# AN EXAMINATION OF THE FLEXURAL CHARACTERISTICS OF REBAR-REINFORCED CONCRETE BEAMS WITH HYBRIDIZATION

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**Abstract**

This study examines the flexural behaviour of concrete beams reinforced by hybridization steel rebar and covered in CFRP sheet. Seven samples were cast and tested under two-point stress, six of which were reinforced with CFRP hybrid steel bar/sheet and one of which served as a control beam and was reinforced with standard steel bars. The hybrid steel bar/sheet CFRP's diameter and the amount of carbon sheet warping steel bar were the two main factors evaluated. Investigations have been made on failure processes, initial and final cracking loads, crack patterns, load-deflection curves, and maximum deflection. A hybrid steel bar/sheet CFRP technique produced the same behaviour as control beams while lowering maximum deflection, according to experiments. In addition, compared to the reference beam, it increased load capacity by 4.35 percent, to 42.61 percent. When compared to the control sample, all augmented specimens displayed an overall reduction in maximum displacement, although the initial cracking load did not change. The hybridization length, which is two-thirds of the length of the beam, offers the best reinforcing length for one and two in terms of ultimate load by 21.74 percent and 39.13 percent, respectively, in comparison to the control beam.

**Keyword**. Flexural; Structural behavior; rebar; Hybridization concrete beam; Reinforced

## 1. Introduction

Concrete is a brittle substance with low tension strength but high compression strength. This was made in response to a demand for rebar in the constructions' tension portions. Traditionally, conventional rebars were used to do this. Over the last five years, a research has shown to be satisfactory in resolving the RC-beam corrosion problem. Techniques including stainless-steel rebars, concrete additives, cathodic protection epoxy coatings, galvanic corrosion, and others have been tried in the past, but none of them have totally solved the corrosion problem. Fiber-reinforced polymers' unique properties suggest that they could be the answer to steel corrosive environment. These qualities include fatigue resistance, a high strength-to-weight proportion, and excellent corrosion resistance. Hybrid composites have a higher level of complexity than standard FRP composites. Hybrids can have many strengthening and matrix stages, or one reinforcing stage with doubled grid stages, or twofold reinforcing and doubled matrix stages.

They are more flexible than other fiber-strengthened complexes. A high-modulus fibre and a reduced fibre are usually used. The high-modulus fibre has load capacity and stiffness1, but the low-modulus fibre is a low-cost material that improves the composite's damage resistance. [1]. The efficiency of concrete beams strengthened with hybrid FRP rebar was studied in terms of flexural strength. [2]. In specimens strengthened with AFRP and steel rebar, the increase in stiffness was more noticeable, as were decreased fracture width and crack spacing values. Kamal, et al. 2008 [3] presented a study to look at the design of reinforced concrete beams by using GFRP rebars instead of typical steel to extend the reinforcing zone. Thirteen RC-beams were used in the experiment.

According to test results, using steel reinforcement in conjunction with GFRP reinforcement improved the flexural behaviour of GFRP reinforced concrete specimens. Lau and Pam (2010) [5] tested twelve beams to failure, including plain concrete beams, steel-reinforced concrete specimens, hybrid FRPRC specimens, and pure FRPRC specimens. Hybrid FRPRC specimens were shown to have better ductility than pure FRPRC specimens. As the amount of over reinforcing in the specimens increased, more ductility was seen in FRPRC-specimens. Yoon, et al.2011 [6] used both experimental and theoretical methods to examine the flexural capacity and deflection of high-strength RC beams. When hybrid reinforcement with steel bars was used instead of FRP bars, the stiffness and ductility increased and the deflection was reduced. In addition, the usage of hybrid bars decreased crack width and regulated crack propagation. Hawileh, 2014 [7] reported an analytical work using FEM to estimate the load deflection response of RC beams using a hybrid bar, which was carried out by Aiello and Ombres.The use of several types of FRP reinforcement provided the beams varying reactions. In addition, when compared to the remaining beams that were merely reinforced with steel, AFRP, and GFRP bars, the reaction of the beam strengthened with hybrid bars predominated. El Refai et al.,2015 [8] published a research on the flexural behaviour of hybrid-RC-beams. The use of steel reinforcement in hybridization with GFRP reinforcement enhanced the ultimate load, cracking load, and stiffness of pure GFRP specimens, according to the findings.

## 2. Experiment scheme

### *2.1. Material Properties*

Every specimen of experimental work was made from a standard concrete mix with a compressive strength of fc (32 MPa). The material components are made of V-sulfate resistant cement in accordance with Iraqi requirements (No.5/1984) [13]. Natural sand has a maximum particle size of 4.75 mm. The maximum coarse aggregate size was 20 mm. The IQS (No.45/1984) criteria [14] is evaluated on both fine and coarse material. For casting and treatment, only pure water is used. The longitudinal rebars and shear reinforcement were made of steel bars with diameters of 12 and ten millimetres, respectively. At compression zones, an

| **Bar dis.(mm) Yield** | Strength (MPa) | Stree (MPs) Ultimate |
|---|---|---|
| **Φ 8** | 696 | 600 |
| **Φ108** | 780 | 686 |
| **Φ 12** | 786 | 694 |

*2.2. Specimens description*

Under two-point load, seven RC beams, one control specimen, and others reinforced with hybrid steel bar/sheet CFRP composite bar are cast and tested. A standard specimen has a total span of 2000 mm, an 1800 mm centre to centre length, a 250 mm section depth, and a 150 mm section breadth. Figure 1 depicted the hybridization method. The reinforcement's properties, size, and loading were presented in Figure 2. The names of the tested beams are also listed in Table 2.

**Figure 1. Hybridization Method**

**Table 2. Description of the Specimen**

| Beams Symbol | BC | B1 | B2 | B3 | B4 | B5 | B6 |
|---|---|---|---|---|---|---|---|
| Hybridzation length (mm) | - | 800 | 1300 | 1900 | 700 | 1300 | 1900 |
| No.of layer | - | 2 | 2 | 2 | 3 | 3 | 3 |

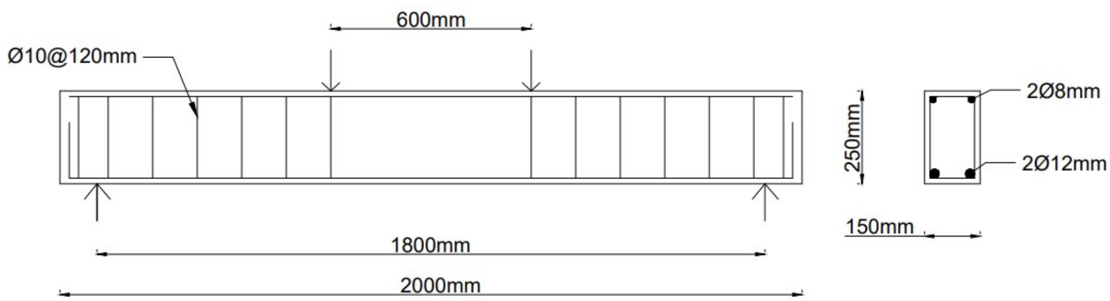


**Figure 2. The Beams' Reinforcement and Loading Plan**

**Figure 3. The universal machine used in testing**

## 3. Discussion

*3.1. cracks Pattern*

Figure (4) depicts the fracture development history of testing samples. The first two fractures in all specimens, such as the control beam, began as a flexural fracture at the bottom surface about within the middle part of the length of the beam with a maximum load of 25 KN. It is because the steel rod is not affected by the CFRP sheet that surrounds it at partial load. More flexural fractures were discovered on the shear span leading to increases of the load applied and related cracks become broader and more noticeable. In contrast to the control column, hybrid enhanced beam toughness and improved maximum throughput by roughly 4.35 percent to 42.61 percent. This could be due to the lengthening of the hybridization process, which increased beam intensity. Furthermore, almost all of the hybrid steel reinforcing beams broke .

**Table 3. Experimental Results**

| **Specimen** | BC | B1 | B2 | B3 | B4 | B5 | B6 |
|---|---|---|---|---|---|---|---|
| **First Crack Load(kN)** | 26 | 26 | 26 | 26 | 26 | 26 | 26 |
| **Ultimate Load Pu (kN)** | 115 | 120 | 140 | 135 | 120 | 160 | 164 |

capacity by (21.74 and 39.13 percent) for one and two layers, respectively. Moreover, a hybrid length of two-thirds of the length of the beam is ideal for ensuring a satisfactory binding between hybrid rebar and concrete with no additional length necessary.

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