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Soil-Structure Interaction Effect on seismic response of Low- and mid-rise steel moment frames equipped with Pall friction damper

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ABSTRACT: This research, investigates the behavior of 3, 5, and 8-story steel structures with medium bending steel frames in four cases without considering interaction (A), considering interaction (B), using damper (C), and in Damper usage mode considering soil and structure interaction (D) and the performance of pal dampers, fragility curve, has been discussed under seven acceleration maps of the near-pulse area. The innovation of the research is in the use of a pal friction damper and considering the effect of soil-structure interaction (SSI) to investigate the dynamic and seismic behavior of low and mid-rise intermediate moment steel. Modeling has been done in ETABS software and Incremental Dynamic Analysis (IDA) by LRFD method in Opensees software. Vulnerability levels introduced in HAZUS MH-MR4 have been used to investigate different failure modes of the models. The studied frames with dampers have been subjected to nonlinear analysis in three damping levels 5%, 10%, and 15%. The obtained results showed that: for state (B) in short structures, the order of displacement of floors remained almost constant and had no difference compared to state (A); But in case (C) it caused a decrease in the movement of floors and on the other hand in case (D) the movement of floors has been relatively reduced; And the pattern of displacement reduction in different records is different. Also, the use of a damper does not affect the amount of base shear of structures, but the amount of base shear has decreased in structures with more floors.

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1- Introduction

During strong movements of the ground, a lot of energy enters the structure, and if this energy exceeds its capacity, it causes damage to the member and ultimately to the entire structure. On the other hand, long-term pulses in near-field earthquakes weaken the performance of structures. Several researchers, including MacRae et al. [1], Tothong and Cornell [2], Alavi and Krawinkler [3], Hall, et al. [4], Champion and Lyle [5], and Özuygur and Norouzinejad [6], the dynamic response of structures in They investigated the area near the fault and found out about the effect of earthquakes near the fault that the effect of this parameter on the response of the structure is that the pulse records near the fault tend to increase the displacement response in structures compared to earthquakes in the far area. This increased displacement demand can greatly increase structural and non-structural damage. For this reason, the use of energy-consuming systems in structures to reduce the response of the structure as well as the damage caused to the components of the structure and as a result to reduce the damage caused by the earthquake, can be an effective solution to deal with the effects of this natural phenomenon. The destruction of structures in recent earthquakes, which has led to much human and financial damage, has led engineers to use energy-absorbing systems and the accumulation of damage caused by earthquakes in certain parts of the structure. Among these energy absorbers is the Pal friction damper. The performance of dampers depends on various components, such as the characteristics of the soil and the type of ground movement. Generally, in the analysis of the structure, the soil under the structure is assumed to be rigid, if the soil is not rigid, this leads to obtaining results that are far from reality. On the other hand, the proposal of using the base isolation method in structures was first proposed by an English doctor named Kalantarintz in 1909. He suggested using oiled free seams along with a layer of soft sand and silica to move the structure on it to reduce the force of the earthquake. This proposal was the first example of a seismic-resistant design philosophy, which later became known as base isolation or seismic structure isolation. Today, the building industry has moved towards the use of structural seismic control equipment including active, semi-active, and passive dampers[7]. The most widely used are passive dampers, which have different types such as metallic, frictional, and viscous dampers, among which, frictional and viscoelastic types have received much attention due to their high ability to dissipate energy.

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Table 1. Drift ratio between floors for each failure mode according to HAZUS

Type	Slight	Moderate	Extensive	Complete
SIL	0.006	0.012	0.030	0.080
SIM	0.004	0.008	0.020	0.053
SIH	0.003	0.006	0.015	0.040

2- Methodology

In the current research, the effect of Pal damper on the fragility curve of structures with the interaction of soil and structure under the earthquake near the pulse area is investigated and it is checked to what extent the damper can improve the fragility curve with soil-structure interaction under various acceleration maps. In the present study, considering the 3, 5, and 8-story two-dimensional medium bending steel frame, under seven accelerometers near the type pulse, the behavior of the structure in four states without considering the interaction (A), considering the interaction (B), Using the damper (C) and in the mode of using the damper considering the interaction of the soil and the structure (D) has been investigated. Each model is first modeled in ITBS software using the LRFD method and then analyzed in Opensees software under incremental dynamic analysis and then based on the results of incremental dynamic analysis, the fragility curve is drawn. In the following, to investigate different failure modes in the models, the vulnerability levels introduced in HAZUS MH-MR4 which is shown in Table 1.

3- Discussion and Results

The performance evaluation of the dampers in structures with the number of 3, 5, and 8 floors showed that: in state B in short structures, the displacement of the floors remained almost constant and had no difference compared to state A; But the use of dampers has reduced the displacement of the floors, on the other hand, the displacement of the floors has been relatively reduced in structures with mode D. Also, the pattern of displacement reduction in different records has been different, which is due to the different frequency content of the records. With the increase in the number of floors, the impact value of the damping effects has been almost constant; however, in structures with more floors, mode B has increased the displacement of floors; the amount of increase depends on the type of records. The increase in damping in short-story structures did not have much effect on the displacement of floors, but in high-rise structures, the displacement of floors decreased with the increase in damping. The results of the nonlinear dynamic analysis show that the use of the damper has no effect on the base shear value of the structures, but the base shear value has also increased in structures with more floors. In structures with mode D, the base shear is reduced. It should be noted that the amount of base cut was different in different records and this pattern of change was almost constant. With the increase in damping high-rise structures, the shear of the base of the floors decreased with the increase of the damping.

4- Conclusions

The results obtained from the incremental dynamic analysis showed that mode C reaches the failure level at a higher spectral acceleration compared to other models, which indicates the performance of the damper in reducing the drift between floors. Also, the effect of soil and structure interaction on increasing the drift between floors and reaching the failure level in lower spectral acceleration has been evident in all models. As the number of floors increases, the failure level occurs at a lower spectral acceleration. By examining the fragility curve in all models, fragility has increased with increasing Sa(T1,5%), and for lower values of Sa(T1,5%), the rate of change in the probability of reaching a failure state is higher than higher values of Sa(T1, 5%) is In all models, the probability of low failure occurs at lower values of Sa(T1,5%), and moderate, extensive and general failure states occur at higher values of Sa(T1,5%), respectively. The results also indicate that as the number of floors increases, the probability of failure increases.

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