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A Study of Plastic Waste as Binding Material

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Abstract. Every day we use plastic in daily lifestyle that is garbage, coffee cup, electronic material, plastic bags etc. Plastic is very harmful to humans, animals, marine and as well as to environment. Although most of the plastics waste are sent to the landfill for disposal, the quantity of waste is never reduced due to the rapid development and production of these materials. Management of solid waste continues to be major challenge, particularly in the urban agglomeration in low and middle-income countries. This project is about recycling waste plastic into pavement blocks and study their characteristics such as structure and strength. Variations in the portion of materials consisting of a mixture of oil, plastic waste, and sand were carried out to obtain the most optimal composition. The composition ratio of 1:1:0.5 of the three materials has given the best results where it can withstand a compressive force of up to 3.5 N/mm^2.

1. Introduction

Plastic is among the most widely utilized materials across communities worldwide. Compared to the past, the availability of plastic waste has significantly increased due to the rapid growth of urbanization and modern development [1][2][3]. It has become nearly impossible to eliminate its use. Plastics are deeply embedded in our daily lives, appearing in garbage bags, coffee cups, electronic components, and packaging materials. However, plastics are highly detrimental to humans, animals, marine ecosystems, and the environment. A critical question arises: where is all the plastic going? Alarmingly, billions of tons of plastic waste are ending up in the world's oceans, posing severe risks to marine life and adversely impacting human health [4].

Although most of the waste plastics are sent to the landfill for disposal, the quantity of waste is never reduced due to the rapid development and production of these materials. There are four major options for the disposal of plastic waste, which are landfilling, incineration, biodegradation and recycling [5]. Although all types of plastics can be disposed of via landfilling or incineration, landfilling is particularly wasteful. It requires extensive space and risks contaminating soil and surrounding ecosystems, rendering it environmentally unsustainable. The proportion of plastics in waste composition remains high, with polyethylene being the most significant component, followed by polypropylene. These statistics underscore the urgency of adopting effective strategies for plastic waste management to mitigate its environmental and health-related impacts.

In all its forms—solid, liquid, or hazardous—waste has become an inevitable consequence of modernization and economic development. This trend has been particularly evident in the twentieth and early twenty-first centuries, as documented in various studies on waste generation [6] The global waste production rate is escalating at an unprecedented pace, with estimates indicating approximately 1.3 billion tonnes of waste generated annually in 2015. This figure is projected to increase to approximately 2.2 billion tonnes by 2025. Over 15 years, per capita waste generation rates are expected to rise from 1.2 to 1.42 kilograms per person per day [7]. These alarming trends highlight the urgency of addressing waste management practices, as experts warn that this growth will persist unless significant changes are made in the utilization and recycling of natural resources.

Solid waste management presents a critical challenge, particularly in urban areas of low- and middle-income countries, where infrastructure and resources often need to be improved to handle increasing waste volumes [8]. Research indicates that plastics can be blended with sand to create composite materials without significantly altering their properties, though minor reductions in strength may occur. This study focuses on recycling plastic waste into pavement blocks and examines their structural and mechanical characteristics. The plastic waste used in this project was sourced from the "Bank Sampah Universitas Budi Luhur" (Budi Luhur University Waste Bank) as shown in Fig. 1, serving as a practical example of how waste materials can be repurposed to address pressing environmental challenges.

Fig. 1. The building of Budi Luhur Waste Bank

The contributions of this study include: (1). investigate the ability of processed plastic waste to function as an adhesive material, especially in manufacturing construction materials in paving blocks (2). examine the opportunity for processed plastic waste to be used as a substitute for cement materials so that it is more economical (3). Determine the most appropriate composition of the materials used to make paving blocks to maximize their strength.

2. Experimental Method

Manufacturing paver blocks using plastic waste requires significant quantities of plastic (such as plastic bags), oil, and sand. The specific quantities depend on the desired composition of the paver blocks. The sorted and suitable waste materials used in this process were collected from the Budi Luhur production facility. The batching process in Table 1 determined the mix proportions of plastic bags, used oil, and sand.

Table 1. Material composition of each sample

Sample	Plastic (gram)	Oil (gram)	Sand (gram)
S1	250	250	125
S2	250	250	150
S3	250	250	175
S4	250	250	200
S5	250	250	225
S6	250	250	250
S7	250	250	300
S8	250	250	375

The production process consists of three main stages:

- **Process 1**: Initialization
  In this initial stage, the processing tank in Fig. 2 is heated until it reaches a temperature of 100°C, preparing it for the next step.
- **Process 2**: Heating the Oil
  In this stage, the oil is heated in the processing tank until it reaches 130°C, at which point it is ready for the subsequent step.
- **Process 3**: Melting and Mixing
  The plastic waste is gradually added to the heated oil from Process 2. Continuous stirring is carried out to ensure uniform heat distribution and thorough melting of the plastic. Once the plastic completely melts, sand is gradually introduced into the mixture. The mixture is stirred thoroughly by hand to ensure homogeneity. This process continues until the temperature of the plastic-sand mixture reaches approximately 260°C.

Once thoroughly mixed, the material is poured into the mould shown in Fig. 3 and allowed to cool and harden for 24 hours. The mold is made of iron plate with a thickness of 2 mm. It has a width, length, and depth of 10 cm, 20 cm, and 3 cm, respectively.

Fig. 2. Mixing and heating tank

Fig. 3. The Mould

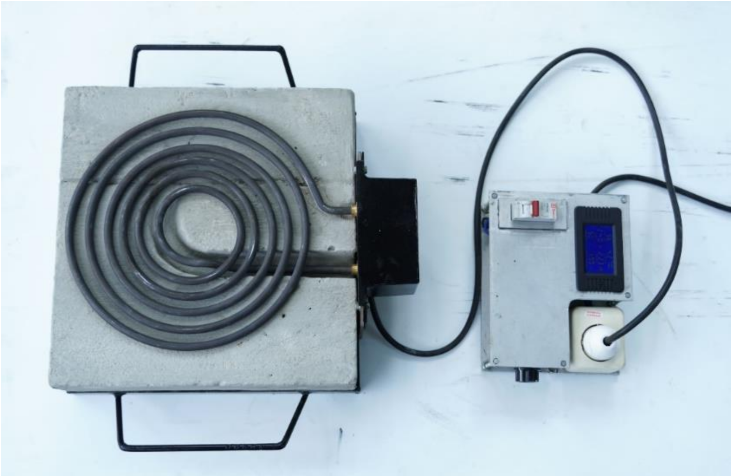

Fig. 4. Temperature control system circuit

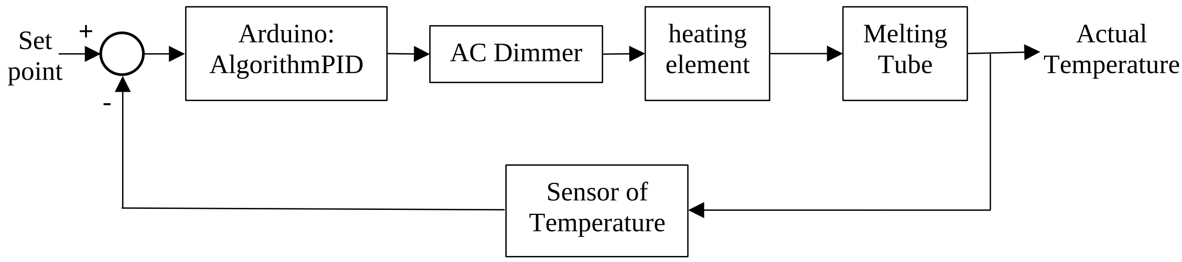

Fig. 5. Temperature control system diagram

The heating uses an electric element with a temperature control system, as shown in Fig. 4. The electric heating element used is a spiral ceramic tube with a maximum power capacity of 4000 Watts and a temperature capability of 700ºC. The heating temperature adjustment is done by adjusting the electric power supplied to the heating element through an AC voltage dimmer circuit. Fig. 5 presents a diagram of the system used to control the temperature during the process.

3. Results and Discussion

The observations in this study consider both the complexity of the preparation process and its environmental implications. In the heating method, plastic bags function as a binding agent. The process involves melting plastic bags in an oven alongside sand and oil. Once the mixture reaches a temperature of 260°C, it is poured into a concrete casting mould. A key challenge associated with this method is maintaining precise temperature control while mixing recycled plastic (RP) with sand and oil, as the RP solidifies rapidly, resulting in potential segregation within the mixture. Furthermore, this method produces significant amounts of smoke during the manual mixing, posing considerable environmental concerns.

In contrast, the compression method utilizes plastic bags as a replacement for sand, as specified in Table 1. The mixture, consisting of sand, oil, and recycled plastic, follows the methodology of interlocking brick production systems employed at Universitas Budi Luhur, Jakarta. Figure 6 presents the compressive strength development of the samples. The results indicate a general decline in compressive strength as sand content increases (Table 2). However, a consistent relationship was observed between the compressive strength and the ratio of plastic bag to sand content, as depicted in Figure 6. Notably, the sample with a 0.50 sand content exhibited the highest compressive strength, even though it is different in sample preparation, but this result is similar to what Sahil Sanjeev Salvi et al. did [9], whereas the sample with 1.50 sand content demonstrated the lowest strength. This study did not include a water absorption test to evaluate the impact of rain or a skid resistance test, which is a critical parameter for ensuring the safety of paver blocks. These assessments are anticipated to be addressed in future research to evaluate the performance of the paver blocks further.

Table 2. Result of Compressive strength test

No.	Sampel ID	Compressive Force Ultimate [N/mm^2]
1	S1-Paving	3,35
2	S2-Paving	3,00
3	S3-Paving	2,38
4	S4-Paving	1,85
5	S5-Paving	1,27
6	S6-Paving	1,15
7	S7-Paving	1,02
8	S8-Paving	0,79

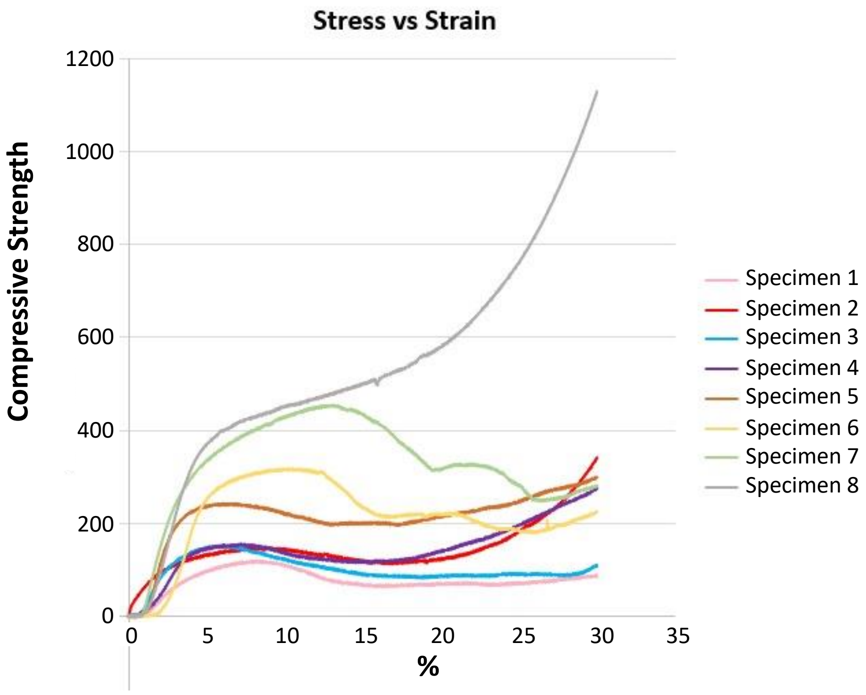

Fig. 6. Compressive strength of sample

4. Conclusion

This paper presents the results of a study on using plastic waste as an adhesive material in the moulding process of paving blocks. The material combines oil, sand, and plastic waste to replace cement. By heating at temperatures up to 260oC, plastic waste material can act as an adhesive to replace cement in manufacturing construction materials in block pavers. Plastic, oil, and sand composition in the 1, 1, and 0.5 ratios gave the most substantial results and could withstand a compressive force of up to 3.5 N/mm2. Using residual plastic waste with no economic value can replace cement as an adhesive in manufacturing construction materials, especially paving blocks. For future research, the ability to absorb water to study the effects of rain and the durability of the surface, which is one of the essential elements in paver blocks for safety reasons, should be investigated.

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