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# Compressive Strength of Bamboo with Variation in Filler Type

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***ABSTRACT :*** *Bamboo has become one of the most widely used materials for building structures and household furniture in tropical areas. Design a bamboo filler mixture that has optimum compressive strength to be used as a structural element, namely a simple building. workability characteristics, elastic modulus and increase in strength. This research uses local bamboo called Petung Bamboo which grows naturally in Luwu Banggai Regency and was chosen to have a minimum diameter of 10 cm. The tests carried out include compressive strength tests, using the same equipment as testing the flexural strength of mortar. From the results of the tests carried out, it can be concluded that Sika Bamboo Mortar shows optimal compressive strength compared to the other four bamboo samples. Therefore, Sika Bamboo Mortar has the potential to become a structural element. This is demonstrated by tests carried out consistently indicating that Sika Mortar Bamboo outperforms the other four bamboo samples in terms of compressive strength with a maximum acceptable compressive strength of 39.68 MPa.*

***KEYWORDS;*** *bammboo,structures,building, materilas, strength*

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## I. INTRODUCTION

The construction of new houses, shophouses and schools has increased drastically so that the need for building materials has also increased, which has led to a scarcity of building materials and has implications for expensive building materials due to high demand and production and distribution constraints. The development of alternative construction materials that are easier to produce locally can increase the development of the infrastructure industry, especially for the construction of housing, schools and shophouses (Amir, F., et al, 2021).

As a result of the need for post-earthquake building materials which have increased in price to date, the right alternative choice is bamboo. According to (Endarto and Zulfiar, 2010), bamboo is a type of organic material consisting of glucose and fiber (cellulose) like wood in general. What makes the difference is the direction of the fibers, so that their benefits and functions as structural elements can be known. The weakness of bamboo is its relatively short lifespan due to exposure to environmental changes, so the use of bamboo as a structural element must be protected. The use of bamboo aggregate has the consequence of reducing the compressive strength value, because bamboo has a high wear rate and ability to expand and shrink, and lower structural strength than conventional aggregate. To anticipate a further decrease in strength due to the limited strength of bamboo, the size of the bamboo aggregate is made in smaller granules so that it has a denser volume. Using bamboo as an aggregate will produce concrete that is lighter than concrete using conventional aggregates, which in turn will make the construction lighter.

Composite bamboo beams according to Amir, F., et al (2021) are an alternative structural element that can be developed as an environmentally friendly, earthquake-resistant building structural component, by adding a mixture of mortar and natural fiber in the form of sawmill waste shavings to pre-preserved bamboo stems. formerly. Wood waste from sawmills was chosen as a mortar mixture because apart from being abundantly available in the city of Palu and its surroundings, this waste has the potential to be further utilized as a filler for fiber concrete. The addition of powdered mortar to bamboo stems is expected to increase the strength, stability and ductility of bamboo as a structural element so that the results of this research are expected to be developed on an industrial scale to encourage the use of local materials in the form of bamboo and sawmill waste as components of earthquake-resistant building structures which not only environmentally friendly but affordable, strong, safe, comfortable and durable.

Bamboo plants have extraordinary resilience. Even after a bamboo grove is burned, it is still able to grow again. Bamboo has sufficient strength, it can even compete with steel in terms of tensile strength. Even so, the high strength of bamboo has not been fully utilized because generally the stems of bamboo structures are connected with pegs or ropes which have lower strength. Bamboo is shaped like a pipe so the moment of inertia is high, therefore bamboo is good enough to withstand bending moments. Coupled with the elastic nature of bamboo, bamboo structures have high resistance to earthquake forces. Apart from that, it can also be considered the possibility of diversifying bamboo products for building construction by developing composite bamboo structural components that combine bamboo with other building materials to increase the strength, stability, ductility and durability of bamboo (Amir, F., et al. 2021). Even though bamboo has many advantages , it is important to remember that the effort to replace wood.

Bamboo without preservation can only last less than 1-3 years if it is in direct contact with the ground and is not protected from the weather. Bamboo that is protected from weather can last more than 4-7 years. But for an ideal environment, as a frame, bamboo can last more than 10-15 years. Thus, for preserved bamboo, of course its durability will be more than 15 years. The next challenge is related to the weakness of bamboo joints which is usually very low due to the use of conventional methods such as nails, pegs, or palm fiber ropes in arranging bamboo structural rods. In bamboo structures that are arranged using nails or pegs, the parallel fibers have low shear strength, so the bamboo breaks easily due to penetration of the nails or pegs. Connecting using rope really depends on the skill of the implementer. The strength of the connection is only based on the frictional strength between the rope and the bamboo or between one bamboo and another bamboo. Therefore, the use of conventional methods in connecting bamboo produces low strength, so that the potential strength of bamboo cannot be maximized. When the rope loosens due to temperature changes that cause the bamboo to expand or contract, its shear strength decreases, and can cause the building to collapse. Therefore, bamboo connections using ropes need to be checked periodically, and the ropes must always be adjusted so that they do not loosen.

Bamboo with the botanical name Dendrocalamus asper (Schult. F.) Backer ex Heyne in Indonesia is known as petung bamboo. This type of bamboo has rather dense clumps, can grow in the lowlands to mountains with an altitude of 2000 m above sea level. Growth is quite good, especially in areas that are not too dry. The color of the bark is yellowish green. The stem can reach a length of 10-14 m, the length of the segments ranges from 40-60 cm, with a diameter of 6-15 cm, wall thickness of 10-15 mm. Petung bamboo is widely used as building material, boats, chairs, cots, water channels, containers for tapping sugar palm water, walls (gedeg), and various types of crafts.


**Fig** 1. *Dendrocalamus asper (Schult. F.) Backer ex Heyne* or petung bamboo

As a building material, the physical properties that need to be known are the swelling and shrinkage properties so that building components can be designed in such a way that they do not experience excessive changes in shape as a result of changes in temperature/humidity. Excessive changes in the shape of structural components not only cause damage to other building components, such as breaking window glass, making doors/windows difficult to open, and reducing the beauty of the building. Fatal consequences can occur when using bamboo as concrete reinforcement. Bamboo reinforcement will shrink after the bamboo dries. This can cause the bond between the concrete and the reinforcement to become loose, so that the reinforcement can escape

Research on bamboo flowering shrinkage due to temperature changes was carried out by Cox and Geymayer (Janssen, 2012) in (Abdulrahman et al., 2019). In Method I, the swelling-shrinkage measurement parallel to the fiber is carried out with a mechanical strain gage. The specimen is coated with wax. Readings indoors at a constant temperature of 38oC and outdoors at –2oC, were each taken after the specimen had been subjected to this temperature treatment for three hours. Method II is carried out by inserting the wax-coated specimen into oil whose temperature can be controlled, namely at 10oC and 38oC for several hours. Method III is carried out with readings like Method II, but the specimen is inserted into a steel tube so that the specimen remains straight and does not experience warping. The results of this research are presented in Table 1

**Table 1. Water content and swelling-shrinkage coefficient based on Cox and Geymayer**

| Eksperiment | n | Water content (%) | | Swell/shrink coefficient | | | |
|---|---|---|---|---|---|---|---|
| | | | | Perpendicular to the Fiber | | Fiber Direction | |
| | | Average | Deviation Standard | Average | Deviation Standard | Average | Deviation Standard |
| 1 | 3 | 12,18 | 1,49 | - | - | 4,12 | 0,27 |
| 2 | 4 | 14,54 | 0,47 | 54,54 | - | 4,07 | 0,86 |
| 3 | 5 | 13,73 | 0,83 | 42,66 | 3,80 | 2,56 | 1,17 |

source: (Janssen, 1991) n = number of specimens

## II. RESEARCH METHODS

Research on the water content of bamboo has also been carried out by Zhou Fangchun from China. The research was carried out on fresh bamboo, while the water content of each bamboo was measured at ten positions. Specimen number 0 indicates the base position, while number 10 indicates the top. The regression of water content along the stem can be presented with Equation 2.1

Water content = 94.5 – 12.7*H + 1.6*H2 – 0.88*H3 ……………………………………………………..….(1)

Bamboo water content is influenced by age and where it grows. To prove this, research was conducted by Lu Xiuxin et. All (1985) in (Ramdhani & Pribadi, 2016). Each type of test and each area of origin of bamboo uses more than 200 specimens. Bamboo was taken from four areas in Handong Province, from 1–7 years old. The results of the experiments carried.The swelling and shrinkage properties and water content of bamboo are quite important in the application of petung bamboo as concrete reinforcement, Morisco et al. (2000) in (Oka, 2005) have measured the water content of Apus bamboo, Ori bamboo, Petung bamboo and Wulung bamboo. Specimens were taken from the base, middle and tip. The bamboo shrinkage expansion test carried out is the overall reinforcement volume shrinkage test, which is a combination of radial and tangential shrinkage expansion. Swelling shrinkage is calculated on the dry volume of air, because this condition is considered to be a condition that approaches the application of bamboo as concrete reinforcement. The steps are as follows.

### II.1. Compressive Strength Parallel to the Fiber

The strength of bamboo to withstand compressive forces depends on the segments and sections between the segments of the bamboo stem. According to ISO 3132-1975, with the size of the test object as in Figure 8, it can be calculated using equation 2.

$$\sigma = \frac{Fult}{A}\left(\frac{N^2}{mm}\right) \qquad \text{...............................................}\dots\dots\dots\dots\dots\dots\dots(2)$$

Information:

$\sigma$ = Compressive Strength Parallel to the Fiber (MPa)

$F_{ult}$ = Bamboo Maximum Compressive Load (N)

A = Thickness x Width = Area of the stressed area ($mm^2$)

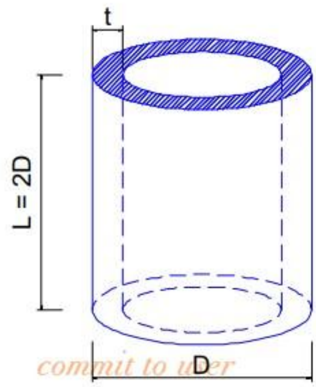

**Fig.2**. Compressive Strength Test Objects Parallel to Fibers

### II.2. Data Collection Techniques

The data collection technique was carried out by calculating the proportions of the mortar mixture in the research referring to (ASTM) C305 based on (Nurasih, 2009) (Table 1) which basically must meet the requirements for water durability. Cement paste consisting of a mixture of cement and water is a binding agent for sand and wood shavings to obtain a mortar mixture that is smooth and easy to work with (workability). The low shear strength makes it difficult to test the tensile strength of bamboo, the specimens easily break due to shear before the tensile strength is exceeded. Therefore, tensile test specimens have to be made to special sizes that do not comply with ASTM, ISO, British Standard, or other standards. This special size concerns the width of the specimen which is only around 1-2mm.

To determine the compressive strength of bamboo, specimens with a length twice the diameter are usually used. To test the flexural strength, specimens of varying sizes are used according to the thickness of the bamboo. The width of the specimen is four times the thickness, while the length of the specimen is 16 times the thickness of the bamboo. The unit of stress used in this book is Mega Pascal (MPa) which is equivalent to one Newton per square millimeter, or can be written as follows:

1 MPa = 1 N/mm2 = 10 kg/cm2 ……………………………………………………………………………….. (3)

The amount of water used can be expressed in terms of weight or volume units. In normal practice, water is usually measured in volume units, namely liters. The quantity (amount) of water to be used for mortar of a certain quality must be calculated after assessing the humidity (water content) of the fine aggregate and coarse aggregate. The moisture content of the aggregate will reduce the amount of water required for the mortar mixture. On the other hand, sometimes the aggregate can absorb water from the mortar mixture. In this case, it is necessary to find a way to overcome this absorption, namely by increasing the amount of water that needs to be added to the mortar mixture. Requirements for water used as a mixture of building materials

Testing of mortar, concrete, bamboo husk ash mortar and sika mortar for building construction is limited to testing compressive strength only.

### II.3. Testing Mortar, Concrete, Husk Ash Mortar, Sika Mortar, Powder Mortar

Testing of mortar, concrete, bamboo husk ash mortar and sika mortar for building construction is limited to testing its compressive strength only. Testing of mortar, concrete, husk ash mortar and sika mortar begins with testing samples 1, 2 and 3 of the required amount for the mortar mixture , concrete, husk ash mortar and sika mortar so it is necessary to mix the design several times as needed to obtain the optimum percentage which is expected to produce maximum compressive strength. After that, mortar viscosity and compressive strength tests were carried out (Figures 2 and 3) for each type of composition by referring to SNI 03-6825-2002 concerning Testing Methods for Compressive Strength of Portland Cement Mortar for Civil Engineering Works.

fig 3. Tools for Testing Mortar Viscosity

Fig 4. Mortar Compressive Strength Test Equipment

### II.4. Bamboo Compressive Strength Testing

The bamboo used in this research is local bamboo with the name Petung Bamboo which grows naturally in Luwu Banggai Regency and was chosen to have a minimum diameter of 10 cm. Tests carried out include compression tests (compressive strength) referring to ASTM D695 (Norma, 1991) using the same equipment as testing the flexural strength of mortar

## III. RESEARCH METHODS

### III.1. Normal Mortar Compressive Strength Test

In this research, a test was carried out on the compressive strength of the mortar to serve as a comparison material to find out how much the sample increased or decreased. From the test results, the normal mortar compressive strength value was obtained, respectively, from sample 1 of 7.35 MPa, sample 2 of 11.36. MPa and sample 3 was 9.41 MPa with the average value of the three samples being 9.37 MPa. It can be seen from the picture above that the condition of the normal mortar sample tested was destroyed from top to bottom of the sample at the maximum load received on sample 1 of 75,000 N. , sample 2 is 116000 N and sample 3 is 96000

**Table 2. Normal mortar compressive strength test results**

| Sampel Number | Sample weight (kg) | Code Sample | Diameter (mm) | Hihg (mm) | Pressure Test results (N) | Container area ($mm^2$) | Compressive Strength (Mpa) |
|---|---|---|---|---|---|---|---|
| 1 | 4,45 | MN | 114 | 228 | 75000 | 10207,03 | 7,35 |
| 2 | 4,45 | MN | 114 | 228 | 116000 | 10207,03 | 11,36 |
| 3 | 4,4 | MN | 114 | 228 | 96000 | 10207,03 | 9,41 |

### III.2 Normal Concrete Compressive Strength Test

Normal concrete compressive strength testing aims to determine the compressive strength of concrete which will be used as a comparison with mortar samples. The concrete used is low quality concrete, namely concrete K125 or fc 9.8 MPa. And we can see the test results in the following table.

**Table 3. Concrete compressive strength test results**

| Sampel Number | Sample weight (kg) | Code Sample | Diameter (mm) | Hihg (mm) | Pressure Test results (N) | Container area ($mm^2$) | Compressive Strength (Mpa) |
|---|---|---|---|---|---|---|---|
| 1 | 4,42 | BN | 114 | 228 | 95779 | 10207,03 | 9,38 |
| 2 | 4,67 | BN | 114 | 228 | 89210 | 10207,03 | 8,74 |
| 3 | 4,55 | BN | 114 | 228 | 89456 | 10207,03 | 8,76 |

From the test results, the normal concrete compressive strength value for sample 1 was 9.38 MPa, sample 2 was 8.74 MPa and sample 3 was 8.76 MPa with the average compressive strength value of the 3 samples being 8.96 MPa.

**Fig 4. test results for normal concrete samples**

### III.3. Testing for Compressive Strength of Blank Bamboo

Testing the compressive strength of empty bamboo aims to determine the compression of the type of bamboo used as research material. The bamboo used in this research is Betung bamboo or in Latin it is called (Dendrocalamus asper (Schult.) Backer). And the test results can be seen in the following table 4.

**Table 4. Test results for empty bamboo or normal bamboo**

| Sampel Number | Sample weight (kg) | Code Sample | Diameter (mm) | Hihg (mm) | Pressure Test results (N) | Container area ($mm^2$) | Compressive Strength (Mpa) |
|---|---|---|---|---|---|---|---|
| 1 | 1,83 | BNN | 130 | 260 | 138000 | 5419,25 | 25,46 |
| 2 | 1,50 | BNN | 138 | 276 | 130000 | 5453,80 | 23,84 |
| 3 | 1,55 | BNN | 135 | 270 | 125000 | 5489,15 | 22,77 |

The results of testing the compressive strength of Bamboo Powder with a mixture composition of 2% of the total weight of sand used to make the three samples showed that the compressive strength value of sample 1 was 38.52 MPa with a maximum acceptable load of 315,000 N, sample 2 was 40.84 MPa with The maximum load that can be accepted is 339,000 N and sample 3 is 35.74 MPa with a maximum load that can be accepted is 310,000 N. The condition of the sample after testing, the bamboo sample cracked and broke followed by the mortar mixture being destroyed in the sample.

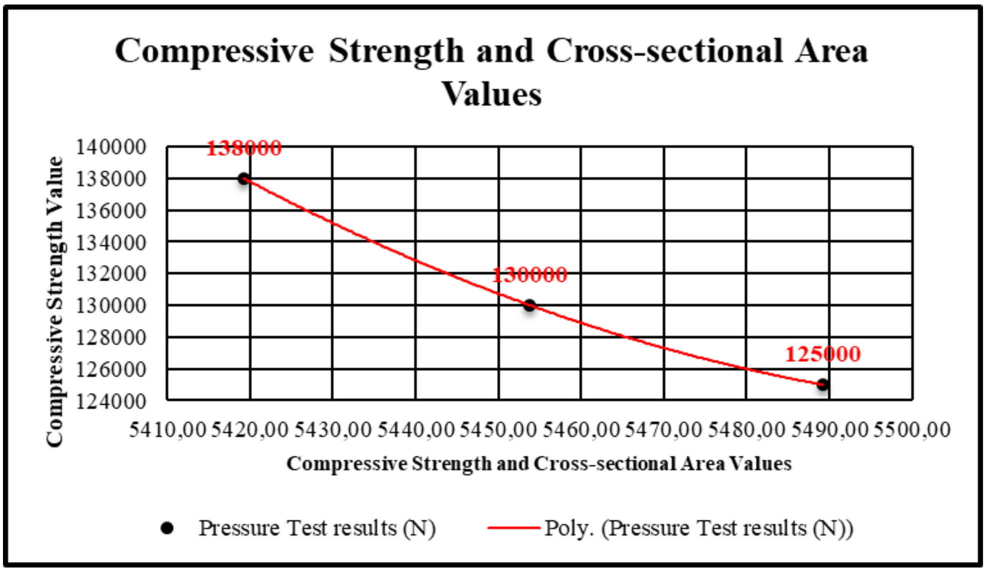


**Fig.5. Graph of test results for normal bamboo compressive strength values vs. cross-sectional area**

### III.4. Testing for Compressive Strength of Bamboo Concrete

The compressive strength test of bamboo concrete was carried out to find the comparative value between Bamboo Concrete and Bamboo Mortar samples. For test results, we can see the following table.

**Table 5. Test results for compressive strength of Bamboo Concrete**

| Sampel Number | Sample weight (kg) | Code Sample | Diameter (mm) | Hihg (mm) | Pressure Test results (N) | Container area ($mm^2$) | Compressive Strength (Mpa) |
|---|---|---|---|---|---|---|---|
| 1 | 2,90 | BKB | 106 | 212 | 182000 | 8824,73376 | 34,91 |
| 2 | 3,05 | BKB | 108 | 216 | 160000 | 9160,88418 | 29,56 |
| 3 | 3,5 | BKD | 105 | 210 | 128000 | 8659,01475 | 25,02 |

From the results of testing the normal compressive strength of Bamboo Concrete, the compressive strength value for sample 1 was 34.91 MPa, sample 2 was 29.56 MPa and sample 3 was 25.02 MPa with an average value of 29.83 MPa. From the graph of test results for Bamboo Concrete samples, the highest value is found in sample 1 with a cross-sectional area of 8824.73 mm2.It can be seen that the condition of the Bamboo Concrete sample broke in part of the sample after testing. On the other hand, there were also samples that broke with the maximum load that could be received by sample 1 of 182,000 N, sample 2 of 160,000 N and sample 3 of 128,000 N.

### III.5.Normal Bamboo Mortar Compressive Strength Test

**T**esting the compressive strength of normal Bamboo Mortar was carried out to determine the compressive strength of normal Bamboo Mortar which will be compared with the results of testing the compressive strength of Bamboo Mortar with several mixed variations. The test results can be seen in the following table.

**Table 6. Compressive Strength of Normal Bamboo Mortar**

| Sampel Number | Sample weight (kg) | Code Sample | Diameter (mm) | Hihg (mm) | Pressure Test results (N) | Container area ($mm^2$) | Compressive Strength (Mpa) |
|---|---|---|---|---|---|---|---|
| 1 | 2,85 | BKM | 109 | 218 | 175000 | 9331,32 | 32,34 |
| 2 | 3,10 | BKM | 110 | 220 | 117000 | 9503,32 | 21,23 |
| 3 | 3,30 | BKM | 111 | 222 | 160000 | 9676,89 | 28,51 |

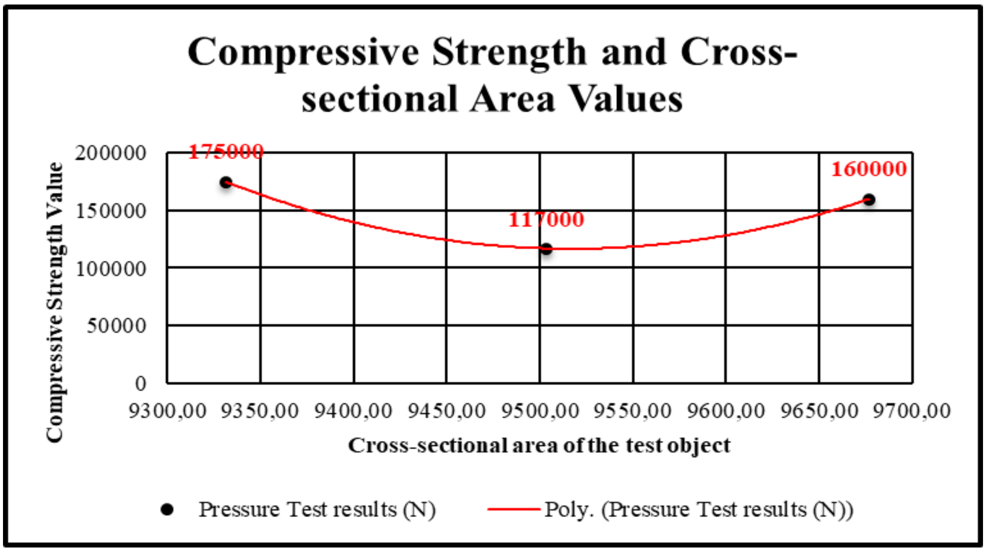


**Fig.6. Test results for Normal Bamboo Mortar Compressive Strength Values Vs Cross-sectional Area**

From the test results, the normal compressive strength value for Bamboo Mortar was obtained, respectively, sample 1 was 32.34 MPa, sample 2 was 21.23 MPa and sample 3 was 28.51 MPa. From the graph of test results for Normal Bamboo Mortar samples, it was obtained that the highest value in sample testing was found in sample 1 with a cross-sectional area of 9331.32 mm2.

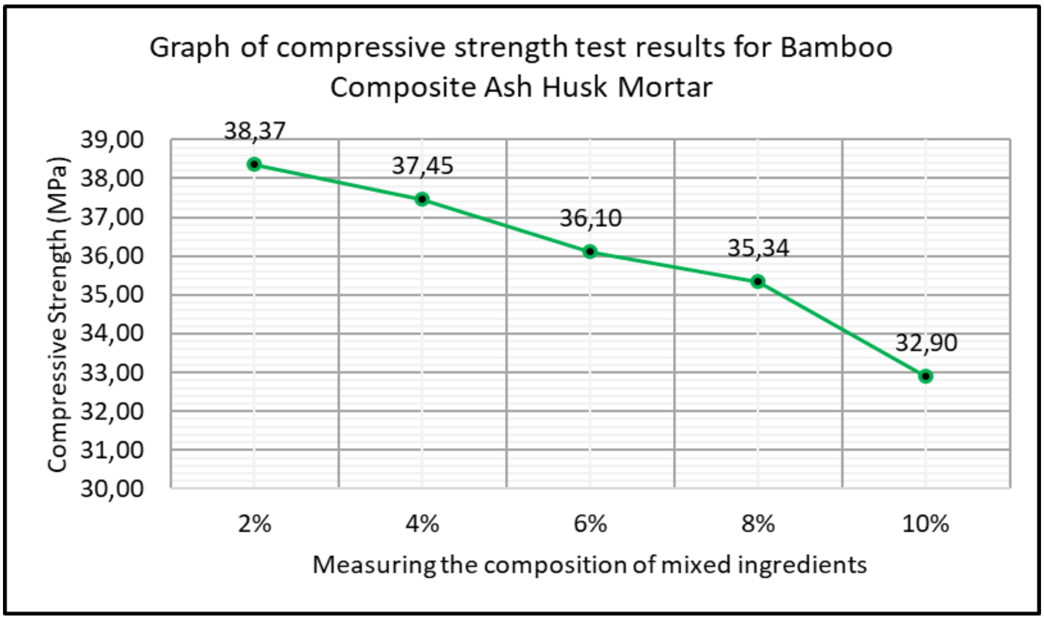


**Fig.7. Graph of compressive strength test results for Bamboo Mortar Powder**

The results of the compressive strength test on Bamboo Mortar with the addition of 2% powder show that this composition produces the highest strength value compared to other composition variations. However, even though it has high strength, this composition is still not effective in its use as part of construction and cannot be recommended for use in construction that requires long-term reliability and durability. This is due to uncertainties in material performance over time, especially in construction situations that face variations in temperature, humidity, and dynamic loads.

The high strength but uncertainty in powder material characteristics of as much as 2% makes this composition less suitable for construction that expects long-term durability and predictability. In construction applications that require a high safety factor, it is more advisable to select materials with more stable and reliable mechanical properties under various conditions. Thus, although the compressive strength results show impressive performance, consideration of the overall properties and characteristics of the material remains important in determining whether a composition with a 2% powder addition is suitable for use in a particular construction context.
Kirim masukan

## IV. CONCLUSION

From the results of the tests carried out, it can be concluded that Sika Bamboo Mortar shows optimal compressive strength compared to the other four bamboo samples. Therefore, Sika Bamboo Mortar has the potential to become a structural element. This is demonstrated by tests carried out consistently indicating that Sika Mortar Bamboo outperforms the other four bamboo samples in terms of compressive strength with a maximum acceptable compressive strength of 39.68 MPa.

The workability characteristics of bamboo's natural resistance to pressure and tension make it an attractive alternative to traditional construction materials. In the context of sustainability, bamboo's rapid regeneration ability also contributes to its positive environmental value in construction practices. Knowing the modulus of elasticity of the material is important in designing which type of bamboo mortar is most optimal so that it can be used as a structural element. And to increase the compressive strength, the composition with 10% Sika was able to effectively increase the compressive strength of the sample as evidenced by the compressive strength value of 39.68 MPa. The Sika Mortar Bamboo sample was the strongest of the 4 other bamboo samples.

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