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# Determination of Some Structural Properties (Flexure And Shear Strength) of Rice Husk/ Palm Kernel Shell- Plywood Sandwich Slab

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**ABSTRACT:** This study exhibits the structural properties (flexure and shear strength) of a sandwich slab made of plywood and rice husk/palm kernel shell. There are concerns about the rising population and the high cost of building materials thereby initiating a need for other affordable materials. The flexural strength and shear strength of the plywood sandwich slab and the traditional slab were tested using the Magnus frame and the T-flange pump, respectively. The average flexural strengths for a 12.5mm plywood thickness with a 100mm plywood sandwich slab thickness of the mix ratios 0.33:1:3, 0.33:1:1, 0.33:1:2, 0.33:2:1, and 0.33:3:1 are 4.27MPa, 4.11MPa, 3.82MPa, 3.66MPa, and 3.76MPa, while the average flexural strength for a 12.5mm conventional slab with a 100mm slab thickness of standard mix ratio 0.45:1:2:4 is 4.68MPa. The average shear strengths for a 12.5 mm plywood thickness with a 100 mm plywood sandwich slab thickness of the mix ratios: 0.33:1:3, 0.33:1:1, 0.33:2:1, 0.33:3:1, are 1.07 N/mm, 1.03 N/mm, 0.96 N/mm, 0.92 N/mm, and 0.94 N/mm. In contrast, the average shear strength for a 12.5 mm conventional slab with a 100 mm slab thickness of standard mix ratio 0.45:1:2:4 is 0.13 N/mm. It is evident that there is a percentage difference of 8.76% to 21.79% between the conventional slab and the rice husk/palm kernel shell plywood sandwich slab. Additionally, the flexural strength of the rice husk/palm kernel shell plywood sandwich slab is increased to 21.79%. The modelling outcome suggest that the variables in the experiment (shear strength, flexural strength, and crushing load) are highly interrelated. Sandwich slabs made of plywood made of rice husk and palm kernel shell can be utilized for lightweight structural elements that don't need to support heavy loads because they weigh significantly less than traditional slab.

**KEYWORDS**: Plywood sandwich slabs, flexural strength, shear strength and conventional slab.

## I. INTRODUCTION

Concrete is the most consumed man made material in the world (Naik, 2008). Concrete, a ubiquitous material in modern construction, provides strength and durability to infrastructure worldwide (Mindess, Young & Darwin, 2003). Its versatility allows for a wide range of applications from skyscrapers to highways, making it very useful in contemporary engineering (Mehta & Monteiro, 2013). Concrete is a composite material formed by combining cement, sand, coarse aggregate, and water in good proportions to get desired strength (Dahiru, Yusuf & Paul, 2018). Concrete in its hardened state is a brittle material, strong in compression but weak in tension (Singh, 2008).

Despite the ubiquity of concrete, researches are ongoing to resolve issues of sustainability and environmental impact (Scrivener, Crumble, & Laugesen, 2018). Another issue of concern is the high cost of concreting materials, hence, the need to look for more affordable and environment friendly alternatives.

Rice husk/Palm kernel shell-Plywood sandwich slab are composite material made up of Resins, Rice husk, Palm kernel and Plywood. In particleboard or sandwich production, adhesives play vital role in bonding the particles together. One material that can be used as an adhesive is Epoxy.

Epoxy plays a crucial role in various industries including construction, aerospace and electronics (Choudalakis & Galiotis, 2020). Epoxies form durable andresilient bonds (Rafiee, Asgari & Ajdari, 2019). Epoxies are created by polymerizing a mixture of two starting compounds, the resin and the hardener. When resin is mixed with a specified catalyst, curing is initiated.

Despite their promise as sustainable building materials, rice husk and palm kernel shell are common agricultural byproducts that are frequently underutilized (Smith, Johnson, & Lee, 2010). An increasing number of people are interested in investigating its use in structural engineering, especially in sandwich slab building, as of late. With the ability to lower material usage and carbon impact, sandwich slabs made of plywood skins and rice husk/palm kernel shell

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cores provide a lightweight and environmentally beneficial substitute for conventional concrete slabs (Jones & Patel, 2012).

For these sandwich slabs to be used effectively in construction, it is essential to comprehend their structural characteristics (Johnson & Lee, 2008). Two important factors influencing sandwich slab performance are flexural strength, or a material's capacity to tolerate bending, and shear strength, or a material's resistance to forces parallel to its surface. Engineers can optimize the design of rice husk/palm kernel shell-plywood sandwich slabs and assure their safe and effective use in a variety of structural applications by looking at the flexural and shear strengths of these materials.

## II. MATERIALS AND METHODS

The study entails laboratory investigation details of the materials and methods used in the research are presented as follows:

**Materials:**

The materials used in this research are: Rice husk, Palm kernel shell, Plywood, Epoxy resin, Aggregate, Cement and Water. Details of the types and nature of these materials are as follows:

**Rice husk**

The Rice husk was obtained from a rice milling company in Abakiliki, Ebonyi State.

**Palm kernel shell**

The Palm kernel shell was obtained from a local palm oil processing farm at Eziobodo in Imo state.

**Plywood**

The Plywood(2400mm x 1200mmx12.5mm) used for the research were obtained from the wood processing market in Ogbo-osisi, Owerri North, Imo state, Nigeria.

**Epoxy Resin (A resin and B hardener)**

The Epoxy resin was purchased from De-Paragon Chuks ventures off 195 Fox road Aba (Chemical zone A).

**Aggregates.**

The aggregates used in this research work were coarse aggregate and fine aggregate. The coarse and fine aggregates were purchased from tipper stand along Naze road at owerri. The maximum diameter of fine aggregates was 5mm while that of the coarse aggregate was 19mm.

**Cement**

The cement used was ordinary Portland cement and was purchased from a dealer in Owerri.

**Water**

Water used for this research work was obtained from a borehole within the premises of Federal University of Technology, Owerri, Imo State. The water is potable and conforming to the standard of BS EN 1008: (2002). Since it meets the standard for drinking, it is also good for making and curing concrete.

**Methods**

The Rice husk/palm kernel shell plywood sandwich slab was manually mixed using ratios of 0.33:1:3, 0.33:1:1, 0.33:3:1, 0.33:2:1, and 0.33:1:2 for epoxy resin (resin A and hardener B), rice husk, and palm kernel shell respectively. The conventional slab mix ratio was 0.45:1:2:4 for water cement ratio, cement, sand, and coarse aggregates respectively. See Figure 1 for a schematic diagram of the mixing method.

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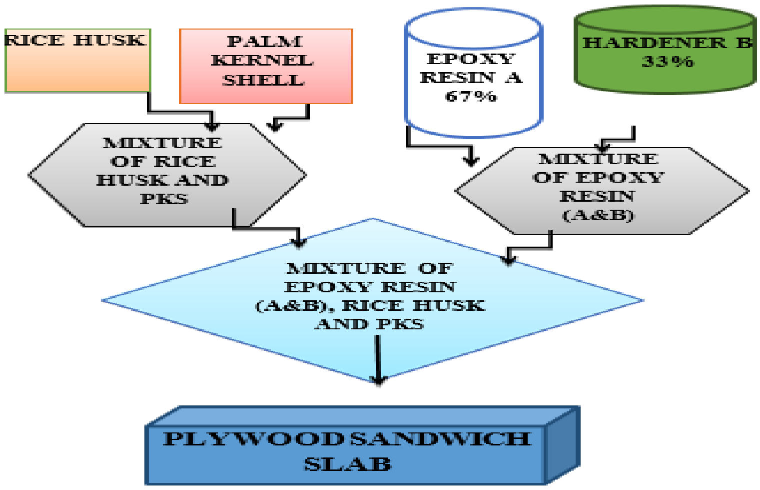


**Figure 1: Flow chart showing the production process**

The plywood sandwich slab molds were cut into 600x600x100mm sizes and assembled using nails and stirrups. Stirrups, spaced 150mm apart, ensured proper bonding between the sawdust/palm kernel shell composite and plywood. Conventional slabs, also 600x600x100mm, used a standard mix ratio of 0.45:1:2:4. Rice husk/palm kernel shell plywood sandwich slabs, also 600x600x100mm, were manually mixed and vibrated for compaction. Fifteen slabs, three from each mix ratio, were produced. Curing methods differed: conventional slabs were water-sprayed for 7 days, while sandwich slabs were air-cured. Magnus frame tests determined flexural strength using Equation (1.0).

**a. Flexural Strength Test of Both Slabs**

Flexural strength tests were carried out in order to determine the Flexural strength of the Sandwich slab, the test was carried out in according to BS EN 12390-5:2000. The flexural strength $f_t$ (in N/mm2) is given by the Equation 1.0

$$F_t = \frac{F}{bd^2} \quad (1.0)$$

Where,

F = the crushing load (N), a = clear distance between the bearing support, b = breath, d = thickness

**b. Shear Strength Test of both slabs**

This is a measure of the ability of the slab to resist shearing and it can be determined from a flexural test and is given as in Equation 2.0

$$f_s = \frac{F}{A} \quad (2.0)$$

Where fs = shear strength, F = shear load at failure, A= cross- sectional area of the test specimen

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## III. RESULTS AND DISCUSSIONS

**Result presentation**

The results obtained for structural characteristics of sawdust/ palm kernel shell plywood sandwich slab are presented here.

**a. Flexural Strength Test**

The flexural strength test for both the sandwich slab and the conventional slab was carried out as specified in the methods section, and table 1and 2 presents the results obtained.

**Table 1: 7th Day Flexural Strength Test Results on Rice husk/Plywood Sandwich Slab**

| Mix Ratios | Sample Size(mm) | Sample Number | Crushing Load(KN) | Flexural Strength(Mpa) | Average Flexural Strength(Mpa) |
|---|---|---|---|---|---|
| 0.33:1:3 | 600X600X100 | A | 67.50 | 4.50 | 4.27 |
| 0.33:1:3 | 600X600X100 | B | 64.50 | 4.30 | |
| 0.33:1:3 | 600X600X100 | C | 60.00 | 4.00 | |
| 0.33:1:1 | 600X600X100 | A | 63.00 | 4.20 | 4.11 |
| 0.33:1:1 | 600X600X100 | B | 60.00 | 4.00 | |
| 0.33:1:1 | 600X600X100 | C | 62..00 | 4.13 | |
| 0.33:3:1 | 600X600X100 | A | 58.50 | 3.90 | 3.76 |
| 0.33:3:1 | 600X600X100 | B | 54.30 | 3.62 | |
| 0.33:3:1 | 600X600X100 | C | 56.10 | 3.75 | |
| 0.33:2:1 | 600X600X100 | A | 57.30 | 3.82 | 3.66 |
| 0.33:2:1 | 600X600X100 | B | 54.20 | 3.61 | |
| 0.33:2:1 | 600X600X100 | C | 53.20 | 3.55 | |
| 0.33:1:2 | 600X600X100 | A | 58.40 | 3.90 | 3.82 |
| 0.33:1:2 | 600X600X100 | B | 56.30 | 3.75 | |
| 0.33:1:2 | 600X600X100 | C | 57.30 | 3.82 | |

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**Table 2:** 7th Day Flexural Strength results for Convention slab

| Mix Ratio | Thickness of Slab(mm) | Sample No | Crushing Load(KN) | Flexural Strength(Mpa) | Average Flexural Strength(Mpa) |
|---|---|---|---|---|---|
| 1:2:4 | 100 | A | 48.50 | 4.60 | 4.68 |
| 1:2:4 | 100 | B | 48.50 | 4.65 | |
| 1:2:4 | 100 | C | 50.00 | 4.80 | |

**b. Shear Strength Test**

The Shear strength test for both the sandwich slab and the conventional slab was carried out as specified in the methods section. Table 3 and Table 4 shows the results obtained for rice husk/palm kernel shell sandwich slab and the conventional slab respectively.

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**Table 3: 7th Day Shear Strength Test Results on Rice husk/Plywood Sandwich Slab.**

| Mix Ratio | Sample No | Weight Of Sample (kg) | Crushing load (KN) | Flexural strength (MPa) | Shear Strength ($N/mm^2$) | Average Shear Strength ($N/mm^2$) |
|---|---|---|---|---|---|---|
| 0.33:1:3 | A | 4.15 | 67.50 | 4.50 | 1.13 | 1.07 |
| 0.33:1:3 | B | 4.24 | 64.50 | 4.30 | 1.07 | |
| 0.33:1:3 | C | 4.10 | 60.00 | 4.00 | 1.00 | |
| 0.33:1:1 | A | 4.24 | 63.00 | 4.20 | 1.05 | 1.03 |
| 0.33:1:1 | B | 4.10 | 60.00 | 4.00 | 1.00 | |
| 0.33:1:1 | C | 4.15 | 62.00 | 4.13 | 1.03 | |
| 0.33:3:1 | A | 4.10 | 58.50 | 3.90 | 0.98 | 0.94 |
| 0.33:3:1 | B | 4.15 | 54.30 | 3.62 | 0.91 | |
| 0.33:3:1 | C | 4.20 | 56.10 | 3.75 | 0.94 | |
| 0.33:2:1 | A | 4.24 | 57.30 | 3.82 | 0.96 | 0.92 |
| 0.33:2:1 | B | 4.20 | 54.20 | 3.61 | 0.90 | |
| 0.33:2:1 | C | 4.15 | 53.20 | 3.55 | 0.89 | |
| 0.33:1:2 | A | 4.20 | 58.40 | 3.90 | 0.97 | 0.96 |
| 0.33:1:2 | B | 4.10 | 56.30 | 3.75 | 0.94 | |
| 0.33:1:2 | C | 4.15 | 57.30 | 3.82 | 0.96 | |

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**Table 4: 7TH Day Shear Strength of Conventional Slab**

| Mix Ratio | Sample No | Crushing Load (KN) | Flexural Strength (Mpa) | Shear Strength ($N/mm^2$) | Average Shear Strength ($N/mm^2$) |
|---|---|---|---|---|---|
| 1:2:4 | A | 48.50 | 4.60 | 0.81 | 0.82 |
| 1:2:4 | B | 48.50 | 4.65 | 0.81 | |
| 1:2:4 | C | 50.00 | 4.80 | 0.83 | |

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**c. Modelling outcome**

A regression model was formulated and the outcome of the analysis are shown below.

**i. Shear strength vs Flexural strength**

Obtained equation: Y= 0.247X + 0.0131 (3.0)

The summary analysis is shown in figure 2 below.

SUMMARY OUTPUT

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.998581174 |
| R Square | 0.99716436 |
| Adjusted R Squ | 0.996946234 |
| Standard Error | 0.003684585 |
| Observations | 15 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *gnificance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.0620635 | 0.06206 | 4571.5 | 6E-18 |
| Residual | 13 | 0.0001765 | 1.4E-05 | | |
| Total | 14 | 0.06224 | | | |

| | *Coefficients* | *tandard Erro* | *t Stat* | *P-value* | *.ower 95%* | *Jpper 95%* | *ower 95.0%* | *pper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.013055166 | 0.0143623 | 0.90899 | 0.3799 | -0.01797 | 0.04408 | -0.01797 | 0.04408 |
| Flexural streng | 0.246969796 | 0.0036527 | 67.6129 | 6E-18 | 0.23908 | 0.25486 | 0.23908 | 0.25486 |

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**ii. Shear strength vs crushing load**

Obtained equation: Y= 0.0164X + 0.0154 (4.0)

The outcome is shown in the figure below.

SUMMARY OUTPUT

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.99853 |
| R Square | 0.99707 |
| Adjusted R Square | 0.99685 |
| Standard Error | 0.00375 |
| Observations | 15 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *gnificance F* |
|---|---|---|---|---|---|
| Regression | 1 | 0.06206 | 0.06206 | 4424.47 | 7.4E-18 |
| Residual | 13 | 0.00018 | 1.4E-05 | | |
| Total | 14 | 0.06224 | | | |

| | *Coefficient:* | *andard Err* | *t Stat* | *P-value* | *.ower 95%* | *Jpper 95%* | *ower 95.0* | *pper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.01544 | 0.01456 | 1.06016 | 0.30837 | -0.01602 | 0.0469 | -0.01602 | 0.0469 |
| Crushing load(KN) | 0.01643 | 0.00025 | 66.5167 | 7.4E-18 | 0.01589 | 0.01696 | 0.01589 | 0.01696 |

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**iii. Flexure vs crushing load**

Obtained equation: Y= 0.0665X + 0.0098 (5.0)

The summary outcome is shown in the figure below

SUMMARY OUTPUT

| Regression Statistics | |
|---|---|
| Multiple R | 0.999913183 |
| R Square | 0.999826374 |
| Adjusted R Squar | 0.999813018 |
| Standard Error | 0.003686462 |
| Observations | 15 |

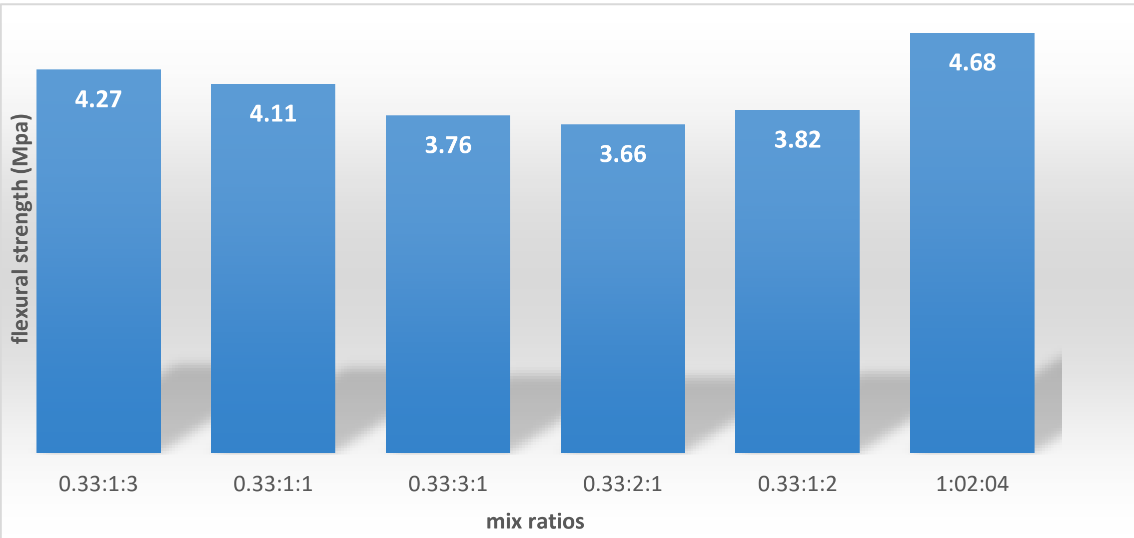
ANOVA

| | df | SS | MS | F | gnificance F |
|---|---|---|---|---|---|
| Regression | 1 | 1.01736 | 1.01736 | 74860.7 | 7.8E-26 |
| Residual | 13 | 0.00018 | 1.4E-05 | | |
| Total | 14 | 1.01753 | | | |

| | Coefficients | andard Err | t Stat | P-value | .ower 95% | Jpper 95% | ower 95.0% | pper 95.0% |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.00980914 | 0.01434 | 0.68427 | 0.50582 | -0.02116 | 0.04078 | -0.02116 | 0.04078 |
| Crushing Load(KN | 0.066511288 | 0.00024 | 273.607 | 7.8E-26 | 0.06599 | 0.06704 | 0.06599 | 0.06704 |

sed nix Pa, nm

conventional slab with 100mm slab thickness of standard mix ratio 0.45:1:2:4 has an average flexural strength of 4.68MPa. Therefore, the resistance to bending stress in flexure of rice husk/ palm kernel shell plywood sandwich slab is less compared to that of the conventional slab. This outcome is shown in the chart below.




**b. Analysis of Results of Shear Strength Plywood Sandwich Slab and Conventional Slab**

The Shear Strength for plywood sandwich slab and conventional slab is discussed below:

For a 12.5mm plywood thickness with a 100mm plywood sandwich slab thickness of the mix ratios: 0.33:1:3, 0.33:1:1,

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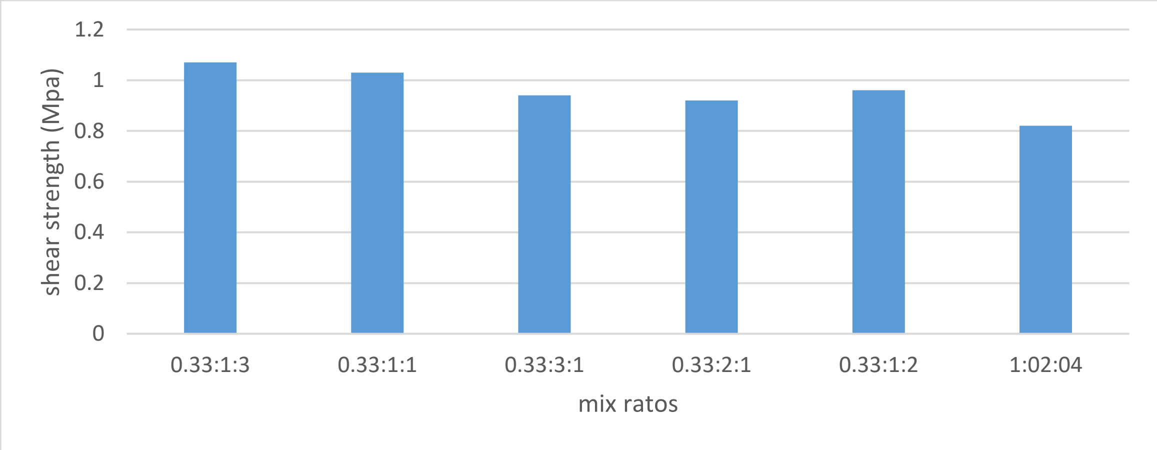
0.33:1:2, 0.33:2:1, 0.33:3:1, has average shear strengths of 1.07N/mm2, 1.03N/mm2, 0.96N/mm2, 0.92N/mm2, 0.94N/mm2 ,the maximum and minimum are 1.07 and 0.92 N/mm2 respectively. While for a 12.5mm conventional slab with 100mm slab thickness of standard mix ratio 0.45:1:2:4 has average shear strength of 0.82N/mm2. This shows that the resistance to shear stress of sawdust/palm kernel shell plywood sandwich slab is higher compared to that of the conventional slab. Therefore, it can resistance more than the conventional slab. This outcome is shown in the chart below.




**c. Modelling outcome**

From the outcomes, it's evident that there are strong correlations between the variables involved in the experiment, namely shear strength, flexural strength, and crushing load. Here's a breakdown of the findings:

a. Shear Strength vs. Flexural Strength:
- Multiple R: 0.998
- R Square: 0.997
- Adjusted R Square: 0.9967
- Standard Error: 0.0036

This indicates an extremely strong linear relationship between shear strength and flexural strength. The high R square value (0.997) suggests that 99.7% of the variation in flexural strength can be explained by the variation in shear strength.

b. Shear Strength vs. Crushing Load:
- Multiple R: 0.998
- R Square: 0.997
- Adjusted R Square: 0.9967
- Standard Error: 0.0036

Again, there's a strong linear relationship between shear strength and crushing load. The high R square value suggests that 99.7% of the variation in crushing load can be explained by the variation in shear strength.

c. Flexural Strength vs. Crushing Load:
- Multiple R: 0.999
- R Square: 0.999
- Adjusted R Square: 0.999
- Standard Error: 0.0036

This indicates an even stronger linear relationship between flexural strength and crushing load compared to the other relationships. The exceptionally high R square value (0.999) suggests that 99.9% of the variation in crushing load can be explained by the variation in flexural strength.

## IV. CONCLUSIONS

The study examined the viability of utilizing waste materials like rice husk, palm kernel shell and plywood using epoxy as an adhesive in the production of sandwich slab. From the results of flexural strength, shear strength, and the percentage

difference between rice husk/palm kernel shell plywood sandwich slab and the conventional slab, the conclusion was drawn.
The average flexural strength of plywood sandwich slab ranges from 3.66Mpa to 4.67Mpa, while that of conventional slab ranges from 4.60Mpa to 4.80Mpa. Therefore, the resistance to bending stress in flexure of rice husk/ palm kernel shell plywood sandwich slab is less compared to that of the conventional slab. In addition, rice husk/ palm kernel shell plywood sandwich slab can be used for light structural members that are not carrying much loads and the weight is much less compared with those of conventional slabs.
The average shear strength results of plywood sandwich slab ranges from 1.07N/mm2 to 0.92N/mm2, while that of the conventional slab ranges from 0.81N/mm2 to 0.83N/mm2. Therefore, the resistance to shear stress of sawdust/palm kernel shell plywood sandwich slab is higher compared to that of the conventional slab. Therefore, it can resistance more than the conventional slab.
The modelling outcome suggest that the variables in the experiment (shear strength, flexural strength, and crushing load) are highly interrelated. Such strong correlations indicate that changes in one variable are highly predictive of changes in another, which can be valuable for understanding and predicting material behaviors in various applications, such as construction or material engineering. Additionally, the consistency in the R square values and adjusted R square values across all relationships further supports the reliability of the regression models.

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