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Laboratory Studies on Compressive Strength of Normal Concrete Using Coral Limestone on Timor Island, East Nusa Tenggara Province as a Substitute for Coarse Aggregate

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Abstract. Coral limestones are called the people of East Nusa Tenggara as Batu Karang, scattered almost all over the island of Timor, especially in the western part of the island of Timor but are not used properly. The use of coral limestone in the building construction industry in East Nusa Tenggara is limited as a filling material for foundation and floor work but has not been used as a structural or non-structural concrete constituent material. Based on these conditions, it is necessary to research the use of coral limestone as a substitute for coarse aggregate so that it can be used as an alternative material for structural and non-structural concrete which is applied to simple house construction. The research method was an experiment on 48 samples with a maximum size of 40 mm coral limestone, and a maximum size of coarse aggregate (gravel) of 20 – 30 mm, variations of coral limestone as a substitute for gravel were 0%, 5%, 25%, 50%. Each variation consists of 12 cylindrical samples with a diameter of 15 cm and a height of 30 cm, while the target quality, fc' = 30 MPa, and the planned age of observation are 7, 14, and 28 days. The test results showed an increase in the compressive strength of concrete from the age of 7 to 28 days. For the 0% variation, the increase was 21,31% and the 5%, 25% and 50% variation were 27,18%, 23.63% and 23,44%, respectively. While the increase was more significant in the 25% variation, which increased by 11,66% with the concrete compressive strength value of 33,37 Mpa at the age of 28 days, and in the 50% variation, the concrete compressive strength decreased by 1,25% with the compressive strength value of 29,51 Mpa. This study concludes that coral reefs on the island of Timor, especially the West Kupang area can be used as an alternative material for structural concrete and non-structural concrete to support infrastructure in the province of East Nusa Tenggara.

Keywords. Coral Limestone, Coarse Aggregate, Normal Concrete, Specific Gravity, Compressive Strength

1. INTRODUCTION

The potential of limestone in Indonesia is very large and is spread mostly in several Indonesian islands. In general, the potential for limestone in Indonesia according to geological maps is estimated to be around 28,678 billion tons (1).

Limestone or coral limestone is often referred to by the people of East Nusa Tenggara as "Coral Rock", is a rock that is spread almost throughout the island of Timor (2). Based on data from the Mining Service of Kupang Regency in 2019, one of the main mining materials in Kupang Regency is Coral Limestone, its distribution covers the areas of West Kupang, Central Kupang, Amarasi, Fatuleu, and Nekamese (3), especially in the western region of the island of Timor, the rate of increase in limestone uplift is 0,33 mm/year, this is because the area is located in the subduction zone of the Indo-Australian & Eurasian plate (4). The distribution of coral limestone is more

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dominant in the western region of the island of Timor also evidenced by the map of the Center for Geological Research and Development, as shown in Figure 1 below (5) :

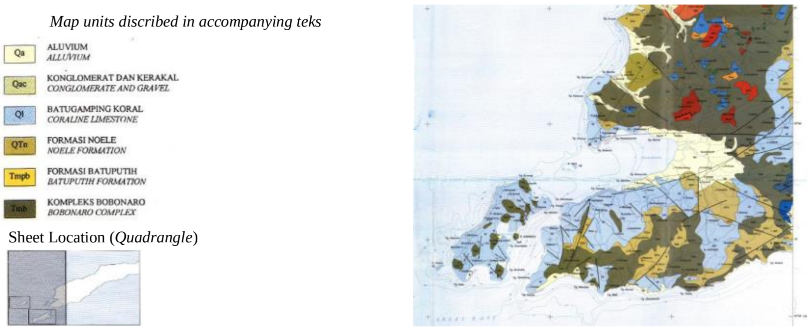

Figure 1. Geological Map Sheet Kupang – Atambua. Rosidi, H.M.D, 1996

The use of limestone or coral limestone in East Nusa Tenggara in the building construction industry is limited to filling materials for house foundation work. Herry's research (2006) shows that geologically limestone consists of Coralline Algae Pack to Grainstone, which can be used for floors or walls of house buildings. (6) Likewise, the use of coral rock as a substitute material for the preparation of concrete is also carried out as a substitute for rock ash as a substitute for cement and coarse aggregate instead of gravel. rock ash, or a mixture of rock instead of gravel (7–10).

The research of Sina, Dantje Arie Trisna, & Hendra (2003), is only limited to the FAS variation in the use of rock as a substitute for coarse aggregate for gravel (11). From the results of this study, further research is needed, namely the use of coral limestone in East Nusa Tenggara as a partial substitute for coarse aggregate (gravel) so that comprehensive data is obtained on the use of coral limestone to make normal concrete.

The contribution of this research strongly supports the utilization of limestone potential in East Nusa Tenggara, in this case, coral limestone can be used as an alternative material for making concrete, namely coarse aggregate as a substitute for gravel which is more economical because this amount of rock is often found on the island of Timor, and later it can also be used as non-structural concrete such as buis concrete culvert, buis concrete U, kansteen concrete, box culvert. Or as a structural concrete composite steel reinforcement such as practical columns, concrete ring beams, sloof, and concrete stairs which are applied to the construction of simple house buildings.

2. REVIEW OF LITERATURES

Concrete is one of the choices as a structural material in building construction. Concrete technology innovation is always required to answer the challenges of demand, the resulting concrete is expected to have high quality including strength and durability without neglecting the economic value. The physical properties of the material greatly affect the quality and specifications of the concrete. Another thing that underlies the selection and use of concrete as a construction material is the factor of effectiveness and efficiency. In general, concrete fillers are made from materials that are easy to obtain, easy to process (workability), and have the durability and strength that are indispensable in construction (12).

The engineering structures field is familiar with concrete using coral limestone (rock) as Coral Aggregate Concrete (CAC). CAC is a material that is becoming increasingly popular in reef concrete structural applications. CAC is made of coral limestone, fine aggregate, cement, and a mixture of minerals and water (which can also be seawater in certain proportions) (13). CAC is

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also similar to lightweight concrete (lightweight aggregate concrete), in terms of intensity, damage mechanism, and damage characteristics (14).

Coral limestone aggregates (coral rocks) are classified as natural lightweight aggregates that can be used as coarse aggregates for the manufacture of concrete and their performance can meet the needs of ordinary construction projects to a certain level, and can also solve the problem of lack of coarse aggregate in construction in an archipelago(14), such as the utilization of the potential of coral reefs in East Nusa Tenggara, especially Timor Island, as a substitute for coarse aggregate for gravel. According to Amheka, A. et al. (2019), in his study that an in-depth study is needed for the development of research in the form of the use of Timor Island coral as a building material, not only limited to its use as bricks, floor coatings, or building walls (2).

Utilization of the potential of coral reefs in various studies in several regions of Indonesia, which is used as a constituent of concrete in the form of fine aggregate, because the chemical compound of coral rock ($CaCO_3$ / limestone) is identical to the chemical compound in cement. One of them is a study with coral rock material from Bengkulu, in the composition of fine aggregate sand substitutes 25%, 50%, 75%, and up to 100%, the results show an increase in compressive strength values up to 33 MPa (8).

Research on coral reefs used as a substitute for coarse aggregate for gravel, using coral from Madura shows the normal compressive strength value of concrete only at 18.83 MPa which is lower than the target (10). For coral from North Bengkulu, the compressive strength value is 24.08 Mpa (15). As for the coral from Jayapura, it shows a normal concrete compressive strength value of up to 27.15 Mpa (9).

The research of Tan, Y. et al., 2018, shows that curing age has a certain influence on the testing strength curve at the age of 28 and 90 days of testing (13). In a similar study in which the coarse aggregate of Crushed coral reef rubble measuring 5-20mm, fine aggregate using Coral sand then added fly ash and silica fume and the days of testing the compressive strength of concrete were 3, 7, 28, 90 days, showing a significant increase in compressive strength up to 50 days Mpa (16). However, in both studies the coral used came from the South China Sea, and the percentage of coral content used in the manufacture of concrete was not reviewed.

Thus, the studies described show that the compressive strength of normal concrete varies according to the rock material used in each region, therefore, it is necessary to develop research on the use of coral limestone from East Nusa Tenggara as a partial substitute for aggregate. So that, normal concrete compressive strength data is obtained and the relationship between the effects of using coral limestone as a substitute for the coarse aggregate, then can be used as further research in developing the potential of coral limestone from East Nusa Tenggara as one of the raw materials. constituent of non-structural concrete or composite structural concrete of steel reinforcement in the construction of simple house buildings.

3. METHODOLOGY

3.1 Research Location and Material

The research location is in East Nusa Tenggara, Timor Island, while the research sample testing location is carried out at the Materials Testing Laboratory, Department of Civil Engineering - Kupang State Polytechnic using fine aggregate (figure 2) and coarse aggregate split 2/3 (figure 3) taken from the same quarry in Takari city. The cement used was PCC cement with the trademark Bosowa, while the coral reef used was a clean rock with a split 2/3 size (figure 4).

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Figure 2. fine aggregate.

Figure 3. coarse aggregate
(maximum size of 20-30 mm).

Figure 4. coral limestone maximum size 40 mm.

3.2 Research Method

The research sample consisted of 48 specimens which were grouped based on 4 variations of the sample using coral limestone as a substitute for coarse aggregate with variations of 0%, 5%, 25%, and 50%. Each sample variation was made of as many as 12 samples of cylindrical specimens with a diameter of 15 cm and a height of 30 cm for compressive strength testing with a concrete quality target of fc' = 30 MPa. The compressive strength test will be carried out at the age of 7, 14, and 28 days of concrete.

The research procedure starts from the material used as a concrete mixture, namely fine aggregate, and coarse aggregate, first testing the characteristics of the material to determine the quality of the material used and whether it has met the required standard specifications. After that, a mix design was carried out to obtain a compressive strength with a concrete quality target of, fc' = 30 MPa. The specimens were made by mixing cement, fine aggregate, coarse aggregate, water, and added coral limestone. The coral limestone used is cleaned of dirt so that it remains in a clean condition, which is then made into a life-size with gravel gradation to be mixed into the concrete. The percentage of addition of coral limestone is based on the ratio to the weight of the coarse aggregate. The compressive strength test for 12 samples of the test specimens was carried out using

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the *Universal Testing Machine* and calculating the compressive strength of the test specimens was based on the formula:

$$fc' = \frac{P}{A} \tag{1}$$

Where :
fc' = compressive strength of concrete (MPa)
P = maximum load (N)
A = cross-sectional area of the test object (mm^2)

4. RESULT AND DISCUSSION

The mix design obtained to make a normal concrete mix for each sample variation is shown in table 1, while the number of samples is in table 2.

Table 1. Composition of the concrete mix.

Concrete constituent materials	Variations of adding coral limestone			
	0%	5%	25%	50%
Cement	30,81	30,81	30,81	30,81
Fine aggregate	65,15	64,97	63,86	62,38
Coarse aggregate	67,24	63,70	48,35	32,19
Water	13,95	13,94	13,94	13,90
Coral limestone	0,00	3,33	16,32	31,88

Table 2. Number of samples tested.

Sample age	Number of Samples			
	Normal concrete	Variations of adding coral limestone		
	0%	5%	25%	50%
7	4	4	4	4
14	4	4	4	4
28	4	4	4	4
Total	12	12	12	12

The shrinkage of the sample size for each variation of the addition of coral reefs shows a value of 0%, meaning that there is no shrinkage. While the shrinkage of the density of each variation of the addition of coral limestone to replace the coarse aggregate (gravel) showed an increase from a variation of 0% to 50%, the largest density shrinkage in the sample with a variation of 50% was decreased by 4,02%. Look at Figure 5.

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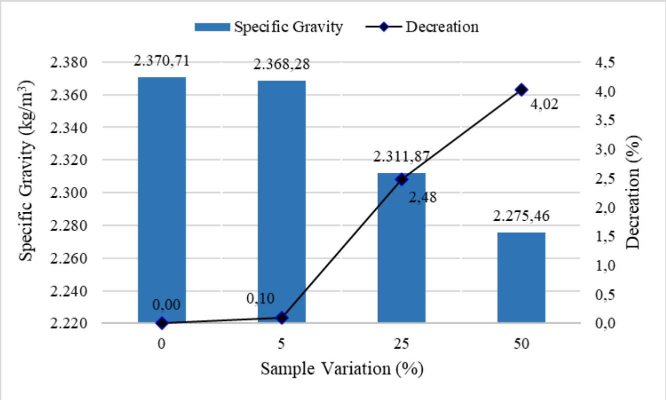

Figure 5. The effect of variations in the addition of coral limestone as a substitute for gravel on specific gravity.

Table 3. The results of the compressive strength test and its increase.

Variation (%)	Compressive Strength (MPa)			Increation per test days (%)	Increation per variation (%)
	7 Days	14 Days	28 Days		
0	23,52	24,88	29,89	21,31	0,00
5	22,83	28,32	31,35	27,18	4,90
25	25,49	27,97	33,37	23,63	11,66
50	22,60	24,96	29,51	23,44	1,25

Based on the results of testing the compressive strength of concrete for each variation of the sample obtained at the age of 7 days the average compressive strength for normal concrete samples is 23,52 Mpa. For samples with variations in the percentage of coral limestone as a substitute for gravel at 5%, 25%, and 50%, respectively, they were 22,83 MPa, 25,49 MPa, and 22,60 MPa.

At the age of 14 days, the average compressive strength for normal concrete samples is 24,88 Mpa. For samples with variations in the percentage of coral limestone as a substitute for gravel at 5%, 25%, and 50%, respectively, they were 28,32 MPa, 27,97 MPa, and 24,96 MPa.

At the age of 28 days, the average compressive strength for normal concrete samples is 29,89 MPa. For samples with variations in the percentage of coral limestone as a substitute for gravel at 5%, 25%, and 50%, respectively, they were 31.35 MPa, 33,37 MPa, and 29,51 MPa.

Figure 6 shows an increase in the compressive strength of concrete from the age of 7 days to the age of 28 days. For normal concrete, the increase in the compressive strength of concrete is 21,31%. For samples with variations in the percentage of coral limestone as a substitute for gravel, 5%, 25%, and 50%, respectively, are 27,18%, 23,63%, and 23,44%.

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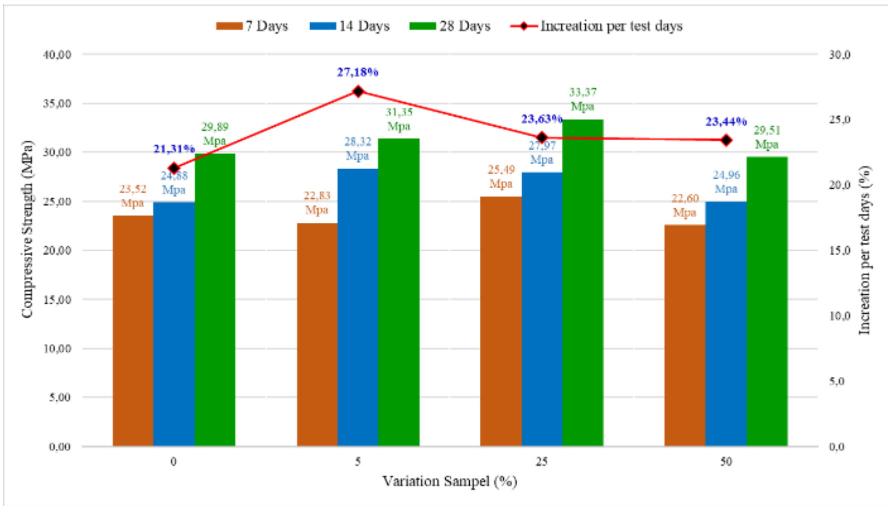

Figure 6. The percentage increase in compressive strength values on days 7, 14, 28 of each sample variation.

The increase in the compressive strength of concrete is more significant in the variation of 25% coral limestone as a substitute for gravel, which is an increase of 11,66% from the 0% variation sample with a concrete compressive strength value of 33,37 MPa at the age of 28 days. While the percentage variation of 50% concrete compressive strength decreased by 1,25% with a compressive strength value of 29,51 Mpa. Look at figure 7.

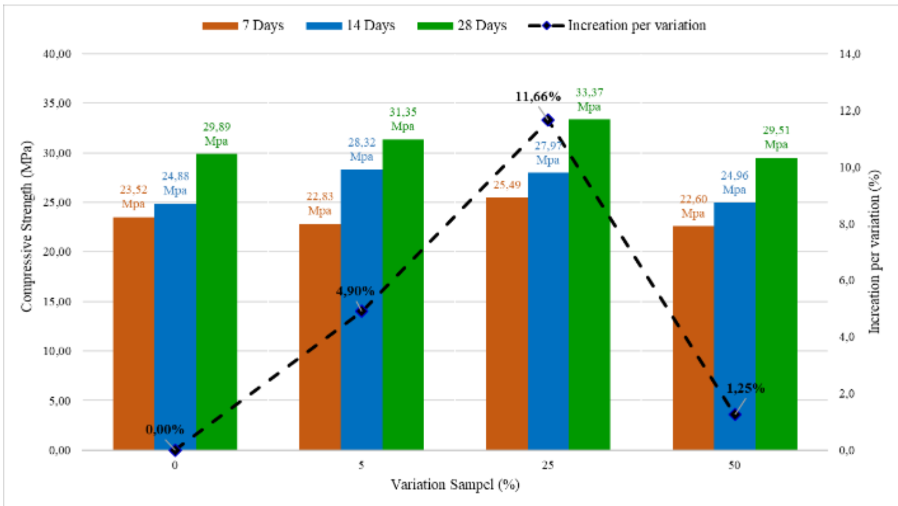

Figure 7. The results of the compressive strength of concrete at the age of 7,14,28 days and an increase in the value of the compressive strength of the sample variation.

Further analysis is the fracture pattern in each sample of the concrete compressive strength test results shown in Figures 8,9,10. Fracture pattern reference based on ASTM C39/C39M-1. For the 5% variation sample at the age of 7 and 14 days, a cone fracture pattern tends to occur, while at the age of 28 days, a columnar fracture pattern tends to occur.

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Figure 8. Fracture pattern of 5% coral limestone variation sample.

For the 25% variation sample, at the age of 7 and 14 days, cone and split fracture patterns tend to occur, while at 28 days, columnar fracture patterns tend to occur.

Figure 9. Fracture pattern of 25% coral limestone variation sample.

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For the 50% variation sample, at the age of 7 and 14 days, cone and shear fracture patterns tend to occur, while at 28 days, columnar fracture patterns tend to occur.

Figure 10. Fracture pattern of 50% coral limestone variation sample.

5. CONCLUSION

The results of research that have been carried out on variations in the use of coarse aggregate (gravel) with coral limestone can be concluded as follows:

1. The replacement of coarse aggregate (gravel) with coral limestone can reduce the density of the concrete.
2. The compressive strength of the concrete in the sample variation of 25% coral limestone as a substitute for coarse aggregate (gravel) gave better results than the 5% and 50% variation sample with the normal concrete compressive strength of 33,37 Mpa which was greater than the quality of the concrete. target is 30 Mpa.
3. Coral limestone (coral rock) in Timor Island often - East Nusa Tenggara, especially West Kupang area Can be used as a substitute for coarse aggregate (gravel) in making structural concrete and non-structural concrete with a percentage change of coral limestone to coarse aggregate (gravel) of 25 %.

6. ACKNOWLEDGEMENTS

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