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Concrete Compressive Strength Test Using Ancol Maras Beach Stone South Bengkulu as Coarse Aggregate in Concrete Mixes

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Abstract

Concrete is a widely used material and is the main element in buildings. One of the main components in the manufacture of concrete is coarse aggregate, coarse aggregate has a very large role in determining the compressive strength of concrete, this is because coarse aggregate is the largest component in the percentage of concrete constituent materials. The purpose of this research is to find out whether ancol beach stone can be a coarse aggregate and meet the standards as a concrete material with fc' 25 Mpa. Based on the research that has been done, it is found that the normal concrete mixture using ancol beach stone by 40% with a curing age of 28 days has an optimal compressive strength value of 35.9846 Mpa. From the research that has been done, it can be concluded that ancol beach stone can be used as alternative for coarse aggregate in concrete.

Keywords: *Concrete, Fc'25 Mpa, Compressive Strength, Stone, Ancol Beach*

Introduction

Concrete is a widely used material and serves as a fundamental component in construction. It is preferred for its ease of formation and relatively low cost compared to other construction materials. Concrete has several advantages, including high compressive strength compared to tensile strength, easy formation, minimal maintenance requirements, readily available components from the surrounding environment, and longer durability than other building materials[1].

One of the primary components in concrete production is coarse aggregate, which plays a significant role in determining the compressive strength of concrete. Coarse aggregate can constitute 70% to 75% of the solid mass volume of concrete [2][3][4]. In this study, the coarse aggregate size used is 20 mm. Crushed stone is commonly used as coarse aggregate compared to coral stones (beach stones) due to the latter's smooth surface, which reduces the bond between the mortar and the aggregate. Despite this limitation, coral stones are relatively affordable and easily sourced from coastal areas[5][6].

South Bengkulu, located in a coastal region, has abundant natural resources, including beach stones. Specifically, the Ancol Maras beach stones are considered a potential coarse aggregate material due to their adequate physical and mechanical characteristics, such as sufficient compressive strength, low water absorption, and compatibility with concrete matrices[7][8][9]. However, environmental studies, including the effects of climate, seawater, and other environmental aspects, must be considered when using Ancol Maras beach stones as coarse aggregates in concrete[10].

This study aims to evaluate the technical and environmental feasibility of using Ancol Maras beach stones as coarse aggregate in concrete mixtures. The findings could provide valuable insights to concrete producers and construction contractors in South Bengkulu and surrounding areas, contributing to the development of sustainable construction materials[11][12]. Given the abundant and relatively inexpensive Ancol beach stones, they should be optimally utilized, especially for producing concrete with a target compressive strength of fc' 25 MPa. However, to ensure the material meets the required standards, laboratory testing is necessary, adhering to the Indonesian National Standard (SNI)[13][14]. This study will focus on the mechanical and physical properties of Ancol Maras beach stones to determine their suitability as coarse aggregate in concrete [15][16].

Methodology

This research was conducted at the Civil Engineering Laboratory of Prof. University. Dr. Hazairin, SH, in February 2024. The research process includes six main stages, namely material preparation, material testing, mixture planning, specimen preparation, specimen care, and specimen testing. Material testing is carried out to ensure the quality of coarse and fine aggregates in accordance with established standards. The concrete mix was designed using the ACI method to achieve the desired compressive strength, with the addition of steel fibers to increase strength. Specimens in the form of cylinders with a diameter of 15 cm and a height of 30 cm were prepared for compressive strength tests at 14 and 28 days. During the treatment process, the specimens are immersed in water to ensure optimal hydration. Tools and materials such as molds, scales and ovens are used to support this research[17].

Literature Review

2.1 Theoretical Foundation

2.1.1 Concrete

Concrete is a mixture consisting of sand, gravel, broken stone, or other aggregates, combined with a paste consisting mainly of cement and water, forming a solid mixture. Sometimes, other materials (admixtures) are added to produce concrete with specific characteristics, such as workability, durability, and setting time [18]

Simply put, concrete is created by mixing cement, water, fine aggregates (sand), and coarse aggregates (crushed stone or gravel). Sometimes, other materials (admixtures) are added to improve the quality of concrete [19]. Concrete has high compressive strength but lower tensile strength. Compressive strength of concrete refers to its ability to withstand compressive forces, which is essential for structural purposes. The higher the structural demand, the higher the compressive strength of the concrete required [20].

The quality of concrete is significantly influenced by its ingredients, the proper proportion of the mixture, the use of supplementary materials in the right amount, and the method of work and curing. The construction process includes mixing, placing, and compacting the concrete. Good fresh concrete is one that can be mixed, placed, and compacted properly without any segregation (separation of aggregates from the mix, known as segregation) or bleeding (separation of water from the mix). Good hardened concrete is durable, water-resistant, fire-resistant, and its shrinkage properties are minimal [21].

Concrete is widely used for various structural applications because it offers several advantages, including:

- Concrete is highly resistant to water and fire.
- It can be easily produced in different sizes.
- It does not require complex maintenance, and maintenance costs are relatively low.
- Concrete has high compressive strength and is resistant to corrosion and environmental factors.

However, concrete also has limitations that need to be addressed during the planning and construction of structures, including:

- Concrete has low tensile strength, making it prone to cracking, which is why steel reinforcement is often used.

- Concrete is difficult to make waterproof perfectly, making it susceptible to water penetration and damage from saline conditions.
- When subjected to significant environmental changes, concrete may expand and crack.

Concrete is brittle (not ductile), requiring careful design and detailing to combine with steel reinforcement to make it more ductile.

2.1.2 Concrete Mix

The mixture of concrete ingredients is done to achieve a solid composition of materials based on a concrete mix design. This is implemented in construction work in the field. The mixing can be done at the laboratory. To maintain consistency in the design, further steps in concrete processing need attention. A good composition results in high compressive strength. However, if not properly controlled during execution, there is a greater likelihood of producing concrete that does not meet the planned design[22].

Once the planned composition is achieved for compressive strength, the next step is field mixing. The composition is adjusted with the capacity of the mixing equipment. Typically, mixing is done until a plastic state is achieved in fresh concrete. Indicators include uniform color, good workability, and homogeneous appearance[23].

During the mixing process, detailed data must be collected regarding the amount of batch produced, material proportions, estimated final placement location, timing, and dates of mixing to prevent segregation and bleeding. Several factors need to be considered in concrete placement to avoid issues like segregation and bleeding:

- The mix to be placed should be as close as possible to the final location to prevent segregation.
- Placement should be done quickly, carefully, and in a manner that maintains the plastic state to ensure that the concrete flows easily into the spaces between reinforcement.
- Hardened concrete or concrete with foreign material contamination should not be placed.
- Concrete that has already started setting or has been re-mixed with water should not be placed unless approved by a qualified supervisor.
- Placed concrete should be compacted with proper equipment thoroughly to ensure that all voids are filled.

2.1.3 Concrete Curing

Curing is done to avoid unwanted heat of hydration caused by cement. The method and materials used for curing will affect the properties of the resulting concrete, especially its strength. Curing should follow a scheduled and precise approach[24]. Concrete will experience proper hardening at 28 days, thus at subsequent days, it will have different compressive strength. Curing can be done in laboratories or in the field. Curing through wet methods can be done using several methods:

- Covering fresh concrete in a damp environment.
- Covering fresh concrete with wet covers.
- Continuous sprinkling of water on fresh concrete.

2.1.4 Compressive Strength of Concrete

For designing structural components using concrete, it is generally assumed that concrete will withstand compressive loads and some tensile loads. Therefore, compressive strength of concrete serves as the main parameter for determining the strength and durability of the material. Other mechanical properties of concrete can be estimated based on its compressive strength[25]. To determine the compressive strength of concrete, tests such as ASTM C39/C39M-20 "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens" are conducted. The procedure includes the following steps:

- The specimen is weighed and its weight is recorded.

- The specimen is placed on the compression machine, and its position is adjusted to ensure it is centered on the machine's plate.
- Loading is applied gradually and continuously using a hydraulic machine until the specimen fails (the load at failure is recorded).
- Compressive strength is calculated using the formula:

$$f'c = P/A$$

Where:

$f'c$ = Compressive strength of concrete (MPa)

P = Applied load (N)

A = Cross-sectional area of the specimen (mm²)

The cross-sectional area (A) can be calculated as:

$$A = \frac{\pi}{4}d^2$$

Where:

π = 22/7 or 3.14

d = Diameter of the specimen.

2.1.5 Ancol Beach Sand

Sand is a product of natural weathering that occurs over a long period, which can harden over time. Sand can be categorized into three types: sedimentary, metamorphic, and igneous. Among these types, some are suitable for construction purposes, such as Ancol beach sand. Ancol beach sand is found along the coast of Jakarta, and it has a combination of colors such as white, black, and varying gradations. The size of the sand varies from small to large.

2.2 Previous Research

Research conducted by NANDA ARI PURRWANTI in 2018. This research focused on the effect of using coral aggregate as a substitute for coarse aggregate in concrete mixtures and its effect on the compressive strength of concrete. This research uses the SNI 7394:2008 method for testing. The research results showed that the aggregate used was coarse aggregate with a coral aggregate value of 16.8% and split coral aggregate of 27.6%. In addition, the absorption rate of fine aggregate was 1.06%, split coral aggregate was 1.34%, and coral aggregate had an absorption rate of 3%. This research shows that coral aggregate waste can be used effectively in concrete production.

Results and Discussion

Research Results

This research was conducted using an experimental method, where several tests were carried out such as gradation, moisture content, specific weight of fine aggregate, and coarse aggregate, followed by Mix Design and calculating the proportions of materials for a concrete with fc' 25 MPa, then continued with the production of concrete cylinders with dimensions Ø150 mm and height 300 mm (ASTM-C315). Several results of the research are as follows:

Aggregate Sieve Analysis

In the concrete production process, it is necessary to inspect the concrete mixture materials to ensure the quality and material requirements are met. The sieve analysis is used to determine the gradation of aggregates. The results of sieve analysis for coarse aggregate and fine aggregate are presented in Table 4.1 and 4.2 below.

Table 4.1 Coarse Aggregate Sieve Analysis

Sieve Opening	Weight Retained (g)	Weight Cumulative Retained (%)	Weight Passing (%)
No 2"	0	0	100
No 1 1/2"	0	0	100
No 1"	1500	100	0
No 3/4"	0	0	100
No 1/2"	0	0	100
No 3/8"	0	0	100
No 4	0	0	100
No 8	0	0	100
No 16	0	0	100
No 30	0	0	100
No 50	0	0	100
No 100	0	0	100
No 200	0	0	100
Pan	0	0	100
Total	1500	100	
FM	12		
Source: Research Results, 2023			

The fineness modulus (FM) of coarse aggregates = Total Cumulative Weight Retained / 100 = 1200 / 100 = 12. From the sieve analysis results shown in Table 4.1 above, it can be seen that the sieve analysis for coarse aggregates resulted in a fineness modulus of 12. Based on the research conducted, the fineness modulus for coarse aggregates does not meet the standard of SK SNI S-04-1989-F where the normal range is between 6.5 - 7.1.

Table 4.2 Fine Aggregate Sieve Analysis

Sieve Opening	Weight Retained (g)	Weight Cumulative Retained (%)	Weight Passing (%)
No 3/8"	0	0	100
No 4	11,500	1.095	98.905
No 8	46,000	4.381	94.524
No 16	56,000	5.333	89.190
No 30	291,500	27.762	61.429
No 50	469,500	44.714	16.714
No 100	157,500	15.000	1.714
No 200	12,000	1.143	0.571
Pan	6,000	0.571	0.000
Total	1050	100	
FM	4.370		
Source: Laboratory Research Results, 2023			

The fineness modulus (FM) of fine aggregates = Total Cumulative Weight Retained / 100 = 436.952 / 100 = 4.370. Based on the sieve analysis results for fine aggregates shown in Table 4.2

above, it can be seen that the sieve analysis for fine aggregates resulted in a fineness modulus of 4.370. The research suggests that the fineness modulus for fine aggregates does not meet the standard of SK SNI S-04-1989-F where the normal range is between 1.5 - 3.8.

Bulk Specific Gravity

Specific gravity is the ratio between the saturated surface dry (SSD) volume weight of the material and the weight of water per m³ (ρ water) at a specified temperature. This test is intended to determine the bulk and absorption (absorption) of aggregates. These values are required to determine the aggregate content percentage in the concrete mixture. The results of bulk specific gravity tests for coarse and fine aggregates can be seen in Tables 4.3 and 4.4 below.

Table 4.3 Coarse Aggregate Bulk Specific Gravity Results

Split Example Name From Batur Ancol Beach	Satuan	Example	Example	Average
Example		I	II	III
Cup	gr	132	125	
Cup + Split	gr	1252,5	1243	
Cup + Split Kerring Overn 24 Hours	gr	1242	1235	
Weight Kerring Sample Split Kerring Overn 24 Hours (W1)	gr	1110	1110	
SSD Split Sampler Weight (W2)	gr	1120,5	1118	
Split Sample Weight In Water (W2)	gr	670	679	
Bulk Specific Gravity $\frac{W1}{W2-W3}$	gr	2,464	2,528	
Bulk Specific Gravity (SSD Basis) $\frac{W2}{W2-W3}$	gr	2,487	2,547	
APPARENT Specific Gravity $\frac{W1}{W1-W3}$	gr	2,523	2,575	
Persentase Absorbsi (Absorption) $\frac{W2-W1}{W1}$ X100%	%	0,946	0,721	0,833

From Table 4.3 above, the results of coarse aggregate testing show dry specific gravity (Dry Specific Gravity) with an average of 2.496 g. Oven-dry specific gravity (SSD Basis) with an average of 2.517 g, and apparent specific gravity with an average of 2.549 g. The absorption percentage is around 0.833%. Specific gravity is used as a factor for determining the quality of coarse aggregate and as a reference for concrete mix design. Based on the conducted research, the coarse aggregate from Ancol Beach meets the SK.SNI.T-15-1990:1 standard, where the results of specific gravity tests in SSD condition are on average around 2.517 g, within the range of 2.5 – 2.7.

Table 4.4 Fine Aggregate Bulk Specific Gravity Results

Sand Sample Name	Satuan	Example	Example	Average
Example		I	II	III

Initial Sample Weight (W)	gr	500	500	
Vinometer Barrett	gr	179,5	179,5	
Berrat Viknomerterr + Sand	gr	679,5	679,5	
Berrat Viknomerterr + Sand + Water (W3)	gr	975	984,5	
Berrat Piknomerterr + Water (W2)	gr	677	669	
Cup Weight	gr	128	132,5	
Weight of Cup + Sand, Kerring Overn for 24 Hours	gr	623,5	627,5	
Sample Weight Kerring Overn 24 Hours (W1)	gr	495,5	495	
Bulk Specific Gravity $\frac{W1}{W2+W-W3}$	gr	2,453	2,683	
Bulk Specific Gravity (SSD Basis) $\frac{W}{W2+W-W3}$	gr	2,475	2,710	
APPARENT Specific Gravity $\frac{W1}{W2+W1-W3}$	gr	2,509	2,758	
Persentase Absorbsi (Absorption) $\frac{W-W1}{W1}$ X100%	%	0,908	1,010	0,959

From Table 4

From Table 4.4 above, the results of fine aggregate testing show dry specific gravity (Dry Specific Gravity) with an average of 2.568 g. Oven-dry specific gravity (SSD Basis) with an average of 2.654 g, and apparent specific gravity with an average of 2.711 g. The absorption percentage is around 0.985%. Specific gravity is used as a factor for determining the quality of fine aggregate and as a reference for concrete mix design. Based on the conducted research, the fine aggregate from Ancol Beach meets the SK.SNI.T-15-1990:1 standard, where the results of specific gravity tests in SSD condition are on average around 2.654 g, within the range of 2.5 – 2.7.

Conclusion

The research findings demonstrate that Ancol Maras beach stones can serve as a viable alternative to conventional coarse aggregates in concrete, achieving a compressive strength of 35.98 MPa at 40% substitution after 28 days of curing. These results not only meet but exceed the target strength of fc' 25 MPa, highlighting the potential of utilizing local materials for sustainable construction practices. This study has practical implications, particularly in promoting cost-efficient and environmentally friendly solutions in regions with abundant coastal resources like South Bengkulu. Future research should explore the long-term durability of concrete incorporating Ancol Maras beach stones under varying environmental conditions and assess its economic feasibility at a larger scale to encourage broader industrial adoption.

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