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# Experimental Study of the Use of Banana Stem Fibre in Paving Blocks

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**Abstract**

Construction can be categorized into two main types: structural and non-structural. One example of non-structural construction is paving, commonly utilized for road surfaces in rural areas or residential developments. During the planning phase, non-structural elements are frequently regarded merely as dead loads, without considering the potential interactions with structural components. However, it is important to note that paving is also subjected to dynamic loads. As a widely used material, paving is generally more cost-effective compared to rigid or flexible pavements. Paving can reduce the weight of buildings. Over time, paving technology has introduced numerous innovations in material usage, including the incorporation of waste materials such as bagasse ash, rice husk ash, sawdust, and iron filings. However, some studies have not achieved the expected quality of paving. Consequently, further discoveries have been made to optimize the use of available environmental resources. The objective of this research is to determine the compressive strength of paving blocks enhanced with banana stem fiber. The research methodology employed is experimental, conducted in a laboratory setting in accordance with applicable SNI standards. The test results indicated that the average compressive strength values for the paving blocks were 22.67 MPa at 7 days, 23.96 MPa at 14 days, and 25.12 MPa at 28 days.

**Keywords:** Banana Stem Fibre; Paving Blocks; Compressive Strength

**Abstrak**

Pembangunan konstruksi dibedakan menjadi dua yaitu konstruksi struktural dan non struktural. Konstruksi struktur non-struktural salah satunya yaitu paving yang biasanya digunakan untuk perkerasan jalan di jalan desa atau kompleks perumahan. Dalam perencanaannya komponen non-struktural sering dianggap sebagai beban mati saja, tanpa melihat interaksi yang dapat ditimbulkan terhadap komponen struktural. Padahal untuk paving juga dilewati beban dinamis. Sebagai material yang cukup populer, paving memiliki harga yang lebih murah dibandingkan rigid pavement atau flexible pavement. Paving dapat membuat bangunan menjadi lebih ringan. Dalam perkembangannya, teknologi paving telah banyak melakukan inovasi dalam penggunaan bahannya, seperti pemanfaatan limbah yang tidak terpakai, seperti penggunaan abu ampas tebu, abu sekam padi, serbuk gergaji, serbuk besi, dll. Namun, studinya terkadang belum mencapai kualitas paving yang diinginkan, dan penemuan lain dilakukan untuk memaksimalkan penggunaan lingkungan yang tersedia. Tujuan dari penelitian ini untuk mengetahui seberapa kuat nilai uji tekan pada paving block yang di innovasikan dengan serat pelepah pisang. Metode penelitian yang digunakan berupa eksperimental di laboratorium dengan SNI yang berlaku. Hasil dari pengujian didapatkan nilai kuat tekan dalam usia paving 7 hari didapatkan rata-rata sebesar 22,67 MPa, 14 hari sebesar 23,96 MPa, dan 28 hari sebesar 25,12 Mpa.

**Kata Kunci:** Serat Pelepah Pisang; Paving Block; Kuat Tekan

## 1. Introduction

Construction is categorized into two main types: structural and non-structural. When planning a structural building, it is crucial to consider various aspects of the construction process. Structural buildings must fulfill requirements related to strength, stiffness, stability, and cost-effectiveness. This includes understanding the types, classifications, and properties of materials used in architectural, structural, mechanical, electrical, and plumbing components. Calculations must also confirm that the building possesses adequate strength and stability to support the loads it will encounter. In contrast, non-structural buildings consist of supplementary components that do not contribute to resisting lateral forces, gravity loads, or the building's envelope. An example of a non-structural component is a wall, which can be constructed from materials such as glass, gypsum, aluminum, fiber, bamboo, plywood, brick, and concrete blocks.

Another non-structural material is paving, which is usually used for pavements in village roads or housing complexes. In planning, non-structural components are often considered as dead loads only, without seeing the interaction that can be caused to structural components. In fact, paving is also subjected to dynamic loads. As a popular material, paving is cheaper than rigid pavement or flexible pavement. Paving can make buildings lighter.


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Throughout its evolution, paving technology has introduced numerous innovations in material usage, including the incorporation of previously unused waste materials like bagasse ash, rice husk ash, sawdust, and iron powder. However, some studies have not consistently met the expected quality standards for paving, leading to further discoveries aimed at optimizing the use of available environmental resources. The use of paving as a wall-making material has several disadvantages including its high specific gravity that will affect the dead load that will act on the building. Dead load due to own weight plays an important role in the safety of the entire structure, especially if it is located in a high earthquake area such as some areas in Indonesia. This is because the earthquake load increases linearly with the weight of a building (Hermanto et al., 2014).

This research aims to explore the application of fiber in paving mixtures. It will specifically examine the use of banana leaf fiber in paving and the impact of adding this fiber to the paving mix. The selection of banana leaf fiber is based on its accessibility, durability, resistance to decay, and economic value.

## 2. Methods

This research employs experimental methods conducted in a laboratory setting. The analysis involves processing data and examining it by taking into account the equations of the relevant variables. The data analysis focuses on the results of calculating the compressive strength of paving that incorporates banana leaf fiber, specifically based on variations observed at 28 days of age.

### 2.1 Literature Review

Non-Structural Components

The structural system of a building is engineered to support or endure various loads imposed on it. Alongside structural components, there are also non-structural components. Non-structural components are elements that are either attached to or contained within a building or its system, but do not form part of the primary load-bearing structural framework of the building (Pah et al., 2023).

Banana Tree *Filler*

*Filler* (reinforcement) which functions as the main load bearer.

**Figure 1:** Banana Frond Fibre

The addition of banana stem fibre as a filler or lightweight brick mix material can strengthen lightweight bricks seen from the type of fibre owned and the content contained in banana stems (Sumbawaty et al., 2018).

Banana Frond Fibre The banana plant is a plant that grows in the tropics. Indonesia is one of the tropical countries that boasts a wide variety of banana plants. These plants are classified as annual crops, meaning they have a life cycle that lasts only one season or produces fruit just once. The fruit of the banana plant is rich in vitamins A, B, and carbohydrates, making it highly valuable and in great demand within the community. Besides the fruit, the leaves of the banana plant are frequently utilized by people. However, the stem of the banana plant remains underutilized. As a result, unused banana stems become waste, and there has yet to be a straightforward method or technology developed for recycling this material. The stem of the banana plant features a layered structure, with younger layers on the inside and older layers on the outside. Additionally, banana stems possess a fine fiber structure. Fibers can be extracted from older banana stems or those with very low moisture content, allowing for easier observation and separation (Rohman & Damara, 2024).

Paving Block

Concrete bricks, also known as paving blocks, are a form of non-structural concrete suitable for various applications such as roads, parking areas, sidewalks, parks, and more. These paving blocks are produced from a blend of Type I Portland cement, water, and aggregate used as filler material (Kurniati et al., 2021).

Classification of concrete bricks (paving blocks) according to SNI 03-0691-1996 (National Standards Agency, 1996) there are 4 based on its function, namely:

1. Grade A concrete bricks (paving blocks) are used for roads,
2. B-grade concrete bricks (paving blocks) were used for the car park,
3. C-grade concrete bricks (paving blocks) are used for pedestrians,
4. Concrete bricks (paving blocks) of grade D are used for city parks and other uses.


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The quality requirements of concrete bricks (paving blocks) according to SNI 03-0691-1989 (National Standardisation Agency, 1989) include:

1. Appearance Properties Concrete bricks (paving blocks) must have a flat surface, no cracks and defects, corners and ribs are not easily smoothed with finger strength.
2. Paving block sizes must have a minimum nominal thickness of 60 mm with a tolerance of ±8%.

Physical Properties Paving blocks must have the following properties:

**Table 1.** Table of physical properties of paving blocks

| **Quality** | **Power (kg/cm2)** | | **Wear Resistance (mm/min)** | | **Average water absorption (%)** |
|---|---|---|---|---|---|
| | Average | Lowest | Average | Lowest | |
| **A** | 400 | 350 | 0,090 | 0,103 | 3 |
| **B** | 200 | 170 | 0,130 | 0,149 | 6 |
| **C** | 150 | 125 | 0,160 | 0,184 | 8 |
| **D** | 100 | 85 | 0,219 | 0,251 | 10 |

Source: SNI 03-0691-1996

Based on SK SNI 03-0691-1996, the classification of paving blocks is distinguished according to its use class as follows:

Paving block A : for road
Paving block B : for the car park
Paving block C : for pedestrians
Paving block D : for garden and other users

## 3. Results

Inspection of paving block stacking materials carried out at the University of Bojonegoro laboratory obtained the following results:

1) Fine Aggregate Gradation (Merapi Sand)

From the results of the gradation check carried out, the fine aggregate is included in gradation no. 2, which is medium gradation with a fine modulus of 2.4998 as can be seen in Figure 1. below.

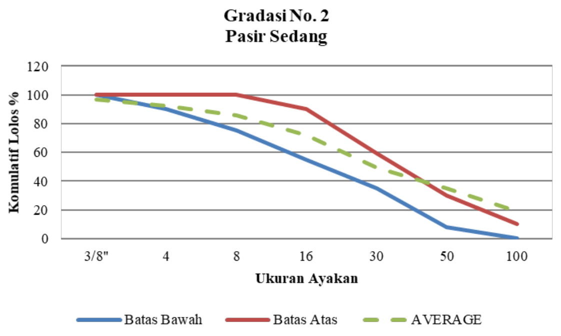


**Figure 2.** Fine aggregate gradation results

2) Fine Aggregate moisture content

The value of water content is taken in field conditions, in this study the sand is dry, because in this state the wetness of the aggregates is almost the same as the state of the aggregates in the paving block. The moisture content of SSD sand obtained from the results of the examination of 0.25% is shown in Table 2. while the original sand moisture content of 0.11% is shown in Table 3. below.

**Table 2:** Moisture content of SSD condition

| SSD | | | |
|---|---|---|---|
| Number | 15 | 40 | 45 |
| Cup Weight | 14,59 | 14,58 | 14,47 |
| Weight of Cup + Wet Sample | 56,44 | 55,38 | 57,83 |
| Weight of Cup + Sample | 56,33 | 55,27 | 57,74 |
| Sample Weight | 41,85 | 40,8 | 43,36 |
| Dry Sample Weight | 41,74 | 40,69 | 43,27 |
| Water Content | 0,26% | 0,27% | 0,21% |
| Average | | 0,25% | |

**Table 3.** ORIGINAL condition moisture content

| ORIGINAL | | | |
|---|---|---|---|
| Number | 51 | 24 | 7 |
| Cup Weight | 14,93 | 14,57 | 14,87 |
| Weight of Cup + Wet Sample | 58,37 | 55,70 | 54,87 |
| Weight of Cup + Sample | 58,33 | 55,65 | 54,82 |
| Sample Weight | 43,44 | 41,13 | 40 |
| Dry Sample Weight | 43,4 | 41,08 | 39,95 |
| Water Content | 0,09% | 0,12% | 0,13% |
| Average | | 0,11% | |

3) Specific gravity and water absorption of fine aggregates

The result of the specific gravity of saturated sand dry face is 2.78 so that the sand is classified as a normal category where the average is 2.6 to 2.8 and the maximum water absorption is 3%. The maximum water absorption value obtained is 0.25% so that it is still in the normal category. Below table 4. calculation of specific gravity and absorption testing on sand.

**Table 4.** Specific gravity and water absorption of fine aggregates

| Calculation of absorption | **A** | **B** | **C** | **Average** |
|---|---|---|---|---|
| Bulk specific gravity | 2,76 | 2,78 | 2,77 | 2,77 |
| Saturated surface dry specific gravity | 2,76 | 2,79 | 2,78 | 2,78 |
| specific gravity | 2,78 | 2,79 | 2,80 | 2,79 |


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| | | | | |
|---|---|---|---|---|
| Absorption (%) | 0,30 | 0,11 | 0,33 | 0,25 |

d. Content weight testing of aggregate

This test is to obtain the content weight value, the greater the unit weight, the more compressible the aggregate. This will affect the process of working on large quantities of paving blocks and affect the compressive strength value. The result of the weight of the contents of SSD sand (pounded) is 1.87 kg / mm³ while for the weight of the contents of sand in loose conditions is 1.69 kg / mm³. Table 5. and Table 6. calculations of the content weight of fine aggregates.

**Table 5.** Test results for weight content of fine aggregate in loose condition

| RELEASE / GEMBUR | I | II |
|---|---|---|
| A. Place weight + of the test piece, (kg) | 5975 | 5879 |
| B. Place weight, (kg) | 967 | 967 |
| C. Weight of test specimen, (kg) | 5008 | 4912 |
| D. Place contents, (dm³) | 2932 | 2932 |
| E. Test specimen content weight, (kg/dm³) | 1,71 | 1,68 |
| F. Average test specimen content weight (kg/dm³) | 1,69 | |

**Table 6**: Test results for weight content of fine aggregates in compacted condition

| SOLID | I | II |
|---|---|---|
| A. Place weight + of the test piece, (kg) | 6432 | 6465 |
| B. Place weight, (kg) | 967 | 967 |
| C. Weight of test specimen, (kg) | 5465 | 5498 |
| D. Place contents, (dm³) | 2932 | 2932 |
| E. Content weight of test specimen, (kg/dm³) | 1,86 | 1,88 |
| F. Average test specimen content weight (kg/dm³) | 1,87 | |

e. Silt content of fine aggregate

The SNI stipulates that the mud content in coarse aggregate must not exceed 5%. Testing the mud content using the Erlenmeyer tube yielded a mud value of 2.36%, while the sieve analysis test indicated the mud weight that passed through sieve number 200. Both methods of assessing the mud content in fine aggregates demonstrated that the levels are below 5%, making these aggregates suitable for concrete mixes. The results of the mud content testing with Erlenmeyer tubes are illustrated in Figure 3, and Table 7 below presents the findings regarding mud content passing through sieve number 200 in the assessment of organic impurities using NaOH solution..

**Table 7**. Test results of fine aggregate mud content

| No. Sample | Maximum Size of Aggregate | | Unit |
|---|---|---|---|
| | I | II | |
| Dry Weight of Test Piece + Container, W1 | 1085 | 1085 | Gram |
| Container Weight, W2 | 85 | 85 | Gram |
| Dry Weight of Initial Test Piece, W3 = W1 - W2 | 1000 | 1000 | Gram |
| Dry Weight of Test Piece After Washing + Container, W4 | 1058 | 1066 | Gram |
| Dry weight of test specimen after washing W5 = W4 - W2 | 973 | 981 | Gram |
| Percent of Material Passing Sieve No. 200 (0.075 mm) | 2,77 | 1,94 | % |
| Average (1 + 2) / 2 | 2,36 | | % |

Organic test results of liquids including No. 3

**4. Discussion**

This study tested the compressive strength of paving blocks using banana tree fibre as a partial replacement of cement at 3% by weight of cement. The volume ratio is 1pc: 5ps with FAS 0.4 at the age variation of 7, 14, and 28 days. The test results can be seen in table 8 below.

Table 8. Test results for compressive strength of paving

| Age Variation | Banana tree fibre (%) | Result Compressive strength of blick paving (Mpa) | | | Average (Mpa) | Quality |
|---|---|---|---|---|---|---|
| | | Sample 1 | Sample 2 | Sample 3 | | |
| 7 days | 3% | 22,30 | 23,36 | 22,34 | 22,67 | B |
| 14 days | 3% | 23,90 | 24,03 | 23.94 | 23,96 | B |
| 28 days | 3% | 24,97 | 25,15 | 25,05 | 25,12 | B |


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## 5. Conclusion

The findings of the research indicate that the compressive strength of the paving blocks has improved.

1. The compressive strength value of paving using banana leaf fibre at 7 days was found to be 22.67 MPa on average, 23.96 MPa at 14 days, and 25.12 MPa at 28 days.
2. The addition of banana leaf fibre percentage of 3% in banana leaf fibre paving gives good results and provides quality B in its classification so that according to SK SNI 03-0691-1996 it can be used for parking lots.

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