



The Effect of Substituting Fine Aggregate with Petroleum Drilling Mud Waste in Eco-Paving Block Manufacturing

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Abstract. Petroleum is one of the fuels still widely used in Indonesia for vehicles. Petroleum exploitation activities produce residue or waste material in the form of unused petroleum drilling mud, which, if not utilized, can become waste. This research used the mud from petroleum drilling into valuable products such as paving blocks. This research uses an experimental method with paving block test objects measuring 20×10×6 cm³. Utilization of petroleum drilling mud is a partial substitution of fine aggregate in manufacturing paving blocks with a percentage variation of 0%, 10%, 20%, and 30%. Tests on petroleum drilling mud include XRF (X-ray fluorescence) and physical characteristics tests. Tests on the specimens were conducted 28 days following SNI 03-0691-1996 on paving blocks in the form of compressive strength and water absorption tests. The results showed that the 30% percentage variation was the best in the compressive strength and water absorption tests. The average compressive strength test results of 0%, 10%, 20%, and 30% percentage variations were 23.9 MPa, 30.2 MPa, 30.5 MPa, and 33.8 MPa, respectively. The average water absorption test results were 7.55, 7.49, 7.07, and 6.66.

Keywords: Compressive Strength Test, Paving Block, Petroleum Drilling Mud, Physical Characteristics Test, Water Absorption Test.

1 Introduction

Petroleum in Indonesia is a widely used industry and has a strategic role in Indonesia's economic development. Indonesia currently still uses petroleum as a fuel source in most vehicles, such as cars, motorcycles, and planes. Petroleum production in Indonesia in 2022 reached 31.4 million tons. The petroleum industry in Indonesia is built with an approach that prioritizes the balance between social, economic, and environmental aspects. Given the high production of petroleum in Indonesia, the by-products or waste from petroleum drilling are also increasing, including the waste produced in petroleum drilling, one of which is mud. Mud produced from petroleum drilling can be a serious problem because it can pollute the environment and health if not managed [1].

Petroleum drilling mud is a type of waste generated during oil and gas exploitation, especially in drilling. This process involves using water, drilling mud, and other chemicals to drill and extract oil from underground. Waste drilling mud is a mixture of water, soil, rock, drilling mud, chemical additives, and oil and gas residues [2]. The composition can vary depending on the drilling location, the drilling technique used, and the geological characteristics of the formation in which the drilling takes place [3]. The volume of drilling mud waste can be significant, depending on the scale of the drilling operation [4]. Drilling petroleum wells tends to generate substantial amounts of garbage. Managing drilling mud waste is a considerable challenge for the oil and gas industry. This petroleum mud must be utilized to reduce the risk of storing the waste mud from petroleum drilling. One way of utilizing it is to use it as a partial substitute for sand in concrete mixes so that it can have a positive impact on reducing waste that previously came from the process of petroleum drilling results so that it can be used as an alternative as a manufacturing mixture such as paving blocks, lightweight bricks, and bricks. The negative impact of stockpiling waste from petroleum drilling is that it will cause oil to seep into the soil layer and pollute the soil. In contrast, the light fraction of oil evaporates due to heat from sunlight and causes air pollution.

Paving blocks are an alternative construction material currently widely used by the community as a covering material and soil hardener. In general, paving blocks are made from a mixture of cement, sand, and hydraulic adhesives such as water, as well as other additives that do not reduce the quality of the paving blocks. Structurally, paving blocks have considerable strength, but ordinary concrete paving blocks also have weaknesses, namely low flexural strength and are easily cracked or destroyed. The quality of paving blocks for compressive strength and water absorption refers to SNI 03-0691-1996 concerning concrete bricks (paving blocks). Paving blocks are widely used to hold loads within certain limits and are easy to install without heavy equipment. The use of paving blocks is very environmentally friendly because water absorption through the installation of paving blocks can maintain the groundwater balance. Paving blocks are currently widely used in certain places, including road pavements, parking lots, streets around the environment, open areas, industrial areas, ports, and airports. The quality of the paving block will be better if it has a higher compressive strength. The quality of paving blocks is influenced by the materials used in their manufacture [5]. Therefore, this study aims to determine compressive strength and water absorption by adding petroleum drilling mud materials.

2 Material and Methods

2.1 Methods

The method used in this research is the quantitative method, which is conducted experimentally and descriptively to explain the results of primary data processing. Primary data is in the form of data on the chemical and physical tests of mud material from petroleum drilling. Primary data is also in the form of data on compressive strength tests and water absorption tests of paving block products.

1. Time and Place of the Research

The research time required is approximately 6 (six) months, namely in March-September 2024. The manufacture of lightweight bricks is located at the Environmental Engineering Laboratory, Faculty of Engineering, Mulawarman University, Samarinda. The waste collection location is PT Pertamina EP Asset 5 Sangatta Field, South Sangatta, East Kutai. Particle distribution, compressive strength, water absorption and specific gravity tests were conducted at the Civil Engineering Laboratory, Faculty of Engineering, Mulawarman University, Samarinda. The physical characteristics testing of waste, namely sludge content, water absorption, specific gravity, fineness modulus and moisture content of oil drilling sludge waste, was carried out at CV Inovasi Consultan Samarinda for the testing of the chemical content of oil drilling mud waste was carried out at PT Sucofindo Samarinda.

2. Data Processing Stage

The compressive strength is calculated with the following formula:

$$\text{compressive strength} = \frac{P}{L} \quad (1)$$

Description:

P = Compressive load (N)

L = Area of the compressive field (mm²)

The average compressive strength of concrete brick samples is calculated from the sum of the compressive strength divided by the number of test samples.

Water absorption is calculated with the following formula:

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

Description:

A = weight of wet paving block

B = weight of dry paving block

3. Data Analysis

The data analysis used in this research is to use quantitative methods. The data obtained after all tests will be described by descriptive and quantitative methods with tables, graphs, and narratives that explain the condition of all parameters used in this study. The data is then analyzed comprehensively and compared according to SNI with the quality standards the government sets. The results of testing the physical properties of paving blocks are then compared with those of SNI 03-0691-1996, including compressive strength tests and water absorption tests.

2.2 Materials

The main objective of this research is to utilize waste mud from oil drilling, which has an enormous volume from the oil drilling process. The study was conducted by substituting filler in paving blocks, namely sand, with a specific composition using petroleum drilling mud obtained from oil drilling. Hopefully, this research can reduce petroleum drilling mud waste by reusing petroleum drilling mud into paving blocks.

This study's independent variables are mixed materials composition, including oil drilling mud waste, sand composition, and cement composition. The fixed variable is the cement composition, while the mixture of oil drilling sludge waste against the sand is given a varied treatment of 10%, 20%, and 30%. This study also used a control variable, eco-paving blocks without a mixture of oil drilling sludge waste. The size used in making this lightweight brick is $20 \times 10 \times 6 \text{ cm}^3$. This composition has adjusted to the needs of the mold used. The composition of these materials can be seen in the following table.

Table 1. Composition of Materials for Making Eco-Paving Blocks

Paving block (kg)	Cement (kg)	Sand (kg)	Waste (kg)	Water (L)
PB0 (0%)	0.52	1.95	0	0.27
PB1 (10%)	0.52	1.76	0.19	0.27
PB2 (20%)	0.52	1.57	0.38	0.27
PB3 (30%)	0.52	1.38	0.57	0.27

Note: This composition adjusts to the size of the mould used.

Table 2. Recapitulation of the Sand Test Results Used

No	Content	Units	Results
1	Moisture Content	%	0.35
2	Mud Content	%	0.72
3	Specific Gravity	-	2.58
4	Water Absorption	%	0.37
5	Fineness Modulus	-	2.10

Table 3. Recapitulation of Mud Test Results from Oil Drilling

No	Content	Units	Results
1	Moisture Content	%	0.64
2	Mud Content	%	36.82
3	Specific Gravity	-	2.61
4	Water Absorption	%	5.30
5	Fineness Modulus	-	0.72

The oil drilling process in the petroleum exploitation process leaves a by-product as waste oil drilling mud. Waste oil drilling mud contains Silicon Dioxide (SiO_2), which has reactive properties and good pozzolanic activity that can react with hard and stiff materials. This chemical characteristics analysis was conducted to determine whether

waste oil drilling mud can be used as a concrete brick mix. The characteristics of waste oil drilling mud from PT Pertamina EP Asset 5 Sangatta Field are as follows.

Table 4. Mud XRF Test Results from Petroleum Drilling Mud.

No	Contents	Units	Test Result	Method
1	Silicon Dioxide (SiO ₂)	%	79.78	PO-MOM-01 (XRF)
2	Iron Trioxide (Fe ₂ O ₃)	%	6.28	PO-MOM-01 (XRF)
3	Aluminium Trioxide (Al ₂ O ₃)	%	7.77	PO-MOM-01 (XRF)
4	Calcium Oxide (CaO)	%	1.51	PO-MOM-01 (XRF)
5	Magnesium Oxide (MgO)	%	0.33	PO-MOM-01 (XRF)
6	Titanium Dioxide (TiO ₂)	%	0.90	PO-MOM-01 (XRF)
7	Potassium Oxide (K ₂ O)	%	2.15	PO-MOM-01 (XRF)
8	Sodium Oxide (Na ₂ O)	%	0.17	PO-MOM-01 (XRF)
9	Manganese Dioxide (MnO ₂)	%	0.67	PO-MOM-01 (XRF)
10	Chromium Trioxide (Cr ₂ O ₃)	%	0.40	PO-MOM-01 (XRF)
11	Ferrous (Fe)	%	4.39	PO-MOM-01 (XRF)
12	Sulphur (S)	%	2.07	PO-MOM-01 (XRF)
13	Phosphorous (P)	%	0.05	PO-MOM-01 (XRF)
14	Loss on Ignition	%	6.60	PO-MOM-BT-01

3 Results

Tests conducted on eco-paving blocks are compressive strength tests and water absorption tests. The compressive strength test determines the paving block's strength if given a certain pressure. The water absorption test determines how much water can seep into the paving block. All tests have been regulated in the Indonesian National Standard, namely SNI-03-0691-1996.

3.1 Compressive Strength Test Results

The compressive strength test was carried out by cutting a cube-shaped test sample, and the ribs were adjusted to the size of the test sample. Pressed until the test sample was destroyed using a speed-adjustable pressing machine. The pressing speed from the start of the load until the test sample is destroyed is set within 1 to 2 minutes. The direction of pressure on the test sample is adjusted to the direction of the load pressure used.

Table 5. Paving Block Compressive Strength Test Results.

Day	Variation (%)	Test Sample	Compressive Strength Value (kN)	Compressive Strength Value (Mpa)	Average (Mpa)	Paving Block Quality	Standardized Compressive Strength
0		1	484	24.2	23.9	B	SNI-03-0691-1996-PAVING BLOCK: A: Min 35 & average 40
		2	472	23.6			
		3	475	23.8			
10		1	601	30.1	30.2	B	
		2	600	30			
		3	607	30.4			

Day	Variation (%)	Test Sample	Compressive Strength Value (kN)	Compressive Strength Value (Mpa)	Average (Mpa)	Paving Block Quality	Standardized Compressive Strength
28	20	1	605	30.3	30.5	B	B: Min 17 & average 20 C: Min 12.5 & average 15 D: Min 8.5 & average 10
		2	610	30.5			
		3	614	30.7			
	30	1	689	34.5	33.8	B	
		2	665	33.3			
		3	670	33.5			

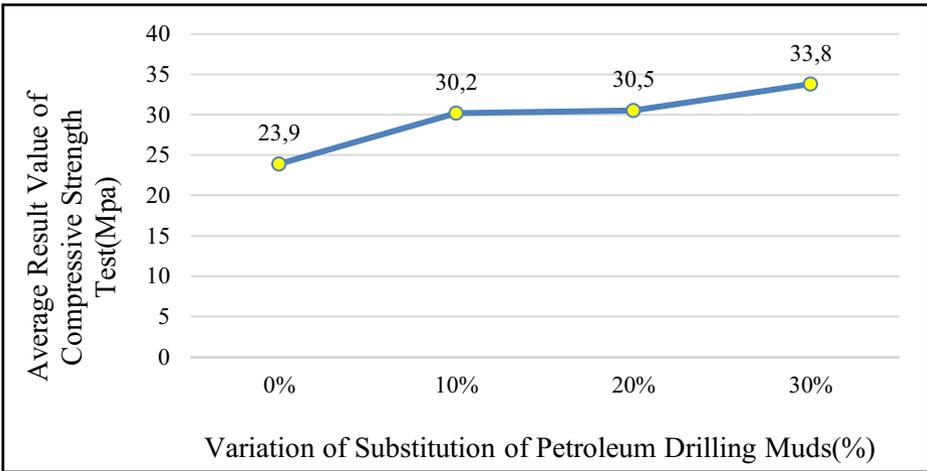


Fig. 1. Graph of Average Press Test Results of Paving Blocks

3.2 Water Absorption Test Results

A water absorption test is helpful to determine the amount of water that can be absorbed by paving blocks. This test is done by soaking lightweight bricks for 24 hours in water. The test is then carried out by heating the paving block with an oven for 24 hours at a hot temperature of 105 – 115° C or until the paving block does not experience a decrease in mass again and then weighed.

Table 6. Paving Block Water Absorption Test Results

Day	Variation (%)	Sample Test	Result (%)	Average (%)	Paving Block Quality	Water Absorption Standard
28	0	1	7.77	7.55	C	SNI-03-0691-1996- PAVING BLOCK:
		2	7.44			
		3	7.44			
	10	1	7.53	7.49	C	Maximum Average A: 3% B: 6%
		2	7.05			
		3	7.89			

Day	Variation (%)	Sample Test	Result (%)	Average (%)	Paving Block Quality	Water Absorption Standard
	20	1	7.30	7.07	C	C: 8% D: 10%
		2	6.89			
		3	7.04			
	30	1	6.41	6.66	C	
		2	6.73			
		3	6.85			

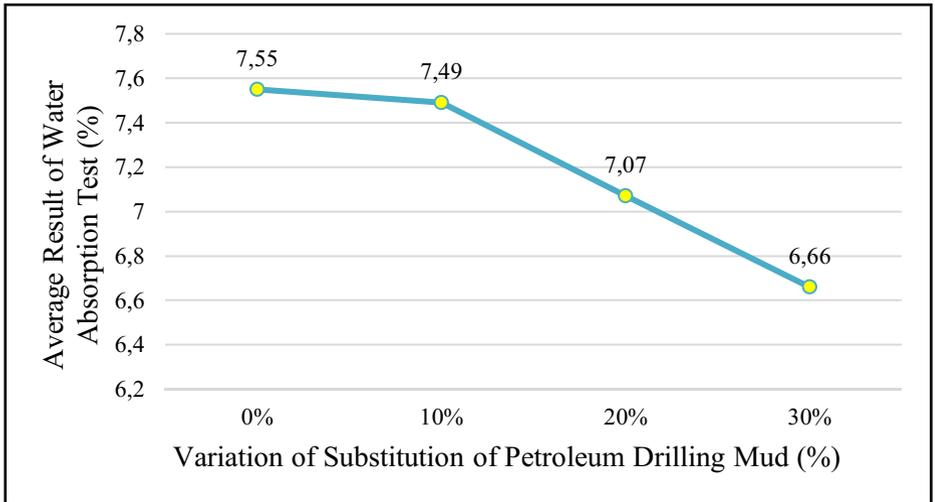


Fig. 2. Graph of Average Result of Paving Block Water Absorption Test

4 Discussion

4.1 Comparison of Compressive Strength Test Results with Quality Standards

Based on the tests carried out on the paving blocks made and the calculations carried out after the test, the test results and comparison with the quality standards are obtained as follows in Table 7.

Table 7. Paving Block Compressive Strength Test Results

Day	Variation (%)	Test Sample	Compressive Strength Value (kN)	Compressive Strength Value (Mpa)	Average (Mpa)	Paving Block Quality	Standardized Compressive Strength
	0	1	484	24.2	23.9	B	SNI-03-0691-1996-PAVING BLOCK;
		2	472	23.6			
		3	475	23.8			

Day	Variation (%)	Test Sample	Compressive Strength Value (kN)	Compressive Strength Value (Mpa)	Average (Mpa)	Paving Block Quality	Standardized Compressive Strength
28	10	1	601	30.1	30.2	B	A: Min 35 & average 40 B: Min 17 & average 20 C: Min 12,5 & average 15 D: Min 8,5 & average 10
		2	600	30			
		3	607	30.4			
	20	1	605	30.3	30.5	B	
		2	610	30.5			
		3	614	30.7			
	30	1	689	34.5	33.8	B	
		2	665	33.3			
		3	670	33.5			

4.2 Comparison Water Absorption Test Results with Quality Standards

Based on the tests carried out on the paving blocks made and the calculations carried out after the test, the test results and comparison with the quality standards are obtained as follows in Table 8.

Table 8. Paving Block Water Absorption Test Results

Day	Variation (%)	Sample Test	Result (%)	Average (%)	Paving Block Quality	Water Absorption Standard
28	0	1	7.77	7.55	C	SNI-03-0691-1996-PAVING BLOCK: Maximum Average A: 3% B: 6% C: 8% D: 10%
		2	7.44			
		3	7.44			
	10	1	7.53	7.49	C	
		2	7.05			
		3	7.89			
	20	1	7.30	7.07	C	
		2	6.89			
		3	7.04			
	30	1	6.41	6.66	C	
		2	6.73			
		3	6.85			

5 Conclusions

Based on the results of the tests carried out, the effect of adding petroleum drilling mud as a substitute for some fine aggregates is an increase in the compressive strength test value of the paving block and a decrease in the water absorption value of the paving block. This result is in line with the reduction of water absorption of a paving block, the stronger the compressive strength value of the paving block. The resulting compressive strength value in PB0 averaged 23.9 Mpa, PB1 averaged 30.2 Mpa, PB2 averaged 30.5 Mpa, and PB3 averaged 33.8 Mpa. The value of water absorption in paving blocks,

namely in PB0, an average of 7.55%, PB1, an average of 7.49%, PB2 an average of 7.07%; and PB3 an average of 6.66%.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

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