Investigation of Damages in Plan Irregular Buildings Due to Seismic Excitation

(Details for Structural Project and Analysis)

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***Abstract*— Buildings suffer much less damages in earthquake than buildings with irregular configurations having simple regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation. In the present study, an attempt has been made to analyze the seismic behavior of G+9 regular building and an irregular re-entrant corner building in zone V seismic zone using Etabs 2016. Irregularity can be vertical as well as horizontal. Vertical irregularities can be classified into four depending upon the distribution of mass, strength, stiffness and vertical setback. Horizontal irregularities are those with asymmetrical plan shapes, re entrant corners, diaphragm discontinuity and also irregular distribution of mass, strength, and stiffness along plan. Parameters such as base shear and time period are found out for the regular building. Base shear, time period, overturning moment and maximum storey displacement of re-entrant corner irregular building is found out. From this study, it is concluded that the re-entrant corner irregular buildings have much lower base shear force produce under earthquake forces as compared with the regular building with same structural configurations.. As a future scope seismic response of more re-entrant corner models with same structural details can be found and comparison can be done.**

Keywords—Regular building; irregular building; re-entrant corner; Seismic Analysis; ETABS2016; IS 1893:2002

I. INTRODUCTION

In this fast moving world, it is important to contribute more from the field of construction for a developing country like India. Demand of low rise buildings increases nowadays and within these buildings, irregular buildings comes due to increase in aesthetic preference and structural demands. The multistorey residential buildings can provide higher number of houses and requires less space of land. Most buildings are constructed by irregular in both plan and vertical configuration. Buildings suffer much less damages in earthquake than buildings with irregular configurations having simple regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation. Irregularity can be basically divided into vertical irregularity and horizontal irregularity. Vertical irregularities can be classified into four depending upon the distribution of mass, strength, stiffness and vertical setback. As per IS 1893:2002, a storey in a building is said to contain mass irregularity if its mass exceeds 200 percent than that of the adjacent storey. If stiffness of a storey is less than 60 per cent of the adjacent storey; in such a case the storey is termed as weak storey, and if stiffness is less than 70 per cent of the storey above, then the storey is termed as soft storey. Strength irregularity and setback irregularity referring to sudden change of strength and geometry results in irregular distribution of forces or distribution over the height of the building. Horizontal irregularities are those with asymmetrical plan shapes, re entrant corners, diaphragm discontinuity and also irregular distribution of mass, strength, and stiffness along plan. An L-, U-, E- or other in plan shaped building where two wings may oscilate out-of-phase, leading to large shear stresses in floor and/or roof diaphragms. If the plan setback is at least 15 % of both plan dimensions, then the setback is considered to form a re- entrant corner. In architectural planning, setbacks on the facade, sections or parts placed at different angles, different plan solutions compared to basic geometries to adapt to the land are common design choices. The shape of H, L, T, U, Y, cross, or a combination of these forms are the typical examples of building configuration which have projections or wings in plan constituting re entrant corners. The building corners formed inwards, or outwards are one of the most common applications of geometric irregularities. These applications are subject to energy concentrations under the dynamic earthquake effects, resulting in severe stress concentration in the corners. Maver (1970) and Peña and Parshall (2001) defined architectural design as a trial-and-error process, which consists of several variables related to economy, aesthetics, functionality, and strength. The architectural design process is the stage of construction where the various features of the building are identified, and decisions are made concerning building characteristics that affect the building's structural behavior. In this phase, earthquake-resistant structure design should be considered if the structures are constructed in regions of high earthquake risk. A suitable structural system for architectural and functional design is determined by architects during the preliminary design phase. Architects need to comprehend the concepts of the necessary structural system and earthquake-resistant design to produce quality structures. Earthquakes usually cause damage to weak spots in the configuration of a building. If the decisions taken in the architectural design phase, which are crucial for the building's behavior against earthquakes, are based on the right information and using the right methods, design success will be increased, and a long-lasting and sustainable structure against earthquakes will be achieved. At this point, it is possible to say that the most acceptable design of the earthquake-resistant structure can be achieved by the efforts of the architects. Architects should remember that in the configuration of a building, they will determine where the seismic damage should occur in the building. Earthquake codes, which are directly related to design and construction, address a wide area (analytical methods, reinforced concrete buildings, steel buildings, masonry buildings, foundations, evaluation and strengthening of existing buildings). At this point, it is useful to understand the philosophy of the codes according to the field of the person concerned. It is very important to understand the earthquake codes to reinterpret information about architecture in the case of an earthquake, which is an unchanging reality, to enable architects to use the right tools effectively in this matter.

II. LITERATURE REVIEW

Aamna Sarfaraz, Rehan A Khan and Shakeel Ahmad(2017) conducted a study and presented a project on seismic vulnerability of irregular building where regular RCC frame building having G+9 storey is compared with irregular 4 number of structures using response spectrum linear static analysis. In this study, The influence of various structural parameters i.e. Natural Time Period, Base Shear, Inter-Storey Drift Ratio, Beam Moment and Column Moments, effect of variation in angle of incidence of earthquake are compared with that of regular building. Pushover Analysis (Non –Linear Static) is also carried out to compare the base shear –roof displacement curves i.e. pushover curve and hinge displacement. From this study, it is concluded that the irregular buildings are more vulnerable under earthquake forces as compared with the regular building.

S. Boopathi Raja and V. Preetha (2017) presented a paper on Effect of Structural irregularities on seismic performance of reinforced concrete building. The study summarizes the different types of structural irregularities i.e. plan and vertical irregularities in RC building along their performance during earthquake using push over analysis. The study concluded that vertically irregular building have performed very poorly during earthquakes. The performance based analysis like push over analysis is very much essential to understand the behavior of the structures. Also they mentioned that the complex shaped buildings are more popular, but they carry a risk of sustaining damages during earthquakes. Therefore, such buildings should be designed properly taking care of their dynamic behavior.

A.Titiksh(2017) studied the effects of irregularities on the seismic response of a medium rise structure and focused on the seismic induced torsion in asymmetric RC buildings. Equivalent Lateral Force Method (ELF) is adopted as per IS:1893(Part-1)-2002 codal provisions to study the induced torsion. ETABS software package is used to carry all the static and dynamic analysis by keeping these models in different seismic zones from Zone II to Zone V. The discontinuities in a lateral force resistance path, such as vertical offsets, are also considered. The results showed that Base shear and lateral displacement were increasing with increase in the seismic intensity from Zone II to Zone V. Also the Base shear for mass irregularity is found more compared to all other irregularities.

Prof. Sujeet Patil, Pooja Matnalli, Priyanka S V, Rajamma (2019) presented a paper on seismic analysis of plan regular and irregular buildings. In this paper is an attempt to evaluate and compare seismic performance of G+14 Storey with 7 bays X 9 bays plan irregular and Regular building using ETABs 2015 software. The building is analyzed in the region of earthquake zone IV on a medium soil. Equivalent static analysis (ESA) and Response spectrum analysis (RSA) method is used. Storey displacement, Storey drift and Base shear are considered as parameters. In that paper a study is conducted to understand the structural behavior of plan irregular building in comparison to regular building under seismic loading. It is recommended that for analysis of plan irregular building dynamic analysis need to be carried out, equivalent static method being more suitable for regular buildings. Hence suggested that response spectrum method of dynamic is good for analysis.

Srishti Bhomaj, Parikshit Ghodake, J.P.Patankar (2019) presented a paper on analysis and design of regular and irregular building. In that paper they analyzed and designed RCC G+3 building, regular as well as irregular, manually and by using Etabs and StaadPro.v8i softwares. In this project the torsional irregularity has been studied and similarly on the same basis other irregularities can also be studied. The effects of irregularity have been shown in this project and it will help the designers to design the buildings in a more efficient way possible.

Siva. Naveen. E, Nimmy. Abraham, Anith. Kumari. S. D (2019) conducted a study on analysis of irregular structure under earthquake loads. A nine storeyed regular frame is modified by incorporating irregularity in various forms in both plan and elevation to form configurations with single irregularity and with combinations of irregularities. Along with the regular configuration, irregular configurations are analyzed and compared. All the frames are subjected to seismic loads and the response of the structure is computed numerically.

After going through the journals and the literature, there is a scope to find the damages caused to re-entrant corner irregularity due to seismic excitation using a software and thus to compare the results with the regular structure.

III. FRAME DETAILS

In the present study G+9 of RCC structure in zone V is being analyzed by equivalent static method by using ETABS2016 software. In case of RCC structure, all structural members are considered as per IS 456:2000 and Steel sections are considered as per steel table and IS 800:2007. The details of RCC regular structure are as follows:-

Seismic Zone	V
Zone Factor	0.36
Importance Factor	1.00
Type of soil	Medium

Analysis and Design parameters:-

Type of Structure	-Residential Building

Materials:-

Concrete -M20 grade

Steel -Fe 415 grade

Seismic Analysis method -Response Spectrum method

Design Philosophy -Limit State method

Geometric parameters:-

Foundation level to ground level -3m

Number of bays in X direction -5

Number of bays in Y direction -4

Spacing of bays in X direction -5m

Spacing of bays in Y direction -4m

Height of each storey -3m

Number of storeys -G+9

Dimensions of structural members:-

Beam cross section -0.35m x 0.35m

Column cross section -0.45m x 0.40m

Thickness of the slab -0.15m

Thickness of external wall -0.23m

Loads considered:-

Unit weight of brick masonry -18kN/m3

Unit weight of R.C.C -25kN/m3

Self weight of external wall =0.23 x 18 x (3-0.35)

=10.97kN/m3

Self weight of slab =25 x 2 x 0.15=7.5kN/m3

Live load on slab -3kN/m

Self weight of floor finish -2kN/m

Live load on floor -6kN/m

Roof treatment -3kN/m

Live roof -2kN/m

Same structural details are followed except, external wall load was not considered for the analysis of re-entrant corner irregular building.

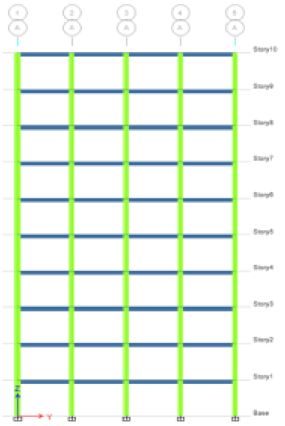


Figure: 1, Elevation of RCC Regular Structure

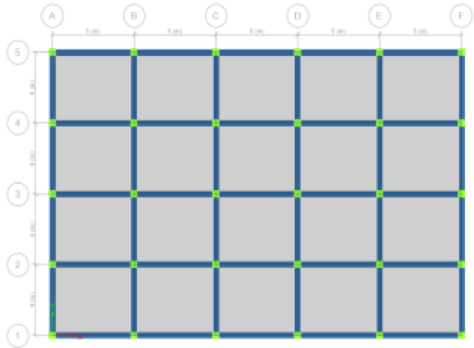


Figure: 2, Plan of RCC Regular Structure

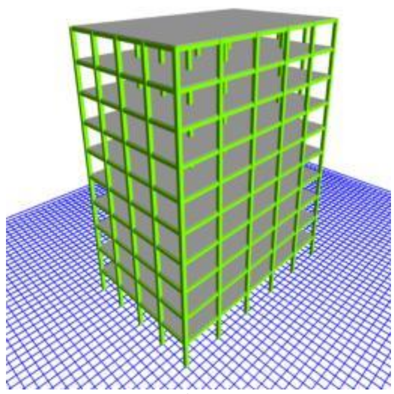


Figure: 3, 3D view of RCC Regular Structure

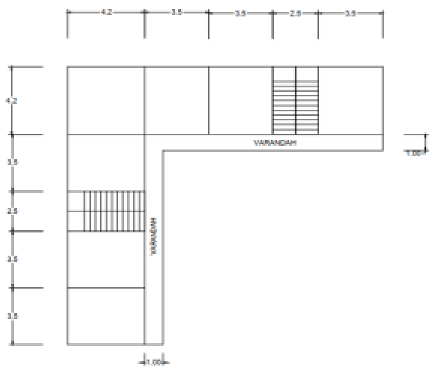


Figure: 4, Plan of RCC Re-entrant corner irregular Structure

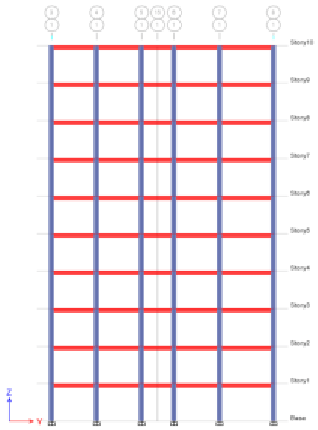


Figure: 5, Elevation of RCC Re-entrant corner irregular Structure

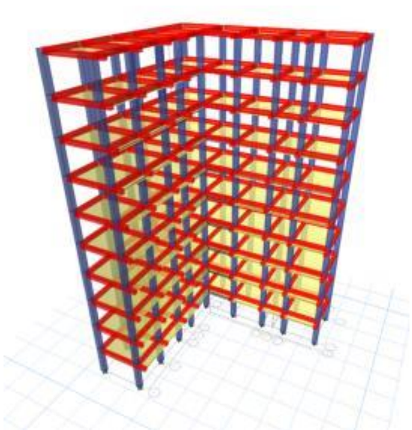


Figure: 6, 3D view of RCC Re-entrant corner irregular Structure

IV. METHODOLOGY

The present comparative study deals with equivalent static method for seismic analysis of G+9 frame structure of a RCC regular building. The analysis of the building model is run in software ETABS2016. For the analysis the parameters like Natural Time Period and Base Shear for seismic forces along X and Y directions are studied significantly for the loading. Also base shear and time period of re-entrant corner irregular structure is found using Response spectrum analysis. In addition to that Maximum storey displacement and overturning moment is found from the analysis. Seismic code varies with the every region across the country. In India standard criteria for earthquake resistant design of structures IS 1893(PART-1):2002 is the main code which gives the idea about the seismic design force according to the various zones. Finally to prove that irregular buildings are more vulnerable in seismic prone zones than regular building.

V. RESULT

A. The Base shear of regular building for seismic forces in X and Y directions are 456.13kN and 471.96kN respectively.

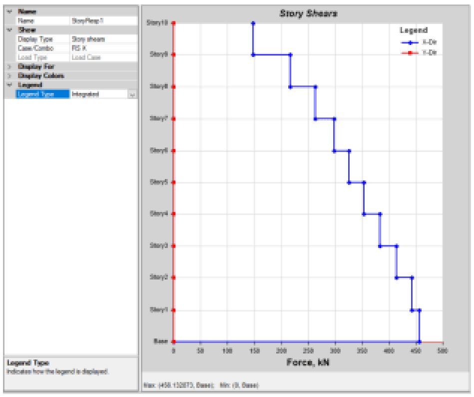


Figure 7, Base shear along X direction of regular building

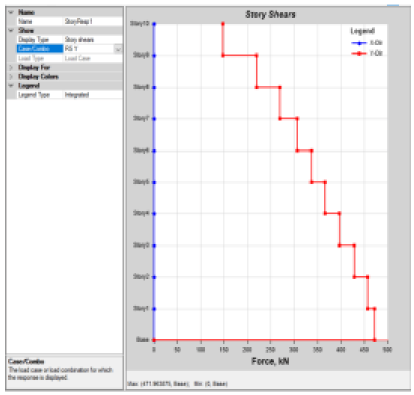


Figure 8, Base shear along Y direction of regular building

B. Natural time period is a primary parameter which regulates the seismic lateral response of the building frame. Natural time period of the regular building is 1.816sec.

Modal Periods and Frequencies

Case	Mode	Period sec	Frequency cyc/sec	Circular Frequency	Eigenvalue rad²/sec²
Modal	1	1.816	0.551	3.4606	11.9756
Modal	2	1.77	0.565	3.5506	12.6066
Modal	3	1.755	0.57	3.5807	12.8213
Modal	4	0.576	1.737	10.9115	119.0605
Modal	5	0.569	1.758	11.0488	122.0765
Modal	6	0.563	1.777	11.1677	124.7176
Modal	7	0.319	3.134	19.6918	387.7661
Modal	8	0.316	3.165	19.886	395.4535
Modal	9	0.314	3.181	19.9857	399.4298
Modal	10	0.21	4.77	29.9697	898.1802
Modal	11	0.206	4.843	30.4276	925.8304
Modal	12	0.203	4.937	31.0226	962.401

Figure 9, Natural time period of RCC regular structure

C. The base shear of re-entrant irregular model for seismic forces along X and Y directions are 223.38kN and 222.35kN respectively.

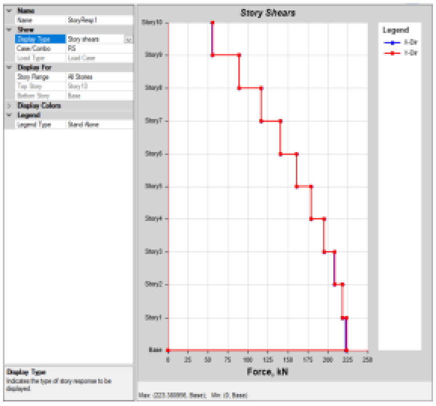
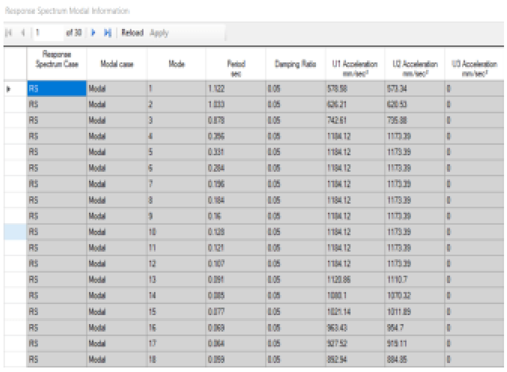


Figure 10, Base shear of re-entrant corner irregular building

D. Natural time period of the re-entrant corner irregular building is 1.122sec.



Response Spectrum Case	Modal case	Mode	Period sec	Damping Ratio	U1 Acceleration mm/sec²	U2 Acceleration mm/sec²	U3 Acceleration mm/sec²
RS	Modal	1	1.122	0.05	578.58	573.34	0
RS	Modal	2	1.033	0.05	626.21	620.53	0
RS	Modal	3	0.878	0.05	742.61	735.88	0
RS	Modal	4	0.356	0.05	1184.12	1173.39	0
RS	Modal	5	0.331	0.05	1184.12	1173.39	0
RS	Modal	6	0.284	0.05	1184.12	1173.39	0
RS	Modal	7	0.196	0.05	1184.12	1173.39	0
RS	Modal	8	0.184	0.05	1184.12	1173.39	0
RS	Modal	9	0.16	0.05	1184.12	1173.39	0
RS	Modal	10	0.128	0.05	1184.12	1173.39	0
RS	Modal	11	0.121	0.05	1184.12	1173.39	0
RS	Modal	12	0.107	0.05	1184.12	1173.39	0
RS	Modal	13	0.091	0.05	1120.86	1110.7	0
RS	Modal	14	0.085	0.05	1080.1	1070.32	0
RS	Modal	15	0.077	0.05	1021.14	1011.89	0
RS	Modal	16	0.069	0.05	963.43	954.7	0
RS	Modal	17	0.064	0.05	927.52	919.11	0
RS	Modal	18	0.059	0.05	892.94	884.85	0

Figure 11, Time period of re-entrant corner irregular building

E. Maximum storey displacement for re-entrant corner irregular model for seismic forces is 32.612mm.

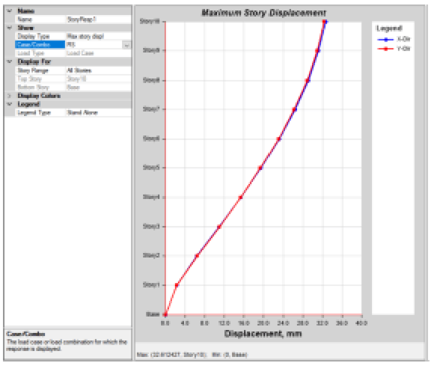


Figure 12, Max. Storey displacement of re-entrant corner irregular building

F. Overturning moment for re-entrant corner model for seismic forces is 4.567kNm.

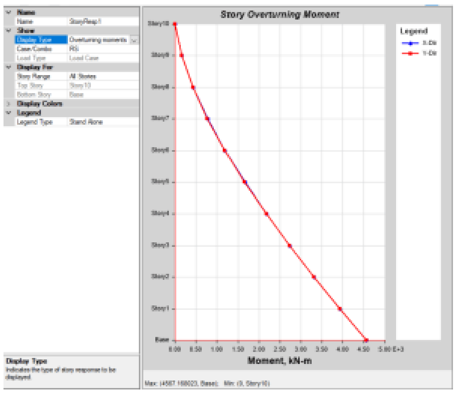


Figure 12, Overturning moment of re-entrant corner irregular building.

VI. CONCLUSION

The major conclusions drawn from present study after the seismic analysis of a regular building and a re-entrant corner irregular building are as follows:-

1. Base shear force of regular building using response spectrum analysis is found to be much different than that of base shear of re-entrant corner irregular building.
2. Natural time period for the RCC regular building is more than that of re-entrant corner irregular building. From this we can say that stiffness is more in re-entrant corner irregular building.
3. Damages in a building can be found from the value of storey displacement. In this work, maximum storey displacement for a re-entrant corner irregular building was much lesser.
4. Overturning moment of the re-entrant corner irregular building after analysis was also found to be much lesser value.
5. Future study can be done on more re-entrant corner type models and thus the damages caused on seismic excitation can be compared with results already calibrated.

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