Seismic Analysis of Regular & Irregular Structures and its Comparison

Purushottam Dewangan[1] & Tushar Saxena[2]

[1]M-Tech Scholar, Dept. of Civil Engineering, BIT, Durg, India
[2]Assistant Professor, Dept. of Civil Engineering, BIT, Durg, India

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Abstract:- *The main objective of earthquake engineering is to design & build a structure in such a way that the damage to the structure and its structural component during an earthquake is minimized. Construction can suffer diverse damages when they are subjected to Seismic excitations. For the same structural configuration, region & earthquake, damages in the systems are neither equal nor homogeneous. Seismic Analysis of building has now become an important part in present era of Modern Structural designs, it is because earthquake causes lots of damages and loss of life. Multi-storey Structures constructed by Reinforced Cement Concrete are subjected to severe actions of Seismic waves during Earthquake. The main reason for the failure of RC building is Irregularity. The Irregularities may be in its plan dimension, lateral force distribution.*

Key Words— *seismic loads, regular, irregular, plan irregularity, multi-storey, static, dynamic, push-over, lateral force, re-entrant corner.*

1. INTRODUCTION

Irregularities are not avoidable in construction of Buildings. However, the behavior of structures with these irregularities during earthquake need to be studied. By taking adequate precautions, the main objective of Earthquake Engineering is to design and build a structure in such a way that the damage to the structure and its structural components during an earthquake is minimized. Constructions can suffer diverse damages when they are put under seismic excitations. Although for a same structural configuration, region & earthquake, damages in the system are neither equal nor homogenous. So, there are several factors for these like – Structural system, Earthquake characteristics, the quality of construction, soil of location and its maintenance that define the seismic behavior of the structure. However, with the experiences in past and recent earthquakes, most of the damages are related to architectural and structural configuration in plan and elevation and site ground effects. Irregular buildings constitute a large portion of the modern urban infrastructure. Adequate precautions need to be taken. A detailed study of structural behavior of the buildings with irregularities is essential for design and behavior in earthquake. Therefore, the structural engineer needs to have a thorough understanding of the seismic response of irregular structures. Several related studies have focused on evaluating the response of 'Regular Structures". However, there is lack of understanding of the seismic response of structure with irregularities. Therefore, a comprehensive evaluation of the effect of horizontal irregularities on the seismic demand of building structures is generally needed.

1.1. Objective of Study.

The foremost objective of the present work is to analyze the behavior of the structures and to adopt the methodology to minimize the damages caused by seismic activities. For this purpose, push-over analysis of various structures with plan irregularity has been done. Furthermore, the objectives are figured out as follows -

1) To understand the behavior of structure during Earthquake with Plan Irregularities.
2) Understanding of Torsion Response of structure due to Plan irregularity.
3) Identification & measure of the Irregularity level produced.
4) Improvement of the structural system considering Torsion Seismic behavior.
5) Comparison between Model analyzed using code, IS: 456-2000 & IS: 13920-1993.
6) To identify the suitable building configuration from this analysis.

2. LITERATURE REVIEW

Dr. S.K. Dubey & P.D. Sangamnerkar. [1] "Seismic behavior of Asymmetric R.C. buildings", they had modelled & analyzed a five storey framed structure using STAADPRO. The building is assumed as commercial complex. Geometry of building is 'T' in shape consisting of open ground storey parking. They analyzed for Zone-IV considering site with medium soil. They concluded that the proposed buildings with irregularities are more prone to earthquake damage & torsion is the most critical factor leading to major damage or complete collapse of building.

Neha P. Modakwar, Sangita S. Meshram & Dinesh W. Gawatre. [2] "Seismic Analysis of Structures with Irregularities", they chose a non-realistic structure with frames 5mX5m of cross shaped & L shaped building. The building is assumed as a commercial complex with fifteen storey & five storey R.C. building. They assumes the site to be located in Seismic Zone-II with medium soil condition. The studied the behavior of structure of re-entrant corner locations. They worked to understand different irregularity and torsional response due to plan and vertical irregularity. They summarized that the re-entrant corner columns are needed to be stiffened.

N. Lakshmanam, K. Muthumani, G.V. Rama Rao, N. Gopalkrishnan & G.R. Reddy. [3], "Verification of Push-over Analysis method with Static Load Testing", they did an experimental investigation on pushover test of a three-storied R.C. model frame. The test results were then compared with analysis results obtained from SAP2000, with default hinge properties and also with modification. They found that the capacity curve needs to be corrected for displacement profile and stiffness reduction beyond yield point is continuous for experiment and discrete and jagged in the analysis.

R.I. Herrera, J.C. Vielma, R. Ugel, A. Alfaro, A. Barbat & L. Pujades. [4] "Seismic Response and Torsional effect of R.C. Structures with Irregular Plan and variations in Diaphragm", they determined the seismic response and torsional effect of an existing reinforced concrete building with irregular plan. The structure analyzed consists of a low-rise R.C. residential building designed as per Venezuelan Seismic Design Code. Two structures were analyzed: the original building & a redesigned version. Non-linear Static and Non-linear Dynamic analysis were applied. They used Zeus NL Software for their analysis. Results showed that the original structure has an adequate resistant behavior and a high probability of exceeding the moderate damage state, while the redesigned structure presents good performance under seismic events according to existing code. It was also observed that maximum torsional effects occur in the re-entrant corners of the irregular plan, which are reduced in mid-rise buildings by using rigid diaphragm.

Magliulo G., Maddaloni G. & Petrone C. [5] "Influence of Earthquake direction on the Seismic Response of Irregular Plan R.C. Frame buildings", they used three multi-storey R.C. building, representing a very common structural topology in Italy for the evaluation. They are respectively a Rectangular Plan Shape, an L Plan Shape & a Rectangular Plan Shape with Courtyard building. The result shows that the angle of Seismic input motion significantly influences the response of R.C. structures. The critical Seismic angle i.e., the incidence angle that produces the maximum demand provides an increase of up to 37% in terms of both roof displacements and plastic hinge rotations.

Raul Gonzalez Herrera & Consuelo Gomez Soberon [6] "Influence of Plan Irregularity of Buildings" they have given analytical description of the damages caused by different plan irregularities during seismic events of different magnitudes. The effect of geometric form in plan eccentricity as well as the plan extension and projections. They plant their models in SAP2000 considering one, two and four levels to determine the effect of the geometric form in the seismic behavior of structures with elastic analysis. They concluded that constructions are more vulnerable when more irregular.

3. METHODOLOGICAL BACKGROUND

The project aims at the behavioral study on seismic analysis and performance of reinforced concrete frames with plan irregularities. For this, different models are considered, with different plan and elevation. Frames has been analyzed using SAP2000 software, referring IS: 456-2000, IS: 1893 (part-1) 2002 and IS: 13920-1993. Safety and minimum damage level of a structure could be the prime requirement of tall buildings. To meet these requirements, the structure should have adequate lateral strength, lateral stiffness and sufficient ductility. Seismic Analysis is a subset of structural analysis and is the calculation of the response of a building (or non-building) structures to earthquake. It is part of the process of Structure design, earthquake engineering or structural assessment and retrofit in regions where earthquakes are prevalent. To ascertain this, Push-over analysis has been the preferred method for seismic performance evaluation of structures by the major rehabilitation guidelines and codes. Push-over analysis is an approximate analysis method in which the structure is subjected to monotonically increasing lateral forces with an invariant height-wise distribution until a target displacement is reached. Push-over analysis consists of a series of sequential elastic analysis, superimposed to approximate a force-displacement curve of the overall structure. Push-over analysis allows tracing the sequence of yielding and failure on member & structural level as well as the progress of overall capacity curve of the structure. Also, Push-over analysis provide information on many response characteristics that cannot be obtained from an elastic static or elastic dynamic analysis.

Structural details of analysis (G +8) building:

i.	Type of Structure	= Framed
ii.	Type of Building	= Residential
iii.	Number of storey	= 9 (G + 8)
iv.	Height of storey	= 3m
v.	Cross-section of beams	= 230x600mm
vi.	Cross-section of columns	= 300x450mm
vii.	Slab Thickness	= 150mm
viii.	Grade of concrete	= M25
ix.	Grade of steel	= Fe 500
x.	Dead Load	= -1 factor
xi.	Live Load on floor	= 4KN/m
xii.	Seismic Load 1893– 2002,	= as per IS:
xiii.	Site Location	= Zone-V

xiv. Soil Condition = Hard

Analysis of Building: Analysis is done by using STAAD. Pro, SAP2000 under design consideration IS: 456 - 2000 and IS: 13920 - 1993.

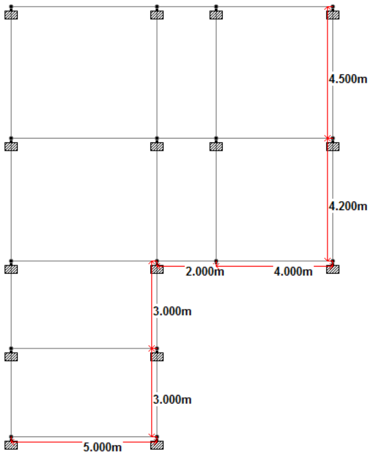


FIG. 3.1: Plan for Irregular Structure Type I

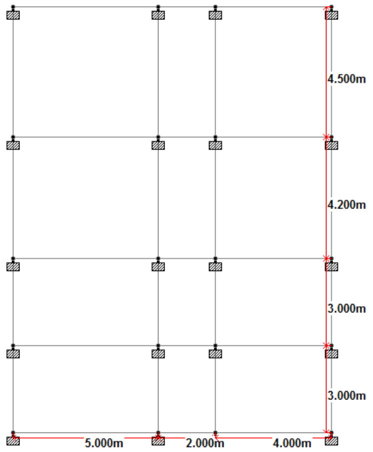


FIG. 3.2: Plan for Regular Structure Type I

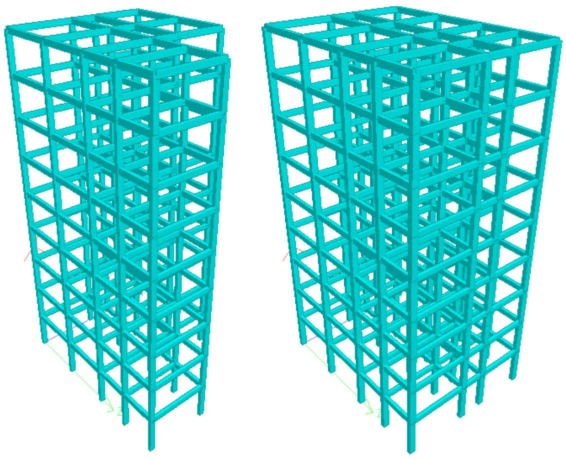


FIG. 3.3: Isometric View for Irregular & Regular Structure Type I

4. RESULT ANALYSIS

Results are obtained for above sections by carrying Push-over Analysis. Comparison of base shear & roof displacement can be seen. Here are the results on the basis of Push-over analysis.

TABULAR RESULTS

Table No. – 4.1 – Base Shear & Roof Displacement.

		Irregular		Regular	
		Base Shear (kN)	Roof Displacement (mm)	Base Shear (kN)	Roof Displacement (mm)
Structure I	X	400	175	552	285
	Y	440	225	630	290
Structure II	X	344	285	370	300
	Y	392	288	415	350

Table No. – 4.2 – Comparison of Shear Force & Displacement at Performance Point.

		Irregular		Regular	
		V (kN)	D (mm)	V (kN)	D (mm)
Structure I	X	266	59	431	52
	Y	382	79	473	51
Structure II	X	279	65	284	64
	Y	278	67	280	67

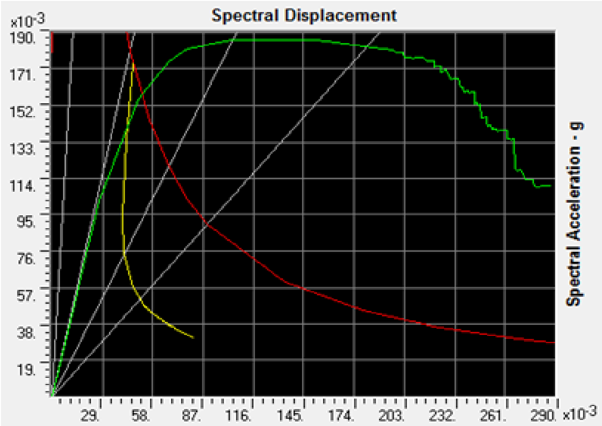
Table No. – 4.3 – Comparison of Bending Moment w.r.t. Demand & Capacity at Performance Point.

			Bending Moment Demand	Bending Moment Capacity
Structure I	Irregular	X	57	50
		Y	60	50
	Regular	X	62	78
		Y	81	96
Structure II	Irregular	X	86	79
		Y	74	68
	Regular	X	87	87
		Y	90	90

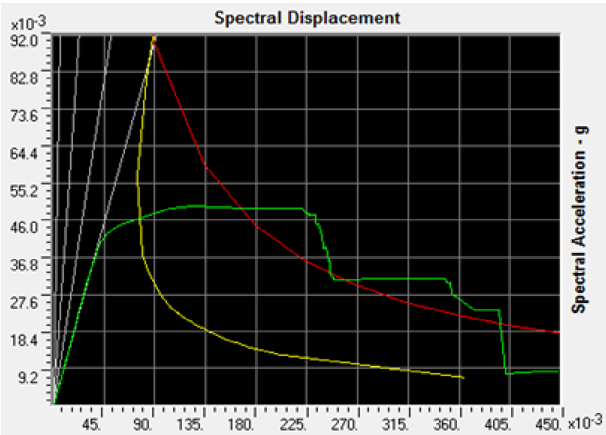
From the above tables, it is observed that the bending moment demand is more than the capacity for both the irregular structures in both the directions.

We need to take care while designing re-entrant corner columns, as moment at the re-entrant corner columns is more than the capacity of the column. It can be seen from graphical table as follows.

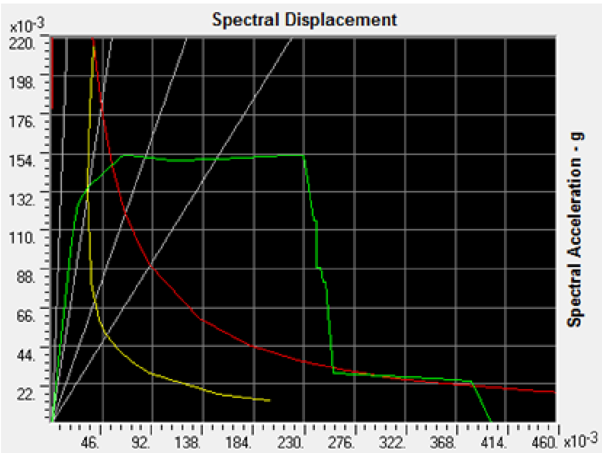
GRAPHICAL RESULTS



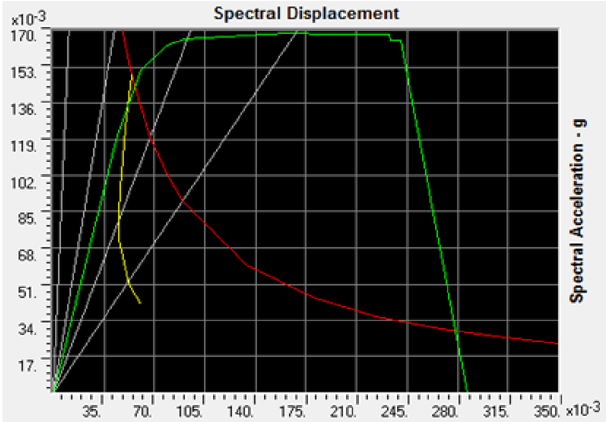
Graph No. 4.1. – Typical Capacity Spectrum for Push-over Analysis of Structure Type I in X direction



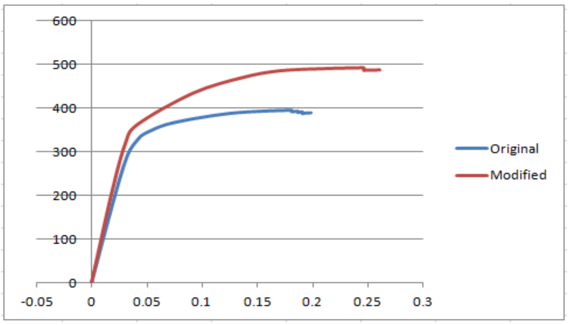
Graph No. 4.2. – Typical Capacity Spectrum for Push-over Analysis of Structure Type I in Y direction



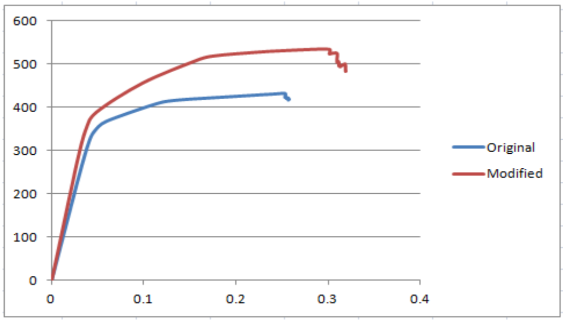
Graph No. 4.3. – Typical Capacity Spectrum for Push-over Analysis of Structure Type II in X direction



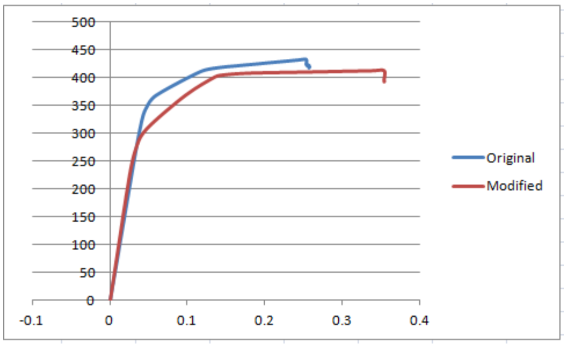
Graph No. 4.4. – Typical Capacity Spectrum for Push-over Analysis of Structure Type II in Y direction



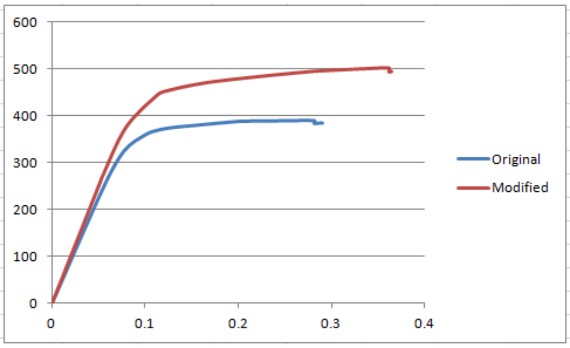
Graph No. 4.5. – Typical Push-over curve for Structure Type I in X direction



Graph No. 4.6. – Typical Push-over curve for Structure Type I in Y direction



Graph No. 4.7. – Typical Push-over curve for Structure Type II in X direction



Graph No. 4.8. – Typical Push-over curve for Structure Type II in Y direction

5. RESULT DISCUSSION.

Results as obtained from tabulated data and graphical representations shows that there is considerable difference in Bending Moment demand and Bending Moment Capacity under applied structural defined loads like; dead, live and seismic loadings. The loads causes significance vibrations, which make structure to deform or get displaced from connecting joints, or say; the node to node displacements. Data shows that the structural entity assembled is at most on critical side as if not properly investigated for seismic performance and its after affects (bursting of column and beams in lateral direction) which might be disastrous.

The confined detailed go-through in this research work study reveals that the after proper modification, the bending moment capacity of re-entrant corner columns can be increased. Highly configured material for columns used at re-entrant corner reduces seismic vibration effect by allowing forces to pass through structural members. Amount of reinforcement required in concrete structure is though more than Normal concrete structures which helps in increasing moment capacity. Danger of story drift under seismic response is reduced by increasing stiffness of members. Ductility of structure is also increased.

6. CONCLUSION

i. After proper modification the bending moment capacity of re-entrant corner column is increased.

ii. Base Shear for Regular Structure is more than that of Irregular Structure.

iii. Base Shear for Modified Structure is more than that of Original Structure.

iv. Irregularity Level is almost about 25% for the irregular Structure Type I and 5% for Structure Type II.

v. Ductility ratio and Response Reduction Factor is more for Regular Structure.

vi. Irregular Structures can behave as a Regular Structures if proper precautions and modifications are made.

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