Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 49(3) (2017) 123-126
DOI: 10.22060/ceej.2015.421

Assessment of Different Pushover Methods to Estimate Seismic Inelastic Demands of SMRF's

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ABSTRACT: Since the nonlinear static procedure (NSP) is one of the most prevalent and useful methods for the Performance-Based-Design (PBD) of buildings, it is considered by several researchers during past decades, so that the capability assessment of NSP in comparison with the nonlinear dynamic procedure (NDP) and improving the NSP accuracy are the basic subject of previous studies. Therefore, in this paper several load patterns used in conventional and advanced NSP such as displacement-based adaptive NSP (DAP) and multi-mode interaction adaptive NSP (APAM) are evaluated and the results are compared with NDP responses. Based on modeling assumptions the results demonstrate that the CPA with elastic load patterns cannot predict displacement and story drift for high-rise models. The maximum differences between CPA and APA is almost 7.9%. In addition, the DAP adaptive method presents an almost accurate prediction of seismic demands and it can consider the effect of higher modes on inelastic responses. However, although the APAM adaptive method considers the interaction between modes, but it cannot predict the interstory drift angle at lower stories accurately. This behavior is intensified while the height of buildings increases.

Review History:

Received: 13 October 2014
Revised: 28 May 2014
Accepted: 31 June 2015
Available Online: 28 September 2015

Keywords:
Nonlinear Dynamic Analysis
Adaptive Nonlinear Static Analysis
Drift Angle
Average Ductility

1- Introduction

Nonlinear or pushover static analysis has been developed in recent decades and used as a widespread way in the seismic assessment of structures. This procedure increases lateral forces with an identical and valid distribution in the structure's height by arrival time to the displacement of the objective. Traditional nonlinear static analysis procedure comprises simplifications causing mitigation of accuracy in the results of it. In general, the pushover procedure with a constant load pattern consists of many constraints, particularly for tall structures, since distribution of the real inertial force varies continuously during the earthquake because of contribution of higher modes and the stiffness decline of the elements and eventually, the stiffness degradation of the whole structure. Hence, the effects of higher modes to estimate seismic demands of tall structures should be designated. Therefore, developed methods of nonlinear static analysis have been represented by different researchers in order to consider action of higher modes and interaction within mode.

In the meantime, the multi-mode pushover procedure was suggested [1]. One of the common multi-mode procedures is the modal Pushover Analysis or MPA in which a structure is analyzed against loading patterns corresponding to each mode and the results of analysis, then, are composed by widespread methods of mode combination.

In this approach, the shape of the vibratory mode is considered as elastic, too [2]. Since entering the nonlinear scope, the stiffness matrix changes, load patterns should be corresponding to these variations, as well. Regarding this, adaptive load patterns have been recommended [3,4] All adaptive methods cannot consider the interaction among responses of different modes known as higher modes effects (HME), well in a way suggested by Aindinoghloo [5].

In this investigation, the traditional pushover procedure with different lateral load patterns such as the triangular load pattern, the first mode of structure variation, the Uniform and the load pattern arising from the spectral dynamic analysis is evaluated and the results are compared with developed procedures of pushover analysis comprising Adaptive pushover procedure based on displacement (DAP) and Adaptive pushover procedure according to the action of mode interaction (APAM).

For this, 5 steel bending frames with the number of 4,7,10,15 and 20 floors with 5 spans and the average ductility and the soil type III are designed and all nonlinear analyses are performed by opensees software.

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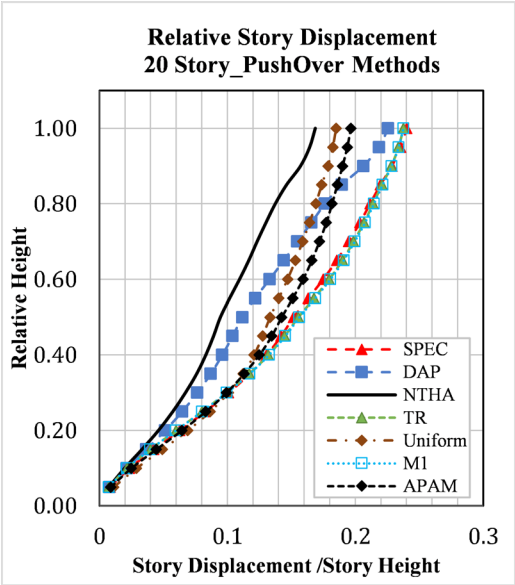

Figure 1. Story Displacement (20 Story Model)

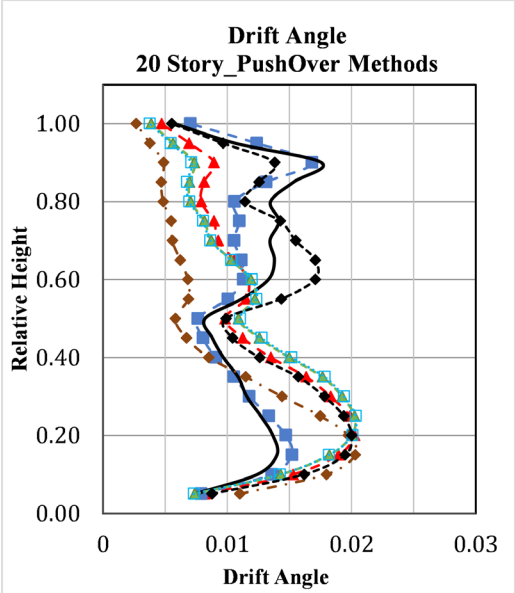

Figure 2. Story Drift Angle (20 Story Model)

2- Research Method

To assess various pushover analysis procedures, 4, 7, 10, 15 and 20-story models with 4 meter-high floors and 5 spans with 5 meters long were applied. Desired frames are from the steel bending frame with average ductility. In order to project structures, AISC-ASD89 regulation and building designing regulation against the earthquake (standard 2800) have been benefited and drawing assumptions are comprised of the soil type III and the zone with too much relative risk. Sections used in these frames consist of box sections and the sheet beam for columns and beams, respectively.

10 accelerograms away from the fault have been utilized to conduct the nonlinear dynamic analysis. All graphs received from the site Peer contain properties of the soil type III based on the seismic design regulation of Iran (standard 2800), or the soil class D based on guideline category of FEMA356.

In this article, measurement of the final angle of drift equivalent to 0.02 radian ratio each earthquake has been applied; therefore, measurement of the earthquake record has been done indirectly. The value of drift angle for the floor equivalent to physical safety performance level is 2 percent on the basis of SEAOC instruction (version2000).

3- Results

Following results arose within the mentioned models:

- Traditional methods do not represent an appropriate estimate of displacement and drift angle through the augmentation of the structure's height as opposed to the nonlinear dynamic analysis. This is due to constancy of load distribution form during the loading process of the structure, not considering the effects of the stiffness matrix of elements and the stiffness matrix of the whole structure, and not considering the effects of higher modes. The difference between traditional pushover procedures and adaptive ones in calculating the drift angle of floors increases through the height augmentation of the structure such that the highest value of this difference is 7.9 percent and belongs to the uniform load pattern.
- Values of displacement and drift angle of various structures are the same for all three traditional pushover methods with the first mode, triangular and spectral load pattern (that all three load patterns are based on the form of the triangular pattern) and there is a paltry difference.
- Among discussed adaptive pushover methods (APAM and DAP) in this study, DAP method estimates the values of displacement and drift angle of different structures well, with the height increase of the structure; while APAM method cannot represent a suitable approximation of drift angle of the lower floors with the height increase of the structure. The highest difference values of DAP and APAM procedures to calculate displacement and drift angle of floors are 3.8% and 3.7%, respectively and belong to the 20-story structure.
- In low-rise structures, methods of developed and traditional nonlinear static analysis are suitably adaptable to the nonlinear dynamic method because of the effects of higher mode.

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Please cite this article using:

M. Gerami, A.H. Mashayekhi, N. Siahpolo, "Assessment of Different Pushover Methods to Estimate Seismic Inelastic Demands of SMRF's", *Amirkabir J. Civil Eng.*, 49(3) (2017) 419-430.

DOI: 10.22060/ceej.2015.421