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Fabrication of Sustainable Sand Brick with an Additive of Elastomer Type Waste Material

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Abstract: At present, the demand for adding recycled materials such as rubber to construction products is becoming more and more important in the production of bricks. Using waste tyres in brick or concrete mixes can reduce the consumption of raw materials. Waste tyres can be used as fine aggregate, coarse aggregate, or part of both. It can be used as an additive to produce sand bricks. Therefore, a mixture of waste tyres is used as part of the sand substitute in sand bricks, with emphasis on thermoplastic elastomers. This study aims to develop sustainable bricks using waste tyres and compare the density, compressive strength, and water absorption efficiency of sustainable bricks and conventional bricks. As part of the sand replacement, 15 specimens were prepared and mixed with different percentages of rubber crumb content, 5%, 10%, and 15%, respectively. The bricks are formed with mould size of 215mm in length, 100mm in width, and 60mm in depth. Density, compressive strength, and water absorption tests carried out and the bricks were tested on the 7th and 28th days. The results obtained show that the compressive strength recorded with 5% rubber crumbs of fine aggregate is not much different from that of traditional sand bricks. This indicates that as the number of rubber crumbs uses as a substitute for fine aggregate in bricks increases, the strength and workability density of concrete will decrease. On the other hand, the water absorption test shows that the rubber-containing bricks have better water absorption capacity. In this study, it was found that 5% rubber is the best percentage to partially replace fine aggregates in bricks production. However, the test results of all percentages are not significantly different from those of conventional bricks. To maintain the mechanical properties of concrete, the rubber powder used to replace aggregate shall not exceed 15%.

Keywords: Elastomer, Rubber Crumbs, Density, Compressive, Water Absorption.

1. Introduction

Thermoplastic elastomer (TPE) is one of the most widely used plastics today. Polymer is a physical mixture of elastic-plastic materials with elasticity and thermoplastic (plastic and rubber). TPE materials are just a mixture of thermoplastics and elastomers, and there is no chemical or covalent relationship

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between them, which is why these two materials have different qualities. This phenomenon paved the way for a new branch of polymer science. Thermoplastic elastomers constitute an important part of the polymer industry. Adhesives, clothing, medical equipment, vehicle parts, and household items are just a few examples [1].

As the main component of concrete, cement emits a large amount of carbon dioxide (CO_2) during the entire manufacturing process, making it a non-green material. It is estimated that for every ton of cement produced, one ton of carbon dioxide and other greenhouse gases (GHG) are emitted into the atmosphere. It emits 5-8% of the world's carbon dioxide, causing these gases to accumulate in the atmosphere and cause global warming [2].

The job of materials engineering here is to recycle these wastes and ensure that these new materials can be used in the industry to manufacture new products and cement compounds at a cheaper cost and with less impact on the environment. Waste tyres are one of the most serious social and environmental problems in the world. With the development of the automobile industry, the world accumulates a large number of waste tyres every year [3].

Use rubber from waste tyres instead of fine aggregates to help solve disposal problems. Therefore, throughout the manufacturing process, rubber crumbs collected from recycled tyres are used to replace fine aggregates in concrete. Rubber concrete has many characteristics and is comparable to ordinary concrete in terms of strength and durability. This is done to verify that rubber concrete can be safely used for construction. Concrete is commonly used due to its durability and high compressive strength. Compared with ordinary concrete, rubber concrete has a unique shape, strength, capacity, and value. The efficacy test of other materials or materials used to make concrete should be carried out in accordance with prescribed standards. Therefore, this study uses recycled waste tyres as a partial substitute for fine aggregates in concrete manufacturing. The main goal of this study is to evaluate the durability of waste tyre rubber concrete as a fine aggregate substitute [4].

2. Materials and Methods

The project's methodology is discussed to achieve the objectives of the project. It also describes the method, procedure, and testing preparation that is applied to the project. Some of the methods and collected information from the literature review were referred to in this chapter.

2.1 Materials

In this work, ordinary Portland Class 53 cement conforming to IS 8112:1989 was used. For fast-paced construction where initial strength must be reached immediately, grade 53 cement is used. The natural aggregates used include natural river sand as the fine aggregate. The waste tyres shown in Figure 1 are obtained from a mechanical crushing process and are known as rubber crumbs.

Figure 1: Rubber Crumbs

2.2 Methods

A laboratory study was conducted to investigate the effect of the use of waste tyres as an aggregate replacement on the properties of sand bricks. Control mixtures were prepared using natural aggregates. The waste tyre is used to replace conventional aggregates at the aggregate percentage levels of 5%, 10%, and 15%. A water-cement ratio of 0.55 was used in this study. The concrete mix was placed in a 215mm × 100mm × 65mm mould and cured for 24 hours. After 24 hours, the specimens were disassembled and cured at room temperature for a minimum of 28 days before the test was performed. The quantity materials are shown in Table 1 below:

Table 1: Quantity Material

	Material (kg)				
Specimens	Cement	Sand	Rubber Crumbs	Water	Total
Sustainable (5%)	2	7.6	0.4	1.1	11.1
Sustainable (10%)	2	7.2	0.8	1.1	11.1
Sustainable (15%)	2	6.8	1.2	1.1	11.1

All the required materials, such as cement, sand, rubber crumbs, and water, are mixed in one batter. The predefined ratio is used to mix the ingredients. The mixing process does not require a long time, it is because the mixture will not deteriorate or solidify.

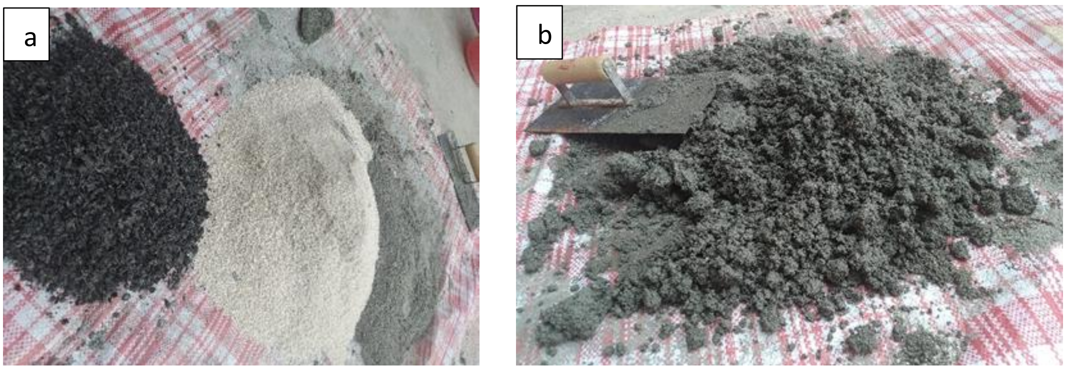

Figure 2: (a) Preparation of cement, sand and rubber crumb. (b) Mixing specimen by a predetermined ratio.

Then put the batter into the brick mould and compress it. Before putting the mixture into the mould, the walls of the mould are greased to facilitate the removal of the bricks. After 24 hours, the bricks were removed from mould.

Figure 3: (a) The mixture poured and compacted into the mould. (b) All specimen already put into mould.

The curing process is important to the strength and durability of the brick. The brick will solidify shortly after solidification and completion. It needs to maintain proper humidity and temperature levels for a long time at the depth and the surface. The complete brick healing process takes about a month, and due to weather variations, concrete mixing and placing, and finishing processes, each project can vary somewhat.

Figure 4: Curing Process

2.3 Mechanical Testing

As shown in Figure 4, the specimens were left for 7 and 28 days to the curing process. The specimens are then tested to determine density, water absorption, and compressive strength. The results were analyzed and compared with the control specimens. Conclusions were drawn based on the test result. Tests are performed throughout the duration of the curing process and each result is recorded for discussion.

2.3.1 Density Test

Raw materials and production procedures have an impact on the density of cement bricks. To obtain sufficient compressive strength and good durability, cement bricks must meet the specifications of BS EN 771-3:2003 [5]. This is because the density of cement bricks containing rubber crumb affects their mechanical qualities. This test was conducted to evaluate the density value of sand cement bricks containing waste tyres as a partial substitute for sand cement bricks. For 28 days, the specimens will undergo a curing process and then undergo a density test. The density is given by the following formula:

$$\text{Density} = \frac{\text{Weight (kg)}}{\text{Volume (m}^3\text{)}} \qquad \text{(Eq. 1)}$$

2.3.2 Water Absorption Test

The water absorption rate is crucial for determining the quality of the produced bricks. The water absorption of a unit brick is directly proportional to its porosity. The high-water permeability of the brick will cause the soil particles in the stabilized brick to swell, resulting in a loss of strength. The water absorption is given by the following formula:

$$\text{Water Absorption} = \frac{\text{Weight of Wet Brick - Weight of Dry Brick}}{\text{Weight of Dry Brick}} \times 100 \qquad \text{(Eq. 2)}$$

2.3.3 Compressive Strength Test

The amount of cement in the mixture, the types of raw materials used, and the water content of the cement bricks will all affect the compressive strength of the bricks. Compressive strength is an important part of evaluating the load-bearing potential of bricks. Due to the performance of sand bricks under the ultimate pressure, the compressive strength of sand bricks can be expressed. Tests were performed to evaluate the strength of conventional bricks and sustainable bricks with different percentages of rubber crumbs.

$$\text{Compressive Strength} = \frac{\text{Maximum Load (kN)}}{\text{Area of Specimen (m}^3\text{)}} \qquad \text{(Eq. 3)}$$

3. Results and Discussion

Brick specimens are tested to check whether the specimens meet the requirements of relevant international standards and compare with existing conventional bricks for use in construction applications.

3.1 Density of Bricks

Table 2 show the density test results. Figure 5 shows the density of conventional sand cement bricks and sustainable bricks on the 7th and 28th days according to the ratio of mixed additives. The results showed that the density of sand cement bricks decreased on the 28th day. The density value of sand cement brick is calculated by using Equation 1.

Table 2: Result of Density Test at Days 7 and 28

	Density (kg/m^3)	
Specimens	Day 7	Day 28
Conventional	2437.24	
Sustainable (5%)	2268.88	2061.37
Sustainable (10%)	2339.21	2066.15
Sustainable (15%)	2142.67	1922.47

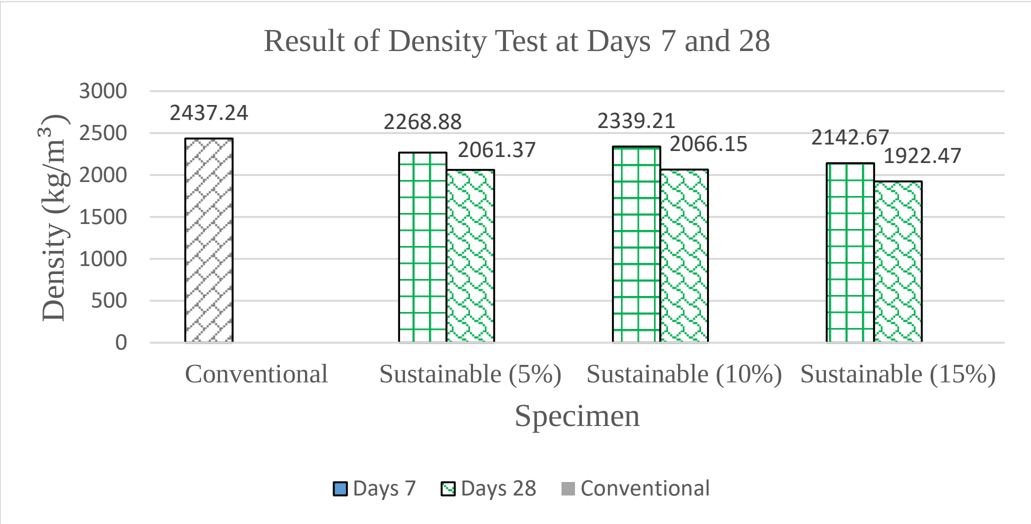

Figure 5: Result of Density Test at Days 7 and 28

According to the results obtained, the density of sustainable bricks with 5% and 10% rubber crumbs is not significantly different from conventional bricks at days 7. The comparison of traditional bricks and sustainable bricks shows that the density of bricks with 10% additives is the highest density recorded after 7 days of curing, with a value of 2339.21kg/m³. Followed by, specimen of adding 5% additives is 2268.88kg/m³, while the density of bricks adding 15% additives is the lowest at 2142.67kg/m³. For the comparison of each additive percentage at days 7 and 28, specimens with 5% additive showed a decrease density of 207.51kg/m³ on day 28. Meanwhile, specimens with 10% and 15% also showed a decrease on day 28 with 273.06kg/m³ and 220.20kg/m³ respectively.

The water-cement ratio and the percentage of additives are the key factors that determine the strength and workability of brick production. Workability is an important factor in determining the density of bricks. A low proportion of additives will increase strength and hardness but will reduce workability, while a high proportion of additives will increase the workability of the mixture during the brick production process. Bricks with good workability will promote the production of high-density bricks. These factors explain the density differences between all tested samples.

3.2 Water Absorption of Bricks

Sand cement bricks can be expressed as the permeability of sand cement bricks through water absorption tests conducted. Table 3 show the average water permeability of the cement brick samples produced. Figure 6 shows the comparison percentage of water absorption of conventional sand cement bricks and sustainable bricks on the 7th and 28th days after curing according to the ratio of mixed additives.

Table 3: Result of Water Absorption Test at Days 7 and 28

	Water Absorption (%)	
Specimens	Day 7	Day 28
Conventional	4.15	
Sustainable (5%)	3.92	3.26
Sustainable (10%)	5.84	5.04
Sustainable (15%)	6.12	5.17

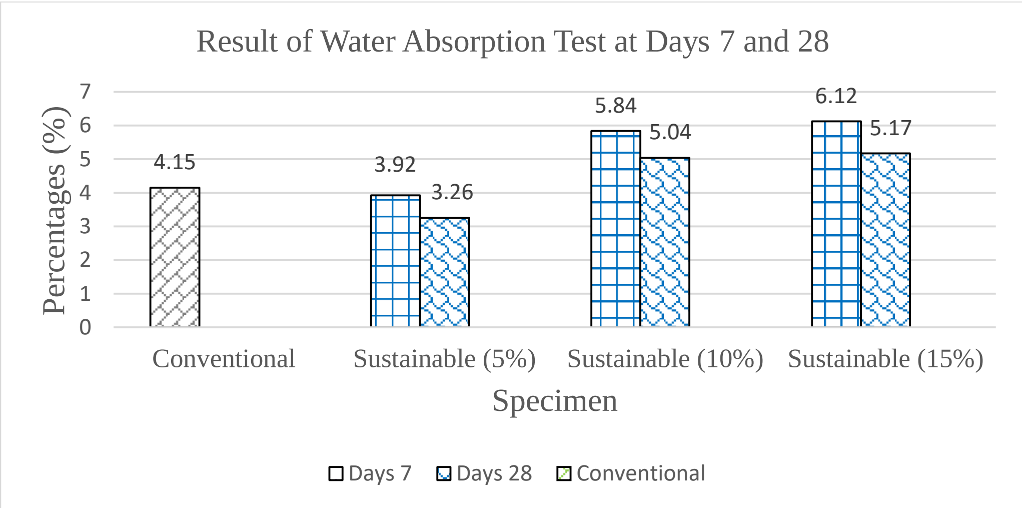

Figure 6: Result of Water Absorption Test at Days 7 and 28

Comparison between conventional sand bricks with sustainable sand bricks shows that water absorption is increased. It is because, the weakening of the bonds between the particles will increase absorption, which allows water to penetrate the voids in the interface between the rubber crumbs and cement due to the increased rubber crumbs. As the percentage of rubber crumbs used on sand bricks increased, the effect of water absorption on sand bricks also showed an increase it is because the elastomer has porosity and will cause more water absorption.

The average water absorption rate of conventional sand bricks is 4.15%. Next, the sustainable sand brick with 5% additives reads 3.95%. At the same time, the sample with 10% additive on the chart shows 5.84%, and the sample with 15% additive records the highest value, which is 6.12%. For the comparison of each additive percentage at days 7 and 28, specimens with 5% additive showed a decrease percentage of 0.66% on day 28. Meanwhile, specimens with 10% and 15% also showed a decrease on day 28 with 0.80% and 0.95% respectively.

Based on the results obtained, it can be concluded that the use of water-cement ratio and additives in the production of bricks will affect the percentage of increasing the water absorption of the bricks. This is because water is a chemical reactant in cement, which can combine all the raw materials in the mixed brick. The use of 5% rubber crumbs in sand bricks is not much different from conventional sand bricks, indicating that the use of 5% additives in the manufacture of sand bricks is very suitable for use in construction projects. Although 10% and 15% additives are still suitable for use, good quality bricks will not consume more than 20% of their weight in water [6],[7].

3.3 Compressive Strength of Bricks

The current worsening situation of the Covid-19 pandemic in Malaysia has caused UTHM to take precautionary measures by not allowing students to use the laboratory temporarily. Therefore, for the compressive strength test have been done through a review of previous studies.

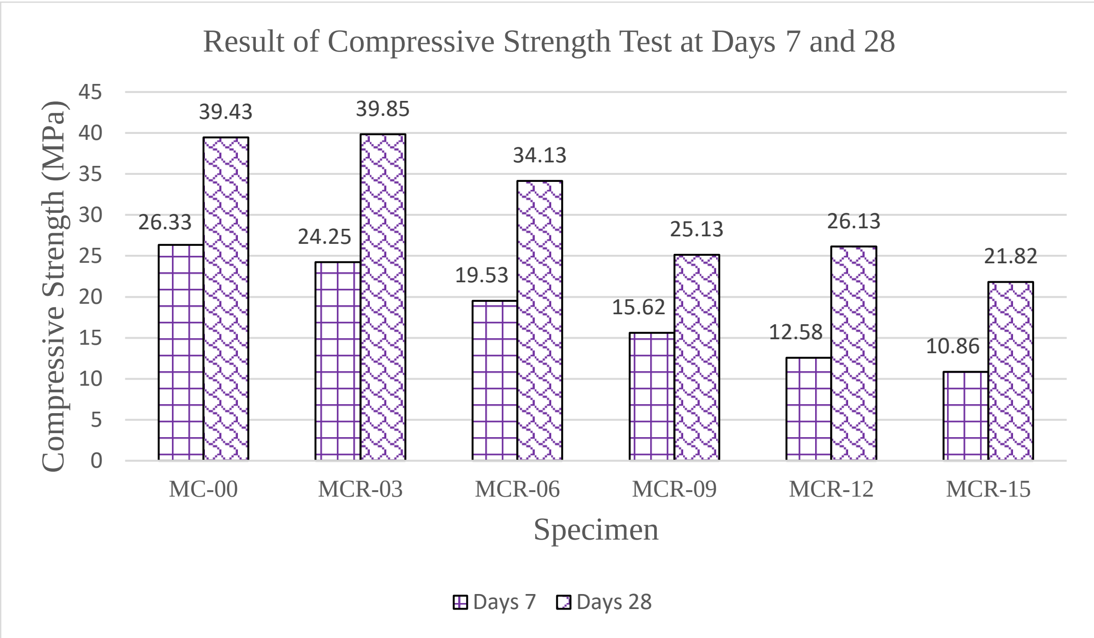

Figure 7: Result of Compressive Strength Test

From a previous study conducted by Parhi et al., (2012) [8] it can be seen from Figure 7 that the compressive strength of the MC-00 on the 7th day is 26.33MPa. Compared with the control mixture (MC-00), the mixtures MCR-03, MCR-06, MCR-09, MCR-12 and MCR-15 reduced by 7.9%, 25.83%, 40.67%, 52.22% and 58.75% respectively. Specifically, the compressive strength of the cube of the control mixture (MC-00) on the 28th day was 39.43MPa. Compared with the control mixture (MC-00), the mixtures MCR-06, MCR-09, MCR-12 and MCR-15 showed a reduction of 13.44%, 35.86%, 33.73% and 44.66%, respectively. However, the mixed MCR-3 gave better results than the control mixture.

There are many reasons for the decrease in the compressive strength of rubber concrete because the tyres rubber aggregate acts as a void in the matrix. The bond between tyres rubber and concrete is weak. As the void ratio of concrete increases, the strength will decrease accordingly. The strength reduction is also because the tyres rubber is more elastically deformable than the matrix and generates high internal stress perpendicular to the direction of the applied load.

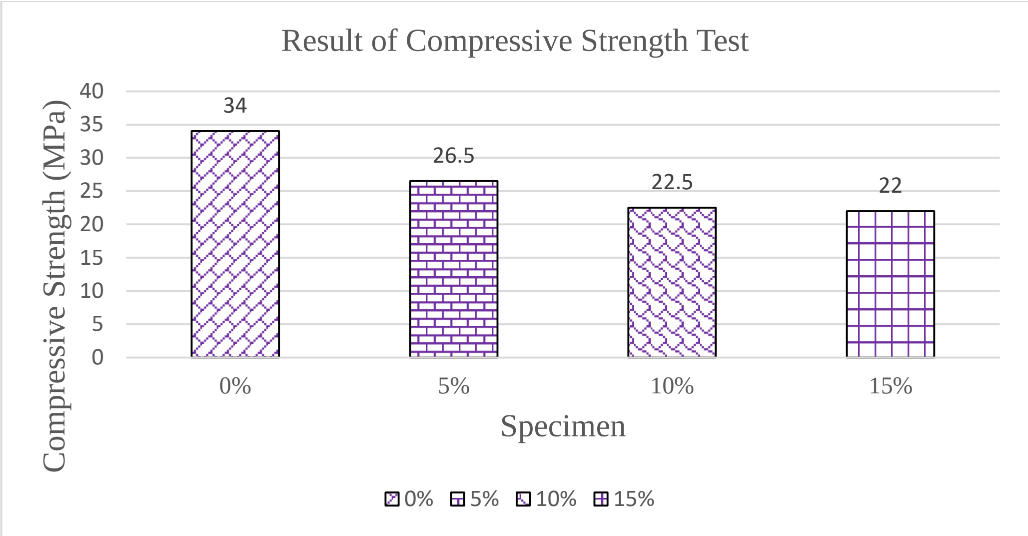

Figure 8: Result of Compressive Strength Test

From a previous study conducted by Mitoulis et al., (2016) [9] the compressive strength of concrete decreases as the percentage of rubber particles in the concrete increases. For 5%, 10%, and 15% samples, the compressive strength was reduced by 21%, 32%, and 38%, respectively, as shown in Figure 8. This behaviour may be attributed to the fact that the rubber crumbs are weaker and more elastic than the surrounding cement paste, and the cement paste propagates cracks from the contact area between the rubber and the cement matrix.

In addition, replacing high-density aggregate with low-density rubber crumbs will definitely reduce the compressive strength of concrete. When 15% by volume of rubber crumbs in the total coarse aggregate are mixed into the concrete mixture, the compressive strength of the concrete is reduced by 38%. The reason for the decrease in strength is that the strength of the rubber crumbs is lower than that of the coarse aggregate after replacement, and the bonding force between the rubber crumbs and the cement slurry is weak.

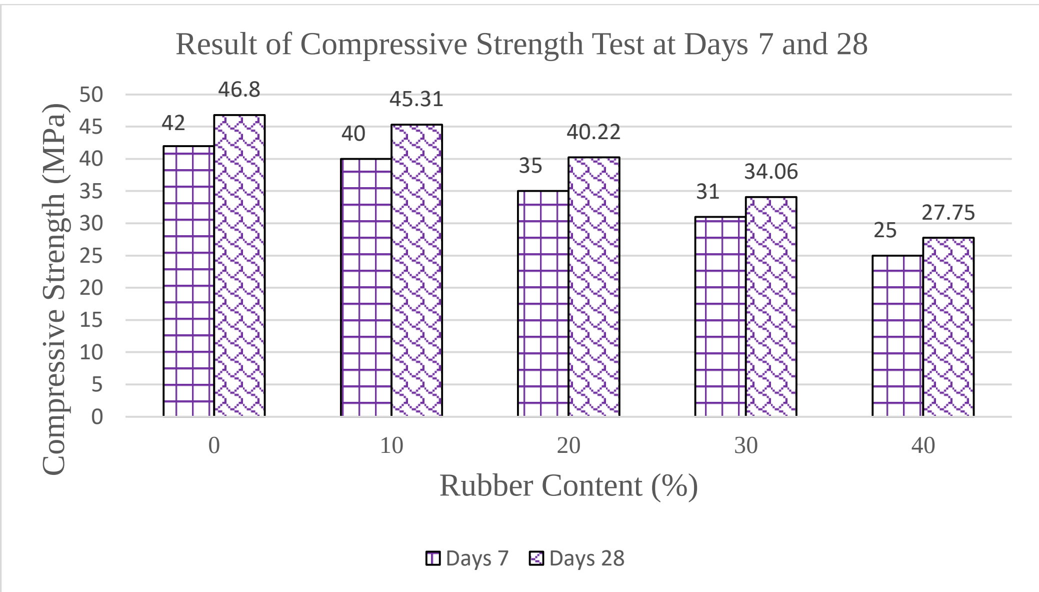

Figure 9: Result of Compressive Strength Test

From a previous study conducted by Euniza et al., (2014) [10] the compressive strength of two-layer concrete paving stones (CPB) with thicknesses of 20mm and 60mm are shown in Figure 9. Each value displayed is the average of five sample measurements. The results show that the compressive strength of double-layer CPB decreases significantly with the increase of rubber content. On the 28th day, the compressive strengths of 10% and 20% rubber concrete blocks were 45.31MPa and 40.22MPa, respectively, while the compressive strengths of 30% and 40% rubber tyre granular concrete blocks were 34.06MPa and 27.75MPa, respectively.

Compared with 20%, 30%, and 40% rubber, adding 10% rubber to CPB produces the highest level of strength. The decrease in compressive strength is due to the lack of proper combination between waste tyre rubber particles and cement slurry. Therefore, the applied stress is not uniform, and cracks are generated at the boundary between the cement and the waste tyre rubber particles.

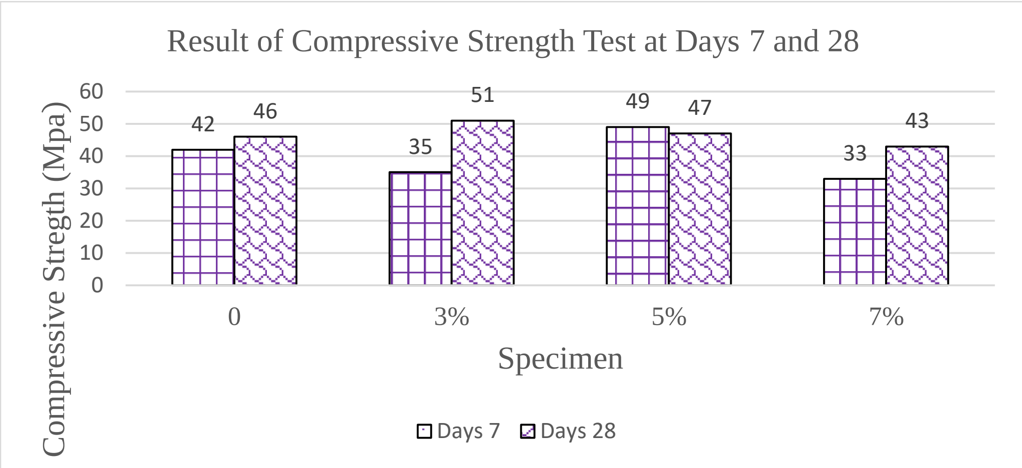

Figure 10: Result of Compressive Strength Test

From a previous study conducted by Senin et al., (2017) [4] Figure 10 shows the compressive strength of the samples after curing for 7 days and 28 days, respectively. In the study, the lowest compressive strength of the concrete sample containing 7% rubber was 43.7MPa, and the highest compressive strength of the concrete sample containing 3% rubber was 50.8MPa. Therefore, it can be concluded that the optimum amount of rubber in concrete is 3%.

The overall research results show that the rubber crumbs with a low replacement percentage of sand in the sand brick shows better performance than conventional sand bricks. The study of sustainable sand bricks shows that the strength of sand bricks conforms to the characteristics of bricks comparable to conventional sand bricks. The compressive strength of the rubber crumbs mixture decreases with the increase of the rubber crumbs substitution percentage.

4. Conclusion

This study shows the results of the impact of waste tyres as an aggregate substitute on the compressive strength, water absorption, and density of sand bricks. According to the results of this study, sand bricks can be produced by replacing aggregates with waste tyres, according to the balance between mechanical properties is highly allowable. Incorporating rubber crumbs into bricks will reduce their strength. Although this reduction can be minimized by limiting the percentage of the rubber crumbs of the total aggregate in the bricks used for structural and non-structural applications.

In terms of strength and durability, sand bricks with additive elastomer have many characteristics that can be compared to ordinary concrete. Based on the results, this indicates that thermoplastic elastomers are suitable for use in the construction process. The water-cement ratio and the percentage of additives are the key factors that determine the strength and workability of brick production. The test results of each percentage of rubber particles show that there is little difference compared with conventional sand bricks and can be classified as lightweight bricks. This proves that adding rubber crumbs during brick-making is not significantly different from those of conventional bricks.

The entire project was completed to compare the performance of sustainable sand bricks and conventional sand bricks. This clearly shows that the rubber crumb mixture is very suitable as a partial substitute for sand bricks. The purpose of this study is to achieve the objectives which are the fabrication of sustainable sand brick with an additive of elastomer type waste material. From the results of the water absorption test, compressive strength test, and density test, the following conclusions can be drawn. To maintain the mechanical properties of concrete, the rubber crumbs used to replace coarse aggregate shall not exceed 15%.

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