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COMPRESSIVE STRENGTH AND WATER ABSORPTION OF SCC MORTAR PAVING BLOCKS BASED ON LOW-VOLUME FLY ASH MODIFIED WITH CORN COB ASH

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Abstract
This experimental study investigates the compressive strength, water absorption, and workability of self-compacting concrete (SCC) mortar paving blocks incorporating low-volume fly ash (LVFA) and corn cob ash (CCA). Fly ash and corn cob ash were used at proportions of 0%, 5%, 7.5%, and 10% of the total cement mass. Compressive strength was evaluated at 7, 14, and 28 days, while water absorption and slump-flow tests were also conducted. The results indicate that increasing fly ash content improves slump-flow and enhances the flowability of fresh SCC mortar. In contrast, increasing corn cob ash reduces slump-flow because its fine, absorptive particles increase water demand. Considering mechanical performance and workability, the optimum mixture contained 10% fly ash and 5% corn cob ash. It achieved compressive strengths of approximately 29.45 MPa at 7 days, 34.65 MPa at 14 days, and 36.57 MPa at 28 days. Water absorption decreased from 5.21% at 7 days to 4.20% at 14 days and 3.00% at 28 days. The results demonstrate the potential of combining LVFA and corn cob ash in durable SCC mortar paving blocks while supporting the beneficial use of industrial and agricultural waste.

Keywords: Compressive Strength; Corn Cob Ash; Fly Ash; SCC Mortar; Water Absorption.

INTRODUCTION

The use of paving blocks in the construction industry has increased significantly and has become increasingly popular compared with several other types of concrete products. However, the growing demand for paving blocks is not always accompanied by improvements in their quality, particularly in terms of strength, durability, and service life. One of the main factors affecting paving block performance is the quality and proportion of the raw materials used in the production process. Inappropriate material composition may result in paving blocks with inadequate mechanical and durability properties. According to data from Statistics Indonesia (BPS) published in 2022, national corn productivity in 2021 reached 57.09 quintals per hectare, indicating the generation of a substantial amount of corn waste. In Indonesia, corn waste has generally been utilized as animal feed, handicraft material, and briquette fuel. Corn cobs account for approximately 30% of the total weight of corn and are generated in large quantities after harvesting. Based on BPS production data, corn cob waste in Indonesia is estimated to reach approximately 5.7 million tons per year. A significant portion of this waste remains underutilized and is commonly disposed of or openly burned, potentially contributing to environmental pollution, greenhouse gas emissions, and global warming.

The utilization of corn cob ash as an alternative material in self-compacting concrete (SCC) mortar for paving blocks may provide an innovative solution for reducing agricultural waste. Corn cob ash contains a relatively high silica content, with approximately 66.38% SiO_2, which indicates its potential as a supplementary material in paving block mixtures. Prior to its application, corn cobs should be burned at temperatures ranging from approximately 650°C to 800°C for about eight hours to obtain ash with the desired characteristics. Corn cobs are composed of approximately 45–50% cellulose, 30–35% hemicellulose, and 10–20% lignin, while the resulting ash may contain more than 60% silica. Therefore, the combined use of corn cob ash and fly ash has the potential to improve the sustainability of SCC mortar paving blocks while reducing the consumption of conventional construction materials.

The objectives of this study are to determine the compressive strength and water absorption of paving blocks incorporating corn cob ash and fly ash as additional materials, to investigate the slump-flow characteristics of SCC mortar with the addition of fly ash and corn cob ash, and to determine the optimum compressive strength of SCC mortar containing 0–10% fly ash and 0–10% corn cob ash.

LITERATURE REVIEW

Corn Cob Ash

A corn cob is the central part of the corn ear to which the kernels are attached. It is enclosed by the husk and constitutes one of the major agricultural residues generated during corn processing. Mature corn cobs are relatively lightweight but have a rigid structure and can serve as a source of furfural, an organic compound derived from five-carbon sugars. Corn cobs primarily consist of complex lignocellulosic compounds, including lignin, hemicellulose, and cellulose. These compounds have the potential to be biologically or chemically converted into other useful materials. When subjected to an appropriate combustion process, corn cobs can be converted into corn cob ash, which has potential for use as a supplementary material in cement-based composites.

Fly Ash

Fly ash is a fine particulate material generated as a by-product of coal combustion in steam power plants. It is classified as a pozzolanic material because it contains reactive silica and alumina compounds that, in the presence of water and calcium hydroxide, can form cementitious compounds with properties similar to those produced during Portland cement hydration. These characteristics make fly ash suitable for use as a supplementary material in cement-based products, including concrete, mortar, paving blocks, tiles, and other construction materials.

Table 1. Classification Based on Fly Ash Percentage

Mutu	Kuat Tekan (MPa)		Keausan (mm/menit)		Penyerapan air rata-rata maks (%)	Keterangan
	Rata-rata	Min	Rata-rata	Min		
A	40	35	0,9	0,103	3	Jalan
B	20	17	0,13	0,149	6	Parkiran
C	15	12,5	0,16	0,184	8	Pejalan kaki
D	10	8,5	0,219	0,251	10	Taman, dll

Source: Thomas (2007)

Paving Blocks

Paving blocks are construction materials commonly used as an alternative surface covering for various outdoor applications, including sidewalks, parking areas, garden pathways, and residential roads. Paving blocks are also commonly referred to as concrete blocks. One of their main advantages is the relatively simple installation process, as the blocks can be placed and compacted over a uniformly prepared sand bedding layer. Paving blocks may also provide environmental benefits because rainwater can infiltrate through the joints between individual blocks, thereby contributing to surface-water management. In addition, paving blocks are available in various sizes, shapes, and colors, allowing them to provide both functional and aesthetic benefits.

Table 2. Paving Block Quality Classification

Mutu	Kuat Tekan (MPa)		Keausan (mm/menit)		Penyerapan air rata-rata maks (%)	Keterangan
	Rata-rata	Min	Rata-rata	Min		
A	40	35	0,9	0,103	3	Jalan
B	20	17	0,13	0,149	6	Parkiran
C	15	12,5	0,16	0,184	8	Pejalan kaki
D	10	8,5	0,219	0,251	10	Taman, dll

Source: SNI 03-0691-1996

Compressive Strength of Paving Blocks

Compressive strength is the ability of a paving block to withstand compressive loads without experiencing failure or excessive deformation. The compressive strength of paving blocks is generally expressed in megapascals

(MPa) or kilograms per square centimeter (kg/cm²). According to the Indonesian National Standard SNI 03-0691-1996, the required compressive strength of paving blocks varies depending on their intended application and traffic loading conditions. Several factors may influence the compressive strength of paving blocks, including the quality of the constituent materials, such as cement, sand, and aggregates; the proportions of the materials in the mixture; the quality of the mold and manufacturing process; environmental conditions, including temperature and humidity; and the curing age of the paving blocks. In general, higher compressive strength indicates better mechanical performance and may contribute to a longer service life.

Water Absorption of Paving Blocks

Water absorption refers to the ability of a paving block to absorb water into its pore structure. This property is an important parameter for evaluating the quality and durability of paving blocks because excessive water absorption may indicate high porosity and potentially reduce resistance to environmental exposure. According to SNI 03-0691-1996, the water absorption requirements for paving blocks can be classified into several quality categories: Quality A has a maximum water absorption of 3%, Quality B has a maximum water absorption of 6%, and Quality C has a maximum water absorption of 10%.

Water absorption is determined by comparing the difference between the wet mass and dry mass of the specimen with its dry mass. The percentage of water absorption can be calculated using the following equation:

Water Absorption (%) = $[(m_\beta - m_k) / m_k] \times 100\%$

where:

m_β = wet mass of the specimen (g)

m_k = dry mass of the specimen (g)

METHOD

This study was conducted at the Laboratory of the Faculty of Engineering, Cenderawasih University, Jayapura, Papua, Indonesia. The study investigated an alternative approach to producing self-compacting concrete (SCC) mortar paving blocks by incorporating corn cob ash and fly ash at proportions of 0%, 5%, 7.5%, and 10%. The experimental program included compressive strength and water absorption tests conducted on paving block specimens at curing ages of 7, 14, and 28 days. The research was conducted through a series of systematic stages, from material preparation to specimen testing and data analysis. The overall research procedures are summarized in the flowchart presented in Figure 2.

Mix Design

The mix design was developed to produce paving blocks that met the required performance criteria. This process involved selecting suitable constituent materials and determining their appropriate proportions in the paving block mixture. The proportions of fly ash and corn cob ash were varied to evaluate their effects on the fresh and hardened properties of the SCC mortar paving blocks.

Trial Mix

Before preparing the trial mixtures, the availability of the required equipment and materials was verified. Trial mixtures were then produced for compressive strength and water absorption testing. The paving block specimens had dimensions of 20 cm in length, 10 cm in width, and 8 cm in thickness. The investigated percentages of fly ash and corn cob ash in the mixtures were 0%, 5%, 7.5%, and 10%. Specimens were prepared for each mixture variation and tested to evaluate their compressive strength and water absorption at curing ages of 7, 14, and 28 days.

Research Location

The research procedures, from the initial stage to the completion of the study, are systematically summarized in a flowchart. The overall stages of the research are presented in the flow diagram below.

RESULTS AND DISCUSSION

The slump flow test was conducted to determine the workability of the paving block mixture using an Abrams cone. During the landing test, a steel plate conforming to the EFNARC (2005) standard was used as the testing surface. The test procedure involved pouring the fresh mixture into the Abrams cone in an upright position. The cone was then lifted vertically, allowing the mixture to spread freely over the steel plate. The diameter of the spread was measured within 2–5 seconds after lifting the cone, and the flow spread was recorded using a measuring tape.

Table 3. Slump Flow Test Results

NO	Benda Uji	Fly Ash	Diamter Rata-Rata (cm)			
			0%ABJ	5% ABJ	7,5% ABJ	10% ABJ
1	SMA	0%	100	100	80	72
2	SMB	5%	100	87	86	84
3	SMC	7,5%	100	100	80	75
4	SMD	10%	100	85	72	70

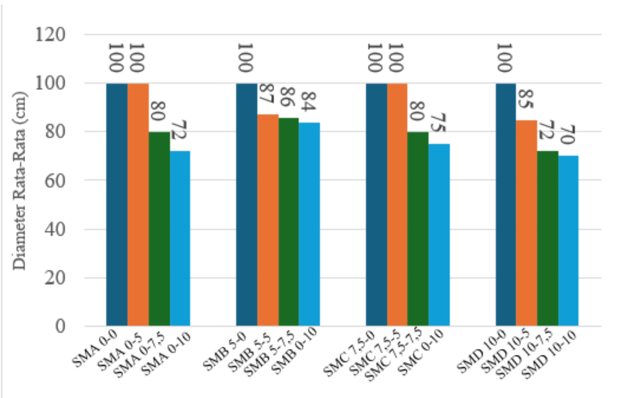

Figure 2. Slump Flow Test Results

As the percentage of fly ash (FA) increased, the slump flow value of the fresh paving block mixture also increased, indicating improved workability. In contrast, the addition of ABJ resulted in a decrease in the slump flow value. This behavior can be attributed to the fact that the number of ABJ particles is greater than that of cement or fly ash under the same conditions. Consequently, ABJ absorbs more water than cement or FA, reducing the amount of free water available in the mixture and resulting in a lower slump flow value.

Average Compressive Strength of Paving Blocks at 7 Days

The compressive strength test results for all paving block mixtures were compared to determine the optimum percentage of fly ash (FA) and ABJ replacement at the age of 7 days.

NO	Benda Uji	*Fly Ash*	Kuat Tekan Rata-Rata 7 Hari (Mpa)			
			0 ABJ	5% ABJ	7,5% ABJ	10% ABJ
1	SMA	0%	26,2	18,3	18,7	19,05
2	SMB	5%	25,15	25,5	20,2	18,8
3	SMC	7,5%	24,4	18,85	18,85	16,8
4	SMD	10%	27,5	29,45	16,57	17,7

Table 4. Average Compressive Strength of Paving Blocks at 7 Days

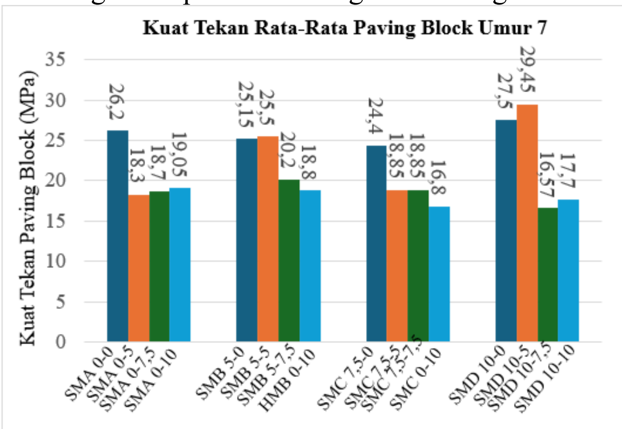

Figure 3. Average Compressive Strength of Paving Blocks at 7 Days

Based on the results of the different mixture proportions, the optimum average compressive strength of the paving blocks at 7 days was achieved with a mixture containing 10% fly ash (FA) and 5% ABJ, resulting in a compressive strength of 29.45 MPa**.**

Average Compressive Strength of Paving Blocks at 14 Days

Table 5. Average Compressive Strength of Paving Blocks at 14 Days

NO	Benda Uji	*FA*	Kuat Tekan Rata-Rata 14 hari	
			5% ABJ	Kuat Tekan Rata-Rata
1	SMD	10%	34,2	34,65
2	SMD	10%	32,6	
3	SMD	10%	37,14	

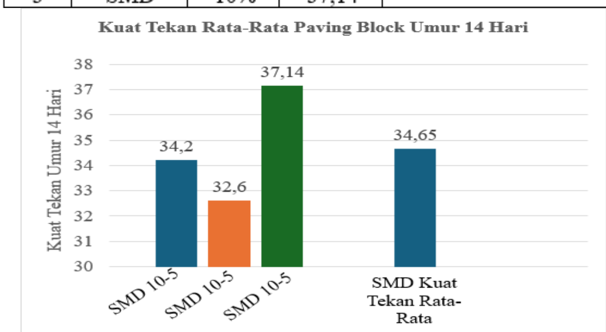

Figure 4. Average Compressive Strength of Paving Blocks at 14 Days

The results show that the paving blocks cured for 14 days with a mixture containing 10% fly ash (FA) and 5% ABJ achieved an average compressive strength of 34.65 MPa, based on three test specimens. This represents an increase in compressive strength from 29.49 MPa at 7 days to 34.65 MPa at 14 days, indicating continued strength development with increasing curing age.

Average Compressive Strength of Paving Blocks at 28 Days

Table 6. Average Compressive Strength Test Results of Paving Blocks at 28 Days

No	Benda	*FA*	Kuat Tekan Rata-Rata 28 hari	
			5% ABJ	Kuat Tekan Rata-Rata
1	SMD	10%	36,2	36,57
2	SMD	10%	34	
3	SMD	10%	39,5	

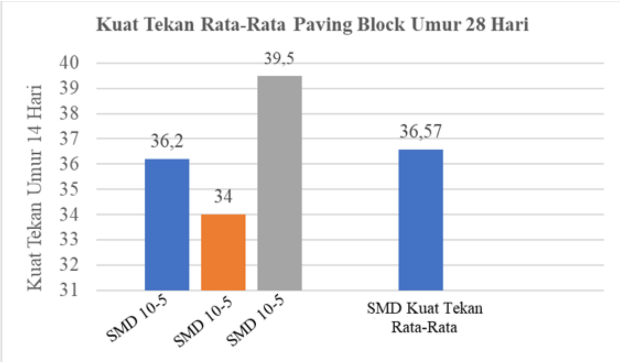

Figure 5. Average Compressive Strength Test Results of Paving Blocks at 28 Days

The results indicate that the paving blocks cured for 28 days with a mixture containing 10% fly ash (FA) and 5% ABJ achieved an average compressive strength of 36.57 MPa, based on three test specimens. This represents a progressive increase in compressive strength with curing age, from 29.49 MPa at 7 days to 34.65 MPa at 14 days, and finally 36.57 MPa at 28 days. This trend demonstrates the continued hydration process and strength development of the paving block mixture over time.

Average Compressive Strength of Paving Blocks at 7, 14, and 28 Days

The average compressive strength tests were conducted on paving blocks with the SMD specimen code, containing 10% fly ash (FA) and 5% ABJ, at curing ages of 7, 14, and 28 days.

Table 7. Average Compressive Strength Test Results of Paving Blocks at 7, 14, and 28 Days

Sampel	*FA*	Kuat Tekan Rata-Rata Paving Block		
		7 Hari	14 Hari	28 Hari
SMD	10%	29,45	34,64	36,57

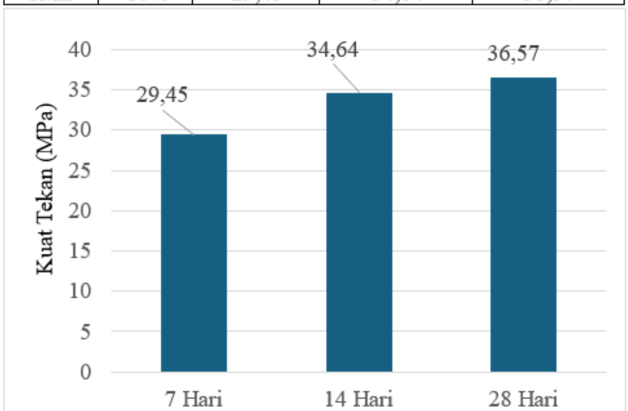

Figure 6. Average Compressive Strength Test Results of Paving Blocks at 7, 14, and 28 Days

The results show that the compressive strength of the paving block specimens containing 10% fly ash (FA) and 5% ABJ increased with curing age. The average compressive strength was 28.70 MPa at 7 days, 34.64 MPa at 14 days, and 36.57 MPa at 28 days. These results indicate a continuous improvement in compressive strength as the curing period increased, reflecting the ongoing hydration process and strength development of the paving block mixture.

Water Absorption of Paving Blocks in Accordance with SNI 03-0691-1996

In this study, a water absorption test was conducted to evaluate the ability of the paving block specimens to absorb water, as this property can significantly affect their durability and service life. The test was performed on paving blocks containing 10% fly ash (FA) and 5% corn cob ash (ABJ). Water absorption was evaluated at curing ages of 7, 14, and 28 days.

Table 8. Water Absorption of Paving Blocks at 7, 14, and 28 Days

No	Sampel	*FA*	Daya Serap Air Paving Block (FA 10% - ABJ 5%)		
			7 Hari	14 Hari	28 Hari
1	SMD	10%	5,21%	4,2%	3%

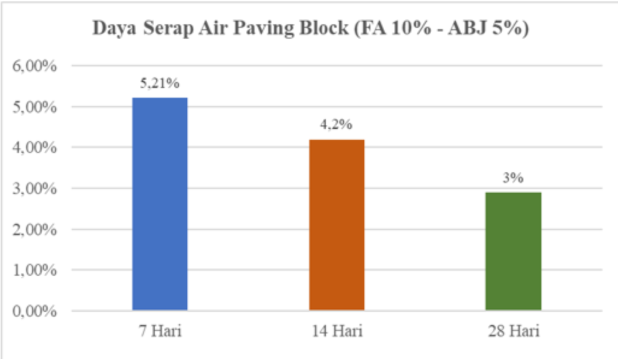

Figure 7. Water Absorption of Paving Blocks at 7, 14, and 28 Days

The test results indicate that the water absorption of paving blocks containing 10% fly ash (FA) and 5% corn cob ash (ABJ) decreased as the curing age increased. The average water absorption was 5.21% at 7 days, 4.20% at 14 days, and 3.00% at 28 days. This decreasing trend indicates that the paving blocks became denser with increasing curing age, thereby reducing their capacity to absorb water. According to SNI 03-0691-1996, the maximum allowable water absorption for paving blocks is 10%. Therefore, all test specimens satisfied the requirements of the standard, as their water absorption values were well below the specified limit.

CONCLUSION

Based on the research entitled **"**Study of the Compressive Strength and Water Absorption of SCC Mortar in Low-Volume Fly Ash (LVFA)-Based Paving Blocks Modified with Corn Cob Ash**,"** the following conclusions were drawn. The compressive strength characteristics of SCC mortar paving blocks incorporating 0%–10% fly ash (FA) and 0%–10% corn cob ash (CCA) showed varying results. The mixture containing 0% FA and 0% CCA achieved a compressive strength of 26.2 MPa, while the mixtures containing 5% FA and 0% CCA, 7.5% FA and 0% CCA, and 10% FA and 0% CCA achieved compressive strengths of 25.15 MPa, 24.4 MPa, and 27.5 MPa, respectively. Meanwhile, the mixture containing 0% FA and 5% CCA achieved a compressive strength of 18.3 MPa, while the mixtures containing 0% FA and 7.5% CCA and 0% FA and 10% CCA achieved compressive strengths of 18.7 MPa and 19.05 MPa, respectively.

The water absorption characteristics of paving blocks containing 10% fly ash and 5% corn cob ash showed values of 5.21% at 7 days, 4.2% at 14 days, and 3% at 28 days. These results indicate that the water absorption value decreased as the age of the paving blocks increased. The use of fly ash as an additional material in SCC mortar mixtures for paving blocks affected the slump-flow value. The slump-flow value increased with an increasing percentage of fly ash. In contrast, the use of corn cob ash as an additional material in SCC mortar mixtures for paving blocks resulted in a decrease in the slump-flow value as the percentage of corn cob ash increased. This is attributed to the greater number of corn cob ash particles compared with cement and fly ash, as well as the higher water absorption capacity of corn cob ash.

For further research aimed at increasing the utilization of fly ash and corn cob ash as additional materials in SCC mortar mixtures for paving blocks, several recommendations are proposed. A specialized furnace equipped with a controlled combustion temperature system should be used for producing corn cob ash, as the combustion temperature may affect the resulting compressive strength. Further research should also investigate higher percentages of fly ash to determine the optimum fly ash content. In addition, a wider range of testing ages should be considered for compressive strength testing, and durability tests should be conducted on SCC mortar paving blocks. Further studies should also include specific gravity testing for each material used to ensure better material quality and suitability for use. During the casting process, molds capable of producing highly precise, flat, and even surfaces should be used to obtain more accurate test results.

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