

# Characterisation of Flexural Properties of Glass Fibre/Pineapple Leaf Fibre (PALF) Hybrid Composite

Mawarnie Ismail<sup>a,\*</sup>, Marlina Mohamad<sup>a</sup>, Leanna Mohd Yunos<sup>a</sup> and Mohammad Hazim Mohamad Hamdan<sup>b</sup>

<sup>a</sup>Mechanical Engineering Department, Politeknik Mukah, 96400 Mukah, Sarawak, Malaysia

<sup>b</sup>Faculty of Engineering and Computing, First City University College, 47800 Petaling Jaya, Selangor, Malaysia

## Abstract

The use of natural resource materials has gained awareness among industries recently. Today, replacing the material with something more environmentally friendly, especially from waste natural products like pineapple leaf fibre (PALF), is a top concern. This research aims to look at the flexural properties of a glass fibre/pineapple leaf fibre (PALF) hybrid composite. The hand layup and cold compression methods were used to manufacture the hybrid composite plates, which provide 30 wt% of fibre and 70 wt% of the matrix. The form of the hybrid composite was unidirectional with a size of 30 cm 30 cm 3 cm and sandwich stacking. Universal testing equipment was used to conduct the flexural test. With a flexural strength of 290.11 MPa, 5 wt% PALF and 25 wt% bi-directional glass fibre were found to have the maximum flexural strength.

**Keywords:** Pineapple leaf fibre (PALF), hybrid composite, flexural strength, morphology

## 1. Introduction

In recent years, environmental degradation has sparked interest among researchers to study natural source materials such as natural fibres, which due to their characteristic properties, are excellent for recycling, safe for the environment, and inexpensive. Therefore, this powerful catalyst has led research partners to carry out endless studies related to the strengthening of different kinds of fibres in polymer composites for applications in various fields such as clothing, packaging, paper production, car components, building materials, and sports equipment [1-4]. Because of its properties, combining some fibre reinforced has benefited industries such as automotive, civil, and sporting equipment [5].

It is stated that the strength of other materials, as well as greater thermal stability and longevity, can be improved by using a hybrid composite [6]. With the goal of generating alternative materials that address concerns about the low sustainability of conventionally reinforced polymer composites, the use of recycled fillers as reinforcements from renewable sources should be considered [7]. Researchers have previously hybridised glass fibre and natural fibre [8,9]. The incorporation of synthetic and natural fibres highlights the difference between these two fibres, which have increased

---

\* Corresponding author. Tel.: + 084-874001; Fax: + 084-874005  
E-mail address: mawarnie@pmu.edu.my

### Manuscript History:

Received 3 December, 2021, Revised 6 April, 2022, Accepted 21 April, 2022, Published 30 April, 2022

Copyright © 2021 UNIMAS Publisher. This is an open access article under the CC BY-NC-SA 4.0 license.

<https://doi.org/10.33736/jaspe.4602.2022>

tensile, flexural, and impact strengths when combined. However, literature on hybridization between glass fibre and PALF as waste material is still limited for flexural properties.

In this study, the PALF-glass fibre reinforced polymer hybrid composite was investigated with the objective of finding the effect of hybridisation on the flexural properties of a hybrid composite, which at the same time may produce a lightweight composite.

## 2. Literature review

Pineapple leaf fibre (PALF) was used as a natural fibre, and glass fibre as a synthetic fibre. PALF was chosen over flax, jute, OPEFB, cotton, sisal, and oil palm mesocarp fibre because of its favourable aspect ratio, better tensile strength, and modulus of elasticity. Furthermore, the PALF is a waste material that requires optimal utilisation for the development of biomaterials in order to prevent waste disposal in landfills. [10]. The electronic glass (E-Glass) has 2.58 g/cm<sup>3</sup> of density, 3445 MPa for tensile strength and 72.5 GPa for tensile modulus [11]. There are many types of a hybrid composite including natural-natural [5,12], natural-synthetic [8,9] and synthetic-synthetic [13] fibre reinforced polymer. Based on the results, the incorporation of different types of reinforcement in composite materials improved the mechanical properties.

Natural fibre hybrid reinforced composites are relatively strong, lightweight, and free of health hazards, and have the potential to be employed as a material for strong components such as building materials, transport, and automobiles [14]. However, when compared to synthetic fibres like glass fibre, they have several weaknesses, such as poor moisture resistance and low strength. Due to this issue, researchers have overcome this problem with the hybridisation of natural glass fibre reinforced polymer hybrid composites to take advantage of natural fibre's advantages as a cheap and lighter material, which provides better stiffness [15]. Fibre hybridisation was achieved at the macroscopic level via layer-by-layer intermixing although, at the time of mat formation, the hybridization of fibres may have been done in the layer itself. The mechanical properties of produced polymer composites are also influenced by the reinforced mat's structure. [16]. Besides the good mechanical properties, the method used is one of the important elements in the formation of hybrid composites. Rana et al. (2017) investigated the mechanical properties of a sisal/glass fibre hybrid composite and discovered some non-uniformities, such as trapped air or porosity. According to Rana et al. (2017), the sisal/glass fibre hybrid composite with the best mechanical properties contained 4% sisal and two layers of glass fibre. [17]. Filho et al. (2019) investigated the effect of hybridisation on the elongation, maximum deflection, and strength properties of piassava/glass fibre reinforced composites. The experiment's results indicated that the values of elongation, maximum deflection, and strength were decreasing, but the trend on modulus was different [18].

## 3. Methodology

PALF was delivered in long fibres from Acheh, Indonesia. Salju Bistari Sdn. Bhd. provided the synthetic fibre used in this study, which was E-glass bi-directional fibre. The matrix was Epoxy Amite 100, which was obtained from Mecha Solve Engineering Sdn Bhd in Malaysia. PALF long fibres were cut into 15 cm lengths, then ground into 1 to 20 mm lengths using a Mini Plastic Crusher (HLong, China) machine. To characterise the fibre size distribution, the short fibre was sieved using a sieve machine. The majority of the PALF was between 3 and 14 mm in length. PALF was dried in a vacuum oven for 24 hours at 80°C to eliminate the remaining 9.67% moisture content in the fibre, then stored in a vacuum bag to prevent air infiltration. Table 1 summarises the weight distribution of PALF, glass fibre, and epoxy resin. PALF's variable weight distribution was 5 wt %, 10 wt %, 15 wt %, 10 wt %, and 5 wt % throughout the mixture, but the bi-directional glass fibre weight fraction was vice versa from PALF. The letters G and P stood for glass fibre and pineapple leaf fibre, respectively. First, the

bi-directional glass fibre was cut using a mould with dimensions of 260 mm x 192 mm. Short PALF fibres were then evenly scattered on top of one layer of bi-directional glass fibre, followed by another layer of glass fibre. The process was repeated until the task was completed. Before pouring the epoxy resin, the mould was prepared and cleansed with a special wax remover. To avoid a cross-epoxy crossbar, the epoxy and hardener were added in a 3:1 weight ratio and blended for 3 minutes at 200 rpm with a mechanical stirrer. The mixed resin was then stored for 5 minutes to ensure that there were no trapped air bubbles. The slurry was then evenly poured into the mould, followed by a layer of bi-directional glass fibre and more epoxy. After that, glass fibre was added, and finally, epoxy was poured and allowed to cure.

Table 1. Summary of weight distribution PALF, glass fibre and epoxy resin

Specimen	Glass fibre ply	Glass fibre wt%	PALF wt %	Epoxy wt %
G30	6	30	-	70
G25P5	5	25	5	70
G20P10	4	20	10	70
G15P15	3	15	15	70
G10P20	2	10	20	70
G5P25	1	5	25	70
P30	0	-	30	70

The sequence of glass fibre and PALF layering is shown in Figure 1. Based on the assumption that the fabrics have similar qualities in each direction, the warp and weft directions of the cloth were ignored because glass fibre woven mats have balanced plies (0°/90°) [12]. The mould was cured for at least 8 hours after manufacturing using a 60-psi cold press machine. Using a HASS VF 6 (Germany) CNC milling machine, the plates were cut precisely according to the American Society for Testing and Materials (ASTM D790) standard test procedure for plastics for flexural. Figure 2 depicts the PALF-glass fibre hybrid composite's sequence of processes

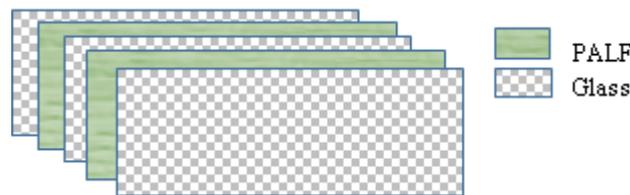


Figure 1. Sequence layering of glass fibre and PALF.

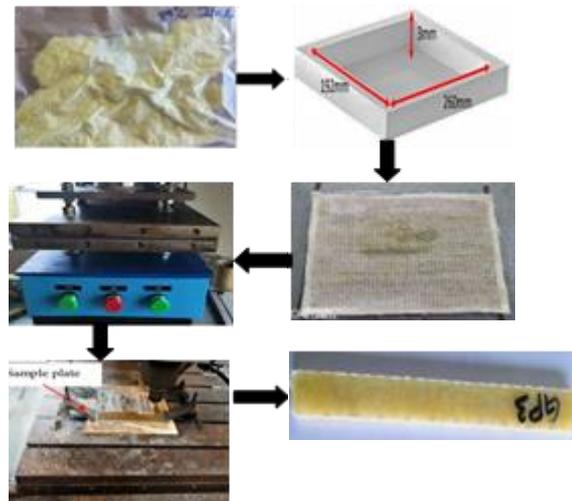


Figure 2. Steps in producing the hybrid composite.

Each plate was cut to flexural test specifications with five specimens for each test. The dimension testing, based on ASTM, had been fixed. The flexural test was carried out according to ASTM D790 [19], with specimens measuring 127 mm in length, 12.7 mm in breadth, and 3 mm in thickness. The tests were carried out using a Universal Testing Machine (Instron Model 3369, Germany) at a loading rate of 2 mm/min at room temperature, with a 62 mm gap between the two noses. The flexural strength and flexural modulus were evaluated using a three-point approach, as shown in Figure 3 (a), by testing five samples of each variant and calculating the average value and standard deviation. Figure 3 (b) shows the fractured samples after testing, with most of the samples failing at the same midpoint.

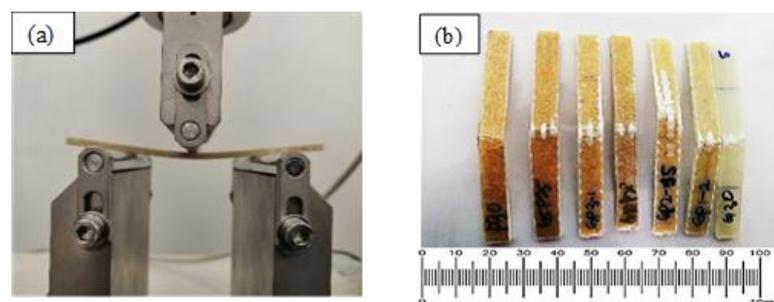


Figure 3. (a) Flexural test setup and (b) Fractured samples after flexural tests.

#### 4. Finding and analysis

Table 2 displays the flexural strength and flexural modulus for different weight fractions of the PALF/glass fibre hybrid composite combination. The flexural strength and modulus are shown in the bar chart in Figure 3. The sample that could bear the highest force to bend was G30, but there was just a small variance (4% difference) with G25P5 as the highest flexural strength PALF glass fibre hybrid composite. The values for G30 and G25P5 were 302.17 MPa and 290.11 MPa, respectively. The lowest flexural strength was P30 (70 MPa), but for hybrid composites it was G25P5 with 166.85

MPa. The difference between both was 50%. The flexural strength increased drastically from P30 to G5P25 compared to G25P5 to G30, which increased slightly. This situation happened because glass fibre has a much higher strength than PALF strength. The trend of the bar chart was a declining slope with an increase in PALF. At the same time, the reduction of glass fibre affected the strength of bending. Meanwhile, for the modulus of flexural, the highest was G10P20 with 16.67 GPa. The lowest sample was P30 (3.77 GPa), but the hybrid composite was G5P25 (6.56). The gap between both was 40%. The flexural result of this PALF glass fibre hybrid composite was similar to the high infection rate even though he used long PALF [3]. Based on the result, the weight of the composite would be affected as the glass fibre increased. By reducing the glass fibre, the weighted composite also reduced its mechanical properties because the PALF characteristics are better than those of other natural waste materials [10].

Table 2. Summary result for flexural

Sample	Flexural strength (MPa)	Flexural modulus (GPa)
G30	302.17±17.5	9.57±0.5
G25P5	290.11±8.5	11.09±0.3
G20P10	255.28±10.6	10.18±0.7
G15P15	237.41±2.6	11.58±0.4
G10P20	189.96±12	16.67±1.2
G5P25	166.85±4.7	6.56±0.3
P30	70.18±2.3	3.77±0.1

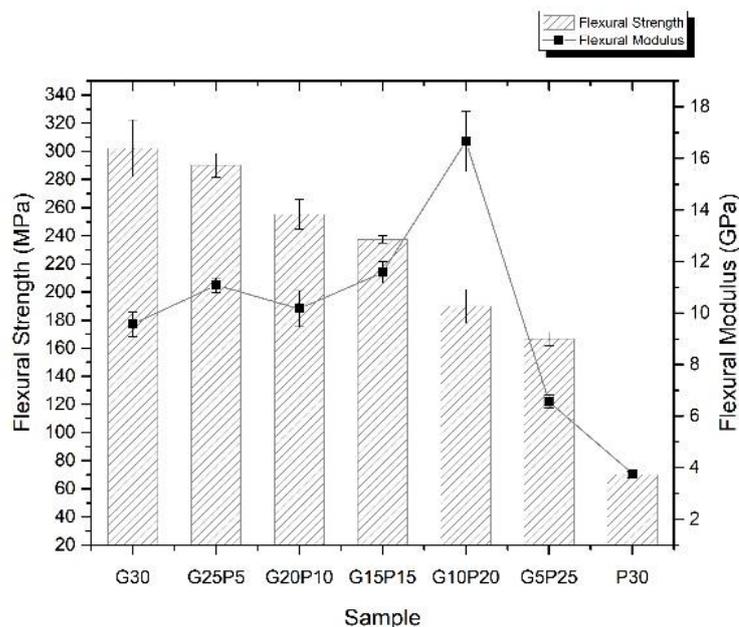


Figure 4. Flexural strength and modulus.

The fracture effect after a flexural test could be observed by scanning the morphology surface using SEM (Figure 5). The glass fibres were fractured without pulling out, but the PALF was pulled out when the PALF increased. Most of the samples had matrix breakage and worsened when PALF was increased. The surface of the fractured area was uneven due to the debris from matrix and fibre when adding PALF. The adhesive interfacial between fibres and matrix became worse when there was increased PALF and reduced glass fibre due to inadequate epoxy to absorb the PALF. As a fact, the PALF is a hydrophilic natural fibre [20].

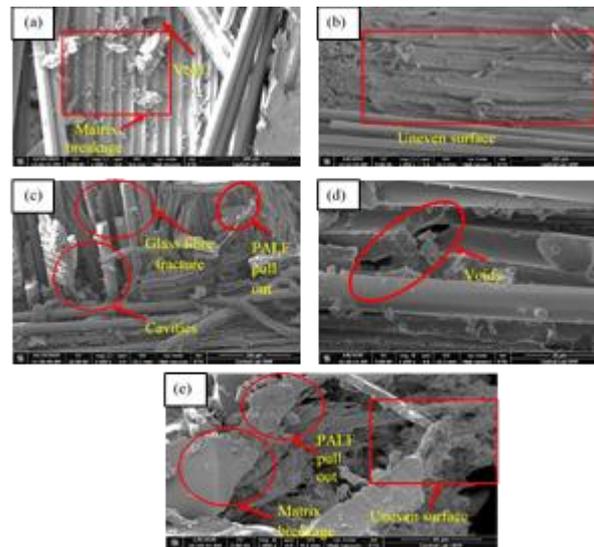


Figure 4. Surface morphology of (a) 5 wt % PALF; (b) 10 wt % PALF; (c) 15 wt % PALF; (d) 20 wt % PALF; (e) 25 wt % PALF.

## 5. Conclusion

PALF has been successfully used to develop natural fibre-glass fibre reinforced polymer hybrid composites. The structure was created using bidirectional glass fibre and short PALF fibres. In the process, hand lay-up and compression moulding were used. The highest flexural strength of PALF hybrid composites was G25P5 but 10% lower than G30. Meanwhile, the highest flexural modulus was G10P20. It may be deduced that raising the number of natural fibres in hybrid composites and decreasing the proportion of glass fibres reduce their strength and weight. The modulus was proved to be independent of the glass fibres and rather dependent on the characteristics of the natural fibre, which imparted stiffness to the hybrid composite. The adhesive interfacial bonding in the internal structure also played a role in having a better composite property. There are some limitations to the results obtained from this study, among which was the bond between the fibre and the epoxy, which did not absorb evenly. This could be seen in the fracturing effect, where there were fibrous epoxy fragments. This PALF glass fibre hybrid composite is a new composite material, making it difficult to obtain comparisons of results with theories or previous studies. Further research on this PALF glass fibre hybrid composite's mechanical qualities such as tensile strength, impact strength, and compression strength should be conducted in the future. Simultaneously, it is necessary to investigate how to optimise the absorption of matrix materials using fibres. With these hybrid composites, it is feasible to create items that are both lightweight and sturdy.

## Acknowledgements

The author would like to thank Jabatan Kejuruteraan Mekanikal, Politeknik Mukah for providing financial, facilities and equipment.

## References

- [1] Siregar, J. P., Jaafar, J., Cionita, T., Jie, C. C., Bachtiar, D., Rejab, M. R. M., & Asmara, Y. P. (2019). The effect of maleic anhydride polyethylene on mechanical properties of pineapple leaf fibre reinforced polylactic acid composites. *International Journal of Precision Engineering and Manufacturing-Green Technology*, 6(1), 101-112. <https://doi.org/10.1007/s40684-019-00018-3>
- [2] Quanjin, M., Rejab, M., Halim, Q., Merzuki, M., & Darus, M. (2020). Experimental investigation of the tensile test using digital image correlation (DIC) method. *Materials Today: Proceedings 2020*. <https://doi.org/10.1016/j.matpr.2019.12.072>
- [3] Quanjin, M., Salim, M., Rejab, M., Bernhardi, O.-E., & Nasution, A.Y. (2019). Quasi-static crushing response of square hybrid carbon/aramid tube for automotive crash box application. *Materials Today: Proceedings 2019*. <https://doi.org/10.1016/j.matpr.2019.10.161>
- [4] Quanjin, M. A., M Sahat, I., Mat Rejab, M. R., Abu Hassan, S., Zhang, B., & Merzuki, M. N. (2019). The energy-absorbing characteristics of filament wound hybrid carbon fiber-reinforced plastic/polylactic acid tubes with different infill pattern structures. *Journal of Reinforced Plastics and Composites*, 38(23-24), 1067-1088. <https://doi.org/10.1177%2F0731684419868018>
- [5] Guna, V., Ilangovan, M., Rather, M. H., Giridharan, B. V., Prajwal, B., Krishna, K. V., ... & Reddy, N. (2020). Groundnut shell/rice husk agro-waste reinforced polypropylene hybrid biocomposites. *Journal of Building engineering*, 27, 100991. doi:<https://doi.org/10.1016/j.jobe.2019.100991>.
- [6] Zin, M. H., Abdan, K., & Norizan, M. N. (2019). The effect of different fiber loading on flexural and thermal properties of banana/pineapple leaf (PALF)/glass hybrid composite. In *Structural health monitoring of biocomposites, fibre-reinforced composites and hybrid composites* (pp. 1-17). Woodhead Publishing. <https://doi.org/10.1016/B978-0-08-102291-7.00001-0>
- [7] Ribeiro Filho, S. L. M., Oliveira, P. R., Panzera, T. H., & Scarpa, F. (2019). Impact of hybrid composites based on rubber tyres particles and sugarcane bagasse fibres. *Composites Part B: Engineering*, 159, 157-164. <https://doi.org/10.1016/j.compositesb.2018.09.054>.
- [8] Ramnath, B. V., Kokan, S. J., Raja, R. N., Sathyanarayanan, R., Elanchezian, C., Prasad, A. R., & Manickavasagam, V. M. (2013). Evaluation of mechanical properties of abaca–jute–glass fibre reinforced epoxy composite. *Materials & Design*, 51, 357-366. <https://doi.org/10.1016/j.matdes.2013.03.102>
- [9] Sanjay, M. R., Arpitha, G. R., & Yogesha, B. (2015). Study on mechanical properties of natural-glass fibre reinforced polymer hybrid composites: A review. *Materials today: proceedings*, 2(4-5), 2959-2967. <https://doi.org/10.1016/j.matpr.2015.07.264>
- [10] Kengkhetkit, N., & Amornsakchai, T. (2012). Utilisation of pineapple leaf waste for plastic reinforcement: 1. A novel extraction method for short pineapple leaf fiber. *Industrial Crops and Products*, 40, 55-61. doi:<https://doi.org/10.1016/j.indcrop.2012.02.037>
- [11] Kulkarni, A. A., Vanakudre, V. M. (2017). Preparation and Analysis of Hybrid Epoxy Composites. *IJESC*, 7.
- [12] Mohamad Hamdan, M. H., Siregar, J. P., Thomas, S., Jacob, M. J., Jaafar, J., & Tezara, C. (2019). Mechanical performance of hybrid woven jute–roselle-reinforced polyester composites. *Polymers and Polymer Composites*, 27(7), 407-418. doi:[10.1177/0967391119847552](https://doi.org/10.1177/0967391119847552).
- [13] Ahmed, M., Kumar, P. V., Shivanand, H. K., & Muzammil, S. B. (2015). A study on flexural strength of hybrid polymer composite materials (e glass fibre-carbon fibre-graphite) on different matrix material by varying its thickness. *Education, 2020*. ISSN 0976 – 6359
- [14] Ismail, M., Rejab, M. R. M., Siregar, J. P., Muhamad, Z., & Quanjin, M. (2019, August). Tensile properties of hybrid woven glass fibre/PALF reinforced polymer composite. In *Proceedings of the international manufacturing engineering conference & The Asia Pacific conference on manufacturing systems* (pp. 448-454). Springer, Singapore. DOI: [10.1007/978-981-15-0950-6\\_68](https://doi.org/10.1007/978-981-15-0950-6_68)
- [15] Kumar, K. K., Karunakar, C., & ChandraMouli, B. (2018). Development and Characterization of Hybrid Fibres Reinforced Composites Based on Glass and Kenaf Fibers. *Materials Today: Proceedings*, 5(6), 14539-14544. <https://doi.org/10.1016/j.matpr.2018.03.043>.

- [16] Manral, A., Ahmad, F., & Chaudhary, V. (2020). Static and dynamic mechanical properties of PLA bio-composite with hybrid reinforcement of flax and jute. *Materials Today: Proceedings*, 25, 577-580. <https://doi.org/10.1016/j.matpr.2019.07.240>.
- [17] Rana, R. S., Rana, S., & Purohit, R. (2017). Characterization of properties of epoxy sisal/glass fiber reinforced hybrid composite. *Materials Today: Proceedings*, 4(4), 5445-5451. <https://doi.org/10.1016/j.matpr.2017.05.056>.
- [18] de Oliveira Filho, G. C., de Sousa Mota, R. C., da Conceicao, A. C. R., Leao, M. A., & de Araujo Filho, O. O. (2019). Effects of hybridization on the mechanical properties of composites reinforced by piassava fibers tissue. *Composites Part B: Engineering*, 162, 73-79. [doi:https://doi.org/10.1016/j.compositesb.2018.10.050](https://doi.org/10.1016/j.compositesb.2018.10.050).
- [19] D790-03, A. (2003). Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials. ASTM International, West Conshohocken, PA.
- [20] Asim, M., Abdan, K., Jawaid, M., Nasir, M., Dashtizadeh, Z., Ishak, M. R., & Hoque, M. E. (2015). A review on pineapple leaves fibre and its composites. *International Journal of Polymer Science*. <https://doi.org/10.1155/2015/950567>