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The utilization of ceramic shard waste and landfill mining residue as a paving block material in the effort to extend landfill lifetime

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Abstract. This study aimed to determine the content of CaO and SiO_2 in landfill mining residue and ceramic shard waste, the best composition variation in accordance with SNI 03-0691-1996 on Paving Block, and the best values in the selected composition variation as paving block material according to SNI 03-0691-1996 on Paving Block. The research consists of six test steps, namely visibility test, size test, compressive strength test, water absorption test, wear resistance test, and sodium sulfate resistance test. The X-Ray Fluorescence method was used to determine the value of Cao and SiO_2 compounds in landfill mining residue and ceramic shard waste. The CaO and SiO_2 content in landfill mining residues were 5.81% and 46.31%, while in ceramic shard waste the concentrations were 4.60% and 64.33%. The selected paving block composition variation which is in accordance with SNI 03-0691-1996 was variation 4 with a composition ratio of 10% ceramic shard waste:20% landfill mining residue:50% sand:20% cement, which has meet the classification of quality C. The best values in the selected variation were a compressive strength test value of 21.69 MPa, water absorption test value of 3.16%, wear resistance test value of 0.169 mm/min, and a sodium sulfate resistance test score of 1%.

1. Introduction

Waste is anything that is no longer desired by the possessor with a solid for the increasing population growth will affect the amount of waste generation. One of the cities that experience this problem is Kediri. Increasing the amount of waste generation will require more land to accommodate the waste. For example, Klotok Landfill Kediri City has very limited land for landfill, so the provision of land for landfill becomes the main problem in waste management in Kediri City. Considering the problem of landfill limitations of landfill, then there should be proper handling of waste so that the impact caused to the environment can be minimized. Several technologies for handling waste in the landfill include composting, thermal cracking, paving block, brick, and other technologies that implement the principle of reduce, reuse, and recycle (3R).

In this study, paving block was tested and compared with SNI 03-0691-1996 [1] on paving block. The physical property tests values and sodium sulfate resistance test values that best suit the physical properties criteria of SNI 03-0691-1996 were chosen as the best variation of landfill soil as coarse aggregate and glass waste as fine aggregate. This is done to reduce landfill soil in the passive zone and extend the lifetime of the landfill, as well as to reduce glass waste in the glass-making industry.

2. Research Methods

2.1. Materials

The materials used in this research were Portland cement; fine aggregate (ceramic shard waste from ceramic manufacture industry in Sidoarjo and sand); coarse aggregate (landfill mining residue at Klotok I Landfill Kediri City), and water.

2.2. Variations of paving block raw materials
Variations of paving block raw materials can be seen in Table 1.

Table 1. Variations of paving block raw materials

Variation Code	Aggregate				Sand		Cement	
	Fine aggregate (ceramic shard waste)		Coarse aggregate (landfill mining residue)					
	(%)	(g)	(%)	(g)	(%)	(g)	(%)	(g)
1	0	0	0	0	80	2,240	20	560
2	20	560	10	280	50	1,400	20	560
3	15	420	15	420	50	1,400	20	560
4	10	280	20	560	50	1,400	20	560
5	5	140	25	700	50	1,400	20	560

2.3. Data analysis
Data analysis in this research used the Indonesian National Standard (SNI) 03-0691-1996. The tests of this research stage comprise of comparing the means of each composition variation 1, 2, 3, 4, and 5 with SNI 03-0691-1996 for each parameter, namely compressive strength test (MPa), water absorption test (%), wear resistance test (mm/min) and sodium sulfate resistance test (%). The average value of each variation of the composition is adjusted to the SNI 03-0691-1996 quality classification. There are 4 classifications of quality, namely quality A, B, C, and D.

3. Result and Discussion

3.1. CaO and SiO_2 in landfill mining residue and ceramic shard waste
The test used to determine the content of SiO_2 and CaO compounds was the X-Ray Fluorescence (XRF) test. CaO and SiO_2 content in landfill mining residue and glass shard waste can be seen in Table 2.

Table 2. Cao and SiO_2 Content in landfill mining residue and ceramic shard waste

No.	Name	Average Compound Value (%)	
		CaO	SiO_2
1.	Landfill mining residue	5.81 ± 0.1613	46.31% ± 0.235
2.	Ceramic shard waste	4.60 ± 0.155	64.33 ± 0.073

Based on Table 2, it is known that the average values of CaO and SiO_2 compounds in landfill mining residue were 5.81% and 46.31%, respectively, while the average values of CaO and SiO_2 compounds in ceramic shard waste were 4.60% and 64.33%, respectively. SiO_2 content is directly proportional to water absorption in paving block. The air cavities in the paving block were filled by water during the sample immersion period.

3.2. Paving block test results in accordance with SNI 03-0691-1996
3.2.1. Paving block visible properties test.
The observation of paving blocks was done visually and thoroughly. A paving block is considered to be good if they meet the SNI 03-0691-1996 quality standard, where the desirable paving block has a flat surface, no cracks and defects, and the corners and ribs are not easily mashed with the strength of fingers. In this study, all paving block products have good visible properties.

3.2.2. Paving block size test.
The average results of paving block measurements can be seen in Table 3.

Table 3. Paving block measurement results

Variation	Dimensions (mm)		
	Length	Length	Thickness
1	210 ± 0.00	105 ± 0.00	55.6 ± 0.03
2	210 ± 0.00	105 ± 0.00	55.4 ± 0.02
3	210 ± 0.00	105 ± 0.00	55.9 ± 0.217
4	210 ± 0.00	105 ± 0.00	55.5 ± 0.07
5	210 ± 0.00	105 ± 0.00	56.2 ± 0.09

SNI 03-0691-1996 quality standard on paving block explains that a paving block must have a minimum nominal thickness of 60 mm with 8% tolerance. The tolerance interval of nominal thickness in paving block is 55.2 mm - 64.8 mm. From the data of Table 3, the measurement test results are in accordance with the required quality standards.

3.2.3. Paving block compressive strength test. The average compressive strength test values and adjusted to SNI 03-0691-1996 quality standard to ensure that the paving block can meet the classifications:

Table 4. Average compressive strength values and their classification based on the SNI 03-0691-1996 quality standard on Paving Block

Variation	Average compressive strength value (MPa)	SNI Classification 03-0691-1996			
		A	B	C	D
1	28.18 ± 4.12		√		
2	19.91 ± 2.34		√		
3	16.89 ± 3.01			√	
4	21.69 ± 2.24		√		
5	21.07 ± 1.62		√		

Table 4 shows the best value available on variation 4 with a value of 21.69 ± 2.24, which includes the B classification used for constructing parking lots. The factor that causes the variations in compressive strength values is the raw material of paving block. SiO_2 content acts as a filler in paving block. Thus, the higher the value of SiO_2 content, the greater the compressive strength. This is because the congestion of an aggregate will result in smaller porosity [2].

3.2.4. Paving block absorption strength test.
The result averages of paving block measurements can be seen in Table 5.

Table 5. Average compressive strength values and their classification based on the SNI 03-0691-1996 quality standard on Paving Block

Variation	Average water absorption rate (%)	SNI Classification 03-0691-1996			
		A	B	C	D
1	3.35 ± 1.016		√		
2	3.58 ± 1.017		√		
3	3.53 ± 0.769		√		
4	3.16 ± 0.912		√		
5	3.27 ± 1.029		√		

Table 5 shows that the average value of water absorption in paving block of the lowest in variation 4 was 3.16 ± 0.912%, which fits with quality B, with a maximum absorption value of 6%. The high rate of water absorption in paving blocks is influenced by the number of pores in less denser samples. Water absorption is related to porosity. Porosity is defined as the ratio of pore volume (volume that can be occupied by fluid) to the concrete volume [3].

3.2.5. Wear resistance testing.
The average values of wear resistance of paving block samples and their classification based on SNI 03-0691-1996 on Concrete Bricks (Paving Block) can be seen in Table 6.

Table 6. Average compressive strength values and their classification based on the SNI 03-0691-1996 quality standard on Paving Block

Variation	Average Wear Resistance Values (mm/min)	SNI Classification 03-0691-1996			
		A	B	C	D
1	0.040 ± 0.0189	√			
2	0.224 ± 0.189				√
3	0.251 ± 0.120				√
4	0.169 ± 0.067			√	
5	0.229 ± 0.164				√

Table 6 shows that the lowest average value of wear resistance was in variation 4, which was 0.169 ± 0.067; it is quality C with an average value of 0.160 mm/min. The factor that can affect the aggregate used in the mix ratio is too much aggregate, so the granules on the paving blocks produce cavities that are partially not filled with adhesive materials.

3.2.6. Sodium sulfate resistance test.
The average wear resistance values of paving block samples and their classification based on SNI 03-0691-1996 on Paving Block can be seen in Table 7.

Table 7. Average natrium sulfate strength values and their classification based on the SNI 03-0691-1996 quality standard on Paving Block

Variation	Mean Sodium Sulfate Resistance Value (%)	SNI Classification 03-0691-1996	
		<1%	> 1%
1	0.85 ± 0.212	√	
2	1.05 ± 0.354		√
3	1 ± 0.141		√
4	1 ± 0.283		√
5	1.35 ± 0.071		√

Table 7 above shows that in accordance with SNI 03-0691-1996 on the quality of paving blocks, variation 1 has a value <1%, while variations 2, 4, 3, and 5 have values of >1%.
The use of 20% landfill mining residue in variation 4 is the preferred composition which is expected to fulfill the reuse and recycle principle to produce paving blocks. The volume of waste generation, when mined and utilized as an alternative for additional paving block material, is predicted to produce 637,500,000 paving blocks.

4. Conclusion
The conclusions of this study are as follows, Firstly, The values of CaO and SiO_2 content in landfill mining residue were 5.81% and 46.31%, while their content in ceramic shard waste were 4.60% and 64.33%. Secondly, The variation of the selected for paving block material was variation 4, which has met the classification of quality C, which is used for pedestrian.
Thirdly, The values produced by the paving block composition selected were 21.69 MPa of compressive strength test value, a water absorption test value of 3.16%, a wear resistance test value of 0.169 mm/min, and a sodium sulfate resistance test value of 1%.

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