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Experimental Analysis in Mechanical Properties of Natural Hybrid Composite

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Abstract
In the scenario the environment the demands for technologies of the best suitable composite materials has begun instead of Roof steel. Materials having required characteristics along-side remaining non-pollutant are being researched and formulated to be put them in use. With the availability of natural fiber composites which share proportionate properties with that of manmade fibers are added together with a matrix to achieve best and good outputs. The hybrid composite materials are a blend of natural and synthetic fibers which are either in same proportion ratio to have desired properties. This present work deals with the study mechanical properties of basalt fiber mat (Unidirectional) composites having bamboo fibers pulps to whichreinforced with epoxy resin as the matrix. The overall mechanical properties of the composites showed improvement to change the roof material into Hybrid composites**.**

Keywords- bamboo fiber ,basalt fiber

I. INTRODUCTION

The word composite is derived from the word "compositus" which means mixing together. Composite materials refer to combining of two or more materials. They constitute of both matrix material and a reinforcing agent. The matrix usually binds the reinforcement stiffly thus creating a firm bonding With the different reinforcement thus forming a composite material. A composite consists of two or more materials of different nature to achieve a material of required property. The material formed after the combination of two materials Will have much better and sophisticated characteristics than the constituent. Paliwal et.al.[l] Investigated about the composites fabricated from glass fibers With epoxy as a matrix material and calcium carbonate as a particulate filler material which showed overall increase

in their mechanical properties.

The reason is that the particulate fillers increase the loading capacity by increasing the bonding strength between the reinforcement and the matrix material. Potluri et.al. [2] used silicon carbide as a filler material With varying proportions in pineapple leaf fiber composites. The specimen With the higher percentage of silicon carbide showed higher strength, Young's modulus and shear modulus. Nguong et.al.

[3] used silicon carbide as a filler material in natural fiber reinforced polymer composites. The results showed significant wear resistance because of the stronger bonds created With the inclusion of the filler material which behaved as a crack arrestor. Chisholm et.al. [4],In his research the carbon epoxy composites are subjected to testing one Without any filler and the Other With filler. results colin that the infusion of brought about good thermal stability and also a goodamount of strength (mechanical

Over the last years, basalt fibers (BFs) have been proposed for the preparation of structural composites in combination With various polymer matrices such as unsaturated polyester, vinyl ester, epoxy, phenol formaldehyde,polyimide,polysiloxane,polypropylene ,polycarbonate,poly(ethyleneterephthalate), poly(butylene terephthalate), polyamide, starch resin, and polylactic acid [11]. Overall basalt libras show several advantages, which make them a goodalternative to glass fibres as reinforcing material incomposites used in several fields such as marine, automotive, sporting equipment, civil, etc [12]. In particular, basalt fibres have mechanical properties similar to those of glass ones. thermal stability that depend from the composition of the raw material and the presence of a large amount of micropores that prevent convection and thermal radiation of the air are reasons to think to use basalt fibres fabrics in thermal insulation and passive fire protection applications . Basalt libre reinforced polymer (BFRP) is of a low price and has a high strength, resistance to chemical attack, and relatively simple handling at site .However, there are no design guides, recommendations, or standards for BFRP .

II. LITERATURE REVIEW

The type, form, quantity and formation of the constituents determine how the mechanical and physical properties of composite materials Will be. rule of mixtures is set of equations which determine these values. It is noted that the unidirectional ply has two different in-plane tensile moduli (El and E2). [3][6]

Rami Eid (2017) has experimented in six FRPTRP confined reinforced concrete columns under compressive axial loading and analyzed the behaviour of circular, square and rectangular columns. the higher the number of FRP layers, the higher the axial concrete compressive strength and its corresponding strain and this is well documented in the literature of Marijn R. et al., (1999), Laura De Lorenzis et al., (2003), Silvia Rocca et al., (2008). Nadeem A. Siddiqui (2014) has experimented on the effectiveness of hoop and longitudinal Carbon FRP (CFRP) wraps in reducing the lateral deflections and improving the strength of slender circular RC columns and was experimented on a total of 12 small- scale circular RC columns of 150 mm diameter. The results showed that CFRP hoop wraps provide confinement to concrete and lateral support to the longitudinal fibers and thus increase the strength of both short and slender RC columns. However, the effect of hoop wraps on the

strength of columns is more significant for short columns than slender columns.

Marinella Fossetti (2018) In this paper a generalized criterion for the determination of the increase in strength, in ductility, and in dissipated energy for varying corner radius ratios of the cross section and liber volumetric ratios is shown. Numerical results using a finite element analysis, calibrated on the basis of experimental data available in the literature, are carried out to calibrate the new analytical models and results shows that the strength increase does not require definition of the lateral confinement pressure.

Thomas Vincent (2015) experimented on the influence of shrinkage on compressive behaviour of concrete filled FRP of FRP-confined normal- and high-strength concrete (NSC and HSC). A total of 30 aramid FRP (AFRP) confined concrete specimens With circular cross-sections were manufactured. Six of the specimens were instrumented to monitor long term shrinkage strain development of the FRP- confined NSC and HSC, With three specimens allocated to each mix. The remaining 24 specimens were tested under axial compression, where nine of these specimens were manufactured With NSC and the remaining 15 With HSC and results shows that there is a decrease in strength enhancement ratio whereas it leads to a significant increase in strain enhancement ratio and also decrease in the ratio of the ultimate axial strains obtained from mid*section and full-height I-VDTs (MLVDT/ FLVDT) due to a partial or complete loss of bond at the interface between the concrete core and FRP shell.

Manal K_ Zaki (2011) experimented on cylindrical reinforced concrete (RC) columns confined With fiber reinforced polymer (FRP) composites. The
columns studied are under combined axial loads and biaxial bending moments. The fiber method modeling (FMM) together With finite element analysis (FEA) are adopted to investigate the behavior of such columns and results shows that a remarkable increase in the tension zone can be achieved due to the contribution of the longitudinal direction of the FRP in flexural capacity. For columns under uniaxial bending, a remarkable increase in Mu and Fxu are recorded by FRP confining. The increase in column capacity of the FRP confined columns compared to the reference columns increases as the balance point is approached and similar results were from J.L. Pan (2007).

III. BAMBOO FIBER

- Bamboo textile fiber is made from bamboo timber which has matured in the forest for at least 4 years. Even in remote areas of China bamboo forests are highly valued and carefully tended and managed.
- Bamboo fiber is 2 – 3 times stronger than timber. Its tensile strength is stronger than steel. That tensile strength comparison is 28,000 per square inch to 23,000 per square inch.
- Bambo fabric of the highest quality is made with production practices that do not extract

cellulose. Instead, a natural enzyme is used on crushed bamboo wood fibers, and these fibers are then washed and spun into yarn. This yarn usually has a silky texture, and the fabric made by this process is sometimes called bamboo linen..

Bamboo flooring disadvantages:

- Bamboo is a hot product now, With everyone wanting to cash in on this great money maker. .
- Another big disadvantage (also related to poor treatment processes) is the release of volatile organic compounds (VOCs) which can cause headaches and allergies in susceptible individuals.

Sample No	Length (m)	Cross-sectional Area (cm^2)	Volume (m^3)	Weight (kg)	Unit Wt (kg/m^3)	Average (kg/m^3)
Bamboo-1	0.51	2.34	0.00011934	0.089	746	
Bamboo-2	0.52	2.55	0.0001326	0.095	716	812
Bamboo-3	0.51	2.16	0.00011016	0.087	790	
Bamboo-4	0.54	1.80	0.0000972	0.097	998	
Steel-1	0.53	0.785	0.000041605	0.31	7451	
Steel -2	0.53	0.785	0.000041605	0.33	7932	7872
Steel -3	0.53	0.785	0.000041605	0.32	7691	
Steel -4	0.53	0.785	0.000041605	0.35	8412	

BASALT FIBERS

Basalt fibres are obtained from a naturally occurring complex silica/alumina/other oxide basalt rock similar to glass in composition and used as an asbestos replacement .Basalt fibers can be applied in a Wide range of application areas, i.e. thermal and acoustic insulation, pipelines, beams, fabrics, structural synthetic materials, various car parts, reinforced concrete, insulating synthetic material or friction material to name a few. Continuous basalt fiber has higher modulus of elasticity, better temperature resistance, impact resistance and chemical stability than ordinary glass fiber, so the composite

Fig :Basalt fibers

materials made up by various kinds of resins have ideal physical and chemical properties, and can be made into complex shapes for long-term use in

One such material of interest currently being extensively used is basalt fiber, which is cost-effective and offers exceptional properties over glass fibers. prominent advantages of these composites include high specific mechano-physico-chemical properties, biodegradability, and nonabrasive qualities to name a few. As a result of its characteristics and properties, basalt fiber can be really considered as the material of our future for a green and sustainable

development.

Basalt fiber has been attractive, such as geopolymer concretes, pressurepipes,fibrous insulators, protective

Fig. 4. Basalt fibre and Application

Many building materials can be produced of basalt fiber. Basalt reinforcement for constructions and roads is effective way to achieve excellent results due to high mechanical properties and good chemicalresistance of basalt fiber. Basalt fiber products can beused for:

•Basalt reinforcement in form of mesh and scrim.

•Geogrid mesh for road reinforcement.

•Basalt rebars and pultruded profiles.

•Basalt fiber reinforced concrete. Basalt fibers are mainly produced for structural and electro-technical purposes and its applications include electromagnetic shielding structures, automobile, aircraft, ship, and household appliance components.

Properties Continuous Basalt

- Density (g/cm3) - 2.63 - 2.8
- Tensile Strength (MPa) - 4100 - 4840
- Elastic Modulus (GPa) - 93.1 - 110
- Elongation at break - 3. I
- Tensile strength of the roving 6-13g is0.6N/Tex
- Elastic modulus is 91GPa
- Elongation at break is 3.1%
- High temperature and light resistance.

It is an inorganic fiber which can be used as aballistics and protection material. It has an explosiveprevention function which when used with ballisticmaterials is useful when there is an explosive blast. Basalt fiber unidirectional fabric is high performanceengineering material with fibers of the fabricproduced by GBF which are coated with sizescomparable with polyester, epoxy, phenolic andnylon resins.

Basalt fiber belongs to the silicate home and has the same thermal expansion coefficient, which makes it the best alternative to carbon fiber applied in the bridge, construction reinforment and repair. Its BDRP & CFRP has outstanding comprehensive property and cost effectiveness.

Features:

- High strength and high modulus fiber.
- Excellent shock resistance - good for ballisticapplications.

- Low cost alternative and can replace carbon fiber in some applications including filament winding.
- High temperature resistance and good light resistance.
- Good fatigue and corrosion resistanceproperties.
- Environment friendly. Basalt-reinforced composites can meet OEM's disposal requirements because complete disposal by incineration is possible. Huge contamination issues are often caused by incinerating glassfiber composites. Can be recycled.
- Exhibit no health and safety risks.
- Compatible with many resins - unsaturated polyester, vinyl ester, epoxy, phenolic, etc.

IV. RAW MATERIAL

Basalt fiber is a continuous fiber made of melting. Stone at 1450 to 1500 degree through platinum rhodium alloy bushing. New Environment protection fiber which is known as the twenty-first Century 'Volcano rock silk', it is also called golden fiber because it's Golden brown.

Fig: Bamboo fiber

Bamboo fiber is made by a mechanical-bacterial process similar to retting flax into linen fibre. In this way, the woody part of the bamboo is crushed mechanically before a natural enzyme retting and washing process is used to break down the walls and extract the fibre. This blast fibre is then spun into yarn.

Fig: Epoxy Resin's

Epoxy resin comes in two parts: a resin and a hardener. Mixing the resin and hardener togetherprompts a chemical reaction between the two, transforming them from a liquid into a solid. Measuring accurately and mixing thoroughly is essential to ensure your epoxy resin cures properly.

V. EXPERIMENTAL PROCEDURE

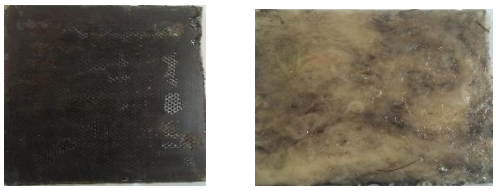


Fig: Fabrication

The 200 mm x 200 mm x 10 mm composite was manufactured using hand-layup method. The resinwas coated with brush and roller and kept between the200 mm x 200 mm pressing plates. A polyester film layer between the plate and the composite surface was provided for easy release and for smooth and uniform surface surfaces on the composites. Araldite LY556 to HY951 hardener in the ratio of (3:1) and mixed well and to different percentages .Alternative Two layers of basalt fabric and bamboo fabric are fabricated with epoxy resin mixed one above the other until the desired thickness is achieved. The composites were then left at room temperature for 24 hours be solidified. Composites were then removed from the mold following the curing process.

Testing of Composite material:

The specimens are derived from the fabricated material and subjected to different mechanical testingprocesses to determine their performance under various loading conditions. The results are then analysed and further the materials are engineered to improve the characteristics so that a better product can be achieved.

A. Tensile test.
B. Flexural test.
C. Shore Hardness test.

VI. TESTING ANALYSIS

Fig: Tensile test

It is one of the most commonly used testing processesto evaluate the mechanical properties of the material. The tests help to evaluate the properties related to elasticity and strength. In a tensile testing process, a specimen is obtained according to a prescribed standard and loaded under uniaxial force applied at two ends until the matrix is fractured. The testing carried out

helps us to determine the elastic deformation and then the plastic deformation. The ductile materials have greater plasticity and have good strength compared to brittle materials whose plasticity is low. The testing process is carried out by constantly and gradually rising the applied load. The change in length of the test piece is noted. Hence a set of collective information is available to calculate the results.

RA(%)	/	UTL(KN)	0.505
UTS(MPa)	4	YL/0.2% PL(KN)	/
YS/0.2% PS(MPa)	/	FL	0.005

SAMPLE ID	1	Type	Flat
Size(mm)	13.59*9.651	Area(mm2)	131.16
IGL(mm)		FGL(mm)	
E(%)	/	FDia(mm)	
RA(%)	/	UTL(KN)	3.314
UTS(MPa)	25	YL/0.2% PL(KN)	/
YS/0.2% PS(MPa)	/	FL	/

Fig: Tensile test observation

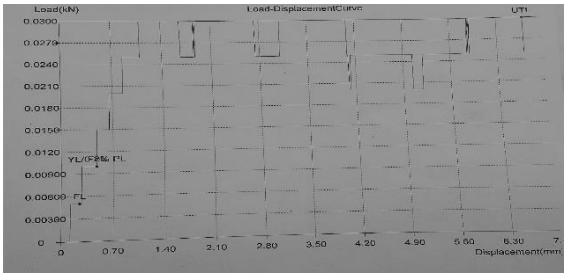


Fig: Tensile test analysis graph

Test Parameter	Observedvalues
Ultimate Tensile Strength (N/mm2 or Mpa)	25.27

Fig: Tensile strength test report

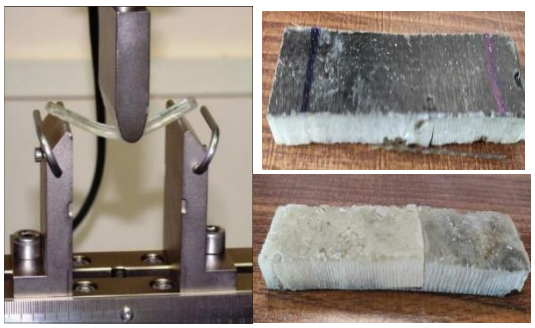


Fig: Flexural test

The specimens used in the testing process are generally rectangular in geometry without any bond or notches. The flexural test helps us to determine thestrength in brittle material because when the same material is gripped and loaded for testing would easily breakdown. Within the elastic range, a linear relation between a load and deflection can be noted. The failure first begins on a thin layer of the surface whichinitiates the cracking process and at-last leads to the specimen break point.

TOCR NO	3370A T1	Test date	2/05/2022

Fig: Flexural test observation

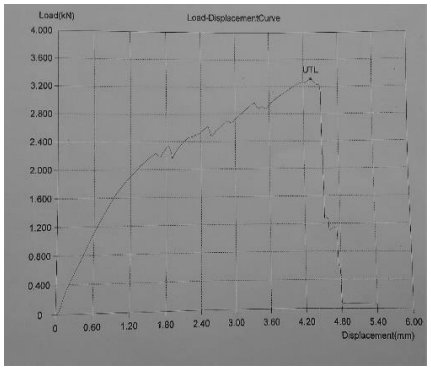


Fig: Flexural test analysis graph

Test Parameters	Observed Value
Flexural Strength(N/mm2 or Mpa)	35.91

Fig: Flexural test report

Fig: Hardness test

Hardness is the mechanical property of the material which helps it to resist the indentation. Hardness is one of the important parameters in the designing of a material. The process of measuring the hardness is by measuring the depth of the indentation mark left on the material when a load of known pressure is applied on it. Hardness is a typical property of a material. Hardness is defined as the resistance to indentation, and it is determined by measuring the permanent depth of the indentation caused on the surface of the test material. The least RHN is for the combination of (Basalt + bamboo) i.e. 70. And when E-glass fiber is present along with the combination of (Basalt + bamboo) the RHN is 72 which signifies the strength imparted by the E- glass fiber to the Composite. From the above results the significance of adding (SiC) in the composite matrix can be seen. This is mainly due to the good bonding with the reinforcement and the epoxy which transmit the entire load to the strong and rigid fibers. In this work we used bamboo fiber, basalt fiber, Epoxy resin Based on observations, it was concluded that the superior mechanical properties of the hybrid- based composite depend strongly upon the position of the reinforcing fiber. Fiber-reinforced polymers (FRPs) offer several attractive features for various engineering sectors, including high performance, light weight, and reduced life cycle costs. Overall basalt fibres show several advantages, which make them a good alternative to glass fibres as reinforcing material in composites used in several fields such as marine, automotive, sporting equipment, civil, etc. In particular, basalt fibres have mechanical properties similar to those of glass ones. The thermal stability that depend from the composition of the raw material and the presence of a large amount of micro-pores that prevent convection and thermal radiation of the air. The composite specimens were subjected to various loads and computer controlled Universal Testing Machine (UTM). The specimens were clamped and tests were performed. The tests were closely monitored and conducted at room temperature. The load at which the completed fracture of the specimen occurred has been accepted as breakage load.

VII. OBSERVATION

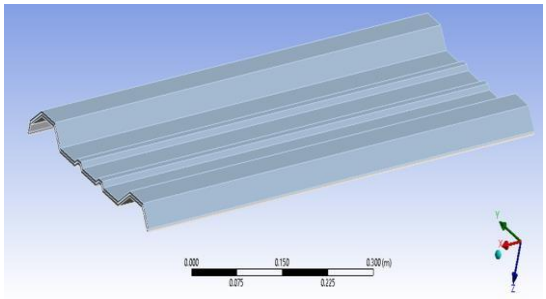
TESTING PARAMETERS	OBSERVED VALUES
Ultimate Tensile Strength(N/mm2)	25.27
Flexural Strength(N/mm2)	35.91
Shore Hardness "D"	83.00

Fig Result

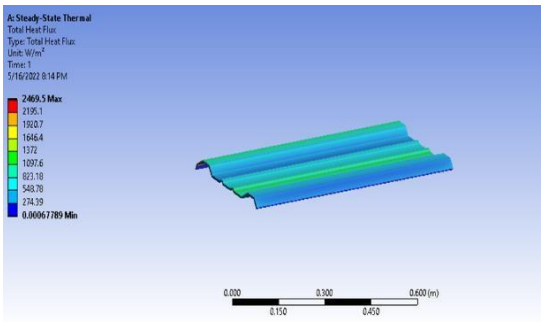
Test Parameter	Observed value
Shore Hardness 'D'	83.00

CREO Design:

- Top layer = Zinc/Bamboo(3mm)
- Bottom layer = Steel/ Basalt (3mm)

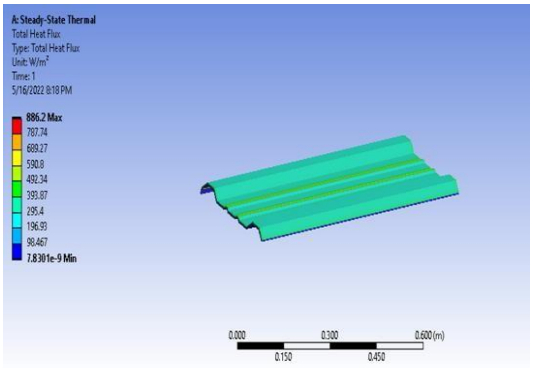


Steel and Zinc Roof Result:



Temperature	Heat Flux
Minimum	0.00067789 W/m2
Maximum	2469.5 W/m2
Average	490.49 W/m2

Basalt and bamboo Roof Result:



Temperature	Heat Flux
Minimum	7.8301e-009W/m2
Maximum	886.2 W/m2
Average	175.59W/m2

Final Result:

Parameter	**Steel & Zinc**	**Basalt & Bamboo**
Total Heat Flux	**2469**	**886**

XI. CONCLUSIONS

The natural hybrid composites consisting of (bamboo fiber, basalt fiber) are fabricated using epoxy resin as the matrix system as the particulate filler with the traditional hand lay-up process. The concentration of silicon carbide is varied in each of the fabricated composites and the mechanical properties such as tensile, flexural, impact, hardness and density are determined experimentally. The orientation of the fibers during fabrication is maintained at 0º throughout the process. The results states that the particulate filled hybrid composite materials have greater mechanical properties when compared with composite materials without particulate reinforcements. When tensile tests were carried out hybrid composites showed the highest ultimate tensile stress than the other composite materials. From the results obtained it can be concluded that the particulate filled composite matrix have a good potential with overall improved properties.

That is due to the fact that the bonds when formed between particles and reinforcements are much stronger than that of the bonds formed between particles themselves i.e. The particle and reinforcement interaction is stronger than that of the particle-particle interaction, which happens when more amount of particles are present in the matrix. Thus particulate reinforced composites have good overall mechanical properties and improved performance which would cater the needs of the modern industry. The cost of manufacturing can be effective when manufactured in bulk quantities thus making it one of the better choices to be used for

enhanced and stabilized performance.

REFERENCE

1. Rozilah, C. N. A. Jaafar, S. M. Sapuan, I. Zainol, and R. A. Ilyas, "The Effects of Silver Nanoparticles Compositions on the Mechanical, Physiochemical, Antibacterial, and Morphology Properties of Sugar Palm Starch Bio composites for Antibacterial Coating," Polymers (Basel)., vol. 12, no. 11,p. 2605, Nov. 2020, doi: 10.3390/polym12112605.
2. N. M. Nurazzi, A. Khalina, S. M. Sapuan, and R. A. Ilyas, "Mechanical properties of sugar palm yarn / woven glass fiber reinforced unsaturated polyester composites : effect of fiber loadings and alkaline treatment," Polimery, vol. 64, no. 10, pp. 12–22 2019, doi: 10.14314/polimery.2019.10.3.
3. F. A. Sabaruddin et al., "The Effects of Unbleached and Bleached Nanocellulose on the Thermal and Flammability of Polypropylene-Reinforced Kenaf Core Hybrid Polymer Bio nanocomposites," Polymers (Basel)., vol. 13, no. 1, p. 116, Dec. 2020, doi: 10.3390/polym13010116.
4. R. S. Ayu et al., "Characterization Study of Empty Fruit Bunch (EFB) Fibers Reinforcement in Poly(Butylene) Succinate(PBS)/Starch/Glycerol Composite Sheet," Polymers (Basel)., vol. 12, no. 7, p. 1571, Jul. 2020, doi: 10.3390/polym12071571.
5. H. A. Aisyah et al., "Thermal Properties of Woven Kenaf/Carbon Fibre-Reinforced Epoxy Hybrid Composite Panels," Int. J. Polym. Sci., vol. 2019, pp. 1–8, Dec. 2019, doi: 10.1155/2019/5258621.
6. T. S. M. Kumar et al., "Characterization, Thermal and Antimicrobial Properties of Hybrid Cellulose Nanocomposite Films with in-Situ Generated Copper Nanoparticles in Tamarindus indica Nut Powder," J. Polym. Environ., pp. 1–10, Oct. 2020, doi: 10.1007/s10924-020-01939-w.
7. N. M. Z. N. Baihaqi, A. Khalina, N. M. Nurazzi, H. A. Aisyah, S. M. Sapuan, and R. Ilyas, "Effect of fiber content and their hybridization on bending and torsional strength of hybrid epoxy composites reinforced with carbon and sugar palm fibers," Polimery, vol. 66, no. 1, pp. 36–43, 2021. N. M. Nurazzi, A. Khalina, S. M. Sapuan, R.
8. Ilyas, S. A. Rafiqah, and Z. M. Hana fee, "Thermal properties of treated sugar palm yarn/glass fiber reinforced unsaturated polyester hybrid composites," J. Mater. Res. Technol., vol. 9, no. 2, pp. 1606–1618, 2020, doi: 10.1016/j.jmrt.2019.11.086.

A. Atiqah, M. Jawaid, S. M. Sapuan, M. R. Ishak, M. N. M. Ansari, and R. A. Ilyas, "Physical and thermal properties of treated sugar palm/glass fibre reinforced thermoplastic polyurethane hybrid composites," J. Mater. Res. Technol., vol. 8, no. 5, pp. 3726–3732, Sep. 2019, doi: 10.1016/j.jmrt.2019.06.032.

9. M. R. M. Asyraf, M. R. Ishak, S. M. Sapuan, N. Yidris, and R. A. Ilyas, "Woods and composites cantilever beam: A comprehensive review of experimental and numerical creep methodologies," J. Mater. Res. Technol., vol. 9, no. 3, pp. 6759–6776, May 2020, doi: 10.1016/j.jmrt.2020.01.013.
10. V. Dhand, G. Mittal, K. Y. Rhee, S. J. Park, and D. Hui, "A short review on basalt fiber reinforced polymer composites," Compos. Part B Eng., vol. 73, no. November 2017, pp. 166–180, 2015, doi: 10.1016/j.compositesb.2014.12.011.

11. R. A. Ilyas and S. M. Sapuan, “Biopolymers and Bio composites: Chemistry and Technology,” Curr. Anal. Chem., vol. 16, no. 5, pp. 500–503, Jul. 2020, doi: 10.2174/1573411016052006030953 11.
12. R. A. Ilyas and S. M. Sapuan, “The Preparation Methods and Processing of Natural Fibre Bio-polymer Composites,” Curr. Org. Synth., vol. 16, no. 8, pp. 1068– 1070, 2020, doi: 10.2174/1570179416082001201056 16. A. B. Omran et al., “Micro- and Nanocellulose in Polymer Composite Materials: A Review,” Polymers (Basel)., vol. 13, no. 2, p. 231, Jan. 2021, doi: 10.3390/polym13020231.
13. R. Jumaidin, M. A. A. Khiruddin, Z. Asyul Sutan Saidi, M. S. Salit, and R. A. Ilyas, “Effect of cogon grass fibre on the thermal, mechanical and biodegradation properties of thermoplastic cassava starch bio composite,” Int. J. Biol. Macromol., vol. 146, pp. 746–755, Mar. 2020, doi:10.1016/j.ijbiomac.2019.11.011.
14. Nazrin, S. M. Sapuan, M. Y. M. Zuhri, R. Ilyas, R. Syafiq, and S. F. K. Sherwani, “Nanocellulose Reinforced Thermoplastic Starch (TPS), Polylactic Acid (PLA), and Polybutylene Succinate (PBS) for Food Packaging Applications,” Front. Chem., vol. 8, no. 213, pp. 1–12, Apr. 2020, doi: 10.3389/fchem.2020.00213.
15. Dorigato and A. Pegoretti, “Fatigue resistance of basalt fibers-reinforced laminates,” J. Compos. Mater., vol. 46, no. 15, pp. 1773–1785, 2012, doi: 10.1177/0021998311425620.
16. X. Zhao, X. Wang, Z. Wu, and J. Wu, “Experimental study on effect of resin matrix in basalt fiber reinforced polymercomposites under static and fatigue loading,” Constr. B