The effect of variation in the length of water hyacinth fiber twisted on split tensile strength high performance fiber concrete

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ABSTRACT

One of the weaknesses of concrete is that it has a very small tensile strength, which makes it brittle. Normal concrete has a tensile strength of 9-15% of its compressive strength. To increase the tensile strength of concrete, it is necessary to add fiber. The types of fibers that can be used in concrete can be either natural fibers or non-natural fibers. Various alternatives can be made as an effort to improve the quality of concrete. One of them is by utilizing weeds or weeds into useful materials. One of these disturbing plants is the water hyacinth plant, which is quite abundant and grows very fast. Water hyacinth plants consist of stems, leaf petals, which are rich in fiber, which allows it to be used as an alternative additive in concrete mixtures for construction. The purpose of this research is to try to apply water hyacinth fiber (SEG) 0,75% in high performance concrete (HPC) to determine the effect of the ratio of water hyacinth fiber twisted length on the compressive strength and split tensile strength of high performance concrete with several variants fiber lengths of 2 cm, 1,5 cm and 1 cm. The results showed that the decrease in the compressive strength of water hyacinth fiber-rolled concrete for variations of 2 cm, 1,5 cm and 1 cm were respectively 10,76%, 14,16%, and 18,76% of the reference concrete compressive strength of 45,42 MPa and the highest splitting tensile strength of concrete is in the 1 cm fiber length variation of 3,65 MPa which is 9.89% of the concrete compressive strength of 36,90 MPa. The modulus value decreases with the variation in the length of the fiber strand,

Keywords: water hyacinth fiber; high performance concrete; fibrous concrete; compressive strength; split tensile strength; modulus of elasticity.

INTRODUCTION

One type of concrete that is widely used is high performance concrete. With the increasing use of high performance concrete in the construction industry, more and more efforts are being made to make it more sophisticated and more economical. With the innovation of concrete technology towards being environmentally friendly, the concrete constituent materials to be used should utilize environmentally friendly materials.

Concrete has one weakness, which has a very small tensile strength so it is brittle. Normal concrete has a tensile strength of 9-15% of its compressive strength (Dipohusodo, 1996). To increase the tensile strength of a concrete it is necessary to add fiber. Types of fibers that can be used in concrete can be fiber or non-natural.

Water hyacinth or Eichornia crassipes (Latin) is a type of floating aquatic plant. Besides being known as water hyacinth, in several areas in Indonesia, water hyacinth has other names such as Kelipuk (Palembang), Ringgak (Lampung), Ilung-ilung (Dayak) and in Manado it is known as Tumpe (Wikipedia.com, 2019b).

According to (Widyaningsih & Sutanto, 2018) the use of this plant is still very rare because the majority of people know the use of this plant water hyacinth is only for making crafts, this plant can grow up to 1.9% per day. Even though the water hyacinth plant has a high fiber content (20% fiber) so that in his research water hyacinth fiber was used as a filler.

Study (Saluria et al., 2020) regarding the use of water hyacinth fiber by 1% to the amount of sand in the concrete mixture, in general it results in a decrease in compressive strength. However, the percentage of tensile strength increases by 8% from the tensile strength of normal concrete.

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According to (Ndoen et al., 2015) Gewang leaf fiber rolled and treated with NaOH can increase the average flexural strength by 22.5% compared to no fiber and the average tensile strength is 17% at a fiber concentration of 0.75% of the total cement. Study(Ndoen et al., 2015)using a maximum aggregate diameter of 40 mm, explained that if the length of the fiber being rolled was > 4 cm, the fibers would agglomerate, so the Ndoen researchers used a fiber length of 3 cm (75% of the maximum aggregate diameter). This means that when compared with the results of Saluria's research with Ndoen, the splitting strength of twisted fiber increased by 47% compared to unrolled fiber.

RESEARCH METHODS

Fibrous concrete

One of the additional ingredients in concrete is fiber. Concrete with added fiber is called fiber reinforced concrete. Because fiber is added, it becomes a composite material, namely concrete and fiber. Fibers can be asbestos, glass/glass, plastic, steel or plant fibers.

Types of fibers that can be used in fiber concrete mixtures can be fibers or artificial fiber. The purpose of adding fiber is to increase tensile strength concrete, so that concrete is resistant to tensile forces, weather, climate and temperature which usually occur in concrete with a wide surface (Wikipedia.com, 2019a).

The use of fiber in the concrete mix is essentially a positive influence on concrete, which can improve the properties of concrete, including increasing the ductility and flexural strength of concrete.

High performance concrete

High-performance concrete (HPC) is a development of the concept of conventional concrete. In the use of conventional concrete, compressive strength is usually a parameter limit that must be met for a concrete work to be declared acceptable. It is different with high performance concrete, the parameters expected to be achieved are not only one but consist of several parameters related to the implementation and end result of a concrete work, with the ultimate goal of achieving the strength and durability of concrete as a material of a structure (Irawan, 2012).

Parameters in high performance concrete include high early strength, high strength, high modulus of elasticity, high abrasion resistance, high durability and permeability. low (low permeability).

Water hyacinth

Water hyacinth or Eichornia crassipes (Latin) is a type of floating aquatic plant. Besides being known as water hyacinth, in several areas in Indonesia, water hyacinth has other names such as Kelipuk (Palembang), Ringgak (Lampung), Ilung-ilung (Dayak) and in Manado it is known as Tumpe (Wikipedia.com, 2019).

Various alternatives can be made as an effort to improve the quality of concrete. One of them is by utilizing weeds or weeds into useful materials. One of these disturbing plants is the water hyacinth plant, which is quite abundant and grows very fast. Water hyacinth plants consist of stems, leaf petals, which are rich in fiber, which allows it to be used as an alternative additive in concrete mixtures for construction.

Figure 1. Water hyacinth plant

According to (Widyaningsih & Sutanto, 2018) the use of this plant is still very rare because the majority of people know the use of this plant water hyacinth is only for making crafts, this plant can grow up to 1,9% per day. Even though the water hyacinth plant has a high fiber content (20% fiber) so that in his research water hyacinth fiber was used as a filler.

Research Utomo (1975) in (Prasetyaningrum et al., 2009) shows that there is a composition of chemical compounds and mineral content in water hyacinth plants, both in wet and dry conditions (Table 1).

Table1. Composition of Chemical Compounds and Mineral Content in Water Hyacinth Plants

Composition of chemical compounds in wet water hyacinth	Rate (%)	Mineral content in dried water hyacinth	Rate (%)
Coarse protein	13,03	K2O	5
Coarse fiber	20,06	cl	3-9
Fat	1,1	Mg	0,96
BETN	25,98	PO4	0,36
Ash	23,8	-	-

Source: (Utomo, 1975)(Prasetyaningrum et al., 2009) (Jalali & Khairil, 2016)

Rahmi (1998) in (Prasetyaningrum et al., 2009) argues that water hyacinth has the potential to be used as an organic material because based on the results of analysis in the laboratory it contains 1,681% N (Sodium), 14,286% K (Potassium), 37,654% C (Calcium). From the chemical composition, water hyacinth has a high enough fiber content (20,06%) but also has a high ash and impurity (vortex) content.(Jalali & Khairil, 2016) (Okwadha & Makomele, 2018).

The results of the water hyacinth ash content test in the laboratory are as follows:

Table 2. Test results for the ash content of 125 grams of water hyacinth

Parameter	Unit	Test results	Method
Silica	%	13,04	Gravimetry
Calcium (Ca)	%	0,33	SSA

Source: Laboratory test of BBTPPI Semarang Journal(Anam et al., 2015).

This means that the silica content in water hyacinth ash is around: = 3,1%$\frac{13,04\ x\ 23,8}{100\ \%}$

Table 3. Composition of Chemical Elements of Water Hyacinth in Oven Dried

No.	Component Analysis	Water hyacinth (%)
1	Ash	12,0
2	Silicate	5,56
3	Lignin	7,69
4	pentosan	15,6
5	Cellulose	64,5

Source: Wahyu Nurramadhan Utilization of water hyacinth as raw material for particle board (2011) Journal (Therti et al., 2012)

From Table 2 and Table 3 the silica content found in water hyacinth ash ranges from 3% - 5%, so it can be concluded that water hyacinth contains minerals that can be used as additives in cement because cement is also a natural mineral used as a binder in mixing high performance concrete.

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Method

This research was conducted at the Mercu Buana University Materials Laboratory, Jakarta, West Java. This research was carried out in 2022 for 4 months of testing time. Water hyacinth samples were obtained from the outskirts of the Citarum river, Karawang, West Java.

Water hyacinth fiber treatment

The water hyacinth material before being used as fiber is dried first, then the water hyacinth is shredded after that the shredded water hyacinth is treated with NaOH for 2 hours. The purpose of this damping process is to remove the elements contained in the fiber such as oil, dirt, color elements, and others. After that, the fiber is dried again (Nawanti, 2018) (Wulandari & Kartikasari, 2019) (Das & Singh, 2016). After being dried again, the treated fiber is rolled and cut into 2cm, 1.5cm and 1cm sizes.

Natural fibers derived from plants are lignocellulosic, where cellulose acts as a reinforcing material, while lignin and hemicellulose provide stiffness and protection to the fiber. The efficiency of plant fiber reinforcement depends on the cellulose content and the crystallization form of the total plant fiber content which includes cellulose, hemicellulose, lignin, pectin and waxes. This fiber content then determines the overall fiber properties (Prasetyaningrum et al., 2009)(Anton, D, 2009) (Kiptum et al., 2019).

Then the fiber needs to be treated / treated using an alkaline solution (NaOH) to reduce unused fiber elements such as hemicellulose, lignin, pectin and other elements until cellulose remains as the main ingredient in fiber. This alkaline treatment is also useful in removing the remaining fibers in the fiber (Ndoen et al., 2015) (Kiptum et al., 2019).

Figure 2. Process of water hyacinth fiber treatment: (a) shredded water hyacinth, (b) soaking with NaOH, (c) drying again, (d) rolling water hyacinth fiber

Data analysis

Equipment used to make concrete specimens are as follows:

1. Concrete mixer
2. Cylinder mold d= 15 cm, t= 30 cm
3. Concrete compressive and tensile strength test equipment
4. Concrete modulus of elasticity test equipment

The materials used in this study are:

1. Coarse aggregate (12,5mm split)
2. Fine aggregate (Bangka sand)
3. Water hyacinth fiber (length variations of 2cm, 1,5cm, and 1cm)
4. PCC Cement
5. Water

The specimens in this study can be described as follows:

a. Compressive Strength and Modulus of Elasticity Test

Table 4. Compressive Strength and Modulus of Elasticity Test Specimens

Concrete Variations	**Diameter (cm)**	**Tall (cm)**	**Age of Concrete (Days)**		**The amount Sample**
			7	**28**	
Reference Concrete	15	30	3	4	7
BA+SEG 2cm	15	30	3	4	7
BA+SEG 1.5cm	15	30	3	4	7
BA+SEG 1cm	15	30	3	4	7
Total					**28**

b. Splitting Tensile Strength Test

Table 5. Split Tensile Strength Test Specimens

Concrete Variations	**Diameter (cm)**	**Tall (cm)**	**Age of Concrete (Days)**		**The amount Sample**
			7	**28**	
Reference Concrete (BA	15	30	3	3	6
BA+SEG 2cm	15	30	3	3	6
BA+SEG 1.5cm	15	30	3	3	6
BA+SEG 1cm	15	30	3	3	6
Total					**24**

The working method used in this study is an analysis test of the mechanical properties of materials which can be explained as follows:

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To obtain the quality of the concrete to be used, a mix design is first made with the aim of obtaining the composition of water, cement, sand and gravel and the addition of water hyacinth fiber of 0,75% of the weight of cement, with a design concrete quality of *fc'* = 45 MPa.

Aggregate Testing (ASTM, 2012)

Aggregate testing needs to be carried out to find out whether the aggregate used meets the requirements, because in concrete, aggregate is the material that has the largest composition and plays an important role in terms of achieving the desired concrete characteristics.

This aggregate testing method refers to the American Society for Testing and Materials (ASTM) testing standards.

Aggregate testing was carried out at the Materials Laboratory of the Civil Engineering Department, Mercu Buana University. The aggregates tested were fine aggregate and coarse aggregate.

***Mix Design* (SNI 03-6468-2000)**

*Mix designs*intended to obtain concrete that meets technical requirements. However, in this study, the compressive strength of concrete was not planned beforehand but determined the water-cement factor value and looked for the compressive strength value.

There are several methods for determining the mix design, but in this study only the SK-SNI method was used (National Standardization Agency, 2000), with the aim of determining the proportion of mixed concrete forming materials.

Before carrying out the composition of the material used, laboratory tests were carried out on these materials.

Treatment Method (Curing)

To obtain the expected test results, after the concrete is removed from the mold, it must be treated immediately by immersing the concrete in water. Rapid loss of water also causes the concrete to shrink, causing tensile stresses to occur in the drying concrete which can cause cracks. Concrete cured for 7 days will be about 50% stronger than untreated. So care is necessary to fill the capillary pores with water, because hydration occurs in them (SNI 03-2834-2000, 2000).

Testing of Compressive Strength and Split Tensile Strength of Concrete

Concrete compressive strength can be achieved up to 14,000 psi or more, depending on the type of mix, aggregate properties and curing time and quality. The strength of concrete most commonly used is about 3,000 to 6,000 psi, and commercial concrete with ordinary aggregates, strength is about 300 to 10,000 psi. (Nawi, 1998).

Calculation of the results obtained from testing the compressive strength of concrete on a compression machine in the form of compressive stress (σ'). The amount of concrete compressive stress is obtained from the equation:

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

where:

P = load

A = surface area of the cylindrical specimen

Testing the Modulus of Elasticity of Concrete (Test et al., 2002)

The modulus of elasticity is the ratio of the normal tensile or compressive stress to the strain. The modulus of elasticity depends on the age of the concrete, the properties of the aggregate and cement, the speed of loading, the type and size of the specimen. From the compression test of the 15/30 concrete cylinder, the modulus of elasticity of the concrete is calculated using the ASTM C 469-02 formula (Test et al., 2002) as follows:

$$E_c = \frac{(\sigma_2 - \sigma_1)}{(\varepsilon_2 - \varepsilon_1)} \quad (2)$$

where:

E_c= Modulus of elasticity of concrete (MPa)
σ_2= Stress at 40% breakdown stress (MPa)
σ_1= Stress when the value of strain = 0.000050ε_1
ε_2= The value of the strain curve that occurs when the stress = (MPa)σ_2
ε_1= 0.000050

Research Flowchart

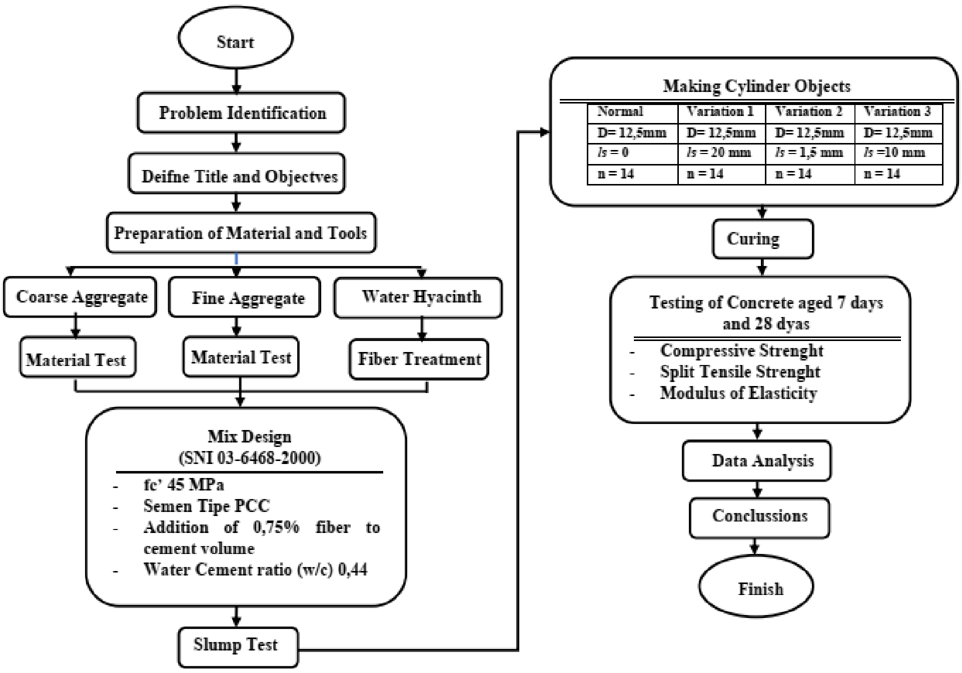

Figure 2. Research flowchart

RESULTS AND DISCUSSION

After the curing process has reached the specified age (7 days and 28 days) then the concrete sample is removed from the water bath for testing the compressive strength and split tensile strength of the concrete using a concrete compression test equipment. The following is a table and graph of the concrete compressive strength test results:

Table 6. Concrete compressive strength results for all variations

Concrete Variations	Concrete Compressive Strength (MPa)	Decrease Percentage (%)
Reference Concrete (BA)	45,42	-
BA+SEG 2cm	40,53	10,76
BA+SEG 1.5cm	38,99	14,16
BA+SEG 1cm	36,90	18,76

In Table 6 the results obtained by adding water hyacinth fiber rolling in this study experienced a decrease in the quality of the plan. Where the design compressive strength (f_{cr}) of the reference concrete and the mixed composition used is 45 MPa.

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The split tensile strength of concrete that meets the criteria of 9-15% of the compressive strength of the concrete is in the BA+SEG 1cm variation of 9,89%. For a comparison of the percentage of concrete tensile strength shown in Table 7.

Table 7. Results of Split Tensile Strength of Concrete for all Variations

Concrete Variations	Concrete Compressive Strength (MPa)	Splitting Strength (MPa)	Percentage of Tensile Strength (%)
Reference Concrete (BA)	45,42	3,74	8,23
BA+SEG 2cm	40,53	2,76	6,81
BA+SEG 1.5cm	38,99	3,47	8,90
BA+SEG 1cm	36,90	3,65	9,89

Table 8. Results of the Concrete Elasticity Modulus Test for all Variations

Concrete Variations	Elasticity Modulus (MPa)	Percentage of decrease (%)
Reference Concrete (BA)	2867,46	-
BA+SEG 2cm	1730,83	39,64
BA+SEG 1.5cm	943,77	67,09
BA+SEG 1cm	444,85	84,49

The modulus of elasticity decreased with the length of the water hyacinth fiber roll. The smallest decrease occurred in the concrete of variation 3 with a fiber length ratio of 1 cm of 444,85 MPa or around 84,49% of the reference concrete shown in Table 8.

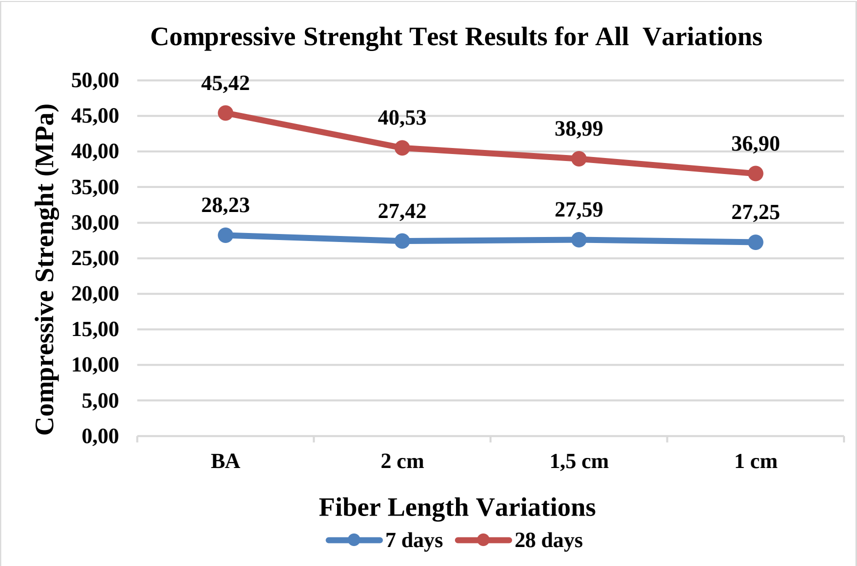

Figure 3. Graph of concrete compressive strength test results for all variations

From Table 6 and Figure 3, above it can be seen that the highest compressive strength results at 28 days are found in reference concrete with a compressive strength value of 45,42 MPa. The decrease in the compressive strength of water hyacinth fiber concrete for variations of 2 cm, 1,5 cm and 1 cm were respectively 10,76%, 14,16% and 18,76% of the concrete compressive strength of 45,42 MPa. From research (Dipohusodo, 1996)(Wulandari & Kartikasari, 2019)(Priyatno et al., 2017) (AS

Rahmi et al., 2015)(A. Sucia Rahmi et al., 2015)(Faculty et al., 2015) The decrease in compressive strength results can be caused by the addition of water hyacinth fiber (natural fiber) which creates cavities which causes the concrete to become brittle due to the fast weathering of water hyacinth fibers. When viewed from the variations in the length of water hyacinth fiber rolls, the highest concrete compressive strength occurs in concrete using water hyacinth fiber roll lengths of 2 cm. According to (Saluria et al., 2020) The longer the fiber, the higher the compressive strength of the concrete. And in research (Ndoen et al., 2015) (Gerung, 2012) (Saputra et al., 2021) the length of the fiber used should not be more than 4 cm will cause clumping of the fibers in the mixture of other concrete ingredients resulting in poor concrete.

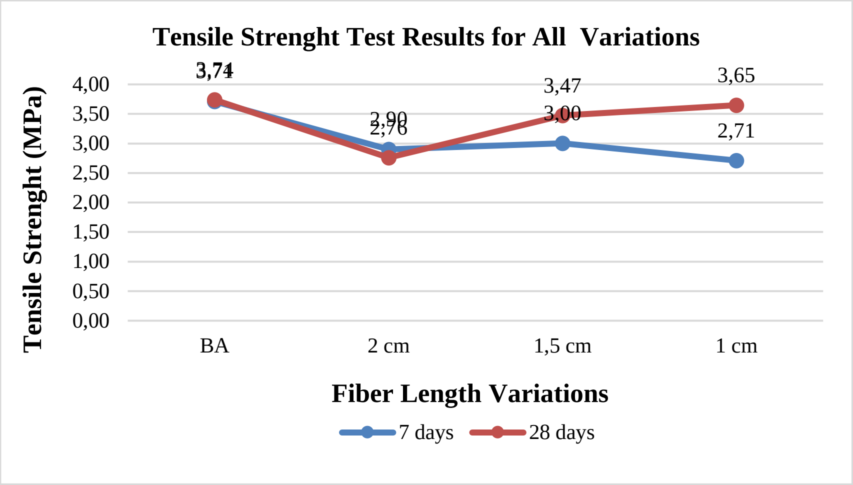

Figure 4. Graph of the results of the Split Tensile Strength Test of Concrete for all variations

From Figure 4, it can be seen that the highest split tensile strength of concrete at 28 days is found in reference concrete with a split tensile strength of 3,74 MPa. Meanwhile, the lowest split tensile strength was found in concrete variation 1 (BA+SEG 2cm) of 2,76 MPa. The treatment of water hyacinth fiber can also affect optimal quality, where drying of water hyacinth fiber aims to reduce moisture and moisture content which causes weathering not to be achieved optimally because drying is carried out in the rainy season and the humidity is high enough so that the fiber is not perfectly dry which can affect concrete tension rod (Priyatno et al., 2017) (Ali et al., 2019) (Villanueva et al., 2019). The decrease in the split tensile strength of concrete occurs due to agglomeration of fibers where at the time of making the concrete sample, the fibers are not spread evenly so that clumping occurs.

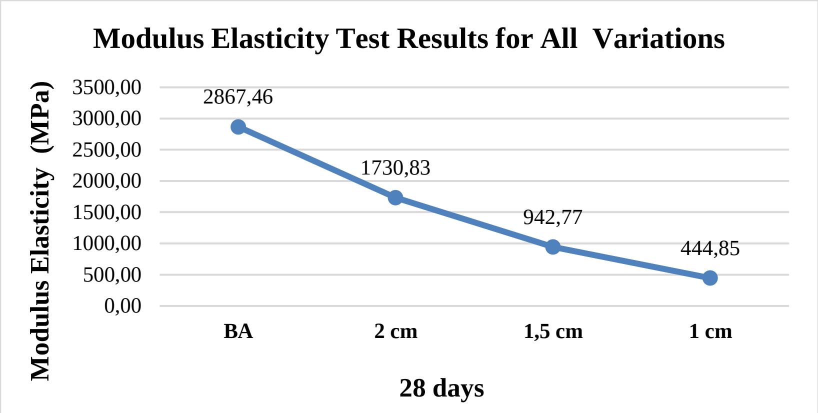

Figure 5. Graph of Concrete Elasticity Modulus results All variations

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From Figure 5, it can be seen the effect of adding water hyacinth fiber rolling to the value of the elastic modulus. The modulus of elasticity decreases with the length of the fiber strand. The smallest decrease occurred in concrete variation 3 with a variation of 1 cm water hyacinth fiber rolling length. The cause of the decrease in the value of the concrete elastic modulus is due to the less homogeneous bonding of cement and aggregate, so that the concrete particles will stretch more easily when given a load (Technology et al., 2021) (Israngkura Na Ayudhya, 2016).

CONCLUSION

Based on the research and discussion it can be concluded that the highest compressive strength results at the age of 28 days are found in the reference concrete with a compressive strength value of 45,42 MPa. The decrease in the compressive strength of water hyacinth fiber-rolled concrete for variations of 2 cm, 1,5 cm and 1 cm were 10,76%, 14,16% and 18,76% respectively of the reference concrete compressive strength of 45,42 MPa. Meanwhile, when viewed from the variation in the length of the water hyacinth fiber roll, the highest split tensile strength of concrete occurs in concrete using a water hyacinth fiber rolling length of 1 cm, which is 3,65 MPa, close to the concrete compressive strength of 9,89% according to what is required 9-15% of its compressive strength. The decrease in the value of the elastic modulus is proportional to the decrease in the compressive strength. This is shown by the smallest settlement value that occurs in concrete variation 3 with a fiber length of 1 cm of 444,85 MPa or around 84,49% of the reference concrete.

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