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Investigating the Seismic Behavior of Slender Buildings, Regarding How to Satisfy Drift Control Criteria

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ABSTRACT

Based on Iranian standard 2800, drift of each storey for the lateral seismic loading should not exceed from mentioned values in this code. It is stipulated in the note of this article that in drift calculation, the period of the building can be determined through experimental formula, mentioned in the code or be calculated by the analytical methods. Regarding that experimental base formula normally give shorter period, so they lead to stronger structures. Application of analytical base period for special moment resisting structure leads to a structure with less weight and strength, which satisfy the criteria and thus is acceptable. In this research, some buildings with special moment resisting slender structures considered and designed twice based on two assumptions, with and without considering the article note. For this, damage index of structures and endurance time of them, after nonlinear three dimensional time-history analyses will be investigated. Analyses show that structure designed based on analytical period not only has lighter structure, but also have better seismic behavior and more endurance time under "in" series of ET records.

KEYWORDS:

Steel Moment Frame, Drift Controlling Criteria, Structure Period Time, Damage Index, Endurance Time

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1- Introduction

To prevent structural damages and safety of residents, seismic codes have several limitations including lateral displacements. Excessive and uncontrolled lateral displacements can have major structural effects. Experimental observations and theoretical studies also have shown the direct relation between the lateral displacement, structural damages and injuries. According to Iranian national seismic code (standard 2800), center of mass displacement in each storey should not exceed from mentioned values. In the note of this standard, the period of the building can be determined through experimental formula mentioned in the code or be calculated by the analytical methods, and also it indicated that in controlling of drifts, we can use analytical period more than 1.25 times of experimental periods which reduce the base shear.

In this research buildings with 5, 8, 10 and 15 stories with steel special moment resisting frame considered and designed twice based on experimental period and analytical period .There are some ways for comparison of seismic behavior of structures like IDA[1], endurance-time method and etc., and each of them has some advantages and disadvantages, but because of ease of use of endurance-time method, in this study, endurance-time method (ET method) was used and Perform software after verifying in the both linear and nonlinear criteria has been used for analysis.

2- IDA method

IDA is a nonlinear dynamic analysis and has suggested by Cornell and Vamvatsikos [1]. In this method, structures are subjected to a series of earthquake time history analysis, the maximum of earthquake acceleration is increased from a very low value in which the response of structure is in elastic criteria and then it is gradually increased until the limit states. The maximum base shear versus displacement of each analysis is drawn up and the curve called IDA-push. From this graph different levels of hazard can be determined.

Dynamic analysis such as non-linear time history dynamic analysis and incremental dynamic analysis are useful in performance based design, however, problems such as records selection, variety of outputs and heavy analysis these methods need, make the use of them limited. In recent years, a method called endurance-time method is presented which can be used easier than IDA.

3- Endurance-time method

With the development of new computational tools, the potential for realistic modeling of complex structures is increased and in this situation, increasing demand for improved and more accurate methods for seismic assessment of structures is reasonable logical expectation. In response to increasing demand for application of complex methods, some new methods were developed which estimate structural behavior realistically due to not only taking dynamic characteristics of structure into account, but also considering earthquake excitation as it takes place [2].

Earthquake-induced ground motions have three translational components. Although three-dimensional analysis under actual records can be considered as the most accurate method for seismic analysis, it has two major drawbacks. Firstly, for a particular site specification, the number of available recorded accelerograms might not be sufficient and the selection of consistent accelerograms complicates the issues. Secondly, analysis of structures under these earthquakes is time consuming and interpretation of results for complex structures is quite difficult. Therefore, it is advantageous to use simplified methods that can estimate structural behavior under multi-directional excitation with satisfactory approximation and with less computational effort [2].

The endurance-time method is a procedure that can be used in both the linear and nonlinear seismic analysis of structures. Its simplicity is one of the priorities of ET method over response history analysis under actual ground motions. In the ET method, the response of a structure can be monitored against time which is correlated to the intensity of excitation [2].

4- Damage index

Park and Ang introduced their index in 1985 [3]. This index was a combination of ductility and energy absorption capacity indexes according to Eq. (1). Although this index was calibrated for concrete elements, this index is used for damage assessment of both concrete and steel structures because of its clear physical concept [4]. The index is well known among

[1] Incremental Dynamic Analysis

all researchers and is one of the most popular indexes.

$$DI_{P\&A} = \frac{\delta_m}{\delta_u} + \frac{\beta}{\delta_u P_y}\int dE_h \quad (1)$$

5- Modeling and analysis

In this research, buildings with 5, 8, 10 and 15 stories with steel special moment resisting frame considered and designed twice based on experimental period and analytical period and these designed structures are modeled in Perform 3D software. Park-Ang damage index of structures calculated after time history analysis with the scaled "in" series of ET method records and also endurance time of each structure be calculated. Averages of calculated Park-Ang damage index of these structures are shown as Fig. 1 and calculated endurance time is according Table 1.

As it can be seen in Fig. 1, average of calculated Park-Ang damage indexes of structures designed using analytical period time in drift control aria are less than those in structures designed based in experimental period time. Also, according to the Table 1, endurance time of structures designed based on analytical period time is more than the other structures.

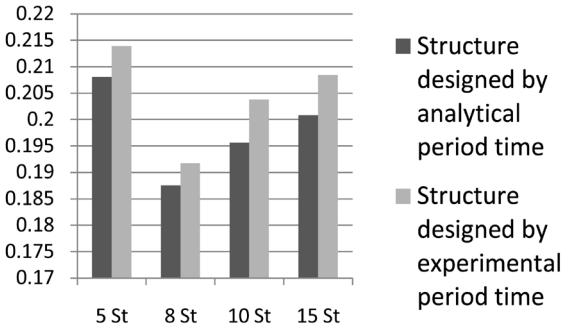

Fig. 1. Average of calculated Park-Ang damage index

6- Conclusions

In seismic design of structures, mass center displacement in each storey should not exceed from mentioned values in the 2800 standard. In the note of this standard, the period of the building can be determined through experimental formula mentioned in the code or be calculated by the analytical methods, and also it indicated that analytical period in controlling of drifts which reduce the base shear can be used. This means that analytical period can be used even more than 1.25 times of experimental periods in drift control criteria. In this research buildings with 5, 8, 10 and 15 stories with steel special moment resisting frame considered and designed twice based on experimental period and analytical period, and then damage index of these structures and endurance time of them according the "in" series of endurance-time method records after nonlinear three dimensional time-history analyses investigated.

As shown in the Table 1, structures designed base on analytical period by considering the note and using analytical period in drift control aria, use less structural steel rather than structures designed by experimental period. These structures also have smaller damage index according scaled "in" series of ET method and have better endurance time in ET method. So, structures designed by considering note and using analytical period have better seismic behavior and lighter structure than structures designed

Table 1. Endurance time of structures (*sec*)

	5 Stories		8 Stories		10 Stories		15 Stories	
	Ana. T^*	Exp. T	Ana. T	Exp. T	Ana. T	Exp. T	Ana. T	Exp. T
in01-xyz	16.96	16.98	16.99	17.01	17.03	17.01	17.06	12.42
in01-yxz	16.98	16.98	16.99	17.01	17.03	17.01	17.05	12.43
in02-xyz	16.77	16.87	16.89	16.85	19.42	16.84	19.95	16.00
in02-yxz	16.77	16.87	16.89	16.86	18.74	16.87	19.95	16.01
in03-xyz	16.77	16.87	19.48	16.86	20.00	13.59	20.00	17.88
in03-yxz	16.77	16.87	19.46	16.86	20.00	13.60	20.00	17.89

T: Period time

according to experimental period.

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