E-ISSN: 2528-388X
P-ISSN: 0213-762X

INERSIA
Vol.19, No.2, December 2023

Utilization of Plastic Bottle Waste as Material for Making Sustainable Cement-Less Aesthetic Paving Blocks

Dwifi Aprillia Karisma*, Fauzie Nursandah, and Fitry Rahmawaty

Civil Engineering Program, Faculty of Engineering, Kadiri University, Kediri 64115, Indonesia

Keywords:
Paving Block
Cement Less
Aesthetic
Sustainable

ABSTRACT

Plastic is a key ingredient in many products around the world, but its existence has caused serious problems due to the buildup of waste it produces. The construction industry is one of the sectors that can play a role in the utilization of plastic waste. One of them is in the production of paving blocks. This study aims to combine aesthetic aspects and environmental attractiveness in paving blocks without sustainable cement. An experimental method was chosen to develop an alternative to making sustainable paving blocks without the use of cement. Variations used to start from 20% PET: 80% aggregate, 25% PET: 75% aggregate, 30% PET: 70% aggregate, 35% PET: 65% aggregate, 40% PET: 60% aggregate. The aggregates used are sand and stone ash. Physical and mechanical qualities of paving blocks, such as compressive strength, absorption is carried out to determine the quality of paving blocks. The aesthetic aspect is also in focus by carrying out the concept of "glow in the dark". The results of physical and mechanical quality evaluation show that this paving block has adequate performance. The ratio of 20% PET and 80% sand reached paving category C with a compressive strength of 19.65 MPa, while the mixture with a ratio of 20% PET and 80% stone ash reached paving category B with a compressive strength of 24.20 MPa. This paving can be applied in the use of parks, pedestrian to parking lots. This suggests that the use of PET in the mixture can achieve sufficient strength in the paving industry. However, higher water absorption in mixtures with a higher percentage of PET needs to be taken into consideration. In addition, morphological and structural analysis reveals the presence of pores in the paving block that can affect the overall strength. These pores are caused by uneven melting of PET plastic during the manufacturing process. Based on the LCC evaluation, a higher economic value was obtained, but the resulting environmental impact made the product worthy of being one of the solutions to reduce plastic waste.

1. Introduction

Plastic is becoming a key ingredient in many products around the world. Plastic is widely used as food packaging, water bottles, children's toys, shopping bags and various other products. At first, plastic was created as an alternative to natural materials such as wood or metal. This is because the nature of plastic is lightweight, durable, and easy to produce [1]. However, along with the times, the use of plastic has increased and caused major problems around the world [2]. It is recorded that in 2022 there are more than 8 billion tons of plastic waste [3]. Indonesia itself is the No. 5 plastic waste producing country in the world as much as 9.13 tons [4]. The hard-to-decompose nature of plastic makes the problem quite serious. If not managed properly, plastic waste can cause negative impacts on the environment and living things in it [5]. Plastic waste requires serious handling that must be done by the government, society, and industry to maintain sustainable survival. Utilization of waste can be done in various ways such as recycling, utilizing it as raw material, to making energy from waste [6]. It can help achieve sustainable development that yields long-term benefits for the environment, society, and economy.

More and more industries are realizing the importance of plastic waste management and utilizing it as an alternative raw material to reduce negative impacts on the

*Corresponding author.
E-mail: dwifi@unik-kediri.ac.id

https://dx.doi.org/10.21831/inersia.v19i2.67250
Received November 6th 2023; Revised December 29th 2023; Accepted December 31st 2023
Available online December 31st 2023

environment [7][8]. The construction industry is one of the sectors that can play a role in the utilization of plastic waste. Several studies related to the use of plastic waste in the construction sector have grown. Plastic waste can be used in the manufacture of asphalt mixture, cement bricks, panels to sandwich beams [9][10][11][12]. All of them are efforts to reduce dependence on conventional raw materials such as clay, bricks, or Portland cement. The use of plastic waste in the construction industry not only reduces plastic waste that pollutes the environment, but also can reduce carbon emissions because it reduces the use of conventional materials that require energy in their production.

Plastic waste can be used in the construction industry in the form of aggregate substitution, as well as cement. Several recent studies and reviews conducted on the use of plastic waste in the construction industry show promising progress and results in terms of recycling [13][14][6]. Researchers conducted a feasibility test of using PET into structural concrete blocks for use in civil construction. The results show from a technical point of view it is feasible to use micronized PET in producing structural masonry blocks. On the other hand, research and development has been carried out to develop paving block production technology from plastic waste that is sustainable and environmentally friendly [15]. The results showed that the use of such waste has a high potential to be sustainable with competitive engineering performance and economic feasibility. There are several types of plastic waste, and the most common in the stream is Polyethylene Terephthalate (PET) waste. PET waste is often used for the manufacture of mineral water bottles, soft drinks, and other food and beverage packaging [16]. Based on several studies, it shows that the use of PET waste in construction materials has become an attraction for researchers. Most of them focused on observing the potential use of PET in the mix. On the other hand, researchers also focused on optimizing the integration of plastic waste in cement mixtures.

However, there are still limited studies investigating the use of plastic bottle waste as a substitute for cement as a whole in the manufacture of paving blocks. In addition, there is a lack of research that combines aesthetic aspects and environmental attractiveness in the use of sustainable paving blocks. This study aims to combine aesthetic aspects and environmental attractiveness in sustainable cementless paving blocks by evaluating physical and mechanical quality, and environmental impact. Thus, this research seeks to create sustainable solutions that are not only technically effective, but also aesthetically pleasing and environmentally friendly in the paving block manufacturing industry.

2. Research Method

This research uses experimental methods to develop alternatives to making sustainable paving blocks without using cement, while maintaining an attractive aesthetic aspect. The research was conducted at the Civil Engineering Laboratory of Kadiri University. Methodological measures include the collection and preparation of PET plastic bottle waste through washing and cutting, the development of optimal mixtures that pay attention to the comparison of PET waste and aggregates to match the required physical and mechanical quality requirements [17]. The sample manufacturing process involves mixing materials, molding, drying, and hardening paving blocks. Samples are analyzed through physical and mechanical quality tests.

The independent variable in this study was the composition of the mixture of materials, including the comparison of PET plastic bottle waste and aggregate. The dependent variables observed were the physical and mechanical qualities of the paving block, such as compressive strength and absorption. Control variables in this study include environmental factors, such as temperature, setting time, compaction and humidity during the drying process, which can affect the quality of the final product. Sustainability is considered by reducing plastic waste and using natural resources more efficiently.

The aesthetic aspect is also in focus by carrying out the concept of "glow in the dark" Sustainability aspects are also a major concern in this study, with an emphasis on the use of plastic waste as an environmentally friendly raw material. In addition, this study also includes LCC (Life Cycle Cost) analysis or life cycle cost analysis, which considers the economic impact of sustainable paving block use in the long term.

2.1 Research Material

The main material used is waste PET plastic bottles, with additional aggregate as a mixed component. The aggregates used are Sand and Stone Ash. The stone ash used is the result of grinding from crushed stone production sourced from the paving block manufacturing industry in Kediri. HDPE type plastic waste is used as an aesthetic support material. In addition, phosphorus and resin are used to produce aesthetics with the concept of "glow in the dark". Paving blocks are designed in the shape of a hexagon with a thickness of 60 mm. To ensure the quality of the mixture and the physical characteristics of the sand used, testing of sand characteristics will be carried out in the early stages of research. This clarification helps to understand the role of sand in paving block mixtures and how their physical and mechanical properties affect the quality of the final product. In addition, XRF (X-ray fluorescence) tests were carried out to determine the characteristics of stone ash compounds.

2.2 Sample Design

In this study, the mixture of materials for the manufacture of sustainable paving blocks was varied in several different ratios to achieve optimum results. The design proportion table is based on the total weight of hexagonal paving blocks that have been set at 4000 grams. Table 1 show the proportion design of paving block. Comparison variations include the use of waste PET plastic bottles, sand, and stone ash in various combinations. This proportion table lists the weights of each component of the mixture, such as the weight of plastic bottle waste, sand, and stone ash, according to a predetermined ratio.

2.1 Sample Making

In the sample making process as illustrated in Figure 1, the prepared aggregate is heated to a temperature of 200°C. Then, the PET plastic waste is put and stirred until it reaches homogeneity in the mixture and reaches a temperature of ± 250 - 300°C. During the hot mixing process, the PET flakes melt and coat the surface of the aggregate particles. After mixing is complete, the liquid mixture is quickly poured into molds and compressed. To create an aesthetic impression, HDPE waste is used which is ovened at 200°C. In addition, photoluminescence technology is used to create paving blocks with interesting aesthetic aspects [9][18][19]. Photoluminescence technology is created by combining photoluminescent materials into the paving block manufacturing mixture. The photoluminescent material used is phosphorus powder mixed with resin as the binding medium. This phosphorus powder has the ability to absorb light and then emit it in the form of light in low lighting conditions, such as at night.

Table 1. Paving Block Design.

Code	Comparison		
	PET	Sand	Stone Ash
	20%	80%	-
	25%	75%	-
PET:Sand	30%	70%	-
	35%	65%	-
	40%	60%	-
	20%	40%	40%
	25%	38%	38%
PET:Sand:Stone Ash	30%	35%	35%
	35%	33%	33%
	40%	30%	30%
	20%	-	80%
	25%	-	75%
PET:Stone Ash	30%	-	70%
	35%	-	65%
	40%	-	60%

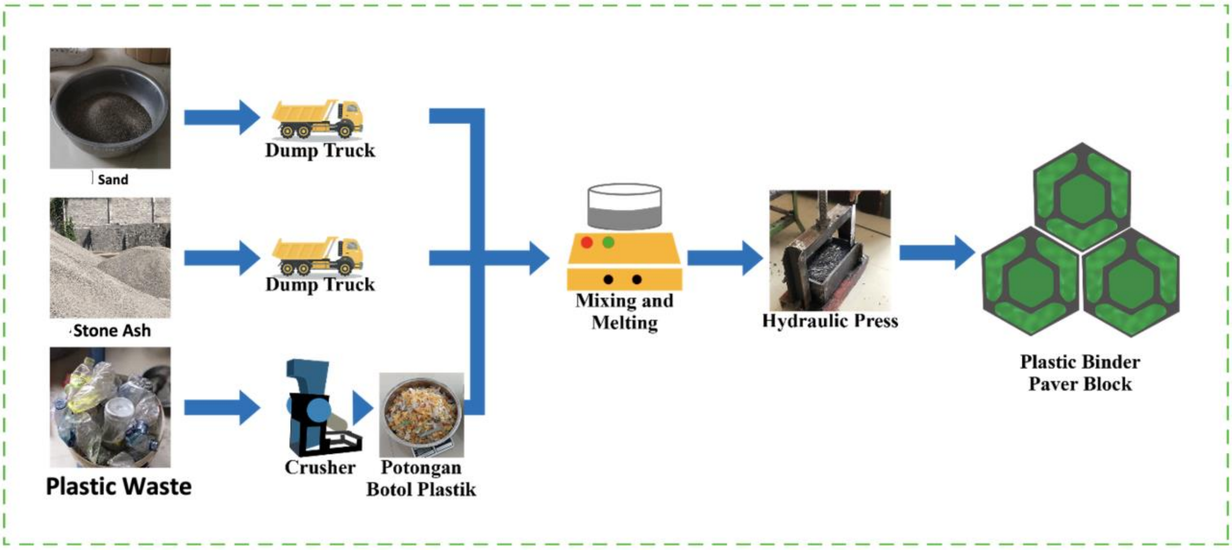


Figure 1. Sampling Flow

2.2 Sample Testing

The resulting tests include compressive strength tests and water absorption tests. In addition, the SEM-EDX (Scanning Electron Microscope-Energy Dispersive X-Ray) Test helps observe the surface structure and morphology of paving blocks on a microscopic scale, providing information on the distribution of plastic bottle waste particles, binders, and detection of defects or cracks that may affect the quality and durability of sustainable paving blocks. The resulting data will be analyzed using descriptive statistical techniques. Descriptive techniques will be used to analyze the data on the physical and aesthetic properties of the resulting paving blocks.

Sustainability Assessment

Life-cycle cost (LCC) is the overall cost of production includes start-up costs, maintenance costs, cleaning costs, overhead costs and management costs. LCC can be calculated using Equation 1.

$$LCC = Ic+(Mc+Ec+Cc+Oc)+UC-Rv \quad (1)$$

3. Result and Discussion

3.1 Stone Ash Characterization X-ray Flouroscene (XRF)

In this study, XRF characterization was carried out at the ITS Energy and Environment Laboratory with the aim of identifying compounds contained in stone ash. XRF data give the percentage result of the composition of certain compounds in stone ash. Table 2 presents the results of chemical composition analysis in stone ash.

Table 2. The contents of the compound in the XRF-produced stone.

Compound	Conc
Al2O3	9.100
SiO2	39.600
P2O5	0.820
SO3	0.440
K2O	1.300
CaO	21.700
TiO2	1.660
V2O5	0.086
MnO	0.577
Fe2O3	24.000
CuO	0.140
ZnO	0.040
SrO	0.400
ZrO2	0.040
BaO	0.200
Re2O7	0.030

XRF results show that the main content of stone ash includes Calcium Oxide (CaO) of 21.7%, Silica Oxide (SiO2) of 39.6%, Iron Oxide (Fe2O3) of 24%, and Aluminum Oxide (Al2O3) of 9.1%. Other ingredients only have a percentage of less than 1%. This result is in line with previous research where stone ash has many dominating contents such as CaO, SiO2, Fe2O3, and Al2O3. The dominating content has a significant impact on the strength of paving blocks. SiO2 is a major component in glass and ceramics, which has high strength properties [20][21]. SiO2 of 39.6% indicates a positive contribution to the compression strength of paving blocks. In addition, the CaO content has the potential to participate in chemical reactions with water, forming hydroxyapatite bonds that increase the strength of the material [22]. However, the binder used in this study is the result of melted PET waste which in the process does not require water, so that CaO in stone ash cannot function like cement in the hydration process.

The presence of Fe2O3 can also improve the mechanical properties of paving blocks [23]. Meanwhile, Al2O3 can provide better resistance to high pressures and temperatures [24][25]. The chemical content of stone ash plays a significant role in influencing the mechanical properties of paving blocks. Certain chemical properties of stone ash contribute significantly to the overall strength of paving blocks. At a temperature of 300°C, PET plastic will undergo a melting process that causes interaction with stone ash [26]. The compatibility between stone ash and PET plastic is highly dependent on the chemical content of the two materials [27]. SiO2 content tends to have an affinity with PET polymers, which can form strong physical bonds between the two. In addition, CaO can react with PET leading to better adhesion between these materials. High temperatures can also cause partial melting of stone ash, which can form a thin film that adheres to the surface of PET plastic. This reaction allows for a strong bond to form between stone ash and PET plastic, which can overall affect the strength of the paving block.

3.2 Compressive Strength

Compressive strength is one of the most crucial characteristics in concrete technology. In developing a new concrete mixture, it is important to ensure that it meets the minimum strength level required for construction applications. In general, on the 28th day after the hardening process begins, it is expected that the concrete reaches its maximum strength. However, in the context of paving blocks without cement, the situation is different. These paving blocks harden quickly after reaching the final setting time, about 30 minutes, and compression tests can be performed in just a few hours, without the need to wait for 28 days like conventional concrete. Since the materials used in paving blocks are different, following concrete mechanical property standards directly may not be appropriate. Nevertheless, standard procedures are still carried out to ensure that samples of cementless paver blocks can be considered as a new alternative to construction materials with adequate performance.

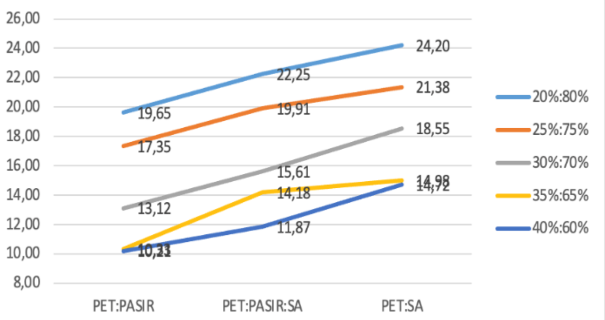


Figure 2. Paving Block Compressive Strength Test

The compressive strength results as Figure 2 showed significant compressive strength variations in various mixture comparisons. The ratio of PET and sand produces compressive strength between 10.21 to 19.65 MPa, with a ratio of 20% PET and 80% sand reaching paving category C with a compressive strength of 19.65 MPa as the best result. Meanwhile, the ratio of PET to stone ash resulted in compressive strength in the range of 11.87 to 22.25 MPa, with a ratio of 20% PET and 80% stone ash reaching paving category B with a compressive strength of 24.20 MPa, showing higher strength compared to sand mixture. The incorporation of PET into structural concrete blocks results in increased absorption and decreased specific gravity and reduced compressive strength, with a ratio of 2.5% and 5.0% PET achieving the category of class B structural blocks as masonry elements above ground level.

However, an increase in the percentage of PET in the mixture tends to result in a decrease in compressive strength values. This may be due to the lack of bonding between the PET plastic and the filler material (sand or stone ash), as well as the physical and chemical characteristics of the PET plastic itself [28][29]. At a ratio of 35% PET and 65% fillers (sand or stone ash) as well as 40% PET and 60% fillers, the result is a quality D paving block suitable for use in parks, which generally has a lower load compared to other areas such as parking lots.

The ratio of 20% PET and 80% sand does not reach category B, but category C that can be used for pedestrians. While the ratio of 20% PET and 80% stone ash reaches category B. This difference can be explained by the different physical and chemical characteristics between stone ash and sand as fillers.stone ash has a higher compression strength than sand due to the strong crystal structure of limestone or crushed stone. In addition, stone ash contains a wide array of minerals and chemical compounds that can interact with PET plastic and other materials in the mixture, affecting the physical and mechanical properties of paving blocks. In contrast, sand has a lower compression strength due to its soft, less dense particles compared to crushed stone, with a simpler chemical composition. The results of this study show that the ratio of 20% PET and 80% stone ash is an effective choice to achieve category B, which is usually used for parking lots.

3.3 Absorption

Paving blocks should have a water absorption capacity below 6% of their weight, with a maximum limit of 7% for individual samples. The advantage of this low water absorption is that it reduces the risk of building damage due to water, such as cracks and the growth of microorganisms. This paving block is suitable for coastal areas that are often exposed to salt water, because the low water absorption capacity reduces salt water damage. However, it is not suitable for absorbing rainwater or standing water because of its limited absorption capacity.

Although this paving block is made of plastic, it still has the ability to absorb water because aggregate is a porous material. Even though it has been bound with plastic, sand and stone ash can still absorb water. Polyethylene plastic usually does not have the ability to absorb water, but polyethylene also has a water permeability level of about 68 x 10 -13 (cm3STP) / (cm2. s. Pa), so this paving block can still absorb water.

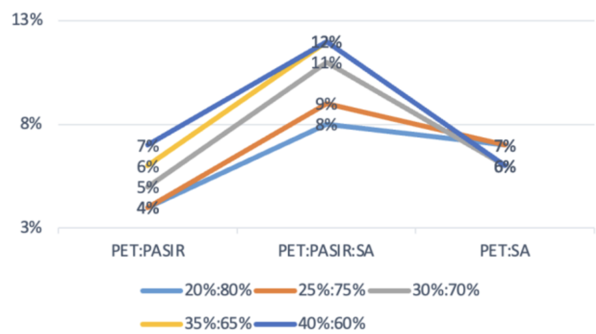


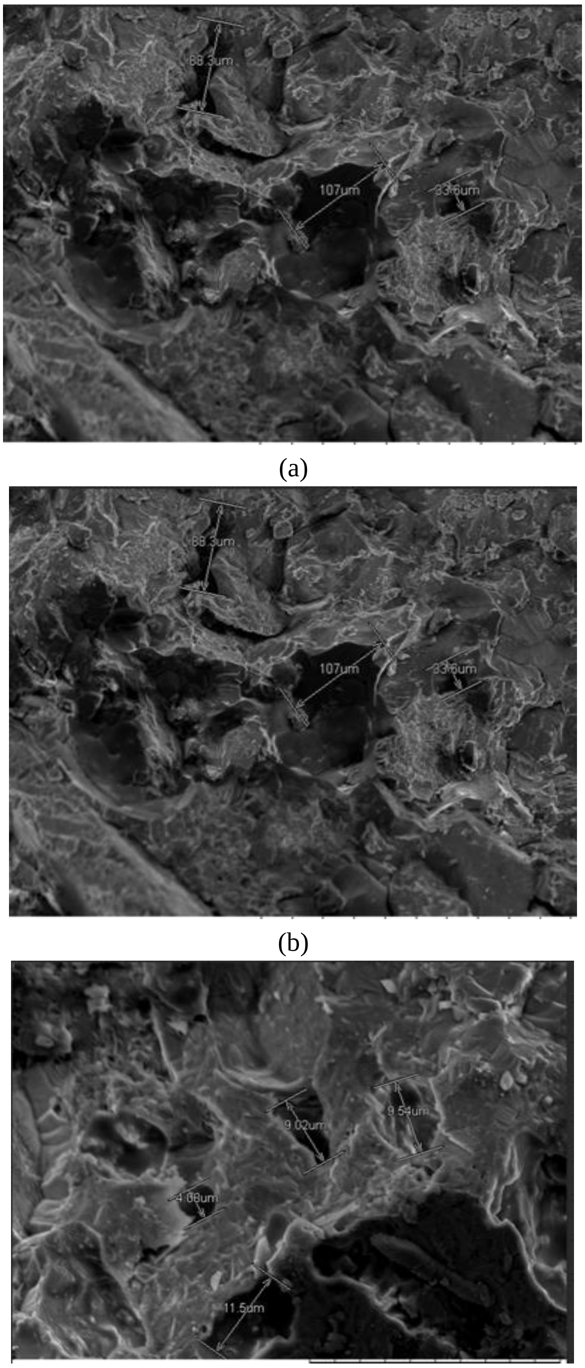
Figure 3. Paving Block Absorption Strong Test

Figure 3 show the result of paving block absorption strong test. The results of this study revealed that plastic paving blocks made from a mixture of PET, sand, and stone ash have a water absorption rate ranging from 4% to 12%. The highest absorption rate occurs in mixtures with 30% PET, exceeding the SNI standard limit which requires a maximum absorption rate of 10% for class D garden use. This happens because the chemical nature of PET plastics, which contain hydroxyl (OH) groups on their molecules, allows the formation of hydrogen bonds with water. Along with the increase in the percentage of PET in the mixture, the number of hydroxyl groups available also increases, which in turn results in an increase in the ability of the mixture to attract and retain water. However, in a mixture of PET and stone ash at a percentage of 30%, there is a decrease in water absorption that attracts attention. This decrease indicates that there may be a saturation point or limitation in terms of the increased absorption that PET plastics can provide in the mixture. There may be physical or chemical limitations in this mixture where further increases in PET content no longer result in significant increases in absorption ability. In addition, the difference in absorption between a mixture of PET and sand and a mixture of PET and stone ash highlights the importance of the role of fillers in the absorption influence. This finding indicates the need to improve the composition of the mixture and adjust to applicable standards to meet the needs of park use in accordance with SNI.

3.4 Characterization Scanning Electron Microscope-Energy Dispersive X-Ray (SEM-EDX)

SEM testing is basically an analysis that examines morphological structures. The resulting data or image is a representation of morphological shapes or surface layers with a thickness of about 20 µm. The resulting surface images display morphological characteristics, such as protrusions, indentations, and holes on the surface. The morphology of bottom ash and paving block samples is shown through SEM micrographic photos. Figure 4 show the morphological observations results at magnifications of 300x, 1000x and 2500x.

The SEM results show that the appearance of many cavities indicates that the structure of the paving block material is relatively porous. This confirms the very high water absorption test results. On the other hand, the presence of these pores can have an impact on the overall strength of the paving block because high porosity can weaken its structure. The cavity formed is caused by uneven melting of PET, giving rise to air bubbles or cavities [16]. In addition, the hardening process that is too fast (± 30 minutes) also causes the PET liquid to be unable to fill the empty cavity due to very fast viscosity changes. Imbalance in the hardening process is a factor causing the appearance of cavities, considering that PET has characteristics that are sensitive to temperature. Thus, to accommodate PET as a binding material in making paving blocks, proper hardening temperature control is needed.



(a) (b) (c)

Figure 4. SEM micrographic photos results with magnification of (a).300x; (b).1000x; (c).2500x

The results of EDX analysis on paving blocks as shown in Figure 5 and Table 3 made of PET and stone ash revealed the dominant elemental composition in the sample, with calcium (Ca) content of about 39.621%, oxygen (O) about 52.215%, carbon (C) about 4.731%, and silicon (Si) about 0.906%. The significant calcium content hints at the presence of a source of calcium in the mixture, which has the potential to act as a binding agent in paving blocks, similar to the role of Portland cement in conventional concrete. Although in this case there is no use of water, the high carbon and oxygen may be related to oxide compounds and organic matter in the material. This will trigger a chemical reaction that is different from the hydration process that usually occurs in conventional concrete production. Potential specific chemical reactions occur between melted plastics, stone ash, and other components present in the mixture, leading to the formation of hydration phases or interparticle bonds that give strength and hardness to the paving block.

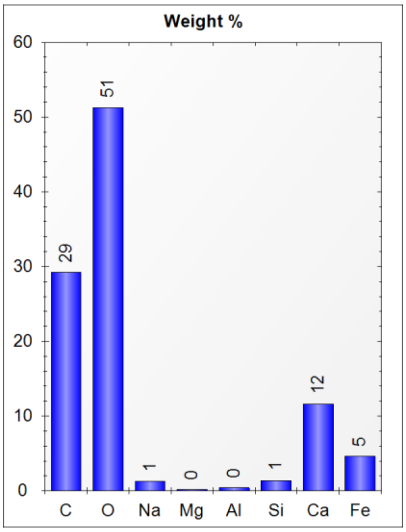


Figure 5. EDX Analysis Results on Paving Blocks.

Table 3. EDX Analysis Results on Paving Blocks.

	Weight %	Weight % σ	Atomic %
Carbon	29.204	0.376	39.621
Oxygen	51.265	0.397	52.215
Sodium	1.278	0.072	0.906
Magnesium	0.187	0.043	0.126
Aluminum	0.392	0.040	0.237
Silicon	1.397	0.052	0.810
Calcium	11.636	0.149	4.731
Iron	4.640	0.177	1.354

3.5 Aesthetic Paving Blocks

The aesthetic aspect plays an important role in creating sustainable solutions that are visually appealing. Figure 6 and Figure 7 represents the aesthetic and beauty potential that can be achieved by using sustainable materials such as waste plastic bottles in the manufacture of paving blocks. Through the visual appearance of the results of this paving block, it is hoped that it will be clearer how this paving block can be an attractive choice in aesthetic and sustainable urban design. In addition to prioritizing quality and sustainability, aesthetically attractive design in paving blocks is also the main objective of this study.

The aesthetics of paving blocks are not only limited to visual appearance under daylight, but also integrate special elements of beauty. This is achieved by combining the use of plastic bottle caps, phosphorus powder, and resin in the manufacture of paving blocks. The result is a paving block that is able to light up in the dark, creating a stunning visual effect when night falls. The unification of these elements creates a unique and stunning look at paving blocks, which not only contributes to the aesthetic aspect, but can also have positive implications on safety in poorly lit urban environments at night. The production of these paving blocks reflects innovation and sustainability in urban design, combining beauty and functionality in one amazing whole.

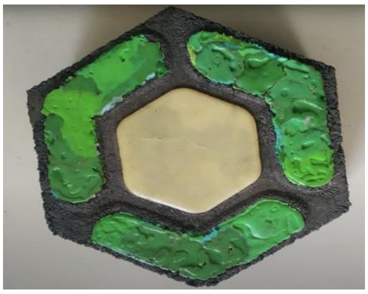
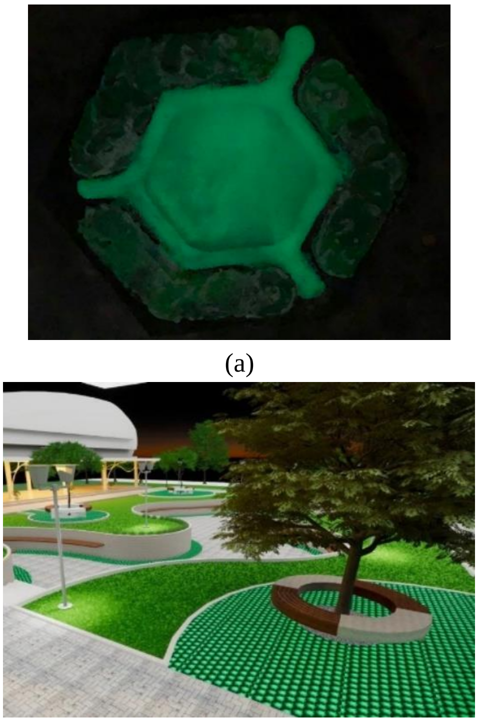


Figure 6. Paving Block Aesthetics.



(a)

(b)

Figure 7 (a). Paving aesthetics at night; **(b).** application of paving in the garden area at night.

3.6 Sustainability Assessment

Life-cycle Cost (LCC) is one of the methods in Sustainability Assessment that helps measure the economic impact of a product or project during its entire life cycle. It involves calculating the initial cost of production, maintenance costs, operating costs, and removal costs. LCC helps in understanding how much cost is associated with a product or project over its lifetime. Hexagonal model in one meter uses 27 Pcs, Each one paving block requires about 0.8kg of plastic waste. So, with one square meter it has removed 21.6 kg of plastic waste from the environment. (production of household waste of plastic bottles per day / number of plastic bottles entering the sea per day). This product is still more expensive than conventional paving blocks. If the price of paving blocks on the market varies between Rp. 90 thousand-Rp. 100 thousand, this paving block is in the price range of Rp. 120 thousand-135 thousand per meter more expensive around 30%-35% compared to ordinary paving blocks. The detail calculation of paving block price shown in Table 4. Although the economic value is higher, the resulting environmental impact makes the product worthy of being one of the solutions to reduce plastic waste. Figure 8 show the LCC vs item percentage.

Table 4. Total Price for Paving Block Production (1 piece).

Category	Item	Unit	Price/Unit	Sum	Price
Material	PET 20 : Sand 80				
	Plastic Waste PET	kg	Rp1,000	00.08	Rp800
	Pasir	kg	Rp133	03.02	Rp427
	PET 20 : Sand 40 : SA 40				
	Plastic Waste PET	kg	Rp1,000	00.08	Rp800
	Sand	kg	Rp133	01.06	Rp213
	Stone Ash	kg	Rp31	01.06	Rp50
	PET 20 : SA 80				
	Plastic Waste PET	kg	Rp1,000	00.08	Rp800
	Abu Batu	kg	Rp31	03.02	Rp100
Raw Material Transportation	PET 20 : Sand 80				
	Plastic Waste PET	L	Rp6,800	0.000449	Rp3
	Sand	L	Rp6,800	0.001125	Rp8
	PET 20 : Sand 40 : SA 40				
	Plastic Waste PET	L	Rp6,800	0.000449	Rp3
	Sand	L	Rp6,800	0.000562	Rp4
	Stone Ash	L	Rp6,800	0.000527	Rp4
	PET 20 : SA 80				
	Plastic Waste PET	L	Rp6,800	0.000449	Rp3
	Stone Ash	L	Rp6,800	0.001053	Rp7
	Worker	Hour	Rp18,750	0.003792	Rp71
	Vehicle Rental	Hour	Rp150,000	0.003792	Rp569
Plastic Shredding Process	Electricity	kWh	Rp1,352	0.144000	Rp195
	Worker	Hour	Rp18,750	0.003200	Rp60
	Vehicle Rental	Hour	Rp1,500	0.003200	Rp5
Mixing and Melting	Gas LPG	kg	Rp17,000	0.000417	Rp7
	Worker	Hour	Rp18,750	0.040000	Rp750
	Vehicle Rental	Hour	Rp1,500	0.040000	Rp60
Printing	Worker	Hour	Rp18,750	0.013333	Rp250
	Vehicle Rental	Hour	Rp800	0.013333	Rp11
Marketing Transportation	Bahan Bakar	L	Rp6,800	0.001265	Rp9
	Worker	Hour	Rp18,750	0.003792	Rp71
	Vehicle Rental	Hour	Rp150,000	0.003792	Rp569

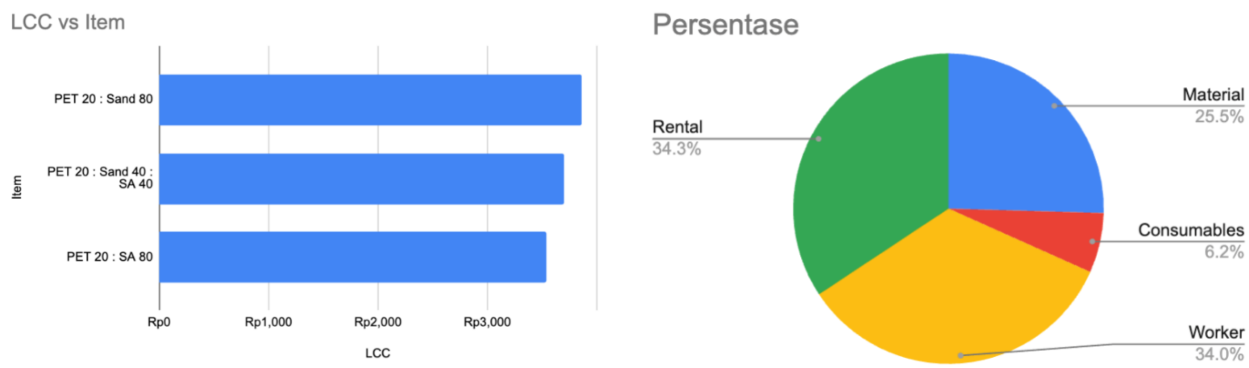


Figure 8. LCC vs Item Percentage.

4. Conclussion

The research conducted has produced significant results in efforts to utilize plastic bottle waste as the main material for making aesthetic paving blocks without cement. Based on the results of the study shows that efforts to combine aesthetic aspects and environmental attractiveness in paving blocks without cement have been achieved through "glow in the dark". The results of physical and mechanical quality evaluation show that this paving block has adequate performance. The ratio of 20% PET and 80% sand reached paving category C with a compressive strength of 19.65 MPa, while the mixture with a ratio of 20% PET and 80% stone ash reached paving category B with a compressive strength of 24.20 MPa. This paving can be applied in the use of parks, pedestarian to parking lots. This suggests that the use of PET in the mixture can achieve sufficient strength in the paving industry. However, higher water absorption in mixtures with a higher percentage of PET needs to be considered in meeting garden use standards in accordance with SNI. In addition, morphological and structural analysis reveals the presence of pores in the paving block that can affect the overall strength. These pores are caused by uneven melting of PET plastic during the manufacturing process. Based on the LCC evaluation, a higher economic value was obtained, but the resulting environmental impact made the product worthy of being one of the solutions to reduce plastic waste.

Acknowledgements

We would like to express our sincere gratitude to the Ministry of Education, Culture, Research, and Technology (Kemendikbudristek) for their financial support that has enabled this research. We would also like to thank Kadiri University for providing invaluable support in completing this research.

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