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Study of Non-linear Dynamic Behavior of Structures with Steel Shear Wall under the Near Fault Earthquakes

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ABSTRACT: This paper deals with study of the steel shear walls and dynamic analysis of such structures under the earthquakes near fault. The studied frames in this paper have a span in 4-meter width and 3-meter height and are included 3 spans. We studied the dynamic of frames after modeling the frames in ABAQUS and giving the earthquake acceleration records near Kobe, Lomaprieta, and Northridge. The results showed that the increase of number of storey increases maximum storey displacement of moment frames. The increase of thickness the shear wall also will decrease the displacement of maximum storey because of decreasing the non-linear effects of shear wall and the delay on submission. Therefore, Base shear in moment frames of 3, 6, and 12-storey, not only depends on maximum acceleration and acceleration records, but also depends on the form of acceleration records. By increasing the number of the storey, this efficacy will be decreased so that the maximum acceleration would be more effective on the storey shear increase or decrease. We can say, by increasing the number of storey of vibration mode, maximum acceleration of storey has the regular process in each 3 acceleration record. It seems that the acceleration of storey not only is based on the type of acceleration record but also is based on the other elements such as increasing the thickness of shear wall and number of the storey. Maximum response in the last storey would not that change by increasing the thickness of shear wall but in the response of other storey, has 6 storey especially storey 3, 4, and 5 in the frame. We can conclude that acceleration of the storey compared to acceleration of column has had the increasing process, by watching the response of acceleration record. The increase of shear wall also decreases the acceleration of storey.
Keywords: Dynamic Analysis, Near Fault, Steel Shear Wall, ABAQUS Software, Base Shear.

INTRODUCTION

Since creation, earthquake has been one of the natural events that exact so many human and financial losses. Therefore, human beings have always been searching for solutions dealing with such event. In the early 20 century, with the advancement of science and being more familiar with earthquake and the behavior of structure against earthquake, possibility of construction and designing resistant and safe structures against the exerted forces has been given so that by designing and construction of structures with high safety, probability of human and financial losses will be decreased. The exerted forces on structures can be divided into gravity structure forces and accessory structure forces. And from accessory forces, we can point out the force of earthquake which has been affected designing of most structures (Astaneh-Asl, 2001).

At structure engineering science, the purpose of designing of safe structures against the exerted forces is the design and the build of those structures not only pay attention to the economic issues but also, be tolerated against the interfered forces. At present time, most of the structures are made based on related instructions. These building regulations are the simplified result of the measures of calculating the force interfered on structure which the stability needed for the structures can also be calculated. Basically, in the building regulations, philosophy of designing a stable building against earthquake has two main rules: first, building in average earthquakes should not be destroyed and second, in the intense earthquakes, building should be stabled without a total destruction. In analysis of a building structure, concepts of a medium an intense earthquake should be specified in total until they can be given in any calculation. For instance, the given concepts in the regulations 2800 of Iran and UBC97, the issues related to necessity of stability of structure and the optimized design of structures for not wasting the finance, leads us to a complete recognition of the interfered forces and the behavior of a structure which is included the different materials with different transportation systems with a true predict of forces and behavior of a structure and an appropriate design, not only the safety and stability of a structure will be provided but also, the project will be done economically. Considering the possibility of a complete cognition of gravity forces and their metrology using practical and laboratory experiments and also behavior of materials and totally, behavior of structure

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under effect of such forces, possibility of detailed and reliable design exists against these types of forces but accurate prediction the behavior of structure under effect of these forces needs a closer look because of lack of a perfect cognition of earthquake and exerted forces (Astaneh-Asl, 2001).

To study response the behavior of a steel shear wall under near fault records, 3type of records so called Kobe, Lomaprieta, and Northridge have been used. The used models in this study are moment frames of 3, 6, and 12-storey which are formed of beam and column. Rigid is intended the connection between beam and column. Also, to affect thickness of the shear wall on structure seismic response, 3 types of thickness 3, 5, and 10 millimeter in the moment frames of 3, 6, and 12storey have been used. The models span are formed from 3-span frames with 4-meter width and 3- meter height. And also in the studied models, dead load 600 kg/m^2 and live load 200 kg/ m^2 were used. Distance between each frame is intended 4.5 meters. Modeling has been done in ABQUS software.

This is a finite -element software that not only has an extended capability, but also is easy to learn. The finite element method (FEM). The ABAQUS software provides the capability of simulation the complex problem in different fields of civil and mechanic engineering and etc. Although doing the practical experiments costs much, simulation the finite elements can be an alternative tool. This software also can provide an extended capability for simulation in linear and non-linear usages. The issues that have several elements and different materials with the explanation of the geometry of each element and specifying their materials and then, the interaction among these elements can be simulated. In the non-linear analysis, ABAQUS automatically selects a suitable convergence tolerance and continuously sets these parameters along the analysis to reach a confident result (Ziaei and Elnaz, 2009).

MATERIALS AND METHODS

Elements of an analytical model (ABAQUS/CAE)

ABAQUS/CAE is a complete environment that has a simple and user-friendly environment for designing the ABAQUS models, analysis and observation the processes of analysis the results of simulation. This software is divided into several module and each module handles part of modeling process. For instance, some modules are specified for explaining the model geometry, characters of materials, and mesh generation. Properties by selecting from one module to another and related modeling process and frequency of this work till last module the finite element model will be provided. When designing the model is done, ABAQUS will make an input file and will deliver the designed model to the processing sector. The standard ABAQUS processors and explicit ABAQUS read the input file and then analyses them and at the same time send the messages to the ABAQUS/CAE to let the user be on the process of analysis.

Then, the station of output data will be provided. And finally, the visualization module is used for reading from the output data station and displaying them (Soroushnia and Beheshtian, 2012)

Using different modeling modules in abaqus software

Using module Part

First, different elements of the steel shear wall in module Part have been made. Different designed elements in this model are:

1. The shear wall beams and columns are made by Wire-Planar so that beams and columns should be made then, such elements are made.
2. The steel shear wall should be made by Shell-Planar capability.

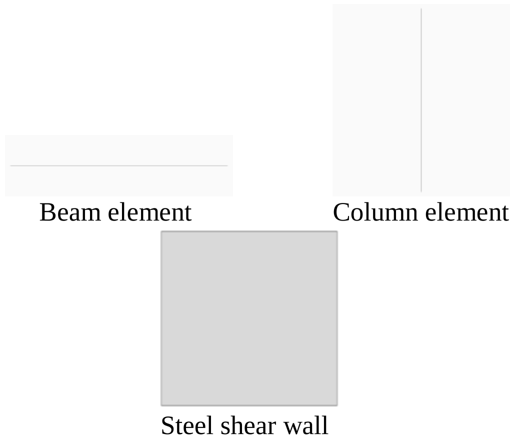

Figure 1. Modeling the elements in the software.

Using property module

In this module, different characters of used steel in this study which is st-37 such as density, elasticity modulus, and explanation of non-linear character will be introduced to the software. Then, regarding to different sheet thickness in different elements of shear wall, the Shell-Homogeneous Capability is used. Next, we will describe the different aspects. The material properties are shown in table 1.

Table 1. Properties of materials

Row	Title	Quantity
1	Yield stress	Fy = 2400 kg/m2
2	failure stress	Fy = 3700 kg/m2
3	Young`s module	E = 2.1E6

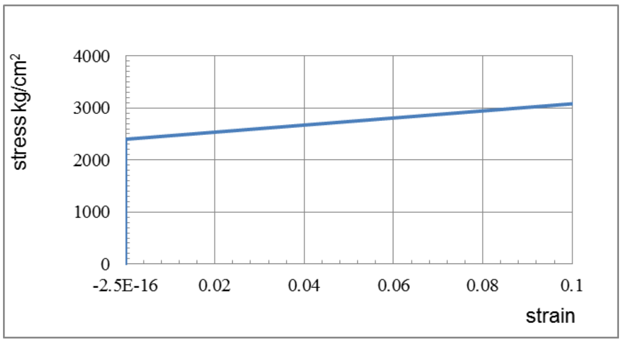

Figure 2. Stress - strain diagram.

To explain the aspect of beams and columns, the beam-beam cross section capability in the software and explanation of the I-Shape profile is used. In the next step, capability of program Assign for assigning the introduced aspects to the elements of different parts of the wall has been used.

Using Assembly module

In this step, we assemble the different parts of a shear wall then, we put each part or its place using different capability of this program such as different transition and restrains. Finally, this assembled model with elements of wire will be merged.

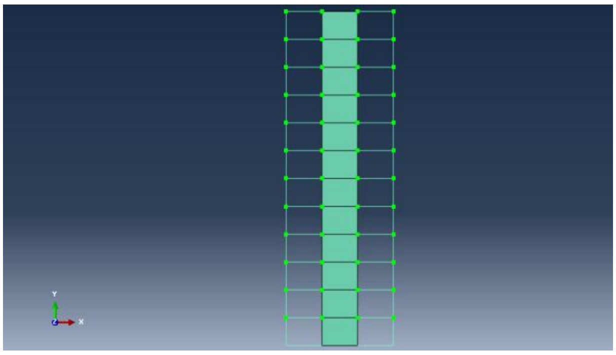

Figure 3. Designed steel shear wall.

Using step module

According to the kind of analysis, type of Step will be determined. In this study, to determine the frequency time of the shear walls with different arrays, firstly, capability of the Linear Perturbation and Frequency of Step module has been used. Number of specific quantity is intended 5. For the non-Linear dynamic analysis, the Dynamic Implicit method has been used. And according to the applied acceleration record, each second of each acceleration record is divided into 10,000 Increment.

Using interaction module

In this study, connection of the steel shear wall to beam and column is determined in rigid.

Using load module

In the study, we stopped moving out of steel shear wall system. This has been done restraining the level of releasing of these edges vertically on a wall. Base of the system of the wall also has been intended jointly. Here is the way of loading. To recording the acceleration based on steel shear wall, firstly, we should release the releasing level on the way of acceleration record. Then we record the acceleration of the earthquake.

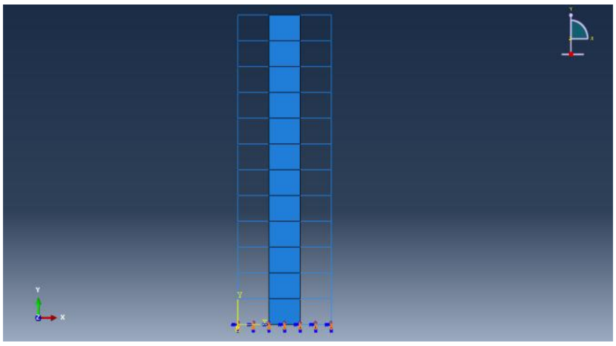

Figure 4. The way of loading and restraining plate shear wall.

Using module Mesh

In this analysis, the element S4R for modeling and meshing the steel shear wall and from element B31 for modeling and meshing the beams and columns has been used. According to simplicity of modeling, resizing mesh didn't much change the results. Meshing process of shear wall is drawn below. Then, by making a job and starting the program, the analysis result will be given.

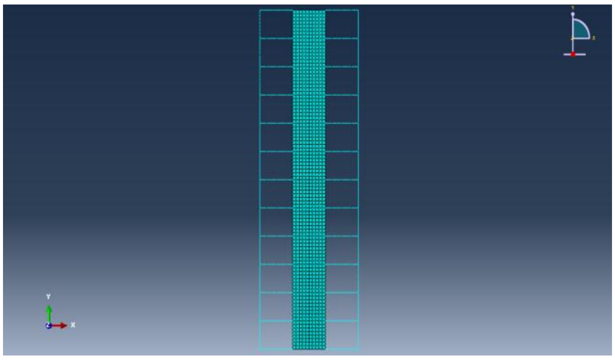

Figure 5. Meshed shear wall in the software.

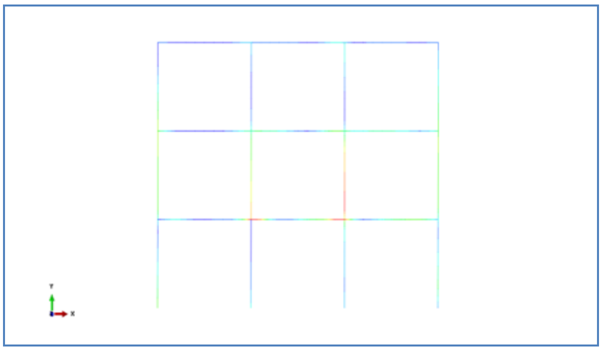

Figure 6. Stress distribution in the 3-storey frame.

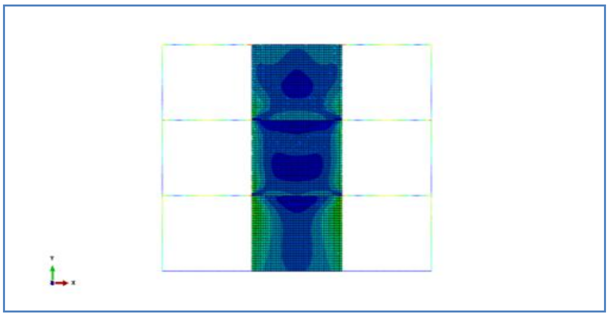

Figure 7. Stress distribution in the moment frame with steel shear wall.

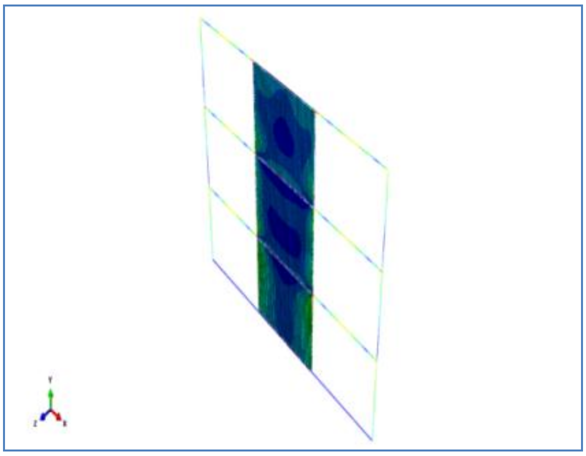

Figure 8. Stress distribution in the moment frame with steel shear wall.

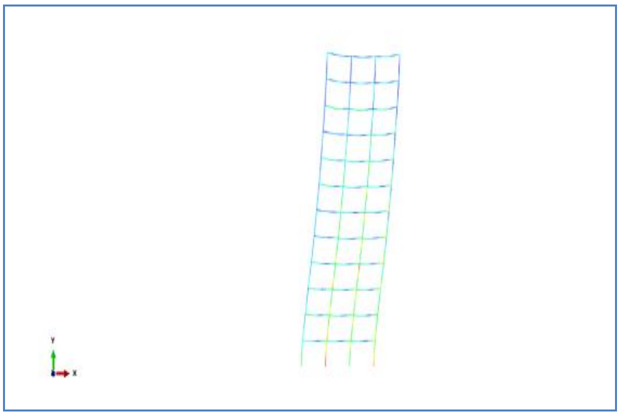

Figure 9. Deformation of 12-storey structure.

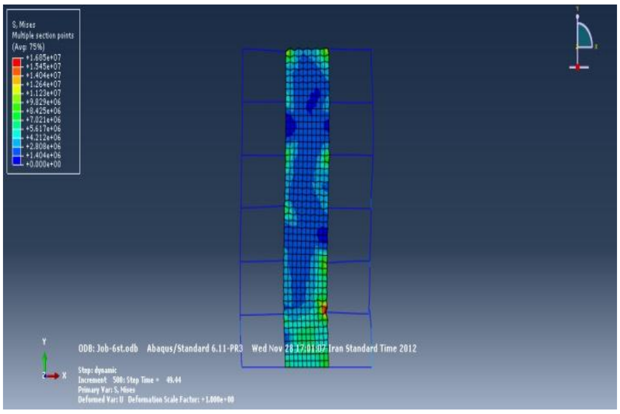

Figure 10. From maize stress distribution in the 6-storey steel moment frame.

Description of samples

To study the response of the behavior of the steel shear wall under records of near faults, three types of records; Kobe, Lomaprieta, and Northridge have been used. The used models in this study are 3, 6, and 12 storey-moment frames which are made of beam and column elements.

The joint between beam and column is rigid. Also, to affect the thickness of the shear wall on vibration response of a structure, 3 types of thickness, 3, 5, and 10 mm in the 3, 6, and 12 storey moment frames have been used.

Span of models is formed of 3-span frames with 4-meter width and 3-meter height. Therefore, in the studied models, the dead load 600kg/m^2 and live load 200 kg/m^2 are used. The distance between each frame is considered 4.5 meters. Modeling is done in the ABAQUS software.

Introduction the models

Table 2. Column sections.

Storey	A-1	B-1	C-1	D-1
1-3	IPB45	IPB45	IPB45	IPB45
3-6	IPB40	IPB40	IPB40	IPB40
6-9	IPB34	IPB34	IPB34	IPB34
9 -Roof	IPB30	IPB30	IPB30	IPB30

Table 3. Beam sections.

Storey	A-B	B-C	C-D	1-2	2-3
1-3	IPE45	IPE45	IPE45	IPE45	IPE45
3 -6	IPE45	IPE45	IPE45	IPE45	IPE45
6 -9	IPE40	IPE40	IPE40	IPE40	IPE40
9 -Roof	IPE36	IPE36	IPE36	IPE36	IPE36

Introduction of acceleration records in Table 4.

Table 4. The earthquake acceleration records data in the present paper.

No	Year	Earthquake	M_W	Mech	PGA (g)	PGV (Cm/s)	PGD (Cm)
1	1989	Lomaprieta	7	OB	0.56	94.81	41.13
2	1989	Lomaprieta	7	OB	0.41	94.26	36.66
3	1994	Northridge	6.7	TH	0.84	174.79	48.96
4	1994	Northridge	6.7	TH	0.84	130.37	31.7
5	1994	Kobe	6.9	SS	0.82	81.62	17.71

RESULTS AND DISCUSSION

This paper has been addressed to study on steel shear walls and dynamic analysis of these structures under the earthquakes near fault. The studied frames had the span with 4-meter width, 3-meter height, and 3 spans. After modeling the frames in ABAQUS and giving the acceleration records of earthquake near faults Kobe, Loma- prieta, and Northridge, we studied the dynamic frames.

The results in this paper are stated below.

As shown in diagram 1, these diagrams indicate the response of maximum acceleration of storey under different earthquakes. Consequently, the increase of thickness diagram 1 is related to maximum acceleration of storey in the moment frame under the earthquakes near faults, Kobe, Lomaprieta, and Northridge. Maximum acceleration of the storey from storey 1 until storey 3 in Lomaprieta and Northridge has increased and in earthquake Kobe, this acceleration comparing to the first floor, has decreased on the second floor and again, increased to 10.53 on the third floor.

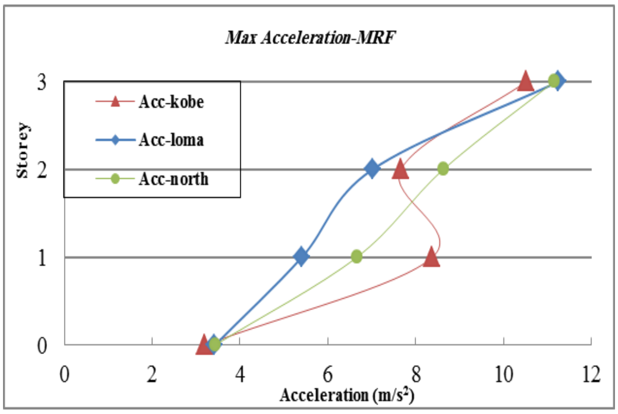

Diagram 1. Comparison amounts of storey max-acceleration in the 3-storey moment frame under near fault Kobe, Lomaprieta, and Northridge.

Therefore, we can say that maximum acceleration of storey from first until third floor in the moment frame has been increased.

As shown in figure 1, the acceleration of storey has been increased from 2.3 cm/s^2 to 11.14 cm/s^2. The shear wall has not affected response of maximum acceleration of the storey at the earthquake, Kobe. But at Northridge and Lomaprieta, shear wall both increases and decreases the acceleration of storey. It seems that the non-linear behavior of shear wall can be affected the response of maximum acceleration of storey.

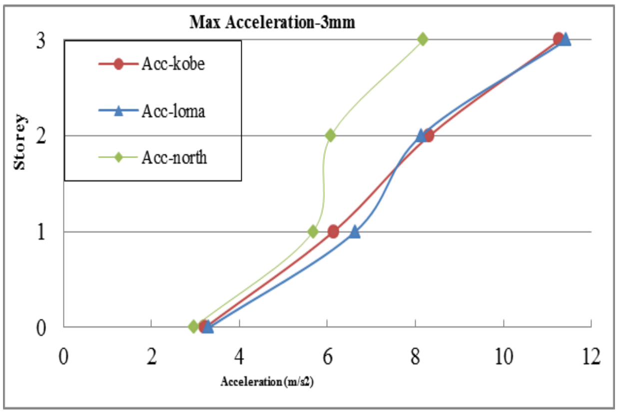

Diagram 2. Comparison amounts of storey max-acceleration in the 3-storey moment frame with shear wall with 3 mm thickness under near fault Kobe, Lomaprieta, and Northridge.

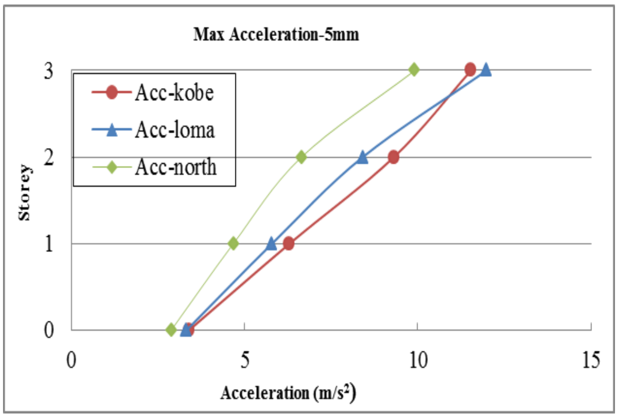

Diagram 3. Comparison amounts of storey max-acceleration in the 3-storey moment frame with shear wall with 5 mm thickness under near fault Kobe, Lomaprieta, and Northridge.

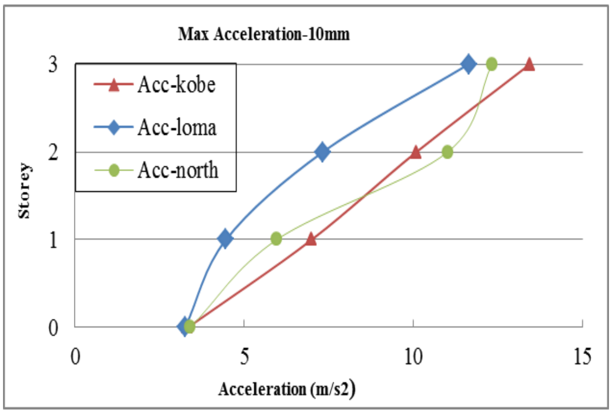

Diagram 4. Comparison amounts of storey max-acceleration in the 3-storey moment frame with shear wall with 10 mm thickness under near fault Kobe, Lomaprieta, and Northridge.

Diagram 5 shows the amounts of the storey maximum acceleration in the 6-floor moment frame. From such diagrams we can conclude that acceleration of storey on the last floor has not that changed compared with the ground floor but irregularity in response of the storey acceleration in other storey compared with samples of a moment frame is 3-storey more.

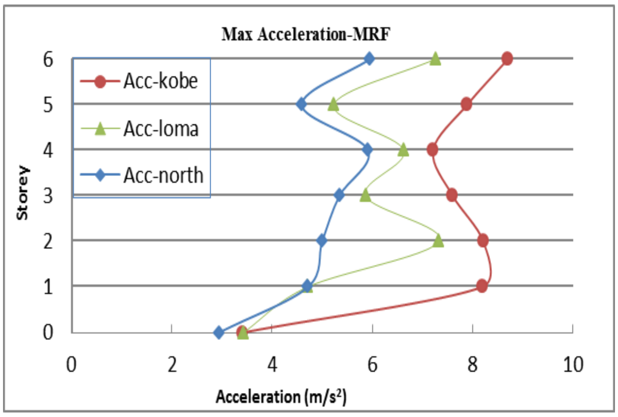

Diagram 5. Comparison amounts of storey max-acceleration in the 6-story moment frame under near fault Kobe, Lomaprieta, and Northridge.

Diagrams 6 until 8, are the amounts of max-acceleration of storey in the 6-floor moment frame with the shear wall with 3, 5, and 10 mm thickness under the earthquakes near Kobe, Lomaprieta, and Northridge.

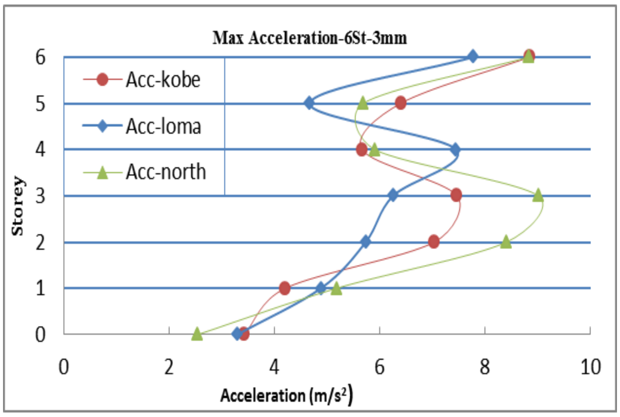

Diagram 6. Comparison amounts of storey max-acceleration in the 6-storey moment frame with shear wall with 3 mm thickness under near fault Kobe, Lomaprieta, and Northridge.

As shown, we can say that the increase of a shear-wall thickness has not changed the vibration mode in the structure. The increase of thickness in a shear wall will either increase the acceleration of storey or will be stabilized compared with the base acceleration.

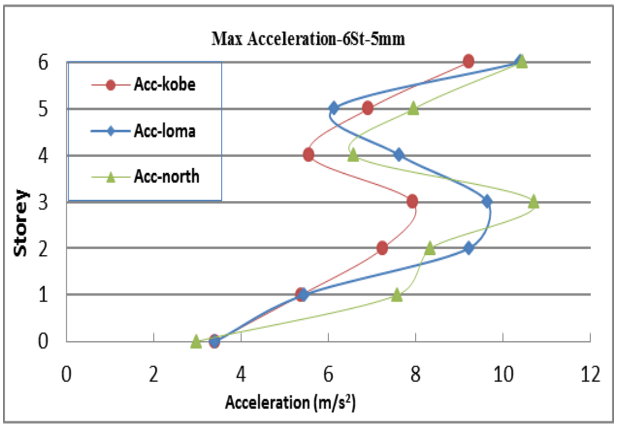

Diagram 7. Comparison amounts of storey max-acceleration in the 6-storey moment frame with shear wall with 5 mm thickness under near fault Kobe, Lomaprieta, and Northridge.

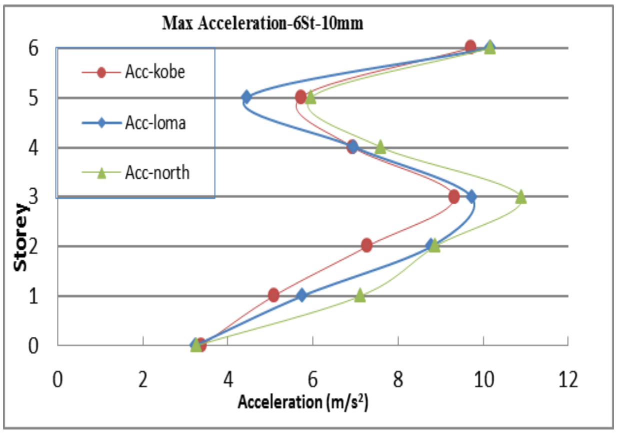

Diagram 8. Comparison amounts of storey max-acceleration in the 6-storey moment frame with shear wall with 10 mm thickness under near fault Kobe, Lomaprieta, and Northridge.

Diagram 9 related to the amounts of maximum acceleration of storey in the moment frame 12-storeys is under near faults Kobe, Northridge, and Lomaprieta.

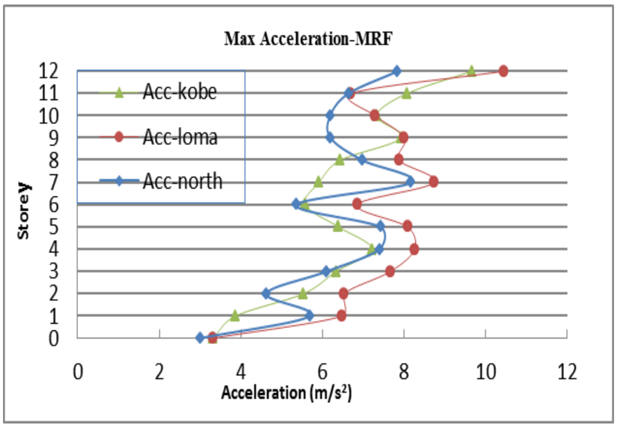

Diagram 9. Comparison amounts of storey max-acceleration in the 12-storey moment frame under near fault Kobe, Lomaprieta, and Northridge.

The results show that the vibration mode of storey acceleration follows a special sample. And also, according to samples of the moment frame 3, 6, and 12 storey, we can say that the increase of storey has decreased the acceleration of storey, compared with each other and will make more regular the form of vibration structure.

Therefore, we can conclude from diagram 10 the increase number of storey from 3-6 will increase the maximized move ability. The result showed that the increase of shear wall thickness would decrease the storey move ability on 6-storey frame.

Diagrams 10, 11 and 12 are the amounts of the storey maximum acceleration on the 12-storey moment frame with shear wall in thicknesses 3, 5, and 10mm under different earthquakes near fault. Due to the figures 10, 11, and 12 thicknesses decreasing would increase the storey acceleration and also the vibration mode of the structure will remain stable.

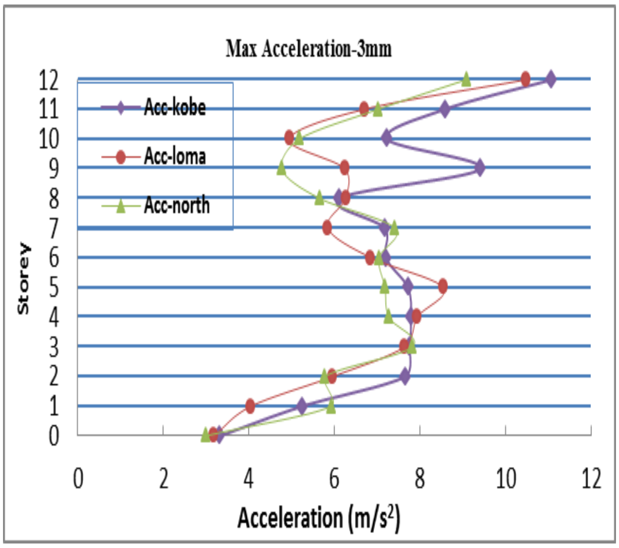

Diagram 10. Comparison amounts of storey max-acceleration in the 6-storey moment frame with shear wall with 3 mm thickness under near fault Kobe, Lomaprieta, and Northridge.

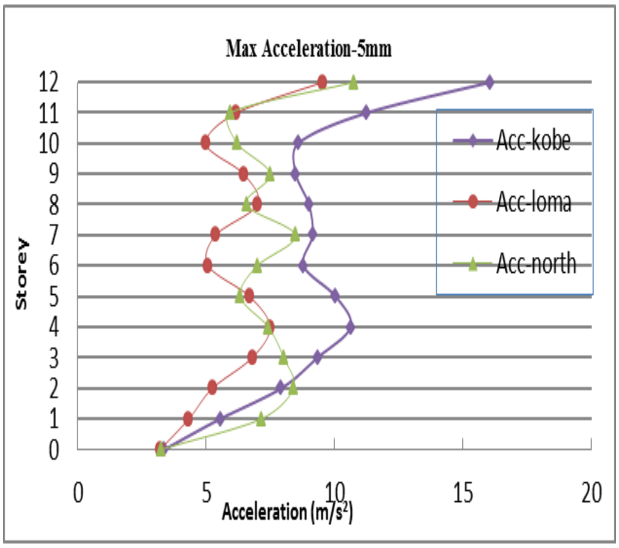

Diagram 11. Comparison amounts of storey max-acceleration in the 12-storey moment frame with shear wall with 5 mm thickness under different earthquakes near fault Kobe, Lomaprieta, and Northridge.

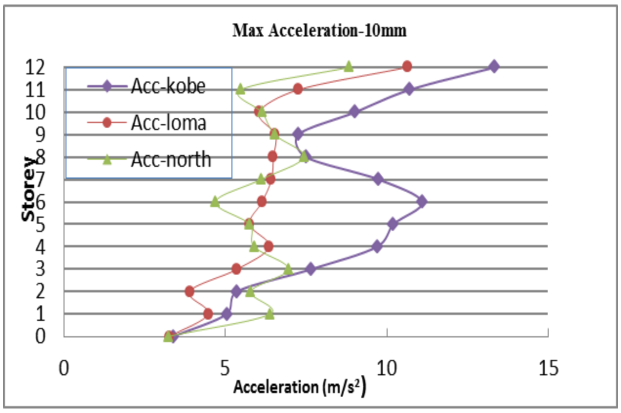

Diagram 12. Comparison amounts of storey max-acceleration in the 12-storey moment frame with shear wall with 10 mm thickness under near fault Kobe, Lomaprieta, and Northridge.

Diagram 13 is related to comparison the amounts of the storey base shear on 3-storey moment frame under earthquakes near Kobe, Lomaprieta, and Northridge.

As shown, the less base shear is related to the earthquake Lomaprieta with the amount of 66Kn and the most base shear is related to the earthquake Kobe with amount of 74Kn. Diagrams 13 and 14 are related to comparison the amounts of the shear in the moment frame with the 3-storey shear wall under earthquakes Kobe, Lomaprieta, and Northridge. As indicated, the increase of shear wall thickness increases the base shear because of the increase of storey.

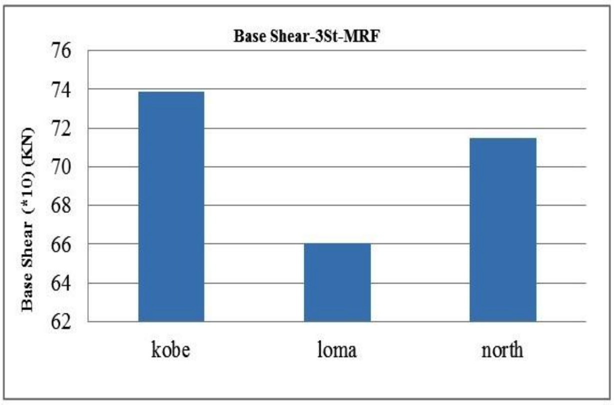

Diagram 13. Comparison amounts of storey base shear in the 3-storey moment frame under different earthquakes.

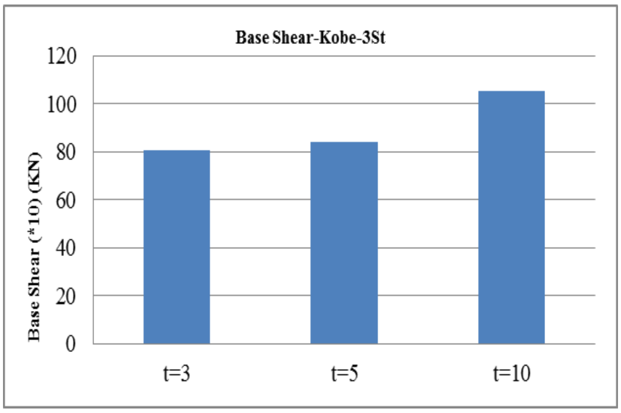

Diagram 14. Comparison amounts of storey base shear in the moment frame with 3-storey shear wall under near fault Kobe.

We can conclude from diagrams 13 and 14 that the earthquake Lomaprieta which has had the less base shear compared to other earthquakes, has acted reversed compared to increasing the shear wall thickness. It seems that increasing the hardness of the moment frame and increasing the earthquake intensity in response of the base shear has direct effect. This process of results has also repeated in the other samples of 6-storey and 12-storey with shear wall in moveable thicknesses under various earthquakes. These results are shown in diagrams 15 to 18.

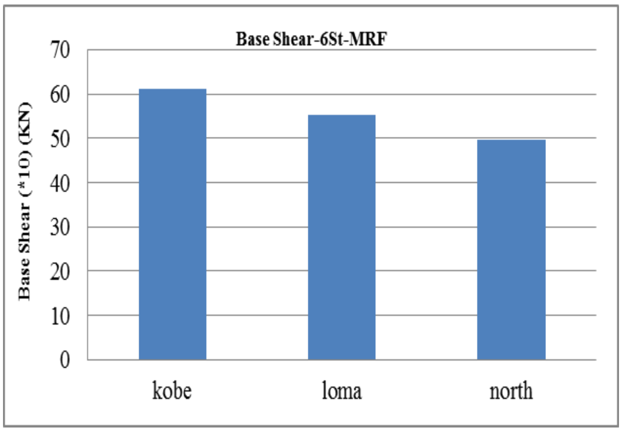

Diagram 15. Comparison amounts of storey base shear in the 6-storey moment frame under different earthquakes.

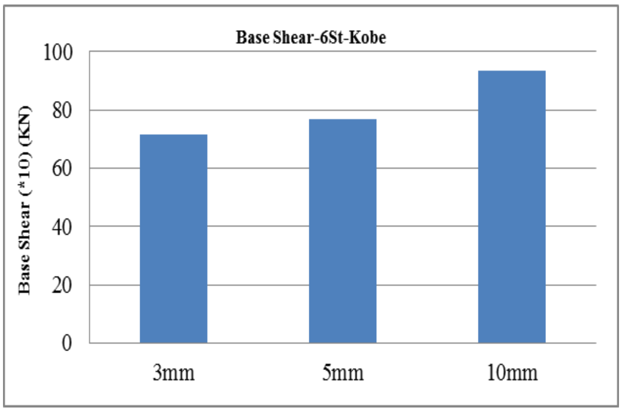

Diagram 16. Comparison amounts of storey base shear in the moment frame with 6-storey shear wall under near fault Kobe.

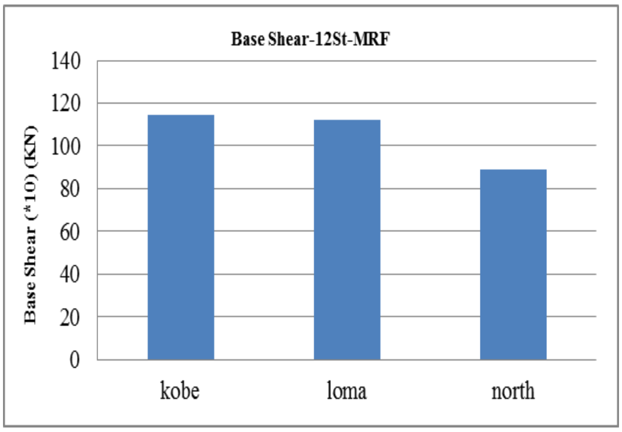

Diagram 17. Comparison amounts of storey base shear in the 12-storey moment frame under different earthquakes.

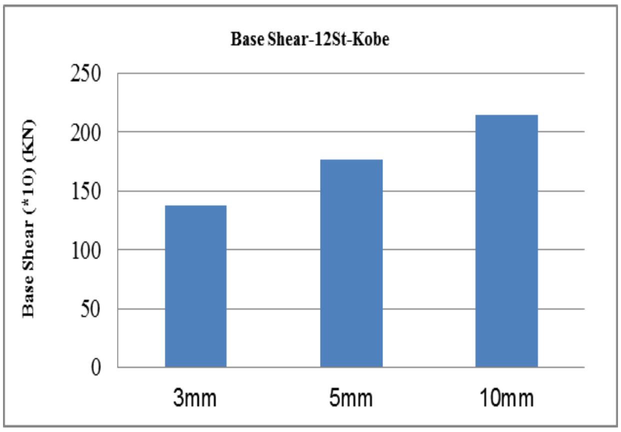

Diagram 18. Comparison amounts of storey base shear in the moment frame with 12-storey shear wall under near fault Kobe.

Diagram 19 is related to the amounts of maximum move ability on 3-storey moment frame under earthquakes near Kobe, Lomaprieta with the amounts of 8.3 and 9.8 cm. diagram 19 is related to the amounts of maximum move ability on 3-storey moment frame which has a shear wall with thicknesses 3, 5, and 10 mm under the earthquake near Kobe, Lomaprieta, and Northridge.

Therefore, the results show that increasing thickness of a shear wall has decreased the move ability of maximum storey on 3-storey moment frame with shear wall. This study deals with the effect of number of storey and thickness of the shear wall on the vibration response of a structure under the earthquakes near fault.

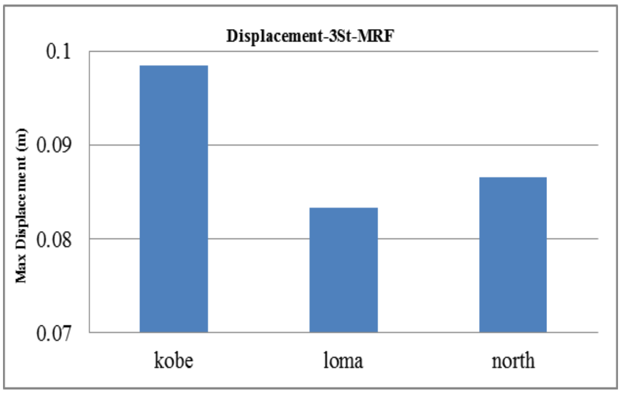

Diagram 19. Amounts of max- displacement in 3-storey moment frame storey under near fault Kobe under near fault Kobe, Lomaprieta, and Northridge.

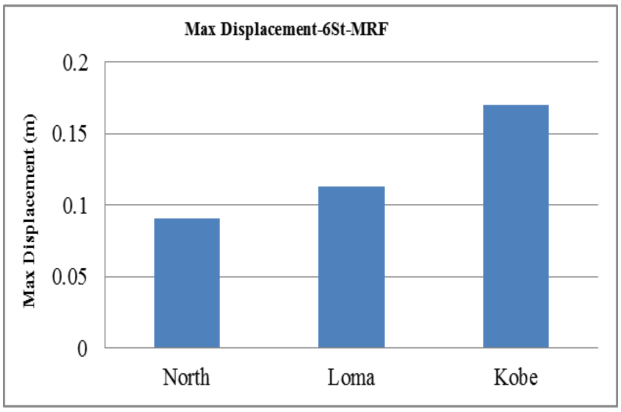

Diagram 20. Amounts of max- displacement in 6-storey moment frame storey under near fault Kobe under near fault Kobe, Lomaprieta, and Northridge.

3 frame as 3, 6, and 12 storey moment frame; the moment frame with the shear wall in thicknesses 3, 5, and 10 mm plus 3, 6, and 12 storey have been studied by the dynamic analysis. The studied frame have had a span with 4-meter width and 3-meter height and 3 spans; after modeling the frames in ABAQUS software, we studied the dynamic response of frames by giving the acceleration records of earthquakes Kobe, Lomaprieta, and Northridge near fault.

CONCLUSION

We dealt with the analysis in details. Therefore, we can state.

The increase the number of storey will increase the maximum move ability of the storey of moment frames.

The increase of shear wall will decrease the maximum move- ability of the storey because of decreasing the liner effects of shear wall and delay on yield stress.

Base shear on 3, 6, and 12 storey moment frames not only depend maximum acceleration of acceleration records but also depends on the acceleration records themselves. Such effect will be decreased by increasing the number of storey so that the maximum acceleration has the most roles on decreasing or increasing the shear of a storey.

By increasing the storey, the vibration mode of maximum acceleration of storey has the regular process in each 3-acceleration record.

It seems that the storey acceleration not only is a dependent on other element such as increasing the thickness of a shear wall and number of the storey. The maximum response on the last storey will not be that changed by increasing the thickness of a shear wall. But there are8-storey in the response of other storey especially on the storey 3, 4, and 5 in the frame.

By seeing the response of acceleration, we can conclude that the storey acceleration has had an increasing process compared with the base acceleration. And also, increasing shear wall will decrease the storey acceleration.

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