



Eco-Friendly Concrete with High Initial Compressive Strength Using Recycled Concrete, Silica Fume and Superplasticiser

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ABSTRACT

The increasing demand for concrete in the construction industry continues to progress every year. Various concrete innovations have been developed to meet the needs of projects that require fast turnaround times and high efficiency but have a negative impact on the environment. Concrete waste as a solution to reduce construction waste, silica fume as a substitute for cement, so that it can reduce the use of natural materials and increase the resistance of concrete to cracks and corrosion, and superplasticizer increases the strength and flow ability of concrete. This research focuses on the use of silica fume and concrete waste as a partial substitution for concrete materials, as well as the use of superplasticizers to increase the compressive strength of concrete. Silica fume is used as a cement substitution with variants of 0%, 5%, 10%, and 15%, concrete waste is used as a substitute for coarse aggregate by 25%, and superplasticizer by 1%. In normal concrete and variants 1 to 4, the compressive strength value at the age of 28 consecutive days is 25,370 MPa; 26,125 MPa; 26,597 MPa; 27,634 MPa; and 29,520 MPa. The tensile strength is 2,025 MPa, 2,122 MPa, 2,146 MPa, 2,334 MPa and 2,594 MPa, respectively. Through this study, the right composition was obtained to make concrete with high initial compressive strength, the percentage increase in high initial compressive strength value at the age of 3 days was 47.110%.

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1. INTRODUCTION

Along with the increasing demand for concrete in the construction industry, technology in the construction field is experiencing significant advancements every year. Today, various innovations in concrete technology have been developed to answer existing challenges, such as meeting the demands of projects that require shorter processing times and higher efficiency with high initial compressive strength. However, the development of concrete technology has a negative impact on environmental sustainability, such as an increase in construction waste both from the rest of the demolition of a construction and the results

of testing as well as the potential for environmental damage. In addition to facing challenges in the management of concrete waste that is increasingly accumulating due to the implementation of construction, especially concrete waste from testing. [1]. Factors such as difficulty finding a suitable disposal site, lack of knowledge about concrete waste management, and additional costs for the disposal process are the main causes of this problem. One solution to reduce environmental impact is concrete waste as a potential solution to social and economic problems [2] by recycling concrete waste so that it can be reused in the production of new concrete [3]. The use of concrete waste as a material in concrete production significantly improves mechanical properties, namely compressive strength, elastic modulus and tensile strength [4], with conventional methods limits it to less than 30%[5][6]. With conventional methods, concrete pouring is an alternative option. This method is effective for treating concrete waste, especially by crushing it to produce coarse aggregate that can be used as a substitute for natural crushed stone. According to [7], the use of concrete waste as a substitute for coarse aggregate can increase the compressive strength of concrete and this study shows that the optimum compressive strength value is achieved in the use of concrete waste by 25%.

The use of concrete as the main component in construction work cannot be separated from the need for four main components, namely coarse aggregate, fine aggregate, water, and cement. Cement acts as a binder in concrete mixtures. The increase in concrete production directly increases the demand for cement. The cement production process has a negative impact on the environment and the lives of the people around the factory. Cement factories are a major source of pollution, where every stage of its production, from limestone mining to the manufacturing process, contributes to environmental damage. These impacts include the erosion of limestone mountains, which can damage forest ecosystems, alter water flows, and cause the loss of springs and rivers [8]. For this reason, a solution to replace cement is sought, namely by using silica fume. Silica fume is a material produced from the production process of silicon iron in a high kiln, stores high silica content, and the particles are very small. The use of silica fume in fresh concrete mixtures tends to decrease workability due to the properties of silica fume that absorbs water, so that fresh concrete will be more viscous [9] [10]. The use of silica fume aims to create concrete with high initial compressive strength, suitable for use in various structures, and improve the ability of concrete to resist corrosion [11]. According to [12] the use of silica fume as a substitute for cement can increase the compressive strength of concrete and this study shows that the optimum compressive strength value is achieved at a proportion of 15% of the use of silica fume, while according to [3] the maximum is at 10%.

Based on research [13] shows that 25% of concrete waste has increased compressive strength, but more than that has decreased compressive strength. To overcome this problem, it can be solved by adding an F-type additive material, namely a superplasticizer, to the concrete mixture, the performance of the concrete can be significantly improved [14]. Superplasticizers are effective in increasing the slump value and strength of concrete, making it easier to work without requiring excessive additional water, which can lead to bleeding or segregation [14].

This study utilizes 25% concrete waste partially coarse aggregate with variations of 0%, 5%, 10% and 15% fume silica as a substitute for cement with the addition of a superplasticizer of 1% of the weight of cement.

2. RESEARCH METHOD

This study uses an experimental mix design, laboratory scale. The main purpose of the applied method is to find out the mechanical properties of concrete.

- a. Mix design concrete based on 25 MPa strength.
- b. Variation of the comparison of 0%, 5%, 10%, 15% silica fume and the addition of 1% superplasticizer from the weight of cement with 25% recycleconcrete waste as coarse aggregate.
- c. Laboratory tests are carried out on coarse aggregate materials and fine aggregates, cement and silica fume. Testing of material physical properties consists of aggregate gradation, unit weight, wear resistance and specific gravity including testing on fine aggregates.
- d. Each variation of the material mixing results is measured by measuring slump, compressive strength and tensile strength by comparing with normal concrete.

3. RESULTS AND DISCUSSION

To facilitate the reading of the test results in the study, each concrete sample was given the sample code VN, V1, V2, V3 and V4 for a mixture of 0%, 5%, 10%, 15% silica fume with concrete waste, 25% and 1% superplasticizer.

1. Laboratory Testing Result

a. Analysis Gradatin of Gravel and Recycle Concrete Test Results

The gradation analysis of gravel and recycle oncrete carried out with the results as shown in Figure 1.

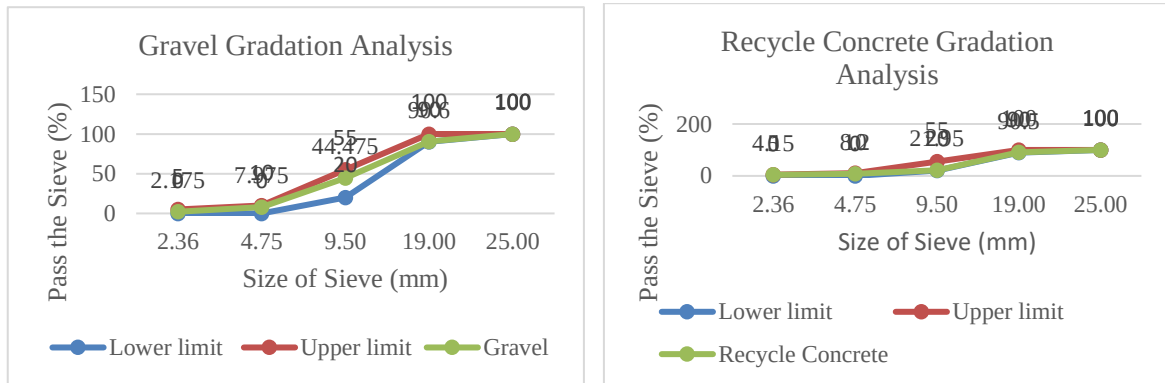


Figure 1. The results of the gravel and recycle concrete analysis test

Based on the results of the coarse aggregate gradation test, it shows that it has a shape that varies in size with a maximum size of 25 mm and is above the lower limit. The result of the fineness modulus of gravel of 6.479 is smaller than the fineness modulus of recycled concrete of 6.683.

b. Gravel and Recycle Concrete Unit Weight Test

The purpose of this test is to obtain the unit weight, which is the comparison of the weight with the volume of the gravel. The results of the unit weight test are found in Table 1.

Table 1. Unit Weight Result of Coarse Aggregate

No	Description	Result Gravel Test	Recycle Concrete Test
1	Container Weight (B1)	5.88 kg	5.86 kg
2	Weight of the test specimens + container	20.96 kg	19.16 kg
3	Weight of the test specimens (B3 = B2 – B1)	14.20 kg	13.30 kg
4	Volume Container (V)	0.01 m ³	0.01 m ³
5	Weight of aaggregate unit (γ) $\gamma = B3/V$	1,322,51 kg/m ³	1,238.69 kg/m ³

From the test results, the weight of the gravel aggregate unit is larger than recycle concrete

c. Gravel Wear Resistance Testing With Los Angeles Machine

The following is a table of gravel wear test results using Los Angeles machines:

Table 2. Wear Resistance Testing on Coarse Aggregates

No	Description	Result Gravel Test	Result Recycle Concrete Test
1	Initial coarse aggregate weight (A)	5.000 gr	5.000 gr
2	Weight after sieving 1,7 mm (B)	3.358 gr	3.543 gr
3	Weight of test object after test (A– B)	1,649 gr	1.457 gr
4	Wear value : $\frac{(A - B)}{A} \times 100\%$	32.84 %	29.14 %

The results of the percentage of gravel wear resistance are higher than recycle concrete.

d. Sand Gradation Analysis Test Result

Sand gradation analysis was carried out with the results as shown in Figure 2.

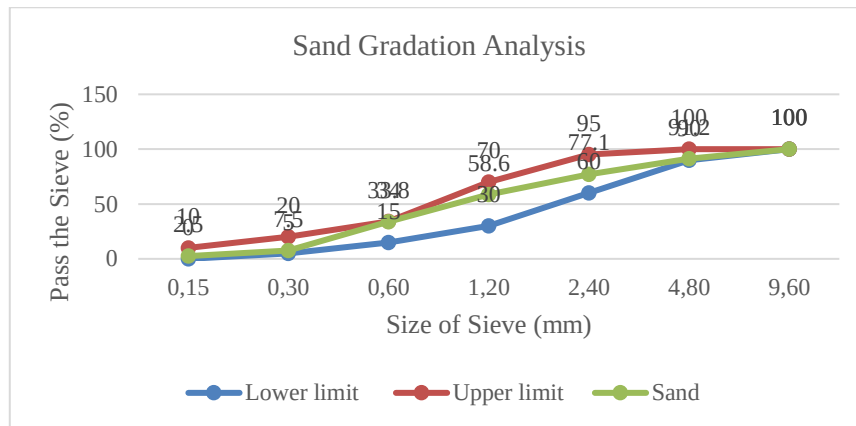


Figure 2. Sand Gradation Analysis Test Results

The test result of the fineness modulus of 3.293 meets the requirements of the fineness modulus of sand 2.3 – 3.1

e. Unit Weight Test on Fine Aggregates

Table 3. Unit Weight Testi on Fine Aggregates

No	Description	Sand Test Result
1	Container Weight (B1)	5.86 kg
2	Container Weight + weight of sand	19.88 kg
3	Weight of sand (B3 = B2 – B1)	14.02 kg
4	Volume container (V)	0.01 m ³
5	Weight of sand units (γ) $\gamma = B3/V$	1,305.74 kg/m ³

f. Specific Gravity Test Results of Cement and Silica Fume

Table 4. Specific Gravity Test Results of Cement and Silica Fume

No	Description	Sand Test Result	Silica Fume Test Result
1	Specimens weight (W)	60 gr	50 gr
2	Kerosene volume (V1)	1.0 ml	1.0 ml
3	Kerosene volume + specimens (V2)	20.30 ml	23.85 ml
4	Specific Gravity specimens = $A/(V2-V1)$	3.023 gr/ml	2.188 gr/ml

The specific gravity of cement is greater than the specific gravity of Silica Fume

2. Slump Test Result

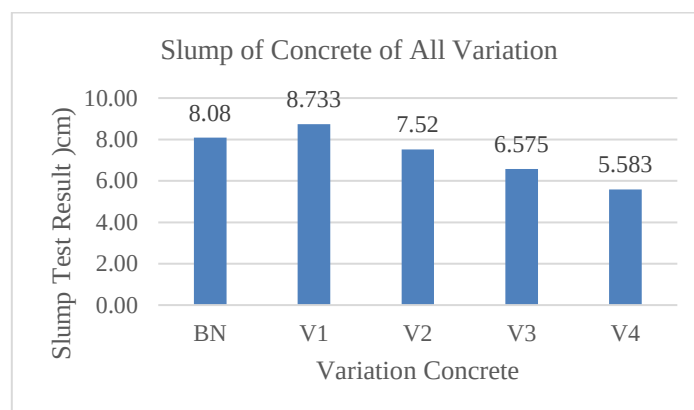


Figure 3 Slump Test Result For All Variation

Based on the results of normal concrete slump testing according to the mix design plan. The addition of superplasticizer increases workability so that the slump value increases as seen in variant 1. However, by substituting silica fume as cement, the slump value will be drastically reduced due to the thickening of concrete.

3. Compressive Strength Concrete Test Results of All Variation

Table 5. Compressive Strength Test Results of All Variations

Variation	Age 3 Days	Age 14 Days	Age 28 Days
Bn	9.809 MPa	19,712 MPa	25,370 MPa
V1	11.129 MPa	20,466 MPa	26,125 MPa
V2	12.638 MPa	21,221 MPa	26,597 MPa
V3	13.015 MPa	21,881 MPa	27,634 MPa
V4	14.430 MPa	21,918 MPa	29,520 MPa

Based on the test value for 28 days of age, all variations increased the compressive strength because of the addition of a superplasticizer which has the property of reducing air and water content, as well as recycle concrete which has lower wear than gravel coarse aggregate and silica fume properties that fill the air cavity so that the density of concrete increases.

a. Compressive Strength Concrete Age 28 Days Test Results

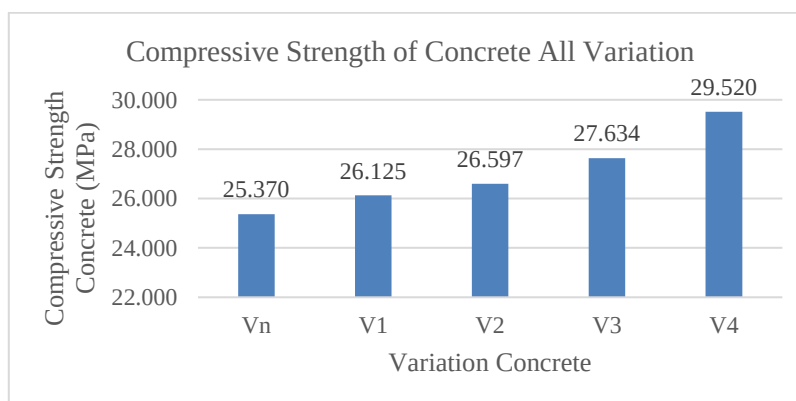


Figure 4. Concrete Compressive Strength Age 28 Day Test Result for All Variation

b. Percentage Increase in Compressive Strength of Concrete

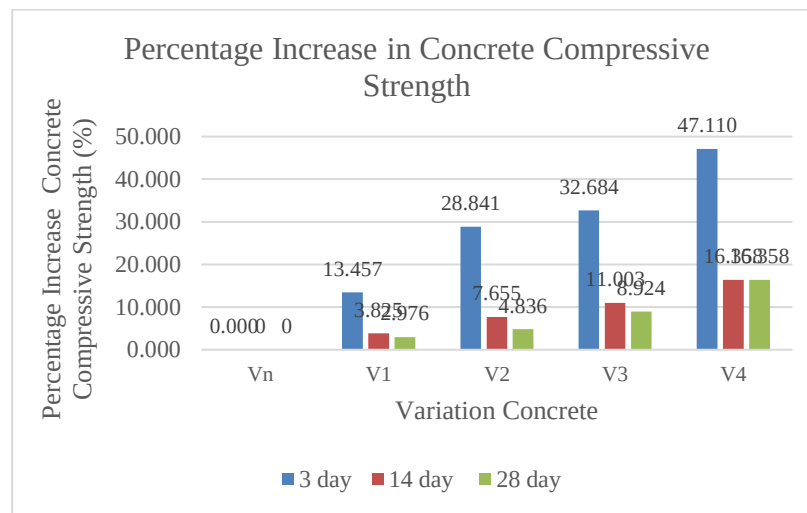


Figure 5. Concrete Compressive Strength Test Result for All Variation

It can be seen that at the age of 3 days all variations are quite significant due to the superplasticizer which reduces air and water content, as well as concrete waste with lower wear value. In variants 2, 3, and 4, the increase in compressive strength is greater because silica fume fills the air cavity, accelerates the Pozzolan reaction which increases the strength of concrete in the early stages.

4. Concrete Tensile Strength Test Results

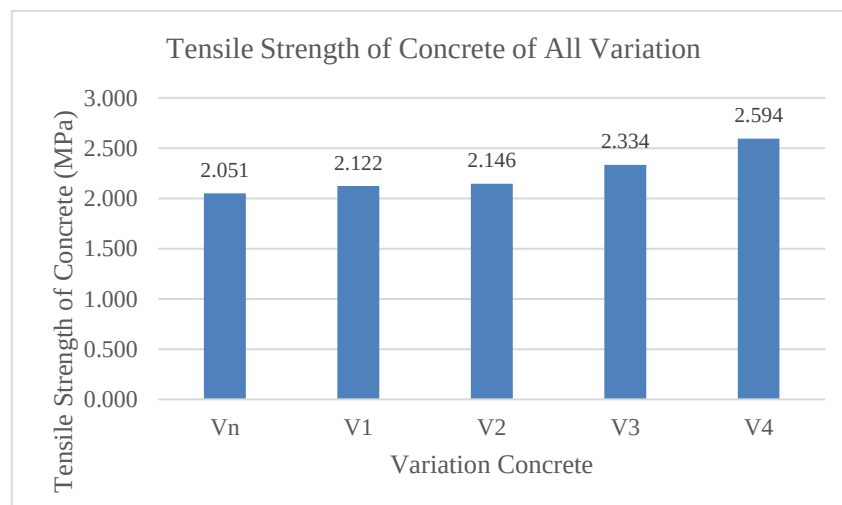


Figure 6 Tensile Strength Test Result for All Variation

From the test results, the tensile strength of concrete is increasing due to the addition of a superplasticizer that closes the pores with a more even distribution of cement particles. And the substitution of silica fume as cement will fill the air cavity and increase the density of the concrete so as to increase the tensile strength.

4. CONCLUSION

The addition of superplasticizer increases workability so that the slump value increases as seen in variant 1. However, with the increase in the substitution of silica fume as cement, the slump value will decrease drastically due to the thickening of concret. Compressive strength and tensile strength increase with the addition of a superplasticizer which has the property of reducing air and water content, as well as concrete waste which has lower wear than coarse aggregate of gravel and silica fume properties that fill the

air cavity so that the density of concrete increases. And the initial strong rise of concrete is faster due to silica fume which accelerates the hardening reaction.

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