A REVIEW ON ADVANCEMENT OF SEISMIC DEMAND ASSESSMENT METHODS BASED ON STATIC PUSHOVER PROCEDURES

[1]Nikhil S. Bembade, [2] Prachi Sohoni,
[1]P.G. Scholar, [2]Assistant Professor,
[1]Applied Mechanics Department,
[1]Walchand College of Engineering, Sangli, Maharashtra, India

Abstract: Earthquake is an uncertain catastrophe that may take place at any time instance and till now one cannot predict when it will occur. This catastrophe may cause mild or severe damage to the structure depending upon its intensity, which may result in loss of life. It is necessary to design the building for seismic forces to prevent its failure and to ensure safety of people by improving seismic performance of the building. For determining these forces different seismic demand assessment methods are used. These methods are given by different codes of practice such as the Indian code of practice, the American code of practice, the European code of practice and the New Zealand code of practice. For linear static analysis, the Equivalent Static Method and for linear dynamic analysis of building Response Spectrum Method is recommended by Indian code (IS-1893 Part 1). Codes other than Indian code also recommend nonlinear static and dynamic analysis by Pushover Analysis Method and Nonlinear Time History Analysis (NLRHA) for assessment of seismic demand of structure. Further, Nonlinear Time History Analysis is suggested as a standard tool for accurate seismic demand estimation. But this Nonlinear Time History Analysis Method has very complicated computation and it is a tedious one. So, the evaluation of a quick, precise and easy method for seismic demand estimation whose results should be almost near to Nonlinear Time History Analysis results was one of the challenging tasks for researchers. And this task is completed by researchers which resulted in Spectrum based Pushover Analysis (SPA) method. This paper presents overview of the advancement of seismic demand assessment method for different structures.

Index Terms - **Tall building, Seismic demand, Nonlinear Time History Analysis (NLRHA), Spectrum Based Pushover Analysis (SPA), Modal Pushover Analysis (MPA), Consecutive Modal Pushover (CMP) Analysis.**

1 INTRODUCTION

As earthquake is an uncertain catastrophe which causes damage to the structure as well as life, it is beneficial to consider the forces resulting from an earthquake in the design to avoid this loss. Recently all codes were based on the force based design methods but earthquakes such as the Northridge earthquake (1994) in America which caused many deaths and structural damage. After this earthquake, the investigation is carried out to check the correctness of the previous analysis and design procedures of earthquake codes, which resulted in use of displacement-based analysis method and performance-based design of the structure. It is later adopted by many developed countries and changes are made for nonlinear analysis and performance-based design in accordance with American code. In addition to Nonlinear Time History Analysis (NLRHA) which is best and accurate method for exact estimation of seismic demand ATC-40, FEMA 356, FEMA 440 recommends nonlinear static displacement-based analysis methods such as Displacement Coefficient Method (DCM) and Capacity Spectrum Method (CSM) for quick assessment of seismic demand. But accuracy of these displacement-based methods for buildings with different nonlinearity is questionable. So advancement in these displacement-based methods is done by many researchers to estimate quick and precise seismic demand of the building. This advancement in seismic demand estimation method is discussed in this paper. Many studies were carried out for seismic demand estimation using tedious and complicated Nonlinear Time History Analysis (Bardakis and Dritsos 2007; Inel et al. 2008; Kappos and Kyriakakis 2000), which later promoted the need for a quick and best method for seismic demand estimation based on a pushover analysis method.

LITERATURE REVIEW

Moghaddam and Hajirasouliha (2006) explored the correctness of pushover analysis to estimate the seismic deformation requirements of a braced steel frame. The reliability of the pushover analysis was verified by performing a nonlinear dynamic analysis for frames with 5, 10 and 15 stories subjected to 15 synthetic earthquakes data representing a design spectrum. It showed that the pushover analysis with a given load pattern provides questionable estimates of story drift. A simplified model of earthquake analysis has been developed to predict seismic demand parameters. The multi-story frame is reduced to a shear equivalent model and pushover analysis was performed on it. It has been shown that modified shear design models give a better estimation of the nonlinear dynamic response of real framework structures in relation to nonlinear static methods. Therefore, by conducting the structural analysis of modified shear design models it was concluded that the analysis and design were quite simple and accurate also.

Kalkan and Kunnath (2007) investigated the effectiveness of some non-linear static methods in the prediction of response characteristics of steel and reinforced concrete (RC) constructed buildings by comparison with the reference response obtained from the complete set of NLRHA. 6 and 13 story steel moment frame buildings and 7 and 20 story RC moment frame buildings were used in the evaluation of the different Nonlinear Static Procedures (NSPs). Different NSPs were carried over these considered models such as Modified Modal Pushover Analysis (MMPA), Upper-Bound Pushover Analysis (UBPA), and Adaptive Modal Combination (AMC) procedure. The seismic response i.e. seismic demand in form of story drift ratio, story displacement, and plastic hinge rotations was calculated. Later same responses were calculated for NLRHA case in which 30 sets of ground motions were selected and applied to considered models. From comparison done amongst all calculated parameters, it was concluded that the FEMA-356 method provided inadequate predictions of drift and plastic rotations of peak elements at top stories when higher modes are important. UPBA was incapable to estimate displacement in a good way which tends to underrate demand such as drift and rotation at the lower part and exaggerate at the upper part of the building. The newly developed AMC process that integrates the inherent advantages of the CSM, Modal combination, and adaptive load scheme provided the best overall results when compared with NTH results.

Poursha et al. (2009) studied the need for consideration of higher mode effects in seismic demand estimation of tall buildings NSP -based pushover analysis was a preferred tool of use in practical applications for evaluating buildings demand and checking design of constructions. But these procedures were suitable for low rise buildings in which the first fundamental mode is dominant. For tall buildings these NSPs were unable to estimate seismic demand with accuracy. These NSPs underrate the demand in top stories. So to overcome this disadvantage new method was introduced as Consecutive Modal Pushover (CMP) procedure which was capable of estimating accurate seismic demand by considering higher mode as well as single-mode effects. The method is applied on four different steel Special Moment Resisting Frames (SMRF) with different heights to check its effectiveness. Results for seismic demand from Modal Pushover Analysis (MPA) and Consecutive Modal Pushover (CMP) were compared with standard Nonlinear Response Time History Analysis (NL-RHA) method result and it was concluded that the CMP procedure was able to effectively overcome the limitations of the traditional pushover analysis and can give accurate prediction by estimating seismic requirements of tall buildings at top stories precisely.

Poursha et al. (2011) explored the effect of higher mode and torsion on seismic demand estimation of an unsymmetrical plan tall building, as seismic demand gets strongly influenced by the effects of higher modes and torsion. The method was expanded to estimate the seismic demand requirements of one-way asymmetric floor plan tall building.. Modal analysis was carried out on considered tall buildings. Seismic forces and moments those were induced with torsion were calculated. It was further used to carryout seismic demand estimation with pushover analysis. These demands were then compared with the results of seismic demand carried out by Nonlinear Response Time History Analysis (NLRHA). The results of different methods i.e. MPA and CMP on 10, 15 and 20 story unsymmetric plan buildings with different torsional cases such as torsionally-stiff (TS), torsionally-similarly-stiff (TSS) and torsionally-flexible (TF) were compared with NLRHA results and it was found that the CMP process represented a significant improvement in the estimation of plastic rotations of hinges for flexible and rigid sides of tall building with an asymmetric floor plan than the MPA method.

Khoshnoudian and Kashani (2012) earlier, Poursha et al. (2009) proposed a CMP procedure to account for the effects of higher modes with acceptable accuracy, particularly for predicting the rotation of the plastic hinge. The CMP procedure was limited to two or three modes and the use of higher modes could result in inaccuracies in the results of the upper stories. By considering the contribution of higher effects on basis of modal mass participation factors, the CMP procedure was renewed by Khoshnoudian and Kashani (2012) and introduced as Modified Consecutive Modal Pushover Analysis (MCMP).To verify the accuracy of MCMP 10, 15, 20, and 30 story Steel SMRF were modeled in SAP2000 software and seismic demand, such as plastic hinge rotation and story drift by MCMP and NLRHA were calculated. From the comparison, it was concluded that the results from MCMP were well within the range with the results of the NLRHA method.

Liu and Kuang (2017) proposed a new Spectrum based Pushover Analysis (SPA) method to estimate the earthquake demand of tall buildings to overcome the drawback of Rapid and accurate estimation of the earthquake requirements of tall buildings .In this method very complicated dynamic coupling effect of mode was solved to simplify the seismic behavior of the building. This simplification was combined with the CMP analysis procedure. Analysis of 9 and 20 story building was done by SPA and NLRHA methods. A comparison of the results of seismic parameters from SPA was compared with the results of NLRHA. From the comparison, it was concluded that results from the SPA were very close to the NLRHA result and so that SPA was a best, fast and accurate method for seismic demand estimation of a tall building.

Liu et al. (2018) introduced a new method named Extended Spectrum-based Pushover Analysis (ESPA) for the determination of seismic forces in tall buildings. To check the correctness of the method two tall steel SMRF frames were analyzed with MPA, CMPA, ESPA, and NLTHA for different earthquake data sets. Results for earthquake-induced forces such as shear force and bending moment were compared for different methods. It was concluded that results from ESPA methods were close to NLRHA results so that ESPA method proposed a best tool for calculation of seismic forces induced in structure due to the earthquake.

CONCLUSIONS

Many codes have recommended NLRHA as a standard tool for seismic demand calculation i.e. plastic hinge rotation and inter-story drift ratio. But this method was tedious, complicated, and time consuming. To overcome these disadvantages, need for a fast and correct seismic demand estimation method based on a pushover analysis method resulted in Spectrum based Pushover Analysis (SPA) procedure and Extended Spectrum-based Pushover Analysis (ESPA) procedure. Both of these methods are capable of calculating seismic demand and seismic forces fast and with better accuracy than MPA and CMA for tall buildings. The results from SPA and ESPA are showing correctness comparable to the NLRHA method. So till now SPA and ESPA are the best methods to calculate seismic demand and seismic induced forces accurately. From this paper, it is easy to understand the advancement of a new method such as SPA and ESPA from the conventional pushover analysis method and MPA. One can easily understand the advantages and disadvantages of each AMC, UPBA, MPA, CMP, and MMPA.

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3 REFERENCES

[1] A. Tamrazyan, Georgievich and M. Z. Seyed , "Study of Monolithic High-rise Buildings with Transfer Floors under Progressive Destruction in the Nonlinear Formulation," in *15th World Conference on Earthquake Engineering*, LISBOA, 2012.

[2] M. A. Yasser, Y. S.-A. Ezzeldin and A. M. Sherif, "High-Rise Buildings with Transfer Floors: Drift Calculations," in *37th International Association for Bridge and Structural Engineering Symposium*, Madrid , 2014.

[3] Prof. P. S. Lande and Parikshit Takale, "Analysis of High Rise Building with Transfer Floor," *International Research Journal on Engineering and Technology*, pp. 1-6, 2018.

[4] Sopna Nair, Dr. G Hemalatha and Dr. P Muthupriya, "Response Spectrum Analysis and Design of Case Study Building," *International Journal of Civil Engineering and Technology*, pp. 1227-1238, 2017.

[5] J. D. Vincent and F. . R. Luis , "New Heights for Florida High Rises," *Structures Congress ASCE*, pp. 2981-2992, 2010.

[6] Y. M. Abdelbasset and M. Sherif, "Seismic analysis of high rise building with transfer floor: state of art of review," *Electronic Journal of structural engineering*, 2016.

[7] Li C.S., Lam S. S. E., Zhang M. Z. and Y. L. Wong, "Shaking Table Test of a 1:20 Scale High-Rise Building with a Transfer Plate System," *ASCE Journal of Structural Engineering*, pp. 1732-1744, 2006.

[8] A. K. Chopra, Dynamics of Structures: Theory and Applications to Earthquake Engineering, 4th ed., University of California at Berkeley: Prentice Hall, 2012.

[9] IS 1893-1, *Code of Practice: Criteria for earthquake resistant design of structures*, Bureau of Indian Standards, 2016.

[10] IS 456, *Code of practice: Plain and Reinforced concrete*, Bureau of Indian Standards, 2000.

[11] IS 875-1, *Code of practice: Design loads (other than earthquake) for buildings and structures*, Bureau of Indian Standards, 1987.

[12] I. 875-2, *Code of practice: Design loads (other than earthquake) for buildings and structures*, Bureau of Indian Standards, 1987.

[13] I. 875-3, *Code of practice: Design loads (other than earthquake) for buildings and structures*, Bureau of Indian Standards, 2015.