SHEAR STRENGTHENING EFFECT OF RC BEAMS WITH PCM SHOTCRETE

A. Arwin AMIRUDDIN Member Kyushu University
Shinichi HINO Fellow Member Kyushu University
Kohei YAMAGUCHI Member Kyushu University
Satoru NAKAMURA Member Satobenec Co., LTD.
Kensi TANIGUCHI Nippon Steel Composite Co., LTD.

I. INTRODUCTION

The use of polymer cement mortar (PCM) in concrete structures is a relatively new technique. This paper discusses the use of flexible PCM wrapped around the RC beams to increase their shear strengths. The results of an experimental and analytical study of the behavior of damaged or under-strength concrete beams retrofitted with polymer cement mortar (PCM) are presented. These PCM are made from the high-strength and low-elasticity. In this study, four types of RC beams reinforced internally with steel and externally with both PCM and CRRP grid were tested under three-point bending.

II. SPECIMENS AND MATERIAL PROPERTIES

The test specimens consisted of 8 RC beams classified into four groups according to the concrete and PCM compressive strength as given in **Table 1**. The group 1 is reinforced concrete (RCB) as control beam as shown in **Fig.1(a)**, group 2 is RC wrapped with PCM-high strength (PHB) shown in **Fig.1(b)**, group 3 is RC wrapped by PCM-low elasticity (PLB) shown in **Fig.1(b)**, and the group 4 is RC wrapped with PCM-high strength-CFRP grid (PGB) shown in **Fig.1(c)**. **Table 2** and **Table 3** show tensile test of steel reinforcement and details of CRFP grid, respectively.

For RCB were installed 3 hoops stirrups D10(SD295) which put 2 on each of the supports and the last put at the middle in 550mm distance of beams spans. Thickness by wrapping PCM high-strength and PCM low-elasticity is 42mm around the RC beams with additional longitudinal reinforcement D22(SD345) and transversal reinforcement D10(SD295)@120mm hence these specimens called PHB and PLB, respectively. For PGB consisted of RC beams wrapped with CFRP-grid where in longitudinal direction was installed CR-10@100mm and transversal direction was installed CR-5@110mm, after that wrapped by PCM high strength with thickness is 18mm.

III. EXPERIMENTAL AND ANALYSIS RESULTS

Table 4 shows details of loads types in this experiment and analysis, namely crack load (P_{cr}), by bending yield load (P_y), shear load (P_s), and ultimate load (P_u). Analysis method to calculate shear performances were applied two types. Analysis-1 and Analysis-2 obtained from JSCE method[1], however for Analysis-1 using variable of effective depth (d) value was determined from distance compression of concrete till the average of steel reinforcement (tension area).

Table 1 Details of material properties

Types	PCM	f'_c, MPa	E_c, MPa	Poisson ratio	f_{tc}, MPa
RCB	-	35.0	3.06×10^4	0.19	2.99
PHB	high strength	59.8	2.48×10^4	0.20	2.91
PLB	low elasticity	25.0	1.33×10^4	0.20	2.16
PGB	high strength	69.5	2.61×10^4	0.21	2.97

Table 2 Details of steel reinforcement

Diameter	Spec.	f_y, MPa	f_t, MPa	E_s, MPa
D10	SD295	323	455	2.10×10^5
D22	SD345	395	582	

Table 3 Details of CFRP grid

CFRP-grid	A_{cf}, mm^2	f_{cf}, MPa	E_{cf}, MPa
CR-5	13.2	1400	1.00×10^5
CR-10	39.2		

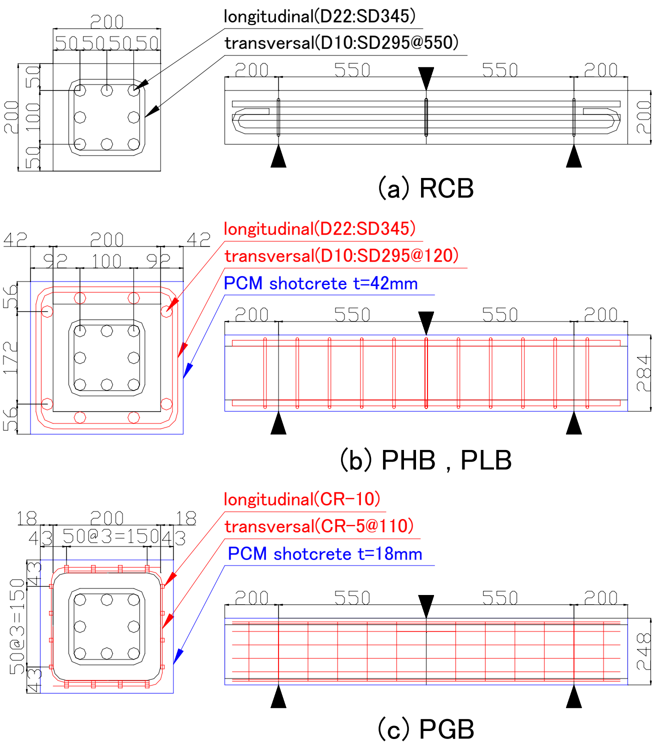

Fig.1 Details of specimens

Analysis-2 calculated using variable of d value was determined from distance compression of concrete till the lowest of steel reinforcement. Lateral strain in hoop steel reinforcing was restrained. The use of hoop steel and CF grid causes confinement of the concrete core resulting in the increase in the effective concrete strength[2]. Focus in shear load, the analysis results were obtained that shear values for analysis-1 less than analysis-2.

Fig. 2 shows comparisons test between shear loaded of each RC beams types. From the test results, RC wrapped by PCM high strength can increasing shear strength of the beams specimens. PHB type has shear strength more than others types. Increases in strength of 219% for PHB, 146% for PLB, and 91% for PGB over the RCB as control, un-retrofitted beams were noted.

Comparing with experimental results (P_s), analysis-2 was giving good agreement with experimental than the Analysis-1. For RCB and PHB types, shear performances of the experiment better than analysis results. This matter caused at the time of the RC beam with and without retrofit applying shear load by there point bend test were not slip bond occurs between interfaces of concrete-PCM and steel reinforcement. The experimental values for PLB and PGB were less than analysis-2, its means that the slip bond between interfaces of concrete-PCM and steel reinforcement occurs (PLB), and for PGB slip bond occurs on interfaces of concrete-PCM and CFRP. The slip between interfaces of CR-10 and CR-5 with concrete-PCM was occurs at the corners of the CFRP-grid.

The load deflection as shown in **Fig.3** plot for beam PHB, PLB, and PGB along with that of the shear control beam, RCB. **Fig. 4** shows relationship of shear load with compressive strain of concrete beams and tensile strain of steel reinforcements. Tensile strain of steel reinforcement of RCB was only up to about 1300μ at the maximum of shear load. On the other hand, types of PHB, PLB, and PGB had ability in tensile strain around 1400μ, 900μ, and 4500μ were respectively and 2000μ not exceeded. The tensile strain of CF grid (RCB) was 14000μ. Therefore, for all of beams specimens had shear failure modes. **Fig. 5** shows crack distribution of beams specimens.

IV. CONCLUSIONS

PCM high-strength and low-elasticity with additional longitudinal and transversal reinforcement can provide in strength and stiffness to existing concrete beams. Increases in shear strength of 219% for PHB, 146% for PLB, and 91% for PGB over the RCB as control, un-retrofitted beams were noted. And also PCM with additional reinforcement and CFRP grid are effective for shear strengthening.

REFERENCES

1) Japan Society of Civil Engineers: Standard specifications for concrete structures-2002, pp. 67-69, 2002.
2) Japan Load Association: Specifications for Highway Bridges PART V, Seismic design, pp. 160-161, 2003.

Table 4 Details of loads types

Types	Note	P_{cr},kN	P_y,kN	P_s,kN	P_u,kN
RCB	Analysis-1	14.1	147	***95.5***	219
	Analysis-2			***111***	
	Experiment	15.1	-	***161***	-
PHB	Analysis-1	48.0	481	***351***	666
	Analysis-2			***428***	
	Experiment	58.1	-	***515***	-
PLB	Analysis-1	36.9	439	***324***	587
	Analysis-2			***398***	
	Experiment	52.7	-	***396***	-
PGB	Analysis-1	29.0	352	***266***	423
	Analysis-2			***328***	
	Experiment	50.4	-	***308***	-

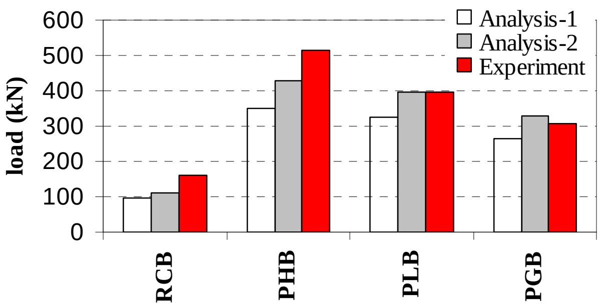

Fig.2 Comparisons between shear load from Analysis and Experimental results

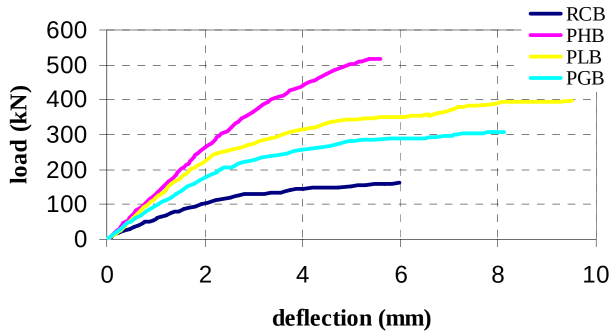

Fig.3 Shear load-deflection relationship

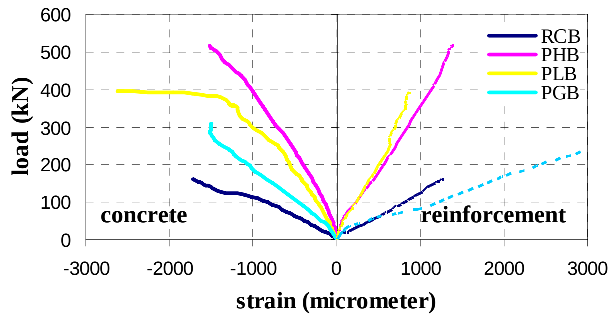

Fig.4 Shear load-compressive strain of concretes and tensile strain of steel reinforcements

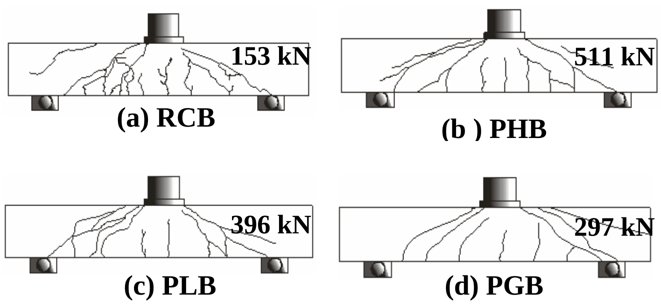

Fig.5 Crack distribution of beams specimens at maximum load