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The Influence of Biocementation on the Compressive Strength of Fireless Bricks

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ABSTRACT

Waste sludge from the Water Treatment Plant (IPA) is used as an additive in the manufacture of environmentally friendly bricks to reduce river pollution. In the process of making these bricks, clay is mixed with sewage sludge at 15% of the total weight of clay. In addition, to reduce the impact of air pollution, the bricks were not burned. This research emphasizes the importance of using environmentally friendly alternative materials in brick production. Bacillus Huizhouensis bacteria was applied to strengthen bricks with variations of bacteria concentration of 8%, as well as bacterial culture age variations of 8 hours, 10 hours, and 15 hours. After the bricks were matured for 14 days, the test results showed that bricks using 8% bacterial solution with 10 hours of culture increased by 70.65% to 1.57 MPa, compared to normal bricks of 0.92 MPa. So that bricks with 8% bacteria with a culture age of 10 hours with a period of 14 days have a higher value than normal bricks.

Keywords: *Bricks; IPA Waste Mud; Bacillus Huizhouensis Bacteria.*

INTRODUCTION

Bricks are one of the construction materials. In general, bricks are made from black soil or clay soil that are burned until they turn into reddish colour. However, if clay soil is used continuously, its natural resources will be depleted [1] and the process of burning bricks could cause environmental pollution. Based on this problem, an eco-friendly idea and technological innovation was created [2] [3] the fabrication of bricks without firing process that aims to obtain bricks with mechanical properties according to the requirements, as well as reduce the amount of carbon dioxide gas produced from high temperature firing process [4].

Perumda Tirta Manuntung's wastewater sludge is a by-growth from the treatment of drinking water systems sourced from surface water. IPA sludge waste is formed due to the precipitation of colloidal particles that are forced to settle faster using aluminium chemicals. [5]. IPA sewage sludge can be utilised because it contains a mineralogical composition that is very similar to clay [6]. One of the most effective ways of managing sewage sludge and producing high economic value is by converting sewage sludge into bricks [7]. In addition to use mud mixture it can also use bacteria, namely Bacillus Huizhouensis which can produce calcite. Clay soil has a very small bearing capacity [8] Therefore, the compressive strength of clay soil can be improved by biocementation method [9] for soil stabilisation with soil improvement techniques using calcite ($CaCO_3$) which is obtained from the life cycle or metabolism of living organisms [2] [10] [11]. Chemical stabilisation has been widely used to improve soil durability [12]. In the making of bricks also need reinforcement to increase the compressive strength of bricks

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using the Microbially Induced Calcite Precipitation (MICP) method where this technique can improve the soil by using microorganisms that are able to change and improve physical and mechanical properties [13].

Figure 1. Isolat Bakteri Bacillus Huizhouensis JAI

Research conducted by [14] It is proven that the addition of 6% Bacillus Subtilis bacterial solution can increase the compressive strength of bricks compared to bricks without bacteria. Where previously obtained a compressive strength value of 20.11 kg/cm² to 32.04 kg/cm², but the study can only increase the strength of bricks by 59% of the standard SNI 15-2094-2000 of 50% kg/cm². Because of this, researchers are interested in conducting further research using Bacillus Huizhouensis bacteria.

METHOD

This research uses experimental method conducted at Laboratory of Balikpapan University for ± 7 months from January to August 2024. This research uses IPA waste sludge of 15% by weight of clay soil. The compressive strength of bricks to be tested is given a solution of Bacillus Huizhouensis bacteria with variations of bacterial concentrations of 8% with bacterial culture age variations of 8 hours, 10 hours, and 15 hours. For comparison purposes, bricks without bacterial reinforcement will also be made. Bricks that will be tested have a size with SNI 15-2094-2000 standard which is 190mm x 90mm x 65mm.

Laboratory Test

Before making these samples, it is necessary to examine the characteristics of clay and IPA sewage sludge in order to identify the true nature of the samples.

Cultivation of Bacillus Huizhouensis Bacterial Culture

Bacterial culture is a method of reproducing bacteria in the laboratory in a controlled manner. Initially the Bacillus Huizhouensis bacteria were in the form of isolates. Then the bacteria are cultured in the Laboratory of the Faculty of Civil Engineering, Balikpapan University. In the culture process, bacteria that have aged 8 hours, 10 hours, 12 hours are transferred to medium B4 and incubated in a bottle. To make medium B4, the ingredients needed are Urea (20 gr), Nutrient Broth (3 gr), $NaHCO_3$ (2,12 gr), $CaCl_2.2H_2O$ (4,1 gr), NH_4Cl (10 gr). Bacteria were cultivated with a culture age of 8 hours, 10 hours, 15 hours.

Preparation of Cementation Solution

A mixed solution consisting of urea and calcium chloride ($CaCl_2$). In the process of making this stone, only 1% cementation solution is needed. to make the cementation solution, it takes a mixture of urea as much as 15.015 g with Calcium chloride (CaCl2) as much as 27.745 g. This solution is used as a growth medium and contains the ingredients needed for bacterial growth [15].

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Manufacture of Test Objects

The stages of making test objects start from drying the clay material naturally or use an oven. While the IPA waste mud is dried under the sun for 2 x 24 hours in order to reduce the mud content. After that, mixing clay and IPA waste mud throughout the sample as much as 15% of the total weight as well as 8% bacterial solution, cementation solution, and water. Printing bricks using iron moulds and after the dough is solid then slowly released then the bricks are dried for the first 3 days at room temperature so that the bacteria can work for lastic993sm in bricks because if the bricks are exposed to direct sunlight the bacteria will die and cause cracks in the bricks.

Compressive Strength Test

The average compressive strength values used as a reference are 50 kg/cm2 dan 5 Mpa.

RESULTS AND DISCUSSION

Characteristics of Physical Properties of Clay Soil

To determine the classification of soil types used in the study, it is necessary to test the physical characteristics of clay soil. The following test results can be seen in Table 1.

Table 1. The results of physical properties of clay

No	Test Type	Results	Unit
1	Natural Water Content	28,02	%
2	Specific Gravity	2,609	gr/cm³
3	Sieve Analysis 200	98,3	%
4	Hydrometer		
	a. Silt	11,25	%
	b. Clay	87,0	%
5	Liquid Limit	30,84	%
6	Plastic Limit	15,79	%
7	Plasticity Index	15,05	%
8	USCS Classification	CLAY	-

The average specific gravity of the tested soil is about 2,609 gr/cm3. This result shows that the soil can be classified as non-organic clay according to SNI 6371:2015 standard [14]. The plasticity value of the soil shows a moisture content of 15.79% with a plasticity index of 15.05%. Based on the research results, the soil can be identified as a type of non-organic clay soil with a low plasticity level.

Physical and Mechanical Properties Characteristics of IPA Sewage Sludge

To determine the classification of the type of soil used in the study, it is necessary to conduct physical tests on sewage sludge. The following are detailed test results which can be seen in Table 2.

Table 2. Test results of physical properties of ipa waste sludge

No	Test Type	Results	Unit
1	Natural Water Content	24,74	%
2	Specific Gravity	2,673	gr/cm³
3	Sieve Analysis 200	42,93	%
4	Hydrometer		
	a. Silt	7,57	%

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	b. Clay	31,97	%
5	Liquid Limit	49,99	%
6	Plastic Limit	33,90	%
7	Plasticity Index	16,10	%
8	USCS Classification	SANDY CLAY	-

The results of the waste sludge test are included in the ML-OL soil classification where the sludge consists of silt and clay. In general, IPA sludge usually has a relatively highwater content. This sludge is created through the separation of solid and liquid materials from residual waste, which is often referred to as sludge or liquid sludge. In this sludge, the water content is dominant while the solid components are only present in small amounts, only a few percent in the form of solids [14].

Compressive Strength Results

To calculate the compressive strength of the brick sample material, data is required from the measurement of the compressive area and the value of the pressure load. Both data are taken using measurements such as a ruler and compressive load measurements using a Compression Machine tool. The following are the results of the compressive strength test:

Test Results of Brick Compressive Strength without Bacteria

The results of testing the average compressive strength of normal bricks are listed in Table 3.

Table 3. Average compressive strength of normal bricks

No	Curing Days	Tool Reading (kN)	Compressive Strength Value (MPa)
1	3 Days	4,33	0,79
2	7 Days	4,83	0,87
3	14 Days	4,97	0,92

In the 3-day incubation to 7-day incubation period, there was an increase of 10.13%. In the next period, from 7 days to 14 days, there was an increase of 5.75%.

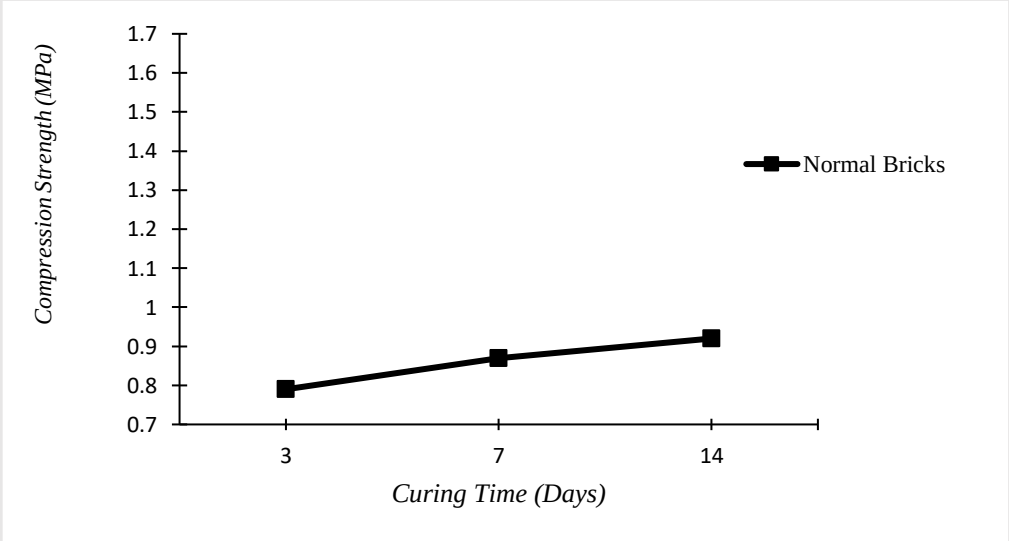

Figure 2. Results of normal brick compressive strength values

In Figure 2, it can be seen that in the 3-day, 7-day, and 14-day curing processes, this increases because during the drying process the condition of the bricks decreases the water content. This

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is in line with research [16] revealed the relation between moisture content and compressive strength that the smaller the moisture content, the greater the compressive strength of the brick, the drier the brick, the more the compressive strength increases. During this process, the clay particles that make up the bricks become more compressed and closer together. As a result, the structure of the brick becomes denser and its density increases, which contributes to its increased strength and resilience [17].

Test Results of Brick Compressive Strength of 8% Bacteria Variation

Below in Table 4 and graph in Figure 3 are the average results of testing the compressive strength of stone with the addition of bacteria as much as 8% and the culture period for 8 hours, 10 hours, 15 hours.

Table 4. Average results of brick compressive strength test of 8% bacteria variation

Culture Period	No	Curing Days	Reading Tool (kN)	Compressive Strength Value (MPa)
8 Hours	1	3 Days	6,37	1,13
	2	7 Days	7,30	1,35
	3	14 Days	8,50	1,55
10 Hours	1	3 Days	6,90	1,22
	2	7 Days	7,57	1,40
	3	14 Days	8,83	1,57
15 Hours	1	3 Days	5,97	1,10
	2	7 Days	7,00	1,29
	3	14 Days	7,83	1,47

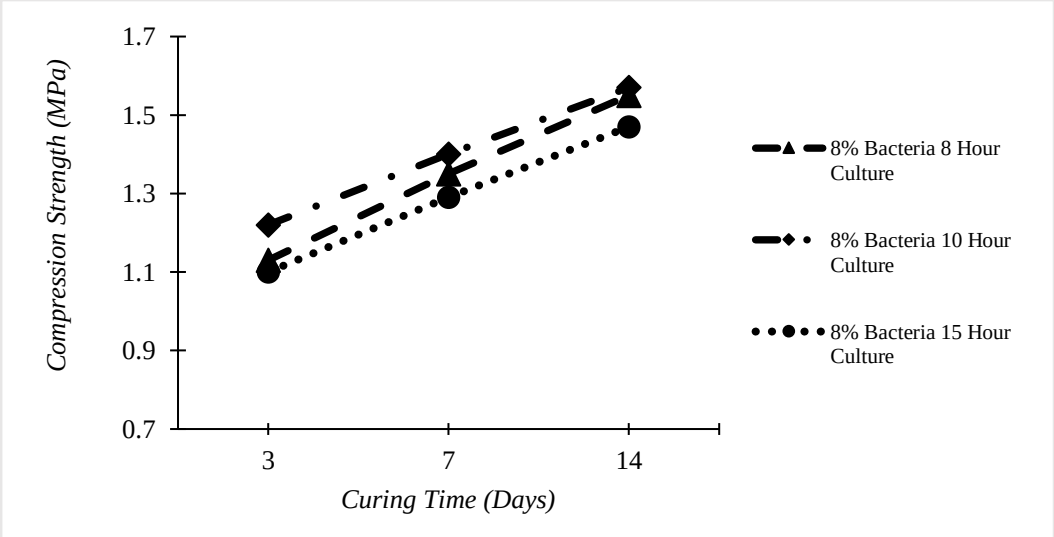

Figure 3. Results of bricks compressive strength value with 8% bacteria variation

The addition of 8% bacteria increases with the period of the culture and the curing days compared to normal bricks. The addition of 8% bacteria produces varying average values. The results of the lowest compressive strength value obtained at the age of 15 hours of culture with a 3 curing days amounting to 1.10 MPa while the highest compressive strength value obtained at the period of 10 hours of culture with a 14 curing days days amounting to 1.57 MPa. [18] showed that the use of bacterial solution resulted in the formation of calcite. This calcite acts as a natural binder that holds small soil particles together, forming a denser matrix and increasing soil strength and stability. [19] shows that during the incubation phase, bacteria continue to adapt to environmental changes and produce various enzymes that stimulate further growth. As a result, the cementation process in the mixture of soil and bacteria occurs, and the

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compressive strength value increases each time bacteria are added during the curing phase. The results of previous research show that the use of bacteria gives promising results in increasing the durability [20]. [21] identified that the increase was due to the increased particle density due to the calcite precipitation process triggered by bacteria. This process results in the formation of dense and strong calcite or calcium carbonate (CaCO3) crystals, which bind together and cause soil hardening.

Comparison of Compressive Strength Test Results of Normal Brick and 8% Bacteria Variaton Brick

Listed below in Table 5 and graph in Figure is the average compressive strength of normal bricks with bricks adding 8% bacteria and a culture period of 8 hours, 10 hours, 15 hours.

Table 5. Average results of pressive strength test of normal bricks and 8% bacteria variation bricks

Normal Bricks		**Curing Days**	**Tool Reading (kN)**	**Compressive Strength Value (MPa)**
		3 Days	4,33	0,79
		7 Days	4,83	0,87
		14 Days	4,97	0,92
Bricks with Bacteria	**Culture Period**	**Curing Days**	**Tool Reading (kN)**	**Compressive Strength Value (MPa)**
8%	8 Hours	3 Days	6,37	1,13
		7 Days	7,30	1,35
		14 Days	8,50	1,55
	10 Hours	3 Days	6,90	1,22
		7 Days	7,57	1,40
		14 Days	8,83	1,57
	15 Hours	3 Days	5,97	1,10
		7 Days	7,00	1,29
		14 Days	7,83	1,47

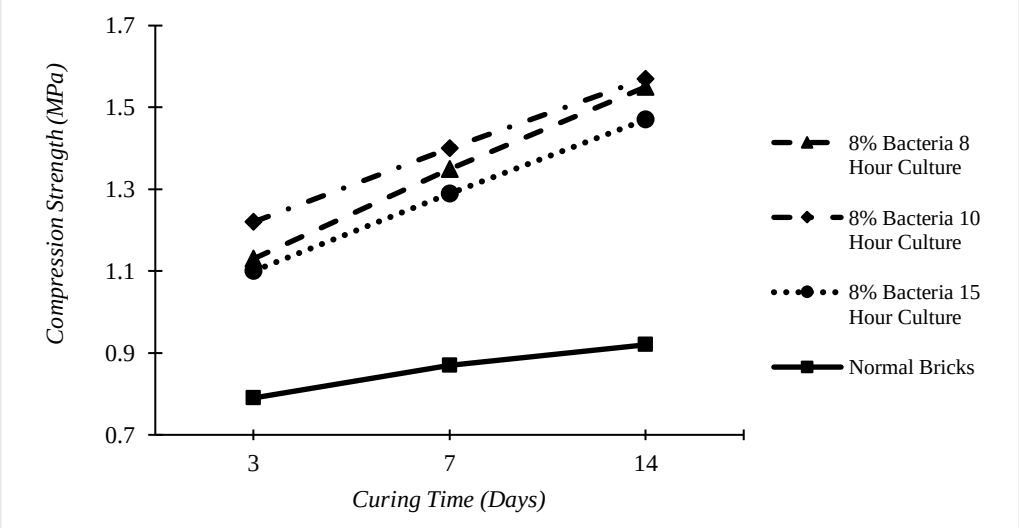

Figure 4. Graph of relation between comparison of normal brick values and 8% bacteria variation bricks

Based on the data in Table 5 and the graph in Figure 4, it shows that bricks with 8% bacteria have a higher compressive strength value than normal bricks. Bricks with 8% bacteria of 8-

hour culture period in the 14-day curing period increased by 68.48% compared to normal bricks. At 14 days, the 10-hour culture period increased by 70.65%, and at 14 days, the 15-hour culture period increased by 59.78%. It was revealed that the addition of bacteria to the test specimen can increase the compressive strength, at each period of bacterial culture [22] In addition, at the age of 10 hours of culture the bacteria reached the peak stage because in this period the bacteria were in the stationary phase. Soil without added bacteria has a very low compressive strength. However, along with the curing process and increasing the concentration of bacteria in the solution, it was observed that the strength of the soil increased over time. [21]. Brick specimens can be seen in figure 5.

(a) (b)

Figure 5. Normal brick (a), 8% Bacteria variation bricks (b)

CONCLUSION

In the test data conducted, it is known that a solution of 8% bacterial variation of 10-hour culture period with the addition of Bacillus Huizhouensis bacteria can be applied to strengthen bricks with the highest variation. The compressive strength value of the 8% bacterial variation has increased by 70.65% with a compressive strength value of 1.57 MPa compared to the compressive strength value of normal bricks.

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