The Effect of Palm Fibers on Concrete Compressive Strength

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ABSTRACT

Due to its superior compressive strength, concrete is a building material that is frequently employed in construction.. The development of technology and infrastructure requires the development of concrete technology to improve concrete performance. Utilizing fiber-reinforced concrete is one method of enhancing concrete's characteristics. Concrete and fiber, both synthetic and natural, are combined to create fiber-reinforced concrete. Palm fiber is one type of natural fiber that can be used as fiber in concrete. This experiment aims to ascertain the impact of palm fiber addition on the compressive strength of concrete. Three cylindrical examples, each measuring 300 mm in height and 150 mm in diameter, were constructed. In this study, the variations are addition of palm fiber of 0%, 1.5%, 2.5%, and 3% of cement weight. The test findings demonstrated that at concrete ages of 14 days and 28 days, adding 1.5% produced the maximum compressive strength of concrete. The 28-day average compressive strength of fine aggregate concrete (gradation IV) is 68.83% higher than that of ordinary concrete. Coarse-grained and fine-grained aggregate concrete (gradation II) has an average life expectancy of 28 days, and its compressive strength is 57.1% higher than that of ordinary concrete.

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1. INTRODUCTION

Using concrete as pavement is one of the common uses of concrete. The development of technology and infrastructure requires the development of concrete technology to improve concrete performance. One of the efforts to improve the properties of concrete is the use of fiber-reinforced concrete. Fiber-reinforced concrete is a mixture of concrete and fiber, both natural and artificial. Fibers are used to prevent cracking, thus making concrete more daktail and increasing the tensile strength of concrete, which makes concrete more resistant to tensile forces due to weather, climate and temperature. The tensile strength[1] and flexural strength[2] of concrete can both be improved by adding fibers to the concrete mixture.

The mechanical qualities of concrete, such as compressive strength, tensile strength, shear strength, flexural strength, ductility, and shock resistance, are intended to be improved by the addition of fibers to concrete mixtures [3]. Winarto [4] conducted research on the use of palm fiber as a concrete mixture to increase the capacity of concrete to withstand compressive loads.

Palm fiber is chosen as fiber because the material is easily available, durable, not easily damaged and economically valuable. At the same time, compressive strength can be increased by increasing or evaluating the water-cement ratio. In this case, researchers use palm with a diameter of 0.1 cm cut into a length of 5 cm and use it in a concrete mixture. The amount of palm fiber varies from 0%, 1.5%, 2.5% and 3% of the weight of cement. It is expected that the addition of palm fiber to the concrete mixture can increase the compressive strength of concrete.

1.1 Fiber-Reinforced Concrete (FRC)

Fine aggregate, coarse aggregate, and fiber fragments are mixed with hydraulic cement to create fiber-reinforced concrete (FRC) [6]. The addition of these fibers is intended to increase the compressive strength of concrete. Types of fibers commonly used in fiber-reinforced concrete include steel fiber, glass fiber, synthetic fiber, and natural fiber. In this study, the type of fiber used was natural fiber, namely palm fiber.

The palm fiber produced from palm trees has physical properties including strands of black thread (fiber), approximately 1 mm in diameter, stiff and tenacious (not easily broken), highly resistant to acid inundation including sea water containing salt. With the characteristics of palm fiber like this, it is hoped that it can improve the unfavorable properties of concrete. So far, palm fiber has only been used for household purposes, with Technological developments allow the expansion of the use of plm fiber as a mixture in concrete.

1.2 Constituent Materials of Fiber-Reinforced Concrete

The constituent materials of fiber-reinforced concrete are as follow:

1. Portland Composite Cement (PCC)
   Composite Portland cement (Portland Composite Cement or PCC) is a variation of hydraulic cement which is composed of a mixture of ordinary Portland cement with the addition of other ingredients that contribute to the hydration reaction of the cement. Additional materials used in PCC cement include fly ash, cracked grains, blast furnace, pozzolan, and other materials [8].

2. Fine Aggregate

Table 1. Fine aggregate gradation

Sieze (mm)	Percentage passing for			
	Gradation 1	Gradation 2	Gradation 3	Gradation 4
9.50	100	100	100	100
4.75	90 – 100	90 – 100	90 – 100	95 – 100
2.36	60 – 95	75 – 100	85 – 100	95 – 100
1.18	30 – 70	55 – 90	75 – 100	90 – 100
0.60	15 – 34	35 – 59	60 – 79	80 – 100
0.30	5 – 20	8 – 30	12 – 40	15 – 50
0.15	0 – 10	0 – 10	0 – 10	0 – 15

Source: SNI 03-2834-2000

A fine aggregate is one whose largest particle size, at most, is number 4 (4,75 mm) [8]. Sludge (granules that pass filter 200), organic waste, and other substances that could harm the concrete mix should not be present in a good fine aggregate. The gradation of fine aggregate is divided into 4 zones, namely coarse sand (gradation zone I), medium sand (gradation zone II), rather fine sand (gradation zone III), and fine sand (gradation zone IV). Table 1 shows the gradation distribution of fine aggregates.

3. Coarse Aggregate
Coarse aggregate is aggregate held on a 4.75 mm sieve [8]. Coarse aggregate should not contain 200 sieve escape grains more than 1%, do not contain substances that damage concrete, and are not porous. The gradation of coarse aggregate is divided into the maximum size of gravel, which is the maximum size of 1 cm, 2 cm, and 4 cm.

4. Water
According to the National Standardization Agency [10], the water used in concrete mixes must be clean and free of damaging ingredients such as oil, acids, alkalis, salts, organic matter, or other ingredients which are detrimental to concrete or reinforcement. These chemical elements in water have the potential to actively influence concrete's chemical reactions and strength development [11].

5. Fiber
Fiber is the core component of fiber-reinforced concrete. In this experiment, palm fiber is used. Palm fiber is a natural material produced by the palm frond (*Arenga pinnata*). Palm fiber is an abundant resource in Indonesia, as it is a native plant to Tropical Asia and naturally spread all across Asia [12]. The abundance of palm tree in Indonesia makes palm fiber easy to obtain and is an option for natural fiber in fiber-reinforced concrete. Palm fiber can last for decades and is resistant to acids and sea salt. Palm fiber has a physical form in the form of black strands, which are stiff and ductile, and resistant to tension. The smaller the fiber diameter, the stronger the tensile strength.

Research conducted by Munandar et al [13] found that small diameter palm fiber groups (0.25 – 0.35 mm) had a tensile strength of 208.22 MPa, strain of 0.192%, and a modulus of elasticity of 5.37 GPa. The characteristics of the palm fiber can be compared with the characteristics of other fibers commonly used for fiber-reinforced concrete, such as steel wire [14]. The higher tensile strength of palm fiber than steel wire causes palm fiber to be a good fiber option for fiber-reinforced concrete.

1.3 Concrete Compressive Strength

When a concrete specimen is loaded with a specific compressive force produced by the compression testing machine, the amount of load per unit area that causes the concrete specimen to collapse is known as the concrete's compressive strength. The procedure for testing the compressive strength of concrete refers to Standar Nasional Indonesia 1974: 2011 [15].

The compressive strength test is carried out by placing the cylindrical specimen on a flat bottom pressure pad with the hard surface facing upwards. Loading must be carried out continuously and without shock until the test object is destroyed and the maximum load received is recorded. Equation 1 shows the calculation of the compressive strength of the concrete test object.

$$f'c = \frac{P}{A} \qquad (1)$$

f’c = Compressive strength of concrete with cylindrical specimens (Mpa)
P = The axial compressive force (N)
A = The cross-sectional area of the specimen (mm^2)

1.4 Concrete Crack Pattern

Cracks are conditions where there is a break in the structure or separation in the concrete structure without collapse. In general, cracks can be caused by several things, such as shrinkage in concrete, poor curing processes in concrete, loads that exceed concrete strength, and an uneven mixture of materials in concrete. Figure 1 is the crack pattern of concrete test specimens.

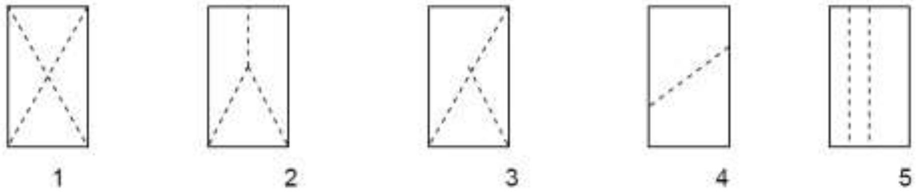

Figure 1. Concrete Crack Pattern
Source: SNI 1974:2011

The crack pattern in type 1 is a conical crack pattern at both ends. Type 2 crack pattern is a conical crack pattern at one end, with a vertical crack at the other end. Type 3 crack pattern is a conical crack pattern at one end, with a shear crack in a diagonal direction at the other end. Type 4 crack pattern is a shear crack in a diagonal direction on both sides of the specimen. Type 5 crack pattern is a crack pattern parallel to the vertical axis (columnar), where this crack pattern does not form a cone.

2. METHODS

The experimental approach was employed in this investigation. Concrete flexural strength testing, concrete compressive strength testing, and mix design testing are performed. The mix design refers to the procedures for making concrete mix plans for normal quality Indonesian National Standard (SNI) 03-2834-2000. The concrete compressive strength (ccs) test carried out refers to the Indonesian National Standard (SNI) 03-1974-1990.

Table 2. Samples Variations and Numbers

Concrete mixture variation		**Concrete age of 28 days**
Fine aggregate type	**Fiber percentage**	**Number of samples**
Grading zone II	0%	2
	1.5%	2
	2.5%	2
	3%	2
Grading zine IV	0%	2
	1.5%	2
	2.5%	2
	3%	2
TOTAL		16

In this study, there were four types of variations in the percentage of palm fiber added to the concrete mix, namely 0%, 1.5%, 2.5%, and 3%. The length of the palm fiber used is ± 5 cm. For each percentage of palm fiber, there are two variations of fine aggregate used, namely coarse-grained fine aggregate (gradation zone II) and fine-grained fine aggregate (gradation zone IV). The number of test objects made can be seen in Table 2.

The research steps can be seen in Fig. 2.

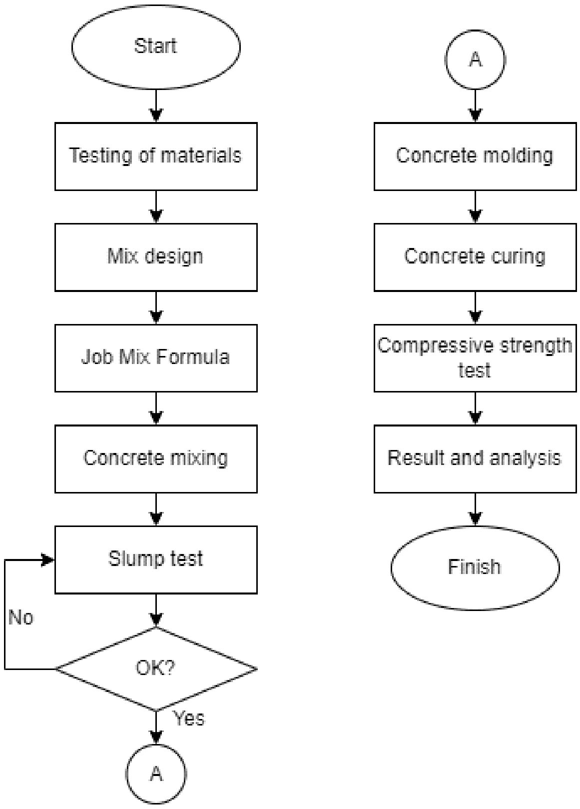

Figure 2. Testing flowchart

3. RESULTS AND DISCUSSION

3.1 Slump and Concrete Unit Weight

In the implementation of mixing, slum and bulk density tests were carried out. The results of the slump test can be seen in Table 3 and Table 4.

Table 3. Slump test result of concrete mixture with gradation IV fine aggregate

Fiber percentage variation (%)	Average slump (cm)	Slump required (cm)	Water addition (kg)
0%	6,10	5.0 – 7.5	0,81
1.5%	6,28	5.0 – 7.5	2,62
2.5%	9,38	5.0 – 7.5	2,43
3%	8,25	5.0 – 7.5	1,86

Slump is the viscosity level of concrete which affects permeability, workability, and processing. Things that affect slump include aggregate grain size, amount of water, and the effect of water on cement. The planned slump value limit is 5 – 7.5 cm. To achieve the planned slump value, water can be added.

Table 2. Slump test result of concrete mixture with gradation II fine aggregate

Fiber percentage variation (%)	Average slump (cm)	Required slump (cm)	Water addition (kg)
0%	6,10	5.0 – 7.5	0,53
1.5%	6,28	5.0 – 7.5	2,99

2.5%	5,13	5.0 – 7.5	3,18
3%	8,25	5.0 – 7.5	3,49

The addition of water is caused by high aggregate absorption and aggregate water content at the time of mixing which is different from the initial water content due to aggregate storage not in a closed place, as well as absorption carried out by palm fiber. Based on the graph in Figure 3, the addition of water to the mixture has increased in direct proportion to the percentage of palm fiber. This happens because the more palm fiber is mixed, the more water absorbed by the palm fiber.

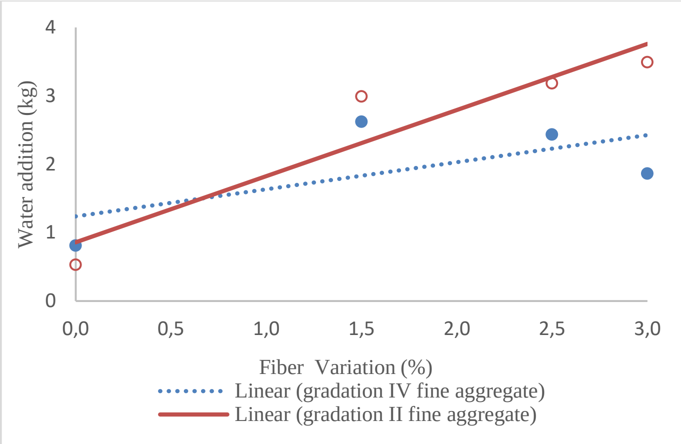

Figure 3. Graph of water addition to concrete mixture

The unit weight of concrete is influenced by the weight of the material, the arrangement of the materials, and the density of the mixture. In addition to fine aggregate, the materials used are of the same type, so the bulk density of the concrete is affected by the density of the mixture. The higher the density of the mixture, the higher the concrete weight. The results of the content weight test can be seen in the graphs in Figure 4 and Figure 5.

In a concrete mixture with gradation 2 fine aggregate, there is an increase in bulk density at variations of 0% to 3%. Meanwhile, for concrete mixtures with fine aggregate gradation 4 there was a decrease in bulk density from 0% to 3%. This is influenced by the distribution of aggregate and palm fiber.

In a mixture with fine aggregate gradation 2, palm fiber fills the cavities between the aggregate mixture properly, causing a denser mixture and heavier bulk density. Meanwhile, the unit weight of concrete mixture with fine aggregate gradation 4 decreased. Apart from the effect of fine aggregate material which has a lower unit weight, too much palm fiber also replaces the fine aggregate material so that the concrete weight becomes lighter.

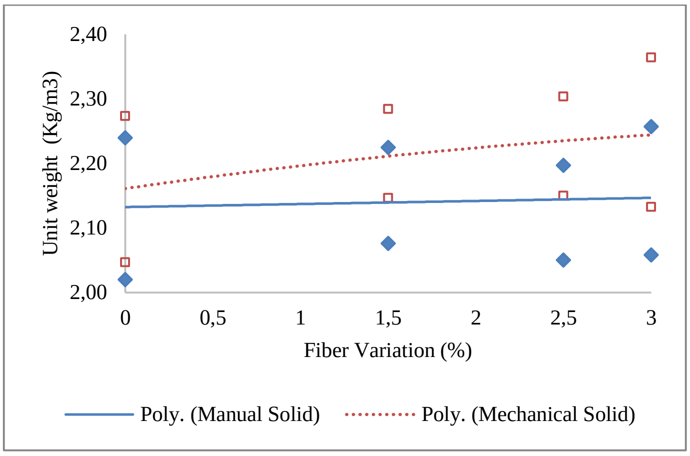

Figure 4. Unit weight chart for concrete mixture with gradation II fine aggregate

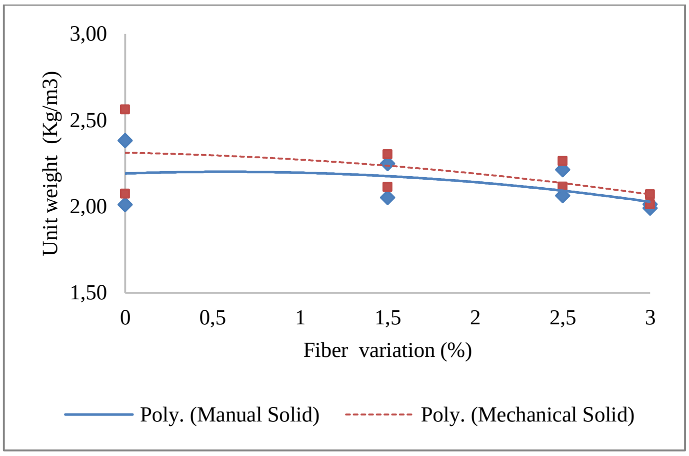

Figure 5. Unit weight chart for concrete mixture with gradation IV fine aggregate

In a mixture with fine aggregate gradation 2, palm fiber fills the cavities between the aggregate mixture properly, causing a denser mixture and heavier bulk density. Meanwhile, the unit weight of concrete mixture with fine aggregate gradation 4 decreased. Apart from the effect of fine aggregate material which has a lower unit weight, too much palm fiber also replaces the fine aggregate material so that the concrete weight becomes lighter.

The concrete compressive strength (ccs) test seeks to ascertain the durability of a cylindrical specimen measuring 150 mm by 300 mm. Concrete was tested for compressive strength using three test samples at both 14 and 28 days of age. Table 5 and Table 6 are the results of concrete compressive strength (ccs) tests.

Table 5. Concrete compressive strength (ccs) in concrete with gradation IV fine aggregate

Fiber percentage variation (%)	Compressive strength of 14 days (MPa)	Compressive strength of 28 days (MPa)
	11,16	12,68
0	9,06	10,29
	9,62	10,94
	18,03	20,50
1,5	17,01	19,33
	15,33	17,42

	16,42	18,66
2,5	18,16	20,63
	17,44	19,81
	9,31	13,75
3	10,77	14,28
	9,96	14,58

Table 6. Concrete compressive strength (ccs) in concrete with gradation II fine aggregate

Fiber percentage variation (%)	Compressive strength of 14 days (MPa)	Compressive strength of 28 days (MPa)
	12,83	14,59
0	12,40	14,09
	13,29	15,10
	19,14	21,75
1,5	21,97	24,97
	19,41	22,06
	21,89	24,87
2,5	21,98	24,98
	19,62	22,29
	9,14	13,11
3	9,42	12,77
	9,69	13,02

Figures 6 and 7 show a graph of the compressive strength trend that was created based on the outcomes of the compressive strength tests that were performed and are shown in Tables 4 and 5.

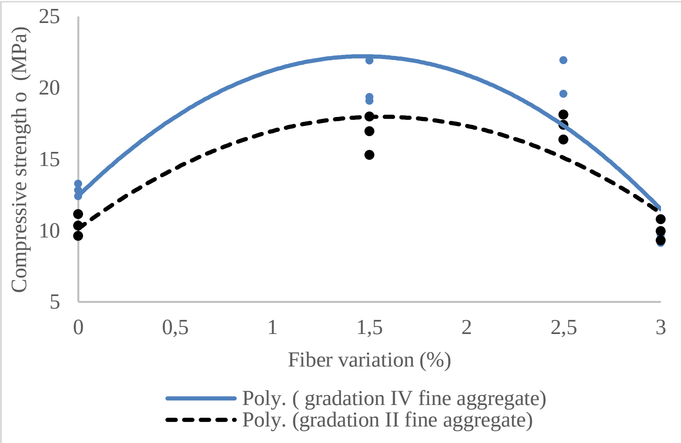

Figure 6. Trend of concrete compressive strength (ccs) of 14 days

The graph shows that, when 1.5% palm fiber is added to regular concrete, the compressive strength of the palm fiber-infused concrete is increased. This means that palm fiber affects the compressive strength of concrete.

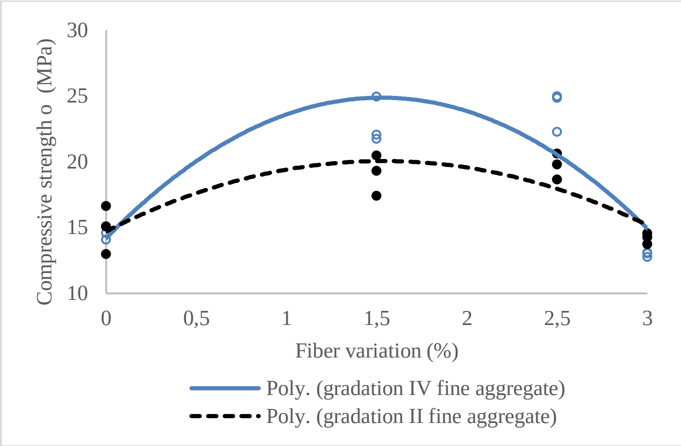

Figure 7. Trend of concrete compressive strength (ccs) of 28 days

However, the maximum compressive strength was achieved at 1.5% palm fiber before finally decreasing. Because so much material is replaced by palm fiber when there is too much palm fiber in the concrete mix, the compressive strength of the concrete decreases. Based on the tendency of the compressive strength in the two graphs, it can be concluded that the optimum compressive strength is obtained in concrete with the addition of 1.5% palm fiber, where the palm fiber fills voids that cannot be filled with aggregate.

The crack pattern that occurs as a result of the compressive strength test can be seen in Figure 8 (a) and (b).

(a) **(b)**

Figure 8. Crack pattern for samples with mixture of (a) 0% palm fiber and (b) 3% palm fiber

The crack pattern that occurs on the concrete is a Type 2 crack pattern, both in the mixture without the addition of palm fiber (0% palm fiber) and with the addition of 3% palm fiber. Despite having the same crack pattern, the two types of concrete have different failures. Concrete without the addition of palm fiber experiences more failure in cracks, so the cavities in the cracks are larger. Concrete with a mixture of 3% palm fiber experienced cracks, but did not collapse. The fibers mixed in the concrete keep the concrete from collapsing when cracks occur.

4. CONCLUSION

Based on the results of the research that has been done, it can be concluded:

1. The proportion of 1.5% palm fiber addition produced the maximum concrete compressive strength (ccs) value, according to the findings of the compressive strength test. When compared

to standard concrete with no palm fiber, the average compressive strength at 28 days for concrete with fine grained aggregate rose by 68.8%. When compared to standard concrete with no palm fiber, the average compressive strength of 28 days for concrete containing coarse-grained fine aggregate rose by 57.1%.The amount of palm fiber added to the mixture affects the strength of the concrete. Palm fiber can strengthen concrete, but the amount of palm fiber that is too much can reduce the strength of concrete.

2. Fiber fibers in the mixture contribute to binding the concrete to the cracked part and reduce collapse, thus preventing the widening of the crack at the location of the concrete crack.

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