INVESTIGATION ON SEISMIC RESPONSE OF 3D SYMMETRIC SINGLE STORY OF RC FRAME WITH RC INFILL WALL

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ABSTRACT

Infill wall is commonly used on construction to enclosure the building and to divide the large area, however they are treated as non-structural on the structural design. In this study, the effect of variation width of infill wall on 3D symmetric single-story frame and the material using assumed as RC material was conducted to understand the contribution for reducing the internal force and for increasing the natural frequencies. From the investigation, the natural frequency and internal force of 3D symmetric model with variation width of RC infill wall increase and decrease respectively if compared with 3D pure frame model. From this investigation, it is better to have the walls on both sides of the column to have better reduction in the internal force, and the effect of floor diaphragm assumption explain that its effect only increase a little frequency and internal force, but the impact of model design is affected the rigid stiffness of beam-slab model. Thus, consideration of RC infill wall or the wall element on the structure model on the seismic response is recommended to become study investigation.

Keywords: 3D-frame model, RC infill wall, Natural Frequency, Internal Force Moment Response

INTRODUCTION

A huge number of structures damage and killing a thousand people is caused by a strong earthquake just a minute or two. Its impacts are not only at the time but also after it finished. Consequently, the designer of structure must find alternative method or structure to resist earthquake. The general alternative design is consideration of infill wall, in this study focus on RC infill wall. This structure member function is to enclosure building structure, to divide the large space into several small places and to provide weather protection. From the experimental observation (Anil and Altin 2007, Anil 2008) explain that partial of infill wall element can increase the strength and the stiffness as compared with bare-frame and the arrangement of the opening, and the infill wall with welding lap splice show significant improvements in the strength and stiffness as compared with the model without welding lap splice. From the numerical observation (Doudoumis 2007) explain that interaction between frame and infill wall has large influenced on the force moment distribution, and the variation of finite element size also influence the stiffness of structure and force distributed. These effects of the infills on the analysis must be considered together with high degree of uncertainty related to the behavior (Pulisi et all 2009);

- The variability of their mechanical properties, and therefore the low

reliability in their strength and stiffness;
- Their wedging condition, that is how tightly they are connected to the surrounding frame;
- The potential modification of their integrity during the use of the building;
- The non-uniform degree of their damage during the earthquake.

In general, the presence of masonry infills affects the seismic behavior of the building as follow (Demir et all 2002).
- The stiffness of the building is increased, the fundamental period is decreased and therefore the base shear due to seismic action is increased.
- The distribution of the lateral stiffness of the structure in plan and elevation is modified.
- Part of seismic action is carried by the infills, thus relieving the structural system.
- The ability of the building to dissipate energy is substantially increased.

Consideration the width of RC infill wall on the 3D-symmetric single story frame is proposed to understand its influence into the stiffness and internal force response by using MIDAS-gen.

RESEARCH METHODS

3D-symmetric single story frame with the properties and the geometric are explained on **Table 1** and **Figure 2**, an eight model frame with slab consist of 1 pure frame model and 8 models with the variation width size of RC infill wall. Column and beam size are also explained on the table properties that the size section 0,5 x 0,5 m and 0,5 x 0,3 m respectively, the thickness of wall and slab are 0,3 m and 0,15 m respectively. The material properties of frame and RC infill wall are the same condition because of cast in place concrete has been used assumed as the modeling on the numerical investigation.

In this study, the size of geometric of frame has used 5 meter for height, 5 meter for width of X directional and 6 meter for width of Y directional. Fix support has been used on the column and wall in order to assume that the model will be experimental investigated, and the detail of model are described on **Figure 2** and **Figure 3**. Input loading explained on **Table 2** uses the dead and live load as the static loading and seismic motion described on **Figure 1** as the dynamic loading. Dead load described about the selfweight of RC frame, RC slab and extra load which are worked above the slab, while the live load is the specific load which is explained on the loading design. For seismic motion, Kobe Earthquake is chosen to investigate the model and to obtain the response of structure. The linear elastic analysis was conducted to avoid the effect of nonlinear behavior of infill wall and frame member which will complicate the discussions on the results. The effects will then be discussed through comparisons of natural frequencies and maximum internal forces (axial force, shear force, bending moment and torsion) of frame members. In each figure showing the maximum internal forces, it contains two parts: one is for internal forces at node-i and the other is for those at node-j. In both parts the abscissa represents the frame member and for each member the results obtained from all relevant models are presented.

Table 1. Section properties for 3D-model case

	Column (m)	Beam (m)	Wall (m)	Slab (m)
Height	0.5	0.6	-	-
Width	0.3	0.3	-	-
Thick	-	-	0.3	0.15

Table 2. Loading description for 3D-model case

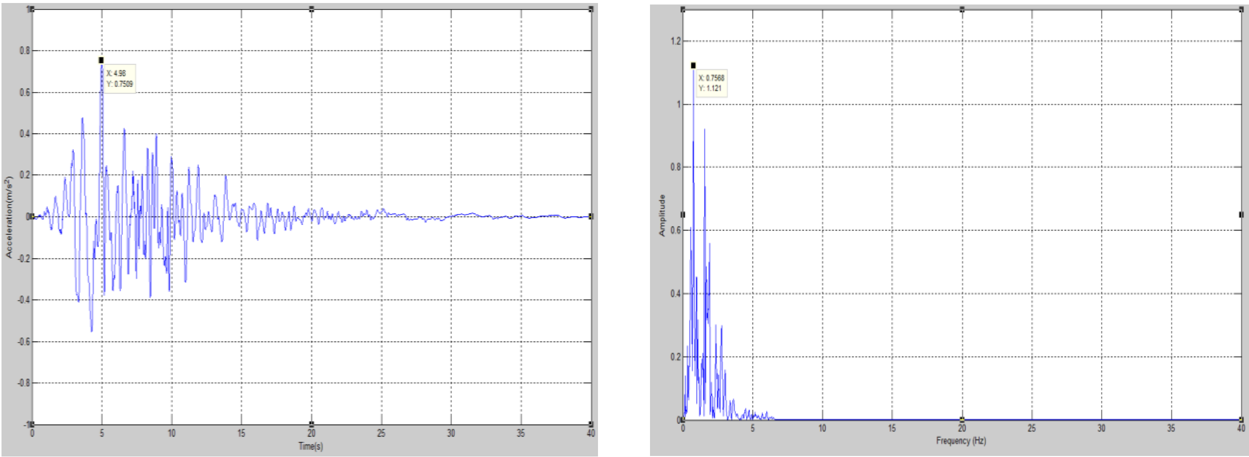
1	Dead Load :	Slab concrete (t = 15 cm)	3.53	Kg/m^2
		Extraload (plafond etc)	1.77	Kg/m^2
			5.35	Kg/m^2
2	Live Load :	loading be acted on floor	1.96	Kg/m^2
3	Time history analysis	: Kobe Earthquake		
4	Load combination	: DL + LL + TH		

Table 3. Geometric information for 3D-symmetric

Element	Discription	Element	Discription
1	Column element	5	Column Element
2	Column element	6	Beam Element
3	Beam element	7	Beam Element
4	Column element	8	Beam Element

Table 4. Model description for 3D-symmetric

No.	Sym	Discription
1	3D-Pf	Pureframe
2	3D-M1	3D Model #1
3	3D-M2(1)	3D Model #2 - add side wall 1m
4	3D-M2(2)	3D Model #2 - add side wall 2m
5	3D-M2(2.5)	3D Model #2 - add side wall 2.5m
6	3D-M3(1)	3D Model #3 - all wall corner 1m
7	3D-M3(2)	3D Model #3 - all wall corner 2m
8	3D-M3(2;2.5)	3D Model #3 - x,y wall corner 2m; 2.5m



(a) (b)

Figure 1. Kobe earthquake record data: (a) Time domain (peak 0.7509g at 4.98 sec.), (b) FFT (Maximum Amplitude at Frequency 0.76 Hz)

NUMERICAL RESULT AND DISCUSSION

In order to understand more realistic behavior of the frame RC infill wall, 3D models are considered on this model. The objective is to understand the effect of infill wall along the beam direction on the seismic response. From **Table 4**, 3D-PF is just a pure frame without any wall. 3D-M1 has a full wall along Line 1 and Line 2 directions. 3D-M2(1), 3D-M2(2) and 3DM2(2.5) models are the extension of 3D-M1 model where the length of wall is 1m, 2m and 2.5m along Line A and Line B direction, respectively. On the other hand, another three models were also developed, denoted as 3D-M3(1), 3D-M3(2) and 3D-M3(2, 2.5). For 3D-M3(1) and 3D-M3(2) models, the length of wall along every direction is 1m and 2m, respectively, and 3D-M3(2,2.5) model has 2-m length of wall along Line 1 and Line 2 and 2.5m length of wall along Line A and Line B.

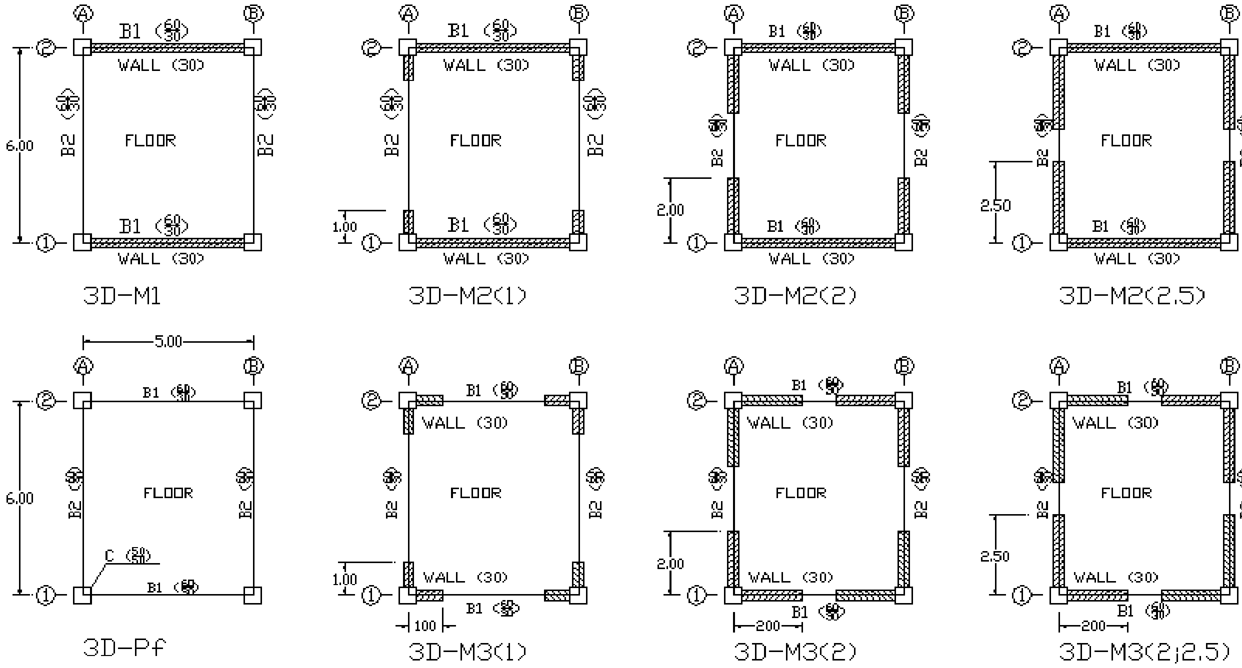


Figure 2. Planning view of model design

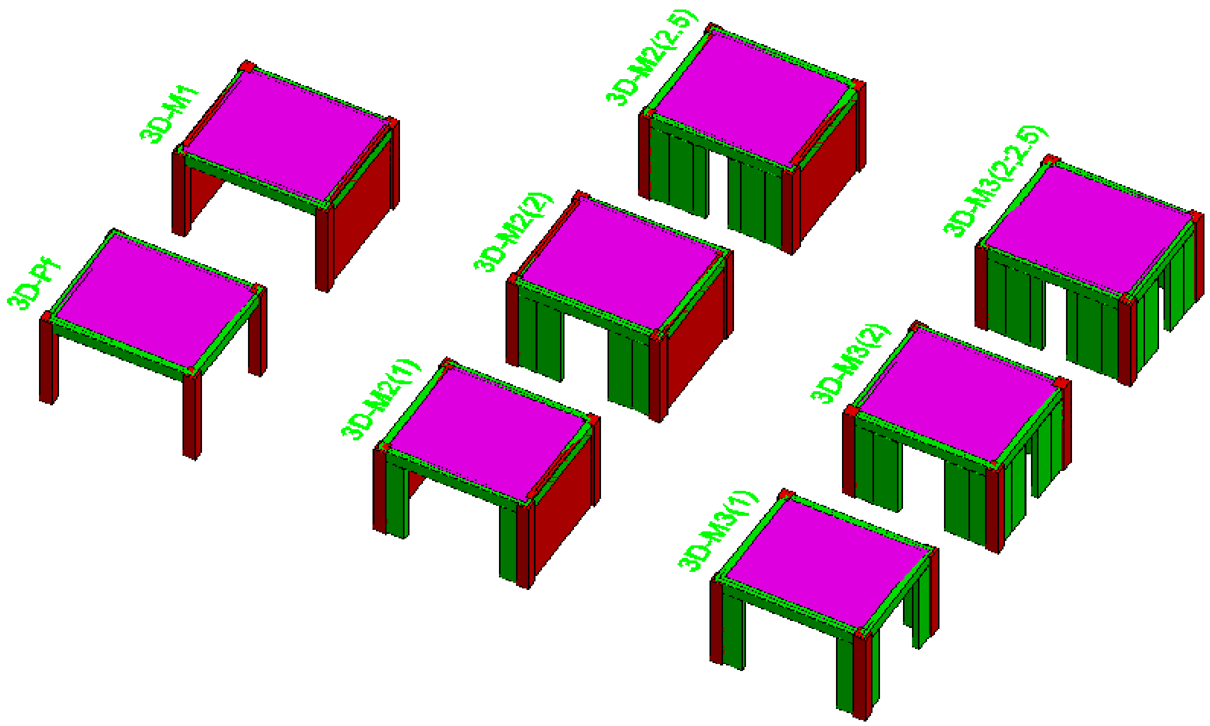


Figure 3. Model design in 3D view

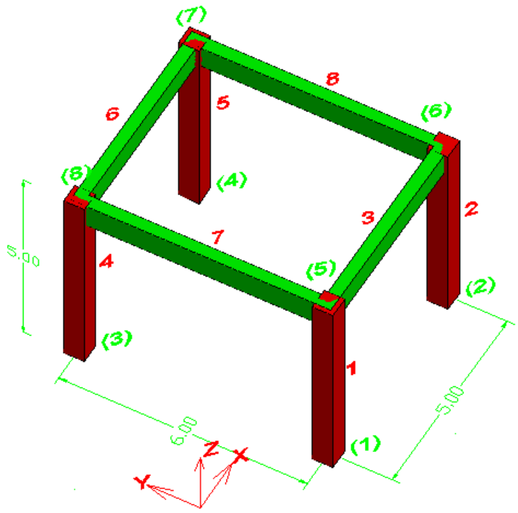


Figure 4. Element number and node number

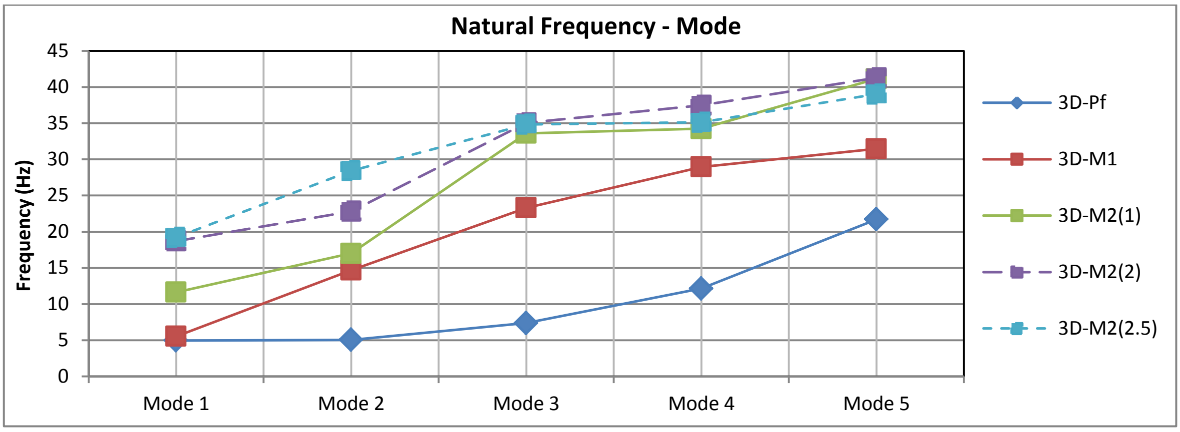
By referring to **Figure 4**, **Table 3** describes the element number and joint number; Element 1, Element 2, Element 4 and Element 5 are columns and Element 3, Element 6, Element 7 and Element 8 are girders (beams). **Table 2** shows the section size of columns, beams and walls. **Table 4** describes the loading conditions for all the models. The earthquake input is the same as the one used for 2D frame models. Since 2D model was considered, the analyses were conducted for applying input along X direction and Y direction separately. A point should be noted that in the analyses the wall and slab were modeled as plate elements. As a result, the commonly used rigid floor (diaphragm) assumption for frames without including the slab was not adopted.

1. Natural Frequency

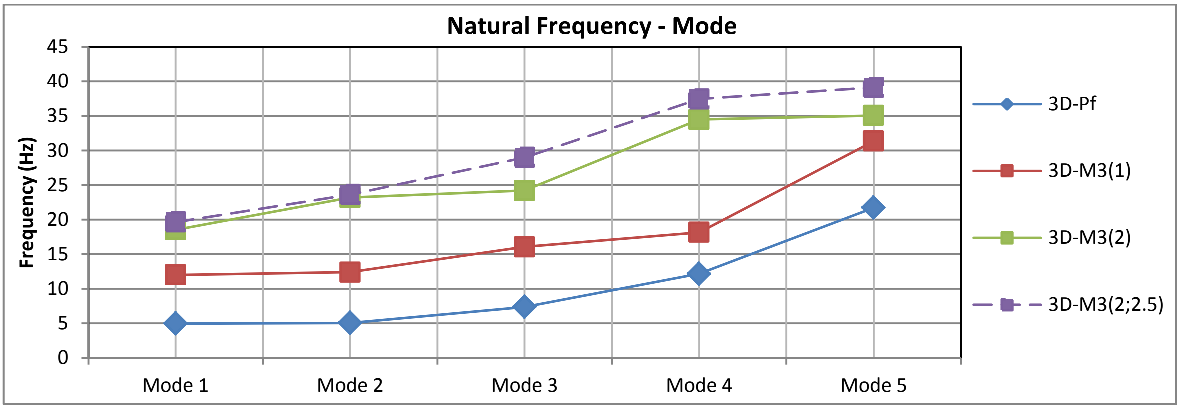
Consideration of 3D model frame is more realistic to model the real condition with high densities finite element on frame and wall element, therefore these parameters are recommended to become alternative simulation modeling. **Figure 5** compares the natural frequencies of first 5 modes for the models 3D-PF, 3D-M1, 3D-M2(1), 3D-M2(2) and 3D-M2(2.5). From the figure, the existence of RC infill wall on the 3D model frame increase natural frequencies, and for mode 1, 3D-PF and 3D-M1 has the same value, indicating that the first mode of both models has the same directions; it means the direction along the line A and line B, however in the higher mode the natural frequency of 3D-M1 are higher than 3D-PF. The natural frequencies significantly increase on model of 3D-M2(1) until 3D-M2(2.5), and the same frequency at first mode is also shown by 3D-M2(2) and 3D-M2(2.5), however the different can be seen for next mode. Comparison the natural frequencies with and without floor diaphragm describe similar pattern except the 3D-M3(2.5) that the pattern has a little change, but it doesn't indicate that the behavior of column will be changed also. However, the effect of variation width RC infill wall showed on **Figure 6** reached the optimum natural frequency when the widths are among 1 to 2 meter, because the natural frequencies increase two times than 3D-PF. The natural frequencies for width more than 2 meter which indicates full enclose the frame or the model similar with shear wall design, has little different and its different shows the change of stiffness.

2. Internal Force - Moment

Input seismic motion is decided on the X direction of global coordinate. **Figure 7** shows the axial force response, from the figure, the end-i of column is support and end-j is the joint between column and beam. At end-i the addition of full wall along Line 1 and Line 2 directions reduces the axial force for all members. However, the addition of wall along Line A and Line B directions increase the axial force with the case adding 1-m long wall having the largest increase.

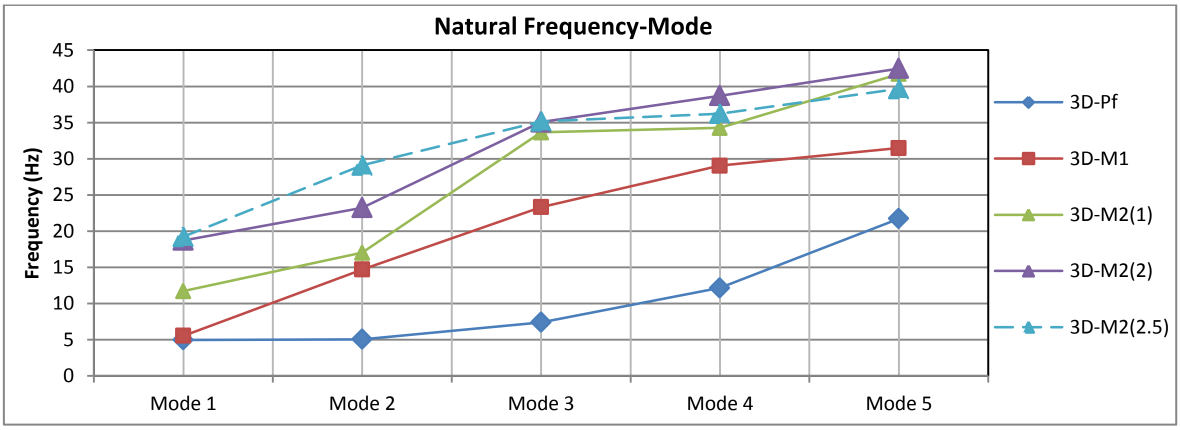


(a)

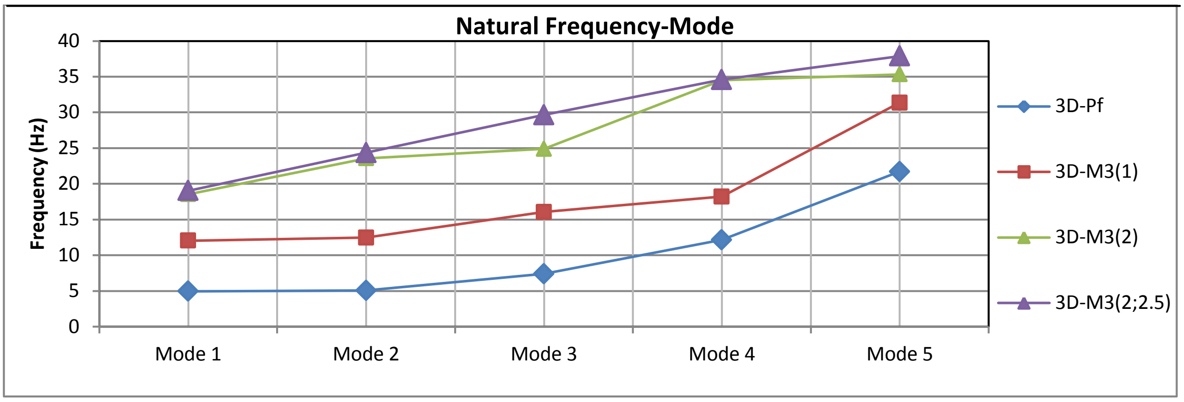


(b)

Figure 5. Natural frequency of single-story 3D-symmetrical model without floor diaphragm: (a) Case-1, (b) Case-2.



(a)



(b)

Figure 6. Natural frequency of single-story 3D-symmetrical model with floor diaphragm: (a) Case-1, (b) Case-2.

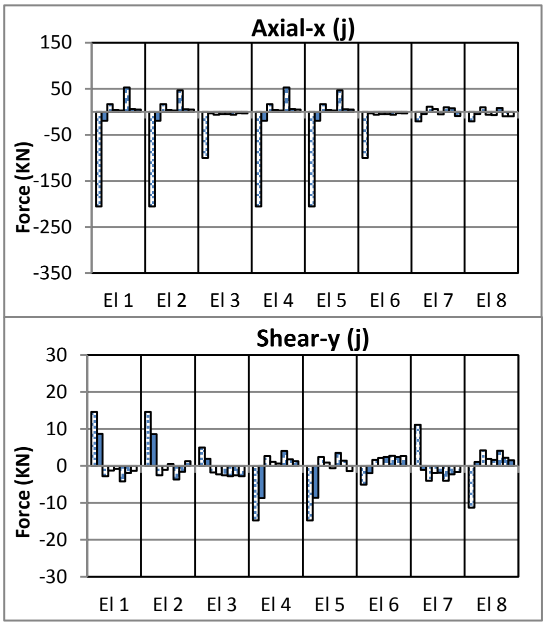
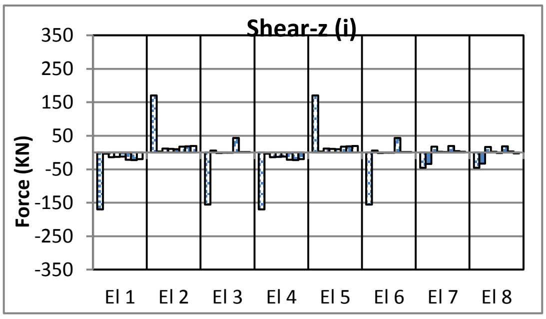
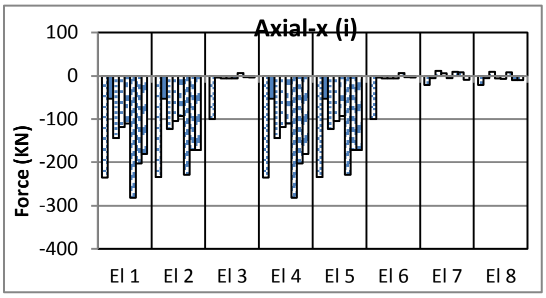


Figure 7. Comparison of maximum axial Force with X direction of input motion

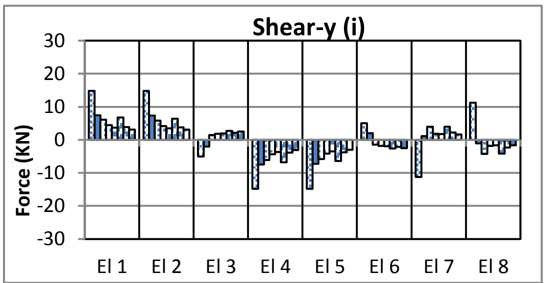


(a)



(b)

Figure 8 (a) (b). Comparison of maximum shear-y force with X direction of input motion



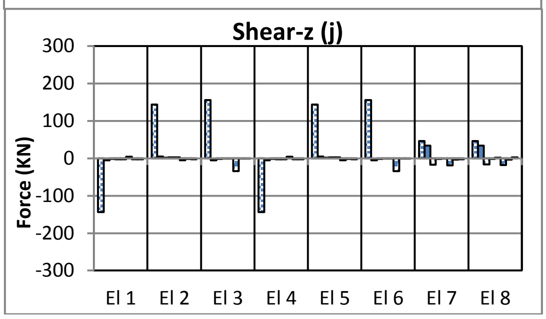


Figure 9. Comparison of maximum shear-z force with X direction of input motion

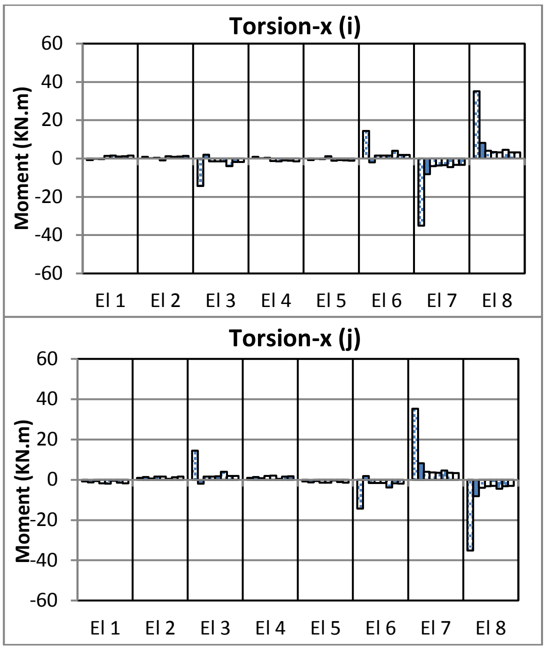


Figure 10. Comparison of maximum torsion with X direction of input motion

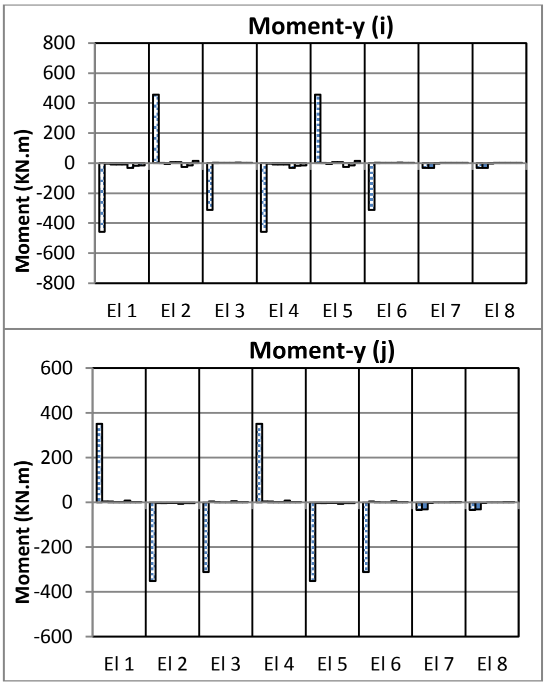


Figure 11. Comparison of maximum bending moment-y with X direction of input motion

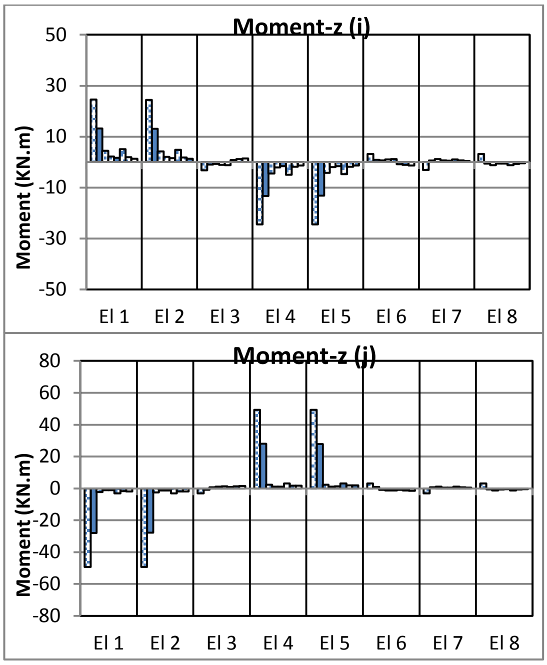


Figure 12. Comparison of maximum bending moment-z with X direction of input motion

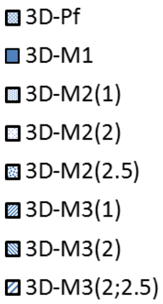


Figure 13. The legend of 3D-symmetric model

In addition, the largest increase is for 3D-M3(1) model. On the other hand, the axial force in the beam is very small. At end j, similar trend can be observed; the values of axial force become very small for models except 3D-PF and 3D-M1. A note should also be pointed out that the 3D-M3(1) model which can be considered as adding the 1m wing wall will induce axial force larger than 3D-PF model at the support. **Figure 8** describes the shear force response. From the figure, general trend observed is that when RC infill wall is added, the shears force of all members will reduce as the wall's length increases. If the other assumption of variation width of RC infill wall, especially 1 meter added, is as a wind wall, thus the model of wind wall is effectively help to reduce the shear force response.

Figure 9 describes shear force response on the z local component, the general reason is similar that it is effectively reduced by the existence of RC infill wall despite the minimum recommendation width is 1 meter. **Figure 10** depicts the torsion moment response of model due to seismic motion on x direction. On this case, the torsion occurs on the beam element and the maximum response is reached on the beam element along line A and line B, its direction is perpendicular with seismic direction. At the end-i it will induce comparatively large torsion for 3D-M1 models for columns, while it will cause larger torsion for beam members of 3D-PF models. However, when the infill walls are used in both directions, the torsion will be reduced significantly. **Figure 11** and **Figure 12** depict the bending moment response. It induces large moment-y for both ends of Element 1 to Element 6 for 3D-PF models and smaller values for Element 7 and Element 8 for both ends; however, this trend is reversed for Y-direction input. For both input, with the use of infill wall the moment-y is significantly reduced.

CONCLUSIONS

From the analysis result, several conclusions can obtained and the recommendation for next investigation are also listed on this part. As a preliminary study, only single-story frame was considered and only linear analyses were conducted using Midas Gen software.

The investigation is used 3D frame to investigate the effect of length of infill wall along the beam direction. It is found that when the RC infill wall is used, it is better to have the walls on both sides of the columns to have better reduction in internal forces. Because of the variations of the RC infill wall in opening and length, it is very difficult to draw a general guideline. Thus, the analyses for frames with infill walls are case-by-case. The recommendation of this investigation is in this study only linear analysis is considered. To see how infill wall will affect the seismic response during strong earthquakes, it is better to consider the nonlinear analysis.

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