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Fireless Brick Making using Water Treatment Sewage Sludge with MICP Action

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ABSTRACT

Bricks materials used in making the walls of building. Currently, brick making has new innovations. As in this study using water treatment sludge waste and bacillus subtilis bacteria. Sludge waste done with percentage of 20% and bacillus subtilis bacteria much as 6%. The process adding bacteria called the Microbially Induced Calcite Precipitation (MICP) process. The process to increase compressive strength clay soil. The purpose study to determine effect of Bacillus subtilis bacteria on the strength bricks using mud and the strength of bricks with bacterial reinforcement. The results showed the compressive strength did not the specifications, where value of the compressive strength of bricks in accordance with SNI 15-2094-2000 is 50 kg / cm². And results of compressive strength only amounted to 22.82 kg / cm² in the 28-day curing period. For compressive strength using mixture of bacteria produces highest strength value the 4-day culture period of 28.11 kg kg/cm².

Keywords: *Brick Sludge, Compressive Strength, Bacillus Subtilis, MICP*

INTRODUCTION

IPA (Installation Water Treatment) sludge waste is waste produced by drinking water treatment systems sourced from surface water. IPA mud waste can be formed due to the presence of sediment particles from the use of aluminum chemicals, so that the waste is formed. As a result of this waste can have an impact on the environment which is very detrimental to the life of living things. Therefore, it is necessary to process or recycle using the sludge waste material. PDAM sludge waste can be utilized as brick making material [1].

Bricks are materials or materials used in making the walls of a building. Bricks are made of clay that has been molded, and in general in the manufacture of bricks after the clay is mixed with water and molded will be burned at high temperatures. The burning method in question is to remove the water content contained in the clay, because clay has a high compressive strength in dry conditions. The compressive strength of clay can be increased by biocementation method [2]. The biocementation method is being widely developed at this time, this method is a testing method that uses a mixture of bacteria that do live in the soil to produce the enzyme urease.

Biocementation is a soil improvement technique that utilizes live bacteria in the soil to produce the enzyme urease [3]. This enzyme can convert urea into ammonia, which increases the calcium carbonate content in the soil, making it denser and harder. This method uses bacteria to improve the soil and increase the strength and density of the soil. To solve the problem of cracks in bricks, we can use the biocementation technique by utilizing the biological activity of bacteria to produce calcium carbonate.

Bacillus Subtilis bacteria are bacteria that can be used in the Microbially Induced Calcite Precipitation (MICP) process to increase the compressive strength of clay soil. Bacillus Subtilis bacteria can be used as a regent for Biocementation, the application of biocementation techniques by Bacillus Subtilis bacteria can make the pores of soil particles closed so that the soil does not flow easily [4]. Bacillus subtilis is a group of mesophile bacteria that can live in the temperature range of 10°C - 47°C. These bacteria can live in extreme environments because they can form protective endospores. This endospore is what makes Bacillus subtilis have resistance to heat, acid, and salt in the environment for a long time [5]. [6] revealed that Bacillus subtilis bacteria have the ability to precipitate calcite where calcite has the property of being able to bind soil grains so that cemented soil is expected to improve the quality of bricks. With this previous research, researchers are interested in developing fireless bricks with biocementation method using Bacillus subtilis bacteria.

MATERIALS AND METHODS

This research was conducted at the Laboratory of Civil Engineering and Planning, University of Balikpapan. The method used in this research is experimental method. This research uses basic materials of clay soil, sludge waste of IPAM Perumda Tirta Manuntung Km.8 Balikpapan City, and Bacillus Subtilis bacteria. This research includes preparation of materials, stages of research implementation, laboratory tests, preparation of bacterial solution and sludge solution, laboratory tests, preparation of bacterial solution and cementation solution, and compressive strength testing. The variation presentation used in this research is 20% mud variation and the addition of reinforcement using bacteria as much as 6% at the age of bacteria 2 days 4 days and 6 days.

Preparation of Materials

Preparation of materials in this research starts with taking the soil that will be used as testing material located in Sepinggan, South Balikpapan sub-district, Balikpapan City with coordinate point -1.217757,116.900794. And also take the sewage sludge at IPA Perumda Tirta Manuntung Km.8 Balikpapan City. Meanwhile, the bacteria used as a binder for the test specimens were purchased from the microbiology laboratory of Hasanudin University Makassar. The mixture variations used in this study are:

Table 1. Composition of Variety of Unburnt Bricks

No	Raw Materials	Material Composition (%)
1	Clay	62%
2	Waste Sludge	20%
3	Bacillus Subtilis	6%
4	Water	12%

Research Implementation Stages

The research carried out in this testing process is by means of laboratory testing and Bacillus Subtilis bacterial culture. The stages of research implementation can be seen in the following explanation Balikpapan City. Meanwhile, the bacteria used as a binder for the test specimens were purchased from the microbiology laboratory of Hasanudin University Makassar. The mixture variations used in this study are:

a. Laboratory Testing

Laboratory tests were carried out with 2 materials of clay soil and sewage treatment plant sludge [7]. What tests were carried out can be seen in the following Table 2.

Table 2. Testing of Clay and Sewage Sludge

No	Testing Type	Number of Test Objects	Testing Standard
1	Water content	3 sample	ASTM D-2216-98
2	Specific gravity	3 sample	SNI 03-1964-1990
3	Sieve analysis	3 sample	SNI 03-1968-1990
4	Hydrometer	3 sample	ASTM D-422-63
5	Liquid limit	4 sample	ASTM D-4318
6	Plastic limit	2 sample	ASTM D-4318
7	Standard proctor	5 sample	ASTM D-698

b. Bacillus Subtilis Bacteria Culture and Cementation Solution

Bacterial culture is a method of multiplying microbes on culture media by breeding in an aseptically controlled laboratory, to determine the type of organism [8]. The stages of making bacterial solutions and cementation are:

1. Mix nutrient broth with 1 liter of water.
2. Heat with a stove at 121ºC for 15 minutes.
3. After the medium is cool, mix the urea solution, $NaHCO_3$, $CaCl_2.2H_2O$, dan NH_4CI
4. After that, the bacteria were inoculated by mixing the bacterial isolates into the B4 medium.
5. The bottle is shaken so that it does not settle.
6. Bacteria grown on medium B4 were then left in the bottle at room temperature.
7. Bacteria used with a culture age of 2 days, 4 days, and 6 days.20 gr Urea.

He process of making cementation solution is as follows.

1. Mix water with 15.1 g Urea and 36.75 g CaCl2 2H2O stir until the ingredients are completely dissolved.
2. Then pour into an Erlenmeyer tube and close it tightly.
3. After that, leave the cementation solution at room temperature for 48 hours or 2 days.

After all solutions are made, they can be used according to the percentage of variation that has been determined in this test.

Compressive strength testing

The research design for brick compressive strength test objects with the addition of biocementation solution with a variation of 20% can be seen in the following table.

Table 3. Composition of Variety of Unburnt Bricks

Testing	Clay (%)	Waste sludge (%)	Bacterial (%)	Number of samples and aging period			
				7	14	21	28
BTB	80	20	0	3	3	3	3
BDB culture (3 days)	80	20	6	3	3	3	3
BDB culture (4 days)	80	20	6	3	3	3	3
BDB culture (6 days)	80	20	6	3	3	3	3

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BTB = Bricks without bacteria
BDB = Bricks with bacteria

Table 4. Compressive strength of bricks

Class	Maximum compressive strength of bricks		Permission Coefficient of Variation
	kg/cm²	MPa	
25	25	2,5	25%
50	50	5	22%
100	100	10	22%
150	150	15	15%
200	200	20	15%
250	250	25	15%

Table 5. Classification of brick sizes

Modules	Thickness (mm)	Width (mm)	Length (mm)
M-5a	65 ± 2	90 ± 3	190 ± 4
M-5b	65 ± 2	100 ± 3	190 ± 4
M-6a	52 ± 3	110 ± 4	230 ± 4
M-6b	55 ± 3	110 ± 6	230 ± 5
M-6c	70 ± 3	110 ± 6	230 ± 5
M-6d	80 ± 3	110 ± 6	230 ± 5

RESULTS AND DISCUSSION

The data has been tested by the researcher regarding the results and analysis of brick making using sludge waste material from Balikpapan City Water Treatment Plant (IPA), and Bacillus subtilis bacteria. The data obtained is in the form of laboratory testing data of physical-mechanical properties of soil and sludge in original condition and after mixed with percentage variation. Laboratory tests are conducted with the aim of obtaining data that will be used as a determinant to identify and classify the characteristics, strength, and compressibility of soil layers. The physical properties laboratory tests included moisture content, sieve analysis, hydrometer, Atterberg limits (liquid limit, plastic limit), specific gravity, and proctor tests.

Testing of Physical Characteristics of Soil and Sludge

After testing at the Civil Engineering and Planning Laboratory of University of Balikpapan, the following soil characteristics data were obtained.

Table 6. Testing of Physical Characteristics of Soil and Sludge

No	Testing	Soil Test Results	Sludge Test Results
1	Water content	24,74%	480,59%
2	Sieve analysis	73,8%	63,8%
3	Hydrometer		
	a. Silt	18.43%	38,09%
	b. Clay	55%	26%
4	Liquid limit	37,60%	46,32%
5	Plastic limit	16,78%	33,13%
6	Specific gravity	2,682	2,481

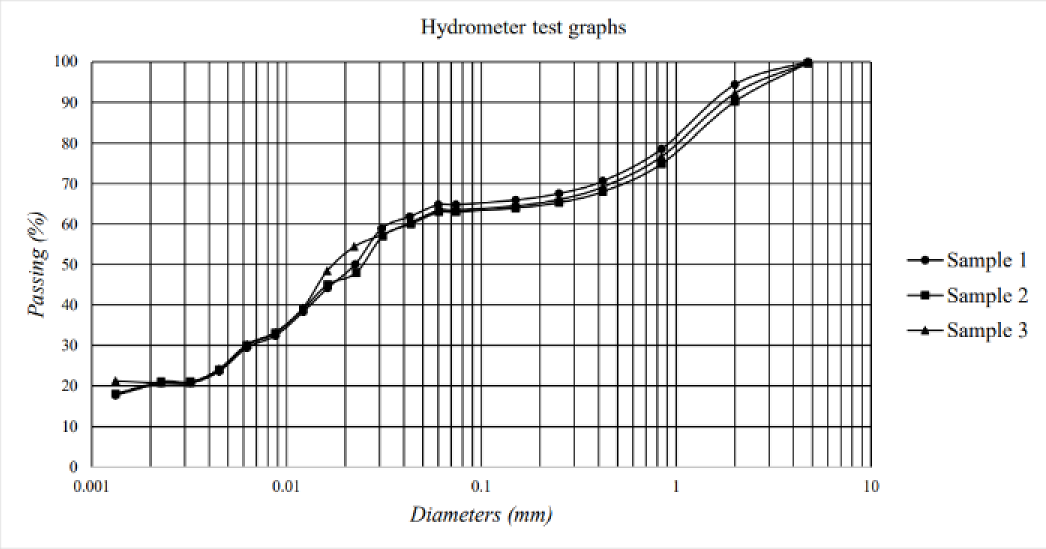

Figure 1. Sludge Hydrometer Test Results Chart

Based on Table 4, it is known that the soil and sewage sludge that have been tested are included in the fine-grained soil category. Because of the two test materials, the soil that passes sieve no 200 gets a value of more than 50%, as described in SNI 15-2094-2000 that the soil is said to be clay if the soil that passes sieve no 200 is more than 50%. Soil sieve analysis testing in this study produced a value of 73.8% and mud sieve analysis testing as much as 63.8%. From the results of soil hydrometer testing, it can be seen that 18.43% of the soil is silt and 55% is clay. And for mud hydrometer testing data it is known that 38.09% of the mud is silt and 26% is clay.

Mechanical Characteristics Testing of Sludge and Sludge Variation Mixture

To determine the characteristics of mechanical properties sludge were tested against the standard proctor test. The results of the sludge mechanical characteristics test can be seen in the following Table 7.

Table 7. Standard Proctor Laboratory Test Result Data

Testing	Result of Sludge Testing	Test Results with Variations
a. Optimum moisture content (OMC)	38,70%	16,00%
b. Dry density Max (MDD)	1,059 gr/cm³	1,647 gr/cm³

From the standard proctor laboratory test of the waste sludge, the maximum dry density of the sludge was 1.059 gr/cm³ and the optimum moisture content of the sludge was 38,70%. For the maximum dry density value of 20% mud variation, the result is 1.647 gr/cm³ and the optimum moisture content is 16%.

Results of Analysis of Brick Compressive Strength Testing

The visible properties of bricks for wall installation in buildings usually have to be in the form of long rectangular prisms, have angled ribs, the planes of the bricks must also be flat and flat which have no cracks in their parts. Data on the results of testing the compressive strength using a mixture of 20% mud variation and bacillus subtilis bacteria with the culture period can be seen in the following explanation.

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a. Test results of compressive strength of mud variation brick

This brick compressive strength test uses a percentage of mud variation as much as 20% The results of the brick compressive strength can be seen in the following Table 8.

Table 8. Data on the results of the Mud Variation Brick Compressive Strength Test

No	Curring (Days)	Tool Reading (kN)	Compressive Strength Brick (kg/cm^2)
1	7 Day	7.4	13,28
2	14 Day	8.2	14,56
3	21 Day	9.8	17,29
4	28 Day	10.3	18,29

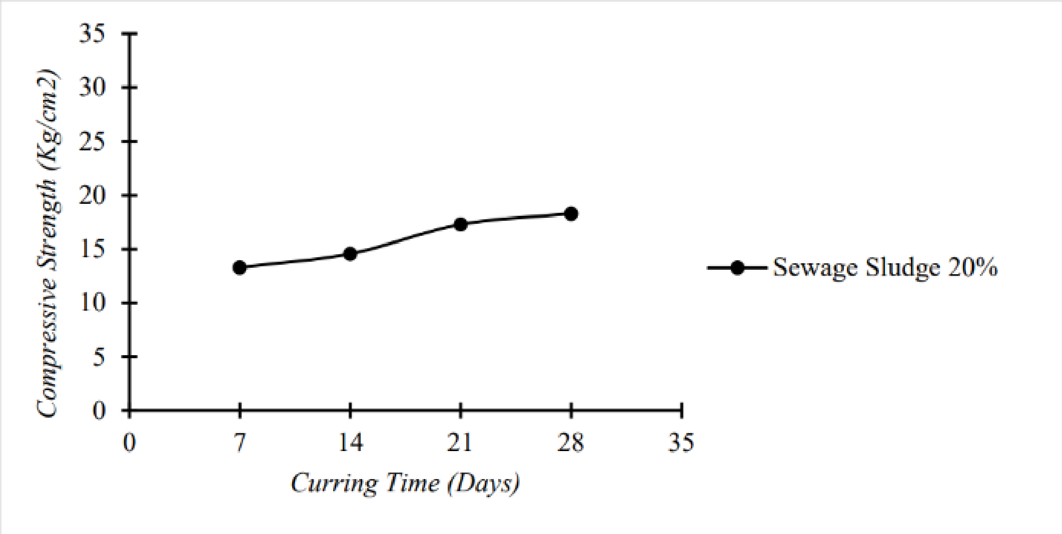

Figure 2. Chart of Compressive Strength Mud Variation Bricks

From the results of the compressive strength of bricks with the addition of 20% mud variation in Table 8 that has been tested to get the highest value in the 28-day holding period of 18.29 kg/cm^2. The results of the compressive strength does not the SNI standards that have been determined on the compressive strength of unburned bricks which is 50 kg / cm^2. Revealed that the process of stirring the brick mixture is not perfect, resulting in a mixture of bricks has not been evenly distributed resulting in a compressive strength value that does not match the standard that has been determined [9].

b. Compressive strength test results of mud and bacteria variation bricks with 2-day culture period

This brick compressive strength test uses a 20% mud and 6% Bacillus subtilis bacteria with 2 days culture period.

Table 9. Data on the results of the compressive strength test of mud variation bricks with the addition of bacteria

No	Curring (Days)	Tool Reading (kN)	Compressive Strength Brick (kg/cm^2)
1	7 Day	9,2	16,78
2	14 Day	10	18,82
3	21 Day	11,3	20,68
4	28 Day	11,8	21,68

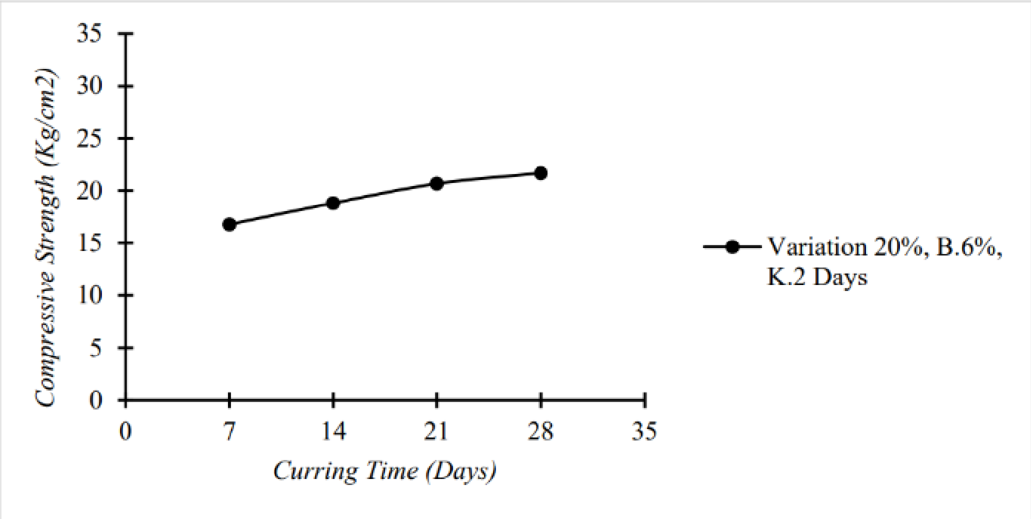

Figure 3. Chart of the compressive strength of bricks with bacterial variation of 2 days aging period

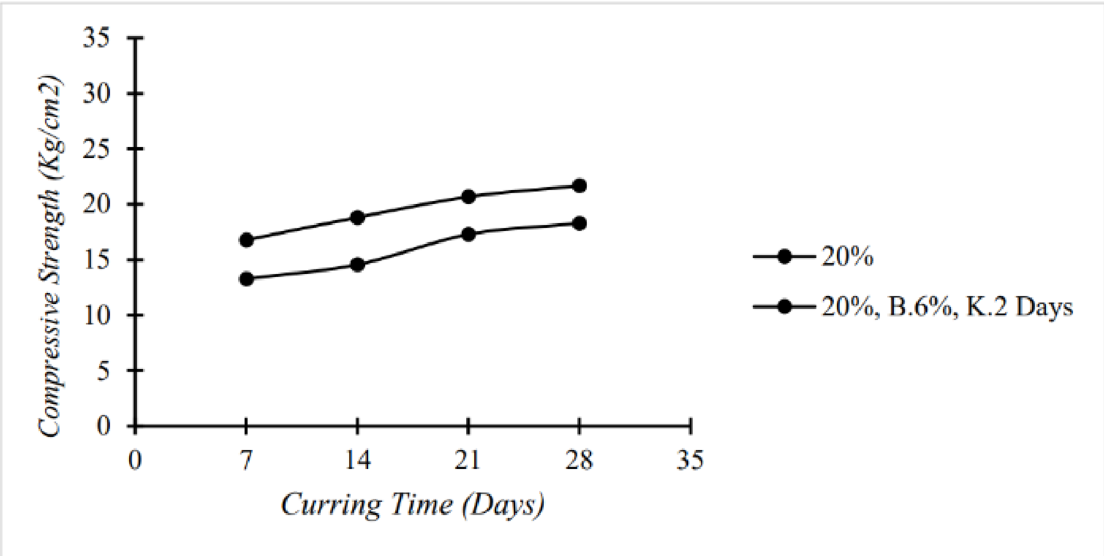

Figure 4. Chart of the compressive strength of bricks with bacterial variation of 2 days aging period

From the results of the compressive strength of 20% mud variation bricks and the addition of 6% bacteria with a culture period of 2 days, it is known that the compressive strength has increased in each period. Revealed that adding bacteria to the test specimen can increase compressive strength, at each period of bacterial culture [10]. The highest compressive strength results are found at the age of 28 days amounting to 21.68 kg/cm². The compressive strength increased by 3.39% of the compressive strength value of 20% bricks without the addition of bacteria.

c. Compressive strength test results of mud and bacteria variation bricks with 4-day culture period

This brick compressive strength test uses a 20% mud and 6% Bacillus subtilis bacteria with 4 days culture period.

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Table 10. Data on the results of the compressive strength test of mud bricks with the addition of bacteria

No	Curring (Days)	Tool Reading (kN)	Compressive Strength Brick (kg/cm²)
1	7 Day	10,3	18,96
2	14 Day	11,4	21,30
3	21 Day	13,3	24,92
4	28 Day	15,1	28,11

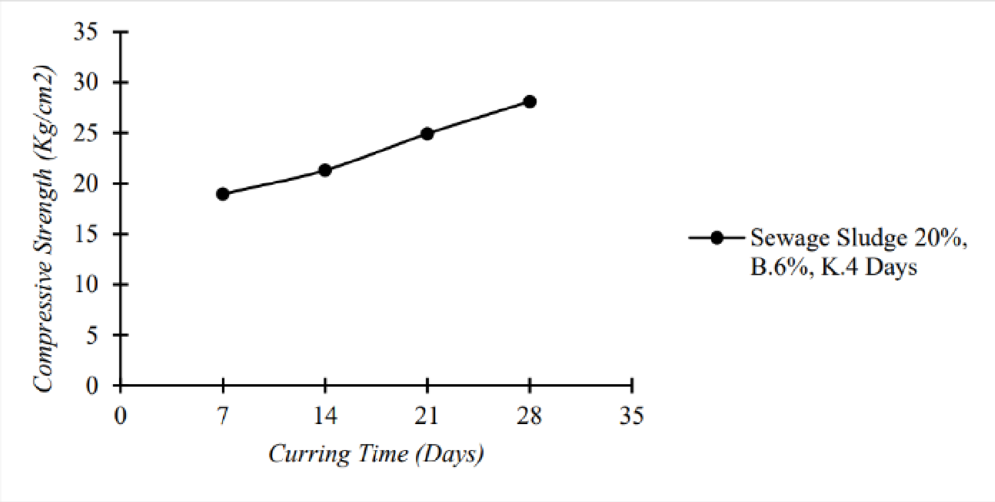

Figure 5. Chart of the compressive strength of bricks with bacterial variation of 4 days aging period

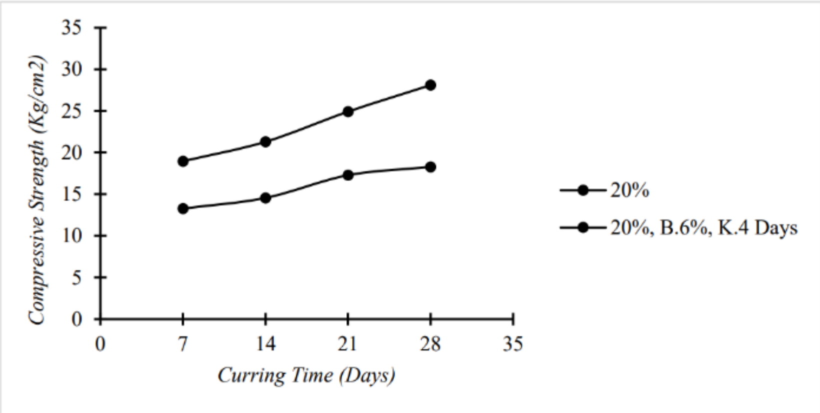

Figure 6. Chart of the compressive strength of bricks with bacterial variation of 4 days aging period

From the results of the compressive strength of 20% mud variation bricks and adding 6% bacteria with a 4-day culture period in Table 10 that has been tested, it can be seen that the compressive strength has increased in each of the peramnya period. The table can also explain that adding 6% bacteria with a 4-day culture period can increase the compressive strength of bricks by 6.4%, the increase occurs because the bacteria contained in the 4-day culture period have entered the stationary phase. The highest compressive strength value in the 28-day curing period is 28.11% (increased from the 4-day culture compressive strength value of 6.43%).

d. Compressive strength test results of mud and bacteria variation bricks with 6 days culture period

This brick compressive strength test uses a 20% mud and 6% Bacillus subtilis bacteria with 6 days culture period.

Table 11. Data on the results of the compressive strength test of mud bricks with the addition of bacteria

No	Curring (Days)	Tool Reading (kN)	Compressive Strength Brick (kg/cm²)
1	7 Day	6,2	11,28
2	14 Day	7,1	13,01
3	21 Day	8,4	15,35
4	28 Day	9,8	18,16

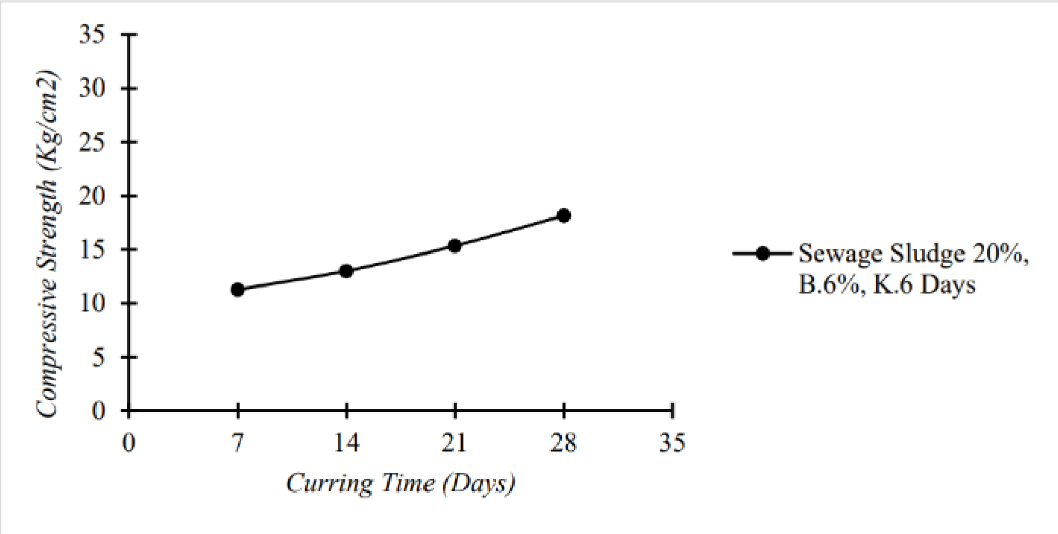

Figure 7. Chart of the compressive strength of bricks with bacterial variation of 6 days aging period

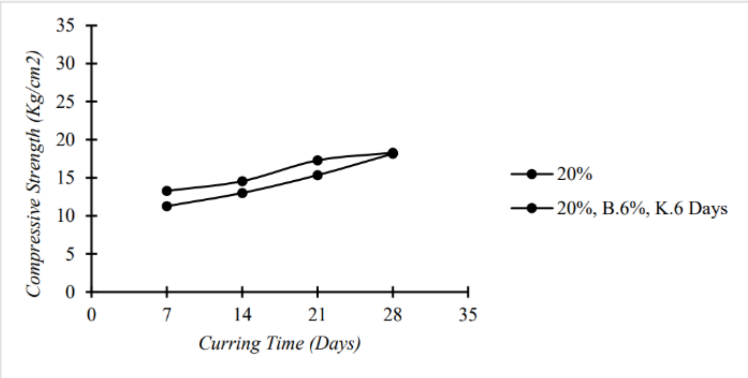

Figure 8. Chart of the compressive strength of bricks with bacterial variation of 6 days aging period

From the results of the compressive strength of 20% mud variation bricks and adding 6% bacteria with a 6-day culture period in Table 11 that has been tested, it can be seen that the compressive strength has increased in each of the periods but has decreased in comparison with the culture period of 2 and 4 days. This is because the bacteria contained in the 6-day culture period have many dead or reduced bacteria and also environmental conditions make bacteria unable to grow and develop again. The highest compressive strength value in the 28-

day period is 18.16% (decreased from the compressive strength value of the 2-day culture by 3.52% and 4 days by 9.95%).

e. Compressive strength test results of mud and bacteria variation bricks

The following test results are the compressive strength test of bricks with the presentation of mud and bacteria variations.

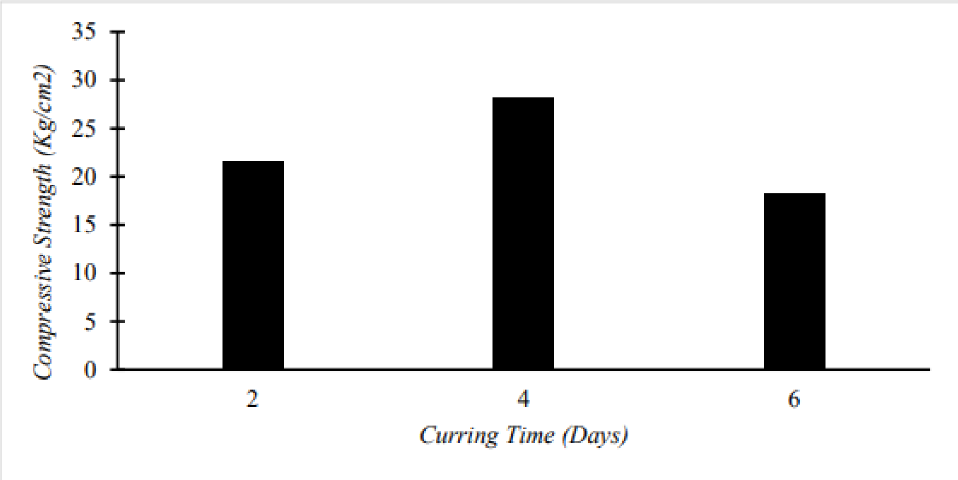

Figure 9. Graph of the results of brick compressive strength of variation and bacterial culture

From the compressive strength graph diagram in Figure 9, it is known that the results of the compressive strength of bricks using a mixture of bacterial reinforcement have increased and decreased in each of their culture periods. as can be seen the results of compressive strength using bacterial reinforcement with the culture period getting the highest value in the 4-day culture period. This is because the bacteria that live in the 4-day culture period have entered the stationary phase. So that the results of compressive strength during the culture period get the highest value compared to the two bacterial culture periods, namely culture 2 days and 6 days.

Results of Analysis of visible properties of bricks

The results of the analysis of the visible properties of bricks in the 28-day curing period can be seen in the following table

Table 12. visible traits before fermentation and after fermentation

Types of Bricks	Apparent properties before the Holding Period	Apparent properties after the maturation period
Sludge 20%		
20% Sludge, 6% Bacteria, 2 Days Culture		
20% Sludge, 6% Bacteria, 4 Days Culture		

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20% Sludge, 6% Bacteria, 6 Days Culture		

Table 13. bricks after compressive strength

Types of Bricks	visible properties After compressive strength	Visible properties
Sludge 20%		Cream colored bricks, has large cracks on the surface
20% Sludge, 6% Bacteria, 2 Days Culture		Cream colored bricks, has slight cracks on the surface
20% Sludge, 6% Bacteria, 4 Days Culture		Cream colored bricks, experienced less cracking on the side sides.
20% Sludge, 6% Bacteria, 6 Days Culture		Cream colored bricks, has cracks on the upper side

CONCLUSION

The results of the research that has been done show that with the addition of mud variations in brick making tests have decreased compressive strength results by 3.14%. The maximum compressive strength value in the addition of 20% mud occurs at 28 days with a value of 18.29%. And the minimum compressive strength value is in the 7-day period of 13.28%. The addition of 6% Bacillus subtilis bacteria in each culture period makes the compressive strength results increase from the compressive strength value of normal bricks without mixture variations. The compressive strength value with the bacterial culture period produces the maximum compressive strength value in the 4-day culture period with a 28-day curing period. The strong value produces a value of 28.11%. While in the culture period of 2 and 6 days the compressive strength produces a lower value than the 2-day culture period. Even so, all the results of compressive strength in the testing of unburned bricks with the presentation of variations in the mixture do not match the value of the compressive strength of bricks in accordance with SNI 15-2094-2000, which is 50 kg/cm².

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