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THE ADVANTAGE OF NYLON MESH FOR BEAM CONFINEMENT
Smart material for beam repair

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Abstract

Indonesia faces the hazard of earthquake disaster, so that the structure resistant becomes the main concern in rehabilitation and repair. The rehabilitation of concrete structure element covers many aspects, one is the ductility performance. Achieving the ductility means improving the structural performance; therefore a special need should be fulfilled in repairing the concrete structure element. Previous researches have emphasized that the using of confinement will increase the ductility of concrete beam. Some materials have been applying to confine the beam such as steel, rubber, synthetic fiber, etc. A promising material which can be used for beam confinement is nylon as proved by previous research. It has great value of tension strength and elongation. The nylon also has unique characteristic of 'yield point elongation' that provides optimal stable crack length when it is embedded in cementitious matrix. According to the advantage of nylon, this research wants to deliver another advantage of nylon, in the form of nylon mesh, when it is used as beam confinement. This research uses experiment method and analytical method. The experiment method is conducted by third point flexural test of 2 kind of concrete beams (confined and unconfined beams) with dimension of 15x20x600 mm with compressive strength f'_c about 30 MPa. The analytical method computes the modulus of rupture of beams and also observes the crack pattern of beams. The research meets several conclusions: (1) The ultimate load of confined beams increase about 30-40% (1489,6 N, 1421 N) compared to the unconfined ones while its displacement also increase about 40-70% (24 mm, 26,7 mm); (2) The increase of displacement emphasizes that the ductility of beams also increases at ultimate load until beams collapse; (3) The modulus of rupture of confined beams increase about 30-40% (22,8 MPa and 21,75 MPa) compared to the unconfined ones; (4) The ductility of beams is clearly maintained by the nylon mesh confinement; (5) It is proven that the nylon mesh has improved modulus of rupture of the beams significantly; and (6) The research has proved that the using of nylon mesh as beam confinement obviously increase the ductility of beam. It is emphasized that the nylon as smart material has advantage for structural concrete element repair.

Keywords: beam, confinement, nylon mesh.

1. INTRODUCTION

Indonesia faces the hazard of earthquake disaster. It has destroyed buildings; infrastructures, and even killed amounts of people. Hence, the structure resistant becomes the main concern in rehabilitation and repair. The rehabilitation of concrete structure element covers many aspects, one is the ductility performance. Achieving the ductility means improving the structural performance; therefore a special need should be fulfilled in repairing the concrete

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structure element.

Previous researches have emphasized that the using of confinement will increase the performance of concrete beam, especially its ductility. Susilorini [1] applies lateral confinement to achieve higher ductility of high strength beams.

Wu and Sun [2] use cement-based composite thin sheet for structural retrofit as external wrap. They use thin CFRC (*continuous fiber reinforced cement*) and CFRC (*continuous fiber reinforced polymer*) sheets. Their research finds that the maximum load is achieved by concrete beams with CFRP confinement (load as 7000 N and deflection as 3.75 mm), followed by concrete beams with CFRC confinement (load as 3000 N and deflection as 4 mm) and concrete beams without confinement (load as 1500 N and deflection as 0.4 mm). While concrete beams with CFRP confinement progressive delamination, concrete beams with CFRC confinement don't suffer any delamination.

Mu and Meyer [3] conduct research on Fiber-Reinforced Glass of Concrete Slabs with crushed-post consumer glass aggregate reinforced by continuous fiber mesh with equal fiber volume ratio. The research emphasizes that The specimens with continuous fiber mesh is more effective than with randomly distributed short fibers because of better interfacial bond between the matrix and the yarn; and the locking phenomenon at the yarn intersection. It is also concluded that the reinforcing effect is higher in two-way bending compared to one-way bending.

A simple and easily applied technology has been introduced by Rafeeqi, Lodi, and Wadalawala [4] to upgrade and strengthen non-engineered structural member in rural population in earthquake prone areas. It is implemented by strengthening beams with ferrocement strips and wraps with one or two layers of wire mesh. It is found that confining the concrete in shear zone by Ferrocement can transform the brittle shear-compression failure to ductile shear failure. The research also notes that ferrocement wraps are more effective than ferrocement strips.

Wiberg [5] applies cement-based carbon fibre reinforced composites to strengthen the existing structural concrete. The beams that are strengthened for bending has observed slightly increase (10-20%) compared to the reference beam. Wiberg also successfully develops WHEST-beam (Wiberg Holmgren Evaluating of Strengthening Beam) with advantage: small dimension of standard beam with prefabricated steel formwork ready for use in laboratory.

Several previous researches noticed about the importance of confinement for raising higher performance of beam with various media such as meshes, sheets, jackets, etc, but no research try to use nylon mesh to confine the beams. Susilorini [6], [7] notices that nylon has great value of tension strength and elongation. It also has unique characteristic of 'yield point elongation' that provides optimal stable crack length [8] when it is embedded in cementitious matrix. It is proved that nylon fibers that are embedded in cementitious composites will improve strain-hardening property [6], [7], tension strength, and elastic modulus [6].

The nylon has proven as 'smart' material. According to the previous researches mentioned above, it is important to provide higher ductility for concrete beam by applying nylon mesh as beam confinement. This research investigates the performance of beam that is using nylon mesh as confinement.

2. METHODS

This research uses experiment method and analytical method. The experiment method is conducted by third point flexural test of specimens. The specimens consist of four concrete beams with dimension of 15x20x600 mm (Figure 1). Two beams are confined with nylon mesh that has 5 cm x 5 cm dimension of each mesh element (Figure 2). They are covered by mortar after being confined by nylon mesh. Two other beams

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are unconfined. The concrete beams are designed with compressive strength f'_c about 30 MPa. All specimens are tested in flexure after 28 days curing.

Figure 1. The confined beam specimen
(Photograph by Setyanegara and Sagita, 2008)

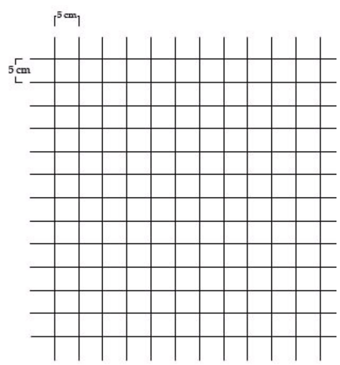

Figure 2. The nylon mesh dimension
(Setyanegara and Sagita, 2008)

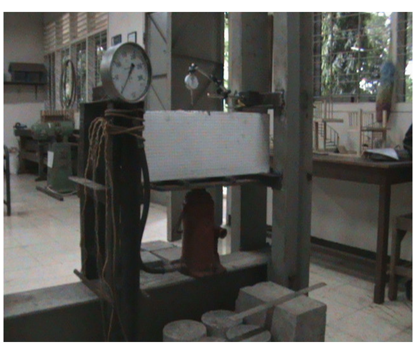

Figure 3. Third point flexural test
(Photograph by Setyanegara and Sagita, 2008)

The analytical method computes the modulus of rupture [9] of beams and also observes the crack pattern of beams. The modulus of rupture [9] is expressed by:

$$R = \sigma = \frac{PL}{bd^2} \qquad (1)$$

Where:
P = maximum total load on the beam
L = span
b = width of the beam
d = depth of the beam

3. RESULTS AND DISCUSSION

The experiment results [10] show (Figure 4) that the ultimate load of confined beams increase about 30-40% (1489,6 N, 1421 N) compared to the unconfined ones while its displacement also increase about 40-70% (24 mm, 26,7 mm). The increase of displacement emphasizes that the ductility of beams also increases at ultimate load until beams collapse. Recall Wu and Sun (2005) results. It is promising that nylon mesh confinement that has fairly ultimate load (1489,6 N) can improve higher deflection (26,7 mm) compared to the CFRC confinement (deflection as 4 mm) and also CFRP confinement (deflection as 3.75 mm).

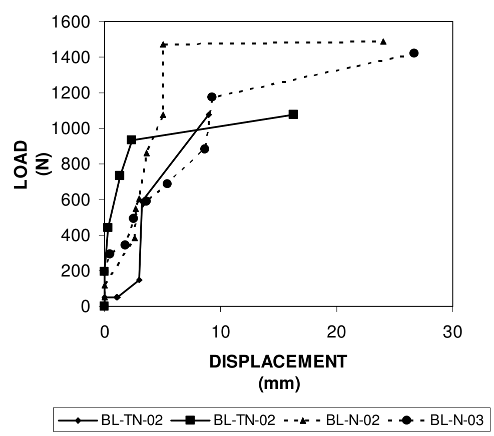

Figure 4. Load-Displacement Relationship
during the Loading History
(Modified from Setyanegara and Sagita, 2008)

The modulus of rupture [10] represents the theoretical maximum tensile stress reached in the bottom fiber of beam (Neville, 1999). It is shown by Figure 5 that modulus of rupture of confined beams increase about 30-40% (22,8 MPa and 21,75 MPa) compared to the unconfined ones. The maximum tensile stress in the bottom fiber

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of beam is high enough to resist the collapse of beams because of the confinement existence. It is explained by the high value of deflection of the beams (24 mm, 26,7 mm). Thus, the ductility of beams is clearly maintained by the nylon mesh confinement. It is proven that the nylon mesh has improved modulus of rupture of the beams significantly.

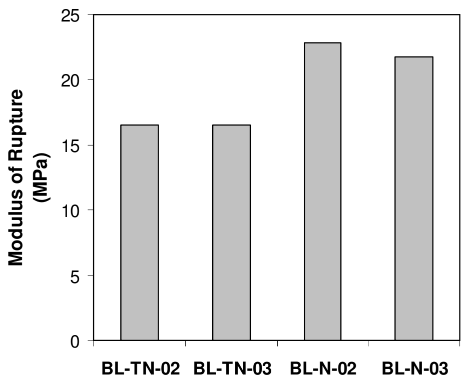

Figure 5. Modulus of Rupture of Confined and Unconfined Beam
(Modified from Setyanegara and Sagita, 2008)

The crack pattern of all specimens [10] is about the same. It is found that crack always lay on the middle of the beams (Figure 6).

Figure 6. The crack pattern of confined beam of specimen BL-N-03
(Photograph by Setyanegara and Sagita, 2008)

It can't be neglected that first crack happened at confined beams even though it lay on the mortar cover. The crack is followed by instantaneous brittle fracture. This brittle fracture is happened instantaneously before the collapse of beams. The nylon mesh is found broken mostly at the joint of the mesh (Figure 7).

It is promising that this research has proved that the nylon mesh confinement obviously increase the ductility of beam. The nylon mesh can be applied simply, cheaply and effectively to increase the ductility of concrete beam. It should be noted that the nylon is smart material for structural concrete element repair

Figure 7. The broken nylon mesh is found mostly at the joint
(Photograph by Setyanegara and Sagita, 2008)

4. CONCLUSIONS

The research meets several conclusions as follow:

1. The ultimate load of confined beams increase about 30-40% (1489,6 N, 1421 N) compared to the unconfined ones while its displacement also increase about 40-70% (24 mm, 26,7 mm)
2. The increase of displacement emphasizes that the ductility of beams also increases at ultimate load until beams collapse
3. The modulus of rupture of confined beams increase about 30-40% (22,8 MPa and 21,75 MPa) compared to the unconfined ones
4. The ductility of beams is clearly maintained by the nylon mesh confinement
5. It is proven that the nylon mesh has improved modulus of rupture of the beams significantly
6. The research has proved that the using of nylon mesh as beam confinement obviously increase the ductility of beam. It is emphasized that the nylon as smart material has advantage for structural concrete element repair

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