

Effect of Bi-directional Loading on the Shear Strength of RC Shear Wall : Finite Element Analysis

Kun-Soo Kim ^{a*}, Junhee Park ^a

^a Structural and Seismic Safety Research Team, Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon, Korea 34057

*Corresponding author: kunsookim@kaeri.re.kr

1. Introduction

RC shear wall of nuclear power plants is an important structure system to resist earthquakes. In most studies, performance of RC shear wall is estimated by considering in-plane behavior. Recently, various failure modes of RC shear wall by bi-directional loading of earthquake were reported in Chile (2010) and New Zealand (2011) [1]. To estimate accurate shear behavior of RC shear wall, the effect of bi-directional loading conditions should be estimated by experimental study and numerical simulation. Nowadays, experimental studies on RC shear wall under bi-directional loading condition were conducted by only few researchers [2,3].

The finite element analysis is adopted by many researchers to predict and compare with experimental results. Also, it can be used to investigate the 3D behavior of RC shear wall. However, finite element analysis of RC shear wall subjected cyclic loading was performed in a limit manner because of difficulties in developing a concrete material under reversed cyclic loading. Some researchers have conducted on finite element analysis for the thin RC shear wall under bi-directional load, also, DIANA software was used to simulate the thin RC shear wall, and the curved shell elements were adopted [4,5].

The shear wall of nuclear power plants is the low-rise wall. Therefore, the studies on low-rise shear wall should be conducted to estimate the seismic performance of nuclear power plant. In this study, finite element analysis was conducted to simulate the RC shear wall subjected cyclic loading using the ABAQUS software [6]. Also, shear strength degradation by bi-directional loading was estimated numerically and compared with experimental result.

2. Finite element model

Fig. 3 shows the finite element model of RC shear wall. The concrete material was depicted by 8 nodes solid elements, and reinforcement material was depicted by 2 nodes truss elements. Fig. 4. Shows the stress-strain relationship of concrete [7]. In the CDP model in ABAQUS, degradation of Young's modulus is represented by compression damage parameter (d_c) and tension damage parameter (d_t). The test results of Sinha et al. were used to determine the d_c and d_t [9, 10]. The reinforcement were modeled using perfect plasticity

model, Poisson's ratio and Young's modulus were 0.3 and 205GPa respectively [8].

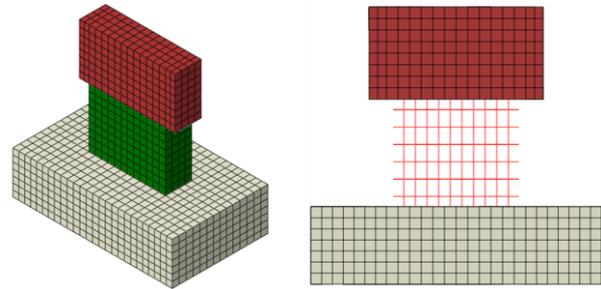


Fig. 3. Finite element model of RC shear wall specimen

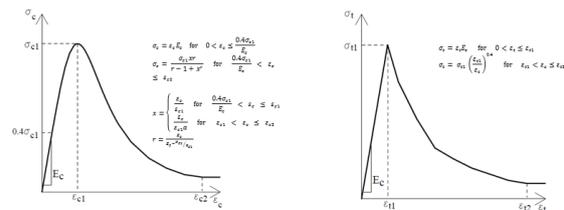
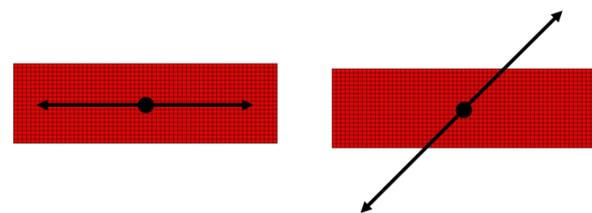


Fig. 4. Stress-strain relationship of concrete

3. Verification of finite element model

To validate the loading direction effects, the results of finite element analysis were compared with the experimental results. Fig. 2 shows the cyclic loading conditions of uni-directional and bi-directional loading tests. The applied drift level of cyclic loading condition was increased to 4 % drift ratio.



(b) Uni-direction path
Fig. 2. Cyclic loading condition

The load-displacement curves and backbone curves of numerical results and experimental results are shown in Fig. 5 and Fig. 6. According to test results, not much difference is observed in ductility. The bi-directional loading test showed a 12 % decrease in shear strength. In case of finite element analysis showed 13 % decrease

in shear strength. Therefore, the proposed finite element model was found to simulate the test results well. However, it was difficult to reflect the hysteresis behavior after concrete shear cracking.

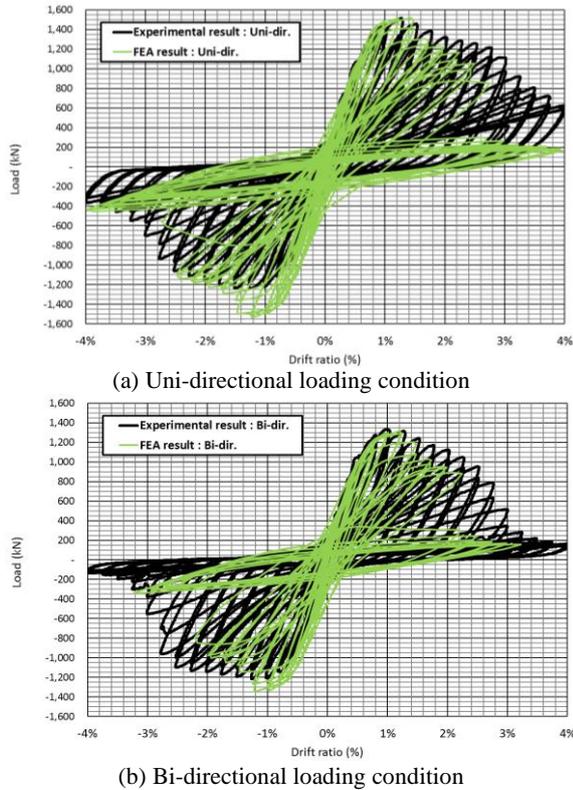


Fig. 5. Load-displacement curves of RC shear wall specimen

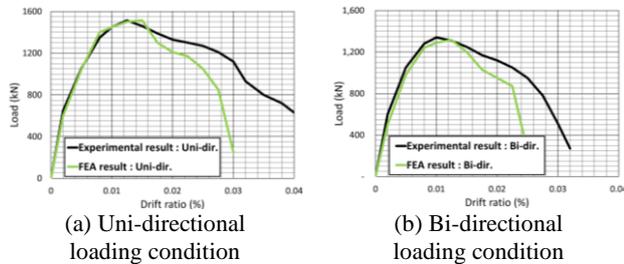


Fig. 6. Backbone curves of RC shear wall specimen

4. Conclusions

This study presents the development of numerical model of RC shear wall under bi-directional loading condition. The model was developed using the ABAQUS software. Simulated hysteresis behaviors of RC shear wall were compared with experimental results, and finite element model capable is proposed. The proposed model can be used for parametric study on RC shear wall. Also, further study considering the confined effects of concrete is necessary to predict more detail hysteresis behavior. Especially, to improve the pinching behavior of the proposed model, the various approaches are currently in progress.

ACKNOWLEDGEMENT

This work was supported by the Korea Institute of Energy Technology Evaluation and Planning(KETEP) and the Ministry of Trade, Industry & Energy(MOTIE) of the Republic of Korea (No. 20171510102020).

REFERENCES

- [1] A. Rosso, J. P. Almeida, and K. Beyer, Stability of Thin Reinforced Concrete Walls under Cyclic Loads: State-of-The-Art and New Experimental Findings. *Bulletin of Earthquake Engineering*, Vol.14, No.2, p. 455-484, 2016.
- [2] A. Niroomandi, A. Pampanin, R. P. Dhakal, and M. S. Ashtiani, Experimental Study on Slender Rectangular RC Walls under Bi-Directional Loading. *Eleventh U.S. National Conference on Earthquake Engineering*, 2018.
- [3] T. Kabeyasawa, S. Kato, M. Sato, T. Kabeyasawa, H. Fukuyama, M. Tani, Y. Kim and Y. Hosokawa, Effects of Bi-Directional Lateral Loading on The Strength and Deformability of Reinforced Concrete Walls with/without Boundary Columns. In *The Tenth US National Conference on Earthquake Engineering*, 2014, July.
- [4] A. Niroomandi, S. Pampanin, R. P. Dhakal, and M. S. Ashtiani, Finite Element Analysis of RC Rectangular Shear Walls under Bi-Directional Loading. In *The New Zealand Society for Earthquake Engineering (NZSEE) Annual Technical Conference*, 2016.
- [5] T. N. O. DIANA, DIANA User's Manual Release 9.6, Delft, The Netherlands, 2014.
- [6] SIMULIA, ABAQUS Version 6.16 Analysis User's Manuals, 2016.
- [7] K. S. Kim, O. Han, M. Gombosuren, and S. H. Kim, Numerical Simulation of Y-Type Perforated Rib Shear Connectors Using Finite Element Analysis, *Steel and Composite Structures*, Vol.31, No.1, 2019(Accepted).
- [8] H. Y. Loh, B. Uy, and M. A. Bradford, The Effects of Partial Shear Connection in The Hogging Moment Regions of Composite Beams Part II : Analytical Study, *Journal of Constructional Steel Research*, Vol.60, No.6, p. 921-962, 2014.
- [9] B. P. Sinha, K. H. Gerstle and L. G. Tulin, Stress-Strain Relations for Concrete under Cyclic Loading. In *Journal Proceedings*, Vol. 61, No. 2, p. 195-212, 1964, February.
- [10] N. H. Nguyen, and A. S. Whittaker, Numerical Modelling of Steel-Plate Concrete Composite Shear Walls. *Engineering Structures*, Vol.150, p. 1-11, 2017.