Comparitive Analysis Of Plan Irregulrities for Steel Structure In high Seismic Zone

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Abstract- *Many buildings in the present scenario have irregularities in plan. This may subject to devastating earthquakes in future. It becomes necessary to identify the performance of the structures to withstand against disaster for both new and existing one. Structures experience lateral deflections under earthquake loads. Magnitude of these lateral deflections is related to many variables such as structural system, mass of the structure, mechanical properties of the structural materials and the irregularities in plan. Plan irregularities are crucial factors which decrease the seismic performance of the structures. The asymmetry may make the structure more vulnerable and lead to collapse under the effect of lateral loads. Reinforced concrete multi-storied buildings are very complex to model as structural systems for analysis. This is due to the irregularities in plan. The paper discusses the performance evaluation of better performance of different plan configurations in Steel building under high seismic zone. The study as a whole makes an effort to evaluate the effect of seismic forces on different plan irregularities for Steel building.*

Keywords- Plan Irregularities, High Seismic Zone, Multi-Storied Buildings, Lateral deflections, Seismic Forces, Steel Building.

I. INTRODUCTION

A multi-story structure between 35-100 meters tall, or a building of unknown height having more than 12 floors used mainly as a residential and/or office building is termed as s high-rise building. High-rise buildings are in use because of the invention of the elevator and cheaper, more abundant building materials. The material like concrete and steel is used for the structural system of high-rise buildings. In a Seismically active region or if the underlying soils have geotechnical risk factors such as high compressibility or soft soil the high-rise structures pose particular design challenges for structural and geotechnical engineers. Structural analysis is mainly concerned with finding out the behavior of a physical structure when subjected to force. This action can be in the form of load due to weight of things such as people, equipment, wind, snow, excitation such as an earthquake, shakingof the ground due to a blast nearby, etc. Earthquake can be termed as the sudden vibration of earth which is caused naturally or manually. We know that different type of plan irregularities buildings are used in modern infrastructure.

During an earthquake, the building tends to collapse. This discontinuity termed as Irregular structures can cause collapse of buildings under the effect of lateral load. The irregular building cannot be avoided during the construction due to space requirement in construction field hence the tall structure has come into demand. Whereas the total seismic base shear as experienced by a building during an earthquake is dependent on the building's natural period, the seismic force distribution depends upon the distribution of stiffness and mass along the height. The behavior of a building during earthquakes depends critically on its overall shape, size and geometry, in addition to how the earthquake forces are carried to the ground.

1.2 IRREGULARITIES

When a building is subjected to seismic forces, horizontal inertia forces are generated in the building. The resultant of these forces is assumed to act through the center of mass (C.M) of the structure. The vertical members in the building resist these forces and the total resultant of these systems of forces act through a point called as center of stiffness (C.S). When the center of mass and center of stiffness does not meet or coincide each other, then the eccentricities are developed in the buildings which further generate torsion. When the buildings are subjected to lateral loads, then phenomenon of torsional coupling occurs due to interaction between lateral loads and resistant forces. Torsional Coupling generates greater damage in the buildings. Eccentricity may occur due to presence of structural irregularities. The irregularities are of two type according to IS 1893:2016 which are Plan Irregularities and Vertical Irregularities.

1.3 PLAN IRREGULARITIES:-

a. Torsion Irregularity:-

It is to be considered when floor diaphragms are rigid in their own plan with respect to the vertical structural elements that sustain the lateral forces. Torsional irregularity need to be considered to exist when the maximum storey drift, calculated with design eccentricity, at one end of the structures transverse to an axis is greater than 1.2 times the average of the storey drifts at the two Ends of the structure.

b. Re-entrant Corners:-

Re-Entrant corners are present in Irregular structures where both projections of the structure beyond the re-entrant corner are greater than 15 percent of its plan dimension in the given direction

c. Diaphragm Discontinuity:-

Diaphragms with abrupt discontinuities or variations in stiffness, including those having cut-out or open areas greater than 50 percent of the gross enclosed diaphragm area, or changes in effective diaphragm stiffness of more than 50 percent from one storey to the next

d. Out-of-Plane Offsets:-

Discontinuities in a lateral force resistance path, such as out-of-plane offsets of vertical elements

e. Non-parallel Systems:-

The vertical elements resisting the lateral force are not parallel to or symmetric about the major orthogonal axes or the lateral force resisting elements.

II. LITERATURE REVIEW

Ercan Işık, Mesut Özdemir and Ibrahim Baran Karaşin [2018], "Performance analysis of steel structures with A3 irregularities". Four different type irregularity cases were considered. The building with no irregularities in its plan was taken as the reference building. The five steel structures were compared by obtaining pushover curves for both the x and y directions. It stated that irregularities in buildings may be taken into account in the same way for concrete and steel structures without any discrimination. It is found that since the damping ratio of steel structures is smaller than that of concrete structures, it will be appropriate to treat steel structure joints more tolerantly .The authors stated that it should not be forgotten that building blocks separated by structural joints carry the risk of collision damage in an earthquake. From the study the authors also concluded that attention must be paid to eccentricity, which forms between the center of mass and the center of rigidity in structures that are irregular in their plans. It is also concluded that presence of irregularities in structures is an unfavorable situation and it is recommended to avoid this situation as much as possible.

2. Dhananjay Shrivastava and Dr. Sudhir Singh Bhaduria [2017] "Analysis of multi-storey RCC frames of regular and irregular plan configuration using response spectrum method". This research paper focused on the structural behavior of multi-storey building for different plan configuration such as regular building along with L- shape and I- shape. In this modeling of G+25 story's RCC framed building is studied for earthquake load using STAAD-pro v8i.It concluded that the response of the building towards the earthquake decreases as the base width increases. So increase in the base width of the structure lesser its chances of failure during earthquake .They have studied from the design results that the overall cost of irregular structure is much higher, due to torsion and high shear force the amount of steel and concrete required is more as compared to regular structure which shows less requirement of Concrete and steel. It is concluded thatirregularities are harmful for the structures and it is important to have regular shapes of frames as well as uniform load distribution around the building.

3. **Albert Philip and Dr. S. Elavenil [2017] "Seismic Analysis of High Rise Buildings with Plan Irregularity"**. Their work describes the three dimensional analytical models of G+12 storied buildings generated for regular and irregular buildings and analyzed using CSI ETABS software (2015 version) for earthquake zone III in India. The paper objectifies the seismic analysis (RSA) of regular and irregular reinforced concrete buildings and to carry out the ductility based design using IS 13920. Results of this analysis were discussed in terms of story displacements, story drifts, story shear and stiffness. From the results it was concluded that story displacements increases linearly with height of the building; maximum storey drift is observed at second floor for irregular structure and at fourth floor for regular structure; maximum storey shear force was observed between ground floor and second floor for regular structure and at ground floor for irregular structure and the value decreases linearly with height; storey stiffness varies non - linearly for both the structures with maximum values at ground floor.

4. Amin Alavi and P. Srinivasa Rao [2013] "Plan irregular RC buildings in high seismic zone". In this purpose a five storey-high building on eight different configurations having re-entrant corners with a regular configuration which served as a comparison, initially were investigated using ETABS 9.7 version. The results proved that, building with severe irregularity are more vulnerable than those with less irregularity especially in high seismic zones. The authors also studied that elastic analysis underestimates the storey drift especially when the building enters to the nonlinear level.

5. Mohammed Rizwan Sultan [2015] "Dynamic analysis of multi-storey building for different shapes". The objective of this study the behavior of the structure in high seismic zone and to evaluate Storey overturning moment, Storey Drift, Displacement, Design lateral forces. During this purpose a 15 storey-high building on four totally different shapes like Rectangular, L-shape, H-shape, and C-shape are used as comparison. The complete models were analyzed with the assistance of ETABS 9.7.1 version. The results indicated that, building with severe irregularity produces more deformation than those with less irregularity particularly in high seismic zones. And conjointly the storey overturning moment varies inversely with height of the storey. It was concluded that the storey base shear for regular building is highest compare to irregular shape buildings.

2.2. SUMMARY OF LITERATURE:-

From above Literature Following points are to be concluded that 1. Building with irregularity producesmore deformation than those with less irregularity particularly in high seismic zones 2. Maximum storey shear force was observed between ground floor and second floor for regular structure and at ground floor for Irregular structure and the value decreases linearly with height 3. Overall cost of irregular structure is much higher, due to torsion and high shear force the amount of steel and concrete required is more as compared to regular structure which shows less requirement of concrete and steel.

2.3. OBJECTIVES:-

The main objective of this is to study the Response spectrum analysis of Steel building with different plan configurations. The comparative study of various factors such as base shear, storey drift, storey shear and storey displacement. Also to study effectiveness of type of building i.e. steel for the different plan configurations in high seismic zone.

2.4 METHODOLOGY:

The different plan shapes of Steel building were modelled in the software ETABS 2016. The different parameters like storey shear, storey drift, storey displacement. Lateral load to storey and base shear are studied to find the effective structure in Zone IV which is a high seismic zone. Also, the review of existing literatures by different researchers was conducted and the structure plan types were selected followed by their modelling and dynamic analysis of them. The comparison of the analysis results was carried out.

3.1THEOREOTICAL FORMULATION:-

1. Equivalent Linear Static Analysis Method: In the equivalent static analysis method, the response of the building is assumed as linear elastic manner. To calculate equivalent linear static the IS 1893 (Part I): 2016 has given a formula as below:-
Vb=Ah*W
Where,

$$A_h = \frac{ZIS_a}{2Rg}$$

Where,
Z is the zone factor,
I is the importance factor,
R is the response reduction factor,

Sa/g is the average response acceleration coefficient which depends on the nature of foundation soil (rock, medium or soil site).

2. Linear dynamic analysis method (RSM): The response spectrum method (RSM) was introduced in 1932.It is a way to be find earthquake response structure using waves or vibration mode shapes. The response spectrum method plays an important role in practical analysis of multistory buildings for earthquake motions. It is also helpful to analyze the performance level of the structure. Response spectra are curves plotted between maximum response of SDOF system subjected to specified earthquake ground motion and its time period can be maximum response of a SDOFSystem for given damping ratio. Response spectra thus helps in obtaining the peak structural responses under linear range, which can be used for obtaining lateral forces developed in structure due to earthquake thus facilitates inEarthquake-resistant design of structures.

IV. PARAMETRIC INVESTIGATION

4.1. Specifications:-

The following specifications were adopted for study:-

1) Length X width: 24 m X 30 m
2) Number of stories: 15
3) Support conditions: Fixed
4) Storey height: 3 m
5) Height of soft storey: - 3 m
5) Grade of concrete: M30
6) Grade of steel: HYSD 500
7) Density of RCC considered: 25kN/ m3
8) Thickness of slab: 150mm

9) Density of wall: 20 kN/m3
10) Thickness of outside wall: 230 mm
11) Thickness of inner partition wall: 115 mm
12) Earthquake Zone: IV
13) Damping Ratio: 5%
14) Importance factor: 1.5
15) Type of Soil: Rocky
16) Type of structure: Special Moment Resisting Frame
17) Response reduction Factor: 5
18) Type of diaphragms: Rigid
19) Modal combination: SRSS
20) Direction of lateral force: X direction only
21) Type of support at base: Fixed
22) Size of columns: - 450 X 750 mm
23) Size of beams: 300mm x 450mm
24) Height of parapet wall: 0.9m
25) Thickness of main wall: 230mm
26) 12 Thickness of parapet wall: 115mm

4.2. Modelling:-

The Rectangular, C-Shape, H-Shape and T-Shape Steel Buildings were modelled in Finite Element Analysis software and then analyzed under Response Spectrum Analysis. The plans of models with different plan configuration are shown below:-

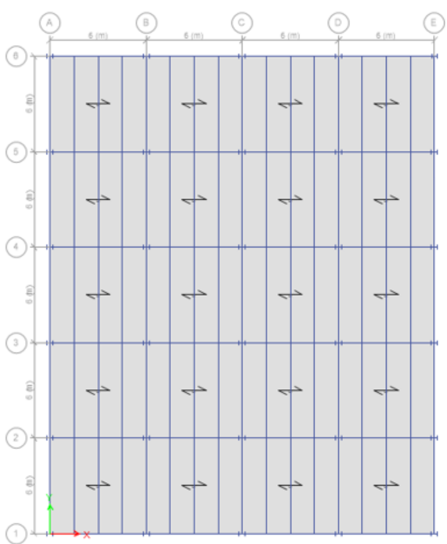


Fig.1. Plan of Rectangular Steel Building

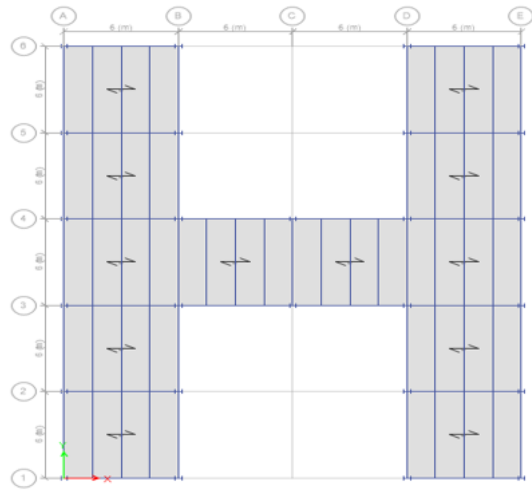


Fig.2: Plan of H-Shape Steel Structure

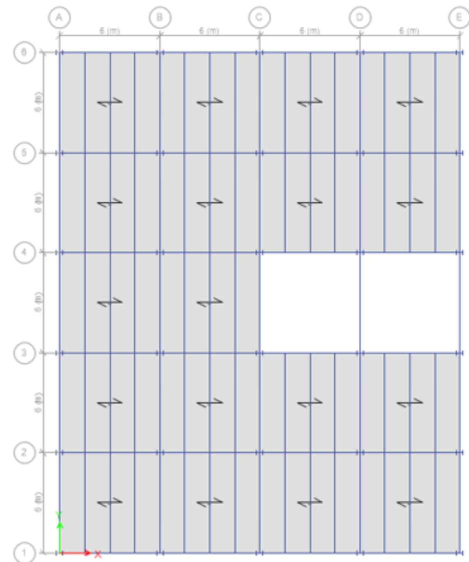


Fig. 3:- Plan of C-Shape Steel Structure

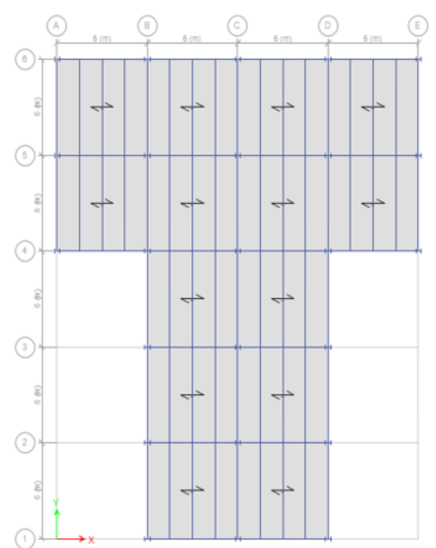


Fig. 4:- Plan of T Shape Steel Structure

V. RESULTS AND DISCUSSION

The following Results were obtained:-

Table 1 :Lateral Load To Storey

Storey	Steel Rectangular Shape	Steel -C Shape	Steel-H Shape	Steel T Shape
Base	0	0	0	0
Story1	0.9251	1.2789	0.9546	1.3277
Story2	3.7005	5.1156	3.8183	5.3108
Story3	8.326	11.51	8.5912	11.9492
Story4	14.8018	20.4622	15.2732	21.2431
Story5	23.1279	31.9722	23.8643	33.1923
Story6	33.3042	46.04	34.3646	47.7969
Story7	45.3307	62.6656	46.7741	65.0569
Story8	59.2074	81.8489	61.0927	84.9723
Story9	74.9343	103.59	77.3204	107.5431
Story10	92.5115	127.8889	95.4573	132.7692
Story11	111.939	154.7456	115.5034	160.6508
Story12	133.2166	184.1601	137.4586	191.1877
Story13	156.3445	216.1323	161.3229	224.38
Story14	181.3226	250.6623	187.0964	260.2277
Story15	207.2993	286.6111	213.9194	297.5989

Table 2: Storey Displacement

Storey	Steel Rectangular	Steel -C Shape	Steel-H Shape	Steel -T Shape
Base	0	0	0	0
Story1	0.000001	1.556E-08	0.000001	0.000001
Story2	0.000002	4.133E-08	0.000003	0.000003
Story3	0.000003	6.876E-08	0.000004	0.000004
Story4	0.000005	9.59E-08	0.000005	0.000005
Story5	0.000006	1.221E-07	0.000007	0.000007
Story6	0.000007	1.471E-07	0.000008	0.000008
Story7	0.000008	1.705E-07	0.000009	0.000009
Story8	0.000009	1.921E-07	0.00001	0.00001
Story9	0.000009	2.117E-07	0.000011	0.000011
Story10	0.00001	0.000000229	0.000012	0.000012
Story11	0.000011	2.438E-07	0.000013	0.000013
Story12	0.000011	2.561E-07	0.000013	0.000014
Story13	0.000012	2.656E-07	0.000014	0.000014
Story14	0.000012	2.723E-07	0.000014	0.000014
Story15	0.000012	2.764E-07	0.000014	0.000015

Table 3: Storey Drift

Storey	Steel Rectangular	Steel -C Shape	Steel-H Shape	Steel -T Shape
Base	0	0	0	0
Story1	3.281E-07	5.186E-09	3.881E-07	3.932E-07
Story2	3.976E-07	8.589E-09	0.000000467	4.774E-07
Story3	3.939E-07	9.143E-09	4.627E-07	4.733E-07
Story4	3.834E-07	9.05E-09	4.508E-07	4.612E-07
Story5	3.688E-07	8.746E-09	4.339E-07	0.0000004
Story6	3.501E-07	8.325E-09	4.123E-07	4.219E-07
Story7	3.277E-07	7.807E-09	3.863E-07	3.953E-07
Story8	3.018E-07	7.203E-09	3.561E-07	3.644E-07
Story9	2.727E-07	6.519E-09	3.221E-07	3.296E-07
Story10	2.406E-07	5.764E-09	2.846E-07	2.913E-07
Story11	2.059E-07	0	0.00000024	2.498E-07
Story12	1.691E-07	0	2.008E-07	2.057E-07
Story13	1.305E-07	0	1.555E-07	1.593E-07
Story14	9.049E-08	0	1.086E-07	1.112E-07
Story15	5.022E-08	0	6.124E-08	6.279E-08

Table 4: Storey Shear

Storey	Steel Rectangular	Steel -C Shape	Steel-H Shape	Steel -T Shape
Base	0	0	0	0
Story1	0.055	0.0592	0.0516	0.0487
Story2	0.0546	0.0587	0.0512	0.0482
Story3	0.0535	0.0576	0.0502	0.0473
Story4	0.0519	0.0559	0.0487	0.0459
Story5	0.0498	0.0536	0.0467	0.0441
Story6	0.0472	0.0507	0.0442	0.0417
Story7	0.044	0.0473	0.0413	0.0389
Story8	0.0404	0.0434	0.0379	0.0357
Story9	0.0363	0.0391	0.0341	0.0322
Story10	0.0319	0.0343	0.0299	0.0282
Story11	0.0271	0.0292	0.0255	0.024
Story12	0.0221	0.0237	0.0207	0.0195
Story13	0.0168	0.018	0.0157	0.0149
Story14	0.0113	0.0121	0.0106	0.01
Story15	0.0057	0.0061	0.0053	0.005

Table 5. Base Shear

Steel	Rectangular	C-Shape	H-Shape	T-Shape
Base Shear	1045.2066	1584.6839	1182.8114	1146.2914

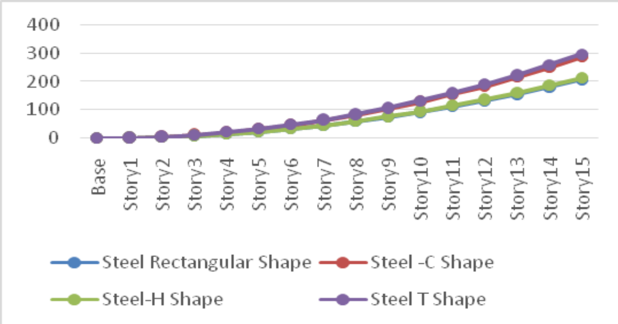


Chart No. 1 – Comparison of Lateral Load To Storey

Observations:-

From the above Chart no 1 Comparison of Lateral Load to Storey of G+ 14 Steel Rectangular, C-Shape, T-Shape, H-Shape following points are observed.

1. The lateral load to storey is maximum for the Rectangular -shape structure.
2. The lateral load to storey is minimum for T shape Plan Configuration.
3. The lateral load is near about equal for H, T shape and Cand Rectangular plan configuration structures.

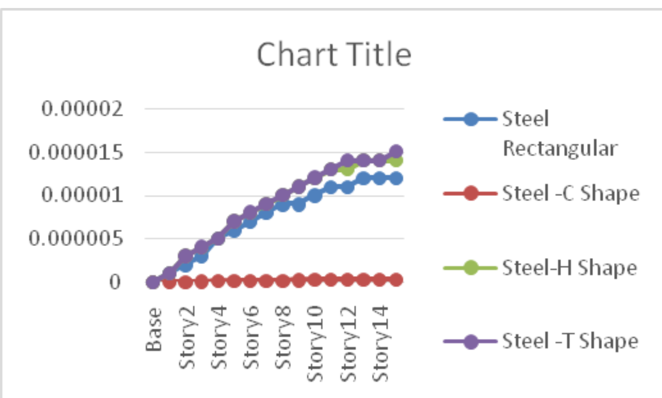


Chart No. 2 – Comparison of StoreyDisplacement

Observations:-

From the above Chart No 2 Comparison of Storey Displacement of G+ 14 Steel Rectangular , C-Shape, T-Shape , H-Shape following points are observed:-

1. The storey displacement is maximum for T – Shape Buildings.
2. The storey displacement is least for C –Shape structure.

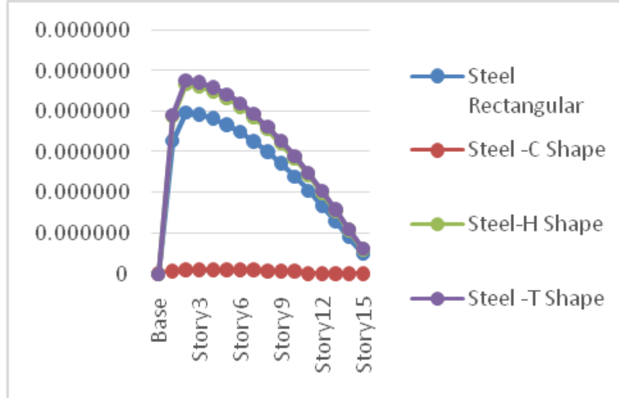


Chart No. 3:- Comparison of Storey Drift

Observations:-

From the above Chart No.3 Comparison of Storey Displacement of G+ 14 Steel Rectangular, C-Shape, T-Shape, H-Shape following points are observed.

1. The storey drift is maximum for T – Shape Buildings.
2. The storey drift is least for C –Shape structure

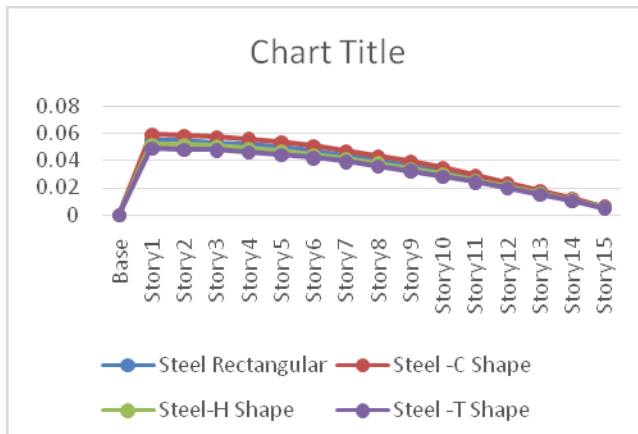
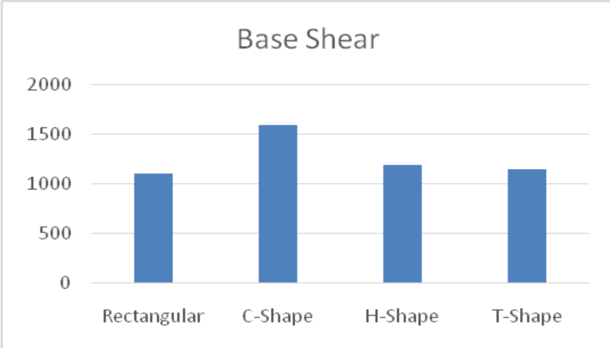


Chart No. 4:- Comparison of Storey Shear

Observations:-

From the above Chart No.4Comparison of Storey Displacement of G+ 14 Steel Rectangular, C-Shape, T-Shape, H-Shape following points are observed.

1. The storey shear is maximum for C – Shape Buildings.
2. The storey shear is least for T –Shape structure.



Observations:-

1. The base shear is maximum for Rectangular shape Steel structure.
2. The base shear is least for T- shape Steel structure.

VI. CONCLUSIONS

1. The base shear is minimum for Rectangular shape and maximum for C shape.
2. The irregularity causes high base shear leading to instability of building under seismic loads.
3. It can be concluded that the Rectangular Shape Steel structure is the safest to take for given parameters under high seismic loads in Earthquake Zone IV.
4. The eccentricity between the center of mass and the center of resistance has a significant impact on the seismic response of structures.
5. The re-entrant corners cause more irregularity in the building making it unsafe to carry seismic loads.

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