The effect of the side bearing resistant system of the rocking brace - viscous damper on the performance of shear frames

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ABSTRACT

According to the experiences gained from past earthquakes, the need for a structure that has less damage and can be easily repaired after an earthquake is essential. One of the methods of depreciating seismic energy and having a repairable structure is to use the rocking brace system. In this study, the effect of using swing brace along with liquid viscous damper in improving the seismic fragility of structures has been investigated. The swing brace is formed by adding a liquid viscous damper. The set of this system has been installed at the base of the structure and in two ways of connecting the cables to the first floor and the last floor. For numerical studies, a three-story shear structural model with nonlinear behavior is considered. The examined structures in an uncontrolled state and equipped with a brace-swing-damper system have been subjected to the vibration of 60 earthquake records recommended in the seismic regulations with different specifications and frequency content. The results of dynamic analyzes are subjected to regression analysis to obtain the relationship between the intensity of earthquake excitation and the response of the structure and to estimate the seismic demand of the structure. Finally, the fragility curves for mild, mild, extensive, and complete performance levels for three performance criteria including drift ratio of structural members, drift ratio of non-structural members sensitive to drift and acceleration of non-structural members sensitive to acceleration have been determined and compared. The results indicate the effective performance of the brace-swing-damper system in improving the seismic fragility of the studied structures, so that the fragility has decreased by 35%.

KEYWORDS

Swing brace, viscous damper, fragility curve

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1. Introduction

The swing brace system was first proposed by Kang and Tagawa [1] as shown in the figure below. They used the viscoelastic damper in the swing brace structure and investigated the performance of this system in controlling the vibration of a three-story steel bending frame. In this study, different number of swing brace structure and viscoelastic damper were considered. Also, the installation of only one base system of the structure and the connection of cables to the last floor, as well as the installation of three systems installed between the floors, were investigated.

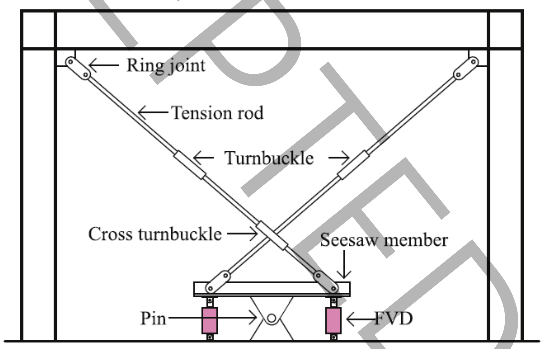

Figure 1. Schematic of brace-swing system [2]

In further research, Kang and Tagawa [3] used liquid viscous damper in the swing brace structure. In this study, the effect of using this system in the form of installation at the base of the structure and connecting its cables to the top floor was investigated for three-story and six-story structures. The results show the effective performance of the swing brace structure with viscous liquid damper in improving the vibration of the structure under earthquake excitation.

Nowrozi [4] used magnetorheological damper (MR) in a swing brace structure in a master's thesis and investigated its performance in reducing the responses of two three- and five-story structures. In this research, the magnetorheological damper was used in passive mode with zero voltage and maximum voltage, which are called passive off and passive on. The results of this research also show the proper efficiency of the swing brace structure along with the magnetorheological damper. It was also shown that the efficiency of this system was the best with the maximum voltage of the magnetorheological damper or in other words passive on.

As mentioned before, all the previous researches related to rocker brace with damper were only related to the evaluation of these systems in reducing the response of the structure and fragility analysis was not done for these structures. Therefore, in this study, the fragility analysis of the structure equipped with swing brace with liquid viscous damper is considered.

2. Methodology

In this part of the article, numerical studies and discussion regarding the obtained results are presented. The brace-swing system along with viscous liquid damper is installed at the base of the structure to improve the seismic performance of the structure. The connection of the swing brace to the structure is considered in two ways, which includes connection to the first floor and also connection to the last floor of the structure. The number of 60 real earthquake records with the probability of different occurrences recommended in seismic regulations have been selected for fragility analysis.

To evaluate the performance of the swing-damper system in improving the seismic fragility of the structure, a three-story shear frame numerical model with nonlinear behavior is considered. The investigated structures have been subjected to dynamic time history analysis and the responses of the structure under 60 earthquake records have been determined and extracted for fragility analysis. In the following, the parameters of the structure's probabilistic requirements are determined by linear regression analysis and used to determine the fragility functions. The fragility curves of the structure equipped with the swing brace system in two installation modes on the first floor and the last floor have been determined according to the numerical model of the three-story structure and compared with the fragility curves of the structure without energy consumption tools. Also, in this study, assumptions are included, which include the following:

- • It is assumed that the behavior of materials is nonlinear with bilinear behavior
- • The floor of all floors of the building is assumed to be solid.
- • The structure is assumed to have a fixed foundation and the effect of the interaction between the soil and the structure is neglected.
- • The deformations created in the cables of the swing brace have been ignored.

It is worth mentioning that all the models have been analyzed and studied using algorithm writing in MATLAB software.

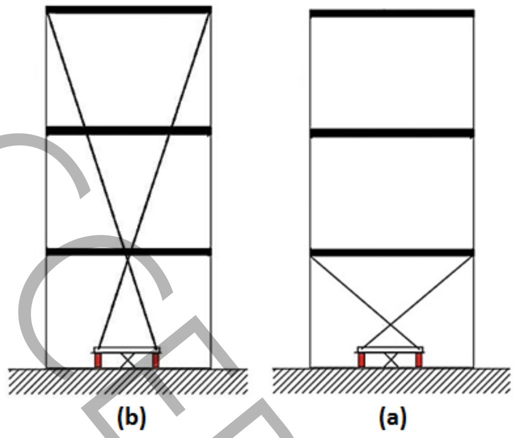

Figure 2. Schematic of the three-story shear frame with the connection of brace-swing-damper system cables to a) the first floor (case 1) and b) the last floor (case 2).

In order to ensure the results obtained from numerical studies, the model of one degree of freedom is simplified in the study of Kang and Tagawa [3] in MATLAB software using modeling algorithm and time history acceleration response of this model with the obtained results. It is compared to the original model in Figure 3.

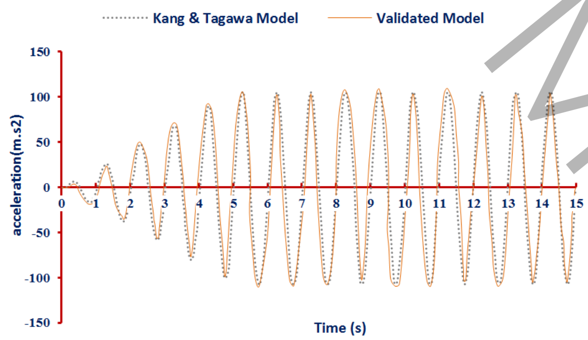

Figure 3: Comparison of the time history acceleration response of Kang and Tagawa's single degree of freedom model [23] with the numerical model in order to validate the numerical results

According to the above diagram, it can be seen that the results of the numerical model made in MATLAB software are in good agreement with the results of Kang and Tagawa's model. Therefore, the results obtained from numerical studies can be trusted.

3. Results and Discussion

In this section, the fragility curves of the three-story structure in the uncontrolled state are drawn under 60 earthquake records

In Figures 4 and 5, the fragility curves of the uncontrolled structure are shown, respectively, related to the functional criterion of the drift ratio of structural members, and the drift ratio of non-structural members sensitive to drift for mild, mild, wide and full performance levels.

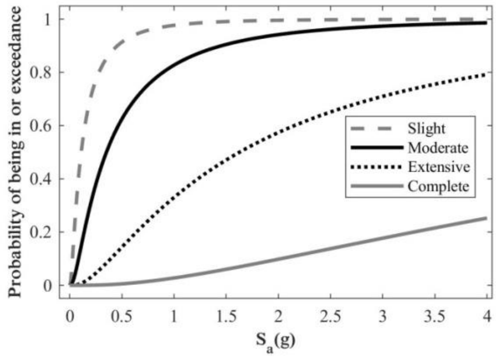

Figure 4. The fragility curve of the uncontrolled structure related to different performance levels and the performance criterion of the drift ratio of structural members

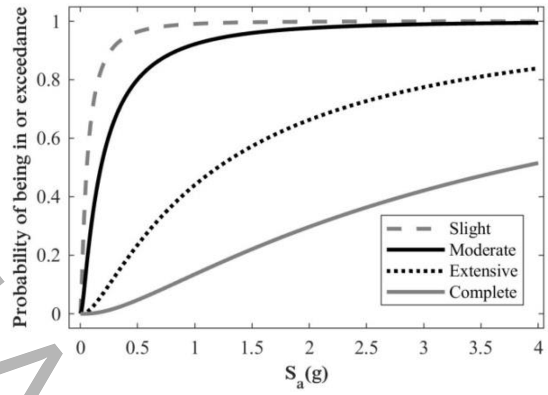

Figure 5. The fragility curve of the uncontrolled structure related to different performance levels and the performance criterion of the drift ratio of non-structural members

In this section, a number of fragility curves of the three-story structure have been extracted in the case where the brace-swing-liquid viscous damper system is used in the two cases of connecting the cable to the first floor (case 1) and connecting the cable to the last floor (case 2).

In Figures 6 to 9, the fragility curves of the uncontrolled structure with the fragility curves of the structure equipped with brace-swing-liquid viscous damper system in four cases (1) connecting the cable to the first floor and the damping coefficient of the damper equal to cd=500 kN.s/m, (2) connecting the cable to the last floor and the damping coefficient of the damper equal to cd=500 kN.s/m, (3) connecting the cable to the first floor and the damping coefficient of the damper equal to cd=1000 kN.s/m, (4) connecting The cable is compared to the last floor and the damping coefficient of the damper equal to cd=1000 kN.s/m. Figures 6 to 7 present the fragility curves considering the functional

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criterion of drift ratio of structural members for mild, mild, extensive, and complete functional levels, respectively. In Figures 7 to 8, the fragility curves related to the functional measure of the drift ratio of

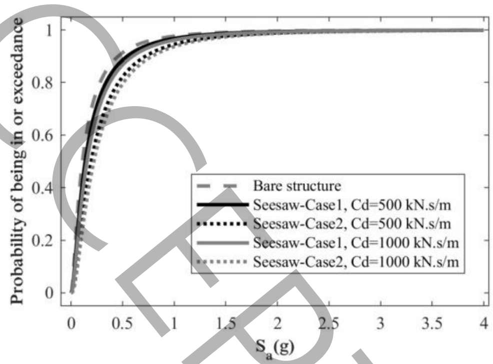

Figure 6. The fragility curve of the uncontrolled structure equipped with the brace-swing-damper system related to the mild performance level and the performance criterion of the drift ratio of the structural members.

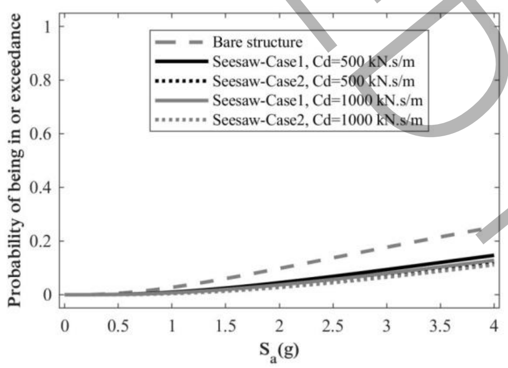

Figure 7. The fragility curve of the uncontrolled structure equipped with brace-swing-damper system related to the full performance level and the performance criterion of the drift ratio of the structural members.

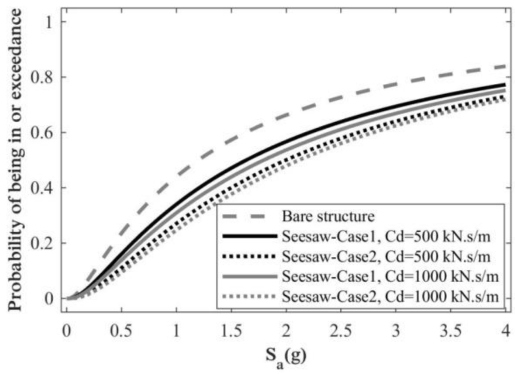

Figure 8. The fragility curve of the uncontrolled structure equipped with brace-swing-damper system related to the wide performance level and the performance criterion of the drift ratio of non-structural members

drift-sensitive non-structural members are compared for these four functional levels. Finally, the fragility curves related to the functional criterion of acceleration of non-structural members sensitive to acceleration are also shown in Figures 7 to 8.

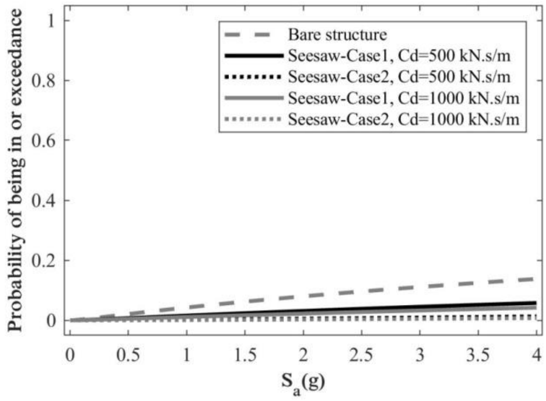

Figure 9. The fragility curve of the uncontrolled structure equipped with brace-swing-damper system related to the full functional level and the performance criterion of the acceleration of non-structural members

4. Conclusion

In this part of the article, the summary and conclusions of the numerical studies are presented. In this study, the effect of using swing brace along with liquid viscous damper in improving the seismic fragility of structures has been investigated. The rocking brace is formed by adding liquid viscous damper, and the set of this system has been installed at the base of the structure and examined in two cases of connecting the cables to the first floor and the last floor. For numerical studies, a three-story shear structure with nonlinear behavior is considered. The examined structures in an uncontrolled state and equipped with a brace-swing-damper system have been subjected to the vibration of 60 earthquake records recommended in the seismic regulations with different specifications and frequency content. The results of dynamic analyzes are subjected to regression analysis to obtain the relationship between the intensity of earthquake excitation and the response of the structure and to estimate the seismic demand of the structure. Finally, the fragility curves for mild, mild, extensive, and complete performance levels for three performance criteria including drift ratio of structural members, drift ratio of non-structural members sensitive to drift and acceleration of non-structural members sensitive to acceleration have been determined and compared. The results of numerical studies can be summarized as follows.

1. The use of swing brace system along with liquid viscous damper is effectively effective in improving the seismic fragility of the three-story structure.

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2. By increasing the thresholds of functional levels and actually by increasing the amount of seismic damage, the fragility of the structure decreases, which has also been observed in the uncontrolled structure and the structure equipped with the brace-swing-viscous damper system.

3. The comparison of the cable connection mode of the brace-swing system shows that the cable connection to the last floor (case 2) has shown a more effective performance in reducing the seismic fragility of the structure than the cable connection mode to the first floor in structure three. However, the force created in the cables of the swing system when connected to the last floor is significantly more than when connected to the first floor. This phenomenon can be due to the greater angle of connection to the last floor with the horizon, which will be a limiting factor.

4. The comparison of the damping coefficient of the damper also shows that the larger damping coefficient for the liquid viscous damper has led to a greater reduction in seismic fragility. Of course, it should be noted that two values of the damping coefficient are considered as examples in the studied models. In general, the design of the liquid viscous damper should be done according to the seismic demand of the damper itself, such as the change of position and speed of the two ends of the damper and the resistive force created in it. Also, the necessary considerations for the design of the cables of the swing brace system should be made with regard to creating a significant force in it.

5. The fragility curves of the functional criterion of the drift ratio of structural members are always larger than the fragility curves of the functional criterion of the drift ratio of non-structural members sensitive to drift. This phenomenon is due to the fact that both these fragility curves are based on the same seismic demand, which is the drift ratio, and the thresholds of the standard performance levels of the drift ratio of structural members are always lower than the thresholds of the standard performance levels of the drift ratio of non-structural members sensitive to drift.

6. In general, it can be said that in a three-story structure, the use of a viscous liquid brace-swing-damper system has been able to reduce the seismic fragility of the structure by about 35% compared to the uncontrolled seismic fragility of the structure.

5. References

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