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Analysis of 25 MPa quality concrete compressive strength with variations in sand zones

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Abstract

The need for aggregate in a concrete mixture is around 60-70% of the total weight of concrete, so the choice of aggregate can affect the quality of the concrete. Generally, when making concrete, coarse-graded sand is preferred over fine-graded sand because fine-graded sand has less strong adhesion between the grains. This condition could potentially lead to environmental degradation due to excessive excavation of coarse-graded sand. This research aims to analyze concrete mixtures in various sand zones to achieve a compressive strength of quality concrete of 25 MPa. The method used is laboratory experimental. The research results show that to achieve a concrete quality of 25 MPa, Water-Cement Ratio (WCR) values of 0.54, 0.53, 0.52, 0.50 are required; the amount of cement was 379.63 kg, 386.79 kg, 394.23 kg, 410 kg; and the percentage of sand to total aggregate is 39%, 39%, 38%, 37% for concrete mixtures using sand zones 1, 2, 3 and 4, respectively. The finer the sand gradation, the greater the amount of cement required, while the WCR value and percentage of sand to total aggregate are lower to achieve a concrete quality of 25 MPa.

Keywords: Concrete; Compressive Strength; Sand Gradation; Water-Cement Ratio

1. Introduction

Sand, as a concrete-forming material, is available in abundance and comes in various types, including from excavations, rivers, seas and mountains. Different quarry locations will produce shapes, surface textures, gradations, densities and other properties that will influence the characteristics of the sand and impact the strength of the concrete produced. There are a lot of sand quarries, so it is necessary to carry out feasibility tests on the quality of the sand. Many studies on this matter have been carried out, including testing the feasibility of the quality of Maubesi river sand with Lumajang sand on the compressive strength of concrete and tensile strength of concrete [1], analysis of the use of Sampur beach sand as fine aggregate on the compressive strength of concrete [2], the effect of gradation sand and cement water factors in mortar on the strength of Prepacked concrete [3], comparative analysis of the compressive strength of concrete using Ulak Paceh Muba sand and Bangka sand [4], the effect of using mountain sand and river sand on the compressive strength of concrete [5], analysis of strength tests press concrete using Banjar Negara sand, Lahat Regency and Tanjung Raja Sand, Ogan Ilir Regency [6], concrete mixture using fine and coarse aggregate from the Ongkak-Dumoga river [7], Compressive Strength of Concrete using Benlelang River Fine Aggregate and Lembur River and Benlelang River Coarse Aggregate [8], Early Age Compressive Strength of Concrete Made With Mountain Sand, River Sand and Portland Composite Cement [9], Experimental Study on Pervious Cement and Pervious Geopolymer Concretes Using Sea Sand and Seawater [10]. These studies report variations in the compressive strength obtained based on the type of sand used.

British Standard (BS) classifies sand for concrete work into 4 zones based on its grain size distribution, namely zones 1, 2, 3 and 4, for coarse sand, rather coarse sand, rather fine sand, and fine sand, respectively. Generally, when making concrete, coarse and slightly coarse-graded sand is preferred. Fine-graded sand is usually fine-grained and round due to the friction process so the adhesion between the grains is less strong [11].

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This condition has the potential for excessive sand excavation in a quarry that has a coarse gradation or characteristics that have a positive influence on the compressive strength of concrete, which can cause environmental degradation. The results of research by Hulukati and Isa [12] reported land damage, disruption of flora and fauna, health and security of the population being disturbed, land becoming prone to landslides and the potential for flooding, pollution of clean water, and damage to roads due to transportation of sand carriers crossing areas around the population due to sand mining in Tumbihe Village. Another study reported the impacts that occurred after sea sand mining in the waters of Bone Malonjo which experienced changes and influenced the current and direction of seawater flow [13]. River degradation due to human behavior in utilizing river resources also affects river water concentration [14]. Based on these problems, not many studies have reviewed the characteristics of sand based on gradation zones for quarries in North Sulawesi, so this research was carried out to analyze the compressive strength of concrete to achieve fc' 25 MPa quality using various sand zones originating from quarries in North Sulawesi.

2. Material and methods

Sand samples were taken from several quarries in North Sulawesi, namely Amurang sand and Biontong sand which are river sand as well as Tendeki sand and Bitung sand which are mountain sand. The characteristics of each sand are presented in Table 1 and the results of the sand sieve analysis are in Figure 1. The coarse aggregate was taken from the Kema quarry, the characteristics of which are shown in Table 2.

Table 1 Results of Sand Characteristics Test

Test Type	Tendeki sand	Amurang sand	Bitung sand	Biontong sand
Specific Gravity				
- Bulk Specific Gravity	2.253	2.408	2.099	2.481
- SSD Specific Gravity	2.357	2.491	2.288	2.521
- Specific Gravity app.	2.514	2.625	2.586	2.585
Absorption (%)	4.614	3.432	8.976	1.620
Volume Weight (kg/dm^3)	1.303	1.388	1.290	1.400
Sludge Levels (%)	1.760	1.387	1.310	1.263
Organic Content	No. 1	No. 1	No. 1	No. 2
Fineness Modulus (FM)	3.209	2.562	2.392	1.652

The results in Table 1 show that the largest to smallest Fineness Modulus (FM) values are Tendeki sand, Amurang sand, Bitung sand and Biontong sand, with values of 3.209, 2.562, 2.392 and 1.652, respectively. These values show that Biontong sand has the finest grains while Tendeki sand has the coarsest grains.

The graph presented in Figure 1 shows the percentage passing the sieve at each sieve hole for each type of sand. Based on the sand zone specifications, Tendeki sand is in Zone 1, Amurang sand is in Zone 2, Bitung sand is in Zone 3 and Biontong sand is in Zone 4.

The test results for the characteristics of sand and crushed stone in Tables 1 and 2, meet the requirements according to normal aggregate specifications for concrete mixtures (SII.0052, ASTM C.33). Based on the results in Table 1 and Figure 1, shows that determining the sand gradation zone is related to its FM. Tendeki sand which is classified as zone 1 (coarse sand) has an FM of 3.209, Amurang sand in zone 2 (rather coarse sand) has an FM of 2.562, Bitung sand in zone 3 (rather fine sand) has an FM value of 2.392 and Biontong sand is zone 4 (sand fine) with an FM of 1.652. The greater the FM of the sand, the coarser the sand and vice versa. The design of a normal concrete mix with a compressive strength fc' of 25 MPa is based on SNI 03-2834-2000, with a design slump of 8-12 cm. The next process is mixing the concrete with a concrete mixer machine, making 6 cylindrical test objects with a diameter of 15 cm and a height of 30 cm for each type of sand, compacting and curing by immersing them in water until the compressive strength test is aged 7 and 28 days. The compressive strength test for cylindrical concrete refers to ASTM C39 with the compressive strength value being the average of 3 test object results. The compressive strength test results are then analyzed again to see whether the compressive strength target is 25 MPa or not. Mixtures that do not reach the target strength are then subject to revision of the mixture based on the analysis results until they reach the target strength.

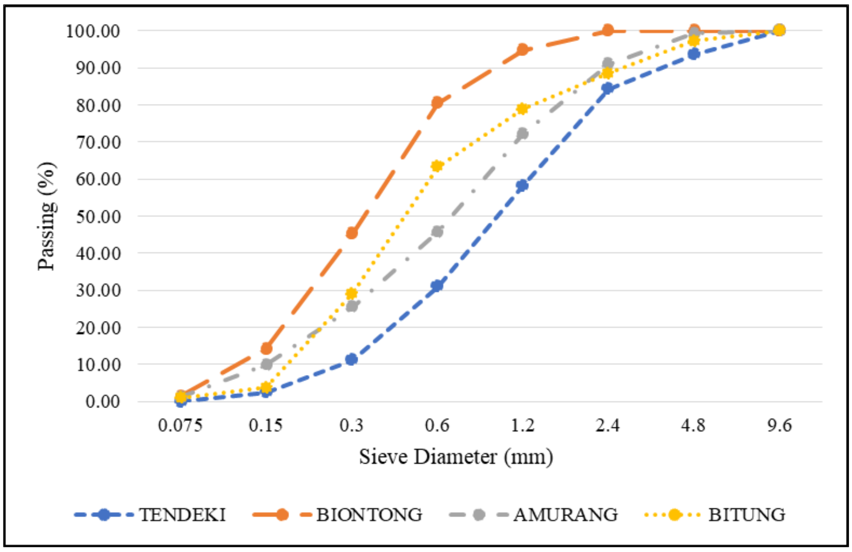

Figure 1 Results of sand sieve analysis

Table 2 Results of Crushed Stone Characteristics Test

Test Type	Crushed Stone 1-2	Crushed Stone 2-3
Specific Gravity		
- Bulk Specific Gravity	2.675	2.676
- SSD Specific Gravity	2.695	2.698
- Specific Gravity app.	2.732	2.736
Absorption (%)	0.781	0.822
Volume Weight (kg/dm^3)	1.420	1.407
Sludge Levels (%)	0.814	0.649
Abrasion	19.360	

3. Results and discussion

3.1. Concrete Mix Design

Table 3 Concrete Mix Composition fc' 25 MPa for 1m^3 Concrete

Material	Unit	Sand Zone			
		Zone 1-Tendeki	Zone 2-Amurang	Zone 3-Bitung	Zone 4-Biontong
Portland Composite Cement (PCC)	kg	379.63	386.79	394.23	410.00
Sand	kg	680.69	689.60	680.49	656.75
Crushed Stone 1-2	kg	383.28	388.30	399.70	402.57
Crushed Stone 2-3	kg	681.39	690.31	710.58	715.68
Water	kg	205.00	205.00	205.00	205.00

The composition of the fc' 25 MPa concrete mix using various types of sand with different gradation zones is shown in Table 3.

3.2. Compressive strength

The results of testing the compressive strength of concrete at the age of 7 and 28 days are presented in Table 4. The test results showed that the planned compressive strength of 25 MPa at 28 days was achieved for all sand zones and was even exceeded. The percentage of compressive strength achieved against design strength of 25 MPa at 28 days is presented in Figure 2.

Table 4 Compressive Strength of Concrete Aged 7 and 28 Days

Sand Zone	Sample	Compressive Strength (MPa)	
		7 days	28 days
Zone 1 - Tendeki	A1	18.03	27.99
	A2	18.66	27.95
	A3	18.52	28.13
	Average	18.41	28.02
Zone 2 - Amurang	B1	17.69	27.11
	B2	17.53	27.54
	B3	18.18	27.93
	Average	17.8	27.53
Zone 3 - Bitung	C1	17.48	26.53
	C2	17.57	27.31
	C3	17.66	27.13
	Average	17.57	26.99
Zone 4 - Biontong	D1	17.25	25.99
	D2	17.51	26.15
	D3	17.05	26.45
	Average	17.27	26.2

The achievement of a design strength of 25 MPa in all variations of the sand zone is greatly influenced by the mixture design made in Table 3. It can be seen that the amount of cement required increases with the finer grains of sand, namely 379.63 kg, 386.79 kg, 394.23 kg and 410 kg, for sand zones 1, 2, 3, and 4, respectively. This increase in the amount of cement is caused by the finer the sand grains, the greater the total surface area of the sand grains (m^2/kg) which must be covered by the cement paste to provide a strong bond, which then fills the voids between coarse aggregate grains thereby increasing the density of the concrete [15]. The research results of Wibowo et al [16] state that the high compressive strength is caused by the bond between the aggregate and the cement that covers all the aggregates. Similar research on the effect of sand gradation zones on the compressive strength of normal concrete [17] reported that the finer the sand zone requires a greater amount of cement to achieve the design's compressive strength. Table 3 also shows that the amount of water is constant in all mixture variations, namely 205 kg so that the WCR value is 0.54, 0.53, 0.52 and 0.50 for concrete mixtures using sand zones 1, 2, 3 and 4, respectively. Based on the compressive strength results in Table 4, it shows that the finer a type of sand, expressed through a smaller FM value, the lower WCR is needed to achieve the same quality, in this case, 25 MPa. The mix design results in Table 3 also show that the percentage of sand to total aggregate varies, namely 39%, 39%, 38%, and 37%, for sand zones 1, 2, 3, and 4, respectively. The percentage of sand to the total aggregate must be considered because if there is too little sand it can produce porous concrete because it means that the percentage of coarse aggregate is too much. This will result in segregation due to excess coarse aggregate, conversely, if there is too much sand, the density of the concrete will decrease and water requirements will increase [15], which will have an impact on reducing the compressive strength of the concrete.

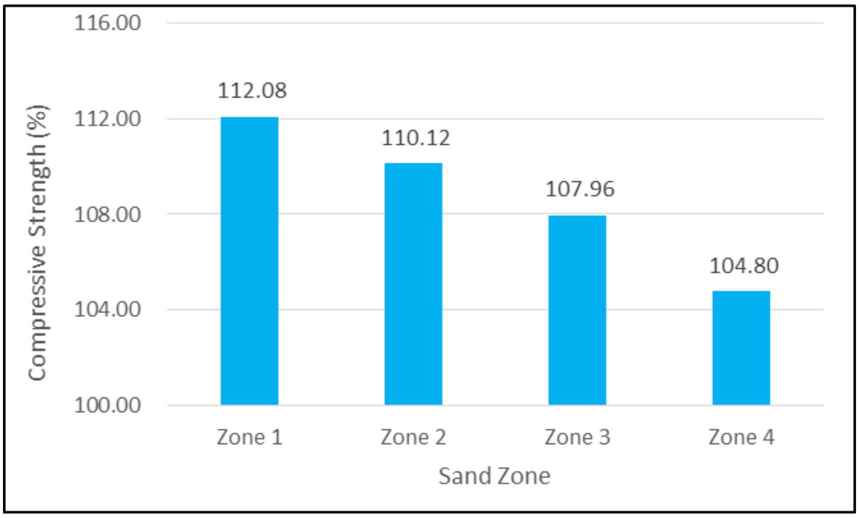

Figure 2 Percentage of Compressive Strength achieved against design strength of 25 MPa

4. Conclusion

Based on the results of the research that has been carried out, to achieve a concrete quality of 25 MPa, you can use various types of sand with different gradation zones. The factor that determines the achievement of the planned concrete quality is the composition of the concrete mixture. The percentage of sand to total aggregate, the amount of cement and the WCR value are important elements that influence the compressive strength of concrete. It is hoped that the results of this research will be useful so that the use of sand is not limited to certain zones so that environmental degradation can be minimized. This research can be developed further for normal concrete with qualities other than 25 MPa, as well as other types of concrete.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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