Optimization of fly ash and bottom ash substitution against paving block manufacture according to SNI 03-0691-1996

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Abstract. The waste of coal burning has a very negative impact on the environment if the waste is not managed as well as possible. The remaining waste of coal combustion consists of fly ash and bottom ash. FA and BA can be developed into substitution materials in the process of making paving blocks. The purpose of this study was to determine the quality of paving block in accordance with SK SNI 03-0691-1996 with optimization in the use of FA and BA. This study uses a 351 paving block sample size of 20x10x6 cm. Paving blocks are divided by 4 categories, namely normal paving block, paving block with FA substitution, BA substitution and combination of FA-BA with each variation 0%, 25%, 50%, 75% and 100%. Each variation amounted to 27 samples. Paving block quality measurement is done through 4 tests: absorption, compressive strength, sodium sulphate resistance and Los Angeles tests. The result of the test shows the absorption of normal paving block is 3,229%, paving block with 25% FA is 3,889%, paving block with 50% BA is 5,560% and paving block with 25% FA-BA combination is 5,794%. Compressive strength in normal paving block is 25,50 MPa, paving block with 25% FA is 25,28 MPa, paving block with 25% BA is equal to 27,61 MPa and paving block with 25% FA-BA is 26,00 MPa. In testing of sodium sulfate resistance, almost all test specimens are eligible except for paving block with 50% FA and 75% FA. In the test of wear resistance, no specimen is eligible according to SK SNI 03-0691-1996. The comparison of the strength of the test specimen can be seen in substitution with 25% BA which reaches maximum strength.

1. Introduction
As times progressed, innovation in the construction world continues to increase, such as the development of construction on concrete. Concrete is one of the most commonly used construction materials. Many other usage of concrete in everyday life. One of them is Paving Block.

The development of Paving Block usage is considered more economical, able to withstand the compressive force given from the outside and is considered to have a beauty value. Paving Block usage is widely used in certain areas such as roads in residential complexes, sidewalks, walkways / alleys, office and home pages, roads in tourist areas and much more.

Paving Block manufacture has a mixture of compositions such as cement, fine aggregate, coarse aggregate, and water. In this study cement and fine aggregate are substituted by Fly Ash and Bottom Ash. Fly Ash is obtained from coal combustion which has silica content of 72.2%. Because it resembles cement so it can serve as an adhesive and can reduce the use of cement. While Bottom Ash is the material of the remaining of imperfect coal combustion which has a particle resembling sand with dark gray, shaped pelleted grains physical characteristics that are considered able to reduce sand usage.
Based on PP. No. 85 of 1999 on the management of hazardous and toxic waste (B3), Fly Ash and Bottom Ash are categorized as B3 waste because there are heavy metal oxide contents that will naturally encroach and pollute the environment. Hazardous and toxic substances (B3) are the remains of an effort and or activity containing toxic hazardous substances due to their nature and or concentration and or amount, either directly or indirectly, may pollute and damage the environment, or may harm life sustainability, health, human survival and other living things.

According to Government Regulation Number 18 of 1999 article 9 paragraph 1 concerning any person conducting an effort and or activity using hazardous and toxic materials and / or producing B3 waste shall perform B3 waste reduction, manage B3 waste and or accumulate B3 waste. So with this research is considered able to reduce the negative impact of Fly Ash and Bottom Ash. The following table contains the content of Fly Ash and Bottom Ash. According to SNI 03-0691-1996 "Paving Block is a building material made of a mixture of portland cement or similar hydrolytic adhesive, water and aggregate with or without other additives which does not reduce the quality of the concrete.

2.1 Fly Ash
Fly Ash is obtained from coal combustion with the temperature of 1600°C which has silica component content of 72.2%. Because it resembles cement it can serve as an adhesive and can reduce cement usage. Class F fly ash is produced from anthracite or bituminous coal combustion, has a pozzolanic nature and to obtain cementitious properties, quick lime, hydrated lime, or cement should be added. Fly ash grade F has a low lime content (CaO <10%). Class C Fly ash class is produced from lignite or sub-bituminous coal combustion in addition to having pozolanic properties also has self-cementing properties (the ability to harden and add strength when reacted with water) and these properties arise without the addition of lime. Fly ash class C contains lime greater than fly ash class F (CaO > 20%). So fly ash from PT. SOCI MAS used in this research is classified into fly ash class F, because lime content in the fly ash is 4.79% (CaO <10%).

![Figure 1. Fly Ash](image1.png)

![Figure 2. Bottom Ash](image2.png)

| Table 1. Elements contained in fly ash |
|---|---|---|---|
| No | Parameter as Unit | Result | Method |
| 1 | Silica as SiO₂ | % | 72.2 | Gravimetry |
| 2 | Aluminium as Al₂O₃ | % | 18.8 | Calculation |
| 3 | Iron as Fe₂O₃ | % | 0.79 | A A S |
| 4 | Calcium as CaO | % | 4.79 | Tiritimetry |
| 5 | Magnesium as MgO | % | 3.50 | Gravimetry |
| 6 | Sodium as Na₂O | % | 0.03 | A A S |
| 7 | Potassium as K₂O | % | 0.04 | A A S |
| 8 | Fosfor as P₂O₅ | % | 0.19 | Spektrofotometri |
| 9 | Sulfur (S) | % | 2.12 | Gravimetry |
| 10 | Mangan | mg/Kg | 81.8 | A A S |

Source: Laboratory of Research Assessment and Standarization, Medan
2.2 Bottom Ash

Bottom Ash is an imperfect combustion coal waste material that has a particle resembling sand with a dark gray physical characteristic, in the shape of a pivot grains that is considered capable of reducing sand usage.

| No | Parameter             | Unit | Result | Method        |
|----|-----------------------|------|--------|---------------|
| 1  | Silica as SiO₂        | %    | 53.4   | Gravimetri    |
| 2  | Aluminium as Al₂O₃    | %    | 6.77   | Perhitungan   |
| 3  | Iron as Fe₂O₃         | %    | 1.27   | A A S         |
| 4  | Calcium as CaO        | %    | 8.74   | Tritimetri    |
| 5  | Magnesium as MgO      | %    | 4.12   | Gravimetri    |
| 6  | Sodium as Na₂O        | %    | 0.06   | A A S         |

Source: Laboratory of Research Assessment and Standardization, Medan

2. Research and Method

![Research Flow Diagram](image-url)

Figure 3. Research Flow Diagram
3. Result And Discussion

3.1 Absorption Test
The results of water absorption test on Paving Block are as follows:

![Graph of absorption value with fly ash and bottom ash substitution](image)

From the graph of the tested composition of Paving Block, the smallest water absorption value occurs in normal Paving Block with water absorption value of 3.229%. The value of water absorption in Paving Block with the smallest Fly Ash substitution is on Paving Block of 25% Fly Ash of 3.998% and the largest in Paving Block of 75% Fly Ash of 15.963%. But in Paving Block of 100% Fly Ash water absorption value can not be calculated because the Paving Block is crushed, caused the Fly Ash only has a low lime content so Fly Ash can not bind perfectly. The value of water absorption in Paving Block with Bottom Ash substitution is the smallest in Paving Block of 50% Bottom Ash of 5.560% and the largest is Paving Block of 25% Bottom Ash of 8.139%. The value of water absorption on Paving Block with the smallest Fly Ash Bottom Ash substitution is on Paving Block of 25% Fly Ash Bottom Ash of 5.794% and the largest is Paving Block of 100% Fly Ash Bottom Ash of 13.461%.

The use of substitution variation of Fly Ash greater than 25% can cause a large absorption value because the physical properties of Fly Ash can not bind perfectly as cement and absorb more water, therefore Paving Block is not solid and causes many pores causing the absorption value to rise as well as the substitution of Bottom Ash.

3.2 Compressive Strength Test
The test results of compressive strength on Paving Block in this study is as follows. From the graph above it can be seen that the highest compressive strength is found in Paving Block with Bottom Ash substitution of 27.61 MPa. And the lowest compressive strength is found in Paving Block with Fly Ash substitution of 7.22 MPa. But on Paving Block with 100% Fly Ash substitution, compressive test can't be done because Paving Block is very fragile and easily crushed.
Figure 5. Graph of relation between Fly Ash and Bottom Ash substitution against compressive strength

According to ASTM, ACI, and SNI, the value of Fly Ash content used in concrete mixture is 15% - 25% by weight of cement. Several studies show the optimum level of Fly Ash is at 10% -20% for improving the quality of concrete. Variations of Fly Ash sits greater than 25% can not achieve a large compressive strength value because Fly Ash can't bind perfectly causing the Paving Block not as solid as cement. This is because Fly Ash can not replace the nature of cement that serves as the main binder material on the concrete. The occurrence of compressive strength in Paving Block substitution of Bottom Ash with variation greater than 25% is due to Bottom Ash having a finer gradation than sand gradation so that Paving Block substitution of Bottom Ash with variation greater than 25% has a compressive strength value under normal Paving Block.

Paving Block that can be included in category B of quality is normal Paving Block, Paving Block of 25% Fly Ash, Paving Block of 25% Bottom Ash, Paving Block of 75% Bottom Ash, Paving Block of 100% Bottom Ash, Paving Block of 25% Fly Ash Bottom Ash, And Paving Block of 50% Fly Ash Bottom Ash. Paving Block with B quality can be used for parking lot.

Paving Block that can be included into the category C of quality is Paving Block of 50% Fly Ash, Paving of Block 50% Bottom Ash, and Paving Block of 75% Fly Ash Bottom Ash. Paving Block category C of quality can be used for pedestrians. Paving Block that can be included into quality D is Paving Block with 100% of Fly Ash and Bottom Ash substitution and can be used for garden and other usage.

Paving Block with 75% substitution of Fly Ash can't be included into category D because the value of Paving Block compressive strength is below the minimum requirement of quality D.

3.3 Wear Resistance Test

The results of wear resistance test on Paving Block in this study is as follows:

Figure 6. Graph of relation between Fly Ash and Bottom Ash substitution against wear resistance
From the graph of the wear resistance test results, it can be seen that Paving Block is normal, Paving Block of 25% Fly Ash, Paving Block of 25% Bottom Ash, Paving Block of 75% Bottom Ash, Paving Block of 100% Bottom Ash, And Paving Block of 50% Fly Ash Bottom Ash have wear resistance value which do not fulfill the standard of Paving Block of B quality according to SNI 03-0691-1996 that the minimum wear resistance is 0.149 mm / minute and average 0.130 mm / minute.

Paving Block of 50% Fly Ash, Paving Block of 50% Bottom Ash, and Paving Block of 75% Fly Ash Bottom Ash have wear resistance value that does not meet the standard of Paving Block of C quality according to SNI 03-0691-1996 that the minimum wear resistance is 0.184 mm / Minutes and an average of 0.160 mm / min. For Paving Block of 100% Fly Ash Bottom Ash has wear resistance value that does not meet the standard of Paving Block of D quality according to SNI 03-0691-1996 which is the minimum wear resistance is 0.251 mm / min and an average of 0.219 mm / min. But on Paving Block with 100% of Fly Ash substitution, wear resistance can not be tested because Paving Block is very fragile and easily crushed. From Paving Block test result against wear resistance, it is found wear resistance value that does not meet SNI 03-0691-1996 because the tool used in this test does not meet the standard of SNI.

4. Conclusion
From the results of research obtained and from the results of the discussion that has been done it can be concluded things as follows:
1. The largest water absorption from all experiment variation is in Paving Block with 75% Fly Ash composition of 15.963%.
2. The largest compressive strength is in Paving Block with 25% of Bottom Ash substitution.
3. From the table of resistance test to sodium sulfate result, it is seen that almost every Paving Block is qualified, except the Paving Block with Fly Ash substitution of 50% and Fly Ash of 75%.
4. From the wear resistance test, the wear resistance value is too big so that it is not in accordance with the standard SNI 03-0691-1996.
5. The comparison of all normal Paving Block test with Paving Block substitution of Fly Ash and Bottom Ash is visible.

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