IPTEK The Journal of Technology and Science, 33(3), 2022 (e/pISSN:2088-2033, 0853-4098)

DOI: 10.12962/j20882033.v33i3.12915 | Received 12 May, 2022; Revised 7 Oct, 2022; Accepted 26 Dec, 2022

ORIGINAL RESEARCH

PAVING BLOCK FROM RESIDUE OF PS/LDPE/PP PLASTIC PYROLYSIS MIXED WITH PALM OIL BOTTOM ASH (POBA)

Lenny Marlinda*[1] | Heriyanti[1] | Rahmi[2] | Ratri Hanifah[3] | Nelson[2] | Sutrisno[2]

[1]Dept. of Industrial Chemistry, University of Jambi, Jambi, Indonesia

[2]Dept. of Chemistry, University of Jambi, Jambi, Indonesia

[3]Dept. of Chemical Engineering, University of Jambi, Jambi, Indonesia

Correspondence

*Lenny Marlinda, Dept of Chemistry, University of Jambi, Jambi, Indonesia.
Email: marlindalenny@unja.ac.id

Present Address

Jl. Jambi – Muara Bulian No.KM. 15, Jambi 36361, Indonesia

Abstract

The residue of plastic mixture pyrolysis can be used for making paving blocks. Fibers in plastics can be used as an adhesive against other materials and can increase the strength of paving blocks. Palm oil bottom ash (POBA) was added to replace the role of cement, which has the same content as cement, i.e., silica (Si). This study aimed to see the effect of palm oil bottom ash and sand added to the residue of plastic mixture pyrolysis (i.e., PS/LDPE/PP) on the quality of paving blocks. The paving block as a test object was made by combining two materials. The residue of plastic mixture pyrolysis and LDPE plastic melt was mixed with a mass ratio of 70:30%, referred to as material I. Furthermore, palm oil bottom ash and sand were mixed with mass ratios of 100, 80, 60, 40, and 20%, referred to as material II. The ratio of ingredients I and II used was 1: 1. Testing of the quality of paving blocks includes a compressive strength test and a water absorption test. The test results showed that the ratio of PS/LDPE/PP mixture (50:25:25) had a compressive strength of 104.1 kg/cm^2 or 102.08 MPa and the water absorption of 2.4% at the ratio of palm oil bottom ash and sand at 80:20%. Adding palm oil bottom ash can reduce the paving block's compressive strength, and the residue's LDPE content can affect water absorption because of its chemical structure properties. Therefore, less LDPE residue is needed to obtain optimal water absorption values in paving blocks and add palm oil bottom ash. Based on this compressive strength in this study and SNI 03-0691-1996, these paving blocks can be used for gardens.

KEYWORDS:

LDPE, Palm Oil Bottom Ash, Paving Block, Plastic, Pyrolysis

1 | INTRODUCTION

Plastic waste is an unsolved problem in its handling. This is because plastics are composed of hydrocarbon polymers with chain bonds that are not easily broken down physically, chemically, and biologically, so decomposing plastics takes a long time [1]. One way to process plastic waste is by converting plastic waste into liquid fuel. The method used to convert plastic waste into liquid fuel is the pyrolysis method. Pyrolysis is a renewable technology that converts plastic waste with little or no air into liquid and gas phases that can be reused. Pyrolysis is a waste treatment that can reduce the weight and volume of waste and produce other products, including gases that contain low to moderate caloric values so that they can be used for alternative fuels and liquid oil that can be used as alternative fuels and residues, in the form of solids that contain high calorific values [2].

So far, the residue from plastic pyrolysis is only used for making briquettes [2]. Besides being used as briquettes, the residue from plastic pyrolysis can also be used in making paving blocks. Paving blocks are a product of building materials made from cement, sand, and water. The ratio closest to the desired grade is 30:70, with LDPE plastic and plastic pyrolysis residue composition with a compressive strength of 10.11 MPa and a low water absorption value [3].

LDPE and PP plastics have high crystallinity properties and strong inter-molecular tensile forces, so their mechanical strength is also large to produce high compressive strength values. In contrast, this type of PS plastic has a low density and has cavities between the particles, causing water to enter these cavities and increasing the water absorption value.

Excessive use of cement in the production of paving blocks can cause environmental damage. Palm oil bottom ash was used to reduce the use of cement and increase the grade from C/D to grade B. Palm oil bottom ash, commonly known as bottom ash, is the boiler's combustion residue bigger than fly ash [4]. The addition of palm oil bottom ash is expected to increase the grade of paving blocks from grade C/D to B and replace the use of cement.

In this work, the effect of the mass ratio of palm oil bottom ash and sand for each variation of residue resulting from the pyrolysis of plastic mixtures (PS/LDPE/PP) of various compositions on the compressive strength and water absorption capacity of paving blocks is investigated. The residue from pyrolysis of plastic, palm oil bottom ash, and sand with a certain composition are mixed and molded into paving blocks. It is expected to obtain paving blocks with grade B characteristics from grade C/D. This innovative application can not only solve problems regarding environmental pollutants. Still, it can also make these materials a substitute for cement which functions as a binding material in the paving block industry.

2 | PREVIOUS RESEARCHES

Using bottom ash on paving blocks with the addition of shellfish waste when viewed from a strong value press to experience an increase to variation third is using bottom ash 30% by weight cement with a value of 26.858 Mpa and the value of water absorption decrease by 6.076%. This condition is included in the class B category [5]. The material with the code CBA70C30 is produced using the ICS test and has high compressive strength, and is suitable as an alternative to cement with high performance. Coal bottom ash, abbreviated as CBA and C, is a cement paste [6]. The compressive strength test of the material with the optimal composition at 30% bottom ash, 15% carbide welding waste was obtained at 15.19 MPa, while for the water absorption test, the optimal composition at 30% bottom ash and 0.15% carbide welding waste were obtained by 7.57% [7].

The use of plastic waste as an alternative binding material for paving blocks has provided higher compressive strength and lower water absorption than control paving blocks, as reported by Agyeman et al. [8]. All previous studies have proven that palm oil bottom ash and plastic waste can be used as a substitute for cement to produce paving blocks, which provide quality according to predetermined standards [9]. The characteristics of each type of plastic in the form of residue from the pyrolysis process would affect the quality of paving blocks. As a previous study reported, the residue resulting from the pyrolysis of the PP/LDPE plastic mixture (40:60) increased compressive strength and decreased the water content in the paving blocks obtained [3]. Other researches by Salih et al. [10] and Shubhra et al. [11] gave different results where increasing the ratio of melted PP/LDPE plastic mixtures without the process of taking plastic oil increased the compressive strength and decreased the water content in paving blocks. However, studies on the material composition of paving blocks, which consist of palm oil bottom ash and pyrolysis residue from a mixture of PS/LDPE/PP plastics, were not reported extensively.

FIGURE 1 The residue from a mixture of PS/LDPE/PP pyrolysis plastics with a composition of (a) 50:25:25, (b) 25:25:50, (c) 25:50:25, (d) 33:33:33.

3 | MATERIAL AND METHOD

3.1 | Material

The materials needed in this study are the residue from the pyrolysis mixture of PS/LDPE/PP plastics with the composition of (50:25:25), (25:50:25), (25:25:50) and (33:33:33) as shown in Fig. 1 , melted LDPE plastic, sand and palm oil bottom ash obtained from PT. Hutan Alam Lestari is located at Kubu Kandang Village, Pemayung District, Batanghari Regency, Jambi.

3.2 | Procedure

The first procedure in this study was to prepare a mixture of PS/LDPE/PP plastic pyrolysis residue with melted LDPE plastic (ratio 70:30) for making paving blocks (material I). Furthermore, a mixture of palm oil bottom ash and sand (material II) is made with a variable ratio of 100, 80, 60, 40, and 20%. Material I and ingredient II are mixed in a 1: 1 ratio. After all the ingredients are mixed, then stir until homogeneous. The mixture of these ingredients is put into a mold previously lubricated so that it is not sticky. Then the mold containing the paving blocks is soaked in water until the paving blocks harden. The process flow diagram used to produce plastic waste pyrolysis residue-bonded sand samples is shown in Fig. 2 . This product obtained is known as a paving block. Compressive strength and water absorption properties are tested on paving blocks to determine product quality according to SNI 03-0691-1996. A compression testing machine was used to obtain the material's compressive strength, and immersion of paving blocks in water at room temperature for measurement at 4, 18, and 12 days was applied to determine water absorption. The SEM-EDX test was then carried out on paving blocks, which provided information about the morphology of the material and its constituent composition. FTIR analysis can be useful to see the functional groups present in the material.

4 | RESULTS AND DISCUSSION

4.1 | Material Characteristics Testing

Material testing in this study is intended to determine the properties and characteristics of the materials used, which are adjusted to SNI 03-0691-1996. In this study, testing the characteristics of the material carried out is testing the oil palm boiler crust using the XRF test.

4.2 | X-ray Fluorescence (XRF)

To test the characteristics of the palm oil bottom ash (POBA), a chemical element level test was carried out, namely the XRF test. Table 1 shows the results of the XRF test of POBA. A study utilizing bottom ash and fly ash type C as substitute materials in the manufacturing of paving blocks found that the highest compound content was 37.8% SiO_2[4]. Table 1 shows the chemical composition of POBA.

4.3 | Paving Block Testing

Using pyrolysis residues from a mixture of PS/LDPE/PP plastic with palm oil bottom ash affects testing paving blocks following existing standards. Paving block testing is carried out through compressive strength and water absorption tests[12].

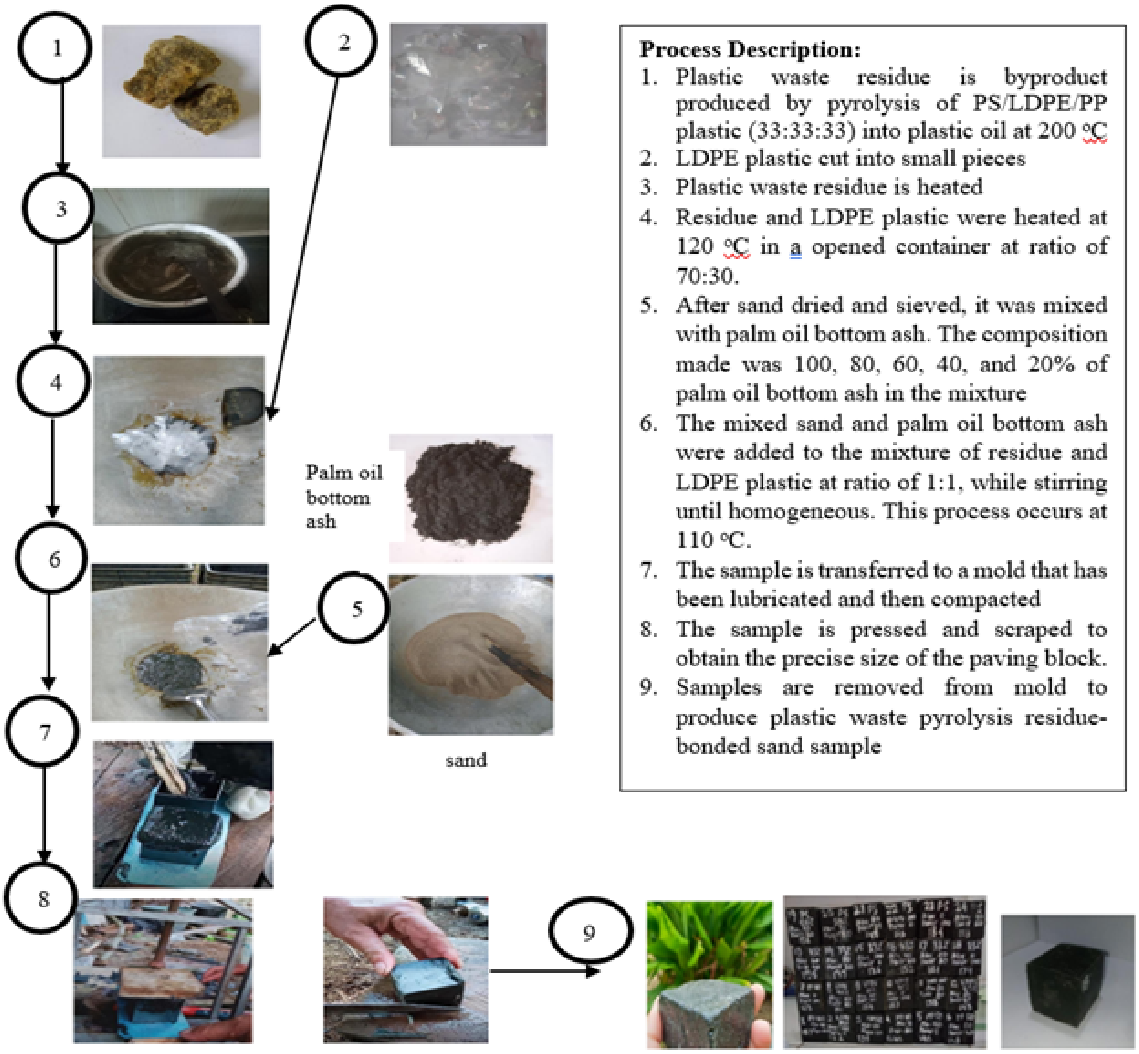

FIGURE 2 The process flow diagram used to produce plastic waste pyrolysis residue-bonded sand samples.

TABLE 1 The chemical composition of POBA.

Compound	Concentration (%)	Compound	Concentration (%)
SiO_2	38.000	P_2O_5	9.000
SO_3	2.500	K_2O	13.600
CaO	29.900	TiO_2	0.390
V_2O_5	0.010	MnO	0.380
Fe_2O_3	5.590	CuO	0.271
ZnO	0.055	Rb_2O	0.160
SrO	0.180	ZrO_2	0.050

4.3.1 | Compressive Strength Test

The compressive strength test is carried out to determine the quality of a paving block. The higher the compressive strength value, the higher the quality. Fig. 3 shows the compressive power test data on paving blocks.

Fig. 3 shows that in the PS/LDPE/PP variation (33:33:33), the highest compressive strength value is 114.82 kg/cm^2 and is in the class D category. This is because the sample has a residual texture from pyrolysis. The best plastic mixture among other samples is its hard and dense texture. The hardness level in a plastic mixture's resin pyrolysis greatly affects the paving blocks'

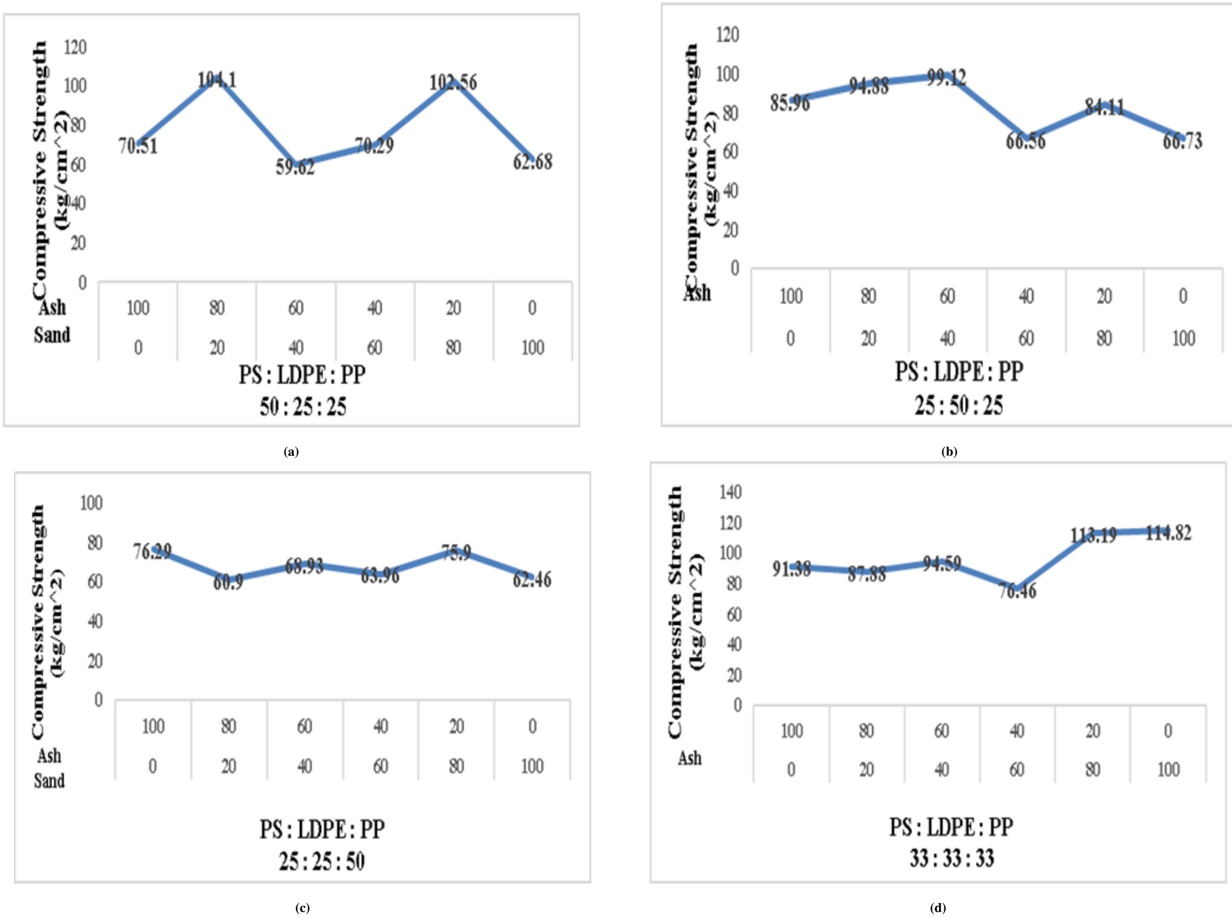

FIGURE 3 The compressive strength test of the paving block with residue from pyrolysis plastic mixture (a) PS: LDPE: PP (50:25:25), (b) PS: LDPE: PP (25:50:25), (c) PS: LDPE: PP (25:25:50) and PS: LDPE: PP (33:33:33).

quality. The harder the residue from the pyrolysis of the plastic mixture obtained, the higher the compressive strength value on the paving block.

In addition, the type of plastic in the pyrolysis residue also affects the compressive strength value of paving blocks. Polyethylene has high crystallinity and strong inter-molecular attractions, so its mechanical strength is also large. This shows that samples with more dominant LDPE plastic variations have a high compressive strength value of 99.12 kg/cm^2 and are in the class D category. The mechanical strength of this polyethylene can contribute to the increase in the compressive strength of the resulting paving blocks[13].

PP plastic variations, which are more dominant in the pyrolysis residue, have a compressive strength value that is low when compared to LDPE plastic variations (which are more dominant). This is consistent with the statement that PP is a type of plastic lighter than LDPE with a specific gravity of 0.89 - 0.92 g/cm^3 and a specific gravity of LDPE that is 0.91 - 0.94 g/cm^3 [14].

Then for the variation of PS plastic which is more dominant in the residue of pyrolysis results, the compressive strength value is lower than that of the more dominant LDPE and PP plastic variations. PS plastic is a relatively light plastic type composed of granules with a low density so that there is space between the granules, which contain air[15]. The presence of cavities between particles causes the attractive force between particles to be low, which is a factor in the decrease in the compressive strength value of the paving blocks.

The composition ratio of the palm oil bottom ash with sand also influences the compressive strength value. Palm oil bottom ash and sand serve as deep fillers in the mixture. The compressive strength test results show that the more the composition of palm oil bottom ash is added, the lower the compressive strength value. In comparison, the less the composition of palm oil bottom ash is added, the higher the compressive strength value.

This is because the palm oil bottom ash particles are finer and lighter than sand so that they bind the entire adhesive surface, causing large shrinkage, and causing many fine cavities, thereby reducing its strength. Therefore, the mixture must be mixed with sand to increase strength, durability, and workability [16].

The test results obtained the highest value for each sample included in the class D category. Significant differences or some discrepancies in the data so that some samples do not meet the compressive strength requirements of class C/D paving blocks on SNI 03-0691-1996 during manufacturing, and printed paving blocks need to be more precise. The lack of precision in a paving block will greatly affect the compressive strength of the paving block.

4.3.2 | Water Absorption Test

Water absorption in paving blocks adversely affects their durability; the more water they absorb, the more their durability and durability will decrease. Fig. 4 is a graph of the results of the water absorption test on paving blocks. Based on Fig. 4 , it is known that the highest water absorption capacity is 2.42% with polystyrene plastic samples which are more dominant in the residues of pyrolysis and the use of more palm oil bottom ash content. Meanwhile, the lowest water absorption capacity is 0.12%, with variations of LDPE plastic which are more dominant in the pyrolysis residue and use less palm oil bottom ash content.

This shows that with the increase in LDPE levels, the density of paving blocks increases so that the resulting water absorption decreases. In addition, the nature of LDPE plastic which is impervious to water and insoluble in water at room temperature and has a non-porous structure (difficult to penetrate by water), causes water absorption in paving blocks to decrease [13].

The variation of PP plastic, which is more dominant in the residue of pyrolysis, is between PS and LDPE plastic variations that are more dominant. The density of polypropylene plastics is lower compared to polyethylene plastics, so the inclusion of water in the PP plastic variation (which is more dominant) is more than the LDPE plastic variation (which is more dominant) [14].

Water absorption in the more dominant variation of PS plastics (in the pyrolysis residue) experienced a high enough increase compared to the variations of PP and LDPE plastics (which are more dominant). PS plastic has a low density, and there are voids between the particles, causing water to enter these cavities and increasing the water absorption value [15].

The decrease in the value of water absorption (absorbability) is caused by the characteristics of the polymer that fills the pores between the aggregate particles (sand). In addition, the hydrophobic nature of the polymer also results in decreased absorbability values. The small absorbability value can be advantageous for building material applications because it reduces the risk caused by water penetration into the cavities of the building material, which can cause damage such as cracks and the growth of unwanted microorganisms [17].

In addition, the use of palm oil bottom ash content also affects the water absorption capacity of paving blocks. In the boiler crust, ash content has the highest SiO_2, where SiO_2 causes the density of paving blocks to decrease due to the formation of air cavities. These air cavities will be filled with water during the immersion period of the sample [13].

If it is related to the previous test, the water absorption and compressive strength values have a relationship. The higher the compressive strength value of the paving block, the lower the paving block's water absorption percentage. This is because the higher the compressive strength value, the narrower the pores in the paving block so that less water enters the paving block, and the absorption value gets smaller. This statement is also supported by the research of a previous study, which wrote that the optimum compressive strength of paving blocks with a mixture of bottom ash as a substitute for cement is found in a 30% bottom ash mixture and also writes that the higher the bottom ash combination used will reduce the compressive strength of the paving block. Meanwhile, the water absorption rate will be greater if the bottom ash combination is greater [18].

4.3.3 | Scanning Electron Microscope - Energy Dispersive X-Ray (SEM-EDX)

Based on the compressive strength and water absorption tests on the paving blocks, the best results were selected for the SEM test, with a compressive strength value of 104.1 kg/cm^2 and a water absorption capacity of 2.4%. The sample has a ratio of

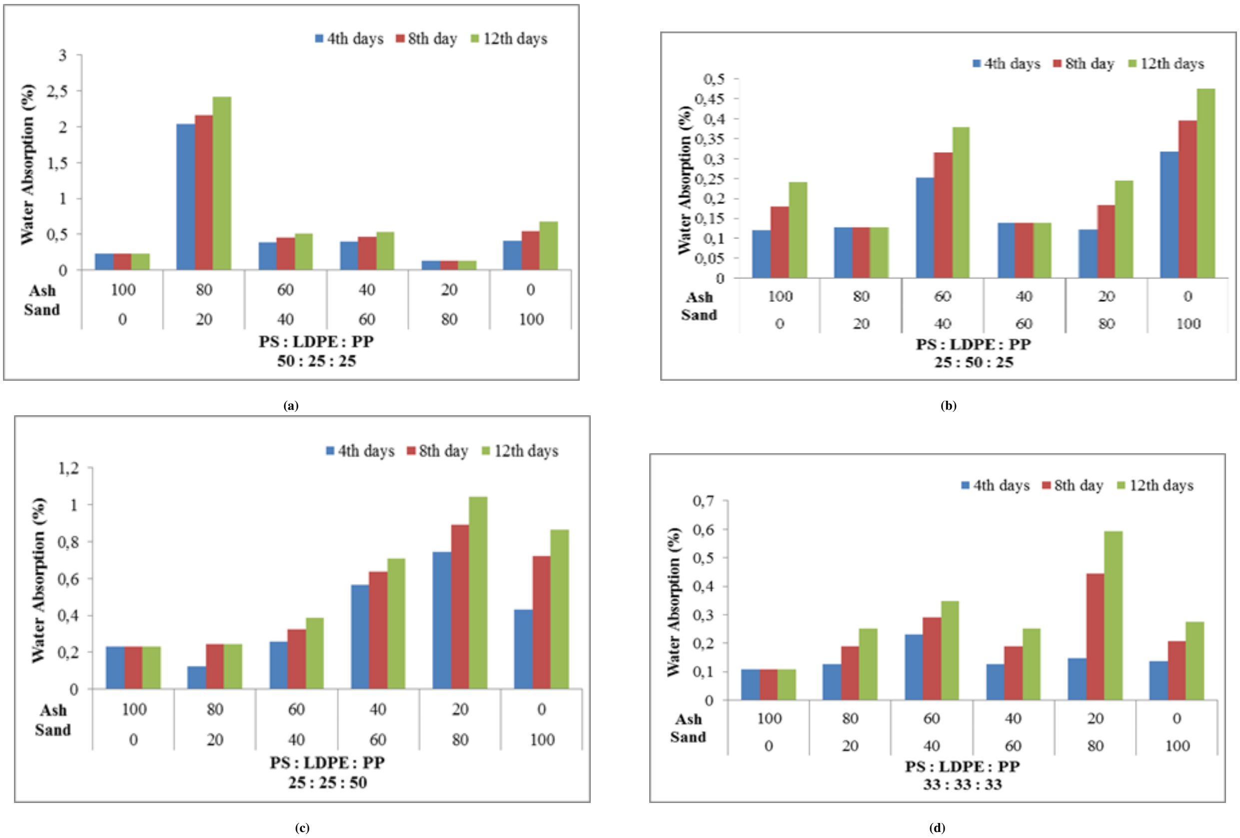

FIGURE 4 The water absorption test of the paving block with the residue of plastic mix pyrolysis (a) PS: LDPE: PP (50:25:25), (b) PS: LDPE: PP (25:50:25), (c) PS: LDPE: PP (25:25:50), and (d) PS: LDPE: PP (33:33:33).

PS/LDPE/PP (50:25:25) and a ratio of 80:20 palm oil bottom ash and sand. The sample selection was due to several considerations: (1) Polystyrene (PS) is a type of plastic whose waste is difficult to recycle or has minimal handling, so PS is usually left to pile up. (2) The sample has a ratio of 80:20 palm oil bottom ash and sand; this can reduce or replace the role of sand.

As a comparison, we have also included SEM tests on paving blocks in general, whose material composition consists of sand and cement (7: 1). With the comparison; it is hoped that it will provide a more comprehensive picture of the results. The results of SEM test characteristics with a magnification of 3000x on sample 1 consist of the residue of plastic mixture pyrolysis and palm oil bottom ash can be seen in Fig. 5 . The paving blocks have a slightly rough surface due to the addition of sand. However, when compared to sample 2 (cement paving blocks), which can be seen in Fig. 6 , the surface is rough because the percentage of the composition of the sand is more dominant than the adhesive (7: 1).

The sand grains in sample 1 are scattered all over the plastic surface, indicating that the sand and other materials can mix and form a composite[19]. Materials in the form of plastic residue from PS/LDPE/PP and palm oil bottom ash function to strengthen the mechanical and physical properties of composite building materials[20]. Fig. 5 shows the interface bond between polymer and sand from the existing sand particles integrated with the polymer matrix.

Related to the absorption capacity of paving blocks, it appears in sample 1 that there are several points of pores scattered on the surface of the paving block. The number of pores is not as much as in sample 2, but the size of the pores is bigger than in sample 2. From this description, sample 1 has adequate water absorption capacity, as a specification needed by paving block products to reduce standing water above it. These pores are formed due to the role of the Silica Oxide compound, both contained in the palm oil bottom ash and sand. This can be seen from the SEM EDX test results shown in Fig. 7 and Table 2 .

Fig. 7 and Table 2 show the dominant element in a paving block, which is carbon, which is mostly contained in plastic (PS/LPDE/PP) and palm oil bottom ash, then oxygen, silica, and other elements in a smaller percentage.

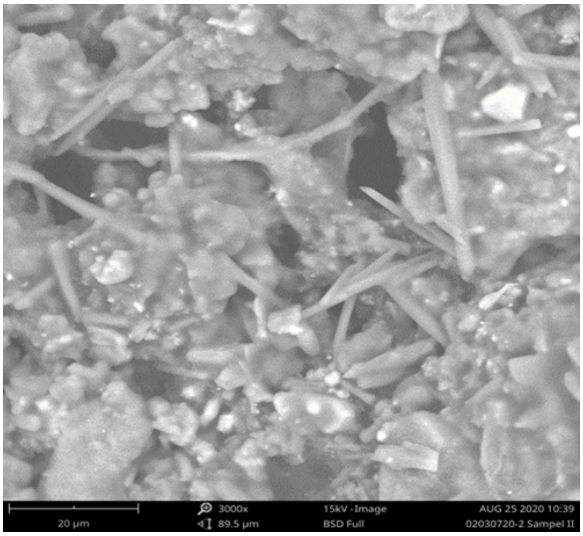

FIGURE 5 The SEM image of paving blocks made from the residue of plastic mixture pyrolysis and palm oil bottom ash..

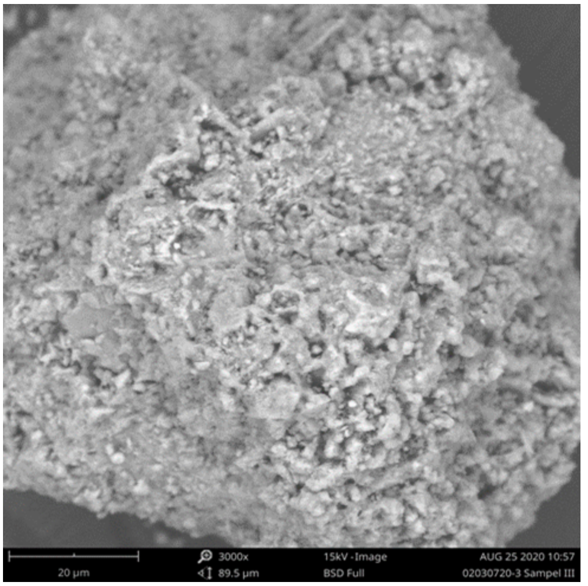

FIGURE 6 The SEM image of paving blocks from cement and sand.

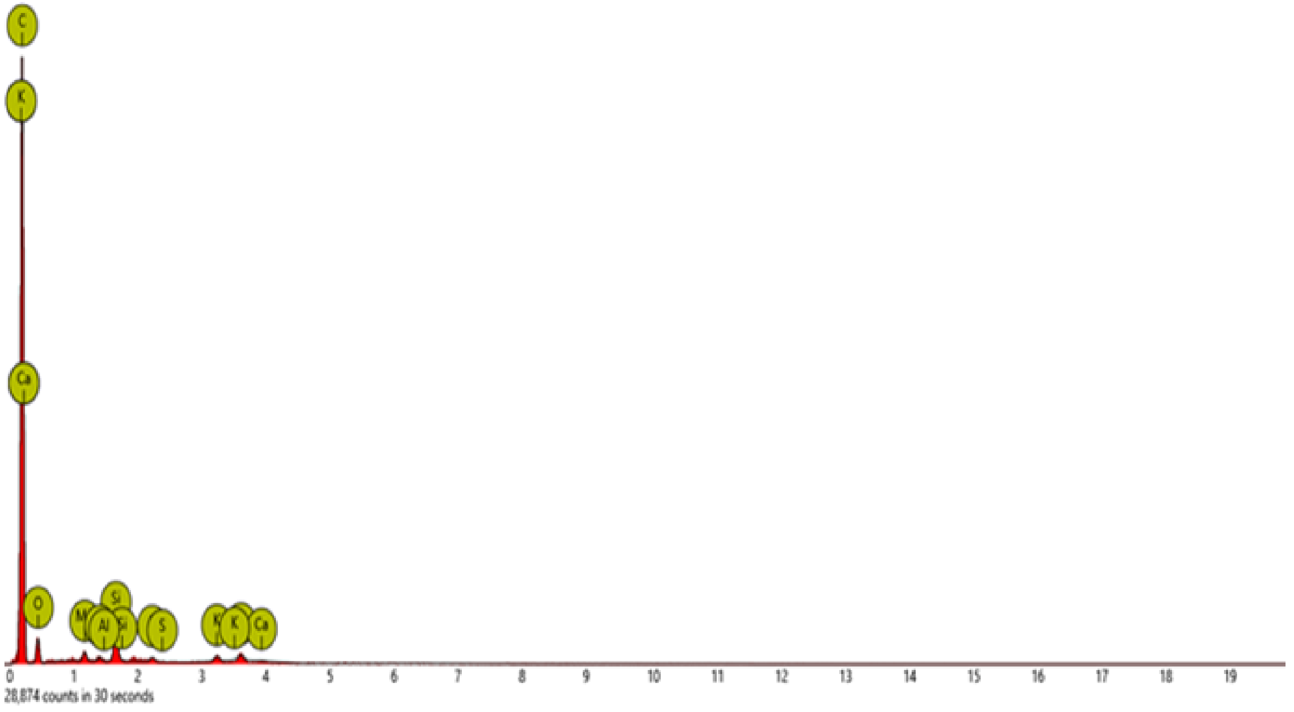

FIGURE 7 The EDX Test of Paving Block on Sample 1.

4.3.4 | Fourier Transform Infrared (FTIR)

The FTIR characterization test was carried out to find the functional groups of the paving block material and compare them with the functional groups of the constituent materials. The results of the FTIR test with the best sample PS/LPDE/PP (50:25:25) are shown in Fig. 8 .

TABLE 2 The EDX results for paving blocks

Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
6	C	Carbon	90.09	85.45
8	O	Oxygen	8.13	10.28
14	Si	Silicon	0.74	1.65
20	Ca	Calcium	0.25	0.79
12	Mg	Magnesium	0.32	0.62
19	K	Potassium	0.19	0.59
16	S	Sulfur	0.14	0.34
13	Al	Alumunium	0.13	0.28

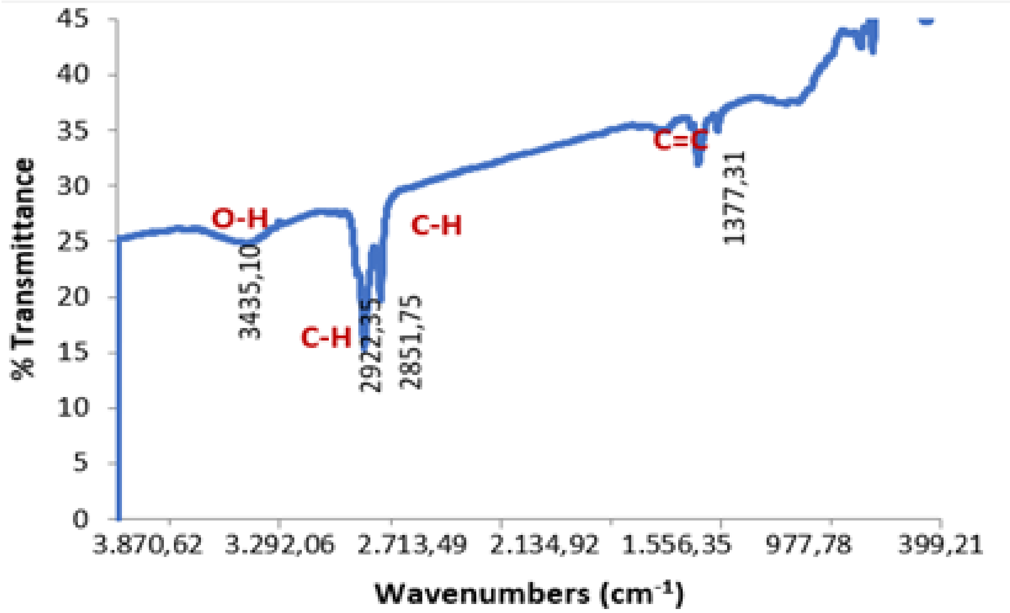

FIGURE 8 The FTIR spectra of paving block with the ratio of PS/LDPE/PP (50:25:25).

Fig. 8 shows the results of the FTIR paving block of the O-H group vibration at several 3,435.10 cm^{-1}. This group indicates the presence of H bonds in palm oil bottom ash formed from stretching the silanol group bonds (Si-OH) bonds [6]. Furthermore, the peaks at wave numbers are 2,922.35 cm^{-1} and 2,851.75 cm^{-1}, which are C-H single bond absorption bands derived from LDPE plastic.

Then at a wave number of 1,462.02 cm^{-1}, there is an absorption band C=C from LDPE plastic; this bond is formed from ethene, a monomer for forming LDPE polymers possible for an imperfect polymerization process in the manufacture of the plastic [15]. At wave number 1,377.31 cm^{-1}, there is a stretching absorption band from the C-H bond, which is a CH_3 absorption band. Functional groups are not visible for aromatic compounds in the spectrum because the number of samples is not the same. In the sample, melted LDPE plastic is added so that LDPE plastic tends to be more dominant and has a high intensity of sharpness.

In the spectrum, the O-H functional group has a low intensity compared to C-H derived from LDPE plastic; this is due to a large amount of plastic and also where the product is in the form of plastic, including solid materials whose molecules are very tightly packed, thus covering most of the palm oil bottom ash scale. It also explains why the O-H functional group (derived from the Si-OH group) has a low intensity due to the loss of water content in the palm oil bottom ash when the palm oil bottom ash has been mixed with plastic by the heating process [21].

The FTIR spectrum states that the paving blocks are physically and chemically bonded by a plastic matrix (PS/LDPE/PP). The test results show the presence of C-H bonds originating from LDPE plastic, so it can be proven that the paving blocks are

TABLE 3 The interpretation of FTIR Spectra on the paving block.

Wave Number in Literature (cm^{-1})	Wave Number on Result (cm^{-1})	Functional Groups
3,361 - 3,458 [18]	3,435.10	Stretching vibration -OH from Si-OH
2,913 - 2,925 [19]	2,922.35	Stretching vibration C-H
2,850 - 2,970	2,851.75	Stretching vibration
1,340 - 1,470 [20]	1,377.31	asymmetry C-H
1,469 - 1,452 [21]	1,452.02	Stretching vibration C=C

chemically bonded. This paving block also has a strong physical bond, which is indicated by the large compressive strength value of this paving block. Table 3 shows the results of interpreting FTIR spectra on paving blocks from several kinds of literature.

5 | CONCLUSION

This study concludes that the test results show that the PS/LDPE/PP mixture ratio (50:25:25) has the best compressive strength, which is 104.1 kg/cm^2, and water absorption 2.4% in the ratio of palm oil bottom ash and sand at 80:20. Based on the compressive strength in this study and SNI 03-0691-1996, these paving blocks can be used for gardens.

The addition of palm oil bottom ash can reduce the compressive power of the paving block but can increase its water absorption. Adding sand as a filler in a mixture heavier than boiler-scale ash can help increase its strength, durability, and workability. A mixture of sand grains, palm oil bottom ash, and plastic can mix and form a composite; this is evidenced by the SEM-EDX test, where it is also stated that the dominant element in paving blocks is carbon which is mostly contained in plastic materials (PS/LPDE/PP) as well as palm oil bottom ash, then oxygen, silica, and other elements in smaller percentages.

The chemical properties of paving blocks can be determined based on the results of the FTIR test. The interaction in the components that make up the paving block occurs through hydrogen bonds from the Si-OH functional group and C-H bonds, as evidenced by the FTIR results with each wave number of 3,435.10 cm^{-1} and 2,922.35 cm^{-1}.

ACKNOWLEDGMENT

Financial support from DIPA PNBP - Faculty of Science and Technology, Basic Research Scheme University of Jambi for Fiscal Year 2020 Number: SP-DIPA-023.17.2.677565/2020 On 27 December 2019, in accordance with the Research Contract Agreement Number: 20/UN21.18/PG/SPK/2020, April 20, 2020.

CREDIT

Lenny Marlinda: Conceptualization, Methodology, Writing - original draft preparation, Writing - review and editing, and Supervision. **Heriyanti:** Conceptualization, Methodology, Writing - original draft preparation, Writing - review and editing, Funding Acquisition, and Supervision. **Rahmi:** Formal analysis and investigation. **Ratri Hanifah:** Formal analysis and investigation, and Writing - review and editing. **Nelson:** Writing - review and editing. **Sutrisno:** Resources.

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How to cite this article: Marlina L., Heriyanti H., Rahmi R., Hanifah R., Nelson N., Sutrisno S. (2022), Paving block from Residue of PS/LDPE/PP Plastic Pyrolysis Mixed with Palm Oil Bottom Ash (POBA), *IPTEK The Journal of Technology and Science*, *33(3):201-212*.