Study on Effect of Confinement of Reinforced Concrete Retrofitted Joints Using Horizontal Haunches

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Damage was observed in the beam-column joints of many reinforced concrete buildings by the Hyogo-ken Nanbu Earthquake of 1995. After the building standards law revised in 2007 in Japan, the retrofit of the beam-column joints in many buildings is necessary.

Therefore, the authors have proposed a method for the retrofit using horizontal haunches. So far, it has been shown that there is much reinforcing effect by horizontal haunches. In this study, the effect of confinement by the prestressing force and the steel plate was investigated experimentally. As a result, it was found that, owing to decrease of confinement, decrease of energy absorption capacity and movement of plastic hinge generation position to the vicinity of the joints are observed, and the joints are prone to be damaged.

Key words *: beam-column joint, retrofit, PC steel bar, shear*

1. INTRODUCTION

In the Hyogo-ken Nanbu Earthquake of 1995, the beam-column joints of many RC buildings designed based on the new earthquake resistant standard suffered great damage. Fig.1 shows an example of joint failure in the earthquake. Some damage of the joints due to the Tohoku Region Pacific Offshore Earthquake that occurred in 2011 was also observed. The necessity of earthquake-resistant design of joints was clarified by enforcement order of revised Building Standard Law in 2007, and the performance of joints in current law is required for extension and remodeling of existing RC buildings over a certain scale However, there is no practical and effective method.

Meanwhile, Uehara, one of authors, and others studied experimentally the properties of joint when the interior beam-column joint with poor seismic performance was seismically reinforced using horizontal haunches[1)]. As a result, it was confirmed that on the specimens reinforced with steel of thickness of 6 mm and prestressing force of 85% of φ13 PC bar yielding, joint damage can be prevented as compared with unretrofitted specimens. Also, the effect of hinge relocation was observed.

In this study, the authors examined the influence of the restraint condition caused by the prestressing force and the thickness of the reinforced steel plate.

Fig.1 Failure of beam-column joint

2. EXPERIMENT OUTLINE

Table 1 shows the test specimen list of this experiment and Table 2 shows the mechanical properties of the materials. The specimen is assumed to be a reduction model of about 30% referring to the structure of apartment complex damaged by the Southern Hyogo earthquake.

Fig.2 shows the retrofit method of the specimen. The specimen has horizontal haunches by the beam and the cross beam. This is a method of thickening the beam width to the column width by mortar, and pressing the steel plate against the side surfaces and crimping them with φ13 PC steel rod. This reinforcement aims to increase the volume of the joint and to move the beam plastic hinge generation position from the beam end to the retrofitted toe end.

Table 1 List of specimens

Number	Specimen name	Reinforcement method
No.1	2015-IJR1	Mortar filling of beam sides + Crimping side steel plate with PC steel bar (Prestress force 68%,6mm thick Checkered steel plate)
No.2	2015-IJR2	Mortar filling of beam sides + Crimping side steel plate with PC steel bar (Prestress force 68%,3mm thick Checkered steel plate)

Table 2 Mechanical properties of the materials

Use		Nominal diameter or Thickness	Yield point	Tensile strength	Compressive strength	Youg's modulus
		(mm)	(N/mm²)	(N/mm²)	(N/mm²)	(10^5N/mm²)
Concrete	No.1				19.7	0.195
	No.2				20.8	0.221
Nonshrinkage mortar	No.1				67.4	0.271
	No.2				65.7	0.3
Latelar Reinforcement		φ3.2	226	355		2.06
Beam bars		D10	362	582		1.88
Column bars		D13	379	569		1.88
Slab Reinforcement		φ6	565	584		1.98
Reinforcing steel plate	No.1	6	312	458		1.93
	No.2	3	328	405		1.93
PC steel bar		φ13	1220	1266		2.01

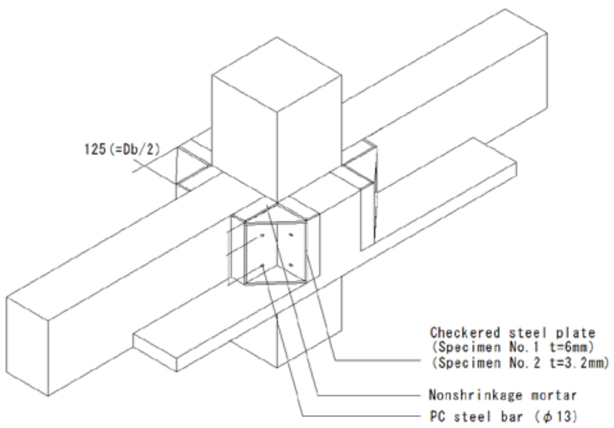


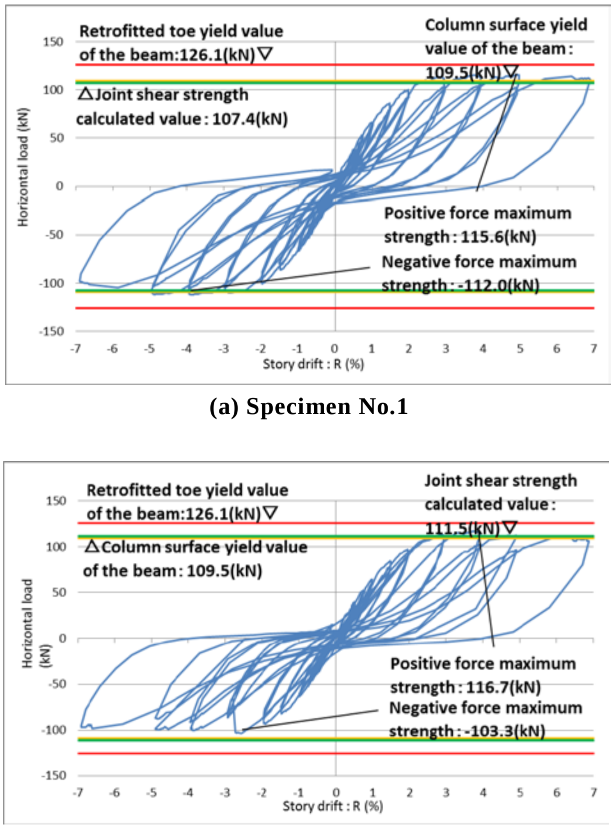
Fig.2 Retrofit method of the specimen

3. EXPERIMENTAL RESULTS

Fig.3 shows the relationship between the horizontal load N and the story drift angle R. In the specimen No.1, the maximum strength was obtained at R=5.0% and the beams were failed by bending at R=7.0%. In specimen No.2, at R=4.0%, the maximum strength was obtained, and at R=7.0%, crushing of the beam ends was less than that of the specimen No.1, so it was considered that joint failure was progressed.

Fig.4 shows difference of energy absorption capacity of each specimen. In the specimen No. 1, it can be said that there is an influence from the steel thickness because the energy absorbing ability is larger than that of specimen No.2.

Fig.5 shows specimens after experiment. Fig.6 shows the inside section of the joint panel after experiment. Comparing the photo of the joint panel of the specimen No.1 of Fig.6-(a) with the one of specimen No.2 of Fig.6-(b), it can be seen that damage is more pronounced in Fig.6-(b).



(a) Specimen No.1

(b) Specimen No.2

Fig.3 Horizontal load and the story drift

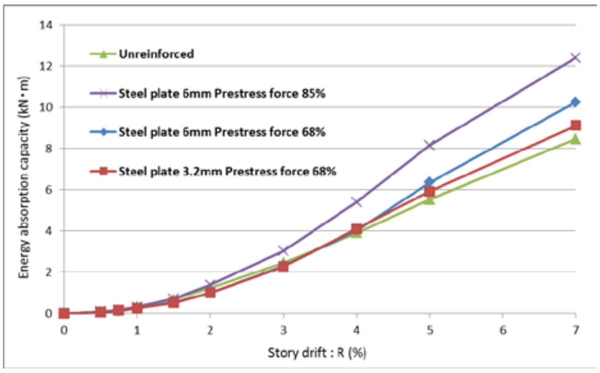


Fig.4 The energy absorption capacity of each specimen

(a) Specimen No.1

(b) Specimen No.2

Fig.5 Specimens after experiment

(a) Specimen No.1

(b) Specimen No.2

Fig.6 Inside section of the joint panel

4. CONCLUSIONS

For the horizontal haunch-like retrofit of the interior beam-column joint, the influence of the restraining force by changing the prestressing force applied to the side face and the steel plate thickness was experimentally studied. As a result, the following matters were clarified.

(1) When the restraining force was weakened due to less prestressing force or reduction in steel sheet thickness, the energy absorption capacity decreases.

(2) When the restraining force was weakened due to less prestressing force or reduction in steel sheet thickness, the hinge generation position moves from retrofit haunch ends to the vicinity of the joint, and the joint is prone damaged.

REFERENCES

1) Kondo T., Uehara S., and Yamakawa T., “Seismic performance of reinforced concrete beam-column joint retrofitted by horizontal haunches” International Symposium on Technology for Sustainability, 2013