THE EFFECT OF ABACA FIBER HYBRIDIZATION WITH GLASS FIBER AS REINFORCEMENT ON THE MECHANICAL PROPERTIES OF POLYMER COMPOSITES WITH EPOXY RESIN MATRIX

Scientific Article

To fulfill some requirements in

Achieving a bachelor's degree in Civil Engineering

By:

ARNIE JASMINE JOHAR

F1A019020

DEPARTMENT OF CIVIL ENGINEERING

FACULTY OF ENGINEERING

UNIVERSITY OF MATARAM

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SCIENTIFIC ARTICLE

Final Project

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By:
Arnie Jasmine Johar
F1A019020

Approved by:

1. Supervisor

Dr. Hariyadi, ST., MSc (Eng.) Date : 21/07/2023
NIP. 19731027 199802 1 001

2. Co-Supervisor

Ni Nyoman Kencanawati., ST., MT., PhD. Date : 17/07/2023
NIP. 19760804 200003 2 001

Approved By,
Head of Civil Engineering Department
Faculty Of Engineering
University Of Mataram

Dr. Hariyadi, ST., MSc (Eng.)
NIP. 19731027 199802 1 001

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Arnie Jasmine Johar
F1A019020

Approved by:

1. Examiner 1

Prof. Buan Anshari, ST., MSc (Eng.), PhD. Date: 17/07/2023
NIP. 19710703 199802 1 001

2. Examiner 2

Ir. Suryawan Murtiadi, M.Eng., Ph.D. Date: 17/07/2023
NIP. 19580718 199303 1 001

3. Examiner 3

Dr. Ngudiyono, ST., MT. Date: 17/07/2023
NIP. 19740505 199903 1 003

Approved By,
Dean of Engineering Department
University Of Mataram

Muhamad Syamsu Iqbal, ST., MT., Ph.D.
NIP. 19720222 199903 1 002

THE EFFECT OF ABACA FIBER HYBRIDIZATION WITH GLASS FIBER AS REINFORCEMENT ON THE MECHANICAL PROPERTIES OF POLYMER COMPOSITES WITH EPOXY RESIN MATRIX

Arnie Jasmine Johar[1], Hariyadi[2], Ni Nyoman Kencanawati[2]

[1]Civil Engineering Major Student, University of Mataram

[2] Civil Engineering Lecturer, University of Mataram

Email: arnie.jasmine1@gmail.com

ABSTRACT

The use of natural fibers as construction materials has been made possible by people's growing awareness of environmentally friendly building materials. Natural fibers are currently used extensively for a variety of uses, such as sills, roof coverings, floor slabs, bio composite reinforcement, fiber composite board materials (*fiberboard*), even pre-cast lightweight bridge components. The mechanical properties of the materials used in civil engineering must adhere to very strict standards. In terms of mechanical properties, switching from natural to synthetic fibers can be a solution, but the resulting products are less eco-friendly. Combining natural and synthetic fibers in a specific ratio, or fiber hybridization, as a composite reinforcement, is one of the options produce a composite that has great mechanical properties while also falling in the category of eco-friendly. In this study the fibers used for hybridization are abaca fiber and fiberglass and the resin used is epoxy with the base ratio of 30% fiber and 70% epoxy resin. The ratios of fiberglass for each type of samples are 0%, 5%, 10%, 15%, and 20%. The results show that there’s a significant increase in mechanical properties when fiberglass are added. According to the tensile test results, the sample that has the best tensile stress (41.162 MPa) and tensile elastic modulus (2336.586 MPa) is TM-4 (20% fiberglass ; 10% abaca fiber) and the flexural test results show that the sample with the highest flexural stress (120.407 MPa) is FM-4.

Keywords: abaca composite, hybrid composite, tensile test, flexural test.

INTRODUCTION

The use of natural fibers as construction materials has been made possible by people's growing awareness of environmentally friendly building materials. Natural fibers are currently used extensively for a variety of uses, such as the construction of banknotes, high-quality fabrics, bio composite reinforcement, and fiber board. Natural fibers provide a number of benefits, quick to decay, environmentally benign, lightweight, non-abrasive, and non-toxic. However, natural fibers also have drawbacks, such as higher absorption, less dimensional stability, less rigid, and a tendency to break more easily, as well as worse mechanical qualities when compared to synthetic fibers.

While the properties and durability of the materials used in civil engineering must adhere to very strict standards. In terms of properties and durability, switching from natural to synthetic fibers can be a solution, but the resulting products are less eco-friendly. Combining natural and synthetic fibers in a specific ratio, or fiber hybridization, as a composite reinforcement, is one of the options put out and researched by earlier researchers. Hybrid fiber composite is the name given to the finished product. Fiber hybridization can take many different forms and models, and it might involve combining natural fibers with synthetic fibers or vice versa.

Abaca fiber were used in this study because according to earlier studies, when compared to other natural fibers like jute, kenaf, sisal, and others, abaca fiber has the advantages of being stronger, longer, more durable, flexible, moisture resistant, and water resistant even salt water. The most popular synthetic fiber is glass fiber, which is used for many purposes, notably in civil engineering and it was used in this study.

As a result, through this Final Project, study on the topic of **"Effect of hybridization of abaca fiber and glass fiber as reinforcement on the mechanical properties of polymer composites with epoxy resin matrixes"** was conducted.

According to the information provided in the introduction section, this study primarily concentrate on three purposes:

1) How does the hybridization of glass and abaca fiber as reinforcement affect the mechanical characteristics of polymer composites with epoxy matrix?
2) What is the compositional ratio of glass and abaca fiber, which significantly affects the mechanical characteristics of the final composite?
3) Based on statistical study, can the hybridization of glass and abaca fibers as reinforcement considerably enhance the properties of the composite?

METHODOLOGY

The hand lay-up technique was used to produce the samples in this study. whereas, the hand lay-up is an open molding technique that can be used to create a wide range of composite products, from small in size to extremely large. Epoxy resin was utilized as the resin, while abaca fiber was used for the natural fiber and fiberglass for the synthetic fiber.

Table 1 shows the ratios of abaca fiber, fiberglass, and epoxy resin used in the production of hybrid composites in this study.

Table 1. Recapitulation Of Sample Variation

Treatment	Code	Material			Type Of Testing
		Epoxy	Abaca	Fiberglass	
Control	CTR-T	70%	30%	0%	Tensile Testing
Modification-1	TM-1		25%	5%	
Modification-2	TM-2		20%	10%	
Modification-3	TM-3		15%	15%	
Modification-4	TM-4		10%	20%	
Sample Amount					15
Control	CTR-F	70%	30%	0%	Flexural Testing
Modification-1	FM-1		25%	5%	
Modification-2	FM-2		20%	10%	
Modification-3	FM-3		15%	15%	
Modification-4	FM-4		10%	20%	
Sample Amount					15
Sample Amount Overall					30

The ASTM standard is used when testing the mechanical qualities of the hybrid composite. For the tensile test ASTM D-3039 was used and for the flexural test ASTM D-790 was the standard. And for the statistical studies, the Minitab application was utilized.

RESULT AND DISCUSSION

- **Tensile Strength (Effect In General)**

The Tensile strength testing of the hybrid fiber composite aims to figure out if hybridization of the fibers in the composites would increase the tensile strength of natural fiber composites. Figure 1 shows the result of the tensile test for the CTR-T (0% fiberglass) and the TM-3 (15% fiberglass) sample.

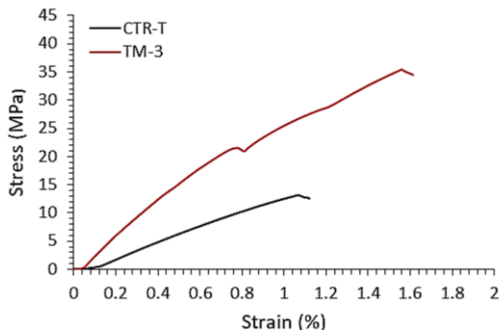

Figure 1. Stress-strain graph of CTR-T and TM-3 (Tensile test)

As it can be seen from figure 1, both sample are considered brittle because both has strain value below 5% however, if we compare the two samples the TM-3 (1.559%) sample is more ductail compared to the CTR-T (1.066%) sample because it has a higher strain. For the tensile stress TM-3 is higher than CTR-T at 35.423 MPa while CTR-T is only 13.170 MPa. The difference in the maximum tensile stress is 91.59%.

- **Flexural Strength (Effect in General)**

Flexure (Bend) tests are generally used to determine the flexural modulus or flexural strength of a material. The flexural strength test seeks to determine the maximum flexural stress value of the composite in order to see the effect of composite hybridization.

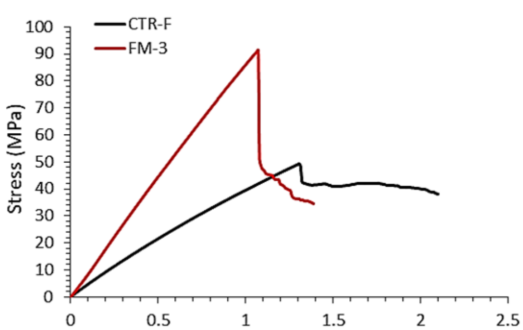

Figure 2. Stress-strain graph of CTR-F and FM-3 (Flexural test)

As observed from figure 2, the flexural stress for CTR-F is lower than FM-3 at 49,332 MPa while the flexural stress for FM-3 is 90,995 MPa. The flexural stress value of FM-3 is 59.3799% higher than CTR-F. The values for both samples are less than 5% which indicates the samples are considered brittle. The strain value of the FM-3 sample is only 0.903%, while the CTR-F is 1.307%.

- **Tensile Strength (Effect of Fiber Proportion)**

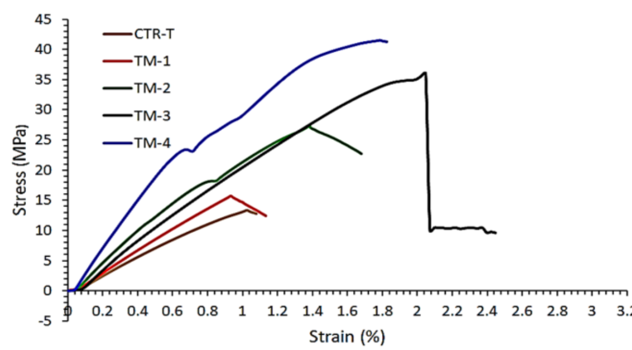

Figure 3. Stress-Strain Graph of Tensile Sample

Figure 3 shows the average strain values of CTR-T, TM-1, TM-2, TM-3 and TM-4 specimens of 1.061%, 1.070%, 1.879%, 1.893% and 1.803%, respectively. The CTR-T specimen is the most fragile of the five specimens, with an average strain value of 1.061%, while the TM-3 specimen is the most ductile of the four, with an average strain average value of 1.893%. The five specimens showed an average strain value of less than 5%. This indicates that the composite is a brittle material.

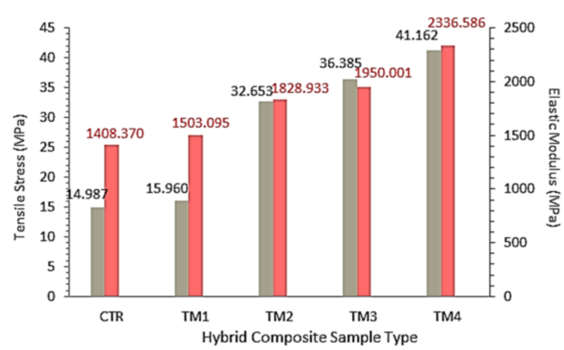

Figure 4. Bar Chart of Tensile Samples

From the graph in figure 4 it is indicated that the tensile stress and elastic modulus of the samples increases parallel to the amount of fiberglass present. CTR-T which is a sample that contains 0% fiberglass has the stress amount of 14.987 MPa while TM-4 which is a sample that has the highest fiberglass present (20%) has the stress amount of 41.162 MPa. These numbers shows that the stress from TM-4 is significantly higher than CTR-T by 93.2341% which means that there is an improvement in the tensile stress by adding fiberglass. TM-1 (25% abaca fiber, 5% fiberglass) has the stress amount of 15.960 MPa, this is 6.28817% higher than CTR-T (14.987 MPa). TM-2 (20% abaca fiber and 10% fiberglass) has the stress amount of 32.653 MPa, this is 74.1646% greater than CTR-T. TM-3 (15% abaca fiber, 15% fiberglass), has the stress amount of 36.385 MPa and this is 83.3061% higher from the CTR-T sample that has 0% fiberglass.

Similar to how the tensile stress increases the more fiberglass present, the elastic modulus also follows a similar pattern. The bar chart in figure 4 also shows that the difference between TM-4's elastic modulus of 2336.586 MPa and CTR-T's elastic modulus of 1408.370 MPa is 49.57%. The elastic modulus of TM-1, which is 1503.095 MPa, is 6.51% higher than that of CTR-T, which is only 1408.370 MPa. Elastic modulus for TM-2 is 1828.933 MPa. Compared to CTR-T (1408.370 MPa), this is 25.98% bigger. The elastic modulus of TM-3 is 1950.001 MPa, 32.26 % higher than that of CTR-T (1343.818 MPa).

- **Flexural Strength (Effect of Fiber Proportion)**

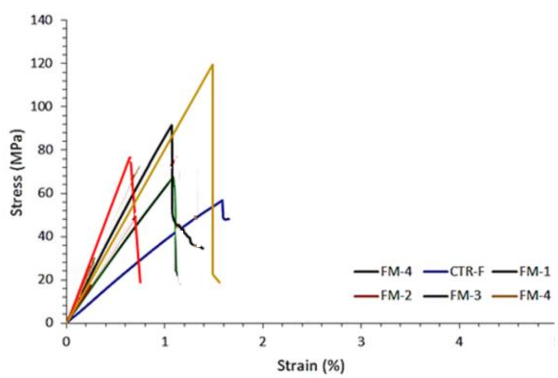

Figure 5. Stress-Strain Graph of Flexural Sample

The average strain values for the CTR-F, FM-1, FM-2, FM-3, and FM-4 specimens are displayed in Figure 5 as 1.447%, 1.031%, 0.923%, 1.290%, and 2.051%, respectively. The sample with the most brittle result was FM-2, with a value of 0.923%, while the sample with the most ductility among the five samples was the FM-4 sample, with a value of 2.051%. Since all samples had values below 5%, they are all considered to exhibit brittle characteristics.

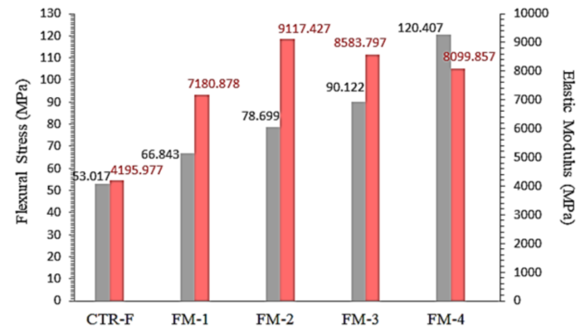

Figure 6. Stress-Strain Graph of Flexural Sample

Based on the graph in figure 6, the samples' flexural stress and elastic modulus rise in correlation to the amount of fiberglass present until the FM-2 sample and then it decreases in FM-3 and FM-4. CTR-F, a sample with 0% fiberglass, has a stress value of 53.017 MPa, while FM-4, a sample with the greatest percentage of fiberglass (20%), has a stress value of 120.407 MPa which is 77.717% higher than CTR-T. The stress amount of FM-1 (25% abaca fiber, 5% fiberglass) is 66.843 MPa, which is 23.0702% larger than the stress amount in CTR-T. The stress amount in FM-2 (20% abaca fiber, 10% fiberglass), is 78.699 MPa, which is larger by 38.996% than the stress amount of CTR-T. The stress amount of the FM-3 (15% abaca fiber, 15% fiberglass) is 90.122 MPa, which is 51.8447% larger than the stress amount of the CTR-T sample, which contains 0% fiberglass.

The FM-4 elastic modulus is 63.499% larger, at 8099.857 MPa, than the CTR-F elastic modulus, which is 4195.977 MPa. Elastic modulus for FM-1 is 7180.878 MPa, which is 52.473% higher than for the CTR-F sample. The elastic modulus of the FM-2 sample is 73.932% higher than that of the CTR-F sample, which is 9117.427 MPa. The modulus of elasticity of FM-3 is 8583.797 MPa, 68.668% higher than that of CTR-F.

- **Analysis of the fiber's proportion's impact on the mechanical characteristics of composites based on the trend line**

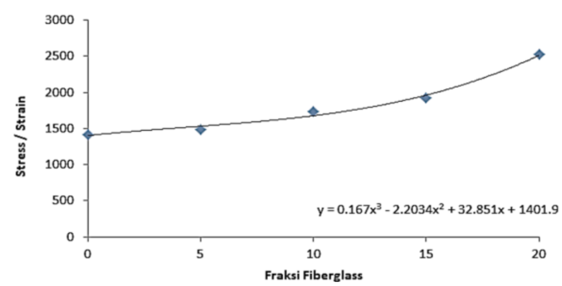

Figure 7. Tensile test trend line

Figure 7 displays the trend line for the tensile test based on the stress divided by strain. From the graph above, the sample that has 20% fiberglass (TM-4) has the best stiffness. Stiffness can be seen by observing the elastic modulus of a material, elastic modulus can be calculated by dividing the stress by strain (illustrated on graph). Stiffness itself is the extent to which an object resists deformation in response to an applied force. So according to the graph above, FM-4 (20% fiberglass) is the best sample in resisting deformation.

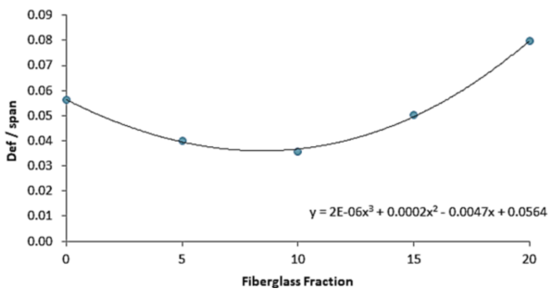

Figure 8. Flexural test trend line

The graph in figure 8 shows the trend line for the flexural test based on the deflection divided by the span. This showed the level of ductail of the material. To find the best proportion in order to produce the most ductail composite, the maximum point needs to be determined first. To do this, the differential of the trend line equation needs to be calculated. The result gave us the best fiberglass proportion of the composite.

The calculation result shows that 8.33% fiberglass, 21.67% abaca fiber, and 70% epoxy resin are the ideal ratios to produce composites that are ductail.

Statistical Analysis

- **The effect of hybridization – a statistical analysis using T-Test**

Two-Sample T-Test : Tensile Stress

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
CTR-T	3	14.99	2.98	1.7
TM	3	36.38	1.18	0.68

Estimation for Difference

Difference	Pooled StDev	95% CI for Difference
-21.40	2.27	(-26.54, -16.26)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-11.57	4	0.000

Two-Sample T-Test : Flexural Stress

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
CTR-F	2	53.02	5.21	3.7
FM	3	90.12	1.94	1.1

Estimation for Difference

Difference	Pooled StDev	95% CI for Difference
-21.40	2.27	(-26.54, -16.26)

Test

Null hypothesis $H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis $H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
-11.95	3	0.001

Figure 9. The T-test result provided by Minitab software for the Tensile and Flexural Stress

t-test table

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	0.50	0.25	0.20	0.15	0.10	0.05	0.025	0.01	0.005	0.001	0.0005
two-tails	1.00	0.50	0.40	0.30	0.20	0.10	0.05	0.02	0.01	0.002	0.001
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	[illegible]	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	[illegible]	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	[illegible]	3.747	4.604	7.173	8.610
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.000	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.000	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.000	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.000	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.000	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	3.733	4.073

t-test table

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	0.50	0.25	0.20	0.15	0.10	0.05	0.025	0.01	0.005	0.001	0.0005
two-tails	1.00	0.50	0.40	0.30	0.20	0.10	0.05	0.02	0.01	0.002	0.001
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	[illegible]	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	[illegible]	4.541	5.841	10.215	12.924
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.000	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.000	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.000	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.000	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.000	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	3.733	4.073

Figure 10. The value of T-tabel based on T-Statistic distribution

The result of T-test analysis for both tensile and flexural stress is presented in Figure 9. The result script form the Minitab15 software gives some important information. The most important information for statistical inference is the T-value and P-value. As it can be seen from the figure, the T-value of the test is -11.57 for tensile stress and -11.95 for the flexural stress. While the P-value analysis for tensile stress is 0.000 and for the flexural test is 0,001. It is important to mention that the value of T-test is an absolute value which means that the value is a non-negative value without regard to its sign. As the T-value, for both tensile stress (11,57) and flexural stress (11.95) exceeds the T-table value which is 2,571 for the tensile stress and 2.776 for the flexural stress, so the null hypothesis should be rejected, implying that the tensile and flexural stresses of a composite reinforced with hybridized fiber are significantly higher than those of a composite reinforced with solely abaca fiber.

- **The effect of hybridisation – a statistical analysis using T-Test**

One-way ANOVA: Tensile Stress

Factor Information

Factor	Levels	Values
Factor	5	CTR-T, TM-1, TM-2, TM-3, TM-4

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	4	1675.9	418.98	34.22	0.000
Error	10	122.4	12.24		
Total	14	1798.4			

One-way ANOVA: Flexural Stress

Factor Information

Factor	Levels	Values
Factor	5	CTR-T, TM-1, TM-2, TM-3, TM-4

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	4	6975.92	1743.98	270.11	0.000
Error	9	58.11	6.46		
Total	13	7034.03			

Figure 11. The F-test result provided by Minitab software

F-table of Critical Values of α = 0.05 for F(df1, df2)

	DF1=1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	∞
DF2=1	161.45	199.50	215.71	[illegible]	230.16	233.99	236.77	238.88	240.54	241.88	243.91	245.95	248.01	249.05	250.10	251.14	252.20	253.25	254.31
2	18.51	19.00	19.16	[illegible]	19.30	19.33	19.35	19.37	19.38	19.40	19.41	19.43	19.45	19.45	19.46	19.47	19.48	19.49	19.50
3	10.13	9.55	9.28	[illegible]	9.01	8.94	8.89	8.85	8.81	8.79	8.74	8.70	8.66	8.64	8.62	8.59	8.57	8.55	8.53
4	7.71	6.94	6.59	[illegible]	6.26	6.16	6.09	6.04	6.00	5.96	5.91	5.86	5.80	5.77	5.75	5.72	5.69	5.66	5.63
5	6.61	5.79	5.41	[illegible]	5.05	4.95	4.88	4.82	4.77	4.74	4.68	4.62	4.56	4.53	4.50	4.46	4.43	4.40	4.37
6	5.99	5.14	4.76	[illegible]	4.39	4.28	4.21	4.15	4.10	4.06	4.00	3.94	3.87	3.84	3.81	3.77	3.74	3.70	3.67
7	5.59	4.74	4.35	[illegible]	3.97	3.87	3.79	3.73	3.68	3.64	3.57	3.51	3.44	3.41	3.38	3.34	3.30	3.27	3.23
8	5.32	4.46	4.07	[illegible]	3.69	3.58	3.50	3.44	3.39	3.35	3.28	3.22	3.15	3.12	3.08	3.04	3.01	2.97	2.93
9	5.12	4.26	3.86	[illegible]	3.48	3.37	3.29	3.23	3.18	3.14	3.07	3.01	2.94	2.90	2.86	2.83	2.79	2.75	2.71
10	[illegible]	[illegible]	[illegible]	3.48	3.33	3.22	3.14	3.07	3.02	2.98	2.91	2.85	2.77	2.74	2.70	2.66	2.62	2.58	2.54
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90	2.85	2.79	2.72	2.65	2.61	2.57	2.53	2.49	2.45	2.40
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80	2.75	2.69	2.62	2.54	2.51	2.47	2.43	2.38	2.34	2.30
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71	2.67	2.60	2.53	2.46	2.42	2.38	2.34	2.30	2.25	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65	2.60	2.53	2.46	2.39	2.35	2.31	2.27	2.22	2.18	2.13
15	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54	2.48	2.40	2.33	2.29	2.25	2.20	2.16	2.11	2.07

F-table of Critical Values of α = 0.05 for F(df1, df2)

	DF1=1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	∞
DF2=1	161.45	199.50	215.71	[illegible]	230.16	233.99	236.77	238.88	240.54	241.88	243.91	245.95	248.01	249.05	250.10	251.14	252.20	253.25	254.31
2	18.51	19.00	19.16	[illegible]	19.30	19.33	19.35	19.37	19.38	19.40	19.41	19.43	19.45	19.45	19.46	19.47	19.48	19.49	19.50
3	10.13	9.55	9.28	[illegible]	9.01	8.94	8.89	8.85	8.81	8.79	8.74	8.70	8.66	8.64	8.62	8.59	8.57	8.55	8.53
4	7.71	6.94	6.59	[illegible]	6.26	6.16	6.09	6.04	6.00	5.96	5.91	5.86	5.80	5.77	5.75	5.72	5.69	5.66	5.63
5	6.61	5.79	5.41	[illegible]	5.05	4.95	4.88	4.82	4.77	4.74	4.68	4.62	4.56	4.53	4.50	4.46	4.43	4.40	4.37
6	5.99	5.14	4.76	[illegible]	4.39	4.28	4.21	4.15	4.10	4.06	4.00	3.94	3.87	3.84	3.81	3.77	3.74	3.70	3.67
7	5.59	4.74	4.35	[illegible]	3.97	3.87	3.79	3.73	3.68	3.64	3.57	3.51	3.44	3.41	3.38	3.34	3.30	3.27	3.23
8	5.32	4.46	4.07	[illegible]	3.69	3.58	3.50	3.44	3.39	3.35	3.28	3.22	3.15	3.12	3.08	3.04	3.01	2.97	2.93
9	[illegible]	[illegible]	[illegible]	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.07	3.01	2.94	2.90	2.86	2.83	2.79	2.75	2.71
10	4.96	4.10	3.71	[illegible]	3.33	3.22	3.14	3.07	3.02	2.98	2.91	2.85	2.77	2.74	2.70	2.66	2.62	2.58	2.54
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90	2.85	2.79	2.72	2.65	2.61	2.57	2.53	2.49	2.45	2.40
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80	2.75	2.69	2.62	2.54	2.51	2.47	2.43	2.38	2.34	2.30
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71	2.67	2.60	2.53	2.46	2.42	2.38	2.34	2.30	2.25	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65	2.60	2.53	2.46	2.39	2.35	2.31	2.27	2.22	2.18	2.13
15	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54	2.48	2.40	2.33	2.29	2.25	2.20	2.16	2.11	2.07

Figure 12. The value of T-tabel based on T-Statistic distribution

The findings of the flexural test data analysis provide almost the same indication, as shown in Figure 12, where the F value is bigger than the F-table value. If a significance level of 95% (α = 0.05) is chosen, 5 levels of factors/treatments (a = 5) and 14 samples (N = 15) are used, the table F-distribution shows that $F_{(0.05;4,10)}$ = 3,63. As the value of F_0 = 270.11 > 3,48, H_0 is rejected, indicating that the level is different; that is, the proportion of fiberglass impacts the flexural stress of the composite significantly. The P-value of flexural stress analysis, which is only 0,000, also indicates that the means differ.

CONCLUSION AND RECOMMENDATION

Conclusion

From the testing that was conducted on the hybrid composite reinforced with abaca fiber and fiber glass and epoxy as the matrix in the laboratory, the following was concluded:

1. Effect of fiber hybridization on the mechanical properties of Epoxy composites with glass and abaca fiber as reinforcement.

   From the testing that was conducted in the laboratory, the tensile stress, tensile elastic modulus, flexural stress, flexural elastic modulus of the hybrid composite was obtained. And by plotting the results into graphs and bar chart, we can conclude that incorporating fiberglass in an abaca natural fiber reinforced polymer mixture enhanced its mechanical properties in general. This can be seen from the values of the control sample and the samples that has 15% fiberglass.
2. The best ratio of glass and abaca fiber that significantly affects the mechanical characteristics of the final composite.

   From the tensile test bar chart in figure 4.4 (chapter 4), it can be seen that the sample with the best tensile stress and tensile elastic modulus is TM-4, this indicates that TM-4 is the best material to choose for a better tensile stress and elastic modulus (stiffness). Meanwhile, if we refer back to figure 4.6 (chapter 4) for the flexural test result it can be seen that the sample that has the best flexural stress is FM-4, while the sample with the best flexural elastic modulus is FM-2. So it can be concluded that FM-4 is the best material to choose for the flexural stress and FM-2 should be picked for the flexural elastic modulus.
3. Effect of fiber hybridization on the mechanical properties of epoxy composites with glass and abaca fiber as reinforcement using statistical analytic.

   By using Minitab, the result obtained from the tests can be statistically proven to analyze further the relevance of adding glass fiber to abaca fiber composites. The statistical tests carried out are the T test and F test, and from both tests it can clearly be seen that incorporating fiberglass has a significant impact on the mechanical qualities of the natural fiber.

Recommendation

1. To prevent defects of the composite, precision is necessary throughout the composite manufacturing process.
2. Make sure that the device used to record the test results doesn't run out of battery or shut down throughout the testing procedure using the universal testing machine.
3. In order to obtain a more precise data, additional investigation is conducted by using a smaller increase in the ratio.
4. Similar studies utilizing different fibers can be conducted to see the which fiber is the best in enhancing the mechanical properties of natural composite.
5. Analyze different mechanical properties of the hybrid composite for example, the durability of the composite.
6. Conduct a microscopic analysis in order to see the surface bonding, breaking pattern etc.

REFERENCES

ASTM D-790-10, *Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Materials*, ASTM Internasional.

ASTM D3039/D3039M–00, *Standard test method for tensile properties of polymer matrix composite materials,* ASTM International.

Gere, James M dan Stephen P. Timoshenko. (2002). Mekanika Bahan, Edisi Keempat. Erlangga: Jakarta.

R, Giridharan. (2019). Preparation and property evaluation of glass/ramie fibers reinforced epoxy hybrid composites. Composites Part B.

Rajak, D.K., Wagh, P.H., Linul, E. (2022). A Review on Synthetic Fibers for Polymer Matrix Composites: Properties, Failure Modes and Applications. Materials 2022.

Sanjay, M.R. and Yogesha, B. (2016) Studies on Mechanical Properties of Jute/E-Glass Fiber Reinforced Epoxy Hybrid Composites. Journal of Minerals and Materials Characterization and Engineering, 4, 15-25.