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STUDY THE PERFORMANCE OF REINFORCED CONCRETE BEAMS STRENGTHENED BY SIDE BONDED CFRP

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Abstract: **This study's primary goal is to discuss the impact of the shear strengthening of Confined concrete beams and compare with control unstrengthened specimen to show the impact of side bonded beams retrofitting externally by Cfrp. Beams are designed to show also size effect impact. Two concrete beams were casted at the laboratory with concrete dimension of 180*40*2200mm while casted concrete strength of 30 MPa with 5Φ22 Bottom Reinforcement and 3Φ16 Top Reinforcement while the web reinforcement of T8 Spaced at 150mm.beams are tested under a/d radio of 2. The first beam used as a control beam without strengthening, and the other beam that are externally strengthened with CFRP strips with full height spaced at 150 mm and leaved for 28 days to gain full strength of epoxy resin as per the manufacturer data sheet before testing the beams. Each of these beams was tested with a particular span-depth ratio under a single point of loading until it failed in shear.**

Keywords: **CFRP, debonding, shear strengthening and concrete beams.**

I. INTRODUCTION

Both reinforced and prestressed concrete members typically fail in a shear failure that is abrupt and brittle. It must be taken into account that the shear strength must be equal to or greater than the flexural strength. Therefore, the cross-sectional area and flexural reinforcement were initially determined by the flexural design. The concrete beams are then shear strengthened to prevent shear failure rather than flexural failure. The majority of shear design codes divided the concrete contribution (Vc) and the shear reinforcement contribution into two parts for the shear strength designs of reinforced concrete members (Vs). Based on the sum of the two terms while taking safety considerations, The use of externally bonded (EB) fiber-reinforced polymer (FRP) composites to enhance degraded reinforced concrete (RC) structures is currently regarded as one of the most common strengthening techniques for enhancing the structural performance of concrete structures. This is because FRP composites, especially carbon fiber (CFRP), have extraordinary features such as high tensile modulus, high strength to weight ratio, high corrosion resistance, and excellent efficiency throughout the strengthening process. Epoxy is commonly utilized in a number of mounting techniques, such as full wrapping, U-wrapping, and side bonding, to attach the FRP Strips to a surface. Strips of side-bonded FRP may be left exposed in order to bolster the bond and maximize the material's shear contribution. Full-wrapping is more productive but less practical in solid slabs when the slab needs to be slotted. Not always the most cost-effective solution Since it only requires access to the sides and bottom of a beam, the U-wrapping design is perhaps the one that is most frequently utilized. There has been a lot of interest in undertaking more study recently. Even though full-wrapping is more efficient and does not require the slab to be slotted, it cannot be the most cost-effective option for solid slabs. Since it only needs access to a beam's sides and bottom, the U-wrapping design is perhaps the most popular. Recently, there has been a lot of interest in looking further into the shear behaviour of RC-strengthened beams that have either side-bonded FRP configurations or U-wrapping [7–12], in order to provide guidance for overcoming the problems. The most frequent means of failure for reinforced beams with U-wrapping or side bonded techniques was the debonding of FRP strips. By reducing debonding and maximizing the use of CFRP strips, the hybrid externally bonding (EB) and mechanically fastened (MF) technology for carbon-FRP strips can provide a higher shear capability [4]. The shear capacity of RC beams is often adequate and higher than the flexural capacity. However, due to potential changes in how buildings function, as well as the corrosion of the steel stirrups due to insufficient concrete cover or other climatic variables, these beams could lose their shear strength. The various problems of RC beams strengthened in shear with EB-FRP composites are studied through both theoretical analysis and experimental research. Besides, shear span/depth ratio of 2.0 are explored to compare strengthening method with distinct shear failure modes. The test findings are displayed and thoroughly discussed. Different theoretical methods are used to evaluate the shear contribution of CFRP strips from the experimental data in comparison to those forecasts. The goal of this study is missing.

The Retrofitting of Existing Structural Elements:

The term "retrofit" refers to the application of new materials after production to repair or enhance an existing construction. The reduction in member ductility and stiffness occurred while the structure was enduring higher loads or was exposed to a powerful environment, such as a flood or earth tremor. The majority of the materials have been utilised in the past to increase the strength and ductility of the member by mounting steel plates on concrete members (Jacket) or by applying external post-tension; all of these approaches are used to enhance the performance of damaged structures. Steel plate is used to boost the flexural strength of the beams, but it is more expensive to install and maintain since it requires more specialised equipment and labourers. The foundation of the construction must be loaded more, however these foundations were not built to support these additional loads. The most popular option for retrofitting structures is FRP since it is a lightweight material with excellent corrosion resistance, high strength resistance, and long-term performance. For rehabilitation, a licenced professional engineer must evaluate the structure to assess the damages caused by shear, flexural, and compression damage before determining the type of FRP and its techniques of installation method and applied areas. This is done after looking at the as-built drawings, figuring out the concrete's compressive strength for the existing members, and seeing if the steel members have corrosion. All of this information provides insight into the functionality of the structure and the areas that require repair. FRP is not only applied to broken members; it may also be used for 11 other nearby structures (beams or columns) because doing so would increase the stiffness of the defective member and may harm the nearby concrete members. For a brief explanation of structural analysis and investigation methodologies, see ACI codes 364.1R and 437R. Epoxy is a popular adhesive for bonding FRP with steel or concrete members because it offers shear resistance between the two materials. Epoxy is used to install FRP with concrete members. (5)

II. EXPERIMENTAL WORK

The test matrix was developed to examine the effects of test variables on the shear capacity of beams using Externally Bonded full height CFRP strips (on what). After being cured for 28 days, two RC beams were casted, evaluated, and tested to have average concrete compressive strengths of 30 MPa, respectively. As control specimen, regular RC beams with reinforcement were used and designated as control, represented specimens with shear span/depth ratios (a/d) of 2. According to the method of strengthening, side bonded CFRP strips and were labelled (SEF). the concrete surface was roughened manually until the coarse aggregates are exposed. Before Adhering to the FRP strips the beam corners were rounded to prevent the fiber rupture due to the high stress concentration. Compressed air was applied to remove dust and the loose particles from the roughned concrete surfaces. The CFRP strips were cutted according to the required length of the strip. Mixing the epoxy resin part(A) and Part (B) with a mixing ratio of 2:1 by weights. Fill the location of both strips and the beam with the epoxy resin with a minimum average thickness of 1.6 mm according to the manufacturer datasheet. Adhere the CFRP strips to the beams at their marked places. The strengthened beams were cured at room temperature approximate of 30 degrees for at least 7 days before testing to ensure the complete strength gained of the epoxy resin. the effectiveness of the FRP composites and concrete can be very critical to the quality of work during the bonding process. Therefore, great precautions had been taken to ensure that the same quality of work is achieved for all specimens. Complete specimen details are provided in Table 1.

III. TEST RESULTS AND ANALYSIS

3.0 Overall response:

At the one-point loading test, all of tested beams failed in shear. The variation of shear failure mode was similar to that of the control specimen. Most of the CFRP strips failed by debonding also by the strip peeling off from the interface between the adhesive and concrete substrate. The shear capacity of the strengthened beams was always higher than that for the control members. Table 1 shows the shear capacities and shear contribution by CFRP composites, whereas Fig.7 presents the shear force-deflection curves for beams. Details of the test results will be discussed in the following sections.

3.1 Failure Mechanism for Tested Specimens:

When the shear-strengthened RC beams exceed the ultimate load, most of the CFRP strips were

observed to fail by debonding Fig.4, while a few strips failed in partial rupture Fig.5. Furthermore, there are a small number of strips (which are located close to the support point) that were not damaged even that they are intersected by the critical shear cracks Figure (6). The main failure modes are sketched in Figure (4) and Figure (5) and summarized as follows:

1.the traditional shear failure for the unstrengthened control specimens for the control Specimen.

2.Combined cracking under the CFRP strips with debonding of CFRP. After debonding the CFRP strip will no longer be able to carry any extra loading. CFRP strips located close to the loading point might fail by debonding after achieving the ultimate load. These strips have very little contribution to the shear capacity of the beam. For the CFRP strips located close to the support, the shear cracks intersect with the strip at a position near to the bottom of the beam, where the FRP is effectively fastened through the side bonded wrapping. If the part of the strip above the crack has a great bond length to avoid the debonding phenomena, The CFRP rupture failure could occur when the FRP stress reaches its tensile strength (Figure 6).

3.2 The strengthening configurations:

The used strengthening configurations was the use of externally side bonded CFRP strips tested under (a/d) ratio of 2 beam SEF strengthened with externally sided bonded epoxy only CFRP. The least load of control specimen of 313 kN we found that the maximum force could carried by each strip was 347.5kN as stated before. At beam SEF2 the force carried by strip under load was 5.4 kN which are 1.6% from maximum force and the strip next to load was 4.65 kN which are 1.4% from the maximum force. So the debonding phenomena which was considered the most common type of failure in shear strengthened beams.

3.3 Strength and Stiffness:

The externally full side bonded specimen (SEF) With (length=350 mm) adhered with epoxy only achieved a shear load gain of 25% than the control specimen.

IV. SUMMARY AND CONCLUSIONS

This experimental study aims to study the enhancing of the concrete load carrying capacity based on the experimental results and the above discussions, the following conclusions can be derived:

1. the steel stirrups strain is considered 10% of the Cfrp Strain.

2.it was noticed that a larger of strains occurred in CFRP compared with the internal transverse stirrup also occurred after the yielding strain of the steel stirrups.

3.Beam SEF adhered with epoxy was failed by debonding of CFRP laminate, it could be noticed that CFRP strains undergo either lesser or similar to the transverse stirrups. This shows that the effect of externally bonded CFRP preserves the integrity of internal transverse stirrups.

4.Effect of the strip-width to strip-spacing ratio on the shear strength of RC beams reinforced with externally bonded FRP composites.

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APPENDIX - A

List of tables:

Table (1): Properties of tested beams used in this experimental work

Group beam	Dimensions (mm)	Strengthening type	(a/d)	Width of fiber (m	Spacing (mm)	Failure load
C2	180*350*2100	Control	2	-	-	313
SEF		EB-CFRP		50	145	392

Table (2): Properties of CFRP used in the experimental work

Master Brace® LAM 50/1.2CFS		Tensile E-Modulus 165,000 N/mm2	
Type	Width	Thickness	cross sectional area
Master Brace	50 mm	1.2 mm	60 mm2
Technical Data			
Density	1.5g/cm3		
Fiber Volume Content	≥68%		
Mechanical/Physical properties			
E-Modulus	values in longitudinal direction of the fibres		
	Mean Value		170,000 N/mm2
	5% Fractile-Value		165,000 N/mm2
Tensile Strength	values in longitudinal direction of the fibers		
	Mean Value		3050 N/mm2

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Table (3): Characteristics of Ordinary Portland Cement.

Properties		Test Results	Limits of the E.S. S
Expansion (mm)		1.4	Not more than 10
Specific Weight of Cement		3.12	3.15-3.16
Initial Setting Time (hr's: min's)		1: 37	Not less than 45 min
Final Setting Time (hr's: min's)		3: 18	Not more than 10 hrs
Fineness of cement, percentage of retained on the standard 0.09 mm sieve by weight		7.77 %	Not more than 10 %
Compression Strength (Kg/cm2)	3 days	247	Not less than185kg/cm2
	7 days	332	Not less than 265kg/cm2

List of Figures:

Figure (1): the Typical Reinforcement of Tested Beam

Fig (2): The Control beam During Testing

Fig (3): The Casted Beams During Testing

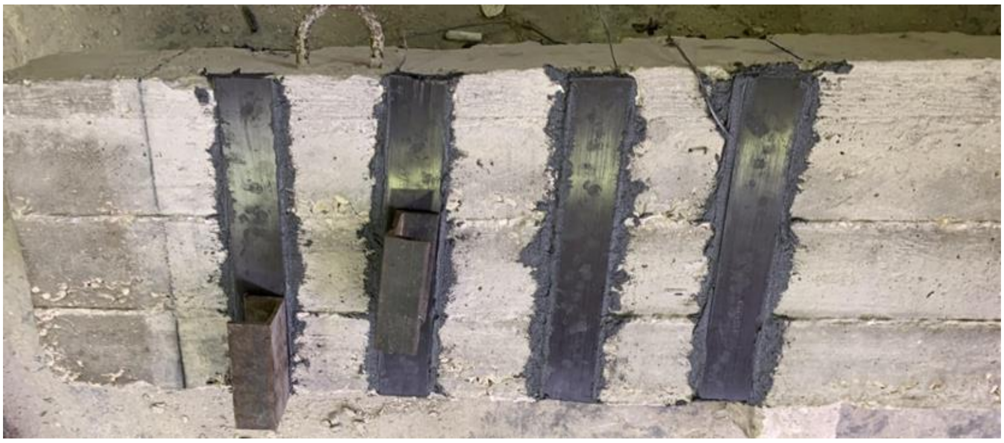

Fig (4): Beam During CFRP Strengthening

Fig (5): crack pattern during testing of specimen.

Fig (6): Tested specimen after failure.

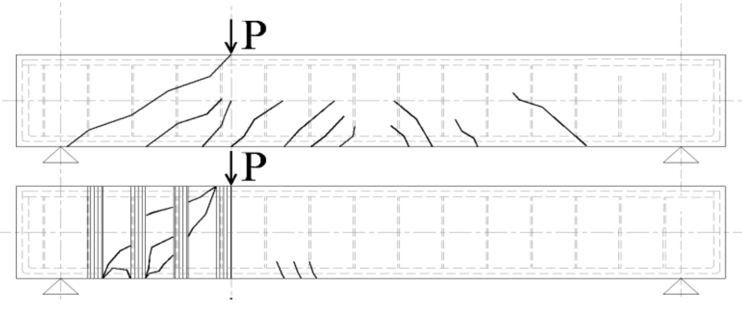

Fig (7): Typical drawing for crack pattern

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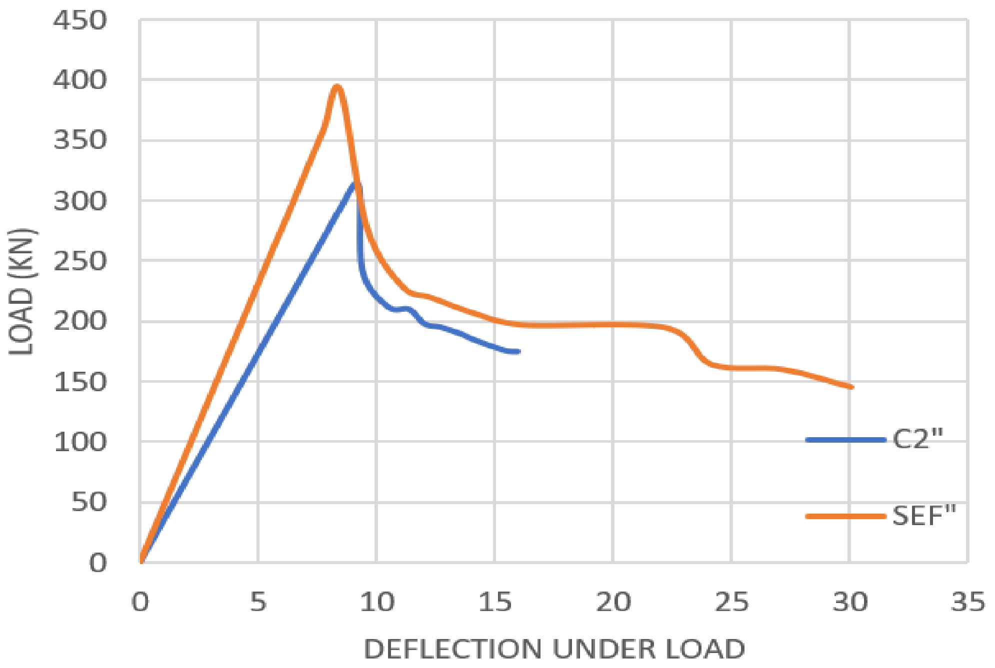

Fig (8): The Under-loading Deflection Curve for Tested Beams

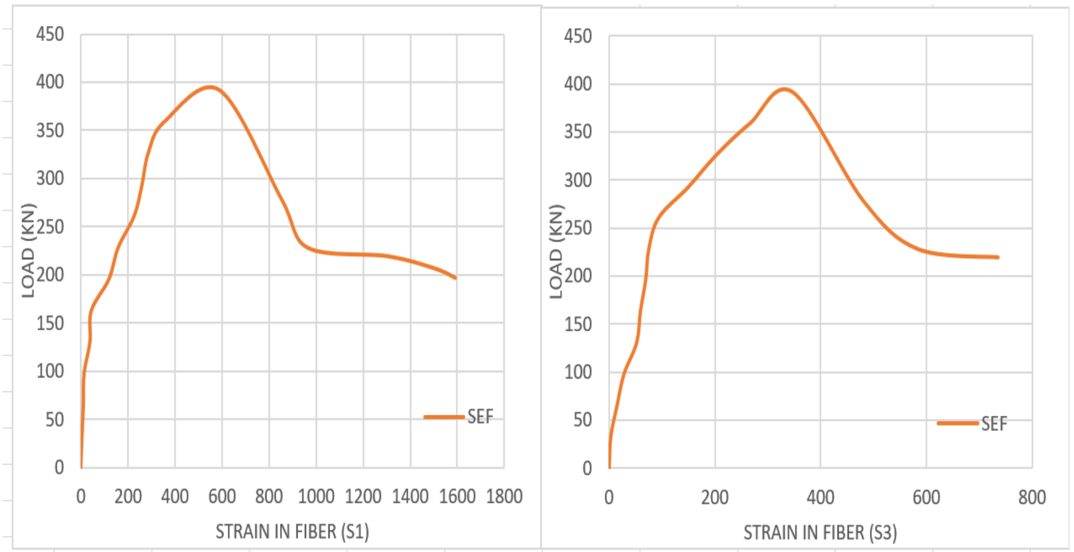

Fig (9): Strain in Fiber for Both Strips.