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Investigating the Displacement of a Structure Equipped with Rotational Friction Damper: Considering the Structure-soil Interaction Effect

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Abstract

In this research, the effect of soil and structure interaction is investigated in a structure equipped with rotational friction dampers, with several earthquake records and two types of soil. It was modeled in SAP 2000 software and analyzed under the nonlinear dynamic analysis of the time history with the records of the San Fernando, Northridge, and Imperial Valley earthquakes. The used soil was considered relatively "hard" and relatively "soft" soil based on two types of two and three soil groups based on the 2800 regulation.

In this research, the soil and structure complex was subjected to the effect of three earthquake records, and after the vibration, the parameter, and the lateral displacement on the desired structure were investigated. Based on the obtained results, it can be said that the displacements in the structure with the damper have been significantly reduced and also the soil interaction effect is minor in type two or hard soils, while the analysis with the interaction effect in a soft soil It has a significant effect on the displacement of the structure, also the rotational friction dampers were able to reduce the displacement of floors and drift in both types of soil. For this reason, the structure was analyzed in two different soil types with damper and with interaction effect, with damper and without interaction effect, without damper and with interaction effect and without damper and interaction effect, in general, it can be said in soft soil. Damping of the soil has a significant role in reducing the forces and deformations of the frame. The effect of the interaction between the soil and the structure in the structures whose underlying soil is soft should be subjected to nonlinear dynamic analysis.

Keywords: Displacement, Rotation Friction Damper, Soil Structure Interaction, Structure Equipped.

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Introduction

By using dampers, the performance of buildings against lateral forces can be improved. Dampers can absorb and depreciate a large amount of earthquake energy input to the structure. Nowadays, Rotation friction dampers are widely used because they have a very high capacity for depreciating and damping earthquake energy and also because of their low cost, easy installation, and easy maintenance [1].

Rotation friction dampers were introduced in the world by Imad Mualla[2] .The first test was carried out in a one-story building, which was equipped with a rotational friction damper in one opening of the building's frame [2 and 3].

Nielson and Mualla [4] came to the conclusion in this experiment that the damping system installed in buildings can be designed and installed in such a way that it dampens and then depreciates all the dynamic loads entering the building.

Liu et al. [5] tested a real-size building equipped with a rotational friction damper system on a Shaking table. In this test, all the necessary outputs were obtained from the fabricated prototype structure, which showed the very good performance of the rotational friction damper. Also, Kim et al. [6] used a type of friction damper with a high capacity. Komachi et al. [7] used rotational friction dampers for the Resalat oil platform.

The effectiveness and performance of passive, active, and semi-active control devices in reducing structural and non-structural damage and in severe and moderate earthquakes to increase good seismic performance have been confirmed [8].

Among the methods of passive control of the structure, friction dampers have a high energy dissipation capacity and are very easily installed in the structure. Also, many experimental studies have been done on friction dampers so far [9]. He attracted the attention of scientists and experts to the damper due to the advantages of using passive structure control methods, its easy implementation in the structure, low cost, and no need for external force particles for direct objects. D'Aniello et al. [10] used a parametric study based on the analysis of the finite element method to simulate two types of innovative friction dampers at the beam-to-column joint.

In the research that Latour et al. [11] conducted with numerical and experimental tests on two, they discussed and investigated the type of simulated friction damper in structural joints, and the results of this research showed the good effectiveness of joints in structures with dampers. Recently, NABID et al. [12] optimized a reinforced concrete structure with a wall friction damper. In this study, they obtained the sliding load to obtain a uniform distribution of the damper in the structure. The dampers are divided into three parts: passive dampers, active dampers, and semi-active dampers, which are passive Rotation friction dampers.

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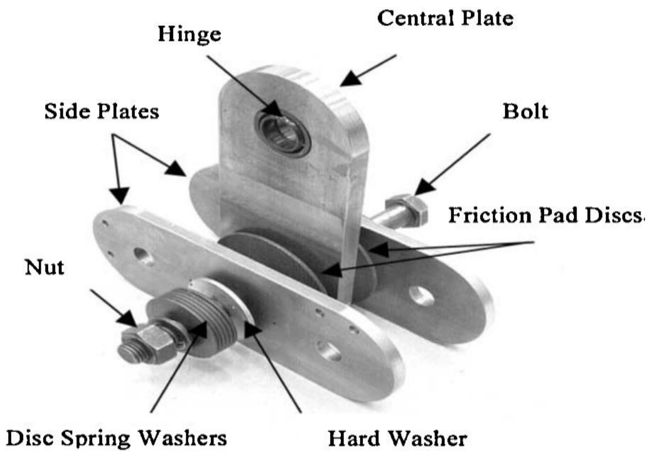

Fig. 1: Rotation friction damper detail [13]

The rotational friction damper is one of the energy absorbers in lateral forces, especially earthquakes in structures, as shown in Figure 1. As seen in Figure 1, this type of damper consists of several friction pad that are placed between steel plates and are placed between them by a pre-tensioned screw and several plate springs, and all of them are compressed together by the pre-tensioned screw. Is. This type of damper consumes the lateral energy of the structure through the mechanism of friction between the rigid bodies that rotate relative to each other and turn it into heat energy. The friction damper is usually installed in the Chevron wind brace, and with a mechanism that is connected to the structure during an earthquake and lateral force, it produces a reciprocating effect. Friction will be proportional to the amount of designed capacity, and damping will be required.

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Fig. 2: Experimental damper in Taiwan using shake table and seismic simulator [14].

In April 2001, an international team of earthquake engineering experts conducted an intensive experimental research program on a three-story building equipped with a rotational friction damper at the National Earthquake Engineering Research and Experiment Center in Taiwan, named NCEER It is known to do [15].

Experimental building A resistant steel structure with a height of 3.0 meters on each floor and a length of 4.5 meters in the direction of vibration was built, and two rotational friction dampers were installed on each floor. Their characteristics were selected based on analysis and extensive numerical analysis. A rotating friction damper device is connected to the heartier, which is shown in Figure 2.

Seismic response using tremors corresponding to pre-defined earthquakes in the shaking plane that simulates earthquake motion in the far and near areas of the Imperial Valley fault 1940: El Centro (United States of America); 1995: Kobe (Japan); 1999: Chi Chi (Taiwan). were carried out, and all tests confirmed the significant effectiveness of damping in reducing lateral movement, lateral control, and drift of the tested building floors.

The most important issue in using Rotation friction dampers is determining the optimal sliding load for this purpose. The point that must be observed when using Rotation friction dampers is to check the performance indicators of the friction damper.

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The performance factors of the friction damper have values between zero and one; the index of one means that the structure is a bending frame and the damper is not used, in which case the sliding force will be zero and there is practically no energy loss in the friction damper.

In the second case, the friction damper in the structure will act as a braced bending frame, and in that setting, the performance indicators of the friction damper will be zero, which is an ideal and unattainable number in theory, and reaching the ideal state will not happen in practice.

Therefore, the minimum performance indicators by Mualla and Belev 4 are introduced and defined as the following:

$$SPI = \sqrt{R_d^2 + R_f^2 + R_e^2} \quad (1)$$

$$R_d = \frac{D_f}{D_P} \quad (2)$$

$$R_d = \frac{V_f}{V_P} \quad (3)$$

$$R_e = \frac{E_i - E_h}{E_i} \quad (4)$$

Response reduction factor R_d in the above equations:

R_f	Base share reduction factor
R_e	Residual energy factor
D_f	Displacement of the structure equipped with rotational friction damper
D_P	Displacement of medium flexural frame structure
V_f	Base shear of structure equipped with frictional damper
V_P	Base shear of medium flexural frame structure
E_i	Input energy of the structure equipped with frictional damper
E_h	hysterical energy loss by the damper

In relations (1), (2), (3), and (4), it is assumed that the members of the structure are elastic according to relation (1) and the factors affecting it. The best damping performance is when the efficiency index of the damper is minimized. Each of the three factors of response reduction, base shear reduction, and residual energy is one of the improvement factors in the performance of dampers, and each of these factors can be used in the improvement of structures according to the opinion of the designer.

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2- Soil and structure interaction

Soil, as a main parameter present next to the structures, will have a great impact on the behavior and performance of the structure when lateral forces are applied, especially in earthquakes, and the effect of soil should be taken into account in the analysis of structures. Unfortunately, today, the analysis of the structure usually ignores the effect of the soil and considers the foundation of the structure to be rigid. In this assumption, the foundation allows movement during the vibration of the structure, and it is assumed that the foundation on the soil allows free rotational movement and displacement during the vibration of the structure. It does not have, and the flexibility and damping of the soil have been neglected. Of course, it has not been possible to accurately formulate the soil next to the structure due to the many uncertainties that this semi-infinite system has, but many relationships that closely resemble the interaction of the soil and the structure have been presented that can be used.

On the other hand, the response of the structure under earthquake vibration can be seen as affected by the interaction between the three components of the structure, the foundation and the underlying soil, which can be defined in several ways to investigate this system, including the effect of the structure-soil interaction and the interaction Soil, foundation, structure, and the interaction of the structure are the soils of the structure. In this article, the foundation is considered a part of the structure with concentrated mass, and the definition of the interaction between the soil and the structure is used. To apply the effect of the interaction between the soil and the building, the method proposed by Takewaki [16] and his colleagues, which is based on the linearization of the extracted non-linear soil, is based on the shear model of the building with one displacement degree of freedom and one rotational degree of freedom of the structure caused by the soil [17].

3-Research method

In this section, as it was said, using the results of the analysis of the constructed models, a ten-story building with five openings in the X direction and five openings in the Y direction was considered, as well as two different soil types for the analysis of this structure. was used, the soil was modeled as a spring and damper to check the interaction, all the dampers were considered for each floor with suitable stiffness, four dampers were installed in each direction of the building on each floor, and a total of forty dampers were installed in the whole building with suitable stiffness. It was agreed that we would discuss the results of the desired goals in this research. These goals can be summarized as follows:

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Checking the behavior of the building equipped with a rotational friction damper under the effect of seismic load on type 2 soil and investigating.

the behavior of the building equipped with rotational friction dampers for seismic load induction on type 3 soil.

The reactions created (displacement, etc.) in the whole structure were investigated with type two and type three soils.

Each of the structures was tested once with type 2 soil, in four cases with a rotational friction damper and a soil-structure interaction effect, with a rotational friction damper without an interaction effect, without a friction damper with an interaction effect, and finally without a damper and an interaction effect. It was analyzed and examined, and all the above cases were examined once again with soil type 3. The comparison of the output results in the four conditions mentioned above in soil type 2 and soil type 3 was also done. All these analyses have been done in four ways.

For better and more acceptable results, three world-famous earthquake records—the Imperial Valley earthquake, the Northridge earthquake, and the San Fernando earthquake—were used, which are all from the same fault. Analysis with damper and with interaction effect, with damper without interaction effect, without damper with interaction effect, and without damper and without soil interaction effect was done in two types of soil, type 2 and type 3.

4: Earth movement in an earthquake

Earth movement in determining the effect of earthquakes on buildings can be obtained directly by changing the acceleration with time in the dynamic analysis of the structure. The use of this method is allowed in all buildings.

The acceleration maps used must have the characteristics listed in the following paragraphs. Acceleration maps that are used in determining the effect of ground motion should represent the actual ground motion at the building site during an earthquake as much as possible.

to select at least three pairs of acceleration maps belonging to the horizontal components of three different recorded earthquakes that have the following characteristics.

Acceleration maps should belong to earthquakes that satisfy the earthquake conditions of the plan and in which the effect of the magnitude, the distance from the fault, and the mechanism of the seismic source are considered.

They should be as similar as possible in terms of geological, tectonic, and seismological characteristics, and especially the characteristics of soil layers with the land of the building site. The duration of strong earth movement in the acceleration maps should be at least 10 seconds or three times the main cycle time of the structure, whichever is greater.

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The duration of extreme movement of acceleration maps particles for a direct object can be determined from valid methods such as the cumulative energy distribution method. In cases where the required number of recorded appropriate mapping acceleration pairs is not available, suitable simulated mapping acceleration pairs can be used to complete their number.

5-The acceleration scale

The acceleration couple of the selected maps for the three-dimensional analysis of the structures should be scaled in the following way:

Each pair of acceleration maps is scaled to its maximum value. This means that the maximum acceleration in the component that has a larger maximum is equal to the acceleration of gravity. The acceleration response spectrum of each of the acceleration pairs of the scaled maps should be determined by assuming a 5% damping ratio.

The spectra of each pair of acceleration maps are combined using the sum of squares absorption method, and a single combined spectrum is made for each pair.

Each pair of acceleration maps should be compared so that for each period in the range of T 0.2 to T 1.5, the average value of the tide spectrum of the sum of squares related to all pairs of components is not more than ten percent of 1.3 times the corresponding value of the spectrum of the standard design, which is the main cycle time of the building.

The factor must be multiplied by the acceleration of the scaled maps in the first paragraph and used in the dynamic analysis. In cases where the analysis of the structure is done in two dimensions, the spectrum of the larger component of the acceleration map should be compared with the standard spectrum.

6-Calculations of dynamic analysis of the structure

In this method, the dynamic analysis of the structure was performed by giving the effect of the acceleration of the ground as a function of time at the base level and calculating the response of the mathematical model of the structure with the assumption of linear behavior. In this analysis, the damping ratio can be assumed to be 5%, unless it is possible. It shows that another value is more suitable for the structure. The acceleration of the ground was determined based on the acceleration maps prepared with the conditions mentioned in paragraph 4. Each pair of acceleration maps mentioned in that paragraph was simultaneously applied in two directions perpendicular to each other, in the main stretches of the structure, and the reflections of the structure were determined as a function of time. The final reflection of the structure is equal to the maximum reflections obtained from the analysis of three pairs of acceleration maps.

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In this analysis method, instead of the three pairs of acceleration maps mentioned in paragraph 4, seven pairs of acceleration maps with the specifications mentioned in that paragraph can be used, and the maximum average value of the reflections obtained from them is considered the final reflection.

7- The results of the structural analysis

In this section, the results of the analysis of the models were presented in the form of different charts. The parameters examined in these charts include: Floor displacements in three famous world earthquake records from a fault in the United States. All the parameters mentioned in the form of time history in the period were considered for the analysis of the frame under the effect of load by SAP2000 software. Next to each chart are the maximum values and the minimum of each axis, which were examined to compare each parameter in different modes.

For each parameter given, there is a title that indicates the name of the investigated parameter, the displacement of the floors, and the period of the structure.

In this part, the results of the analysis of the rotational friction damper with soil type two for four cases with rotational friction damper and soil interaction effect, with damper and without soil interaction effect, without damper and with soil interaction effect, and without damper and without soil interaction effect are considered. To make a better comparison in each step, first, the results of the analysis related to the case where the interaction effect is not considered are given, and then the diagram is given in the case where the soil interaction effect is considered in the analysis of the rotational friction damper. In the output graphs given in this article, all units for changing locations were considered millimeters.

The analyzed structure is a ten-story building; the distance between each opening is 5 meters, and the floor-to-floor height is 3.4 meters. The area of each floor is 625 square meters, and the total area is 6250 square meters. The floors can be seen in the curves as well as the cut of the floors, while the effect of dampers is greater in tall buildings than in short buildings.

8. The structure specifications for the analysis using the soil type II

No. of stories: 10
Building height: 34.0 m
Structure specification in x axis direction:
Structural system: flexural frame system
Resistant system versus lateral forces: medium flexural frame structure
$R_u = 5; H_m = 50m; \Omega_o = 3; C_d = 4$

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Y axis structure specifications:
Structure system flexural frame system
Resistant system versus lateral forces: medium flexural frame structure
Construction site specifications:
Project site location: Tehran City
Relative seismic risk: Very high
Project base acceleration ratio 0.35
Soil type: Type II
Calculation of the structure *time period*
The interframe's effect on structures has not been considered.

$T_x = 0.08 \times H^{0.75} = 0.08 \times (34.0)^{0.75} = 1.13\ Sec$

$T_y = 0.08 \times H^{0.75} = 0.08 \times (34.0)^{0.75} = 1.13 Sec$

Soil specifications:

$soil\ type\ II: T_o = 0.1; T_s = 0.5; S = 1.5; S_o = 1$

Calculation of X direction axis reflection coefficient:

$T > T_s \Longrightarrow B1 = (S+1) \times (T_s/T) = 1.11$

$A = 0.35, T_s \leq T < 4 \Longrightarrow N = .7 \times (T - T_s)/(4 - T_s) + 1 \Longrightarrow N = 1.13$

$B = 1.25$

Calculation of Y direction axis reflection coefficient:

$T > T_s \Longrightarrow B1 = (S+1) \times (T_s/T) = 1.11$

$A = 0.35, T_s \leq T < 4 \Longrightarrow N = .7 \times (T - T_s)/(4 - T_s) + 1 \Longrightarrow N = 1.13$

$B = 1.25$

Seismic coefficient calculation:

$C_{min} = 0.12 \times A \times I = 0.0420$

$C_x = A \times B_X \times I/R_{ux} = 0.35 \times 1.25 \times 1.0/5 = 0.0874 > C_{min} O.K$

$C_y = A \times B_y \times I/R_{ux} = 0.35 \times 1.25 \times 1.0/5 = 0.0874 > C_{min} O.K$

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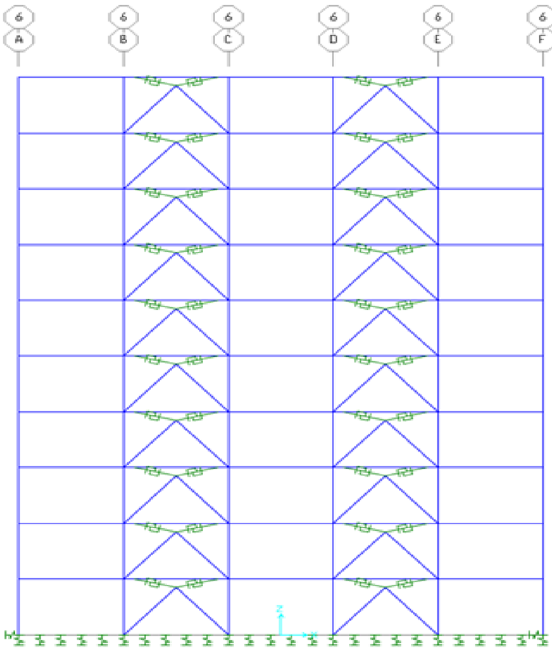

Fig. 3: The 10-story modeled building with rotational friction damper

As you can see in the building under analysis, two dampers with proportional stiffness are installed on each floor on each side of the building, which means that each floor has eight dampers and a total of eighty dampers are considered on the floors.

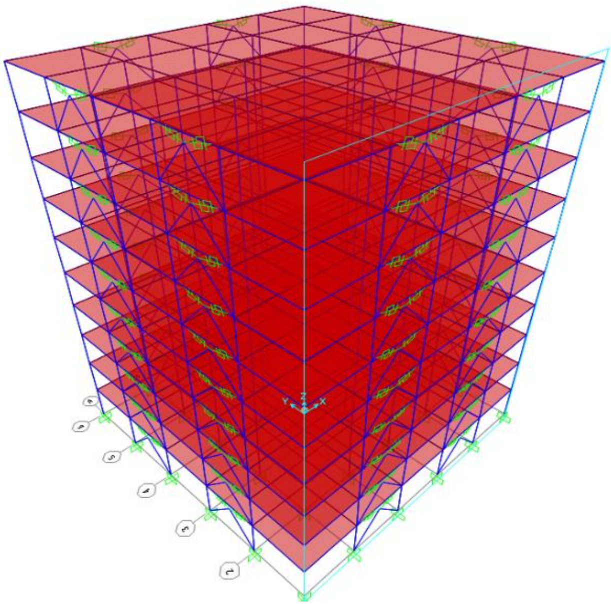

Fig.4: The 3D modeled building using spring for the soil

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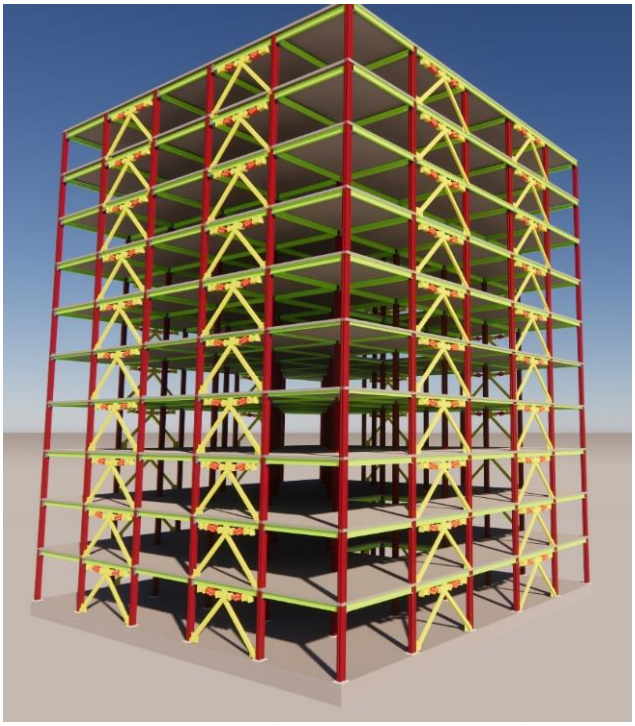

Fig. 4-1: The 3D modeled building using spring for the soil

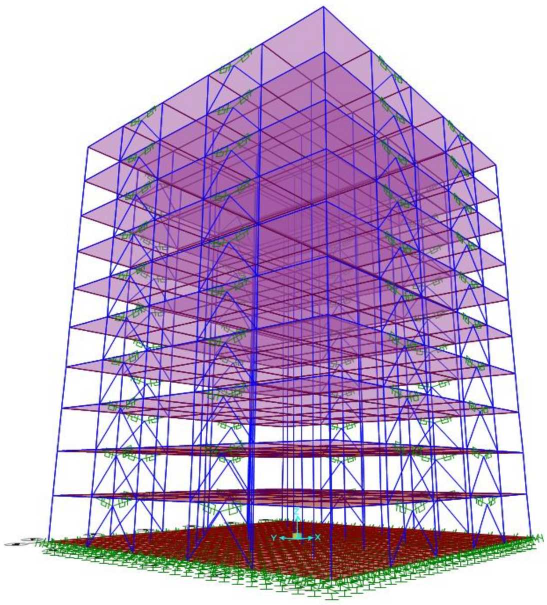

Fig. 5: The modeled building using rotational friction damper

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As seen in Figures 3, 4, and 5, the building has ten floors, and each floor has eight dampers. The soil under the foundation is also modeled as a spring, and the total area of the structure is 6250 square meters.

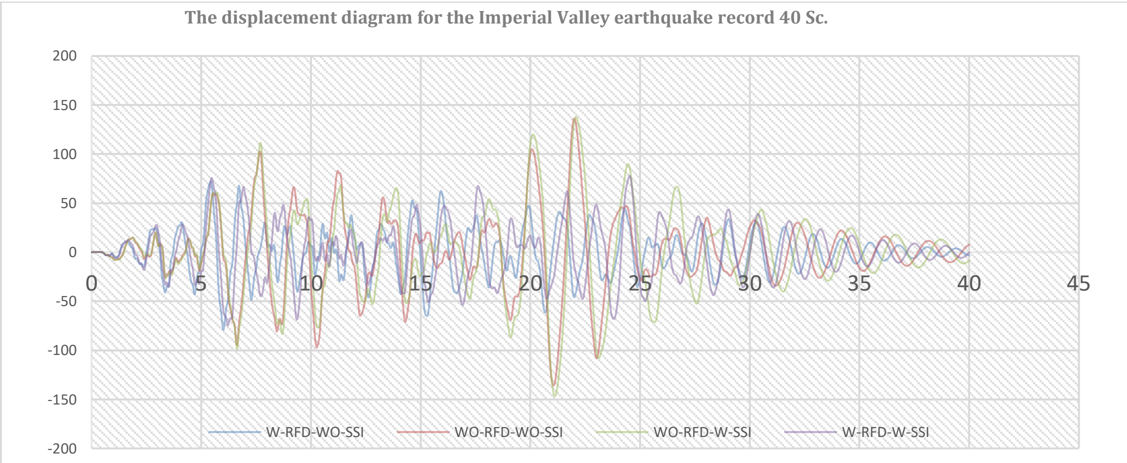

Fig. 6: The roof displacement diagram for the Imperial Valley earthquake record with the aforementioned four states

As can be seen from the above curves, the lowest displacement of the floors corresponds to the time when the effect of soil interaction is not seen and the damper is installed in the structure, which is about seventy millimeters, and the worst case of displacement of the floors is related to the time when there is no damper. It has been seen with the effect of soil interaction that, in this case, it has become about 150 mm.

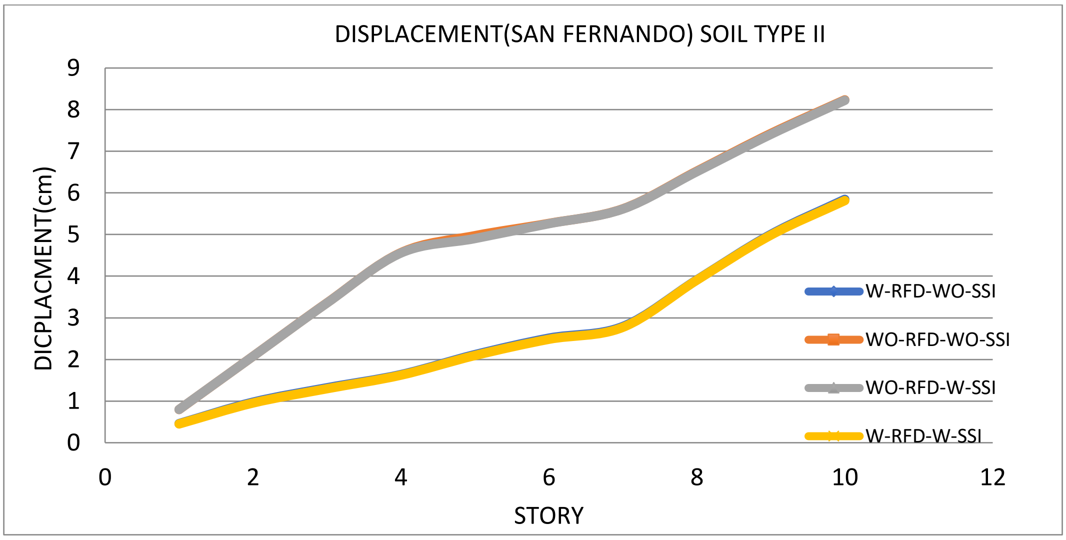

Fig. 7: Maximum floor displacement curve of San Fernando earthquake record with soil type II

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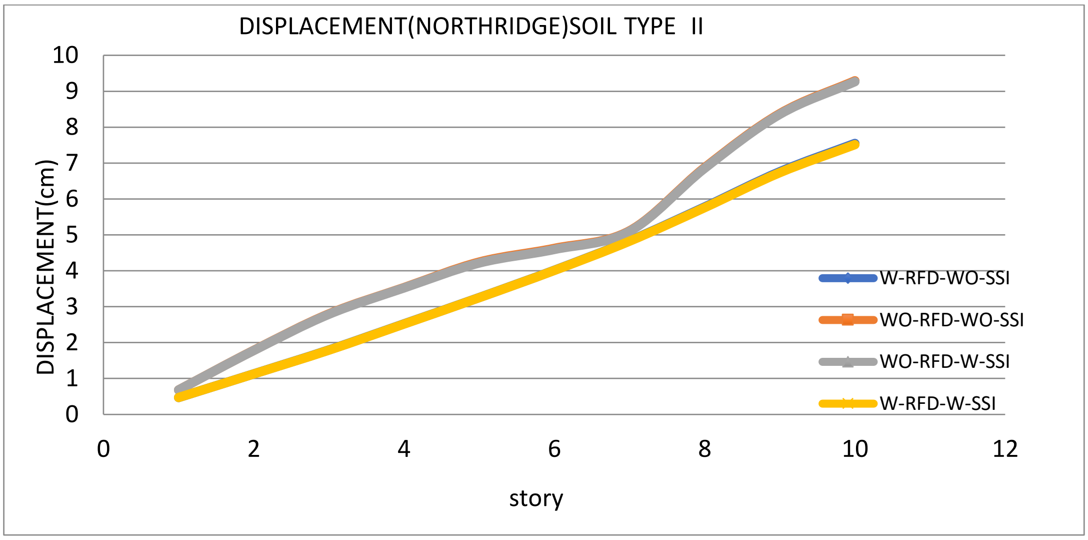

Fig. 8: Maximum floor displacement curve of Northridge earthquake with soil type II

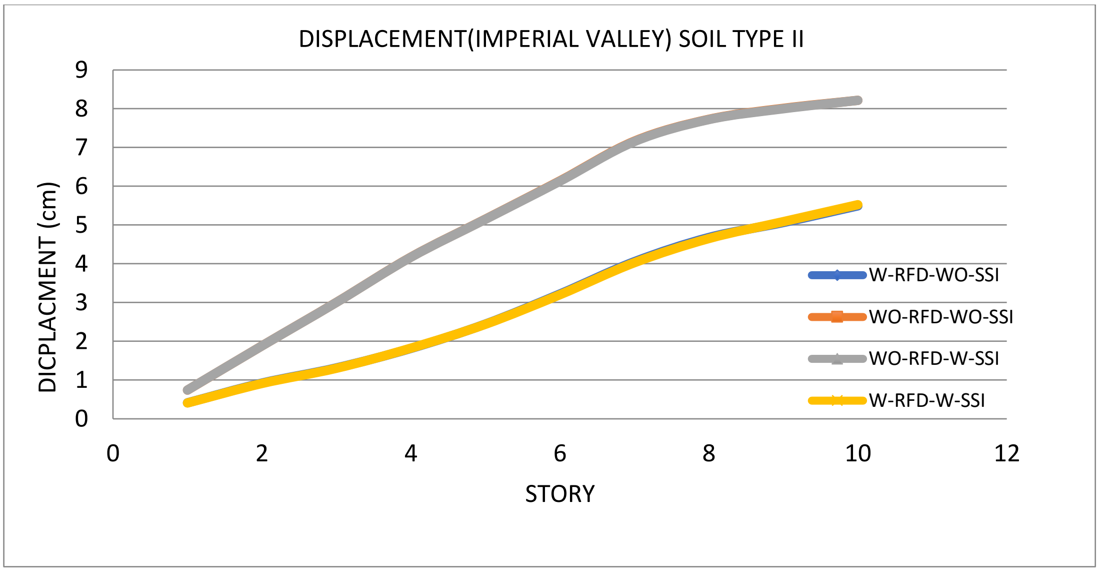

Fig. 9: Maximum displacement curve of the floors in the record. Imperial Valley earthquake with soil type II

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In the analysis and analysis of curves 7, 8, and 9, which are related to three earthquake records from a fault in The United States of America, the lowest displacement is related to the use of the damper in the structure, as it is clear in the blue curve in the three earthquake records, if we ignore the effect of soil interaction and use the rotational friction damper we will have the least movement, now in the worst case, it is when the effect of soil interaction is seen and friction damper is not used, the regulation 2800 mentions that if the hard subsoil is used in the structure, the effect of soil interaction can be and ignored the structure, as can be seen in the mentioned curves, taking into account the effect of soil and structure interaction, the displacement of the structure is slightly more than the case that is not considered.

9. The project characteristics for the analysis of soil type III

No. of floors: 10 floors
Building height: 34.0 m
Structure specifications in X axis direction:
Structure system: flexural frame system
system resisting against lateral forces: medium flexural frame structure
$R_u = 5; H_m = 50m; \Omega_o = 3; C_d = 4$
Structure specifications in Y axis direction:
Structure system: flexural frame system
system resisting against lateral forces: medium flexural frame structure
$R_u = 5; H_m = 50m; \Omega_o = 3; C_d = 4$

Construction site specifications
Project site location: Tehran City
Relative earthquake risk Too much
Design basis acceleration ratio: 0.35
Soli type: Type III
Calculation of structure time period

The interframe's effect on structures has not been considered.
$T_x = 0.08 \times H^{0.75} = 0.08 \times (34.0)^{0.75} = 1.13\ Sec$
$T_y = 0.08 \times H^{0.75} = 0.08 \times (34.0)^{0.75} = 1.13 Sec$

Soil specifications:
$soil\ type\ III: T_o = 0.15; T_s = 0.7; S = 1.75; S_o = 1.1$
Calculating the reflection coefficient in X axis direction
$T > T_s \Longrightarrow B1 = (S + 1) \times (T_s/T) = 1.71$
$A = 0.35, T_s \leq T < 4 \Longrightarrow N = .7 \times (T - T_s)/(4 - T_s) + 1 \Longrightarrow N = 1.09$

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$B = 1.25$
Calculating the reflection coefficient in Y axis direction
$T > T_s \Longrightarrow B1 = (S + 1) \times (T_s/T) = 1.71$
$A = 0.35, T_s \leq T < 4 \Longrightarrow N = .7 \times (T - T_s)/(4 - T_s) + 1 \Longrightarrow N = 1.09$
$B = 1.25$

Calculating the seismic coefficient
$C_{min} = 0.12 \times A \times I = 0.0420$
$C_x = A \times B_X \times I/R_{ux} = 0.35 \times 1.85 \times 1.0/5 = 0.1304 > C_{min} O.K$
$C_y = A \times B_y \times I/R_{ux} = 0.35 \times 1.85 \times 1.0/5 = 0.1304 > C_{min} O.K$

In this part of the analysis, according to the characteristics of the relatively soft soil of the third type, all the curves, such as the displacement of floors, were investigated in four cases: with a damper with the interaction effect, with a damper without the effect of the interaction effect, without a damper with the interaction effect, and without a damper without the effect of soil and structure interaction with relatively soft soil.

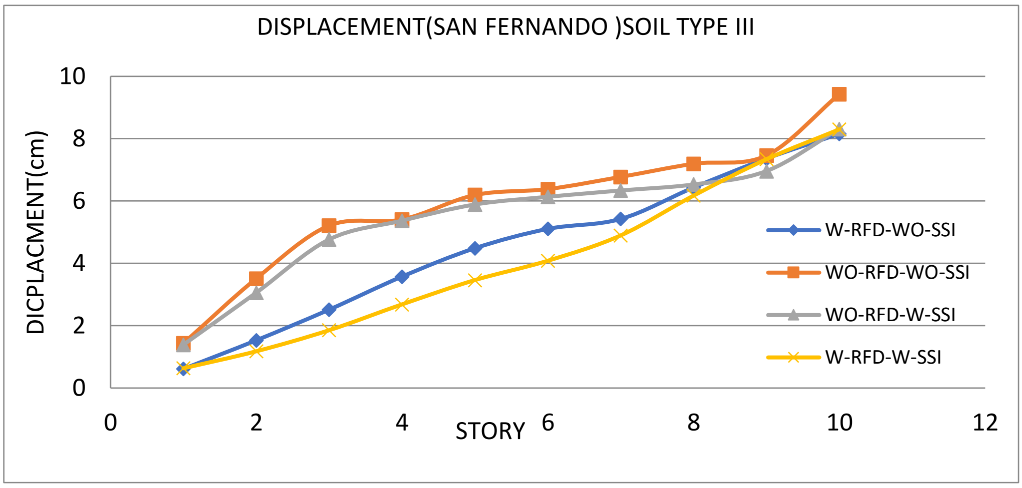

Fig. 10: Maximum displacement curve of floors in the record of San Fernando earthquake using the soil type III

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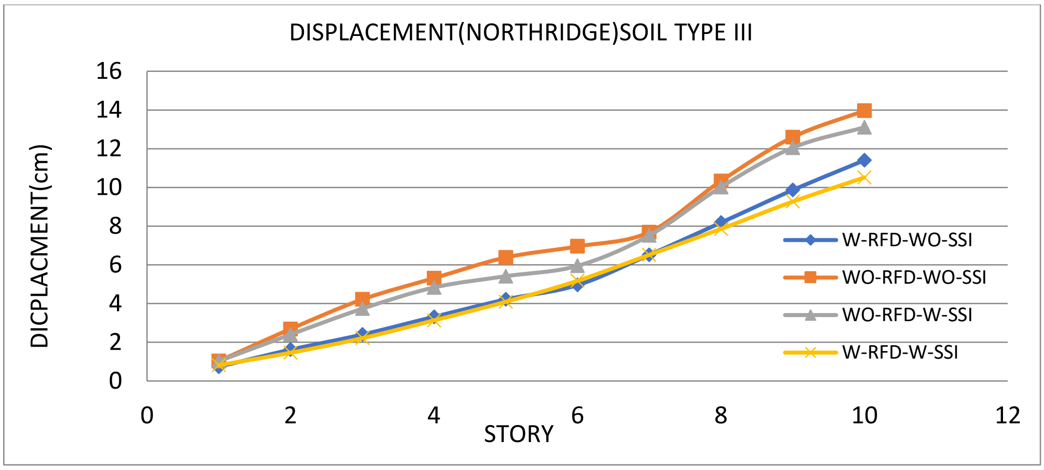

Fig. 11: Diagram (6): The maximum displacement curve of floors in the record of Northridge earthquake using the soil type III

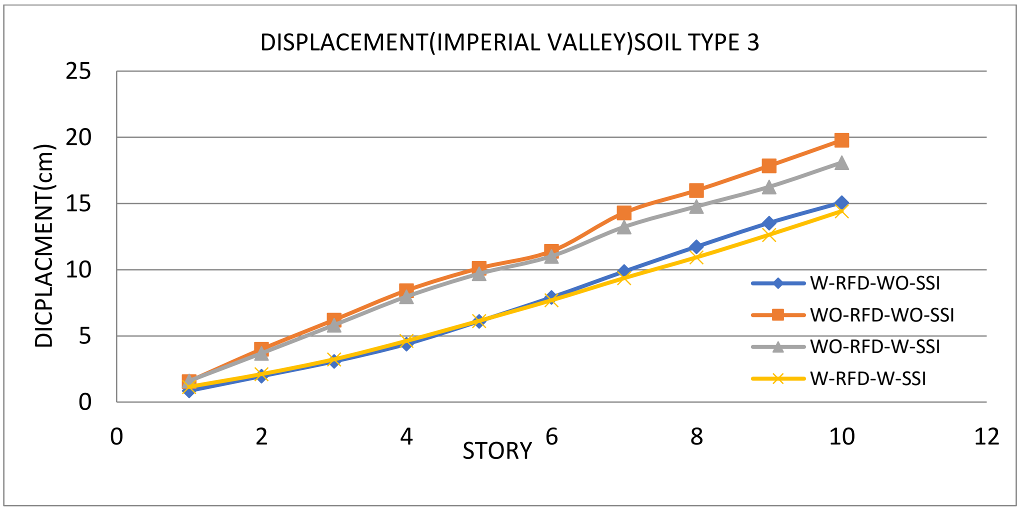

Fig. 12: The maximum displacement curve of floors in the record of Imperial Valley earthquake using the soil type III.

Seeing the three curves 10, 11, and 12, which are related to the records of the Imperial Valley, San Fernando, and Northridge earthquakes, and taking into account type 3 soil, it can be concluded that in soft soils such as type 3 and type 4, special attention should be paid to the design of structures. In high-rise structures, the effect of soil and structure interaction can be seen, and the structure should be designed according to the outputs, so it can be concluded that in structures with hard or relatively hard soil (type two) and relatively soft soil (type three), it is recommended to design and install a damper because it improves the behavior and

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performance of the structure in moving the floors of both types, and the effect of the interaction between the soil and the structure is very evident in soft soils, and the effect of the interaction between the soil and the structure must be included in the designs. can also be seen. In curves 10, 11, and 12, the yellow line curve corresponds to the ten-story structure with the effect of soil interaction and a rotational friction damper.

As seen in Figures10, 11, and 12, the installation of the damper in the structure has caused relatively linear changes and displacement. If that is the case in structures without dampers, especially in the record of the San Fernando earthquake, we have many displacements in the middle floors of the structure.

10: Spectrum of special design of construction site

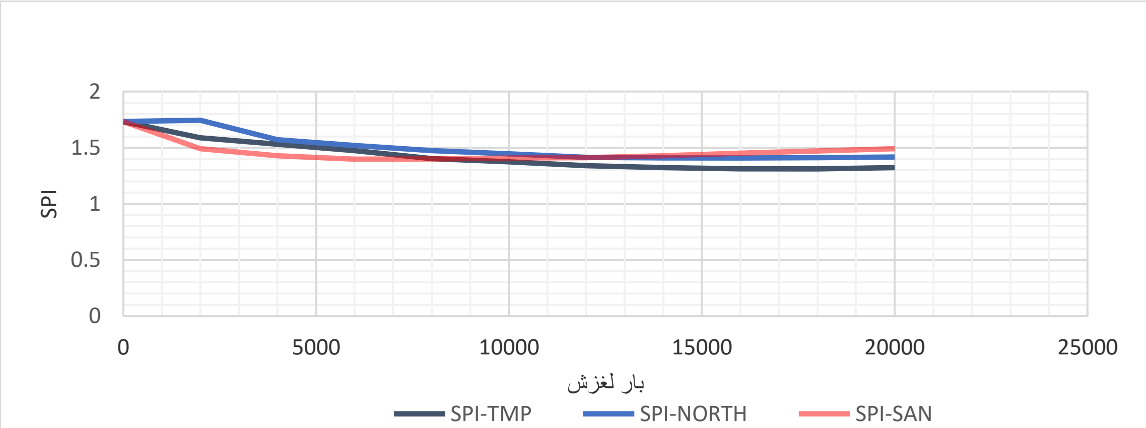

Fig. 13: Standard design spectrum values as per the slip loads for the above three earthquakes

Finally, by plotting the spectrum values of the special design of the building in terms of sliding loads for 3 earthquakes in diagram 8, we have to find the load that is the average of the spectrum values of the special design of the building minimized in 3 earthquakes. [18]

As can be seen in Figure 13, the load of 16000 KG can be selected as the sliding load. First, we introduced a damper sample called RFD (160KN) to the SAP software and analyzed the structure, then the energy absorption index and the energy lost We checked the dampers on the floors. In the first stage, it was determined from the hysteresis diagrams and indicators of the energy absorbed by the structure and the energy lost by the dampers in the floors that the dampers with a sliding load of 160 KN in floors one to three performed well, and were able to absorb a larger amount of incoming energy. but on higher floors, because the energy input to the dampers is less than 160 KN (slip force limit), the dampers did not work and acted as a windbreak, which changed the behavior of the structure, so we introduced three types of

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dampers, which reduce the sliding force of other dampers. Through the above process and examination, the energy absorption index was set to equal to 120 KN and 60 KN [19].

11: Verification and type of damper used on different floors with hysteresis curves

Floors 1 to 3 with damper	RFD (160KN)
Floors 4 to 8 with damper	RFD (120KN)
Floors 9 to 10 with damper	RFD (60KN)

Since it is not possible to directly model the behavior of the friction damper in SAP 2000 software, it can be modeled with another element with similar hysteretic behavior.

I use the LINK-PLASTIC WEN element to model this type of damper. The displacement force behavior of this element is determined by a two-line diagram determined by four parameters: initial hardness, hardness after yielding, yield load (sliding force), and YIELD EXPONENT.

These parameters should be determined in such a way that the rectangular shape of the hysteretic rings of the friction damper is maintained. To model the damper in the software using this LINK, the initial stiffness should be set to a large number (enough that the stiffness matrix does not diverge)[20].

We set the stiffness after yielding equal to zero and the yield load equal to the sliding load of the damper. Below is the hysteresis diagram (force).

The displacement of each of the dampers for three earthquakes is shown on the floors. Considering that the shape of the hysteretic rings is rectangular, it shows that the dampers functioned well and that a high percentage of the energy entering the dampers was well dampened.

The method of analyzing the hysteresis curves for the lower forms is as follows , according to the record time of each of the earthquakes used in this research, which includes the three San Fernando, Northridge and Imperial Valley earthquakes , in fact, three 160 KN dampers for the floors 1 to 3 have been used and as soon as an earthquake occurs, it starts to move in the hysteresis cycle, and in fact, the movements are carried out in the direction of back and forth until the time of the earthquake is over, and in this back and forth in the earthquake cycle in fact, the damping action appears as heat , the hysteresis cycle should be exactly like Figures14, 15, 16 and 17, if it is a horizontal line in the analysis and output of the SAP program , it indicates that the earthquake could not make the damper move, and in fact, the frame for it The damper is designed not to move, and it works like a wind brace, but because the damper frame was supposed to be installed for it and not a wind brace, in this case, if the damper is installed at a high capacity and does not work in an earthquake, the displacement and drift of the floors will

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be greater, and in fact, the damper It will have the opposite effect, so it is very important to design the right damper, choose the right capacity, and review the hysteresis curves and their back and forth movement. For this reason, after choosing the right dampers, the hysteresis curves must be carefully analyzed In every earthquake record, we make sure that the damper moves, and this movement of the damper is a verification of the test, and it works correctly in the hysteresis cycle until the end of the earthquake time.

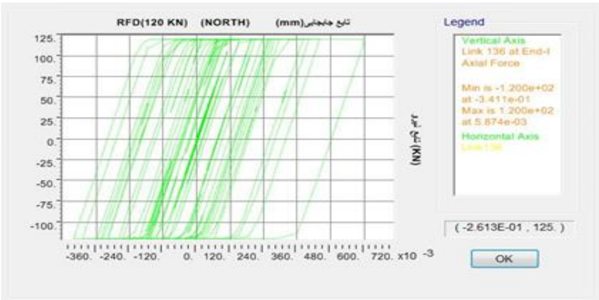

Fig. 14: Hysteresis diagram of damper RFD(120KN) installed in the frame 6-B-C of fourth floor for the earthquake Northridge

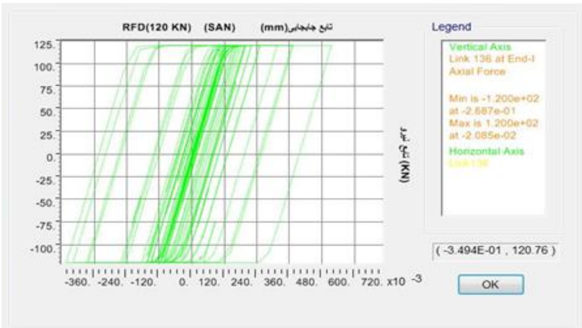

Fig. 15: Hystersis diagram of damper RFD(120KN) installed in the frame 6-B-C of fourth floor for the earthquake San Fernando

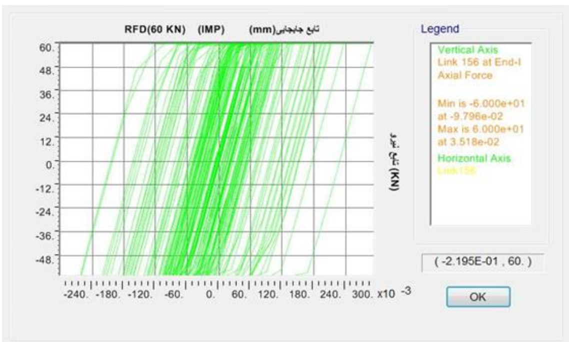

Fig. 16: Hystersis diagram of damper RFD(160KN) installed in the frame 6-B-C of fourth floor for the earthquake Northridge

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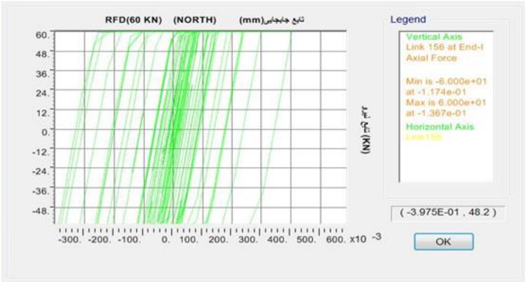

Fig. 17: Hysteresis diagram of damper RFD(160KN) installed in the frame 6-B-C of fourth floor for the earthquake San Fernando

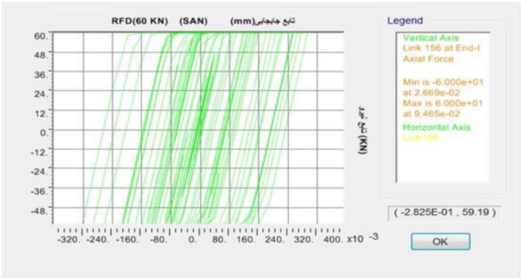

Fig. 18: Hysteresis diagram of damper RFD(160KN) installed in the frame 6-B-C of tenth floor for the earthquake San Fernando

12-Diagrams comparing the displacement of the structure in two soil types, two and three, in three earthquake records

Now, in this article, the displacement of the floors in the structure between soil type two and soil type three with four states with damper and with interaction effect, with damper and without interaction effect, without damper and with interaction effect, without damper and without interaction effect was compared.

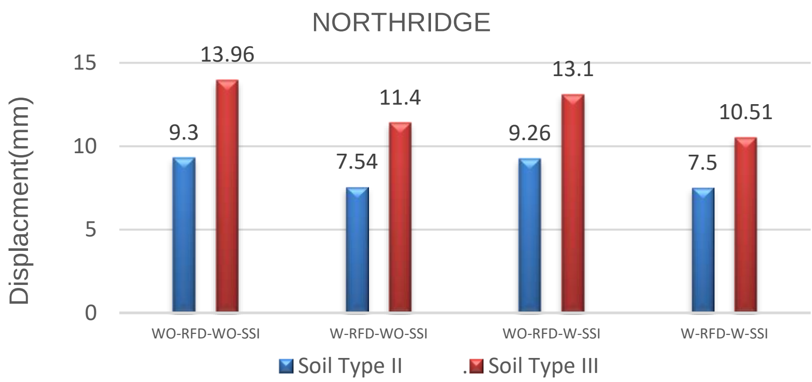

Fig. 19: Comparison of the floor's displacement considering the Northridge earthquake record using the soil types II and III

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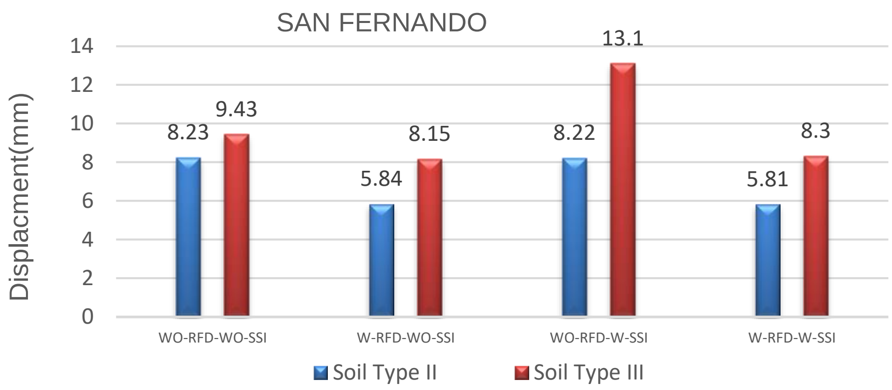

Fig. 20: Comparison of the floor's displacement considering the San Fernando earthquake record using the soil types II and III

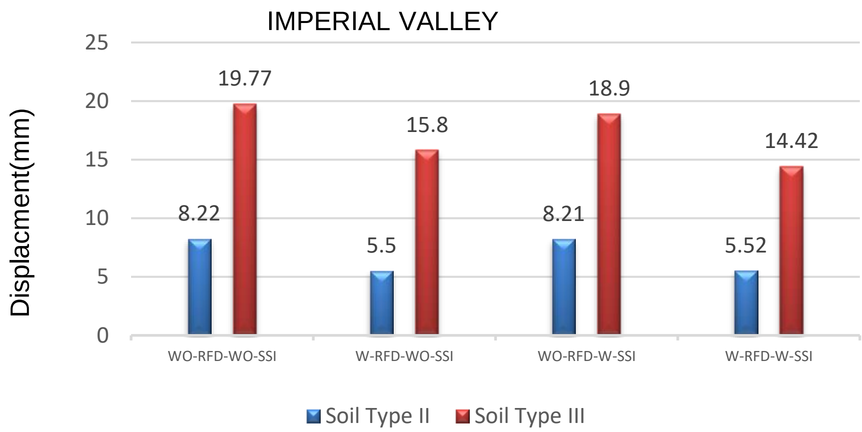

Fig. 21: Comparison of the floor displacements in the Imperial Valley earthquake using soil types II and III.

Three graphs 19, 20, and 21, which are related to the displacement of floors in the three earthquakes of Northridge, San Fernando, and Imperial Valley, are compared in two types of soil, two and three, and the comparison is made in four cases: with damper and with interaction, with damper and without interaction, without damper and with interaction, and without damper and without interaction. It can be concluded that the displacements in type three soil are greater than those in type two soil, and all four conditions can be observed.

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13-Conclusion

To design structures resistant to earthquakes and the dynamic forces caused by earthquakes, the best design solution is a non-linear dynamic design. Because in this mode, the design is much more optimized compared to the static design mode. Here are the analysis results for the four structural analyses. It was compared and evaluated with rotational friction dampers without the effect of soil interaction and with the effect of soil interaction and without rotational friction dampers without the effect of soil interaction and with the effect of soil and structure interaction. By analyzing the results of the article and summarizing them, the following can be listed:

According to the obtained results, the displacement of the floors in the case with the rotational friction damper is always better than without the damper, and the worst case is without the installation of the friction damper, which will always increase the displacement of the floors. The result obtained from this analysis is that the damper will always improve the condition of the building.

Also, always considering the issue of interaction between the soil and the structure will worsen the condition of displacement most of the time, and this issue can bring this message to structural engineers and structural experts who always consider the interaction effect in their analysis. Consider the soil and the structure, and without considering the interaction of the soil, the correct answer to the behavior of the structure will not be received. Soil damping has played a significant role in reducing the forces and deformations of the frame, and in fact, the interaction between the soil and the structure in soft soils has reduced the forces and, as a result, the deformations caused by bending in the frame equipped with a rotational friction damper.

After conducting the current research, analyzing many models, and facing many issues and problems on the way to completing this article, the following content is offered as a suggestion to continue the path:

Considering the influence of soil and structure interaction in the analysis and design of structures equipped with rotational friction dampers, it is suggested that soil effects be considered in the design of these systems.

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