Effect of Fabric Waste Addition on the Compressive and Flexural Strength of Fiber-Reinforced Concrete

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Abstract

This study aims to investigate the effect of adding fabric scrap fibers on the improvement of flexural strength in fiber-reinforced concrete. Fabric scraps were used as additional material in the concrete mix with variations of 0%, 1.5%, 2.5%, 3.5%, and 4.5% by volume. The tests conducted included flexural strength, compressive strength, and crack pattern observation after loading. The results show that the addition of fabric scrap fibers can enhance the flexural strength of concrete, with the highest value of 3.62 MPa achieved at a 3.5% dosage. Beyond this percentage, the flexural strength tended to decrease. The addition of fibers also reduced crack widths and improved concrete ductility. However, the compressive strength decreased with higher fiber content due to void formation and reduced workability. Therefore, the use of fabric scrap fibers is recommended for non-structural applications requiring higher flexural resistance.

Keywords: Concrete, Fabric Scrap, Compressive Strength Flexural Strength, Additional Fiber, Concrete Cracks

1. INTRODUCTION

The increasing demand for infrastructure development in Indonesia requires innovation in construction materials that are not only high-performing but also environmentally friendly. Concrete is one of the primary materials widely used in construction, both for building structures and other infrastructure elements. However, one of the main weaknesses of concrete is its brittle nature, especially when subjected to flexural loads. Therefore, efforts are needed to enhance the flexural strength of concrete to make it more resistant to cracking and damage.

The use of fiber-reinforced concrete (FRC) has become an effective solution to improve the mechanical properties of concrete, including its flexural strength. FRC incorporates fibers into the concrete mix, acting as micro-reinforcement to inhibit the propagation of cracks. The fibers used in FRC can be derived from various materials such as steel, polymers, and even recycled materials.

On the other hand, textile waste is a significant environmental issue. The continuously growing textile industry generates large amounts of fabric waste, much of which is poorly managed. Utilizing textile waste as a fiber material in concrete presents a promising solution to reduce the negative environmental impact of textile waste while simultaneously improving the performance of construction materials.

Previous studies have shown that incorporating fibers from waste materials such as plastics or metals can enhance the flexural strength of fiber-reinforced concrete. However, the use of fabric scraps—particularly from textile waste—has not been extensively explored. Fabric scraps possess unique characteristics such as high flexibility, energy absorption capacity, and a surface texture that supports good adhesion with the concrete matrix, thus potentially contributing significantly to the improvement of concrete's flexural strength.

Based on this background, this study aims to investigate the effect of adding fabric scraps to fiber-reinforced concrete on the enhancement of its flexural strength. This research is expected to contribute to the development of more sustainable construction materials while helping to mitigate the problem of textile waste through recycled material innovation.

1.1. Concrete

Concrete is a composite material composed of cement, fine and coarse aggregates, and water, with or without chemical admixtures, which upon hardening forms a strong and stable structural mass (SNI 7656:2012). In its fresh state, concrete is plastic and workable, allowing it to be molded before it undergoes a gradual hardening process. However, a key limitation of concrete is its relatively low tensile strength, typically ranging from 9–15% of its compressive strength, which often necessitates the addition of reinforcing steel to produce reinforced concrete that combines the compressive strength of concrete with the tensile capacity of steel (Pithaloka, 2021). According to Nugraha (2007), concrete comprises three main components—cement paste, mortar, and aggregate—which together form a two-phase composite system consisting of a matrix and a dispersed phase. The use of chemical admixtures is common practice to modify the properties of both fresh and hardened concrete, including adjusting setting time, enhancing workability, reducing water demand, and improving overall performance.

1.2. Concrete Composition Materials

Concrete is a composite material composed of cement, fine and coarse aggregates, water, and additional substances such as admixtures or additives, which are used to enhance specific properties of the concrete. Each component plays a specific role in influencing the overall characteristics and performance of the concrete (SNI 7656:2012; Nugraha, 2007).

1.1.1 Portland cement

Cement is a primary binding material in construction that forms cement paste when mixed with fine aggregates and water, and produces fresh concrete when coarse aggregates are added. The most commonly used type is Portland cement, a hydraulic binder produced by grinding cement clinker containing calcium silicates, along with calcium sulfate and other additives (SNI 15-2049-2004). Portland cement primarily consists of lime (CaO), silica (SiO_2), and alumina (Al_2O_3), with smaller amounts of magnesia (MgO), alkalis, and iron oxides. Gypsum ($CaSO_4 \cdot 2H_2O$) is also added to regulate setting time (Mulyono, as cited in Gunawan, 2016). According to SNI 15-2049-2004, Portland cement is classified into five types based on its specific applications: Type I for general use, Type II for moderate sulfate resistance or moderate heat of hydration, Type III for high early strength, Type IV for low heat of hydration, and Type V for high sulfate resistance. In general, the chemical composition of Portland cement includes approximately 60–65% CaO, 20–25% SiO_2, and 7–12% Fe_2O_3 and Al_2O_3 (Mulyono, 2004).

1.2.2 Coarse Aggregate

According to SNI 03-1970-2008, fine aggregate is a granular material derived from the natural disintegration of rock or produced by stone crushing industries, with a maximum particle size of 4.75 mm. Based on PBI-1971, fine aggregate used in concrete must consist of hard, sharp grains, free from excessive organic matter, and must not contain more than 5% silt by dry weight; if the silt content exceeds this limit, the aggregate must be washed. The use of sea sand is generally prohibited unless approved by an authorized materials testing agency. Fine aggregate must also meet specific gradation requirements based on standard sieve sizes, which are categorized into four grading zones—ranging from coarse to fine—as outlined by Tjokrodimulyo (1992).

1.2.3 Fine Aggregate

Coarse aggregate, according to SNI 03-1969-2008, refers to natural gravel or crushed stone produced by industrial rock crushing, with particle sizes ranging from 4.75 mm to 40 mm. To be used in concrete mixtures, coarse aggregate must meet certain requirements as specified in PBI-1971. These include: originating from natural rock, being hard and non-porous, weather-resistant, containing no more than 20% flat particles, having a maximum mud content of 1% (if exceeded, the aggregate must be washed), and being free from substances that could damage the concrete.

1.2.4 Water

Water plays a vital role in concrete mixtures by enabling cement hydration and improving workability. It is essential for forming cement paste and ensuring proper mixing and placement. Nugroho and Antoni (2007) emphasize that without water, cement cannot form a paste, and hydration would not occur. The optimal water demand for hydration is approximately 35–37% of the cement weight. Water demand is influenced by aggregate size, shape, gradation, and the presence of impurities like clay or silt. According to SNI 03-6861.1-2002, mixing water must be clean and free from harmful substances such as excessive acids, organic matter, suspended solids, chlorides, and sulfates to maintain concrete quality and durability.

1.3 Fiber Reiforced Concrete

Fiber Reinforced Concrete (FRC) is an innovation in concrete technology that incorporates randomly distributed fibers into the mix to enhance performance (ACI 544.1R-96; Hidayat, 2018). ACI Committee 544 classifies FRC into four types: steel (SFRC), glass (GFRC), synthetic (SNFRC), and natural fibers (NFRC). The addition of fibers improves ductility, shock resistance, tensile and flexural strength, and reduces shrinkage (Malino, Wallah, &

Handono, 2019). Two theoretical approaches—Spacing Concept and Composite Material Concept—explain how fibers control crack propagation and improve tensile behavior. Liu et al. (2019) note that fibers enhance post-crack strength through bridging effects and contribute to non-linear structural behavior. According to Li et al. (2018), macrofibers bridge macro-cracks while microfibers suppress micro-cracks, both improving flexural toughness. Suhendro (1991) demonstrated that adding 34 kg/m³ of local cloth-cut fibers to a 1:2.5:2.5 concrete mix with a 0.55 water-cement ratio improved ductility, compressive strength by 10%, tensile strength by 58%, flexural strength by 50%, and impact resistance by up to 400%.

1.4 Patchwork

Textile waste, particularly from synthetic fibers, is a persistent environmental concern due to its non-biodegradable nature (Putra & Noorhidana, 2020). Utilizing fabric scraps as fiber reinforcement in concrete has been shown to improve mechanical properties by bridging cracks, enhancing toughness, and reducing internal defects (Amna et al., 2017). The tensile strength of the fabric is influenced by weaving techniques and structural factors such as yarn density and pattern type (Risdianto & Tobing, 2019). Cotton-based fabrics, while effective in improving tensile and flexural strength (Eldin & El-Tahan), show variability in mechanical performance due to natural inconsistencies in fiber composition and moisture absorption. Despite these limitations, fabric waste—particularly offcuts containing natural or polyester fibers—presents a cost-effective reinforcement alternative. However, degradation in alkaline cement environments, through alkali attack and fiber mineralization, can reduce performance. Thus, proper pretreatment of fabric is necessary to ensure durability in cementitious matrices.

1.5 MATERIAL TESTING

Before being used in concrete mixtures, all materials must undergo a series of tests to ensure compliance with mix design standards, based on applicable Indonesian National Standards (SNI). These tests include: (1) moisture content of aggregate (SNI 1971:2011), to determine the percentage of water in the aggregate; (2) bulk density (SNI 03-4804-1998), to measure the mass per unit volume; (3) and (4) specific gravity and water absorption of coarse and fine aggregates (SNI 1969-2008 and SNI 1970-2008), covering bulk specific gravity, saturated surface-dry specific gravity, apparent specific gravity, and absorption; (5) and (6) sieve analysis of coarse and fine aggregates (ASTM C136-2012), to identify particle size distribution and fineness modulus; and (7) silt content in sand (SNI 03-4428-1997), which limits silt content to a maximum of 5%. These tests are essential to ensure the quality, stability, and performance of the resulting concrete.

1.6 Concrete Mix Design

According to Antoni and Nugraha (2007), the primary objective of concrete mix design is to select appropriate constituent materials and determine their optimal proportions to produce concrete that is both high in quality and cost-effective. The performance of hardened concrete is influenced by the type of structure and the placement methods, including transportation, laying, and compaction processes—factors that directly affect mix composition and require consideration of on-site supervision levels. One widely used design method in Indonesia is based on the Ministry of Public Works standard (SK.SNI.T-15-1990-03), adapted from the Department of Environment (DoE), Building Research Establishment, UK. Currently, mix designs follow the updated national standard, SNI 7656:2012, which provides procedures for designing mixes for normal concrete, heavy concrete, and mass concrete. This standard serves as a reference in determining the precise proportion of each material component in the concrete mix.

1.7 Flexural Tensile Strength of Concrete

Flexural strength refers to concrete's ability to resist bending stress before failure, expressed in MPa. It can be tested using two standard methods: single-point loading (SNI 4154:2014) and two-point loading (SNI 03-4431-1997). Each method employs different formulas based on the location of fracture along the specimen. If the fracture occurs outside the specified region, the test results are deemed invalid. Flexural testing is crucial in evaluating the structural performance of concrete, especially in elements subjected to bending moments.

1.8 Previous Research

Several studies have investigated the effects of incorporating textile waste into concrete mixtures. Sari, Mustakim, and Kasmaida (2024) from Universitas Muhammadiyah Parepare found that adding 5% cotton waste increased compressive strength to 31.33 MPa on the 28th day, while 10% reduced it to 27.27 MPa. However, a 10% cotton addition enhanced flexural strength to 3.822 MPa. Similarly, research by Iata Nur Kholis (2022) from Universitas Tidar showed that adding 6% textile waste and 9% glass shards resulted in a compressive strength of 15.592 MPa and a flexural strength of 4.496 MPa. Meanwhile, Bartulović et al. (2022) studied the influence of knitted cotton waste and reported that the mechanical properties of concrete—such as compressive strength, flexural strength, and workability—were significantly affected depending on the percentage and distribution of textile fibers.

2 METHOD

2.2 Research Methods

The research method is a scientific approach used to obtain data for specific objectives. Every research activity must fulfill scientific characteristics, namely being rational, empirical, and systematic. In this final project, the method applied is an experimental method. According to Sugiyono (2008), the experimental method is a research approach aimed at testing the effect of a treatment on another variable under controlled conditions. This study uses an experimental approach to evaluate the flexural strength of concrete mixed with textile fibers. A control concrete mix with a target compressive strength of f'c = 25 MPa was also prepared to serve as a reference, allowing conclusions to be drawn regarding the influence of textile fiber addition on the flexural strength of the concrete.

2.3 Research Location

This research was conducted at the Structure and Materials Laboratory of the Faculty of Technology and Vocational Education, Indonesia University of Education, located at Jl. Dr. Setiabudhi No. 207, Bandung City, West Java Province, Indonesia.

2.4 Research Sample

The number of samples used in this study consisted of 15 specimens for flexural strength testing. These were prepared based on the substitution of tile waste at varying percentages: 0%, 1.5%, 2.5%, 3.5%, and 4.5% of the total concrete volume. For easier identification, the specimens were labeled using the code BFKP, which stands for *Beton Fiber Kain Perca* (Concrete with Scrap Fabric Fiber).

Table 2.3 Research Sample Distribution

Code	Concrete Classification	Scrap Fabric Percentage (by Volume)	Curing Age	Flexural Test	Compressive Test
BFKP 0%	0% Scrap Fabric	0%	28 Days	3	3
BFKP 1.5%	1.5% Scrap Fabric	1.5%	28 Days	3	3
BFKP 2.5%	2.5% Scrap Fabric	2.5%	28 Days	3	3
BFKP 3.5%	3.5% Scrap Fabric	3.5%	28 Days	3	3
BFKP 4.5%	4.5% Scrap Fabric	4.5%	28 Days	3	3
Total				**15**	**15**

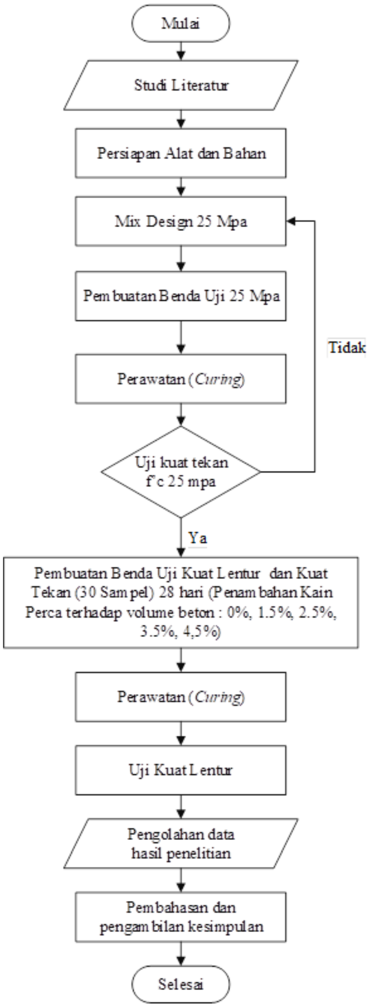
(Source: Author, 2025)

2.5 Research Materials

The materials used in this research consist of cement, fine and coarse aggregates, water, and textile fiber waste in the form of fabric scraps. The cement used is Portland Composite Cement (PCC) of the *Tiga Roda* brand. Fine aggregate in the form of concrete sand was sourced from Galunggung, Tasikmalaya, and tested for characteristics such as moisture content (2.11%), silt content (6.56%), and a specific gravity of 2.49 in SSD condition. Coarse aggregate, crushed stone with a nominal size of 20 mm from Lagadar, showed an abrasion value of 26.44% and a bulk specific gravity of 2.33 (SSD). Clean water from the laboratory was used for mixing and curing the concrete. Fabric scraps, obtained from the Cigondewah area in Bandung, served as the added fiber material. According to tests adapted from Bartulović et al. (2021), these scraps consisted of 100% cotton, had a density of 1500 kg/m³, and a water absorption capacity of 43.2 g/m². These materials were selected and tested to ensure they met the requirements for producing fiber-reinforced concrete with the desired mechanical properties.

2.6 Research procedures

This research investigates the effect of cotton fabric waste (kain perca) as a fiber additive in concrete to evaluate its influence on flexural strength. The study was conducted in accordance with relevant national and international standards (SNI and ASTM) and supported by references from books, journals, and previous studies figure 2.5 1 Research Flow Diagram



2.5.1 Tools and Material Preparation

Materials such as cement, fine aggregate, coarse aggregate, and fabric waste were stored properly in the FPTI UPI Structural Laboratory to maintain quality. Equipment for material testing, mixing, fresh concrete testing, and strength testing was checked and prepared.

2.5.2 Concrete Mix Design (f'c = 25 MPa)

The control mix was designed for 25 MPa compressive strength based on SNI 7656-2012. The composition per cubic meter is summarized in Table 2.5.2 :

Table 2.5 1Concrete Mix Design (Corrected Water Content)

No	Material	Value	Unit
1	Cement	525	kg/m^3
2	Water	210	kg/m^3
3	Fine Aggregate (SSD Condition)	611.20	kg/m^3
4	Coarse Aggregate (SSD Condition)	834.94	kg/m^3

2.5.3 Casting

Concrete casting was done following SNI 2493:2011, ensuring accurate material proportions and proper mixing.

2.5.4 Specimen Preparation

Specimens for compressive and flexural testing were made according to SNI 2493:2011.

2.5.5 Curing

Curing was conducted to support uninterrupted hydration. Improper curing may cause cracking due to rapid moisture loss.

2.5.6 Density Test

Density was calculated using the formula:

$y = W / X$

Where:

- y = Density (kg/m³)
- W = Weight of concrete specimen (kg)
- X = Volume of specimen (m³)

2.5.7 Flexural Strength Test

Flexural strength was tested at 28 days at the Structural and Materials Laboratory, Bandung State Polytechnic, using the third-point loading method (SNI 03-4431-1997).

2.5.8 Compressive Strength (Trial Mix)

Compressive strength tests were conducted at 14 days to validate the trial mix. The results are shown in Table 3.6.

Table 2.5 2Compressive Strength Trial Mix Results (14 Days)

Sample	Weight (kg)	Density (kg/m³)	Area (cm²)	Load (kN)	MPa	Converted MPa	Average MPa
1	3.565	2269	78.540	180.1	22.942	26.100	25.499
2	3.646	2321	78.540	180.0	22.929	26.086	
3	3.547	2258	78.540	173.6	22.114	25.158	
4	3.481	2216	78.540	170.1	21.668	24.651	

Source: Author, 2025

3 Results and Discussion

3.1 Presentation of Research Data

The tests conducted in this study included compressive strength, slump, density, flexural strength, and crack observation on flexural beams. The compressive strength test was carried out on concrete specimens at 28 days of age. The slump test aimed to assess the effect of fabric waste addition on the workability of the concrete. The density test was performed by dividing the concrete's mass by its volume to determine the impact of fabric waste on concrete density. Crack observation was conducted to evaluate how the addition of fabric waste influenced the crack width at failure on flexural beams.

3.2.4 Concrete Compressive Strength Test Results

Table 3.1 Compressive Strength Test Results at 28 Days

No	**Concrete Type**	**Age (Days)**	**Specimen Weight (Kg)**	**Cross-Section Area (mm²)**	**Load (kN)**	**Compressive Strength (MPa)**	**Average (MPa)**
1	BFKP 0%	28	3.624	7853.982	194.3	24.75	24.69
2		28	3.551	7853.982	197.23	25.12	
3		28	3.654	7853.982	190.00	24.20	
4	BFKP 1.5%	28	3.636	7853.982	163.2	20.79	18.17
5		28	3.694	7853.982	141.7	18.05	
6		28	3.638	7853.982	122.9	15.66	
7	BFKP 2.5%	28	3.642	7853.982	115.3	14.69	13.87
8		28	3.450	7853.982	89.6	11.41	
9		28	3.437	7853.982	121.7	15.50	
10	BFKP 3.5%	28	3.318	7853.982	103.3	13.16	12.50
11		28	3.427	7853.982	84.6	10.78	
12		28	3.419	7853.982	106.5	13.57	
13	BFKP 4.5%	28	3.217	7853.982	87.6	11.16	11.02
14		28	3.474	7853.982	93.6	11.92	
15		28	3.421	7853.982	78.3	9.97	

(Source: Author, 2025)

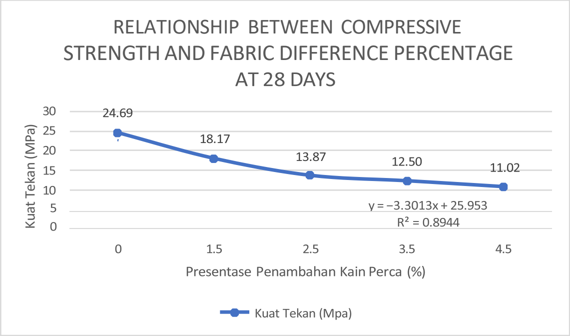


Figure 3. 1 Relationship between Compressive Strength and the Addition of 28-Day-Old Cloth Scraps

Based on the compressive strength test results at 28 days, the addition of fabric waste fibers (BFKP) had a noticeable impact on the concrete's performance. The control concrete (BFKP 0%) achieved the highest average compressive strength of 24.69 MPa. As the fiber content increased, the strength decreased: 1.5% fiber resulted in 18.17 MPa, 2.5% in 13.87 MPa, 3.5% in 12.50 MPa, and 4.5% in the lowest strength of 11.02 MPa. This reduction is likely due to uneven fiber distribution, the formation of more air voids from mixing challenges, and the weakened bond between cement paste and aggregates caused by the presence of the fabric fibers.

3.2.5 Slump Test Results

This test was conducted to determine the workability level of the concrete mixture. The slump test was carried out based on the SNI 03-1972-1990 standard. The results of the slump test in this study are presented in Table 3.2

Table 3. 2 The Effect of Fabric Scrap Percentage on Slump Value

No	Concrete Name	Textile Fiber Content (%)	Slump Value (mm)
1	BFKP 0%	0	70
2	BFKP 1.5%	1.5	50
3	BFKP 2.5%	2.5	45
4	BFKP 3.5%	3.5	40
5	BFKP 4.5%	4.5	35

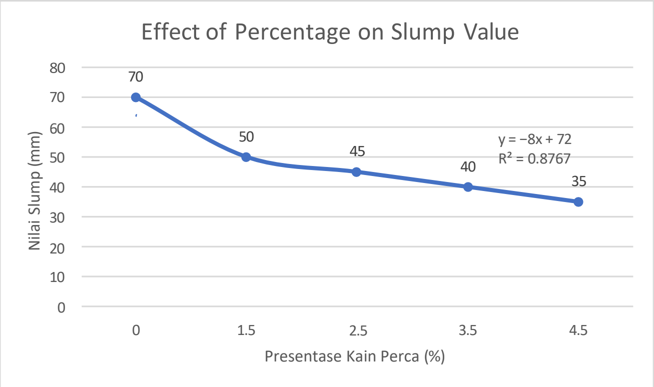


Figure 3. 2 The Effect of Fabric Scrap Percentage on Slump Value

Based on the concrete specimen preparation using a constant water-cement ratio according to the mix design, the slump test results showed variation. The data indicate that the addition of textile fiber waste (kain perca) gradually reduces the slump value of the concrete. This suggests that a higher percentage of textile fiber decreases the workability of the concrete. The highest slump value of 70 mm was recorded for concrete without fiber, while the lowest value of 35 mm was observed with 4.5% fiber content. The slump values for 1.5%, 2.5%, 3.5%, and 4.5%

fiber additions were 50 mm, 45 mm, 40 mm, and 35 mm respectively, reflecting slump reductions of 28.57%, 35.71%, 42.85%, and 50%. This decline indicates that the presence of textile fibers significantly impacts the slump value, thereby reducing the overall workability of the concrete.

3.2.6 Concrete Specific Gravity Results

The density was calculated by dividing the mass by the volume, using the measured weight of the concrete (kg) and its volume (m^3) as parameters.

Table 3. 3 specific gravity

Sample Name	**Sample**	**Age (Days)**	**Specimen Weight (Kg)**	**Specimen Volume (m^3)**	**Density (Kg/m^3)**	**Average Density per Variant (Kg/m^3)**	**Overall Average Density (Kg/m^3)**
BFKP 0%	1	28	30.2	0.0135	2237.04	2239.51	2196.54
	2	28	30.2	0.0135	2237.04		
	3	28	30.3	0.0135	2244.44		
BFKP 1.5%	1	28	29.9	0.0135	2214.81	2212.35	
	2	28	29.9	0.0135	2214.81		
	3	28	29.8	0.0135	2207.41		
BFKP 2.5%	1	28	29.9	0.0135	2214.81	2212.35	
	2	28	29.9	0.0135	2214.81		
	3	28	29.8	0.0135	2207.41		
BFKP 3.5%	1	28	29.8	0.0135	2207.41	2175.31	
	2	28	29.1	0.0135	2155.56		
	3	28	29.2	0.0135	2162.96		
BFKP 4.5%	1	28	28.1	0.0135	2081.48	2143.21	
	2	28	28.9	0.0135	2140.74		
	3	28	29.8	0.0135	2207.41		

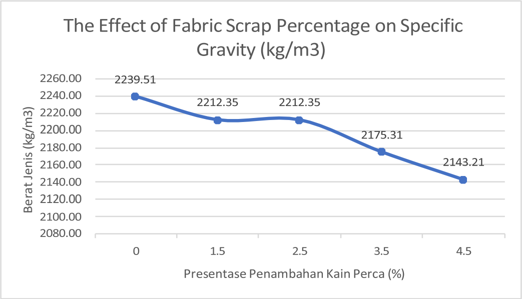


Figure 3. 3 The Effect of Fabric Scrap Percentage on Specific Gravity (Kg/m^3)

Based on Table 3.3 and Figure 3.3, the density of concrete gradually decreases with the increase in fabric waste fiber content. Normal concrete without any fiber addition (0%) has the highest density at 2239.51 kg/m^3, while the lowest density of 2143.21 kg/m^3 is observed at 4.5% fiber addition. This reduction is due to the lower specific gravity of the fabric fibers compared to the aggregates they partially replace. Additionally, the non-dissolving nature of the fibers in the mix may introduce small voids or pores, further reducing the overall density of the concrete.

3.2.7 Flexural Strength Test Results

The flexural strength test was conducted on concrete specimens in the form of beams after 28 days of curing, during which the specimens had been submerged in water. The variations in fabric fiber content used in the concrete mix were 0%, 1.5%, 2.5%, 3.5%, and 4.5%. The results of the flexural strength test are presented in Table 3.4.

Table 3. 4 Specific gravity

Sample Name	Specimen	B	H	Maximum Load (KN)	Flexural Strength (Mpa)	Average Flexural Strength (Mpa)
BFKP 0%	1	150.69	150.66	20.41	2.69	2.68
	2	151.21	151.03	20.62	2.69	
	3	151.07	149.3	19.98	2.67	
BFKP 1.5%	1	151.13	152.4	27.51	3.53	3.28
	2	152.79	152.36	25.72	3.26	
	3	151.11	151.57	23.58	2.06	
2.5%	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.45
	2	151.17	152.6	27.82	2.56	
	3	150.76	152.16	25.30	3.26	
BFKP 3.5%	1	151.16	151.48	28.15	2.65	3.62
	2	151.73	151.18	28.00	3.63	
	3	151.31	153.35	28.16	3.56	
BFKP 4.5%	1	152.37	149.23	22.24	2.95	3.06
	2	150.72	150.6	24.07	3.17	
	3	150.09	149.13	23.09	3,05	

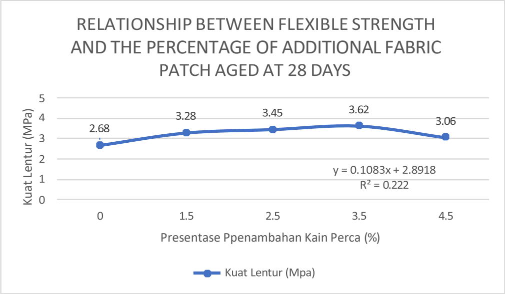


Figure 3. 4 Relationship between Flexural Strength and the Percentage of Added Fabric Scraps Aged 28 Days

Based on Table 3.4 and Figure 3.4, the addition of fabric fiber improved the flexural strength of concrete beams. The lowest flexural strength was observed in the control mix (0%) at 2.680 MPa, while the highest was recorded at 3.620 MPa with 3.5% fabric fiber. The values increased with fiber content up to 3.5%, then declined at 4.5% (3.060 MPa), likely due to reduced workability and segregation. This indicates that moderately added fabric fibers enhance crack resistance and flexural capacity by bridging micro-cracks, but excessive fiber disrupts mix uniformity and weakens mechanical performance.

3.2.8 Cracks in Flexural Beams

The results of measuring the crack width in concrete can be seen in Table 3.4.

Table 3. 5 Average Crack

Concrete Type	Crack Location	Average Crack Width (mm)
BFKP 0%	0 cm (bottom)	11.17
	5 cm	6.08
	10 cm	5.00
	15 cm (top)	5.00
BFKP 1.5%	0 cm (bottom)	7.42
	5 cm	3.50
	10 cm	2.25
	15 cm (top)	0.92
BFKP 2.5%	0 cm (bottom)	1.58
	5 cm	1.08
	10 cm	0.50
	15 cm (top)	0.00
BFKP 3.5%	0 cm (bottom)	1.58
	5 cm	1.00
	10 cm	0.33
	15 cm (top)	0.00
BFKP 4.5%	0 cm (bottom)	0.75
	5 cm	0.50
	10 cm	0.17
	15 cm (top)	0.00

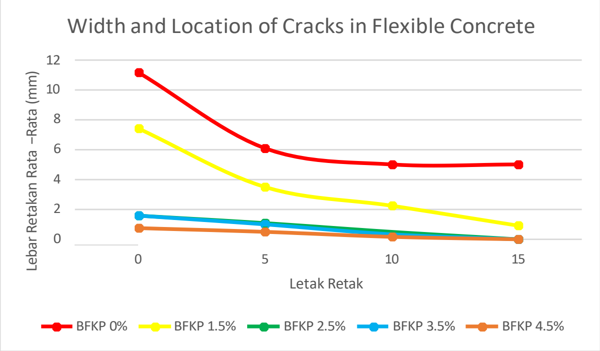


Figure 3. 5 Width and Location of Cracks in Flexible Concrete

Based on the crack measurements of the flexural concrete beams, the BFKP 0% specimen fractured completely, splitting into two parts, indicating that concrete without fabric fiber reinforcement cannot resist tensile stress caused by bending. The addition of 1.5% fabric fiber showed a noticeable effect in reducing cracks, with average widths of 7.42 mm at 0 cm, 3.50 mm at 5 cm, 2.25 mm at 10 cm, and 0.83 mm at 15 cm. In the 2.5% variation, cracks were significantly reduced, and no cracks were found at the top (15 cm). The 3.5% variation showed further improvement with smaller crack widths, while the 4.5% variation demonstrated the best performance, with minimal cracking and none observed at the top. This indicates that increasing fabric fiber content improves crack resistance, especially at higher percentages.

3.3 Discussion of Research Results

Based on the research results on flexural strength, slump, and concrete density, it was found that adding fabric waste to the total concrete volume affects all three parameters. The greater the amount of fabric waste added, the higher the flexural strength and density of the concrete, while the slump value tends to decrease.

3.3.4 Specific Gravity Discussion

Concrete without fabric waste addition had a density of 2239.51 kg/m³. The addition of fabric waste at 1.5%, 2.5%, 3.5%, and 4.5% resulted in concrete densities of 2212.35 kg/m³, 2212.35 kg/m³, 2175.31 kg/m³, and 2143.21 kg/m³, respectively. These results show that as the percentage of fabric waste increases, the concrete density tends to decrease. This indicates that the use of fabric waste as an additive reduces the overall mass of the concrete mixture.

According to SNI 03-2847-2002, concrete is classified by density as follows:

- Lightweight concrete: ≤ 1900 kg/m³

- Normal concrete: 2200–2500 kg/m³
- Heavyweight concrete: > 2500 kg/m³

Based on this classification, all concrete samples in this study fall within the normal concrete category, even though the density decreases with higher fabric waste content. This demonstrates that adding up to 4.5% fabric waste still meets the density requirements for normal concrete as defined by SNI 03-2847-2002.

3.3.5 Discussion of Slump Value and Flexural Strength

The addition of fabric waste fiber (BFKP) significantly affects the slump value of concrete. As the fiber content increases, slump decreases—from 70 mm (0%) to 35 mm (4.5%). Although all slump values remain within the acceptable range for structural work (25–100 mm), the mix becomes less workable. This decline is due to the fibers absorbing water and obstructing mix flow. Prior studies (Sudarmoko, 1993; Suhendro, 1991) confirm that higher fiber volume and aspect ratio reduce workability, which can be improved by adjusting mix proportions or adding superplasticizers.

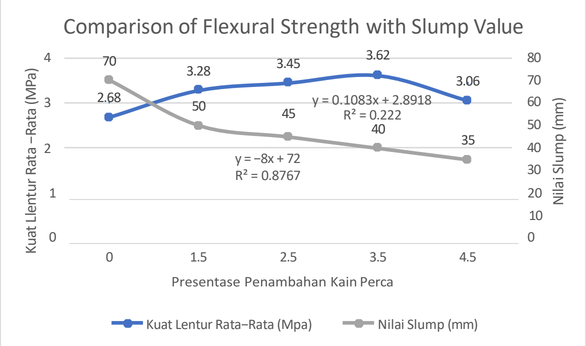


Figure 3. 6 Comparison of Flexural Strength with Slump Value

From the comparison graph of slump and flexural strength, BFKP 3.5% shows the highest average flexural strength at 3.63 MPa, but with a slump value of 40 mm. Meanwhile, BFKP 4.5% has a lower flexural strength of 3.05 MPa and the lowest slump value of 35 mm. This indicates that the optimal percentage of fabric waste fiber addition for maximizing flexural strength is at 3.5%. Beyond this point, further increases in fiber content reduce the slump value and do not improve strength.

Table 3. 5 Recommended Slump Values for Various Construction Works

Type of Construction	**Slump (mm)**
	Maximum
Reinforced concrete foundations (walls and spread footings)	75
Unreinforced spread footings, pile foundations, underground walls	75
Reinforced beams and walls	100
Building columns	100
Pavements and floor slabs	75
Mass concrete	50

According to SNI 7656:2012, the required slump value for structural concrete in beam and column elements ranges from 25 mm to 100 mm. Based on the test results, all concrete variations met this standard. However, lower slump values indicate reduced workability, likely due to excessive addition of fabric waste fibers that absorb water from the mix, hindering proper mixing and manual handling. A very low slump can lead to segregation, poor compaction, and weak bonding, negatively affecting the strength and durability of the concrete.

From the experiment, BFKP samples with 0%, 1.5%, 2.5%, 3.5%, and 4.5% fiber content all meet the slump criteria. However, as the fiber percentage increases, the slump decreases, which could eventually result in concrete that falls outside the normal classification.

Table 3. 6 Comparison of Flexural Strength and Slump

Sample Name	**Fabric Waste Fiber Percentage (%)**	**Slump (mm)**	**Average Flexural Strength (MPa)**	**Normal Concrete Criteria**
BFKP 0%	0	70	2.68	Normal
BFKP 1.5%	1.5	50	3.28	Normal
BFKP 2.5%	2.5	45	3.45	Normal

BFKP 3.5%	3.5	40	3.62	Normal
BFKP 4.5%	4.5	35	3.05	Normal

3.3.6 Discussion of Cracks in Beams

Figure 3. 7 Concrete Breaks Without Patchwork

The crack observation after flexural testing revealed that concrete without fabric waste fiber experienced total failure, splitting into two parts (Figure 3.7). Microcracks quickly developed into macrocracks, leading to sudden structural collapse.

As the volume of fabric waste fiber increased, average crack width decreased. The added fibers provided a bridging effect across cracks, improving flexural strength and toughness, and preventing total failure at maximum load. The fibers distributed stress more evenly and enhanced concrete’s resistance to bending.

Figure 3. 8 Patchwork Concrete Fracture
with Bridging Effect

This aligns with Liu (2019), who found that macro fibers effectively bridge cracks and enhance ductility due to their shape and length. Similarly, fabric waste fibers in this study helped maintain concrete integrity by reducing stress concentration around cracks.

4. Conclusion

This study found that adding fabric waste fibers to concrete significantly improves flexural strength, with the highest increase of about 35% achieved at 3.5% fiber content (3.62 MPa) compared to plain concrete. This improvement is attributed to the fiber's ability to bridge cracks and enhance internal bonding. However, fiber content beyond 3.5% led to reduced flexural strength due to poor distribution and decreased workability, as shown by lower slump values. Conversely, compressive strength decreased with fiber addition. The highest compressive strength (24.69 MPa) was observed in plain concrete, while the lowest (11.02 MPa) occurred with 4.5% fiber

content. This drop is due to increased voids, water absorption by the fibers, and poor compaction, making fabric fibers unsuitable for load-bearing structural concrete.
For optimal performance, fabric waste fiber should be limited to 3.5% of the total concrete volume. To counter reduced workability, superplasticizers are recommended. Future research should explore other types or combinations of fibers to assess their mechanical benefits. Additional testing under extreme weather, freeze-thaw cycles, or aggressive environments is also advised to evaluate the long-term durability of fiber-reinforced concrete for outdoor applications.

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