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Effect of Reinforcement of Hybrid Layer FRP (GFRP and CFRP) on Bending Behavior of Reinforced Concrete Beams

Jasman*, Rudy Djamaluddin, Rita Irmawaty, A. Arwin Amiruddin

Civil Engineering Department, Faculty of Engineering, Hasanuddin University, Indonesia

*Corresponding author:
E-mail:
jasmanjasmann02@gmail.com

ABSTRACT

FRP (Fiber Reinforced Polymer), such as glass fiber or GFRP (glass fiber reinforced polymer) and carbon fiber or CFRP (carbon fiber reinforced polymer), are environmentally friendly materials that can be added to structural materials. This material has a high level of flexibility and resistance, corrosion resistance, and elasticity, with low installation costs, so it has the potential as a building material especially in earthquake-resistant areas. This study aims to determine the flexural capacity of standard reinforced concrete beams with hybrid FRP layer reinforcement (GFRP-s and CFRP-s) using various glass fiber and carbon fiber concentrations. The research was designed by designing loads and beams for the flexural capacity of reinforced concrete beams using FRP Hybrid layers (GFRP-s and CFRP-s). Six specimens of reinforced concrete beams were made with 2 specimens, namely BN (standard beams without using U-wrap and FRP) and BGC (beams using 2 layers of FRP reinforcement, namely GFRP-s and CFRP-s using U- wrap GFRP- s). Load cell readings for beam testing are carried out every 1 kN loading. Three LVDT (Linear Variable Displacement Transducers) are installed at the bottom of the beam to record the deflection in the beam. Installation of Strain Gauge (SG) to measure the beam's pressure and (deformation or strain). The test was carried out on a frame made of steel profiles designed with simple bearings (roll-joints) to test the flexural strength of the beam with a beam length of 3300 mm and a rectangular cross- section with dimensions of 150 x 200 mm. The results showed that the addition of FRP with 100% GRFP and 75% CFRP had optimum stress with a significant strain value, so it was perfect for flexural reinforcement of reinforced concrete.

Keywords: FRP reinforcement, hybrid FRP layer, flexural capacity

Introduction

Structural repair aims to restore or increase the strength of structural elements to withstand the load by the design load. Generally, the structure needs to be strengthened if there is a change in function so that additional safety factors are needed at the time of planning. Several innovations related to the planning of higher quality building structures to increase the capacity to carry loads, one of which is by adding a layer of FRP (Fiber Reinforced Polymer) such as glass fiber or GFRP (glass fiber reinforced polymer), carbon fiber or CFRP (carbon fiber reinforced polymer), and aramid fiber or AFRP (aramid fiber reinforced polymer). Fiber Reinforced Polymer (FRP) is a material resistant to corrosion, has high strength, and excellent quality, has a golden ratio of strength and weight, does not interfere with operational conditions at the job site, and has low installation and maintenance costs.

FRP composite materials have been widely used in various fields because it has better advantages than conventional materials. Reinforcement of reinforced concrete beam structures

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using FRP sheet as external reinforcement with GFRP flexural reinforcement resulted in an increase in load up to 75.13% and an increase in maximum deflection. The use of GFRP sheets on reinforced concrete beams that have been loaded until the reinforcement melts has a higher flexural capacity than the original beam (Djamaluddin & Hino, 2011). Djamaluddin et al. (2014) also found that reinforced concrete beams reinforced with GFRP sheets showed increased maximum flexural capacity. Reinforcement of reinforced concrete beams using CFRP in the form of NSM strips and sheets as longitudinal reinforcement can increase the bending moment capacity and the use of shear reinforcement. In addition, CFRP sheets in the form of a U-wrap can increase the ductility of the beam (Rasheed et al., 2010). The different reinforcement systems were originally designed to produce a flexural strength equivalent to the crushing of the concrete at an ultimate compressive strain of 0.003.

FRP composite materials have been widely used in various fields because it has better advantages than conventional materials. Naresh et al. (2018) found that there was a significant effect of strain rate on the tensile strength (0°/90°) of GFRP and hybrid composites, while the effect of strain rate on the tensile strength of carbon fiber cross-coated composites was more petite, for an increase in the strain rate of 8,3 × 10^{-3} becomes 542 s^{-1}. SEM micrographs show the failure mechanism, namely micro-cracks between the fiber-matrix surfaces and micro-cracks of the matrix under quasi-static loading and debonding occurs in the fiber-matrix, matrix cracks, and matrix damage under dynamic loading.

Hawileh et al. (2014) conducted a study related to the flexural behavior of reinforced concrete beams using an externally bonded FRP hybrid system (GFRP/CFRP). The mechanical properties of the hybrid FRP sheet obtained with a property test were carried out. The beam test consisted of a standard beam and four beams reinforced with hybrid GFRP, CFRP, and FRP sheets, to study the flexural effectiveness, load-deflection response, specific strain, and failure modes.

The use of an FRP hybrid layer can be applied to reinforced concrete beams to know the flexural behavior of variations in FRP properties. The FRP variations in the form of carbon and glass properties with different percentages were tested in this study.

Material and Methods

Location and time of research

The process and implementation of the test were carried out at the Materials and Structures Laboratory of the Department of Civil Engineering, Hasanuddin University, Gowa, for 3 months.

Research tools and materials

The equipment used as a measuring tool in this study:

a. Reinforcing steel strain gauge
   In the lower longitudinal reinforcement, a strain gauge type FLAK-2 - 11-5LJC-F (gauge factor 2.12±1%) is installed, and placed in the middle of the span (maximum moment). The adhesive used to attach the strain gauge to the surface of the reinforcement is CN Adhesive.
b. Concrete strain gauge
   The concrete strain gauge is a strain gauge type PL-60-11-5LJC-F (gauge factor 2.07±1%) attached to the test object's upper surface. CN-E adhesive is used to attach the strain gauge to the concrete surface.
c. FRP strain gauge
   The FRP strain gauge is a strain gauge type FLAB-2-11-5LJC-F (gauge factor 2.12±1%) attached to the FRP surface in the middle of the span. The adhesive used to glue the strain gauge on the FRP surface is CN Adhesive.

d. The materials used are:
Ready-mix concrete quality f'c = 25 MPa, GFRP fiber produced by Fyfe. Co.LLC type Tyfo SEH-51 and CFRP fiber type Tyfo SCH-41 produced by Fyfe. Co.LLC, adhesives, wire, and reinforcement produced by PT. Barawaja and clean water to mix.

Research design

The dimensions and reinforcement of the beams were analyzed using the ultimate strength design method, and beam testing was carried out using standard general beam testing instruments. The load and beam design can be seen in Figure 1.

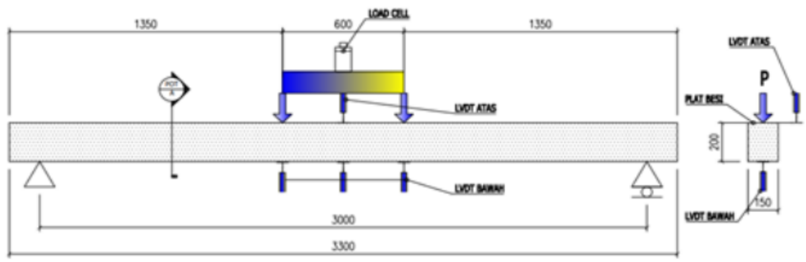

Figure 1. Load and beam design

Testing the tensile strength of reinforcing steel

This test includes testing the tensile strength of plain reinforcing Steel with a diameter of 8 mm as reinforcement in compression fibers, plain reinforcement with a diameter of 8 mm as shear reinforcement, and threaded reinforcement with a diameter of 13 mm, which will be used as flexural reinforcement in tensile fibers. The testing process was carried out using the Universal Testing Machine (UTM), following the strain analysis model (Figure 2).

Figure 2. Tensile testing with Universal Testing Machine (UTM) 1000 KN capacity

FRP mechanical properties testing

The mechanical property testing of GFRP, CFRP, and FRP hybrid refers to the ASTM D-3039 standard (Figure 3). The properties of FRP used in this study are arranged in variations of Carbon (C) and glass (Glass), with the variations shown in Table 1. The composition is calculated based on the width of the reinforcement sheet.

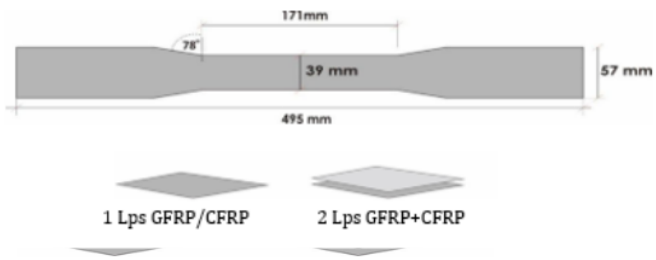

Figure 3. FRP property test object (ASTM D3039)

Table 1. Variation of FRP properties for reinforced concrete

Sample Code	FRP Percentage	Variation in Number of LayerFRP	Number of sample (pcs)
G1	100%	1 layer of Glass	3
C1	100%	1 layer of Carbon	3
C2	75%	1 layer of Carbon	3
C3	50%	1 layer of Carbon	3
G1C1	100% + 100%	1 layer of Glass+1 layer of Carbon	3
G1C2	100% + 75%	1 layer of Glass+1 layer of Carbon	3
G1C3	100% + 50%	1 layer of Glass+1 layer of Carbon	3

Results and Discussion

Tensile testing of reinforcing steel

The tensile test results for steel 8 used in reinforced concrete as shear reinforcement and reinforcement for the compression area can be seen in Table 2.

Table 2. Steel tensile test for shear reinforcement and compression area

Tensile Test	Test Result			Mean	SNI requirements BJTP 280 SNI 2052: 2017
	Sample 01	Sample 02	Sample 03		
Stretch Limit, N/mm	375.796	367.038	365.844	369.559	280 - 405
Pull Limit, N/mm	495.621	488.057	486.465	490.048	Min 350
Strain, %	23.70	24.81	24.81	24.444	12

The tensile test of D13 steel used in reinforced concrete as reinforcement in the flexural area is shown in Table 2. The tensile strength test results for 8 mm plain reinforcement show the average yield stress is 385.72 MPa. So with the modulus of elasticity Es = 200,000 Mpa, the average yield strain value is 1912. For the 13 mm thread reinforcement test, the average yield stress was 338.85 MPa, so the average yield strain value was 1684. It can be seen that the test results meet the requirements of SNI 2052:2017 so that the type 8 reinforcement can be grouped, including the type of plain steel BjTP 280 based on the tensile test results data on the mechanical properties of reinforcing steel. The type of reinforcement D13 includes the type of threaded steel BJTS 280.

FRP property tensile strength test

The average stress, strain, and modulus of elasticity for each variation of FRP are shown in Table 3.

Table 3. Average stress, strain, and modulus of elasticity for each variation of FRP

Kode Sampel	Tegangan **σ** (MPa)	Regangan Ε (mm/mm)	Modulus Elastisitas E (GPa)
G1	255	3,60	22
C1	671	1,90	34
C2	574	1,70	22
C3	455	1,67	17
G1C1	412	3,20	10
G1C2	348	3,50	9,8
G1C3	291	3,90	7,8

Table 3 shows the results of the tensile test of the FRP property, the values of stress, strain, and elastic modulus are obtained for each variation. Hybrid composites with a higher weight fraction of glass fiber reinforced basalt fiber with carbon fiber (GC table 3) showed a linear stress reduction. However, the strain increased, although not significantly. These results are in line with the research of Subagia et al. (2015), which investigated the effect of basalt-carbon fiber hybridization of epoxy composites with variations in the number of fibers and the position of the laminate on bending loading. The higher the weight fraction of basalt fiber, the stress decreased with a 43.2% difference in modulus of elasticity for composites with carbon/epoxy fibers. However, the strain of the carbon/epoxy composite increased. The same thing was conveyed by Greco et al. (2014).

Fiber has several advantages over other materials. The fiber fraction produces high capacity and rigid cross-section (in the same area (Gohari et al., 2012). This material is sensitive to shrinkage when a matrix is used. This shrinkage property creates additional stresses that produce strain (Albert & Fernlud, 2002). Furthermore, with the more incredible amount of carbon fiber, the stress increases, followed by an increase in the modulus of elasticity, but the ductility of the composite decreases. The decrease in ductility is due to the nature of carbon fiber which has tensile stress more excellent than that of glass fiber. The mechanical properties of the hybrid epoxy composite with carbon fiber and glass fiber reinforcement are also greatly influenced by the hand layup fabrication. This study's composition showed that the fibers are grouped into the arrangement of glass fibers as the core of the composite material.

The percentage of glass fiber is 100% for carbon fiber with percentages of 100%, 75%, and 50% (Table 2), the results obtained for variation G1C1 have the most considerable tensile stress and modulus of elasticity compared to variations G1C2 and G1C3, but the strained material is getting bigger. This characteristic is due to carbon having high stress but minor strain. At the same time, glass fiber has lower stress but a more significant strain. Variations of 100% glass fiber and 75% carbon fiber resulted in optimum stress values with higher strains. It shows that these variations have great potential for carbon fiber and glass fiber for structural needs that are more efficient and environmentally friendly.

Conclusion

The addition of FRP (Fiber Reinforced Polymer) material with variations of 100% GFRP (glass fiber reinforced polymer) + 75% CFRP (carbon fiber reinforced polymer) produces optimum stress with an enormous strain value, so it is perfect for reinforced concrete reinforcement. This material variation has the potential as an environmentally friendly structural material in the future.

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