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Investigating the Effect of Active Tuned Mass Damper on the Endurance Time Diagram of Tall Buildings

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ABSTRACT: Nowadays, designing structures follow designs that are based on performance. Regarding the structures, designing based on performance requires dynamic, heavy and repetitive analyses. The endurance time method is a dynamic modern method based on the performance of the structure, which leads to the reduction of the number of structural analyses. In this method, the structure gets exposed to increasing acceleration functions that are getting more during time and then the structure`s seismic performance is evaluated using various demand parameters. In this article, though, using the endurance time method, the performance of a structure having an active mass damper was evaluated under endurance time acceleration functions of the ETA20e series. To this end, an 11-story structure having an active mass damper was modeled in MATLAB software using one of the fuzzy control methods. Having investigated the results of the endurance time diagram that had drawn the before and after statuses of the refinement process using active tuned mass damper, the efficiency of this system in reducing the interstory- drift and maximum final story drift was explored. Moreover, the results of endurance time under acceleration function of ETA20e series were compared with the time history analysis of 7 selected accelerograms. The results indicated that endurance time function could present an appropriate prediction in estimating the behavior of the structure under selected accelerograms. The results indicated the significant impact of adding mass dampers under increasing the endurance time of the building under investigation.

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1- Introduction

The controlling structure can be classified into four categories: passive, active, semi-active and combined control. One of the most common inactive control systems is the passive mass damper. This damper has limitations such as limited control capacity and problems with regard to not tuning the main frequency of the structure in a limited frequency range. To improve these defects, an idea entitled active mass damper was presented. The efficiency of this active control system in reducing the responses of the structure has been proven by researchers [1, 2]. In the active control system, the external force must be optimized and tuned by one of the control methods. In this respect Pourzeynali et al. [3], using a fuzzy genetic algorithm achieved the improvement of the results of the active mass damper in reducing the response of the structure. So far, various analytical methods, such as static and dynamic methods, have been presented to evaluate structures. But, due to the defects and limitations existing in these methods, they have been used less in performance analysis. For this purpose, to and remove the defects of the previous methods, a new idea called the Endurance Time method as an incremental dynamic method was proposed for the first time by Estekanchi et al. [4]. The Endurance Time method by presenting an appropriate estimate of the structure's response in the intensity of various stimuli in proportion to the design spectrum saves the number of analyses to evaluate the structure compared to other methods. Also, this method has no restriction in considering the behavioral complexities of the structure such as nonlinear behavior, control systems impact, and so on [5]. In the conducted studies, the efficiency appropriate to this method in the analysis of the structure equipped with a variety of inactive dampers has been investigated [6, 7], but so far in the field of evaluating the behavior of active control system with the help of endurance time method, limited researches have been performed. In fact, the distinctive feature of this research is that by using the endurance time method for the first time examines the seismic performance of an 11- story structure equipped with an active tuned mass damper.

2- Methodology

The endurance time method is a seismic analysis method. The steps for evaluating the structure by the endurance time method are as follows: in the first step, preparing a set of acceleration functions of the endurance time suitable for doing

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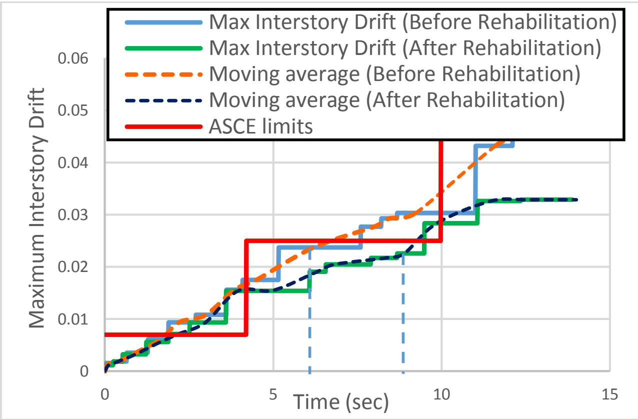

Fig. 1. Performance curve of the 11-story structure before and after the improvement

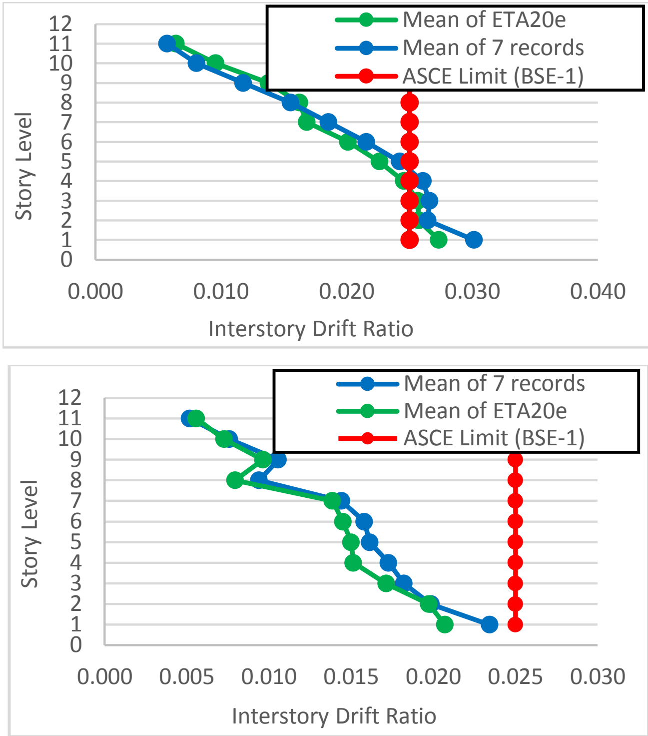

Fig. 2. Relative displacement under endurance Time function and averaged 7 record at BSE-1 risk level in the structure pre- and post-improvement.

analysis; in the second step, scaling the acceleration functions according to the criteria of the regulation; in the third step, determining the target time; in the fourth step, analyzing the time history for the modeled structure using the acceleration functions of endurance time; and in the last step, the response curve of the structure for various demand parameters is drawn and then by comparing these obtained results with the allowable values of the regulation in the target time is specified and the performance of the structure is investigated. The stages of modeling an 11-story building equipped with an active tuned mass damper and controlling its vibrations are as follows: first, the mass, stiffness and damping matrix of the structure is defined, then considering the parameters of the mass damper (ATMD) including mass and stiffness and dampness of the damper are determined and added to the matrices of the main characteristics of the structure, and afterwards, the equation of structure motion equipped with the damper is determined.

3- Results and Discussion

The results obtained from the analysis of the endurance time method are presented with incremental curves. In Figure 1, the endurance time curve for the structure in the pre- and post-improvement modes has been shown.

As it is observed, the structure has a weak performance before improvement, but by adding the active mass damper, the performance of the structure has been improved, and the endurance time of the structure has been increased from 6.31 (s) to 9.56 (s). In Figure 2, a comparison between the relative displacement of the floors in the pre- and post-improvement modes for BSE-1 risk levels has been depicted to better evaluate the performance of the active mass damper in reducing the seismic response of the structure, using the endurance time method. As it is observed, the structure had a performance close to the regulation limits and even beyond it before improvement, but after improvement, the performance of the structure improved and the relative displacement values between the floors have a declining trend. For example, at the BSE-1 risk level, the maximum relative displacement of the structure has been reduced by 24% ratio, which indicates the appropriate efficiency of the active mass damper.

In general, regarding the results, a maximum reduction in the displacement of the last floor and delaying to reach the maximum limits of the regulation drift, provided that the optimal active mass damper is used, can be mentioned.

4- Conclusions

In this article, using the ET method the structure equipped with active tuned mass damper (ATMD) is evaluated and the new findings of this study are as follows:

1-In the structure equipped with an active mass damper, the maximum displacement of the last floor is reduced between 40% and 50%. It reduces the relative displacement between the floors and the maximum allowable limits determined in regulation are observed.

2- Using the endurance time curve in the pre- and post-improvement modes, it can be concluded that the structure equipped with an active tuned mass damper reached the allowable limits of the regulation in 9.65(s), while before the improvement, this time has been 6.31(s), that this endurance time increase of the structure indicates that the use of an active tuned mass damper will improve the performance of the structure.

3-The endurance time method has the capability to predict the behavior of complex structures with a minimum number of analyses.

4-In general, regarding the results, the maximum reduction in the displacement of the last floor and delaying to reach the maximum limits of the regulation. Drift, provided that the optimal active mass damper is used, can be mentioned.

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