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The Effect Of Adding Water Hyatonic Fiber (Eichornia Crassipes) To Paving Block K-90

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ABSTRACT

Paving block is one of the pavement layers that are often used as an alternative, including in Indonesia. Today, many consumers prefer paving block compared to other pavements such as concrete or asphalt. However, to fulfill those needs, the improvement needs to be done to improve the quality, in terms of strength and age using the paving block itself. Therefore, the use of water hyacinth fiber as a composite material is a good step for experiment to improve the properties of paving block by adding water hyacinth fiber to the sand and cement mixture. With this experiment, the test object that will be made is a test object with a 1:5 mixture with FAS 0.54 by compaction using manual/conventional method. The test object is made as many as 3 pieces from the normal test without additives, then followed by paving block with the same ingredients added by water hyacinth fiber from 1%-5% of the cement weight used. The result of each test object that has been tested is the compressive strength score from the normal test object to the test object with a fiber content of 5%. The average result of the calculation of compressive strength in sequence from the test objects are: normal, 1%, 2%, 3%, 4% and 5%, namely 93.6 kg/cm2, 81.6 kg/cm2, 78 kg/cm2, 65.6 kg/cm2, 51.2 kg/cm2, and 52.3 kg/cm2. Therefore, it can be concluded that the addition of water hyacinth fiber cannot improve the quality of paving block because the more fiber mixture added, the more decrease the compressive strength score.

1. INTRODUCTION

Paving blocks are widely used as surface pavement materials for pedestrian walkways, parking areas, residential roads, and public open spaces due to their ease of installation, maintenance, and replacement. Compared with conventional asphalt and cast-in-place concrete pavements, paving blocks offer several advantages, including better permeability, environmental friendliness, shorter construction time, and improved aesthetic value. These characteristics have contributed to the increasing demand for paving blocks in both urban and rural infrastructure development [1].

The quality and performance of paving blocks are primarily determined by their mechanical properties, particularly compressive strength. Compressive strength is an important parameter because paving blocks are continuously subjected to static and dynamic loads during service. Therefore, numerous studies have been conducted to improve the mechanical performance of paving blocks through modifications in material composition, manufacturing techniques, and the incorporation of supplementary materials [2].

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In recent years, the construction industry has shown increasing interest in the utilization of natural fibers as reinforcing materials in cement-based composites. Natural fibers have attracted attention because they are renewable, biodegradable, lightweight, and widely available. Several researchers have reported that natural fibers can improve certain properties of concrete and mortar, including crack resistance, toughness, and impact resistance [3]. The use of natural fibers also supports sustainable construction practices by reducing dependence on synthetic materials and promoting the utilization of agricultural and biological waste.

One natural resource with significant potential for engineering applications is water hyacinth (Eichhornia crassipes). Water hyacinth is an aquatic plant that grows rapidly in rivers, lakes, and reservoirs, often causing environmental and ecological problems. Excessive growth of water hyacinth can obstruct water transportation, reduce dissolved oxygen levels, disrupt aquatic ecosystems, and increase maintenance costs for water bodies [4]. Consequently, efforts to utilize water hyacinth as a value-added material have gained considerable attention in recent years.

Water hyacinth fibers contain cellulose and lignocellulosic components that provide potential reinforcement characteristics when incorporated into cementitious materials. Previous studies have investigated the application of natural fibers in concrete products and reported varying effects on mechanical performance depending on fiber type, fiber content, and production methods [5]. However, the influence of water hyacinth fiber on the compressive strength of paving blocks remains insufficiently explored, particularly for low-strength paving block mixtures produced using conventional manual compaction methods.

The incorporation of water hyacinth fiber into paving block mixtures may provide environmental benefits through waste utilization while potentially enhancing the engineering properties of the product. Nevertheless, excessive fiber content may adversely affect the bonding mechanism between cement paste and aggregate particles due to the high water absorption capacity of natural fibers. As a result, the actual effect of water hyacinth fiber on paving block performance requires experimental investigation.

Therefore, this study aims to evaluate the effect of water hyacinth fiber addition on the compressive strength of K-90 paving blocks. Experimental testing was conducted by incorporating water hyacinth fiber at proportions ranging from 1% to 5% of cement weight. The compressive strength of each mixture was compared with that of conventional paving blocks without fiber addition. The findings of this study are expected to contribute to the development of sustainable paving materials and provide insight into the feasibility of utilizing water hyacinth fiber as an alternative reinforcing material in paving block production.

2. METHODS

This study employed an experimental laboratory approach to investigate the effect of water hyacinth fiber (Eichhornia crassipes) on the compressive strength of K-90 paving blocks. The experimental program consisted of material characterization, specimen preparation, mix design development, and compressive strength testing. Various fiber contents ranging from 0% to 5% of cement weight were incorporated into the paving block mixtures to evaluate their influence on mechanical performance.

2.1. Research Design

This study employed an experimental laboratory method to investigate the effect of water hyacinth fiber (Eichhornia crassipes) on the compressive strength of K-90 paving blocks. The experimental program was conducted in the Civil Engineering Laboratory of Universitas Islam Lamongan. The performance of paving blocks containing various percentages of water hyacinth fiber was compared with that of conventional paving blocks without fiber addition, which served as the control specimen.

2.2. Materials

The materials used in this study consisted of Portland cement, fine aggregate (sand), water, and water hyacinth fiber. Portland cement was used as the primary binding material, while sand served as the fine aggregate. Water was added according to the specified water-cement ratio to facilitate the hydration process.

Water hyacinth fiber was utilized as an additive material. The fibers were obtained from mature water hyacinth plants and were processed prior to mixing. The preparation process involved drying the fibers under natural conditions, combing them to separate individual strands, and trimming excess fiber lengths to obtain a more uniform fiber distribution.

2.3. Material Testing

Preliminary testing was conducted to determine the physical properties of the constituent materials and to ensure compliance with applicable standards.

2.3.1 Cement Testing

The cement properties were evaluated through the following tests:

- Normal consistency test in accordance with ASTM C187 to determine the standard water requirement for cement paste.
- Specific gravity test in accordance with ASTM C188 to determine the density of the cement.

2.3.2 Fine Aggregate Testing

The sand used in this study was subjected to several laboratory tests, including:

- Moisture content test (ASTM C566).
- Specific gravity test (ASTM C128).
- Water absorption test (ASTM C128).
- Bulk density and void content test (ASTM C29).

These tests were conducted to determine the suitability of the aggregate for paving block production.

2.4. Mix Design

The paving blocks were produced using a cement-to-sand ratio of 1:5. The water-cement ratio was maintained within the range commonly used by paving block manufacturers to achieve adequate workability while maintaining strength performance.

Water hyacinth fiber was added as a percentage of cement weight. Six mixture variations were prepared, consisting of one control mixture without fiber and five mixtures containing different fiber contents. Each mixture was represented by three specimens.

Table 1. Mixture Proportions and Specimen Codes

Specimen Code	**Water Hyacinth Fiber Content (%)**	**Number of Specimens**
BU-0	0	3
BU-1	1	3
BU-2	2	3
BU-3	3	3
BU-4	4	3
BU-5	5	3

A total of eighteen paving block specimens were produced for compressive strength testing.

2.5. Specimen Preparation

The paving block specimens were prepared according to the following procedure:

1. Cement and sand were mixed thoroughly at a ratio of 1:5.
2. Water hyacinth fiber was gradually added according to the designated mixture proportion.
3. The dry materials were mixed until a uniform distribution of fiber was achieved.
4. Water was added gradually while mixing continued until a homogeneous mixture was obtained.
5. The fresh mixture was placed into paving block molds.
6. Manual compaction was applied using a tamping rod to achieve the desired density.
7. The specimens were removed from the molds and stored for curing.

The same manufacturing procedure was applied to all specimen groups to ensure consistency throughout the experiment.

2.6. Compressive Strength Testing

Compressive strength testing was conducted to evaluate the mechanical performance of the paving block specimens. Prior to testing, the dimensions and cross-sectional area of each specimen were measured.

The specimens were then placed in a compression testing machine and loaded continuously until failure occurred. The loading rate was controlled to ensure that failure took place within approximately one to two minutes, in accordance with the procedures specified in SNI 03-0691-1996 for concrete paving blocks.

The compressive strength of each specimen was calculated using the ratio between the maximum applied load and the loaded cross-sectional area. The average compressive strength for each mixture variation was subsequently determined from three replicate specimens.

3. RESULT

This section presents the experimental results obtained from the production and testing of paving block specimens containing different proportions of water hyacinth fiber. The results include the mix design composition, specimen weight measurements, compressive strength performance, and the relationship between fiber content and compressive strength. The findings are presented objectively, while their implications and underlying mechanisms are discussed in the subsequent section.

3.1. Mix Design Composition

Six paving block mixtures were prepared consisting of one control mixture and five mixtures containing water hyacinth fiber. The fiber content was varied from 1% to 5% by weight of cement. The quantities of cement, sand, water, and fiber used in each mixture are presented in Table 2.

Table 2. Mix Design Composition

Fiber Content (%)	Cement (g)	Sand (g)	Water (g)	Water Hyacinth Fiber (g)
0	2086	11449	1034	0
1	2044	11449	1034	20
2	2044	11449	1034	41
3	2023	11449	1034	62
4	2003	11449	1034	83
5	1982	11449	1034	104

The amount of fiber was increased gradually while maintaining relatively constant proportions of sand and water throughout the experiment.

3.2. Specimen Weight Measurement

The weight of each paving block specimen was measured after the curing process. Three specimens were prepared for each mixture variation, and the average weight was calculated.

Table 3. Average Weight of Paving Block Specimens

Fiber Content (%)	Average Weight (kg)
0	2.946
1	2.891
2	2.878
3	2.838
4	2.758
5	2.735

The results indicate a gradual reduction in specimen weight as the percentage of water hyacinth fiber increased.

3.3. Compressive Strength Test Results

Compressive strength testing was performed on all specimens at the age of seven days. The measured values were subsequently converted to equivalent 28-day compressive strengths using the conversion factor commonly applied in paving block testing.

Table 4. Average Compressive Strength of Paving Blocks

Fiber Content (%)	**7-Day Compressive Strength (kg/cm²)**	**Equivalent 28-Day Compressive Strength (kg/cm²)**
0	60.9	93.6
1	53.1	81.6
2	50.7	78.0
3	42.7	65.6
4	33.3	51.2
5	34.0	52.3

The control specimen without fiber addition exhibited the highest compressive strength of 93.6 kg/cm² at the equivalent age of 28 days. The compressive strength decreased progressively with increasing fiber content. The lowest compressive strength was observed in the mixture containing 4% fiber, which achieved a strength of 51.2 kg/cm². Figure 1 illustrates the relationship between water hyacinth fiber content and compressive strength. A decreasing trend in compressive strength was observed as the percentage of fiber increased.

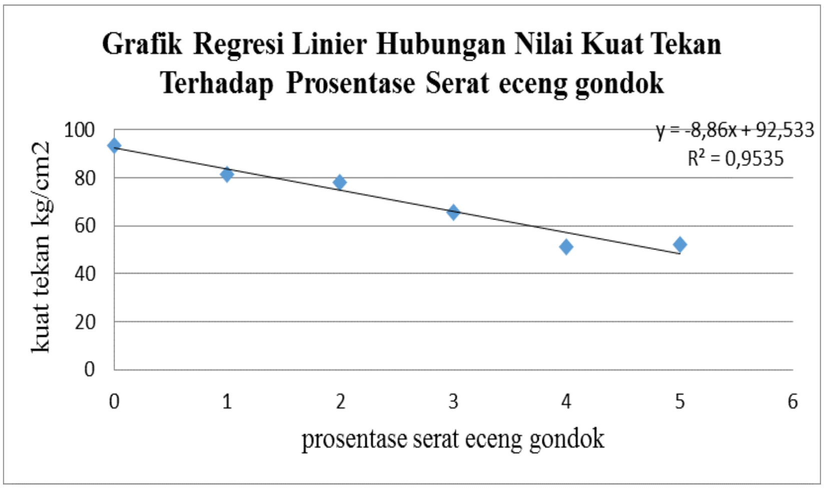

Figure 1. Relationship Between Water Hyacinth Fiber Content and Compressive Strength

A nonlinear regression analysis was performed to describe the relationship between fiber content and compressive strength. The regression model produced a coefficient of determination (R^2) close to 1.0, indicating a strong correlation between the experimental data and the fitted curve.

3.4. Percentage Reduction in Compressive Strength

To evaluate the influence of fiber addition, the compressive strength of each mixture was compared with the control specimen.

Table 5. Reduction in Compressive Strength Relative to Control Specimen

Fiber Content (%)	**Compressive Strength (kg/cm²)**	**Strength Retention (%)**	**Strength Reduction (%)**
0	93.6	100	0
1	81.6	87	13

Fiber Content (%)	Compressive Strength (kg/cm²)	Strength Retention (%)	Strength Reduction (%)
2	78.0	83	17
3	65.6	70	30
4	51.2	54	46
5	52.3	56	44

The results demonstrate that all mixtures containing water hyacinth fiber experienced lower compressive strength than the control mixture. The reduction became more pronounced as the fiber content increased, with the greatest decrease observed in the mixture containing 4% fiber.

4. DISCUSSION

The experimental results demonstrated that the incorporation of water hyacinth fiber into K-90 paving blocks resulted in a reduction in compressive strength. The control specimen without fiber addition achieved the highest compressive strength of 93.6 kg/cm², whereas specimens containing water hyacinth fiber exhibited progressively lower strength values as the fiber content increased. The lowest compressive strength was recorded in the mixture containing 4% fiber, which reached only 51.2 kg/cm².

A similar trend was observed in the weight measurements of the specimens. The average weight decreased from 2.946 kg for the control mixture to 2.735 kg for the mixture containing 5% fiber. This reduction in weight indicates a decrease in material density. In cement-based products, density is closely associated with mechanical performance because denser materials generally contain fewer internal voids and possess higher load-bearing capacity. Consequently, the lower density of the fiber-reinforced specimens contributed to the observed reduction in compressive strength.

The decrease in compressive strength may also be attributed to the physical characteristics of water hyacinth fiber. Natural fibers possess a relatively high water absorption capacity due to their cellulose content and porous structure. During the hydration process, a portion of the mixing water may be absorbed by the fibers rather than remaining available for cement hydration. This condition can interfere with the formation of hydration products and weaken the bond between cement paste and aggregate particles. As a result, the overall structural integrity of the paving block is reduced.

Another factor influencing the results is the distribution of fibers within the mixture. The manual mixing process used in this study may not have ensured uniform dispersion of fibers throughout the matrix. Fiber agglomeration can create localized weak zones and increase the formation of internal voids. These defects reduce the effectiveness of load transfer within the paving block and contribute to premature failure under compressive loading.

The compaction method employed during specimen preparation may have further affected the compressive strength results. Manual compaction generally produces lower and less uniform compaction energy than mechanical or hydraulic compaction systems commonly used in industrial paving block production. Insufficient compaction can leave unfilled voids within the paving block matrix, thereby reducing density and strength. The influence of compaction quality becomes increasingly significant when fiber content increases because fibers may hinder particle rearrangement during densification.

Interestingly, the compressive strength increased slightly from 51.2 kg/cm² at 4% fiber content to 52.3 kg/cm² at 5% fiber content. However, the difference was relatively small and did not indicate a meaningful improvement in performance. This minor fluctuation is likely attributable to experimental variability associated with manual specimen preparation and testing procedures.

Overall, the findings indicate that water hyacinth fiber was not effective in improving the compressive strength of K-90 paving blocks under the experimental conditions adopted in this study. The results suggest that the addition of untreated water hyacinth fiber tends to reduce paving block density and interfere with cement hydration, leading to lower compressive strength values. Therefore, the use of water hyacinth fiber as a direct replacement or additive in paving block mixtures should be carefully evaluated.

Despite the unfavorable effect on compressive strength, water hyacinth fiber remains an environmentally attractive material because of its abundance, renewability, and potential contribution to waste utilization. Future studies should investigate alternative treatment methods, fiber dimensions, water-cement ratios, and compaction techniques to improve the compatibility between water hyacinth fiber and cementitious materials. Chemical treatment of the fibers or the use of mechanical compaction systems may enhance bonding characteristics and produce more favorable mechanical properties.

5. CONCLUSION

This study investigated the effect of water hyacinth fiber (Eichhornia crassipes) on the compressive strength of K-90 paving blocks. Water hyacinth fiber was incorporated into the paving block mixture at proportions ranging from 1% to 5% of cement weight, and its performance was compared with that of conventional paving blocks without fiber addition.

The experimental results revealed that the addition of water hyacinth fiber did not improve the compressive strength of the paving blocks. The control specimen achieved the highest compressive strength of 93.6 kg/cm², while the specimens containing fiber exhibited lower compressive strengths ranging from 81.6 kg/cm² to 51.2 kg/cm². In general, increasing the fiber content resulted in a progressive reduction in compressive strength. The reduction was associated with decreased specimen density, the high water absorption capacity of the fibers, and the limitations of manual compaction during specimen preparation.

Based on the findings, untreated water hyacinth fiber is not recommended as a direct additive for improving the compressive strength of K-90 paving blocks under the conditions investigated in this study. Nevertheless, considering the abundance and environmental benefits of water hyacinth utilization, further research is recommended to explore alternative fiber treatment methods, optimized water-cement ratios, improved compaction techniques, and different mix proportions to enhance the compatibility of water hyacinth fiber with cement-based materials.

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