# Evaluation of Mechanical Properties of Raffia Palm Fibre-Groundnut Shell Powder/Fine Clay Filler Reinforced Epoxy Composite for Partition Wall Applications

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DOI: https://doi.org/10.5281/zenodo.15394563

Published Date: 13-May-2025

*Abstract:* **High-rise buildings minimize the use of high-density construction materials to reduce the weight of the building. One of construction parts that can be employed to reduce weight in buildings is a partition wall. Partition walls compartmentalize the building and define the spaces within it and are traditionally made of concrete masonry. Because of the high weight of concrete, there is need for a sustainable light weight alternative material. In this work, raffia palm fibre-groundnut shell powder/fine clay filler reinforced epoxy composite has been developed for application in interior partition walls of buildings. The composite was produced using hand lay-up lamination technique. Mechanical properties such as tensile strength, flexural strength, compressive and impact resistance which are critical for materials used in the partition walls were evaluated. The results indicate; the tensile strength of composite is in the range 7.056-17.845 MPa. The Young's modulus of composite is in the range of 67.18-220.04 MPa. The modulus of elasticity (MOE) values ranged from 2343.75-3906.25 MPa. The modulus of rupture (MOR) values ranged from 25.78-70.31 MPa. Compressive strength of composite ranged from 9.4-29.0 MPa. The impact strength values ranged from 0.70-3.60 J/mm$^2$ in the composites. The study concluded that, based on the results obtained, the composite has sufficient mechanical properties suitable as an alternative construction material for replacement of concrete masonry in partition wall applications.**

*Keywords:* **Partition wall, Concrete masonry, Composite, Fine clay and Hand lay-up.**

## 1. INTRODUCTION

High-rise buildings minimize the use of construction materials of high weight to reduce the building load and as an effort to minimize construction costs. One of construction parts that can be deployed to minimize weight is a partition wall construction. Partition in buildings are flexible room dividers. This partition serves as a separator between two spaces that had different functions, limiting people's views, and giving a sense of security in a different space (Maneschi and Melhad 2010; Wijaya *et al.*, 2022). The materials of partition wall include; glass, gypsum, concrete wood, ply wood and glass fibre composite. According to Wijaya *et al.* 2022) partition walls can also function as decorative accents to conceptualize interiors such as backdrops. This has encouraged the emergence of alternative substitute lightweight materials for partition walls.

Currently, the use of natural fibre composite as an alternative material for partition wall is on the increase, [Domke and Mude (2015) and Wijaya *et al.* (2022)] because they have the advantage of being light in weight and easy to install. Utilizing these materials for Partition walls do not overload the building structure so no additional load calculations are required (Wijaya *et al.*, 2022). Natural plant fibre composites as environmentally attractive materials have emerged as an alternative to the glass reinforced composites and other traditional materials such as concrete masonry used in partition walls due to environmental concerns associated with their use (Sanjay *et al.*, 2016). In addition, weights saving opportunities are obtained by replacing these materials with natural fibre composites.

Natural fibre along with clay fillers has been used to manufacture hybrid composite with improved mechanical properties (Kusmono and Zainal, 2013). The use of clay fillers and low-density renewable natural materials such as raffia palm fibre and groundnut shell powder in polymer composite materials is a viable means to reduce environmental impact and support sustainable development in the manufacturing industry.

Tile and Nyior (2023), studied the effect of alkaline treatment on tensile properties of raffia palm fibres obtained from Benue State Nigeria for reinforcement in polymer composites with good results indicating that, it could be a potential alternative for reinforcement in composite materials for moderate strength applications. Other researches also, reported good tensile strength of raffia palm fibre (Elenga *et al.*, 2009). The characterization of raffia palm fibre by Ipilakyaa *et al*. (2024) for reinforcement in polymer composite for specialized applications was studied and it was concluded that, the fibres could be used as a source of reinforcement in polymer composite applications where moderate strength and stiffness are required.

According to Domke and Mude (2015) groundnut shells have been utilized in the manufacture of buildings panels, building blocks, for making chip boards, roofing sheets and particle boards. Tile *et al.* (2024) studied the characterization of alkaline treated groundnut shell powder for reinforcement in polymer composite for production of prosthetic sockets. The study showed that, groundnut shell is amorphous, safe and suitable for deployment as a filler in polymer composites. Addition of groundnut shell particulate to polymer composites reduces thermal conductivity, and increase the glass transition temperature of the composites (Raju *et al.*, 2012, Nyior *et al.*, 2018 and Sesugh *et al.*, 2019).

Najafi *et al.* (2012) and Makaremi *et al.* (2017) reported that, clay is widely available in nature and can be used as a filler in composite due to its high mechanical, thermal, barrier, high benignity, and stability, low cost, availability, and sustainability. It significantly enhances the mechanical, physicochemical and degradable properties of composite even at a lower filler load (< 10 wt%).

In this work, woven raffia palm fibre-groundnut shell powder/fine clay (RPF-GNS/fine clay) epoxy composite has been produced by hand lamination lay-up technique. Mechanical properties of the composite such as; tensile strength, flexural strength, compressive and impact resistance strength have been evaluated to determine the material's suitability for deployment in partition wall applications in the building industry.

## 2. MATERIALS AND METHODS

### 2.1 Materials

The materials used for this research include Epoxy resin (885) part A, Hardener (995) part B, Raffia palm fibres, Groundnut shell powder, Sodium hydroxide (NaOH), Fine clay, Distilled water, Mould release agent: Laminating Leather and Hand gloves.

### 2.2 Methods

The following experimental procedure were followed in the research.

#### 2.2.1 Preparation of raffia palm fibre, groundnut shell powder and fine clay

The raffia palm fibres used in this research were treated in line with Tile and Nyior (2023). The fibres were weaved into bidirectional 0/90$^{o}$ fibre mat. Plate 1(a) shows the photograph of woven raffia palm fibres.

Groundnut shell powder was treated in line with Tile *et al.* (2024). The powder was sieved using standard test sieves to a particulate size of 300 µm. Plate 1(b) shows the photograph of alkaline treated groundnut shell powder.

Clay was collected and processed into fine clay powder in line with the process for extracting fine clay from a layered clay in line with Chi-Kang Lo, (2010). The clay was sieved using standard test sieves to fine powder of 75 µm. Plate 1(c) shows the photograph of fine clay powder.

**(a)**

**(b)**

**(c)**

**Plate 1: (a) Photograph of Woven Raffia Palm Fibre Mat (b) Photograph of Alkaline Treated Groundnut Shell Powder (c) Photograph of Fine Clay Powder**

### 2.2.2 Production of hybrid composite with fine clay filler

Lamination of the woven raffia palm fibre-groundnut shell powder epoxy hybrid composite with fine clay as filler was carried out by hand lay-up technique in line with Tile (2024). A Wooden mould of size 18cm × 13cm × 0.8cm was used for producing the composite. The wooden mould was covered with a lining (lamination leather) as mould release agent. Woven Raffia palm fibre mat was cut based on the mould dimensions and laid in the mould by hand layer by layer until the required thickness of composite was obtained. Five laminates were produced based on 1-layer woven raffia palm fibre-groundnut shell powder and fine clay filler (1-layer woven RPF-GNS/fine clay), 2-layer woven raffia palm fibre-groundnut shell powder and fine clay filler (2-layer woven RPF-GNS/fine clay), 3-layer woven raffia palm fibre-groundnut shell powder and fine clay filler (3-layer woven RPF-GNS/fine clay), 4-layer woven raffia palm fibre-groundnut shell powder and fine clay filler (4-layer woven RPF-GNS/fine clay) and 5-layer woven raffia palm fibre-groundnut shell powder and fine clay filler (5-layer woven RPF-GNS/fine clay). Epoxy resin (885) part A and the hardener (995) part B were mixed in the ratio of 2:1 in a plastic container. These were stirred for 15 minutes to enable effective reaction. Measured quantities; 5.40, 10.39, 14.95, 19.08 and 22.8 $cm^3$ of fine clay powder as shown in Table 2, were added to the epoxy resin and groundnut shell particulate in the plastic container and the mixture was again stirred for 10 minutes before it was poured onto the woven raffia palm fibre mat in the mould. The fibre was saturated with epoxy resin and a roller was used to ensure good compaction and freedom from porosity. The mould was closed and kept under pressure using hydraulic press at room temperature for 24 hours before the composite was removed from it. Photograph of laminated samples shown in Plate 2, were cut for the various tests. Table 2 shows the composition of woven raffia palm fibre-groundnut shell particulate/fine clay filler (RPF-GSP/fine clay) epoxy composite.

**Table 2: Composition of Woven Raffia Palm Fibre-Groundnut Shell Particulate/fine clay filler (RPF-GNS/fine clay) Epoxy Composite**

| Composite Sample | RPF Mat Volume ($cm^3$) | GNS Particles ($cm^3$) | Reinforcement (%) | Epoxy Resin Volume ($cm^3$) | Fine Clay Powder ($cm^3$) | Volume of Sample ($cm^3$) |
|---|---|---|---|---|---|---|
| 1layer RPF-GNS/3% Clay | 3.52 | 3.52 | 3.8 | 174.76 | 5.40 | 187.2 |
| 2layer RPF-GNS/6% Clay | 7.04 | 7.04 | 7.5 | 162.73 | 10.39 | 187.2 |
| 3layer RPF-GNS/9% Clay | 10.56 | 10.56 | 11.3 | 151.13 | 14.95 | 187.2 |
| 4layer RPF-GNS/12% Clay | 14.08 | 14.08 | 15.0 | 139.96 | 19.08 | 187.2 |
| 5layer RPF-GNS/15% Clay | 17.60 | 17.60 | 18.8 | 129.2 | 22.8 | 187.2 |

### 2.2.3 Evaluation of the Hybrid Composite for Partition Wall

#### i. Tensile Strength Test

The experimental procedure to determine the ultimate tensile strength and the Young's modulus of the composite was carried out using a digital tensile testing machine in accordance to the ASTM D-638 procedure at room temperature. The composite samples (of dimensions 100 × 15 × 8 $mm^3$ and a guage length of 40mm) were mounted individually into the grips of the tensile testing machine. The test was conducted by gripping each end of the sample and slowly pulling it with a cross head speed of 2 mm/min until catastrophic failure occurred. Five samples were tested and the average value taken, the graph of tensile stress versus strain was plotted. Based on the tensile test, tensile strength, strain as well as the Young's modulus were obtained.

#### ii. Flexural Test

The flexural test was performed using 100 kN capacity universal materials testing machine. This was done as per ASTM D-790 using the 3-point bending fixture, utilizing centre loading on a simple supported beam. The dimension of the sample was 100 mm × 30 mm × 8 $mm^3$ with a gauge length of 80 mm. The sample was placed on two supports and was loaded by means of a loading nose midway between the supports. The maximum axial fibre stresses occurred on a line under the loading nose. Five samples were tested and the average values of the modulus of rupture and modulus of elasticity were obtained using equations 3 and 4 respectively.

Modulus of Rupture MOR = $\frac{3pl}{2bt^2}$ (MPa) (3)

Modulus of Elasticity (MOE) = $\frac{pl^3}{4bt^3{}_Y}$(MPa) (4)

Where, p is max. load applied on test specimen (N)

l is gauge length (mm)

b is the width of specimen (mm)

t is thickness of specimen (mm)

Y is the deflection.

#### iii. Compression Test

Compression test was conducted according to ASTM D3410. Universal (digital) compression testing machine was used. The dimension of the sample was 10 mm × 5 mm × 3 $mm^3$. Two load blocks in the machine exerted a compressive force on the test specimen with a test speed of 2 mm/min. The compressive strength of a material was calculated using equation (5) according to Syapawi *et al.* (2024):

$$fc = \frac{P}{A} \quad (5)$$

In this formula:

fc = Compressive Strength (MPa)

P = Maximum Load (Newtons)

A = Surface Area ($mm^2$)

**Impact Test**

The unnotched Charpy impact test was conducted according to the ASTM D-256. The specimen dimensions were 75 mm x 8 mm x 7 $mm^3$. In this method, the unnotched specimen is supported horizontally as a simple beam and fractured by a blow delivered in the middle of the specimen by the pendulum. Five samples were tested and the average of the values of the energy required for fracture in joules was recorded by a dial gauge fitted on the machine.

## 3. RESULTS AND DISCUSSION

### i. Tensile Test

Results of the tensile properties of the composite is presented in Table 3. The results show that, the tensile strength of composite is in the range 7.056-17.845 MPa. The tensile strength increased to a maximum value of 17.85 MPa in 2layer RPF-GNS/6% Clay composite as the reinforcements increased, the tensile strength decreased to a minimum value of 7.06 MPa in 5layer RPF-GNS/15% Clay composite. The decrease in tensile strength according to Nyior *et al.* (2018) could be due to weak filler-matrix adhesion resulting from insufficient wetting of the fibres by the resin for higher reinforcements. During tensile loading partially separated micro spaces are created which obstructs stress propagation between the fibre and the matrix (Ismail *et al.*, 2002). As the fibre reinforcement increases, the degree of obstruction increases, which in turn decreases the strength of the composite.

Tile (2024) obtained maximum tensile strength of 10.80 MPa in 2 layers of woven RPF-GNS/epoxy hybrid composites. The addition of 6% fine clay in the composite resulted to a significant increase in tensile strength by 65.28 %. The result of this study agrees with Onyedika *et al.* (2020) where addition of fine clay to polymer composite yielded high tensile strength. This was as a result of increase in surface area of the clay particle size that increased the rate of attraction of clay powder to the recycled low-density polyethylene.

According to AlQudah and Freewan (2020) and Onyeka (2019) the tensile strength of a typical concrete masonry ranges from 2 to 5 MPa Whereas the tensile strength of the composite under investigation is in the range of 7.056 - 17.845 MPa. The values of the five composite samples are way higher than that of concrete masonry for partition wall application.

### a. Young's modulus

Results of Young's modulus of the composites are shown in Figure 2. The Young's modulus was found to increase to a maximum value and then decrease as the reinforcement increased. The Young's modulus of composite is in the range of 67.18-220.04 MPa. It was observed that, 3layer RPF-GNS/9% Clay composite gave the highest Young's modulus value of 220.04 MPa.

Tile (2024) obtained the maximum Young's modulus value of 184.93 MPa in 2 layers of woven RPF-GNS/epoxy hybrid composites. The addition of 9% fine clay in the composite resulted to 18.99 % increase in the Young's modulus this could be as a result of the addition of fine clay which increased the stiffness in the composite.

**Table 3: Tensile Properties of the Composite**

| Sample | Tensile Strength (MPa) | Strain at Max. Stress (%) | Young's Modulus (MPa) |
|---|---|---|---|
| 1layer RPF-GNS/3% Clay | 7.216 | 4.744 | 152.12 |
| 2layer RPF-GNS/6% Clay | 17.845 | 8.919 | 200.08 |
| 3layer RPF-GNS/9% Clay | 15.779 | 7.171 | 220.04 |
| 4layer RPF-GNS/12% Clay | 8.406 | 6.551 | 128.32 |
| 5layer RPF-GNS/15% Clay | 7.056 | 10.503 | 67.18 |

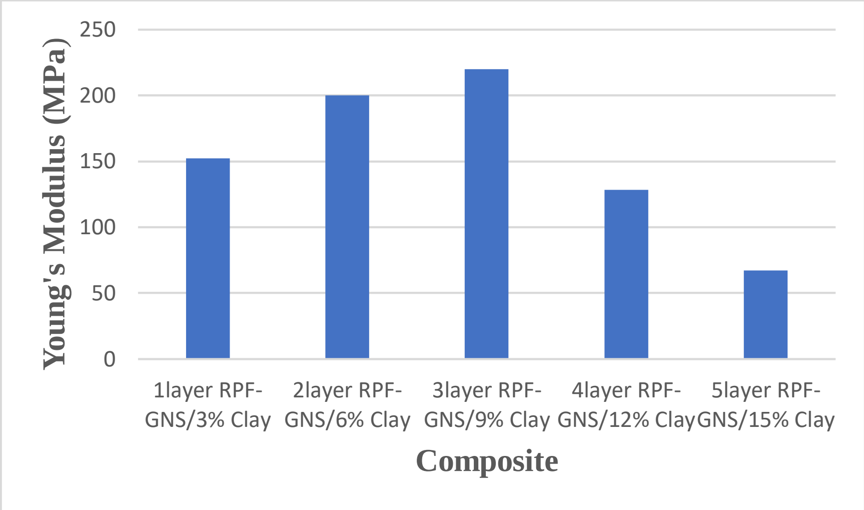


**Figure 2: Bar graphs showing Young's Modulus for the various composites**

**ii. Flexural properties of the composite**

The results of the flexural properties of the composite are shown in Figures 3 and 4 for modulus of elasticity (MOE) and modulus of rupture (MOR) respectively. The MOE values ranged from 2343.75-3906.25 MPa. 2layer RPF-GNS/6% Clay composite had the highest MOE of 3906.25 MPa.

Tile (2024) obtained maximum MOE value of 1701.39 MPa in 2 layers of woven RPF-GNS/epoxy hybrid composites. The addition of 6% fine clay in the composite resulted to 129.6 % increase in the MOE of the composite.

The results of the modulus of rupture are shown in Figure 4. The modulus of rupture (MOR) also known as flexural strength is the maximum stress a material can withstand before fracture or breaking when subjected to bending forces. The MOR values ranged from 25.78-70.31 MPa. 2layer RPF-GNS/6% Clay composite had the highest MOR of 70.31 MPa. Tile (2024) obtained maximum MOR value of 30.63 MPa in 2 layers of woven RPF-GNS/epoxy hybrid composites. The addition of 6% fine clay in the composite resulted to 129.6 % increase in the MOR of the composite. According to AlQudah and Freewan (2020) and Onyeka (2019) the flexural strength of a typical concrete masonry ranges from 2 to 5 MPa the values of the five composite samples obtained in this study are way higher than that of concrete masonry for partition wall application.

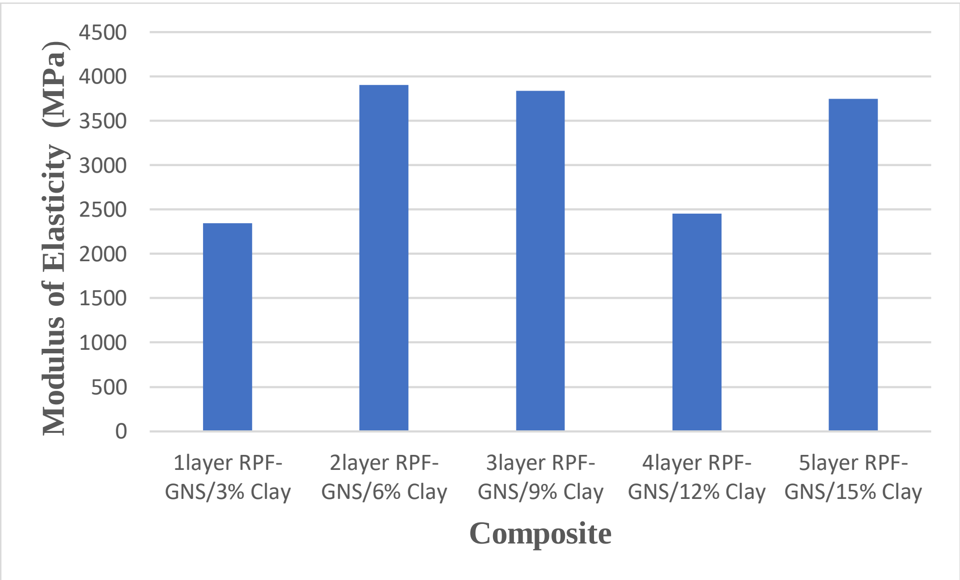


**Figure 3: Bar graphs showing Modulus of Elasticity for the various composite**

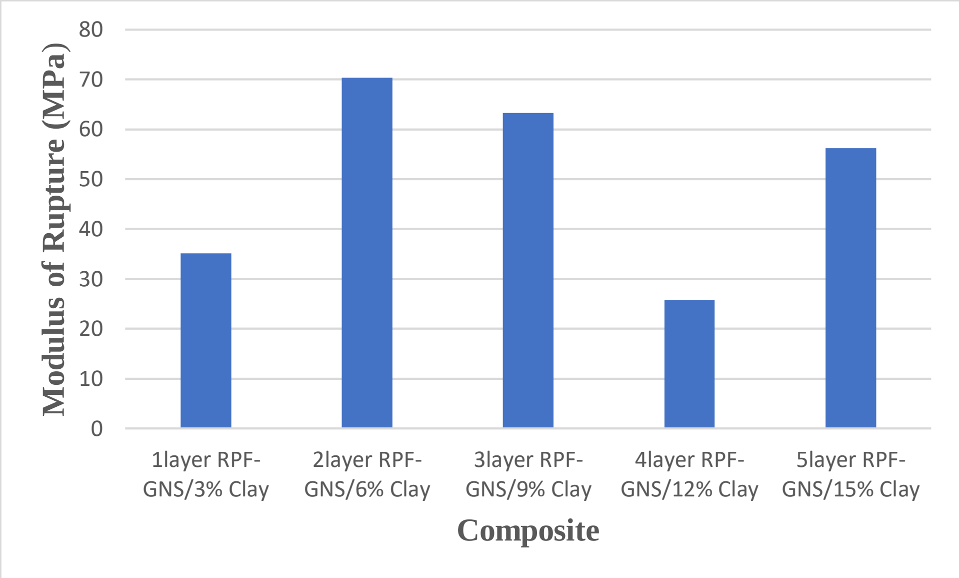


**Figure 4: Bar graphs showing Modulus of Rupture for the various composite**

**iii. Compressive Test**

Compressive strength of partition walls is important to ensure that the walls can withstand vertical loads whether it be the weight of the wall itself or additional vertical loads experienced in construction. The results of the compressive test of the composites are presented in Table 4. The result show; compressive strength ranged from 9.4-29.0 MPa. 1layer RPF-GNS/3% Clay composite had the highest compressive strength of 29.0 MPa, 2layer RPF-GNS/6% Clay composite gave compressive strength of 22.0 MPa. It is observed that, 4layer RPF-GNS/12% Clay composite gave the least compressive strength of 9.4 MPa.

Tile (2024) obtained 13.73 MPa as maximum compressive strength from the reinforcement of 2 layers of woven RPF-GNS/Epoxy composite. The addition of 6% fine clay filler in the composite resulted to 62.3 % increase in compressive strength of the composite. This means that, the sample can withstand moderate compressive forces without significant deformation.

A typical concrete masonry’s compressive strength ranges from 20 to 50 MPa (Bošnjak *et al.* 2019, AlQudah and Freewan, 2020). Therefore, three samples of the composite compressive strength have met the minimum compressive strength requirements for partition wall applications.

**Table 4: Compressive Strength**

| **Sample** | **Maximum Compressive Strength (MPa)** |
|---|---|
| 1layer RPF-GNS/3% Clay | 29.0 |
| 2layer RPF-GNS/6% Clay | 22.0 |
| 3layer RPF-GNS/9% Clay | 21.0 |
| 4layer RPF-GNS/12% Clay | 9.4 |
| 5layer RPF-GNS/15% Clay | 13.3 |

**iv. Impact Strength of the Composite**

The results of the impact strength of the composite are presented in Table 5. The results show that, impact strength values ranged from 0.70-3.60 J/mm$^2$ in the composites. 3layer RPF-GNS/9% Clay composite gave highest impact strength of 3.60 J/mm$^2$ in the composite. The impact strength obtained in this composite from all samples is higher than that of ply wood used for partition wall. According to Kumar (2018) the impact strength of plywood for partition wall is 0.174 J/mm$^2$. Based on this result, the clay filler composite performs better in impact strength than plywood.

**Table 5: Impact Strength (15 J used)**

| Sample | Strength (J/mm$^2$) |
|---|---|
| 1layer RPF-GNS/3% Clay | 0.70 |
| 2layer RPF-GNS/6% Clay | 1.65 |
| 3layer RPF-GNS/9% Clay | 3.60 |
| 4layer RPF-GNS/12% Clay | 1.15 |
| 5layer RPF-GNS/15% Clay | 2.95 |

## 4. CONCLUSION

The study evaluated the tensile strength, flexural strength, compressive and impact resistance of hybrid composite material for partition wall applications produced from a blend of alkaline treated raffia palm fibres and alkaline treated groundnut shell powder using epoxy resin as matrix with fine clay as filler. From the results:

The tensile strength of composite is in the range 7.056 - 17.845 MPa. 2layer RPF-GNS/6% Clay composite gave the maximum tensile strength of 17.85 MPa. The tensile strength values of the five composite samples are way higher than that of concrete masonry for partition wall.

The Young's modulus of composite is in the range of 67.18-220.04 MPa. It was observed that, 3layer RPF-GNS/9% Clay composite gave the highest Young's modulus value of 220.04 MPa.

The modulus of elasticity (MOE) values ranged from 2343.75-3906.25 MPa. 2layer RPF-GNS/6% Clay composite had the highest MOE of 3906.25 MPa. The modulus of rupture (MOR) values ranged from 25.78-70.31 MPa. 2layer RPF-GNS/6% Clay composite had the highest MOR of 70.31 MPa. The values of the flexural strength of the five composite samples obtained in this study are way higher than that of concrete masonry for partition wall.

Compressive strength of composite ranged from 9.4-29.0 MPa. 1layer RPF-GNS/3% Clay composite had the highest compressive strength of 29.0 MPa, 2layer RPF-GNS/6% Clay composite gave compressive strength of 22.0 MPa. Therefore, the compressive strength of three of the composite samples have met the minimum compressive strength requirements for partition wall.

The impact strength values ranged from 0.70-3.60 J/mm$^2$ in the composites. 3layer RPF-GNS/9% Clay composite gave highest impact strength of 3.60 J/mm$^2$ in the composite. The impact strength obtained in this composite from all samples is higher than that of ply wood used for partition wall. Based on the results, obtained from the study, the results suggest the composite has sufficient mechanical properties suitable as an alternative construction material for partition walls.

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