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Utilization of Plastic Waste as Paver Block, Economic Potential, and Environmental Impact

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[1]Abstract. One of the main factors that cause environmental damage in Indonesia is waste. Reducing waste by burning it directly without an incinerator will cause air pollution for the environment. CO2 is a substance produced by a complete combustion process. The amount of waste produced by Bandung Regency reaches 1,480.1 tons/day, with 20% of the waste being plastic waste. One way to utilize plastic waste is to recycle it into materials to produce paver blocks. Producing paver blocks requires a series of machines, such as crushing machines, plastic melting machines, and pressing machines. Plastic waste that has been sorted is put into a chopping machine and cut into 10 mm pieces. The plastic that has been cut is then melted down and printed, then re-pressed with a press machine. The type of plastic used in this research is polypropylene, with a melting point of 160-170°C. The size of the paver block produced is compatible with the market size. During the production of paver blocks, the CO2 concentration was monitored to see the effect of resin melting. In the analysis of paver blocks' economic potential, we found that the production cost using plastic waste is relatively expensive compared to conventional paver blocks. However, this type of paver block is not harmful to the environment. The results of this study indicate that plastic waste paver blocks can be used as paver block materials because they have quite an impact on the environment, although their economic value cannot compete with conventional paver blocks.

Keywords: Plastic Waste, Paver Block, Economic Potential, Environmental Impact

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1. Introduction

According to UU No. 18 2008 about waste management, waste is human activities or environment residual in a solid or semi-solid shaped, organic or inorganic, could be decomposed or not, useless, and had been thrown away to the environment. Badan Pusat Statistik Bandung at 2018 showed that 7503 m3 waste buried every day. Until 2020, at least 130 tons of waste in Bandung couldn't be transported to the Sarimukti landfill each day. Those numbers reach 10% of total volume of daily waste managed by Dinas Lingkungan Hidup dan Kebersihan (DHLK) Bandung [1]. In general, there are two kinds of waste, organic and inorganic. Organic waste is organism residual which easy to decompose without human intervention. Meanwhile, inorganic waste is non-organism residual, such as plastic. Plastics are one of the most used materials in household appliances, and there are several disposable types. The use of disposable plastic makes plastic one of the most waste contributors.

The number of plastic-waste increases each year along with the human need for plastic. Plastic waste

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is one of the prominent environmental issues in every part of the world because it is hard to decompose, yet the number of plastics is increasing. Thus far, plastic waste management is conducted by burying and burning plastics. Waste burning causes environmental pollution through combustion emissions, such as carbon dioxide [2]. Besides, the European Fireplaces Association (EFA) states that waste burning could emit toxic substances into the air, such as Nitrogen oxide, Carbon monoxide, and Particulate Matter.

Plastic waste management could be handled with the 3R concept, i.e., Reuse, Reduce, and Recycle. Recycling could reduce and resolve the environmental pollution issues caused by plastic waste, such as recycling it into paver blocks. Plastic can be used as the key materials in paver block making as sand substitute materials. The utilization of plastic waste as paver blocks is believed to reduce the waste pile in the world [3].

This study used Polypropylene (C3H6) to produce paver blocks. Polypropylene is a widely used thermoplastic material in the commercial sector and is compatible with many processing techniques. This type of plastic has a melting point of 160-170°C [4]. Polypropylene is the two most used plastic after Polyethylene. In 2017, in the U.S.A., the city waste from Polypropylene plastic reach 8000 tons/year, and 50 tons were successfully recycled [5].

Past research stated that Polypropylene (PP) has lower specific gravity than other plastics. PP has a high chemical resistance yet low impact strength [6]. Generally, PP is light, waxy, resistant to oils and chemicals, and usually used as kitchen/eating utensils. This study used wasted mineral-drink plastic cups packages with a size of 240 ml. The wasted plastic cups were shredded and melted down until producing gasses and solid residue.

This study also monitored the CO2 concentration emitted by the melting process of plastics in the paver block making and saw the potential of plastic waste in paver blocks. This study also aims to analyze the economic potential and pH quality of water produced by proposed paver blocks to show the environmental impact. Lastly, the economic analysis of the proposed paver blocks was analyzed with the conventional or commercial paver blocks in the market, with the same quality.

2. Method

2.1 Paver Blocks Making

There are several paver block-making machines, namely the chopping machine, melting machine, and press machine. Each machine is made of U-canal iron material for the frame and an iron plate for the machine's body part. The overall dimensions of the machine measure 250 cm X 50 cm X 50 cm (length X width X height).

The shredding machine is used to shred plastic waste before the melting process, with a knife cut size of 10 mm, and made of steel. The shredding process is supported by a knife drive tool using a gasoline-fueled drive engine with a power of 4101.35 Nm/s. After the shredding process, the plastic is dried with the help of sunlight to reduce the moisture content in plastics. Once the plastic has dried, it is ready to enter the melting process. The melting process used a semi-automatic melting machine, and there was a driving machine to push the melted plastic out. The heat source in the melting process uses ignition with LPG gas fuel. Plastic is put into the melting machine when the engine temperature has almost reached the melting temperature of the plastic. Therefore, the plastic is perfectly melted when put into the machine.

After the melting process, the printing mat collected the plastic from the melting machine. A printed mat full of plastic melts is ready to be pressed with a press. After pressing and forming the paver block, then is immersed in water to adjust the temperature of the paver block. Therefore, the paver block does not bulge due to the hot temperatures. The schematic procedure to make the proposed paver block shows in Fig. 1.

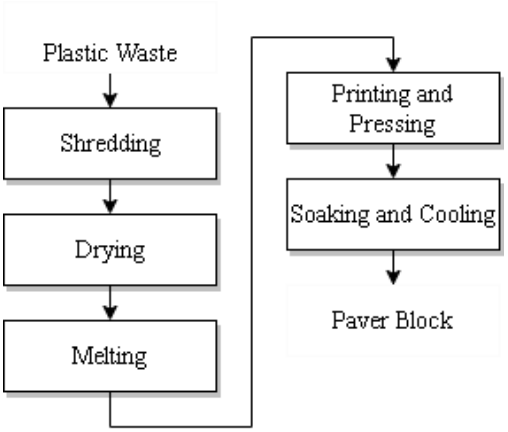

Fig. 1. Schematic of paver block making.

2.2 CO_2 Measurement

The measuring instrument used in this study consists of a CO2 gas sensor (SKU: SEN0219) and a temperature and humidity sensor (DHT22) connected to an Arduino Uno microcontroller with an RTC Data Logger. Then the sensors and other components are packed with a measuring box and given a fan to produce a flow rate to pull the air into the measuring chamber. We used a fan with a diameter of 6cm, a working voltage of 5 V, and a current of 0.4 A. The fan is optimized using Pulse Width Modulation (PWM) from (0-100)% at rotational speeds of up to ~4200 rpm [7].

The CO_2 gas sensor working principle is based on Non-dispersive Infrared (NDIR). It has a measuring range of 0-5000 ppm with a maximum current of 60 mA at a voltage of 5 V. Sensor requires a pre-heating time (± 1 hour) until the sensor output voltage is about 0.4 V, equal to 0 ppm. The maximum generated voltage is 2 V, equal to 5000 ppm [8]. This sensor has been calibrated by comparing the sensor to the CO_2 Meter (Lutron GCH-2018) for one hour under room conditions. Measurement comparison data is taken every two minutes and obtained a value of R2 0.49 [7].

To measure humidity and temperature DHT22 sensor is used. The DHT22 sensor produced a calibrated digital signal. Each sensor on this model has been calibrated accurately, and the calibration coefficient is stored and calculated in the OTP memory program.

2.3 Location of Paver Blocks Making

The process of making paver blocks and measuring the CO_2 concentration was conducted in the RW 05 Office, Panundaan Village, Ciwidey, Bandung Regency, on January 18-19, 2020. The location is at an altitude of 1,260 meters above sea level with latitude coordinates of 7^{oo} 06'43" LS and longitude 107^{oo} 26'32" BT.

During the measurement process, the surrounding conditions at the measurement site did not produce much CO2 gas emissions. There were only a few motor vehicles passing by. The distance between the measurement location to the road is about three meters, so it did not affect the measurement.

3. Findings

3.1 CO_2 Concentration During the Melting Process

In this study, a pre-study observed the CO_2 gas concentration emitted from the combustion of organic, inorganic, and mixed waste using incinerators. The measuring instrument was placed 30 cm from the chimney. The material used in inorganic waste is plastic waste bottles with a type of PET of 3 kg. From the combustion results, the CO_2 concentration reached an average of 1712 ppm, and the highest CO_2 concentration reached 3000 ppm. Combustion was conducted at a temperature of 800 °C [8].

During the melting process of plastic waste in the paver block making, this study also measured the CO_2 concentration emitted by the machine. The plastic waste used is plastic cups for mineral-drink packages. The measuring instrument was placed 30 cm from the output chimney.

The concentration of CO_2 before the melting process was around 600 ppm and increased when it started to melt the plastics. The highest CO_2 gas concentration reaches 1200 ppm during the melting process. Based on data from the measuring station in the Tokong Nanas Building, Telkom University's average CO_2 in January was 547 ppm.

As a reference, temperature and humidity data on that day (19 January 2020) were obtained from the Bandung Geophysical Station (Latitude: -6.88356, Longitude: 107.59733), accessed Online from the BMKG Database Centre. The data shows that the average daily temperature was 25.3 °C and the daily average humidity was 79%. The measured CO2 gas concentration, temperature, and humidity are described in Fig. 2.

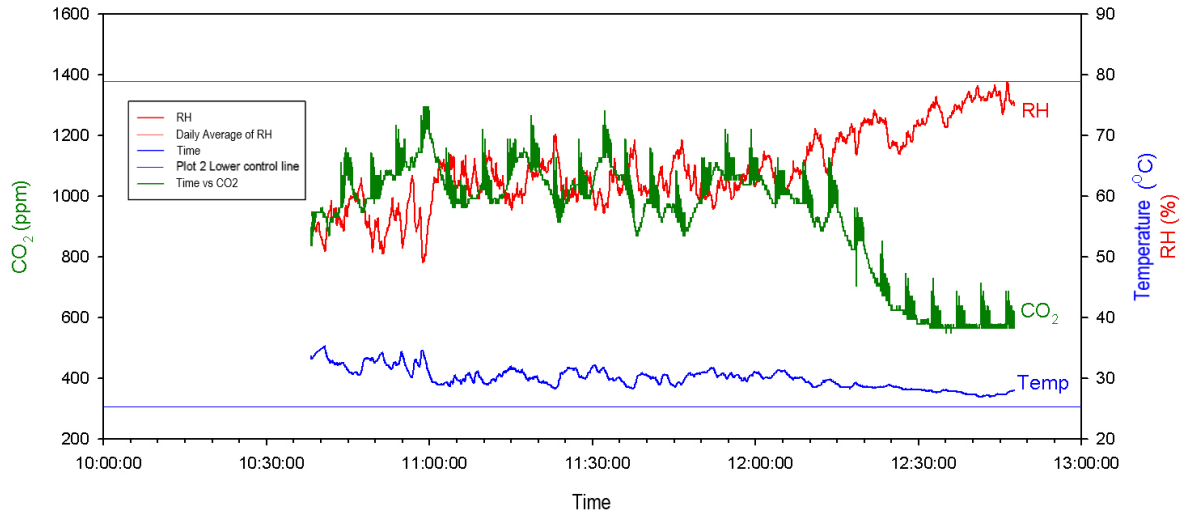

Fig. 2. The data of CO2, Temperature, and Humidity during pavin block making.

3.2 Proposed Paver Block Quality

The quality test of the proposed paver block was conducted on two parameters, compressive strength, and water absorption tests. A compressive strength test was conducted at the *Puslitbang Permukiman Testing Laboratory* (PUSKIM) using a Universal Testing Machine, Tokyo Koki, with a capacity of 100 TF, and the test method referring to SNI-03-0691-1996. The test was conducted on February 3, 2020, with six proposed paver blocks using the same material composition. This test did not variate the dimensions and size of the proposed paver blocks. The size of proposed paver blocks followed the size of paver blocks in the market. The results of the compressive strength test are shown in Table 1.

Table 1. The Proposed Paver Blocks Compressive Test Result.

Samples-	Compressive Strength (MPa)
1	47,99
2	57,17
3	44,49
4	37,35
5	35,87
Average	44,57

Based on the test results, the average compressive strength of the proposed paver blocks is 44.57 MPa. Within this value, the proposed paver blocks are categorized as A-quality in SNI-03-0691-1996 and can be used for road-making materials. In the testing process, there was an anomaly in the proposed paver blocks sample number-6, which had a cavity in the middle of the test sample, causing the compressive strength value to differ significantly from the other samples and was not listed in Table 1.

Plastic also can be used as a mixture of paver blocks as an adhesive material. The plastic is melted and then mixed with other paver blocks materials. However, the performance was not as good as the 100% plastic paver blocks. The composition of the mixture with 11 plastics: 1 sand is the finest yet only categorized into B-quality paver blocks [9].

A water absorption test was conducted at the Laboratory, Telkom University. The absorbency was calculated by finding the mass of paver blocks when dry and after soaking for 24 hours in water. The absorbency of polypropylene plastic is in the range of 0.1-0.2 % [4]. Equation (1) shows the formula to calculate the absorbency.

$$\text{Absorbency} = \frac{B-A}{A} \times 100\,\% \text{Absorbency} = \frac{B-A}{A} \times 100\,\% \quad (1)$$

With:
A = Mass when dry
B = Mass after soaking

The results of the water absorption test found that paver blocks have an average absorbency rate of 0.2%. Therefore, this study assumed that they do not absorb water. This value corresponds to the reference value of the absorbency of polypropylene plastic [4]. The results of the water absorption test are shown in Table 2.

Table 2. The Proposed Paver Blocks Water Absorption Test Results.

Samples-	Initial Mass (gr)	First Day Mass (gr)	Second Day Mass (gr)	First Day Absorbency (%)	Second-day Absorbency (%)
1	1205	1206	1206	0.083	0.083
2	883	886	887	0.340	0.453
3	1125	1128	1128	0.267	0.267
4	1101	1102	1102	0.091	0.091
5	1023	1024	1025	0.098	0.196
Average of Absorbency				0.176	0.218

3.3 Potential Economic Value

Plastic paver blocks, an alternative solution to reduce plastic waste, must be able to be sold at a price below conventional paver blocks. Using plastic raw materials in the amount of 8 kg can produce five units of paver blocks. Therefore, 1 unit of paver block requires about 1.6 kg of plastic.

The production process of 8 kg plastics needed gasoline as fuel for driving the engine in the amount of 2.5 liters and one cylinder of LPG gas of 3 kg. The production costs of making paver blocks are shown in Table 3. By dividing the total cost into five units of concrete bricks, the production cost with a side dimension of 10 cm is Rp 7,275. The amount of paver blocks required in one square meter area is 38 units, so the price per square meter reaches Rp 276,450.

Table 3. Concrete Brick Production Cost.

Types of Materials	Amount	Unit	Unit Price (Rp)	Total (Rp)
Plastik	8	kg	0	0
Bensin (Premium)	2.5	liter	6,550	16,375
Gas 3 kg	1	tabung	20,000	20,000
Cost Total				36,375

Compared to conventional paver blocks with a side size of 12 cm, K-400 quality (compressive strength 400 kg / cm2), and a thickness of 6 cm, the price per square meter is Rp 135,000. So one square meter requires 27 paving units. The home industry can produce conventional paver blocks 360 units/day, thus making the same amount of daily production, then the required amount of plastic is 576 kg.

Based on data from the Ministry of Environment and Forestry in 2017-2018, Bandung Regency produced 1485.9 tons of waste per day, with 20% of this amount being a plastic waste. If the total population of Bandung Regency is 3,525,149 people, each person produces 0.08 kg per day of plastic waste.

The total population in *Panundaan Village* in 2017 was 14,125 people (Central Statistics Agency of Bandung Regency, 2018). It means that one village is estimated to be able to produce paver blocks of 706 units per day. The amount is almost doubled the daily production of conventional paver blocks.

Since the production cost of fully plastic paver blocks is quite expensive, the other solution is to use plastic as a material for conventional paver block mixtures. Plastic is melted to be used as an adhesive material for concrete bricks [9]. In the process of melting, it is not required to shred the plastic, to reduce production costs.

3.4 Environmental Impact

Paver blocks from plastic can reduce the amount of plastic waste in the environment. However, the environmental impact of the proposed paver block production is left unknown. Therefore, in this study, testing the immersion of paver blocks in water was conducted. Also, the pH water quality will be measured after immersion to see the impact of plastic paver blocks on the pH water quality. The soaking process was conducted for 24 hours at room temperature and used as an aqueous as the soaking liquid.

The pH value of the distilled water does not change after soaking in the water for 24 hours. The pH value, which was 7, remains in the range of that value. Based on the Regulation of the Minister of Health of the Republic of Indonesia Number 32 of 2017 concerning Water Health Quality Standards, the pH value of 7 is still in the water health quality standards for sanitary hygiene purposes. It means the water can still be consumed and used for bathing and washing foodstuffs and tableware.

The plastic will degrade and become microplastics after soaking for 60 days and being exposed to sunlight with the help of oxygen. It is called the process of photooxidation degradation. The degradation process does not affect the pH level of water. The degradation process will occur due to exposure to sunlight, oxygen levels, and living organisms [10]. In this study, no further observations were made regarding water quality due to the plastic degradation.

4. Conclusion

Based on the results of the research, the following conclusions were obtained:

1. Alternative use of plastic waste can be used as paver blocks material and is assumed to have the ability in reducing the amount of plastic waste produced by *Panundaan Village*, Ciwidey, Bandung Regency.
2. The quality of plastic paver blocks is in the A quality category, with a compressive strength value of 44.57 MPa and a water absorbency of 0.2%.
3. The price of plastic paver blocks reaches twice the price of conventional paver blocks at the same quality due to the high cost of production.
4. The quality of CO2 due to the plastic waste melting process is still high, reaching a value of 1200 ppm.
5. The impact of plastic paver blocks on water quality is not visible in a short period since there is no significant change in pH.

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