Shear Resistance Mechanism of RC Column Retrofitted by using PC Bars

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Summary

It is a known fact that the compressive strength and ductility of concrete can be considerably improved by lateral confinement. In this study, a ductility-type seismic retrofitting technique of RC columns by utilizing high-strength steel bars (PC bars) prestressing was applied, which is arranged on the four faces of the RC columns as external hoops. Hence, active confinement due to the tensile forces in the PC bars as well as passive confinement and transverse reinforcement can be expected. Recent axial compression tests showed that the active and passive confinement using PC bar prestressing can considerably improve the stress–strain characteristics of confined concrete. In this paper, the shear resistance mechanism and shear strength of RC columns retrofitted using PC bar prestressing was experimentally investigated under constant axial force and cyclic lateral forces.

Keywords: prestress; shear strength; truss mechanism; arch mechanism; seismic retrofit.

1. Test plan

The retrofitting details of the test specimens are shown in Table 1 and Fig. 1. To investigate the shear resistance mechanism (truss and arch mechanism), two kinds of specimens are considered in this study. One group consisted of retrofitted RC columns without a bond force between the concrete and the embedded longitudinal reinforcement to generate the arch mechanism. The other group consisted of retrofitted RC columns with the bond force of the rebars to check the truss mechanism, which relies heavily on the bond resistance between rebars and concrete.

Table 1: Details of specimens

Specimens	$M/(VD)$	${}_c\sigma_B$ (MPa)	η	${}_pS$ (mm)	ε_{pt} (μ)	σ_r (MPa)	Bond performance of rebar
R10S-P65LB	1.0	23	0.2	65	535	0.31	Bond
R10S-P65LU					628	0.37	Unbond
R11S-P65LBh		19.6	0.4		723	0.42	Bond
R11S-P65LUh					727	0.42	Unbond
R10S-P65MB		23	0.2		2429	1.42	Bond
R10S-P65MU					2448	1.43	Unbond
R10S-P65MBh		19	0.4		2413	1.41	Bond
R10S-P65MUh					2506	1.46	Unbond
Common details	Cross section: 250x250mm, Bonded rebar: 8-D19 (p_g=3.67%), Unbonded rebar: 12-D10 (p_g=1.36%), Hoop: 3.7ϕ-@105						

Notes: $M/(VD)$ = shear span to depth ratio, ${}_c\sigma_B$ = compressive strength of concrete cylinder, η = axial force ratio, ${}_pS$= interval of PC bars, ε_{pt} = initial tension strain of PC bars, σ_r = lateral confining pressure.

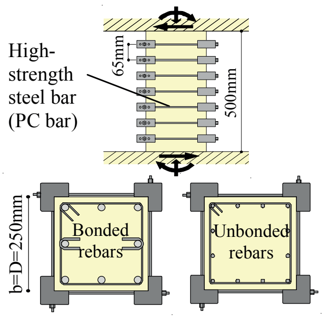

Fig. 1: Test specimens retrofitted with PC bars

The column specimens used in this test were square with cross-sectional dimensions of 250x250 mm, a height of 500 mm, and a shear span-to-depth ratio (M/VD) of 1.0. The longitudinal reinforcement ratio (p_g) of retrofitted specimens with the bond force of the rebars is 3,67% (diameter = 19 mm, number of rebars is eight, σ_y = 526 MPa), and that of retrofitted specimens with

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unbonded rebars is 1,36% (diameter = 10 mm, number of rebars is twelve, σ_y = 912 or 847 MPa). The shear reinforcement ratio (p_w) of the column specimens is 0,08%. Consequently, RC columns are under high flexural strength and shear failure is likely to occur after retrofitting the columns with PC bar prestressing.The test parameters of the column specimens with and without the bond force of the rebars, the initial tension strain of PC bars and axial force are listed in Table 1. The cyclic loading test was carried out with a drift angle of ±0,125%, ±0,25%, ±4,0%, and ±5,0% at one cycle, ±0,5%, ±0,75%, ±1,0%, ±1,5%, ±2,0%, ±2,5%, and ±3,0% at two successive cycles.

2. Experimental results

The experimental shear force (V) and drift angle (R) relationships are shown in Fig. 2. In Fig. 2, the lateral confining pressure σ_r is calculated by Eq. (1),

$$\sigma_r = (2\,{}_P a)/(b\,{}_P s)\cdot {}_P E \cdot \varepsilon_{pt} \qquad (1)$$

where ${}_P a$ is the cross-sectional area of the PC bar, b is the width of the column, ${}_P s$ is the interval of the PC bars, ${}_P E$ is the Young's modulus of elasticity of the PC bar, and ε_{pt} is the initial tension strain level. In the retrofitted specimens (Fig. 2 (a), (c), (e), and (g)), flexural cracks appeared at the tension side of the top and bottom of the columns at a drift angle (R) of 0,125–0,25%, and diagonal cracks were generated at R = 0,25–0,5%. The lateral force reached the maximum lateral force capacity at R = 0,5–1,5%, after which it gradually decreased due to the increase in the diagonal cracks. In the retrofitted specimens with unbonded rebars (Fig. 2(b), (d), (f), and (h)), flexural cracks appeared in the tension side of the top and bottom of the columns at R = 0,125–0,25%. With increasing cracks in the compression side of the top and bottom of the columns at R = 0,25–0,5%, the maximum lateral force capacity was observed at R = 1,0–2,0% through the generation of diagonal cracks. In specimen R10S-P65MU, diagonal cracks appeared after the maximum lateral force capacity. In Fig. 2, the lateral stiffness and maximum lateral force capacity of the retrofitted specimens with bonded rebars is larger than that of the retrofitted specimens with unbonded rebars.

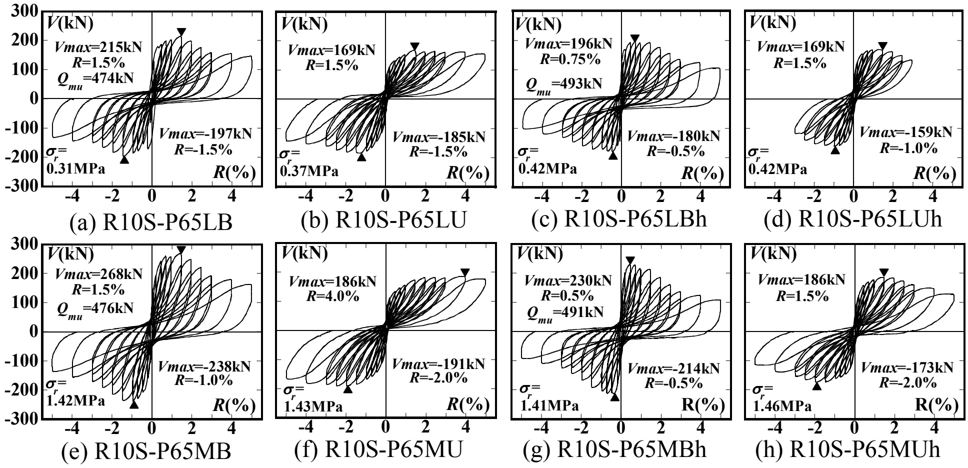

Fig. 2: Experimental V–R relationships

3. Conclusions

(1) The initial tension force of the PC bars enhances the shear strength of the truss mechanism.

(2) By applying lateral confining pressure to the RC column without the bond force of the rebars, the shear strength of the arch mechanism can be increased.

(3) The shear strength of arch mechanism increases with increasing axial force.

(4) The slope of the line of thrust and the depth of the compression zone of the arch mechanism correlate with the lateral confining pressure and vertical axial load.