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Physical-Mechanical Properties of Paving Block from Plastic Shopping Bags Waste and Sand

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Abstract. Plastic shopping bags are easy to obtain for free or at low prices, hence contribute as the highest quantity among plastic waste. The plastic shopping bags waste has no economic value. Usually they are just thrown away. An alternative solution is by utilizing them to produce paving block by mixing with sands. The objective of this experiment is to evaluate the best ratio composition of plastic shopping bags waste and sand, followed by evaluation of the physical-mechanical properties of this particular paving block. Several different mixture ratios of weights of plastic shopping bag and sand were evaluated to obtain the best physical-mechanical properties of the paving block. The mixture ratios of weight of plastic shopping bags waste and sand were 1:1, 1:2, 1:3, 1:4 and 1:5, respectively. The shopping plastic bags waste was melted before mixed with sand. The different mixture ratios were mixed with same pressure. The paving block mixture with ratio of 1:4 exhibited the best physical-mechanical properties as revealed by no defect, no crack and fine surface. The compressive strength of 17.4 MPa, friction resistance of 0.138 mm/sec and water absorption of 2.518% can be achieved, which is suitable for parking area construction.

Introduction

Indonesia contributes significantly to the generation of plastic in the world [1, 2]. Plastic shopping bags are easy to obtain for free or at low prices. Most of traditional market, shopping mall and retail market in Indonesia give plastic shopping bag for free to the consumer. Hence, people tend to use disposable plastic bags, lead to become the dominant plastic waste. Plastic waste takes many decades to decompose in soil and can cause many environmental problems [3].

The waste bank, a community based initiative for waste collection and recycling, is one of the ways to solve pollution problems due to plastic waste. People collect garbage from house and separate them into valuable items, and send to the waste bank to earn some money. Unfortunately, waste banks do not accept all kinds of plastics waste, moreover, the plastic shopping bags waste is deemed not to have economic value. Usually they were just thrown away and contributes negative impact on environment [4, 5]. One of the alternatives in dealing with plastic shopping bags is utilizing it to produce alternative paving block by mixing with sands.

The conventional paving block 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 that do not reduce the quality of the concrete bricks [6]. Paving blocks are building material products in the form of interlocking concrete. Paving blocks are used as a cover or hardening of the ground surface and usually used for parking lots, courtyards or small roads [7].

Studies on plastic paving blocks production provide an understanding on the ability of plastics as binders on composite paving blocks. Plastic waste can be used as additive in mixture of sand and cement to make paving block [8]. Plastic LDPE (Low Density Polyethylene) waste can be used in paving block production [9]. The mechanical properties such as compressive strength of paving blocks can be increased by adding PET (Polyethylene) fiber [10, 11], melted LDPE [12], and melted LDPE, coarse aggregate and sand [13]. Additionally, plastic waste was used as binding material for paving block [14]. By using plastics waste LDPE as cement replacement it would reduce production

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cost[15]. In Indonesia, paving block products made from plastic waste type mineral bottles, plastic bags and bottle caps based on SNI 03-0691-1996 as standard requirement [16].

Therefore, in order to produce a good paving block, this study was conducted to find out the best ratio composition of plastic shopping bags waste and sand, followed by evaluation of the physical-mechanical properties of paving block produced.

Materials

The plastic shopping bag waste was obtained from the waste bank association of the Special Region of Yogyakarta. They were separated from other waste and then reduced into small pieces and weighted. Sand was collected from the river of Kulonprogo, Yogyakarta. The sand was cleaned from dust, sun dried and sieving to obtain uniform size (40 Mesh) before mixed with plastic bag waste.

Method

Paving Block Production

The ratio of melted plastic bag waste and sand were 1:1, 1:2, 1:3, 1:4 and 1:5, respectively. Simultaneously, the hot cleaned sand was added into the mixture while continue stirring. The homogenous mixture was then molded as soon as possible by using 75 kg/m^2 molded pressure to make 5 x 5 x 5 cm iron plate molding.

Physical Properties Evaluation

Water Absorption

Absorbability testing of paving block was carried out by determining the changes in mass of dry samples and wet samples after being soaked in water. Paving blocks were evaluated for their water absorption by soaking paving block in the water until saturated for 24 hours [17]. The absorption of water occurs due to the pores between particles in the sample [10]. The water absorption test procedure was based on SNI 03-0691-1996 [6]. The sample is weighed and recorded. Wet samples were then drained in room temperature followed by weighing the drained samples. Samples were then dried again in an oven at 105^{o}C until the difference in weight reached not more than 0.2% after a minimum two times of weighing [6]. Water absorption can be calculated by Eq. 1 [18].

$$WA\ (\%) = \frac{SSD - W_{Dry}}{W_{Dry}}\ x\ 100\% \quad (1)$$

where,

WA (%): Water Absorption (%)

W_{SSD} : The mass of saturated surface dry of the sample (g)

W_{Dry} : The completely dry mass of the sample (g)

Determination of Porosity and Specific Gravity

The porosity shows number of pores in sample. The porosity is defined as ratio of total volume of pores to total volume of sample [18]. The specific gravity can be calculated by ratio from the mass of sample and the mass of water at 40^{o}C in the same volume of water [18].

Resistance to Sodium Sulfate

Based on SNI 03-0691-1996, one of the determinants of the quality of paving blocks is the resistance to sodium sulfate to determine defective or brittle of sample. The testing procedure was done by weighing a sample of paving blocks and recorded the first weight. Then the sample was immersed in a saturated sodium sulfate solution for 16 to 18 hours. Samples were drained and dried in an oven at 105^{o}C ± 2^{o}C for 2 hours and cooled at room temperature. The process was repeated up to 5 times soaking and drying. The sample was then washed with a $BaCl_2$ solution to remove sulfuric salt. Clean samples of sulfuric salt then wash with hot water 40-50^{o}C until clean then dry at 105^{o}C in an oven for 2-4 hours. The sample was chilled in an excitatory and weighed to the near 0.1 gram difference. Observe the sample after the sodium sulfate test for cracks, clusters or other defects. If the defect is more than 1%, then the sample is defined unfit or defective [6].

Mechanical Properties Evaluation of Paving Block

Compressive Strength of Paving Block

Testing of compressive strength used a pressure machine for testing the compressive strength on paving blocks according to SNI 03-0691-1996. The sample was pressed with a certain speed until destroyed. The first occurrence of fracture on a pressed paving block shows the compressive strength of the material. The compressive strength of a paving block shows the ability of a paving block to hold a load. The compressive strength unit that refers to SNI 03-0691-1996 is MPa. Compressive strength can be calculated by the Eq. 2 [19].

$$F_C = \frac{P}{A} \tag{2}$$

where,

F_C: Compressive strength (MPa)

P : measure load at failure (N)

A : Area of compressive area (m^2)

Friction Rate

Friction resistant testing on paving blocks used a friction machine that has been integrated with a computer that refers to SNI 03-0028-1987 standards on how to test cement tiles. Friction resistance of a paving block shows the ability of a paving block against repetitive friction [6].

Result and Discussion

This study was to determine the effect of the composition of the mixture of plastic shopping bags waste and sand at the same molded pressure in paving blocks production.

Physical Properties of Paving Block

The physical properties are important in order to decide the quality of paving block [13]. The Indonesian standard SNI 03-0691-1996 is used to define classification of paving block quality and usability based on physical properties which have been obtained in this research. The physical properties of the paving blocks studied were weight, water absorption, porosity, specific gravity and resistance to sodium sulfate of paving block in several weight ratio compositions. The paving block was molded in same dimensions, of 5 cm x 5 cm x cm. The physical properties of paving block in several weight ratio of mixing shopping bag plastics waste and sand mixture is shown in Table 1.

Table 1. The Physical Properties in Several Weight Ratio Compositions of Paving Block (5x5x5cm)

Weight Ratio (Plastic bag waste : Sand)	Weight (gram)	Water Absorption (%)	Porosity (%)	Specific Gravity	Resistance to sodium sulfate
1 : 1	218.4	1.212	7.08	2.43	fracture
1 : 2	230.2	1.890	8.90	2.51	fracture
1 : 3	251.7	2.010	11.81	2.67	no defect
1 : 4	278.9	2.518	15.34	2.79	no defect
1 : 5	283.4	2.981	15.89	2.91	fracture

The result showed that weight of paving block was higher at the addition of sand. This is because sand has higher specific gravity than shopping bag plastics waste. Based on Table 1, showed that the higher weight ratio of mixing shopping bag plastics waste and sand caused the increase of percentage of water absorption, porosity and specific gravity of paving block caused by the more volume of sand as fine aggregate used, causing more porous make it easier and faster way to pass or absorb water [18]. One of the requirements for paving block is good water absorption. This is useful for ground water balance.

Meanwhile, the resistance to sodium sulfate is used to determine paving block defects. Paving blocks that have been tested for sodium sulfate resistance are physically observed have no defects or damage and no water loss of more than 1% [6]. Table 1 shows that too much added plastic will cause paving block has no sodium sulfate resistance and fracture. This is possible for the reaction that occurs between sodium sulfate and plastic in the paving block. However, the melted plastic in the paving block is used as an adhesive. If too much sand is used the product is relatively brittle and has low sodium sulfate resistance. The ratio 1:3 and 1:4 mixtures of shopping bag plastic waste and sand are recommended to be used in paving block production. They have no defect after tested for sodium sulfate resistance. Based on the whole tested physical properties, the ratio 1: 4 mixture of shopping bag plastic waste and sand is the highly recommended as the best ratio. It results 278.9 g of weight, water absorption 2.518%, porosity 15.34%, specific gravity 2.79 and no defect after testing by sodium sulfate resistance. The paving block produced by this current method is as recommended by SNI 03-0691-1996 as grade B quality category of paving blocks. The grade B quality category of paving blocks is usually considered to install in parking area.

Mechanical Properties of Paving Block

The mechanical properties are the main properties to determine the quality and usability of paving blocks. Good paving block must have the mechanical properties such as compressive strength and friction resistance [13]. The compressive strength of the paving block is a major determinant of its quality and intended use [20]. Compressive strength indicates the maximum load that can be supported by paving blocks [11, 21]. Meanwhile, friction resistance shows the ability of paving blocks to receive repeated friction [6]. The ratio of shopping bag plastic waste and sand mixing in paving blocks is predicted to affect its mechanical strength. The compressive strength and friction resistance of paving block in various mixture ratio of plastic shopping bags waste and sand in at the same dimension and molded pressure can be depicted in Fig. 1 and Fig. 2.

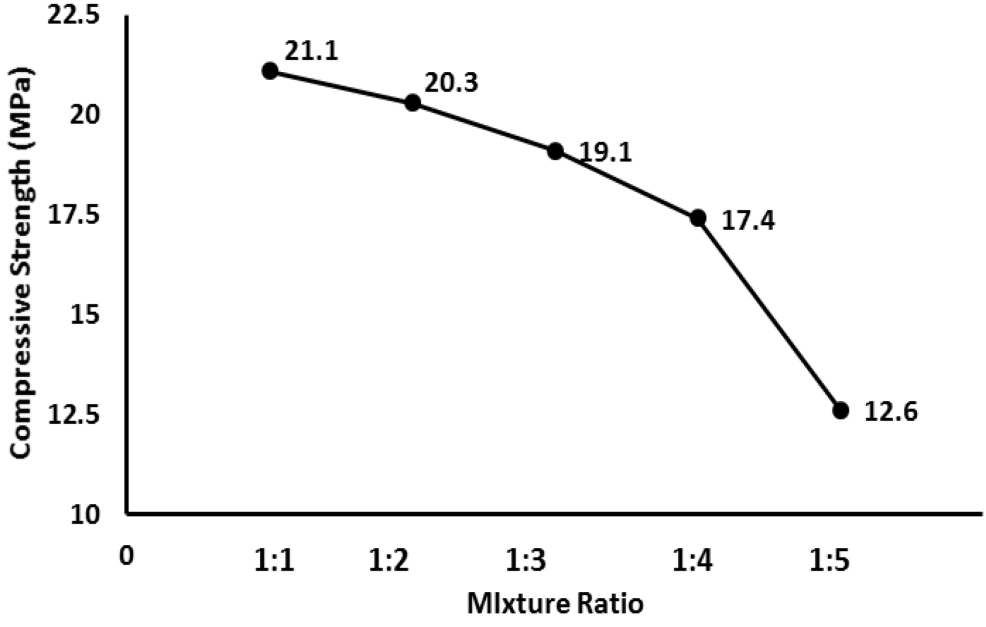

Fig. 1. The compressive strength of paving block under various mixture ratios

Based on Fig. 1, the compressive strength of paving block was greatly influenced by mixture ratio of shopping bag plastic waste and sand. The higher quantity of sand provided the more porous and the lower adhesive of paving block. It can be causes the lower compressive strength. The mixing ratio 1:1 has highest compressive strength due to mixture ratio formed the more adhesive and stable bond of melted plastics and sand providing tough and greater strength of paving block.

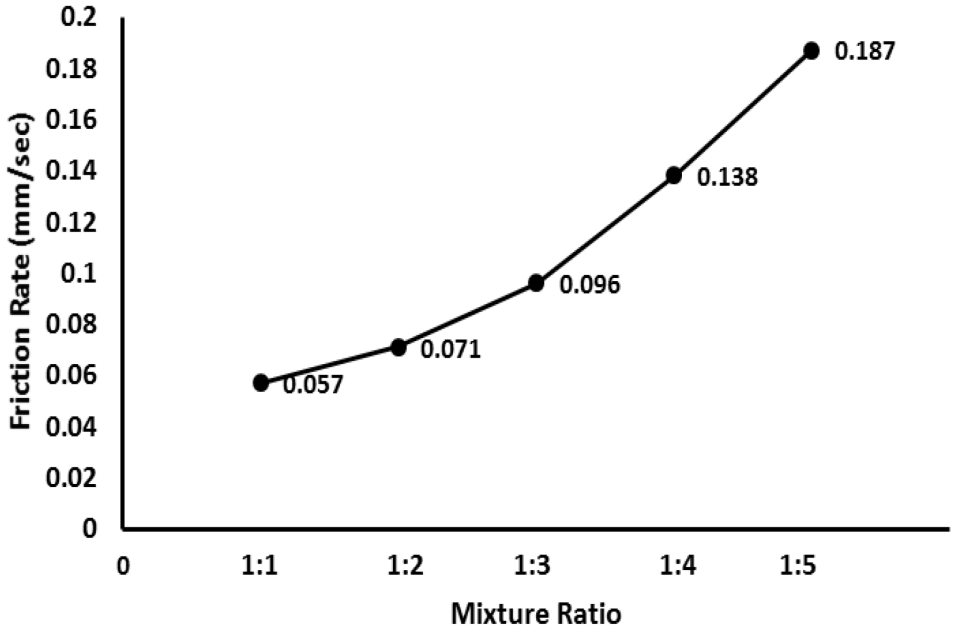

Fig. 2. The friction rate of paving block under various mixture ratios

The friction rate of paving block also was affected by mixture ratio of shopping bag plastic waste and sand. Based on Fig. 2, the mixture ratio of 1:5 resulted in higher friction rate of 0.187 mm/sec. It indicated the more sand as coarse aggregate used resulted in the greater friction, so it causes the more losses due to repeated friction. However, based on whole physical and mechanical properties tested the mixture ratio of 1:4 is highly recommended as the best formula resulted in water absorption 2.518%, friction rate of 0.138 mm/sec, compressive strength is 17.4 MPa and no defect after testing by sodium sulfate. It was included grade B category of paving blocks quality by SNI 03-0691-1996. Therefore, paving block produced by his ratio can be used in parking area.

Conclusions

The ratio of shopping bag plastic waste and sand mixing in paving blocks affects its physical and mechanical properties. The paving block mixed with ratio of 1:4 resulting in the best physical-mechanical properties where no defect, no crack and fine surface. The highest compression strength of 17.4 MPa, friction rate of 0.138 mm/sec, water absorption of 2.518 %, porosity 15.34% and specific gravity 2.79. According to SNI 03-0691-1996, these paving blocks can be categorized into the grade B and can be used for parking area construction.

References

[1] N. K. Putri, Local Concerns on Plastic Bag Charge in Indonesia : Do we really care ?, in Advances in Social Science, Education and Humanities Research (ASSEHR). 98 (January 2018) 326–329.

[2] Supriyadi et al., Analysis of Development Block Paving with Plastic Waste Material Adhesive Leaves, Int. J. Adv. Sci. Res. Eng. 9, 5 (2019) 1–7.

[3] T. Landi and Arijanto, Perancangan dan uji alat pengolah sampah plastik jenis LDPE (Low Density Polyethylene) menjadi bahan bakar alternatif, J. Tek. Mesin, 5, 1 (2017) 1–8.

[4] M. A. Jalil, M. N. Mian, and M. K. Rahman, Using Plastic Bags and Its Damaging Impact on Environment and Agriculture: An Alternative Proposal, Int. J. Learn. Dev. 3, 4 (2013).

[5] M. Gogte, Are Plastic Grocery Bags Sacking the Environment?. Int. J. Qual. Res. 3, 4 (2009) 363–375.

[6] National Indonesia Standard. SNI 03-0691-1996, Bata Beton.1996.

[7] M. Hambali, I. Lesmania, and A. Midkasna, Pengaruh Komposisi Bahan Penyusun Paving Block terhadap Kuat Tekan dan Daya Serap Airnya. J. Tek. Kim. 19, 4 (2013) 14–21.

[8] S. Pawar and S. A. Bujone, Use of Fly ash and Plastic in Paver Block. Int. Res. J. Eng. Technol. 4, 11 (2017) 1542–1547.

[9] S. K. Sohani, D. Soni, D. Shukla, A. Telang, and A. Sahu, Design of Pavement Blocks Utilizing Low Density Poly Ethylene (LDPE) Waste , and It's Evaluation, J. Emerg. Technol. Innov. Res. 5, 7 (2018) 1440–1444.

[10] D. P. Putra, S. T. Wicaksono, A. Rasyida, and R. Bayuaji, Studi Pengaruh Penambahan Binder Thermoplastic LDPE dan PET terhadap Sifat Mekanik Komposit Partikulat untuk Aplikasi Material Bangunan, J. Tek. ITS Vol. 7, 1 (2018) 26–30.

[11] G. Lavanya and K. P. Vasantha, Experimental Study On Paver Blocks Utilize In Pet Fibres, Int. J. Adv. Eng. Res. Technol. 4, 4 (2016) 73–79.

[12] A. Daftardar, R. Patel, R. Shah, P. Gandhi, and H. Garg, Use of Waste Plastic as a Construction Material, Int. J. Eng. Appl. Sci. 4, 11 (2017) 148–151.

[13] J. Constantin, S. M. Shitote, Z. C. A. Gariy, and E. Ronoh, Influence of Coarse Aggregate on the Physical and Mechanical Performance of Paving Blocks made using Waste Plastic, Int. J. Eng. Res. Technol. 12, 6 (2019) 912–916.

[14] S. Agyeman, N. K. Obeng-Ahenkora, S. Assiamah, and G. Twumasi, Exploiting Recycled Plastic Waste as An Alternative Binder for Paving Blocks Production, Case Stud. Constr. Mater. 11 (2019).

[15] B. Shanmugavalli, K. Gowtham, and P. J. Nalwin, Reuse of Plastic Waste in Paver Blocks, Int. J. Eng. Res. Technol. 6, 2 (2017) 313–315.

[16] Burhanuddin, Basuki, and M. R. S. Darmanijat, Pemanfaatan Limbah Plastik Bekas untuk Bahan Utama Pembuatan Paving Block, J. Rekayasa Lingkung. 18, 1 (2018) 1–7.

[17] A. R. Ingole, N. N. Sonole, and C. R. Thakur, Utilisation of E-Waste, Fly Ash in Manufacturing of Paver Blocks and Tiles, Int. J. Innov. Technol. Explor. Eng. 8, 10 (2019) 2392–2396.

[18] F. Dervishi and E. Luga, Relation between Physical and Mechanical Properties of Concrete Paving Blocks, in The 2nd International Congress on Roads in Albania 24th-25th of September 2015, Tirana-Albania, (September 2016).

[19] Y. Amran, Pemanfaatan Limbah Plastik untuk Bahan Tambahan Pembuatan Paving Block sebagai Alternatif Perkerasan pada Lahan Parkir di Universitas Muhammadiyah Metro, TAPAK. 4, 2 (2015) 125–129.

[20] O. Gencel, C. Ozel, F. Koksal, E. Erdogmus, G. Martínez-Barrera, and W. Brostow, Properties of Concrete Paving Blocks Made with Waste Marble, J. Clean. Prod. 21, 1 (2012) 62–70.

[21] P. Vila, M. N. Pereyra, and Á. Gutiérrez, Compressive strength in concrete paving blocks. Results leading to validate the test in half-unit specimens, Rev. ALCONPAT. 7, 3 (2017) 247–261.