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Contribution of Plastic Waste in Recycles Concrete Aggregate Paving Block

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ABSTRACT

Road pavements generally use asphalt and cement concrete as flexible and rigid pavements. A flexible pavement covering material with concrete paving blocks has been developed for low-traffic road structures. Paving block compressive strength tests still use beam samples; some have used cube samples. Concrete waste and plastic waste can reduce material requirements and support environmental sustainability. Therefore, it is used as a recycled material. This research utilizes concrete waste and plastic waste in the composition of the concrete paving block mixture. Compressive and flexural strength tests with a cement and aggregate ratio 1:3 was used in this study. The aggregate comprises screening, sand, stone ash, recycled concrete aggregate, and plastic waste additives. The test results showed that the concrete paving block test objects in the form of cubes and beams produced different characteristics. Cube-shaped concrete paving blocks make more realistic compressive strength test values. Judging from the results of the compressive strength and flexural strength tests, the addition of plastic decreased the strength of the concrete paving block. Still, the addition of 4-6% plastic waste positively contributed to the value of flexural strength.

1. Introduction

Road pavements generally consist of flexible pavements and rigid pavements. Porous and flexible pavements have been developed using paving block surface layers when the vehicle and traffic loads are moderate. Pavement block paving is widely used because of its fast production, easy installation, and maintenance [1]. In addition, paving blocks have the ease of working, so they are widely used in road pavement construction. In its application, paving blocks are often used to construct roads, intersections, sidewalks, garages, and parking lots [2]. Concrete paving blocks are generally used in areas without vehicle traffic, such as sidewalks, yards, and barriers, or areas with low traffic, such as residential streets, rural roads, and car parks. However, with certain materials, it is also used in areas

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with medium traffic, such as urban roads, to areas with high traffic, such as industrial areas with a lot of heavy equipment and bus terminals [3].

In the manufacturing process, there are several methods of making paving blocks. The method commonly used is the dry and wet mixed method. Where for the dry method it is made with very little water with low slump and compacted by a hydraulic machine. In comparison, the wet method is prepared in a mixture with sufficient water and compacted with a vibratory machine [4]. Concrete paving blocks are generally made with cement as a binder, sand as a fine aggregate, and split as a coarse aggregate.

Various mechanical properties tests were carried out to see the performance of the paving block mix. Laboratory tests and field tests on the structural performance of concrete paving blocks show that this pavement system has adequate structural capacity [5]. The thickness of the concrete paving block affects the structural value of the paving block. Field test results showed that the higher the thickness of the paving block, the lower the deflection value [6].

The shape of the paving block also affects the strength value of the paving block. For example, comparing the uni-block and rectangular block shapes of paving blocks shows that the uni-block shape produces a better strength value than the rectangular shape [7]. Several other studies have shown the same tendency that the shape of paving blocks affects the strength value. For example, block I and uni-style shapes produce the same strength values, while clover block shapes produce the lowest strength [8].

Infrastructure development is increasing yearly, indicating the increasing use of materials. This increase has an impact on the limited natural aggregate. Using recycled materials can reduce the use of natural aggregates, which are currently widely programmed in the infrastructure industry, especially in road pavement [9]. Sustainability in the construction sector is related to the zero-waste scenario. Its application can be in the form of using recycled materials in construction, one of which is recycled concrete aggregate waste (RCA). Utilization of RCA aggregates can be in the form of mixing in the manufacture of concrete materials, which is beneficial to the environment and financially. RCA has great potential to develop the latest concrete technology, drive economic activity, and optimize natural resources [10]. The use of RCA in paving block mixes can increase the strength value of concrete. Replacing natural aggregate by 15% will increase strength up to 28% compared to a composition without RCA. This increase is due to adding aggregate and paste bonds [11]. In addition, by carrying out proper compaction, paving block composition with RCA content can increase the strength of paving blocks. RCA can increase the strength value of paving blocks by up to 156% against natural aggregate by carrying out proper compaction [12]. However, when the mixed composition with more dominant RCA will reduce the strength of the mixed composition. Paving blocks with the addition of RCA can reduce strength values by up to 10% after soaking for 24 hours [13].

Another waste is plastic waste, a source of problems that are difficult to manage worldwide. In 2050 the accumulation of plastic waste is estimated to reach 12,000 million metric tons [14]. The increasing increase in plastic waste makes many people use this plastic waste, including in the construction sector. Therefore, using plastic waste in development is one of the waste management programs to support environmental sustainability [15].

This research has conducted tests on aggregate and plastic recycled concrete to contribute to environmental sustainability programs and reduce the use of natural materials.

2. Methodology

This study used cement, screening aggregate, rock ash, sand, Recycled Aggregate Concrete, and water. The cement used is a type of cement that is generally used in construction, while aggregate is obtained from PT. Master Block is a paving block manufacturing company. RCA is obtained from the remaining concrete waste from the mixer truck and then processed using a concrete recycling machine. Finally, washing RCA is carried out to remove the mortar content attached to the aggregate.

2.1 Cement

The cement used in the concrete paving block mix is a type of Portland cement used as a binder. Cement material is a type of cement that is commonly used in the manufacture of concrete. The specific gravity value is 3.1 kg/dm^3 in a clean condition without clumping cement particles, so the concrete block mixture has a good bond.

2.2 Natural Aggregate

Natural aggregate consists of screening aggregate material, sand, and rock ash. Screening aggregate (SC) has an aggregate size of 12.5 mm to 2.35 mm. While sand with a size of 4.75 mm to 0.075 mm. Stone ash (SA) obtained from the results of breaking rock using a stone crusher has an aggregate size of 4.75 mm to 0.075 mm. The results of the screening aggregate properties test, rock ash, and sand can be seen in Table 1.

Table 1
Properties of Agregate

Test type	Standard	SC	SA	Sand	RCA	Unit
Los Angeles abrasion	ASTM C131	36.2	-	-	36.4	%
Specific gravity	ASTM C127	2.43	2.64	2.45	2.3	kg/dm^3
Absorption	ASTM C127	6	2.8	1.5	8.6	%

2.3 Recycled Concrete Aggregate

Recycled Concrete Aggregate (RCA) (Figure 1) is obtained from the remaining disposal of the Batching Plant, which accumulates in the stockpile area and contains mortar, so it still needs to be managed. RCA is processed by separating the hardened concrete using a concrete recycling machine. The waste concrete recycling machine produces various sizes of aggregates ranging from coarse, medium, and fine. Furthermore, washing is carried out until the mortar content is lost.

Fig. 1. Recycled Concrete Aggregate

2.4 Plastic Waste

Plastic waste of the LDPE type is an added ingredient in a mixture of concrete paving blocks. This waste comes from plastic bags, so processing is required before use. The first process is cleaning the plastic from adhering dirt and then grinding it into a fine and uniform powder. Processing into a fine powder is done by chopping the plastic using a chopping machine. The enumeration results were then filtered using filter No. 16 with a grain size smaller than 1.18 mm.

2.5 Water Cement Ratio

By visual observation, water must be clean and not contain mud, oil, and other floating objects. Water will react directly with the cement so that the cement's hydration takes place, releases heat, and helps the hardening process. The cement water factor is very influential on the compressive strength of concrete. The higher the water content will affect the decrease in compressive strength, and bleeding can occur in the concrete. At this stage, the water requirement will be determined to be used in the paving block mixture, which is 10% of the total mixture.

2.6 Sample mixtures

The mixture composition used between cement and aggregate is 1:3, with water as much as 10% of the total mixture. There are three types of samples with different heights, namely 10 cm, 8 cm, and 6 cm, with the same width and length of 10 cm and 20 cm. Each weigh 4.13 kg, 3.6 kg, and 2.44 kg. Next, plastic is added to the total weight with a percentage of 4%, 6%, 8%, and 10%. Detailed mixture properties can be seen in Table 2, and a picture of the gradation composition can be seen in Figure 3.

Table 2
Mix Proportion of Concrete Paving Blocks

No	Mix	Water (%)	Cement (%)	SC (%)	Sand (%)	SA (%)	RCA (%)
1	Control I	10	22	13	27	27	-
2	NA+RCA I	10	22	13	20	20	13
3	Control II	10	22	13	27	27	-
4	NA+RCA II	10	22	13	20	20	13
5	Control III	10	22	13	27	27	-
6	NA+RCA III	10	22	13	20	20	13

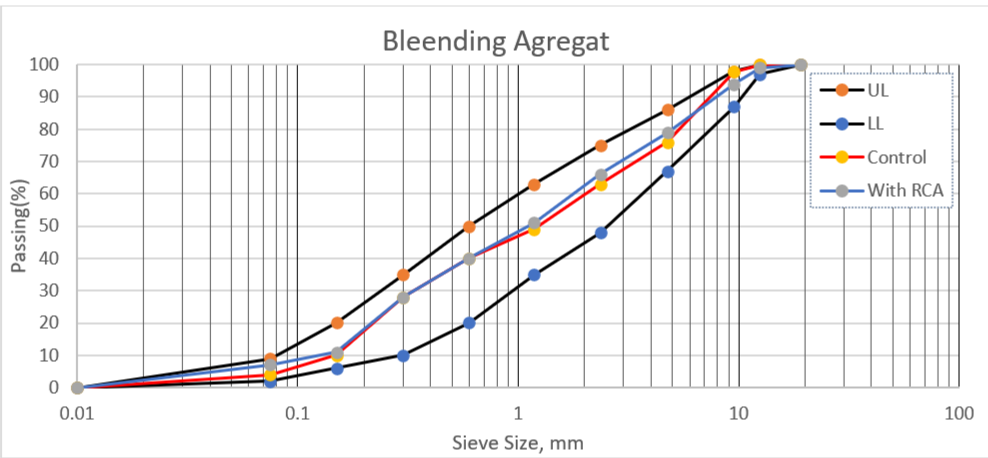
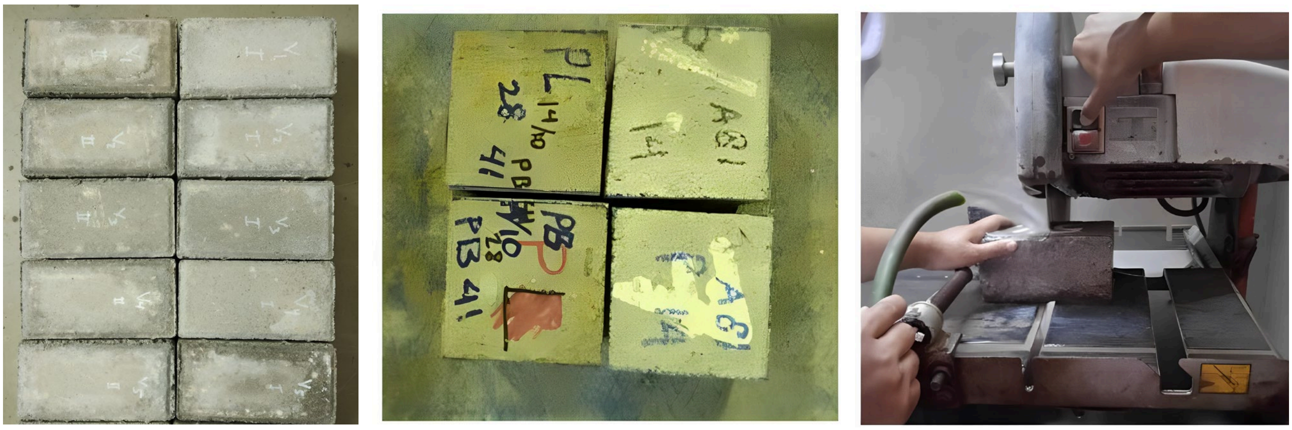


Fig. 2. Blending Aggregate (a) without RCA (b) Modified RCA

2.7 Sample Preparation

The concrete paving block sample process is done manually by preparing tools and materials. First, the mold is greased with oil so that it does not stick to the mold when removing the test object. The compacting concrete paving blocks using a manual compactor. The compaction process is carried out by dividing the three layers, each being punched 45 times until the mold is filled. Then the mold and compactor were removed and left to stand for up to 3 hours before the test object could be moved. After the specimens have hardened, the specimens are divided into beams and cubes. The cube test object obtained from the sample beam is cut into cubes of 90 mm, 70 mm, and 50 mm.



(a) (b) (c)

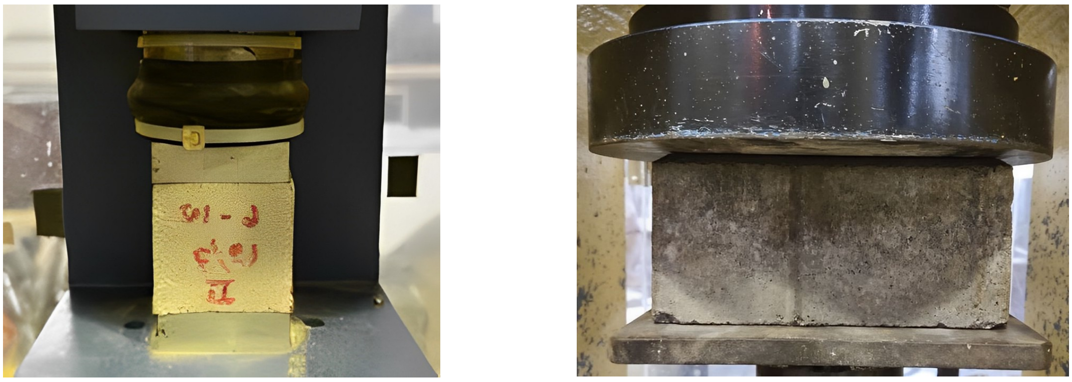
Fig. 3. (a) beam sample (b) cube sample (c) Process of cutting cube sample

2.8 Compressive Strength

Compressive tests were carried out on beams with a width and length of 10x20 cm with a height of 10 cm, 8 cm, and 6 cm, respectively. In comparison, the test object is in the form of a cube with a size of 9 cm, 7 cm, and 5 cm. The cube test object is obtained from the beam test object being cut to become a cube per SNI 03-0691-1996 standards [16]. The specimens with variations in shape and height are then tested for compressive strength. This test is carried out to estimate the amount of compressive force that can be resisted by paving blocks before failure. The compressive strength test was tested by curing for 14 and 28 days and then allowed to stand for 24 hours. After that, a compression test using a compression machine with a capacity of 250 kN at a 1 mm/minute speed until it fails. The compressive strength test can be seen in Figure 4. and the following equation is used to calculate the compressive strength:

$$\sigma = \frac{F}{A} \tag{1}$$

where σ is the compressive strength (Kg/Cm^2), F is the compressive load crushed concrete (Kg), and A is the surface area (cm^2).



(a) (b)

Fig. 4. Compressive strength test (a) cube sample (b) beam sample

2.9 Flexural Strength

They tested the flexural strength of concrete paving blocks using the 3-point method with a test object size of 100 x 100 x 200 mm. Tests were carried out at one-third of the span and the middle of the span at the load above using a compression machine with a load of 0.1 MPa per second. The flexure test was carried out when the concrete paving block was 28 days old. The following equation is used to calculate flexural strength, and the test scheme can be seen in Figure 5:

$$\text{Flexural Strength, MPa} = \frac{3PL}{2bd^2} \quad (2)$$

where P = load at failure (Kg); l = span length (cm); b = width of specimen (cm); d = depth of specimen (cm).

Fig. 5. Flexural strength test setup

3. Results

3.1 Characteristics of the Beam Test and Cube Test

In this study, the aggregate material used RCA to preserve the environment. However, the test results showed that the compressive strength was lower than the compressive strength value of the new aggregate material. This recycled paving block material is then used to compare the compressive strength tests of the beam and cube methods.

These two tests produce different compressive strength characteristics for samples with different thicknesses, namely for sample beams with heights of 6 cm, 8 cm, and 10 cm and sample cubes with heights of 5 cm, 7 cm, and 9 cm. Figure 6 shows the results of a cube-shaped concrete paving block test with the same mixture variation and different heights, showing a strength value where a higher thickness indicates a higher compressive strength value.

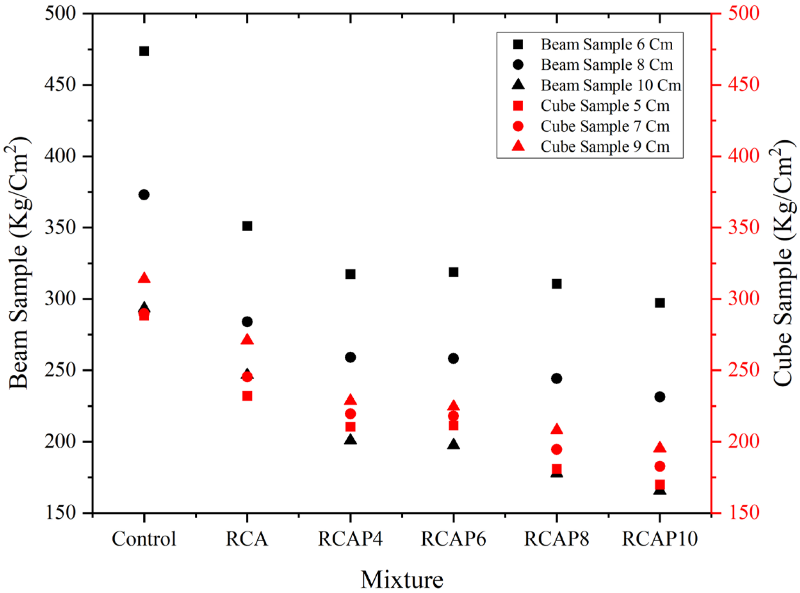


Fig. 6. Comparison of compressive strength values of beam and cube samples

On the contrary, the beam test for samples with lower thickness shows higher compressive strength values. Results like this also occur in samples with added plastic material. Whereas cube-shaped concrete paving blocks produce a more realistic value, this is in line with the recommendation of [16]that a cube sample is used to test paving blocks.

Statistical observation of concrete paving block samples in the form of beams cannot be used as a direct reference. Instead, a conversion value is required from the beam test to the cube test, where the amount depends on the thickness of the concrete paving block.

3.2 Effect of Plastic Waste on Paving Block Performance

Flexibility testing was carried out using concrete paving blocks with length, width, and height dimensions of 20 cm, 10 cm, and 10 cm. First, the plastic is treated with a chopping machine, and then the finely chopped pieces are filtered through sieve number 16 with a size of less than 1.16 mm. Mixture variations used are RCA and RCA + Plastic 4%, 6%, and 8%, and Figure 7 shows the flexural strength test results for variations in paving block concrete mixes.

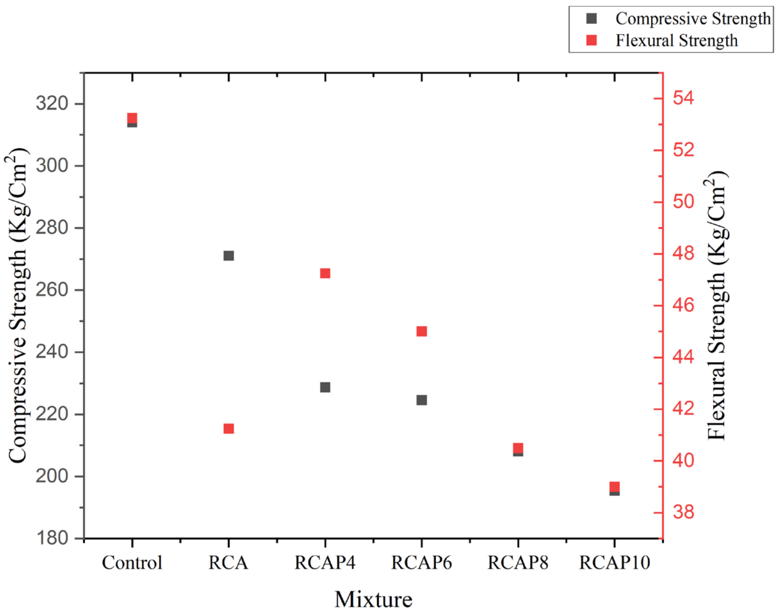


Fig. 7. Compressive strength and flexural strength

The test results show a difference in the tendency of the compressive strength and flexural strength test results. The new paving block material (sample control) produces the same value of compressive strength and flexural strength. Whereas in testing the compressive strength of the material with added plastic, it decreases according to the increase in the plastic content in the mixture. Using RCA resulted in lower performance than the sample control test results. This decrease is very dependent on the condition of the RCA material. However, the compressive strength value is still sufficient for road pavement material.

Figure 6 shows that adding 4% and 6% plastic resulted in a higher flexural strength than the plastic RCA + mixture. Using 4% and 6% plastic contributed to better flexural strength and compressive strength characteristics than other RCA compositions. This contribution indicates the addition of 4-5% plastic to using RCA as recycled paving block material. Several studies explain that the research results with the addition of plastic will reduce the compressive strength value [17]. In other research, it was explained that adding RCA decreased the strength of concrete paving blocks by up to 10% [13]. Some of the results of these studies align with the research conducted; namely, the addition of RCA resulted in a decrease in strength values.

4. Conclusions

In short, the findings are concluded as following:

i. The results of laboratory tests on compressive strength using beam samples show unrealistic results where thinner beams have higher compressive strength values. In contrast to the compressive strength test using cube samples, where the compressive strength values are more realistic, this follows the recommendation of SNI 03-0691-1996 that cube samples are used for paving block tests.
ii. RCA substitute paving block concrete produces a lower compressive strength value than new materials. However, 40% of RCA still performs sufficiently as a pavement material for pedestrian facilities or light traffic.

iii. The use of 4% and 6% plastic waste has shown benefits in increasing the value of flexural strength. This increase indicates that adding plastic can contribute to flexural strength and environmental sustainability.

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