Exploring Mechanical Behaviour of Different Fiber Types in Concrete Pavement

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Abstract. The strength of the concrete greatly determines the quality of the rigid pavement construction itself. Concrete's flexural strength is considered much smaller than the compressive strength value. This is because concrete has a brittle nature, so an elastic material is needed to be able to withstand loads optimally. To optimize it, adding fiber is one way that can be used in the concrete mixture. Three types of fiber were prepared in this research: synthetic fiber (Polypropylene), natural fiber (palm fiber), and waste fiber (crumb waste). This research aims to determine the comparative influence of these fiber types on the flexural strength of rigid concrete pavement. Apart from that, this research also reviews the influence of fiber type on changes in the workability value and bulk weight produced by each type of fiber. To obtain accurate and accountable results, the use of fiber in the concrete mixture is only fiber content percentage: 1% of fine aggregate. The results show that crumb fibers provide the most optimal effect in increasing the flexural strength of concrete up to 7,48 Mpa, followed by polypropylene fibers with results of 7,29 Mpa. On the other hand, palm fiber has the lowest flexural strength result, which is only 6,24 Mpa, which is lower than the normal concrete of 7,02 Mpa.

Keywords: Rigid Pavement, Fiber, Flexural Strength, Workability, Content Weight.

1 Introduction

The infrastructure supports a nation's civilization. The availability of appropriate infrastructure is capital for Indonesia to rise to become a developed country and be free from the middle-income trap (developing country) [1] Indonesia is intensively building roads to connect regions so that the economy can run well. According to the Directorate General of Highways, the road network in Indonesia is dominated by rigit pavement up to 67.71% compared to flexible pavement [2]

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Concrete is a composition of coarse aggregate, fine aggregate, water, and a binder in cement with or without admixture/addictive. Concrete's tensile strength and flexural strength values are assessed only to be around 9% - 15% of the compressive strength values [3]. This causes the concrete to be brittle, so the concrete must be accompanied by a ductile material to withstand load. Based on the literature that has been carried out in previous studies, many researchers have carried out experiments by adding various types of fiber to the concrete mixture in the form of synthetic, natural, and waste fibers. From the results of this research, adding fiber to the concrete mixture has been proven to increase the strength value of the concrete. However, each of these studies only focuses on using one type of fiber with different parameters and treatments, so it will be difficult to compare and determine which type of fiber has the most optimal effect in correcting weaknesses in concrete.

As much as 0.75% - 1% of the mix volume is considered to provide optimal results on concrete strength [4]. Experts and researchers from various developed countries have tried many research and experiments by adding chemical and physical admixtures to concrete mixtures. One experiment was carried out by adding fiber to the concrete mixture. Addition of fiber In this research, the Author will try to apply three different types of fiber: synthetic fiber (Polypropylene), natural fiber (fiber), and fiber derived from waste (used tire rubber) with the same parameters and treatment. Each fiber will be spread evenly (uniformly) in each concrete mixture for each test object with a fiber content percentage of 1% to the amount of fine aggregate.

2 Research Method

This research was conducted at the laboratory testing material of Polytechnic State of Sriwijaya. The material characterization began with aggregate properties evaluation, such as sieve analysis, specific gravity, absorption, water content, clay content, and abrasion. For the specimen of concrete, four kinds of mixtures were prepared, i.e., Normal Concrete (BN), Concrete with Polypropylene (BP), Concrete with Palm Fiber (BI), Concrete with Rubber Tire Waste (BB), as displayed in Table 1. The fiber added for all of the mixtures is only 1% of the fine aggregate. The density, cement consistency, and setting time of concrete were examined for fresh concrete evaluation.

Furthermore, the flexural strength of concrete was examined to evaluate the mechanical properties of concrete for rigid pavement. The test was following Indonesia Standard National (SNI). All equipment used in this research starts from examining concrete materials, making and maintaining test objects, and testing flexural strength using tools provided in the laboratory. The ingredients for the concrete mixture used in this research are 1) Cement-type OPC I and 2) Natural sand (uncrushed) from the Tanjung Lubuk area. Coarse aggregate in the form of splits with a maximum size of 25mm and material fiber as admixture: polypropylene fiber, fiber palm fiber, and tire waste fiber. The specimen size of concrete was evaluated using a concrete beam 15 cm x 15 cm x 60 cm, and was made three samples for every mixture.

Table 1. Number of Test Objects.

Concrete Type	% fiber	Testing Age 7	14	28	Total
		Number of Samples			
Normal Concrete (BN)	0%	3	3	3	9
Concrete with Polypropylene (BP)	1%	3	3	3	9
Concrete with Palm Fiber (BI)	1%	3	3	3	9
Concrete with crum Rubber (BB)	1%	3	3	3	9
Grand Total					36

Before making test objects, planning needs to be done with mixed design [5] to achieve the targeted proportion. The results of mixture proportion planning can be seen in **Table 3**.

Table 2. Mix design normal and fiber concrete in kg/m^3.

Concrete	Cement	Aggregate Fine	Coarse	% Fiber 1%	W/C Ratio
Normal	620,34	528,47	1042,83	-	158,36
Fiber	620,34	528,47	1042,83	5,28	158,36

3 Result and Discussion

3.1. Fine Aggregate Testing

This test includes sieve analysis [6], solid and loose weight testing [7], specific gravity and absorption testing [8], water content testing [9], and sludge content testing [10], whose results are shown in Table 3.

Table 3. Fine Aggregate Test Results

Testing Type	Result	Unit
Fineness modulus	2,89	%
Solid content weight	1,64	kg/liter
Loose content weight	1,55	kg/liter
Bulk density (S_d)	2,50	-
Saturated bulk density (S_s)	2,53	-
Pseudo bulk density (S_a)	2,57	-
Water absorption	1,21	%
Water content	4,55	%
Sludge level	0,55	%

3.2. Coarse Aggregate Testing

This test includes sieve analysis [6], solid and loose unit weight testing [7], specific gravity and absorption testing [8], water content testing [9], sludge content testing [8], and aggregate wear [11] whose results are shown in Table 4.

Table 4. Coarse Aggregate Test Results.

Test Type	Result	Unit
Fineness Modulus	7,90	%
Solid Content Weight	1,42	kg/liter
Loose Content Weight	1,29	kg/liter
Bulk Density (S_d)	2,56	-
Saturated bulk density (S_s)	2,60	-
Pseudo bulk density (S_a)	2,66	-
Water absorption	1,46	%
Water content	1,89	%
Sludge level	0,73	%
Abrasion	11,40	%

3.3. Cement Testing

In order to ensure the cement properties, it is necessary to carry out several tests in the laboratory, including testing specific gravity or density [12], normal consistency [13], initial setting time [13], and final setting time [13]. The results of cement properties are displayed in Table 5.

Table 5. Test Results for Cement OPC Type I

Test Type	Result	Unit
Cement density	3,12	gr/cm^3
Cement consistency	25	%
Initial setting time	97,5	Minute
Final setting time	150	Minute

3.4. Workability of Concrete

In order to see the homogeneity and workability of fresh concrete mix with a certain viscosity, it is necessary to carry out a slump test [14] with a water-cement ratio of 0.26. Comparison of slump or workability values from each variation of concrete mix are shown in Fig. 1.

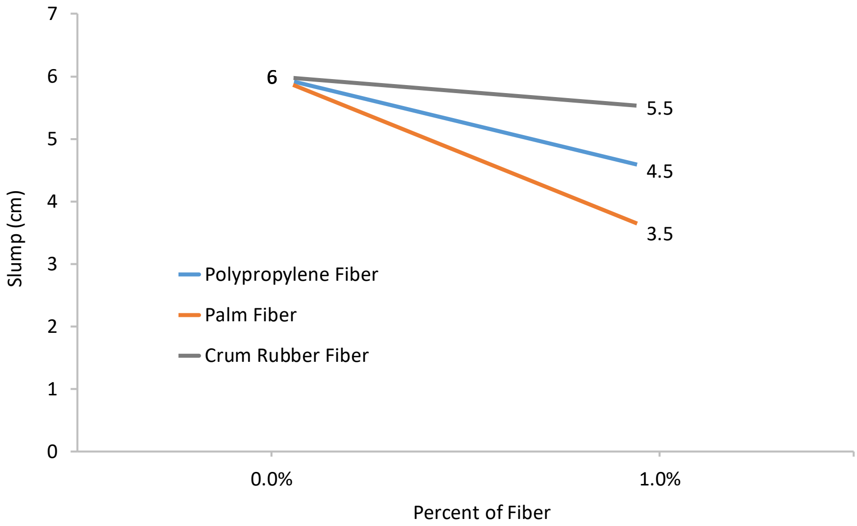

Fig. 1. Comparison Graph of Slump Values.

Based on Fig. 1, a significant decrease in slump value occurs in concrete mixtures with the addition of polypropylene fiber and palm fiber. This happens because both types of fiber are able to absorb water and decompose very quickly, so the resulting workability will be lower and more difficult. In contrast to used crumb rubber fiber, the resulting decrease in slump value is not very significant because the surface of used tire fiber is smooth and does not absorb water, so using used tire rubber with a content of > 1% can still produce good workability values.

3.5. Concrete Density Testing

This test aims to determine the density value of fresh concrete produced by comparing the mix weight and volume. A comparison of the weight of each mixture variation is shown in Fig. 2.

Based on Fig. 2, the addition of fiber (polypropylene, palm fiber, and crumb rubber) to concrete can reduce the weight of its contents. The most significant reduction in bulk density occurred in concrete Polypropylene, which dropped to 3% (2279.09 kg/m^3) from the normal mixture. This happens because the concrete mixture is filled with a lot of fiber, which should provide space for the aggregate. Filling the aggregate space will make the bulk weight of the concrete lighter so that the bulk weight of the concrete will decrease.

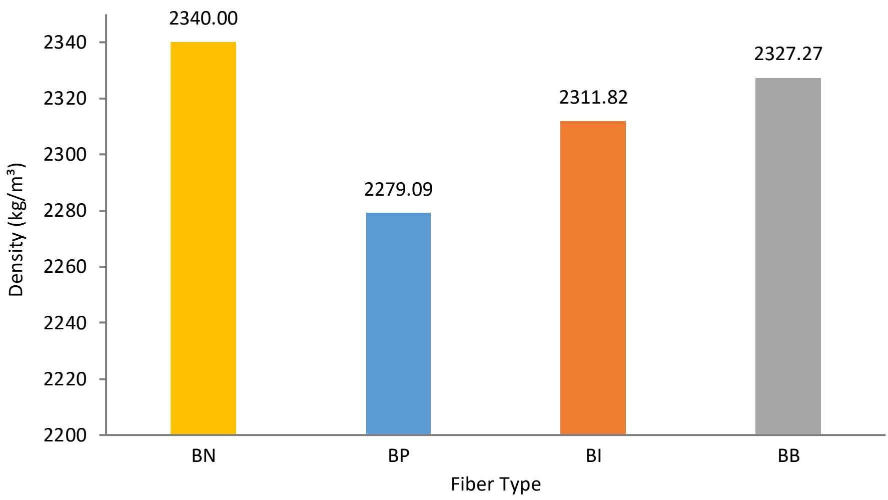

Fig. 2. Comparison graph of concrete content weight.

3.6. Concrete Flexural Strength

The flexural strength (fs) test was evaluated using a Hydraulic Universal Testing Machine (UTM), following [15][16] with the used parameter two points bending. The test

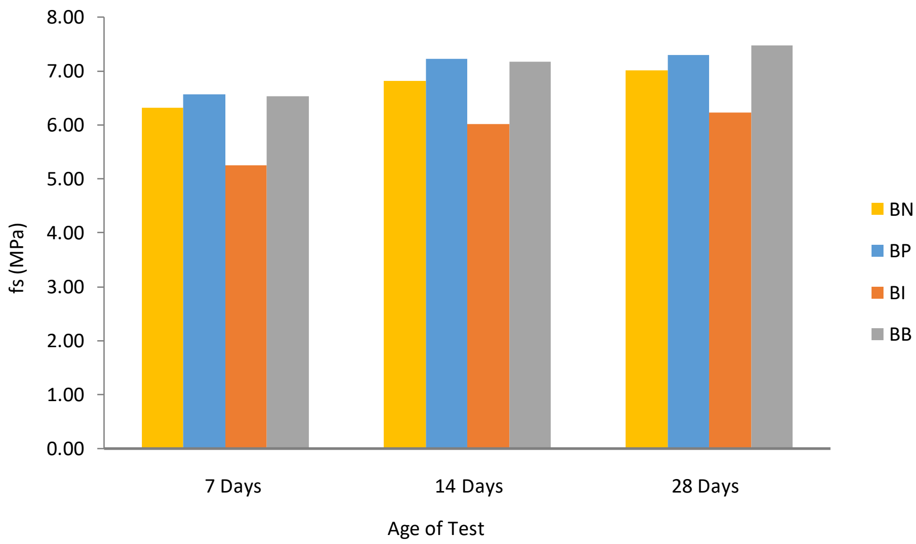

Fig. 3. Summary of Flexural Strength Results

method is to place the beam on two supports , which function to support the force in a direction perpendicular to the axis until the test object breaks, expressed in MPa (Mega Pascal) units. The summary of the flexural test results is presented in Fig. 3

Based on Fig. 3, at a test age of 28 days, the addition of polypropylene fiber (BP) and crum rubber fiber (BB) with a content of 1% increased the flexural strength up to 4% and 6% of normal concrete (BN). On the other hand, A quite large drop occurred with the addition of palm fiber (BI), which dropped up to 13% of normal concrete. These results are relevant to the basic properties of the raw material of each fiber, which crum rubber is more elastic than Polypropylene, and palm fiber is an organic material, which has a weakness per stem of palm fiber.

3.7. Comparison of Effect of Fiber Type on Flexural Strength

After testing the flexural strength (fs) on each variation of concrete, the next step is to analyze the comparison of flexural strength (fs) values to find out the type of variation that has the most optimal influence on the flexural strength of the concrete, the results of which are shown in Fig. 4.

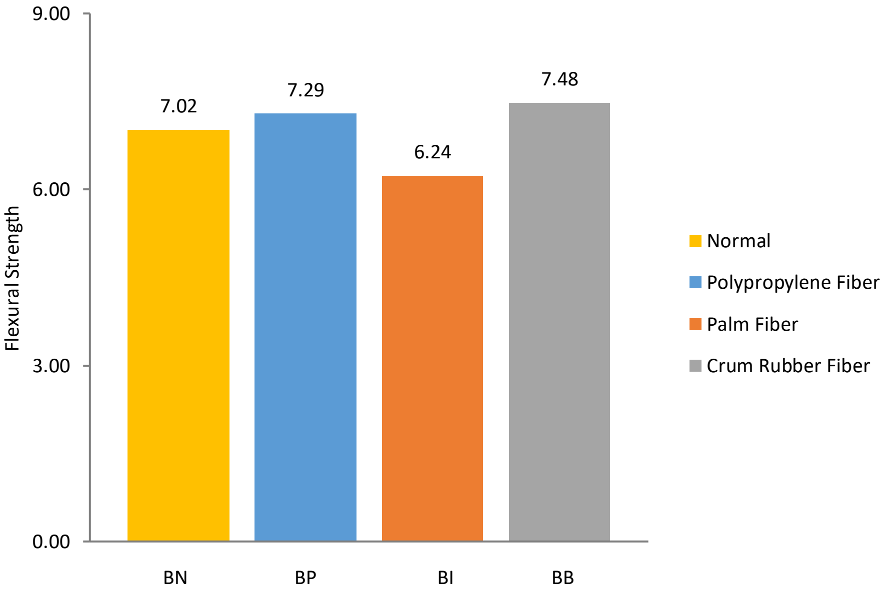

Fig. 4. Comparison of Effects of Fiber Variation on Flexural Strength (fs)

After data analysis, a clustered graph was obtained comparing the effect of fiber type on the flexural strength (fs) value shown in Fig. 4. The most optimal effect is produced by crumb fiber. The flexural strength (fs) results up to 7.48 Mpa, which increased by

6% from normal concrete. From the results of the analysis of crumb fiber concrete, it is predicted that if the fiber content is increased (> 1%), the flexural strength value will increase. It can be seen in Fig. 4, which shows that the flexural strength (fs) value produced by used crumb fibers dominates up to 1% of fiber content. This indicates that the optimum fiber content that can be used for concrete mixed with used tires could exceed>1%.

4. Conclusions

Based on the test results and data analysis in this research, the Author can draw several conclusions as follows:

1. From the workability test results for each mixture variation, concrete with palm fiber has the lowest level of workability. fibers in the concrete mixture (BN = 6 cm; BP = 4.5 cm; BI = 3.5 cm; BB = 5.5 cm).
2. After an analysis, palm fiber has properties that can decompose and absorb water very quickly. This makes the resulting workability increasingly difficult, so more admixture is needed to increase the slump value. In contrast to used crumb fiber, this type of fiber has fine characteristics and does not easily absorb water, so its use can still produce good workability.
3. The addition of polypropylene fiber, palm fiber, and used tire rubber can reduce the unit weight value of concrete. This happens because the concrete mixture is filled with a lot of fiber, which should provide space for the aggregate. Filling the aggregate space would make the weight of the concrete lighter.
4. The results of a comparative analysis of the influence of synthetic fiber (Polypropylene), palm fiber (fiber), and waste fiber (crumb rubber) on the flexural strength (fs) of concrete on rigid pavement are 1) At a fiber content percentage of 1 %, 2) the use of fiber in the form of used tires produces the most optimal flexural strength (fs) value compared to other types of fiber.

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