International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 21 (2018) pp. 15060-15067

The Effect of Sediment Powder Addition on Compressive Strength, Sodium Sulfate Resistance, and Water Absorption in Paving Block

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Abstract

The use of sediment waste as an added material for the making of *Paving Blocks* has many advantages, such as lower price and the ability to strengthen concrete bricks, so that it can be used in the area of city parks, sidewalks, roads and parking lots.

This research aimed to find out the characteristics and strength of the structure of paving blocks (concrete bricks) in terms of compressive strength, sodium sulfate resistance and water absorption percentage using sedimentary mud taken from Kendari bay. This research used experimental method by making normal and special specimens and adding sediments as much as 5%, 10%, 15% and 20% with rectangular and worm paving block models. There were also laboratory tests performed, including: quality of material test by using the Indonesian National Standards (SNI)-T-15-1990-03, mud level test, organic materials test, testing of Bulk Specific Gravity test, Saturated Surface Dry (SSD) value test, brick compressive strength test, resistance to sodium sulfate test, and water absorption test. The results showed that the addition of 15% sediment powder obtained the highest and the lowest concrete compressive strength of 16,64 MPa and 13,65 MPa (10% sediment content), respectively, with a worm paving block models. For water absorption test, the water absorption ability of paving blocks in a certain time and at 28 days old with 5% sediment content of 9,49% still met the standards required by SNI which should be in a range between 3% - 10%. The results of the test on sodium sulfate resistance in paving blocks showed exceed the normal limits of paving blocks and the highest result was obtained in the 20% mixture at 10,59% in the three-diamond model.

Keywords: Sediment, Paving Block, Compressive Strength, Sodium Resistance, Water Absorption.

INTRODUCTION

The research conducted by the researchers from the UHO Environmental Research Center (2014) showed that the availability of Kendari bay sediments in the form of mud and materials sourced from the Wanggu, Kambu, and Mandong Rivers contributed to the largest sedimentation of about 1.330.281 m3/year with a silting rate of 0,207 m/year. The availability of Kendari bay sedimentation has reached 90 million tons and will cause Kendari bay to become land and endanger the sustainability of the surrounding ecosystem [7]. Until now, Kendari bay sediments have not been used properly. The empowerment of local resources, for example, by utilizing mud waste or sediment, will certainly reduce environmental pollution and can be used as an alternative building materials. Kendari bay sediments will be powdered which later will be the right solution as an alternative material or substitution for cement. The use of Kendari bay sediment powder will be able to reduce the use of cement as well as an alternative to the use of Kendari bay sediment which has been a waste and can cause continuous damage to the surrounding environment.

Based on the results of experiment conducted in laboratory scale in the period of 2016-2017, it is very possible that the sediment of Kendari bay can be used for making supporting materials for building construction, one of which is paving blocks and bricks. It is expected that paving blocks using sediment mixture will have greater power than the existing ones so far. The economic value of the Kendari bay sediment as a building material will be an alternative building material that will enhance the empowerment of local natural resources in the environment around us. Various types of paving blocks are expected to be used as road surface pavement for yards, parking areas, highways and decorations for garden. In addition, it can also be used in special areas such as container port, open field and industrial areas.

This study tried to utilize sediment powder as an additive and reduce cement in the manufacture of paving blocks and to find out the effect of the addition of sediment powder in reducing the percentage of cement on compressive strength, sodium sulfate effect and the application of water at the age of 7 and 28 days old paving blocks, so that the paving blocks produced in this study are expected to be useful and applied in the work of infrastructure development, especially for office or pedestrian parking areas, city parks and be able to carry heavier loads with the use of local materials optimally to be able to increase regional income.

LITERATURE REVIEW

A. Paving Block

Paving block is one of the building materials composed of cement, sand and water which is often used as road pavement. Road Pavement experience some innovation, one of which is the use of *Paving block*s as pavement materials replacing asphalt and concrete. As a pavement material, the *Paving*

*block*s used must have high compressive strength to avoid breaking when getting passed by vehicles. Some of the advantages in using Concrete Bricks (*Paving block*s) are material saving, lower price when compared to asphalt which is composed of layers of materials.

Table 1. Standards of Physical Strength of Paving Block

Quality	Utilization	Compressive Strength (Mpa)		Wear Resistance (mm/minute)		Average Water Absorption (%)
		Average	Min	Average	Min	
A	Road Pavement	40	35	0,09	0,103	3
B	Parking Lot	20	17	0,130	0,149	6
C	Pedestrian Zone	16	12,5	0,160	0,184	8
D	City Park	10	8,5	0,219	2510	10

Source: SNI 03-0691-1996

If a paving block is damaged at one point, it can be easily fixed by replacing the damaged block with a new one without having to replace all blocks. capacity because there is no use of cement but sand, which is useful as water absorption.

Paving blocks with good quality are those which have high compressive strength (MPa), as well as a low absorption rate (percentage of water absorption). In connection with these quality standards, the type of quality characteristics studied are the larger the better for compressive strength, and the smaller the better for the percentage of water absorption. The higher the compressive strength, the better the paving block. For the percentage of water absorption, the lower the absorption value, the stronger the paving block. Based on SNI 03–0691–1996, the lowest quality paving block (quality D) has at least a compression of 8,5 MPa and a maximum percentage of water absorption is 10%.

Paving block is a composition of building materials made from a mixture of portland cement or similar hydraulic adhesive materials, water and fine aggregates with or without other additional materials that do not reduce the quality of the paving blocks (SNI 03-0691-1996). Paving block is composed of water, cement and sand as for the quality requirements and the size of the Paving block visually paving block must have a flat surface, there are no cracks and defects, the corners and sides are not easily damaged by fingers. Paving blocks that are used for pedestrian zones, parking lots, parks and other purposes that do not receive heavy loads can use class III quality, by comparing the mixture of 1:5 between cement and sand [1,2,11].

The next step is compacting, followed by pressing with a certain intensity and the treatment is done by wetting the surface of the paving block and allowing it to be solid. As in other concrete manufacturing processes, the requirements for aggregates, cement and water must meet the requirements in the specifications of concrete materials. Especially for paving block molds in this study, there were 2 paving block models, namely rectangular and three-diamond models, as shown in the following figure:

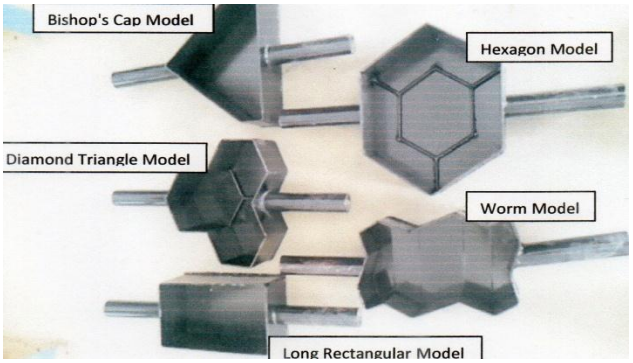


Figure 1. Paving block molds

Paving blocks must also have physical strength as per the standards set by SNI 03-0691-1996 according to table 1.

A. Portland Cement(PC)

Portland Cement is the core material for making paving block containing hydraulic calcium silicate, which is generally in the form of calcium sulfate as an additional material which is milled together with the main ingredients. The main function of cement is to bind fine aggregates to form a solid mass, to strengthen, and fill the air cavities between fine aggregates. This study used Tonasa cement from South Sulawesi Indonesia.

B. Fine Aggregates

Fine aggregates is a hard mineral granule of which shape is almost round, sharp and eternal with a grain size, mostly ranged between 0,07-5,00. Fine aggregate is used as a filling material for paving block mixture to increase strength, reduce shrinkage, and reduce the use of adhesive material/cement because the quality of fine aggregates determines the quality of paving blocks produced.

In order to produce good paving blocks, fine aggregates must meet the following requirements:

1) Fine aggregates must be composed of sharp and hard grains and have continuous gradations.
2) The large structure of grains has a smoothness modulus between 1,50-3,80.
3) The mud level/grain content is smaller than 0,07 m, 5% maximum.
4) Organic material content is determined with 3% sodium hydroxide.
5) Grain hardness must not be higher than 2,20.

C. The Characteristics of Kendari Bay Sediment

The characteristics of Kendari Bay sediment are dominated by 80% clay soil which is a soil with microcononic size derived from weathering of the chemical substances of rock constituents. The clay soil is very solid in dry conditions, and not easily peeled using fingers. The permeability of clay soil is very low and plastic in moderate water content. In order to overcome this problem, the processing and characteristics of sediment is performed by drying and crushing using a crusher.

The method of applying sediment was done by conducting initial characterization, namely by heating and sieving. The grain size of the sediment powder used was put through sieve 200 (grain size <0.075 mm). To remove various solvents and other unnecessary elements, such as carbon and sulfur, the sediment powder was then heated at 800 degrees Celsius for 4 hours to then be used as an addition to the mixture of Paving blocks.

The use of paving blocks must meet the quality requirements according to SNI 03-0691-1996, as follows:

a. Visibility, Paving Block must have a flat surface, as there should be no defective cracks, and the corners and sides should not be easily trimmed using fingers.

b. The size of a Paving Block must have a minimum nominal thickness of 60 mm with a tolerance of 8%

   Paving Block for floors should not be deformed and has maximum allowable weight loss of 1% with physical properties when getting tested using Sodium Sulfate.

c. Water

   In the mixture of paving block, water functions to help the chemical reactions that cause the binding process to take place. The use of water in the mixture must be appropriate since excessive use of water will cause a lot of water bubbles and after the hydration process is completed and this will reduce the strength of the produced paving blocks. Whereas, the lack of water will cause the hydration process failed, as it will affect the strength of the produced paving block.

METHODOLOGY

Laboratory tests in this study include quality of material test using SK-SNI-T-15-1990-03, namely mud level test, organic material test, bulk specific gravity test, saturated surface dry (SSD) test, compressive strength and water absorption tests. This research was conducted in the Kendari bay area, Southeast Sulawesi Province, with sediment sampling conducted at 3 (three) points in the area and the sediment used was the sediment which passed the filter no.200. This research was conducted at the Laboratory of Soil Mechanics and Laboratory of Building Materials and Structures of Department of Civil Engineering, Faculty of Engineering, Haluoleo University of Kendari.

This research was an experimental research that tested the quality of paving blocks by using sediment powder as a partial

replacement of cement. Then, the cement used was tonasa cement and fine aggregates used were from Pohara sand from Pohara river in Konawe district. Variations in the partial replacement of sediment were 5%, 10%, 15% and 20%. The characteristics in this research were compressive strength, sodium sulfate resistance, and water absorption. The specimens used were paving blocks with rectangular model in a size of 7 x 10 x 20 cm, 3 pieces of each variation, and three-diamond model in a size of 7 x 5 x 20 x15 cm, 3 pieces per variation. The total paving blocks sample can be seen in the table 2 below:

Table 2. Total Sample

No.	Replacement Percentage	Total Sample	
		Worm Model	Rectangular Model
1.	0%	3	3
2.	5%	3	3
3.	10%	3	3
4.	15%	3	3
5.	20%	3	3
Total Sample = 30			

A. Compressive Strength Test

This test was conducted by giving a load to the test object until it was damaged. With rectangular and bishop-cap mold models and following the procedures of SNI 03-0691-1996, the test was conducted in the following procedures:

1) Preparing the object that will be tested and weighed.
2) The test object is placed on a pressing machine with the position of the test object which has been set in such a way that the test object is right in the middle of the pressing device.
3) Load is given slowly on a continuous basis using a hydraulic machine until the test object getting cracked or damaged.
4) The maximum load shown by the pointer is recorded continuously.

The measurement of compressive strength for paving blocks was conducted according to SNI 03-0691-1996 standard on

paving block using the following formula:

$$fc = \frac{P}{A} \quad (1)$$

Where :

fc = Compressive Strength of Paving Block (kg/cm)

P = Maximum Compressive Strength (Kg)

A = Surface Area of Test Object (cm^2)

B. Water Absorption Test

The water absorption test was conducted after 28 days of paving block age to find out the percentage of water absorption of paving block, by conducting immersion for 24 hours, then drying at 105 degrees Celsius and weighing for 2 times until obtaining the final difference in weighing not more

than 0.2%. Then, the absorption value was calculated from the weight of wet paving block subtracted by the weight of dried

paving block, divided by the weight of dried paving block, then multiplied by 100% by using the following formula:

$$\text{Water Absorption} = \frac{A - B}{A} \times 100\% \quad (2)$$

Where:

Pa = Water Absorption(%)

A = Weight of Fresh Paving Block (gram)

B = Weight of Dried Paving Block(gram)

C. Sodium Sulfat Resistance Test

The test object was firstly cleaned from the dirts and was then dried in an oven at a temperature of 105^0 degrees until getting stable weight, and was then cooled. Sodium sulfate resistance test was conducted by soaking the paving block into saline sodium sulfate solution for 8 to 16 hours then washing the paving block using water and drying it. After getting the sample dried, the sample was then re-weighed and then soaked, repeated for 5 times, to find out the saline sodium sulfate resistance, whether getting damaged or was still intact according to SNI-03-0691 standards.

In order to speed up the washing process, it can also be done using hot water at a temperature of approximately 40- 50^0C. The test object was then dried in an oven. After the cooling, the sample was weighed to the level of accuracy of 0,1 gram. The state of the sample or test object was then observed to check whether there was any crack, cluster or other defect found after the immersion [13]. If the difference in weighing before and after soaking is not greater than 1% and the specimen is not defective, it can be stated that the test object is good, vice versa.

D. The Composition of Sediment Mixture

The mixture of paving blocks was done by trial and error in the laboratory. This method is the simplest, with a principle of making a mixture of paving blocks with a variety of different mixture compositions. The composition of the paving block mixture began with the use of no sediment then with a ratio between the use of cement and sandf for 1: 3 (1 kg of cement and 3 kg of sand), the composition is as follow:

The compositions of the mixture are as follows:

1. Composition with Sediment for 20% of the cement.

   (Cement:Sand:Sediment =0,80 :3:0,20)

2. Composition with Sediment for 15% of the cement.

   (Cement:Sand:Sediment =0,85:3:0,15)

3. Composition with Sediment for 10% of the cement.

   (Cement:Sand:Sediment =0,90:3:0,10)

4. Composition with Sediment for 5% of the cement.

   (Cement:Sand:Sediment =0,95:3:0,05)

Obtained at 3 points of the research location which included mechanical characteristics test and the results are shown in table 3:

Table 3. The Results of sediment sample test

Sediment Sample Test	Sediment Sampling Location		
	Point 1	Point 2	Point 3
Liquid Limit (LL) (%)	58,72	30,58	37,74
Plastic Limit (PL) (%)	39,87	23,51	28,34
Plastic Index (PI) (%)	18,85	7,07	9,40
Specific Gravity (Gs) gram/cm^3	2,45	2,68	2,66
Percentage of Passing the Sieve 200 (%)	79,63	81,22	75,43
Water content (%)	85,70	50,49	49,28

From the results of the test, the classification of Kendari bay sediment has the following characteristics:

1. Fine-grained soil is a type that is more than 50% of the weight of the soil sample that passed sieve no. 200
2. This sediment is part of saturated soil where the porous space is filled with water so that it does not require much water because the water content in the sediment content is quite high.
3. The test of sediment grain size was conducted by sieving using sieve no. 200 and >50% of the test object passed, as the sieved and sediment granules were classified into fine gradations or Clay and Silt categories.
4. Based on the test of Atterberg limits, according to UNIFIED's soil classification, in order to determine the soil plasticity, the sediment was classified in inorganic clay type with high plasticity (CH).

A. Results of The Test of Characteristics of Pohara Sand

Based on the results of sieve analysis for the fine aggregates of Pohara Sand, the results are shown in table 4 below:

Table.4 The results of sieve analysis of fine aggregates of Pohara sand

Sieve No.	Sieved Weight (gram)	TotalSieved %	
		Sieved	Passed
4	101	10,1	100
5	197	19,7	89,9
30	317,5	31,75	70,2
50	144	14,4	38,45
100	120,5	12,05	24,05
200	69,6	6,96	12
Pan	50,4	5,04	5,04
Total	1000	100	0
Fineness Modulus		**0,195**	

Based on the analysis, it can be seen that the pohara sand tended to be soft as shown in the results of calculating the

Fineness Modulus, as follow:

$$FM = \frac{\sum(No.4-No.100)}{100} \quad (3)$$

where:

FM = Fineness Modulus

∑ (No.4 – No.100) = Cumulative Percentage of the sieved samples in sieve no. 4 and no. 100.

Based on the above formula, the Fineness Modulus value obtained was 0,195

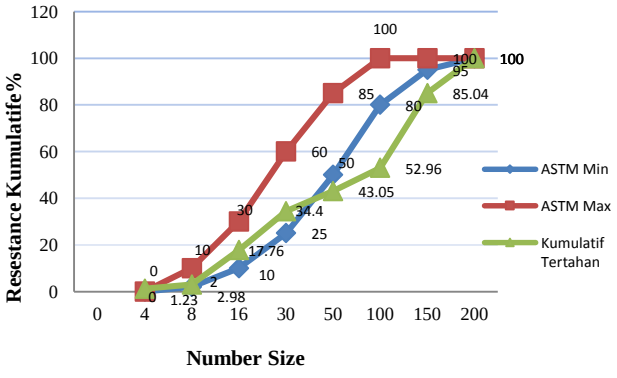


Figure.2 The results of sieve test of fine aggregates of Pohara sand

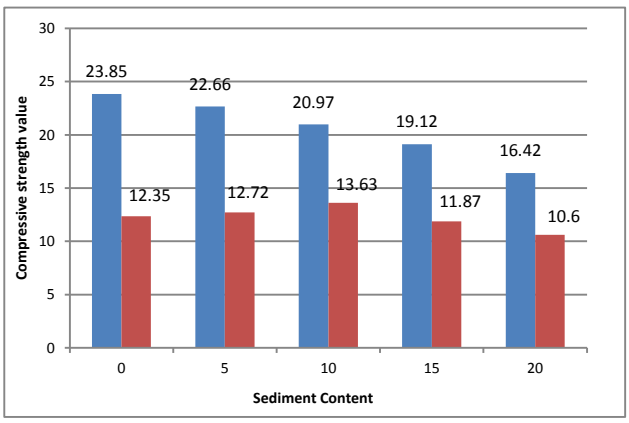
B. Results of Physical Characteristics Test of Paving Block

The characteristics of Kendari bay sediment as a fine aggregate supporting material in the mixture will increase its quality for the implementation in construction work of which results of compressive strength test of samples are recapitulated in table 5 and Figure 3.a-b and 4.a-b below:

Table. 5 The Compressive Strength and Water Absorption of Paving Block using 1: 3 ratio between Cement and Sand

Rectangular Model			
Compressive Strength (Kg/Cm3)	Compressive Strength (Mpa)	Average Water Absorption (%)	Sediment Content (%)
238,48	23,85	3,17	0
226,64	22,66	6,94	5
209,71	20,97	7,60	10
191,22	19,12	8,66	15
164,23	16,42	10,05	20
Worm Model			
Compressive Strength (Kg/Cm3)	Compressive Strength (Mpa)	Average Water Absorption (%)	Sediment Content (%)
123,49	12,35	0,98	0
127,18	12,72	4,59	5
136,28	13,63	5,52	10
118,70	11,81	6,09	15
105,98	10,59	6,89	20

Table 5 shows that the higher the addition of sediment in the paving block mixture, the lower the quality of paving blocks, as well as for the test of 28-day paving block sample for rectangular model with 0% sediment content with a compressive strength of 23,85 MPa decreased to 16,42 MPa in the 20% sediment content. For the test samples of 28-day paving block for the worm model with 0% sediment content with compressive strength of 13,63 MPa decreased to 10,67 MPa in the sediment content of 20%.



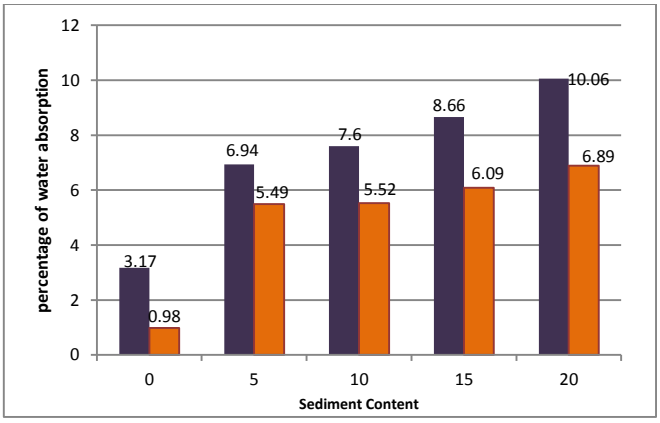


Figure .3.a and b The Results of Compressive Strength and Water Absorption Tests using a ratio 1 : 3 of Cement and Sand

C. Results of Water Absorption Test

In the water absorption test on the 28-day paving block sample, the test was conducted based on SNI 03-0691-1996 standards on paving block and the results are shown in table 5 and figure 3.a and 3.b. Table 5 also shows the water absorption value in the rectangular model with 0% sediment content with an absorption value of 3,17% increased to 10,05% in the 20% sediment content. For the water absorption test for the worm model with sediment content of 0% with an absorption value of 0,98% increased to 6,89% in 20% sediment content.

Some of the water absorption values in the existing paving block are suitable and some others are less than the standard set by SNI, ranging between 3% -10%, and in this study, the water absorption value is inversely proportional to the compressive strength of paving block, as seen in figure 3.a and 3.b. It was due to the mixed water content does not meet the optimum water content, so that the specific gravity of paving blocks is also not maximum, so that the quality and absorption of paving blocks tend to increase.

D. Sodium Sulfate Resistance

The Sodium Sulfate resistance test on 28-day paving block sample was conducted based on SNI 03-0691-1996 on the weight reduction of paving block. The results obtained are shown in table 6.

The sodium sulfate resistance is intended to determine the ability of paving block to withstand the weather and the results of test, according to table 6 above, show that with the addition of sediment mixture in paving block, there is a good high weight increase in the paving blocks in the 1:3 ratio mixture.

Based on the results of this test, the 5% sediment addition on sample 2 and 3 and 10% sediment addition on sample 2 and 3 are the best mixture, because the conditions are good and there are no cracks found and there are also high compressive strength and low absorption of 1,28 in the 5% sediment addition on sample 3.

Table.6 Sodium Sulfate Resistance Value of Paving Block (Rectangular Model)

Sediment Content	Weight Addition (1 : 3)		Difference (%)	Information
	Weight after saline solution immersion for 17 hours (Gram)	Weight after hot water washing at a temperature of 50˚C (Gram)		
(0% sample-1)	2813,33	2812,31	1,02	Good
(0% sample-2)	3006,12	3004,7	1,42	Good
(0% sample-3)	3142,56	3139,68	2,88	cracked
(5% sample-1)	4105,31	4100,47	4,84	cracked
(5% sample-2)	3847,75	3846,25	1,50	Good
(5% sample-3)	3656,45	3654,99	1,46	Good
(10% sample-1)	4002,38	3998,23	4,15	cracked
(10% sample-2)	3905,23	3903,87	1,36	Good
(10% sample-3)	3754,42	3753,14	1,28	Good
(15% sample-1)	3921,09	3914,23	6,86	cracked
(15% sample-2)	3862,69	3857,18	5,51	cracked
(15% sample-3)	3874,86	3867,32	7,54	cracked
(20% sample-1)	3921,09	3914,23	6,86	cracked
(20% sample-2)	3862,69	3857,18	5,51	cracked
(20% sample-3)	3874,86	3867,32	7,54	cracked

Table 7. Sodium Sulfate Resistance Value of Paving Block (Worm Model)

Sediment Content	Weight Addition (1 : 3)		Difference (%)	Information
	Weight after saline solution immersion for 17 hours (Gram)	Weight after hot water washing at a temperature of 50˚C (Gram)		
(0% sample-1)	2821,33	2817,45	3,88	Good
(0% sample-2)	3187,23	3182,13	5,1	Cracked
(0% sample-3)	3109,51	3102,31	7,2	Cracked
(5% sample-1)	4096,56	4093,14	3,42	Cracked
(5% sample-2)	3896,74	3889,48	7,26	Good
(5% sample-3)	3748,43	3741,08	7,35	Cracked
(10% sample-1)	4134,09	4128,45	5,64	Cracked
(10% sample-2)	3986,92	3979,11	7,81	Good
(10% sample-3)	3856,24	3847,98	8,26	Good
(15% sample-1)	3974,87	3968,12	6,75	Cracked
(15% sample-2)	3906,69	3898,34	8,35	Cracked
(15% sample-3)	3807,45	3802,87	4,58	Good
(20% sample-1)	4089,34	4083,27	6,07	Good
(20% sample-2)	3862,69	3853,53	9,16	Cracked
(20% sample-3)	3874,86	3864,27	10,59	Cracked

CONCLUSIONS

Based on the results of laboratory test and analysis, it can be concluded as follows:

1. The higher the addition of sediment in the paving block mixture, the lower the quality of paving blocks on the test conducted on the 28-day sample for rectangular model with 0% sediment content with a compressive strength of 23,85 MPa decreased to 16.42 Mpa in the 20% sediment content. As for the worm model with 0% sediment content with compressive strength 12,35 MPa decreased to 10,60 Mpa in 20% sediment content.
2. The water absorption value in the rectangular model with 0% sediment content with an absorption value of 3,17% increased to 10,05% in the 20% sediment content. For the water absorption test for the Worm model with sediment content of 0% with an absorption value of 0,98% increased to 6,98% in 20% sediment content.
3. In the addition of sediment mixture in paving block, there is a good high weight increase in the paving blocks in the 1:3 ratio mixture. Based on the results of this test, the 5% sediment addition on sample 2 and 3 and 10% sediment addition on sample 2 and 3 are the best mixture, because the conditions are good and there are no cracks found and there are also high compressive strength and low absorption of 1,28 in the 5% sediment addition on sample 3.
4. The implication of this research becomes an input for the local government that the use of sediment in the paving block mixture can only be applied to the construction of parking lots and pedestrian zones according to the results of analysis of compressive strength, sodium sulfate resistance, and water absorption.

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