The Effectiveness of Substitution Fine Aggregate by Pacitan Coral Sand to the Compressive Strength of Concrete.

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Abstract. The south Pacitan district's coastal area in Indonesia has become a tourist place because of the more beach with captivating coral. However, that area's natural resources have not altered the function of construction material. Many research uses the coral reef to admixture concrete material in other countries that affect compressive strength. In this research, the coral reef from Pacitan modified the original dimension of fine aggregate for material substitute o to become the coral sand of fine aggregate with the different material characteristics from other coastal areas. The sample variation was created into four categories, and five samples in every category were concrete without coral sand or 0% coral sand content, 75% with coral sand, 85% with coral sand, and 90% with coral sand. All samples were tested when the concrete age was achieved 28 days after immersing for 14 days, so the concrete was in the maximum setting time condition. The result shows that the percentage effectiveness of coral sand content is 75% as fine aggregate substitution by increasing the compressive is 15.24%, however higher coral sand content causes the decrease until 27.12% to concrete without coral sand, this result can effect by the material characteristic of coral sand when changing the dimension.

***Keywords**: coral sand, fine aggregat, compressive strength, concrete*

1. Introduction

The Indonesian government has been expanding infrastructure construction in various regions for economic improvement in the last decade before and after the covid-19 attack. It causes an increase in aggregate needed for concrete, either natural or factory product resources. One natural concrete material is sand, a fine aggregate with different characteristics from different resources as the primary concrete material.

In coastal areas and islands, fine aggregate is not always available for good quality sand to concrete and obstacle mobilization, which affects cost. Construction development in the coastal area can select the natural concrete material with increasing concrete substance. One of the coastal areas on Java Island is Pacitan District. This district has natural products from coral reefs carried by waves to the mainland. Appropriate for the government purpose, coral-based material obtained the benefit of economy and environment for the construction (Da et al, 2016). The dominant compound in the coral reef is carbonate, and calcium is up to 98% (Liu et al, 2018). The researcher is encouraged to choose the coral reef as a material substitution because the material properties of coral are similar to the cement-based content. Huang et al. comparing coral concrete, natural concrete, and recycled concrete, showed that coral concrete has the highest compressive strength of both concrete types (Huang et al, 2018). Therefore, coral reefs from Pacitan selected a material substitution of sand or fine aggregate with special treatment to produce the original size of coral to become coral sand.

The porosity and water absorption of Coral reefs or coral stones are higher than other stones, which can affect their durability (Manohar et al, 2020). In this research, the purpose of the coral reef modified to coral sand is to reduce the porosity of the concrete, which can decrease the compressive strength. The special treatment of the coral reef from nature aims to reduce the seawater before being applied in construction. The main problem is the effect of seawater content such as chloride, sulfate, and pH value of pore on reinforced concrete durability (Ebead et al, 2022). Varying amounts of coral sand determined about 75%, 85%, and 90% to measure the effectivity of increasing the compressive strength. The previous research achieved 9.2 % compressive strength with a 75%

substitute of coral sand to fine aggregate (Kurniawan et al, 2016), so this research searches for the most effective substitution for coral reef percentage.

2. Material and Methods

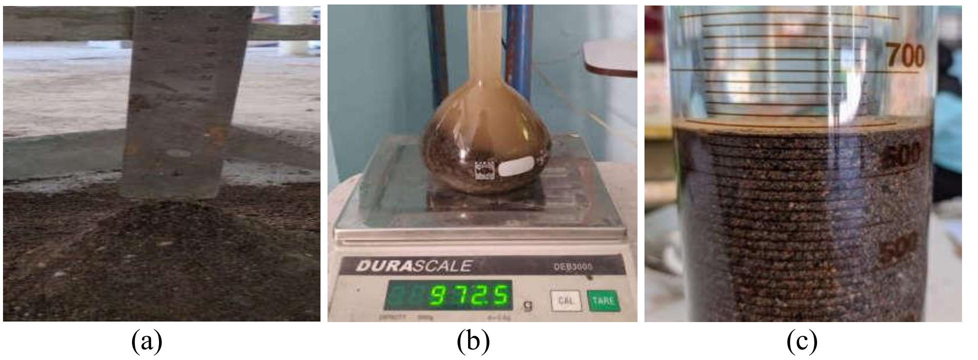
2.1. Material investigations

a. Fine aggregate

Table 1 represents the result of the degradation of Saturated Surface Dry (SSD), specific gravity value, absorption, clay content, and fine particle modulus included in the standard value. The first, Saturated Surface Dry, investigated by Abram cone, shows that the degradation of fine aggregate is half from the cone height of 15 cm. The second, the specific gravity value and absorption tested, use pycnometer, and the result indicates that the value in appropriate standard capture the process test by figure 1. The clay content test was conducted to determine the sludge rate in the sand that affects compressive strength using the sand dissolving method in measuring glass 1000 ml. The last test of fine aggregate investigation is the fine particle modulus test and sand gradation using a sieve machine with the result between standard value and zone 2.

Table 1. Test result of fine aggregate

Sand type test	Standard	Result
Saturated Surface Dry value (SSD)	>1/2 depth cone	15 cm
Specific gravity	2.50 – 2.90	2.66
Absorpsion	< 3 %	2.88 %
Clay content	<5 %	0.5 %
Fine Particle Modulus	1.5 - 3.8	2.88, 2.95, 2.58



(a) (b) (c)

Figure 1. (a) Saturated Surface Dry test. (b) Specific gravity and absorption test. (c) clay content test.

b. Coarse aggregate

Table 2 displays the test result of coarse aggregate, including the standard value of specific gravity, absorption, and maximum particle. The specific gravity and absorption were conducted five times with the value average that qualifies for mix design. That step is displayed in figure 2 when the weight measurement procedure. The sieve machine test obtained coarse aggregate gradation with a maximum particle state of 20 mm.

Table 2. Test result of coarse aggregate.

Sand type test	Standard	Result
Specific gravity	2.50 – 2.70	2.7
Absorpsion	< 3 %	0.75 %
Maximum particle	20 mm	20 mm

Figure 2. Specific gravity and absorption test.

c. Coral sand

The coral reef brought from coastal area Pacitan that still natural in shape and size and has seawater content. The coral sand preparation starts with material immersion for a week, and after that, maximum washing step to cleaning dirt. The next step is material drying in an oven or dried in the sun for a month to reduce the salinity. The coral reef is crushed into small particles similar to sand size or fine aggregate using the crushing tool, and then the last step is sifting to obtain the gradation of fine aggregate shown in figure 3.

Figure 3. Coral sand

2.2. Mix Design

The mix design calculation was carried out to determine the material composition in this research based on fine and coarse aggregate tests and gradation particles. The comparison of water of cementitious ratio and maximum cement needed to measure the cement weight. Table 3 explains the 1 m³ requirement of mix design, then necessary account for the material weight for cylinder in table 4. The composition of concrete material and percentage of coral sand represent in table 5 with the substitution of 75%, 85%, and 90% of coral sand to sand.

Table 3. Component of mix design per 1 m³

Component of mix design	Value	Units
Compressive strength	20	MPa
Standard deviation	7	MPa
Additional value	12	MPa
Strength average	32	MPa
Cement type	Portland 1	
Aggregate type		
Coarse	Stone crushed	
Fine	Natural	
Free water cement ratio	0,5	
Maximum water cement ratio	0,55	
Slump	50 - 75	mm
Maximum size aggregate	20	mm
Moisture content	210	L
Cement content	420	kg
Maximum cement content	325	kg
Minimum cement content	420	kg
Adjustment water cement ratio	-	
Fine aggregate composition	Zone 2	
Combination coarse aggregate composition	-	
Fine aggregate persentage	26%	
Relatif specific gravity aggregate	2,66	
Concrete weight	2560	kg
Combination aggregate content	1930	kg
Fine aggregate content	501,8	kg
Coarse aggregate content	1428,2	kg

Table 4. Component of mix design for a cylinder

Component of mix	Value	Units
Water	1.113	liter
Cement	2.225	kg
Sand	2.569	kg
Stone crush	7.568	kg

Table 5. Material of 5 cylinder samples

Concrete sample with coral sand	Volume (m^3)	Material Concrete				
		Water (liter)	Cement (kg)	Sand (kg)	Stone crushed (kg)	Coral sand (kg)
0% coral sand	0.0265	5.56	11.12	12.84	31.5	0
75% coral sand	0.0265	5.56	11.12	3.2	31.5	9.6
85% coral sand	0.0265	5.56	11.12	1.95	31.5	10.9
90% coral sand	0.0265	5.56	11.12	1.3	31.5	11.55

2.3. Test methods

a. Slump test

Table 5 represents the slump test result of concrete with additional coral sand and the test process shown in figure 4. This test aims to analyze the viscosity and workability of fresh concrete before pouring it into the mold. The equipment test uses a slump cone with a top diameter of 10 cm and a bottom diameter of 30 cm. The coral sand influences the resulting test to this water absorption of coral sand from Pacitan but can be applied to understructure and mass concrete. According to previous research (Armugam et al,1996), coral aggregates are normal-weight aggregates with higher water absorption characteristics than conventional aggregates.

Table 6. Slump test

Additional coral sand	Slump value
0%	7 cm
75%	5 cm
85%	6 cm
90%	6 cm

Figure 4. Slump test process to concrete

b. Compressive strenght test

The first procedure of the test is to prepare the concrete material, such as cement, sand, stone crushed, and coral sand, as a material substitution according to the mix design. Samples make by variation coral sand 75%, 85%, and 90% and samples without material substitution. The 20-cylinder samples were saturated for 14 days to reduce the hydrating process of fresh concrete after shaping in cylinder mold. A compressive test was conducted on all samples in concrete age 28 days. Figure 5 depicts that the number of every variation is five samples tested using the compressive testing machine.

The formula of compressive strength by RSNI 2005 is :

$$f'c = \frac{P}{A} \tag{1.1}$$

where *f'c* is compressive strength (MPa), *P* is maximum load (N), and A is the width of cross section (mm2)

Figure 5. Cylinder samples of concrete.

3. Results and Discussion

3.1. Compressive strength

Table 7 display the result of all variation concrete with 28 days of age concrete and obtained different value of compressive strength. In the previous study, the various mixed design parameters influence the strength response of size, shape, and friction effect (Talaat et al, 2021). The particle size of coral sand significantly affects the characteristic particle stress so that the particle has a wide range to influence the compressive strength (Shen et al, 2020). Another factor in the effect of compressive strength is that water quality contributes to the setting time of cement (Ojo, 2019). The compressive strength average is calculated based on five samples in every concrete sample variation to explain the effect of coral sand content and to analyze the deviation of the compressive strength average.

Table 7. Result of compression test

Concrete sample variation	Concrete age	Compressive strenght (MPa)	Compressive strenght average (MPa)	Compressive strenght average + Deviation (MPa)
0% coral sand	28 days	22.25	23.85	21.23
		23		
		26.2		
		23.09		
		24.74		
75% coral sand	28 days	27.11	28.14	21.44
		27.62		
		25.36		
		25.42		
		35.21		
85% coral sand	28 days	22.1	21.58	18.74
		21.79		
		22.42		
		21.34		
		20.28		
90% coral sand	28 days	18.79	17.38	14.51
		19.36		
		17.32		
		15.11		
		16.32		

Figure 6 shows the chart of the combination of all compressive strength results that the highest value in sample 5 of 75% coral sand is 35.21 Mpa, and the lowest is sample 4 of 90% coral sand by 15.11 MPa. Three samples of 75 % with coral sand represent twenty samples' higher compressive strength value.

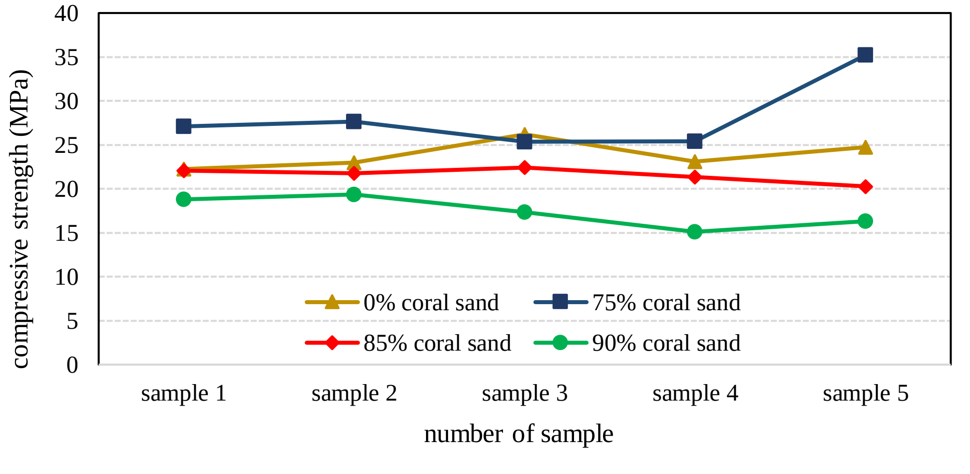


Figure 6. The chart of compressive strength of all concrete sample

Figure 7 represents the chart of the compressive strength average of 4 coral sand variations. The highest compressive strength average is 28.14 Mpa of 75% coral sand content, and the lowest compressive strength average is 17.38 MPa of the most coral sand content. This result showed that the effect of coral sand on compressive strength in this research caused an increase of 15.24 % after replacing 75% fine aggregate, whereas decreasing is 27.12 % after substituting the 90% of fine aggregate with coral sand from the concrete without coral sand. In this case, Shen's et al (2020) research found that the particle's characteristic stress decreased with the grain size increase and the crushing strength.

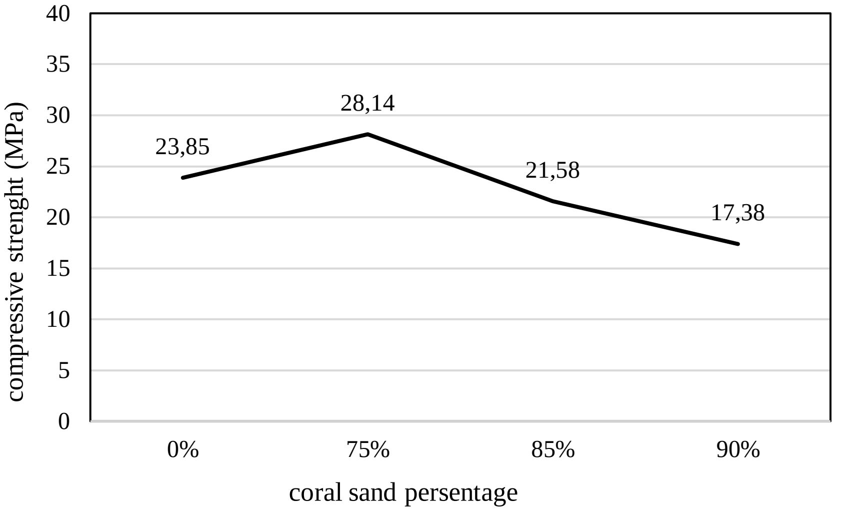


Figure 7. Compressive strength average of concrete sample

4. Conclusion and Recommendation

The compressive strength of coral sand substitution for fine aggregate can increase the concrete without coral sand to 15.24%. However, the higher the coral sand content can reduce the compressive strength more than increasing by 75% coral sand substitution. So, the most effective substitute for coral sand is 75% to fine aggregate.

The sequence of all results compressive strength from the highest is 75% with coral sand, the concrete without coral sand, the 80% with coral sand, and then the lowest is 90% with coral sand because the increasing of coral sand particles affects the characteristic stress.

5. Recommendation

For further research, the coral sand can be substituted with a lower of 75% to know the effectiveness of the percentage for fine aggregate and combined to substitute for coarse aggregate. The coral reef can combine with other materials to encourage the increased compressive strength and ductility of concrete, whereas not only compressive strength but also the flexural strength and durability of reinforced concrete structure with the potential natural resource.

References

[1] Da, B., Yu, H., Ma, H., Tan, Y., Mi, R., & Dou, X. (2016). Experimental investigation of whole stress-strain curves of coral concrete. Construction and Building Materials, 122, 81-89.Liu, J., Ou, Z., Peng, W., Guo, T., Deng, W., & Chen, Y. (2018). Literature review of coral concrete. Arabian Journal for Science and Engineering, 43(4), 1529-1541.

[2] Liu, J., Ou, Z., Peng, W., Guo, T., Deng, W., & Chen, Y. (2018). Literature review of coral concrete. Arabian Journal for Science and Engineering, 43(4), 1529-1541.

[3] Huang, Y., He, X., Sun, H., Sun, Y., & Wang, Q. (2018). Effects of coral, recycled and natural coarse aggregates on the mechanical properties of concrete. Construction and Building Materials, 192, 330-347.

[4] Manohar, S., Bala, K., Santhanam, M., & Menon, A. (2020). Characteristics and deterioration mechanisms in coral stones used in a historical monument in a saline environment. Construction and Building Materials, 241, 118102.

[5] Ebead, U., Lau, D., Lollini, F., Nanni, A., Suraneni, P., & Yu, T. (2022). A review of recent advances in the science and technology of seawater-mixed concrete. Cement and concrete research, 152, 106666.

[6] Kurniawan, A., Afrizal, Y., & Gunawan, A. (2016). Pengaruh Pemanfaatan Pecahan Terumbu Karang Sebagai Pengganti Agregat Halus Terhadap Kuat Tekan Beton. Inersia: Jurnal Teknik Sipil, 8(2), 17-24.

[7] Arumugam, R. A., & Ramamurthy, K. (1996). Study of compressive strength characteristics of coral aggregate concrete. Magazine of Concrete Research, 48(176), 141-148.

[8] Talaat, A., Emad, A., Tarek, A., Masbouba, M., Essam, A., & Kohail, M. (2021). Factors affecting the results of concrete compression testing: A review. Ain Shams Engineering Journal, 12(1), 205-221.

[9] Shen, J., Dongsheng, X. U., Liu, Z., & Wei, H. (2020). Effect of particle characteristics stress on the

mechanical properties of cement mortar with coral sand. Construction and Building Materials, 260, 119836.

[10] Ojo, O. M. (2019). Effect of water quality on compressive strength of concrete. European Scientific Journal, 15(12), 172.

[11] Shen, J., Dongsheng, X. U., Liu, Z., & Wei, H. (2020). Effect of particle characteristics stress on the mechanical properties of cement mortar with coral sand. Construction and Building Materials, 260, 119836