Compressive behavior of low strength concrete confined with water hyacinth and jute NFRP

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1 Introduction

Recently, there are many researches on confined concrete, which is one of the main applications of FRP sheets. FRP sheets are used as external jackets for the confinement for reinforced concrete columns for enhancement in strength and/or ductility.[2)] Natural fiber reinforced polymer, NFRP is low-cost material and it has less environmental burden than conventional FRPs such as carbon-FRP or aramid-FRP.[3), 4)] In this study, we used Jute fiber and Water hyacinth fiber as inexpensive environment-friendly material for confinement which can be used for low-cost RC structures. In addition, adverse effects of water hyacinth in aquatic environment is concerned due to its abnormally reproductive nature, so finding of industrial application for water hyacinth will play an important role.

There are still a lot of RC structures which have small capacity due to low material strength.[1)] However, we can continue using existing RC structure with low strength concrete if it is possible to strengthen low strength concrete with economically and technically feasible way. This is preferable in economic and environmental view point to demolishing the structure and constructing new structure.

2 Experimental test set

2.1 Coupon tensile test

We conducted coupon tensile test to obtain mechanical properties of Jute-NFRP and Water hyacinth-NFRP. Design of coupon specimens is showed in Figure 1. Fiber sheets were cut into coupons with 30 mm in width and 300 mm in length and impregnated with epoxy resin. Surface of the grip were treated by a sandpaper. Table 1 summarizes the result of coupon tensile test.

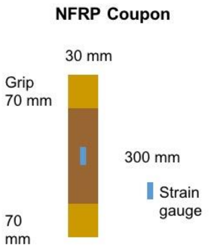

Figure 1 Coupon design

Table 1 Summary of tensile test result

	Design thickness (mm)	Tensile strength (MPa)	Young's modulus (GPa)	Rapture strain (%)
Jute	0.43	378	30.6	1.84
Water Hyacinth	0.59	63.2	8.52	1.70

2.2 Cylinder compression test

Cylinder concrete was 200 mm in height, 100 mm in diameter. NFRP sheet was attached by impregnating adhesive epoxy resin. After one week curing, cylinders were tested under monotonic concentric compression using Universal Testing Machine. The number of layers varied from 1 to 4. Table 2 shows the summary of experiment parameters.

Table 2 Experiment parameter

	Fiber	F'c	Layer	Label
NC-control	None	25	0	NC
LC-control	None	6	0	LC
(a) Nomal concrete confined with Jute	Jute	25	1	NC-J1
			2	NC-J2
			3	NC-J3
			4	NC-J4
(b) Low strength concrete confined with jute	Jute	6	1	LC-J1
			2	LC-J2
			3	LC-J3
			4	LCJ4
(c) Normal concrete confined with water hyacinth	Water hyacinth	25	1	NC-WH1
			2	NC-WH2
			3	NC-WH3
			4	NC-WH4
(d) Low strength concrete confined with water hyacinth	Water hyacinth	6	1	LC-WH1
			2	LC-WH2
			3	LC-WH3
			4	LC-WH4

4 strain gauges were mounted in the middle of height at every quarter of circumference to obtain strain in lateral direction. As Figure 2 shows, 2 LVDTs were set in compressometer and measured axial strain.

Figure 2 Measurement of axial strain

3 Experimental result and discussion

3.1 Failure mode

Failure mode of each specimen is shown in Figure 3. Jute-confined concrete failed in NFRP rupture with sudden loud noise. Crack in Jute-NFRP developed suddenly and axial stress decreased rapidly. Rupture of Water hyacinth-NFRP developed gradually. Loud noise and sudden drop of axial stress were not seen in water hyacinth-confined concrete.

Figure 3 Photographs of specimen

3.2 Relationship between stress and strain

Compression test result is summarized in Table 4. Confinement with Jute-NFRP enhanced compressive strength of normal concrete by 171.61 % at most compared to un-confined specimen. Only slight difference between 3-layer and 4-layer cases was seen. Water hyacinth-NFRP confinement did not increase compression strength of normal concrete. Low strength concrete confined with Jute-NFRP showed 5.06 times larger compressive strength than the un-confined concrete did. As this shows, confinement for low strength concrete has large reinforcing effect. Only wrapping 1 layer can enhance the compressive strength of low strength concrete as high as the durable design strength (18 MPa) specified by JASS 5.[5)] There was little difference between 3-layer confinement and 4-layer confinement cases like the cases of normal concrete. Confinement for low strength concrete with Water hyacinth-NFRP improved compressive strength by 224.6 %.

Stress strain curves are shown in Figure 4. Lateral strain is negative value, and axial strain is positive value in this graph. The more layers of Jute-NFRP were applied, the larger axial strains were developed and gave the larger compressive strength. This means that confinement with jute improves specimens' ductility. Inappropriate attachment of NFRP made a gap between 3rd layer and 4th layer, and considered to be the reason why difference between 3-layer confinement and 4-layer confinement was not seen. Water hyacinth-NFRP has so small stiffness that NFRP sheet does not have enough hoop stress to generate confinement effect on normal concrete. Low strength concrete more deforms than normal concrete, so that water hyacinth-NFRP had high enough confining stress and compressive strength was enhanced.

Table 3 Summary of compression test result

	Unconfined concrete strength (MPa)	Fiber	1-layer	2-layer	3-layer	4-layer
Normal concrete	33.10	Jute	40.84	48.28	56.80	56.56
		Water hyacinth	35.67	35.15	36.11	35.49
Low strength concrete	7.69	Jute	21.38	31.36	37.75	38.91
		Water hyacinth	12.69	13.89	17.25	17.25

4 Conclusion

This study aims to investigate the strengthening effect of Jute-NFRP confinement and Water hyacinth-NFRP confinement for normal and low strength concrete. Compression tests were conducted on confined concrete with normal and low strengths, varying the number of layers from 1 to 4. The outcomes of this study can be summarized as follows:

1) Tensile properties of Jute-NFRP and Water hyacinth-NFRP were obtained as follows:
Jute-NFRP has 378 MPa of tensile strength, 30.6 GPa of modulus of elasticity and 1.84 % of rapture strain. Water hyacinth-NFRP has 63.2 MPa of tensile strength, 8.52 GPa of modulus of elasticity and 1.70% of rapture strain.

2) In axial compression, compression strength and ductility of both normal concrete (33.1 MPa) and low strength concrete (7.7 MPa) was improved by Jute-NFRP confinement.

3) Jute-NFRP confinement enhanced compression strength of low strength concrete by 5.06 times at most. This suggests that RC structure in which the concrete has low compression strength can be strengthened by Jute-NFRP jacketing.

4) Water hyacinth-NFRP sheet used in this study has less stiffness, so that application to confinement is not efficient for normal strength concrete. However, Water hyacinth-NFRP jacketing has reasonable strengthening

effects by jacketing for low strength concrete.

5 Acknowledgement

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6 References

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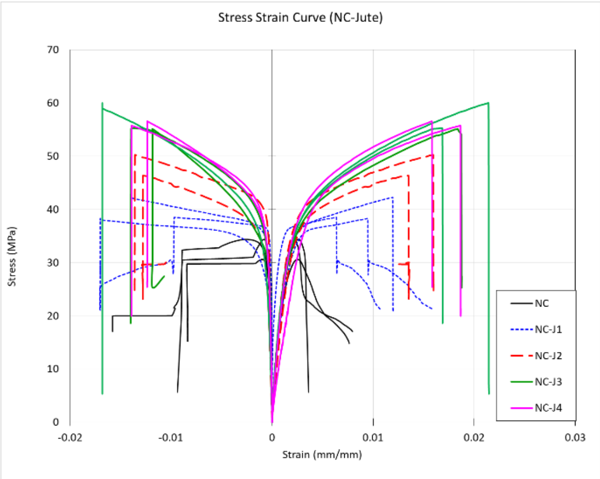
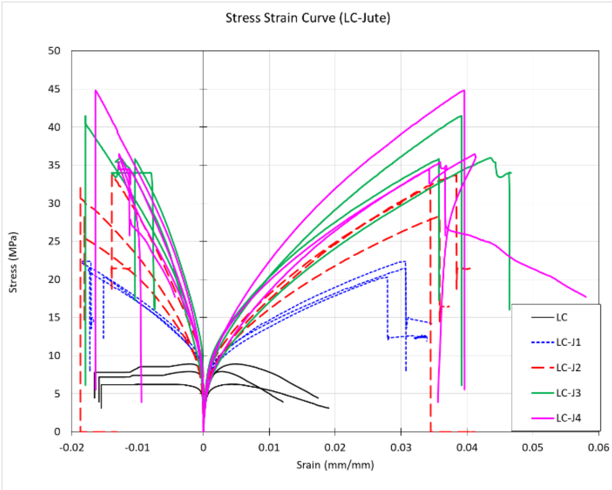
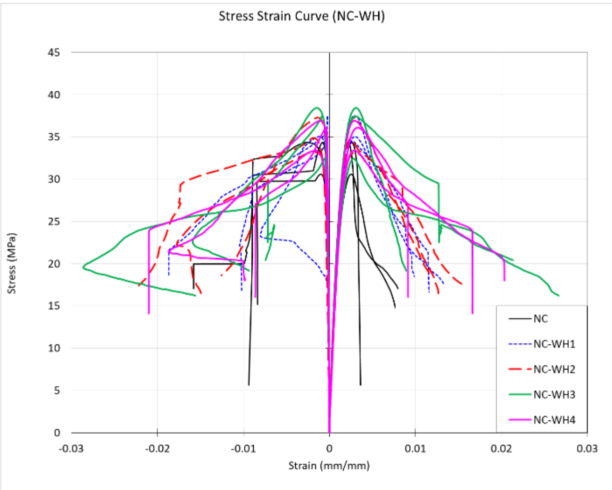


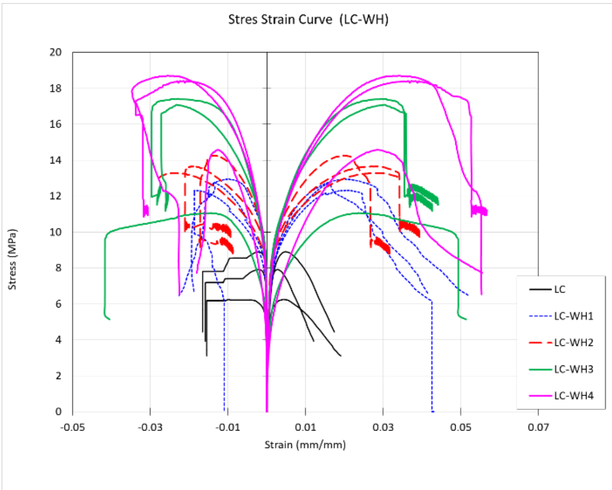
(a) Normal concrete confined with Jute NFRP



(b) Low strength concrete confined with Jute NFRP



(c) Normal concrete confined with Water hyacinth NFRP



(d) Low strength concrete confined with Water hyacinth

Figure 4 Stress Strain Curve