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Utilization of Rembang PLTU Coal Burning Waste for Paving Blocks Material

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Abstract Accumulating coal combustion waste will negatively affect the neighborhood. Over time, more waste will be generated, which will take time. Processing methods are needed to reduce the increasing amount of coal waste. One processing method is to use ash and bottom ash as a mixture in paving. The study used paving blocks as a control sample for one cement : 3 sand. Fly ash addition variation consists of 0%, 10%, 20%, and 30% of the cement weight. The compressive strength test results at 28 days and 60 days of control paving blocks with a standard mixture were 17.8 MPa and 24 MPa. The compressive strength results from 0% variations are 10.9 MPa and 15.6 MPa. The 10% variation has a compressive strength of 10.5 MPa and 13.6 MPa. The 20% variation has a compressive strength of 10.25 MPa and 14.5 MPa. The variation is 30%, with compressive strength of 11.5 MPa and 14.86 MPa.

Keywords: Paving, Fly ash, Bottom ash

INTRODUCTION

The increasing population requires human resources thinking that can adapt to change and creative thinking skills. Electricity needs are also increasing along with the population. The government has developed a Steam Power Plant (PLTU) using coal as fuel to meet this need. However, burning coal produces waste in fly ash and bottom ash called FABA. PLTU Rembang produces around 67,000 tons of FABA per year [1], and this waste needs to be appropriately managed to prevent environmental pollution. FABA comprises around 80% fly ash and around 20% bottom ash from coal combustion [2]. Figure 1. shows the solid waste formed from this process.

(a)

(b)

FIGURE 1. Coal Waste from PLTU

Fly ash and bottom ash are two types of industrial waste that can be used in construction. Fly ash, with fine texture and finer particle characteristics than cement with hydraulic properties [3], can be used instead of cement and sand. Meanwhile, bottom ash has a different texture than sand and can be used instead of cement and sand. Sari et al. (2003: 27) state that this type of waste has different properties; fly ash has high silica content, and bottom ash has high iron content.MPa [5].

Conversely, the Indonesian government focuses on infrastructure development, especially road construction. Paving blocks, or concrete bricks, are an alternative that can be used to cover the ground surface with relatively high water absorption capabilities. The aesthetic advantages, structural strength, and adaptability to various designs make paving blocks a popular choice [14]. Pangestuti (2023: 52), the absorption of regular paving with a composition ratio of cement and sand of 1:3 is 8.91% [4]. In this research, researchers used FABA (Fly Ash and Bottom Ash) as an alternative material for making paving blocks to reduce the use of cement fine aggregate and industrial waste. Using fly ash in paving blocks is an innovation in developing infrastructure materials [12]. Based on SNI 03-0691-1996, paving blocks are classified according to quality and use values, namely as in Table 1

TABLE 1. Classified of Paving Block based on SNI 03-0691-1996

Class	Compressive Strength (MPa)		Abrasion Resistance (mm/minutes)		Water absorption max
	Average	Min	Average	Min	(%)
A	40	35	0,090	0,103	3
B	20	17	0,130	0,149	6
C	15	12,5	0,160	0,184	8
D	10	8,5	0,219	0,251	10

Fly Ash and Bottom Ash

Fly ash is excellent coal ash that comes from coal burning activities in the furnace of a power plant boiler. Particle filtration will generally capture fly ash before the flue gas reaches the chimney. The components of fly ash vary greatly depending on the source and composition of the coal burned. Still, all fly ash contains significant amounts of silicon dioxide (SiO2), aluminum oxide (Al2O3), and calcium oxide (CaO).

Fly ash is divided into two classes, namely class F and class C, as shown in Table 2. Class F fly ash is produced from burning anthracite or bituminous coal and has pozzolanic properties. Quick lime, hydrated lime, or cement must be added to obtain cementitious properties. Class F fly ash has low lime content (CaO < 10%). Class C fly ash, where fly ash is produced from burning lignite or sub-bituminous coal, apart from having pozzolanic properties, also has self-cementing properties (the ability to harden and increase strength when reacting with water), and this property occurs without the addition of lime. Usually contains lime (CaO) > 20% [6].

TABLE 2. Classified of Fly Ash Based on SNI 2460:2014

Properties	Class		
	N	F	C
$SiO_2 + Al_2O_3 + Fe_2O_3$, min %	70	70	50
SO_3, max %	4	5	5
Water Content, max %	3	3	3

Bottom ash is ash formed from the combustion process in the furnace in the form of a mixture of coal ash, quartz sand, and fragments of the furnace wall that are eroded during the combustion process. The bottom ash is larger and heavier than fly ash, so when burning, the bottom ash falls into the boiler and collects in the ash hooper [7].

Bottom ash has physical properties (porous), a density of 2,230 kg/m³, and a particle size of 0.5 – 2 mm. The physical description of bottom ash is similar to sand with fine and large sand gradations, and bottom ash grains make researchers interested in using them as a substitute material in concrete production [8] (Singh & Siddique, 2016). Johnson Alengaram (2022) said that bottom ash has a similar appearance and size to fine aggregate or sand. The particles have physical characteristics that are rough and porous, like glass, granular, and grayish [9].

Pangestuti et al. (2023) showed that the use of fly ash and bottom ash from PLTU Tanjung Jati Jepara produced quality B paving blocks with a compressive strength value of 18.73 MPa in the mix design (1 S : 3 BA) and quality C paving blocks with water absorption of 7.5% in mix design and ((0.5 S: 0.5 FA): 3 BA). Each additional percentage of fly ash will reduce the compressive strength value and the paving block's water absorption capacity. Meanwhile, using bottom ash as a substitute for sand will reduce the compressive strength value but increase the water absorption capacity of the paving block [4].

(a)

(b)

FIGURE 2. Physical Form of FABA (a) Fly Ash (b) Bottom Ash

Miftakhussurur (2020) stated that Polymer Block Paving with Coal waste in a mix design of 1 cement: 2 aggregates with varying percentages of 25% Fly Ash: 75% Bottom Ash obtained the highest compressive strength of 17.79 MPa. In the mix design, one cement: 3 aggregates with varying percentages of 25% Fly Ash: 75% Bottom Ash gets the highest compressive strength value, 10.04 MPa [10]. Apart from increasing compressive strength, adding fly ash increases paving blocks' long-term durability [14].

RESEARCH METHODOLOGY

In this research, two paving block test objects were made. The first type was paving blocks using cement and sand as control test objects, and the second type was using fly ash as a substitute for the cement mixture and bottom ash as a substitute for sand. The composition of the mix design used and number of test objects are in Table 3 and Table 4.

TABLE 3. Composition of The Paving Mix Desain

Composition					
Type	**Cement**	**Fly Ash**	**Sand**	**Bottom Ash**	**Water**
Normal	1	0	3	0	0,6
FA 0	1	0	1	2	0,6
FA 0,1	0,9	0,1	1	2	0,6

Composition					
Type	**Cement**	**Fly Ash**	**Sand**	**Bottom Ash**	**Water**
FA 0,2	0,8	0,2	1	2	0,6
FA 0,3	0,7	0,3	1	2	0,6

TABLE 4. Number of Object Tests

Type	Cement	Fly Ash
Normal	10	8
FA 0	10	8
FA 0,1	10	8
FA 0,2	10	8
FA 0,3	10	8
Total	50	40

The compressive strength test of concrete is carried out when the specimen is 28 days old and 60 days old using a compression testing machine to obtain the maximum load. Compressive strength test using 8 sample cylinders.

RESULT AND DISCUSSION

Research Result

Sand

Sand testing includes gradation, specific gravity, unit weight, and sludge content. A summary of the test results of sand can be seen in Table 5.

TABLE 5. Summary of Sand Testing

Test	Result	Standard
Specific Gravity	2,66	SNI 1970-2008 (2,50 – 2,70)
Graduation	Zona II	SNI 03-2834-2000 (Zona I – IV)
Fine Modulus	3,142	SNI 03-6861.1-2002 (1,50 – 3,80)
Density Weight	1,60 – 1,81	SNI 03-4804-1998 (0,8-1,9)
Absorption	1,78%	SNI 1971-2011 (< 3%)
Sludge	6,94%	ASTM C33-03-2003 (< 3%)

The value of the mud content contained in the sand does not meet the quality standards. The maximum sludge content, according to SNI, is 5%. Meanwhile, the mud content contained in the sand reached 6.94%. It is necessary to carry out treatment in the form of washing the sand so that the paving blocks produced are of good quality. The value of the sludge content contained in the sand does not meet the quality standards. The maximum sludge content, according to SNI, is 5%. Meanwhile, the sludge contained in the sand reached 6.94%. It is necessary to carry out treatment in the form of washing the sand so that the paving blocks produced are of good quality.

Cement

PPC cement testing was used to set time and specific gravity, and time tests were set using the Vicat test method. The purpose of setting time testing is to find the cement's initial setting time, as shown in Figure 3. A summary of cement testing can be seen in Table 6.

TABLE 6. Summary of Cement Testing

No	Test	Result	Standard
1	Specific Gravity	210 minutes	SNI 15-7064-2004 (45 – 480 minutes)
2	Gradation	3,02 gram/cm^3	SNI 2531-2015 (3,00 – 3,2 gram/cm$^{3)}$

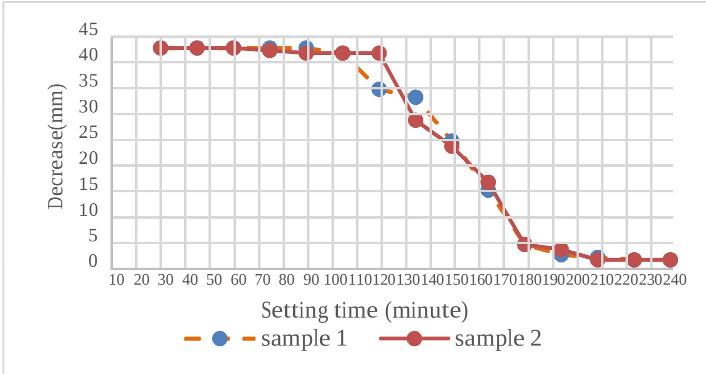
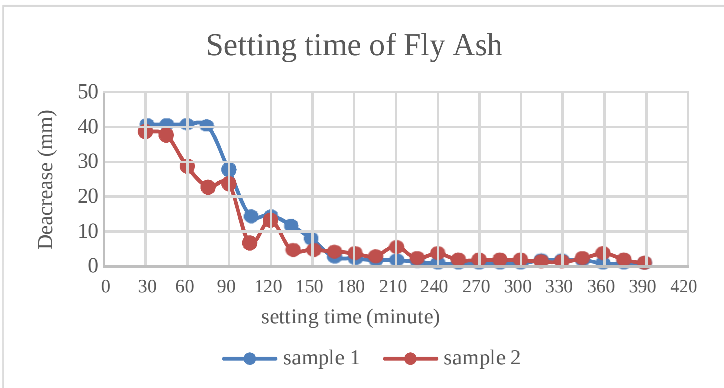


FIGURE 3. Chart of Vicat Test Cement

Fly Ash

Fly ash testing is setting time and specific gravity—testing of setting time using the Vicat test method. The purpose of setting time testing is to find fly ash's initial setting time, as shown in Figure 4. A summary of fly ash testing can be seen in Table 8.



FIGURES 4. Chart of Setting Time of Fly Ash

The highest percentage of content is SiO2, at 25%. After that is Fe2O3, with a rate of 17.3%. Al2O3 has the third highest content, with 12.7%. The SO3 content in fly ash is 1.83% in SNI 2460:2014, the SiO2 + Fe2O3 + Al2O3 content for class F is at least 70%, and class C is 50%. The SiO2 + Fe2O3 + Al2O3 content in Rembang PLTU fly ash is 55% if added. These results show that Rembang PLTU fly ash can be categorized into class C. A further summary of the tests on fly ash can be seen in Table 7.

TABLE 7. Content of PLTU Rembang Fly Ash

No	Content	Percentage (%)
1	SiO_2	25
2	Fe_2O_3	17,3
3	Al_2O_3	12,7
4	CaO_3	9,77
5	TiO_2	0,88
6	K_2O	1,36
7	MgO	0,888
8	SO_3	1,83

TABLE 8. Summary of Fly Ash Testing from PLTU Rembang

No	Test	Result	Standard
1	Setting Time	330 – 360 minutes	45 – 480 minutes
2	Specific Gravity	2,78 gram/cm^3	3,00 – 3,2 gram/cm^3
3	Chemical Compounds	$SiO_2 + Fe_2O_3 + Al_2O_3$ = 55% SO_3 = 1,83%	Type C

Bottom Ash

The tests carried out include gradation tests, specific gravity tests, sludge content tests, and bulk density tests. Furthermore, a recapitulation of all test results on the Rembang PLTU bottom ash that will be used in this research is in Table 9.

TABLE 9. Summary of Bottom Ash Testing from PLTU Rembang

Test	Result	Standard
Specific Gravity	2,66	SNI 1970-2008 (2,50 – 2,70)
Graduation	Zona II	SNI 03-2834-2000 (Zona I – IV)
Fine Modulus	2,47	SNI 03-6861.1-2002 (1,50 – 3,80)
Density Weight	1,08 – 1,18	SNI 03-4804-1998 (0,8-1,9)
Absorption	3%	SNI 1971-2011 (< 3%)
Sludge	1,2%	ASTM C33-03-2003 (< 3%)

Compressive Strength

The compressive strength test of concrete is carried out when the specimen is 28 days old and 60 days old using a compression testing machine to obtain the maximum load. Compressive strength test using 8 sample cylinders, the results of the average concrete stress of the samples were kgf/cm^2 or if converted in MPa units.

FIGURE 5. Compressive Strenght Test

TABLE 10. Summary of Bottomg Ash Testing from PLTU Rembang

Test Object	Object Number	Compressive Strenght						Decreased (%)
		Average at 28 days			Average at 60 days			
		kg/cm^2	Mpa	kg/cm^2	kg/cm^2	Mpa	kg/cm^2	
Normal	1	188	181,75	17,8	247	245,25	24	0%
	2	195			219			
	3	177			234			
	4	167			281			
FA 0	1	139	111,25	10,9	167	159,25	15,6	37%
	2	82			164			
	3	119			136			

Test Object	Object Number	Compressive Strenght						Decreased (%)
		Average at 28 days			Average at 60 days			
		kg/cm^2	Mpa	kg/cm^2	kg/cm^2	Mpa	kg/cm^2	
	4	105			170			
FA 0,1	1	126	107,00	10,5	108	138,25	13,56	42,50%
	2	86			161			
	3	109			143			
	4	107			141			
FA 0,2	1	98	104,50	10,25	174	148,25	14,5	41,50%
	2	97			164			
	3	107			119			
	4	116			136			
FA 0,3	1	108	117,00	11,5	124	151,50	14,86	37%
	2	104			136			
	3	137			183			
	4	119			163			

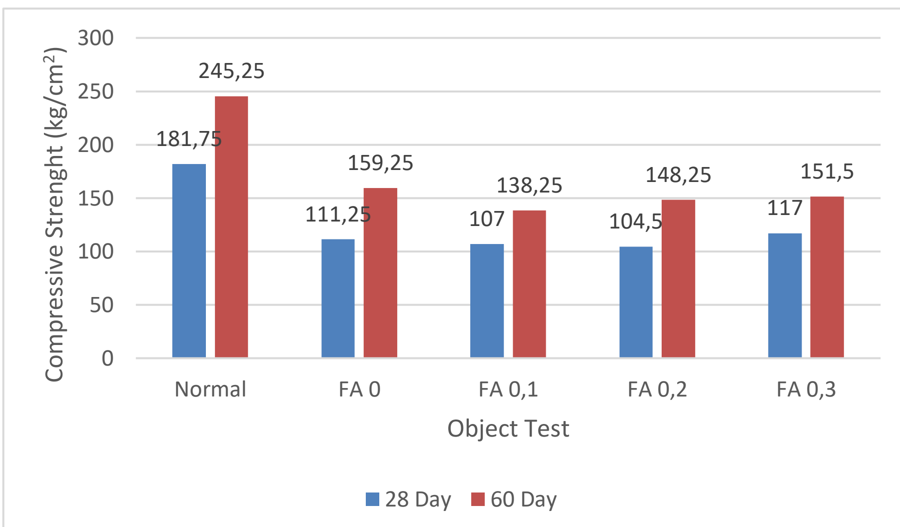


FIGURE 6. Comparison Chart of Compressive Strenght of Paving Block at 28 days and 60 days

From the results of testing the compressive strength of block paving at 28 days, standard paving has a compressive strength of 181.75 kg/cm2, the addition of 20% bottom ash as a sand substitute reduces the compressive strength of standard block paving by up to 39%, namely 111.25 kg/cm2 and when 20% bottom ash added with 10% fly ash, the compressive strength of the paving blocks decreased again by 41%, namely 107 kg/cm2. Then, when bottom ash was 20% plus 20% fly ash, the compressive strength of the paving blocks decreased again by 43%, namely 104.5 kg/cm2, and when bottom ash was 20% plus fly ash by 30%, it decreased by 36%, namely 117 kg/cm2.

Compressive strength of paving at 60 days standard paving has a compressive strength of 245.25 kg/cm2; the addition of 20% bottom ash as a sand substitute reduces the compressive strength of standard block paving by 35%, namely 159.25 kg/cm2 and when bottom ash is 20 10% added fly ash, the compressive strength of the paving blocks decreased again by 44%, namely 138.25 kg/cm2. Then, when 20% bottom ash plus 20% fly ash, the compressive. The strength of the paving blocks decreases again by 40%, namely 148.25 kg/cm2, and when 20% bottom ash plus 30% fly ash decreases by 38%, 151.5 kg/cm2.

CONCLUSIONS

1. The highest compressive strength of paving is FA 30%, with a compressive strength of 151.5 kg/cm^2 at 60 days, which is class C quality—usually used for making pedestrian roads. It can also be seen that every additional percentage of fly ash used in the mix design will reduce the compressive strength value of the paving block. In addition, using bottom ash as a substitute for sand also impacts the compressive strength value of paving blocks. This is because bottom ash does not have a better density than sand.
2. As an alternative material, making paving blocks to reduce the use of cement and sand and reduce industrial waste pollution as an alternative material in making paving blocks to minimize the use of cement and sand and reduce industrial waste pollution.

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