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Evaluation of Concrete Compressive Strength with Coral Stone as a Fine Aggregate Replacement

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ABSTRACT

This study examines the effect of using coral stone as a substitute for fine aggregate on the compressive strength of concrete. Tests were conducted with varying coral stone replacement percentages ranging from 0% to 100%. The results showed that coral stone can enhance the compressive strength of concrete, with an optimal replacement level of 80%, resulting in a 21.16% increase compared to normal concrete. However, replacements above 80% led to a decline in compressive strength, particularly at the 100% replacement level, which showed a 9.37% reduction in strength compared to normal concrete. This decrease was caused by increased porosity, varying aggregate quality, and an imbalance in the water-cement ratio, which disrupted the hydration process and microstructure formation of the concrete. Based on these findings, coral stone can be an effective alternative to replace fine aggregate such as sand, but its use should be limited to 80% to maximize the strength improvement without reducing performance.

Keywords: *Coral Stone; Fine Aggregate; Compressive Strength; Aggregate Replacement*

INTRODUCTION

Indonesia is a tropical country with many coastal areas that host a variety of coral reefs. Coral reefs are underwater ecosystems formed by groups of coral animals that produce calcium carbonate structures, similar to limestone [1]. Coral reefs are marine ecosystems formed by groups of coral organisms that produce calcium carbonate structures, similar to limestone. Concrete, on the other hand, is a composite material made from a mixture of several materials, with its primary components consisting of a blend of cement, fine aggregate, coarse aggregate, and water [2] Concrete has long been one of the most widely used building materials in construction due to its strength, durability, and versatility. The main components of concrete cement, water, coarse aggregate, and fine aggregate play a crucial role in determining the mechanical properties of concrete, particularly compressive strength. Among these components, fine aggregate such as sand serves to improve the density and workability of the concrete mixture. However, with the depletion of natural sand resources commonly used as fine aggregate, the need for affordable and sustainable substitute materials has become increasingly important in today's construction industry. Several studies have been conducted to identify alternative materials for replacing fine aggregates, one of which is coral stone. Coral stone was chosen due to its physical characteristics similar to sand and its easy availability in coastal areas. Given its significant potential, research on the use of coral stone as a substitute for fine aggregate in concrete mixtures continues to grow. Replacing fine aggregate with coral stone is expected to maintain or even improve the compressive strength of concrete while utilizing more affordable, locally sourced materials.

Research by Kurniawan, Afrizal, and Gunawan investigated the effect of replacing fine aggregate with crushed coral reef in concrete with variations of 25%, 50%, 75%, and 100%. They found that the highest increase in compressive strength occurred at 75% replacement, with an increase of 9.219% compared to normal concrete. The optimal compressive strength reached 33.04 MPa, while 100% replacement showed a decrease in compressive strength. These results highlight that partial replacement of coral reef fragments can significantly improve concrete strength, but full replacement may reduce performance[2]. Meanwhile, a study by Wijaya also found that replacing fine aggregate with ginger coral reef at 25%, 50%, and 75% improved the compressive strength of K-225 and K-250 grade concrete. At 75% replacement, K-225 grade concrete achieved the highest compressive strength of 17.32 MPa, while K-250 grade concrete reached 18.07 MPa. This study showed that the use of ginger coral reef can enhance concrete strength, particularly due to the hydrolysis reaction of calcium carbonate (CaCO3), which forms a binding agent, improving the inter-particle bonding of the concrete [3]. Additionally, research by Pararuk, Phengkarsa, and Tonapa tested the replacement of fine aggregate with coral stone in variations of 0%, 35%, 40%, and 45%. Their results showed that 45% coral stone replacement produced the highest compressive strength, reaching 28.030 MPa, higher than the planned strength of 25 MPa. This study reinforces the idea that using coral stone as a partial replacement for fine aggregate can positively contribute to the compressive strength of concrete, although excessive replacement may reduce the concrete’s performance[4]. The influence of the addition of coral stone ash on the durability of the asphalt concrete mixture shows that the Marshall test results for the addition of coral stone ash yield the best value at a 6% addition level. At this percentage, the stability of the mixture reaches 1066.55 kg [5]. The analysis of the characteristics of normal concrete using coral stone from Mount Madura as a substitute for gravel shows that the obtained compressive strength does not meet the planned target of 25 MPa. Therefore, the values of tensile strength and compressive strength do not affect normal concrete [6]. The presentation of the use of coarse coral in normal concrete mixtures shows that coral stone can be utilized as a component in standard concrete. Research and testing of the compressive strength of concrete with the addition of coral stone at percentages of 10%, 20%, and 30% yielded significant results [7]. Based on research on the effect of adding coral as a substitute for fine aggregate in the production of paving blocks, the data analysis results show that the compressive strength test with 25% coral substitution for normal fine aggregate led to an increase in compressive strength values of 22.1 MPa, 20.3 MPa, and 19.9 MPa, with an average of 21.8 MPa [8]. Portland cement is relatively expensive for simple constructions. Using local materials like coral reef ash and rice husk ash offers a solution. This study tested concrete with 2.5%, 5%, 7.5%, and 10% cement replacement, using 70% coral reef ash and 30% rice husk ash. The highest compressive strength was achieved at 7.5% replacement (384.76 kg/cm^2), compared to normal concrete (368.24 kg/cm^2), with a slight decrease at 10% (367.40 kg/cm^2) [9].

Based on previous studies, it is clear that replacing fine aggregates with alternative materialsuch as coral stone has significant potential in improving concrete performance, particularly in terms of compressive strength. However, further research is needed to determine the optimal percentage of coral stone usage that can yield the best results in real-world applications. Therefore, this study aims to evaluate the effect of coral stone replacement as fine aggregate on the compressive strength of concrete at various replacement levels, namely 60%, 70%, 80%, 90%, and 100%. Concrete with a design compressive strength of 20 MPa serves as the reference in this study. This research is expected to provide deeper insights into the use of coral stone as a fine aggregate substitute in concrete mixtures, thereby supporting more sustainable construction practices by utilizing environmentally friendly and affordable local materials.

METHOD

This research employs a laboratory experimental method to examine the effect of coral stone replacement as a fine aggregate substitute on the compressive strength of concrete. The primary materials used include Portland cement type I, clean water, coarse aggregate in the form of crushed stone, and fine aggregate, which is partially replaced by coral stone. The coral stone was sourced from the coastline, crushed, and sieved to resemble sand in size. The replacement variations tested were 60%, 70%, 80%, 90%, and 100% of the total weight of the fine aggregate, with normal concrete as the control. The concrete mix was designed to achieve a target compressive strength of 20 MPa, and cylindrical test specimens were made following standard dimensions. After a 28-day curing process, compressive strength tests were conducted using a compression testing machine in accordance with SNI standards. The test results were analyzed to determine the effect of coral stone replacement and identify the optimal percentage that yielded the highest improvement in compressive strength.

The following is the calculation of the proportion of the material requirements for concrete production using Coral Stone as a substitute for fine aggregate:

Table 1: Calculation of Concrete Mixture with Coral Stone.

Number	Percentage of Coral Stone (%)	Cement. (kg)	Crushed Stone (kg)	Sand (kg)	Water (L)	Coral Stone (kg)
1	0	27,74	65,31	38,35	13,59	0
2	60	27,74	65,31	15,34	13,59	23,01
3	70	27,74	65,31	11,505	13,59	26,845
4	80	27,74	65,31	7,67	13,59	30,68
5	90	27,74	65,31	3,835	13,59	34,515
6	100	27,74	65,31	0	13,59	38,35

Figure 1 shows the process of grinding coral into sand. This process involves crushing coral taken from the sea until it reaches a fine grain, which can then be used as aggregate in concrete production. Coral sand has unique characteristics that can affect the quality and durability of the resulting concrete. Normal concrete using sand is made to obtain information and further results regarding the application of dead coral from Simeulue in normal concrete mixtures, . concrete mix planning is based on SNI 7656:2012 [10].

Figure 1. Grinding Coral Into Sand

RESULTS AND DISCUSSION

The following are the results of the concrete compressive strength tests obtained from the hydraulic pump machine in the laboratory for normal concrete and concrete mixes with coral stone as a substitute for fine aggregate:

Table 2. Average Compressive Strength of Coral Stone Concrete Variations at 28 Days

Concrete Variations	Test specimen (MPa)			Concrete Compressive Strength
	I	II	III	(MPa)
0%	22,777	23,484	23,201	23,154
60%	24,333	26,172	25,465	25,323
70%	26,88	27,587	26,455	26,974
80%	28,153	27,587	28,436	28,058
90%	26,031	25,323	25,606	25,653
100%	22,069	21,362	19,523	20,985

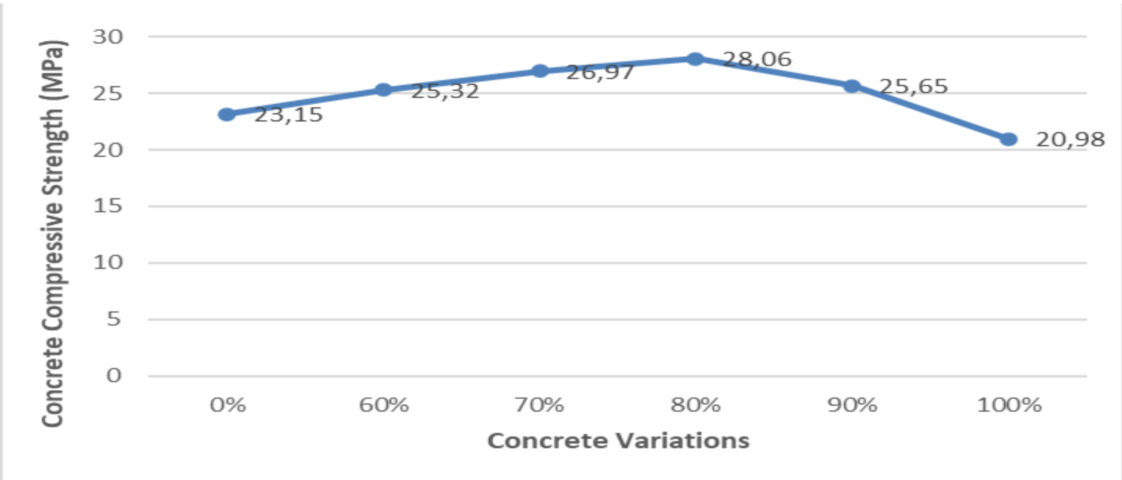

Figure 2. Average Compressive Strength of Coral Stone Concrete Variations at 28 Days

The compressive strength test results reveal that using coral stone as a substitute for fine aggregate in concrete significantly affects its overall strength. The control or normal concrete, without any coral stone replacement (0%), exhibited a compressive strength of 23.15 MPa. This value serves as the baseline for comparison with the different concrete mixtures containing varying percentages of coral stone. When coral stone was introduced at a 60% replacement level, the compressive strength increased to 25.32 MPa. This marked a 9.37% improvement over the normal concrete, demonstrating that coral stone can effectively enhance the strength of concrete up to a certain point. A more substantial improvement was observed with a 70% coral stone replacement, where the compressive strength reached 26.97 MPa, reflecting a 16.5% rise compared to the control. These results suggest that coral stone can potentially replace fine aggregate like sand, improving the compressive strength of the resulting concrete mix.

The highest strength was achieved at an 80% replacement level, where the concrete exhibited a compressive strength of 28.05 MPa, representing a 21.16% increase over normal concrete. This indicates that coral stone at 80% is the most effective proportion for enhancing concrete's compressive strength, making it the optimal replacement percentage for fine aggregate. However, as the replacement percentage increased further to 90%, the compressive strength began to decline, reaching 25.65 MPa, although it was still higher than that of the control concrete. This suggests that while coral stone improves compressive strength at lower replacement levels, excessive use may start to diminish its effectiveness.

The most significant drop in strength occurred at 100% coral stone replacement, where the compressive strength decreased to 20.98 MPa. This value was 9.37% lower than that of the normal concrete, indicating that replacing all the fine aggregate with coral stone negatively impacts concrete performance. These results emphasize the importance of determining the right balance between coral stone and traditional fine aggregates. The optimal replacement percentage is 80%, which offers the best improvement in compressive strength. Replacing more than 80% leads to diminishing returns and even a decrease in performance at 100% replacement. Therefore, coral stone can be a viable alternative to sand in concrete production, but its usage should be carefully controlled to maximize its benefits.

The research findings indicate that the addition of coral stone as a substitute for fine aggregate in concrete can enhance compressive strength up to a certain level, but there is also a decline in strength at higher proportions. In this context, analyzing the causes of decreased compressive strength due to increased proportions of coral stone can be explained as follows:

a. Influence of Proportion on Strength
   The study noted that compressive strength increased at replacement levels of 60%, 70%, and peaked at 80%. This aligns with the fact that at these proportions, the physical characteristics of coral stone positively contribute to the interaction among particles. However, at 90% and 100% replacement, a decline in compressive strength was observed, which correlates with changes in the composition of the mix and the physical properties of coral stone starting to dominate the concrete mix.
b. Influence of Porosity and Density
   The research results showed that at replacement levels above 80%, a decrease in compressive strength occurred. This can be explained by the increased porosity of coral stone, which leads to a reduction in the amount of water available for cement hydration. The excess water absorbed by the coral stone at high proportions may hinder the hydration process, explaining the observed decline in compressive strength at 90% and 100% replacements.
c. Aggregate Quality and Contaminants
   As the proportion of coral stone increases, it is likely that variations in aggregate quality begin to affect the final results. If the coral stone used contains dirt or contaminants,

this can interfere with the interaction between cement and aggregate, which is reflected in the decrease in compressive strength at higher replacements.

d. Unbalanced Water-Cement Ratio
The research findings indicate that after 80% replacement, a decline in compressive strength was observed. This emphasizes the importance of balancing the water-cement ratio. At higher replacement levels, if not properly adjusted, this ratio can lead to concrete becoming less optimal in the hydration process, thus reducing the final strength.

e. Microstructure and Voids Formation
The research indicated that compressive strength decreased at 100% replacement. This suggests that the chemical interactions and the formation of the microstructure in the concrete mix were disrupted. With all fine aggregates replaced by coral stone, the formation of voids and weaknesses in the microstructure can occur, explaining the significant drop in compressive strength observed.

Overall, the relationship between the research findings and the analysis of the causes of decreased compressive strength due to the addition of coral stone indicates that although coral stone can enhance concrete strength at certain proportions, excessive use without proper control can lead to performance declines. Therefore, this research emphasizes the importance of finding the right balance in the use of coral stone to maximize its benefits in concrete mixes.

CONCLUSION

This study shows that using coral stone as a substitute for fine aggregate in concrete has a significant impact on the compressive strength of concrete. At replacement levels of 60% to 80%, coral stone effectively increases the compressive strength of concrete, with the maximum strength achieved at an 80% replacement level, resulting in a 21.16% improvement compared to normal concrete. The 80% proportion proved to be the optimal replacement level for enhancing concrete strength. However, higher replacement levels, such as 90% and 100%, led to a decrease in compressive strength. This can be attributed to the increased porosity of coral stone, variations in aggregate quality, and an imbalance in the water-cement ratio, which ultimately disrupted the cement hydration process and the concrete's microstructure. The most significant reduction in strength occurred at 100% replacement, where compressive strength dropped by 9.37% below that of normal concrete. These results emphasize the importance of controlling the proportion of coral stone used. While coral stone can provide benefits as fine aggregate, it should be limited to an 80% replacement level to maximize strength improvement without sacrificing concrete performance. This research highlights the need for proper balance in the use of coral stone to achieve optimal benefits in concrete production.

REFERENCE

[1] R. F. P. Andini Ayu Sugesti Harahap, Suryanti Suraja Pulungan, “Pengaruh Penggunaan Serbuk Terumbu Karang (Batu Karang) Dalam campuran Beton Sebagai Pengganti Sebahagian Agregat Halus Terhadap Kuat Tekan Beton,” *Statika J. Tek. Sipil*, vol. 7, no. 1, pp. 108–115, 2024.

[2] A. Kurniawan, Y. Afrizal, and A. Gunawan, “Pengaruh Pemanfaatan Pecahan Terumbu Karang Sebagai Pengganti Agregat Halus Terhadap Kuat Tekan Beton,” *J. Inersia Oktober*, vol. 8, no. 2, p. 17, 2016.

[3] C. Wijaya, “Studi Pemanfaatan Pecahan Terumbu Karang Jahe Pasir Putih Sebagai Pengganti Material Agregat Halus Terhadap Kuat Tekan Beton,” 2021, *UNIVERSITAS HASANUDDIN*.

[4] E. Pararuk, F. Phengkarsa, and S. R. Tonapa, “Pengaruh Penggunaan Agregat Batu Karang Sebagai Pengganti Agregat Halus Terhadap Beton,” *Paulus Civ. Eng. J.*, vol. 5, no. 2, pp. 225–231, 2023, doi: 10.52722/pcej.v5i2.630.

[5] S. F. B. Muh. Miftahulkhair, Muhammad Ridwan Muhlis and B. Andi Alifuddin, “Pengaruh Penambahan Abu Batu Karang Terhadap Durabilitas pada Campuran Aspal Beton,” *JILMATEKS*, vol. 4, no. 2, pp. 49–57, 2024.

[6] Z. A. Pertiwi, A. Suryadi, and A. Sugiarto, “Analisis Karakteristik Beton Normal Dengan Batu Karang Gunung Madura Sebagai Substitusi Kerikil,” *J. JOS-MRK*, vol. 2, no. 3, pp. 267–272, 2021, doi: 10.55404/jos-mrk.2021.02.03.267-272.

[7] D. Bakarbessy, “Presentasi Karang Kasar Terhadap Kuat Tekan Beton Normal.,” *Dinamis*, vol. 2, no. 12, pp. 41–48, 2015.

[8] E. Gardjito, A. I. Candra, and Y. Cahyo, “Pengaruh Penambahan Batu Karang Sebagai Substitusi Agregat Halus Dalampembuatan Paving Block,” *UKaRsT*, vol. 2, no. 1, p. 35, 2018, doi: 10.30737/ukarst.v2i1.374.

[9] Y. Afrizal, N. Ramahayati, and M. Islam, “Pengaruh Pemanfaatan Abu Pecahan Terumbu Karang Dan Abu Sekam Padi Sebagai Pengganti Semen Terhadap Kuat Tekan Beton,” *Inersia, J. Tek. Sipil*, vol. 11, no. 2, pp. 12–16, 2019, doi: 10.33369/ijts.11.2.12-16.

[10] W. Wesli, A. Fuadi, and Y. Chandra, “Kuat Tekan Beton Ringan Non-Pasir Pada Pemanfaatan Batu Karang Simeulue Sebagai Alternatif Agregat Kasar,” *Teras J. J. Tek. Sipil*, vol. 13, no. 2, p. 443, 2023, doi: 10.29103/tj.v13i2.979.