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Residue Mass Ratio from Pyrolysis Mixed LDPE/PP Plastic and Its Effect on Quality of Paving Blocks

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ABSTRACT

Plastic waste consisting of a mixture of polypropylene (PP) and low-density polyethylene (LDPE) has been successfully hydrolyzed into plastic oil as an alternative to fuel oil. Solid waste in the form of residues that emit odors that pollute the environment are also produced from this process. This pyrolysis residue mixture and LDPE plastic melt in a certain ratio were studied in this study with the aim of finding a source of raw materials to replace cement for paving block production. The residue used was pyrolysis residue produced from polypropylene (PP) and low-density polyethylene (LDPE) plastic waste with a mass ratio of 100% PP, 75:25%, 50:50%, 40:60%, 25:75%, and 100% LDPE 100% LDPE. The mass ratios of LDPE plastic and pyrolysis residue were 70:30%, 60:40%, and 50:50%, respectively. The ratio of sand to residual pyrolysis of plastic waste used was one to one. The surface condition of the paving blocks obtained was carried out using a Scanning Electron Microscope (SEM) and performance tests which showed the quality of the paving blocks in the form of compressive strength and water absorption properties. SEM analysis reveals the presence of a connection between sand and plastic pyrolysis residues. Variations in the kind of plastic ratio during the pyrolysis process suggest that the paving blocks' compressive strength and water absorption vary.

***Keywords**: paving block; pyrolysis residue; plastic; PP; LDPE*

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ABSTRAK

Limbah plastik yang terdiri dari campuran polypropylene (PP) and low-density polyethylene (LDPE) telah berhasil dipirolisis menjadi minyak plastik sebagai alternatif bahan bakar minyak. Limbah padat berupa residu yang mengeluarkan bau yang mencemari lingkungan juga dihasilkan dari proses ini. Campuran residu pirolisis ini dan lelehan plastik LDPE dengan perbandingan tertentu telah dipelajari dalam penelitian ini dengan tujuan untuk mencari sumber bahan baku pengganti semen untuk produksi paving block. Proses pirolisis residu yang digunakan adalah residu hasil pirolisis campuran sampah plastik polypropylene (PP) dan low density polyethylene (LDPE) dengan perbandingan massa PP 100%, 75:25%, 50:50%, 40:60%, 25 : 75, dan 100% LDPE. Perbandingan massa plastik LDPE dan residu pirolisis adalah 70:30%, 60:40%, dan 50:50%. Perbandingan pasir dan residu pirolisis sampah plastik yang digunakan adalah 1:1. Kondisi permukaan paving block yang diperoleh dilakukan dengan menggunakan Scanning Electron Microscope (SEM) dan tes performa yang menunjukkan kualitas paving block berupa sifat compressive strength and water absorption. Hasil analisis SEM menunjukkan adanya ikatan antara pasir dan residu hasil pirolisis plastik. Variasi rasio jenis plastik pada proses pirolisis menunjukkan adanya perbedaan kuat tekan dan daya serap air pada paving block.

***Kata kunci:** paving block; residu pirolisis; plastik; PP; LDPE*

INTRODUCTION

Research related to converting various types of plastic is still being carried out by converting plastic into fuel oil as an alternative energy and reducing the use of plastic in everyday life. Pyrolysis generates char and fumes in addition to liquid fuel. Char is a solid residue that contains fixed carbon; it can still be utilized as fuel, briquettes, and a material for paving stones. When plastic undergoes a pyrolysis process to become plastic oil, a residue with a strong odor is also produced from this process. So that these residues do not become solid waste that can pollute the environment, lightweight and strong paving blocks are the solution by making the residues the raw material for this product. Because of their high crystallinity and strong molecular affinity, PP and LDPE polymers have excellent mechanical strength [1]. Furthermore, the LDPE plastic has a non-porous structure that can prevent water absorption in paving blocks [2].

When compared to typical paving blocks, the quality of paving blocks made from plastic waste is projected to be more stronger and less readily broken. For paving blocks containing plastic fibers, the compressive strength increases to 41.83% compared to similar products [3]. According to Hambali et al. [2], the higher the compressive strength and lower water absorption as the polyethylene content in paving blocks increases. Previous research on the pyrolysis of plastic waste has focused on the results in the form of liquid fuel only [4], while other studies have utilized plastic waste as construction material in the manufacture of bricks and paving blocks, namely the melting method of plastic waste mixed with sand [5,6]. This study tries to optimize the utilization of plastic waste from pyrolysis residues into paving blocks.

LITERATURE REVIEW

According to SNI 03-0691-1996 paving block is defined as a composition of building materials made from a mixture of portland cement or similar hydraulic adhesive materials, water and aggregates with or without other additives that do not reduce the quality of the paving blocks. The classification of paving blocks is as follows:

- Quality A: used for roads
- Quality B: used for the parking place
- Quality C: used for pedestrians
- Quality D: used for gardens and other uses

The compressive strength of each paving block quality is as shown in Table 1.

Table 1. Quality of paving block

Quality	Average Compressive Strength (MPa)	Compressive Strength (min - MPa)	Water Absorption (max - %)
A	40	35	3
B	20	17	6
D	15	12.5	8
	10	8.5	10

SNI 03-0691-1996

Paving block is also called interblock concrete, since the 1950s it has been widely used in the Netherlands as a substitute for conventional bricks for road work. According to Amran (2015), the advantages of using paving blocks compared to red bricks are as follows [3]:

1. Easy to maintain and market
2. The quality of concrete is better than that of clay
3. Can be produced mechanically, semi-mechanically, or hand-printed
4. More guaranteed size
5. Not easily damaged by vehicles

6. The anti-slip factor (Skidding Resistance) on the paving block is bigger so it is safe for traffic
7. Weather resistant

METHOD

Materials

The materials used were LDPE plastic waste in the form of food wrap were collected from landfills around residential areas in Jambi, sand as coarse aggregate, and plastic waste pyrolysis residue with a ratio of 100% LDPE, (PP: LDPE) 75%: 25%, 50%: 50%, 40%: 60%, 25%: 75%, and PP 100% (The resulting residue is about 2 kg of a total of 4 kg of plastic material in the pyrolysis process).

Experiment

LDPE plastic debris was washed with soap and sun dried. Plastic pyrolysis leftovers are combined with LDPE plastic waste at a mass ratio of 70, 60, and 50 %. The mixture was placed in a container and cooked over a gas fire until it melted. This melt is added to sand with a mass ratio of 1:1 while stirring. After obtaining an even mixture, this is transferred into paving block molds measuring 5x5x5 cm. Previously, this mold was smeared with lubricant so it would not stick. The process flow diagram used to produce plastic waste pyrolysis residue-bonded sand samples is shown in Figure 1. This product sample is known as paving block.

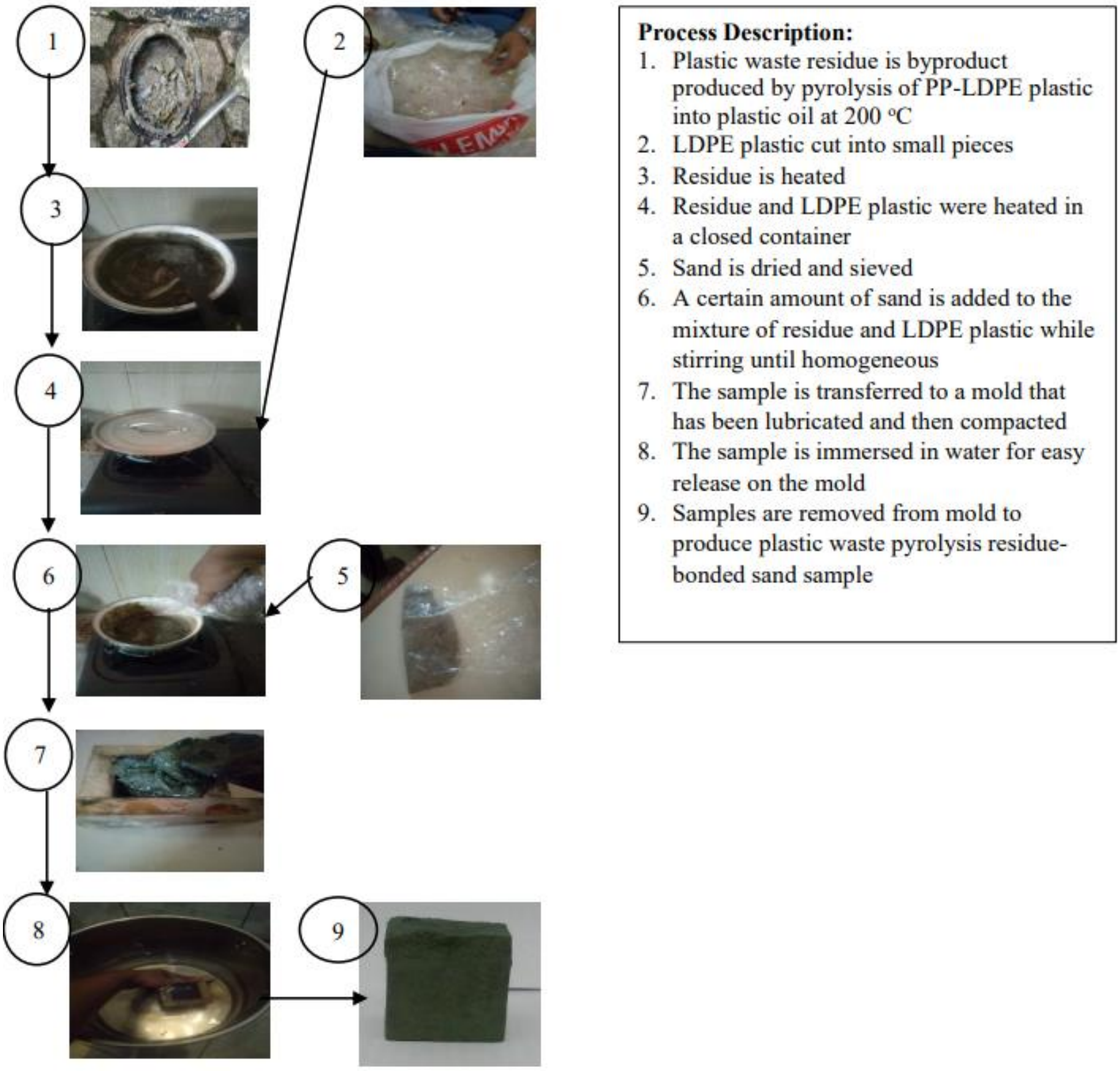


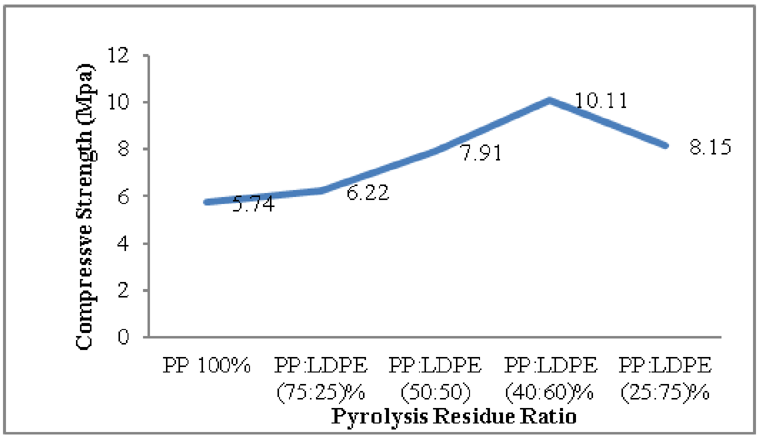
Figure 1. The process flow diagram used to produce plastic waste pyrolysis residue-bonded sand samples.

Compressive strength and water absorption properties are tested on paving blocks to determine product quality. A compression testing machine was used to obtain the compressive strength of the material [3] and immersion of paving blocks in water at room temperature for 4, 18 and 12 days was applied to determine water absorption [2]. The SEM test was then carried out on paving blocks which provided optimal compressive strength and water absorption properties.

RESULTS AND DISCUSSION

Compressive Strength Test

To determine the quality of a paving block, the compressive strength test is performed. The higher the compressive strength, the better the paving block. The test results of paving block compressive strength can be seen in Figure 2.



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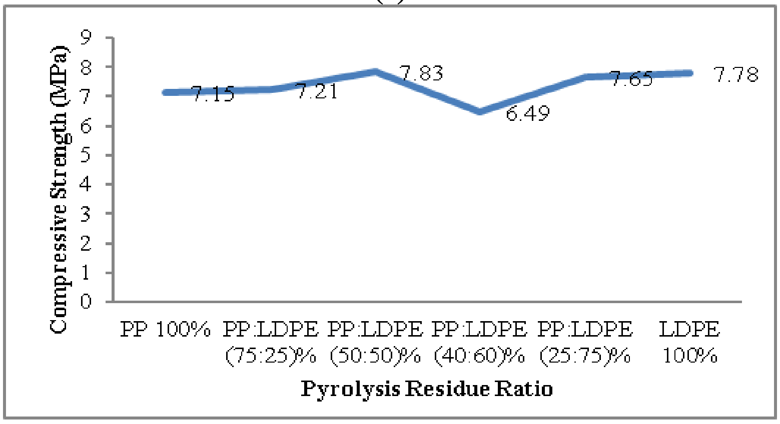

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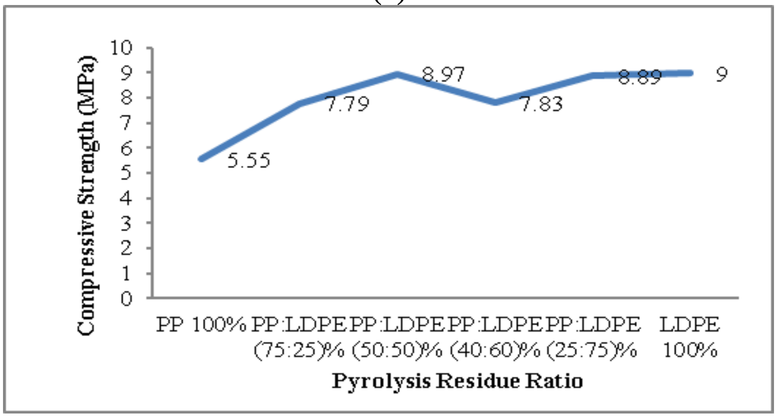

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Figure 2. The compressive strength of the paving block (a) LDPE: residue (70: 30) %, (b) LDPE: residue (60: 40) %, (c) LDPE: residue (50: 50) %.

Because PP is stronger than LDPE [7] increasing the PP/LDPE ratio will increase the compressive strength of paving blocks [8,9]. However, Figure 2 shows a higher ratio of LDPE plastic to PP in the pyrolysis process, which increases the compressive strength of the paving blocks. The amount of PP plastic pyrolysis residue is proportional to the amount of LDPE. The lower the residue, the higher the PP/LDPE ratio. As the PP residual ratio to LDPE increases, the compressive strength decreases. The value of the compressive strength of paving blocks is higher as the mass ratio of melted LDPE plastic and pyrolysis residue is added. The addition of this pyrolysis residue can increase the cohesiveness of the product. This happens because the plastic fibers contained in the residue become fillers in the paving block composite so that the bond strength of the polymer and sand interface can increase.

The nature of the polymer that has filled the pores of the material also increases the mechanical strength of the composite material [10, 11]. For paving blocks produced from a mixture of LDPE plastic and PP/LDPE plastic pyrolysis residue (60:40) % with a mass ratio (70:30) %, the compressive strength value reaches the highest value of 10.11 MPa as shown in Figure 2a. This is consistent with previous studies which reported that the average compressive strength of paving blocks was 10.93 MPa [9]. When it's compared with the data in SNI 03-0691-1996, the paving blocks in this study are classified as D quality with an average compressive strength of 10 MPa which can be used for gardens and other uses. The addition of LDPE plastic functions as reinforcement which is distributed evenly in the paving blocks so that this material can withstand the loads received to prevent the formation of cracks or fractures. It can be said that plastic fibers can prevent unexpected collapse and increase the strength of paving blocks to withstand loads [13]. One of the factors affecting the low compressive strength of paving blocks is the less compact nature of the material. The compact paving block mix affects its strength after the hardening process. Optimal compactness and loss of air voids can be achieved through the process of compacting the material [14].

Water Absorption Test

Water absorption, along with compressive strength, is a test criteria for paving block quality. A paver block's high absorption indicates that it has porous qualities, which have big pores and rapidly absorb water. If the pore paving block pores are filled with water for an extended period of time, it will degrade faster and lose compressive strength. Figure 3 depicts the results of a water absorption test with an absorption value in the range of 1% and this value is not in accordance with the criteria of SNI 03-0691-1996, where the value of water absorption is 3%. The existence of paving block porosity and the polarity of LDPE and PP towards water can control the rate of water absorption in the material [15]. The greater the porosity of paving blocks, the greater the absorption of water. Water absorption reduces owing to LDPE plastic fibers can seal holes and reduce porosity on paving block specimens. In addition, the hydrophobic properties possessed by polymer compounds as a constituent of LDPE/PP pyrolysis residues also have a major contribution in efforts to reduce water absorption in paving blocks [2].

Scanning Electron Microscopyc (SEM)

Figure 4(a,b) shows the SEM results at 2500x and 10000x magnification. The paving block appears to have a rough surface due to the presence of sand as a matrix in the paving block composite [13]. Sand and pyrolysis residue succeeded in forming composites as evidenced by the presence of sand grains scattered throughout the surface of the plastic. From previous research, the addition of thermoplastic PP and LDPE actually improved the mechanical and physical qualities of composite materials [7]. The SEM image as shown in Figure 4b clearly shows the sand particles integrated with the polymer matrix. This integration is in the form of interfacial bonds between polymer and sand [13]. Sand which is spread evenly on the matrix can improve the properties of the composite.

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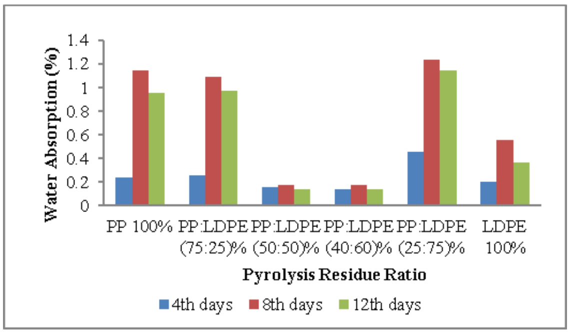

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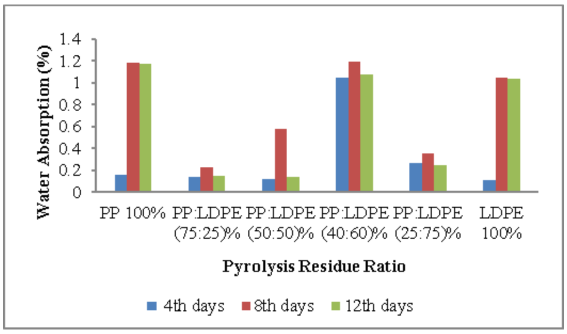

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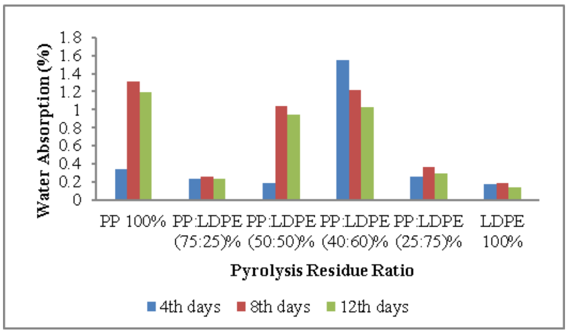

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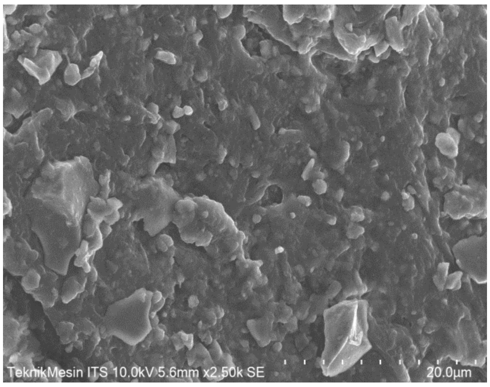
Figure 3. The water absorption of the paving block (a) LDPE: residue (70:30)%, (b) LDPE: residue (60:40)%, (c) LDPE: residue (50: 50)%.



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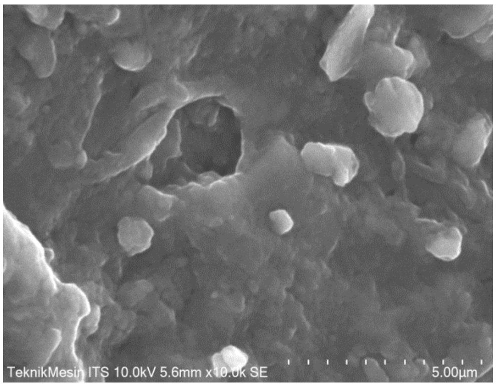

(b)

Figure 4. The SEM Characterization at (a) 2500x, (b) 10000x magnification

CONCLUSION

The addition of plastic pyrolysis residue and sand to paving stones can boost their compressive strength. The more plastic pyrolysis and sand residue added, the higher the compressive strength value and the lower the water absorption capacity.

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