Shear Strengthening of RC without Stirrups for Deep Beams with Near Surface Mounted CFRP Rods

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Abstract— **The main objective of the work in this paper is to study Shear Strengthening of RC without stirrups Deep Beams with Near Surface Mounted CFRP Rods.**

The experimental work consists of fabrication and testing simply supported reinforced concrete deep beam with Near Surface Mounted CFRP Rods (NSM) beams , consists of five beams failed in shear and each beam had with dimensions (150 mm x400 mm x 1300 mm), with concrete compressive strength of about 30.54 MPa were casted and tested at 28 days.

This research is devoted to investigate the behavior and load carrying capacity of reinforced concrete strengthened and repaired with carbon fiber reinforced polymer (CFRP) rods in shear. For NSM beams designed to fail in shear investigate how the orientation and spacing of CFRP rods affect the shear behavior and the load carrying capacity. The results, show that the beams strengthened externally by CFRP rods provided improvement in ultimate loads. The increase in ultimate loads reached (28.57 %) the behavior of strengthened and repaired NSM beams by CFRP rods increasing the ultimate strength and reducing the ultimate central deflection for increasing the load at the cracking stage and also the load capacity and reducing shear crack widths compared with the control beam.

Keywords—Concrete; deep beam; CFRP rods

I. INTRODUCTION

The last few years, it has been experimentally observed that externally bonded FRP laminates may be used to increase the shear capacity of reinforced concrete beams (Khalifa, 1999). Although only few studies have specifically addressed shear strengthening, the experimental tests carried out showed that even small amounts of FRP external reinforcement can provide considerable safety against brittle shear failures. Many different FRP shear reinforcement configurations can be used: continuous reinforcement, series of stirrups, configurations with mechanical anchorage. The fibers can be perpendicular to the beam axis or oriented at 45 degrees to best reinforce shear cracks, or it may be convenient to create pseudo-isotropy by orienting the fibers in two perpendicular directions.

The effectiveness of the strengthening reinforcement, that is, the ultimate load carried by the FRP, depends on its failure mechanism. As experimental tests showed, failure of the FRP reinforcement may occur either by peeling-off (debonding) at the concrete-FRP interface, or by tensile fracture at a stress which may be lower than the tensile strength of the composite material, because of stress concentrations (e.g. at rounded corners or at debonded areas). Which of the two mechanisms will occur depends on many factors, particularly on the bond conditions, the type of attachment at the FRP ends and others. In many cases, the actual failure mechanism is a combination of FRP debonding at certain areas and fracture at others.(De Lorenzis and Nanni,2001)

As an alternative to externally bonded FRP laminates, NSM FRP rods can be used for shear strengthening of RC beams. This technique involves cutting vertical or inclined grooves on the side surfaces of the beam and embedding the FRP rods in the epoxy-filled grooves. The advantage of NSM rods with respect to FRP laminates in this application is that no surface preparation is required in the former case, as opposed to the case of externally bonded laminates where adequate bond to the concrete surface has to be ensured to achieve an effective strengthening system

so in this research will studying Shear Strengthening of RC without stirrups Deep Beams with Near Surface Mounted CFRP Rods

II.EXPERIMENTAL WORK

Several tests are conducted in order to view the differences in the behavior of NSM in its hardened states as well as the structural behavior. The hardened concrete tests are compressive strength, flexural strength, splitting tensile strength, and static modulus of elasticity.

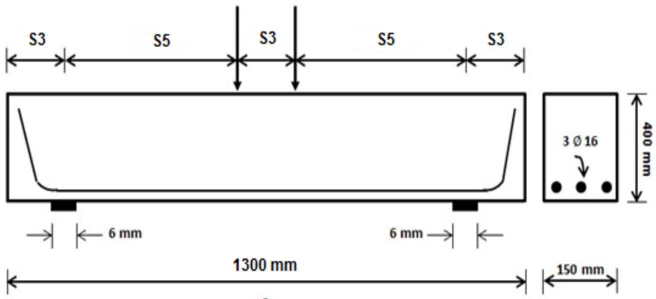
Test deep beams had a rectangular cross section 150 mm wide by 400 mm depth, with an effective depth (d) of 355 mm with a total length of 1.3 m for all specimens. The clear span of the beams 1.0 m, and two concentrated loads were placed at 0.425m from support of the beam. The ratios of shear span to effective depth (a/d) were applied on the test beams is (1.158). Straight bar anchorage lengths were used on the tested beam ends. The properties of the test specimens are summarized in Table(1). Details of specimens and reinforcement arrangement are illustrated in Fig. (1). All beam specimens were tested under a static two-point load test to study their shear behavior and to compare the experimental results with the control beam. A hydraulic jack with a capacity of 2000 kN was used to apply the load to the test beam through a spreader steel beam. The load was applied in load control mode at a load rate of 5 kN/min, and the strain gauges data were collected by a data acquisition system. The test was stopped every 5 kN to register the evolution of cracks, strains and the deflections along the beam. The crack pattern was drawn on the front face of the beam to make easy the positioning and identification of cracks during and after the test.

The specimens were positioned in the universal testing machine for midpoint loading . A steel plate was inserted between the concrete and the steel roller to ensure that local failure did not occur at the support. It was necessary to place two 30 cm height stiffened W shape sections under each support to elevate the beams so that the stroke of the testing machine could reach the specimen. For the two–point loading conditions, a 150mm stiffened steel W shape was used to transfer the load evenly from the testing machine to the surface of the test specimen.

The device located mid span under the beam is the external mechanical dial gauge which was used to measure the deflection of the beam as it was loaded.

The test started with a small pre-load cycle of about 2 kN to settle the beam and to maintain positioning before the beginning of the test. Once the readings and observations were taken, the loading was then increased by the next increment and the procedure was repeated. Test was terminated until Crushing of concrete.

The crack pattern was studied and additional photographs were taken. Finally, the beam was removed from the testing frame and the concrete surface was checked at different locations.



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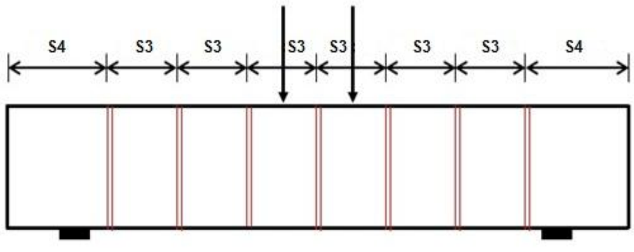

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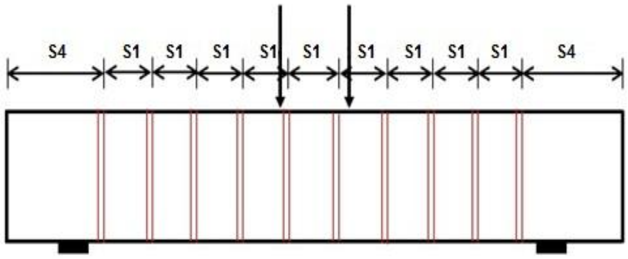

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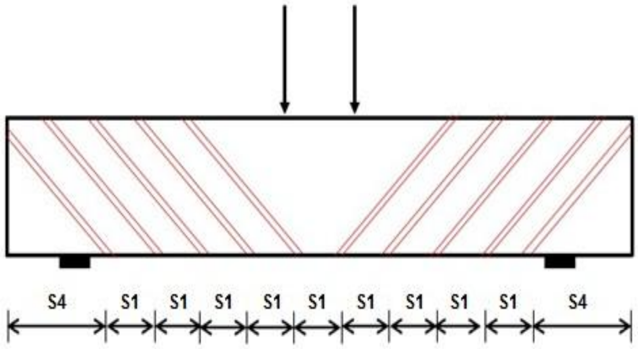

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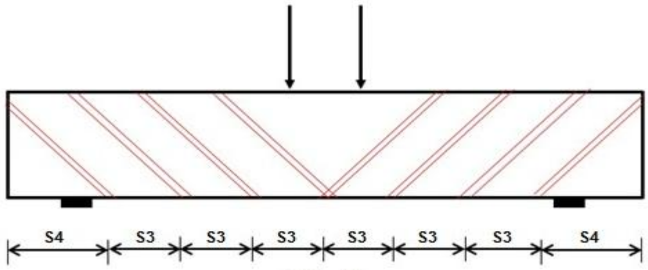


-N 45 – 15-

Where : s1=100 mm ; s2=125mm ; s3=150mm ; s4=200mm ; s5 =425mm

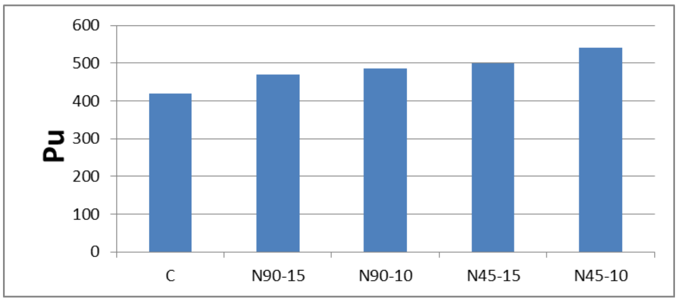
Figure (1) Details of specimens and reinforcement arrangement

Table(1) Description of the Specimens

Beam Code	Steel Stirrups	NSM FRP Rods	
			Angle (°)
C	-	-	-
N90-15	-	2No.2@150mm	90
N90-10	-	2No.2@100mm	90
N45-15	-	2No.2@150mm	45
N45-10	-	2No.2@100mm	45

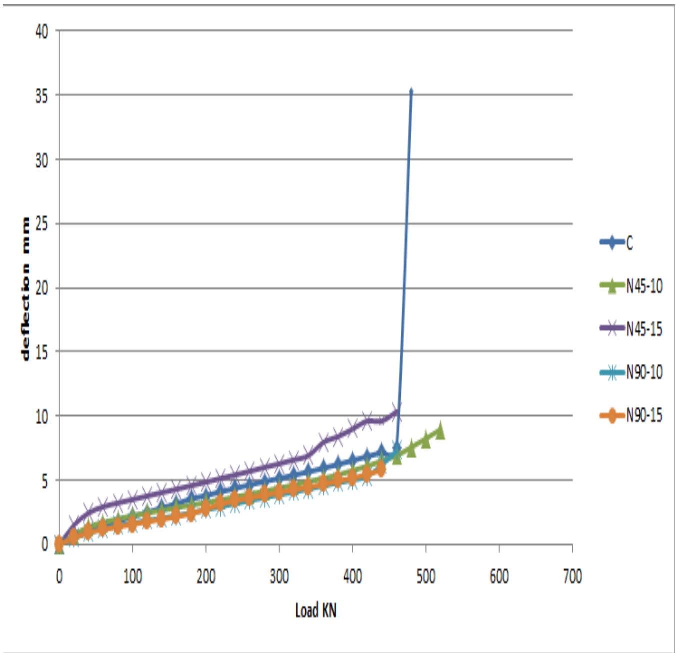
III. EXPERIMENTAL RESULTS

Six cylinders (150 × 300 mm) were cast to determine the 28-days compressive strength, f'c , from the batch. The mix was designed for 30.54MPa of compressive strength it was found all the beams in this study which was under-reinforced and failed by crashing of concrete after the tension reinforcement had yielded. The first visible shear cracks noticed at 30.4to 50 % of failure load. These cracks were vertical, started from the bottom side of the beam between the two point applied loads. As the load increased the cracks propagated diagonally towards the concentrated loads. crack pattern for the beams are presented in figures (4)and Summary of test results are presented in figure(2)



Figure(2): ultimate load

Deflection was measured at midspan of the beams at different loading stages. The decreased in deflection for beams is attributed the orientation and spacing of CFRP rods Shear Strengthening of RC without stirrups Deep Beams with Near Surface Mounted CFRP Rods used in making these beams.



Figure(3) : load –deflection curves

IV. CONCLUSIONS

1. The use of NSM FRP rods is an effective technique to enhance the shear capacity of RC beams. In absence of steel stirrups, an increase in capacity as high as 12-28.57% with respect to the control beam could be obtained.

2. One of the observed failure modes was debonding of one or more FRP rods due to splitting of the epoxy cover. Test results seem to indicate that this mechanism can be prevented by using 45-degree rods at a sufficiently close spacing, which provides a larger bond length;

3. Reducing distance between the CFRP rods gave an increase in shear strength by 8% .

4. CFRP rods Orientation 45-degree angle inclined to increase resistance to shear given by (6.4-11.3)% compared with 90 degrees.

5. CFRP NSM had a limited effect on decreasing the deflection of deep beams it may be noted that the midspan deflection decreased by about (3%).

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