Evaluation of Rotation Effects in Steel Structures with Irregular Plan Under Earthquake in Project Management

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Abstract. Because of lacking specific relationships and criteria for steel structures with bending frames and braces along with the uneven bearing system in Iranian regulations, the need to study the behavior of such structures has been considered by researchers. In this paper, with three-dimensional modeling of steel structures with six types of plans, each of which indicates a degree of asymmetry of the load-bearing system, a total of 18 models of structures under two types of linear dynamic loading and overload were studied. It is indicated that with increasing unevenness of the load-bearing system, the rotation of the structures also increases. This increase is up to 18 times more for short-term structures and up to five times more than for parallel structures than parallel structures. The discrepancy causes unexpected results. Increasing the height of the structure reduces the rotation in the diaphragm. There is no difference between the rotation of the diaphragms in terms of elastic and inelastic, while the load in the other direction of these changes for the inelastic state is sometimes up to more than 50 times the elastic state.

Keywords: *Loose bearing system, steel bending frame, convergent bracing, diaphragm rotation, linear dynamic analysis, overload analysis*

1. Introduction

Earthquakes are a natural hazard that can cause devastating damage to buildings around us. Moderate and strong earthquakes in recent decades have caused many areas of the world to generate vibrations. The philosophy of proper structural design is that the structure withstands mild earthquakes with linear performance and is damaged against moderate or large earthquakes. Non-linear range Buildings are divided into two general categories according to the 2800 standard: regular and irregular. Irregular buildings are also divided into two categories: irregular buildings in plan and irregular buildings in height. Standard 2800 Standard Edition IV Definition For irregular structures, this definition includes two parts: irregular buildings in plan and irregular buildings in height. The definition is as follows: According to the standard 2800 edition, all buildings are considered regular unless they have one of the mentioned conditions is according to the standard of 2800, fourth edition. Irregular definition of load-bearing systems in the standard of 2800, fourth edition, is as follows: in cases where some lateral loading sections will not be parallel to the main orthogonal axes of building (1). Also, US Loading Regulations defined structures with an asymmetric load-bearing system. The definition of an asymmetric load-bearing system in the said regulation is presented as follows: Do not withstand seismic force. Due to the different behavior of irregular buildings, they are more vulnerable than regular buildings and absorb more force from earthquakes and are destroyed. On the other hand, due to the interest of contemporary architecture in designing irregular buildings, it is necessary to focus and research more on this type of buildings is more common. For this purpose, in this article, we have tried to study the irregular effects and seismic performance in 2, 6 and 12-story structures by increasing the irregularity (bearing of the bearing system). Ali and Kravinkler [3] investigated the effects of vertical irregularities by considering irregular changes along the height of the structure on seismic needs. They concluded during their research that mass irregularities on the seismic responses of irregular structures in height have the least effect and the effect of resistance irregularity is greater than the effect of hardness irregularity. Khoshnam and Khairuddin [6,4] After a three-dimensional study of structures with a non-naming load-bearing system, they concluded that these structures are twisted from their first mode, while this is the case for regular structures before The third mode does not occur. They also concluded that applying a load in one direction causes more relative displacement in the other direction. Another result was that increasing the laterality of the lateral bearing system reduces the main periodic oscillation time of the structure. Aranda [7] made a comparison of the ductility requirements between regular and retrograde structures using a recorded earthquake on soft soil. He observed that higher ductility requirements were achieved for the backward structure than for the regular structure, and this increase was more evident in the backward tower section. Atanasiado [8] evaluated the seismic performance of two 10-story reinforced concrete frames with recoil in the upper stories. These frames were designed in accordance with EC8 2004 and for high and medium ductility degrees. After analysis studies, he concluded that displacement ratios Relative inside irregular frames are twice as low as regular frames, even for earthquakes with twice the magnitude of design earthquakes. (Relative class displacement) and studied class displacement response. They concluded that by considering a weak class (low strength) or soft (low hardness), the relative displacement needs of the class in adjacent classes increased and the relative displacement needs of the

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class in other classes decreased. Das and Nao [10] in They investigated the definition of irregular structures at different heights, such as structures with discontinuous explanations of mass, stiffness and strength along the height of the structure, and that the same factor, as specified in the structural instructions, causes the presence of non-structural mounds. The presence of irregularity changes the inelastic response of the structure and signs of increase in the relative displacement of the inelastic story are seen in the presence of irregularity. For the case of increased stiffness, the stiffness of all members of that class are multiplied by 2, while for the case of reduced stiffness, the stiffness of all members of that class are divided by 2. Therefore, irregularities are determined by KI and irregular cases are determined by SI Be [11]. Hashemi and Mofid [12] used the method of modal overload analysis based on energy to estimate the seismic needs of irregular concrete frames in height. According to the energy-based modal overload analysis method, it is close to the relative displacement accuracy of the classes obtained through the nonlinear time history analysis method. According to the review of studies conducted above on bounced structures to estimate its seismic response. It can be seen that various results are obtained. Homer and Wright [13] studied the seismic response of retrograde steel frames using an earthquake. They concluded that the story drift in the tower part of the low-rise structure is larger than the relative story displacement of regular structures. Kavasilis et al. [14] conducted an extensive parametric study on the seismic response of refractory flexural steel frames. They concluded that the maximum deformation needs are concentrated in the narrow part of the tower-like structure adjacent to the regression for other geometrically irregular structures.

Moghadam et al. [15] proposed a method for developing load analysis in addition to asymmetric and retrograde multi-story structures that takes into account the effects of higher and three-dimensional modes induced by rotation to the structure and the analysis of the elastic spectrum of the structure. It is used to obtain target displacement and load distribution in incremental load analysis. They concluded that the use of response spectrum analysis in pushover analysis makes the results worse for the backward structure compared to asymmetric structures. Crawinkler [16] seismic requirement parameters based on one-line two-line freedom systems and stiffness reducers and three types of multi-degree freedom structures with 3, 5, 10, 20, 30 and 40 classes and with main periods, 2.051, 1.635, 1.22, 0.725, 0.431, 0.217 seconds, respectively. They observed that a weak first story leads to an increase in ductility needs and overturning anchor needs. To evaluate the regressive irregular structures, Roma et al. [17] considered three structures with reinforced concrete flexural frames of varying degrees of irregularity and compared them with the corresponding regular structure. They concluded that when axial force changes occur, the ability to change the lateral shape of the structure increases. Ruiz and Diedrich [18] studied the seismic performance of structures with a weak first story in a single earthquake. They studied the effect of lateral resistance discontinuities on the need to participate on the first story under the acceleration record, with the largest peak acceleration achieved on soft soil in Mexico City during the September 19, 1985, earthquake in Mexico. Based on analytical studies, Shahrooz and Mohl [19] concluded that the damage is concentrated in the tower part of the low-rise structure due to high rotational ductility. They also concluded based on experimental studies that the main mode gives a stereotyped response in a direction parallel to the regression [19]. Tana and Klunga [20] studied the effect of single-span frames instead of multi-span frames in the direction of narrow irregular structures with regression on the seismic performance of structures. For this purpose, they developed two reinforced concrete flexural strength structures (narrow regression). Designed in accordance with the 1993 Mexican Seismic Code on soft soils and concluded that the direction of the lower crater of a retracted structure with the capability of a crater when designed with a relative lateral angle of the story close to (Δ = 1.2%). Velmodsson and Nao [21] focused their attention on assessing the requirements of structural guidelines for irregular height frames. They concluded that when the mass of a class increases by 50%, the increase in the need for ductility does not exceed 20%. By reducing the stiffness of the first story by 30% and keeping the relative lateral strength of the first story constant by 20% to 40%, which depends on the ductility of the design (μ), it increases. Wang and Tsu [22] studied the seismic response of the regressed structure using the analysis of the elastic response spectrum. Modal Higher modes are obtained by the static method of the larger code. Researchers have concluded that in triangular structures in the plan, the placement of the center of mass between the center of gravity and the center of resistance necessarily reduces the class rotation or relative interclass displacement. It should not be, but the center of mass should be located as close as possible to the center of resistance and also joining the walls will reduce the lateral displacement of structures by 38% [23]. Maniei et al. [24] by examining the possibility of collapse of irregular buildings in the plan, concluded that with the increase of eccentricity of the plan decreases sharply. In this article, we first try to review the researches and studies done from the past to the present in order to provide a suitable approach for doing the article. In the following, the rules of design regulations and seismic regulations of structures in Iran have been studied and studied. Considering different 3D models of 2, 6 and 12 stories of structures that show the irregularity and inconsistency of the bearing system and by designing and analyzing them according to the rules of steel structures and relevant regulations and applying linear and additional dynamic loads in both north-south and east-west directions and separately, the desired parameters are obtained. In the end, by examining and comparing the obtained parameters, an attempt is made to obtain the required and predicted results.

2 - Method

In this study, to evaluate the behavior of structures and to study the rotation of diaphragms, three residential buildings of 2, 6 and 12 stories with different plans have been considered, each of which indicates a degree of incompatibility of the bearing system. The systems used are medium bending frame in X direction and special convergence brace in Y direction. The distance of all openings is 5 meters and the height of the stories is assumed to be 3.2 meters. The dead load of the roof with the partition is 550 kg / m2 and the live load is 200 kg / m2. Seismicity of the site is of high type and soil of type 2 is assumed according to the standard 2800 fourth edition. To eliminate the shooting factor in the results, shooting is considered checkered. Also, the north direction of the structures is assumed to be in the Y direction (special convergent bracing). The steel used is st37 type, which is the common steel used in Iran. The tensile stress is 2400 kg / cm2. The final stress is 3700 kg / cm2. The Young's modulus is 106 × 2.39 kg / cm2. Also in the nonlinear analysis section, the behavior of steel is considered nonlinear without considering the strain hardening of steel. Another is that in the definition of the joints of the column and the brace at the distance between 10 and 90% and for the beam at the distance between 8 and 92% of the length of the section is articulated.

2-1- Naming the models

The naming of the structure is based on alpha with an index that the alpha index indicates the degree of asymmetry of the load-bearing system in the structures. The alpha index is equal to the ratio of the lengths of the removed openings to the total length of the structure obtained from Equation (1).

$$x = L_r / L \tag{1}$$

where X is the value of the variable to indicate the degree of asymmetry of the load-bearing system, Lr and the length of the removed openings, and L the total length of the structure. Figure (1) shows the values of Lr, L as well as the location of the braces in model 0.6α.

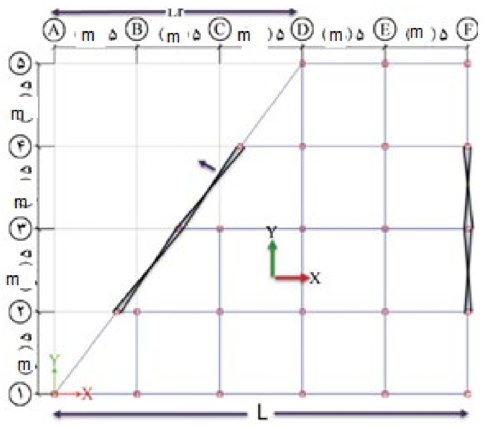

Figure 1- Lr and L values and location of braces in sample 0.6α

2-2- Introducing the models

In this article, three structures with the number of 2, 6 and 12 stories have been studied and studied, each of which has six different types of plans to take into account the effect of bearing system in structures. The plan of the first structure is rectangular and plan the last model studied is triangular in shape. In the first plan, the system is completely parallel and regular, and the two axes in which the brace is located intersect each other indefinitely. The shape in which the two axes in which the brace is located intersects at a point inside the structure. Table (1) shows the plan of the studied models as well as the location of the braces.

3. Structural analysis methods

All structural models studied in this paper have been subjected to the analysis of load in two directions as well as the analysis of dynamic linear time history. In the analysis of linear dynamic time history, two accelerations of Heitbes and Alcentro record mapping have been used. It should be noted that clauses 3-1-4, 3-3-2 and 3-3-10, standard 2800, which are about the rule 30-100, the indefinite coefficient of the structure and the coefficient of excess strength, respectively, in the design and analysis of structures. Table (2) shows the acceleration characteristics of the mappings used. Figures (2) and (3) also show the time history chart of the Tabas and El Centro records.

Table 1- Plan of the studied models

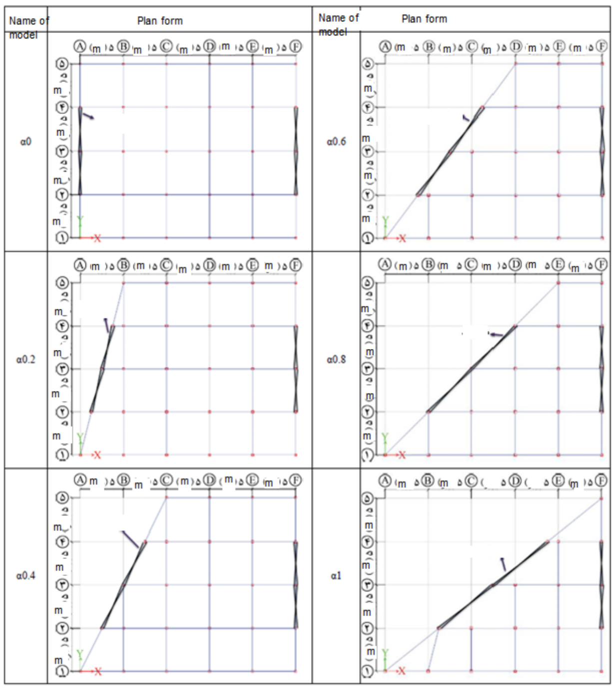

Table 2 - Specifications of earthquake records

Fault (Faulting)	Time duration (Sec)	effective design acceleration (g)	dominant period (Sec)	accelerometer
reverse	33	0.85	0.2	Tabas (Iran)
slide	30.1	0.21	0.58	El Centro (USA)

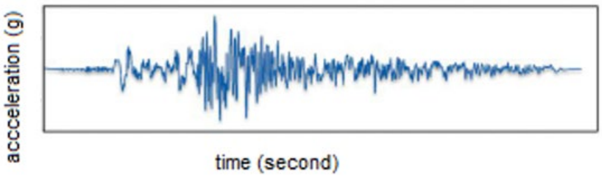

Figure 2- Acceleration mapping of Tabas earthquake in Iran

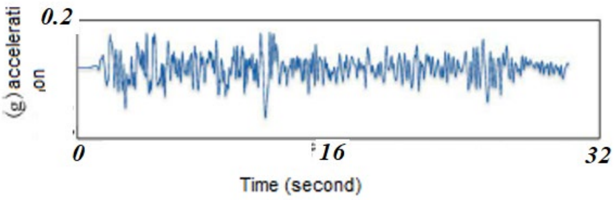

Figure 3- Acceleration mapping of the El Centro earthquake in the United States

Loads are located in the Y direction (brace). Excess loads are applied taking into account P-Δ. The target point is considered to analyze the additional load 0.004 height of the structure. Also, the additional load analysis has been done from the loading method on the roof story and in the form of displacement control.

3-2- Analysis of linear dynamic time history

As mentioned earlier, two acceleration maps of Tabas and Al-Centro earthquakes have been used to analyze the linear dynamic time history. Due to the selection of type 2 soil (according to the 2800 standard of the fourth edition), both acceleration maps have been adapted to type 2 soil.

4- Discussion on the results

In this part of the paper, the results of incremental load analysis and linear dynamic time history are presented separately for 2, 6 and 12 storey buildings and the type of loading. The results provide a better understanding of the behavior of structures with asymmetric bearing system with asymmetric plan.

4-1- Incremental load analysis results

In this section, the class rotation of incremental loading, which includes incremental loads in the X direction and incremental loads in the Y direction, is calculated and presented. It is expected that due to the relative displacement of the maximum in the middle stories during the design of the structures, the highest amount of rotation will occur in the middle stories of the studied structures. In this section, due to the large number of diagrams, only the 0.8 α model diagram is shown in Figures (4), (5) and (6) to show in which categories the maximum rotation of each structure has occurred. Considering the above figures, it can be seen that the most twists of 12-story structures occur on the story, 8 6-story structures on the 4th story and 2-story structures on the 2nd story. It is also noteworthy that the rotation in the structure 0α because it has a perfectly regular plan, so the amount of rotation is so small that it can be considered zero.

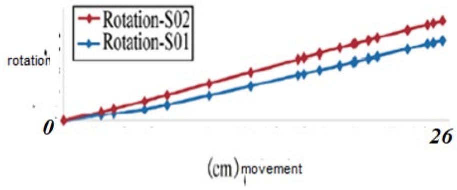

Figure 4 -Rotation of stories of 2-story structures of model 0.8α under additional load in the direction x

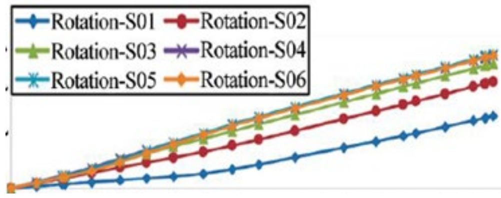

Figure 5 - Rotation of 6-story structures of model 0.8α under additional load in the x direction

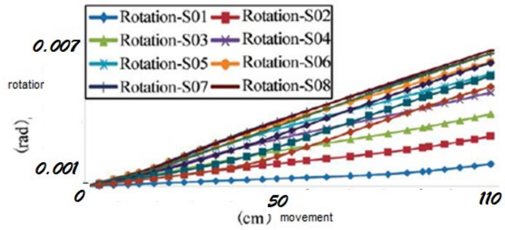

Figure 6- Rotation of stories of 12-story structures of model 0.8α under additional load in the x direction

4-1-1- Investigation of 8th story rotation of 12 story structures

In this section, to compare the irregular amount of 8th story diaphragm rotation is used to present the results. The reason for choosing this story as a criterion is that according to the previously presented shapes, this story has the highest rotation among all stories and also in terms of displacement. It has a higher numerical value than other classes.

4-1-1-1- Rotation of 8th story 12-story structures under additional load in the direction of x

In this part, his loading is applied in the vertical direction of the uneven bearing system (x) because the rotation of the 8th story was more than the other stories, so in the following figure, the rotation diagram of the 8th story under additional load analysis is presented 8 structures of 12.

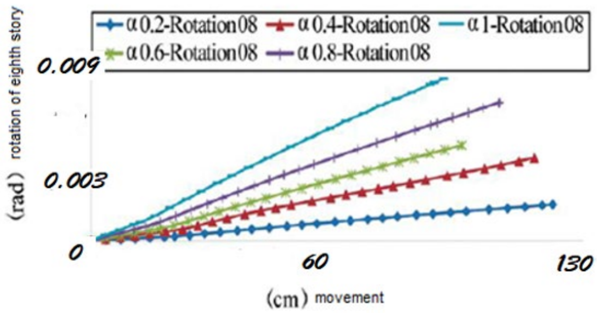

Figure 7- Aperture of the 8th story of 12-story structures under the effect of increasing load in the x direction

As can be seen from Figure (7), as the lateral displacement of the structure increases, the displacement increases with the amount of rotation. As expected, with increasing asymmetry of the irregular bearing system, as the lateral displacement increases, the rotation also increases. Consider the structure 0.2α (the structure with the least amount of asymmetry of the load-bearing system) as the basis. As can be seen from Figure (7), the rotation behavior of structures after the roof displacement is different from the numerical value of 18 cm, so to investigate and compare the rotation of structures in both parts, the section before the 18 cm section displacement The elastic and then the non-classical part are considered and the amount of rotation of the structures is measured, the ratio of which is presented in Figures (8) and (9).

According to Figures (8) and (9) as well as a quantitative comparison of other structures compared to the 0.2α structure, it can be seen that before the plastic stage, the amount of rotation in the structures 0.4α, 0.6α, 0.8α, 1α, compared to Structures 0.2α increased 2.27, 3.28, 4.82, and 6.86, respectively. With the increase of lateral load and the entry of the structure into the plastic stage, the above values have decreased to 2.26, 3.3, 4.4 and 6.13, respectively. It can be said that in 12-story structures, the amount of rotation in the elastic and plastic behavior increases in proportion to the unevenness of the bearing system.

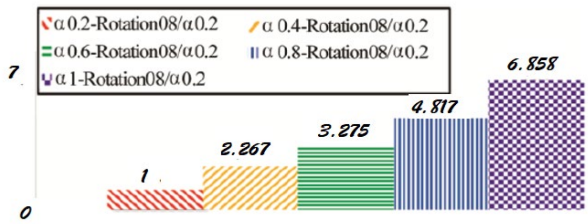

Figure 8 - Rotation ratio of 8th story of 12-story structures to 8th story of 0.2α structure under additional load in the x direction in the elastic range

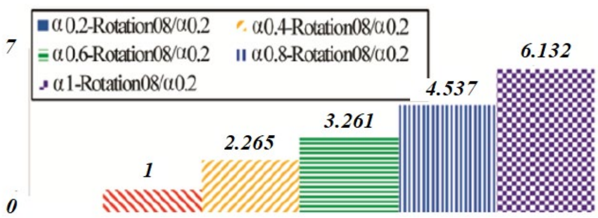

Figure 9- Rotation ratio of 8th story of 12-story structures to 8th story of 0.2α structures under additional load in the x direction in the plastic range

4-1-1-2-Rotation of 8th story 12-story structures under additional load in Y direction

In this part, loading is applied along the uneven bearing system (Y), because the rotation of the 8th story and other stories was more, so in Figure 10, the diagram of the rotation of the 8th story is presented under the effect of additional load analysis.

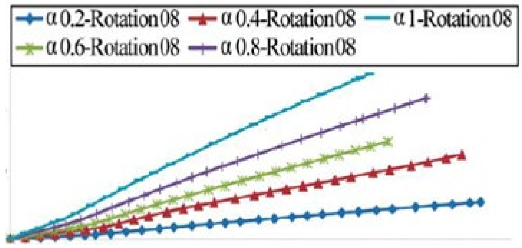

Figure 10 - Class 8 diaphragm rotation of 12-story structures under the effect of additional load in the Y direction

As can be seen from Figure (10), with the increasing unevenness of the bearing system, the rotation of the 8th story of the structures has increased. This indicates that increasing the non-parallelism of the bearing system increases rotation and consequently rotation in structures. It can also be seen from Figure (10) that in this type of loading, the last two structures, i.e. structures 0.8 α and 1 α, have more rotation than other structures in these two loadings, due to the fact that in the model structure 0.8α The angle that the non-parallel axis makes with the bracket with the base of the structure is 45 degrees, so the amount of rotation after the angle of the bearing system exceeds 45 degrees (ie decreasing angle) has sudden changes in this part after moving the roof to The value of 15 cm is the plastic behavior and before that the elastic behavior is considered. Figures (11) and (12) show the values attributed to the rotation of the structure to the reference structure.

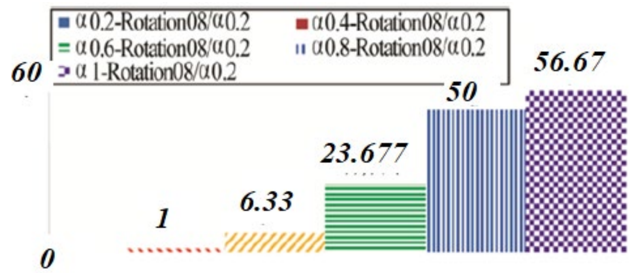

Figure 11- Rotation ratio of 8th story of 12-story structures to 8th story of 0.2α structures under additional load in the Y direction in the elastic range

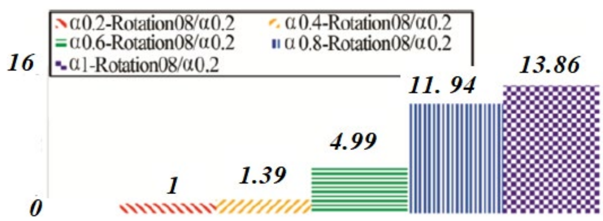

Figure 12- Twist ratio of 8th story structures to 12th story structures to 8th story structures 0.2α under additional load in the Y direction in the plastic range

As can be seen from cities (11) and (12), the rate of change in the rotation of the 8th story of different structures under increasing load in the Y direction in the elastic state is changing with a greater slope than in the plastic state. It is also observed that the amount of rotation changes of the 8th story of the structures compared to the 8th story of the 0.2α structures is 6.39, 23.66, 50 and 56.66 for the elastic state and 1.39, 4.99, 11.93 and 13.85 for the plastic state, respectively. It is observed that in this type of loading, the elastic behavior of structures is more different than their plastic behavior relative to each other.

4-1-2- Investigation of 4th story rotation of 6-storey structures

In this section, to compare the irregular amount of Class 4 aperture rotation is used to present the results. Relative has a higher numerical value than other classes.

4-1-2-1 Story rotation 4 4-story structures under additional load in the X direction

In this part, the load is applied in the direction perpendicular to the non-parallel bearing system (X) because the rotation of the 4th story and other stories was more, so in Figure (13) the diagram of the rotation of the 4th story under additional load analysis is presented. .

Figure 13- Class 4 diaphragm rotation of 6-story structures under the effect of additional load in the x direction

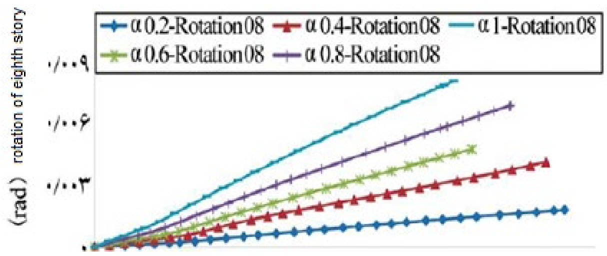

Figure (13) shows that with the increasing unevenness of the rotation bearing system of the 4th story, the 6-story structures under increasing load in the X direction have also increased. The structural curve of model 0.2α is approximately linearly smooth, because the structure has the lowest value of the bearing system angle compared to other structures, so its rotation curve also has the lowest ascending slope. Comparing the curve of model 1α, i.e. a triangular structure with model 0.2α, it can be seen that changes in the angle of the bearing system have many effects on the slope of the rotation curve. The upward trend and slope of the curve of structure 1α are quite visible in Figure 13. In these diagrams, the rotations are considered elastic and then inelastic before the displacement of 10 cm of the structures, and Figures 14 and 15 are assigned values. They show rotation in the elastic and plastic range.

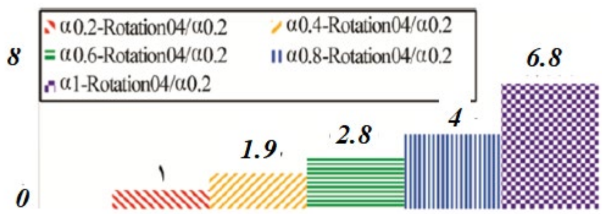

Figure 14- Rotation ratio of 4th story of 6-story structures to 2nd story of 0.2α structure under additional load in X direction in elastic range

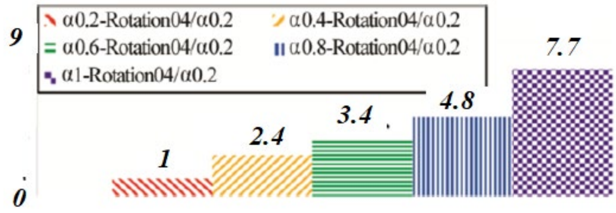

Figure 15- Rotation ratio of 4th story of 6-story structures to 2nd story of 0.2α structure under additional load in the X direction in the plastic range

Consideration of Figures 14 and 15 shows that the amount of rotation changes of the 4th story of 6-story structures to the 4th story of structures under additional load in the X direction in both elastic and plastic states are almost close to each other, but the rotational changes in the plastic state have a trend. And the slope is relatively steeper than the elastic state. It can be seen that the rotation changes of the 4th story structure to the 4th story of the 0.2α structure in the elastic state are 1.89, 2.82, 4.01 and 6.77 times in the plastic state, respectively, 2.43, 23.38, 4.77 and 7.65 is equal to. Compared to the previous comparison of 12-story structures, in the case of applying additional load in the X direction of 12-story structures, the trend of changes in rotation in the elastic and inelastic state in this type of loading is observed, the difference they do not have much in common.

4-1-2-2 Story rotation 4 6-storey structures under additional load in the Y direction

In this section, unloading is applied along the load bearing system because the rotation of the 4th story was higher than the other stories, so in Figure 16, the diagram of the rotation of the 4th story is presented under the effect of additional load analysis.

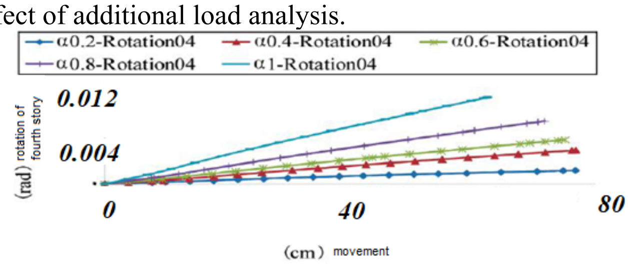

Figure 16- Class 4 diaphragm rotation of 6-story structures under the effect of additional load in the Y direction

Figure 16 shows that the rotation of structures increases with increasing non-parallelism of the load-bearing system. A noteworthy point is the rotation of the 4th story of structure 1α (triangular-shaped structure), which has much more rotation than other structures. As mentioned earlier, in the Model 1α structure, the bearing system angle is less than 45 degrees and has more rotation than other instruments. In the Y load section in the Y direction of 12-story structures, we also saw a change in the rotation changes of structures with a bearing system angle of 45 degrees and less. In this section, the rotation of the structures before the displacement of 10 cm is considered elastic and then non-elastic. Figures 17 and 18 show the relative values in the elastic and plastic states.

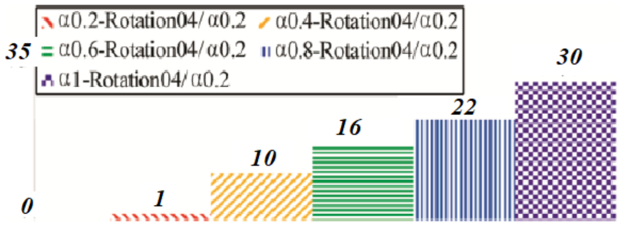

Figure 17- Rotation ratio of 4th story of 6-story structures to 4th story of 0.2α structures under additional load in Y direction in the elastic range

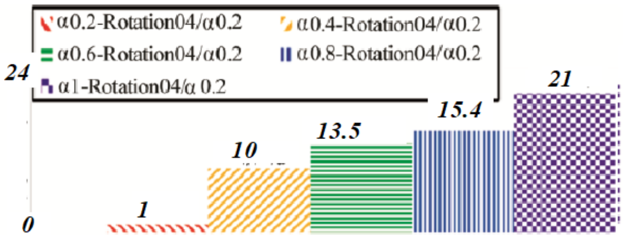

Figure 18- Rotation ratio of 4th story of 6-story structures to 4th story of 0.2α structures under additional load in the Y direction in the plastic range

Figures 17 and 18 show that the rotational changes of the 4th story of 6-story structures under additional load in the Y direction in the elastic state are greater than in the plastic state. In relation to the changes in the rotation of the 4th story, the 6-story structures increased to 0.2 α of the 4-story rotation of the 4th story in the elastic state, 9.93, 16.33, 21.8 and 30.2, respectively, and in the plastic state, 9.61, 13.46, 15.34, and 21.15, respectively. It can be seen that from the very beginning, with only a slight asymmetry of the bearing system, the rotation has increased more than 9 times, which shows the effect of the bearing system angle on the rotation of the stories.

4-1-3- Investigation of 2nd story rotation of 2-storey structures

In this section, to compare the irregular amount of story aperture of the 4th story is used to present the results. The reason for choosing this story as a criterion is that according to the previously presented shapes, this story has the highest rotation among all stories and also in terms of displacement. Relatively, it has shown a higher numerical value than other classes.

4-1-3-1- Class 2 rotation Two-story structures under additional load in the X direction

In this part, the load is applied in a direction perpendicular to the uneven bearing system (X), because the rotation of the 2nd story was more than the other stories, so in Figure 19, the diagram of the rotation of the 2nd story is presented under the effect of additional load analysis.

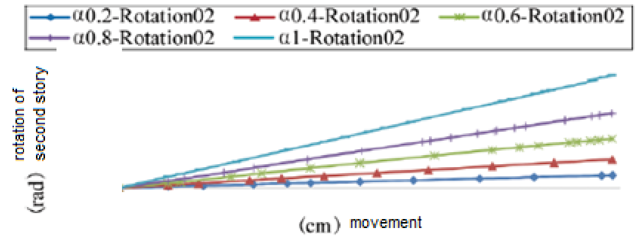

Figure 19- Class 2 diaphragm rotation 2-story structures under the effect of additional load in the X direction

Figure 19 shows that in the 2-story structure, the amount of story rotation has also increased with the increase of unevenness of the bearing system. According to the study on 12- and 6-story structures, it was observed that 2-story structures also showed more elastic behavior under increasing load in the X direction, a problem that we also saw in 12- and 6-story structures. To determine the elastic and inelastic position, the rotation curve is considered to be greater than the displacement of the 8 cm inelastic and previously elastic roof. Figures 20 and 21 show the elastic and plastic values of the rotation of the 2nd story of the structures.

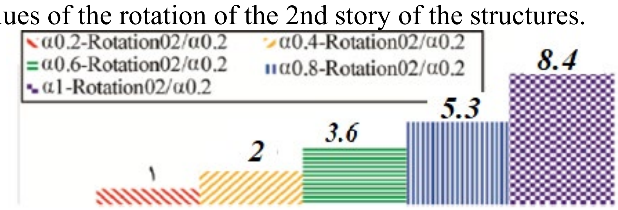

Figure 20- Rotation ratio of 2nd story of 2-story structures to 2nd story of 0.2α structure under additional load in the X direction in the elastic range

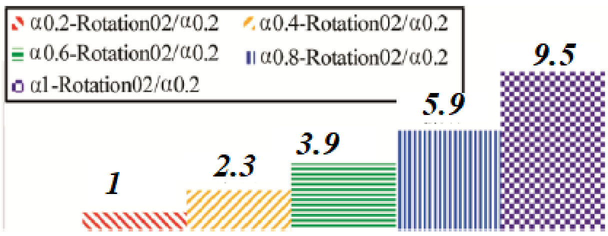

Figure 21- Rotation ratio of 2nd story of 2-story structures to 2nd story of 0.2α structure under additional load in the X direction in the plastic range

Considering Figures 20 and 21 shows that in low-rise structures and in this paper 2 layers, the ratio of changes in the rotation changes of the stories in the plastic and elastic state under additional load in the X direction are not much different from each other. The rotation ratio of the 2nd story The 2-story structures in the elastic state are 2.12, 3.58, 5.31, and 8.41 times, respectively, and in the plastic state are 2.28, 3.89, 5.86, and 9.42 times, respectively. In this type of loading in 2 and 6-story structures, we also saw not so much twisting changes in the elastic and plastic state.

4-1-3-2- Class 2 rotation of two-story structures under additional load in the Y direction

In this part, the loading is applied in line with the uneven bearing system, because the rotation of the 2nd story was higher than the other stories, so in Figure 22, the diagram of the rotation of the 2nd story is presented in the analysis with.

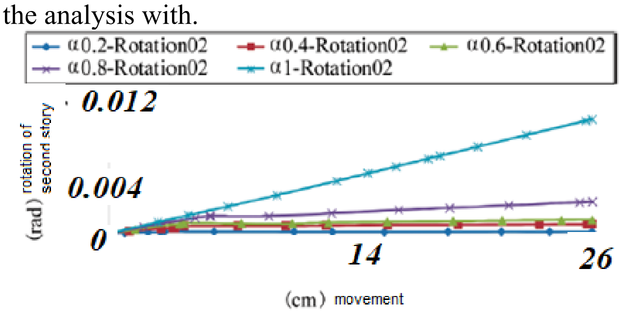

Figure 22- Class 2 diaphragm rotation 2-story structures under the effect of additional load in the Y direction

In this section, considering the diagram of Figure 22, it can be seen that the rotation of the 2nd story of the 2nd story structure of 1α is much higher than other structures, as observed in previous structures. Structure 1α (triangular structure) is significantly larger than other structures. This has happened in all structures with 2, 6 and 12 stories. In this part, the rotation curve is considered inelastic after moving 5 cm and elastic before that. Which 23 and 24 show the values of the rotation ratio in the elastic and plastic states.

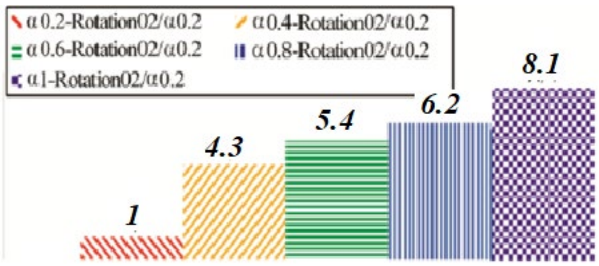

Figure 23- Rotation ratio of 2nd story of 2-story structures to 2nd story of 0.2α structure under additional load in Y direction in the elastic range

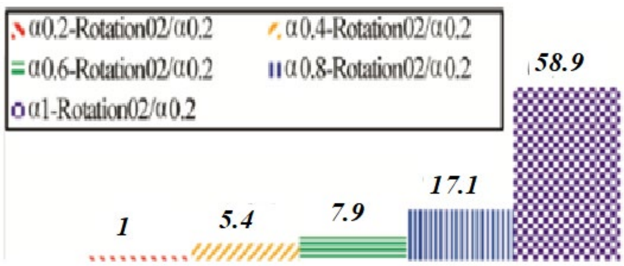

Figure 24- Rotation ratio of 2nd story of 2-story structures to 2nd story of 0.2α structure under additional load in Y direction in the plastic range

In this section, considering the diagrams of sentences 23 and 24, it can be seen that the rotational changes of the 2nd story of 2-story structures under additional load in the Y direction in the plastic state and especially in the 1 α structure are much greater than the rotation in the elastic state. The rotation ratio of the 2nd story of the 2-story structures is 4.3, 5.4, 6.2 and 8.1 times in the elastic state and 5.41, 7.81, 17.12 and 58.83 in the plastic state, respectively. It can be seen that in the plastic state of structure 1 α has shown many changes compared to other instruments. Compared to the plastic state diagrams of 6 and 12 storey structures, it can be seen that in 2-storey structures, the amount of rotation model 1α has suddenly increased.

4-2- Results of linear dynamic time history analysis

In this section, the rotation of the stories is calculated and examined by linear dynamic analysis. The calculated rotations are the ratio of the rotation of each story to the rotation of its lower story, which is applied under four linear dynamic loads in two directions: south-north and east-west. The results of separating each load separately are given below.

4-2-1- Rotation of structures under the Tabas earthquake record in the X direction

From Figures 25, 26 and 27, it can be seen that in all structures with different stories, the rotation of the stories has increased with increasing unevenness of the bearing system. As can be seen, the rotation of the stories in this case of loading has a direct relationship with the amount of asymmetry of the bearing system, ie increasing the asymmetry of the bearing system has increased the rotation of the stories, which means that structures with a more inverted bearing system under more rotation They are placed on regular structures with a parallel bearing system; another requirement that can be seen from the observation of diagrams is to reduce the amount of rotation by increasing the height of the structure. In the rotational dynamic state, the 0.8 α and 1α models have a leap relative to the rotation of other structures. In the incremental load analysis section, it was observed that the structures with a bearing system angle of 45 degrees and less had a higher rotation than other structures.

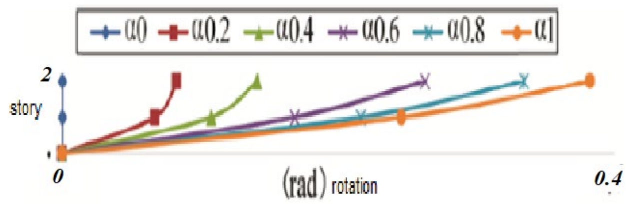

Figure 25- Rotation of the stories of 2-story structures under the Tabas earthquake in the X direction

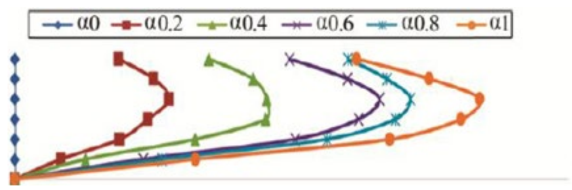

Figure 26- Rotation of the stories of 6-story structures under the Tabas earthquake record in the X direction

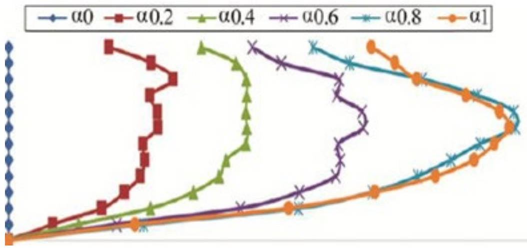

Figure 27- Rotation of the stories of 12-story structures under the Tabas earthquake record in the X direction

4-2-2- Rotation of structures under the Tabas earthquake record in the Y direction

It can be seen from Figures 28, 29 and 30 that in all instruments and with different heights, with the increasing unevenness of the bearing system, the unevenness of the story twist has also increased. It should be noted that the rotation of a regular structure, 0 α, is not zero, but is so small that it can be considered zero. As can be seen in the loading in the direction of the uneven bearing system, with increasing the height of the structures, the rotation of the stories has decreased. Thus, 2-storey structures have the most rotation and 12-storey structures have the least rotation. In loading applications in this direction, if we examine the maximum diaphragm rotation of each structure, it is observed that in models 0.8α and 1 α they have much more rotation than other structures, so that the rotation of these two models has grown exponentially in the graph. . The effects of the amount of angle between the bearing systems can also be seen in the results.

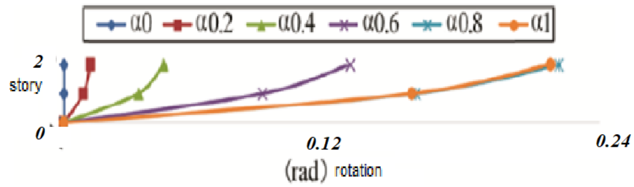

Figure 28- Rotation of stories of 2-story structures under the Tabas earthquake record in the Y direction

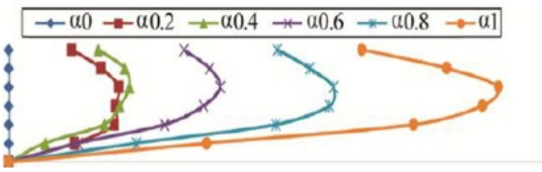

Figure 29- Rotation of the stories of 6-story structures under the Tabas earthquake record in the Y direction

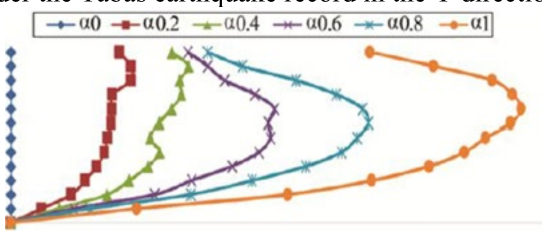

Figure 30- Rotation of stories of 12-story structures under the Tabas earthquake record in the Y direction

4-2-3- Rotation of structures under the Centro earthquake record in the x direction

In this section, where linear dynamic loading is applied perpendicular to the bearing system of the nomadic bearing (X), it is observed that increasing the bearing of the bearing system increases the rotation. Codes 31, 32 and 33 show that with increasing bearing of the bearing system increases , The rotation has increased and this increase has decreased to 0.6α the amount of this upward trend. Stories are also increased in this phenomenon is seen in all three structures with different stories.

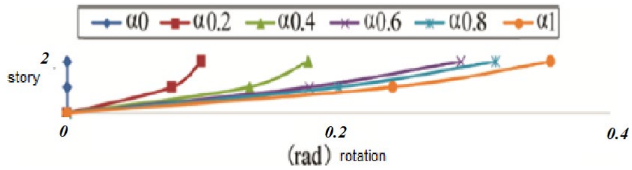

Figure 31- Rotation of the stories of 2-story structures under the El Centro earthquake record in the X direction

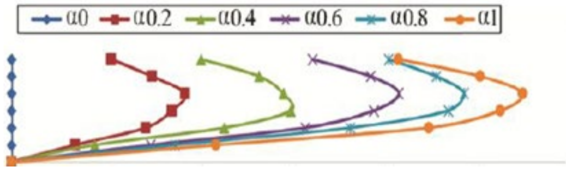

Figure 32- Rotation of the stories of 6-story structures under the El Centro earthquake record in the X direction

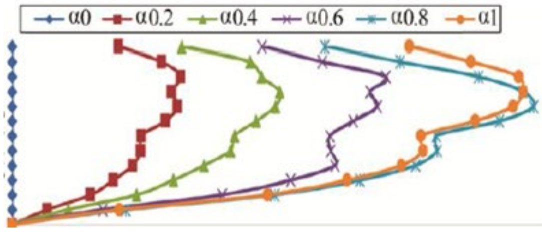

Figure 33- The rotation of the stories of 12-story structures under the El Centro earthquake record in the X direction

4-2-4- Rotation of structures under the Centro earthquake record in the Y direction

In this section, loading along this uneven bearing system is applied and the following results are obtained. It can be seen from Figures 34, 35 and 36 that with increasing unevenness of the bearing system, the rotation of the stories has also increased. In 2-story structures, the rotation changes of structure 1 α are greater than other structures. Excluding the rectangular model, ie 0α, the rotation of the stories to the structure has increased by 0.8 α with an almost certain ratio, but in the structures of 1 α, this ratio has decreased.

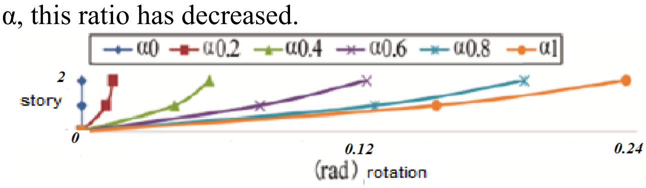

Figure 34- Rotation of the stories of 2-story structures under the El Centro earthquake record in the Y direction

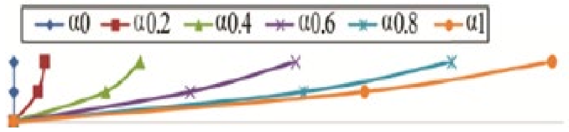

Figure 35- Rotation of the stories of 6-story structures under the El Centro earthquake record in the Y direction

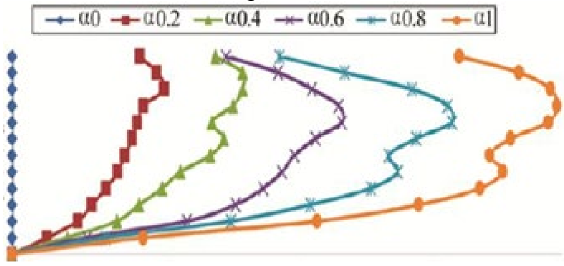

Figure 36- The rotation of the stories of 12-story structures under the El Centro earthquake record in the Y direction

4-2-5- Comparison of story rotation with reference structure

In Figures 37, 38 and 39, the rotation of 2, 6 and 12 storey structures is compared to the rotation of 2, 6 and 12 storey structures 0.2α and compared with different loads. Due to the fact that maximum rotation occurred in 2-storey structures on the 2nd story, in 6-storey structures on the 4th story and in 12-storey structures on the 8th story, the rotation of the mentioned stories has been attributed. Figures 37, 38 and 39 show that in all structures, with different stories and all loads, with increasing unevenness of the bearing system, the rotation of the stories has also increased, so it is obvious that in any structure, increasing unevenness is equal to increasing the rotation in it. It is a structure. The rotation of structures under load along the uneven bearing system (Y) has much greater and more intense relative displacement changes than the loading applied perpendicular to the uneven bearing system. This effect is much more noticeable in short structures than in tall structures because it is observed that with increasing the height of the structures, the difference between the rotation ratio of the structures between the loads in the direction of parallel and perpendicular load-bearing system has decreased. For example, the changes in the rotation of 2-story structures with increasing unevenness of the load-bearing system and under loading by Tabas in the Y direction are equal to 3.77, 10.85, 18.77 and 18.44, respectively, while this ratio is 1.59, 2.61 for 12-story structures, respectively. 3.48 and 5.06 are equal. Therefore, it can be concluded that the load rotation in the direction of the non-parallel bearing system is critical for short critical structures, but for taller structures, there is not much noticeable difference in the results measured compared to the reference structure.

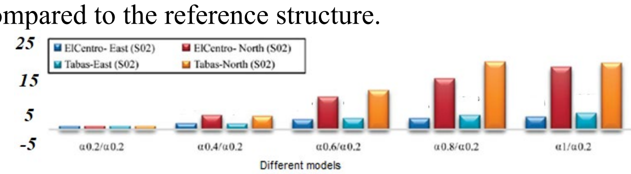

Figure 37- Rotation of 2nd story of 2-story structures to rotation of 2nd story of 0.2α structures under linear dynamic loading

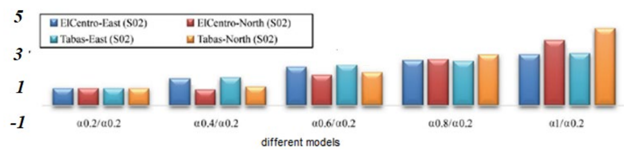

Figure 38- Rotation of 4th story of 6-story structures to rotation of 4th story of 0.2α structures under linear dynamic loading

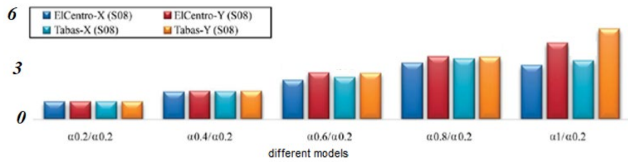

Figure 39- Rotation of 8th story of 12-story structures to rotation of 8th story of 0.2α structures under linear dynamic loading

5. Conclusion

By three-dimensional modeling of the introduced structures and applying the non-parallel bearing system by changing the plan of the structures and by applying the loads of linear dynamic time history and incremental load in two directions separately, the results are obtained as follows. We first deal with the results of nonlinear static analysis. In structures that have an uneven bearing system, the maximum diaphragm rotation is related to the story, which is between 60 to 70% of the height of the structure from the base level. Examining the diaphragm with the highest rotation in each structure, it was found that as the load-bearing system is uneven, the rotation of the story also increases. It was also observed that in the application of loads in the direction of uneven bearing system (Y), the rotation for tall structures is up to 56 times and for short structures up to 8 times more than parallel structures (model structure 0.2α) This occurs when the ratio for loading in the direction perpendicular to the bearing system (X) is 6 and 8 times, respectively, so in this type of structure loading along the bearing system (Y) has critical results Terry is in line with other loading operations. The results of rotation in the plastic state are different from other loads in the application of overload in the direction of (Y), in the load of overload in the direction of (X) the elastic and inelastic behavior of structures are not much different from each other and their differences can be ignored. But in the analysis of linear dynamic time history, the results are as follows. The two models 0.8 α and 1α in both directions of load application have a sudden rotation of the diaphragm relative to other structures. For structures with different number of stories and the same plan, the amount of maximum rotation aperture decreases with increasing height. In short-term structures, the rotation of non-parallel structures is up to 18 times higher than the rotation of 0.2 α model structures, this value is up to 5 times higher for 0.2α model structures. Increasing the height reduces the amount of rotation, and increasing the height also reduces the rotation ratio of non-parallel structures to less non-parallel structures. The bottom line is that loading in a state along the uneven (Y) bearing system produces more unpredictable and critical results.

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