Introducing Building Casketing as a new Technique for Seismic Retrofit of Existing Buildings with Endurance Time Method

Payam Dindar
Dept. of civil Engineering, Islamic Azad University, Booshehr, Iran

Mahmood Hosseini
Dept. of structural Eng, Int'l Inst. of Earthquake Eng & Seismology (IIEES), Tehran, Iran

Hossein Mohammadirad
Dept. of civil Engineering, Shahrood University of technology, Shahrood, Iran

SUMMARY:
In order to retrofitted by the peripheral frames method for structures with L,T,U shape plans, we have 18 models to examine the effect of change in plan dimensions and elevation of building be considered. Frames are with moment resisting frame system that has been designed with the old seismic and concrete regulations. Nonlinear static and nonlinear dynamic and endurance time analysis methods on the models were done. According to the results, the frames don't have life safety performance level and need to retrofit. By adding peripheral frames to the structures, seismic performance level of the frames was improved. The retrofitted frames were evaluated by the new regulations. The result of retrofitted frames reach to life safety performance level and target displacement has decreased.

Keywords: Reinforced Concrete Frames, Evaluation of Seismic Performance, Peripheral Frames, Endurance Time Method, Nonlinear Analysis

1. INTRODUCTION

Reduceing of the building vulnerability and lifeline against earthquake can be considered one of the important issues in earthquake engineering. In fact, in case of occurring massive and devastating disasters such as earthquake in large cities, can be understood this problem. Since most of the old structures are not resistant against earthquake and haven't experienced a major earthquake, need to rehabilitation. Also many old buildings due to weak enforcement and flaws in design and the changes in seismic and loading regulations and understand that they are vulnerable. As regards most important structures such as office buildings, hospitals, schools, power plants, industrial facilities due to specific conditions, rehabilitation of these structures is needed so that doesn't have effect on the serviceability for a long time. Thus providing a new method for retrofitting that could rehabilitate such buildings against earthquakes so that without interruption in building function exist. Also most of the rehabilitation methods require changes in the interior of buildings. For retrofitting these buildings operations should perform outside the buildings, so that it has not entered any damage to the building interior. One of these methods, to retrofit buildings against earthquake by peripheral frames. The research on retrofitted buildings with L,T,U shape plans with moment resisting reinforced concrete frame system was done. This method requires no drilling operations for foundation rehabilitation and all retrofitting operations were done in out of the building. The retrofitting doesn't damage to the nonstructural components and doesn't exist any problems such as noise of destruction and interruption in structure activities. In recent years, studies on rehabilitation of outside the building have been done, (Fujimura, Horyo, Okuzono, Ono, Suzuki, 1999 and Yamanaka, 2001) investigated the peripheral frames. In these studies scientists have added shear wall and steel brace to the structure to increase lateral stiffness out of building.

In this study has been used three methods for analysis. These methods are: nonlinear static analysis (pushover), nonlinear dynamic time history analysis and endurance time (ET) analysis method. For dynamic time history analysis has been used 7 accelerograms and has been considered average

resposes of 7 accelerograms as a final answer. Endurance time method is fundamentally a simple dynamic pushover analysis that foretell damage measure of structures at different intensity measures by disposable them to some precalculated amplifying dynamic excitations. (Estekanchi et al., 2004; Riahi et al., 2009). For this analysis have 3 accelerograms that called (e) series ET accelerograms. Considered average responses of 3 accelerograms as a final answer.

2. THE PERIPHERAL FRAME METHOD INTRODUCTION

In rehabilitation by the peripheral frame method, the peripheral frame covers the structure like the sheath and the stiffness of the structure increased and target displacement reduced. These frames inhibit and joint together by beams top of the structure, in order that integrated performance of these peripheral frames hasn't disturbance. Rehabilitation by this method, foundation of main structure doesn't need to retrofit and perform separate foundation for peripheral frame.

3. SELECTION THE STRUCTURAL MODELS PROCESS

In this study, 18 structural models with 4,7 and 10 stories and with 3 and 5 span with length of span 5 meters and height of the stories 3.5 meters was considered. Modeled plans are visible in figure 1. Structural models have been created by using opensees have been designed with the first edition iranian national building code (INBC) standard 2800 and other old regulations (BHRC, 1987). Then frames performance level has been evaluated by fema 356 and understood these models don't have life safety performance level (FEMA 356, 2000). These models have been retrofitted by peripheral frames method and then have been evaluated with new seismic regulations (BHRC, 2005). The use of this rehabilitation methods, performance level reached to the life safety level. The models situated on soil type II (INBC) and site location has the risk of earthquake with high intensity.

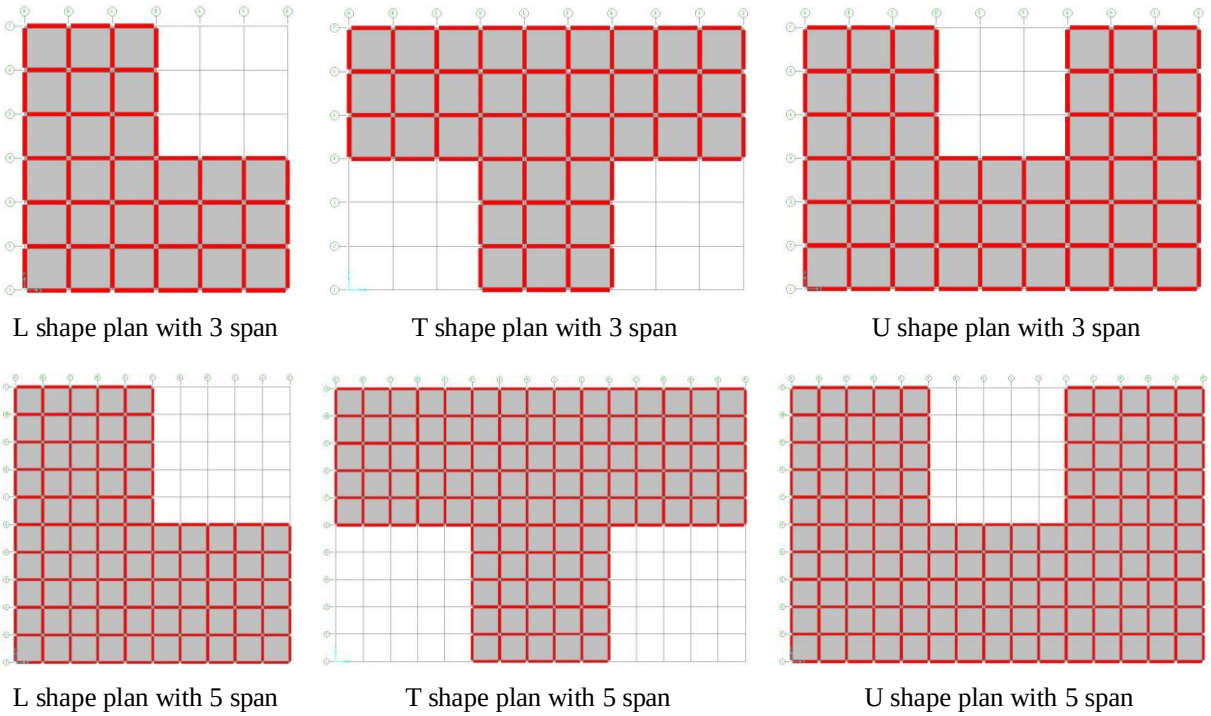


Figure 1. Plans with 3 span and Plans with 5 span

In table 1 accelerograms have been used in nonlinear dynamic time history analysis have been shown. These accelerograms have a good accommodation with the accelerograms have been used in a creating (e) series accelerograms for endurance time method analysis.

Table 1. Description of 7 ground motions used in this study

Record ID	Date	Earthquake	Magnitude (M)	PGA (g)
P0873	1992/06/28	Landers	7.3	0.818
P0779	1989/10/18	Loma Prieta	6.9	0.512
P0745	1989/10/18	Loma Prieta	6.9	0.644
P0736	1989/10/18	Loma Prieta	6.9	0.555
P0744	1989/10/18	Loma Prieta	6.9	0.541
P0450	1984/04/24	Morgan Hill	6.2	0.578
P1017	1994/01/17	Northridge	6.7	0.883

In figure 2 a typical ET accelerograms that says (e) series accelerograms, have been shown. These accelerograms have a good accommodation with a soil type II according to iranian national building code (INBC) standard 2800 (Estekanchi et al., 2006, 2007).

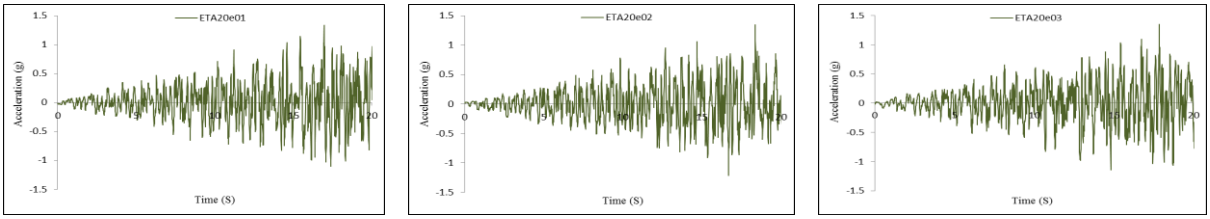
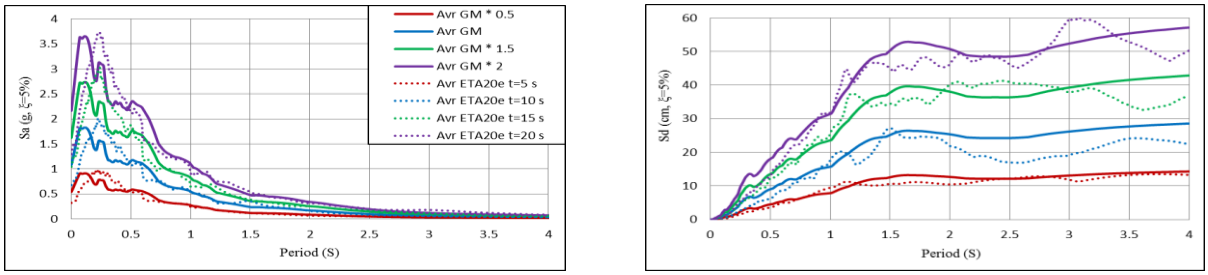


Figure 2. A typical ET accelerograms (ETA20e01-03)

By comparing the average of nonlinear dynamic time history accelerograms with the average of (e) series endurance time method accelerograms, in the graphs acceleration spectra and displacement spectra, we found that the average (e) series accelerograms until 10 seconds is coinciding with the average of time history accelerograms with scale factor 1. For endurance time method until 5, 15 and 20 seconds, respectively the scale factors 0.5, 1.5 and 2 should be used in nonlinear dynamic time history analysis that have been shown in figure 3 (Riahi et al., 2007).



(Acceleration spectra) (Displacement spectra)

Figure 3. Comparison of total acceleration and displacement spectra of ETA20e series acceleration and displacement functions at different time and 7 real ground motions

In figure 4 behavior curve of force-deformation for deformed shape member (RC) to define in a software, was given. In this curve range of plastic hinge and performance level can be visible.

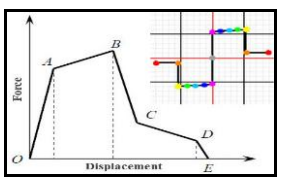


Figure 4. Performance level curve

4. RESULTS

After nonlinear analysis on all models, the final sizes of peripheral frames were obtained which were shown in table 2.

Table 2. Dimension peripheral frames

Models	Dimension of Columns (m)	Dimension of Beams (m)	Dimension of Top Beams (m)
4 story with 3 span	2×0.3	2×0.3	0.3×1
4 story with 5 span	2×0.3	2×0.3	0.3×1.5
7 story with 3 span	3×0.3	3×0.3	0.3×1
7 story with 5 span	3×0.3	3×0.3	0.3×1.5
10 story with 3 span	4×0.3	4×0.3	0.3×1
10 story with 5 span	4×0.3	4×0.3	0.3×1.5

The results of the weak frames performance level determination by nonlinear analysis have been shown in figure 5. These models don't have life safety performance level.

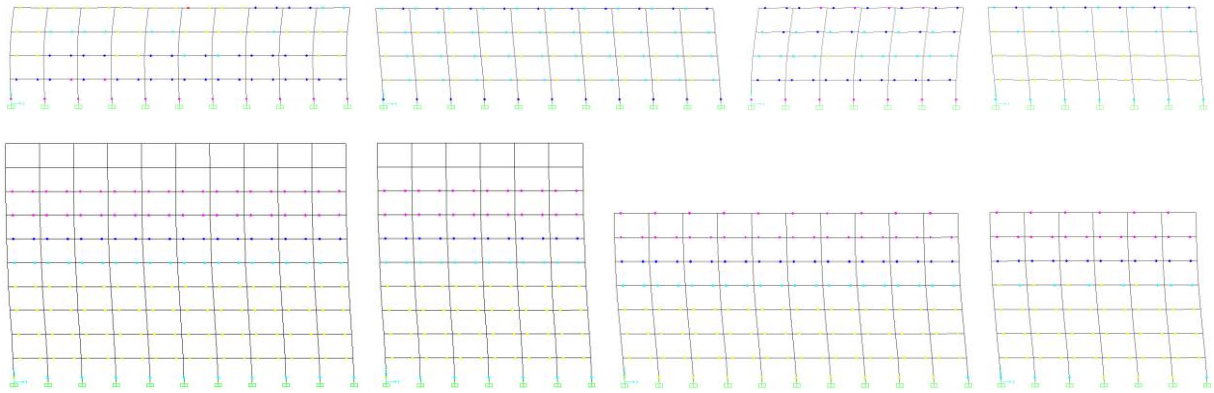


Figure 5. View of the plastic hinge for weak frame members obtained by endurance time، dynamic time history and pushover analysis

The results of the performance level determination for retrofitting frames by nonlinear analysis have been shown in figure 6. With this method performance level reached to the life safety.

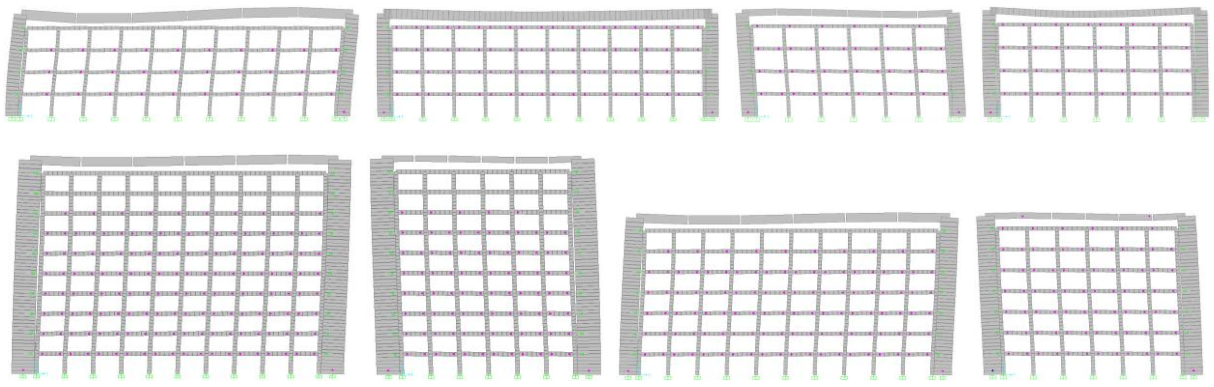
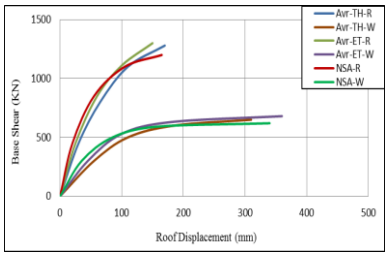
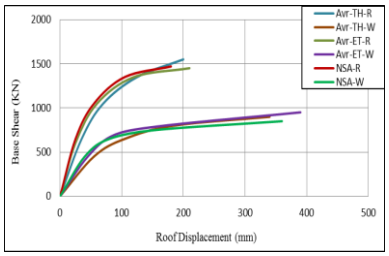


Figure 6. View of the plastic hinge for retrofitting frame members obtained by endurance time، dynamic time history and pushover analysis

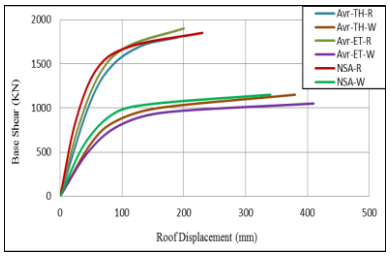
Capacity curve of all models that have been calculated with 3 nonlinear analysis methods (TH, ET, NSA), have been shown in figure 7. As you can see the results of the 3 nonlinear analysis methods (TH, ET, NSA), are approximately close together. But the results of endurance time method are closer to the results of nonlinear dynamic time history analysis. According to the results, the models with 5 span have larger capacity curve than the models with 3 span. The roof displacement for 3 and 5 span models were obtained, are similar to each other. As you can see the retrofitting by peripheral frame could reduce the roof displacement of models. Also, in retrofitting frames base shear have increased than the initial frames.



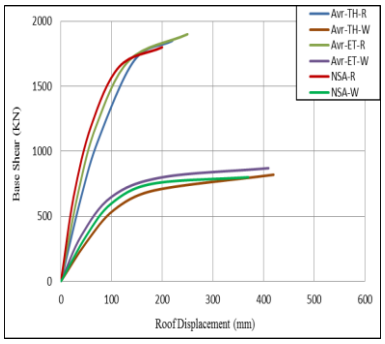
L shape 4 story with 3 span



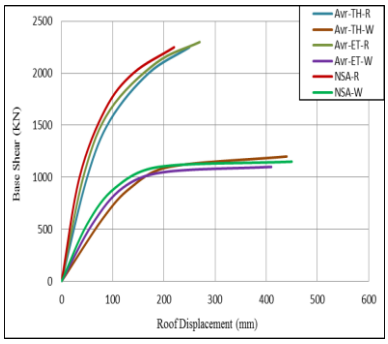
T shape 4 story with 3 span



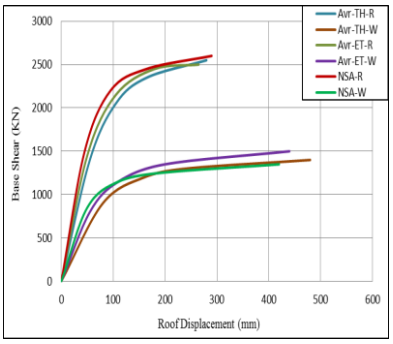
U shape 4 story with 3 span



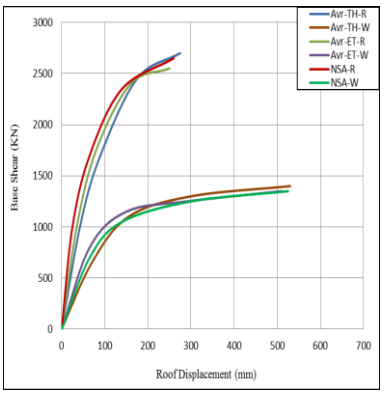
L shape 7 story with 3 span



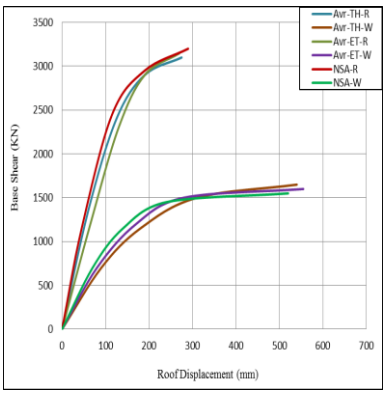
T shape 7 story with 3 span



U shape 7 story with 3 span



L shape 10 story with 3 span



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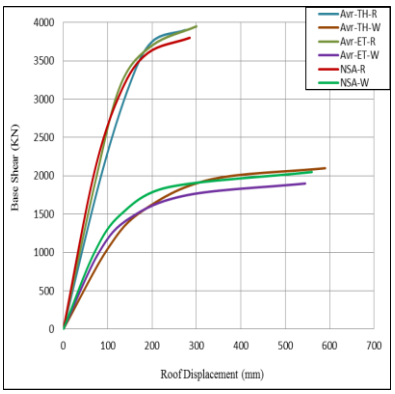

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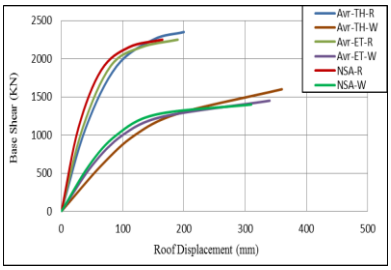
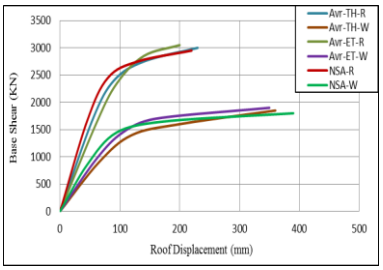
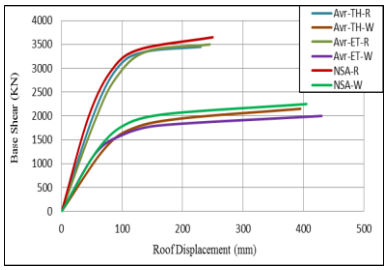


L shape 4 story with 5 span



T shape 4 story with 5 span



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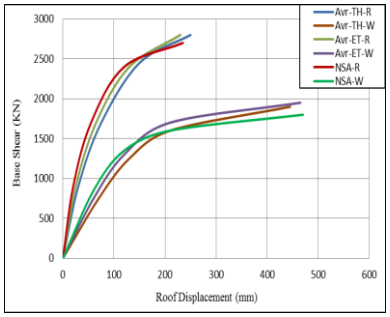

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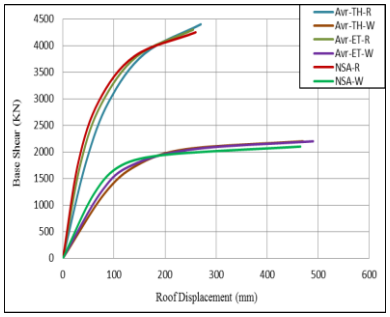
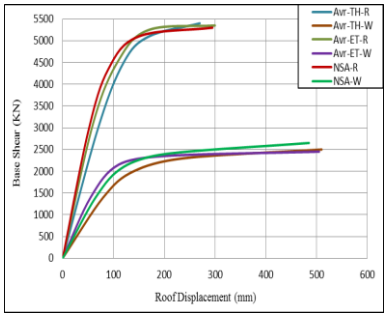
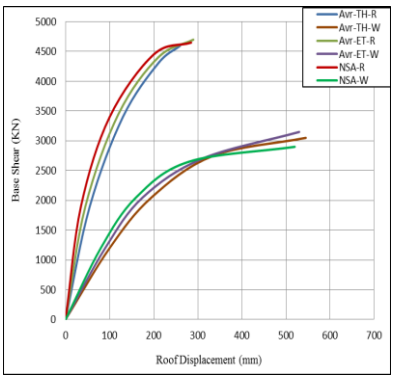


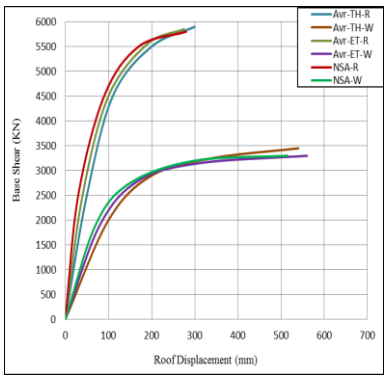
T shape 7 story with 5 span



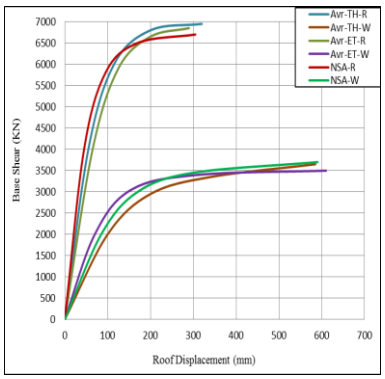
U shape 7 story with 5 span



L shape 10 story with 5 span



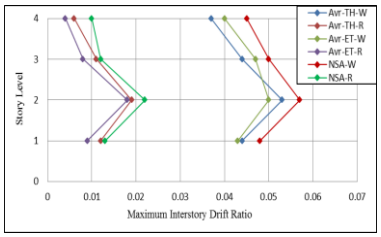
T shape 10 story with 5 span



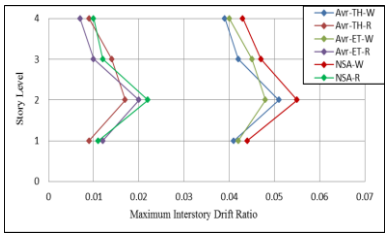
U shape 10 story with 5 span

Figure 7. Comparison of capacity curves for all models obtained by ET، time history and pushover analysis

The maximum interstory drift ratio of all models that have been calculated with 3 nonlinear analysis methods (TH, ET, NSA) as shown in figure 8. As you can see the results of the ET method are closer to the results of nonlinear dynamic time history analysis. According to the results, the models with 5 span have less than maximum interstory drift ratio than the models with 3 span. As you can see the retrofitting by peripheral frame could reduce the maximum interstory drift ratio of models.



L shape 4 story with 3 span



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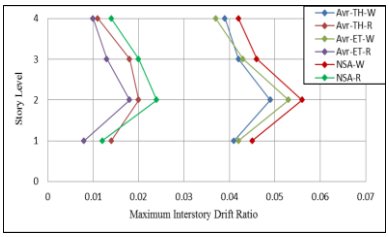
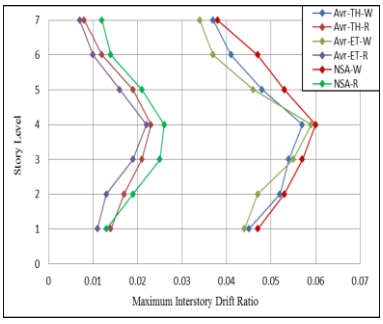
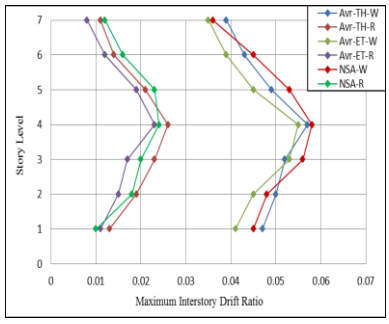


U shape 4 story with 3 span



L shape 7 story with 3 span



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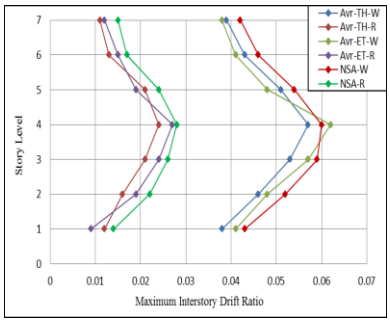

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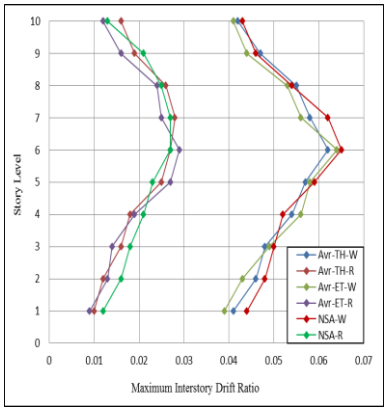

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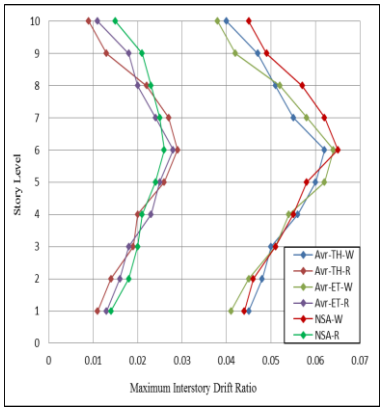
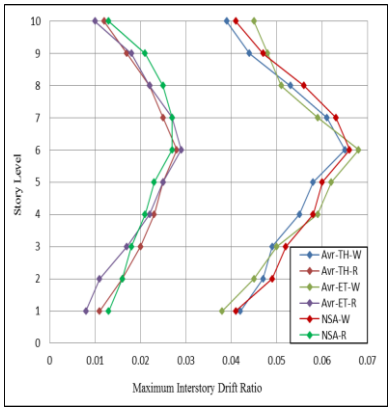
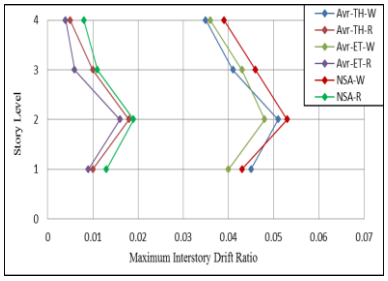


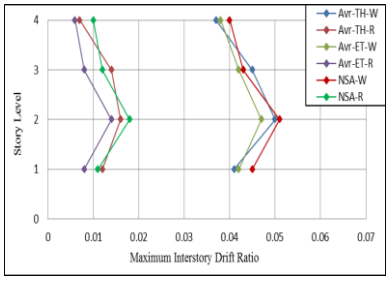
T shape 10 story with 3 span



U shape 10 story with 3 span



L shape 4 story with 5 span



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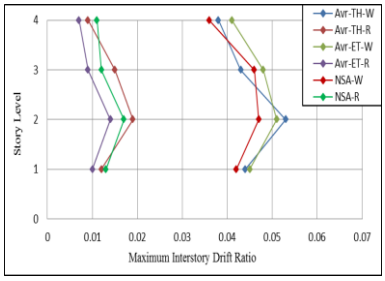
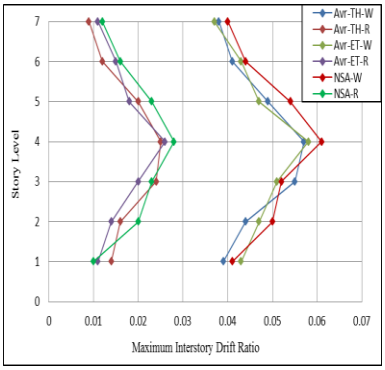
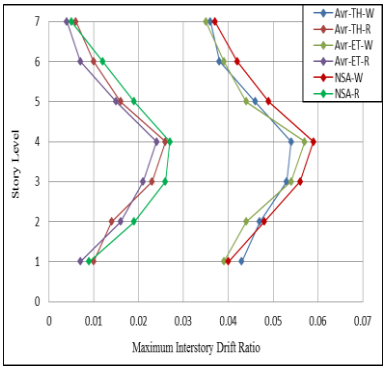


U shape 4 story with 5 span



L shape 7 story with 5 span



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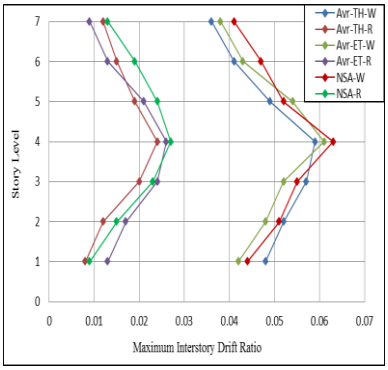

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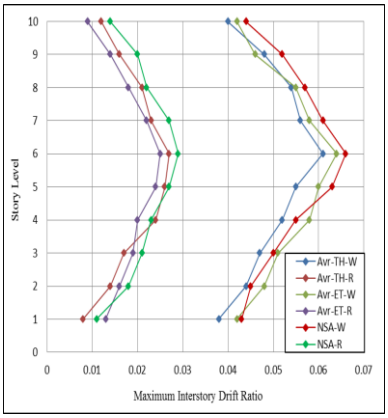
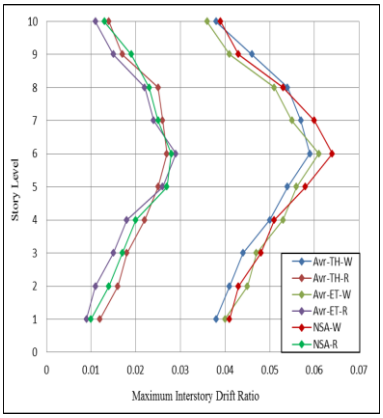
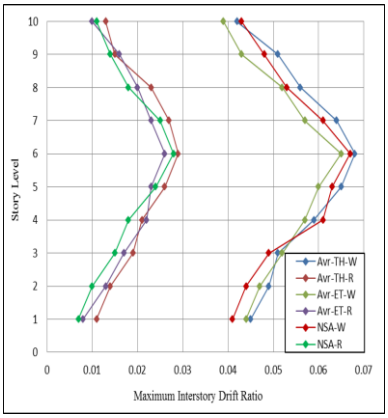


L shape 10 story with 5 span



T shape 10 story with 5 span

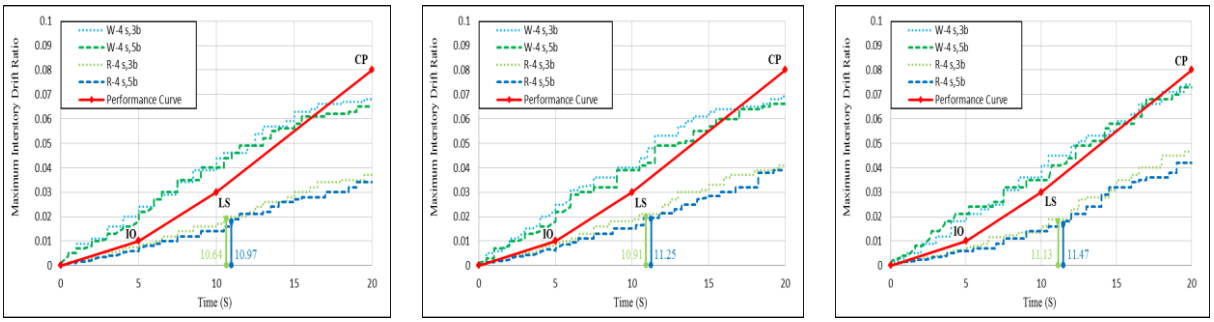


U shape 10 story with 5 span

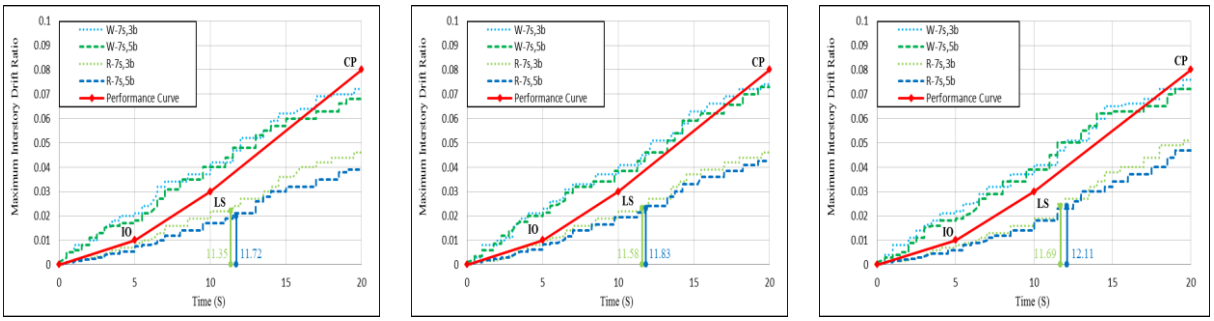
Figure 8. Maximum interstory drift ratios for all models obtained by ET، time history and pushover analysis

The results of endurance time method were compared with time history analysis method. According to the intensity measures should be considered an equivalent time in endurance time method that can be a representative intensity measures of time history analysis method. In this study first mode spectral acceleration (*Sa*) is used as intensity measures to calculate the equivalent time. To compare the results of time history analysis records with the results of endurance time analysis the average of the first mode spectral acceleration of the records (*Sa,Ave*) should be calculated. To generate endurance time method acceleration functions (*Sa,ET*) at the first mode period (Ti) are used response spectrum. So that the equivalent time is calculated according to the equation 4.1. By using this equation an equivalent time for each structural model is calculated. The average of maximum interstory drift ratios for endurance time acceleration functions through time are presented for all models as shown in Figure 9. According to observations endurance time method by compering with other methods has better ability to estimate structure performance level. Specially when both of the models are in same performance level.

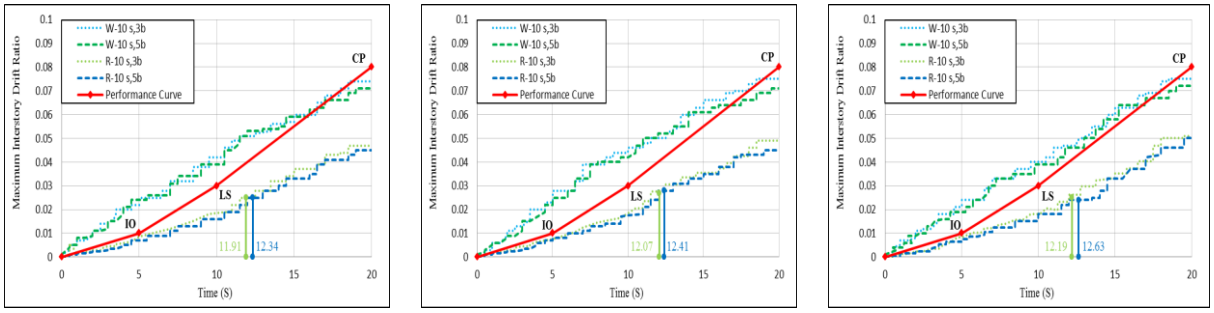
$$t_{eq} = \frac{S_{a,Ave}}{S_{a,ET}} \times 10 \tag{4.1}$$



L shape with 4 story model | T shape with 4 story model | U shape with 4 story model



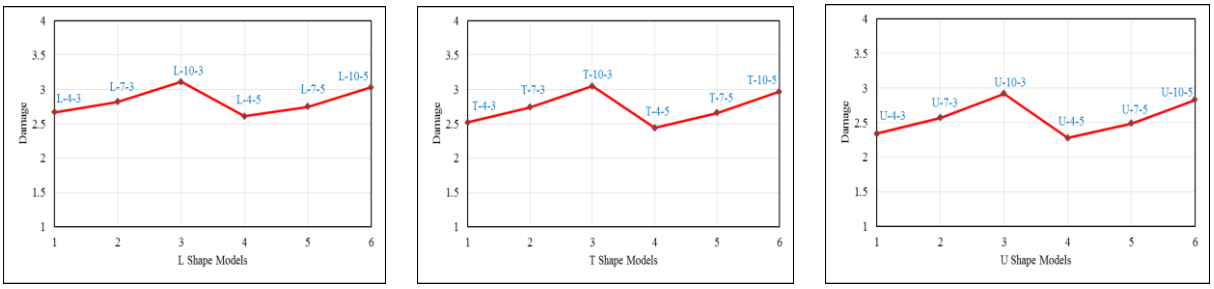
L shape with 7 story model | T shape with 7 story model | U shape with 7 story model



L shape with 10 story model | T shape with 10 story model | U shape with 10 story model

Figure 9. ET maximum interstory drift ratio curves of the ETA20e set for all models and values of equivalent time of the dynamic time history analysis

By observating of the peripheral frame and structure displacement with each other and producted compressive force between them damage value caused by structure and peripheral frame dynamic impact together is considerable so that this value mainly occurs in the cover of concrete. In figure 10 all of the models damage value are shown. Compressive displacement of the structure and peripheral frame in 3 span model plan is more than 5 span model plan. As well as this value for L shape plans is more than T and U shape plans.



L shape models T shape models U shape models

Figure 10. Damage value caused by structure and peripheral frame dynamic impact together for all models

In rehabilitation of building by peripheral frames dosn't need to rehabilitate foundation. Only that needs to design peripheral frames foundation. The results of design shown in table 3.

Table 3. Dimension peripheral frames foundation

Models	Foundation Width (m)	Foundation Height (m)
4 story with 3 span	2	1
7 story with 3 span	3	1.3
10 story with 3 span	4	1.5
4 story with 5 span	2	1
7 story with 5 span	3	1.3
10 story with 5 span	4	1.5

5.CONCLUSIONS

Based on the results of this study, the following conclusions can be drawn:
- By comparing the results of endurance time and nonlinear dynamic and static analysis were observed with a good approximation these results are close together.
- By using endurance time method can spend less time and fewer number of analysis will reach to exact answer.
- The peripheral frame method has been used for seismic upgrading could structural performance level increase into the level of life safety. In order to structure can stay safe in earthquake with 0.35g maximum acceleration.
- Retrofitting by adding the peripheral frames to the structure could increase the structural stiffness and decrease maximum interstory drift ratios. With increase the number of spans maximum interstory drift ratios have reduced.
- The results of the determination roof displacement by 3 analysis methods were obtained are approximately close together.
- According to the endurance time analysis results, retrofitting by adding peripheral frames for plans with 5 span is more durability than plans with 3 span.
- Damage caused by dynamic impact of the peripheral frame and structure together in L shape plans is more than T and U shape plans. Also this damage value by decreasing number of the spans and increasing number of the stories increases.

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