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Comparative Study on Adaptive Displacement Based Pushover Analysis

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ABSTRACT

Current trend in the estimation of seismic demand for reinforced concrete structure has been widely been based on forced based analysis. Adaptive Pushover method is advancement in the convention methods. Forced based scaling in adaptive pushover (FAP) analysis involves forced based controlling parameters. The force vector for pushover is incremented with every step of analysis, rather than Modal Pushover analysis which has the force vector based on the modal shapes until 90% modal participation factor is attained. Displacement based adaptive pushover analysis shows relatively appealing concept. In the present paper 8 storey MR frame is studied and comparison is done among force based adaptive pushover, displacement based adaptive pushover and non-linear time history analysis considering NTH analysis to be exact.

Keywords: Pushover analysis, displacement based, Adaptive pushover.

I. INTRODUCTION

Estimation of accurate loading pattern in an important aspect of performance based analysis for performing pushover analysis. Displacement based analysis on its own shows various drawbacks when compared to its forced based counterpart when carrying out pushover analysis. But if the displacement vector is updated with every mode, for the pushover analysis it has shown a conceptually appealing displacement based analysis.

For estimating the seismic demand of structures Nonlinear Static Procedures (NSPs) has been used as a practical tool. A lot research work has been done to minimize errors of NSPs, while the exact method considered is the Nonlinear Time History Analysis (NTHA). In a typical pushover procedure, the pattern and technique of loading is the most essential element which is computed based on fundamentals of structural dynamic.

A particular lateral load pattern is to be selected as a first step in any Pushover analysis, which influences the resulting capacity curves under- or over-estimating the building seismic capacity. Hence, particularly in pushover analysis, the selection of a reasonable lateral load pattern is important. **Tetsuro et al.**[2] estimated seismic capacity curves of three types of buildings consisting of frame, shear wall, and frame-shear wall and under different lateral load patterns performed pushover analysis and concluded that for low-to-mid-rise shear-bending type and low-rise bending type of buildings both the two-phase load pattern proposed and the invariant uniform pattern can be used. No suitable load patterns have been found for high-rise buildings.

Mohsen et al.[3] involved a meta-heuristic optimization algorithm suggesting the coefficients of modal force combination for estimating the optimum load pattern such that in comparison to the NTHA counterpart, it resulted in a response with minimum amount of errors. **Rania et al. [4]** analyzed the effect on seismic performance of lateral load patterns on low-to-mid-rise Reinforced Concrete (RC) frame buildings. The buildings consisted of 6, 9, and 12 storey reinforced concrete frames were designed based on Egyptian codes ECP-203 and ECP-201. The base shear, the top drift of the building, and the peak inter-story drifts were analyzed. Based on the seismic responses of the RC frame buildings the effect of the selected lateral load patterns was illustrated.

The conclusion derived was that the capacity curve and interstorey drifts are affected by the loading pattern **Javadein & Taghinezhad [5]** performed pushover and nonlinear dynamic time history analyses for 3, 5, 7, 9 and 13-story moment steel frame structures and for a variety of natural periods and various load patterns, evaluated the performance of the frame structures The loading pattern for pushover analyses selected were IBC (k=2), triangular and rectangular. **Sadegh and Mohammad[7]** obtained capacity curves from pushover analysis by proposing a new lateral load pattern for pushover analysis of structures and with the proposed lateral load pattern and compared the capacity curve with curves from the incremental dynamic analysis (IDA) considering it as exact solution.

Two lateral resisting systems, namely steel moment-resisting frames (MRF) and concrete special moment-resisting frames (SMRF) and three frames with 4, 12 and 20-story were put into consideration. **Pour et al.[8]** performed pushover analysis using some conventional lateral load patterns, and proposed a new accurate pattern and evaluated the same. New proposed load pattern had load distribution according mode shape of structure, weight and stiffness variation in height. The conclusion derived was that compared to other pushover load patterns, proposed load pattern results were closer to nonlinear dynamic analysis (NDA) especially in tall and medium-rise buildings having difference of mass and stiffness with the increase in height. **Pinho et al.[9]** studied an enhanced adaptive pushover methodology mitigating some of the inherent limitations of static procedures. A fully adaptive procedure was suggested and considering the modal properties of the structure at various levels of inelasticity and current stiffness state, the lateral load distribution along the height was updated.

This research includes various lateral loading patterns and comparing the global response parameters or the capacity curves among them, and comparing all interstorey drift ratio and roof displacement with the NTH analysis considering NHT analysis as exact. To perform NTHA, 11 strong motion data, near-fault, normal component were selected. The target displacement was obtained from the NTHA and structures were pushed up to the specified target displacement for comparison purpose.

II. METHODOLOGY

The present study has been carried out on 8 storey MR frame. The design and analysis has been done in E-Tabs. Then pushover analysis was carried out in Seismostuct software. For the NTH analysis Strong motion parameters are the characteristics of earthquakes that make each one unique. The strong motion data for various earthquakes could be derived from various databases such as PEER. Special attention has been given to the type of record of the earthquake from the Epicenter to the site. Two types of records are available in the name of far-fault and near-fault data. In the case respond to such vibration of near-fault earthquakes, the structure is imposed with significant amount of energy in a short time and the structure does not get enough time to respond to such vibration.

Analysis and design have been done in E-Tabs-2015 with the following initial data. The structural configuration considered for the present research are three symmetric in plan typical Reinforced Concrete frame structure designed in 4, 8 and 12 storey model configuration, planned to be used as a regular office building located in seismic zone IV according to IS 1893 [3]. The seismic demands of the structures are estimated as per IS 1893. The Reinforced concrete design of the buildings is as per IS 456 guidelines and IS 13920 provisions are used to estimate the (seismic) ductile detailing of the sections. The structures design base shear is calculated as:

$$V_b = \frac{Z}{2}\frac{I}{R}\frac{S_a}{g}W$$

Where Z depicts zone factor (for zone IV) =0.24, I denotes the importance factor of the structure(for regular buildings)=1, R = 5.0 for special moment resisting frames (SMRF) or ductile design, and W is the structures seismic weight, Sa denotes the spectral acceleration.

Proposed structures has the plan configuration with numbers of bays = 4 (5.0 m each) in x and y directions as is shown in figure. The floor to floor height is 3.5 m for common storeys and the base storey taken as 4.5 m. The structure of MR frame type, is selected to essentially represent ‘medium’ time period structures. Target displacement is derived from NTH analysis for the force based loading vector.

TABLE 1: Design of 8 storey MR frame.

ELEMENT	STOREY	DIMENSION	DIRECTION	A_{ST}	BARS
beam	1 to 4	300*500	Top	2420	25# 5 no.
			Bottom	1778	25# 4 no.
column		600*600		7939	25# 16 no.
beam	5 to 8	300*500	Top	2230	25# 4 no.
			Bottom	15	25# 3
				61	no.
column		450*450		4755	25# 12 no.

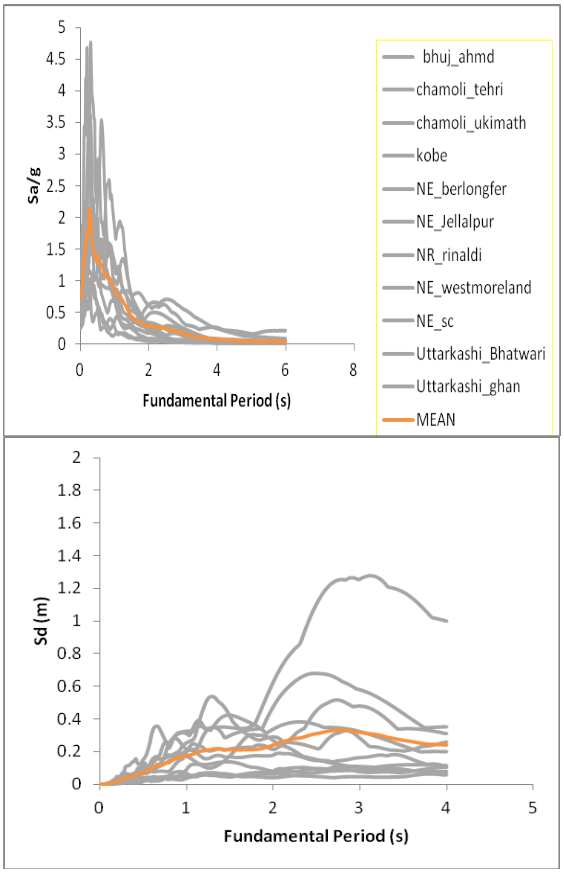

Fig 1. Elastic acceleration (left) and displacement (right) spectrum of near-field earthquakes

III. RESULTS AND DISCUSSION

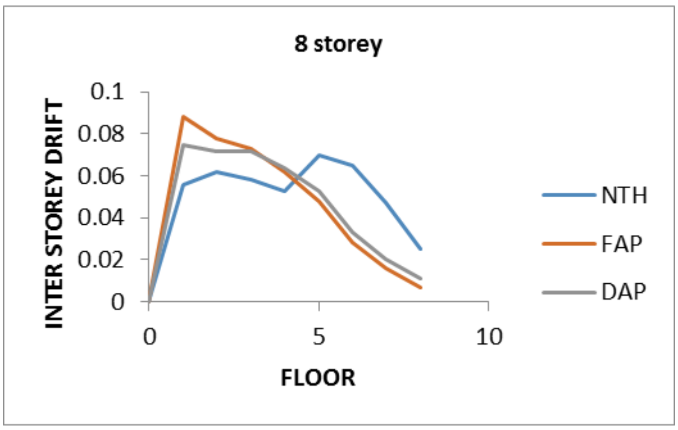

Fig 2. Inter Storey Drift for 8 storey structure.

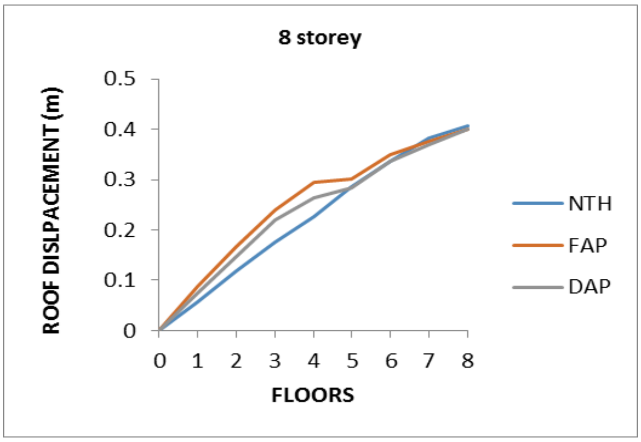

Fig 3. 8 storey Roof Displacement Curves

IV. CONCLUSION

The present study has been conducted on 8 storey moment resisting frame using Force based adaptive (FAP) and displacement based adaptive pushover (DAP) analysis. Spectral magnification was not incorporated in both FAP and DAP.

It is seen that none of the method is fully sufficient to estimate the seismic demands of frame.

The DAP analysis shows better estimation of the intersorey drift for lower as well as higher storeys when compared to FAP.

The error in higher storeys seems to increase, that IS error is increased with increase in height. The reason being that higher modes of vibration are not accuratelyu estimated.

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