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# THE EFFECT OF ADDING WATER HYACINTH FIBER TO A SAND AND CEMENT MIXTURE FOR MAKING PAVING BLOCKS

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## ABSTRACT

Paving block is one of the most widely used pavement materials in many places, including Indonesia. Currently, many consumers prefer paving blocks over other pavements such as concrete and asphalt. However, to meet these needs, the quality of paving blocks needs to be improved, in terms of both strength and service life. Therefore, the use of water hyacinth fiber as an additive is a promising step for an experiment aimed at improving the characteristics of paving blocks by adding water hyacinth fiber to the sand and cement mixture. In this experiment, the test specimens were made with a 1:6 mix and a water–cement ratio (w/c) of 0.54, compacted using a manual (conventional) method. Three normal specimens without any additive were made, followed by paving blocks with the same materials plus water hyacinth fiber at 1%–5% of the original cement weight. The average compressive strengths at 7 days, correlated to 28 days, for specimens N, 1%, 2%, 3%, 4% and 5% were 6.46 MPa, 5.69 MPa, 6.15 MPa, 4.46 MPa, 4.46 MPa and 4.15 MPa, respectively.

## 1. INTRODUCTION

Paving block is one of the pavement layer materials that is often used as an alternative, including in Indonesia. Paving blocks are an especially good alternative on roads with low traffic volumes, offering advantages such as easier construction and maintenance. A paving block is a building material composed of a mixture of Portland cement or a similar binder, water, and fine aggregate, with or without other additives that do not reduce the quality of the concrete [1].

Paving is commonly found on sidewalks, in parks, on residential neighborhood roads, and in many other places. However, to meet all these needs, efforts are required to improve the quality of paving blocks, in terms of both strength and service life. One way to improve the unfavorable properties of paving blocks is to experiment with adding fibers to the mixture. Several types of fiber that can be used to improve the properties of concrete are steel, plastic, glass, and carbon. For non-structural purposes, natural fibers such as bamboo, sugar palm fiber (*ijuk*), or other plant fibers can be used [2], as cited in [3].

Natural fiber composites are one of the alternative materials currently being developed to replace metals and synthetic composites. Natural fibers offer important benefits such as stiffness and good mechanical properties. Indonesia has a great many natural fibers that can be used as composite reinforcement. One of the natural fibers widely used is water hyacinth fiber.

Water hyacinth has a water content of about 90% by weight, with a weight reduction from 10 kg

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when wet to 1 kg when dry. In the dry state, water hyacinth contains 13.03% crude protein, 20.6% crude fiber, 1.1% fat, 23.8% ash, and the remainder is vortex containing polysaccharides and minerals [4]. Water hyacinth has potential for development in natural fiber–based composites, because the plant is regarded as having tough fiber, a fairly high fiber content, an abundant raw material supply (*sustainable resources*), low cost, ease of availability, and non-toxicity.

The purpose of this study is to determine the compressive strength of paving blocks made with added water hyacinth fiber, and to find out whether the addition of water hyacinth fiber is able to improve the compressive strength of paving blocks.

## 2. METHODS

### *2.1. Research Design*

This research used an experimental testing method in the Civil Engineering laboratory of Universitas Islam Lamongan. The study compares paving blocks without additives, as a reference (control), with paving blocks containing additives, in order to determine the differences in results between the two.

### *2.2. Water Hyacinth Fiber Material Investigation*

1. Take the dried water hyacinth fiber.
2. Comb the water hyacinth fiber with the wire brush provided.
3. Trim the clumped fibers so that the fibers look neat.

**Table 1** Fiber Mixture Proportions

| No | Specimen Code | Fiber Addition | Number of Specimens |
|---|---|---|---|
| 1 | N | 0% | 3 |
| 2 | 1% | 1% | 3 |
| 3 | 2% | 2% | 3 |
| 4 | 3% | 3% | 3 |
| 5 | 4% | 4% | 3 |
| 6 | 5% | 5% | 3 |

*Source: Research results, 2018*

Note: Water hyacinth fiber is added as a percentage of the weight of cement used in the paving block mixture.

### *2.3. Making of Paving Block Test Specimens*

In this study, 6 specimen codes were prepared, with 3 samples for each code. Because there is no SNI regulation on paving block mix design, the paving block mixture was prepared by referring to the SNI concrete regulations for the proportions of materials, in order to approach the quality stated in the title of this study, with an adjustment to the proportion of water. The specimens were made with a 1 : 6 mix and a water–cement ratio (w/c) of 0.54, compacted manually (conventionally). The flow chart of the research activities is shown in Figure 1.

Before making the normal paving block without fiber, the mortar that serves as the raw material of the paving block is prepared first, by mixing cement and sand in a 1:6 ratio in accordance with the established theoretical basis, and adding water at a w/c of 0.54 to the mixture. Make sure that the mortar is not too wet. Set up the mold parts beforehand and make sure everything is in good condition. Pour the mortar into the mold, with a volume matching the mold. Use a rod to compact the paving block mortar in the mold by tamping it repeatedly until the desired degree of compaction is obtained. Next, remove the finished molded specimen and place it in a storage area with a flat surface to avoid damaging the specimen. The specimens with fiber percentages are made in the same way as the normal specimens.

### *2.4. Compressive Strength Testing*

Concrete compressive strength is the magnitude of load per unit area that causes a concrete specimen to fail when subjected to a particular compressive force produced by a compression testing machine. This method is intended as a guide for determining the compressive strength. The purpose of the test is to obtain the compressive strength value using the correct procedure, based on the Indonesian

standard (SK SNI) literature. The compressive strength test of concrete must follow these steps:

1. Take the specimen to be tested and calculate its cross-sectional area before testing, as data for calculating the compressive strength of the paving block.
2. Compress the prepared specimen until it fails, using a compression machine whose loading rate can be adjusted. The loading rate, from the start of load application until the specimen fails, is set so that it takes 1 to 2 minutes. The direction of loading on the specimen follows the direction of the load in actual use [1].
3. Record the load at which the specimen fails (kg), then calculate the resulting compressive strength. The compressive strength test was carried out when the paving blocks were 7 days old.

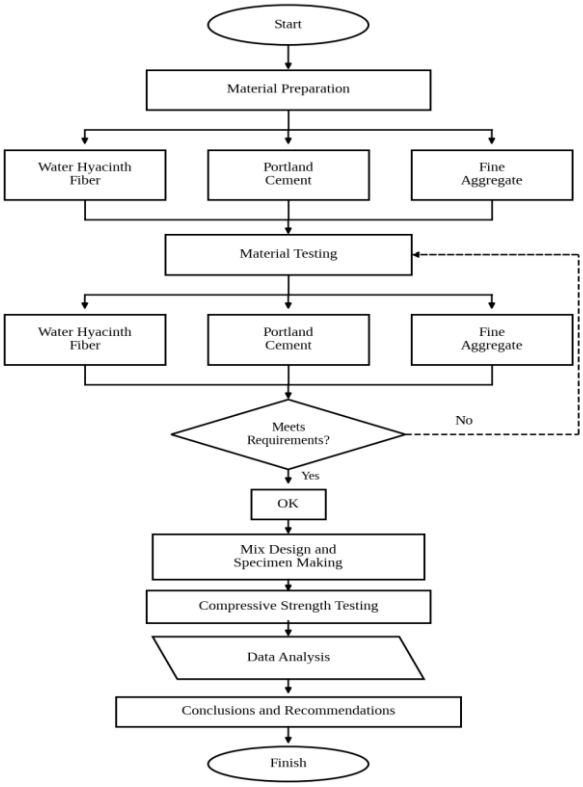



**Figure 1** Flow chart of the research

## 3. RESULTS AND DISCUSSION

The paving block specimens were made with a 1 : 6 mix and a w/c of 0.54. The material requirements calculated for the mix produced the mixture shown in the following table.

**Table 2** Material Requirements (Mix Design)

| Specimen | Cement | Fiber | Sand | Water |
|---|---|---|---|---|
| N | 478 g | - | 1278 g | 344 g |
| 1% | 478 g | 4.78 g | 1278 g | 344 g |
| 2% | 478 g | 9.56 g | 1278 g | 344 g |
| 3% | 478 g | 14.34 g | 1278 g | 344 g |
| 4% | 478 g | 19.2 g | 1278 g | 344 g |
| 5% | 478 g | 23.9 g | 1278 g | 344 g |

*Source: Research results, 2018*

The specimens were made in the Civil Engineering Laboratory of Universitas Islam Lamongan. The following data were obtained from testing the paving block specimens.

### *3.1. Weighing of Test Specimens*

In accordance with university regulations, the specimens were tested in the Civil Engineering Laboratory of Universitas Islam Lamongan on paving blocks that were 7 days old. Each specimen was

weighed to determine its weight. Weighing began with the normal mix (N), followed by 1%, 2%, 3%, 4% and 5%. The recorded weighing results were processed into the data presented in the following table.

**Table 3** Weighing Results of Test Specimens

| No | Specimen Code | Sample | Weight (kg) | Average (kg) |
|---|---|---|---|---|
| 1. | N | 1 | 2.952 | 2.967 |
| | | 2 | 2.970 | |
| | | 3 | 2.980 | |
| 2. | 1% | 1 | 2.870 | 2.820 |
| | | 2 | 2.800 | |
| | | 3 | 2.790 | |
| 3. | 2% | 1 | 2.870 | 2.806 |
| | | 2 | 2.730 | |
| | | 3 | 2.820 | |
| 4. | 3% | 1 | 2.750 | 2.683 |
| | | 2 | 2.630 | |
| | | 3 | 2.670 | |
| 5. | 4% | 1 | 2.720 | 2.663 |
| | | 2 | 2.580 | |
| | | 3 | 2.690 | |
| 6. | 5% | 1 | 2.680 | 2.650 |
| | | 2 | 2.620 | |
| | | 3 | 2.650 | |

*Source: Research results, 2018*

### *3.2. Compressive Strength Testing*

The compressive strength is obtained from the average of the specimens, calculated as the sum of the compressive strengths divided by the number of specimens. The compressive strength results for the 7-day-old paving blocks were calculated as described below. Because paving blocks have chamfered edges, the calculation follows the procedure based on the chamfer factor, which is 1.18 for paving blocks 8 cm thick [5].

**Table 4** Chamfer Factor Values

| Block Thickness (mm) | Plain Block | Chamfered Block |
|---|---|---|
| 60 or 65 | 1.00 | 1.06 |
| 80 | 1.12 | 1.18 |
| 100 | 1.18 | 1.24 |

*Source: Specification for Precast Concrete Paving Blocks, Cement and Concrete Association / County Surveyors Society (Interpave), 1980 [5].*

Note: The row marked in red is the one used.

The compressive strength of the paving blocks was therefore calculated using the following formula:

$$\text{Compressive strength (kg/cm}^2) = (P / L) \times Fc \quad (1)$$

where $P$ is the compressive load (kg), $L$ is the cross-sectional area (cm$^2$), and $Fc$ is the chamfer factor.

**Table 5** Compressive Test Results of 7-Day-Old Paving Blocks

| No | Specimen Code | Sample | Crushing Load (ton) | Compressive Strength (kg/cm$^2$) | Average (kg/cm$^2$) |
|---|---|---|---|---|---|
| 1. | N | 1 | 9 | 53.1 | 51.1 |
| | | 2 | 8 | 47.2 | |

| No | Specimen Code | Sample | Crushing Load (ton) | Compressive Strength (kg/cm$^2$) | Average (kg/cm$^2$) |
|---|---|---|---|---|---|
| | | 3 | 9 | 53.1 | |
| | | 1 | 7 | 41.3 | |
| 2. | 1% | 2 | 8 | 47.2 | 45.2 |
| | | 3 | 8 | 47.2 | |
| | | 1 | 8.5 | 50.1 | |
| 3. | 2% | 2 | 8 | 47.2 | 49.1 |
| | | 3 | 8.5 | 50.1 | |
| | | 1 | 6.5 | 38.3 | |
| 4. | 3% | 2 | 6 | 35.4 | 35.3 |
| | | 3 | 5.5 | 32.4 | |
| | | 1 | 6.5 | 38.3 | |
| 5. | 4% | 2 | 5 | 29.5 | 35.4 |
| | | 3 | 6.5 | 38.5 | |
| | | 1 | 6 | 35.4 | |
| 6. | 5% | 2 | 6 | 35.4 | 33.4 |
| | | 3 | 5 | 29.5 | |

*Source: Research results, 2018*

As shown in the table above, the average compressive strengths obtained when the paving blocks were 7 days old, from the normal specimen through 5%, were 51.1 kg/cm$^2$, 45.2 kg/cm$^2$, 49.1 kg/cm$^2$, 35.3 kg/cm$^2$, 35.4 kg/cm$^2$ and 33.4 kg/cm$^2$, respectively. Presented in graph form, the results are as follows.

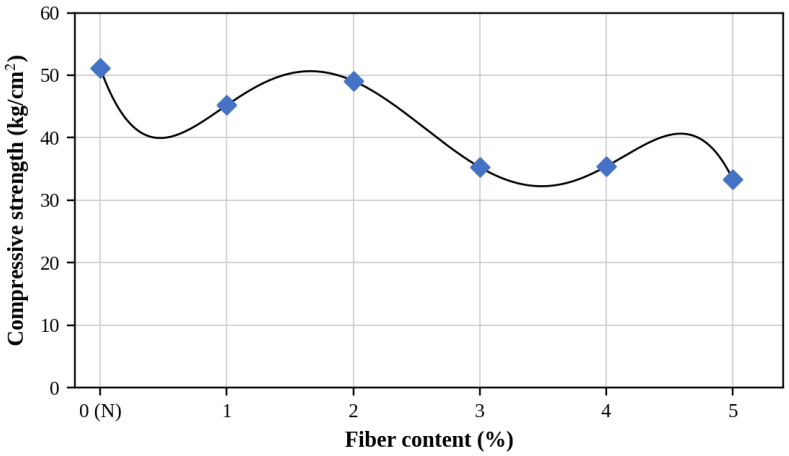



**Figure 2** Graph of the relationship between compressive strength and water hyacinth fiber percentage

The compressive strength values in kg/cm$^2$ were then converted to MPa according to the following provisions:

**Table 6** Comparison of Concrete Compressive Strength for Various Specimens

| Specimen | Compressive Strength Ratio |
|---|---|
| Cube 15 × 15 × 15 | 1.00 |
| Cube 20 × 20 × 20 | 0.95 |
| Cylinder ⌀15 × 30 | 0.83 |

*Source: Indonesian Reinforced Concrete Regulations (PBI) 1971 N.I.-2 [6].*

Note: The row marked in red is the one used.

First, it should be understood that concrete quality *fc'* means that the compressive strength is

taken when the concrete reaches 28 days, using concrete cylinder specimens 15 cm in diameter and 30 cm high, referring to SNI 03-2847-2002, which in turn refers to the ACI (American Concrete Institute), with the unit MPa (Mega Pascal), where 1 MPa = 1 N/mm$^2$ = 10 kg/cm$^2$. Meanwhile, the Characteristic Concrete Quality (K) states the minimum characteristic compressive strength when the concrete reaches 28 days, using 15 × 15 × 15 cm concrete cubes, referring to PBI 71, which in turn refers to the old European standards. To determine the practical equivalent between PBI and SNI concrete, the following applies:

1. Conversion factor from cube specimen to cylinder specimen = 0.83.
2. Unit conversion from MPa to kg/cm$^2$: 1 MPa = 1 N/mm$^2$ = 10 kg/cm$^2$.
   For example, K-150 kg/cm$^2$ concrete is equivalent to (150/10) × 0.83 = 15 × 0.83 = 12.45 MPa.

**Table 7** Conversion of Compressive Strength Units from kg/cm$^2$ to MPa

| No | Specimen Code | Compressive Strength (kg/cm$^2$) | Compressive Strength (MPa) |
|---|---|---|---|
| 1. | N | 51.1 | 4.2 |
| 2. | 1% | 45.2 | 3.7 |
| 3. | 2% | 49.1 | 4.0 |
| 4. | 3% | 35.3 | 2.9 |
| 5. | 4% | 35.4 | 2.9 |
| 6. | 5% | 33.4 | 2.7 |

*Source: Research results, 2018*

From the conversion of compressive strength from kg/cm$^2$ to MPa, the compressive strength of the 7-day-old paving blocks was then correlated to 28 days, giving the results shown in the following table.

**Table 8** Compressive Strength of Paving Blocks at 7 and 28 Days

| No | Specimen Code | 7 Days (MPa) | 28 Days (MPa) |
|---|---|---|---|
| 1. | N | 4.2 | 6.46 |
| 2. | 1% | 3.7 | 5.69 |
| 3. | 2% | 4.0 | 6.15 |
| 4. | 3% | 2.9 | 4.46 |
| 5. | 4% | 2.9 | 4.46 |
| 6. | 5% | 2.7 | 4.15 |

*Source: Research results, 2018*

When the compressive strength data above are displayed as a model graph, the result is as follows.

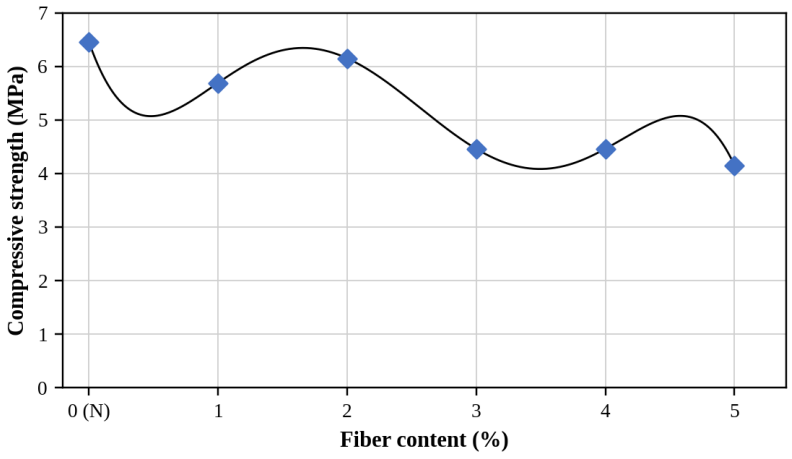



**Figure 3** Graph of the relationship between fiber percentage and paving block compressive strength

**Table 9** Percentage Increase and Decrease in Compressive Strength

| Specimen Code | Failure Stress (MPa) | Percentage (%) | Percentage Decrease (%) |
|---|---|---|---|
| N | 6.46 | 100 | - |
| 1% | 5.69 | 88.08 | -11 |
| 2% | 6.15 | 95.20 | -4 |
| 3% | 4.46 | 69.04 | -30 |
| 4% | 4.46 | 69.04 | -30 |
| 5% | 4.15 | 64.24 | -35 |

*Source: Research results, 2018*

### *3.3. Discussion*

Because the initial aim of this study was to experiment with increasing the compressive strength of paving blocks by adding water hyacinth fiber at 6 mix variations — normal (N) without fiber, then 1%, 2%, 3%, 4% and 5% — the discussion focuses on the compressive strength results of the tested paving block specimens.

Several factors may be related to the decrease in compressive strength of these paving blocks. One possible cause is the difference in weight between the specimens, which results from uneven compaction: the lower the compaction effort, the lower the compressive strength of the paving block, because of the empty voids inside it. With greater compaction, the compressive strength of the paving block increases, because the voids become filled. This study obtained the compressive strength of paving blocks with a mix ratio of 1 cement : 6 sand and a w/c of 0.54. The compressive strength obtained at 7 days was 4.2 MPa, equivalent to 51.1 kg/cm$^2$, which, converted to 28 days, becomes 6.46 MPa, equivalent to 77.83 kg/cm$^2$. Based on these results, the paving blocks in this study do not meet the criteria set by SNI 03-0691-1996 for concrete bricks (paving blocks) [1].

## 4. CONCLUSION

1. The average 28-day compressive strengths of paving blocks produced with added water hyacinth fiber, for specimens N, 1%, 2%, 3%, 4% and 5%, were 6.46 MPa, 5.69 MPa, 6.15 MPa, 4.46 MPa, 4.46 MPa and 4.15 MPa, respectively. The average 28-day compressive strength of the normal paving block was 6.46 MPa; the highest average strength among the fiber mixes was found in the 2% mix at 6.15 MPa, while the lowest was found in the 5% mix at 4.15 MPa.
2. The percentage changes in compressive strength for specimens N, 1%, 2%, 3%, 4% and 5% were 0%, −11%, −4%, −30%, −30% and −35%, respectively. Based on the results of this study, water hyacinth fiber cannot be used as an additive to improve the compressive strength of paving blocks.

### *4.1. Recommendations*

Further research is needed on the use of water hyacinth fiber as an additive in paving block production. Such follow-up research should use a hydraulic molding machine with a measured load and consistent molding, so that the test specimens have accurate results, and should also vary the w/c value in order to obtain better compressive strength.

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