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Comparative Study of the Static and Dynamic Seismic Analysis of RC regular and irregular frame structures

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Abstract - Occurrence of the earthquake is unpredictable, but we can adopt preventive measures to overcome problems during earthquake. It was found that one of the main reasons for failure of RC structure is irregularity in its plan dimension and its lateral force resisting system. In this paper an analytical study is made to find response of regular and irregular structures by nonlinear static analysis and nonlinear dynamic analysis. The study includes the Pushover Analysis and Non linear Time History Analysis of four storied regular and irregular structures in SAP 2000 platform.

Key Words – Frame Structure**,** Irregular Structure, Regular Structure, Nonlinear Static Analysis, Nonlinear Dynamic Analysis, Pushover Analysis, Time History Analysis.

1. Introduction

Earthquake is generated by sudden release of energy in earth's crust that creates seismic waves. In nature, earthquake forces are accidental & uncertain natural hazards. An engineer requires the tools for analyzing structures under the effect of these types of forces. Earthquake loads are modeled to assess the action of structure with a clear understanding that hazard is to be anticipated but it should be regulated. In this paper an analytical study is made to find response of different regular and irregular structures by static and dynamic methods. The study includes the Pushover Analysis and Non linear Time History Analysis of four storied regular and irregular structures in SAP 2000 platform. For time history analysis past earthquake ground motion record - El Centro is taken to study response of the structures. For analyzing seismic behavior of structures, mathematical model of the structures are required to determine the force and displacement characteristics in various components of the structure. Behaviors of structures were found by comparing responses in the form of storey displacement for regular and irregular structures.

It was found that main reason for failure of RC building is irregularity in its plan dimension and its lateral force resisting system. In actual practice, the structures will usually be built in having one of the irregularities i.e. stiffness, diaphragm, mass, re-entrant corner, and torsion irregularity. In the structures damages due to earthquake are usually at the weak points. This weakness is due to strength, variation in stiffness etc. So if a structure can perform well in earthquake means it should possess adequate strength, stiffness, ductility and simple configuration. Therefore these types of structures should be well designed under earthquake loading accounting the specified seismic design philosophies so that they can sustain moderate to strong earthquakes.

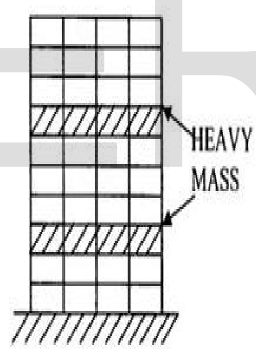

Fig 1: Mass irregularity

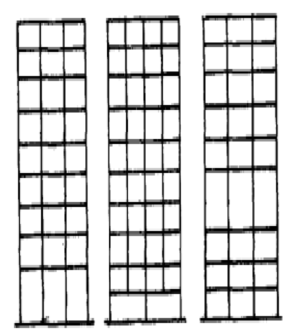

Fig 2: Stiffness irregularity

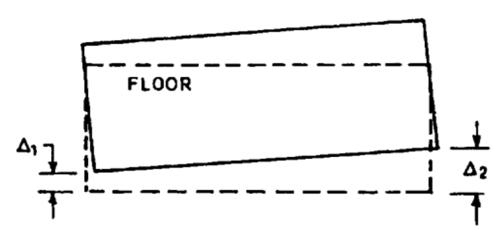

Fig 3: Torsion irregularity

2. Methods of Analysis of Structure

2.1 Pushover Methodology

It is an incremental static analysis used to determine the force-displacement relationship, or the capacity curve, for a structure or structural element. The analysis involves applying horizontal loads, in a prescribed pattern, to the structure incre-

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mentally, i.e. pushing the structure and plotting the total applied shear force and associated lateral displacement at each increment, until the components of structure will fail. In technique a computer model of the building is subjected to a lateral load of a certain shape (i.e. Inverted triangular or uniform). The intensity of the lateral load is slowly increased and the sequence of yielding, plastic hinge formation and failure of various structural components is recorded. Pushover analysis can provide a significant insight into the weak links in seismic performance of a structure.

2.2 Time History Analysis

Time-History analysis is a step-by-step procedure where the loading and the response history are evaluated at successive time increments, Δt – steps and provides more detailed information regarding the seismic behavior of a structures. The most common way to describe a ground motion is with a time history record. The motion parameters may be acceleration, velocity, or displacement, or all the three combined together. Time histories of ground motions are used directly for the time domain analysis of structures subjected to deterministic seismic inputs. At any measuring station, ground motions are recorded in three orthogonal directions; two of them are in horizontal directions and the third is in the vertical direction. Thus, three components of ground motions are available from any measuring station. The Time Vs Acceleration of El Centro, Array 6, Huston Rd is plotted in Figure 4. The Time-History function is used to perform Linear and Non – Linear Time-History Analysis of structures to understand the actual behaviour of structures under Seismic Excitation.

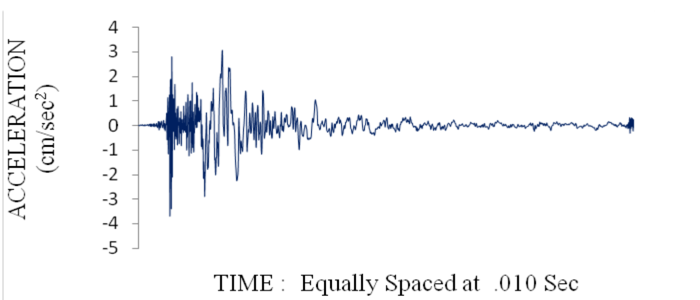

Fig 4: Time-History Function of El Centro, Array 6, Huston Rd

3. Details of the Models

3.1 General

The objective of this paper is to study the behavior of structure under nonlinear static and nonlinear dynamic analysis to avoid catastrophic failure of structure. For this purpose Static Pushover Analysis and Time History Analysis is used to evaluate the real behavior of the structure.

3.2 Description of structure

Four storied R.C. buildings with Case I – regular plan and Case II – Irregular plan are considered for seismic analysis. The plan and isometric view of buildings are shown in Figure 6 to Figure 8. The columns are placed at a centre to centre distance of 3.0 m in both X & Z direction for regular structure and 3.0 m in X & 3.0, 6.0 m in Z direction respectively with 3.0 m height of each storey. The sectional properties of various elements: Column: 0.3 m X 0.3m
Beam: 0.3 m X 0.3 m

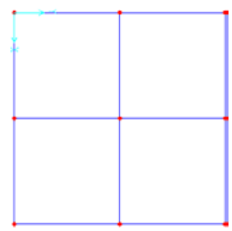

Fig 5: Plan (Case I)

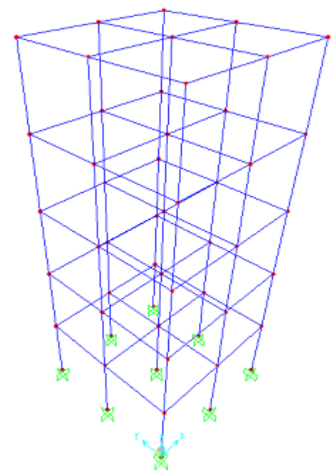

Fig 6: Isometric View (Case I)

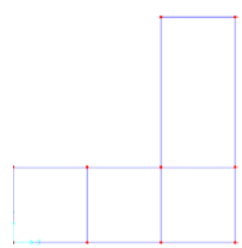

Fig 7: Plan (Case II)

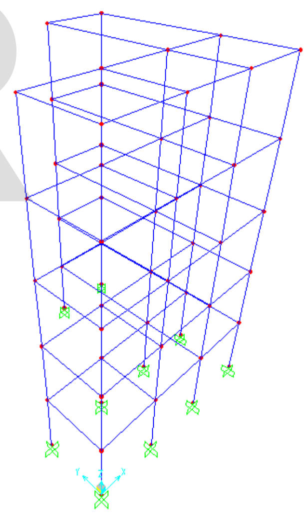

Fig 8: Isometric View (Case II)

4. Results and Discussions

The maximum displacements of building in different stories for Static Pushover Analysis and Time History Analysis have been compared and shown in Figure 15. Also, the maximum roof displacement is considered to indicate the difference between nonlinear static and nonlinear dynamic analysis. It is observed that with increasing the height of building, the difference between the displacements is gradually increased, by considering the maximum displacement of each storey. It is observed that, the maximum displacement is increasing from first storey to last one.

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Results of Pushover Analysis of Regular Structure

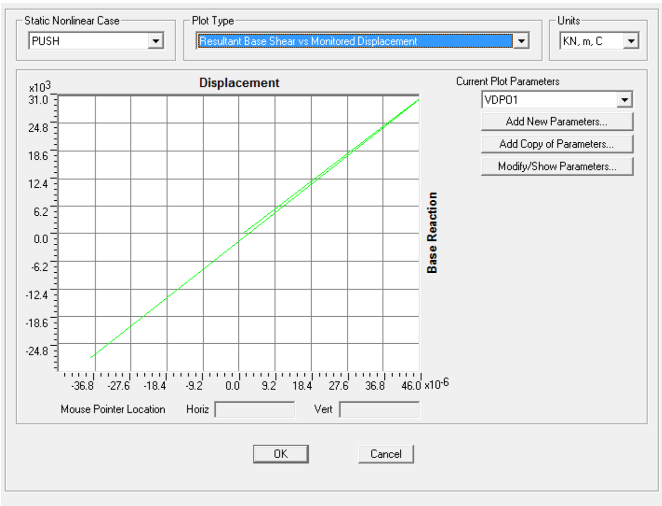

Fig 9: Pushover Curve

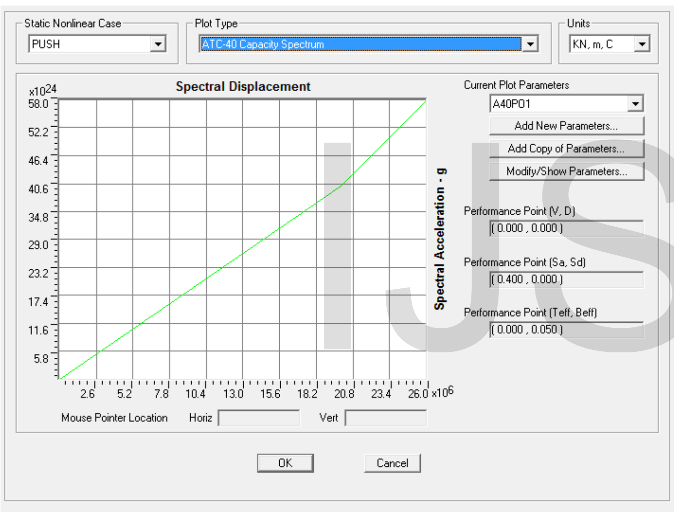

Fig 10: Capacity Spectrum

Results of Pushover Analysis of Irregular Structure

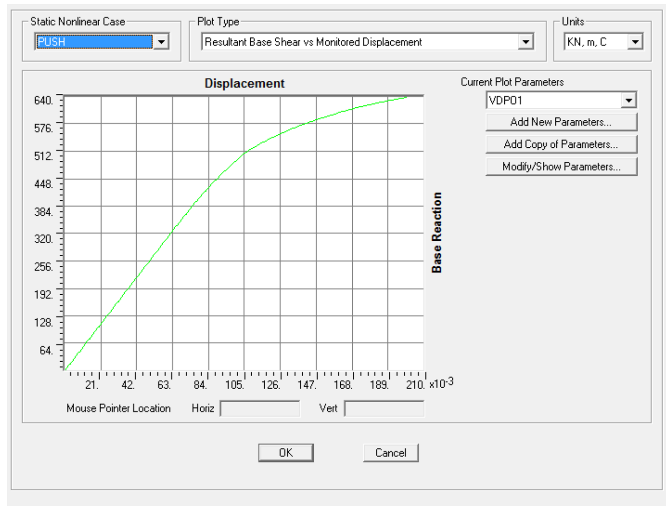

Fig 12: Pushover Curve

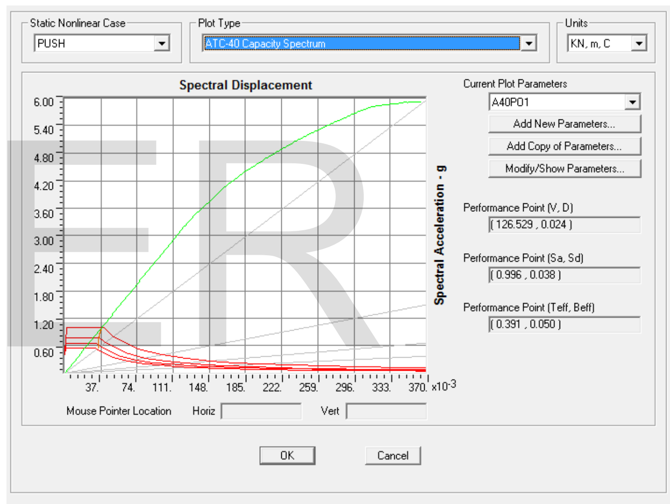

Fig 13: Capacity Spectrum

Results of Time History Analysis of Regular Structure

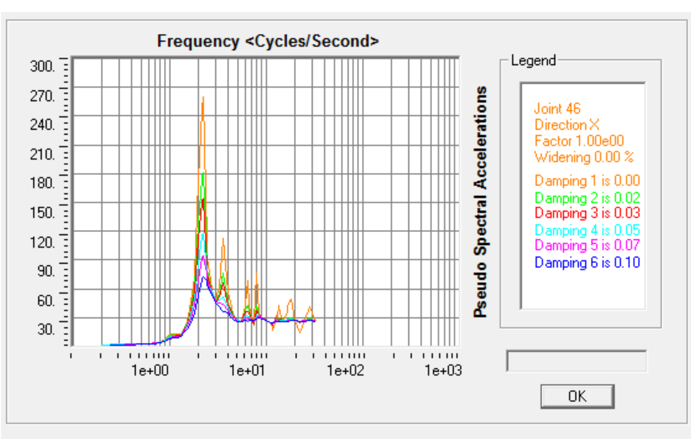

Fig 11: Response Spectrum

Results of Time History Analysis of Irregular Structure

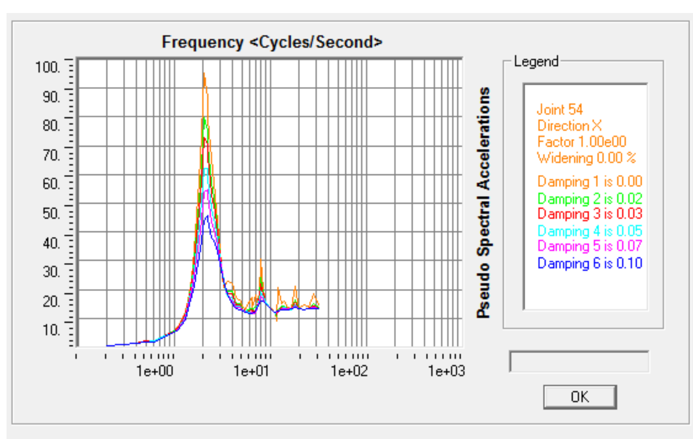

Fig 14: Response Spectrum

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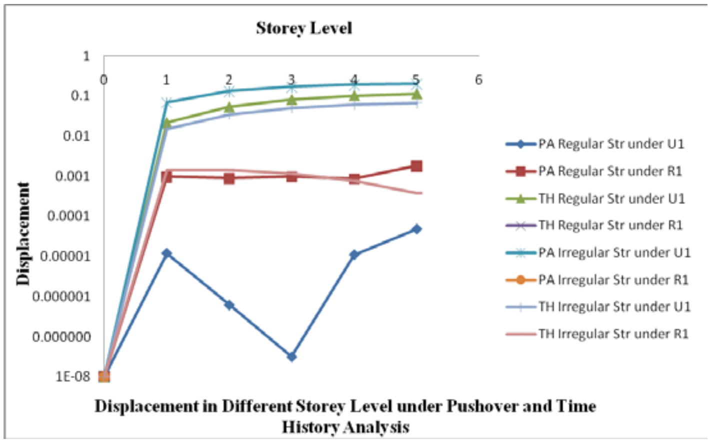

Fig 15: Maximum Displacement of floors under Pushover Analysis and Time History Analysis

5. CONCLUSION

[1] As a result of comparison between nonlinear static and nonlinear dynamic analysis it is observed that the displacement obtained by static analysis are higher than dynamic analysis for irregular structure and displacement obtained by dynamic analysis are higher than static analysis for regular structure.

[2] The difference of displacement values between static and dynamic analysis lower stories are insignificant but it increased in higher stories reached at its peak in top storey or roof.

[3] Time History analysis is an elegant tool to visualize the performance of a building under a given earthquake. Seismic Analysis of structure is done by selecting an adequate record of ground motion for time history analysis.

[4] For important structures Time History analysis should be performed as it predicts the structural response more accurately in comparison with Pushover Analysis.

[5] To evaluate the seismic behavior of structure with significant higher mode effects, the nonlinear dynamic analysis methods generally provide more reliable assessment of earthquake performance than other methods. In this paper, the nonlinear dynamic procedure produces results that are different from those given by the nonlinear static analyses. It can be concluded that the nonlinear dynamic analysis are more reliable than the nonlinear static analysis in tackling seismic analysis of structure.

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