Contemporary Engineering Sciences, Vol. 8, 2015, no. 18, 817 - 823
HIKARI Ltd, www.m-hikari.com
http://dx.doi.org/10.12988/ces.2015.57198

Strengthening of Non-Seismic Reinforced Concrete Frames with Steel Element

Sun-Woong Kim

Department of Convergence Systems Engineering, Chungnam National University, 99 Daehak-ro Yuseong-gu, Daejeon, 305-764, Republic of Korea

Young-Il Jang

Professor, Department of Construction Engineering Education, Chungnam National University, 99 Daehak-ro Yuseong-gu, Daejeon, 305-764
Republic of Korea

Wan-Shin Park

Professor, Department of Construction Engineering Education, Chungnam National University, 99 Daehak-ro Yuseong-gu, Daejeon, 305-764
Republic of Korea
Corresponding author

Nam-Yong Eom

Department of Technology Education, Chungnam National University, 99 Daehak-ro Yuseong-gu, Daejeon, 305-764, Republic of Korea

Hyun-Do Yun

Professor, Department of Architectural Engineering, Chungnam National University, 99 Daehak-ro, Yuseong-gu, Daejeon, 305-764
Republic of Korea
Corresponding author

Sun-Woo Kim

Professor, Department of Construction Engineering Education, Chungnam National University, 99 Daehak-ro Yuseong-gu, Daejeon, 305-764
Republic of Korea

Abstract

Low or medium earthquakes in South Korea are dangerous. They exemplify the true power of nature and cannot be avoided. In addition, indirect effects of earthquakes include tsunamis, floods, fires, etc. So over the last years, seismic retrofitting methods for reinforced concrete frames with non-seismic details have been developed to resist earthquake. The aim of this study is to investigate the load-displacement relationship and strain characteristics of reinforced concrete frame with grid shape frame as an innovative retrofitting method for improving the seismic performance of school buildings.

Keywords: Seismic performance, Grid shape, Seismic retrofitting, School building

1 Introduction

Most of the existing reinforced concrete residential buildings in South Korea are seismically deficient. In building design codes, buildings having less than 3 stories and a floor area less than 1000m^2 in South Korea are generally exempted from seismic requirements. Recent earthquakes around the world have shown that non-seismic reinforced concrete (RC) buildings are vulnerable to severe damage or complete collapse [1, 2]. The primary deficiencies of these buildings are inadequate strength, stiffness, deformation capacities and insufficient energy-dissipation capacities [3, 4]. Due to the low lateral strength and stiffness of these kinds of buildings, the buildings experience large lateral displacements under earthquake [5, 6].
In this work to quantify the improvement in reinforced concrete frame depending upon retrofitting method and connection details compared to control specimens without grid steel frame in series of experiments.

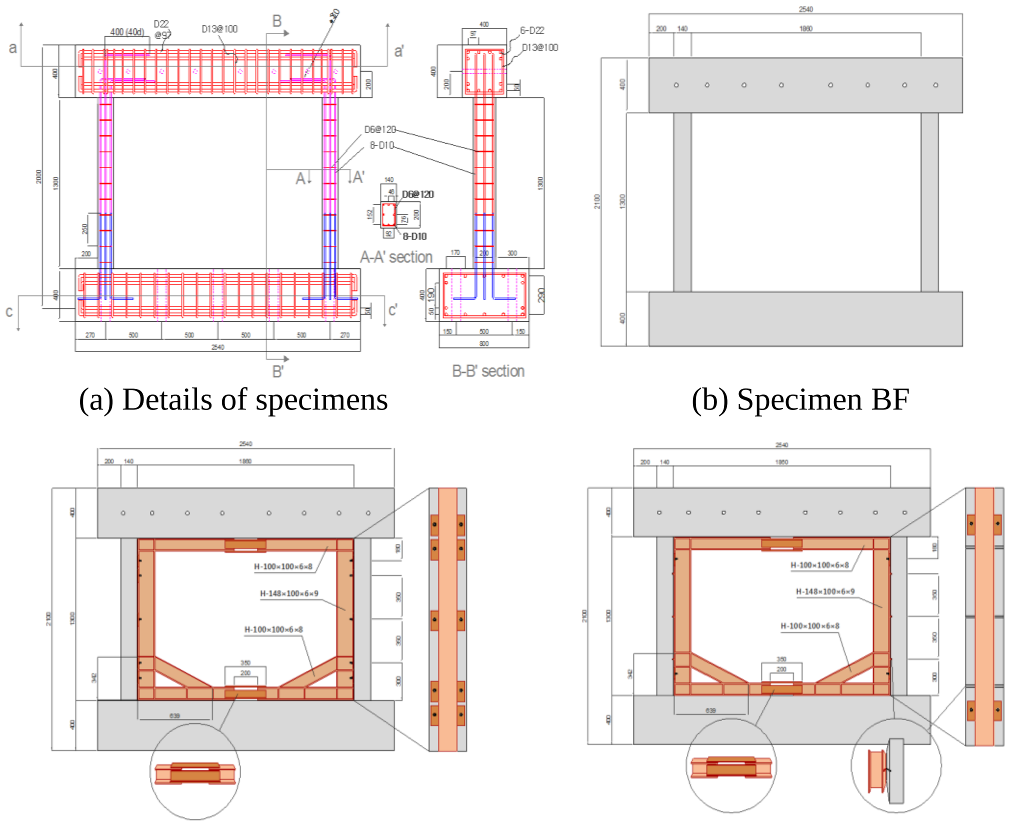
Table. 1 Test Variable

Specimen name	Retrofitting method	Material	Column reinforcement details		Connection details
			Longitudinal bars	Stirrup	
BF	-	Concrete	8-D10	D6@120	-
SR-A	Steel frame	Concrete	8-D10	D6@120	Anchor bolts
SR-S	Steel frame	Concrete	8-D10	D6@120	Shear key

2 Experimental Programs

Table 1 and Figure 1 show the test variables and specimen details. These three specimens have identical dimensions and longitudinal reinforcement details. Test variables of this study are types of retrofitting method and connection details for non-seismic reinforced concrete frame.

Fig. 2 (a) and (b) showed the slump flow test and air content test, respectively. The consistency and workability of all the concrete mixtures was determined through slump flow tests to achieve target slump flow of about 145mm. The slump flow tests were performed according to ASTM C 143. The air content tests were performed to achieve target air content of 4.0± 1.5%.using gravimetric methods according to ASTM 231. Tests were taken to determine actual properties for compressive strength of concrete and tensile strength of concrete. The concrete compressive strength was approximately 18MPa, as shown in Fig. 2 (c). The flexural strength of concrete material under monotonic load is about 4.25MPa, as shown in Fig. 2(d).



(a) Details of specimens (b) Specimen BF

(c) Specimen SR-A (d) Specimen SR-S

Fig. 1 Details of specimens

(a) Slump

(b) Air content

(c) Compressive strength

(d) Flexural strength for SFRC

Fig. 2 Mechanical property

Fig. 3 Test set-up

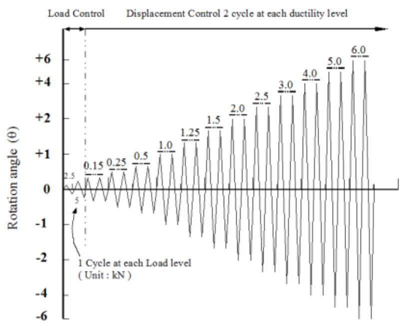


Fig. 4 Loading History

The test setup is shown in detail in Fig. 3. A hydraulic actuator with a capacity of 1000kN is fixed to the reaction wall. It is then able to exert forces onto the top steel strong frame in both positive and negative directions. The displacement of all the specimens was controlled to follow similar load and displacement histories with progressively increasing amplitude.

Instrumentation was provided to measure the load, displacement and strain at critical locations. The testing procedure included load-controlled and displacement-controlled cycles, as shown in Fig. 4.

3 Experimental Results

Table 2 and Figure 5 show the maximum strengths and the hysteretic response plotted against the displacement. As listed in Table 2, the first specimen BF reached its peak load of 31.83kN in the positive loading direction and 29.39kN in the negative loading direction. In addition maximum displacement (rotation angle) was 51.12mm (3.93%) corresponding to maximum load in positive direction.

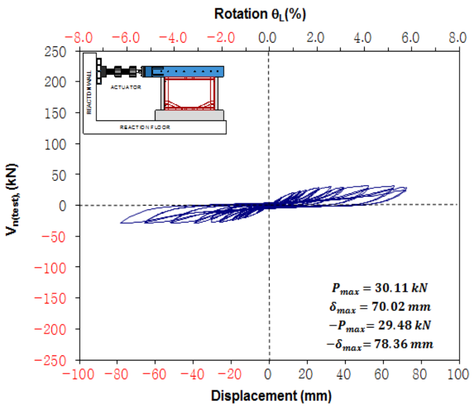
The second specimen SR-A reached its peak load of 241.74kN in the positive loading direction and 236.58kN in the negative loading direction. The specimen SR-A maximum displacement (rotation angle) was 26.10mm (2.0%). The third specimen SR-S reached its peak load of 379.90kN in the positive loading direction and 393.33kN in the negative loading direction. The specimen SR-S maximum displacement (rotation angle) was 30.72mm (2.36%). The average maximum strength of specimens BF, SR-A and SR-S were 30.61kN, 239.16kN and 223.47kN respectively. In addition, average maximum strength of SR-A and SR-S specimens were 7.81 and 7.30 times higher than those of specimen BF, respectively.

Figure 6 shows the strain characteristics of longitudinal bars plotted against the displacement for specimens BF, SR-A and SR-S. The maximums strain of specimen BF, SR-A and SR-S in failure were 909.85μ strain, 815.96μ strain and 896.71μ strain, respectively. In addition, average maximum strength of SR-A and SR-S specimens were 0.87 and 0.99 times lower than those of specimen BF, respectively.

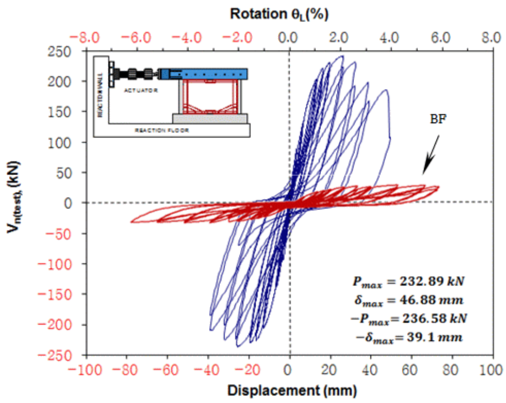
Based on the observation of stains, longitudinal bars of all the specimens did not yield throughout out the test. This was attributed to premature connection failure before longitudinal bar of column yielded.

Table. 2 Maximum strength

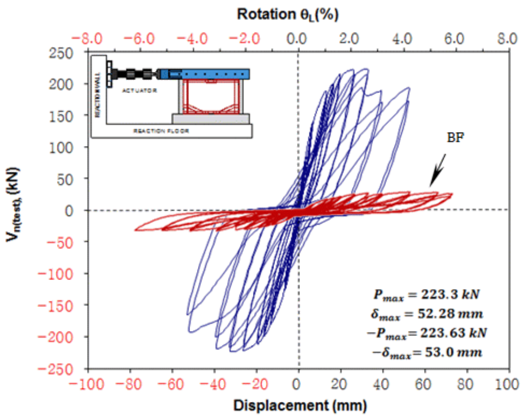
Specimen	Maximum strength				
	Positive loading	Displacement (rotation angle)	Negative loading	Displacement (rotation angle)	Comparison Ratio (BF/Specimen)
BF	31.83kN	51.12mm (3.93%)	29.39kN	51.56mm (3.97%)	-
SR-A	241.74kN	26.10mm (2.00%)	236.58kN	25.72mm (1.98%)	7.81
SR-S	223.30kN	32.74mm (2.52%)	223.63kN	30.72mm (2.36%)	7.30



(a) Specimen C-1

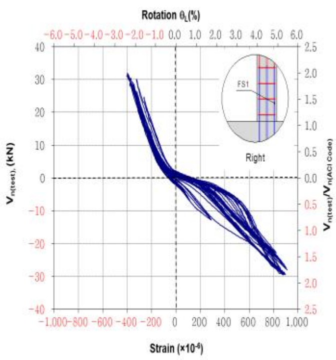


(b) Specimen C-2

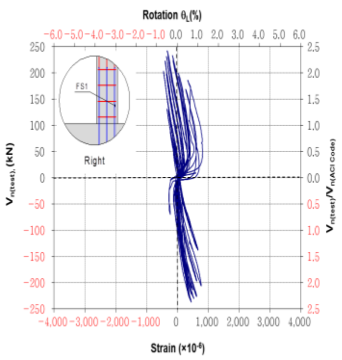


(c) Specimen C-3

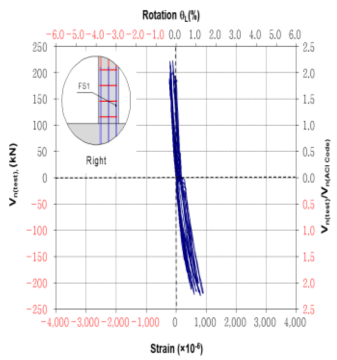
Fig. 5 Hysteretic loop



(a) BF



(b) SR-A



(c) SR-S

Fig. 6 Strain Characteristics

4. Conclusion

Base on the observation of test results, average maximum strength of specimens BF, SR-A and SR-S were 30.61kN, 239.16kN and 223.47kN respectively. In addition, average maximum strength of SR-A and SR-S specimens were 7.81 and 7.30 times higher than those of specimen BF, respectively. In addition, strain characteristics of longitudinal bars plotted against the displacement for specimens BF, SR-A and SR-S. The maximums strain of specimen BF, SR-A and SR-S in failure were 909.85μ strain, 815.96μ strain and 896.71μ strain, respectively. Based on the observation of stains, longitudinal bars of all the specimens did not yield throughout out the test. This was attributed to premature connection failure before longitudinal bar of column yielded.

Acknowledgements. This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT & Future Planning (2014R1A1A2057931) and this work was supported by research fund of 2014 Chungnam National University (2014-0756).

References

[1] C.V.R. Murty, M. Greene, S.K. Jain, N.P. Prasad and V.V. Mehta, Earthquake rebuilding in Gujarat, India—a recovery reconnaissance report. Oakland (CA): *Earthquake Engineering Research Institute*, 2005.

[2] W.S. Park and H. D. Yun, Seismic Performance of Pseudo Strain-Hardening Cementitious Composite Coupling Beams with Different Reinforcement Details, *Composite: Part B*, **42** (2011), no. 6, 1427-1445. http://dx.doi.org/10.1016/j.compositesb.2011.04.049

[3] R. S. Dipti and C. R. Durgesh, Seismic strengthening of non-ductile reinforced concrete frames using aluminum shear links as energy-dissipation devices, *Engineering Structures*, **32** (2010), no. 11, 3548-3557. http://dx.doi.org/10.1016/j.engstruct.2010.07.023

[4] A. Sinan, A. Ozgur and M E. Kara, Strengthening of RC nonductile frames with RC infills: An experimental study, *Cement & Concrete Composites*, **30** (2008), no. 7, 612-621. http://dx.doi.org/10.1016/j.cemconcomp.2007.07.003

[5] Y. Higashi and S. Kokusho, The strengthening method of existing reinforced concrete buildings, US–Japan Cooperative Research Program in Earthquake Engineering, Honolulu, Hawaii, 1975.

Received: July 21, 2015; Published: September 9, 2015