COMPARITIVE ANALYSIS OF PLAN IRREGULRITIES FOR RCC 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 RCC 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 RCC building.*

***Key Words*: Plan Irregularities, High Seismic Zone, Multi-Storied Buildings, Lateral deflections, Seismic Forces.**

1. 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 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, shaking of 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.

2. LITERATURE REVIEW:-

1. Kusuma B [2017]"Seismic Analysis of a High-rise RC Framed Structure with Irregularities". In this study the analysis was carried out on a model of G+49 stories of RC framed structure with unsymmetrical floor plan located in Zone IV, soil type III, using finite element based ETABS (V 13.1) software. The various structural response parameters such as, storey displacement, storey drift, base shear and storey stiffness were determined by considering different irregularities such as mass irregularity, vertical geometric irregularity, re-entrant corner, diaphragm discontinuity and stiffness irregularity in the model and the structural parameters stated above are compared for the models having different irregularities. In this research Seismic analysis was carried out using response spectrum method for both symmetrical and unsymmetrical building. It was studied that regular structure with RC moment resisting frame and with masonry walls, perform better under the action of seismic load, compared to irregular structure. The irregular structures, especially the re-entrant corner structure showed the worst performance when subjected to seismic excitation compared to other type of irregular structures compared to other irregular structures.

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 that irregularities 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 severe irregularity produces more 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 RCC 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. RCC for the different plan configurations in high seismic zone.

2.4 METHODOLOGY:

The different plan shapes of RCC building were modelled in the Finite Element Method Analysis Software. 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:-

$V_b = A_h * W$

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 (or frequency). Response spectrum can be interpreted as the locus of maximum response of a SDOF system 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 in earthquake-resistant design of structures.

4. 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/ m^3

8) Thickness of slab: 150mm

9) Density of wall: 20 kN/m^3

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

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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 RCC Buildings were modelled in ETABS 2016 software and then analyzed under Response Spectrum Analysis. The plans of models with different plan configuration are shown below:-

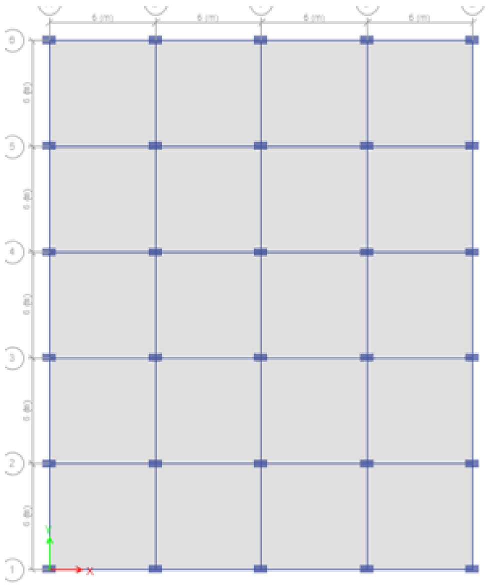

Fig.1. Plan of Rectangular RCC Building

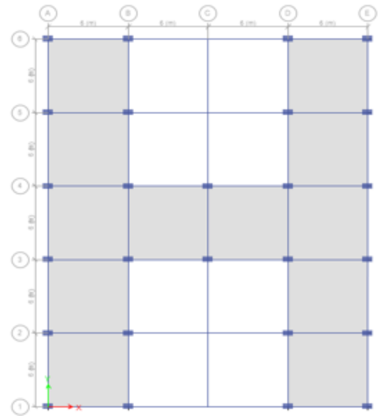

Fig.2: Plan of H-Shape RCC Structure

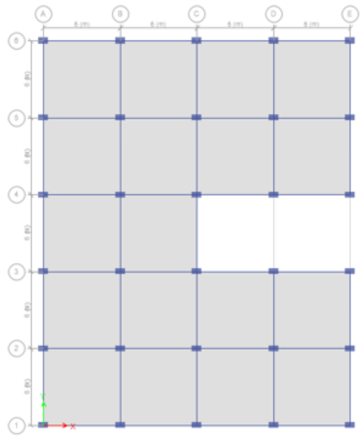

Fig. 3:- Plan of C-Shape RCC Structure

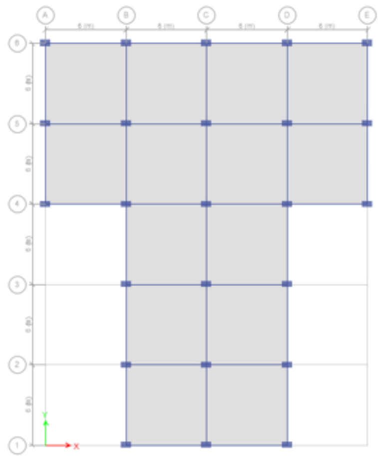

Fig. 4:- Plan of T Shape RCC Structure

5. RESULTS AND DISCUSSION:-

The following Results were obtained:-

Storey	RCC-Rectangular	RCC-C Shape	RCC-H Shape	RCC-T Shape
Base	0	0	0	0
Story1	0.859	2.2988	16.4905	1.7459
Story2	3.4359	9.1954	65.9619	6.9836
Story3	7.7309	20.6896	148.414	15.713
Story4	13.7438	36.7816	263.848	27.9343
Story5	21.4746	57.4712	412.262	43.6473
Story6	30.9235	82.7585	593.657	62.8521
Story7	42.0903	112.644	808.033	85.5486
Story8	54.9751	147.126	1055.39	111.737
Story9	69.5778	186.207	1335.73	141.417
Story10	85.8985	229.885	1649.05	174.589
Story11	103.9372	278.161	1995.35	211.253
Story12	123.6939	331.034	2374.63	251.408
Story13	145.1685	388.505	2786.89	295.056
Story14	168.3611	450.574	3232.13	342.195
Story15	193.2717	495.449	3548.37	375.983

Table 1 :Lateral Load To Storey

Storey	RCC-Rectangular	RCC-C Shape	RCC-H Shape	RCC-T Shape
Base	0	0	0	0
Story1	0.000002	3.5E-08	0.000058	0.000001
Story2	0.000005	1.1E-07	0.000058	0.000002
Story3	0.000008	2.01E-07	0.000058	0.000003
Story4	0.00001	2.96E-07	0.000058	0.000005
Story5	0.000013	3.92E-07	0.000058	0.000006
Story6	0.000016	4.86E-07	0.000058	0.000007
Story7	0.000019	0.000001	0.000058	0.000008
Story8	0.000021	0.000001	0.000058	0.00001
Story9	0.000023	0.000001	0.000058	0.000011
Story10	0.000025	0.000001	0.000058	0.000011
Story11	0.000027	0.000001	0.000058	0.000012
Story12	0.000028	0.000001	0.000058	0.000013
Story13	0.000029	0.000001	0.000058	0.000013
Story14	0.00003	0.000001	0.000058	0.000014
Story15	0.000031	0.000001	0.000058	0.000014

Table 2: Storey Displacement

RCC	Rectangular	C-Shape	H-Shape	T-Shape
Base Shear	1065.14	2828.77	20286.20	2148.061

Table 3. Base Shear

Storey	RCC-Rectangular	RCC-C Shape	RCC-H Shape	RCC-T Shape
Base	0	0	0	0
Story1	0.000001	1.17E-08	0	2.59E-07
Story2	0.000001	2.52E-08	0	4.25E-07
Story3	0.000001	3.01E-08	0	4.5E-07
Story4	0.000001	3.17E-08	0	4.46E-07
Story5	0.000001	3.19E-08	0	4.32E-07
Story6	0.000001	3.14E-08	0	4.13E-07
Story7	0.000001	3.04E-08	0	3.89E-07
Story8	0.000001	2.9E-08	0	3.61E-07
Story9	0.000001	2.72E-08	0	3.28E-07
Story10	0.000001	2.51E-08	0	2.92E-07
Story11	0.000001	2.27E-08	0	2.52E-07
Story12	4.57E-07	2E-08	0	2.09E-07
Story13	3.56E-07	1.71E-08	0	1.64E-07
Story14	2.54E-07	1.41E-08	0	1.18E-07
Story15	1.57E-07	1.14E-08	0	7.48E-08

Table 4: Storey Drift

Storey	RCC-Rectangular	RCC-C Shape	RCC-H Shape	RCC-T Shape
Base	0	0	0	0
Story1	1.4267	0.5841	0	0.5466
Story2	1.4183	0.5807	0	0.5433
Story3	1.3958	0.5715	0	0.5346
Story4	1.3584	0.5562	0	0.5202
Story5	1.3062	0.5349	0	0.5002
Story6	1.2397	0.5077	0	0.4746
Story7	1.1595	0.4749	0	0.4439
Story8	1.0665	0.4369	0	0.4081
Story9	0.9616	0.3939	0	0.3678
Story10	0.8459	0.3464	0	0.3234
Story11	0.7206	0.2949	0	0.2752
Story12	0.5871	0.24	0	0.2238
Story13	0.4468	0.1821	0	0.1698
Story14	0.3012	0.122	0	0.1137
Story15	0.1517	0.0602	0	0.0561

Table 5: Storey Shear

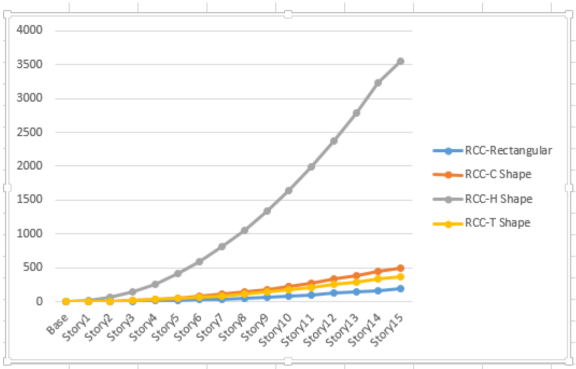

Chart No. 1 – Comparison of Lateral Load To Storey

Observations:- From the above Chart No 1 Comparison of Lateral Load to Storey of G+ 14 RCC Rectangular, C-Shape, T-Shape, H-Shape following points are observed:-

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

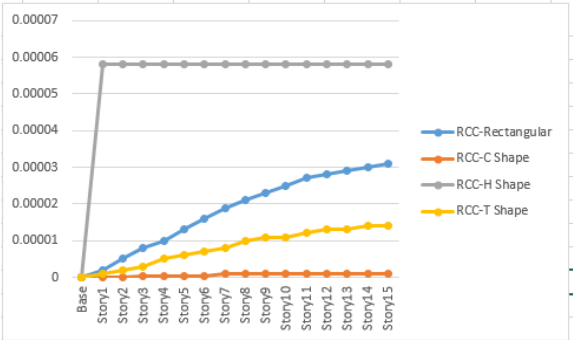

Chart No. 2 – Comparison of Storey Displacement

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

1. The storey displacement is maximum for H – Shape Buildings and minimum for C-Shape
2. The storey displacement is least for C-Shape.
3. The storey displacement is constant for H-shape with maximum value.

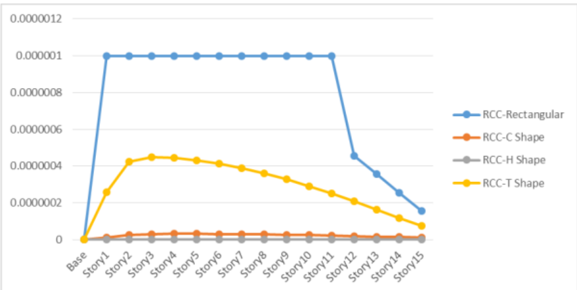

Chart No. 3:- Comparison of Storey Drift of RCC Structures

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

1. The storey drift is maximum for the Rectangular plan configuration and minimum for H-Shape.

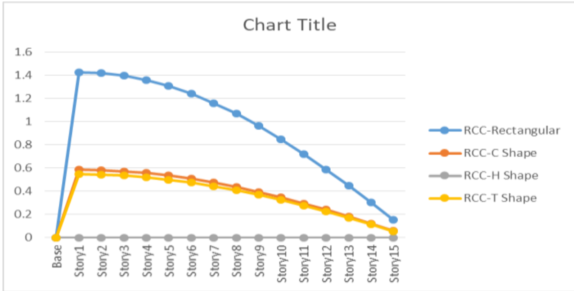

Chart No. 4:- Comparison of Storey Shear of RCC Structures

Observations:- From the above Chart No 4 Comparison of Storey Shear of G+ 14 RCC Rectangular, C-Shape, T-Shape and H-Shape following points are observed:-

1. The storey shear is maximum for the Rectangular plan configuration and minimum for T-Shape.

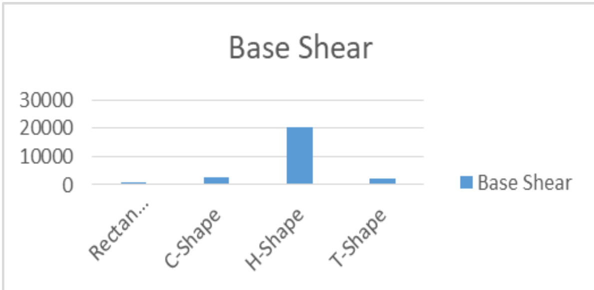

Chart No. 4:- Comparison of Base Shear of RCC Structures

6. CONCLUSIONS:-

1. The base shear is maximum for H-shape and least for rectangular shape building.

2. The re-entrant corners cause more irregularity in the building making it unsafe to carry seismic loads.

3. It can be concluded that the Rectangular structure is the safest in Earthquake Zone IV to take the seismic loads.

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 results also have been proved that, building with severe irregularity are more vulnerable especially in high seismic zones.

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