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DYNAMICS HISTORY ANALYSIS FOR MULTI-STORY STRUCTURE BUILDING IN YEMEN

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Abstract: One of the significant difficulties in performance-based earthquake engineering is to create simple and practical methods that will be able to estimate the capacity level. The primary role of this paper is to operate and compare different nonlinear evaluation strategies for evaluating the seismic performances of structures. For these purposes, simple models are considered to symbolize low-rise structure. This consist of a moment resisting reinforced concrete structures with no shear walls, placed in a high-seismicity region of Yemen in Dhammar City. They are designed in accordance to (ACI-318-11) - (UBC-97) codes, considering each seismic and gravity loads. In this paper, the reliability of the DAP in locating out the seismic response of building moment resisting reinforced concrete frames responding inside inelastic range is verified. Therefore, (IDA) by way of skill of applying a large set of original records, and FEMA 440 static pushover are carried out for comparison. The capacity curves of the structure, as determined by utilizing of each DAP and FEMA440 pushover bends are compared with IDA envelopes by using a SeismoStruct. The performance stages of systems are also expected and in assessment using way of acting DAP and Incremental Dynamic evaluation the usage of the SeismoStruct software.

Keywords: Multi-Mode Pushover Analysis, SeismoStruct, Incremental Dynamic Analysis (ACI-318-11) (UBC-97) codes, and Nonlinear Static Analysis.

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Introduction

Over the decades, researchers in performance-based earthquake engineering strive to create particular and easy methods for predicting seismic capacity and demand on structures using taking into account their inelastic behavior. The nonlinear static procedure (NSP) has grown to be a favorite tool for design verification and performance assessment of structural systems. The utilization of NSP approach is obviously going to be preferred, amongst engineers, instead of complicated and impractical methods of nonlinear time-history analysis (NTH). The NSP is confined to single-mode response; for that reason, NSP is suitable for regular low-rise structures where a higher mode contribution is not significant. The conventional NSP substantially underestimate the upper stories seismic needs of irregular-plan and high-rise constructions due to the fact the tactics do not take into account higher modes contributions to the response. The multi-mode nonlinear static analysis methodology that has been proposed by Antoniou and Pinho (2004) will be evaluated by this paper and which may take into consideration higher modes contributions on structure response.

The procedure, which has been named the Displacement-based Adaptive Pushover Analysis (DAP), is applied to simple RC frame with different elevations. Therefore, the primary goals of this paper will be to analyze and compare performances of proposed Adaptive Pushover Analysis (Pinho and Antoniou, 2004b). Analysis (IDA) envelopes, as well as restrict states capacity of structures. The outcomes point out that; Adaptive Pushover Analysis can successfully overcome the restrictions of conventional pushover analysis and also estimate the limit state capacity and determine seismic demand of high-rise buildings with desirable exactness or accuracy.The accuracy of Adaptive Pushover Analysis techniques will be assessed in predicting the global response, via a comparison of Adaptive Pushover Analysis curves with Incremental Dynamic.

Modeling

One RC structure, with different elevation, is considered to represent low-rise RC structure for this paper. The structure has a moment resisting RC elements without any shear walls and is supposed to be located in a high seismicity region of Yemen in Dhammar City. The structure is designed according to (ACI-318-11)-(UBC-97) Codes, taking into account seismic and gravity loads. The sample structures considered in this paper are described as follows:

• All the floors are the same height of 3 m in elevation.

• The dimension of a structure (width/elevation) used in this paper is the same ratio.

• A typical RC structure with high ductility level is considered.

•To design structure, Equivalent static analysis, defined by an (ACI-318-11)-(UBC-97) response spectrum and fully rigid design method are used.

• The Response Modification Factor for Systems of high Ductility level according to (ACI-318-11)-(UBC-97) is $R_x = R_y = 8.5$

• Seismic evaluation has been applied according to the American Seismic Code (UBC97) with Ground Motion Acceleration of 0.3 in zone 3 as Figure 1 and soil type SE (Stiff Soil Profile) has been used.

• Purpose of occupancy Considered Residential, so Importance Factors is equal to 1 (I=1) according to (UBC-97) code.

• Consider the limitation of relative story drift according to (UBC-97).

$$\frac{(\delta_i)max}{h_i} \leq 0.02$$

• The participating live load (30% of live load) and dead load on the structure are $3\frac{KN}{m^2}$ *and* $5\ \frac{KN}{m^2}$ respectively.

• The longitudinal and transverse reinforcement of the yield strength was assumed to be 420 MPa, and 28 MPa is equal to the characteristic compressive strength of concrete. In the potential plastic hinge regions, Simple layouts with 0.1m, 0.15m, and 0.2m spacing are used for transverse reinforcement.

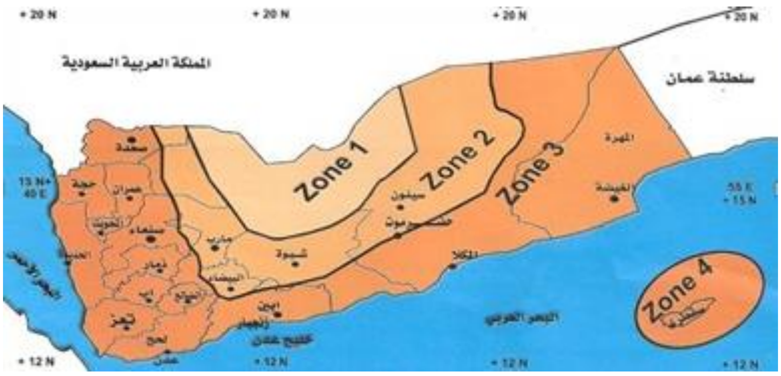

Figure 1. Al-Zafiri map of seismic zones in the Yemeni areas

Figure 2 represents 3D of the sample models and, plan view of the building structure is shown in Figure 3.

Figure 2. 3D models of symmetric-plan 3-story

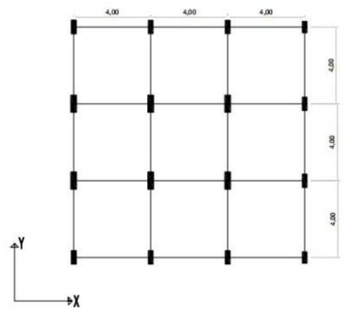

Figure 3. structure and story RC structure is 12 m by 12 m in plan

The RC frame of the building is 9 m in elevation, and all the floors are considered the same height of 3 meters. The frame has simple bays with 4-meter span length. Longitudinal beam and column reinforcement amount and, column dimensions are demonstrated in Table 1.

The section area of all beams is 0.2m0.5m. The amounts of the top and bottom reinforcement in (cm^2) and beam section characterizations are displayed in the elevation is demonstrated in Table 2

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Table 1. Columns section characterizations

Story	Dimension (cm)	Reinforcement	Stirrup
Story 1	50x25	10∅20	∅8/20
Story 2	50x25 - 40x25	10∅20, 8∅18	∅8/20
Story 3	40x25	8∅16	∅8/10

Table 2. Beam section characterizations

Type	Dimension (cm)	Top	Bottom	Stirrup
Occupancy Building	50x20	3∅18	3∅18	∅8/15

Methodology

Computing and defining inelastic frame elements

In this paper, for carrying out nonlinear analysis finite element software, SeismoStruct is chosen. Modeling of structure and, determining geometric and material nonlinearities is the primary idea for selected programs. Inter-story drift profiles were used to achieve valuable results data on the failure mechanism and illustrate the influence of yielding derived from the inelastic procedures that are directly correlated to non-structural and structural damage (FEMA440, 2005). In this paper, according to FEMA 356, simple limit states including collapse prevention (CP), life safety (LS) and immediate occupancy (IQ) will be defined. For an RC frame without any shear walls, the IQ is determined when inter-story drift ratio reaches 1% of the floor height. Similarly for LS is defined at $\theta_{max} = 0.02$ and finally CP is considered for $\theta_{max} = 0.04$, as shown in Table 3 (FEMA356, 2000).

Table 3. Structural Performance Levels (FEMA356, 2000)

Element	Type	CP	LS	IQ
Concrete Frame	Drift	4% transient	2% transient	1% transient

- Lowest moment magnitude of the earthquake should be 6.5.
- AGA and PGV should be higher than 0.2g and15 cm/sec, respectively.
- At least 10km must be chosen as a source to site distance
- Less than 0.25Hz is recommended to be the lowest usable frequency for the record. This will make sure that there is no removal of low-frequency content by the ground motion filtering process.

There was no consideration of station housing when ground motion records selected to be free-field. Selected Fault Mechanism in all records is Strike-slip to be inconsistent with Yemen. The limitation mentioned above or restrictions described were considered in the selection of twenty ground motions.

The next step is to apply these records to the RC Frames to determine maximum inter-story drift ratio of the systems and finally drawing IDA envelopes.

SeismoStruct Software

One sort of analysis that can be run directly in Seismostruct software is incremental Dynamics analysis. For performing IDA, the user is requested to enter the Incremental Scaling Factors in the first step and then requires to well define the time history curve (usually a natural or artificial accelerogram) and corresponding curve multiplier (scaling factor).

Results and Discussions

16%, median and 84% IDA curves had been accomplished via summarizing the multi-record IDA envelopes for each of the simple case studies as defined above. Then, limit states have been defined at each performance level, as shown in Table 4 Figures 4 two show multi-record IDA envelopes (84%, median and 16% fragility curves) of each period.

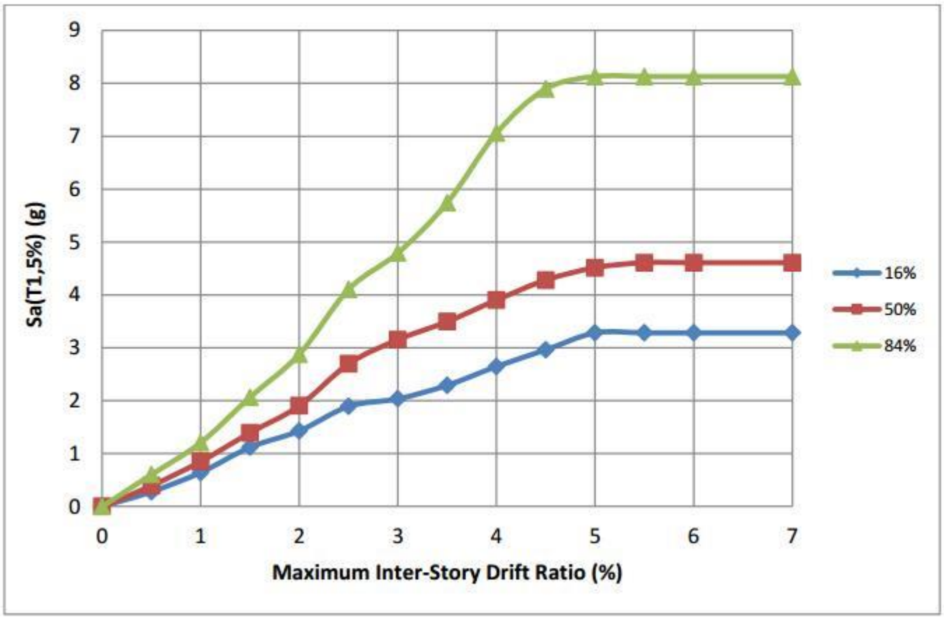

Figure 4. The Summary of the IDA Curve for RC Building Frame

Table 4. Summarized capacities for each limit-state for RC building Frame

	S_a (T$_1$, 5%) (g)			θ_{max}		
	16%	**50%**	**84%**	**16%**	**16%**	**16%**
Immediate Occupancy	0.644	0.851	1.210	0.01	0.01	0.01
Life Safety	1.430	1.903	2.880	0.02	0.02	0.02
Collapse Prevention	2.648	3.920	7.060	0.04	0.04	0.04

Fragility curves are vital tools that are used for determining potential and probability of structural damage as a result of earthquakes as a function of top displacement and peak ground acceleration. Fragility curve can be decided primarily based on the standard probability distribution (assume to be lognormal). The average distribution fragility curves concerning first-mode spectral acceleration and top waft (m) at the predefined restrict states are displayed in Figure 5 and Figure 6, respectively. The probability of each performance level for specific earthquake zones is furnished in Table 5.

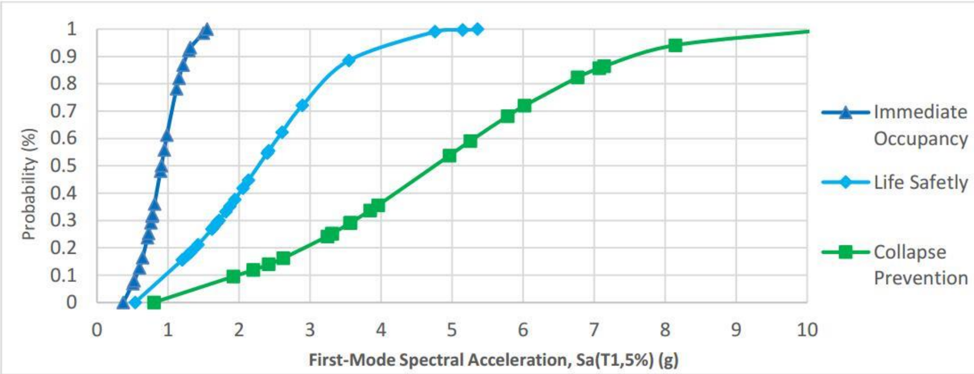

Figure 5. The normal distribution probabilistic fragility curves regarding PGA RC building Frame.

Table 5. Seismic performance levels of Structures by performing Incremental Dynamics Analysis using SeismoStruct software.

Structure Frame	Limit state	Seismic Zone-Model Spectral Acceleration (g)		
		$S_a = 0.7$	$S_a = 0.9$	$S_a = 1.1$
		The probability of Exceeding %		
Occupancy Building	IQ	22	49	76
	LS	0	0	13
	CP	0	0	0

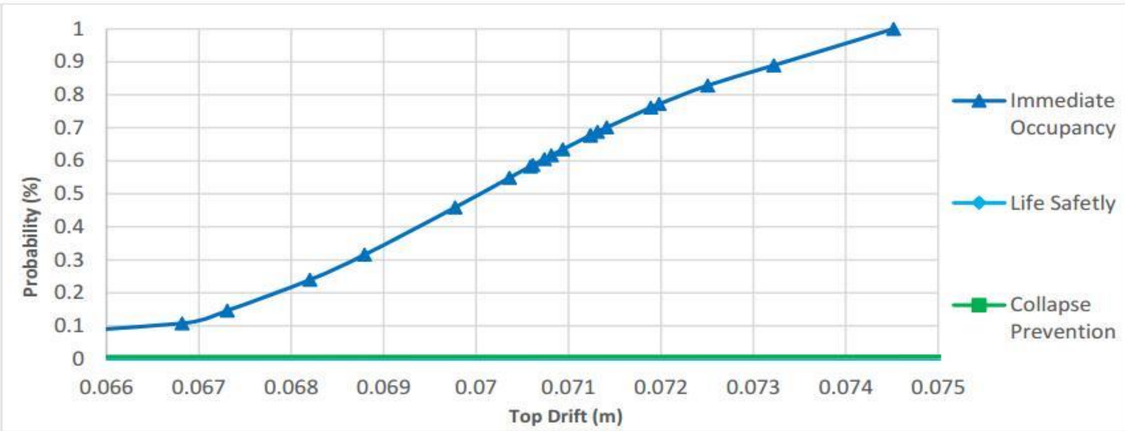

Figure 6. the normal distribution probabilistic fragility curves regarding top drift (m) RC building Frame.

Inter-Story Drift Profiles derived by DAP Method

Target displacement for RC building frame is equal to 0.071 meters, At this point; the body has the probability of 64% to be in IO level, and no chance exists that the performance level of structure be in LS level and CP level, as derived from the Figure 7, in accordance to IDA outcomes using SeismoStruct software.

Dario (2008) states that the DAP characteristic is positive and encouraging in the estimating of the drift profiles shape of high-rise RC structures. In Figure 7, the obtained inter-story drift profiles of the simple RC frames are demonstrated by performing DAP method using the SeismoStruct software.

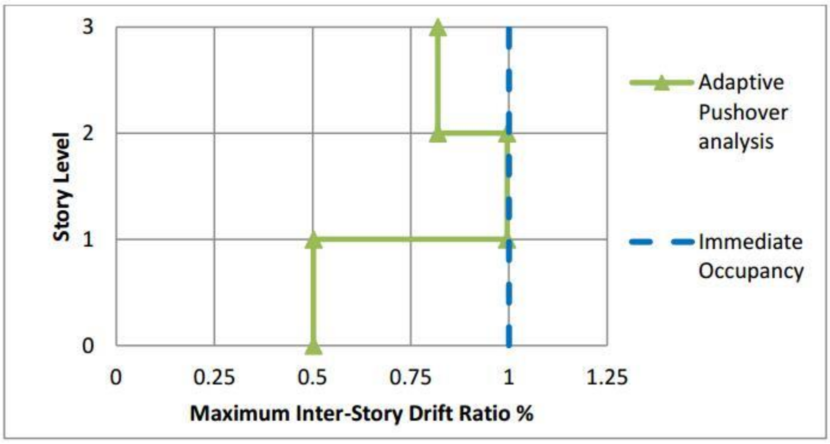

Figure 7. Inter-story drift profiles of RC Building Frame

As illustrated in Figures 7, the maximum inter-story drift ratio of building frame has approached 1%, and the limit state criterion at this level is immediate occupancy by FEMA 356.

Comparison between Nonlinear Dynamic and Static Analyses - Base Shear vs. Top Displacement Curves (Capacity Curve)

One of the necessary steps in post-processing of nonlinear structural analysis is to obtain the capacity curve (base shear versus top displacement). The capacity curve can disclose crucial features of structural response, consists of yield displacement, whole strength and initial stiffness estimation of the structure. Thus, it is essential and imperative to examine the new methods of pushover analysis to nonlinear dynamic analysis envelopes regarding the base shear vs. top displacement curve. The purpose of comparing different analyses method is to identify and apprehend the variations in the outcomes completed by using distinct methods and confirm their accuracy compared to dynamic and static analyses, making use of variable or fixed load distributions. The results of capacity curves received using different nonlinear analyses are shown in Figure 8 all the nonlinear analysis carried out via the usage of SeimoStruct software for decreasing errors.

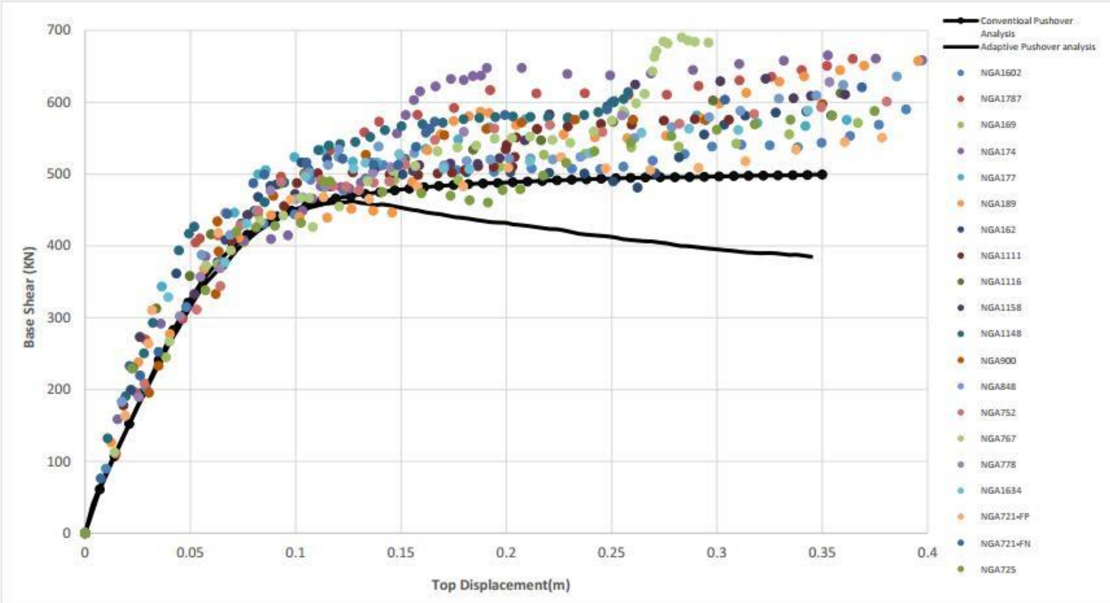

Figure 8. Capacity curves of RC Building frame, determined by performing conventional pushover and DAP, compared against IDA envelopes

The capacity curves for RC Building are shown in Figure 8 The paper result of RC Building frame exhibits that adaptive and conventional pushover analyses are suitable procedures when the fundamental modes dominate the response. The figure demonstrates that the accuracy of the regular pushover and DAP methods seems to be satisfying up to the displacement which is equal to 1.4 % of total height. After the negative post-yielding stiffness is observed in DAP technique because of reducing the post yielding stiffness of the structure and the methods could not trace the exact behavior to the collapse point of the structure.

Static analyses, regarding its pushover curve, can examine the response of the structure beneath seismic load with appropriate accuracy in the case of structures where the structural response is dominated by usage of the first mode, as in the case of regarding the RC Building frame.

In particular, the standard pushover curve solely in the case of the Building frame gives a pushover curve nearer to the IDA envelope, but DAP demonstrates higher consistency in leading to much less faulty estimations.

Performance Limit States of Nonlinear Dynamic and Static Analyses

The acceptance limits and actual damage level that obtained by different nonlinear procedures are shown in Tables 6 By comparing the Structural seismic performances achieved with damage predicted performing DAP, IDA using SeimoStruct software, in Building frame, all the procedures were found to have approximately the same level of performance.

Table 6. Seismic performances of Structures by performing DAP and Pushover Analyses and IDA Methods.

Structure Frame	S_t (FEMA440) (m)	DAP	Pushover Analysis	Incremental Dynamic Analysis	
		Limit State Criteria	Limit State Criteria	Limit state	The probability of Exceeding (%)
Occupancy Building	0.071	Immediate Occupancy (IQ)	Immediate Occupancy (IQ)	IQ	64
				LS	0
				CP	0

Summary and Conclusion

Summary

The general description of the structure is as follows; Simple RC Occupancy Structure Building is regarded to represent low-rise RC structure Building for this paper. The structures have a common RC aspect barring any shear walls and are supposed to be positioned in a high-seismicity region of Yemen in Dhammar City.

Structures are designed in accordance to (ACI-318-11)-(UBC-97) Codes, taking into account seismic and gravity loads. The simple reinforced concrete structure is assessed by way of employing some nonlinear analysis methods in this paper. The nonlinear static analysis, following FEMA440, has been defined and used. The conventional nonlinear static analysis method is a relatively simple method for assessing seismic capacity and demand of RC structure as described in the paper. However, the further article is still wanted to determine limitations of the technique and show the accuracy and reliability of the method. The performance of the Displacement-based Adaptive Pushover (DAP), proposed using Antoniou and Pinho (2004(b)), has been evaluated and compared with conventional pushover analysis and IDA in the cases of RC Building frames by the usage of the SeismoStruct software.

Through this paper, the detailed and fundamental methodology of Incremental Dynamic Analysis has been discussed. Twenty ground motion records have been applied on the considered frames and then nonlinear time history analysis has been done for different levels of scaling of all the twenty ground motion records using the SeismoStruct software. Finally, IDA envelope curves have been derived from the analysis, and then damage levels of structures have been demonstrated following FEMA356 of limit states for a different stage. Consequently, probabilistic fragility curves are also accomplished regarding top drift and PGA for each considered degrees of broken and the probability of each performance level for different drift ratio and earthquake zones given in the code calculated. The primary objectives of this paper have been to determine and compare performances of the traditional pushover and dynamic analyses (IDA) with those bought with the more currently proposed multi-mode nonlinear static analysis (DAP) and verify the reliability of the procedures for RC-frame structure Building.

Conclusion

In modern engineering design practice, the conventional pushover analysis represents greater comfortable and more practical technique concerning nonlinear dynamic analyses. The major pitfalls in time-history analyses avoided in this method requiring simulating time history ground motions record compatible with target reaction or response spectrum, and they remain computationally demanding especially in evaluating a 3D shape model that has thousands of elements. According to the results of the paper, displacement-based adaptive pushover analysis represents an enhancement related to other static procedure, even though most suitable or desirable solution was not achieved using this method. In fact, the capacity curves display that DAP provides higher estimates in which the effects of vibration higher modes are significant. In different words, results acquired in a current paper shows the advantages of the use of DAP analysis over non-adaptive methods in estimating of the seismic response evaluation of low-rise structure responding in the inelastic range of behavior. Hence, DAP represents simplify and practical procedure that capable of predicting the response structure of low-rise RC structures with suitable accuracy, though it can't estimate entirely satisfactory compared with dynamic methods.

Recommendations

In this paper, the number of analyzed models is not sufficient to make any definite conclusion, therefore, further and profound study of adaptive and conventional pushover analyses have to be carried out to determine limitations of the methods and establish the generality of the results. Furthermore, all the assessments have been carried out on 2D regular plan models which may not explicitly highlight the high-mode effects. Thus, more case studies are required mainly for taller irregular plan building structures Various multi-mode pushover analysis methods have been proposed and developed over many years by many researchers to take to account the structural responses in numerous modes, and these strategies can be compared to each other to find the best useful multi-mode pushover analysis approaches. The most straightforward procedure that is as close to reality as possible is usually the best one.

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