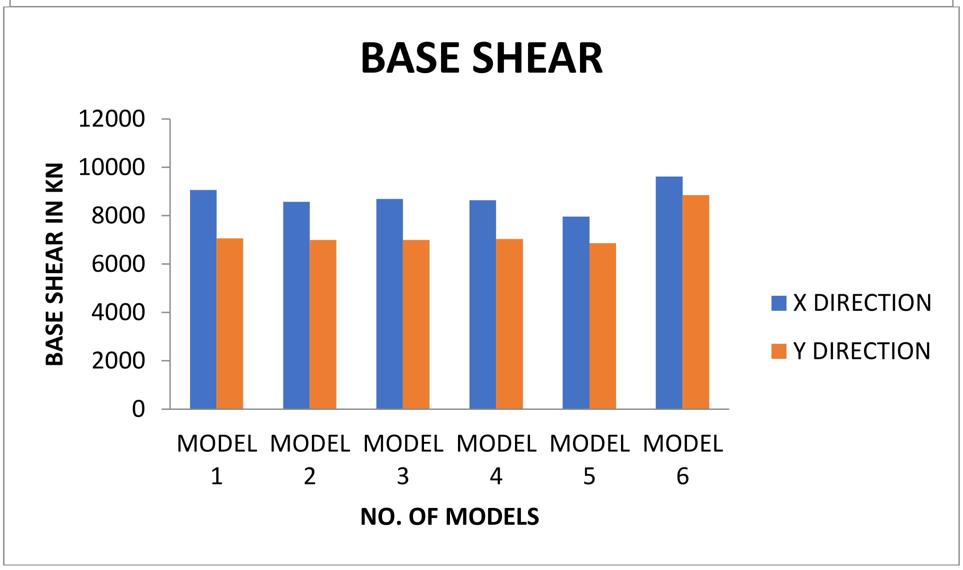



STOREY V/S DISPLACEMENT IN X DIRECTION
DISPLAEMENT IN mm.
70
60
50
40
30
20
10
0
TOP
Storey 8
Storey 4
Base
NO. OF STOREYS
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5
MODEL 6


STOREY V/S DISPLACEMENT IN Y DIRECTION
DISPLAEMENT IN mm.
80
60
40
20
0
TOP
Storey 8
Storey 4
Base
NO. OF STOREYS
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5
MODEL 6


STOREY V/S STOREY DRIFT IN X DIRECTION
DRIFT 1 x 10-4
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Top
Storey 28
Storey 24
Storey 20
Storey 16
Storey 12
Storey 8
Storey 4
Base
NO. OF STOREYS
MODEL 1
MODEL 2
MODEL 3
MODEL 4
MODEL 5
MODEL 6





5. CONCLUSIONS –

The results for the irregular building were acquired using response spectrum analysis are as follows -

1. The study's findings suggest that irregularities in structures significantly affect their seismic response, particularly in terms of displacement and drift. Because of different symmetries in the x and y directions, the values of displacement and drift have increased by 22% and 28%, respectively.
2. The use of a shear wall reduces drift by 26% and displacement by 18% for an L-shaped structure when compared to a building without a shear wall.
3. The stiffness of the actual stairs also has an impact on the overall performance of the structure because it reduces lateral movement by 8%.
4. According to IS 1893(part-1):2016, the acceptable maximum for $\Delta Max/\Delta Min$ is <1.5. The permissible torsional irregularity ratio was determined for models III and IV, which were L-shaped structures with shear walls at the center and corners, implying that the correct position of the shear wall is also an important factor to consider when designing such structures in severe seismic zones.

5. Proper use and arrangement of shear walls, core walls, and other structural elements will also prevent torsional irregularity. Because of the torsional irregularity, shear forces in columns are extremely large.

6. The value of base shear in model VI is 20% higher than in previous models, showing that the structure is substantially stiffer for seismic reaction. It has been discovered that the value of base shear for such buildings with shear walls is 2.4 times more than that of buildings without shear walls.

7. Introducing the actual stiffness of stairs is more suitable in severe seismic zones than an ordinary moment resisting frame because it lowers drift and displacement by 6% and 8%, respectively.

Recommendation:

Because of the uneven location of stiff parts in an irregular shape structure, the center of mass does not coincide with the center of rigidity. Torsion is the most significant component that causes major damage or collapse of a building, hence irregular constructions should be thoroughly analyzed for torsion and designers should aim to prevent excessive irregularities, especially in multi-story buildings. Shear walls and other lateral load resisting features must be properly positioned for stability.

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