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MORALITY BEFORE KNOWLEDGE

Utilization bottom ash from incinerator become paving block (Study case : PT. X)

YUNITA ISMAIL MASJUD[1], AFINA MAULIDA[1],*
[1] *Environmental Engineering, University of President*
*Correspondence: afinamaulida1106@gmail.com

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ABSTRACT
Bottom ash incinerator produced by PT. X from various waste from production industrial activities has physical characteristics like cement, so it is possible to use it as a substitute for cement in paving block mixtures. Chemicals include Si, Mg, Ca, Fe, Al, K, and CL as well as other metals, including heavy metals, are present in bottom ash and the paving block composition. This utilization aims to determine the effect of using bottom ash on paving blocks according to the compressive strength and water absorption parameters. The composition of cement, and bottom ash in making paving blocks was varied in this experiment, for the amount of sand and water used were the same. Drying process for the paving block took 28 days. The bottom ash replace cement by 0 %, 5 %, 10 % and 15 % respectively, and two replications done for measurement. The quality of paving blocks was tested based on the SNI 03-0619-1996 to determine the level of quality of paving blocks. The results of this study indicate that the treatments used were significantly different based on compressive strength but were not significantly different based on water absorption parameters. From the results of the compressive strength test, it was found that paving blocks with a mixture of bottom ash substituted with 10% bottom ash were complied with quality B and 15% substituted with quality D of standard paving blocks. Apart from the pressure test, a water absorption test was also carried out by substituting bottom ash 0%, 5% and 15% complied with quality D and substituting 10% complied with quality B. From these results it is known that the mixture using bottom ash from the incinerator can replace the cement used in making paving blocks.

KEYWORDS: bottom ash; compressive strength; incinerator; paving block; waste utilization; water absorption

1. Introduction

It is reported that Indonesians have been aware of and used paving blocks since 1997. One of the building materials with practical use as a ground surface hardener or cover that we frequently come across along roadsides is paving stones. Paving block manufacturing will rise as a result of planning for infrastructure development and growing human requirements. Paving block product demand was shown to have significantly increased in one investigation. The study's attachment contains historical data from PT. XYZ, a firm that produces concrete bricks, during the months of April 2021 through March 2022 (Iqbal Ikhsan et al., n.d.). This rise in demand results in a steady decline in the natural resources that are utilized as building blocks' raw materials. These circumstances have prompted research into the environmental effects of bottom ash from home garbage incinerators, which shows that bottom ash may replace natural aggregates in processes like making cement, concrete, and road paving (Shen et al., 2021; Silva et al., 2019). PT. X handles domestic waste from industrial activities of investors/tenants through incinerator

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installation. The process produces Fly Ash and Bottom Ash, which are fine dust particles from the combustion process in the Primary and Secondary Chambers. The bottom ash, which consists of Wet Ash and Dry Ash, accumulates and spreads around the Incinerator area, causing environmental pollution. The bottom ash produced per 3 months is 40 kg, causing environmental harm around PT. X.

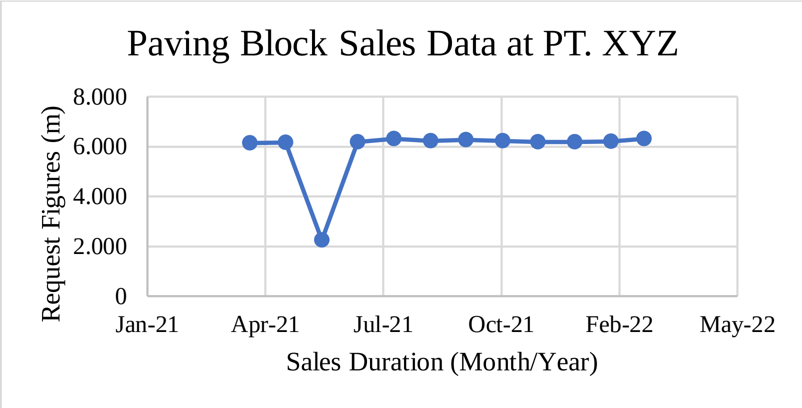

Fig.1. Historical data of paving bock customer sales demand PT. XYZ (Source: Iqbal Ikhsan et al., n.d)

Bottom Ash is the byproduct of burning garbage using thermal technology, specifically in an incinerator installation. This process involves burning waste at a specific temperature to create bottom ash. Domestic trash, comprising both organic and non-organic materials, is burned at the incinerator at PT. X. The properties of Bottom Ash, which are irregularly shaped particles of different sorts, are discussed in the chemical composition of Bottom Ash from several study sources. The Bottom Ash Incinerator mostly holds glass, ceramics, minerals, and metal compounds (Assi et al., 2020; Giro-Paloma et al., 2019). Since bottom ash from burning household waste is mostly inert, there aren't many environmental concerns. However, depending on the waste's makeup, it could contain traces of other pollutants or heavy metals. Therefore, to guarantee its safe and responsible administration, it is essential to carry out the necessary tests and adhere to the rules. As per Malaiškienė et al. (2023), bottom ash is a waste material that may be utilized again as an alternative to aggregate, which is mostly composed of silica compounds. The bottom ash produced by burning coal is another kind. The results of the chemical constituent composition show how bottom ash from burning coal waste differs from that from burning household garbage. It is evident from the chemical content value of bottom ash residential waste that it is higher than coal waste. Fundamentally, post-combustion treatments, storage methods, and operational process factors determine the content of the Bottom ash compound (Sales Bandarra et al., 2021).

Table 1. Content of chemical compounds bottom ash

No.	Parameter	Bottom Ash Chemical Content	
		Domestic Waste	Coal Waste
1	Si	40.0 – 55.6	11 – 19.60
2	Ca	14.5 – 29.4	7.56 – 33
3	Fe	6.08 – 7.4	43 – 57.71
4	Al	8.3 – 10.38	4.3 – 5.50

(Source: Ghozali & Wardhono, 2018; Kennedy, 2019; Laila & Risdianto, 2018; Malaiškienė et al., 2023; Maldonado-Alameda et al., 2020; Shen et al., 2021)

Compressive strength is a crucial physical property for paving blocks to meet quality requirements in SNI 03-0691-1996. It refers to the ability of a block to hold a load per unit area until crushed due to press pressure. It is also crucial for casting implementation. The longer a block's life, the stronger its compressive strength. The maximum average compressive strength characteristics are reached when blocks are 28 days old. Concrete casting experiments were conducted for 1 day, 7 days, 14 days, and 28 days, with the best results at 28 days. The concrete strength increased by 99%, close to the maximum compressive strength results of concrete (CivilTeam, 2022). This study demonstrates the importance of compressive strength in paving block quality and casting implementation (I. Setiawan & Nugraheni, 2018).

Based on previous research the compressive strength values for paving block with bottom ash variations of 5%, 10%, 15%, 20% and 25% were proven in research conducted by Kennedy, 2019 is produce quite satisfactory results. The results of this research resulted in the addition of 5%, 10% and 15% bottom ash which was the optimum result of their compressive strength result and water absorption. The compressive strength values is 29.71 MPa, 22.05 MPa and 20.14 MPa with all three qualities is B. Then, the water absorption results are 8.64%, 9.45% and 10.11% with all three qualities is D. The other experiment was carried out by Hilal, Ghozali & Wardhono (2018) (Ghozali & Wardhono, 2018) using variations of 10%, 20%, 30%, 40% and 50% with the results 22,594 MPa, 24,571 MPa, 26,858 MPa, 20,346 MPa and 12,972 MPa. Then, for results of water absorption showed the values of paving blocks were 9.044%, 7.425%, 6.076%, 7.616% and 9.985%. The results of this study are different from the Kennedy, 2019 that the results have decreased, then increased again, then decreased again. This is because the binding capacity of cement with bottom ash at a percentage of 30% binds optimally, so that less water enters the paving block (Ghozali & Wardhono, 2018).

The problems that can be formulated are whether there is a difference in each variation of treatment carried out and whether the paving block which is substituted with bottom ash meets the compressive strength and water absorption requirements according to SNI 03-0691-1996. While the objectives to be achieved based on the formulation of the problem are to find out whether there are differences in each variation of treatment carried out and to find out whether the paving blocks that are given bottom ash substitution meet the compressive strength and water absorption requirements according to SNI 03-0691-1996.

The limitations used include: (1) Research conducted at PT. X; (2) The bottom ash used comes from the combustion of domestic waste incinerators belonging to PT. X; (3) The bottom ash used is a residue originating from the secondary chamber incinerator; (4) The dimensions of the Paving Block are 20 cm long, 10 cm wide and 6 cm high; (5) Age of paving blocks set for testing at the age of 28 days. There are quality requirements contained in SNI 03-0691-1996 which as a requirement for paving block samples to pass the tests carried out in this study using the Compressive Strength Test and Water Absorption Test, as follows:

Table 2. Parameters requirement for paving block

Quality	Compressive Strength (MPa)		Maximum average water absorption	Quality Classification
	Average	Min	%	Note
A	40	35	3	For the road
B	20	17,0	6	For parking equipment
C	15	12,5	8	For pedestrians
D	10	8,5	10	For parks and other users.

(Source: Standar Nasional, 1996)

2. Methods

2.1 Experimental design

In this study, the planned paving blocks measuring 20 cm × 10 cm × 6 cm are in the form of rectangular blocks. Each treatment percentage of 0%, 5%, 10%, 15% will be repeated 6 times with a total number of 24 paving blocks. By using a ratio of cement and sand 1: 3. By making a mixed design, we can find out how much is needed from the constituent materials in the experimental design of this experimental research. Each paving block will be given a code as a marker for the paving block. It can be seen in Table 3. 1 the percentage of material requirements for each planned treatment.

The research location was at PT. X for the manufacture of test objects and conducted on April 7th, 2023. Testing of the compressive strength and water absorption of paving blocks will be carried out in different places and conducted on May 5th, 2023. Compressive strength testing was carried out at the laboratory of PT. X and water absorption tests were carried out at the Environmental Engineering Laboratory at President University.

Table 3. Treatment variations

Sample Code	**Treatment Presentation (%)**		**Parameter**
	Bottom Ash (%)	**Cement (%)**	
A	0	25	Compressive Strength and Water Absorption
B	5	20	
C	10	15	
D	15	10	

The composition ratio for Portland Cement and Sand is 1 Portland Cement (PC) : 3 Sand (PS). As for the calculation of the composition of the paving block mixture using the method of calculating previous research on the preparation of paving blocks (R. Setiawan, 2022), calculations with a planning size of 20 cm in length, 10 cm in width and 6 cm in height and using the average weight of paving blocks in general for that size of 3000 gr between cement, sand and bottom ash as follows:

- Cement Needs for Paving Blocks

$$1 \text{ PC} + 3 \text{ PS} = 100\ \%$$
$$PC = \frac{1}{(1+3)} \times 100\ \%$$
$$PC = 25\ \%$$
$$= 25\ \% \times 3000 \text{ gr}$$
$$= 750 \text{ Gr} = 0{,}75 \text{ Kg}$$

The amount of cement for one sample is 0.75 Kg/sample
The amount of Cement for all samples is 0,75 Kg × 24 Samples = 18 Kg

- The need for sand for paving blocks

$$1 \text{ PC} + 3 \text{ PS} = 100\ \%$$
$$PS = \frac{3}{(1+3)} \times 100\ \%$$
$$PS = 75\ \%$$
$$= 75\ \% \times 3000 \text{ gr}$$
$$= 2250 \text{ Gr} = 2{,}25 \text{ Kg}$$

The amount of sand for one sample is 2.25 Kg/sample
The amount of sand for all samples is 2,25 Kg × 24 Samples = 54 Kg

The paving block mold that will be used is a manual paving block mold with dimensions of 20 cm x 10 cm x 6 cm with iron material along with a manual mold press which will compact the printed dough mixture in the paving block mold. The mold will be used to print the planned 24 paving blocks. Paving block molds belong to PT. X, where this research was conducted.

2.2 Experiment

The steps in carrying out the experiment of making paving blocks are as follows:

1) Prepare the tools and materials needed. The tools needed are Barrow, Digital Scales, Concrete Mixer, Iron Raskam, Paving Block Mold and Analog Scales. Then, for the materials needed are Tayan Sand, Bottom Ash, Cement Portland and Water.

Fig.2. Manual paving block mold

2) Weighing each planned paving block material.

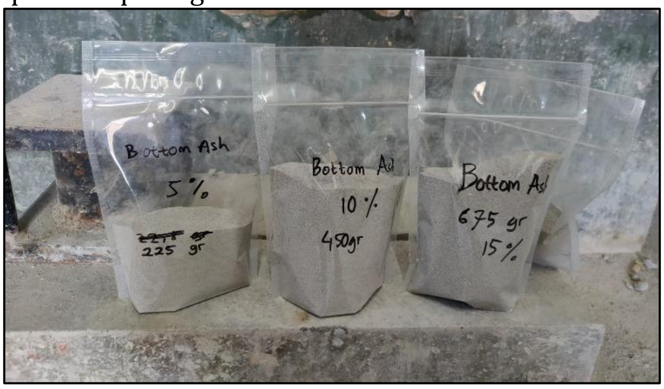

Fig.3. Bottom ash

3) Make sure the material stirrer is clean from other materials.
4) Preparing paving block molds by smearing them with oil so that the paving surface is smooth and the printed material is easily removed.
5) Start mixing the material that has been weighed into the concrete mixer until it is mixed evenly.

Fig.4. Concrete mixer machine

6) The concrete mix is taken out to a small cart as a place to put the homogeneous concrete mixture.
7) Then, put the concrete mixture into the mold until it exceeds the height of the mold and then mash it so that the top surface of the paving block is even and reaches the right level of density. Add the dough back into the hollow gap and mash again with the pounder evenly.
8) After pounding, check again whether the paving block is solid enough. If there are still holes or gaps, fill them back in by adding the concrete mix and mashing it again.
9) Thereafter the sample is finished, place it in a safe place until it dries and hardens. Don't forget to sign the name so the samples don't get mixed up.
10) Mixing and printing were repeated 4 times with each session printing 6 samples.

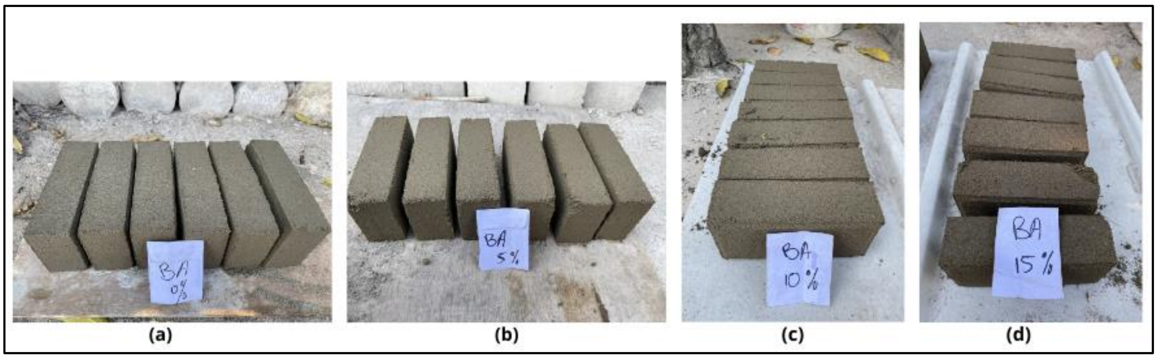

Fig.5. Molded samples

2.3 *Treatment of paving block (curing treatment)*

This curing process aims to prevent paving blocks from losing hydration and maintain quality. After the paving blocks have dried within one day after printing, the paving blocks are placed in a tub filled with water for 28 days. This process can be seen in Figure 3.9 paving blocks that are put into the water.

Fig.6. Paving blocks in Curing treatment

2.4 Parameter measurement

1. Compressive Strength Testing
   Compressive strength testing is carried out in accordance with SNI 03-0691-1996 as a quality requirement for paving blocks by testing using a digital compressive machine test kit available at PT. KBN Prima Beton with ADR brand from Esa Makmur Jaya Teknik.

Fig.7. Compressive strength test machine

The steps for testing the compressive strength of paving blocks are as follows:
1. Make sure the Compressive Strength Test Equipment can be used and has been turned on.
2. Make sure the base mat for the Paving Block touches the top wall.
3. Next, place the Paving Block on the base symmetrically.
4. After that, start applying pressure to the Paving Block until the pressure value on the machine screen stops and a cracked Paving Block will appear.
5. Then, record the maximum load that occurs during the test.

The calculation of Compressive Strenght uses the following formula:

$$Compressive\ Strenght = \frac{Press\ Load}{Press\ Area} \times 100\ \%$$

Equation 1

2. Water Absorptiong Testing
   The water absorption test aims to determine the ability of paving blocks to absorb water through their pores. The oven used is a Heating Oven from the Memmert brand with a heat capacity of 30°C - 230°C. Based on SNI 03-0691-1996, there are procedures for carrying out water absorption tests as follows:
   1. Prepare a medium-sized tub filled with water as a place to soak the Paving Block.
   2. In one piece, soak the paving block for 24 hours.
   3. After 24 hours, remove the paving block and weigh it while it is wet.

4. Then, prepare the oven as a dryer for 24 hours with a temperature of approximately 105°C.
5. Take out the Paving Block which has been heated for 24 hours then start weighing it dry.


Fig.8. Water absorption test

The calculation of Water Absorption uses the following formula:

$$Water\ Absorption = \frac{Wet\ PB\ Weight - Dry\ PB\ Weight}{Dry\ PB\ Weight} \times 100\ \%$$

Equation 2

3. Results and Discussion

3.1 Result

3.1.1 Compressive strength

The results of the compressive strength of paving blocks with cement substitution with bottom ash variations of 0%, 5%, 10% and 15% can be seen in Figure 3.1. Tests carried out using a compressive strength machine which can be seen in Figure 2.6 will display the results in units of Kg/cm^2 which will be converted to MPa. To determine the quality of paving blocks and the effect of Bottom Ash substitution on the quality of paving blocks is the aim of this test. The compressive strength test was carried out on paving blocks at the age of 28 days. The test results will be displayed in the form of tables and Graphs.

Example of compressive strength value conversion:
Known :
The value of the compressive strength of paving blocks is 224,537 Kg/cm^2
Convert to MPa :
It is known,
Mpa = Mega Pascal
1 Mpa = 1 N/mm^2 = 10.1971 = 10.2 kg/cm^2 (M Hadi H, 2020)

So,
Kg/cm^2 converted to $MPa = 224.537\ Kg/cm^2 \div 10.2 = 22.01\ MPa$

From the results of the compressive strength test of paving blocks with bottom ash substitution in cement material, it can be seen in the graph in Figure 3.1 that it has decreased with every addition of bottom ash. It can be seen that the results of the average value of compressive strength for 0% is 22.01 MPa. At the addition of 5% treatment by weight of cement, paving blocks decreased in compressive strength is 11.30 MPa. Then, the addition of 10% treatment is 20.07 MPa and the addition of 15% treatment is 13.28 MPa. The addition of bottom ash to paving blocks which affects the compressive strength of paving blocks can be concluded to produce a decreasing value and there is an optimum result from mixing bottom ash of 10%.

It can be seen that by substituting bottom ash for paving blocks it gives results that affect the compressive strength value. The results of the average value of compressive strength for 0% treatment is 22.01 Mpa. At the addition of 5% treatment is 11.30 MPa. Then, the addition of 10% treatment is 20.07 MPa and 15% is 13.28 MPa. This is the same as previous research conducted by Hilal, Ghozali & Wardhono (2018) which was discussed previously in chapter two in the compressive strength sub-chapter. This research carried out bottom ash substitution with treatment variations of 10%, 20%, 30%, 40% and 50% with optimum compressive strength results occurring in the 30% treatment variation (Ghozali & Wardhono, 2018). With this it can be stated that in this experiment there was optimal binding of bottom ash and cement with 10% bottom ash treatment.

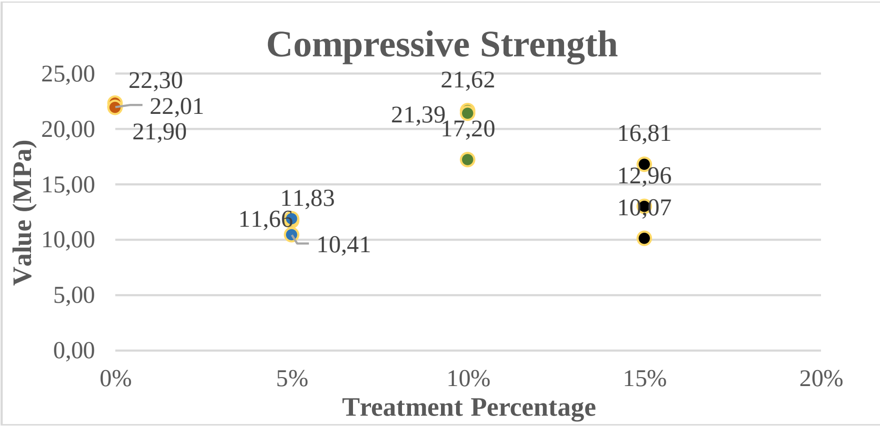

Fig.9. Compressive strength data for paving block

The difference between the treatment test using ANOVA, and the result of ANOVA test is shown in Table 3. It showed that there are significant differences among the treatments (p-value 0.0006731 < 0.05) means accept by H, reject by H0. Each treatment used bottom ash in making paving blocks has a different impact on compressive strength. This means there are significant differences between each treatment for test results of the compressive strength in 0%, 5%, 10% and 15% treatment.

Table 4. Compressive strength ANOVA test

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	243,19227	3	81,0640909	17,78564	0,0006731	4,0661806
Within Groups	36,462718	8	4,55783981			
Total	279,65499	11				

The compressive strength from the four treatments showed distribution around quality grade B and D, and a hypothesis was created for that grade of quality. The result of t-test showed at Table 3.2. Based on the distribution of data, the hypothesis was created like this:

Treatment A	Treatment B	Treatment C	Treatment D
Level B	Level D	Level B	Level D
μ = 20	μ = 10	μ = 20	μ = 10

$\mu \neq 20$ $\mu \neq 10$ $\mu \neq 20$ $\mu \neq 10$

Table 5. T-Test for compressive strength of paving block

	Treatment 0%		Treatment 5%		Treatment 10%		Treatment 15%	
	Data	*Standart*	*Data*	*Standart*	*Data*	*Standart*	*Data*	*Standart*
Mean	22,07	20	11,30	10	20,07	20	13,28	10
Variance	0,04	0	0,60	0	6,18	0	11,41	0
Observations	3,00	3	3,00	3	3,00	3	3,00	3
Pooled Variance	0,02		0,30		3,09		5,71	
Hypothesized Mean Difference	0		0		0		0	
df	4		4		4		4	
t Stat	17,57		2,91		0,05		1,68	
P(T<=t) one-tail	0,00		0,02		0,48		0,08	
t Critical one-tail	2,13		2,13		2,13		2,13	
P(T<=t) two-tail	0,00		0,04		0,96		0,17	
t Critical two-tail	2,78		2,78		2,78		2,78	

From Table 4. 3, found that treatment 0% and 5% reject by H1 and accept by Ha, it means treatment 0% don't complied for quality B and treatment 5% don't complied for quality D. For treatment 10% and 15% accept by H1 and reject by Ha, it means treatment 10% complied for quality B and treatment 15% complied for grade C.

3.1.2 Water absorption

The water absorption test on paving blocks aims to determine how much filtration power or absorption a paving block is capable of if there is a puddle. The quality of paving blocks will Greatly affect the water absorption capacity, the stronger the quality, the lower the water absorption capacity of the paving blocks. Nothing but the main objective to determine the effect that paving blocks have with a mixture of bottom ash with a variation of treatment 0%, 5%, 10%, and 15%. In obtaining data on the value of this water absorption test, Equation 2 will be used. An example of the results of testing the water absorption of paving blocks substituted with bottom ash can be seen as follows:

Is known :

Wet Paving Block Weight = 2,569 Kg

Dry Paving Block Weight = 2,353 Kg

$$W_{absorption} = \frac{\text{Wet Paving Block Weight} - \text{Dry Paving Block Weight}}{\text{Dry Paving Block Weight}} \times 100\%$$

Thus :

$$W_{absorption} = \frac{2{,}569\ Kg - 2{,}353\ Kg}{2{,}353\ Kg} \times 100\% = 9{,}18\%$$

The result of the measurement water absorption is shown in Figure 3.2. There is no pattern in water absorption with the four treatments. Based on the result of the measurement, the hypothesis could created for quality grades B and D. The bottom ash substituted for paving blocks has an effect on the ability of water absorption. Data were obtained from the results of the paving block water absorption test with a 5 % variation with an absorption rate of 10 %, a 10 % variation with an absorption rate of 6 %, a 15 % variation with an absorption rate of 9 % and normal paving blocks without bottom ash mixture of 9%. based on these data, there was a decrease that occurred until there was an increase again when a variation of 10 % bottom ash was given. This happens because the bottom ash particles are larger and the surface is porous so that potential water can enter through the small cracks of the paving block which results in increased water absorption (Kennedy, 2019).

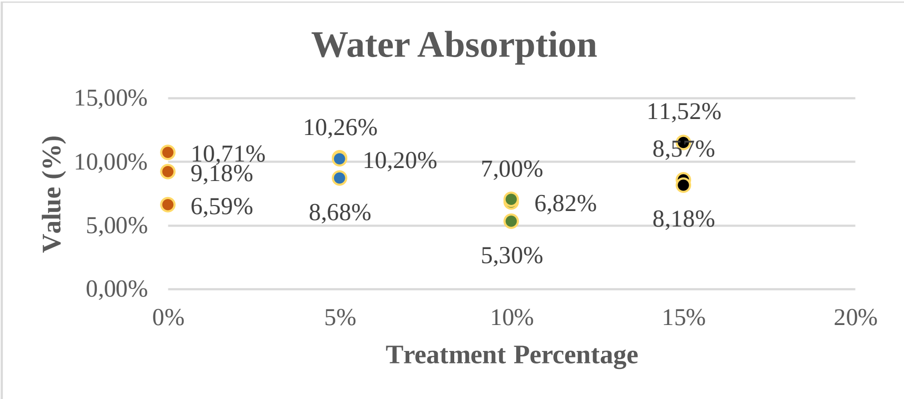

Fig.10. Water absorption data for paving block

A graph of the decrease and increase that occurred in the various paving block treatments that were carried out. Based on the results of water absorption, the 10 % variation mixture is the most optimum result which is capable of achieving quality B. The mixing that occurs optimally so that it is mixed optimally makes the 10 % variation the highest result in achieving the quality of Paving Block Water Absorption determined by SNI 03-0691-1996.To find the significant difference among the treatments based on the water absorption parameters shown at Table 3.3.

Table 6. Water absorption ANOVA test

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0,0020777	3	0,00069258	2,964138	0,0973835	4,0661806
Within Groups	0,0018692	8	0,00023365			
Total	0,003947	11				

The difference between the treatment test using ANOVA, and the result of ANOVA test is shown in Table 3.3. It showed that there are no significant differences among the treatments (p-value 0.0973835 > 0.05). Each treatment used bottom ash in making paving blocks has no different impact on water absorption. This means there are no significant differences between each treatment for test results of the water absorption in 0%, 5%, 10% and 15% treatment. Based on the distribution of data of water absorption, the hypothesis created like this:

Treatment A	Treatment B	Treatment C	Treatment D
Level D	Level D	Level B	Level D
μ = 0.1	μ = 0.1	μ = 0.06	μ = 0.1
μ ≠ 0.1	μ ≠ 0.1	μ ≠ 0.06	μ ≠ 0.1

Table 7. T-Test for water absorption for paving block

	Treatment 0%		Treatment 5%		Treatment 10%		Treatment 15%	
	Data	*Standart*	*Data*	*Standart*	*Data*	*Standart*	*Data*	*Standart*
Mean	0,09	0,10	0,10	0,10	0,06	0,06	0,09	0,10
Variance	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Observations	3	3	3	3	3	3	3	3
Pooled Variance	0,00		0,00		0,00		0,00	
Hypothesized Mean Difference	0		0		0		0	
df	4		4		4		4	
t Stat	-0,98		-0,55		0,69		-0,55	
P(T<=t) one-tail	0,19		0,30		0,26		0,31	
t Critical one-tail	2,13		2,13		2,13		2,13	
P(T<=t) two-tail	0,38		0,61		0,53		0,61	
t Critical two-tail	2,78		2,78		2,78		2,78	

From Table 3.4, found that treatment 0%, 5%, 10%, and 15% accept by H1 and reject by Ha, it means treatment 0%, 5%, 15% complied for quality D and treatment 10% complied for quality B.

3.2 Discussion

Based on the ANOVA test, the four treatments are based on compressive strength significance difference, but based on the water absorption parameter, no significant difference. In terms of substituted cement with bottom ash, these treatments could be seen as a treatment for substitution of the cement in making paving blocks. Utilization of bottom ash as become paving block could give the quality grades B and D. Table 4.1 shows the recapitulation of the quality grade of the paving block.

Table 8. Recapitulation of test results of paving block

Treatment Presentation	**Compressive Strength (MPa)**	**Water Absorption (%)**	**Grade**
0%	Not complied grade B	Complied grade D	-
5%	Not complied grade D	Complied grade D	-
10%	Complied grade B	Complied grade B	B
15%	Complied grade D	Complied grade D	D

Based on the parameter compressive strength and water absorption, paving blocks made with 10% and 15% bottom ash replacing cement complied with the national standard with quality grade B (treatment 10%), and grade D (treatment 15%). This is different from previous research conducted by Kennedy, 2019 the results of compressive strength and water absorption from each treatment have a different quality grade, where there is a difference in the quality classification of the paving block variations due to differences in grade in each treatment. the water absorption ability of paving blocks shows that the higher the bottom ash treatment given, the higher the percentage of water absorption for paving blocks. This could happen because the bottom ash particles are larger and the surface is porous so that potential water can enter through the small cracks of the paving block which results in increased water absorption (Kennedy, 2019). The compressive strength of the paving block with the treatments in this research does not give a certain pattern. Treatment with 10% gives the highest compressive strength compared with 5% and 15% addition.

These results are different from previous research showing the addition of bottom ash reduced the compressive strength (Kennedy, 2019). From the research of Hilal, Ghozali & Wardhono (2020). The experimental results prove that every addition of botom ash will not only reduce the compressive strength of the paving block. It happened that the optimum results in this research were that the 30% treatment was an increase from the variation treatment carried out at 10%, 20%, 30%, 40% and 50%. Then there was a decrease in the compressive strength results again when the variation was 40% and 50%. This can also be concluded from the results of this research that there was optimum binding of bottom ash with cement at a treatment variation of 10%.

4. Conclusions

The use of incinerator bottom ash at PT. X by making paving block substitution materials has an influence on the results of the compressive strength test and water absorption test. The compressive strength of the paving block gives the highest at a 10% addition of bottom ash, and the water absorption reached the lowest value at that addition. The treatments used are significantly different based on the compressive strength parameter, but there is not have significant difference in water absorption parameter. Testing parameters to standard showed that treatment 10% complied with quality grade B, and treatment 15% complied with quality grade D. With the results of this study based on the problem statement at the beginning of the study by giving bottom ash as a substitute for paving blocks, the results were in accordance with the requirements of the parameters tested, namely compressive strength and water absorption. Then, looking at the results shown, each variation treatment gives a significant difference.

In this study related to the use of bottom ash for substitution of paving block materials, there are several suggestions for this research :

(1) It would be great to do a laboratory test to determine the chemical content of bottom ash first so that the bottom ash content can be determine.

For further research, it can be suggested adding waste/other aggregates which can increase the content of calcium (Ca), Silica (Si), or Aluminum (Al).

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Author Contribution

Conceptualization, A.M. and Y.I.; Methodology, A.M. and Y.I.; Software, A.M.; Validation, A.M. and Y.I.; Formal Analysis, A.M.; Writing - review & editing, A.M. and Y.I., Writing – Original Draft Preparation, A.M. and Y.I.

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Biographies of Author(s)

YUNITA ISMAIL MASJUD, lecturer at Environmental Engineering, University of President.

- Email: yunitaismail@president.ac.id
- ORCID: https://orcid.org/0000-0002-3297-8850
- Web of Science ResearcherID: -
- Scopus Author ID: https://www.scopus.com/authid/detail.uri?authorId=57205019607
- Homepage: https://sinta.kemdikbud.go.id/authors/profile/6068346

AFINA MAULIDA, student at Environmental Engineering, University of President.

- Email: afinamaulida1106@gmail.com
- ORCID: -
- Web of Science ResearcherID: -
- Scopus Author ID: -
- Homepage: -