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Research paper

Investigation of Behaviors of Concrete Shear Wall in High-Rise Steel Buildings

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Abstract

This study focuses on an analytical study on reinforced steel structures with concrete shear wall. The structures studied was analyzed using nonlinear time history method and the effect of installing concrete shear walls in the structural plan on the target point displacement. By comparing the roofs' displacement diagrams in different structures with different layout of the shear wall in the plan, it is concluded that in order to achieve the proper result in the design of the structures, the shear walls must be located in the middle of the plan in form of core and enclosed with structural columns.

Keywords: *concrete shear wall, core shear walls, nonlinear time history, steel structures*

1 Introduction

Various systems are used in order to withstand lateral forces in high-rise structures, the most common of which are the shear wall. Since the invention of the accelerator and utilizing it for recording various earthquakes and estimating earthquake forces applied on the structures, it is noted that these forces are much larger than those recommended by the various codes. Since the forces of the codes were explained in the reactionary range and, on the other hand, the actual forces of the earthquake are much larger, it is deduced that the structures have entered into the plastic range and plastic deflection.
Nowadays it is possible to use the shear walls along the bending frames in such a way that the behavior of the structure is soft, resistant and ductile. In steel structures with concrete shear wall, the location for a shear wall and how it is placed, reduces the lateral displacement of the structure significantly and also the absorption of a larger contribution from the lateral force.

2 Characteristics of Analytical Structures

In the present study, a high-rise building with 42 floors and height of 138.6 m has been selected and structural analysis has been done considering the different ways of installing a shear wall in the plan. Comparison of the results of the analysis with the aim of finding the best location of the shear wall has been done. These steps are carried out in ETABS software using nonlinear dynamics analysis of time history under three different earthquake mapping accelerations.
In order to investigate and compare the behavior of the shear wall with change in its location in the plan, seven models with the following specifications has been modeled on the ETABS software. The number of floors 42 with a height of 3.3 meters with 6 spans of 8 meters in orthogonal directions, seismic areas and type 4 soil. The plan is shown in Figure (1-7)

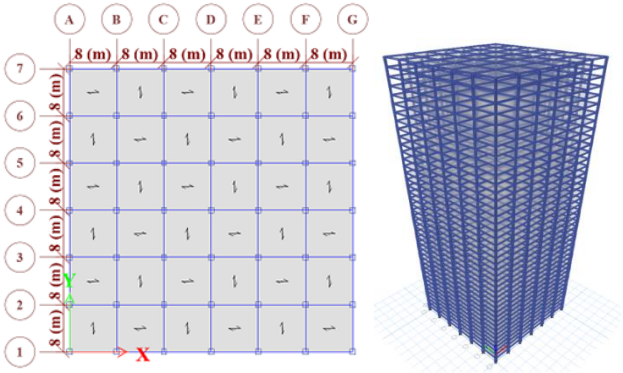


Fig. 1: Plan and 3D geometry of the first model

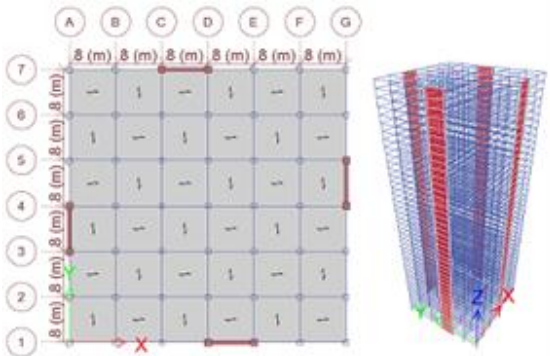


Fig. 2: Plan and 3D geometry of the second model

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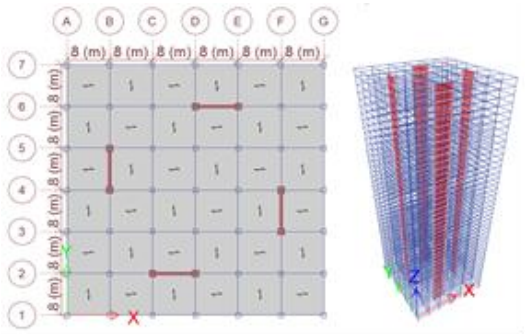


Fig. 3: Plan and 3D geometry of the third model

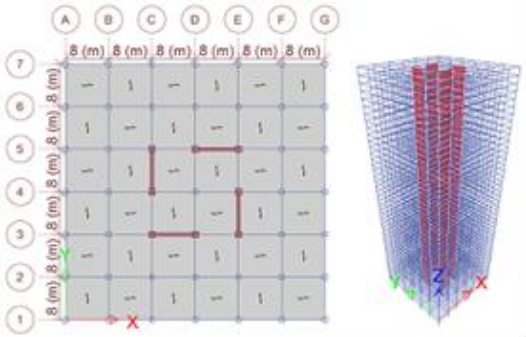


Fig. 4: Plan and 3D geometry of the fourth model

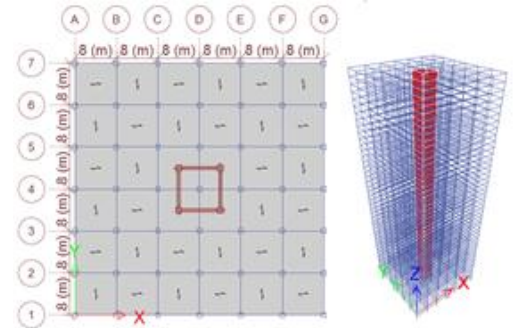


Fig. 5: Plan and 3D geometry of the fifth model

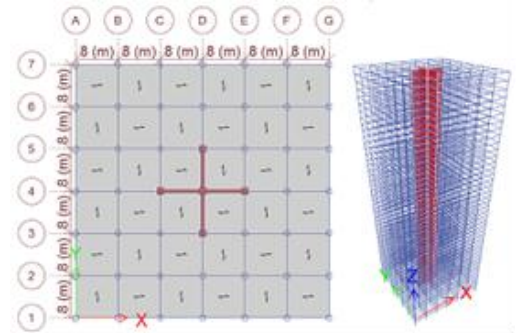


Fig. 6: Plan and 3D geometry of the sixth model

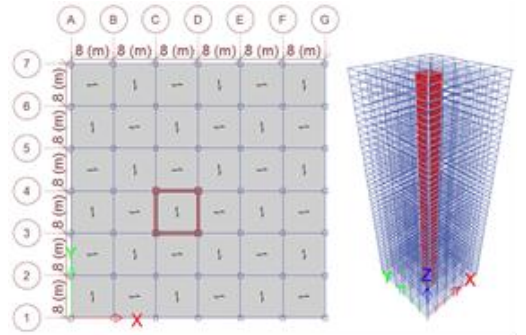


Fig. 7: Plan and 3D geometry of the seventh model

Regarding loading topics of different cods for buildings, the probability of coincidence of the effects of loads is given in the (1-1) table.

Table 1:

Chromite roof dead load - kg / m 2 300	Dead
Exterior walls loading - kg / m 600	Dead
Parking live loading - Kg / m 2 600	Lnr
Corridors and crowded centers loading - kg / m 2 500	Lr1.0
Live loading of floors - Kg / m 2 200	Lr0.5
Live loading of interior walls - kg / m 2 200	L Part
Roof live loading - Kg / m 2 200	L Roof
Roof snow loading - kg / m 2 105	Snow
Seismic mass adjustment load on the roof	MASS
Earthquake force in axis X direction and exclusion of positive and negative center in direction of Y axis	EXALL
Earthquake force in axis Y direction and exclusion of positive and negative center in direction of X axis	EYALL
The effects of initial geometrical defects for steel structures N L	NDX
The effects of initial geometrical defects for steel structures N l	NDY
The effects of initial geometrical defects for steel structures N L	NLnrX
The effects of initial geometrical defects for steel structures N L	NLnrY
The effects of initial geometrical defects for steel structures N L	NLr1.0X
The effects of initial geometrical defects for steel structures N L	NLr1.0Y
The effects of initial geometrical defects for steel structures N L	NLr0.5X
The effects of initial geometrical defects for steel structures N L	NLr0.5Y
The effects of initial geometrical defects for steel structures N L	NLPartX
The effects of initial geometrical defects for steel structures N L	NLPartY
The effects of initial geometrical defects for steel structures N L	NLRoofX
The effects of initial geometrical defects for steel structures N L	NLRoofY
The effects of initial geometrical defects for steel structures N L	NSX
The effects of initial geometrical defects for steel structures N L	NSY
Wind force in direction of X	WX
Wind force in direction of Y	WY
Spectral earthquake load in direction of X	SPX
Spectral earthquake load in direction of Y	SPY

AISC-LRFD Code by combining the relevant loads included in the software is used for the analyzed structure. In order to take into account the effects of anchor amplification due to the lateral displacement of the structure, the P-Delta analysis has been activated. Due to the fact that nonlinear analysis and design based on performance is a method for controlling design, therefore, a spectral dynamical analysis is required along with nonlinear analysis. Therefore, after designing the structure using spectral dynamic linear analysis method and obtaining sections, a nonlinear dynamic analysis has been performed. The structure was first analyzed in an equivalent static method in order to perform a dynamic spectral analysis and after dynamic spectral analysis, the base shears were matched. After designing the structure using a dynamic spectral analysis method, necessary measures have been taken to optimize the model **Fig. 8.**

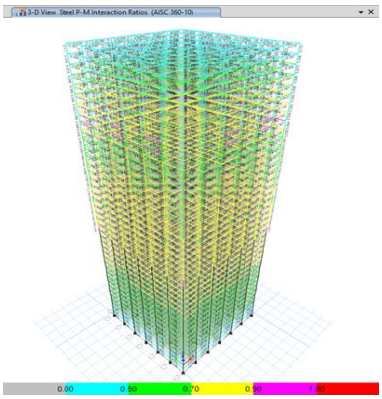


Fig. 8

Three accelerograms with the characteristics of the **Table 2** table are used in the nonlinear dynamics analysis of the time history.

Table 2:

Record	Year	PGA	Magnitude
Imperial Valley (El Centro)	1940	0.31	7
Kobe	1995	0.59	6.8
Bam	2003	0.81	6.6

The steel used in this model is steel ST37 and ST52 and the concrete has f'c = 210 kg/cm^2.

In this study, Fully Encased Steel Column design method was used to model the concrete shear wall in steel building **Fig. 9.**

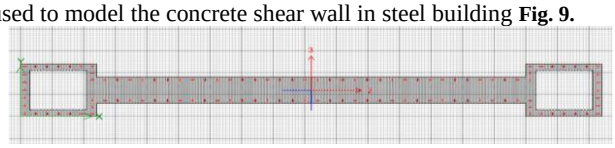


Fig. 9: Fully Encased Steel Column

The amount of base shear force is extracted for different earthquakes to study and compare the behavior of seven models under different shear walls layouts. In addition to the base shear force, the diaphragm center of mass displacements is compared. The results of the center of mass displacements of floor 42 (UX) and the maximum and minimum base shear force and the corresponding times in models one to seven under three different accelerograms is described in the **Table 3**.

Table 3

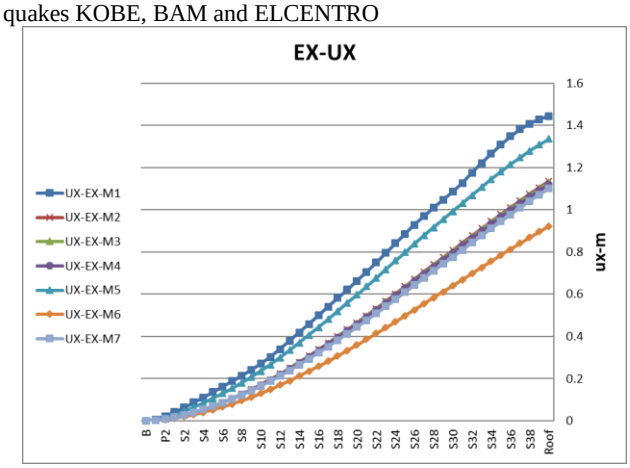
	MODEL.NO	1	2	3	4	5	6	7
ELCEN-TRO	MAX(TON)	3158	5258	5193	5150	4175	6267	5187
	T(SEC)	5.53	7.01	7.01	7.02	7.53	3.12	6.88
	MIN(TON)	-3237	-5867	-5823	-5733	-4296	-5858	-4775
	T(SEC)	4.46	5.85	5.86	5.86	4.44	2.25	9.35
BAM	MAX(TON)	4686	8501	8709	8788	4041	10106	8438
	T(SEC)	21.18	20.33	20.33	20.33	20.91	19.81	20.11
	MIN(TON)	-5085	-8415	-8602	-8674	-5734	-9116	-8038
	T(SEC)	17.88	22.59	22.59	22.59	17.86	21.97	19.31
KOBE	MAX(TON)	5245	3317	3296	3278	6208	12310	5246
	T(SEC)	8.52	8.97	8.97	8.96	8.27	9.7	8.4
	MIN(TON)	-5850	-5226	-5157	-5266	-5578	-11569	-6139
	T(SEC)	7.87	5.14	6.68	6.69	7.64	9.07	6.58
	UX(CM) AT R.S	144	114	113	112	134	92	110

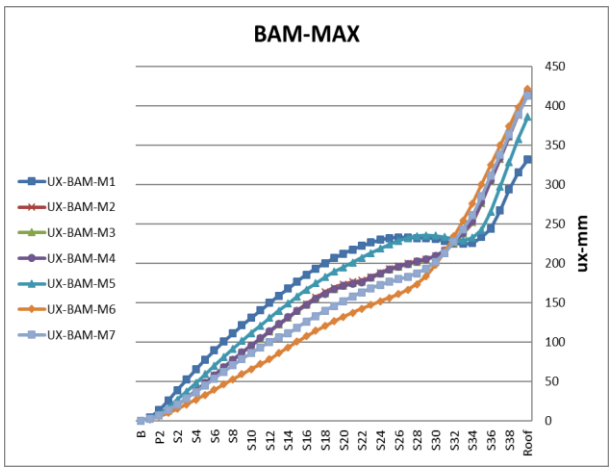
The above table are shown in the **Charts 1:**

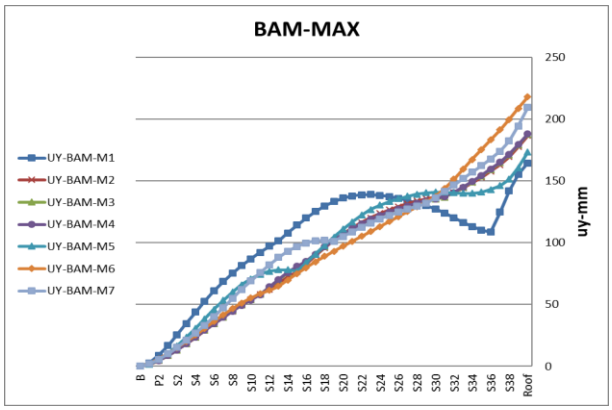


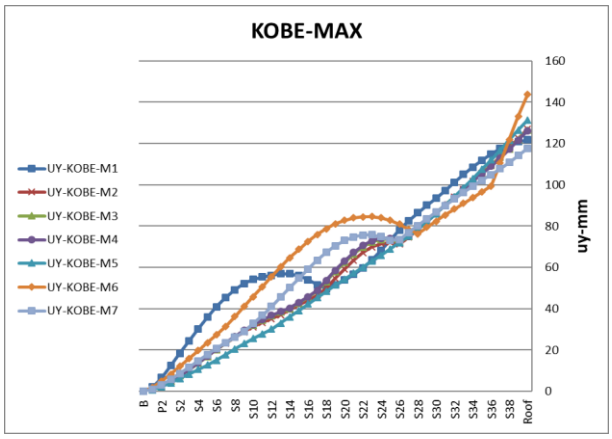
Charts 1: Show comparison of base shear force under different earthquakes in seven geometric models

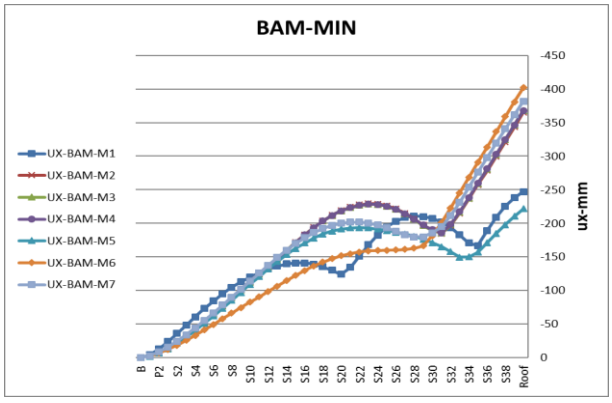
In order to investigate the behavior of the structure, the displacement of the classes of different models is drawn and compared by the following diagrams under static loading of EX and earthquakes KOBE, BAM and ELCENTRO

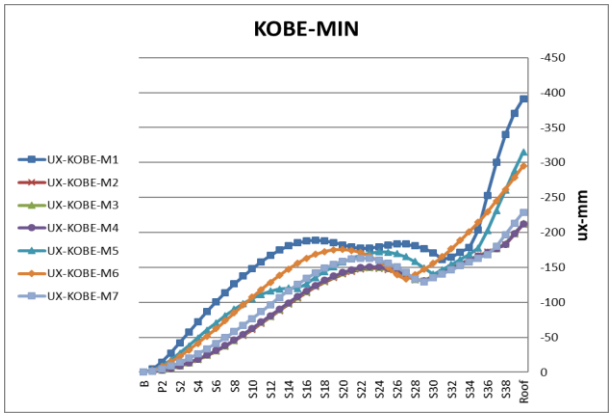


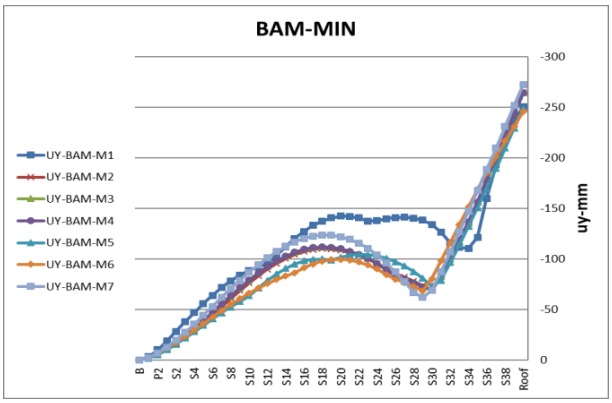


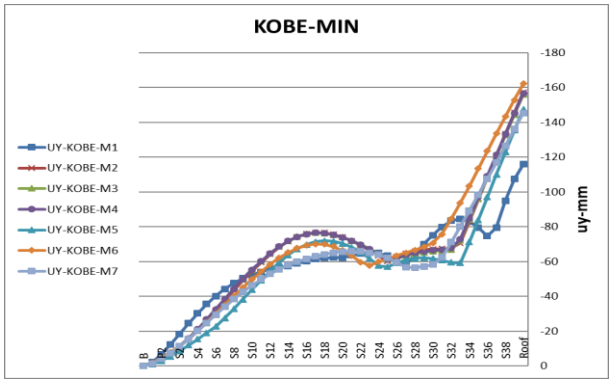

BAM-MAX
UY-BAM-M1
UY-BAM-M2
UY-BAM-M3
UY-BAM-M4
UY-BAM-M5
UY-BAM-M6
UY-BAM-M7
uy-mm
B P2 S2 S4 S6 S8 S10 S12 S14 S16 S18 S20 S22 S24 S26 S28 S30 S32 S34 S36 S38 Roof

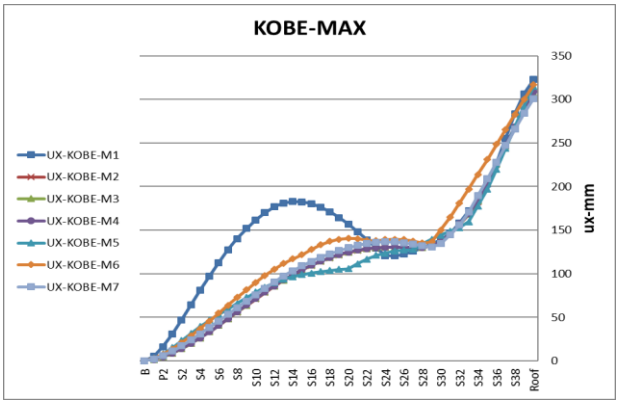

KOBE-MAX
UY-KOBE-M1
UY-KOBE-M2
UY-KOBE-M3
UY-KOBE-M4
UY-KOBE-M5
UY-KOBE-M6
UY-KOBE-M7
uy-mm
B P2 S2 S4 S6 S8 S10 S12 S14 S16 S18 S20 S22 S24 S26 S28 S30 S32 S34 S36 S38 Roof

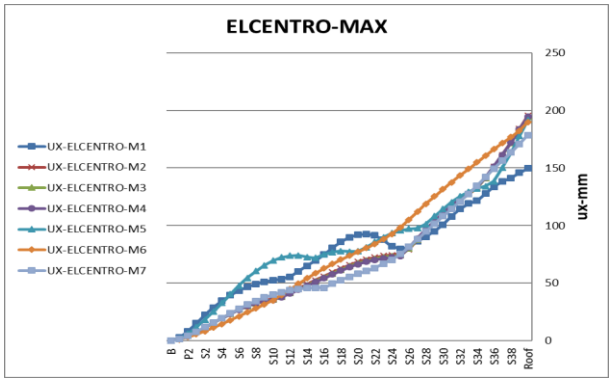

BAM-MIN
UX-BAM-M1
UX-BAM-M2
UX-BAM-M3
UX-BAM-M4
UX-BAM-M5
UX-BAM-M6
UX-BAM-M7
ux-mm
B P2 S2 S4 S6 S8 S10 S12 S14 S16 S18 S20 S22 S24 S26 S28 S30 S32 S34 S36 S38 Roof

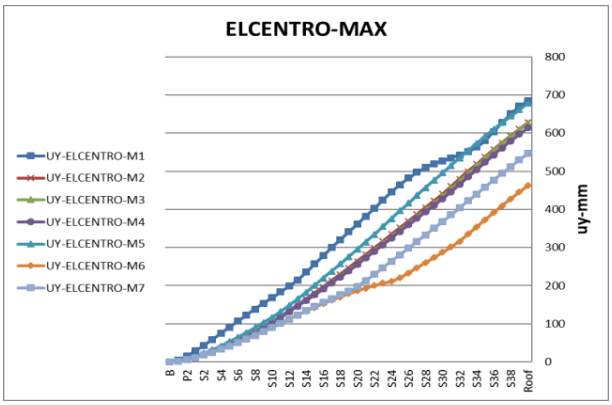

KOBE-MIN
UX-KOBE-M1
UX-KOBE-M2
UX-KOBE-M3
UX-KOBE-M4
UX-KOBE-M5
UX-KOBE-M6
UX-KOBE-M7
ux-mm
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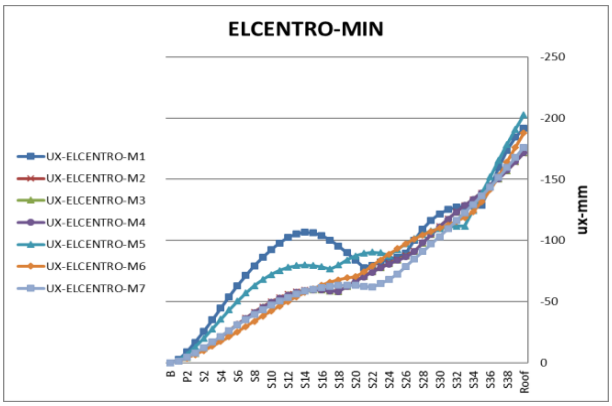

BAM-MIN
UY-BAM-M1
UY-BAM-M2
UY-BAM-M3
UY-BAM-M4
UY-BAM-M5
UY-BAM-M6
UY-BAM-M7
uy-mm
B P2 S2 S4 S6 S8 S10 S12 S14 S16 S18 S20 S22 S24 S26 S28 S30 S32 S34 S36 S38 Roof

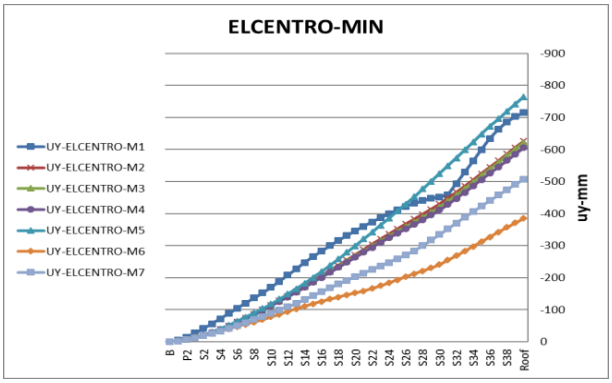

KOBE-MIN
UY-KOBE-M1
UY-KOBE-M2
UY-KOBE-M3
UY-KOBE-M4
UY-KOBE-M5
UY-KOBE-M6
UY-KOBE-M7
uy-mm
B P2 S2 S4 S6 S8 S10 S12 S14 S16 S18 S20 S22 S24 S26 S28 S30 S32 S34 S36 S38 Roof


KOBE-MAX
UX-KOBE-M1
UX-KOBE-M2
UX-KOBE-M3
UX-KOBE-M4
UX-KOBE-M5
UX-KOBE-M6
UX-KOBE-M7
ux-mm
B P2 S2 S4 S6 S8 S10 S12 S14 S16 S18 S20 S22 S24 S26 S28 S30 S32 S34 S36 S38 Roof


ELCENTRO-MAX
UX-ELCENTRO-M1
UX-ELCENTRO-M2
UX-ELCENTRO-M3
UX-ELCENTRO-M4
UX-ELCENTRO-M5
UX-ELCENTRO-M6
UX-ELCENTRO-M7
ux-mm
B P2 S2 S4 S6 S8 S10 S12 S14 S16 S18 S20 S22 S24 S26 S28 S30 S32 S34 S36 S38 Roof







Charts (1-3) show comparison of classes' drift in different plans of shear wall under different earthquakes in seven geometric models

1. Reviewing the graphs shows that in all accelerometers, the maximum amount of base shear force occurs in the sixth model (cross-section shear wall).
2. By examining the shear force diagrams, it is observed that the performance of the structure in terms of the comparison of the base shear force in the fifth geometric model was the best.
3. Reviewing the graphs shows that the minimum displacement of the classes related to the sixth geometric model (cross-section shear wall) is due to the hardness caused by the continuous length of the shear wall.
4. Reviewing the graphs shows that the maximum displacement of the floors in the models with shear walls is related to the fifth model due to the structure's inconsistency with the shear wall.
5. Reviewing the diagrams shows that in all models having shear wall, from classes (29-29) on, due to the shear wall, a large displacement is created in the structure, which even increases to more than 50%.
6. Reviewing the diagrams shows that due to the dynamic forces of the earthquake, the best situation is related to the fifth and seventh models, and it is inferred that in order to obtain the appropriate result, we have tried to construct the shear walls in the middle of the plan in form of Core and certainly to be enclosed with the columns of the structure.
7. By checking the graphs that are determinant in the structure's DRIFT control and comparing the displacement value in the models with and without shear wall, it is observed that there is a significant difference in DRIFT results, and this difference is in the range of 8 to 37%.

3 Summary of results

1. Evaluation of the results of shear force diagrams of the maximum classes in seven different shear wall layouts show that the performance of the structure in the fifth geometric model in which the shear walls are located in the center of the structural plan is the best and then the seventh geometric model has a better structural performance than any other geometric models.
2. Examining the values of the floor drift in seven geometric models shows that the changes in drift of stories in the sixth geometric model is the lowest, and then the fifth and seventh geometric models are located.
3. By examining the results obtained from the research, it is deduced that the best model is selecting the fifth model with the appropriate length of the walls in two directions and enclosing the walls with the columns.

Recommendations

1. It is suggested that different methods of the *steel column-shear wall* connection system to be modeled and compared so that three different modeling are done, including the *steel column-shear wall* connection, fully encased, such as this study, the semi- encased model and disjunctive model and ultimately their performance is compared with each other.
2. It is suggested that the steel shear wall in high-rise steel buildings should be compared in a plan and the common conditions of modeling with concrete shear-wall in a high-rise steel building technically and their structural performance should be compared.
3. Since one of the important issues of decision making on structural systems, in addition to the technical topics is the parameters related to economic comparison of alternatives, it is suggested that the economic comparison of the concrete shear wall system in high-rise steel buildings to be compared with other alternative systems such as steel shear walls, steel bracing systems, etc., and economic analysis should be done about them.
4. It is suggested that the concrete shear wall from the 30th floor on should be removed in the examined models observing the lack of creating soft floor and the displacement of the structures should be investigated.

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