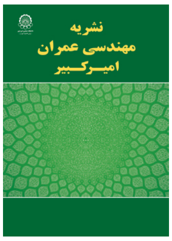

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A Proposed Method to Satisfy Code Drift Criteria to Achieve Building with Higher Seismic Performance

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ABSTRACT: The first step in designing structures is choosing sufficient elements for the applied loads, including dead, live, wind and earthquake ones. Then, drifts of all stories are compared with allowable values and if required some structural elements are so resized to satisfy the drift criteria. The process of resizing is normally carried out by trial and error and relied mostly on engineering judgment. In other words, there are many approaches for satisfying the drift criteria, which some of them may lead to structures with poor seismic behavior. Moreover, based on Iranian Standard 2800, the designer is allowed to use analytical period of vibration in drift controlling process, instead on one calculated by the code proposed formula.

In this study, a method is proposed to find the best elements for resizing and subsequently satisfying the drift controlling criteria in order to achieve a building with better seismic behavior. Furthermore, it is shown that applying the analytical period of vibration leads to structures with better seismic behavior. For the purposes, Endurance Time method is applied in which nonlinear behavior of slender special moment resisting frame steel structures and their damage indices are considered.

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1- Introduction

Design for drift and lateral stability is an issue that should be addressed in the early stages of design development. In many cases especially in tall buildings or in cases where only moment frames are used to resist lateral load, the drift criteria can become a governing factor in structural design process. The lateral displacement or drift of a structural system under wind or earthquake forces is important from three different perspectives, including: structural stability, architectural integrity and human comfort during and after the building experiences these motions [1]. For structural and the resident safety, seismic codes have limited the lateral displacements of the floors. According to Iranian code of practice for seismic resistant design of buildings (Standard No. 2800), the mentioned limitations are presented in section 2.5.4 and the note of this section; it authorizes the designer to use the experimental period or analytical period for satisfying drift criteria [2].

In this research, a method is proposed to find the best elements for resizing and subsequently satisfying the drift controlling criteria. In order to evaluate the seismic behavior of the structures, the Park-Ang damage index and endurance time of the structures were calculated to evaluate the seismic behavior of the structures.

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2- Proposed method

First of all, according to this method, drift controlling criteria are checked for the structure. While these criteria are not satisfied, the base shear is slightly increased and the structure is redesigned based on the new increased forces. This procedure is repeated until drifts of all floors are satisfied. In this method, nonlinear distribution of base shear is applied to the structure in order to better distribution of seismic force at the structure height, according ASCE 41 [3]. The proposed method algorithm is shown in Figure 1. For the considered structures of this paper, the increase in the amount of base shear was between 20 to 25 percent.

3- Endurance-Time method

The endurance time (ET) method is an innovative dynamic time history analysis procedure, having less computational effort but giving more information from seismic performance of structures in comparison with regular time history analyses. In this method the structures are subjected to predesigned intensifying excitation functions and their performance is assessed based on their response at different excitation levels. The concept of endurance time method is analogous to the exercise test used in medicine for assessing fitness of athletes or patients. In this method basic response of the structure, such as story drift or any kind of damage indices could be monitored at any step of the analysis. The time from the beginning of the analysis until exceeding the allowable criteria or corresponding damage indices called the endurance time of the structure [4].

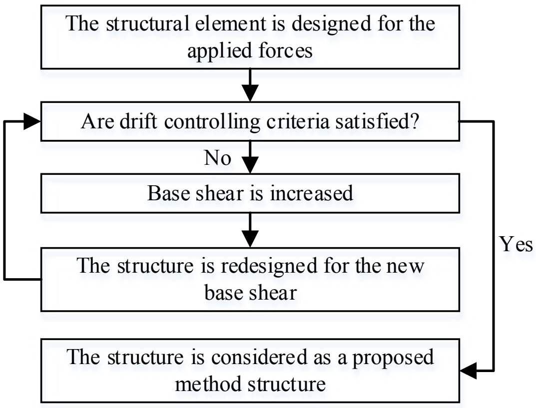

Figure 1: A proposed method algorithm

Several endurance time excitation functions were developed for different purposes. One of the ET method functions are "IN series" which have been produced resembling the ground motion records of FEMA 440 [4, 5] for soil condition C. Three sets with names of "in01" to "in03" each having three x, y and z components (containing overall 9 acceleration records) are used for non-linear dynamic time history analysis.

In this study, three criteria were investigated to calculate the endurance time of structures; First and second criteria are the times when drift of one story exceed the limit of 0.0025 and 0.005. These criteria for steel moment frame is equivalent to exceed the Life Safety (LS) and Collapse Prevention (CP) performance levels, according to ASCE 41 [3]. Third criteria is the time when the first plastic hinge occurred in the column of structures. This criteria show the beginning of progressive collapse in the structures.

4- Damage index

Park and Ang introduced a damage index in 1985 [6]. The index was a combination of ductility and energy absorption capacity indexes according to equation 1. This index was calibrated for concrete elements, however, it is also used for damage assessment of steel structures because of its clear physical concept [6]. The index is well known among all researchers and is one of the most popular indexes.

$$DI_{P\&A} = \frac{\phi_m}{\phi_u} + \frac{\beta}{\phi_u P_y} \int dE_h \frac{1}{2} \qquad (1)$$

5- Modeling and analysis

In this research, four slender regular buildings with 5, 8, 10 and 15 stories having steel special moment resisting frames are selected for stydy. Regarding how to satisfy drift control criteria, the buildings are designed three times; for the first and second structure, the base shear for calculating the story drifts are calculated based on analytical and experimental periods of vibration, respectively. The obtained structures are called "T_{ana}" and "T_{exp}", respectively. For the third structure, called "T_{pro}", the drift controlling criteria is satisfied by the proposed method of this study. These structures are modeled by ETABS and PERFORM 3D and their damage indices and endurance times were calculated for 3D non-linear time history analyses under scaled "IN series" records. Each structure is analyzed under six different excitation, regarding that each of three component of the record can be applied on the structure in X, Y or Z direction. The average results of the six analyses are applied for the comparison; in Figures 2 to 5, Park-Ang damage indices and endurance times of the structures are shown and it should be noted that the damage indices and endurance times of the proposed method structures are generally better than the two others.

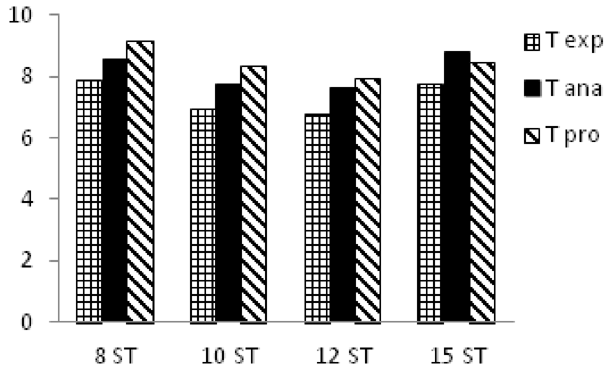

Figure 2: Average of calculated Park-Ang damage index

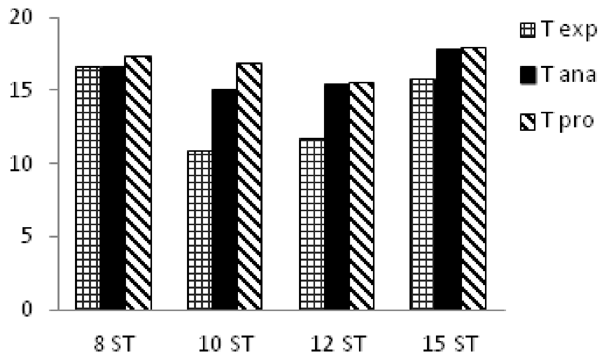

Figure 3: The average endurance time when plastic hinge occur in the column (sec)

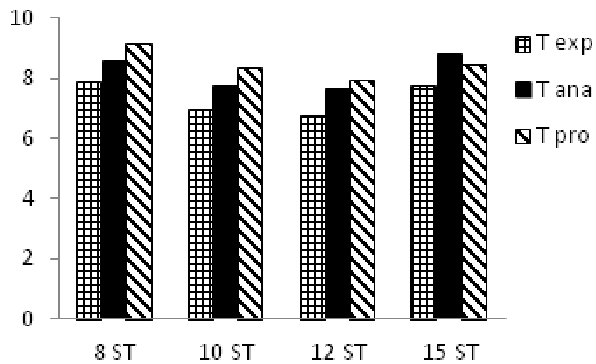

Figure 4: The average endurance time when story drift exceed the LS performance level (sec)

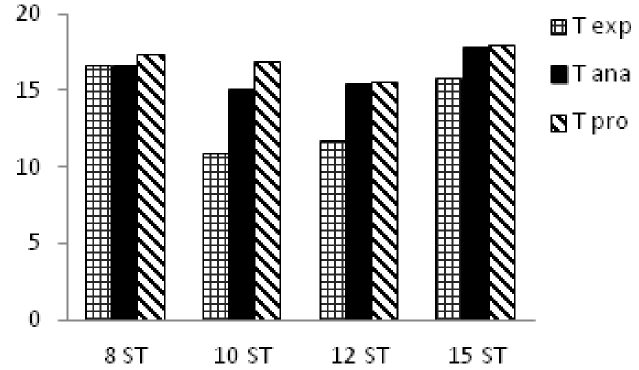

Figure 5: The average endurance time when story drift exceed the CP performance level (sec) Conclusions

A simple and applicable method is proposed here to satisfy drift control criteria for regular slender structures. To show efficiency of the method, damage index and endurance time of the structures are compared. Four regular slender steel structure with 8, 10, 12 and 15 stories were considered and the drift controlling criteria were satisfied in three different methods. The results showed that the overall seismic behavior of proposed method structure is better than two others and seismic behavior of experimental period structures despite of having more weight is generally worse than two others.

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