Investigation of RC Shear Wall Dimensions and Arrangement on the RC Structure Seismic Behavior

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ABSTRACT

The novel goal of this study is to investigate shear wall dimensions and arrangement on the seismic behavior of a reinforced concrete structure. To achieve the goal, an eight story concrete structure was modeled using nonlinear finite element software. Nonlinear time history dynamic analysis according to 2800 code used. Northridge acceleration was applied on the structure. Usual dead load and live load were also applied on the stories surface. Shear walls with 3 meters and 5 meters length were placed in four different arrangement, therefore totally eight models have been created. Maximum displacement of structure and absorbed base shear by walls will be discussed. Results generally showed that when shear wall length increases, absorbed base shear by shear wall and maximum displacement of the highest story increase too.

Key words: Dual system, RC shear wall, dynamic analysis,
Absorb base shear, Maximum displacement.

INTRODUCTION

Moment resistance frame, bracing frame and shear wall are the most common systems which are used to resist lateral forces in a structure. Research show that using shear wall and moment resistance frame together in a structure can be effective more than other systems. In this system both of shear wall and moment resistance frame can affect each other and also they have advantages of shear wall and moment resistance frame. In this system, shear wall resists lateral forces while moment resistance frame resists gravity forces. Dimensions and arrangement of shear walls are the most important part of concrete structure design which can reduce overturning risk and element (such as beam and column) dimensions (Talaii Taba, 2010).

Shear wall is the most important element of a concrete structure which could improve seismic behavior of a structure by resisting lateral loads.

Shear wall is a vertical RC shell which is transversally and longitudinally reinforced so that the steel bars continue from the foundation to the top level of wall (Ching *et al*, 2006). As shown in figure 1, shear wall performs as a contriver column. In fact shear wall increases structure stability by resisting shear and moments due to lateral forces such as wind or earthquake.

Using shear wall in a 30 to 40-story buildings can be economical. In the buildings with more than 40 stories, shear wall width will be so great to resist stresses of wind and earthquake loads that using it would not be economical (Kheyroddin, 2010). So moment resistance frame or dual systems (like as moment resistance frame and shear wall together) can be used in the buildings with more than 40 stories. According to 2800 code, the maximum allowable height for structures which are located in high seismic zone risk and low seismic zone risk is 70 meters and 200 meters, respectively.

As mentioned before, the most effective lateral loads resisting system, is dual system including shear walls and moment resistance frame. That's because using shear wall or brace in a structure, can control structure lateral displacement by increasing structure stiffness. Shear wall or brace, also can resist major lateral forces applied to the structure due to earthquake or wind.

2800 Code Requirements for 3d Dynamic Analysis

In this section, 2800 code requirements for three dimensional dynamic analysis is going to be presented. In the time history analysis, at least three couples of accelerators regarding the zone shall be considered. All of the accelerators shall be scaled to the maximum acceleration. In other words, the maximum acceleration of each accelerator shall be equal to "g". The response of each couple accelerator shall be mixed together using SRSS[1] method to make a single mixed spectrum for each couple accelerator. Scale factor which is multiplied in the accelerator shall be chosen so that the average of mixed spectrum in the period range from 0.2T to 1.5T be less than 1.4 times of the related spectrum in the standard spectrum.

After scaling accelerators, each couple accelerator is applied to the structure in two directions at the same time (as figure 2 shows). Response of the structure will be determined as a time equation. Final structure response in every time, is equal to the maximum response obtained in the analysis using three couples of accelerators.

It should be mentioned that, according to 2800 code, if seven accelerators are used instead of three accelerators, the average of responses can be considered as final structure response.

Loading

Dead load and live load were applied on the floor of each story in size of 600 kg/m^2 and 500 kg/m^2, respectively. Dead load due to structure elements weight was considered by the finite element software. Acceleration of Northridge earthquake which is scaled according to 2800 code is applied to the structure. Northridge acceleration is shown in the figure 3.

Geometry of Beams, Columns and Shear Walls

In this section, characteristics of models such as beam and column dimensions, wall arrangements and etc. will be presented.

Beam, Column and Shear Wall Dimensions

Dimensions of structure elements (beams, columns and shear walls) were chosen according to dimensions which are used in common buildings. It should be mentioned that dimensions of 5, 6, 7 and 8 stories elements were chosen smaller than bottom stories elements to reduce dead load due to concrete weight. Dimensions and reinforcement of structure elements used in the models were as table1.
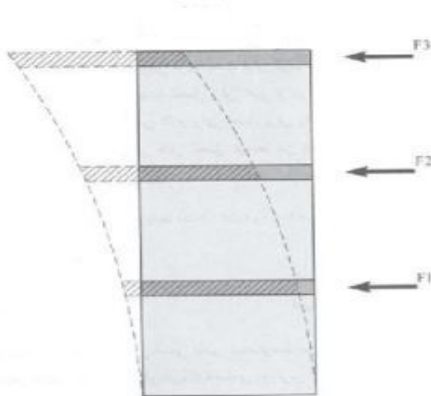

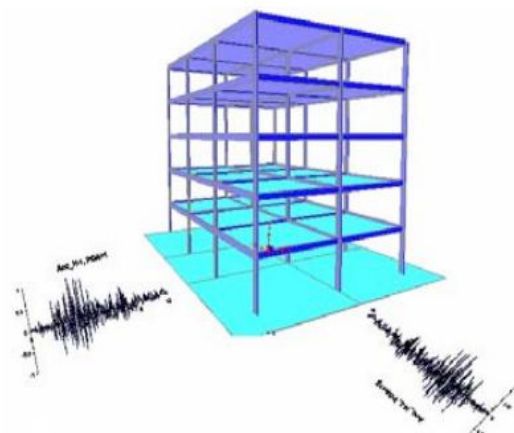**Fig. 1: Cantilever behavior of shear wall (Kheyroddin, 2010)**

Fig. 2: Structure dynamic analysis under earthquake accelerators

Shear Wall Arrangements

In this study, four different arrangements for shear walls placing in the structure were considered. Moreover shear walls were modeled in two different lengths (three meters and five meters). Figure 4 shows the shear walls arrangements.

Results and Discussion

The main goal of this study is to investigate the effect of RC shear walls dimensions and arrangements on the seismic behavior of RC structure. In this section, the results obtained from nonlinear finite element software are presented. Results can be classified in two main parts: a) absorbed base shear by shear walls b) maximum

displacement of structure area center for each model.

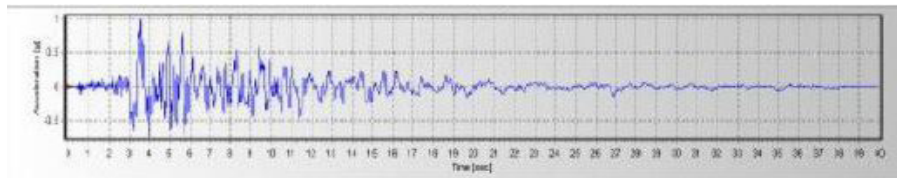**Absorbed Base Shear**
Five-Meter Shear Walls

Table 2 presents absorbed base shear by the five-meter shear walls which are located in four different arrangements in each story.

To have a better comparison for absorbed base shear wall in each arrangement, figure 5 is presented.

As figure 5 shows, absorbed base shear by walls in arrangement 4 with the average of 89.11% is greater than other arrangements. Absorbed base

Table 1: Characteristics of numerical models

	Element type	Section	longitudinal reinforcement	Transverse reinforcement
stories 1, 2, 3, 4	beam	B50X55	-	-
	column	C50X50	12Ø20	Ø10@15 cm
	shear wall	W25	Ø12@15 cm	Ø12@15 cm
	boundary element reinforcing	c50x50	12Ø25	Ø10@15 cm
stories 5, 6, 7, 8	beam	B40X45	-	-
	column	C40X40	12Ø18	Ø10@15 cm
	shear wall	W20	Ø12@15 cm	Ø12@20 cm
	boundary element reinforcing	c40x40	12Ø20	Ø10@15 cm

شکل۴- ۱۴. شتاب نگاشت مربوط یه زلزله نورثریج (مولفه طولی)
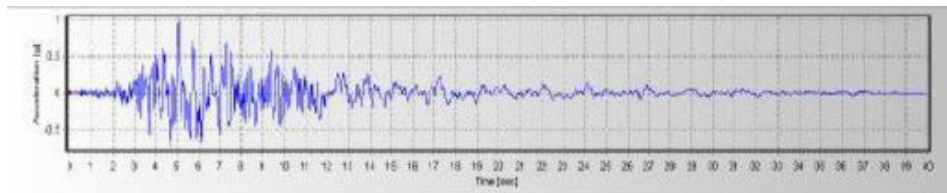
شکل۴- ۱۵. شتاب نگاشت مربوط یه زلزله نورثریج (مولفه عرضی)

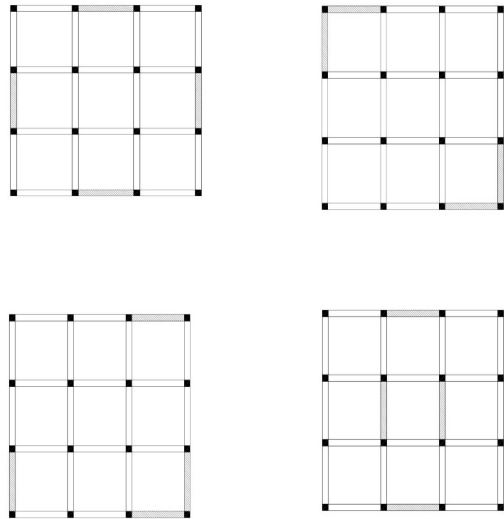**Fig. 3: Northridge Acceleration a) longitudinal direction, b) transverse direction**

shear by shear walls in arrangements 1, 2 and 3 are 68.68, 85.93 and 82.45 percent of total absorbed base shear by the structure, respectively.

Three-Meter Shear Walls

Table 3 presents absorbed base shear by the three-meter shear walls which are located in four different arrangements in each story.

Figure 6 shows the column chart diagram which is presented to compare absorbed base shear by three-meter shear walls in four different arrangements.

As figure 6 indicates, the most absorbed base shear belongs to arrangement 4 by the average of 72.31%. Absorbed base shear by shear wall in arrangement 1, 2 and 3 are 66.49, 66.92 and 62.40 percent of total absorbed base shear by structure, respectively.

Fig. 4: Shear wall arrangements

Table 2: Absorbed base shear by five meters shear walls

	Arrangement 1	Arrangement 2	Arrangement 3	Arrangement 4
Ground floor	1299460	1198148	1161535	1369729
Story 1	1181566	1070940	1043138	1228925
Story 2	1006630	910934	867340	1060252
Story 3	826309	763486	675978	929464
Story 4	813145	751636	682762	887388
Story 5	675682	601141	555433	722480
Story 6	472299	421641	396311	512408
Story 7	192059	166701	159395	221439
Story 8	0	0	0	0

Table 3: Absorbed base shear by 3 meters shear walls

	Arrangement 1	Arrangement 2	Arrangement 3	Arrangement 4
Ground floor	822362	863475	707140	1011179
Story 1	761014	797082	666596	917400
Story 2	641926	679183	554895	775672
Story 3	494366	521434	416901	616275
Story 4	559610	593536	492484	662687
Story 5	442919	475286	389252	542388
Story 6	305953	329583	264481	380127
Story 7	97099	113577	81815	142297
Story 8	0	0	0	0

Maximum Displacement of Structure Area Center for Each Model
Five-Meter Shear Wall

Figure 7 shows the maximum displacement of structure area center for each arrangement in eight-story building with five-meter shear walls.

As figure 7 shows, the maximum displacement of structure area center for the models are 17.81 cm, 14.09 cm, 16.3 cm and 15.4 cm in arrangement 1, 2, 3 and 4, respectively. The maximum displacement belongs to arrangement 1 and is 3.72cm, 1.51cm and 2.41cm greater than arrangements 2, 3 and 4.

Three-Meter Shear Wall

Figure 8 shows the maximum displacement of structure area center for each arrangement in eight-story building with five-meter shear walls.
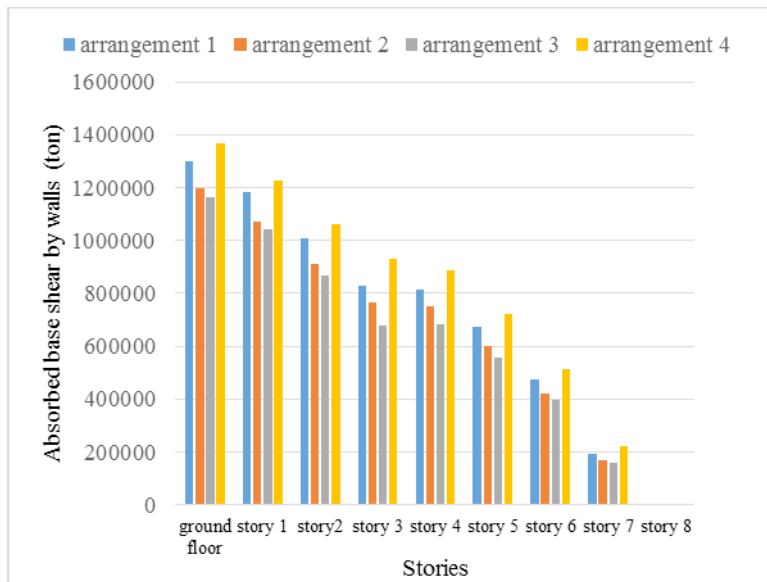

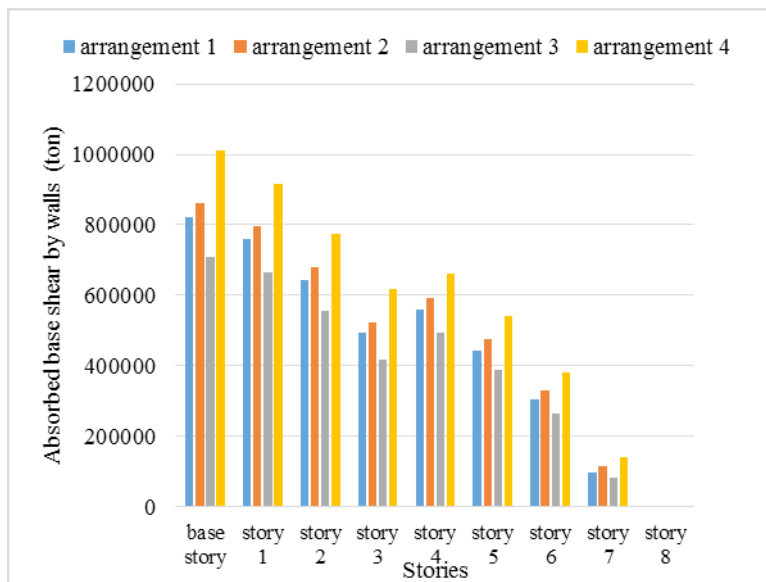Fig. 5: Absorbed base shear by five meters shear walls in each story (ton)

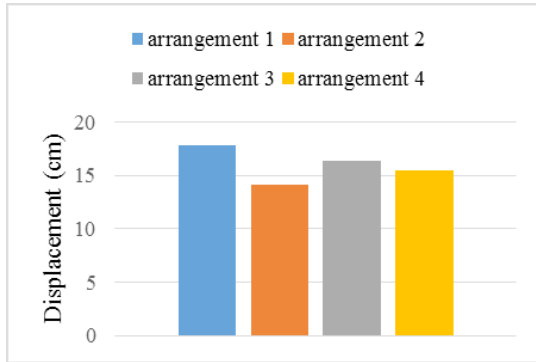Fig. 6: Absorbed base shear by three meters shear walls in each story (ton)

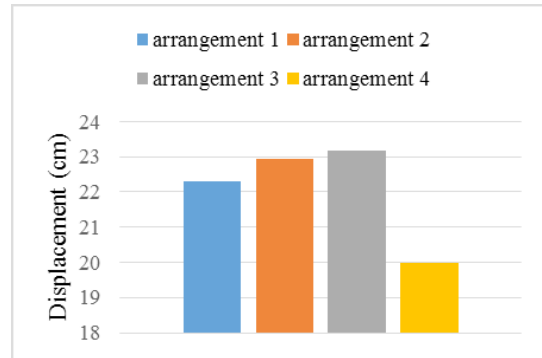**Fig. 7: Displacement of highest story area center**

Fig. 8: Displacement of highest story area center

As figure 8 shows, the maximum displacement of structure area center for the models are 22.29 cm, 22.93 cm, 23.18 cm and 19.98 cm in arrangement 1, 2, 3 and 4, respectively. The maximum displacement belongs to arrangement 3 and is 0.89cm, 0.25cm and 3.2cm greater than arrangement 1, 2 and 4.

CONCLUSIONS

To investigate the effect of RC shear wall dimensions and arrangements on the seismic behavior of RC structure an eight story concrete structure was modeled using nonlinear finite element software. Northridge acceleration was applied to the structure. Following conclusions can be driven from results obtained in section 5.

1. When shear wall length increases, absorbed base shear by shear wall increases too.
2. Placing shear walls in the inner axes of a structure, can increase absorbed base shear by shear walls.
3. Any increase in shear wall length, increases the maximum displacement of area center of the highest story.

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