Tensile Strength of Various FRP Hybrid Between Glass Fiber and Carbon Fiber

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Abstract— **Hybrid composite materials are composite materials with different material strengths, which have a great potential to be developed as engineering materials. Hybrid polymer composite materials offer an economical design to obtain optimal performance according to the workload with reference to the choice of fiber and matrix. Optimal performance of the material can be achieved by combining two different types of fibers and composited with an epoxy. This hybrid composite material is made by hand lay-up method. The objective of this study is to analyze the tensile strength of the FRP hybrid between carbon and glass fiber. The variation of the specimen in the form of the percentage of carbon fiber width to glass fiber is 35%, 40% and 45% respectively. Carbon fiber and glass fiber are bonded using epoxy according to ASTM D 3039. Tensile strength test is based on ASTM D 3038, to obtain tensile strength and modulus of elasticity. The test results show a significant change in the stress and strain, where the 45% FRP hybrid specimen gives the highest ultimate tensile strength and behaves slightly brittle. Meanwhile, FRP 40% showed almost the same strength as FRP 45%, with a higher strain value, thus giving a ductile behavior. In general, it can be concluded that the specimens with a high percentage of carbon fiber showed an increase in tensile strength and modulus of elasticity, but resulted in a significant decrease in strain.**

Keywords— **FRP Hybrid, Carbon Fiber, Glass Fiber, Tensile Strength, Elastic Modulus**

I. PENDAHULUAN

Composite materials have advanced fast as an alternative for traditional materials in the previous two decades [1], owing to their superior mechanical qualities, corrosion resistance, light weight, and low density. FRP composites are used extensively in aircraft bodies, cars, ships, sports equipment, building materials, and civil projects [2]. Brittleness, on the other hand, is a disadvantage of composite materials. This feature is extremely hazardous because it can shatter without warning. Both glass fiber (GFRP) and carbon fiber (CFRP) are materials with their own set of benefits and drawbacks. The most extensively used fiber today is GFRP, which is relatively affordable and has high deformation (strain), good impact resistance, and shatter resistance, making it an excellent reinforcement material.

Glass fiber composites and carbon fiber composites have stronger strength and modulus, however hybrid composites have higher failure strain. The use of hybrid composites has the advantage of reducing the undesirable qualities of GFRP and CFRP composites. Hybridization is a technique for improving the poor qualities of composites. Hybridization techniques have been employed by many researchers to improve the weaknesses of composite materials [2-7]. Hybridization of glass fiber and carbon fiber, for example. Component weight can be reduced via GRPC. Carbon fiber, on the other hand, can help to reduce weight while also increasing strength. Because of its light weight, higher strength and stiffness, and decreased elongation, CRPC is favoured [1-3].

In his paper Effect of carbon/glass fiber symmetric inter-ply sequence on mechanical properties of polymer matrix composites, Dipak Kumar Jesthia (2018) stated that carbon fiber reinforced polymer composites had better mechanical properties than fiber reinforced polymer composites. However, due to the carbon fibers' poor elongation, catastrophic failure was found in the carbon fiber composites. It is necessary to build carbon/glass hybrid composites and assess their mechanical properties in order to achieve design adaptability and cost reduction. Tensile strength, tensile strain, fracture toughness, hardness, flexural strength, and elastic modulus might all be improved, according to the findings. As a result, more modifications must be investigated in order to maximize the mechanical properties of hybrid composites.

A study was undertaken by K Naresh et al (2018). Statistical examination of the strain rate effect on the tensile strength of GFRP, CFRP, and hybrid composites More glass fibers and less carbon fibers in the epoxy matrix can enhance the sensitivity of hybrid composites; glass composites are more sensitive to strain rate, whereas carbon composites are less or not sensitive to strain rate. The findings show that strain rate has a substantial effect on the tensile strength (0°/90°) of GFRP and hybrid composites, while strain rate has a lower effect on the tensile strength of carbon fiber cross-coated composites. The results of SEM micrographs point to a cracking failure mechanism. Microcracks in the matrix and interfacial microfibers during quasi-static loading

Ary Subagia, I.D.G. (2015) This study created a composite hybrid material with two types of fibers linked together using epoxy. Carbon fiber and basalt fiber with a single woven structure are the two fibers. A vacuum mold is used to make composites. The test findings demonstrate a considerable change in stress and strain, with sequential arrangement increasing the tensile stress, modulus of elasticity, and composite hybrid durability. Tensile stress reduces as the quantity of hybrid basalt fibers with carbon fibers grows. However, the composite hybrid's strain increased.

Irina M.M.W1 et al. (2015) investigated the mechanical properties of three different arrangements of hybrid composites made of glass fiber (plain woven and bi-axially stitched 45°) and plain weave carbon fiber in the study Evaluation of Mechanical Properties of Hybrid Fiber Reinforced Polymer Composites and Their Architecture. Method of resin transfer molding with vacuum assistance. Mechanical parameters of the hybrid composite, such as tensile strength, flexural strength, and volume fraction, were determined according to ASTM standards. The experimental results reveal that the arrangement with C and G representing woven carbon fiber and glass fiber, respectively, has superior mechanical capabilities.

K. Naresh, K. Naresh (2016) Effect of high strain rate on glass/carbon/hybrid fiber reinforced epoxy laminated composites was investigated. Tensile strength (66.3 percent) and modulus (3.8 times) increased with increasing strain rate for glass/epoxy composites, according to the findings. Tensile strength (6.3 percent) and modulus of carbon/epoxy composites do not differ much (1.3 times). Carbon/epoxy composites are stiffer materials, hence breaking the specimen from quasi-static to dynamic loading requires almost the same load. Carbon fiber and epoxy matrices are fragile in general. For dynamic loading rates, the combination of these two materials has almost the same tensile strength and quasistatic modulus. The tensile strength and modulus of hybrid (glass-carbon/epoxy) composites rise by 39 percent and 2.8 times, respectively, as the strain rate increases. For GFRP, CFRP, and hybrid composites, the quasi-static failure strain was larger than the dynamic loading strain. Failure happens over time. The time of contact between the structure and the loading device is significantly shorter at greater strain rates. As a result, the material becomes more brittle, leading to lower failure stresses at high strain rates. Because of their higher strain rate sensitivity, glass/epoxy composites are the best of the three composites. Hybrid composites, on the other hand, have been successfully coupled with glass/epoxy and carbon/epoxy composites. CFRP and GFRP are two types of composite materials. During dynamic loading, SEM micrographs of tensile test materials reveal rough surfaces, matrix fissures, matrix degradation, fiber tension, and fiber matrix debonding.

Hand lay up was used to create this composite. The goal of this research is to look at the mechanical properties of a carbon fiber and glass fiber hybrid FRP layer under tensile load (tensile). The percentage of carbon fiber in the test object varies, with 35 percent, 40 percent, and 45 percent of the percentage of glass fiber. An epoxy composite was used to connect carbon and glass fibers according to the ASTM D 3039 standard. To determine mechanical parameters such as tensile strength and elastic modulus, tensile strength tests were performed on hybrid specimens according on ASTM D3038.

II. Material and Methods

A. Tools and Materials

The following items were employed in this study:

- Universal testing Tensile test machine with a capacity of 100 tons, modulus of elasticity
- A data logger is used to automatically record the strain gauge data.
- The strain gauges for glass fiber (GFRP) and carbon fiber (CFRP) in the middle of the test item are strain gauge type FLAB-2-11 (gauge factor 2.121%), which are affixed to the surface of glass fiber (GFRP) and carbon fiber (CFRP).

The materials used in this research are:

- Glass fiber (GFRP) type Tyfo SEH-51 produced by Fyfe.Co.LLC.
- Carbon fiber (CFRP) type Tyfo SCH-41 produced by Fyfe.Co.LLC.
- Tyfo S Epoxy type adhesive produced by Fyfe.Co.LLC.
- Epoxy Resin, namely the adhesive used in the research, is a product of Fyfe Co. under the name Tyfo S, component A and component B.

The type of reinforcing fiber used is as shown in Figures 1a and 1b.

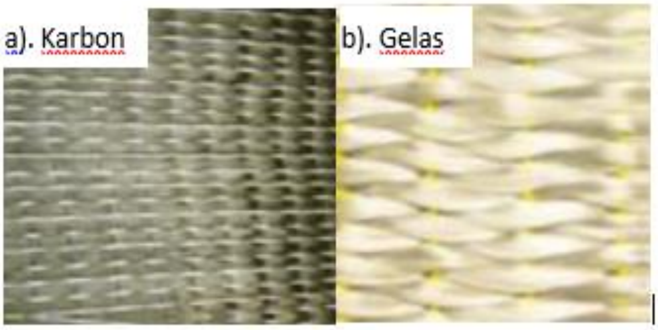

Figure 1 Single fiber weave (a). carbon fiber (CFRP), (b). glass fiber (GFRP)

B. Object To Test

The mechanical properties of GFRP, CFRP, and FRP hybrid, as defined by ASTM D-3039, are the test object in this study.

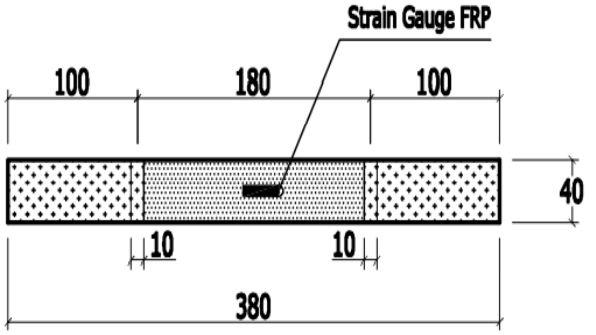

Figure 2 FRP Property Test Object (ASTM D-3039)

The following diagram shows the composition of hybrid GFRP, CFRP, and FRP materials:

TABLE 1
PROPERTY TEST OBJECT WITH GFRP, CFRP, AND FRP HYBRID VARIATIONS (GFRP AND GFRP)

Sample Code	FRP Percentage	Variation Number of FRP Layers	Size (cm)
G1	100%	1 Ply Glass	38x4
C1	35%	1 Layer Carbon	38x1,2
C2	40%	1 Layer Carbon	38x1,4
C3	45%	1 Layer Carbon	38x1,6
G1C1	100%+35%	1 Layer Glass + 1 Layer Carbon	(38x4) +(38x1,2)
G1C2	100%+40%	1 Layer Glass + 1 Layer Carbon	(38x4) +(38x1,2)

G1C3	100%+45%	1 Layer Glass + 1 Layer Carbon	(38x4) +(38x1,2)

The hand lay up method is used to print GFRP, CFRP, and FRP hybrid composite panels for test specimens. Figure 2 depicts the panel manufacturing process. Each GFRP panel is 380 x 40 mm when printed.

C. Fabrication of Test Objects

The preparation of test specimens begins with the preparation of rolls of GFRP Tyfo SEH-51 and CFRP Tyfo SCH-41, followed by the cutting of the sheet to the appropriate size variation as shown in table 1, and the preparation of a 2:1 combination of epoxy resin adhesives component A and component B. Apply the adhesive to the surface of the GFRP Tyfo SEH-51 and CFRP Tyfo SCH-41 sheets, attach the two reinforcement materials that have been cut and glued and gently pressed against the adhesive that is still wet, the air cavity trapped between the two layers of reinforcement will be released with the air cavity trapped between the two layers of reinforcement will be released with the air cavity trapped between the two layers of reinforcement will be released with the air cavity trapped between the two layers of reinforcement will be released with the air cavity trapped between the two layers of reinforcement will be released with roller pressure in the direction of the reinforcement fiber, after that the test object is allowed to stand for at least 72 hours, after which it is continued with the test.

Figure 3 The process of making test objects

D. Research Set Up

As indicated in Figure 4, tensile testing was performed using a UTM machine with a capacity of 1500 KN and a speed of 0.5 mm/sec. The test was repeated three times for each variation.

Stress and strain diagrams are used to examine the material's strength, strain, and modulus of elasticity. Figure 5 depicts the tensile test. The value of stress, strain, and modulus of elasticity of the specimen is computed for each variation using (**Hooke's law**) and the equation:

$$\sigma_{max} = \frac{P_{max}}{A_{max}} \quad (1)$$

$$\varepsilon_i = \frac{\delta_i}{L_g} \quad (2)$$

$$E_i = \frac{\Delta_\sigma}{\Delta_\varepsilon} \quad (3)$$

Where: (MPa) is the maximum stress, (mm/mm) is the tensile strain, E (GPa) is the modulus of tensile elasticity, P (N) is the load, and A (mm2) specimen cross-sectional area, (mm) the length increase due to the extensometer designation, L (mm) the specimen's starting length.

Figure 4 Tensile test process of test object with Universal Testing Machine (UTM) 1500 KN . capacity

The FRP strain gauge is a FLAB-2-11-5LJC-F strain gauge with a gauge factor of 2.091% that is affixed to the FRP surface in the middle of the specimen span. CN Adhesive was used to adhere the strain gauge to the FRP surface.

Figure 5 Strain gauge and adhesive used in the test

Data logger, to automatically record the data measured by the strain gauge, as shown in Figure 6

Figure 6 Data logger TDS-530

III. Result and Discussion

A. *Tensile Strength Test*

The average values of stress, strain, and elastic modulus were obtained from the FRP Tensile Strength test performed using UTM on GFRP, CFRP, and FRP hybrids three times each test:

TABLE 2
AVERAGE VOLTAGE, STRAIN AND ELASTIC MODULUS FOR EACH VARIATION

Sample Code	Tension σ (MPa)	Strain E (mm/mm)	Modulus Elastisitas E (GPa)
G1	273	3,7	7,28
C1	397	1,8	21,97
C2	403	1,2	32,43
C3	453	1,9	23,60
G1C1	329	3,65	9,03
G1C2	350	3,75	10,17
G1C3	363	2,35	15,44

Curve of stress–strain relationship

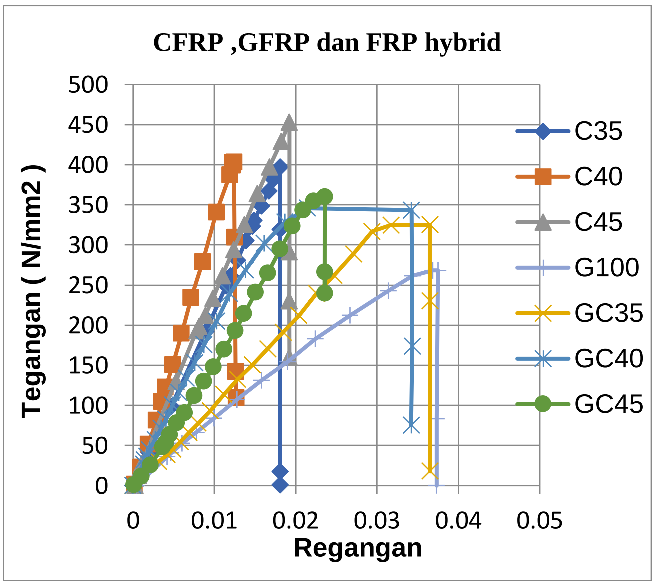

Figure 7 Stress-Strain Relationship (Carbon Fiber-Glass Fiber –FRP hybrid)

Curve of stress-strain relationship

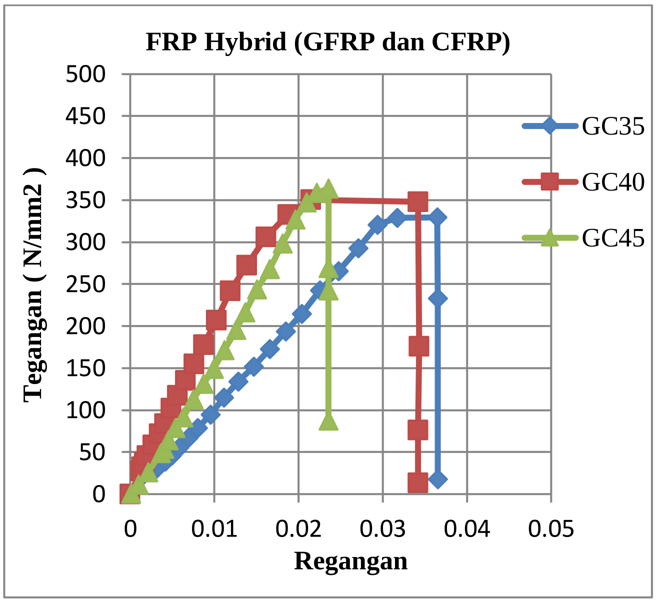

Figure 8 Stress–Strain Relationship of hybrid FRP (Carbon Fiber (GFRP) and Glass Fiber (CFRP))

Figure 7 depicts the results of the FRP material's tensile test, including the stress, strain, and elastic modulus values for each change. Table 1 shows that the FRP hybrid composite with the bigger carbon fiber percentage placed in the glass fiber layer has a higher volume of carbon fiber fraction. The test findings demonstrate a substantial difference in stress and strain, with the 45 percent FRP hybrid test item (GC45) having the greatest breaking stress value when compared to the specimen. other tests, but this test object has a more brittle behavior, which is extremely risky since it might fail without warning, whereas the 40% hybrid FRP test object (GC40) has nearly the same stress as the 45 percent hybrid FRP, but a different strain value. This is owing to the fact that glass fiber has a higher tensile strength than carbon fiber. The 35 percent FRP hybrid test item (GC35) has a lower tensile stress value, a higher tensile strain, but a lower ductility value than GC40. The FRP hybrid layer, which contains a higher percentage of carbon fiber, has a higher tensile stress and modulus of elasticity, but a lower tensile strain. These findings are consistent with previous research [8,10,11,15]. The 40 percent hybrid FRP variation (GC40) demonstrates that this variation has a lot of promise for structural reinforcement. Based on the findings, it can be inferred that combining glass fiber with carbon fiber has a substantial impact on the mechanical properties of FRP.

B. *Hybrid FRP Failure Mode*

Figure 9 depicts the fracture characteristics of the test specimen FRP hybrid 35 percent due to tensile load (tensile) (GC35) Figure 9(a), FRP hybrid 40% (GC40), and FRP hybrid 45 percent (GC45) (GC45) Carbon fiber and glass fiber reinforcement in Figure 9(c).

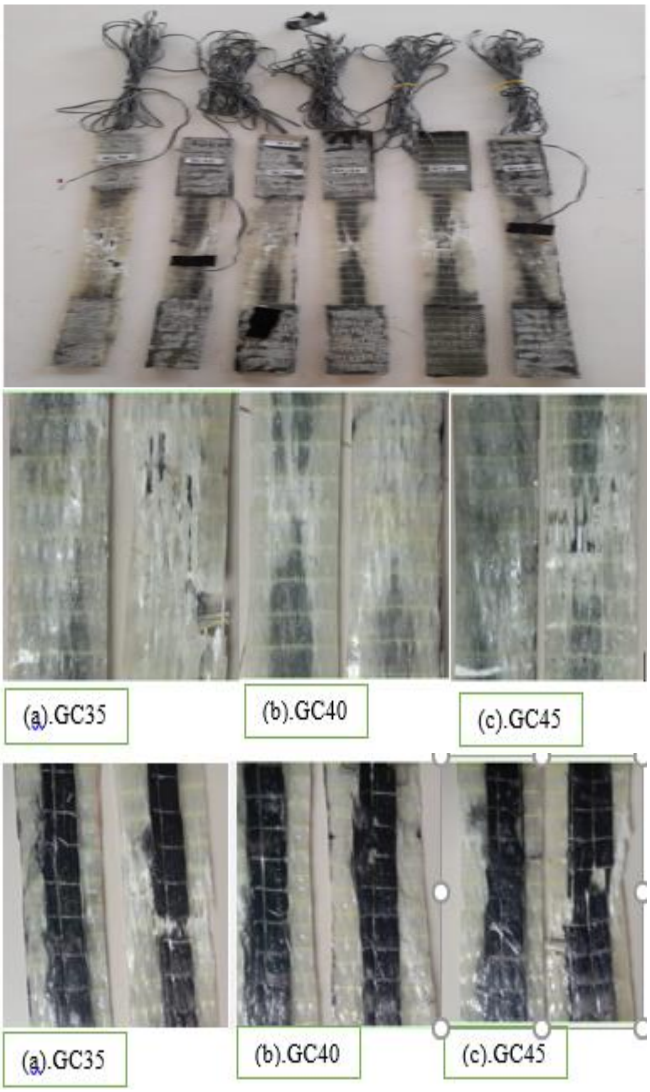

Figure 9 Failure mode of FRP Hybrid Tensile Test (a).GC35, (b).GC40 and (c) GC45

Figure 9(a) GC35 FRP hybrid When tensile loading is applied before the fracture occurs in the stress concentration area, a loud sound is heard, followed by a change in color to a lighter whitish on the side of the glass fiber, indicating the occurrence of plastic deformation in the glass fiber, which indicates that it has ductile properties because it has a greater stretch. The FRP hybrid GC35, on the other hand, has uneven fibers on the carbon fiber side, and the fracture is indicated by flat and partially fibrous portions. CFRP is brittle and has poor strain characteristics, as evidenced by this fracture behavior.

Figure 9(b) FRP Hybrid GC40 shows the observation on the side of the glass fiber that it has an uneven and fibrous cross section in the middle area, which appears whitish in color, then on the side of the carbon fiber, it appears that the fractured carbon fiber is slightly spread on the surface area of the glass fiber, and this fracture has an uneven surface due to the nature of the fiber, then before it breaks, Figure 9 (b) shows the occurrence of delamination behavior, This issue is more common in the webbing's transverse direction.

Figure 9(c) FRP hybrid GC45 displays fault observations that are comparable to those seen in previous versions. These traits are comparable to those found in prior research [8,11,15]. Meanwhile, a pull-out condition occurs in the direction of the fiber in the direction of tensile loading, even though the number is less than 5% of the total fiber in the fracture cross section.

IV. CONCLUSION

The mechanical properties of tensile loading for FRP hybrid composite material with glass fiber and carbon fiber reinforcement were tested in this work. The hand lay up approach was used to create this composite. GC35, GC40, and GC45 hybrid FRP are examples of composite hybrid FRP. The test results show a significant change in stress and strain, with the 45 percent hybrid FRP test object having the highest breaking stress value compared to other test objects, but also having a more brittle behavior, and the 40 percent hybrid FRP test object having nearly the same stress as the hybrid FRP. Although it is only 45 percent, it has a high strain value. Although the strain value is higher, the stress on the 35 percent FRP hybrid test object is lower, and the ductile property is lower. The tensile stress and modulus of elasticity increase as the percentage of carbon fiber in the test object increases. The tensile strain is reduced when the volume of carbon fiber is increased. The mechanical properties of the composite material are greatly influenced by the hybridization of carbon fiber and glass fiber. There is a lot of delamination between the epoxy and fiber in the warp direction and pull-out in the weft direction due to the influence of tensile stress.

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