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6th UNDERGRADUATE SEMINAR ON BUILT ENVIRONMENT AND TECHNOLOGY (USBET) 2023

SUSTAINABLE BUILT ENVIRONMENT

25 - 27 SEPTEMBER 2023

E-PROCEEDING

USBET 2023

e-Proceeding

6th UNDERGRADUATE SEMINAR ON BUILT ENVIRONMENT AND TECHNOLOGY (USBET) 2023

SUSTAINABLE BUILT ENVIRONMENT

Published by,
Department Of Built Environment Studies And Technology
Faculty Of Architecture, Planning & Surveying
Universiti Teknologi MARA Perak Branch, Seri Iskandar Campus
usbet.fspuperak@gmail.com

eISSN 2821-3076
9 772821 307002

02 October 2023 | Perak, Malaysia
Universiti Teknologi MARA, Perak Branch, Seri Iskandar Campus

Editors-in-Chief

6th Undergraduate Seminar on Built Environment and Technology 2023

- E- Proceedings-

Organized by,

College of Built Environment (KAB) UiTM Perak Branch

OIL PALM EMPTY FRUIT BUNCH (OPEFB) IN THERMOSETTING POLYMER COMPOSITE

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ABSTRACT

The study of characteristics in natural fibres has intensified in recent decades. However, the application of its use is still not widespread due to the issue of environmental conditions. It affected increasing carbon dioxide (CO_2) emissions, significantly changing climate and weather. This research paper offers an idea that can be commercialised as a more decisive step in introducing natural fibre reinforcement polymer composite (NFRPC) products, especially on the performance of oil palm empty fruit bunch (OPEFB) into the Construction Industry market. The selection of methods in forming innovative products for this structural material is also essential to guarantee the condition of the more robust product. It is able to compete with the current market that is leading the industry. This is the reason for the future shift in the use of products or construction methods to ensure the sustainability of construction while simultaneously offering environmental conservation. This paper is prepared through a qualitative study, which wants explicitly to collect data with the proof of the study through laboratory experiments. This leads to the acquisition of performance data according to the purpose and objective of the study in fulfilling the desire to commercialise this innovation idea. The results of the study also lead to unique innovations contained in the study, allowing potential users to have confidence in evaluating and thus moving forward to the development of this product.

Keywords: *Natural fibre, Polymer composite, Construction industry, Environmental conditions, Performance data.*

INTRODUCTION

The Construction Industry is moving towards becoming green and sustainable. The current conventional wet construction widely practised worldwide depends on using sand, cement, steel, and water. The level of carbon emissions to the surface of the atmosphere nowadays is at a very alarming level. The problem involves thinning the ozone layer, which can add ultraviolet radiation to the earth's surface. The use of conventional techniques for construction is a traditional method with many areas for improvement in every aspect that affects the construction and delays productivity and efficiency at the work site. These can arise due to negligence and liability in handling contractors and labour. From that aspect, bio-composite use in building structures and components is needed in the Construction Industry and is constantly growing. It increases material cost savings by using natural fibres and benefits the strength of the structure.

In addition, most climate change scenarios predict annual temperature increases of 1.8 to 4.0°C within an average of 3.0°C in Malaysia (Rahman, 2018). It follows excessive carbon emissions out of control and the negligence of some who ignore the limits imposed on manufacturing processes related to carbon emissions. Human activity has contributed to climate change by creating CO2 and other heat-trapping gases since 1750. Finally, the Construction Industry uses many non-renewable resources and generates much waste, and construction activities account for half of all carbon emissions. It is worse when the built environment, specifically the Construction Industry, emits 40% of the world's carbon, the main contributor to carbon emissions into the atmosphere (Lu *et al.*, 2016). This study focused specifically on existing products from Tasblock (M) Sdn. Bhd. Products from this tasblock material focus on building and infrastructure components such as a wall, beams, slabs, planks, bollards, manhole cover, benches, and boards. This study uses the empty fruit bunch from oil palm wastes to get the properties that will undergo the laboratory test and the product's marketability at maximum cost savings. In addition, to prove the ability and benefits of using OPEFB in the biocomposite industry, which is not only able to promote the widespread use of environmentally friendly materials, thus ensuring the priority of sustainable development in Malaysia.

Thus, this study will examine the suitability of natural fibres interacting with resin under thermoset heat stress. This leads to replacing synthetic materials with OPEFB, which gives high characteristic value to producing fibre-reinforced polymer composite (FRPC) products.

LITERATURE REVIEW

Construction materials are raw resources. To finish a construction project on time, building materials must be enough. Some contractors also struggle with using materials that cost more than construction when costs keep rising. Iron and synthetic materials dominate all industrial sectors despite their high prices and long-term implications on atmospheric health.

Most nations embrace modernism nowadays. The nation must protect the environment. In this environment, building infrastructure is rapidly becoming a key component of national development as a significant consumer of natural resources (Ravindra *et al.*, 2016). This development is predicted to raise CO2 emissions, causing climate change, temperature increases, and social and economic changes.

National energy demand is predicted to rise by 6% each year from 2010 to 2018. In 2018, 41%–65% of energy consumption came from the industrial and transport sectors. Residential and commercial buildings consume 15% of energy and 50% of electricity (National Energy Policy, 2022). Malaysia's consumption rate demonstrates productivity growth. This indicates more significant CO2 emissions to the atmosphere's surface. Thus, precautionary actions for future planet restoration.

Composite Polymer

Bulleted Polymer composites are polymeric materials with reinforcement, where the polymer acts as a matrix resin that penetrates the reinforcement bundles and bonds to the reinforcement (Anand *et al.*, 2022). These polymers are commonly combined with glass fibres. They have specific characteristics, including a cycle time of fewer than 2 minutes, a service temperature of 60–70°C, and low-cost glass fibre and resin materials (P. Greene, 2021). This technology introduces a green environment that allows a construction project to achieve zero-wastage construction. This shows the productive transition from conventional systems to unique and cost-effective Industrialised Building System (IBS) innovation technology.

- Thermosetting Polymer

  Thermosets, or thermosetting resin or polymers, are usually liquid at ambient temperature before becoming rigid upon heating or adding a chemical (Mondal, 2020). They are typically created via reaction injection moulding (RIM) or resin transfer moulding (RTM), and during the curing process, they create irreversible chemical connections. Thermoset polymers are heat-sensitive and take on a specific shape when heated, yet excessive heat can cause them to break down without transitioning to a fluid phase.

Fibre Reinforce Polymer Composite (FRPC)

Fibre-reinforced polymer composites based on synthetic fibres such as glass, kevlar, and carbon fibres have advanced significantly in recent decades to meet the needs of high-tech engineering applications. However, the well-known environmental awareness towards achieving the sustainability of manufactured goods has called for great potential in promoting more environmentally friendly materials with a focus on renewable raw materials in product design. Reference results found that FRP-based building component products have been established in Malaysia for nearly a decade. A product known as "Tasblock" that uses aerospace technology applied in construction products creates the latest variation. Tasblock is a polymer synthetic composite product created utilising commercial techniques recognised by the aerospace, marine, and other industries. To replace the typical building methods used today, Tasblock is an eco-friendly option that is incredibly light, termite resistant, simple to construct, and environmentally beneficial. The tasblock formulation combines polyester-based resin as a matrix (binder) compound with synthetic fibreglass fibres. The product will undergo compressive, tensile, flexural, and other testing, including fire resistance and water absorption. Due to that, this technology is unique and extraordinary for FRP as an alternative to unusual building products.

Table 1: FRPC Tasblock Component.

BENEFITS	DESCRIPTIONS
Foundation Cost	• Due to lightweight components (12% weight of clay brick wall). • Save on structural weight up to 6 times compared to reinforced concrete systems.
Installation Speed	• Can achieve up to 20m2 of build-up area per man day. • For example: - Eight hundred sf – 2.5 days. 1000 sf – 3 days.
Thermal Control	• Better thermal insulation due to the presence of air in hollow panels. • Light thermal mass is suitable for tropical weather with a low nocturnal difference as it does not absorb heat.
Sound Control	• Air insulation in hollow gaps denies sounds from the outside.

For instance, Figure 1 shows the Tasblock wall panel that uses the interlocking system as the method of thermosetting composite polymer:

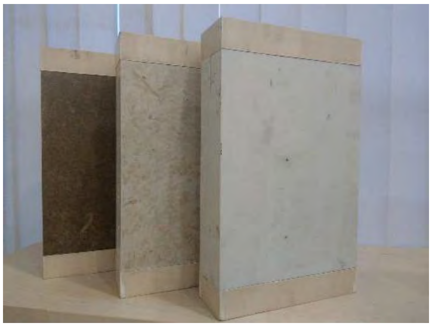

Figure 1: Tasblock wall panel.

Oil Palm Empty Fruit Bunch (OPEFB*)*

In 2021, oil palm was planted on Malaysia's 5.73 million hectares of land. Malaysia is the world's second-largest palm oil producer, behind Indonesia (Malaysia, 2022). Its production is predicted by the Malaysian Palm Oil Council (MPOC) to be about 23 million metric tons of palm oil in 2022 (Salim & Wyn, 2022). Specifically, OPEFB is the lignocellulosic residue after extracting crude palm oil (CPO). Based on the study, EFB accounts for about 22% by weight of every oil palm fresh fruit bunch (FFB) (Adnan & Mokhtar, 2000). Therefore, it can be concluded that the EFB production estimate based on 22% of the total FFB production is 4.03 million metric tons in Malaysia by 2022. This calculation is based on previous studies, and the actual amount may increase or decrease the production of the actual EFB yield. EFB has low commercial value and constitutes a disposal difficulty due to its large quantity. EFB is conventionally burned, disposed of in landfills, or composted to provide organic fertiliser (Ajekwene *et al.*, 2022).

Figure 2: Oil Palm Fibre Bunch (*Sources: Google Images)*

EFB comprises 35-65% cellulose, 20-45% hemicellulose, and 15-30% lignin (Intasit *et al.*, 2019). Due to its high cellulose concentration, EFB has a strong potential as a source of cellulosic-derived products, such as cellulose. According to Bernama reports, Datuk Azmin Ali stated that Exports of agricultural products increased by 42.6% to RM10.47 billion compared to August 2021, the 17th consecutive month of double-digit growth (Zainuddin, 2022). This shows that palm oil is the primary resource contributing to Malaysia's economy's progress. The data analysis provides a study on using EFB as a natural fibre substitute that the prolificate export demand for palm-based products can support.

METHODOLOGY

This study is about the research for natural fibre EFB that can be used instead of artificial synthetic fibre because they are better for the environment. The findings of this study will form new bio-composite materials that are better for sustainable development in the future.

In this part, qualitative research is preferable based on establishing observations, interpreting an article as references, interviewing the manufacturer and the point of view from the contractor side, and collecting data from the experiments to get the data analysed. In addition, data collection is also obtained from the collaboration with the Tasblock company using polymer resin technology, hot compress machine facilities, and wall panel moulds. To get product properties data, the request to carry out laboratory tests at the Malaysian Nuclear Agency was also supported by the company in terms of helping them obtain information related to the study. However, this study involves matters that cannot be disclosed regarding the formulation of Tasblock resin. Therefore, the study obtained a non-disclosure agreement (NDA) with the Tasblock material production company. The research strategies are more in-depth to show credibility in this research for the output of collection data, an analysability of the testing in performing the experiment of the sample, transparency of the detail properties and the benefits of uses material, and the usefulness of the quality outcomes. The framework is shown in Figure 3.

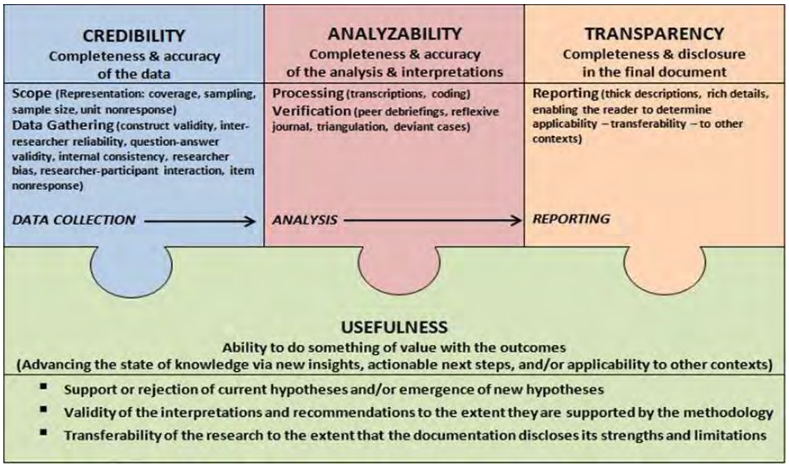

Figure 3: A Total Quality Framework Approach.

(Sources: (Roller & Lavrakas, 2021) https://researchdesignreview.com/

Therefore, conducting laboratory experiments is the method chosen for the research process. Research on the renewal of Tasblock products is classified as joint venture research in this funding collaboration between Tasblock and the Malaysian Nuclear Agency. As a result, all of the research is completed, which enables the company to get information related to the study data and aids in the acquisition of this research paper.

FINDING AND DISCUSSION

Fibre Reinforced Polymer (FRP) composites have gained significant attention in various industries due to their exceptional mechanical properties and lightweight nature. The finding of this study focuses on the performance evaluation of FRP composites in structural applications.

Innovation of Product

This product uses almost 96% of the same material found in the original Tasblock product that uses synthetic fibre. So, the concept, design, connection and interlocking method remain the same. This coincides with the primary purpose of this product innovation: to increase sustainable development in Malaysia. Therefore, the featured design that can be used as an example is shown in Figure 3, where the ability to change the landscape from conventional to innovative materials is used. This will provide a significant renewal of energy efficiency, faster construction periods, efficient cost reduction, the ability to achieve zero-rated wastage in construction projects and necessarily provide the best features for built structures with overall benefits to the environment and users. Figure 3 shows an example of a wall panel product design that will be applied according to existing specifications with the innovation of using natural rather than synthetic fibre. This design development is unique; this panel is designed in a hollow but reinforced section that divides the interior, contributing excellent strength characteristics.

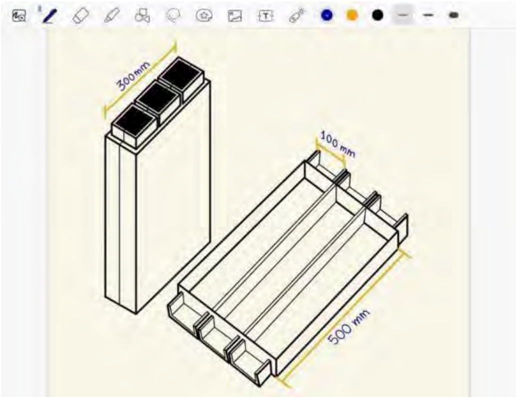

Figure 4: Example of Design Specification of Innovation Product.

In addition, the wall panel has a height of 500 mm and a width of 300 mm, and the size of each connection tooth is 100 mm, allowing the adapter to be connected to the next wall layer. This dimension specification is intended to ensure stability and the ability to withstand the filling. However, the thickness and height of the wall panels are seen to be in accordance with the stability of the component when erected.

The following section is the primary type of material used for this innovation research. This section is explained based on Table 2, where the description of ingredients focuses on the main ingredients contained in the mixture.

Table 2: Main Material of Product.

NO	MATERIAL	DESCRIPTION
1.		Polyester resin is the main ingredient in the production of the product. Polyester resin is known for its high strength, durability, and resistance to chemicals and impact. It is also relatively inexpensive and easy to use, making it a popular choice for various industrial and consumer products.
2.		Styrene acrylic polymer is a type of copolymer that is made by combining styrene and acrylic monomers. It has excellent adhesion properties, water resistance, and colour stability. This type of polymer is often used in manufacturing paints, coatings, and adhesives.
3.		Empty Fruit Bunch (EFB) fibre is a by-product of the oil palm industry. It is obtained from the empty fruit bunches left over after palm oil extraction. EFB fibres are long, strong, and durable, and they have a variety of industrial uses.

Testing Method

Based on this study, four test approaches were taken to test the ability and resistance to tensile, flexural, durometer hardness, impact, and deflection temperature. The study method used in determining the capability characteristics of this innovative product is based on the standards from the American Society for Testing and Materials (ASTM). ASTM testing methods cover many industries, including construction, materials science, petroleum, metals, textiles, and plastics. Table 3 shows the methods participating in this innovation in testing the FRPC product.

Table 3: ASTM Method for Product Testing.

TEST	DESCRIPTION
Tensile strength test (ASTM D638:2014) – Standard Test Method for Tensile Properties of Plastics.	The test begins with the specimen being clamped in the grips of a testing machine. The grips are then pulled apart at a constant rate of speed, and the machine measures the force required to stretch the specimen. As the specimen is stretched, it will reach a point where it will begin to yield or permanently deform and eventually break.
Flexural Test **(ASTM D790:2015:2) –** Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Material.	Flexural or bending tests are unsuitable for rubber to determine ultimate flexural and bending strength. These two terms are different. The flexural test is designed to measure the bending strength of a brittle material, whereas the bend test measures the crack resistance of a ductile material.
Durometer Hardness **(ASTM D2240:2015) –** Standard Test Method for Rubber Property.	The durometer is a standardised method of measuring the hardness of materials such as rubber (elastomers) and plastics. This test is not a good predictor of material qualities like resistance to scratches, wear, or abrasion and should only be used as a supplement to design specifications.
Impact test **(ASTM D256:2010) –** Standard Test Method for Determining the Izod Pendulum Impact Resistance of Plastics.	This test measures a material's ability to absorb energy when hit with force. The test is typically performed on a notched or un-notched bar-shaped material specimen. The impact strength is calculated by measuring the energy absorbed by the specimen during the test.
Deflection Temperature **(ASTM D648:2016) –** Standard Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position.	This is a standard test method for determining the deflection temperature of polymers under flexural load. The test entails creating specimens of specific sizes, conditioning them to achieve balance, and delivering a weight on the specimen's centre. This method provides a standardised approach for testing plastics' heat resistance and dimensional stability, assisting in material selection for high-temperature applications.

Assembly of Innovation Product

The installation process has been specifically through 3 primary processes: Fiber extraction, sheeting, and hot compress. Bunches of fresh fruit picked from the trees are processed to produce commodity materials from the fruit, including the food industry, beauty products, cooking oil, and others. First, the critical process of obtaining fibre from empty fruit bunches from oil palm plants then empty fruit bunches or OPEFB will go through a preservation process and pre-treatment, sterilisation, fibre extraction (mechanical and chemical extraction), drying, and packaging and storing. The illustration of the process is as follows (Figure 5):

Figure 5: Assemble Process.

Table 4 shows the procedure for producing fibre from EFB.

PROCEDURE IN PRODUCING FIBRE FROM EFB.	DESCRIPTION
1) Collection and Pre-Treatment	● Collect the EFB from palm oil mills or plantations. ● Remove any extraneous material such as stones or sand. ● Shred or cut the EFB into smaller pieces to facilitate further processing.
2) Sterilization	● Sterilized the EFB to eliminate any pests or pathogens.

3) Fiber Extraction	a. Mechanical Extraction ● Pass the shredded EFB through a mechanical fibre extractor. It will separate the fibres from the rest of the material. ● The extracted fibre will contain some residual moisture. b. Chemical Extraction ● Soak the shredded EFB in a chemical solution to loosen the fibre. (e.g., sodium hydroxide) ● Rinse and wash the extracted fibres to remove residual chemicals.
4) Drying	● Spread the fibres flat or use drying equipment to remove the moisture. ● Ensure proper ventilation during the drying process to prevent mould or mildew growth.
5) Packaging and storing.	● Bundle them into bales and stack them on the pallet for storage. ● Storage in a room or low temperature to protect the fibres from moisture and physical damage.

After extracting the fibre, the process continues with the sheet moulding compound (SMC) method. This process is done after finishing the process of mixing matrix resin materials. Cut the fibre according to the required size to prepare the small sample. This SMC process requires size requirements and calculations according to a ratio of (1:3) to ensure that the resin and fibre can be combined evenly.

After these two processes, this object will be placed in a mould container to get the desired shape.

Plate 1: SMC Method.

Plate 2: Moulding.

Next, the process continues with the last technique, the thermosetting method, by placing the mould between the plates of the hydraulic hot pressure machine and setting the heat at 150 degrees Celsius at a pressure of more than 20 tons. This intense pressure ensures that the object is compacted to a thickness according to the shape of the mould container.

This thermosetting process is the last process before the product is released. The variety of techniques in the use of mould containers is very flexible. However, the famous and often used former mould technique is the male-female mould, also used in thermoplastic. Hence, there are many benefits from using former moulds like this, including increasing precision in the final product and providing versatility in creating complex shapes and intricate designs.

Performance of The Innovation Product

For the performance after the sample undergoes the process of mixing, brushing, heating and pressing, which is also channelled as the thermosetting process. The pressed sample will be according to the standard thickness of the Tasblock product at a thickness of 0.45 mm and will be cut according to the shape of the dog bone and a rectangular specimen size using a waterjet.

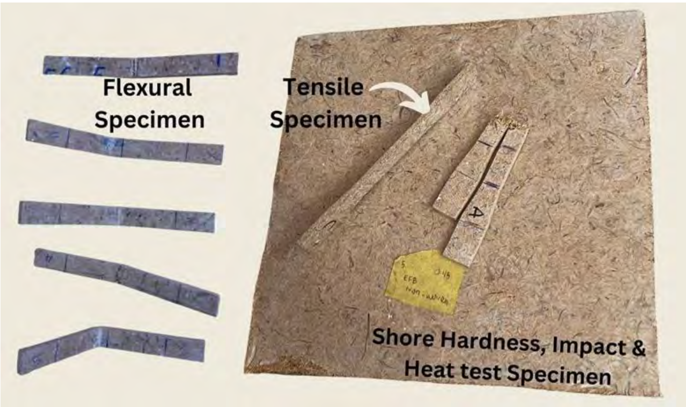

Plate 3:Shapes of Specimen.

Table 5 shows the properties carried out on the sample in Figure 3. This table shows the results of tensile, bending, shore hardness, Izod impact and thermal deflection tests and records also taken to analyse the compatibility and capabilities of innovative products.

Table 5: Result of Finding.

NO.	PROPERTY	RESULT
1.	**Tensile Strength** a) Glass Fibre Composite (FRP) b) OPEFB Composite (FRP)	(40.3 ± 9.0) MPa (34.1 ± 8.9) MPa
2.	**Elongation at Break** a) Glass Fibre Composite (FRP) b) OPEFB Composite (FRP)	1.0% 1.5%
3.	**Flexural Strength** a) Glass Fibre Composite (FRP) b) OPEFB Composite (FRP)	(108.5 ± 21.9) MPa (57.3 ± 8.5) MPa
4.	**Flexural Modulus** a) Glass Fibre Composite (FRP) b) OPEFB Composite (FRP)	(10,100 ± 989) MPa (5,660 ± 678) MPa
5.	**Shore Hardness, Shore D** a) Glass Fibre Composite (FRP) b) OPEFB Composite (FRP)	(90.1 ± 0.3) MPa (89.0 ± 0.3) MPa
6.	**Izod Impact Strength** a) Glass Fibre Composite (FRP) b) OPEFB Composite (FRP)	(116.3 ± 4.3) MPa (97.9 ± 3.0) MPa
7.	**Heat Deflection Temperature Stress:** 0.45 MPa a) Glass Fibre Composite (FRP) b) OPEFB Composite (FRP) 1.8 MPa a) Glass Fibre Composite (FRP) b) OPEFB Composite (FRP)	More than 200°C

Based on the data shown in Table 5, the difference between the ability of glass fibre and OPEFB is slight and not much. The collection of this data demonstrates that natural fibre and polymer materials can react appropriately in thermoset applications. As a result, reinforced components are created with new strengths that can match or surpass the demands of the standards being applied. It was discovered that the component, which is 0.45 mm thick, has strength more significant than that of regular concrete with grades of 20, 25, 30, and 35 MPa. In conclusion, this research demonstrates the potential for using natural fibres in novel ways in thermoset-base polymer composites. In particular, it helps protect nature from artificial materials by maximising the range of products obtained from palm oil plants.

Existing product comparison

Table 6 outlines a study on selecting the primary material to be combined with OPEFB fibre to form a product innovation to a new material with more commercial value in terms of offering features and functional advantages of its strength.

Table 6: Existing Product Comparison.

INTERLOCKING WALL PANEL TYPES CHARACTERISTICS	INTERLOCKING PRECAST CONCRETE	COMPOSITE ICF	LEGO WALL PANEL	COMPOSITE WALL PANEL TASBLOCK
Weight per Component	529 1 lbs	30 lbs	1.72 lbs	7.5 lbs
Type	Concrete	Concrete + Polystyrene	Thermoplastic Polypropylene	Thermoset (resin + synthetic fibre)
Compressive Strength	920.00 lbf	8064.00 lbf	1161.32 lbf	19,662.00 lbf
Density	94.25 lbs/ft²	7.85 lbs/ft²	4.74 lbs/ft²	1.82 lbs/ft²
Water Absorption (%)	8.11	7.30	0.1	0.08
Tensile Properties	700 psi	43 psi	5076.7 psi	6,461.7 psi
Wastage (%)	Up to 2%	Up to 2%	Can reach 0%	Can reach 0%
Fire Test	4hrs	4 hrs	2¾ minute	1 hr

Based on observations from the data collection and according to Table 6, several characteristics are considered when selecting materials. This selection finds features that produce highly added value in strength, heat resistance, product lightness per component, and the ability to reduce wastage.

The crucial issue that needs to be considered in choosing resin from this Tasblock is the compressive and tensile strength offered after this thermosetting process. Due to that, this selection is used as the primary basis for considering the functionality of this product when it is widely used, especially in the Construction Industry using FRPC innovation. In addition, this light product feature adds confidence to product innovation done in depth. This increases workability with greater efficiency without expecting large machinery and only using labour according to project capacity.

Moreover, the third advantage that makes Tasblock technology a choice is that this product is low in water absorption, which is suitable for improved durability, where the material with low water absorption is less susceptible to damage caused by water. They are less likely to warp, swell, crack, or deteriorate when exposed to moisture. This advantage also helps reduce maintenance, chemical resistance, and enhanced insulation, which can improve energy efficiency in buildings.

The final selection factor for this product innovation is also closely related to the issue of sustainable development in Malaysia, not only due to the widespread production of carbon dioxide. Sustainable development aims to minimise waste and promote efficient use of resources. Therefore, this innovative research can conclude that the ability to use this technology leads to the achievement of 0% wastage, which helps to restore the health of the environment and the local habitat. Overall, this comparison helps produce new products where changes, improvements or innovations can be created. The data regarding the Tasblock composite polymer is essential to compare the significance of the innovations made when the replacement of synthetic fibre (fibreglass) is replaced by natural fibre (Empty Fruit Bunch, EFB).

CONCLUSION

Overall, this research provides a new perspective of the Construction Industry to NFRPC technology by applying the plastic thermoset method. This opens a new scope that can penetrate the construction market and be classified in the IBS innovation. The study found results from the use of natural fibres through laboratory experiments. The results prove that the ability of this new product is able to compete with the existing market by offering various features. The study also found that the benefits of OPEFB waste will reduce this waste material part of a new commodity that can contribute to the country's economic results. In addition, the conversion of synthetic fibres to natural fibres will be able to contribute to the conservation of nature by reducing the use of artificial materials. This is not only able to reduce synthetic material production but also helps reduce carbon dioxide emissions. Buildings built using this innovative product material are also expected to help the energy efficiency of this building with features found in the adaptability of the thermoset method with various customisations. Therefore, this research leads to a precise conclusion about the characteristics that go beyond the standard requirements and the ability of the natural fibre response in the interaction between the resin polymer and the thermoset method used. Last but not least, this research is believed to be commercialised. However, improvements need to be continued in-depth and innovated over time to obtain a synergistic effect in producing products that may be better in the future.

ACKNOWLEDGEMENT

Alhamdulillah, all praise be to God, who is Most Merciful and Most Generous. First of all, I would like to express my gratitude to Ts. Normila Binti Ahmad is the supervisor who has worked tirelessly throughout preparing this research paper. Madam was very supportive and patiently guided me from knowing nothing to almost having everything. The experience of participating in USBET is excellent. It expanded my knowledge and understanding of time management, research methodology, assignment formatting, and how to generate ideas for my proposal paper. It is an advantage for me to get a broad scope of study, good management, and highly recommended products with perfect quality.

I make the best use of time, opportunities, tasks, and responsibilities with teamwork, encouragement, and great ideas from all parties, directly or indirectly, that have contributed to this success in completing my innovation proposal report. In that regard, I would like to express my gratitude to the Tasblock company that is willing to accept cooperation involving the use of facilities and materials available in the factory and not forgetting the Malaysian Nuclear Agency that allows the use of the laboratory as a well-equipped test site to obtain data related to biopolymer composite materials using (EFB).

Finally, thank you to the parents for their sacrifices over the years. The contribution they channel every month, especially in ensuring the success of this innovation project, is beneficial. My father financed all the costs and cooperation agreed upon by the company Tasblock (M) Sdn. Bhd. Hopefully, this collaboration will last in developing the innovation of this product.

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