Compressive Strength of Concrete with Laterite Aggregate As Substitute of Coarse Aggregate

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***Abstract*—The rough aggregate of broken stone is quite difficult to obtain in East Kalimantan until it must be imported from Palu, causing material innovation in the construction field. In this case many laterites are used on the island of Borneo as coarse aggregates instead of broken stones, containing low organic matter with a relatively dense and sturdy texture, having almost the same hardness as broken stones. This study aims to find the optimum composition of the ingredients for optimum compressive strength to determine whether laterite meets the concrete mixture, resulting from 6 mixed designs for normal f'c 25 MPa concrete, with a percentage of laterites of 62.0% (medium laterite composition 50% decreased to 42% and rough 12% laterite increased to 20%), using cylindrical specimens with a height of 200 mm and a diameter of 100 mm at the age of testing 1,3,7,14,28 and 56 days. The results of the analysis of compressive strength obtained maximum compressive strength of 17.87 MPa and optimum compressive strength of 17.2 MPa with a composition of 38.0% sand, moderate laterite 46.0% and coarse laterite 16.0% so that laterite concrete as a coarse aggregate substitute could used for mix concrete.**

Keywords*— *Laterite, Aggregates, Coarse Aggregates, Concrete Compressive Strength

I. INTRODUCTION

Concrete is a flexible material to be developed in the application of infrastructure development. The design of the concrete structure requires accuracy at the design and implementation stages by considering the price and strength aspects of the concrete structure which has a high strength but with a low cost. Both of these can be achieved by optimizing the design and innovation of materials used by using certain material innovations that have lower prices, but do not reduce quality or strength, can even improve the quality or strength of the structures designed.

The use of coral / gravel or coarse aggregate and fine aggregate / sand material as an aggregate of concrete mixtures for the East Kalimantan region must bring from outside the island of Borneo [1], the closest from Palu to Central Sulawesi, requires expensive transportation costs, making the price of coral soar high so that the impact of construction costs is also high, so it takes innovation in the form of other materials whose strength is not much different from gravel but has an affordable price. Examples of abundant material on the island of Borneo are laterite soil, so far only used as pavement coating material.

Laterite soil is a land that has several characteristics, among others: old-aged soil that has fused with different types, is infertile because of its low organic content suitable only for certain plants, neutral acidity and not too acidic, many in areas that are not too hot, humid, cold and lots of puddles, easy to absorb water, solid and sturdy texture. The spread of laterite land is the island of Borneo, Lampung, West Java, East Java and parts of Central Java.

Lateritic soils are found mostly in tropical and humid climates, the iron oxide content is high, has a red color like rust in Figure 1, generally contains large amounts of quartz and titanium, zircon, iron, tin, aluminum and manganese oxides, which are left behind in the wear process, depending on location, climate, and depth. The tropical climate and the influence of chemical elements determine the thickness, quality, and mineral content. Old-age Laterite soil, containing low organic matter with a relatively dense and sturdy texture, brownish red in color because it predominantly contains iron and aluminum.

Noting the price of coral in East Kalimantan is quite high, but many laterite soils this material is worth trying to be used as a substitute for coral material to be made into concrete mixtures [2]. Because in terms of strength, laterite soil has a compressive strength that is not inferior to the coarse aggregate of coral / gravel in the concrete mixture.

The problem formulated in this study, how does the influence of laterite soil as a substitute for coarse aggregate (coral / gravel) in the concrete mixture by analyzing the compressive strength of concrete against the time of the hydration process? Why is it just compressive strength? Because the compressive strength of concrete is the initial test of the strength of concrete. To answer the problem, the purpose of this study is confirmed to determine whether lateritic soil can be used as a mixture of concrete and evaluate the characteristics of concrete mixtures with compressive strength between normal concrete and laterite concrete.

Fig. 1. *After chopping laterite and laterite in crusher*

II. Research Methode

A. *Cement and Aggregates*

This research uses cement of portland composite. The cement criteria used refer to the technical specifications of composite portland cement [3]. Whereas the fine aggregate of the sand type from Palu and the coarse aggregate of comparable concrete using broken stone from Palu and laterite soil from the Kec. Palaran, Kutai Kartanegara, East Kalimantan refers to technical specifications [4], [5].

B. *Properties of Concrete Mechanics*

The mechanical properties of concrete are obtained by tests of compressive strength, tensile strength, stress-strain characteristics (modulus of elasticity), and physical properties including the hardening, deformation, response to environmental conditions.

The compressive strength of concrete is the basis of the characteristics of concrete, if the compressive strength of the concrete of a composition is good, then the other mechanical properties will be good. At this initial stage testing of compressive strength is carried out. The properties of hard concrete can be stated as follows :

Aggregate testing begins with testing the aggregate filter analysis to determine the gradation of broken stone / gravel and the gradation of sand and the gradation of laterite soil. Coarse / gravel aggregate distribution of grain for a maximum diameter of 20 mm according to the standard [6] there is a shortage of coarse grains, fine grains / sand gradation in the category 1 zone, while laterite soil as a coarse / gravel aggregate substitute standard used for coarse aggregate / gravel.

The variation of mixture initially calculated for normal concrete without laterite by experiment with a percentage of combined sand gradation on broken stones obtained a ratio of 30.0% sand, 45.0% broken stone 1/2 (medium aggregate) and 25.0% broken stone 2/3 (coarse aggregate). Percentage of 38.0% sand as a fixed composition, while the subsequent variation in the percentage of 1/2 substituted coarse / gravel 1/2 laterite soils compared with the replacement of laterite soil by 50.0%; 48.0%; 46.0%; 44.0% and 42.0%; while the percentage of 2/3 laterite soil increases compared to 2/3 aggregate replacement of 12.0% 14.0%; 16.0%; 18.0% and 20.0% of the total aggregate for the concrete mixture meets the concrete aggregate specifications shown in Figure 2 and Figure 3.

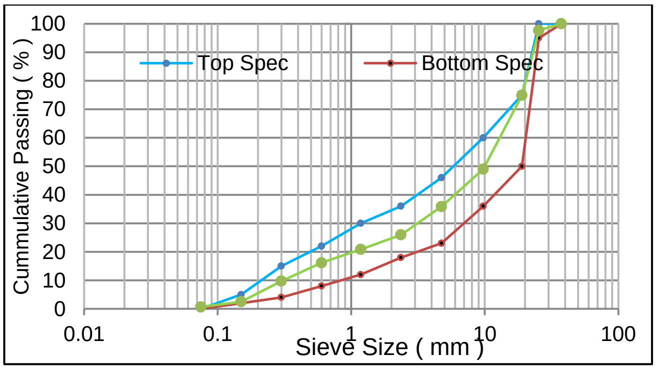

Fig. 2. *Grading curve for combined sand 30%: stone crusher 70%*

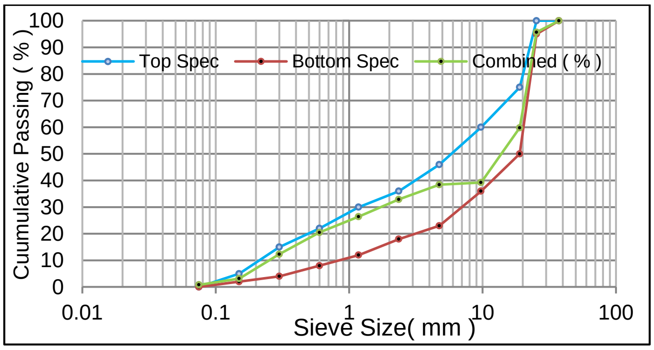

Fig. 3. *Grading curve for combined sand 38%: laterite 62%*

Furthermore, taking into account the results of the aggregate moisture test, aggregate absorption, specific gravity testing and absorption of fine aggregate / sand, coarse aggregate/ gravel, and laterite soil, calculated in the concrete mix design format with 5 laterite soil variations and variations to 6 normal concrete designs according to the calculation of material requirements for each 1 m^3 is like table 1.

TABLE I. Results of material composition calculations for 1 M3 of concrete mixture

Var	Ce ment	Water	Palu Sand	Laterit e 1/2	Laterit e 2/3	Palu Stone 1/2	Palu Stone 2/3
V1	380,00	256,64	613,80	750,26	174,30		
V2	380,00	257,60	613,80	720,25	203,35		
V3	380,00	258,56	613,80	690,24	232,40		
V4	380,00	259,52	613,80	660,23	261,45		
V5	380,00	260,48	613,80	630,22	290,51		
V6	380,00	145,77	547,98			856,04	452,21

C. *Concrete compressive strength*

The most important characteristic of concrete is the compressive strength of concrete, because it is related to other properties, meaning that if the compressive strength of the concrete is high, the other properties are also good. The concrete strength value of this research is known by testing the compressive strength of cylindrical specimens (diameter 100 mm, height 200 mm) of 144 cylinders loaded with compressive forces to reach the maximum load using a compression testing machine. Concrete compressive strength is defined as the amount of pressure that can be held by the concrete surface area so that the concrete is destroyed. The calculation equation for concrete compressive strength and procedure for testing refers to the standard [7].

III. Results and Discussion

In the analysis of compressive strength, the average value obtained from 4 specimens was determined. The results of compressive strength for various test ages were carried out to find the relationship between age and compressive strength of the test. This is done on concrete made from various variations of laterite soil content. Increased compressive strength of each mixture variation based on hydration time is given in Figure 4. All paragraphs must be indented. All paragraphs must be justified, i.e. both left-justified and right-justified.

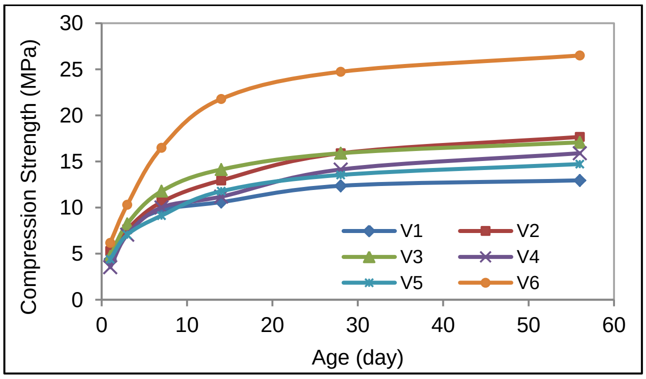

Fig. 4. *Relationship of concrete compressive strength to test age*

Figure 4. shows the curve of increasing the compressive strength of concrete against the age of the test. Increasing the compressive strength of concrete shows that for all variations of concrete increases with increasing age of hydration. Before reaching the age of 28 days, concrete with a coarse aggregate substitute variation indicates the development of compressive strength looks slower when compared to normal concrete, however with increasing age the hydration difference in the development of compressive strength increases.

Increasing the compressive strength of concrete is higher at the age of initial hydration, up to 14 days, and then the increase tends to be lower even the development of compressive strength begins to experience stabilization. Concrete made using laterite soil as a substitute for coarse aggregate develops a lower / smaller compressive strength when compared to normal / control concrete which is made without substitute material for laterite soil.

From the calculation of concrete compressive strength at the age of testing for each variation of laterite soil and normal concrete, then converted to a compressive strength of 28 days [8], unless the testing at the age of 1 day is not calculated, by taking the average value of each mixed variation, the strength average press is obtained graphically the relationship between the compressive strength of laterite soil concrete to the variation of laterite soil content used [9], [1]. Using the help of polynomials the optimum compressive strength is generated as shown in Figure 5.

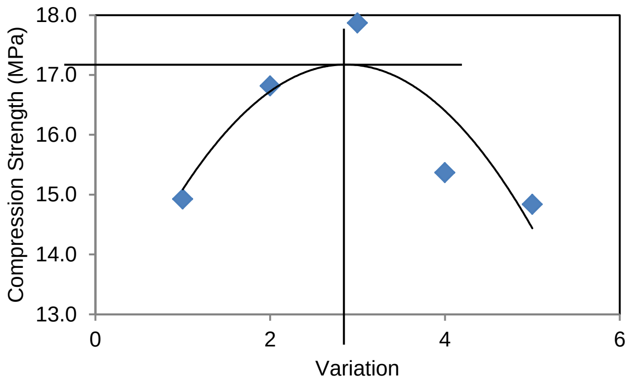

Fig. 5. *Optimum concrete compressive strength*

Based on Figure 5. By not entering the value of normal / control concrete compressive strength the optimum compressive strength of each variation was obtained and the optimum value of compressive strength of 17.2 MPa was approached to variation 3 with the composition of the mixture of sand 38.0%, 1/2 laterite soil by 46.0% and 2/3 laterite soil at 16.0%.

By using the compressive strength value equation based on the time function according to [10], [11], [2], the results are shown in Figure 6 graph of the relationship of the compressive strength ratio with the age ratio of concrete testing Variation 1. Figure 7 is a graph of the relationship of age ratio and compressive strength ratio of concrete variation testing 2. Figure 8. graph of relationship of age ratio and compressive strength ratio of concrete variation variation 3. Figure 9. Graph relationship of age ratio and compressive strength ratio of concrete testing variation 4. Figure 10. Graph relationship of age ratio and compressive strength ratio of concrete testing variation 5. Figure 11. graph of relationship between age ratio and compressive strength ratio of concrete variation test 6.

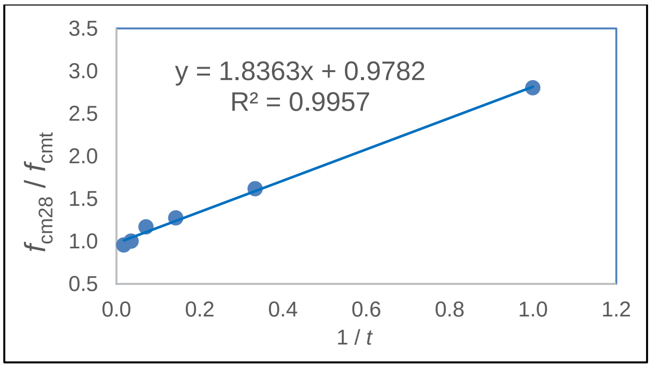

Fig. 6. *Graph of ratio of age and compressive strength ratio of concrete Variation 1*

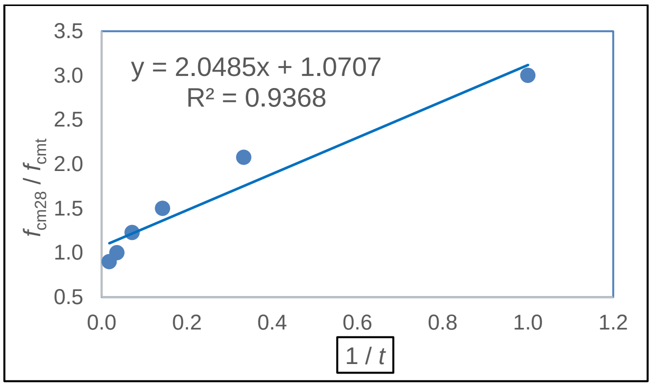

Fig. 7. *Graph of ratio of age and compressive strength ratio of concrete Variation 2*

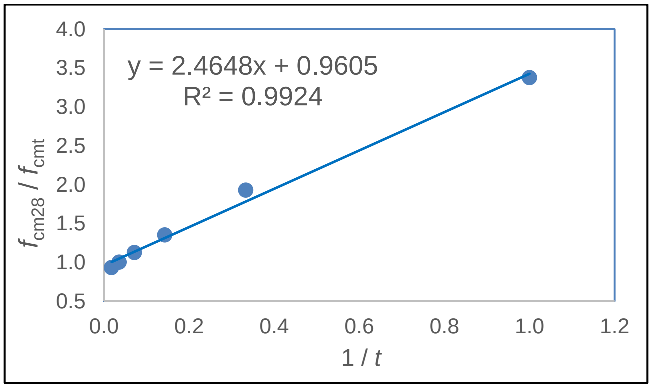

Fig. 8. *Graph of ratio of age and compressive strength ratio of concrete Variation 3*

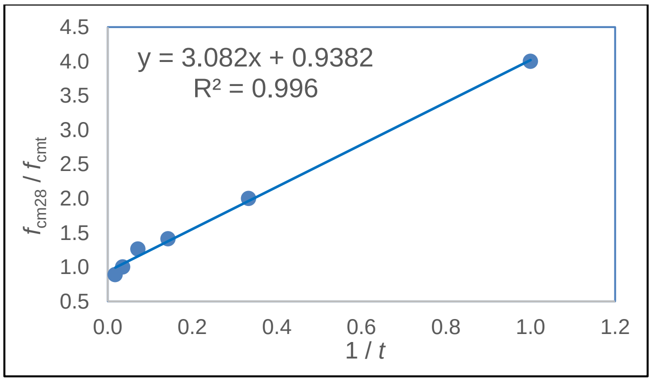

Fig. 9. *Graph of ratio of age and compressive strength ratio of concrete Variation 4*

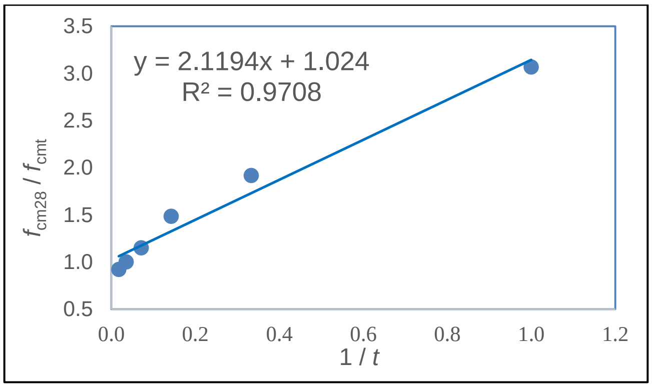

Fig. 10. *Graph of ratio of age and compressive strength ratio of concrete Variation 5*

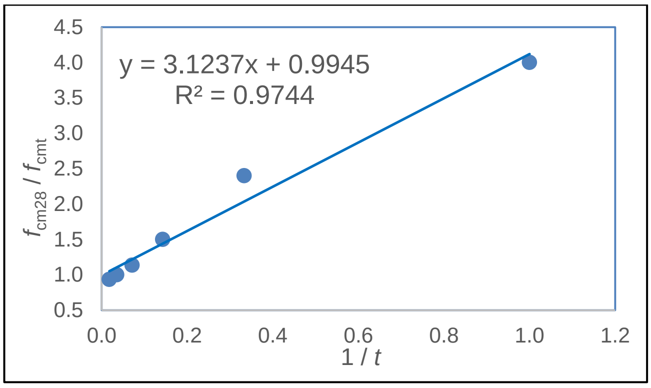

Fig. 11. *Graph of ratio of age and compressive strength ratio of concrete Variation 6*

Based on Figure 6 to Figure 11 the relationship of compressive strength equations with time functions can be written as in equation 1; 2; 3; 4, 5 and 6 in the order of variations in the composition of the concrete mixture.

$$f'_{c\,V1.(t)} = \left[\frac{t}{(1{,}8363\,t + 0{,}9782)}\right] f'_{c\,V1.28} \quad (1)$$

$$f'_{c\,V2.(t)} = \left[\frac{t}{(2{,}0485\,t + 1{,}0707)}\right] f'_{c\,V2.28} \quad (2)$$

$$f'_{c\,V3.(t)} = \left[\frac{t}{(2{,}4648\,t + 0{,}9605)}\right] f'_{c\,V3.28} \quad (3)$$

$$f'_{c\,V4.(t)} = \left[\frac{t}{(3{,}082\,t + 0{,}9382)}\right] f'_{c\,V4.28} \quad (4)$$

$$f'_{c\,V5.(t)} = \left[\frac{t}{(2{,}1194\,t + 1{,}024)}\right] f'_{c\,V5.28} \quad (5)$$

$$f'_{c\,V6.(t)} = \left[\frac{t}{(3{,}1237\,t + 0{,}9945)}\right] f'_{c\,V6.28} \quad (6)$$

Furthermore, validation of equation 1, 2, 3, 4, 5 and 6 by calculating the compressive strength of the results of the formulation. The results of this calculation are compared with the compressive strength of the test results. The comparison of the two values is plotted in Figure 12. graph the relationship between the compressive strength of the formula and the compressive strength of the test results.

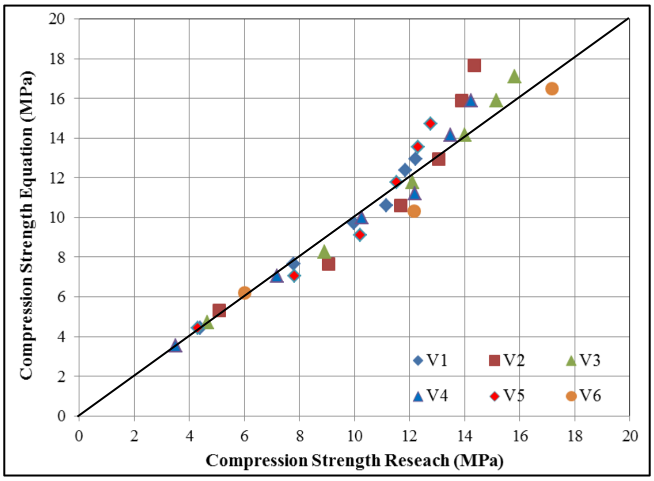

Fig. 12. *Comparison of the compressive strength of the test results and the compressive strength of the equation*

Based on Figure 12, by comparing the distribution of the results of the compressive strength of the test and the compressive strength of the equation with respect to the equity line, the compressive strength of the calculation results in an over estimate and there are also results that under estimate. At the age of 1 day the calculation results do not deviate from the position of the equity line, at the age of 3 and 7 days the results of the compressive strength calculation result under estimate means that the test results are lower than the results of the equation can be stated that the concrete press hardening process is slow, while at the age of 14 , 28 days and so on the opposite, that is, producing a compressive strength above the equity line or over under estimate means that the test results are higher than the results of the equation so that it can be stated that the concrete press hardening process is faster based on the equity line analysis.

IV. Conclusions

Based on the graph of the compressive strength with time, the compressive strength of laterite concrete does not reach the 25 MPa plan compressive strength, only 17.87 MPa is achieved but the pattern of increasing linear compressive strength of linear laterite to normal concrete is obtained with optimum compressive strength of 17.2 MPa with variation 3 (38.0% sand, 1/2 laterite soil 46.0% and 2/3 laterite soil 16.0%), obtained a low strong increase in young concrete age to 14 days of age, but increased and exceeded the results of the equation after age 21 days and so on. Because the compressive strength does not reach the compressive strength of the plan but is able to reach low quality concrete, the concrete uses laterite soil as a coarse aggregate substitute can be used for mix concrete.

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