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SEISMIC RESPONSE OF ASYMMETRIC REINFORCED CONCRETE STRUCTURES USING STATIC PUSHOVER AND ADAPTIVE PUSHOVER ANALYSIS

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Abstract*—With the immense loss of life and property witnessed in the last couple of decades alone in India, due to failure of structures caused by earthquakes, attention is now being given to the evaluation of the adequacy of strength in RC framed structures to resist strong ground motions. To determine structural response beyond yield point, out of two types of nonlinearity material and geometrical, material nonlinearity is considered in present thesis. As such, nonlinear analysis can play an important role in the analysis and design of new and existing buildings. In Nonlinear Static procedure both predetermined target displacement and force distribution pattern are based on a false assumption that the structural behavior and its responses are dominated by the fundamental vibration modes. Therefore, over the past decades, there have been a great number of studies on considering higher mode contribution in nonlinear static results. The Displacement-based Adaptive Pushover Analysis (DAP) is one of the performance assessments tool for improving the accuracy of the obtained results of nonlinear static analysis in estimating the seismic demands of the structures. In the present thesis, RC Moment Resisting Irregular Frames (inverted L Shape) of 6 Storey is analyzed for seismic Zone IV and designed as per IS code provisions, considering both seismic and gravity loads. Further, performance evaluation of above frames is done using Nonlinear Static Pushover Analysis, Displacement based Adaptive Pushover Analysis using SeismoStruct software. Performance evaluation is done from the performance criteria mentioned in ATC-40 and FEMA-356 in terms of capacity curve.

***Keywords*— Plan Irregularity, Seismic Analysis, Non-Linear static Analysis, Displacement-based Adaptive Pushover Analysis, SeismoStruct**

I. INTRODUCTION

In performance based design, the response of structure is considered beyond elastic limit. Static and dynamic non-linear analysis are the analysis techniques used for performance based design. Elastic analysis gives a good indication of the elastic capacity of the overall structure and indicates where first yielding occur. It can't predict failure mechanisms and account for redistribution of forces during progressive yielding. Inelastic analysis procedures helps to understand that how the building really works by identifying modes of failure & the potential of progressive collapse. The goal of earthquake engineering is to minimize loss of life due to the collapse of the yielding structure. However, the costs involved in replacing and rehabilitating structures damaged by the relatively moderate earthquakes have proven that the "Life-Safe" building design approaches are economically inefficient.

The structural member's capacity to undergo inelastic deformations governs the structural behavior and damageability of multi-storey buildings during earthquake ground moments. From this point of view, in addition to stresses caused by the amorous static forces as defined in serval seismic regulations and codes, evaluation and design of buildings should be focused on elastic deformations required by earthquakes. In general, researching the inelastic seismic responses of buildings is not only useful in improving the guidelines and code requirements to minimize potential damage to buildings, aut also critical in providing economic design by making use of the building's reserved strength as it experiences inelastic deformations.

II. NON-LINEAR STATIC ANALYSIS

Nonlinear static analysis is an improvement over linear static. It is practical method in which analysis is carried out under permanent vertical loads and gradually increasing lateral loads to estimate deformation and damage pattern of structure. Nonlinear static analysis is the method of seismic analysis in which behaviour of the structure is characterized by capacity curve that represents the relation between the base shear force and the displacement of the roof. It is also known as Pushover Analysis.

A. Displacement based Adaptive Pushover Analysis

Antoniou and Pinho have proposed a displacement-based adaptive pushover analysis (DAP) in 2004 to take into account the updated loading vector at each analysis step according to current dynamic characteristics of the building. The aim of adaptive pushover analysis is to evaluate the seismic performance of the structure by predicting seismic demands and capacity of a building and considering its dynamic response characteristics includes the effect of the frequency content and deformation of input motion.

The lateral load distribution in the adaptive pushover method, continuously updated during the analysis, depending to modal shapes and participation factors obtained by performing eigenvalue analysis at each step of analysis. DAP is fully multi-modal method that take into account the modification of the inertia forces, the structural stiffness softening, and its period elongation due to spectral amplification.

DAP has the capability to update and change the horizontal load distributions based on the constantly changing modal properties of the structure and solves the drawback of fixed-load pattern of the pushover analysis, providing a more accurate tool for assessing structural performance and better response estimator than conventional pushover methods, particularly, in structures that the effects of higher modes play a major role in its dynamic structural response.

B. Static Pushover Analysis

In this method analysis is carried out under permanent vertical loads and gradually increasing lateral loads to estimate deformation and damage pattern of structure. The structural model is subjected to an incremental lateral load whose distribution represents the inertia forces expected during ground shaking. The lateral load is applied until the imposed displacements reach the so-called "target displacement," which represents the displacement demand that the earthquake ground motions would impose on the structure. Once loaded to the target displacement, the demand parameters for the structural components are compared with the respective acceptance criteria for the desired performance state. System level demand parameters, such as story drifts and base shears, may also be checked. In the nonlinear static procedure, a control point is defined for the target displacement usually at the top (roof level) of the structure. The plot of the resulting base shear force as a function of the control point (roof) displacement is often recognized as the "pushover curve" of the structure. The pushover curve can be further simplified by idealized sloping branches of elastic, post-yield hardening and softening (degrading) behavior and used to examine overall building performance.

Pushover analysis can be performed as either force-controlled or displacement controlled depending on the physical nature of the load and the behavior expected from the structure. Force-controlled option is useful when the load is known (such as gravity loading) and the structure is expected to be able to support the load. Displacement controlled procedure should be used when specified drifts are sought (such as in seismic loading), where the magnitude of the applied load is not known in advance, or when the structure can be expected to lose strength or become unstable.

The analysis is conducted until the displacement at the control point reaches the target displacement. Several methods are available for calculating the target displacement, the two most prevalent being the so-called "coefficient method" and the "capacity spectrum method". The intersection of the pushover curve with the capacity spectrum curve defines the target displacement (or performance point).

III. METHODOLOGY

A. Description of Structure

6-storey asymmetric (inverted L-Shape) RC moments resisting frame with typical storey heights of 3 m and ground storey height of 3 m is considered for the study. It was located in Zone-IV and assumed to be constructed on firm soil condition. Response Reduction factor of 5 was used for design of special RC moment-frame. The loading considered was self- weight of beams, columns and slabs, floor finish and live load on slabs. The frame was then designed for load combination as per IS Code. The design acceleration spectrums were used, which corresponds to IS 1893 (Part 1): 2016 for firm soil for 5% damping.

B. Methodology of Adaptive Pushover Analysis

DAP is fully multi-modal method that take into account the modification of the inertia forces, the structural stiffness softening, and its period elongation due to spectral amplification.

DAP has the capability to update and change the horizontal load distributions based on the constantly changing modal properties of the structure and solves the drawback of fixed-load pattern of the pushover analysis, providing a more accurate tool for assessing structural performance and better response estimator than conventional pushover methods, particularly, in structures that the effects of higher modes play a major role in its dynamic structural response.

C. Seismostruct Model

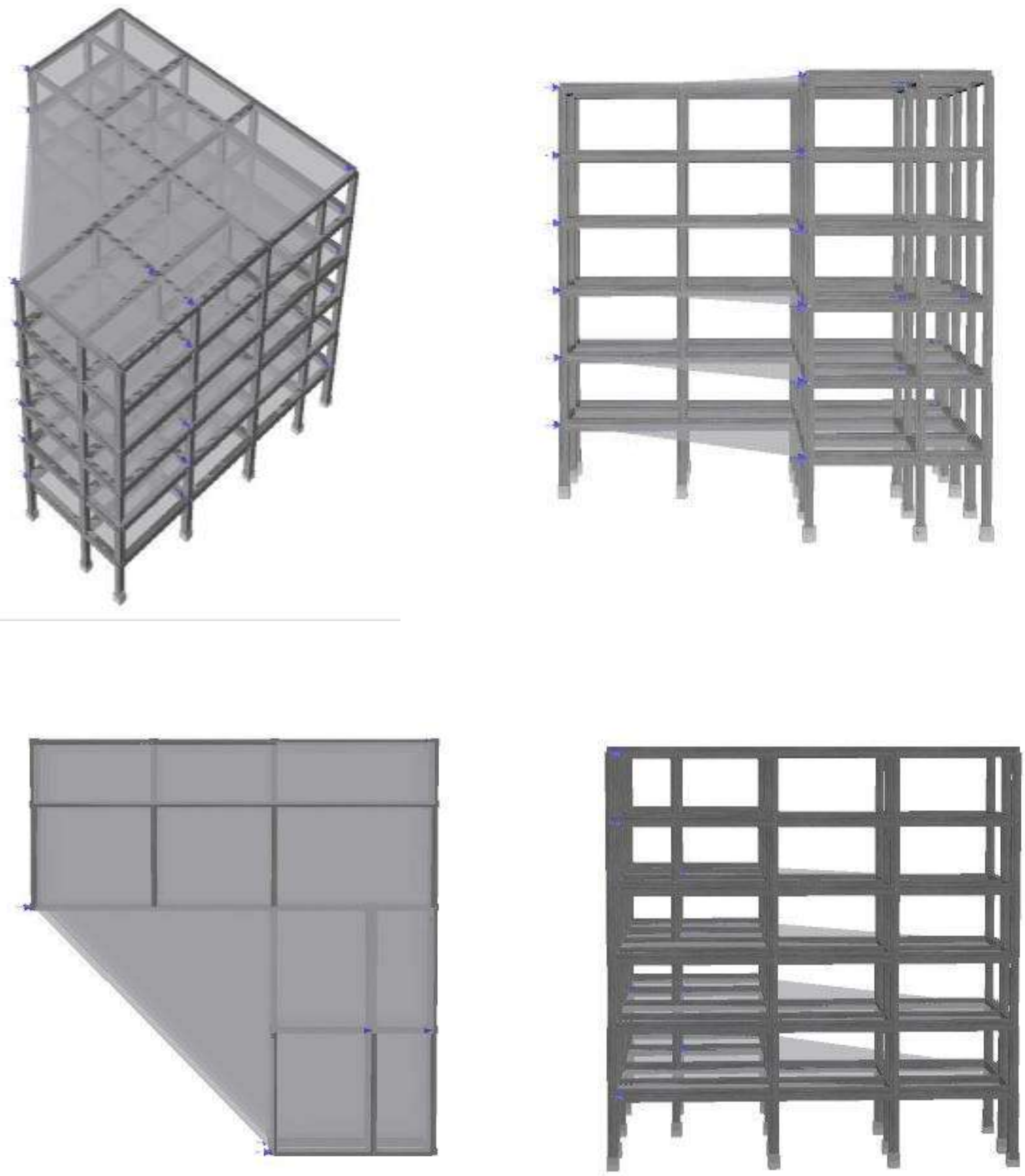

Figure-1 6-Storey (inverted L-Shape) Seismostruct Model

IV. RESULTS AND DISCUSSION

Capacity Curve is the plot between Base Shear v/s. Roof Displacement. It is representation of structure's ability to resist the seismic design. It is obtained from Nonlinear Static Analysis from which the maximum base shear capacity of structure can be obtained. In this study, three Structural Performance Levels i.e. Immediate Occupancy (IO), Life Safety (LS), Collapse Prevention (CP) are defined on Capacity Curve as per ATC-40 guidelines. The results of Capacity Curve obtained by nonlinear static analysis for 3% Total Drift of 6 storey RC Moment Resisting Irregular Frame (L Shape) is shown in Figure.

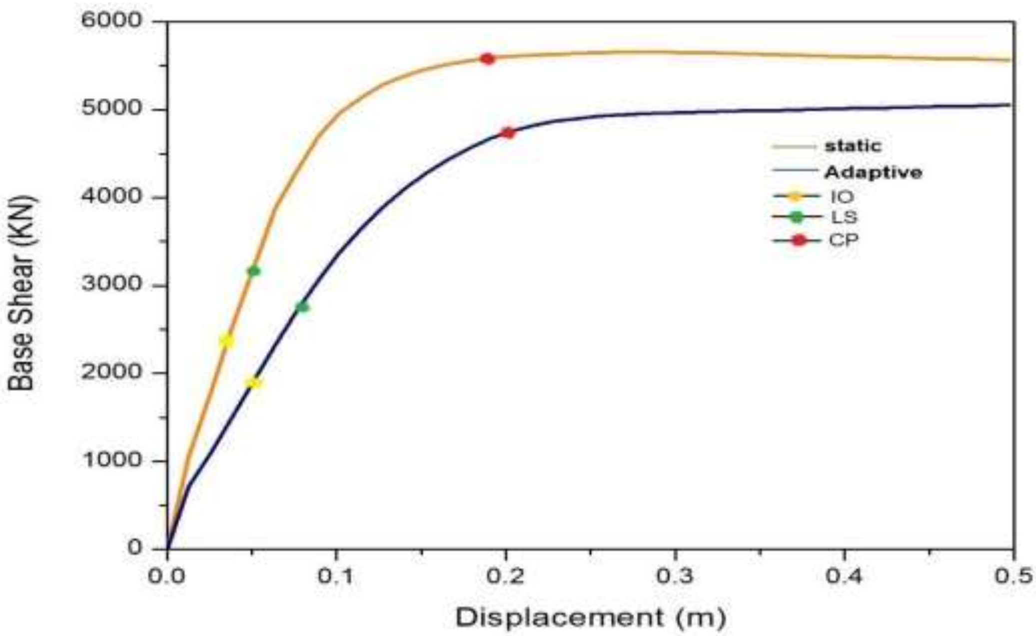

Figure 2- Capacity Curve

V. CONCLUSIONS

As observed from Nonlinear Static methods, Static Pushover Analysis gives less capacity as compared to Displacement based Adaptive Pushover Analysis as seen from the capacity curve. From the plots of Interstorey Drift Ratio Profile plotted for 2% Total Drift, it is seen that the values of maximum interstorey drift ratio for Nonlinear Static Pushover Analysis are higher compared to Displacement Based Adaptive Pushover Analysis (DAP). The better performance of Displacement Based adaptive Pushover Analysis procedure can be attributed to the consideration of higher mode effects, lateral load continuously updated according to the modal shapes and participation factors derived by eigenvalue analysis carried out at the current step.

REFERENCES

[1] Anil K. Chopra, "Dynamics of Structures" by Pearson.
[2] Applied Technology Council, ATC 40, "Seismic Evaluation and Retrofit of Concrete building" Vol. 1, Red wood city, California.
[3] Ali Ruzi Özuygur [2016] "Performance-based seismic design of an irregular tall building – a case study." Research Journal of The Institution of Structural Engineers (Volume 5, Pages 112–122).
[4] Christos Zeris & Elisabeth Vintzileou "Evaluation of the Seismic Performance of Existing RC Buildings: A Case Study for Regular and Irregular Buildings", Journal of Earthquake Engineering, (Volume 10, No. 3 (2006) 429-452).
[5] Chandrasekaran Srinivasan, "Seismic design aids for nonlinear analysis of reinforced concrete structures" by CRC press, Taylor & Francis Group.
[6] Clough R.W. and Penzien J., "Dynamics of Structures" by Mcgraw-Hill, New York,1993.
[7] Dimitrios Vamvatsikos & C. Allin Cornell "The Incremental Dynamic Analysis and its Application to Performance-Based Earthquake Engineering"12th European Conference on Earthquake Engineering (Paper Reference 479).

[8] Fabio Mazza "Modeling and nonlinear static analysis of reinforced concrete framed buildings irregular in plan." Engineering Structures 80 (2014)98-108.
[9] Helmut Krawinkler & G.D.P.K. Seneviratna "Pros and cons of a Pushover Analysis of seismic performance evaluation." Engineering Structures (Volume 20, Pages 452-464).
[10] H. J. Shah, "Reinforced concrete Design-code of practice Vol.I" by Charotar Publication House.
[11] K. I. Majid, "Non-Linear Structures: Matrix Methods of Analysis and Design by Computers" byButterworth & Co. Ltd.
[12] IS 1893 (Part1):2002 Indian Standard, "Criteria for earthquake resistant design of structure General provision and buildings", Bureau of Indian Standard, New Delhi.
[13] IS-456:2000, "Plain and reinforced concrete-code of practice" by Bureau of Indian Standard, New Delhi.
[14] Manish Shrikhande and Pankaj Agarwal, "Earthquake Resistant Design of Structures" by PHI Learning Pvt. Ltd.
[15] SEAOC Seismic Design Manual – Volume 1.
[16] William McGuire, Richard H. Gallagher and Ronald D. Ziemian, "Matrix Structural Analysis" by John Wiley & Sons, Inc.
[17] Oren Lavan and Mario De Stefano, "Seismic Behaviour and Design of Irregular and Complex Civil Structures" by Springer.
[18] S. Antoniou & R. Pinho[2010] "Development and verification of a displacement based adaptive pushover procedure," Journal of Earthquake Engineering (Volume 8, Pages 643-661).
[19] SeismoStruct. (2016). A computer program for static and dynamic nonlinear analysis. Available from URL: http://www.seismosoft.com: Seismostruct_2016_Release_4.