SHEARCAPACITY OF RCBEAMSRETROFITTED WITH WIRE MESH AND SCC

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ABSTRACT

Theaim of this study was to evaluate shear performances of reinforced concrete beams retrofitted by using wire mesh and Self Compacting Concrete (SCC). Four concrete beams reinforced internally with steel and externally with both wire mesh (Ø4,06mm) and SCC (25mm) applied to the specimens were tested under three-point bending. The shear failure was initiated by a major diagonal crack within the beam shear span. This diagonal crack extended horizontally at the level of the wire mesh. Results show that SCC with wire mesh is very effective for shear retrofitting. Increases in shear capacity of 71.82% for BWS over the BN as control, un-retrofitted beams were noted.

Keywords: retrofitted, wire mesh, SCC, shear capacity.

1. INTRODUCTION

Strengthening reinforced concrete (RC) beams with fiber-reinforced polymer (FRP) composites is becoming an attractive for the construction industry. Unidirectional CFRP grid materials used in concrete reinforcement applications are linear elastic up to failure, and CFRP grid does not exhibit the yielding behavior that is typically displayed by conventional reinforcing steel (A. A. Amiruddin, *et al*, 2009). CFRP grid (high strength and high elasticity carbon fiber) materials generally have much higher strength than the yield strength of steel, although CFRP grid does not exhibit yield.

Nowadays in Eartquake Engineering Riset Laboratory, Civil Engineering Department, Faculty of Engineering, Hasanuddin University, wire mesh and self-compacting concrete (SCC) had been developed to retrofitting of RC structures such as to increase the shear capacity of RC beams (A. A. Amiruddin, *et al*, 2015). The contribution of the wire mesh transverse strengthening to the shear capacity on retrofit of RC beams is studied in this research.

In this paper, a new technique for seismic strengthening of RC beams is presented. Beams in existing structures are externally reinforced by means of high-strength wire mesh. The reinforcement is performed by wrapping wire mesh and SCC around the beams.

2.EXPERIMENTAL PROGRAM

2.1 Shear transfer actions and mechanisms

Shear transfer actions and mechanisms in concrete beams are complex and difficult to clearlyidentify. Complex stress redistributions occur after cracking, and those redistributions have beenshown to be influenced by many factors. Different researchers impose different levels of relativeportance to the basic mechanisms of shear transfer. Fig. 1 shows the basic mechanisms of sheartransfer that are now generally accepted in the research community. In 1973 the ASCE-ACI Committee 426 and, again in 1998, its current counterpart the ASCE-ACI Committee 445, reported five important sheartransfer actions for beams with shear reinforcement: shear in the uncrackedcompression zone of the beam; interface shear transfer due to aggregate interlock or surfaceroughness along inclined cracks; dowel action of the longitudinal reinforcement; residual tensilestresses across inclined cracks; and shear transfer of the shear reinforcement.
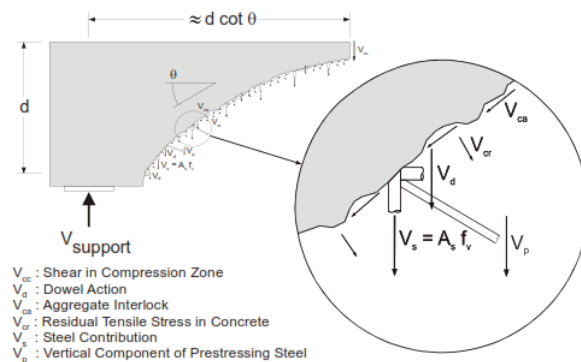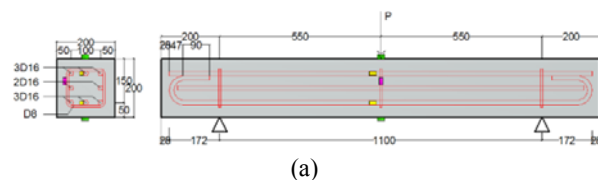

Figure-1. The basic mechanisms of shear transfer.

2.2 Test beam specimens

The test specimens consisted of four RC beams (200mm x 200mm x 1500mm) classified into two types according to wire mesh retrofitting system is shown in Figure-2.
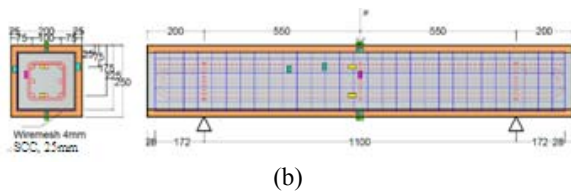

(a)

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(b)

Figure-2. Beam test for the: [a] normal beam [BN], [b] retrofitted beam [BWS].

Table-1. Summary of specimen types.

Beam types	Wiremesh	SCC
BN (control)	-	-
BWS	Ø4,06mm	25mm

Table-2. Position of strain gauges.

Beam Types	Longitudinal bars (FLK, gf: 2.1*)	Transverse bars (FLK, gf: 2.1)	Wire mesh bars (FLK, gf: 2.1)	Concrete and SCC (PL, gf: 2.13)
BN (2)	4	2	-	4
BWS (2)	4	4	6	4

*gf : gauges factor

Two beams were tested without retrofittiing (BN)and served as a control specimen for comparison purposes to evaluate the improvement in shear capacity provided by externally bonded wire mesh and SCC with

thickness of 25mm. Two beams (BWS) were retrofitted with wire mesh systems using wire mesh (Ø4,06 mm) rebars. A summary of these beams is given in Table-1.

In Table-2 describes the position of strain gauges is installed on longitudinal and transverse of steel bars, and also on the normal concrete or and SCC. Strain gauge installed on steel bars using FLK type (gauge factor of 2.1 ± 1%), placed at the points specified. While strain gauges for concrete/SCC usingPL type (gauge factor of 2.13 ± 1%), which is attached to the top surface and the bottom of the beam at the point of ½ length of the beam (middle span).

A design and experiment of material properties values of the concrete and SCC are given in Table-3. The beam test is designed with compressive strength of concrete, f'c of 30MPa. Moreover, Table-4 shows kinds of steel rebars and wire mesh were found in the experiment by tensile test.This test includes tensile test of steel rebarsØ16 to be used as longitudinal of steel rebars in the tension and compression areas. The shear of steel bars using Ø8 and wiremesh M4 228s Ø4.06as a retrofit materials. This test aims to determine the yield stress (f_y) and modulus of elasticity (E_s) of steel rebars. This test using a Universal Testing Machine (UTM) and as following SNI 07-2529-1991 Tensile Strength Test Method of Steel in Concrete.

Table-3. Material properties of concrete and SCC.

Beam types	Materials	Design values		Experimental values	
		f'_c (MPa)	E_c (MPa)	f'_c (MPa)	E_c (MPa)
BN	Concrete	30	25,743	32.66	23,412
BWS	SCC			35.68	25,187

Table-4. Material properties of steel rebars and wire mesh.

Diameter (mm)	Directions	f_y (MPa)	f_t (MPa)	E_s (MPa)	ε_y
ø 8	Transversal	320.860	465.220	159,423	2013.5
ø 16	Longitudinal	438.870	649.827	217,852	2014.5
Wiremesh M4 ø 4.06	Transversal and longitudinal	240.839	524.136	120,275	2002.4

Ratio of steel bars not less than 0.01 (1%) and no more than 0.08 (8%). In normal beams (BN) for steel rebars volume of 0.0026 m^3 and a concrete volume of 0.0574 m^3. So the ratio is equal to 0.0026 / 0.0574 x 100% = 0.0451 x 100% = 4.51%. While retrofit wiremesh (BWS)forsteel rebars volume of 0.0006 m^3 and concrete volume of 0.0574 m^3.So, the ratio is equal to 0.0006 / 0.0338 x 100% = 0.0181 x 100% = 1.81%. Thus steel bars ratio of BN type and BWS type meet the requirements.

2.3 Test set-up

All beams were loaded in three-point bending that the subjected to static load is shown in Figure-3. The beams were instrumented with a displacement meter (LVDT) at the mid-span and both of loading point to monitor displacement, as well as strain gauges bonded on concrete, SCC, steel bars and wire mesh surface to measure the strain values. A 500kN load cell was used to measure the applied load.Equipment and testing instruments required are: crane, actuator (vertical jack)

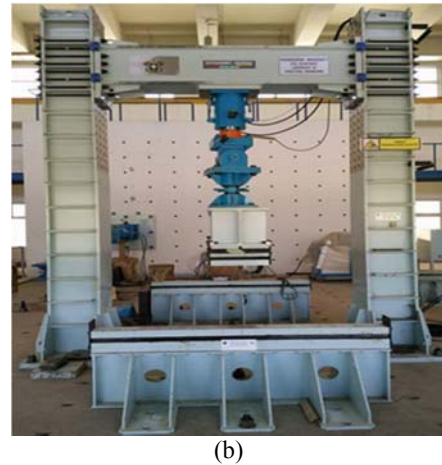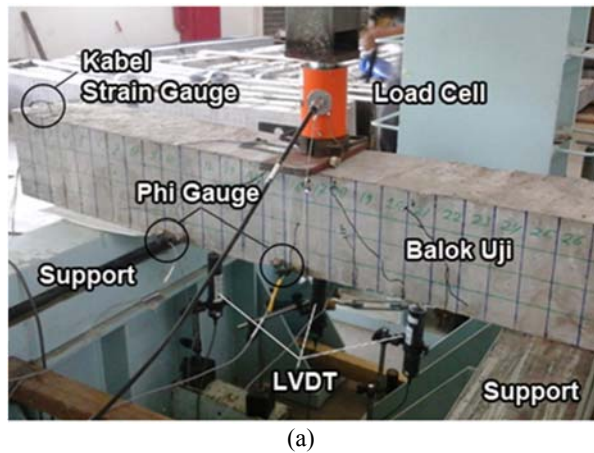with a capacity of 1500 KN, phi gauges of 3mm, logger data and switching box.

(a)

(b)

Figure-3. (a) Framework for testing and placement of testing instruments, (b) testing installation.

3. TEST RESULTS AND DISCUSSIONS

3.1 Comparison of experiment and analysis value of P_s

The design of load is divided into four parts, load at first crack (P_{cr}), first yield at steel reinforcement in tension area (P_{y0}) so that steel bars was separated with concrete, ultimate strength (P_u), and shear strength (P_s). In particular for P_s, the analysis was carried out based on Japan Road Association (JRA) Bridge Part V method. In design, the shear failure was proposed on $P_{y0} / P_s > 1.5$. In experiment result, it was obtained that for all of specimen types had propagation of cracks showed shear failure behavior. The comparison of experiment and analysis value is given in Table-5 and Figure-4, respectively.

Table-5. Comparison of experiment and analysis values.

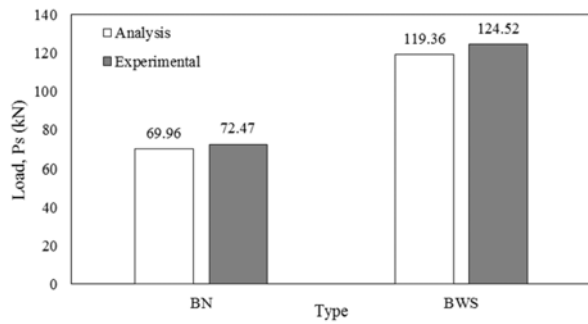| Type	Item	First crack P_{cr}(kN)	First yield P_{y0}(kN)	Ultimate P_u (kN)	Shear strength P_s (kN)	Comparison of P_s Experiment / Analysis
BN	Experiment	10.75	83.3	144.95	72.47	1.04
BN	Analysis	10.74	96.03	139.92	69.96	1.04
BWS	Experiment	15.25	119.87	249.04	124.52	1.04
BWS	Analysis	10.47	130.5	238.47	119.36	1.04

Figure-4. Shear strength values.

Based on the experimental results were found that the percentage increase in shear load capacity (P_S) and ultimate load (P_U) to control beam (BN) of 71.82%.

3.2 Load -displacement relationship

The load displacement (P-Δ) as showed in Figure-4 plot for beam BWS along with that of the shear control beam, BN. The control beam failed in shear and also for BWS type. BWS type had shear strength more than BN type and increases in shear strength of 71.82% for BWS over the BN, un-retrofitted beams.

Based on load and displacement relationship describes displacement on BN occurs at each beam when the ultimate load (P_u). On the BN type, displacement occurs of 5.89 mm when the load of 144.95 kN was reached. Then for BWS type, the load reaches on 249.04 kN with displacement of 9.61 mm.

This indicates that the restraint by wire mesh and SCC with retrofit method can increase the shear capacity due to the contribution of the wire mesh M4 and SCC with thickness of 25 mm transverse strengthening to the shear capacity. Thus the deficiencies of shear reinforcement in the existing beam can be reduced with the addition of wire mesh and SCC.
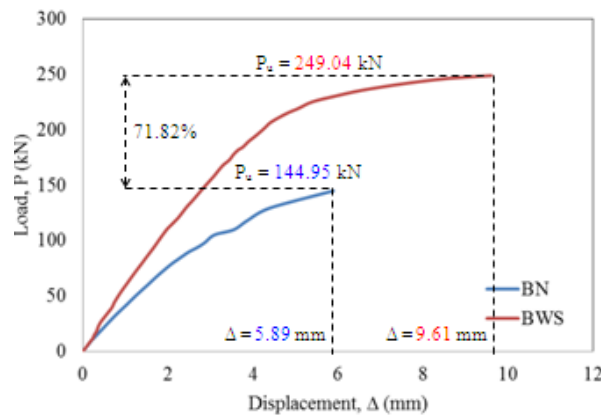

Figure-5. Load displacement relationship.

3.3 Load -compressive strain of concrete/SCC and tensilestrain of steelbars/Wire mesh relationship

Figure-6 shows relationship of load with compressive strain of concrete/SCC and tensile strain of steel bars/wire mesh.

The compressive strain values of concrete (BN) of 1189.5 μ and 1088.5 μ for SCC (BWS) but less then 3500 μ as an ultimate strain value of concrete. This indicate that compressive failure not occurs on BN and BWS types after the shear load applied to the beams.The strain valuesof BWS has decreased when compared with BN,especially for the tensile strain of concrete, which the strain values decrease were quite far from BN. On the tension area of concrete/SCC, the BN type found that the tensile strain of concrete more then 3500 μ. However, the tensile strain of BWS type less then ultimite tensile strain of concrete.

The tensile strain value of steel bars of BN was achieved up to about 1497.14 μ but less then 2014.5 μ at the maximum of shear load. It means that, the steel bars at the tension area in the beams not yielded, so that the flexure failure not occurs to the beams. On the other hand, tensile strain of BWS type was achieved up to 2048,57 μ more than 2002.4 μ as a design value for tensile strain of wire mesh. This indicate that on the wire mesh yield on the maximum shear load and the result was found that flexure-shear failure occurs at the BWS beams. Therefore, all of beams had shear failure modes.
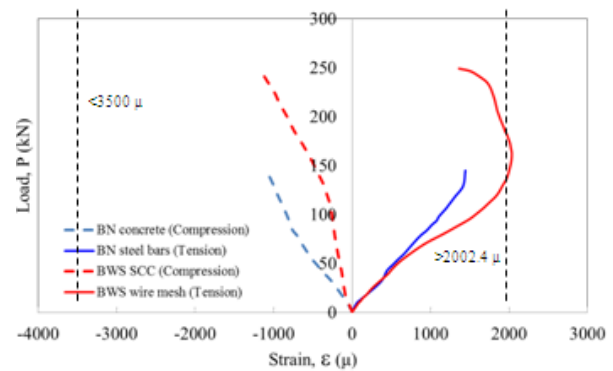

Figure-6. Compressive strain of concrete/SCC and tensile strain of steel bars/wire mesh.
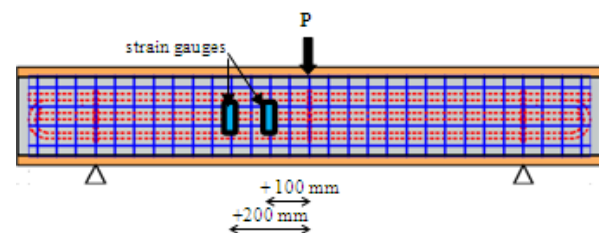
3.4 Load -Shear strain relationship

Figure-7. Shear strain of wire mesh.

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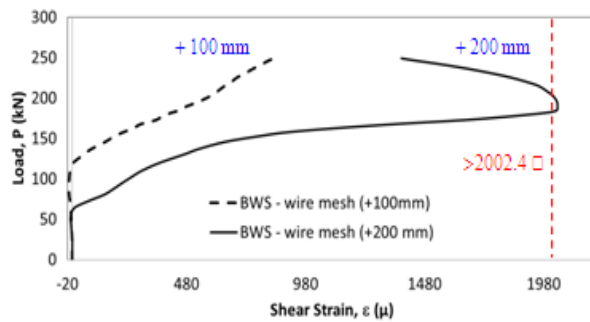**Figure-8.** Shear strain values of wire mesh at a distance of 100 mm and200 mm from middle of span.

Figure-7shows a illustrate instalation of shear strain of the beam. Strain gauges installed on wire mesh at a distance of 100 mm and 200 mm from the middle of span for evaluating and monitoring the amount of shear strain on the retrofit beam in order to know the effectiveness of the wire mesh as a retrofit material.

Figure-8 shows shear strain values of wire mesh at a distance of 100 mm and 200 mm from middle of span. Based on the test results were found that the BWS, tend to have the same value for shear strain of wiremesh (+ 100mm from midspan of the beam) when the yield load condition of the beam up to failure. Wherein at yield load conditions of 119.869 kN with shear strain of 4.143 μ wiremesh to beam collapse at ultimite load of 249.032 kN load with shear strain wiremesh of 846.31 μ .Meanwhile for the BWS the shear strain of wiremesh (+ 200mm from midspan of beam), on the yield load of 119.869 kN with shear strain wiremesh of 368.452 μ up to beam collapse on the load of 249.032 kN with shear strain of wire mesh of 1382.38 μ .
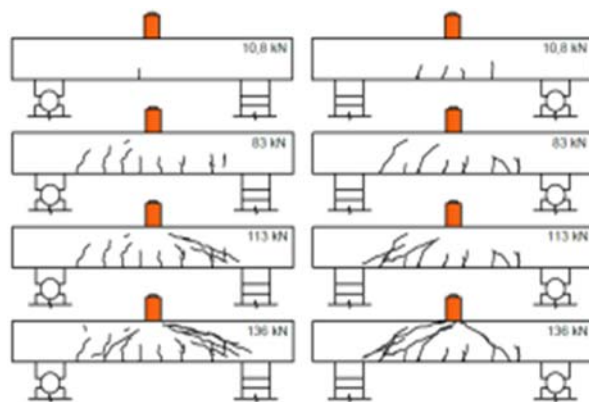
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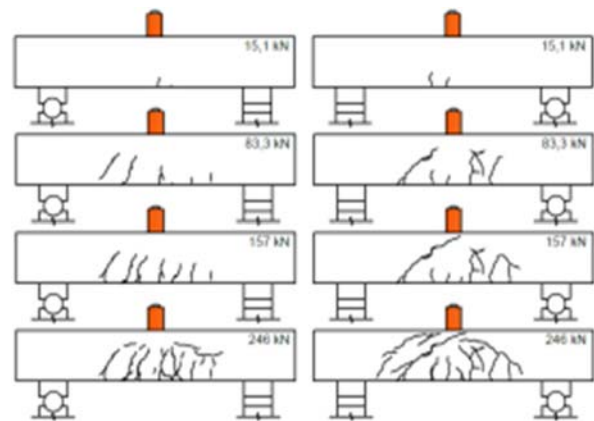
(b)

Figure-9. Crack pattern and failure mode of beams under test,(a) BN and (b) BWS.

However, before the beam up to collapse, the shear strain of wire mesh (+ 200 mm) had the maximum tensile strain at 2048.57 μ when the load of 189.091 kN for BWS. This indicated that wire mesh was yielded due to shear strain values of wire mesh ε_{sy} =2002.4 μ was exceed. Therefore, all of beams had shear failure modes. Figure-9 shows the crack pattern and failure mode of the beam under test.

4. CONCLUSIONS

From the discussion above, a number of conclusions as follow:

a) In three-point bending test results, BN type as control beam or un-retrofit type failed by shear.However, the retrofit specimens (BWS) also were failed at shear and these conditions parallel with design concept.

b)The retrofit of RC beams (BWS) have revealed that shear capacity increase 71.82% as significantly to control beam.

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