Study of Utilizations of Recycled LDPE Plastic and Stone Ash Waste from Remaining Split Stone Fragments for Block Paving Application

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Abstract. Several waste materials have been continuously investigated for possible use as substitutes for materials in the field of civil engineering; one of them is plastic waste, due to the fact that plastic waste is simultaneously increasing. In this study, the block paving was made from recycled plastic bag (LDPE) with the addition of stone ash from stone crusher process waste for the value of 0%; 2.5%, 5%, 7.5%, and 10%. These additions of stone ash were intended in order to increase water absorption and increase surface roughness. Several physical and mechanical tests were carried out according to SNI-03-0691-1996. From the compressive test, the highest compressive strength is 13.43 MPa. Based on the results of the sodium sulphate resistance test and the external appearance tests, it showed that all block paving was in good condition with solid surface. In accordance to SNI-03-0691-1996, the paving block was included in the class-C quality which can be used for pedestrians.

Keywords: block paving, recycled LDPE polymer, stone ash waste

1. Introduction
Block paving (brick paving) is a civil engineering building material that is widely used due to its resistance to compressive forces and can relatively absorb runoff so that it can reduce the potential for standing water. Block paving is generally made from a mixture of sand, cement and water, with a ratio of 1: 3 which is printed according to the desired size and shape. According to SNI-03-0691-1996, block paving can be used for roads, parking lots, pedestrians, parks, and other uses. The classification of the use of block paving is distinguished by its compressive capacity.

The use of block paving is in demand because it has several advantages, including being cheaper than other types of pavement, easy maintenance, good absorption because water runoff can be absorbed through the gaps between the paving blocks, and fast installation with shapes and colours that can be adjusted.

Nowadays there have been many studies conducted to study the potential use of waste or recycled waste as building material compilers. Plastic waste is one of the garbage which becomes its own problem for the environment because of its nature which is difficult to decompose by nature. According to the Ministry of Environment and Forestry (2018), national waste production reaches around 65.8 million tons annually, of which 16 percent is plastic waste.

Plastic began to be used as a civil engineering material since non-corroosive, durable, easily formed, and relatively inexpensive. Low-density polyethylene (LDPE) is a type of plastic that is usually used for making plastic bags. LDPE plastic is a polymer plastic with thermosetting properties, i.e., at certain temperatures the constituent monomers can be separated from each other, and when the temperature
returns to normal then the monomers will bind together again. The thermosetting properties of this LDPE plastic type make it possible to do the recycling process.

Block paving is usually made from a mixture of fine aggregate and binder in the form of cement. Fine aggregate used in general is normal sand. This research emphasizes the use of waste material in the form of rubbish or waste, therefore for fine aggregate, an alternative replacement is used, namely stone ash. Concrete composed of split rock fragments instead of fine aggregates has relatively good workability and high compressive strength, reaching 31.77 MPa [1].

The proposed block paving in this study was made from a mixture of split rock waste and LDPE plastic waste with different compositions. Plastic waste is expected to increase the durability of block paving. The addition of stone ash can increase strength and contribute to absorption in compressed bricks.

2. Literature Review

2.1. Block paving

Block paving is a building material that can be used for vehicle road floor linings, pedestrian roads, parks, and other uses. Paving blocks are still widely used for parking, sidewalks, parks, and connecting between buildings. Block paving is not yet widely used for roads because there are no standard criteria for pavement layers [2].

Block paving is a composition of building materials made from a mixture of portland cement or similar hydraulic adhesives, water and aggregates with or without other additives, without reducing the quality of the concrete bricks [3]. Block paving has several advantages compared to other materials, which are easy to install, relatively quickly applied on site, able to absorb water, inexpensive to process and maintainance.

The function of the block paving is to cover the floor cleanly and for a long period of time. Block paving can be installed without using cement adhesive. This makes it an inexpensive and easy alternative for water absorption and a place free of mud. Block paving can be found in various forms, motifs, and patterns to suit consumer tastes [4].

With the increasingly widespread use of block paving construction in the community, an effort is needed to improve the quality of block paving. In addition to the quality of this paving block, it is necessary to find a solution so that the selling price of this product is affordable in the community; this can be done by using additive which can improve the quality of block paving, and are widely available at very cheap prices [5].

Block paving must meet the required quality requirements, including [3]:

a. The quality requirements for block paving that it should have a flat surface, no cracks and defects, and the corners and ribs do not break easily with the strength of the fingers.

b. The size requirements for block paving that it should have a minimum nominal thickness of 60 mm with a tolerance of +8%.

c. The physical properties for block paving that it should have those as seen in table 1.

| Quality | Compressive strength (MPa) | Wear resistance (mm/minute) | Max. average water absorption (%) |
|---------|---------------------------|-----------------------------|----------------------------------|
| A       | 40                        | 0.090                       | 3                                |
| B       | 20                        | 0.130                       | 6                                |
| C       | 15                        | 0.160                       | 8                                |
| D       | 10                        | 0.219                       | 10                               |

Based on these qualities, Quality A can be used for roads, Quality B can be used for parking equipment, Quality C can be used for pedestrians, and Quality D can be used for parks and other uses.
2.2. Low density polyethylene (LDPE)

Plastic is a material that can be softened and has a lower elasticity compared to fiber. Plastics can be made in accordance with the desired characteristics by copolymerization, lamination, or extrusion [6]. Plastics can be grouped into two types, namely thermoplastic and thermoset [7]. Thermoplastic is a plastic that can be softened repeatedly by using heat, including polyethylene, polypropylene, polystyrene, and polyvinylchloride. Whereas thermosets are plastics which cannot be softened by heating, including phenol formaldehyde and urea formaldehyde.

Low density polyethylene (LDPE) is one type of plastic that is usually used as material for making plastic bags. LDPE has a density value smaller than pure water around 0.920 g/cm³ [8]. The differences in density will affect the properties of polyethylene including thermal properties (melting point), optical properties (haze, gloss, clarity), and physical properties (notch resistance, tear resistance, and tensile strength) [9].

LDPE is a chocolate-typed plastic often used for food containers, plastic packaging, and soft bottles. LDPE plastic has the characteristics such as strong, fairly translucent, flexible, and slightly greasy surface. LDPE has a density between 0.91–0.94 g/mL, half of it is crystalline (50 – 60%), and has a melting point of 115°C [10].

2.3. Stone ash

Crushed stone is an aggregate material obtained by crushing large stones into certain sized aggregates using a stone crushing machine. Broken stone can be used as an alternative to sand, gravel, or crust. The form of broken stone used as a substitute for sand is often referred to as stone ash because of its subtle grading size. Stone ash is often used as a material for making concrete bricks or culverts.

3. Research Objective and Problem Scope

3.1. Research Objectives

This research has several research objectives, including:

a. Producing block paving from waste materials, namely LDPE plastic waste, split stone fragments waste, and limestone waste
b. Knowing the feasibility of block paving from waste materials, namely LDPE plastic waste, split stone fragments waste, and limestone based on testing results according to SNI-03-0691-1996;

c. Knowing the percentage ratio between LDPE plastics, split stone fragments, and limestone which produces the highest compressive strength.

3.2. Problem Scope

There are several scopes used in this research, namely:

a. The used LDPE-typed plastic waste used is obtained from local collectors of the recycled plastic waste in Magelang;
b. The used split stone fragments waste come from local mixing plant
c. The dimensions of the block paving are determined to be 200-mm long, 100-mm wide, and 75-mm thick.
d. The test is based on SNI-03-0691-1996 about block paving
e. The mixture proportion can be seen in Table 2 as follows:

| No | Test Specimen Code | LDPE Plastic (%) | Stone ash (%) |
|----|--------------------|------------------|---------------|
| 1  | P100               | 100              | 0             |
| 2  | P97.5              | 97.5             | 2.5           |
| 3  | P95                | 95               | 5             |
| 4  | P92.5              | 92.5             | 7.5           |
| 5  | P90                | 90               | 10            |
4. Achieved Outcome and Result

4.1. Result of Research

The tests carried out for the block paving consisted of: visible test, size test, compressive test, wear resistance test, and natrium sulphate resistance test.

4.1.1. Visible Test and Size Test. The visible test was done by observing the surface mechanism of the block paving made of the mixture of LDPE plastic and the split stone waste. The size test was done by measuring the outer dimension of the block paving by making 3 (three) measurements for the length, width, and thickness of the block paving. Based on the test results, that the more split stone waste added, it would affect the weight of the paving block. This was because the density of the split stone waste, in the form of stone ash, was higher than the density of the LDPE plastic. The graph illustrating the increase in the block paving weight in this research can be seen in Figure 1.

4.1.2. Compressive Test. The test was carried out on 10 pieces of test specimens by means of a cube-shaped cut, and the ribs were adjusted to the size of the test specimens’ example. The test specimens’ example, which was ready, was pressed to shreds using the press machine whose speed can be adjusted. The pressure rate from the start of loading until the test example had been destroyed was set within 1 to 2 minutes. The compressive direction on the test example was adjusted to the direction of the load pressure in the use. Based on the test results, there was an increase in the compressive strength on the stone ash addition of the split stone fragments waste, but this increase was not significant. The graph illustrating the average compressive strength results of the block paving from the LDPE plastic waste and the stone ash of split stone waste can be seen in Figure 2.

4.1.3. Wear Resistance Test. The test was carried out on 5 squared test examples with the size of 50 mm x 50 mm and a thickness of 20 mm. The good wear resistance test was on a flat surface of block paving which was not rough, so it was resistant to the wear. Based on the test results it shows that there was a decrease in abrasion resistance with the addition of stone ash. The lower the abrasion value the higher the abrasion resistance. The graph illustrating the average results of the wear resistance in the block paving from the LDPE plastic waste and the split stone waste stone ash can be seen in Figure 3.
4.1.4. Natrium Sulphate Resistance Test. The condition of the block paving was reported in good words/not deformed if there were no visible cracks or other changes, and reported defects/cracks when there were visible cracks, brittle, clusters, and others. If the difference between the weighing before the immersion and after the immersion was not more than 1%, and the test example was not defective, then the test example was stated in good condition. If the difference in weighing of 2 of the 3 specimens was greater than 1%, while the test specimens were good (not defective), then it was declared in defective condition. Based on the natrium sulphate resistance test results it shows that there was seemingly a random fluctuated increase with the addition amount of stone ash. The graph illustrating the average results of the natrium sulfate resistance in the block paving from the LDPE plastic waste and the split stone waste stone ash, can be seen in Figure 4.

4.1.5. Water Absorption Test. The test was carried out on 5 test examples that were immersed in a whole to saturated condition (24 hours), then weighed in a wet condition. The test examples were then dried in a drying kitchen for approximately 24 hours, at a temperature of approximately 105°C, until the weight at twice the weighing was not more than 0.2% of the previous weighing. The graph illustrating the relationship between increasing the amount of split stone waste stone ash and the water absorption in the block paving, can be seen in Figure 5. Based on the test results it shows that the increase of stone ash added will directly affect the increase in water absorption paving block. Due to the density of these stone ash is higher than the density of the LDPE plastic.
4.2. Discussion
Based on the tests results of the, it was concluded that the addition of split stone fragments waste stone ash had a direct effect on the compressive strength and the water absorption of the block paving. The visible and size tests showed that the block paving had a flat, smooth surface, and a relatively stable dimension size.

The wear resistance test and the natrium sulphate resistance test showed that the block paving from the LDPE plastic was capable and strong against those outside factors. Based on the compressive strength, the LDPE block paving was classified into the Class C which was suitable for pedestrians. In accordance with the SNI 03-0691-1996, the tests conducted based on the one-way Anova statistical approach can be concluded, that the addition of the stone ash amount from the split stone fragments waste directly affected the increase in the compressive strength and the water absorption.

5. Conclusion

5.1. Conclusion
Based on the test results of the block paving of LDPE plastic waste and the stone ash of split stone fragments waste, the following conclusions are obtained:

a. The highest compressive strength is 13.43 MPa for the ratio of 100% LDPE plastic waste and 0% split stone fragments waste stone ash. The lowest compressive strength is 12.86 MPa for the ratio of 90% LDPE plastic waste and 10% split stone fragments waste stone ash. Based on the compressive strength, the LDPE block paving is categorized into the Class C, means it is suitable for pedestrians.
b. Based on the test results, the lowest wear resistance for the ratio of 90% LDPE plastic waste and 10% split stone fragments waste stone ash, is 0.117 mm/minute. The highest wear resistance, for the ratio of 100% LDPE plastic waste and 0% split stone fragments waste stone ash, is 0.129 mm/minute.

c. The highest natrium sulphotate resistance test results, for the ratio of 90% LDPE plastic waste and 10% split stone fragments waste stone ash, is 0.150%. The lowest natrium sulphotate resistance, for the ratio of 100% LDPE plastic waste and 0% split stone fragments waste stone ash, is 0.125%.

d. Based on the test results, the highest absorption, for a ratio of 90% LDPE plastic waste and 10% split stone fragments waste stone ash, is 0.026%. The lowest water absorption test, for the ratio of 100% LDPE plastic waste and 0% split stone fragments waste stone ash, is 0.013%.

e. The visible examination and the size examination show that the block paving has a flat and smooth surface, and the size dimension is relatively stable. The tests carried out for the block paving consisted of: visible test, size test, compressive test, wear resistance test, and natrium sulphotate resistance test.

5.2. Suggestion
There are a couple of suggestions can be taken based on the results of the block paving test from the LDPE plastic waste and the split stone fragments stone ash, namely:

a. Furthermore, it is necessary to consider the process of burning the LDPE plastic waste in the manufacturing process, since it creates relatively dangerous air pollution.

b. Further research can be done with different forms of block paving so that the interlocking effect can be further evaluated. Materials in the form of LDPE plastic waste, and split stone fragments were, prepared.

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