# 1.k. Characterization of Brick Made From Sewage Sludge of Water Treatment Installation 2 Pdam Bandarmasih as a Construction Material

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# Characterization of Brick Made From Sewage Sludge of Water Treatment Installation 2 Pdam Bandarmasih as a Construction Material

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***ABSTRACT:*** *The increasing price of light brick and clay brick quality, it is deemed necessary to make bricks using materials that are cheaper and easier to obtain, namely by utilizing sludge of Water Treatment Installation 2 PDAM Bandarmasih. For this reason, a study is needed to utilize the abundant sludge waste, while also aiming to reduce the negative effects caused by the accumulation of sludge.*
*This study aims to determine the physical and mechanical characteristics of bricks made from sludge of Water Treatment Installation 2 PDAM Bandarmasih.*
*Based on this research obtained that most of the visual physical characteristics did not meet the requirements of SNI 15-2094-2000, because the bricks produced were uneven and cracked. There is no brick size that meets the SNI 15-2094-2000 requirements because the bricks are experiencing considerable depreciation. The salt crystal content meets NI-10, 1978 requirements, so it is in the no hazard category. For mechanical characteristics only apparent density that meets SNI 15-2094-2000 requirements, while compressive strength and water absorption do not meet the requirements.*

***KEYWORDS:*** *sludge, brick, characteristics*

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## I. INTRODUCTION

Banjarmasin City is currently experiencing rapid economic growth, especially in the trade and services sector. As a result, many buildings appear, such as shop houses, malls and housing. This causes an increasing need for building materials, especially bricks.

Increasing the price of light brick and clay brick quality due to the cost of procurement of materials that are not cheap, it is deemed necessary to make bricks using materials that are cheaper or even can be obtained free of charge, namely by utilizing materials or waste that is not used anymore. One source of material that is not utilized and the amount is very much is the sludge of Water Treatment Installation 2 PDAM Bandarmasih.

Based on data obtained from PDAM Bandarmasih that at Water Treatment Installation 2 located on Pramuka Street Complex Dharma Tirta Km. 6 Banjarmasin City, South Kalimantan Province, Indonesia, in one year, about 1,752.96 $m^3$ of solid sludge waste can be used as material for brick making. Until now, the sludge waste is just thrown away in a storage area and is not utilized, so that if left unchecked it will potentially become a pile of sludge waste. In addition, PDAM Bandarmasih needs to continue to increase the holding land as a result of the increasing number of sludge. Therefore there needs to be a study to utilize the abundant sludge waste.

This study aims to determine the physical and mechanical characteristics of bricks made from sludge of Water Treatment Plant 2 PDAM Bandarmasih.

## II. LITERATURE REVIEW

A brick is a part of a building used to make a building made from clay with or without a mixture of materials intended for building construction and which is made from the soil with or without a mixture of other materials which are then burned at high temperatures so that it cannot be destroyed again when immersed in water.

Brick Standard

2.1 Visibility

Brick for wall must have visible properties, which are rectangular prism-shaped, have elbow-shaped and flat-shaped and do not show cracks.

2.2 Size

The brick standards in Indonesia by the National Standard Agency, SNI 15-2094-2000 set the standards for the size and tolerance of solid brick for wall as listed in Table 1.

**Tabel 1.** Size and Tolerance of Solid Brick for Wall.

| Model | Tickness (mm) | Width (mm) | Length (mm) |
|---|---|---|---|
| M-5a | 65 ± 2 | 92 ± 2 | 190 ± 4 |
| M-5b | 65 ± 2 | 100 ± 2 | 190 ± 4 |
| M-6a | 52 ± 3 | 110 ± 2 | 230 ± 5 |
| M-6b | 55 ± 3 | 110 ± 2 | 230 ± 5 |
| M-6c | 70 ± 3 | 110 ± 2 | 230 ± 5 |
| M-6d | 80 ± 3 | 110 ± 2 | 230 ± 5 |

2.3 Compressive Strength

The average compressive strength and coefficient of variation allowed for solid brick for wall according to the compressive strength value. The compressive strength of bricks based on SNI 15-2094-2000 can be seen in Table 2.

**Tabel 2.** The Average Compressive Strength and Variation Coefficient for Solid Bricks for Wall.

| Class | The minimum average compressive strength of 30 bricks tested | | Coefficient of variation of the average compressive strength tested (%) |
|---|---|---|---|
| | kg/cm$^2$ | MPa | |
| 50 | 50 | 5 | 25 |
| 100 | 100 | 10 | 15 |
| 150 | 150 | 15 | 15 |

2.4 Harmful Salt

According to NI-10, 1978 there are 3 criteria for salt content in bricks, that is:

a. No harm, if the area of the salt crystal white layer is less than 50% and the thin layer.

b. Possibly harm, if the area of the white salt crystal is more than or equal to 50% and the layer is rather thick, but the brick parts do not become powder.

a. Harmfull, if the area of the white salt crystal is greater than 50% and thick and the brick parts become powder.

2.5 Apparent Density

Apparent density is defined as the quotient between the weight of the specimen which is dried in the oven for 24 hours at a temperature (110 ± 5) $^{o}$C with the difference between the weight of the saturated specimen in the air and in the water, then multiplied by water density value, which is 1.0 g/cm$^3$. Based on SNI 15-2094-2000 the minimum apparent density value of solid brick for wall is 1.2 g/cm$^2$.

2.6 Water Absorption

Water absorption is defined as the difference between the weight of the saturated specimen in the water with the weight of the oven dry specimen then divided by the weight of the oven dry specimen. Oven dry specimens are specimens that are dried in an oven at a temperature of (100-110) $^{o}$C for 24 hours until the weight remains. The maximum water absorption value of bricks for wall based on SNI 15-2094-2000 is 20%.

## III. MATERIALS AND RESEARCH METHODS

3.1 Materials

The material for making bricks is sludge from raw water that has been compacted at the Water Treatment Installation 2 PDAM Bandarmasih is located on Pramuka Street Complex Tirta Dharma Km. 6 Banjarmasin City, South Kalimantan Province, Indonesia and PDAM water used in the process of dozing the material so that the texture becomes homogeneous. The Water Treatment Installation 2 PDAM Bandarmasih and solid sludge waste as shown in Figure 1.


**Figure 1**. Water Treatment Installation 2 PDAM Bandarmasih and Solid Sludge Waste

3.2 Research Methods

The stages in this study can be described in the form of a flowchart as Figure 2.

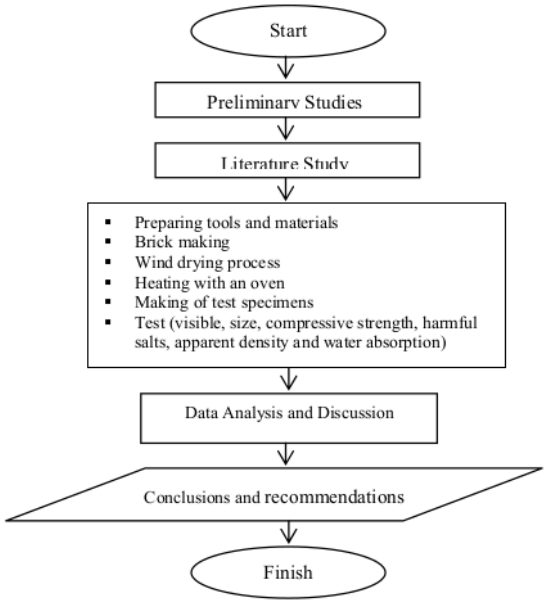


**Figure 2.** Research Flow Chart

## IV. RESULT AND DISCUSSION

4.1 Visibility Analysis

4.1.1 The Bricks Visibility in Oven-Dry Condition

Based on the visible properties test results of the bricks in oven-dry condition as listed in Table 3, it was found that of the 10 bricks tested none of them met the flat-shape, elbow-shape and has no cracks as required in SNI 15-2094-2000. Although out of the 10 bricks there are 7 pieces (70%) bricks that have a flat-shape and all bricks (100%) have an elbow-shape, all bricks are considered not to meet the SNI 15-2094-2000 standards because all bricks have cracks which cracks included in the weight category. The bricks visibility test in oven-dry condition as shown in Figure 3.

**Figure 3.** The Brick Visibility Test in Oven-Dry Condition

**Table 3.** The Bricks Visibility Test Results in Oven-Dry Condition

| Specimens (*i*) | The Bricks Visible Characteristics in Oven-Dry Condition | | | | | | | | Description |
|---|---|---|---|---|---|---|---|---|---|
| | Flatness | | Elboweness | | Crackness | | | | |
| | Yes | No | Yes | No | High | Medium | Low | Nothing | |
| S1 | V | | V | | V | | | | Doesn't meet |
| S2 | | V | V | | V | | | | Doesn't meet |
| S3 | | V | V | | V | | | | Doesn't meet |
| S4 | V | | V | | V | | | | Doesn't meet |
| S5 | V | | V | | V | | | | Doesn't meet |
| S6 | V | | V | | V | | | | Doesn't meet |
| S7 | | V | V | | V | | | | Doesn't meet |
| S8 | V | | V | | V | | | | Doesn't meet |
| S9 | V | | V | | V | | | | Doesn't meet |
| S10 | V | | V | | V | | | | Doesn't meet |
| Total | 7 | 3 | 10 | 0 | 10 | 0 | 0 | 0 | |

4.1.2 The Bricks Visibility in Wind-Dry Condition

Based on the visible properties test results of the bricks in wind-dry condition as listed in Table 4, it was found that of the 10 bricks tested there were 5 (50%) bricks that met the flat-shape, elbow-shape and has no cracks as required in SNI 15-2094-2000. Out of these 10 bricks, there are 7 bricks (70%) that have a flat-shape, 3 bricks (30%) with curved-shape, 10 bricks (100%) have elbow-shape, 5 (50%) light cracked bricks and 5 (50%) bricks with no cracks at all. The brick visibility test in wind-dry condition as shown in Figure 4.

**Figure 4.** The Bricks Visibility Test in Wind-Dry Condition

**Table 4**. The Bricks Visibility Test Results in Wind-Dry Condition

| Specimens (*i*) | The Bricks Visible Characteristics in Wind-Dry Condition | | | | | | | | Description |
|---|---|---|---|---|---|---|---|---|---|
| | Flatness | | Elboweness | | Crackness | | | | |
| | Yes | No | Yes | No | High | Medium | Low | Nothing | |
| S11 | V | | V | | | | V | | Doesn't meet |
| S12 | V | | V | | | | | V | Meet |
| S13 | V | | V | | | | V | | Doesn't meet |
| S14 | V | | V | | | | | V | Meet |
| S15 | | V | V | | | | V | | Doesn't meet |
| S16 | | V | V | | | | V | | Doesn't meet |
| S17 | V | | V | | | | | V | Meet |
| S18 | V | | V | | | | | V | Meet |
| S19 | | V | V | | | | V | | Doesn't meet |
| S20 | V | | V | | | | | V | Meet |
| Total | 7 | 3 | 10 | 0 | 0 | 0 | 5 | 5 | |

4.2 Size Analysis

4.2.1 The Bricks Size in Oven-Dry Condition

Based on the test results of the length, width and thickness of 10 bricks in oven-dry condition, the results obtained are listed in Table 5 where the average value of the length, width and thickness of bricks do not meet the standard size and tolerance as required in SNI 15-2094-2000 for all brick models. This is indicated by the difference in the average value of the length, width and thickness of the brick against the standard model size of SNI 15-2094-2000, far greater than the tolerance value of the permitted size.

**Table 5.** The Bricks Size Test Results in Oven-Dry Condition

| Model | Average length (mm) | Δ $p_{allowed}$ (mm) | Δ p (mm) | Average width (mm) | Δ $l_{allowed}$ (mm) | Δ l (mm) | Average thickness (mm) | Δ $t_{allowed}$ (mm) | Δ t (mm) | Description |
|---|---|---|---|---|---|---|---|---|---|---|
| Test object | 160.4 | - | - | 82.3 | - | - | 32.0 | - | - | |
| M-5a | 190.0 | 4.0 | 29.6 | 92.0 | 2.0 | 9.7 | 65.0 | 2.0 | 33.0 | Doesn't meet |
| M-5b | 190.0 | 4.0 | 29.6 | 100.0 | 2.0 | 17.7 | 65.0 | 2.0 | 33.0 | Doesn't meet |
| M-6a | 230.0 | 5.0 | 69.6 | 110.0 | 2.0 | 27.7 | 52.0 | 3.0 | 20.0 | Doesn't meet |
| M-6b | 230.0 | 5.0 | 69.6 | 110.0 | 2.0 | 27.7 | 55.0 | 3.0 | 23.0 | Doesn't meet |
| M-6c | 230.0 | 5.0 | 69.6 | 110.0 | 2.0 | 27.7 | 70.0 | 3.0 | 38.0 | Doesn't meet |
| M-6d | 230.0 | 5.0 | 69.6 | 110.0 | 2.0 | 27.7 | 80.0 | 3.0 | 48.0 | Doesn't meet |

The material used in making these bricks is sludge from Water Treatment Installation 2 PDAM Bandarmasih which has fine grained characteristic, high shrinkage and more sensitive to temperature rises than non-plastic soil. Shrinkage of the bricks size that is heated using an oven is smaller than the bricks that are dried by the wind, because the outflow of water in the soil pore is greater than the shrinkage rate of the soil, consequently the shrinkage of the brick volume is reduced and the brick becomes less dense.

4.2.2 The Bricks Size in Wind-Dry Condition

Based on the test results of the length, width and thickness of 10 brick in wind-dry condition obtained the results as listed in Table 6 where the average value of the length, width and thickness of the bricks do not meet the standard size and tolerance as required in SNI 15- 2094-2000 for all brick models. This is indicated by the difference in the average value of the length, width and thickness of the brick against the standard model size of SNI 15-2094-2000, far greater than the tolerance value of the size permitted.

**Table 6.** The Bricks Size Test Results Wind-Dry Condition

| Model | Average length (mm) | Δ $p_{allowed}$ (mm) | Δ p (mm) | Average width (mm) | Δ $l_{allowed}$ (mm) | Δ l (mm) | Average thickness (mm) | Δ $t_{allowed}$ (mm) | Δ t (mm) | Description |
|---|---|---|---|---|---|---|---|---|---|---|
| Test object | 151.3 | - | - | 77.4 | - | - | 30.8 | - | - | |
| M-5a | 190.0 | 4.0 | 38.7 | 92.0 | 2.0 | 14.6 | 65.0 | 2.0 | 34.2 | Doesn't meet |
| M-5b | 190.0 | 4.0 | 38.7 | 100.0 | 2.0 | 22.6 | 65.0 | 2.0 | 34.2 | Doesn't meet |
| M-6a | 230.0 | 5.0 | 78.7 | 110.0 | 2.0 | 32.6 | 52.0 | 3.0 | 21.2 | Doesn't meet |
| M-6b | 230.0 | 5.0 | 78.7 | 110.0 | 2.0 | 32.6 | 55.0 | 3.0 | 24.2 | Doesn't meet |
| M-6c | 230.0 | 5.0 | 78.7 | 110.0 | 2.0 | 32.6 | 70.0 | 3.0 | 39.2 | Doesn't meet |
| M-6d | 230.0 | 5.0 | 78.7 | 110.0 | 2.0 | 32.6 | 80.0 | 3.0 | 49.2 | Doesn't meet |

The bricks have a high shrinkage caused by the material used as a material for making bricks is soil from sludge of Water Treatment Installation 2 PDAM Bandarmasih which has a high shrinkage. The bricks that are dried by the wind will shrink more than bricks that are burned or roasted, because the water coming out of the soil pore slowly is proportional to the rate of shrinkage of the soil, this causes the bricks to shrink maximally and become denser.

4.3 Compressive Strength Analysis

Based on the compressive strength test results obtained the average compressive strength value of 17.79 kg/cm$^2$, as listed in Table 7. The average compressive strength value of bricks does not meet the SNI 15-2094-2000 standard, where the minimum compressive strength value of 30 bricks tested for the lowest class, which the lowest compressive strength of class 50 is 50 kg/cm$^2$. The bricks compressive strength test as shown in Figure 5.

**Figure 5.** The Bricks Compressive Strength Test

**Table 7.** The Bricks Compressive Strength Test Results

| Specimen | Dimension | | Compressive Force | Press Area | Compressive Strength | |
|---|---|---|---|---|---|---|
| | Panjang (cm) | Lebar (cm) | (kN) | cm$^2$ | kN/cm$^2$ | kg/cm$^2$ |
| P1 | 7.5 | 7.5 | 12.0 | 56.25 | 0.21 | 20.92 |
| P2 | 7.0 | 7.5 | 10.0 | 52.50 | 0.19 | 18.68 |
| P3 | 7.3 | 7.5 | 12.0 | 54.75 | 0.22 | 21.49 |
| P4 | 7.5 | 7.5 | 12.0 | 56.25 | 0.21 | 20.92 |
| P5 | 7.3 | 7.5 | 12.0 | 54.75 | 0.22 | 21.49 |
| P6 | 7.0 | 7.5 | 14.0 | 52.50 | 0.27 | 26.15 |
| P7 | 7.5 | 7.5 | 8.0 | 56.25 | 0.14 | 13.95 |
| P8 | 7.8 | 7.8 | 10.0 | 60.84 | 0.16 | 16.12 |
| P9 | 7.5 | 7.4 | 10.0 | 55.50 | 0.18 | 17.67 |
| P10 | 7.5 | 7.2 | 8.0 | 54.00 | 0.15 | 14.53 |
| P11 | 8.3 | 8.0 | 10.0 | 66.40 | 0.15 | 14.77 |
| P12 | 7.3 | 7.8 | 12.0 | 56.94 | 0.21 | 20.67 |
| P13 | 7.5 | 7.8 | 12.0 | 58.50 | 0.21 | 20.12 |
| P14 | 7.2 | 7.5 | 14.0 | 54.00 | 0.26 | 25.42 |
| P15 | 7.5 | 7.8 | 12.0 | 58.50 | 0.21 | 20.12 |

| | | | | | | |
|---|---|---|---|---|---|---|
| P16 | 7.4 | 7.6 | 10.0 | 56.24 | 0.18 | 17.44 |
| P17 | 7.7 | 7.5 | 10.0 | 57.75 | 0.17 | 16.98 |
| P18 | 7.2 | 7.2 | 10.0 | 51.84 | 0.19 | 18.92 |
| P19 | 7.7 | 7.8 | 10.0 | 60.06 | 0.17 | 16.33 |
| P20 | 7.5 | 7.5 | 12.0 | 56.25 | 0.21 | 20.92 |
| P21 | 7.2 | 7.5 | 8.0 | 54.00 | 0.15 | 14.53 |
| P22 | 7.3 | 7.7 | 8.0 | 56.21 | 0.14 | 13.96 |
| P23 | 8.2 | 8.2 | 10.0 | 67.24 | 0.15 | 14.58 |
| P24 | 7.6 | 7.4 | 8.0 | 56.24 | 0.14 | 13.95 |
| P25 | 7.2 | 7.3 | 10.0 | 52.56 | 0.19 | 18.66 |
| P26 | 7.5 | 7.5 | 10.0 | 56.25 | 0.18 | 17.43 |
| P27 | 7.7 | 7.5 | 8.0 | 57.75 | 0.14 | 13.58 |
| P28 | 7.7 | 7.5 | 8.0 | 57.75 | 0.14 | 13.58 |
| P29 | 7.0 | 7.5 | 6.0 | 52.50 | 0.11 | 11.21 |
| P30 | 7.0 | 7.5 | 10.0 | 52.50 | 0.19 | 18.68 |
| | | Average | | | 0.18 | 17.79 |

The compressive strength value of the bricks is very low because sludge of Water Treatment Installation 2 PDAM Bandarmasih which is used as material for making the bricks has fine-grained characteristic, loose and high water absorption. Excessive water content in the bricks structures can reduce the bonding capacity between soil particles, thereby reducing the compressive strength of the bricks.

4.4 Harmful Salt Analysis

The bricks used in the harmful-salt test are bricks that are dried by the wind. This test is done by checking how much salt crystals cover on the brick surface. Based on test results of 5 bricks obtained 100% of bricks have a salt crystal surface area of less than 50% of the total surface area of the bricks, so according to NI-10, 1978 these bricks are categorized as not harm. The harmful salt test results can be seen in Table 8. Soaking bricks for salt crystal observation can be seen in Figure 6.

**Figure 6.** Soaking Bricks for Salt Crystals Observation

Table 8. The Bricks Harmful Salt Test Result

| Specimens (*i*) | Percentage of Salt Crystals Area on the Bricks Surface | | | Description |
|---|---|---|---|---|
| | < 50% (Thin crystal layer) | ≥ 50% (Rather thick crystal layer) | > 50% (Thick crystal layer) | |
| G1 | V | - | - | No harm |
| G2 | V | - | - | No harm |
| G3 | V | - | - | No harm |
| G4 | V | - | - | No harm |
| G5 | V | - | - | No harm |
| Total | 5 | 0 | 0 | |

The Sludge of Water Treatment Installation 2 PDAM Bandarmasih as the material for making bricks is formed from weathering feldspatic rocks that move very large distances from the main rock. On the way due to water and wind, this soil is mixed with organic and an organic materials, thus changing the chemical and physical properties of clay into particles that produce finer and more plastic clay. In the process of forming this soil type is not dominated by elements that contain high levels of salt.

4.5 Apparent Density Analysis

Based on the apparent density test results was obtained the average of apparent density value is 1.33 g/cm$^3$. The apparent density value of bricks meets SNI 15-2094-2000 because it is higher than the minimum apparent density value required in SNI 15-2094-2000, which is 1.2 g/cm$^3$. The apparent density test results of 10 bricks can be seen in Table 9. The brick apparent density test as shown in Figure 7.


**Figure 7.** The Brick Apparent Density Test

**Table 9**. The Brick Apparent Density Test Results

| Specimens (a) | Weight | | | $Q_{sch}$ |
|---|---|---|---|---|
| | Dry (g) | SSD (g) | In the Water (g) | |
| (a) | (b) | (c) | (d) | e = (b (c-d))* 1 g/cm$^3$ |
| D1 | 449.3 | 552.1 | 214.7 | 1.33 |
| D2 | 457.2 | 554.7 | 215.6 | 1.35 |
| D3 | 495.1 | 599.4 | 230.1 | 1.34 |
| D4 | 466.1 | 569.5 | 219.8 | 1.33 |
| D5 | 446.5 | 541.6 | 210.2 | 1.35 |
| D6 | 453.3 | 552.4 | 213.7 | 1.34 |
| D7 | 411.5 | 514.5 | 183.5 | 1.24 |
| D8 | 486.5 | 585.3 | 224.1 | 1.35 |
| D9 | 470.2 | 574.5 | 223.5 | 1.34 |
| D10 | 506.2 | 617.4 | 239.6 | 1.34 |
| | | | Average | 1.33 |

The average of apparent density value of bricks meets the minimum apparent density value standard required in SNI 15-2094-2000. The soil from sludge of Water Treatment Installation 2 PDAM Bandarmasih as brick making material has fine grained characteristic and high shrinkage, so when it is perfectly dry, this soil will solidify optimally and be resulting a high apparent density material.

4.6 Water Absorption Analysis

Based on the water absorption test results was obtained the average value of water absorption is 22.01%. The value of water absorption of bricks does not meet the requirements of SNI 15-2094-2000 because the value of water absorption is higher than the maximum water absorption required in SNI 15-2094-2000, which is 20%. The water absorption test results of 10 bricks can be seen in Table 10. The bricks water absorption test as shown in Figure 8.

**Figure 8**. The Bricks Water Absorption Test

**Table 10.** The Brick Water Absorption Test Results

| Specimens (*i*) | Weight | | Water Absorption (%) |
|---|---|---|---|
| | In the Water (g) | Dry (g) | |
| (a) | (b) | (c) | (d) = ((b-c) c)*100 |
| D1 | 552.1 | 449.3 | 22.88 |
| D2 | 554.7 | 457.2 | 21.33 |
| D3 | 599.4 | 495.1 | 21.07 |
| D4 | 569.5 | 466.1 | 22.18 |
| D5 | 541.6 | 446.5 | 21.30 |
| D6 | 552.4 | 453.3 | 21.86 |
| D7 | 514.5 | 411.5 | 25.03 |
| D8 | 585.3 | 486.5 | 20.31 |
| D9 | 574.5 | 470.2 | 22.18 |
| D10 | 617.4 | 506.2 | 21.97 |
| | | | 22.01 |

The average water absorption value of bricks does not meet the maximum water absorption standard required in SNI 15-2094-2000, because the soil from sludge of Water Treatment Installation 2 PDAM Bandarmasih as material for making bricks has high water absorption characteristic, so that even when condition are dry the ability of soil water absorption is not lost.

## V. CONCLUSIONS AND SUGGESTIONS

Based on the results of this study it is known that the sludge in the Water Treatment Installation 2 PDAM Bandarmasih with a 100% content cannot be used as brick making material, so it needs to be added with other materials in order to produce better bricks. This is evidenced from the results of testing the physical and mechanical character of many bricks that do not meet the standards. Therefore it is necessary to have further studies on what materials can be mixed with sludge as material for making bricks, so that the resulting bricks are of high quality according to the expected standards.

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# 1.k. Characterization of Brick Made From Sewage Sludge of Water Treatment Installation 2 Pdam Bandarmasih as a Construction Material

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