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Effect of substitution of coconut coir waste on the compressive strength of non-structural concrete

Imam Heru Nurfais [a,1]**,** ***Nur Azizah Affandy*** [a]**,** ***Salwa Nabilah*** [a]

[a]*Department of Civil Engineering, Faculty of Engineering, Universitas Islam Lamongan, Jl. Veteran 53A, Lamongan, Jawa Timur 62214, Indonesia.*

[1]*E-mail: heruimam6@gmail.com*

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ABSTRACT

Using coconut fiber waste (LSK) in concrete mixes has good prospects because Indonesia has abundant natural resources. The addition of this fiber aims to improve the properties of concrete. This study aims to determine the effect of adding coconut fiber waste (LSK) as a substitute for coarse aggregate on the compressive strength of non-structural concrete and utilizing coconut fiber waste to reduce the accumulation of coconut waste and increase the selling value of coconut fibers. Making concrete mixtures with standard SNI 03-2834-2000, concrete compressive strength f'c 16.9 MPa concrete age 28 days, with 4 variations of the mixture, namely LSK 0%, LSK 0.5%, LSK 1%, LSK 1.5%, and LSK 2%. The test object is cylindrical with a diameter of 15 cm and a height of 30 cm, with 30 specimens. According to the findings of this study, the addition of coco fiber reduced the compressive strength of the concrete. In the compressive strength test of concrete, aged seven days and 28 days, the highest average compressive strength values of LSK 0 were 14.72 MPa and 21.62 MPa. Of the three variations of LSK, LSK 0.5 and LSK 1 are closest to normal concrete. The relationship between the uses of LSK on the compressive strength of concrete at the age of 28 days. Its effect on the decrease in compressive strength occurs in LSK 0.5, LSK 1, LSK 1.5, and LSK 2. The equation obtained from the linear regression equation y=-4.764+19.88 with a value of R2 = 0.827. The results show that the coconut fiber mixture (LSK) cannot provide a compressive strength of concrete that exceeds the compressive strength of normal concrete.

ABSTRAK

Penggunaan limbah sabut kelapa (LSK) dalam campuran beton memiliki prospek yang bagus karena Indonesia memiliki sumber daya alam yang melimpah. Penambahan serat ini bertujuan untuk memperbaiki sifat-sifat beton. Penelitian ini bertujuan untuk mengetahui pengaruh penambahan limbah serat sabut kelapa (LSK) sebagai subtitusi agregat kasar terhadap kuat tekan beton non-struktural, dan memanfaatkan limbah sabut kelapa sehingga bisa mengurangi penumpukan limbah kelapa dan menambah nilai jual dari sabut kelapa. Pembuatan campuran beton dengan standar SNI 03-2834-2000, kuat tekan beton f'c 16,9 MPa usia beton 28 hari, dengan 4 variasi campuran, yaitu LSK 0%, LSK 0,5%, LSK 1%, LSK 1,5% dan LSK 2%. Benda uji berbentuk silinder dengan diameter 15 cm dan tinggi 30 cm, dengan jumlah benda uji 30 buah. Hasil dari penelitian ini adalah penambahan serat sabut kelapa mengakibatkan terjadinya penurunan kuat tekan pada beton. Pada uji kuat tekan beton umur 7 hari dan 28 hari nilai kuat tekan rata-rata tertinggi LSK 0 adalah 14,72 MPa, dan 21,62 Mpa. Dari ketiga variasi LSK, LSK 0,5 dan LSK 1 yang paling mendekati beton normalnya. Hubungan penggunaan LSK terhadap kuat tekan beton pada umur 28 hari pengaruhnya pada penurunan kuat tekan yang terjadi pada LSK 0,5, LSK 1, LSK 1,5 dan LSK 2. Persamaan yang didapat dari persamaan regresi linear y = -4,764+19,88 dengan nilai R^2 = 0,827. Hal ini menunjukkan bahwa campuran sabut kelapa (LSK) tidak bisa memberikan kuat tekan beton melebihi kuat tekan beton normal.

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1. Introduction

More than 10 billion tons of concrete are produced every year. Annual production represents about 1.5 tonnes for every person on the planet. Aggregate is the largest constituent in concrete. Around 70–80% of the volume of structural concrete is made up of aggregate, of which 25–30% is fine aggregate and 40–50% is coarse aggregate [1]. Concrete with a mixture of fibrous materials or what is often referred to as fibre-reinforced concrete can be in the form of synthetic fibres or fibres to improve the mechanical properties of the concrete [2]. Fibrous concrete has several advantages, including increased concrete resistance to abrasion and impact, also compressive, tensile and flexural resistance can also be increased [3]. Meanwhile, non-structural concrete is concrete mixed with Portland cement, coarse, fine-textured aggregate and mixed with water, or without a mixture of additives to form a solid mass according to SKSNI T-15-1990-03 [4].

Coconut husk, a horticultural waste, is obtained from the cocoa husk (mesocarp) of coconut (Cocos nucifera) from coconut trees belonging to the palm family group. If not managed properly, this waste can develop social and ecological problems. There must be more productive management and business by utilizing it as a concrete innovation. This utilization also helps in reducing the cost of using concrete materials [2, 5-6]. Coir that can absorb water is coconut coir. One way to make cement is by mixing coconut coir. Strong durability in the manufacture of coconut coir cement has good resistance. Therefore, a mixture of coconut fibre can give hope to producing good quality fibre. There are properties possessed by coconut coir, which are persistent, water can be absorbed, and have long durability and are good if there is no direct relationship with the weather.

Previous studies have tried to mix coconut coir into a concrete mixture. Research [8] with coconut coir has 4%, 3%, 2%, and 1% concrete volume mixed. The findings show that when 1 % coconut fibre is added, the maximum flexural strength gain is 15% compared to the flexural strength without fibre. Through the alkalization process, the chemical NaOH is used to increase the strength of the coconut coir fibre. Some of the ingredients needed are 10, 9, 8, 7, 6, 5, 4, 3, 2, and 1 gram. With just 4 grams of NaOH composition per 100 ml of water, the outcome is a 35 % improvement in the fibre's tensile strength [9]. The use of fibre with percentages of 1%, 0.5%, and 0.75%, fibre without alkali treatment for each volume of concrete, alkali treatment for fibre 1.25 M and 1 M. Based on the results of tests that have been carried out, there is an increase coconut fibre waste (LKS) with a percentage of 0.5% produces an optimum composition with alkaline treatment. It is proven that with 1.25 M alkali treatment, the increase in the compressive strength value of conventional concrete has a percentage of 17.8%. For 1 M alkali treatment, the compressive strength value of conventional concrete has a percentage of 13.5%, the presence of alkali treatment which has the highest strength value among concretes that combine other fibre variations provides an additional fibre percentage of 0.75% [10].

Research with concrete quality planning in K-225 with 28 days can be tested for pressure. This study increased the amount of coconut coir waste (LSK), resulting in a pressure strength of 244.84 kg/cm^2 with a percentage of 0.125% and a pressure strength of 272.14 kg/cm^2 with a percentage of 0.5%. There was an increase in the pressure strength test with a percentage of 29.55% and 16.56% of normal concrete [11]. Research [5] used concrete quality f'c 25 MPa with variations of coconut fibre 0.75%, 1%, 1.25%, and 1.50%, as an alternative material to the strength of the split tensile and compressive strength test concrete for 28 days. The test results show that the results of the split tensile strength and compressive strength of cylindrical concrete can be drawn into the conclusion that the largest compressive strength can be obtained from coconut husk 0.75% with a characteristic value of f'c 23.44 Mpa for 28 days and the largest split tensile strength can be obtained, obtained 0.75% coconut husk with a characteristic f'c value of 2.11 MPa for 28 days. The addition of coconut coir fibre with a percentage of 2% increased the flexural strength and split tensile strength but experienced a decrease in the compressive strength. Therefore, 2% is the optimum level of addition of coconut coir fibre in terms of split tensile strength and flexural strength with an average flexural strength of 5.705 MPa and split tensile strength of 2.38 MPa [12].

The purpose of this study was to understand the relationship between the addition of coco fibre waste (LSK) as a substitute for coarse aggregate on the compressive strength of concrete with a mixed variation of 0.5%, 1%, 1.5%, and 2% of the reduction in the percentage of coarse aggregate in non-solid concrete. -structural. This study aims to understand the composition and effect of adding coconut coir waste (LSK), which increases the compressive strength of non-structural concrete and is useful for overcoming premature damage to concrete and digging deeper to find the effect of this addition on the compressive strength of concrete. The coconut coir waste used is from the many coconut sellers in Pojok Hamlet, Wonorejo Village, Sambeng District. The coconut shards pile will get bigger if we cannot use it yet [13]. This research is expected to reduce the accumulation of coconut waste and increase the selling value of coconut coir waste. The best mixing of coconut coir waste (LSK) in a concrete mixture with a 2% variant is the best [12]. From this study, the authors took different variants under 2%, namely 0%, 0.5%, 1%, 1.5% and 2% and on non-structural concrete f'c, which is useful for finding the effect of adding LSK on the compressive strength of concrete.

2. Research Methodology

In this study, the method used is the experimental method. Using SNI standards, the research was conducted at the Civil Engineering Laboratory, Universitas Islam Lamongan. Several processes that need to be carried out in this research activity are divided into three stages, including the initial stage in preparing materials, the second stage in the form of tools used to test research and the third stage in testing.

2.1. 2.1. Material Preparation Stage

Characteristic testing in the form of coarse and fine aggregates must be prioritized. The coarse aggregate and fine aggregate results can be seen in Table 1. From table 1, the characteristics for coarse and fine aggregate have met the requirements so that fine and coarse aggregate materials can be used. Before conducting research, the preparation that needs to be done is to prepare the tools used. Several materials are the research object, namely Lumajang sand, 1-2 inch gravel, water, cement, and coconut fibre. The source of the data in this study was obtained from the results of laboratory tests of the Department of Civil Engineering, Universitas Islam Lamongan, adjusting data from several works of literature that already have Indonesian national standards (SNI) or foreign standards, namely ASTM [14].

2.2. Coconut Fiber Waste

Taking coconuts, which are taken from the coir and cut with a diameter of 3-5 cm, can be seen in Figure 1. The test results on coconut coir fibre (SSK) with a test of water that has been absorbed from coconut husk can be seen in Figure 2. The results of laboratory tests showed that the average water value absorbed from coconut fibre was 2.67%. Standard quality is required in testing for gravel infiltration water (ASTM C 127-8893) permitted with a value of 4-1%. The coconut coir fibre is included in the requirements category, picture. Figure 1 shows the coconut coir used, and Figure 2 shows the moisture test results of the coconut coir.

Table 1. Characteristics of coarse and fine aggregates.

Aggregate type	Test	Result	Condition
Coarse aggregate	Density	2.51 gr/cm^3	2.2 – 2.7 gr/cm^3
	Water absorption	2.92 %	
	Weight	1.43 gr/cm	>1.2 gr/cm
	Filter analysis	5.4	3.0 – 8.0
Fine aggregate	Density	2.48 gr/cm^3	2.2 – 2.7 gr/cm^3
	Water absorption	3.34 %	
	Weight	1.69 gr/cm	>1.2 gr/cm
	Filter analysis	3.07	1.5 – 3.8

(*Source: Preliminary analysis, 2021*)

Figure 1. Coconut fiber.
(*Source: Preliminary analysis, 2021*)

Figure 2. Coir fiber moisture test.
(*Source: Preliminary analysis, 2021*)

2.3. Calculation Stage of Mix Design and Making Test Items

The calculation of the composition of the concrete material in this research carried out a comparison between the compressive strength and weight of the concrete and the design of low-strength (non-structural) concrete. The concrete mix design refers to SNI 03-2834-2000, regarding several ways of making normal concrete mixes. The purpose of strengthening the concrete compression requirement (f'c) at the age of 28 days of concrete is f'c 16.9 MPa. Four types of mixture variations will be made in this study, namely LSK 0 for concrete mixtures without coconut fibre mixture, LSK 0.5 for concrete with coconut fibre of 0.5%, LSK 1 for concrete with coconut husks of 1,%, LSK 1.5 with coconut fibre is 1.5%, and LSK 2 with coconut fibre is 2%. The concrete mix design in this study can be seen in Table 2.

Table 2. Concrete mix proportion 16.9 MPa.

No	Mixed code	Varian	Cement	Sand	Gravel	Water	Added material
			Kg	Kg	Kg	Liter	Kg
1	LSK 0	0%	394	761	1050.00	205	0.00
2	LSK 0.5	0.5%	394	761	1044.75	205	5.25
3	LSK 1	1%	394	761	1039.50	205	10.5
4	LSK 1.5	1.5%	394	761	1034.25	205	15.75
5	LSK 2	2%	394	761	1029.00	205	21

(*Source: Preliminary analysis, 2021*)

2.4. Testing Stage

Two test equipment are carried out, namely fresh concrete and hardened concrete testing. Fresh concrete testing uses the slump test, where this test is carried out before the fresh concrete is poured into the formwork. In comparison, testing the concrete using a compressive test (compressive test) [15]. The main performance of concrete is part of its compressive strength [16]. The ability of concrete to accept compressive forces per unit area is part of compressive strength performance. According to the Indonesian National Standard, the meaning of pressure strength is that the concrete test object will crumble if it is burdened with a certain pressure force caused by a unit area load [17]. For testing hard concrete, the test object is made of concrete with a cylindrical shape with a diameter of 15 cm and a height of 30 cm. Inspection and testing of specimens on the compressive strength of concrete at the age of 7 and 28 days. The number of test objects used was 3 for each variant, so the total of all test objects was 30.

Figure 3. Cylindrical test object with coconut fiber (SSK)
(*Source: Preliminary analysis, 2021*)

Figure 4. Concrete compressive test.
(*Source: Preliminary analysis, 2021*)

3. Results and Discussion

3.1. Slump Test

The test is carried out to know the viscosity of fresh concrete (fresh concrete) with the slump test. The slump test value shows the workability value of the concrete made. The higher the slump test value, the better the workability. Figure 5 is the average slump test value of adding coconut fibre waste (LSK) at a certain level to reduce the workability of concrete. Figure 5 is the average slump test value of adding coconut fibre waste (LSK) at a certain level to reduce the workability of concrete. The outcome is a reduction in slack with an increase in the amount of LSK, which is impacted by the coir geometry, which binds together, causing the new concrete to be unable to flow during the slump test. As a result, this fresh fibre reinforced concrete has weaker mechanical properties than conventional fresh concrete.

Table 3. Slump test results.

Mixed variety	Slump height (cm)		Mean (cm)
	I	II	
Normal + 0 % LSK	13	12	12.5
Normal + 0.5 % LSK	9	11	10
Normal + 1 % LSK	10	10	10
Normal + 1.5 % LSK	9	9.5	9.3
Normal + 2 % LSK	11	9	10

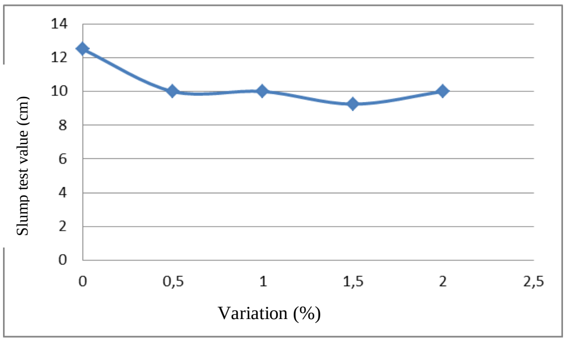

Figure 5. Average slump test value
(*Source: Preliminary analysis, 2021*)

3.2. Effect of Addition of LSK on Concrete Density

The addition of coconut coir waste also affects the density of normal concrete. The specific gravity values of conventional concrete (without LSK) and LSK concrete can be seen in Table 4.

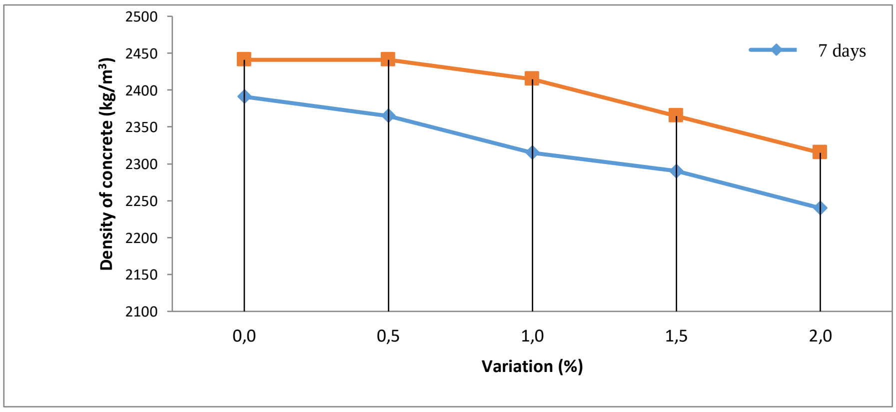

Figure 6. Graph of specific gravity of concrete.
(*Source: Preliminary analysis, 2021*)

Table 4. The results of the concrete density test.

Mixed variety (%)	7 days old concrete			28 days old concrete		
	Weight (kg)	Concrete density (kg/m³)	Average concrete density	Weight (kg)	Concrete density (kg/m³)	Average concrete density
0	12.6	2,377.92		13.2	2,491.15	
0	12.6	2,377.92	2,391	13.2	2,491.15	2,441
0	12.8	2,415.66		12.4	2,340.17	
0.5	12.6	2,377.92		13.0	2,453.41	
0.5	12.6	2,377.92	2,365	12.8	2,415.66	2,441
0.5	12.4	2,340.17		13.0	2,453.41	
1	12.2	2,302.43		12.6	2,377.92	
1	12.4	2,340.17	2,315	13.0	2,453.41	2,416
1	12.2	2,302.43		12.8	2,415.66	
1.5	12	2,264.69		12.6	2,377.92	
1.5	12.2	2,302.43	2,290	12.4	2,340.17	2,365
1.5	12.2	2,302.43		12.6	2,377.92	
2	12	2,264.69		12.4	2,340.17	
2	12	2,264.69	2,240	12.2	2,302.43	2,315
2	11.6	2,189.20		12.2	2,302.43	

(*Source: Preliminary analysis, 2021*)

Figure 6 is a graph of the specific gravity of concrete, where the calculation is obtained by dividing the weight of the concrete specimen by the volume of the concrete specimen. The value of specific gravity of concrete with coconut coir waste (LSK) was lower in value than normal concrete. For concrete, aged seven days, the lowest specific gravity value was with LSK 2 and for concrete, aged 28 days. For 7-day-old concrete, the specific gravity of the concrete has not met the normal specific gravity, while for the 28-day concrete, only LSK 0.5 and LSK 1 have met the normal density of concrete. The results of this slump test indicate that the addition of the proportion of fibre will affect the decrease in slump and density. The higher the proportion of fibre used, the lower the density. [18].

3.3. Compressive Strength of Concrete

Figures 7 and 8 show a comparison of the compressive strength of concrete vs quantity fluctuations at 7 and 28 days of age. Figure 7 is a comparison diagram of the compressive strength of 7 days. In sample 3 of non-fibre concrete (0%), the highest compressive strength occurred with a strength value of 16.45 MPa. Meanwhile, sample 1 of 2% LSK concrete is the lowest strength with a compressive strength of 7.05 MPa. Figure 8 is a comparison diagram of the compressive strength of 28 days of age, where the highest concrete compressive strength was obtained in 3 samples of non-fibre concrete (0%) with a strength value of 24.91 MPa. In comparison, the lowest strength occurred in sample 2 of 2% LSK concrete, namely the compressive strength of 8.69 MPa. The average compressive strength of each sample can be seen in Table 5.

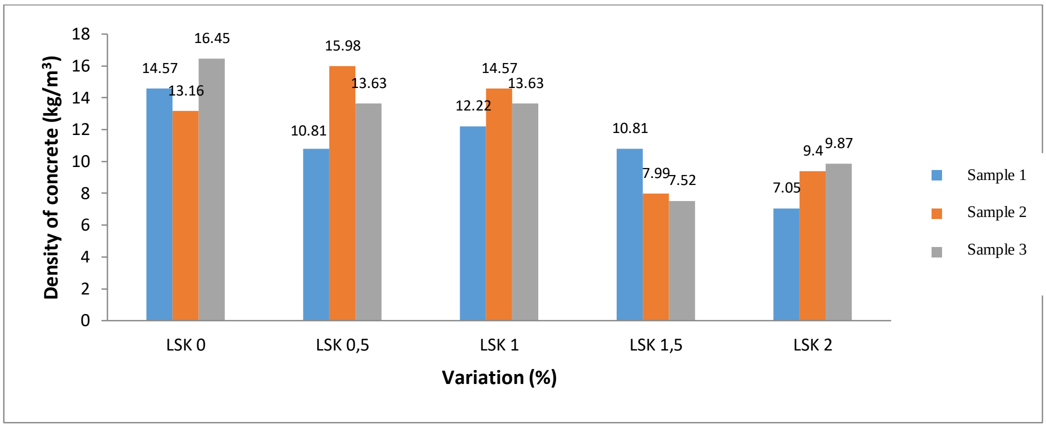

Figure 7. Comparison diagram of the compressive strength of 7 days old.
(*Source: Preliminary analysis, 2021*)

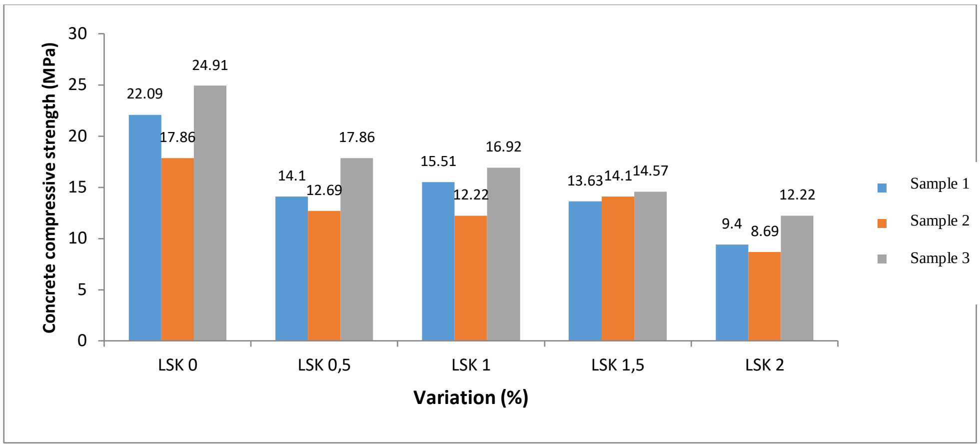

Figure 8. Comparison diagram of the compressive strength of 28 days old

(*Source: Preliminary analysis, 2021*)

Table 5. Average concrete compressive strength test results.

Mixed code	Average concrete compressive strength (Mpa)	
	7 days	**28 days**
Normal + 0 % LSK	14.72	21.62
Normal + 0.5 % LSK	13.47	14.88
Normal + 1 % LSK	13.47	14.88
Normal + 1.5 % LSK	8.77	14.10
Normal + 2 % LSK	8.77	10.10

(*Source: Preliminary analysis, 2021*)

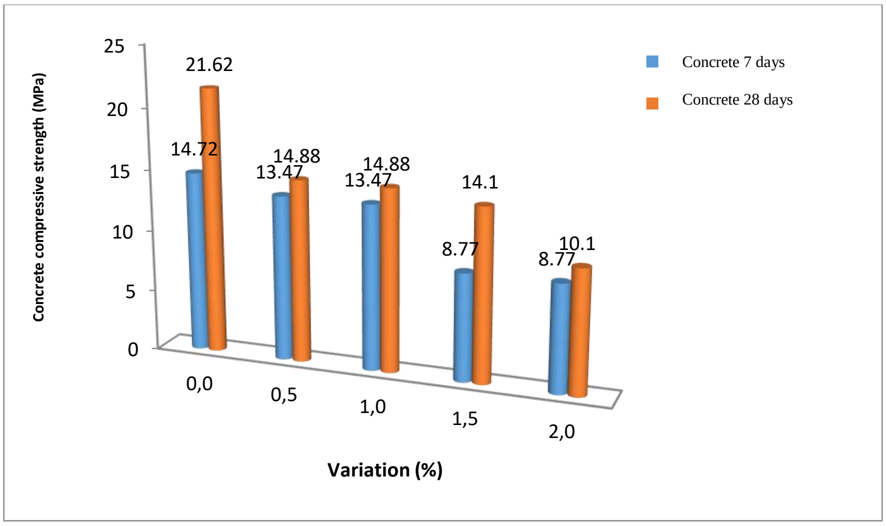

Figure 9. Compressive strength test of concrete with an average age of 7 days and 28 days.

(*Source: Preliminary analysis, 2021*)

There was a change in the development of each compressive strength of each test age and LSK variations. Figure 9 shows the average compressive strength achieved by concrete aged 7 and 28 days. At the age of 7 days, the average compressive strength of concrete has not reached the design compressive strength, which is still less than 16.9 MPa, in contrast to the average compressive strength of 28 days of concrete which has exceeded the compressive strength of the design concrete. The maximum compressive strength of concrete, aged 7 and 28 days, is at LSK 0 without substitution of coconut coir waste. The average compressive strength value in 7-day-old concrete with LSK 0 variation is 14.72 MPa, then at LSK 0.5 and LSK 1, the compressive strength value is 13.47 MPa, experiencing a decrease of 8.5% from normal concrete.

Meanwhile, LSK 1.5 and LSK have the same compressive strength value of 8.77 MPa, decreasing 40% from normal concrete. While at the age of 28 days, the average compressive strength of LSK 0 is 21.62 MPa, already exceeding the compressive strength of the design concrete, while at LSK 0.5 and LSK 1, the compressive strength value is 14.88 MPa, a decrease of 31% from normal concrete. Of the three variations of LSK, LSK 0.5 and LSK 1 are closest to normal concrete. Further analysis of the effect of adding coconut fibre waste (LSK) to the compressive strength of concrete, using linear regression analysis, using Microsoft Excel on concrete aged 7 and 28 days.

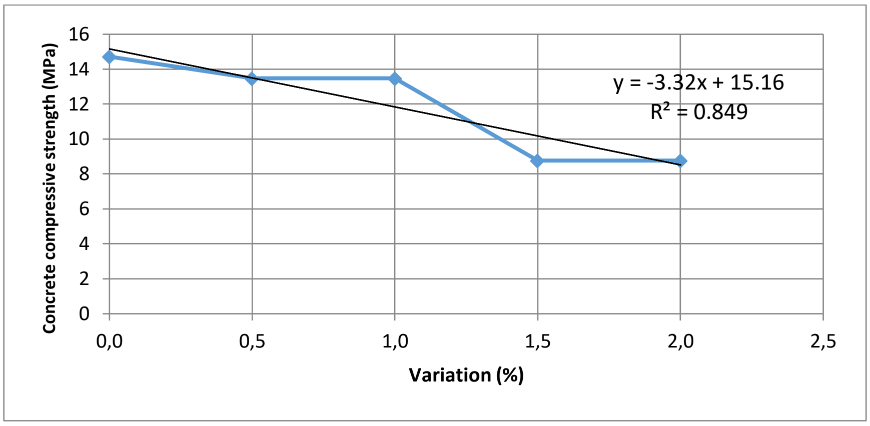

Figure 10. Linear regression analysis of the effect of the addition of LSK on the compressive strength of 7 day old concrete.
(*Source: Preliminary analysis, 2021*)

Figure 10 shows the relationship between the use of LSK and the compressive strength of concrete at the age of 7 days. It can be seen that the addition of LSK in the concrete mixture affects the compressive strength of the concrete. The effect with the addition of LSK can be seen from the decrease in compressive strength that occurs in LSK 0.5%, LSK 1%, LSK 1.5% and LSK 2%. The regression results of the relationship between the increase in the average compressive strength of concrete and the percentage of LSK stated that there was a similar relationship between the addition of variations in LSK and the compressive strength of concrete. The value of the relationship obtained from the regression equation $y = -3.32x + 15.16$ with a value of $R^2 = 0.849$. Figure 11 depicts the link between the usage of LSK and the compressive strength of concrete after 28 days, which is almost identical to the age of 7 days. The addition of LSK to the concrete mix affects the compressive strength of the concrete. The effect on the decrease in compressive strength occurs in LSK 0.5, LSK 1, LSK 1.5 and LSK 2. The equation obtained from the linear regression equation $y = -4{,}764x + 19.88$ with $R^2 = 0.827$.

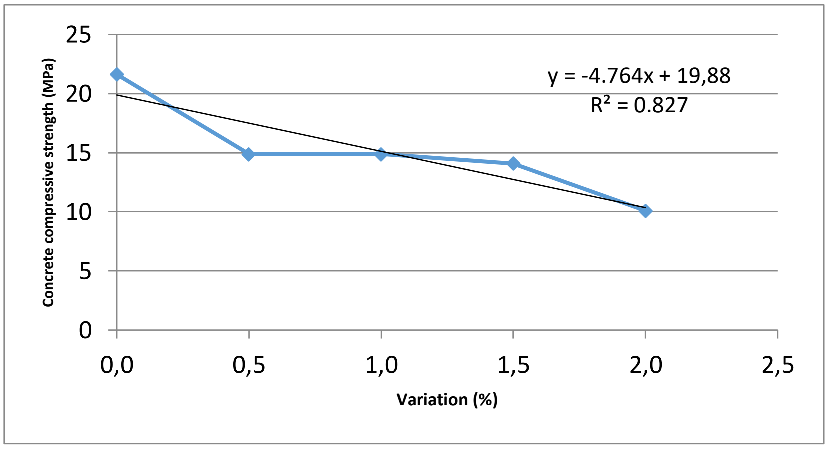

Figure 11. Linear regression analysis of the effect of the addition of LSK on the compressive strength of 28 day old concrete.
(*Source: Preliminary analysis, 2021*)

4. Conclussion

The addition of coco fibre resulted in a decrease in the compressive strength of the concrete. In the compressive strength test of 7 days old concrete, the average compressive strength value of LSK 0 is 14.72 MPa, then at LSK 0.5 and LSK 1, the compressive strength value is 13.47 MPa, which has a decrease of 8.5% from normal concrete. Meanwhile, LSK 1.5 and LSK have the same compressive strength value of 8.77 MPa, decreasing 40% from normal concrete. In contrast to the average compressive strength of concrete, aged 28 days, the average compressive strength value of LSK 0 is 21.62 MPa which has exceeded the compressive strength of the design concrete, while at LSK 0.5 and LSK 1, the compressive strength value is 14.88 MPa. 31% reduction from normal concrete. Of the three variations of LSK, LSK 0.5 and LSK 1 are closest to normal concrete. The effect of LSK on concrete compressive strength after 28 days is almost identical to that at seven days. The addition of LSK to the concrete mixture affects the compressive strength of the concrete. The effect on the decrease in compressive strength occurs in LSK 0.5, LSK 1, LSK 1.5 and LSK 2. The equation obtained from the linear regression equation for 28 days is $y = -4.764x + 19.88$ with a value of $R^2 = 0.827$. The results show that the coconut coir mixture (LSK) cannot provide a compressive strength of concrete that exceeds the compressive strength of normal concrete.

Reference

[1] Shetty, M. S. (2005). *Concrete Technology Theory and Practice (23rd Revision)*. New Delhi: S. Chand Company Limited.

[2] Kumar, G. R., & Kesavan, V. (2020). Study of structural properties evaluation on coconut fiber ash mixed concrete. *Materials Today: Proceedings*, vol. 22, pp. 811-816.

[3] Tjokrodimulyo, K. (1996). *Teknologi Beton*. Yogyakarta: Navitri.

[4] Dipohusodo, I. (1994). *Struktur beton bertulang: berdasarkan SK SNI T-15-1991-03 Departemen Pekerjaan Umun RI*. Jakarta: Gramedia Pustaka Utama.

[5] Rafianda, E. (2021). Pengaruh penambahan sabut kelapa terhadap kuat tekan dan kuat tarik belah beton Fc' 25 Mpa. [*Final Project*]. Palembang: Universitas Muhammadiyah Palembang.

[6] Prahara, E., Liong, G. T., & Rachmansyah, R. (2015). Analisa pengaruh penggunaan serat serabut kelapa dalam presentase tertentu pada beton mutu tinggi. *ComTech: Computer, Mathematics and Engineering Applications*, vol. 6, no. 2, pp. 208-214.

[7] Wahyudi, T. (2014). Penggunaan ijuk dan sabut kelapa terhadap kuat tekan pada beton K-100. *Media Neliti*. Accessed at 1 October 2021. Available on https://media.neliti.com/media/publications/110668-ID-penggunaan-ijuk-dan-sabut-kelapa-terhada.pdf.

[8] Mawardi. (2006). Tinjauan pengaruh penambahan serat sabut kelapa pada kuat lentur beton. *Media Infotama*, vol. 1, no. 2, pp.22–30.

[9] Darmanto, S., Umardani, Y., Sumantri, H., & Sutanto, A. (2011). Peningkatan kekuatan serat sabut kelapa dengan perlakuan alkali. *Teknis*, vol. 6, no. 3, pp. 1-8.

[10] Fandy, Anita, & Handoko. (2013). Pengaruh pemanfaatan serat sabut kelapa dengan perlakuan alkali terhadap kuat tekan dan kuat tarik beton. *Jurnal Dimensi Pratama Teknik Sipil*, vol. 2, no. 2, pp. 1-8.

[11] Sahrudin, S., & Nadia, N. (2016). Pengaruh penambahan serat sabut kelapa terhadap kuat tekan beton. *Konstruksia*, vol. 7, no. 2, pp. 13-20.

[12] Risdianto, Y., & Tobing, G. R. L. (2019). Pengaruh penambahan serat sabut kelapa (*coconut fiber*) terhadap kuat tekan, kuat tarik belah dan kuat lentur pada beton. *Jurnal Mahasiswa UNESA*, vol. 1, no. 2, pp. 1-8.

[13] Kishore, K., & Gupta, N. (2021). Mechanical characterization and assessment of composite geopolymer concrete. *Materials Today: Proceedings*, vol. 44, pp. 58-62.

[14] American Standard Testing and Material. (2015). 876-15. *Standard Test Method for Corrosion Potentials of Uncoated Reinforcing Steel in Concrete*. West Conshohocken: ASTM International.

[15] Badan Standardisasi Nasional. (2011). *SNI 1974-2011: Cara Uji Kuat Tekan Beton Dengan Benda Uji Silinder*. Jakarta: Badan Standardisasi Nasional.

[16] Adelizar, A. S., Olvianas, M., Adythia, D. M., Syafiyurrahman, M. F., Pratama, I. G. A. A. N., Astuti, W., & Petrus, H. T. B. M. (2020). Fly ash and bottom ash utilization as geopolymer: Correlation on compressive strength and degree of polymerization observed using FTIR. *IOP Conference Series: Materials Science and Engineering*, vol. 742, no. 1, pp. 012042.

[17] Kamiński, K., & Plis, A. (2015). Research on compresive strength and strain of expansive concrete. *Applied Mechanics and Materials,* vol. 797, pp. 79-87.

[18] Syafwan, R. A., & Hayu, G. A. (2020). Pemanfaatan serat sabut kelapa sebagai bahan tambah coconut fiber concrete (CFC) untuk meningkatkan kuat tekan dan tarik belah. *Prosiding Seminar Nasional Teknik Sipil,* pp. 260-267.