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Effects of HDPE Plastic Waste Aggregate on the Properties of Concrete

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Abstract: Polymer waste volumes have surged in recent years as a result of growing industrialization and fast improvements in living standards. In Malaysia, the majority of polymer waste is discarded rather than recycled. This circumstance results in major issues such as waste of natural resources and pollution of the environment. Polymer products, such as synthetic fibres, plastics, and rubber, are petrochemical compounds that disintegrate slowly in nature. Even after a long amount of time, plastic materials are not easily biodegradable. In reality, a wide range of waste materials can be used as a cement matrix inert. For the manufacture of the polymer concrete, trash bag plastics were employed as polymer wastes HDPE in this study (PC). The purpose of this research is to investigate the characteristics and characterisation of polymer HDPE as a coarse aggregate replacement in concrete. Temperatures of 160°C, 170°C, 180°C, 190°C, and 200°C were used in the heating procedure. By volumetric approach, five compositions of coarse aggregate with varied crushed stone: HDPE waste ratios of 0:100, 15:85, 30:70, 45:55, and 60:40 were utilised. The use of polymerwaste as coarse aggregate in traditional concrete was examined. With fresh and hardened concrete tests, the effects of polymer wastes on the workability and strength of the concrete were investigated. After 28 days, the compressive strength of the PC was determined to be suitable for nonstructural use. The findings of the cost research revealed that the PC is more cost effective than traditional concrete.
Keywords: Polymer Wastes HDPE; Coarse Aggregate; Compressive Strength; Properties

I. INTRODUCTION

Because landfills are becoming overcrowded and expensive for waste disposal procedures, materials going to landfills should be limited whenever possible. If waste creation cannot be avoided, it is more appealing to find a new application for the waste in another process before considering disposal. His recycling can be cost-effective due to lower trash removal expenses, as well as a reduction in pollution and contamination (Dhir Newlands Csetenyi, 2003). This report gives statistics demonstrating that Malaysian polymer wastes are not entirely recycled. Reprocessing waste materials into other polymeric goods or energy recovery from complete combustion have both been used to recycle polymers. Polymer reprocessing, on the other hand, has a limited number of recycling cycles due to contamination and thermal deterioration caused by the melting and reshaping phases (Mustafa, 2007).

To improve the qualities of the concrete and minimise costs, non-conventional aggregates such as polystyrene foam wastes, HDPE, PET, and other plastics were employed in its development. The use of these plastic wastes in concrete will result in a more durable concrete design as well as a greener environment.

A. Experimental Procedure

The goal of the experiment was to see how much of a role waste aggregate type played in the development of constrained concrete's strength behaviour. The experimental program also comprises thefollowing:

1) To study the characterization of HDPE polymer waste aggregate to compare withcrushed stone coarse aggregate.
2) To compare the properties of fresh and hardened concrete containing polymer wastecoarse aggregate to those of ordinary concrete.
3) To create a lightweight polymer concrete that can be used for a variety of purposes.

II. RAW MATERIALS

A. Ordinary Portland Cement

Ordinary Portland cement, as a cementitious substance, is the most essential raw ingredient. OPC isexcellent for standard concrete and a variety of construction applications. Lime, silica, alumina, and iron oxide are the raw components used to make Portland cement. It's made by heating a limestone and clay mixture until it practically melts, then grinding the clinker to a fine powder [M.Tajudin, 2006]. Portland cement is a calcium, silicon, and aluminum-based dry flour-like substance. The aggregate will be held together by the cement when it hardens.

B. Sand as Fine Aggregate
River sand is a fine aggregate made up of particles that are 14 inches (600 mm) or smaller. River sand is the most widely utilised fine aggregate in concrete to offer volume at a reasonable cost. Aggregates include sand and gravel. Both aggregate types should be present in a good concrete mix.

C. Plastics Waste
Waste trash bag plastics were gathered from the landfill and the environment and used to make lightweight aggregates. The discarded plastic sheet was moulded into a desired shape, such as a 25-30 mm diameter ball. The heating temperature for its reach is between 160 and 200 degrees Celsius. Heat treatment was used to alter the plastic waste aggregate. The heat treatment involved heating the plastic waste aggregates in a laboratory oven for 10 minutes at temperatures over the melting point, Tm, such as 160°C, 170°C, 180°C, 190°C, and 200°C. After then, the heated aggregate was taken out of the oven and left to cool at room temperature.

As a result of the heating process, the physical properties of plastic wastes will shrink, and microstructure changes will occur. The spherical diameter of the sample plastics waste will reduce in the region of 14-20 mm in diameter. The shape and texture of the samples are not uniformly circular, but rather angular and spherical, similar to crushed stone.

D. Water
The amount of water utilised in the concrete mix is crucial. This is the single most essential fact determining concrete's workability. A particular amount of water is required for a set of particles. Water is absorbed on the particle surface and in the spaces between particles, providing "lubrication" to allow particles to travel more freely past one another. As a result, finer particles, which are required for plastic behaviour, necessitate more water. Impurities in the water will reduce the curing strength of concrete. For mixing concrete, only potable water was used. Small amounts of water can be supplied as needed,but none can be taken away. The less water used, the stronger the concrete.

E. Characterization
Thermal investigation was carried out utilising a Research Instrument Differential Scanning Calorimeter (DSC) with a constant nitrogen flow rate of 20 ml/min. The temperature range that was studied was 20°C to 180°C. The samples were heated at 15°C/min to 180°C, kept for 5 minutes at that temperature, and then cooled at 15°C/min to 20°C. Each sample was weighed and sealed in an aluminium vessel (4-6 milligrammes).

Heat the plastic trash in the oven after shaping it according to the DSC melting temperature result. Heat the plastic trash at various temperatures, such as 160-200°C, to find the ideal temperaturefor aggregate qualities in concrete.

The size and form of the aggregates, as well as the surface roughness, water absorption, colour, and compression test, were all determined after the heat treatment.

The Universal Testing Machine was used to determine the compression test cube test and the flexural test for the beam at a crosshead speed of 3.0 kN/sec. All of the calculations were completed after the cubes failed. The compression and flexural test results were calculated by averaging the values of at leastthree measurements.

F. Procedure
Water, Portland cement, sand, and coarse aggregate were mixed together. The design mix is determined by the mix percentage ratio of 1:1.75:2.75. This ratio was derived from Yun-Wang Choi, et al., 2005 [12], in which trash PET bottles were employed as coarse material. In this study, varied ratios of plastic waste to crushed stone (100 percent plastic waste, 80:20, 60:40, and 100 percent crushed stone) were employed with the same water cement ratio of 0.5. The homogenous mixing technique ensures that the cement is properly coated on the aggregate. Additionally, the mixing process must be thorough and not rushed. While mixing the basic components together, drizzle in little amounts of water. It should have a consistency similar to cookie dough.

G. Mixing Proportion
The elements were divided into fractions to calculate the mixture proportions that would result in the desired compressive strength after 28 days of testing. Cement, sand, coarse aggregate, plastics waste, and water are the best proportions for a cubic metre of concrete. Table 1 shows that all of the waste coarse aggregate concrete mixes were created using the volumetric approach with the same water cement ratio of 0.5 for all of the sampling plastics.

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Table 1: Mix proportion for concrete design

Model	Cement (kg/m^3)	Sand (kg/m3)	Crushed stone (kg/m^3)	Plastics Waste aggregate (kg/m^3)	Water (kg/m^3)	Ratio Mix Proportion
M1	380	665	0	286	190	1 : 1.75 : 2.75
M2	380	665	209	229	190	1 : 1.75 : 2.75
M3	380	665	418	172	190	1 : 1.75 : 2.75
M4	380	665	1045	0	190	1 : 1.75 : 2.75

Mix Proportion
(Plastics waste: Gravel)M1 (100: 0%)
M2 (80: 20 %)M3 (60:40 %)
M4 (0: 100 %)

H. Slump Test

The ability of concrete to be laid, compacted, and finished is determined by its workability. The quantity of mechanical energy, or work, necessary to thoroughly compact concrete without segregation is typically used to determine workability. The slump test, compacting factor test, and Vebe test can all be used to determine workability. The slump cone test was used to measure the whole model of mix proportion in the lab.

I. Preparation of Test Samples

Concrete test specimens were created in accordance with British and Malaysian standards to measure mechanical properties of concrete such as compressive and flexural strength as a function of age and mixing ratio. After the mixing procedure, build a sample using 100x100x100 mm mould cubes and a 100x500x100 mm beam that has been air cured for one day. Then they were removed from the moulds and cured in water for 28 days until they reached the necessary age.

J. Result and DiscussionAnalysis DSC

The sample was measured with the DSC result shown in Figure 1 below, the analysis for melting temperature, Tm. As coarse aggregate, any sort of plastic waste polymer was used in the study. The plastic trash was moulded into a spherical shaped as a little ball and heated over the melting temperature, Tm, according to the DSC study. According to the graph, plastic garbage begins to melt ata temperature of 130°C.

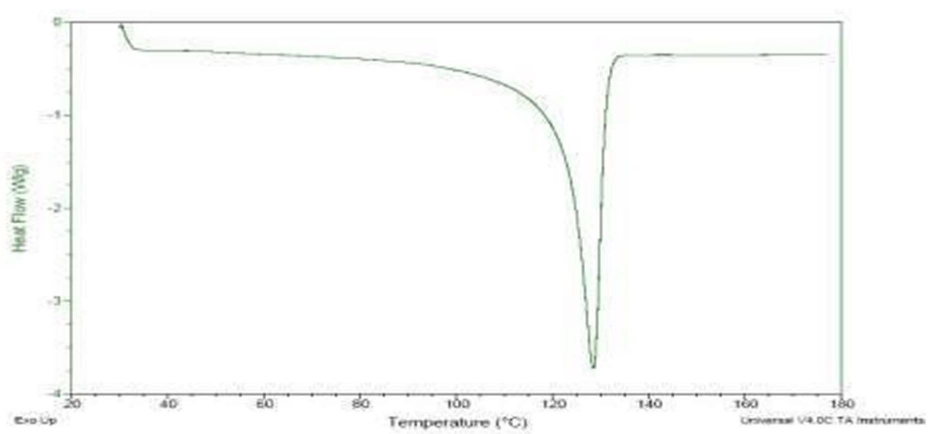

Figure 1: Analysis DSC for plastics waste
Size and shape

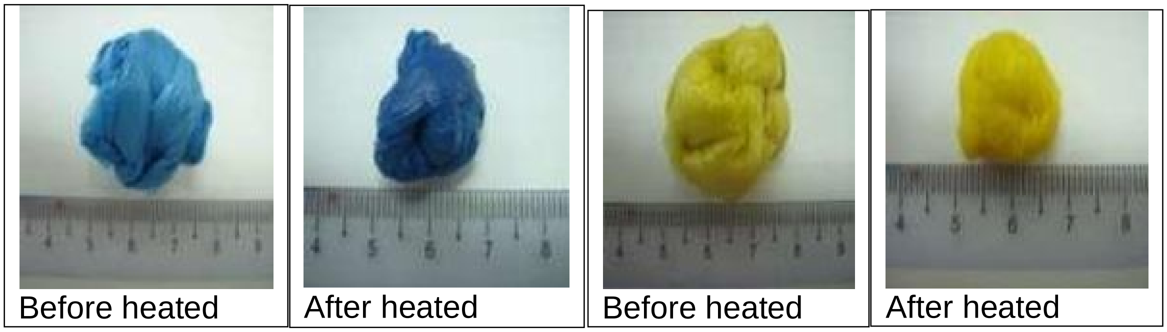

Figure 2: Plastic waste aggregate comparison before and after heated

According to Figure 2, aggregate sizes in this study range between 14 and 20 mm. Before the heating procedure, the plastic waste was shaped into a small ball with a spherical diameter. Before heating, the little ball has a diameter of roughly 30 mm. The little ball will shrink and shrink from its original size after being heated in the oven at 180 degrees Celsius. The plastic debris will continue to melt, so remove the aggregate from the oven after a few minutes. After cooling, the plastic will maintain its spherical shape, resembling a little ball with a diameter of 14-20 mm. This is the usual coarse aggregate size in concrete.

K. Compression Test for Aggregate

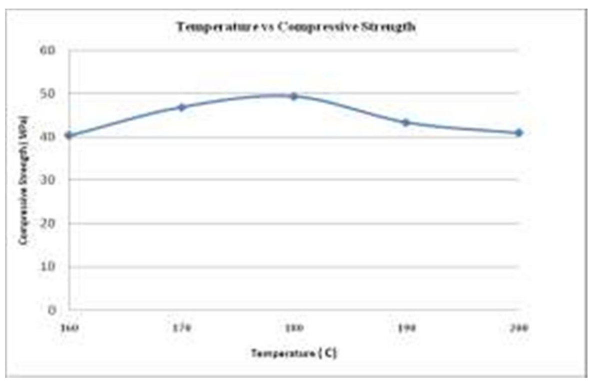

Figure 3: Compressive Strength for Aggregate

The result for compressive strength aggregate was shown in Figure 3. Around 5 pieces with various coloured aggregates were cooked at various temperatures. After a few minutes, the aggregate was cooled and each aggregate was given a compression test. The temperature of 180°C produced the best results, as shown in the graph below. The best qualities were given to the aggregate when it was heated to this temperature. Until the MPa, their strength is at its peak. As a result of this, come to the conclusion that the best temperature for heating plastic garbage is 180°C.

L. Surface and Texture

Aggregate is a term used to describe three-dimensional masses. Their shape, size, and surface texture have an impact on the properties of concrete, as well as the workability of new concrete and the binding between aggregate and mortar paste. External characteristics include shape and surface roughness.

Concrete is made from aggregate particles with a smooth and rounded surface. Interlock between aggregate particles, on the other hand, diminishes the strength of the aggregate mortar bond. When compared to crushed aggregate with the same water cement ratio, smooth and rounded aggregate polymers have a lower compressive strength.

M. Water Absorption

Before water absorption, weigh the aggregate after it has been baked in the oven. The sample is then immersed in water for 7 or 1 week. Allow the water to cool to room temperature. Wipe the aggregate surface and re-weigh after 7 days. The absorption value is the increase in mass after immersion in water from the initial dry state. Table 2 shows a calculation for % water absorption:

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Table 2 : Water absorption result

color	weight before, w1 (g)	weight after, w2 (g)	water absorpti on (%)
Red Blue	1.6	1.6	0
Yellow	1.6	1.68	5
Green	1.6	1.65	3
Black	1.6	1.68	5
	1.7	1.82	7

$$\%\text{ water absorption} : \frac{W_2 - W_1}{W_1} \times 100$$

Where is W_1 = weight before immerse (dry condition) W_2 = weight after immerse (wet condition)

N. Compressive Strength and Flexural Strength

Table 3: Properties of Plastics Waste Coarse Aggregate Concrete and Conventional Concrete Mixes at 28 days

Mix	w/c	cement content (kg/m^3)	Types	Slump (mm)	Compressive Strength (MPa)	Flexural Strength (MPa)
100 % Waste	0.5	380	Cubes	1	11.79	
80 : 20 (Waste : Gravel)	0.5	380	Cubes	3	13.37	
60 : 40 (Waste : Gravel)	0.5	380	Cubes		19.85	
100 % Gravel	0.5	380	Cubes	5 5	29.19	
100 % Waste	0.5	380	Beam	1		9.37
80 : 20 (Waste : Gravel)	0.5	380	Beam	3		12.56
60 : 40 (Waste : Gravel)	0.5	380	Beam			15.47
100 % Gravel	0.5	380	Beam	5 5		17.56

Table 3 shows the mechanical characteristics of plastic waste coarse aggregate. According to the data in the table, fresh plastics waste coarse aggregate has a lower water absorption rate and a smoother surface texture than plastics waste coarse aggregate. Plastics do not absorb water in most cases, even after the aggregate has been heated, making the plastic waste aggregate more dense. It is possible to reduce the amount of water utilised during the mixing procedure.

Cube compressive strength ranged from 11 to 19 MPa. The basic trend in the behaviour of plastics wastecoarse aggregate concrete in terms of strength is not considerably different from that of traditional crushed stone aggregate for lightweight concrete.

The flexural strength ranged between 9 and 15 MPa. The flexural strength differences between plastic waste concrete and normal concrete are extremely modest. The fracture surface revealed that the plastic trash has a weak interlocking bond with the cement.

III. CONCLUSION

The aim of this research was to evaluate the recyclability of domestic plastics waste as coarse aggregate for concrete. From the results and discussion, the following conclusions are drawn:

A. The physical study of plastic waste coarse aggregates revealed compressive strengths of 12-17 MPa, density concrete density of 1400-1550 kg/m3, water absorption of 5-7 percent, and suitability as coarse aggregate for concrete. However, the size and shape can be obtained in the 14-20 mm range, but the aggregate has a smooth surface that is thought to have a negative impact on its workability.

B. As the amount of plastic waste in concrete increases, the compressive and flexural strength of the concrete decreases. The concrete with the highest strength qualities was made with plastic waste aggregate in a 60:40 percent mixing ratio. The combination of plastic waste aggregate with crushed stones will result in increased strength and improved characteristics.

C. Additionally, there were no significant variations in the mechanical properties of the concrete based on the colour of the plastic waste aggregate. The hue or pigment of plastic garbage will attract people to decorative items.This research also has more potential application to produce light weight concrete, cost saving on raw materials from plastics waste and to minimize the polymer waste as a municipal solid waste and suitable for decorative andlandscaping product for attractive appearance.

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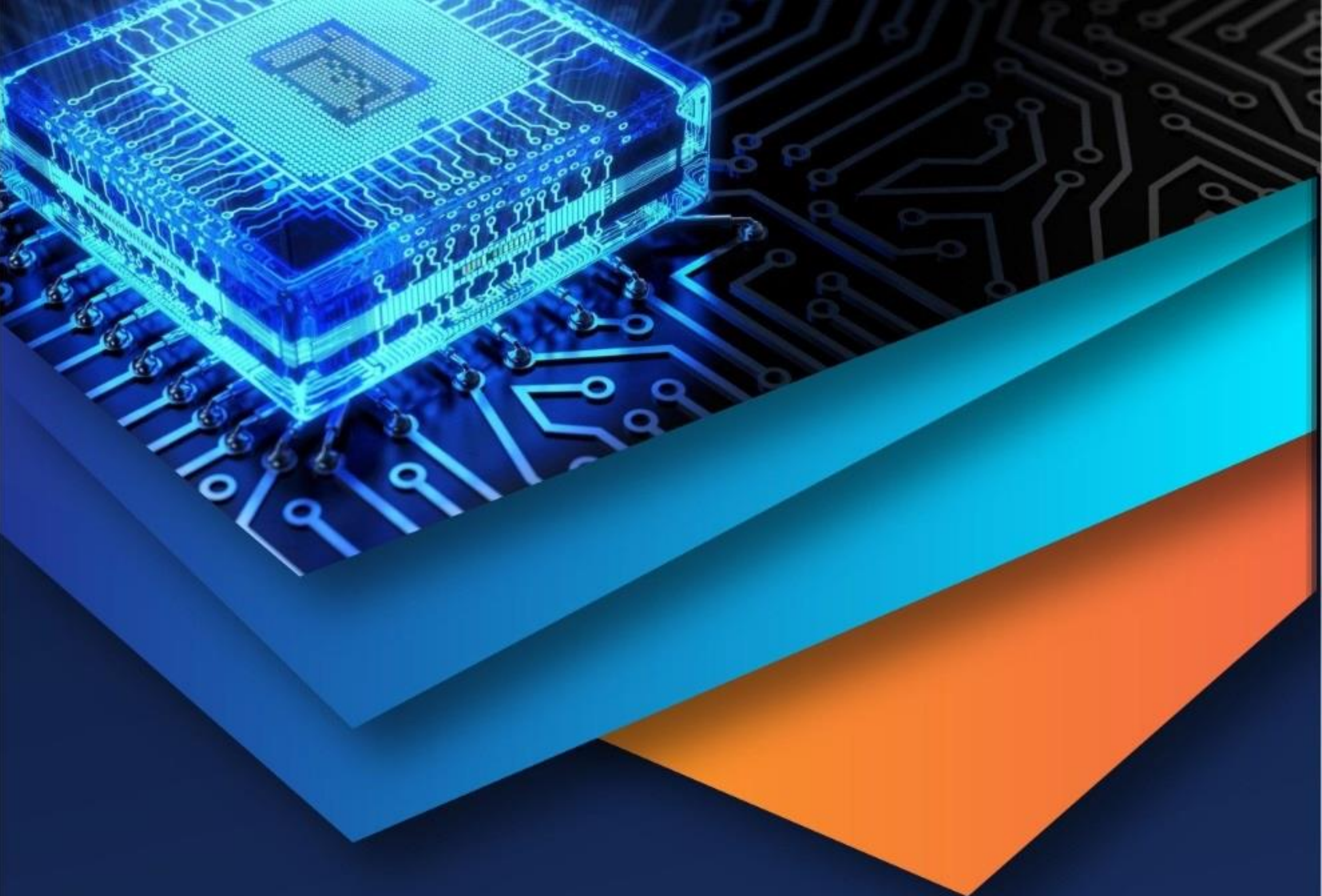

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