Compressive strength, sound absorption coefficient (SAC) and water absorption analysis of HDPE plastic waste reinforced polystyrene and Portland cement for lightweight concrete (LWC)

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Abstract. This project research presents compressive strength, sound absorption coefficient (SAC) and water absorption analysis of High-Density Polyethylene (HDPE) plastic waste reinforced polystyrene and Portland cement for lightweight concrete (LWC). The research is aimed into the issue of waste materials such as HDPE plastic waste and polystyrene waste into lightweight concrete (LWC) application. Modifications with waste material may improve the qualities of lightweight concrete (LWC), and HDPE plastic waste may serve as a partial substitute for natural aggregates, which are rapidly depleting. It has been proposed that HDPE plastic waste and polystyrene be used as an alternative aggregate material to reduce environmental impact. In this study, four composition ratio of HDPE plastic waste reinforced polystyrene and Portland cement to produce LWC; which are (a) 0.5 HDPE plastic waste : 1.0 polystyrene : 1.0 Portland cement, (b) 1.0 HDPE plastic waste : 1.0 polystyrene : 1.0 Portland cement, (c) 1.5 HDPE plastic waste : 1.0 polystyrene : 1.0 Portland cement, and (d) 2.0 HDPE plastic waste : 1.0 polystyrene : 1.0 Portland cement. The highest rate of compressive strength attained was 97.28 kN with the composition ratio of 1.5 HDPE plastic waste : 1.0 polystyrene : 1.0 Portland cement. It was discovered that a larger proportion of plastic lowered the strength of concrete. On the other hand, the optimum composition ratio of HDPE plastic waste reinforced concrete for lightweight concrete (LWC) produces the appropriate strength for LWC when the composition ratio is optimized. For sound absorption analysis, the higher coefficient is 0.42 SAC at 350 Hz to 1500 Hz for the composition ratio of 1.5 HDPE plastic waste : 1.0 polystyrene : 1.0 Portland cement. Water absorption characteristics of HDPE plastic waste and polystyrene for LWC dropped with increasing plastic waste content up to 0.50%.
1. Introduction
A modern lifestyle, along with technological advancements has resulted in an increase in the amount and variety of waste generated, resulting in a waste disposal in Malaysia [1]. Global waste management market is flourishing, and while home-garbage remains the most prominent segment, with electronic goods quickly gaining demand, plastic recycling remains the main area of concern that has most countries focused on. Although recycling can help reduce the amount of garbage that ends up in landfills, waterways and ecosystems, only a few types of plastics can be recycled by most municipal governments [2]. When it comes to single-use things, the fraction does get recycled still requires a lot of energy and water, which is simply not a good proposition [3]. Plastic garbage that ends up in landfills and oceans take hundreds of years to degrade, and there’s increasing concern about the toxins they release into the environment [4]. Many publications in the literature review are devoted to the use of plastic waste such as Polyethylene Terephthalate (PET), High-Density Polyethylene (HDPE), Polyvinyl Chloride (PVC), Low-Density Polyethylene (LDPE), Polypropylene (PP), Polystyrene (PS) and others [4]. According to a recent study by Ambrieres [5], a non-governmental organization that acts as umbrella group for the stakeholders of the food and beverages sector, PET plastic recycling escalated 50 percent in 2016 in the region of Americas [6]. In other words, as much as 57 percent of total plastic consumed by the region was recovered, which is a remarkable effort from the vendors operating in the waste management market in North America [7].

According to previous researcher, Babafemi et al (2018) was conducted the test of addition of the plastic particles led to a reduction in strength properties for a 20% replacement the compressive strength shows a sharp reduction up to 72% of the original strength. With 5% replacement the compressive strength shows a 23% reduction [8]. Similar behavior, but in a lower effect, was observed in both splitting and flexural strengths of the tested samples. Similar to Saikia (2013) was concluded that the compressive strength of concrete with a Polyethylene Terephthalate to glycol ratio of 2:1 is more than that of concrete with a ratio of 1:1. Higher Polyethylene Terephthalate to glycol ratios were not investigated because they would cause the polymer components to become brittle. This experiment was conducted between three distinct groups [9]. In term of sound absorption, Girijappa (2019) investigated how different types of lignocellulosic fibers reinforced polymer matrix composites effect the acoustic material components. The lignocellulosic fibers used was rice straw. In this study, sodium hydroxide and heat treatment were used to modify the hydrophilic properties of natural fibers. The surface modification will effect on sound absorption, mechanical and dielectric properties of composites [10].

2. Methodology
2.1. Preparation of samples
In this research, the different composition ratio of HDPE plastic waste mixed with Portland cement, and polystyrene is the main material to produce lightweight concrete (LWC) samples. The different composition ratio of HDPE plastic waste was used as stated in Table 1. The four main processes involved were grinding process, mixing process and curing process. The HDPE plastic waste and polystyrene were shredded by using grinder machine with a particle size of 0.5 – 1.0 mm as shown in Figure 1 (a) and (b) were used as the raw materials to produce lightweight concrete (LWC) samples. The different composition ratio of HDPE plastic waste mixed with Portland cement, and polystyrene were measured the weight using Mettler Toledo electronic precision balance. Then, the materials was...
mixed until it becomes a viscous thoroughly, the final mixture was spread over the mould for test compressive strength test and sound absorption test. The mold for compressive strength test with dimension of 190 mm in length, 85 mm in width and 35 mm in height with the curing time for 7 days in room temperature (25-30 °C).

2.2. The curing process
For curing process, the main raw materials of HDPE plastic waste, polystyrene and Portland cement was mixed together until viscous thoroughly become slurry, the slurry then was spread over mould for compressive test and sound absorption test. The mold for compressive strength follows the ASTM standard C-109 – Standard Test Method for Compressive Strength of Hydraulic Cement Mortars with dimension of 50 mm x 50 mm x 50 mm. For sound absorption test under ASTM C423 – Standard Test Method for Sound Absorption Coefficients. Next, the slurry was post-curing process to produce ligghweight concrete (LWC) samples for 7 days in room temperature (25-30 °C). Figure 2 and Figure 3 shows the sample of LWC based on different composition ratio of HDPE plastic waste mixed with polystyrene and Portland cement.
3. Results and Discussion

3.1. Compressive strength test
Figure 4 exhibited the graph of force versus time for different composition ratio of HDPE plastic waste. It is clearly exhibited that ratio of 1.5 of HDPE plastic waste withstand the higher maximum compressive strength value of 97.28 kN, followed by composition ratio of 1.0 HDPE plastic waste with value of 97.19 kN. The composition ratio of 0.5 of HDPE plastic waste with value of 96.98 kN and composition ratio of 0.0 of HDPE plastic waste at 96.32 kN, finally the lowest compressive strength at 96.08 kN for 2.0 HDPE plastic waste. For previous research had studied the compressive strength plastic waste used concrete was lowered by the addition of plastic. The reduction loss may be attributed to the poor bond strength between plastic particles and Portland cement. Composition ratio of 1.5 of HDPE plastic waste had higher compressive strength due to strong cohesion bonding of HDPE plastic waste, polystyrene and Portland cement [12].

The compressive strength decrease start to the composition ratio of 2.0 HDPE plastic waste is mainly due to the production of LWC samples with high crack resistance require reduction in adhesive strength between the surface of the HDPE plastic waste, polystyrene and Portland cement. The hydration of cement is one of the factors restricted by means of using HDPE plastic waste which it is a hydrophobic material [13]. In addition, higher composition ratio of HDPE plastic waste presence of plastic aggregate relatively less performance when compared with effectively used others waste materials as a conservation point of view, hydrophobic material which may restrict the hydration of cement. The reduction in split tensile strength and flexural compressive strength [14].

Figure 4: Compressive strength versus time at different composition ratio of HDPE plastic waste to produce LWC samples.

3.2. Sound absorption coefficient (SAC) analysis
HDPE plastic waste mix with polystyrene and Portland cement to produce lightweight concrete (LWC) is one of potential as good in sound absorption properties. In this study, the sound absorption coefficient test was conducted by impedance test tube with the range of 350 Hz to 1500 Hz. This range classified as low frequency region, as thicker composite absorbency is better for absorption for lower frequency than higher frequency region [15]. In Figure 5, the graph shows the rate of sound absorption coefficient (SAC) at low frequency 350 Hz to 1500 Hz. Based on the result, the ratio of 1.5 HDPE plastic waste has the highest sound absorbency compare to others with SAC value of 0.42 at 350 Hz and 0.47 at 1500 Hz. The data can be analyzed as 42% sound absorbed at 350 Hz. The composition ratio of HDPE plastic waste present in this sample was only 1.0. Hence, the present of lignocellulose are less compared to other sample since lignocellulose fibers are good in reduction of sound energy [16]. Moreover, 1.0 plastic waste sample has the average sound absorption coefficient. As a conclusion, when the ratio of
plastic waste increases, the absorbency of sound energy also decreases [17]. Lowest reflection energy indicates higher sound absorption result in good absorbency of sound energy [18].

3.3. Water Absorption test

The graph in Figure 6 shows the water absorption analysis at different composition ratio of HDPE plastic waste for lightweight concrete (LWC) samples. The highest value water absorption test is 11.06% for the composition ratio of 0.5 HDPE plastic waste and the lowest value of water absorption is 2.0 HDPE plastic waste at 8.28%. It is revealed that 2.0 of HDPE plastic waste have the higher water resistance compared to other samples due to less presence of voids and the material of higher composition of HDPE plastic waste the reason of water resistance characteristic of the samples [19]. Meanwhile, the 0.5 HDPE plastic waste have more voids present in LWC samples that leads to higher water absorption. For ratio of 1.0 of HDPE plastic waste and 1.5 of HDPE plastic waste, the water absorption was 9.81% and 9.20%, respectively. This can be analyzed as the average range of voids present in both samples that influence the water absorption rate. In conclusion, the ratio of the increasing of HDPE plastic waste in LWC samples will produce lower water absorption properties [20].

![Figure 5. Sound absorption coefficient (SAC) at different composition ratio of HDPE plastic waste for LWC samples](image1)

![Figure 6. Water absorption test at different composition ratio of HDPE plastic waste for LWC samples](image2)

4. Conclusion

In conclusion, the optimum composition ratio of HDPE plastic waste is 1.5 reinforced with polystyrene and Portland cement. From the findings, the compressive strength test of 1.5 HDPE plastic waste produce 97.28 kN, sound absorption coefficient (SAC) at 0.42 at 350 Hz and 0.47 at 1500 Hz and water absorption at 9.2% is better physical and mechanical properties to be potential apply in lightweight concrete (LWC) for partition panel application. The additional of waste substances of HDPE plastic waste and polystyrene waste give environmental impacts of LWC production.

5. References

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