Seismic Vulnerability Assessment of RC Buildings with Plan Irregularities using Pushover Analysis
Shilpa Haranaganera1 Prof.Shridevi Angadi2
1Student 2Associate Professor
1,2Department of Civil Engineering
1,2BLDE CET, Vijaypur, Karnataka, India

Abstract — Earthquakes are the most dangerous and unpredictable forces in nature. Seismic behaviour of structures is always an area of concern and requires special attention from structural designers. Presence of plan and vertical irregularities further complicates the seismic behaviour of the structures and also makes the structures more vulnerable to seismic forces. Pushover analysis, which is gaining popularity as an effective tool to quantify the seismic vulnerability of structures, is a good method of analysis to deal with structures with irregularities. In the present study, an attempt is made to study the seismic vulnerability of buildings with plan irregularities using pushover analysis. In the present study 3 storey, 6 storey and 9 storey structures of regular configurations as well as varying amount of irregularities have been modelled and analysed. ETABS, an efficient FE analysis tool, has been used for the analysis. The modelling and loading considerations are according to relevant Indian codes while pushover analysis has been carried out according to FEMA and ATC codes. The parameters compared involve base shear carrying capacity, displacement capacity, performance point and the status of hinges formed. An attempt was also made to study and quantify the improvement in the seismic capacity of the structure by strengthening it using shear wall elements. The results of the analysis revealed that the structures with plan irregularity are more vulnerable to seismic forces compared to regular structures. Irregular structures possessed much lower base shear capacity compared to regular structures and the states of hinges formed were also at higher damage states. The introduction of shear walls proved to be an effective solution against the plan irregularity. The structures strengthened with shear walls exhibited tremendous improvement in the base shear carrying capacity (3 to 5 times) and also overall ductility of the structures. The improved states of hinges formed during pushover analysis also indicated the lesser vulnerability of irregular structures with shear walls.

Key words: Pushover Analysis, Base Shear Carrying Capacity, Displacement Capacity, Performance Point and the Status of Hinges Formed, Shear Wall Element

I. INTRODUCTION
Earthquake can be defined as a sudden release of stress disturbance associated with a brittle rupture of rock causing ground motion. The phenomenon of ground shaking due to earthquake is complicated one because of parameters such as source effect, path effect and local site effect. Earthquake makes the ground to shake and structures supported on ground in turn are subjected to this motion. It can be seen that the fluctuated loading on the structure is not from any external source but it is self-induced.

Earthquakes are events in which losses mainly occur because of damage to or collapse of buildings and other man-made structures. It has been experienced that, a structure built with proper care against earthquake forces can minimise the loss and damage to the property. In case of existing structures, retrofitting to suit the needs of an earthquake resisting structure can enhance the structural resistance against seismic forces. Many parameters including structural and non-structural buildings get affected at the time of earthquake. Every building should have sufficient strength and ductility. So that at the time of earthquake less damage may occurs. Earthquake is a natural phenomenon so its occurrence time, day date cannot be predicted. Earthquake effects large number of human population. Hence social awareness plays an important role. The technology to prevent earthquake are not yet developed. However, damages due to earthquake can be minimised to the structure by taking proper care. From the data collected during the past earthquakes the desirable geometry, form and material of construction can be arrived at. Hence, much is there to learn from the past experiences of failure and learning could be crucial in future design.

| Number of Bays | 4 bays in both directions |
| Spacing of Bays | 5m in both directions |
| Beam Size | 230x450 |
| Column size | 300x300 for 3 storey, 450x450 for 6 storey and 550x550 for 9 storey structure |
| Grade of Materials | M20 and Fe 415 |
| Slab Thickness | 150mm |
| Live Load Considered | 2 kN/Sqm |
| Finishing and Wall Load | 1.5 kN/Sqm and 12kN/m respectively |
| Seismic Zone and Soil Type | Zone III and Medium Type soil |
| Response Reduction Factor | 3 |

Table 1: Material Properties

Plan considered for 3, 6, 9-storey structure with plan regular and irregularity as show below

[Fig. 1: Structures]

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As shown in above mentioned figures it is observed that irregular structure-1,2 & 3 of a building are differ by 25%,50% & 75% respectively to that of regular structure.

II. LOAD CONSIDERATION
Structural details considered for the analysis dead load of 1.5 kN/m², live load of 2 kN/m², finishing and wall load of 1.5 kN/m² and 12kN/m respectively, earthquake loads as per IS 1893:2002(Part-1), pushover analysis using ACT 40.

III. ETABS MODEL
ETABS version 9.6 version is used for modeling, analysis and design. Pushover analysis is carried out created linear model for gravity analysis is converted by assigning frame non-linear hinges into non-linear model.

IV. ANALYSIS
In this work, Non-linear static (pushover analysis) is used for analyzing the structure to evaluate their seismic performance. In the present study, an attempt is made to quantify the influence of plan irregularity on the seismic behaviour of RC framed structures and its possible strengthening using shear wall. For this purpose typical RC structures with G+3,G+6 and G+9 with varying amount of plan irregularities are modelled analysed using ETABS software. The preliminary sections chosen are first analysed and designed for gravity loads before carrying out pushover analysis using ATC40 code.

V. DISCUSSIONS AND RESULTS
The results of analysis compared include base shear capacity, maximum displacement, performance point and the status of the hinges formed. The pushover curves for 3,6 & 9-storey structure are as shown. And the base shear carrying capacity, displacement capacity are compared.
ETABS model of 3 storey structure strengthened with the help of shear wall elements.

Fig. 8: Structures

Fig. 9: 3-Storey irregular structure with shear wall – 3D Model

The comparison of pushover curves for irregular structure-3 with and without shear wall. The base shear capacity and the displacement capacity resulting from pushover analysis are as shown

Fig. 10: Comparison of pushover curve – 3 Storey Irregular structure with and without shear wall

Fig. 11: Comparison of base shear capacity – 3 Storey Irregular structure with and without shear wall

Fig. 12: Comparison of displacement capacity – 3 Storey Irregular structure with and without shear wall

Present work is aimed at explaining the modelling considerations and the results drawn from the current analytical work. The various structural modelling details of 3, 6 and 9 storey regular and irregular models presented and the results describing the influence of plan irregularity on the seismic behaviour of RC structure is then explained. The results of irregular structures with and without the strengthening using shear walls are then presented to quantify the improvement in the performance of seismic deficient plan irregular buildings by the introduction of shear walls.

VI. CONCLUSION

In the present study, an attempt has been made to study the seismic deficiency of plan irregular buildings and their possible improvement by the introduction of shear walls using pushover analysis. Pushover analysis is a convenient and efficient tool to quantify the seismic behaviour of RC framed structures. The response of the structure in terms of base shear capacity, displacement ductility, performance point and status of the hinges formed helps in quantitative comparison of RC structures.

The conclusions are presented as below

– It was seen that introduction of plan irregularity resulted considerable degradation in the seismic performance of RC framed structures.
– The base shear carrying capacity of the structure significantly degraded because of the presence of plan irregularity. It was also found that increase in the amount of plan irregularity resulted in decrease in the base shear carrying capacity of the structure.
– The decrease in the base shear carrying capacity due to plan irregularity was found in the range of 44.4% for 3-storey structure, 42.09% for 6-storey structure and 22.52% for 9-storey structure for the maximum irregular structure considered.
– The reduction in base shear capacity was more prominent in case of low rise buildings.
– The performance point of the plan irregular structures were placed in more vulnerable damage states and also the status of hinges formed at performance point reached more vulnerable damage states for irregular structures. The same trend was seen in case of 3-storey, 6-storey and 9-storey structures.
– A close study on the status of the hinges formed during pushover analysis clearly reveals the increased possibility of both local and global damages for structure with plan irregularity as the hinges formed were corresponding to higher damage states (Collapse prevention and beyond)
- Introduction of shear walls resulted in tremendous improvement in the base shear carrying capacity of the structure. The increase in base shear capacity because of shear was about 4.2 times for 3-storey structure, 3.12 times for 6-storey structure and 2.21 times for 9-storey structure and the effect was more pronounced in case of low rise structures.

- Introduction of shear walls also brought down the vulnerability of the hinges formed during the performance point of the pushover analysis.

  The conclusions drawn from the present study can be summarised as follows:

- Pushover analysis carried out on RC framed structures as per the recommendations of ATC 40 is an effective tool in assessing seismic performance of structures.

- Comparison of seismic behaviour of RC framed structures with and without plan irregularity has shown the poor performance of RC structures with plan irregularity.

- An attempt to quantify the influence of amount of irregularity on the seismic behaviour of RC structures has shown that with increase in the amount of plan irregularity there is a decline in the seismic performance of the structure.

- Observation of Base shear capacity, displacement, Performance point & the nature of hinges formed for the cases of plan regular and plan irregular structures it was found that structures with plan irregularity are highly vulnerable and needs suitable strengthening.

- Introduction of shear walls is found to be an effective solution for improving the seismic capacity of plan irregular buildings.

REFERENCES


