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Seismic Assessment of Concrete Shear Wall with Rectangular Openings in Near Fault Earthquake

Yashar Yasrebinia[1], Maryam Poursharifi[2]

1- Department of Civil Engineering, Shabestar Branch, Islamic Azad University, Shabestar, Iran
2- Department of Civil Engineering, Sahand University of Technology, Tabriz, Iran

yasrobinia@tabrizu.ac.ir

Abstract

In this study, effect of rectangular opening in different sizes and variant locations on concrete shear wall ductility and their base shear, maximum displacement as well as energy dissipation in near fault earthquake is investigated. In this investigation the model of concrete shear wall is performed using ABAQUS Finite Element Software. The results of numerical study are validated with results of experimental test. There is a good agreement between results of numerical model and experimental test. The openings have area of 0.1, 0.2, 0.25 as well as 0.3 shear wall area. They are also located in center, up and right of concrete wall and up and right side of concrete wall. The models are subjected to two near fault earthquake records. Energy absorption, base shear and maximum displacement of models are compared. Results indicated that openings decrease energy absorption, base shear and lateral load carrying capacity. Also behavior of shear wall was sensitive about location of opening.

Keywords: Opening, Concrete Shear Wall, Near-Fault Earth quake.

1. INTRODUCTION

The shear wall is a structural element designed to resist lateral forces. The importance of shear walls in seismically active zones is noticeable, because shear forces are increased during earthquake. Shear walls should provide adequate strength and stiffness to control lateral displacement of structure. In order to minimize the torsional effects, shear walls were preferred to situate regularly both in plan and elevation. The shear walls in structures may have openings for the windows, doors and duct spaces for functional reasons as well as architectural purposes.

Some of the first studies of the behavior of reinforced concrete shear walls were carried out by Elnashahi and Pinho [1]. They tested a coupled shear wall at real scale. In their work, the load capacity and stress distribution around the openings were analyzed by conducting three-dimensional (3D) nonlinear pushover analyses on typical shear wall dominant building structures. Saheb and Desayi [2] considered U shaped shear wall with rectangular opening in the web, under shaking table tests. To investigate the behavior of the shear walls, and to assess the validity of the numerical tool, a 3-D refined non-linear analysis was conducted. In that investigation, it was shown that the refined model is able to describe the global behavior of the structure and qualitatively the distribution of damage at the base of the specimen. Hui and Bing [3] have modeled a coupled shear wall under lateral load. Experimental analysis has shown a considerable increase in lateral strength with diagonal tensile tie and compressive strut. In another research, two concrete shear walls with opening have been assessed [4]. This coupled shear walls were 120*120*10 cm, with an opening with dimensions 30*30 cm. This study has been carried out to find a better behavior for shear walls; FRP was also used to increase the strength of the shear wall. Kheyroddin and Naderpour [5] retrofitted the link beam in coupled shear walls using CFRP; they indicated a statistical method to increase the strength and ductility of the shear wall. Khatami [6] studied coupled shear walls under cyclic loading and recommended optimization side for openings on concrete shear walls. Barjari [7] investigated coupled shear walls that have been retrofitted; on these, the effect of steel reinforcing plates was seen to significantly increase the ultimate strength of coupled shear walls. The purpose of this study is to investigate the behavior of reinforced concrete shear walls with openings subjected to near fault ground motions. Twelve models were developed in ABAQUS finite element software [8]. The models are subjected to Northridge earthquake record and Chi-

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Chi earthquake record. Behavior was evaluated in terms of base shear, maximum displacement and absorbed energy amount.

2. NUMERICAL ANALYSIS

2.1 DESCRIPTION OF THEORETICAL MODEL

The models are developed in ABAQUS finite element software (ver. 6.10). Solid elements are used for modeling of concrete and rebar model are used for modeling of reinforcement. First model is called control specimen and used for validate the numerical analysis. The properties of models 1-9 are mentioned in table 1.

Table 1- properties of models

Model Name	Location of Opening	Opening Dimension (cmxcm)	Ratio of opening area to entire shear wall area
Model 1	Centre	34x34	8%
Model 2	Centre	38x38	10%
Model 3	Centre	41x41	12%
Model 4	Centre	46x46	15%
Model 5	Up Right	34x34	8%
Model 6	Up Right	38x38	10%
Model 7	Up Right	41x41	12%
Model 8	Up Right	46x46	15%
Model 9	-	-	-

The shape of models that are used in this investigation have three categories. These modeles are illustrated in figure 1 and figure 2. The other models that are selected without have any opening. Figure3.

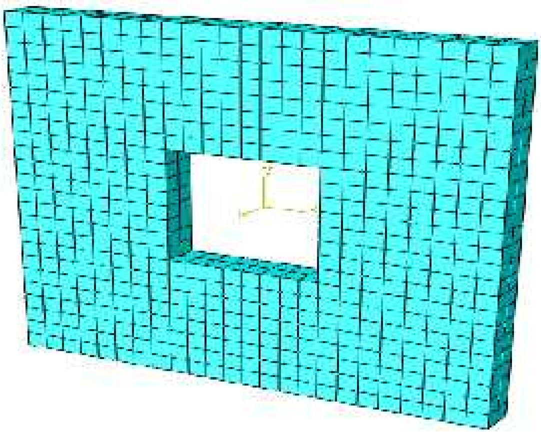

Figure 1. Shape of first category

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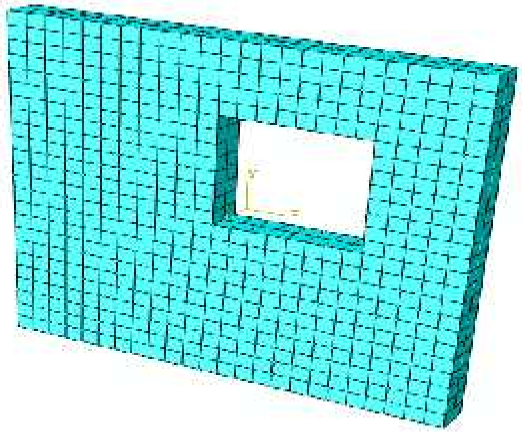

Figure 2 Shape of second category

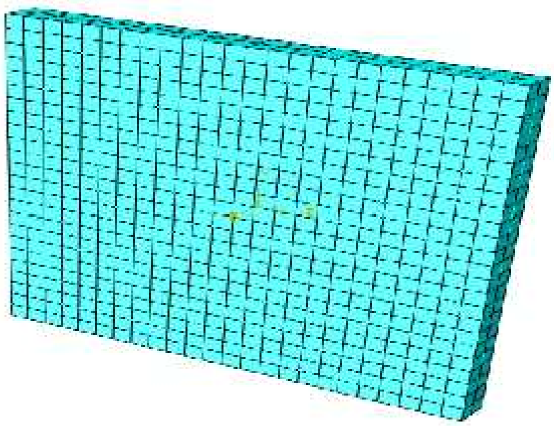

Figure 3. Wall without any opening

2.2 VALIDATION OF NUMERICAL RESULTS

To verify the finite element model, a shear wall from an experimental study that previously carried out by Doh and Fragomeni (2004) were here in used. Figure 4 shows the developed finite element model. This concrete square shear wall has a 30 cm square opening in the middle. The wall dimensions were 120*120*10 cm (length, width and thickness, respectively) as represented in Figure 4. The shear wall is reinforced with #14 bars, positioned every 10 cm. A lateral load was applied at top of the shear wall in order to push it. Explicit dynamic analysis was performed. According to experimental test, loading was applied at top of the wall. The results from finite element method compared with published experimental analysis. Load-displacement curves for both experimental work and finite element analysis are shown in Fig. 5. There is a good agreement between two curves.

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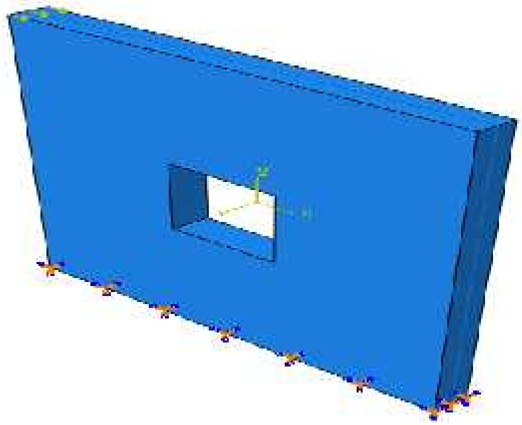

Figure 4. Developed model for Validation (control)

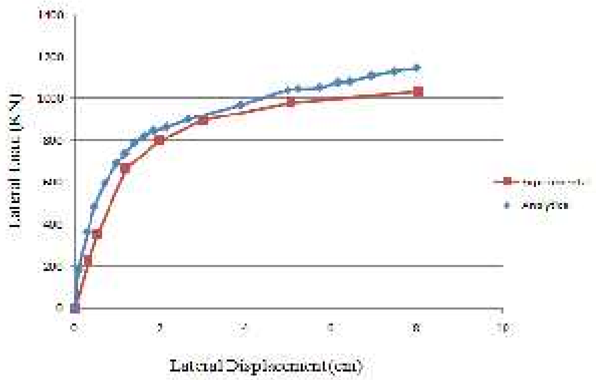

Figure 5. Comparison of Numerical results with Experimental results.

2.3 NUMERICAL MODELING ASSUMPTION

2.3.1 Material Properties

2.3.1.1 Concrete

The plastic damage model was used in order to model concrete's behavior. The compressive strength measured in experimental work was 2.5 KN/cm2. In plastic damage model two failure modes are compressive crushing and tensile cracking.

2.3.1.2 Steel Reinforcement

One types of steel were used to reinforce the concrete column. In this type steel was assumed as an elastic-perfectly plastic material. The Poisson's ratio for both types was 0.2. Properties of steel types used in experimental work are as follows, E=20594 KN/cm^2, F_y= 40 KN/cm^2.

2.3.2 Loading

All models are subjected to two near fault earthquake records which are which are applied at the base of shear wall. In this investigation, two earthquake records are used: Northridge and Chi-Chi. The Northridge Seismic excitation was strong with a magnitude of 6.70; in this record PGA was 0.349g, which occurred at epicenter distance of 11.7 km. The other record used for the analysis Chi-Chi Taiwan, which occurred on 20 September 1999 with a magnitude of 7.6, this earthquake had a maximum PGA of about 0.416 which occurred at epicenter distance of 16.03 km. These two earthquake records (shown in Figure 6 and Figure 7)

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have been selected for a comparative analysis of the results of the three different types of shear walls used in the 3D building considered. In this study these two records are scaled about 0.35g.

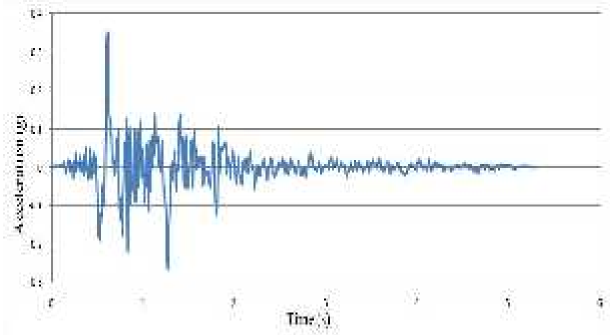

Figure 6. Shape of Northridge Near-field record

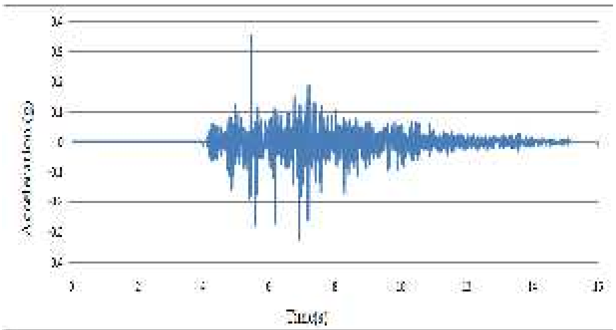

Figure 7. Shape of Chi-Chi Near-field record

3. RESULTS

In order to evaluate the effect of openings size and location on shear walls performance, dynamic explicit analysis had performed. The results are described in three parameters which are base shear, maximum displacement as well as absorbed energy amount in models.

3.1. Comparison of Base Shear for models

Firstly all models are analyzed under Northridge near-fault earthquake record. Then models are subjected to Chi-Chi record. The results are indicated in table 2.

Table 2- Base shear of models

Model name	Base shear under Northridge record(KN)	Base shear under Chi-Chi record(KN)
Model 1	25	14
Model 2	23.5	12.5
Model 3	22	11.5
Model 4	21.2	11.1
Model 5	22	12.5
Model 6	21	11
Model 7	20.5	10.5
Model 8	19.5	10.2
Model 9	27	16

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The results in table2 shows that with increasing the opening size of shear wall base shear decrease also 8% opening area corresponds to 25 KN and 15% opening area correspond to 21.2 KN base shear. In the models with opening in the center of shear wall base shear is greater than the models that opening in the up right of shear wall. For example in the model 5 the base shear is 22 KN while in the model 1 the base shear is 25 KN. Base shear- time diagram about model 3 in record Northridge and Chi-Chi are shown in figure 8 and 9 respectively.

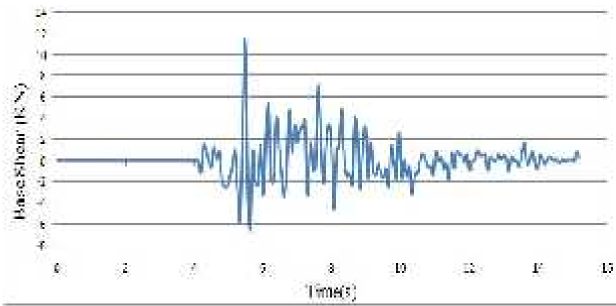

Figure 8. Base Shear of model 3 in Northridge record

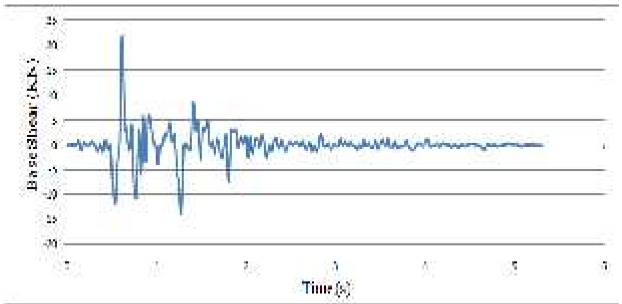

Figure 9. Base Shear of model 3 in Chi-Chi record

3.2 Comparison of Maximum Displacement for models

Maximum displacements of models are measured on top of model in both previously mentioned records. The results are mentioned in table 3. Maximum displacement in model 1 under Northridge record was 6 cm as well as under Chi-Chi record was 6.5 cm. Also Maximum displacement in model 4 under Northridge record was 6.4 cm as well as under Chi-Chi record was 7.5 cm. In model 9 without any opening maximum displacement is about 5.5 cm under Northridge record as well as 6 cm under Chi-Chi record.

Table 3- Maximum displacement of models

Model name	Maximum Displacement under Northridge record(cm)	Maximum Displacement under Chi-Chi record(cm)
Model 1	6	6.5
Model 2	6.1	6.7
Model 3	6.2	7
Model 4	6.4	7.5
Model 5	6.2	6.7
Model 6	6.4	7
Model 7	6.5	7.5
Model 8	6.7	8
Model 9	5.5	6

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3.3 Comparison of Absorbed Energy Amount in models

Results of analysis in the models about total energy amount are shown in the table 4. The results show that in model 1 under Northridge record total absorbed energy was about 27 KN.cm as well as 4.5 KN.cm about model 1 under Chi-Chi records. Also in model 4 under Northridge record total absorbed energy was about 21.5 KN.cm as well as 3.5 KN.cm under Chi-Chi records.

Table 4- Absorbed total energy of models

Model name	under Northridge record(KN.cm)	under Chi-Chi record(KN.cm)
Model 1	27	4.5
Model 2	25.5	4
Model 3	23	3.8
Model 4	21.5	3.5
Model 5	26	3.5
Model 6	25.5	3.2
Model 7	24.5	3.1
Model 8	23.5	3
Model 9	28	5

4. CONCLUSION

Analysis results show that with increasing opening size maximum displacement was increased and base shear was decreased. With increasing the opening size absorbed energy amount was decreased.

Location of opening is important in the behavior of shear wall as the behavior of the shear wall with opening in the center is better than the shear wall with opening in the up right. The base shear in the model with opening in the center of wall was greater than the shear wall with opening in the up right. Also the maximum displacement in the models have opening in the center was smaller than the others. Absorbed energy about shear wall with opening in the center was greater than the walls with opening in the up right.
About walls without opening amount of maximum displacement was smaller than the other models and the base shear and absorbed energy amount was greater than the other models.

5. REFERENCES

1. Elnashahi, A.S. and Pinho, R. (1998),"*Repair and retrofitting of RC walls using selective techniques*", Journal of Earthquake Engineering, Vol. 2, No. 4, pp. 525-568.

2. Saheb, S.M. and Desayi, P. (1990),"*Ultimate strength of RC wall panels with openings*", Journal of Structural Engineering, ASCE, Vol. 116, No. 6, pp. 1565-1578.

3. Hui, W. and Bing, L. (2003),"*Investigating the load paths of RC shear wall with openings under reversed cyclic loadings*", Pacific Conference on Earthquake Engineering. Paper No. 123.

4. Doh, J.H. and Fragomeni, S. (2004),"*Evaluation and experimental work for concrete walls with openings in one and two-way action*", The Third Civil Engineering Conference in the Asian Region (3 CECAR), Seoul, Korea.Trifunac, M. D. (2008),"*Wind and Micro tremor Induced Vibration of a 22 Story Steel Frame Building*", Earthquake Engineering Research Lab., Report EERL 70-01, California Institute of Technology, Pasadena California.

5. Khatami, S.M. (2010),"*Investigation of linear and nonlinear behavior of flanged section shear walls*", MSc Thesis in Civil Engineering (Structures) supervised by Prof. A. Kheyroddin, Islamic Azad Univerity (Takestan Branch), Iran.

6. Kheyroddin, A. and Naderpour, H. (2010),"*Nonlinear finite element analysis of composite RC shear walls*", Iranian Journal of Science & Technology, Vol. 32, No. B2, pp 79-89.

www.SID.ir

Archive of SID

7. Barjari, S.H. (2012),"*Investigation of nonlinear behavior of openings in shear walls*", MSc Thesis in Civil Engineering (Structures) supervised by Prof. A. Kheyroddin, Islamic Azad University (Takestan Branch), Iran.

8. ABAQUS. (2010),"*ABAQUS/User's manual and Theory manual*", Ver. 6.10, Inc.

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