Rehabilitation of RC Deep Beams for Shear after Pre-crack by Near Surface Mounted CFRP Rods

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***Abstract*— The main objective of this paper to study the effective of using the Near Surface Mounted NSM CFRP technique as rehabilitation for shear in deep beam after 50-60% of ultimate load.**

Keywords*— *Strengthening ; Deep Beam; NSM CFRP rods.

I. INTRODUCTION

The using of Fiber Reinforced Polymer (FRP) composites for strengthening material in the civil engineering construction was a famous technique that during thirty years ago , Japanese and Swiss were firstly that used this applications (Enochsson,2005). A lot of project used this technique around the world and it increasing as the new style to rehabilitation for existing construction.

The maintenance of the old construction are consider alternative and an important way to reduced cost and increase design live time of existing construction.

Some of researchers have used this method (maintenance) for the development of carrying samples for shear and flexural.

MAKI,2010 presented an experimental and theoretical investigation of flexural behavior of reinforced concrete two-way slabs strengthened or repaired with externally bonded carbon fiber reinforced polymer (CFRP) sheets. The experimental work includes testing of eleven reinforced concrete slab specimens with dimensions (1050mmx1050mmx60mm), Seven of these slabs were strengthened, three slabs were repaired with carbon fiber reinforced polymer (CFRP) strips and one specimen was tested without strengthening acts as reference slab (control) for comparing the performance of CFRP strengthened or repaired slabs. The experimental variables considered in the test program include the location, quantity, shape and dimensions of CFRP sheets. All the reinforced concrete slab specimens were designed of the same dimensions and reinforced identically to fail in flexure. All slabs had been tested in simply supported conditions subjected to central concentrated load.

Al Fedhly,2010 has been observed that strengthening concrete deep beam with CFRP sheets is a successful solution to enhance ultimate load capacity with up to 53% increment.

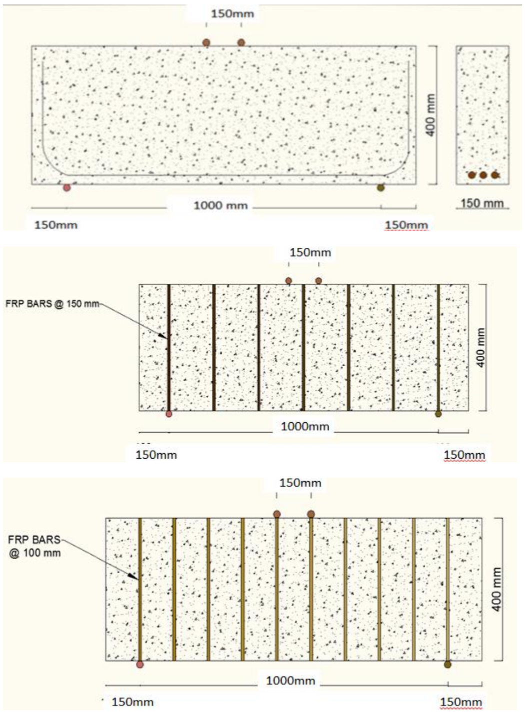
Thieab,2012 presented full-scale experimental and theoretical investigation into the behavior of reinforced concrete beams flexurally strengthened with carbon fiber reinforced polymer CFRP strips by NSM technique. The experimental work includes testing of Twenty-one reinforced concrete beam specimens with dimensions (200 mm x300 mm x 3200 mm), Thirteen of these beams were strengthened by NSM technique, one beam was strengthened with external CFRP strip, one beam was repaired with carbon fiber reinforced polymer CFRP strips and six specimens were tested without strengthening acts as control beam for comparing the performance of CFRP strengthened or repaired beams. The experimental variables considered in the test program include the location, dimensions and number of CFRP strips, compressive strength of concrete and the amount of the tensile reinforcement. All the reinforced concrete beam specimens were designed of the same dimensions and reinforced identically to fail in flexure. All beams had been tested in simply supported conditions subjected to four point load.

Shear design is a very important consideration when dealing with deep beam design .The ACI code 11.8 classifies a deep beam as having a clear span to depth ratio less than five for a distributed loading condition. This translates into a shear span to depth ratio of 2.5 or less for concentrated mid-span loads. Beams in this work are designed to have a shear span to depth ratios of (1.158) , which classifies it as a deep beam for shear by the ACI code.

So in this work will studying Shear Strengthening of RC deep beam with Near Surface Mounted CFRP Rods as repairing or maintenance.

II. EXPERIMENTAL WORK

It has been tested of five specimens of rectangular reinforced concrete deep beam with the dimension 400x150x1300 mm with 1000mm as clear span. All beam specimens were tested under a static two-point load test with 150mm distance between loads at middle span . All specimens without stirrups reinforcement and reinforced with 3#5 steel bars for flexural . One of them tested to failure as a base line(control) and other specimens uploaded until the emergence of cracks or the amount of carrying up to 50-60% from ultimate load, then it has been re-rehabilitation of using NSM CFRP technique by grooves were made using a Hilti diamond saw cutter machine on the both sides of specimens with different spacing and different inclination, two spacing were taken 100mm and 150mm. on the other hand, vertical and inclination with 45 degree was made as shown in figure (1) and table (1) show the description of test specimens. The grooves were cleaned with water under pressure and the slits were cleaned with compressed air figure (2). All the grooves had square cross-section, with size of 10 mm. Then the epoxy paste of type Sikadur-30 was prepared by mixing the two components (resin and hardener) in 3:1 proportion by volume with a power mixer. The groove was filled half-way with the paste, the CFRP rod was then placed in the groove and lightly pressed. This forced the paste to flow around the CFRP bar and fill completely between the CFRP bar and the sides of the groove. Then the groove was filled with paste again and the surface was leveled figure (3) .After completing the CFRP installation, two days before the testing date,



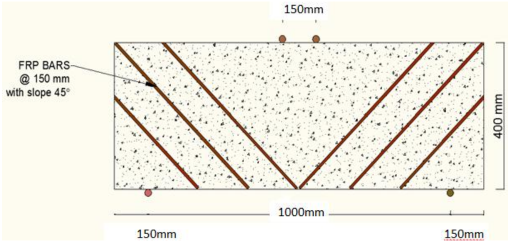


Figure (1) specimenes discription

Figure (2) Grooves Preparation on Beam Side Face

Figure(3)Application NSM Strengthening Technique

Table (1) Description of Test Specimens

Beam Code	NSM FRP Rods after loaded to 50-60% for ultimate load		Notes
		Inclination	
C	-	-	
RN 90-15	2No.2@150mm	90	Repairing loaded to 50-60%
RN 90-10	2No.2@100mm	90	Repairing loaded to 50-60%
RN 45-15	2No.2@150mm	45	Repairing loaded to 50-60%
RN 45-10	2No.2@100mm	45	Repairing loaded to 50-60%

III. EXPERIMENTAL RESULTS

During casting of deep beams group, nine (100×200 mm) cylinders were made. After cleaning and lubricating the molds, concrete was cast and compacted and then cured under the same conditions. cylinder compressive strength and cylinder tensile strength were obtained by standard tests. The cylinder compressive strength was obtained by testing six cylinders and the results are given in Table (2).Three cylinders were tested according to ASTM C496(1990) for the assessment of splitting tensile strength of concrete .The results of each three cylinders are averaged and given in Table (3).

Table (2) Concrete Compressive Strength Results

Number of Cylinders	Ultimate Compressive Strength f'_c (MPa)
1	29.72
2	28.73
3	30.52
4	30.4
5	31.2
6	32.67
Average	30.54

Table (3) Concrete Splitting Tensile Strength Results

Number of Cylinder	Ultimate Strength f_t (MPa)
1	3.4
2	3.14
3	3.02
Average	3.19

Table(4) brief the ultimate load ,crack load and failure mode for each specimen, figure (4) shows the ultimate load for all beams with respect to ultimate load of the reference beam . capacity load Percentage for rehabilitation specimens was increased 9.5-17.1% compare with control beam. Figures (5-9) show the crack width for each beam.

Table(4) Summary of Test Results

Beam	Ultimate Load kN	Percentage increasing	Cracking load	Failure Mode
C	420	-	160	Shear-compression
RN90-15	460	9.5%	120	Bond Failure of NSM Rods
RN90-10	470	11.9%	100	Bond Failure of NSM Rods
RN45-15	492	17.1%	180	Bond Failure of NSM Rods
RN45-10	475	13.09%	140	Bond Failure of NSM Rods

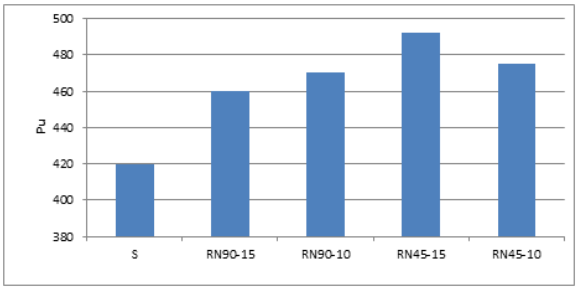


Figure (4)Ultimate Loads of All Beams

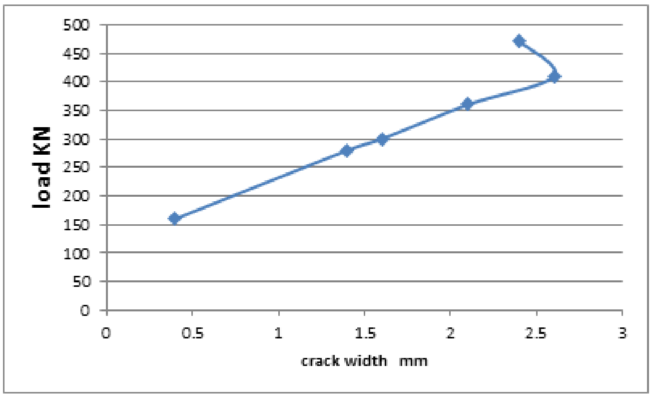


Figure (5) Crack Width of Beam C

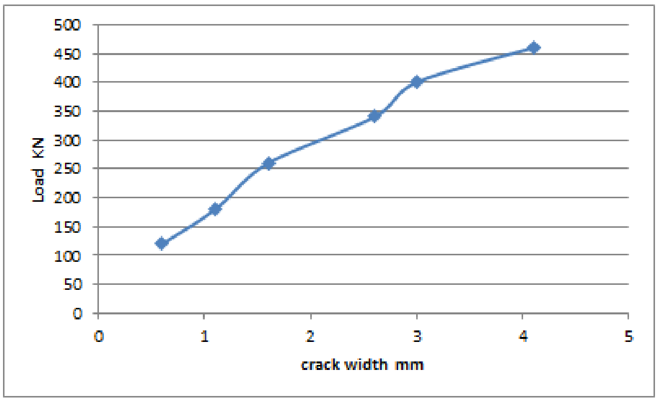


Figure (6) Crack Width of Beam RN90-15

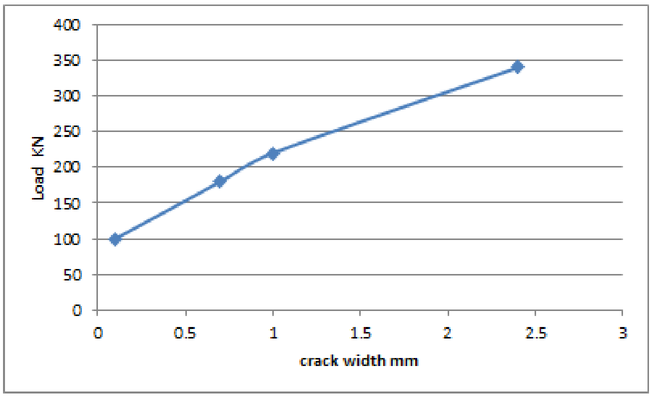


Figure (7) Crack Width of Beam RN90-10

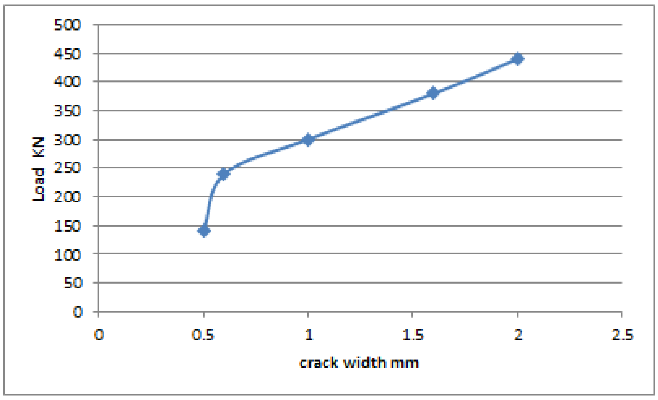


Figure (8) Crack Width of Beam RN45-15

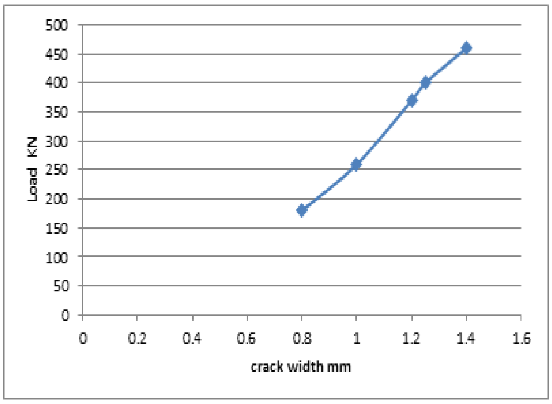


Figure (9) Crack Width of Beam RN45-10

Rehabilitation for pre-crack deep beam gave more increasing for shear value approximately 9.5 % - 17.1 % compared with control deep beam as shown in table (5) and figure (10) explain the load- deflection curve for control deep beam and repairing deep beam after pre-crack.

Table (5) Summary of Experimental shear strength

Beam	Vc,kN	Vs,kN	VFRP,kN	Vn,kN
C	210	-	-	210
RN90-15	210	-	20	230
RN90-10	210	-	25	235
RN45-15	210	-	36	246
RN45-10	210	-	27.5	237.5

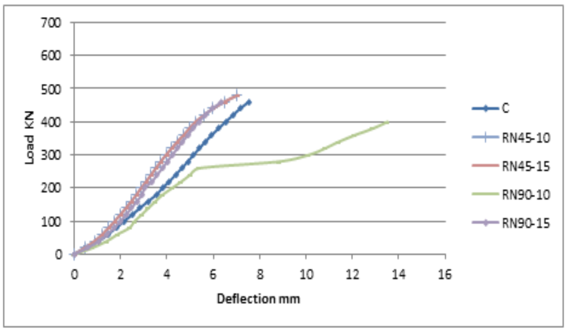


Figure (10) load –deflection curve

IV. CONCLUSIONS

Rehabilitation by NSM CFRP for shear was a good way to increase shear strength for deep beam . the ultimate load increasing was about 9.5 % - 17.1 % compared with control deep beam . all specimens mode failure were by bond that between epoxy and concrete surface that means the CFRP bar and epoxy have a good strengthening for shear and no failure until splitting from concrete face (bond). The crack width for control beam was 2.6 mm with 410 KN load and the average of crack width for rehabilitation beams was 1.8 mm that means the percentage of decrease for crack width was about 44.44 % .

On the other hand, this increasing for shear will be more than 17% if the bond between NSM CFRP bar and concrete become more strong or use another way to install it**.**

REFERENCES

[1] Al Fedhly,K.A.M.,2010 Behavior of Reinforced Concrete Deep Beam Strengthened with CFRP Sheeets, A THESIS, May 2010

[2] Anis A.Mohamad Ali , and thaer M.Matlab (2015)." Shear Strengthening of RC without stirrups for Deep Beams with Near Surface Mounted CFRP Rods"IJERT,volume 4,Issue.06,June2015

[3] Enochsson, O., "CFRP Strengthening of Concrete Slabs with and without Openings", Licentiate Thesis, Lulea University of Technology, Lulea, Sweden, 2005.

[4] Maki.R.F.,2010 Experimental And Theoretical Investigation Of The Structural Behavior Of R. C. Slabs Strengthened By (Cfrp), A THESIS, January 2010

[5] Thieab,H.M. ,2012, Full-Scale Experimental and Theoritical Investigation into The Beavior of Reinforced Concrete Beams Flexurally Strengthened with CFRP STRIPS BY NEAR-SURFACE MOUNTED TECHNIQUE.,augast 2012