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Production of Job Mix Design FC 25 SF (Silica Fume) with SFRC (Steel Fiber Reinforcement Concrete)

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Abstract. When building anything, concrete is a must-have ingredient. There has been a recent uptick in studies examining the tensile strength of concrete. In order to make concrete more resistant to tensile pressures generated by temperature and weather fluctuations encountered by expansive surfaces, steel fiber concrete is being developed. Adding steel fiber to concrete is one way to boost its tensile strength. When used in conjunction with steel fiber, silica fume is an additive that may seal and compress the concrete surface. Adding silica fume to concrete improves its quality and makes it weatherproof. This research aims to enhance the compressive strength of concrete by using steel fiber and silica fume. Some of the ingredients needed to make concrete include steel fiber and silica fume. At 7,14, and 28 days of curing time, cylinders measuring 15 x 30 cm were used in the investigation. Methods and procedures based on concrete standard test and SNI 03-2834-2000 were used to perform in this study at the PT. Remicon Widyaprima Laboratory. A projected concrete compressive strength of 25 MPa was determined by the study's findings. After 28 days, the concrete with the maximum compressive strength was 28.30 MPa, achieved by a combination of steel fiber and silica fume, according to the findings of this research. In comparison, regular concrete had a compressive strength of around 26.25 MPa.

Keywords: Compressive Strength of Concrete, Steel Fiber Reinforcement, Silica Fume Concrete

1 Introduction

The increasing demand for concrete as a common building material is proportional to the expansion of development. Due to its malleable nature, concrete is widely used in the construction industry. For years, concrete has been considered one of the most popular building materials for both large and small projects. Compared to other materials, concrete offers several advantages, such as resistance to environmental conditions, ease of shaping according to construction design specifications, low maintenance costs, and high compressive strength [1]. Concrete is one of the most widely used materials in various construction projects. As the total population increases, the demand for concrete continues to rise, thus driving the need for innovation in the development of concrete composites. This condition has implications

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for the decreasing availability of concrete components, while also requiring efforts to improve the quality of the resulting concrete [2].

The diverse applications of concrete require it to withstand extreme conditions, especially in areas exposed to water. Therefore, concrete with a mixture that has a higher pore density is required. Concrete admixtures are one area where new strategies are being tested and implemented to increase concrete strength. This is achieved by adding various materials to the concrete mix, such as coarse and fine aggregates, cement, and other commonly used additives. These additions alter the properties of the concrete, making it more suitable for specific applications and more cost-effective. One way to seal the pores in concrete is by using silica ash. When creating reinforced concrete in areas that are consistently wet, one of the biggest challenges is the installation of reinforcing bars. To simplify construction while maintaining the same quality as reinforced concrete, Steel Fiber Reinforced Concrete (SRF) is an alternative. The addition of steel fibers to concrete acts as reinforcement, evenly distributed throughout the mix in a specific proportion. Parts of the concrete subject to tensile stress are reinforced with steel fibers to reduce the likelihood of cracking. Working load, shrinkage, or heat from hydration are the most common causes of these cracks, and the shape and number of steel fibers used determine the tensile strength of the concrete [3].

The effectiveness of steel fibers in improving concrete performance is not only determined by their presence but also by the number of bends and the quality of the bond between the fibers and the concrete matrix. Furthermore, steel fibers contribute significantly to crack control in concrete structures [4].

With this background, the purpose of this study was to measure the compressive strength of concrete on days 7, 14, and 28 using cylindrical samples (15x30 cm) consisting of a mixture of silica ash and steel fiber reinforced concrete. The addition of silica ash to concrete has two purposes: to make the mixture denser through the saturation process and to increase the compressive strength of the mixture by approximately 5% according to the mix design. Steel fiber reinforced concrete, which is added at a ratio of approximately 5% by volume, is beneficial because the steel fiber can withstand the compressive and tensile strength of concrete. Specifically, this study aims to 1) determine how the addition of 5% silica ash and 5% steel fiber to concrete affects the compressive strength of concrete on days 7, 14, and 28; and 2) determine how the compressive strength compares between concrete mixtures with and without silica ash and steel fiber.

Several limitations were applied to the study to narrow its scope: 1) The study focused solely on how the addition of silica ash and steel fiber to concrete affects the compressive strength of concrete. 2) All samples and test objects contained a 5% mixture of both additives. 3) The SK SNI 03-2834-2000[5] method was used to calculate the concrete mix design. 4) The study's objective was to determine how the addition of silica ash and steel fiber to concrete affects the slump value and compressive strength of concrete.

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2 Method

The study employed an experimental/testing design. To evaluate concrete performance, researchers compared 25 MPa concrete with and without additives. The compressive strength of both types of concrete was measured. Various additives, including silica ash and steel fiber-reinforced concrete, were used to determine the concrete strength. The purpose of this study was to determine how the addition of silica ash and steel fiber-reinforced concrete affects the compressive strength and durability of concrete by analyzing the results of research observations conducted on the tested concrete.

In steel fiber-reinforced concrete, several factors must be considered. For example, when making fiber-reinforced concrete, it is important to regularly incorporate the steel fibers into the mixture to ensure uniform distribution. Furthermore, the mixture must be easy to work with. To achieve a certain quality with sufficient capacity, the working/compression process involves instructions and difficulty in mix/proportion design [6].

Concrete Filler Materials, the materials used in concrete mixes are the basic ingredients: cement, coarse aggregate, fine aggregate, water, and admixtures. Steel Fiber Reinforcement Concrete and silica fume (5%) are used as additives in this mix. The materials used in concrete mix production must be of high quality and meet specified requirements to produce concrete with high tensile and compressive strength.

Raw Materials, in the study, several types of raw materials were used for concrete:

1. Cement
   Serves as a filler and binder in the concrete mix. In the study, 40 kg of cement was used for the experiment.
2. Coarse Aggregate
   The coarse aggregate used in this study was 3/4 size coarse aggregate from Tanjung Balai Karimun.
3. Fine Aggregate
   The sand used in the study was Dabo sand, which was screened before concrete production to determine its sand filterability and silt content.
4. Water
   The water was initially used from the PT Remicon Widyaprima Laboratory. Visually, the water appeared clean, colorless, and odorless.
5. Silica Fume
   This is a byproduct made from the combustion ash produced during the production of silicon metal in electrical incinerators. Silica Fume is also a pozzolan (a material containing silica and aluminum oxide as the main compounds). This additive has a very high silica (SiO^3) content (>90%), and the finest particle size, approximately 1/100th the average particle size of cement.
6. Steel Fiber
   The hooked steel fiber used was purchased from Bekaert, type 4D, with a diameter of 1 mm and a length of 55 mm.
7. Super plasticizer, the naphthalene sulfonate polymer used in this for super plasticizer
8. Retarder, the types used in this study were Types B (Retarding) and D (Water-reducing & retarding).

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3 Results And Discussion

3.1 Aggregate Inspection

Coarse and fine aggregate tests were conducted at the PT. Remicon Widyaprima Laboratory, adhering to ASTM and SNI standards for aggregate testing, and following the concrete practicum manual of the Civil Engineering Study Program at Batam University. The fine aggregate (sand) used in the test was Dabo sand, and the coarse aggregate (granite) was sourced from Tanjung Balai Karimun. Aggregate inspections included sieve analysis, silt content testing, specific gravity testing, and aggregate wear testing.

Fine Aggregate Sieve Analysis, Sieve analysis is used for the initial assessment of fine aggregate. Figure 1 displays a graph of the results of the sieve analysis. With a score of 2.63 for aggregate fineness modulus, this material meets the Medium Sand category standard (2.60-2.90) and ASTM C-136 norms (2.3-3.1). Three thousand five hundred grams of sand.

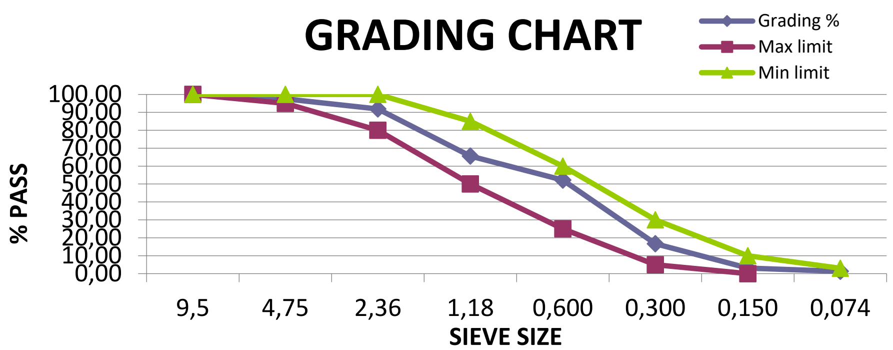

Fig. 1. Fine Aggregate Graph

3.2 Silt Content

The average silt content of the tested fine aggregate was 3.80%, based on the silt content test. This experiment was conducted in two trials. The clay percentages in the two trials were 3.74% and 3.84%, respectively. According to SNI S-04-1998-F (1998), these values are within the permissible range of less than 5%.

3.3 Specific Gravity and Absorption of Fine Aggregate

In accordance with established standards, namely Dry, SSD, and Pseudo, with scores of 2.54, 2.57, and 2.63, and an average absorption of 1.50%. The average specific gravity of the SSD sample was 2.59, based on specific gravity and absorption tests conducted on the fine aggregate studied. In accordance with ASTM C 128 standards, which state that good absorption is below 2%, the fine aggregate produced had an absorption score that met the criteria.

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3.4 Coarse Aggregate Sieve Analysis

The coarse aggregate fineness modulus value of 2.55, determined through laboratory tests for coarse aggregate analysis (figure 2), meets the required criteria of 5.00-7.50 for the gravel (crushed stone) category with a maximum size of 40.

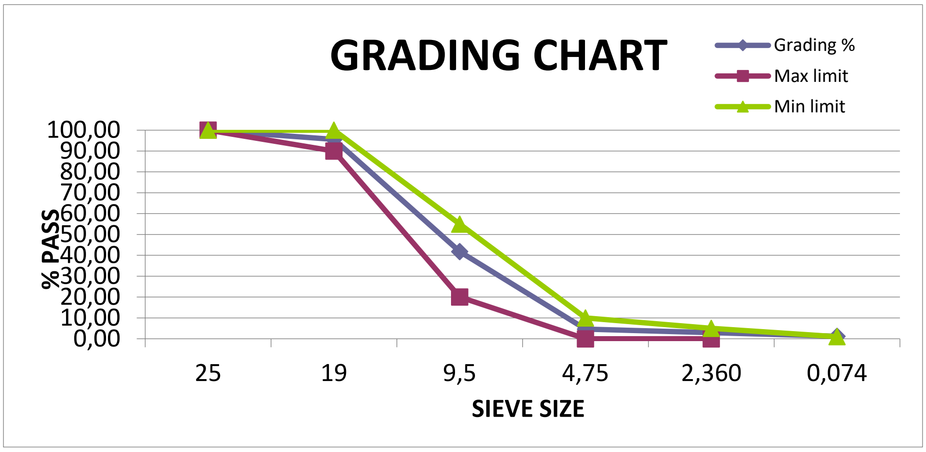

Fig 2 Coarse Aggregate Graph

3.5 Specific Gravity and Absorption of Coarse Aggregate

The data collected from the investigation, which allows for the determination of the specific gravity and absorption of the studied fine aggregate shown three forms of specific gravity—apparent specific gravity, SSD, and combined specific gravity—are shown in the accompanying table. If the specific gravity of the dry sample is less than or equal to both the SSD and apparent specific gravity, the aggregate specific gravity is met.

The specific gravity of the dry sample was 2.696 g/cm³, the specific gravity of the SSD was 2.716 g/cm³, and the specific gravity of the pseudo-sample was 2.75 g/cm³, according to the experimental results. The specific gravity and absorption values for the coarse aggregate were both determined through this test. The average absorption value was 0.752%. The maximum absorption value for coarse aggregate is 4% according to ASTM C 127, and the test result is lower than that.

3.6 Aggregate Wear Using the Los Angeles Machine

The coarse aggregate wear test was conducted using the ASTM C33 (1982) standard regarding aggregate hardness and the Los Angeles Machine. Based on the findings of the inspection carried out, the coarse aggregate resistance score for wear and tear of the test findings above was 18.60% and the results were in accordance with the established standard, namely <50% based on (SNI 2417:2008).

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3.7 Concrete Mix Design

Based on data obtained during the material tests (table 1), the desired concrete mix was obtained. Therefore, the concrete mix design, in accordance with SNI-03-2834-2000 standards, uses a mixture of Silica Fume and Steel Fiber Reinforcement Concrete (SFC) at 5%.

The actual mix design can be described as follows:

a. The concrete compressive strength is set at 25 MPa for curing time 7, 14, and 28 days.
b. The cement used is Type I.
c. The aggregate types are:
   - Fine aggregate: Sand from Dabo
   - Coarse aggregate: Stone from TG Balai Karimun.

The concrete mix design was carried out under two conditions: one without silica fume (normal concrete condition) and the other with silica fume.

Table 1. Baseline Data Analysis

No	Baseline Data	Value
1	Specific gravity of coarse aggregate	2,62 gr/cm^3
2	Specific gravity of fine aggregate	2,59 gr/cm^3
3	Silt content of coarse aggregate	0,76 %
4	Silt content of fine aggregate	3,80 %
5	Bulk density of coarse aggregate	1,47 gr/cm^3
6	Bulk density of fine aggregate	1,55 gr/cm^3
7	FM of coarse aggregate	2,55
8	FM of fine aggregate	2,63
9	Water content of coarse aggregate	0,6 %
10	Water content of fine aggregate	2,65 %
11	Absorption of coarse aggregate	0,98 %
12	Absorption of fine aggregate	1,50 %
13	Design slump test value	120 $\pm$ 2mm
14	Maximum aggregate size	20 mm

3.8 Test Specimen Preparation

In this study, cylinders measuring 15 x 30 cm were used as test specimens. A total of eight test specimens were designed. To make the concrete, a mixer is used. Three different parts of water are used for different purposes. The coarse aggregate is added first, then the fine aggregate, followed by the next third of water, then the cement, and finally the final third of water are added to the mixer. A uniform and uniform mixing of the materials is achieved by adjusting the mixer. The concrete is then loaded into a wheelbarrow after being thoroughly mixed, a mix test was conducted using a combination of Steel Fiber Reinforced Concrete and Silica Fume with a quality of FC 25 and a ratio without any additional admixtures. The two mix designs will be compared using a 15 x 30 cm cylindrical mold. On days 7, 14, and 28, two mold sections will be examined without additional admixture and six sections with additional admixture, with

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volumes of approximately 0.02 m³ and approximately 0.05 m³, respectively, without admixture. Table 2 shows the volumes and compositions of all materials for concrete mix design with silica fume and steel fiber that need to be calculated.
For the use of silica fume and steel fiber reinforced concrete additives at a volume of 0.05 m³, 5% of the cement volume will be used. The required amount of silica fume and steel fiber reinforced concrete is 5% for one test specimen. 5/100 x Cement Weight x 0.05 =5/100 x 400 kg x 0.05 =1 kg

Table 2 Concrete Mix Design with Silica Fume and Steel Fiber

Concrete Mix Design Proposal				
Mix Design For Concrete Class	Normal Mix - Silica Fume - Steel Fiber Reinforced Concrete FC 25 SF -SFRC			
1.1. Characteristic Strength at 28 Days			25	MPa
1.2. Slump			120 ± 20	mm
1.3. Free Water / Cement Ratio			0,41	
2.1. Cement Type	Portland Composite Cement (PCC) Bulk			
2.2. Fine Aggregate Type	Natural Sand			
2.3. Admixture Type I	Silica Fume			
Dosage Rate	5%	of Cement		
2.4. Admixture Type II	Steel Fiber Reinforcement Concrete			
Dosage Rate	5%	of Cement		
2.5. Admixture Type III	Retarder			
Dosage Rate	120	ml per 100 kg Cement		
2.6. Admixture Type IV	Superplasticizer			
Dosage Rate	750	ml per 100 kg Cement		
3.1. Specific Gravities of Material				
3.2. Cement		3,10		
3.3. Coarse Aggregate		2,62		
3.4. Fine Aggregate		2,59		
3.5. Silica Fume		2,20		
3.6. Steel Fiber		7,86		
3.7. Retarder		1,07		
3.8. Super Plasticizer		1,20		
4.1. Maximum Aggregate Size		20 mm		
4.2. Grading of Fine Aggregate		Zone Two		
4.3. Proportion of Fine Aggregate		47,0 %		
4.4. Specific Gravity of Combined Aggregate		26.059		
5.1. Free Water Requirement	165	kg/m3 =	165	liters/m3
5.2. Cement Content	400	kg/m3 =	129,03	liters/m3
5.3. Silica Fume Content	20	kg/m3 =	9,09	liters/m3
5.4. Steel Fiber Content	20	kg/m3 =	2,54	liters/m3
5.5. Air Content	1,5%	=	15,00	liters/m3
5.6. Total Aggregate Content		=	679,33	liters/m3
6.1. Fine Aggregate Content	47%	=	803	kg/m3
6.2. Coarse Aggregate Content	53%	=	905	kg/m3

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6.3. Design Density of Concrete	=	2293	kg/m3
7.1. Remarks	1. Strength will be reach 100% at 28 Days 2. The mix composition confirm to ASTM C-150, C136, C-1240 or SNI-03-2847		

Summary of Batch Weight (SSD) per Cubic Meter of Concrete

Design	Cement	Water	Fine Agg	Coarse	Admix I	Admix II	Admix III	Admix IV
Volume	PCC		Sand	20 mm	Silica Fume	Steel Fiber Reinforcement Concrete	Retarded	Super Plasticizer
m^2	kg	kg	kg	kg	kg	kg	kg	kg
1 (one)	400	165	803	905	20	20	0,51	3,60

3.9 Molding, Concrete Curing and Slump Test

A flexibility test is performed before pouring the concrete into the mold. Then, using a small scoop (ladle), the concrete mixture is poured into the previously prepared mold. Ensure that each scoop of mixture represents a good portion of the mixture. Once the mold is one-third full, use a 16 mm diameter iron rod to pierce it 25 times to compress it. When the mold is two-thirds or three-quarters full, tap the outside with a rubber mallet to release any trapped air. The next step is to level the mold surface and cover it with glass to prevent the water in the freshly mixed concrete from evaporating. After 20 hours, but no more than 48 hours, remove the mold from the test specimen.
Concrete Curing, after the mold is removed, the concrete is weighed and then immersed in a water bath (curing) until the specified age. The storage area must be shock-free for the first 48 hours after immersion. The slump test is performed by filling three layers of fresh concrete into the Abrams cone, with each layer covering approximately one-third of the cone's capacity. After filling each layer, prick the concrete 25 times; the stick should reach the bottom of each layer. Ensure the cone surface is level, then lift the mold 300 mm in 5 ± 2 seconds without lateral movement or torsion. Complete the entire test process, from start to finish, in no more than 2.5 minutes, without stopping the process to lift the mold. Determine the slump value by measuring the height of the mixture and subtracting it from the height of the cone. Normal concrete achieved the highest slump value of 12 cm, while concrete with silica ash mixture decreased to 11 cm, which compares the slump values of normal concrete with silica ash mixture and steel fiber reinforced concrete with 5% content. Therefore, the findings of this study suggest that the slump value decreases when steel fiber and silica ash are added to the concrete mixture; conversely, the slump value increases when the silica ash content is reduced.

3.10 Test Specimens, Curing and Concrete Compressive Strength

After the concrete mix viscosity test (slump test) has been conducted and the results meet the specified standard criteria, the next step is to prepare the test specimens. Eight cylinders measuring 15cm x 30cm prepared. Two for normal concrete and six for silica fume-containing steel fiber reinforced concrete will be tested at 7, 14, and 28 days.

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Careful attention was required during the test specimen preparation process to ensure the concrete is compacted and voids are eliminated, ensuring optimal results.
After approximately one day, the cylinder mold is removed and placed in a curing tank filled with clean water. This is to maintain the moisture and temperature of the concrete during the hardening process.
Some cube samples will be left in the curing tank until the compressive strength test is completed. The cubes will be dried first, so that it is ensured that there is no water content on the surface of the sides of the cube and it is completely dry so as not to affect the strength of the concrete during the compressive strength testing process.
Concrete Unit Density Calculation, The concrete volumetric density test can be calculated as follows: analyzing the components of the concrete mix, including water, sand, gravel, and cement. Different types of aggregate have different grain sizes and fineness, which in turn affect the concrete's volumetric density. Proper compression is necessary to ensure that the concrete's volumetric density meets the specified requirements.
Measurement of concrete unit density is as follows:

1. Sample Weight	= 12,632 kg
2. Volume	= ¼ x ρ x d2 x t
	= ¼ x ρ x 0,0152 x 0,03
	= 0,0053 m3
3. Volumetric Unit Density	= (Sample Weight) / (Sample Volume)
	= 12,440 / 0,0053 = 2.347 kg/m³

After 28 days of curing, the concrete density is determined. Lightweight concrete is defined as concrete with a density of less than 1900 kg/m³, ordinary concrete as concrete with a density between 2200 and 2500 kg/m³, and heavy concrete as concrete with a density > 2500 kg/m³, in accordance with SNI 03-2847-2002. The results of the study indicate that the concrete is ordinary concrete, considering that the test specimens have a density ranging from 2200 to 2500 kg/m³.
Concrete Compressive Strength, on days 7, 14, and 28, a compression machine with a capacity of 2000 kN was used to measure the concrete's compressive strength. Cylinders measuring 30 cm long and 15 cm in diameter served as test samples for the compressive strength tests. The following equation was used to calculate the concrete's compressive strength, which is based on the compressive strength per unit area:

$$f'c = P/A.$$

where: $f'c$ = *concrete compressive strength (MPa)*
P = *maximum load (N)*

Concrete with and without additives, as well as with and without silica ash and steel fiber additives, was tested for compressive strength (Table 3).

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Table 3 Compressive Strength Test

Concrete Class		FC 25 SF-SFRC				
Cylinder Size		Ø 15 x 30cm				
COMPRESSIVE STRENGTH TEST REPORT						
Sample No.	Age (day)	Slump (mm)	Weight (gram)	Maxload (kn)	MPa	Percentage (%)
1	7	110	12.505	326,30	18,46	73,86
2	7	110	12.495	314,70	17,81	71,23
Average	18,14 MPa			Percentage Average		72,55%
Sample No.	Age (day)	Slump (mm)	Weight (gram)	Maxload (kn)	MPa	Percentage (%)
1	14	110	12.585	407,90	23,08	92,33
2	14	110	12.780	408,30	23,10	92,42
Average	23,09 MPa			Percentage Average		92,37%
Sample No.	Age (day)	Slump (mm)	Weight (gram)	Maxload (kn)	MPa	Percentage (%)
1	28	110	12.580	504,50	28,55	114,20
2	28	110	12.480	495,60	28,05	112,18
Average	28,30 MPa			Percentage Average		113,19%
Concrete Class		FC 25				
Cylinder Size		Ø 15 x 30cm				
COMPRESSIVE STRENGTH TEST REPORT						
Sample No.	Age (day)	Slump (mm)	Weight (gram)	Maxload (kn)	MPa	Percentage (%)
1	28	120	12.790	468,40	26,51	106,20
2	28	120	12.740	495,50	26,00	104,01
Average	26,25 Mpa			Percentage Average		105,20%

4 Conclusion

Based on the findings of tests and studies conducted in the laboratory, comparing normal concrete with concrete mixed with silica fume and steel fiber reinforced concrete, the following conclusions were drawn:

1. The concrete strength test findings revealed a significant effect of the percentage of silica fume added to steel fiber reinforced concrete as an admixture, resulting in higher compressive strength.
2. Based on the concrete compressive strength data, the percentage of concrete compressive strength tests comparing normal concrete with concrete mixed with silica fume and steel fiber reinforced concrete can be seen in the influence of the concrete quality obtained at 28 days:

- Concrete with silica fume and steel fiber reinforced concrete obtained at the same percentages at 7 and 14 days.
- The comparison of normal concrete with concrete mixed with silica fume and steel fiber reinforcement concrete can be calculated as the difference in percentage scores in the form of normal concrete in the range of 26.25 MPa with a percentage of around 105.02% and concrete with a mixture of silica fume and steel fiber reinforcement concrete in the range of 28.30 MPa with a percentage of 113.19%, so the difference in comparison is around 2.05 MPa with a percentage of around 8.17%.

5 Acknowledgement

Thank you to all parties at Universitas Batam who have provided support. Further studies are needed on concrete mixed with silica fume and steel fiber reinforced concrete to obtain more comprehensive results at various percentages. Further studies can be conducted on the effects of concrete mixed with silica fume and steel fiber reinforced concrete on other additives.

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