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The Compressive Strength of Normal Concrete and the Effect of Fine Aggregate Gradient

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ABSTRACT
Sand with suitable gradation and specifications for concrete mixtures is unavailable in certain isolated regions. It is imperative to investigate the utilization of fine aggregates in the form of a combination of sands with varying gradations to produce fine aggregates that satisfy the predetermined criteria for infrastructure development, as certain regions produce sand with varying gradations. Consequently, researchers employ fine aggregate variations, including coarse sand and fine sand, in the production of standard concrete formulations without the addition of air. The optimal variation will be determined through a subsequent comparison. The mix design of normal concrete with a compressive strength of 17.17 MPa was conducted in this investigation using SNI 7656:2012. The average dry volume weight of concrete with coarse sand was 2437.206 kg/m³, the average compressive strength was 26.956 MPa, and the modulus of elasticity was -12862.495 MPa at 28 days of age. The compressive strength was 18.780 MPa, the modulus of elasticity was 506475.865 MPa, and the average dried volume weight of the concrete with fine sand was 2372.563 kg/m³. The compressive strength of the mixed concrete was 21.052 MPa, its modulus of elasticity was 36838.795 MPa, and its dried volume weight was 2380.069 kg/m³. In the case of coarse sand, the average split tensile strength of concrete was 2.618 MPa, while fine sand had an average of 2.099 MPa. Mixed sand had an average of 2.230 MPa.

Keywords: Concrete, Physical Properties and Compaction Methods.

I. INTRODUCTION

Concrete is a critical component of the construction industry for the present day. Compared to other construction materials, concrete is in high demand due to its numerous benefits. A few of the benefits of concrete construction materials are their ability to be readily shaped to meet the requirements of the construction project, their ability to support large burdens, their resistance to high temperatures, and their low maintenance requirements. Furthermore, the advancement of concrete is exceedingly rapid, encompassing its manufacturing process and its implementation technology [1]. A solid mass is formed by the combination of Portland cement or other hydraulic cement, fine aggregate, coarse aggregate, and water, together with or without additives [2].

Normal concrete is a mixture of construction materials consisting of cement, fine aggregate, coarse aggregate and water. The specific gravity of normal concrete is in the range of 2200 kg/m3 to 2500 kg/m3 with a maximum compressive strength of 40 MPa. The composition of these concrete constituents before being used in the mix design needs to be tested for its characteristics and feasibility. One of the things that will be observed is the testing of fine aggregate gradation. The fine aggregate gradation has a regular arrangement of grains from fine to coarse, which is ideal for use as a concrete aggregate because the grains can fill each other so that high density concrete will be obtained, easy to work with and easy to flow. The fine aggregate gradation is designed to meet the specifications in normal concrete mix design.

Along with the increasing need for concrete in construction development, the need for sand material as a fine aggregate in the manufacture of concrete is increasing. Fine aggregate consists of natural or manufactured sand that has a grain size smaller than 4.8 mm. The influence of aggregate strength on concrete is great, because generally the strength of the aggregate is greater than the strength of the cement paste. Fine aggregates must be clean and free from organic impurities such as mud, soil, or other organic materials that can affect the quality of the concrete..

This investigation was initiated due to the fact that there are instances in which sand with suitable gradation and specifications for concrete mixtures is unavailable in a particular region. Sand with varying gradations is produced in certain regions; therefore, it is imperative to conduct research on the utilization of fine aggregates in the form of a combination of sands with varying gradations to generate fine aggregates that satisfy predetermined criteria. In this investigation, air-entrained normal concrete mixtures are produced using fine aggregate variations in the form of coarse sand and fine sand. The effectiveness of these variations on concrete strength will be assessed.

II. METHODOLOGY

This research will be conducted at the Materials and Construction Laboratory, Department of Civil Engineering, Faculty of Engineering, Tanjungpura University. This research employs the experimental method to conduct a series of tests on a variety of test objects in accordance with SNI testing standards. The resulting data will be analyzed to determine the impact of water variation on the strength of concrete.

2.1 Materials

Materials utilized in the production of concrete include:

1. The cement utilized was PCC cement.
2. The sand that will be employed is a combination of coarse and fine sand.
3. Use stone with a maximum particle size of 20 mm.
4. Water derived from PDAM with a pH range of 6-7.
5. Normal concrete is anticipated to have a compressive strength of 17.17 MPa sans air addition.

2.2 Equipment

The following equipment is utilized in this test: a compressive testing machine, bearing block, compressometer, cylinder mold, Shieve-Sekker machine, material furnace, balances, mixer, Los Angeles machine, Vicat tool, and other complementary tools.

2.3 Research Procedure

The following are the various phases of implementing this research:

1. Inspection and preparation of materials
   a. This research is supported by a collection of theoretical foundations and previous research journals.
   b. Prepared materials and material testing, including fine aggregate (sand), coarse aggregate (stone), water testing, and cement testing.

2. The combination of planning

Concrete mix SNI 7656: 2012 calculation for a standard concrete mix design with a compressive strength of 17.17 MPa. The calculation of the necessity for the creation of test objects that include a minimum of three variations of samples, including three variations of coarse sand, fine sand, and a combination of sand.

3. Casting of test specimens

For each sample variation, the test specimens were constructed as cylinders with a diameter of 15 cm and a height of 30 cm. A concrete mixer machine is utilized to assist in the casting of test objects.

4. Test specimen treatment

The test objects are treated by immersing them in a container of water that is maintained at ambient temperature. The treatment is administered from the day following the casting to the day prior to the testing.

5. Testing of volume weight

The accuracy of 0.05 kg was used to test the volume weight of concrete slinders at the age of 3, 7, 14, 21, and 28 days using electric scales.

6. Compressive strength measurement

Using the MTB brand compressive testing equipment with a capacity of 2000 kN and an accuracy of 5 kN, this study evaluates the compressive strength of concrete at the ages of 3, 7, 14, 21, and 28 days in accordance with SNI 03-1974-2011.

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2.4 Analysis Method

1. The formula for volume weight is as follows:

$$W_c = \frac{m}{V} \quad (1)$$

Where :
Wc = volume weight (kg/m^3)
m =concrete weight(kg)
V = concrete volume (m^3)

2. The formula for calculating compressive strength is as follows:

$$f_c = \frac{P}{A} \quad (2)$$

Where :
f_c = compressive strength value (MPa)
P = maximum test loads(N)
A = area of contact (mm^2)

3. Employ the following formula to determine the modulus of grain refinement (MHB):

$$MHB = \frac{\text{Total Percentage Cumulative Retained Weight}}{100}$$

4. The formula for calculating split tensile strength is as follows:
:

$$f'_{ct} = \frac{2P}{\pi tD} \quad (4)$$

Where :
f'_{ct}= split tensile strength of concrete (N/mm2) P = The maximum compressive strain can be achieved when a concrete cylinder divides or collapses(N)
π = phi (3,14)
t = height/length of concrete cylinder (mm)
d = diameter of concrete cylinder (mm)

III. RESULTS AND DISCUSSION

3.1 Material Testing Results

Materials testing methodologies are based on ASTM and SNI.

3.1.1 Sand Testing

In addition to acidic humus, the decay of leaves generates organic materials. If organic materials are present in the aggregate of the concrete mix, the strength of the concrete will be diminished, as concrete hydration will be diminished. In light of this, it is imperative to assess the organic content of fine aggregate (sand). This inspection is intended to ascertain the organic content that will be incorporated into the concrete mix. The organic content must not surpass the standard color of organic plate number 4, which is a white solid with the chemical formula NaOH, also known as caustic soda or alkali. This base metal is highly corrosive and sturdy. In addition to NaOH, chlorine gas is generated during the manufacturing process. Industrially, sodium hydroxide is synthesized as a 50% solution by volume through a modification of the electrolytic chloralkali process (SNI 2816-2014).

3.1.1.1 Analysis of Fine Aggregates

This investigation employs a blend of fine sand and coarse sand, which is classified as zone III sand, or rather fine sand, as a component of the concrete mix component. In order to ensure that the material satisfies the specifications, it is imperative to conduct these tests:

a. Organic Content Testing (SNI 7656:2012)

Based on the findings of this experiment, the organic content of fine aggregate is situated at the third position on the organic plate. Due to the fact that the organic content is within the established parameters, this test specimen is suitable for concrete production.

Figure 1. Organic Content Experiment Results

b. Mud Content Testing (SNI 03-4142-1996)
From the results of the mud content experiment on the fine aggregate, the percent of material passing the sieve amounted to 0.82%.

c. Water Content Testing (SNI 1971:2011)
From the results of the experiment, the percentage of water contained in the fine aggregate is 3.412%.

d. Fine Aggregate Gradation Analysis Testing (SNI 03-1968-1990)

The examination of sand gradation is carried out to determine the gradation of sand used in accordance with the required gradation or not. The results of the examination will show that the gradation of sand meets the gradation standards used in Indonesia for the time being. The fine aggregate gradation analysis test using coarse sand

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and fine sand obtained a fine modulus value of 2.301.

By using a gradation chart that refers to SNI 03-2384-2000, it is obtained that the sand used is classified into zone III, namely rather fine sand. The results of the gradation analysis test are as follows:

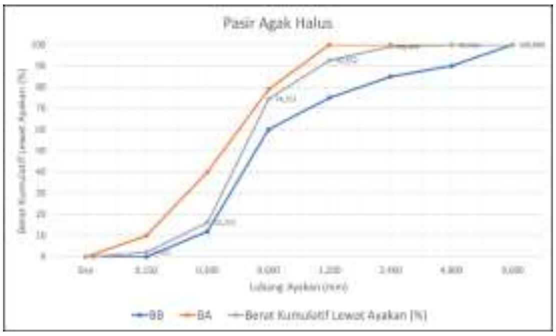

Figure 2. Fine Aggregate Gradation (Somewhat Fine))

e. Specific gravity and absorption test (SNI 1970:2008)

After (24±4) hours in water, this test is employed to ascertain the dry specific gravity, evident specific gravity, surface dry saturated specific gravity, and water absorption. Based on the test results, the dry specific gravity of fine aggregate was 2,617 grams, the evident specific gravity was 2,658 grams, and the surface dry specific gravity was 2,632 grams. In addition, the fine aggregate exhibited a water absorption value of 0,593%.

f. Volume Volume Weight Testing (SNI 03-4804-1998)

Solid and loose conditions were employed to conduct the volume weight test of fine aggregates in this investigation. Based on the experiment's findings, the content weight of fine aggregate in the loose condition was (1545 kg/m3), while the content weight of fine aggregate in the dense condition was (1708.333 kg/m3). The average content weight of the loose and dense conditions was (1626.666 kg/m3).

3.1.2 Testing of Coarse Aggregates

The concrete mix material utilized in this investigation was stone with a maximal aggregate dimension of 20 mm. The material must satisfy the specifications; therefore, it is imperative to conduct the following testing:

a. Water Content Testing (SNI 1971:2011)

The concrete mixture's performance is significantly influenced by the water content of the particulate aggregate. The coarse aggregate's water content was determined to be 0.200% during the testing process.

b. Specific gravity and absorption test (SNI 1969:2008)

This test is employed to ascertain the dried specific gravity, apparent specific gravity, specific gravity in surface dry saturated conditions, and water absorption. The dry specific gravity of the coarse aggregate was 2.648 grams, the evident specific gravity was 2.661 grams, and the surface dry specific gravity was 2.654 grams, according to the test results. Furthermore, the coarse aggregate exhibited a water absorption value of 0.100%.

c. Coarse Aggregate Gradation Analysis (SNI 03-1968-1990)

Testing the gradation analysis of coarse aggregate with a single sample yielded a fine modulus value of 7.037. The coarse aggregate utilized has a maximum dimension of 20 mm, as determined by the gradation chart in Table 4.10, which is based on SNI 03-2384-2000.

d. Volume Weight Test (SNI 03-4804-1998)

The volume weight measurement of coarse aggregate was conducted in both solid and porous conditions in this investigation. The content weight of coarse aggregate in the loose condition was determined to be (1464.5 kg/m3), it was (1569.5 kg/m3) in the solid condition, and the average content weight of the loose and solid conditions was (1508 kg/m3), as indicated by the results of the aforementioned investigations.

e. Aggregate Wear Testing (SNI 2417:2008)

The aggregate wear assessment yielded a wear percentage of 15.078%. The test was performed using gradation B, with the weight of the test specimens retained on the 12.5 mm and 9.5 mm sieves being 2500 ± 10 grams each after 500 machine revolutions. The weight of coarse aggregate that has been tested should not decrease by more than 20%, as per SNI 2417:2008. According to this standard, the coarse aggregate that was tested still satisfies the standard, as its percentage value is less than the standardized maximum of 20%.

3.1.3 Water Testing

a. Acidity Testing of Water

The pH value of the tested water was determined to be 7. This information was obtained from the water acidity check experiment. This

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indicates that the water that was tested is in a neutral state, indicating that it is suitable for use in concrete mixtures.

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Figure 3. Litmus paper test results

b. Testing of Water's Temperature

The water temperature was determined to be 29˚C as a result of my experiments. This indicates that the water is in a well-maintained state and is suitable for inclusion in concrete solutions.

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Figure 4. Thermometer Temperature Readings

c. Testing the Organic Content of Water through Testing

Based on the findings of the water organic content investigation, the TDS value of water is 175.2 ppm, which qualifies it for both drinking and concrete production.

Figure 5. Organic Water Content Experiment Results

d. Water Density Testing

The test object's density was determined to be 1.015 gr/ml as a result of the tests and calculations conducted.

3.1.4 Testing of Cement

a. Test of specific gravity (SNI 15-2531-1991)

From the test results, the average specific gravity of Portland cement was 3.048 gr/ml.

b. Testing of Cement Consistency with the Vicat Tool

The fineness of Portland cement is an important factor that can affect the speed of reaction between cement particles and water. The finer the Portland cement grains, the faster the cement hydration reaction will be, because hydration starts from the grain surface. Cement is a binder that serves to bind fine aggregates and coarse aggregates with water in a mixture, such as concrete or plastering mortar. This test was conducted to determine the fineness of Portland cement. Based on the calculation results, the normal consistency of Portland cement with a peneteration of 40 mm with a moisture content of 26% was obtained.

c. Time Testing of Cement Bonds

The cement bonding time is the duration of time necessary for the cement to solidify, from the moment it reacts with water to the point that it becomes cement paste, until the cement paste is sufficiently rigid to withstand pressure. The binding time measurement is designed to determine the initial and ultimate binding times. The initial binding time of pcc cement (normal consistency) at a 25 mm drop is 5 minutes, as indicated by the experimental results.

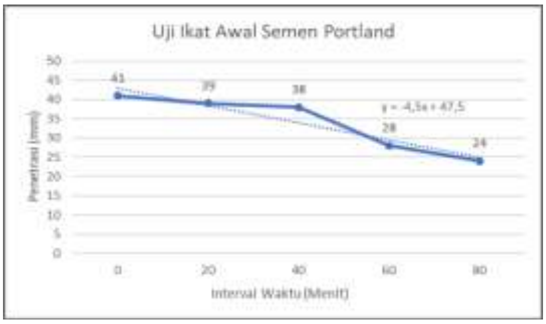

Figure 6. Portland cement bonding test

d. Cement Weight Test

The weight of solid cement was 2.525 kg, and the weight of dispersed cement was 1.995 kg, as determined by the experiments that were

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conducted. This assertion implies that solid cement is heavier than dispersed cement as a result of its large porosity. padacity is the weight of a material per unit volume, or its density. The bulk of solid cement is heavier than that of dispersed cement, which has a significant amount of vacant space between the granules and contains little air. In other words, dense cement is heavier due to its closer granules and the presence of a greater quantity of material in a given volume.

3.1.5 Concrete Mix Results

The concrete mix results are as follows: the ACI 522R-10 Report on Pervious Concrete was used to calculate the concrete mix.

Table 1. Composition of Concrete Mix

No.	Material	Volume	Satuan
1	Weight of Cement	325,696	Kg/m3
2	Weight of Water	203,000	Kg/m3
3	Weight of Coarse Aggregate	777,506	Kg/m3
4	Weight of Fine Aggregates	kg/m^3	Kg/m3
Total		2285,351	kg/m^3

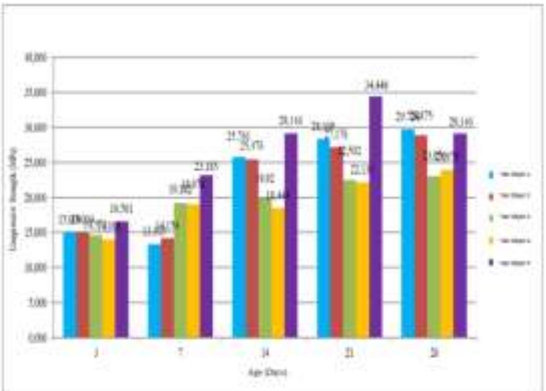

Figure 7. Compressive Strength Test of 5 Samples

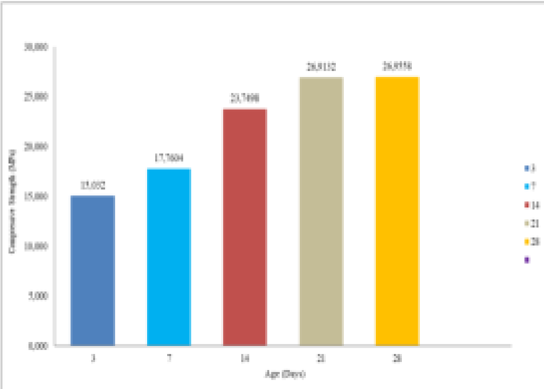

Figure 8. Average compressive strength test

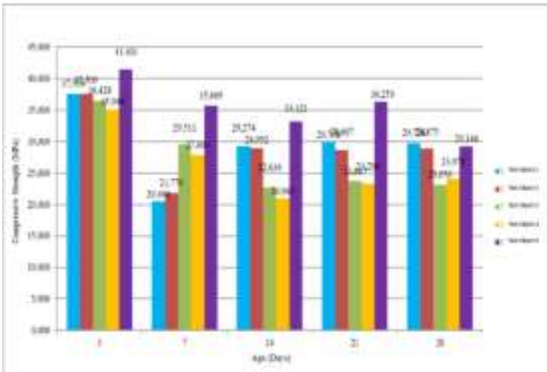

Figure 9. Illustrates the theoretical correlation of each sample from the 28-day compressive strength test

3.2 Testing

3.2.1 Compressive Strength Testing

Testing the compressive strength of concrete was conducted after curing by immersing it in water to preserve a consistent temperature. At 3, 7, 14, 21, and 28 days of age, concrete was subjected to testing. The concrete that has been subjected to testing is at least three days old and has been moistened.

3.2.1.1 Type Of Concrete For Granular Grit

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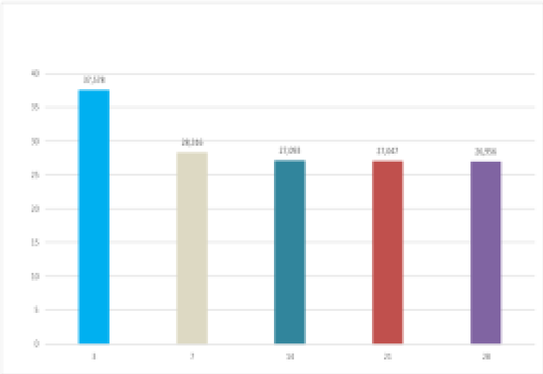

Figure 10. Correlation-Based 28-Day Average Compressive Strength Test

3.2.1.2 Concrete With Fine Sand Type

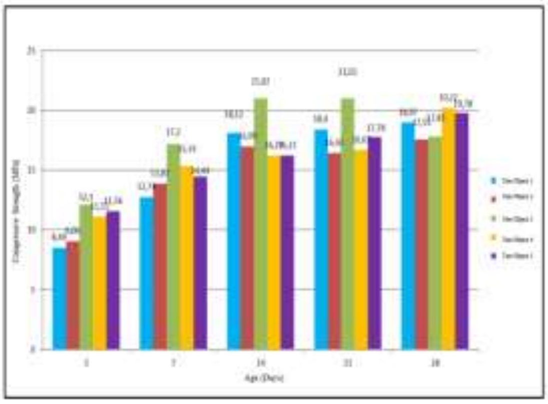

Figure 11. Compressive Strength Test of 5 Samples

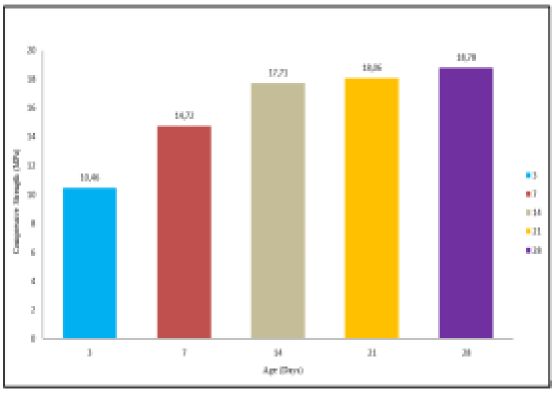

Figure 12. Average compressive strength

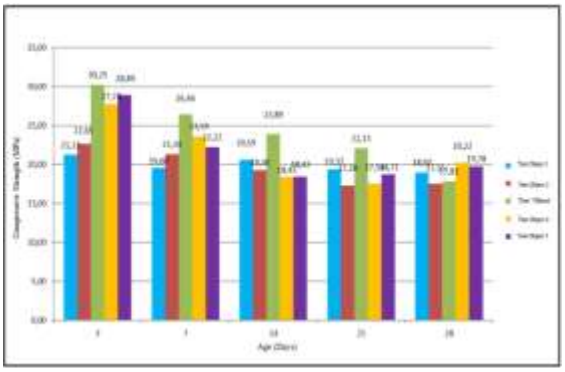

Figure 13.Illustrates the theoretical correlation of each sample with respect to the 28-day compressive strength test.

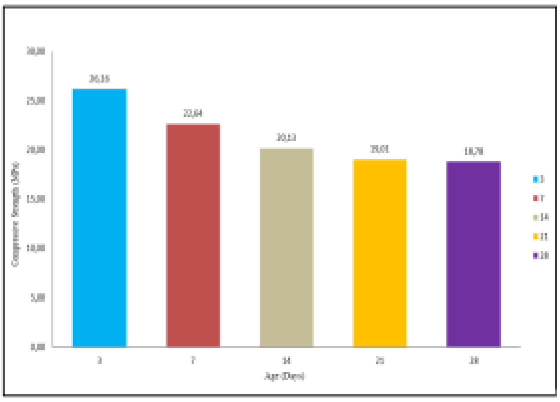

Figure 14.Correlation-Based 28-Day Average Compressive Strength Test

3.2.1.3 Concrete With Coarse And Fine Sand Mix Type

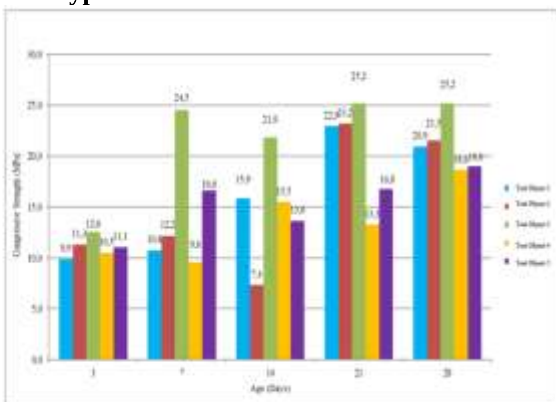

Figure 15. Strength test of 5 samples

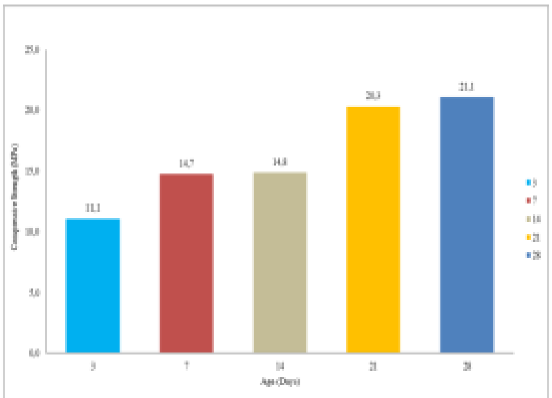

Figure 16. Average compressive strength test

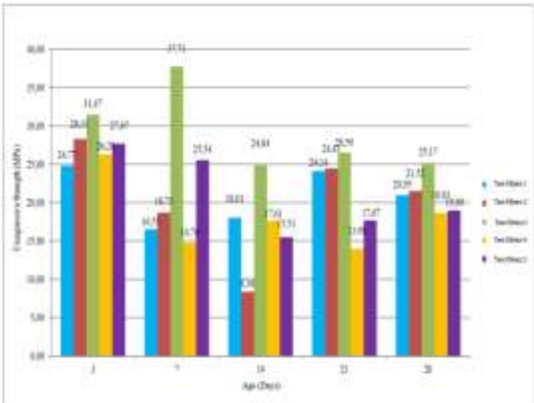

Figure 17. Illustrates the 28-day compressive strength measurement. Theoretical Correlation of Each Sample

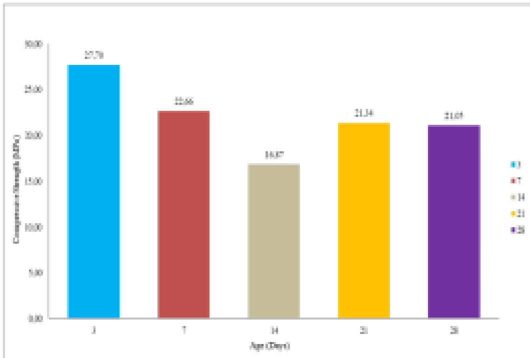

Figure 18.Correlation-Based 28-Day Average Compressive Strength Test

As a large-scale manufacturer, we specialize in the production of a variety of mining machinery, such as sand and gravel equipment, milling equipment, mineral processing equipment, and construction materials equipment.

3.2.2 Modulus of Elasticity Testing

a. Type Of Concrete For Granular Grit

The first sample of the modulus of elasticity analysis for 28-day normal concrete is indicated in the following table:

Table 2. Modulus of elasticity values

Code	Compressive Strength 40% (MPa)	Compressive Strength 20% (MPa)	Modulus Elasticity (N/mm^3)	Modulus Elasticity Based on SNI (N/mm^3)
ME 1	11,776	5,888	-1214,168	25501,560
ME 2	11,324	5,662	-24510,822	25007,356

b. Concrete with fine sand type

Table 3. Modulus of elasticity values

Code	Compressive Strength 40% (MPa)	Compressive Strength 20% (MPa)	Modulus Elasticity (N/mm^3)	Modulus Elasticity Based on SNI (N/mm^3)
ME 1	7,587	3,793	67452,130	20469,020
ME 2	7,021	3,510	945499,600	19689,600

c. Concrete with coarse and fine sand mix type

Table 4. Modulus of elasticity values

Code	Compressive Strength 40% (MPa)	Compressive Strength 20% (MPa)	Modulus Elasticity (N/mm^3)	Modulus Elasticity Based on SNI (N/mm^3)
ME 1	9,172	4,586	21877,800	22506,050
ME 2	9,285	4,643	51799,790	22644,550

The elastic modulus value of the concrete mixture containing fine sand is lower than that of the concrete mixture containing coarse sand and a mixture of coarse sand and fine sand, as can be inferred from the table and graph above.

3.2.3 Split Tensile Strength Testing

a. Concrete with coarse sand type

Table 5. Calculation Data of Tensile Strength

Split Tensile Strength								
NO	Code	Ages	Weight (Kg)	Length (mm)	Diameter (mm)	Loads (kN)	Split Tensile Strength (MPa)	Average split tensile strength (MPa)
			a	L	D	P	f_t= 2P/(π*L*D)	
1	TB 1	28	12,90	300	150	180	2,547	2,6183
2	TB 2	28	12,4	300	150	175	2,477	
3	TB 3	28	12,85	300	150	200	2,831	

b. Concrete with fine sand type

Table 6. Calculation Data of Tensile Strength

Split Tensile Strength								
NO	Code	Ages	Weight (Kg)	Length (mm)	Diameter (mm)	Loads (kN)	Split Tensile Strength (MPa)	Average split tensile strength (MPa)
			a	L	D	P	f_t= 2P/(π*L*D)	
1	TB 1	28	12,60	300	150	140	1,981	2,099
2	TB 2	28	12,30	300	150	145	2,052	
3	TB 3	28	12,40	300	150	160	2,264	

c. Concrete with coarse and fine sand mix type

Tabel 7.Split Tensile Strength Calculation Data

Split Tensile Strength								
NO	Code	Ages	Weight (Kg)	Length (mm)	Diameter (mm)	Loads (kN)	Split Tensile Strength (MPa)	Average split tensile strength (MPa)
			a	L	D	P	f_t= 2P/(π*L*D)	
1	SB-11	28	12,75	300	150	155	2,190	2,230
2	SB-12	28	12,70	300	150	160	2,260	

The use of coarse sand in the concrete mixture results in a relatively higher split tensile strength value than the use of fine sand or a combination of coarse sand and fine sand, as indicated by the table and graph above.

IV. CONCLUSIONS

The results indicated that the dry volume weight and compressive strength of concrete with coarse sand variation were higher than those of concrete with fine sand or a mixture of coarse and fine sand at different testing ages. The average dry volume weight of coarse sand concrete was 2437.206 kg/m³, the average compressive strength was 26.956 MPa, and the modulus of elasticity was -12862.495 MPa at 28 days. The compressive strength was 18.780 MPa, the modulus of elasticity was 506475.865 MPa, and the average dried volume weight of the concrete with fine sand was 2372.563 kg/m³. The compressive strength of the mixed concrete was 21.052 MPa, its modulus of elasticity was 36838.795 MPa, and its dried volume weight was 2380.069 kg/m³. The average split tensile strength of the concrete with coarse sand was 2.618 MPa, fine sand was 2.099 MPa, and mixed sand was 2.230 MPa. In summary, the results of this study have confirmed the initial hypothesis regarding the impact of fine aggregate variation on the characteristics of normal concrete, as concrete with coarse sand variation exhibits the most favorable characteristics in terms of volume weight, compressive strength, split tensile strength, and modulus of elasticity.

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