p–ISSN: 2723 - 6609 e-ISSN: 2745-5254
Vol. 5, No. 9 September 2024 http://jist.publikasiindonesia.id/

Effect of Compressive Strength and Tensile Strength Value on Fiber Concrete Using Bendrat Wire Fibers

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Keywords: fiber concrete; bent wire fiber; compressive strength; tensile strength.

ABSTRACT

Concrete is a material used in modern construction and is a very important component in the manufacture of structures. Concrete has advantages, but also disadvantages, namely low tensile strength. To increase the tensile strength of concrete, fibers are added to the mix. One of the efforts made to increase the tensile strength of concrete is the addition of fibers to the fiber-concrete mixture. The purpose of this study is to examine the compressive strength and tensile strength values in fiber concrete if added with variations in fiber addition. An innovation in increasing the value of mechanical quantities in concrete is the use of bent wire fibers as a mixture in fiber concrete. This material is taken from former pieces in construction projects to connect steel reinforcement with Sengkang reinforcement and is also widely found in building shops. The fibers were also analyzed for microstructure using SEM (Scanning Electron Microstructure) tools. The length of this bent wire fiber is 13 mm with a diameter of 0.82 mm and has a minimum tensile strength value of 334.5 MPa. The variations in the addition of these bent wire fibers are 0%, 3%, 6%, and 9% of the total weight of the steel fiber. The soaking life of concrete is 7 days, 14 days, and 28 days. The results of this study show that the more variations in the addition of bent wire fibers, the compressive strength value of concrete and the tensile strength value of concrete will also increase. It can be seen that fiber concrete with an immersion life of 28 days with a variation of 9% added bent wire fiber has a maximum compressive strength value of concrete which is 63,645 MPa and a maximum value of tensile strength of 3,294 MP.

Introduction

Concrete is a material that is often found in construction projects and is one of the materials that is often used in construction in Indonesia, both in the construction of buildings, roads, irrigation, and others (Indrayani et al., 2022). The things that make concrete materials more often used in construction in Indonesia are concrete constituent materials that can be easily found in various regions with a relatively low-cost budget compared to other civil construction materials. According to (Kawulusan et al., 2019), the properties of concrete are that it has a high compressive strength value but a low tensile strength value (Arman et al., 2023). The use of concrete as the main material in construction has several advantages, including relatively high compressive strength value, concrete can be easily shaped, economical cost, durable, and tends to have better resistance in various conditions such as the environment (Sahid & MM, 2017).

In addition to the advantages of the material, concrete also has several disadvantages that can cause a reduced service life. The brittle nature of concrete materials causes cracks and damage to occur very easily if tensile force is applied. If a tensile load exceeds its capacity, then cracking will occur. (Putra, 2021). However, if the concrete is continuously allowed to crack, it can reduce durability and can even cause corrosion of the rebar steel in it if water and air have reacted. The shortcomings found in concrete are certainly the most important focus for researchers to increase the tensile capacity of concrete. So the researcher made a study by utilizing waste materials to be used as fiber as a mixture in concrete, which is called fiber concrete. (Ramadhani, 2021).

Fiber concrete is made by adding fibers to increase its tensile strength, making it more resistant to the tensile forces caused by weather, climate, and temperature that usually occur in concrete with a large surface. Fiber concrete can be made from natural or artificial fibers. Natural fibers usually come from plants, such as palm oil, coconut fiber, and sisal, among others. Artificial fibers are usually made of compounds, which are highly weather-resistant polymers. Polypropylene, polyethylene, and other fibers are the most commonly used artificial fibers. (Tjokrodimuljo, 2007).

In the bent wire fiber, it has a relatively high modulus and strength. This fiber also cannot be deformed due to the influence of alkaline cement and can be mechanically installed as an increase in adhesion data to concrete materials. The effect of the addition of local fibers on the concrete material mixture can be seen from the compressive strength, ductility, and impact resistance of the resulting concrete fibers. Some factors that are of special concern in fiber concrete are mixing techniques so that the distribution of the fibers becomes even in random directions. However, this can be overcome by adding proportions to the concrete mixture such as adding a superplasticizer. In these fibers, it is also said that there is a decrease in workability due to the addition of variations in fiber addition and an increase in the fiber fineness ratio. (Haq & Andayani, 2017).

Although there have been many studies that use fiber as a concrete mixture material as reinforcement in improving the mechanical performance of fiber concrete, this scientific writing is more focused on concrete with a mixture of bent wire fibers. The development of this study is somewhat different from previous studies, but this study aims to investigate the analysis of microstructure in bentrat wire fibers, test the slump flow value, check the volume weight of fiber concrete, test the compressive strength of fiber concrete, and test the tensile strength of fiber concrete.

Method

Experimentally, this research includes preparatory work such as materials to be used and examination of materials.

1. Material

The materials used in this study include the following:

a. Fine Aggregate (Sand)

This fine aggregate or sand, is taken from a building shop in the city of Medan, North Sumatra where the source of the material is taken from the city of Binjai, North Sumatra. Before the sand was mixed on fiber concrete, mechanical properties testing was carried out at the Laboratory of Concrete Materials and Engineering, University of North Sumatra with the following data results below.

Table 1
Hasil Pengujian Mechanical Properties Agregat Halus

Types of Testing	Technical Specifications	Test Results	Standard	Conclusion
Sieve Analysis (Sieve Analyze)	2,2 – 3,2	FM = 1,97	ASTM C136 – 84a	Not OK!
Specific Gravity (Specific Gravity)	Bulk < SSD < Apparent	SSD = 2,48	ASTM C128 – 88	OK!
Absorption (Absorption)	< 5%	2,88 %	ASTM C128 – 88	OK!
Contents Weight (Unit Weight)	> 1.125 kg/m3	1.324,38 kg/m3	ASTM C29/C29 M – 90	OK!
Sludge Content (Washing By No. 200)	< 5%	2,3 %	ASTM C117 - 90	OK!
Up Air (Water Content)	-	9,20 %	ASTM D1864-89	OK!

b. Semen PCC (Portland Composite Cement) Type 1

In this PCC Type 1 cement, the material used is Dynamix cement which is a product of PT. Semen Indonesia (Persero) Tbk. with a packaging of 1 zak of 40 kg.

c. Silica Fume

Silica fume is a very fine granular material with a diameter of 1/100 of the diameter of cement and this material has a SiO_2 content of more than 85% (Kusumo, 2013). The silica fume material used is SikaFume which is a product of PT. SIKA Indonesia, Tbk. with 1 zak 20 kg packaging.

d. Superplasticizer

This superplasticizer is an additional material that aims to make concrete easily melt and can be self-compacting concrete. The superplasticizer material used is Sika ViscoCrete 3115 N which is produced from PT. SIKA Indonesia, Tbk. with 20 liters / 20 kg packaging.

e. Bendrat Wire Fiber

This bent wire fiber is taken from former pieces from a construction project with a length of 13 mm and a fiber diameter of 0.82 mm. The tensile strength test on this wire was carried out at the North Sumatra Provincial Industry Office, with the result of the tensile strength value of the wire being 334.5 MPa.

Stages of Research

After the materials have been attached, the next stages of research are made as follows:

a. Preparing Materials

The materials that will be used in this fiber concrete mixture are PCC (Portland Composite Cement) Type 1 cement, fine aggregate, superplasticizer, bitrate wire fiber, and water.

b. Providing Equipment

After preparing the material to be used, the equipment also needs to be prepared, including molds of concrete cylinder test pieces, scales, mixer boxes, buckets, cement spoons, abrams cones, meters, and digital compression machine tests.

c. Mix Design Mix Planning

In the planning of the mixed design of fiber concrete, it was adopted by referring to research made by (Tayeh et al., 2013). However, specifically, this study refers to the materials that have been presented above, namely PCC (Portland Composite Cement), river sand, silica fume, water, superplasticizer, and adjustment with variations in the addition of bent wire fibers as listed in Table 2. below.

Table 2
Composition of Fiber Concrete Mixture

Material Type	**Volume of Fiber Concrete**			
	0%	**3%**	**6%**	**9%**
	(kg/m3)			
Air	144	144	144	144
Semen PCC Type 1	768	768	768	768
Silica Fume	192	192	192	192
Superplasticizer	40	40	40	40
River Sand	1.140	1.140	1.140	1.140
Bendrat Wire Fiber	0,00	4,71	9,42	14,13
Cement Water Factor (f.a.s.)	0,1875	0,1875	0,1875	0,1875
Rasio *w/b*	0,15	0,15	0,15	0,15

d. Slump Flow Testing

The slump flow test is carried out to determine the viscosity result in concrete and then test the velocity when the concrete flow reaches a diameter of 50 cm (T50) on the fiber concrete mixture. The equipment used for slump flow testing is Abram cones and also plywood materials that have been marked with circle boundaries with diameters of 20 cm, 50 cm, 65 cm, and 85 cm. The steps of this slump flow test are that the abrams cone is placed on a plywood board that has been marked in the middle of the circle boundary which will later be filled with fresh concrete of bent wire fiber without compaction or vibration, try when fresh concrete fills into the abrams cone so that the material does not spill out from inside the cone. The time recording must also be done after the abrams cone is lifted vertically, and the time of the test result T50 (seconds) is recorded when the concrete flow reaches the 50 cm line. After recording the results of the T50 test, look at the concrete flow again until the flow process is completed, and also record the diameter of the slump flow.

e. Fiber Concrete Cylinder Test Specimen Sample

The number of samples of the fiber concrete cylinder test piece used is differentiated according to the type of test. In the concrete compressive strength test, the size of the concrete cylinder used is 12.5 cm in diameter and 19.6 cm in height. Meanwhile, in the tensile strength test of concrete, the size of the concrete cylinder used is 15 cm in diameter and 30 cm in height. Samples of fiber concrete cylinder test specimens are loaded in Table 3. below.

Table 3
Fiber Concrete Cylinder Test Specimen Sample

No.	Sample or Specimen Code	Cylinder Based Test Specimen			
		Compressive Strength of Concrete			Tensile Strength Concrete Slats
		7 Days Old	Age 14 Days	Age 28 Days	Age 28 days
1	SF-0%	3	3	3	3
2	SF-3%	3	3	3	3
3	SF-6%	3	3	3	3
4	SF-9%	3	3	3	3

f. Fiber Concrete Volume Weight Inspection

After the test piece is made, before conducting the test, the weight of the concrete volume is checked, namely the weight of the concrete that has been weighed per the volume of the concrete cylinder test piece. According to (Tjokrodimuljo, 2007), the classification of concrete types is differentiated based on the weight of the volume of concrete as stated in Table 4. below.

Table 4
Classification of Types of Concrete Based on Weight of Concrete Volume

Types of Concrete	Volume Weight (kg/m3)	Concrete Function
Ultra-light concrete	< 1,000	Non-structure
Lightweight Concrete	1.000 – 2.000	Lightweight structure
Concrete Normal (Ordinary Concrete)	2.300 – 2.500	Structure
Heavy Concrete	> 3,000	X-ray shielding

g. Concrete Compressive Strength Testing

The compressive strength of concrete is the amount of load pressed per unit area on the concrete base which causes the cylinder of the concrete test piece to collapse when loaded with a certain compressive force by the influence of the press machine. The compressive strength equation of concrete can be seen in equation (1) below.

$$f'_c = \frac{P}{\frac{1}{4} \cdot \pi \cdot D^2} \qquad (1)$$

Information: f'_c = Compressive strength of concrete (kN/m^2)
P = Compressive force on concrete (kN)
D = Diameter of concrete cylinder (m)

h. Concrete Screed Tensile Strength Testing

The tensile strength of concrete is the result of the indirect tensile strength value of the cylinder of the concrete test piece which is placed parallel to the table surface when the testing machine is pressed (SNI 2491:2014). The tensile strength equation of concrete can be seen in equation (2) below.

$$f_{ct} = \frac{2P}{\pi \cdot L_S \cdot D} \qquad (2)$$

Description: fct = Tensile stress of concrete slats (kN/m2)
P = Maximum applied tensile load (kN)
Ls = Height of concrete cylinder (m)
D = Diameter silinder beton (m)

Results and Discussion

Slump Flow Test Results and T50 Test

This test begins with the creation of a mix design on fiber concrete that is adjusted to the variation in the addition of bent wire fibers. Below is the slump flow testing data of fiber concrete in Table 5. and Figure 3. and is in line with EFNARC regulatory standards and JSCE regulations.

Table 5
Slump Flow Test Results on Fiber Concrete

No.	Variation in Percentage of Bentate Wire Fiber	Diameter *Slump Flow* (cm)	Requirement *EFNARC* (55 – 85 cm)	Requirement *JSCE* (50 – 65 cm)
1	0%	101,1	Not OK!	Not OK!
2	3%	97,8	Not OK!	Not OK!
3	6%	93,7	Not OK!	Not OK!
4	9%	88,4	Not OK!	Not OK!

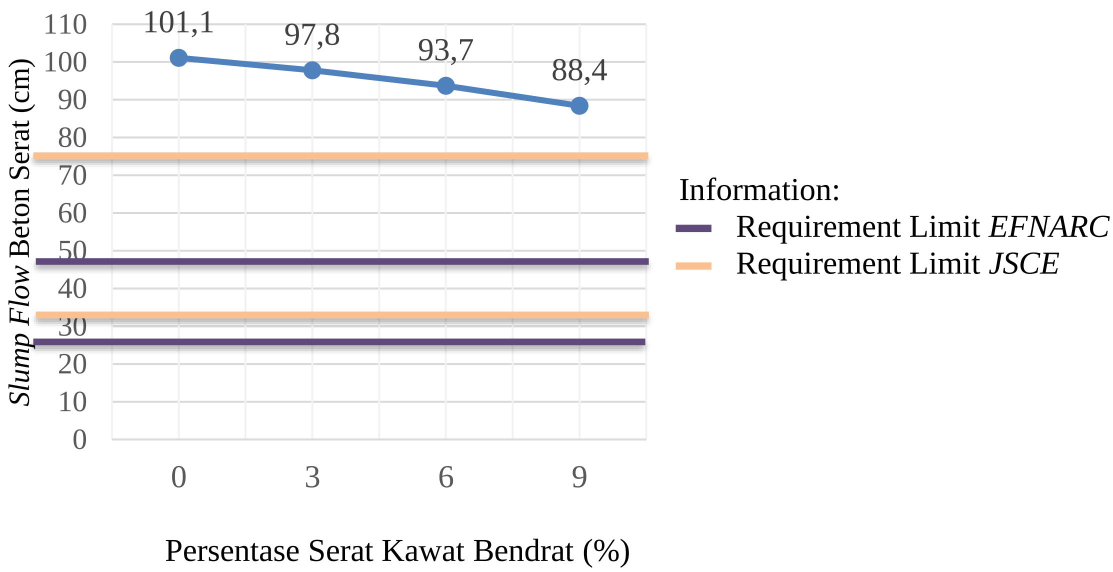

Figure 3.
Relationship of *Slump Flow* to Variation in Addition of Bendrat Wire Fibers

Table 6
T50 Test Results on Fiber Concrete

No.	Variation in Percentage of Bentate Wire Fiber	T50 (sec)	Requirement *EFNARC* (< 6 seconds)	Requirement *JSCE* (3-15 seconds)

1	0%	04,34	OK!	OK!
2	3%	05,06	OK!	OK!
3	6%	05,51	OK!	OK!
4	9%	06,12	Not OK!	OK!

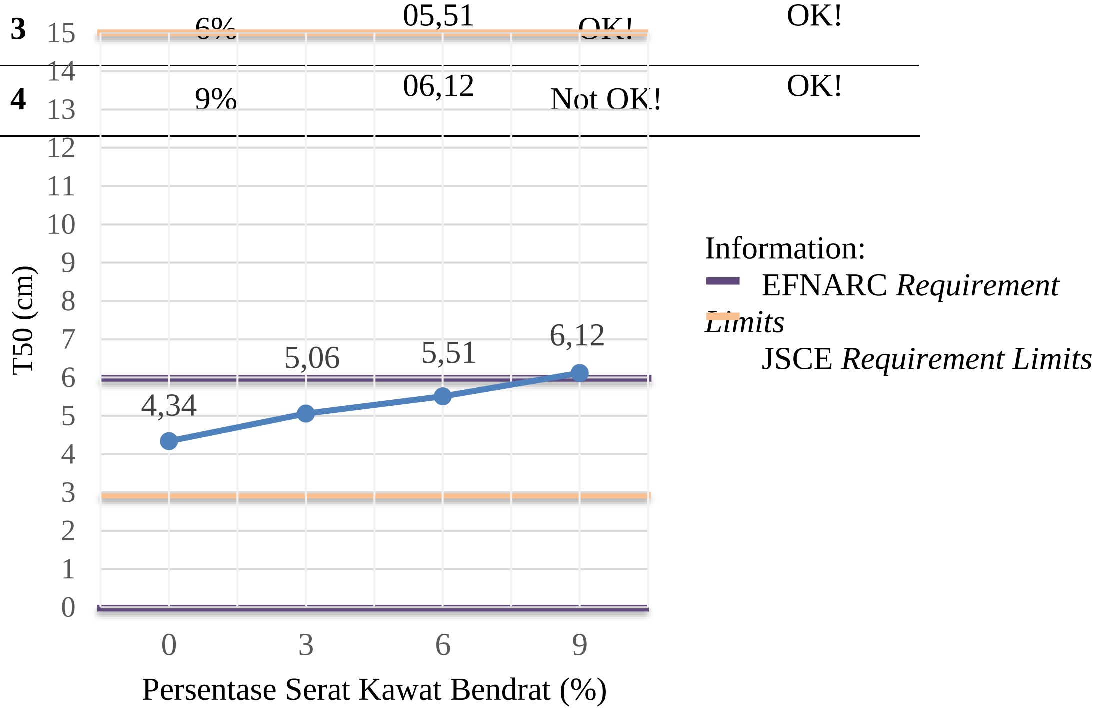

Figure 4
Relationship of T50 Test to Variation in Addition of Bendrate Wire Fibers

In the slump flow test of concrete fibers above, it can be concluded that the influence of increasing bent wire fibers can reduce the diameter flow process in concrete, this is because there is a decrease in workability along with the increase in the mixture of variations in the percentage of added bent wire fibers. Then in the T50 test of fiber concrete above, it can be concluded that the influence of increasing bent wire fibers will slow down the diameter flow process time in concrete, this is because the fiber has resisted the components of the fiber concrete mixture mixture so that the flow process becomes slow. (Haq & Andayani, 2017).

Results of Weight Inspection of Fiber Concrete Volume

After conducting slump flow testing and T50 testing, then the next step is to check the volume weight of fiber concrete, both for the test specimen cylinder for concrete compressive strength testing and concrete tensile strength testing. (Arman et al., 2023).

It is known that the size of the cylinder is differentiated based on the testing of its mechanical magnitude. Therefore, the weight check data of the volume of fiber concrete before testing the compressive strength of concrete in Table 7 below is made.

Table 7
Volume Weight Inspection on Fiber Concrete
Before Concrete Compressive Strength Testing

Specimen Code	Weight of Concrete Test Specimen (kg)	Volume of Concrete (m3)	Concrete Volume Weight (kg/m3)	Concrete Volume Weight Average (kg/m3)
Concrete for Compressive Strength Testing of Concrete 7 Days Life				
SF – 0%	5,880 5,940 6,080	0,0024308	2.343,366 2.367,277 2.423,072	2.377,905
SF – 3%	5,620 5,920 6,080	0,0024308	2.239,747 2.359,307 2.423,072	2.340,709
SF – 6%	6,280 6,300 6,060	0,0024308	2.502,778 2.510,749 2.415,101	2.476,209
SF – 9%	6,400 6,380 6,320	0,0024308	2.550.602 2.542.631 2.518,719	2.537,318
Concrete for 14-Day Life Concrete Compressive Strength Testing				
SF – 0%	5,799 5,952 5,853	0,0024308	2.385,631 2.448,573 2.407,846	2.414,017
SF – 3%	5,895 6,036 5,455	0,0024308	2.425,124 2.483,129 2.244,114	2.384,122
SF – 6%	6,160 6,454 6,100	0,0024308	2.534,141 2.655,089 2.509,458	2.566,230
SF – 9%	6,291 6,224 6,344	0,0024308	2.588,033 2.560,470 2.609,837	2.537,318
Concrete for Compressive Strength Testing of Concrete 28 Days Life				
SF – 0%	6,000 5,940 5,920	0,0024308	2.468,320 2.443,636 2.435,409	2.449,122
SF – 3%	5,940 5,640	0,0024308	2.443,636 2.320,220	2.435,409

	6,180		2.542,369	
SF – 6%	6,420	0,0024308	2.641,102	2.558,825
	6,060		2.493,003	
	6,180		2.542,369	
SF – 9%	6,640	0,0024308	2.731,607	2.770,003
	6,820		2.805,657	
	6,740		2.772,746	

Results of the weight inspection of fiber concrete volume before concrete compressive strength testing are in Table 7. The above states that the average weight of concrete volume with variations in the addition of 0% and 3% bent wire fiber for the age of 7 days, 14 days, and 28 days is categorized as normal concrete because the requirements for the type of concrete are at an integral of 2,300 – 2,500 kg/m3. Meanwhile, the average volume weight of concrete with variations in the addition of 6% and 9% of bent wire fibers for the age of 7 days, 14 days, and 28 days is categorized as heavy concrete, because the average volume weight value reaches more than 2,500 kg/m3.

After that, the weight of the volume of fiber concrete is checked before testing the tensile strength of the concrete as stated in Table 8. below.

Table 8
Volume Weight Inspection on 28-Day-Old Fiber Concrete
Before the Concrete Shear Tensile Strength Test

Specimen Code	Weight of Concrete Test Specimen (kg)	Volume of Concrete (m3)	Concrete Volume Weight (kg/m3)	Concrete Volume Weight Average (kg/m3)
SF – 0%	12,220	0,0053036	2.304,108	2.315,421
	12,280		2.315,421	
	12,340		2.326,734	
SF – 3%	12,400	0,0053036	2.338,047	2.333,019
	12,380		2.334,276	
	12,340		2.326,734	
SF – 6%	12,820	0,0053036	2.417,239	2.414,725
	12,900		2.432,323	
	12,700		2.394,613	
SF – 9%	12,660	0,0053036	2.387,071	2.384,557
	12,640		2.383,300	
	12,640		2.383,300	

The results of the weight check of the volume of fiber concrete before the tensile strength test of 28-day-old concrete are in Table 8. The above states that the average weight of concrete volume with variations in the addition of 0%, 3%, 6%, and 9% bent wire fibers are categorized as normal concrete because the requirements for the type of concrete are integral 2,300 – 2,500 kg/m3.

Results of Fiber Concrete Compressive Strength Test

After checking the weight of the volume of fiber concrete, the next step is to make fiber concrete with a mixed design mixture as attached to Table 2. above. The concrete cylinder test specimen used in the concrete compressive strength test was made with a diameter of 12.5 cm and a height of 19.8 cm, and then the concrete was soaked for 7 days, 14 days, and 28 days. The results of the compressive strength test of fiber concrete can be seen in Table 9. below below.

Table 9
Results of Fiber Concrete Compressive Strength Test

Specimen Code	Maximum Load (kN)	Average Maximum Load (kN)	Compressive Strength of Concrete (MPa)	Compressive Strength of Concrete Average (MPa)
For Concrete with a Soaking Life of 7 Days				
SF – 0%	263	428,333	20,760	33,811
	473		37,337	
	549		43,336	
SF – 3%	318	481,333	25,102	37,995
	703		55,492	
	423		33,390	
SF – 6%	728	612.667	57,466	48,362
	492		38,837	
	618		48,783	
SF – 9%	688	622	54,308	49,098
	456		35,995	
	722		56,992	
For Concrete with 14 Days Soaking Life				
SF – 0%	401	473	31,653	37,337
	498		39,310	
	520		41,047	
SF – 3%	645	616,667	50,914	48,677
	593		46,809	
	612		48,309	
SF – 6%	802	658,333	63,307	51,966
	696		54,940	
	477		37,653	
SF – 9%	687	673,667	54,229	53,177
	686		54,150	
	648		51,151	

For Concrete with a Soaking Life of 28 Days

SF – 0%	814	624	64,254	49,256
	625		49,335	
	433		34,179	
SF – 3%	694	667,010	54,782	52,650
	711		56,124	
	596		47,046	
SF – 6%	810	769,022	63,938	60,702
	679		53,598	
	818		64,570	
SF – 9%	863	803,990	68,122	63,465
	768		60,623	
	781		61,649	

After Table 9. The data of the compressive strength test results of fiber concrete has been loaded, so a clear graph of concrete compressive strength testing is made in Figure 5. below.

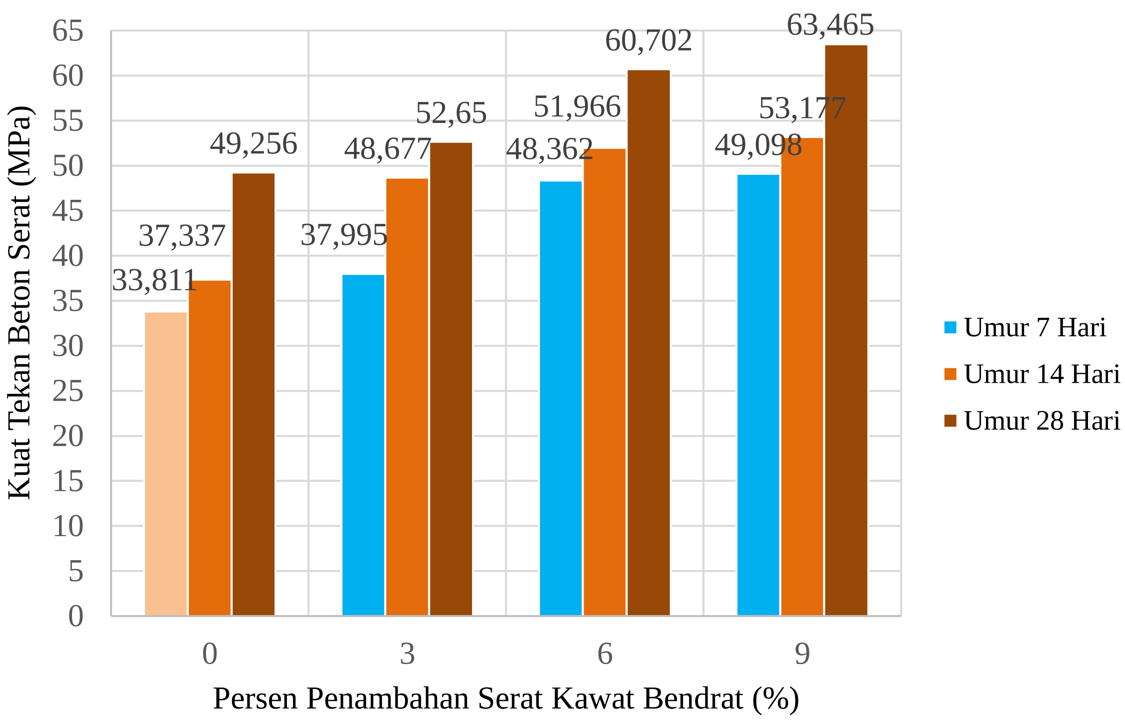

Figure 5. Graph of Fiber Concrete Compressive Strength Test

Based on Table 9. and Figure 5. above, that the increase in bitrate wire fibers above both at the time of soaking concrete and the percentage of addition of bent wire fibers. It can be seen that for a concrete soaking life of 28 days with the addition of 9% bent wire fibers can reach 63,465 MPa.

Concrete Tensile Strength Test Results

After the concrete compressive strength test, the tensile strength test of concrete is made with the data presented in Table 10. below.

Table 10
Hasil Pengujian Kuat Tarik Belah Beton Serat

Specimen Code	Maximum Load (kN)	Average Maximum Load (kN)	Strong Tensile Strength of Concrete (MPa)	Strong Tensile Strength of Concrete Average (MPa)
SF – 0%	160	176,667	2,258	2,494
	180		2,542	
	190		2,683	
SF – 3%	160	183,333	2,256	2,588
	240		3,389	
	150		2,117	
SF – 6%	230	210	3,245	2,964
	240		3,386	
	160		2,259	

Specimen Code	Weight of Concrete Test Specimen (kg)	Volume of Concrete (m3)	Concrete Volume Weight (kg/m3)	Concrete Volume Weight Average (kg/m3)
SF – 9%	220	233,333	3,105	3,294
	230		3,247	
	250		3,529	

After Table 10. The data of the tensile strength test results of fiber concrete have been loaded, so the graph of the tensile strength test of concrete is made in Figure 7. below.

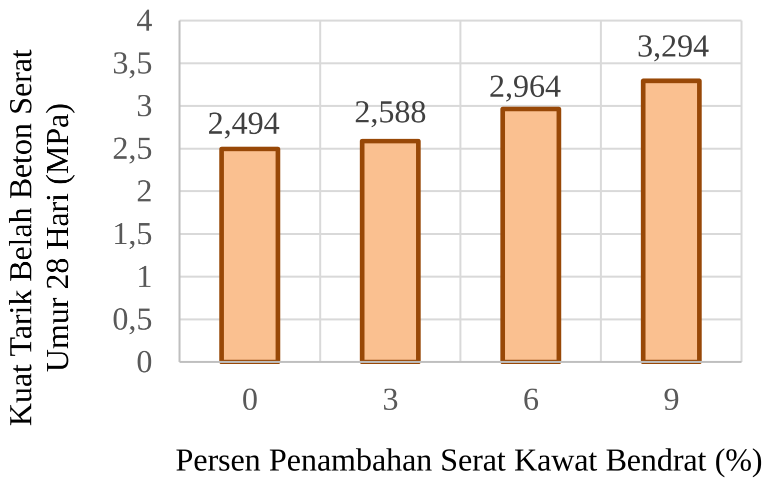

Figure 6. 28 Days Lifespan Fiber Concrete Shear Strength Test Chart

Based on Table 10. and Figure 6. above, that the increase in bent wire fibers above both at the time of soaking the concrete and the percentage of added bent wire fibers, as happened in the compressive strength test of concrete. It can be seen that for a concrete soaking life of 28 days with the addition of 9% bent wire fibers can reach 3,294 MPa.

Conclusion

Based on the results of the research that has been carried out, a conclusion can be drawn that bent wire fiber material can cause a decrease in workability in concrete. Of course, the decrease is not significant, because of the addition of superplasticizer so that in the slump flow test, the difference in concrete flow is not too large compared to concrete without the use of bent wire fiber. It can be seen in the compressive strength test of fiber concrete, that both the variation in the soaking time of concrete and the variation in the addition of the percentage of bent wire fibers are seen to have increased significantly.

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