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Comparative Study of Response Spectrum and Pushover Analysis for G+8+T RCC Buildings

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ABSTRACT: Performance based design procedures are mainly used for designing new buildings or for up gradation of existing building for seismic loads. This helps in understanding the failure modes of the structure in future earthquakes. The pushover analysis gives the pushover curves, capacity spectrum, plastic hinges and performance level of the building. It gives a better understanding and more accurate results for the damage or failure in the structural elements. The method may also help in predicting potential weak areas in the structure and also keeps a track of the sequence of the damages of each and every member in the structure.

The objective of this research is aimed at presenting a comparison between Response spectrum analysis and Pushover analysis methods on a G+8+T Building model using Etabs software. The building is designed as per the IS 456-2000 and IS 1893-2002 in the context of Performance Based Seismic Design procedures. In this study, it was found that, the values of maximum displacement, Story drift and base shear etc. were increased after performing pushover analysis.

KEYWORDS: Performance Based Design, Pushover Analysis, Response Spectrum Analysis, Etabs, Capacity Curve, Demand Curve, performance point etc.

I. INTRODUCTION

A structure must be designed to safely resist any ground motion of an intensity which might occur during their construction or use. The most accurate procedure to analyze the structures exposed to strong ground motions is the time-history analysis. It involves MDOF (Multi-Degree-of-freedom) system. But this method is time consuming for all practical purposes and hence a faster analysis method is required. It led us to Pushover analysis (Performance Based Design) which ensures us with a reliable design or assessment of structures subjected to earthquake.

This method enables us to understand the progressive failure of an existing building and seismic upgradations or for designing a new building. The structural criteria are expressed in terms of achieving a performance objective. As per FEMA 356, Performance objectives are operational (O), immediate occupancy (IO), life safety (LS), collapse prevention (CP) [3]. Life safety is the main focus so as to reduce the threats to the life safety of the structure. In this method, performance levels are defined in terms of displacements as damage is better correlated to displacement rather than forces.

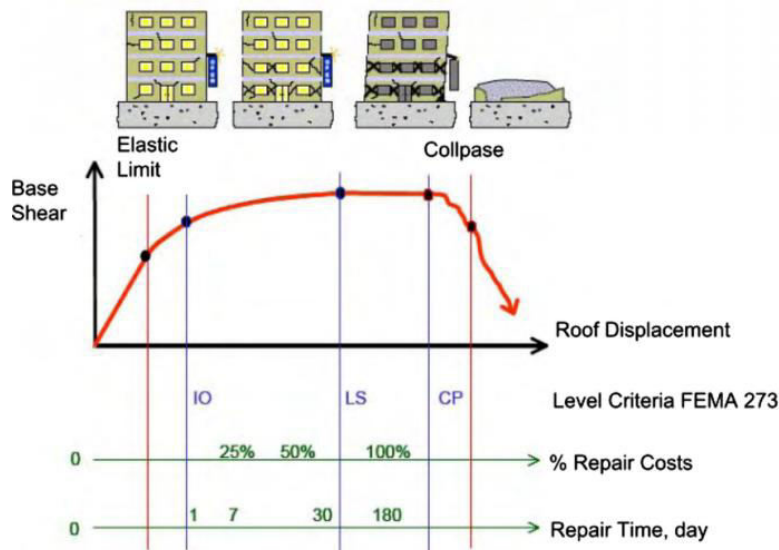


Fig 1. Illustrations of Performance Based Designs.

The Pushover analysis is a static Non-Linear Analysis of a structure under vertical loads and lateral loads which are increasing gradually. [1] In this method, the model is pushed monotonically with an invariable distribution of lateral load. Due to increasing lateral load pattern that is applied on a building, stiffness in structural elements decreases. Pushover analysis method is well documented by ATC-40 and FEMA 356. A graph between base shear and top displacement in a structure is obtained which represents weakness in structure. Where, base shear is the sum of all horizontal support reactions in that direction and Roof top displacement at the center of the mass of the general roof.

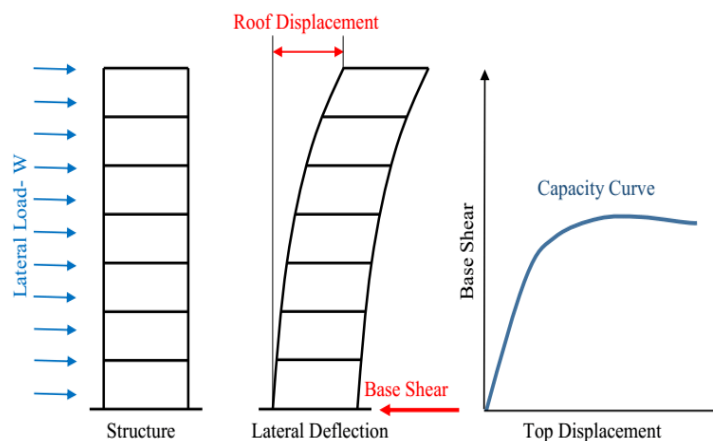


Fig 2. Pushover analysis

In this method beams and columns which will reach to yielding are identified. This analysis method is helpful in detecting members which are likely to reach critical states when earthquake occurs for which special attention should be given when designing and detailing. But the procedure assumes that the response is controlled by the fundamental mode, and its changes after the structure starts yielding can be ignored.

Non-Linear Building Model and Non-Linear Hinges: Non-linear hinges are inserted into a linear elastic model which is generated using a common analysis and design software packages such as Etabs, SAP2000, Staad Pro, MIDAS etc. Hinges are points on a structure where one can expect cracking and yielding to occur in relatively higher intensity [4]. So, they shows higher flexural/shear displacements under a cyclic loading. So, these are the locations where cross diagonal cracks can be observed in an actual building structure after an earthquake. A hinge represents localized force-displacement relation of a member through its elastic and inelastic phases under seismic loads. Hinges

are of various types, namely a flexural hinge, shear hinge and axial hinge. A flexural hinge represents moment rotation relation of a beam. The Flexural and shear hinges are inserted into the either ends of the beams and columns. The axial hinges are inserted at either ends of the diagonal struts.

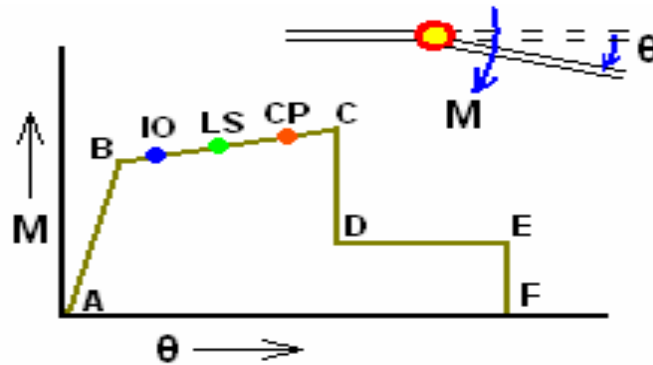


Fig 3. Flexural hinge.

The figure above shows the property of a typical hinge. Where, AB represents linear range from unloaded state (A) to its effective yield (B). BC shows an inelastic but linear response of reduced (ductile) stiffness from B to C. and CD represents a sudden reduction in load resistance, followed by a reduced resistance from D to E. and E to F shows a total loss of resistance from E to F.

II. LITERATURE REVIEW

The present work is aimed at performing pushover analysis for a G+8+T RCC building. And a comparison is made between Response Spectrum Analysis and pushover analysis to understand the result variations in terms of displacement, base shear, story drift, etc. and to understand the hinge formation in order to evaluate the failure pattern of the structure. Various studies have been carried out till date for pushover Analysis on buildings considering different types of irregularities. Hence, a literature review is carried out and some of their work is presented in the following paragraphs.

Joheb Ahmed and Syed Ahamad Raza [5] carried out a study in 2014 on seismic vulnerability of RC buildings by considering various plan irregularities using pushover analysis method. Various models such as rectangular, diaphragm discontinuity, Y-shaped were modeled in order to identify the performance of the structures to withstand against earthquake disaster for building structures. They have conducted study on G+9 storey building situated in zone V. Pushover analysis has been performed using FEM based analytical software ETABS. The results are presented in terms of pushover demand, capacity spectrum and plastic hinges. They have concluded that base shear for rectangular model is greater than diaphragm discontinuity and Y-shaped models. Point displacements are greater for diaphragm discontinuity model as there is an opening in the center for that model. It was then concluded that, among the three models considered rectangular model is most vulnerable to seismic effect.

In 2014, **Dr. Mohd. Hamraj** [6] also performed a study on pushover analysis for a RCC building with Irregular plan. They developed three new buildings with unsymmetric plans and were design as per IS 456:2000 guidelines. 4, 8 and 20 Floor models were prepared using ETABS software to cover the broader spectrum of low rise, medium rise & high-rise building construction. Different modeling issues were incorporated through six model for each building were; bare frame (without infill), having infill as membrane, replacing infill as an equivalent strut in previous model and a comparative study was made. The results of analysis are compared in terms of Base Shear, Storey Displacement and Drift Ratio. The buildings were designed to meet the performance level, whose damage is limited to Grade 2 (slight structural damage, moderate nonstructural damage) in order to enable Immediate Occupancy.

Kavita Golghate et al [2] carried out a study in 2013 to evaluate the behavior of a G+3 RC building under seismic action of zone IV. The building structure was analyzed by pushover analysis (Non-linear static analysis) by using SAP2000 software. The pushover analysis shows the pushover curves, capacity spectrum, plastic hinges and performance level of the building.

In 2013, **M. A. M. Akberuddin et al** [7] also carried out a study on pushover analysis of medium rise multi-storey RCC frame with and without vertical irregularity using ETABS software. Their study aims at evaluating and comparing the response of five reinforced concrete building systems by the use of different methodologies described by ATC 40 and FEMA 273 using non-linear static procedures. The methodologies are applied to a three storey frames system with and without vertical irregularity, both designed as per the IS 456:2000 and IS 1893 (Part I): 2002 in the context of Performance Based Seismic Design procedures. A Non-linear Static Analysis (Pushover Analysis) had been used to obtain the inelastic deformation capability of frame. Their analysis results compared the bare frame models with and without irregularity. It was concluded that G+3 storey bare frame without vertical irregularity shows more lateral load capacity as compared to bare frames with vertical irregularity. Also, the seismic performance of irregular building is reduced by 11 to 12.5% for 200% vertical irregularity and 28 to 30 % for 300% vertical irregularity as compare to symmetric base model.

III. METHODOLOGY

A basic frame model of G+8+T is created in etabs software and properties are defined. Model is then run for static analysis and response spectrum analysis. The program includes several built-in default hinge properties. These properties are based on average values from ATC-40 for concrete members and average values from FEMA-356 for steel members. [2] Then, Pushover cases and hinge properties are defined. Pushover load case is used to apply gravity load and then lateral pushover load cases are specified to start from the final conditions of the gravity pushover. [2] Pushover load cases can be defined either by a controlled displacement or by a defined controlled force level. The built in properties can be useful for preliminary analyses, but user defined properties are recommended for final analyses [2]. Pushover hinges are then located on the model by selecting the beams/columns/walls and assigning hinges at their ends.

The analysis is then performed to check for hinge formations. Plastic hinges formation are obtained at different displacement levels or performance points. At each step of deformation, it determines the locations of plastic hinge in the element and which hinge is reaching the ultimate states (IO, LS, and CP) using different colours. Parameters such as Maximum displacement, Inter storey drift and base shear etc. are then checked and can be compared by the values from Response Spectrum Analysis.

IV. EXPERIMENTAL RESULTS

After Performing Response spectrum and pushover Analysis following results were obtained,

1. Base Shear:

For Response Spectrum Analysis, the value of base shear for X – direction is 2681.8174kN, and for Y direction it is 2145.4529kN. Whereas, in pushover Analysis, the values of base shear are 7713.252kN for X-directions and 4591.169kN for Y-direction. So, an increase of 187.613% was observed for X direction and 113.995% increase in base shear in Y-direction.

2. Maximum Displacement:

Maximum displacement observed at terrace floor level after Response spectrum Analysis for RSX and RSY was 25.649mm and 19.936mm respectively. Maximum displacement values for Pushover Analysis are 118.052mm and 32.893mm in X and Y Directions respectively. This shows an increase of 360.26% in X- direction values and 64.993% in Y direction respectively.

3. Inter Story Drift:

Maximum value of drift in Response spectrum Analysis is 0.001174 measured at third Floor whereas in Pushover Analysis Maximum Drift is 0.00738 measured at first Floor.

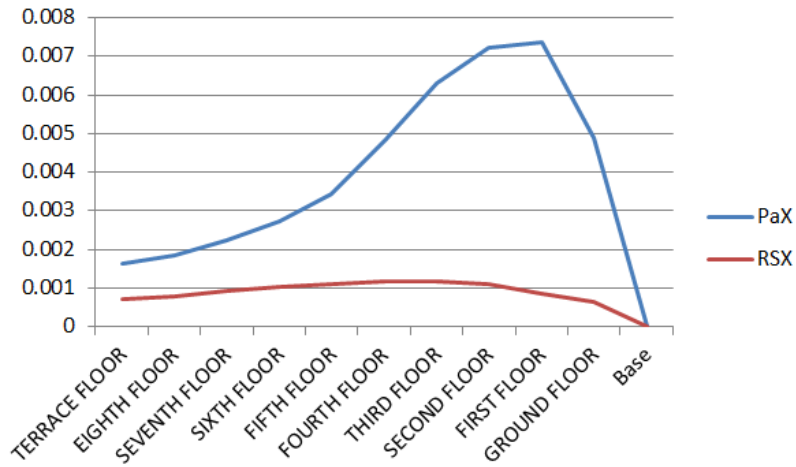


Fig. 4. Inter Story graph comparison for G+8+T model in Response Spectrum and Pushover Analysis.

4. Performance Point

Performance point is obtained by superimposing capacity spectrum and demand spectrum and the intersection point of these two curves is known as performance point. The fig 7 below shows performance point of the studied model.

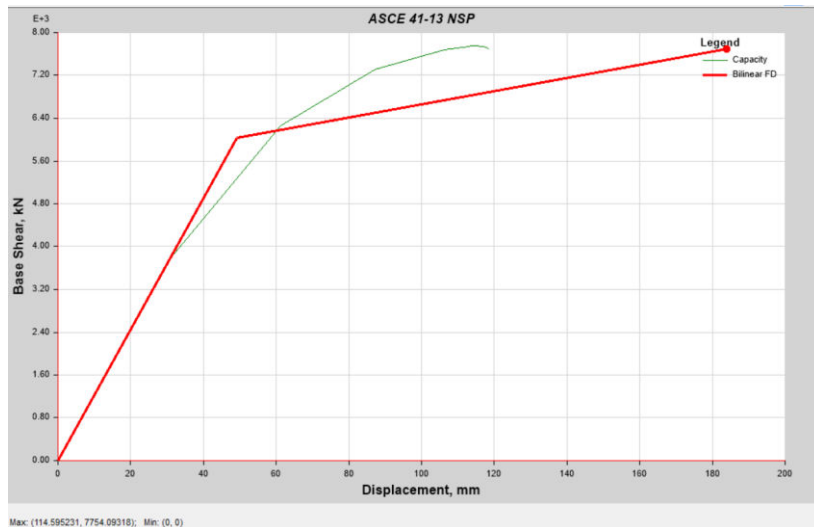


Fig. 5. Performance point after performing Pushover Analysis.

5. Hinge Formation:

The numbers of plastic hinges formed are shown in the fig 8 and fig 9 below for Pa-X and Pa-Y cases respectively.

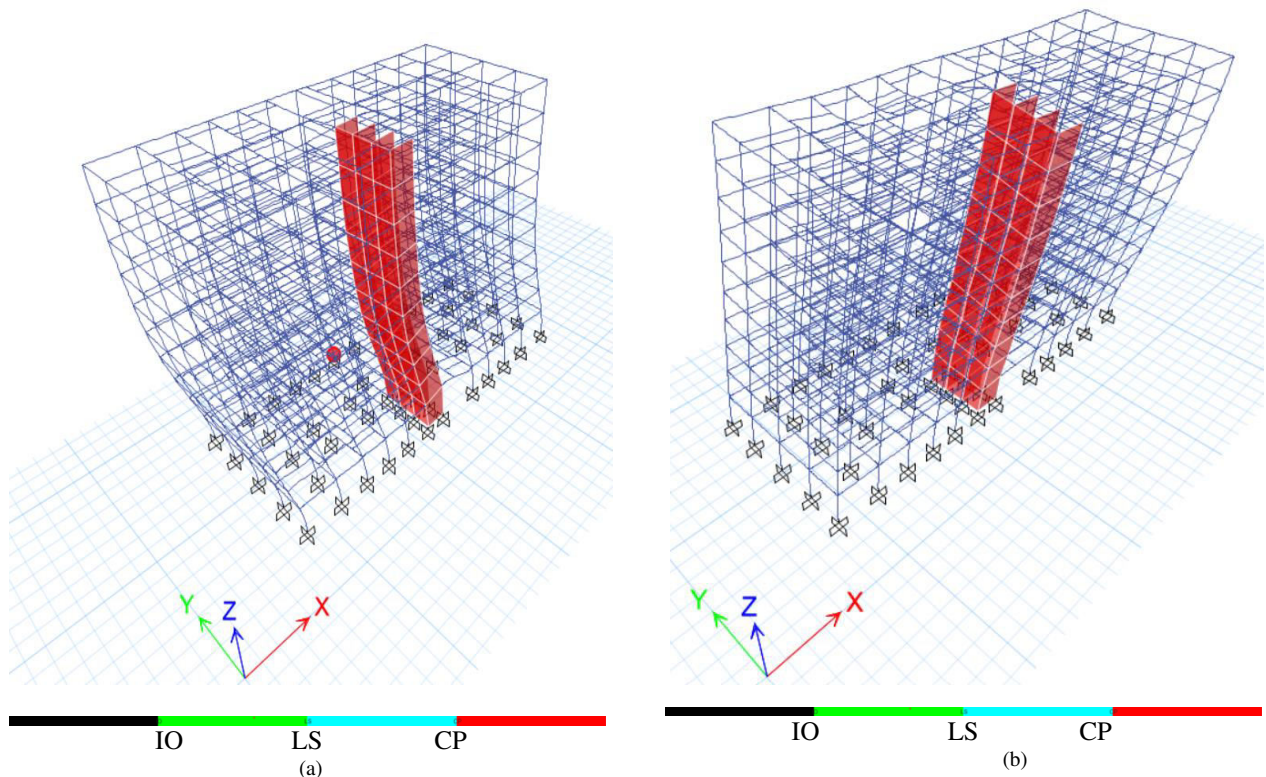


Fig. 6. Hinge Formation in G+8+T model in etabs. (a) Hinge formation in PaX Load Case. (b) Hinge formation in PaY Load Case.

V. CONCLUSION

A G+8+T storied model is analyzed by Response spectrum and Pushover Analysis methods using Etabs software. After the analysis, results are obtained and compared in terms of Base Shear, Maximum Displacement, story Drift and performance Point. Hinge formation in the building is also studied after performing Pushover Analysis.

In this study, it was found that, the values of maximum displacement, Story drift and base shear etc. were increased after performing pushover analysis. Since, pushover Analysis is approximate in nature; it cannot represent dynamic phenomena with a higher degree of accuracy as it is based on static loadings.

It is also studied that this method may not detect some important deformation modes caused by severe earthquakes. And hence, it must be used in addition with some other methods for analyzing a structure.

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