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The Development of Plastic Concrete Mix with Recycled Plastic (HDPE) in Concrete Production for Flat Roof of Sustainable Building

Huan Kok Wei[1], Mohd Fahmi Abdul Rahman[1]*

[1]Department of Civil Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Johor, MALAYSIA

*Corresponding Author Designation

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Abstract: Flat roof is the common roof design in modern building. Plastic waste is the main pollution in the environment. Recycling and reuse of plastic is method to reduce pollution. This study focused on the development of plastic concrete with the addition of High Density Polyethene (HDPE). The aim of the study is to investigate the optimum plastic concrete mix by determine the properties of compressive strength, thermal conductivity and water absorption. The samples of plastic cement ratio of 1:50 (2.00 %), 1:25 (4.00 %) and 3:50 (6.00 %) are prepared and tested. The sample of 2.00 % plastic-cement percentage achieved the compressive strength requirement of Grade 20 in 7days and 28days. The compressive strength reduced with addition of HDPE. The 4.00 % plastic-cement percentage sample had the greatest reduction in thermal conductivity about 12.00 %. Water absorption of plastic concrete had an increasing trend with addition of HDPE. The 2.00 % plastic-cement percentage sample is proposed to be the optimum plastic concrete mix as flat roof concrete. The addition of HDPE in concrete mix affect the properties of concrete.

Keywords: Plastic Concrete Mix, HPDE, Flat Roof

1. Introduction

Concrete is the construction material used for more than century. Concrete with various grade is used in different loads and purposes in the building. In Malaysia, the compressive strength of concrete is required to comply with the standard provided by the Malaysian Public Works Department (JKR). The proportion of concrete mix affect the properties and performance of the concrete. Flat roof design is one of the common designs adopted in modern building. The design of flat roof is widely implemented on building globally [1]. Concrete used in flat roof must be able to resist weathering effect. Flat roof is the major external heat source to the building. Indoor temperature is affected by heat from the roof [2]. Energy is required to maintain the comfort of the occupant in the building. The flat roof with sustainable feature reduces the temperature of roof surface [3].

Corresponding author: mohdfahmi@uthm.edu.my

Plastic is an artificial synthesis compound that widely used in modern life. Plastic pollution is a serious global issue. Method to recycle and reuse plastic can be the solution. High-Density Polyethylene (HDPE) has been an ideal material in packaging application with remarkable resistance. The application of plastic in concrete had been conducted by researcher. The addition of HDPE in concrete mix reduce the workability of the concrete [4]. The strength of the plastic concrete mix is the main physical properties in construction. Concrete mix with mixture ratio of HDPE will have a reduce in concrete strength.

The aim of the study is to investigate the HDPE plastic concrete mix in properties of compressive strength, thermal conductivity and water absorption. The optimum plastic concrete mix will be determined to fit the criteria as flat roof concrete. Previous research on the application of plastic in concrete provide related information and guideline for this study.

2. Materials and Methods

2.1 Materials

Sample of HDPE plastic concrete is prepared to perform laboratory test. The preparation of plastic concrete sample is Grade 20 design mix of the JKR specification with the ratio of 1:2:4 (cement: sand: aggregate). The materials used to prepare plastic concrete sample are Portland cement, sand, coarse aggregate, water and HDPE. Three sample for each of the plastic cement percentage of 2.00 %, 4.00 % and 6.00 % including control sample. Total of 24 sample of plastic concrete are prepared.

2.2 Methods

The laboratory testing is conducted at UTHM Pagoh campus. The flowchart of research methodology is presented in Figure 1.

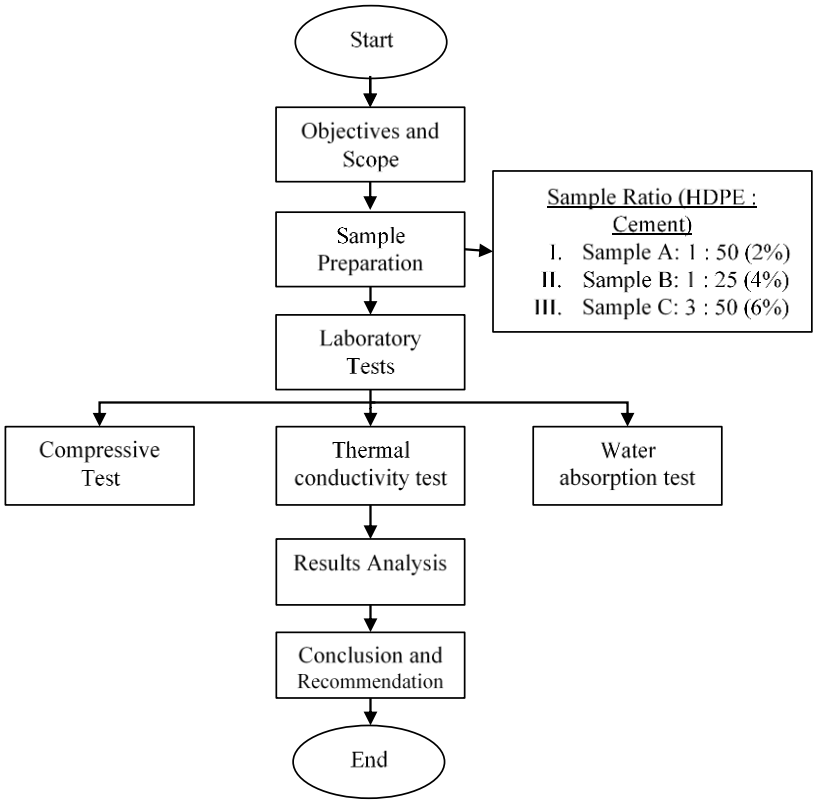

Figure 1: Research Methodology Flowchart

The data on compressive strength, thermal conductivity and water absorption are obtained from laboratory tests. Compressive strength of the sample is determined with Cube test. The cube test is done

on the 7 days and 28 days comply with JKR standard. Guarded hot plate is conducted to determine the thermal conductivity of plastic concrete. The thermal conductivity is identified using steady state method [5]. Water absorption test is conducted to determine the percentage of water absorption. The results obtained are then analyze with table and graphical method.

3. Results and Discussion

3.1 Compressive Strength

The compressive strength is the primary property of the concrete. The design concrete mix is Grade 20 according to JKR standard. The compressive strength is acquired at the 7 days and 28 days of curing. Table 1 shows the results of compressive strength of plastic concrete samples.

Table 1: Result of compressive strength

No	HDPE percentage	Compressive Strength (N/mm^2)	
		7 days	28 days
1	0% (Control)	18.67	22.22
2	2%	17.00	20.26
3	4%	14.65	16.11
4	6%	10.88	14.29

Based on the table, the compressive strength on the 7 days of sample with 2.00 % and 4.00 % HDPE were 17.00 N/mm^2 and 14.65 N/mm^2 respectively. The samples of 6.00 % HDPE sample p recorded the lowest strength of 10.88 N/mm^2 at 7 days. For 28 days, the 2.00 % HDPE sample was 20.26 N/mm^2.The samples concrete of 4.00 % and 6.00 % HDPE recorded 16.11 N/mm^2 and 14.29 N/mm^2 respectively. According to JKR standard, the requirement compressive strength of Grade 20 concrete on the 7 days is 14.00 N/mm^2 and 28 days is 20.00 N/mm^2. Sample with 2.00 % HPDE is the only sample achieved the requirement of Grade 20 for both 7 days and 28 days.

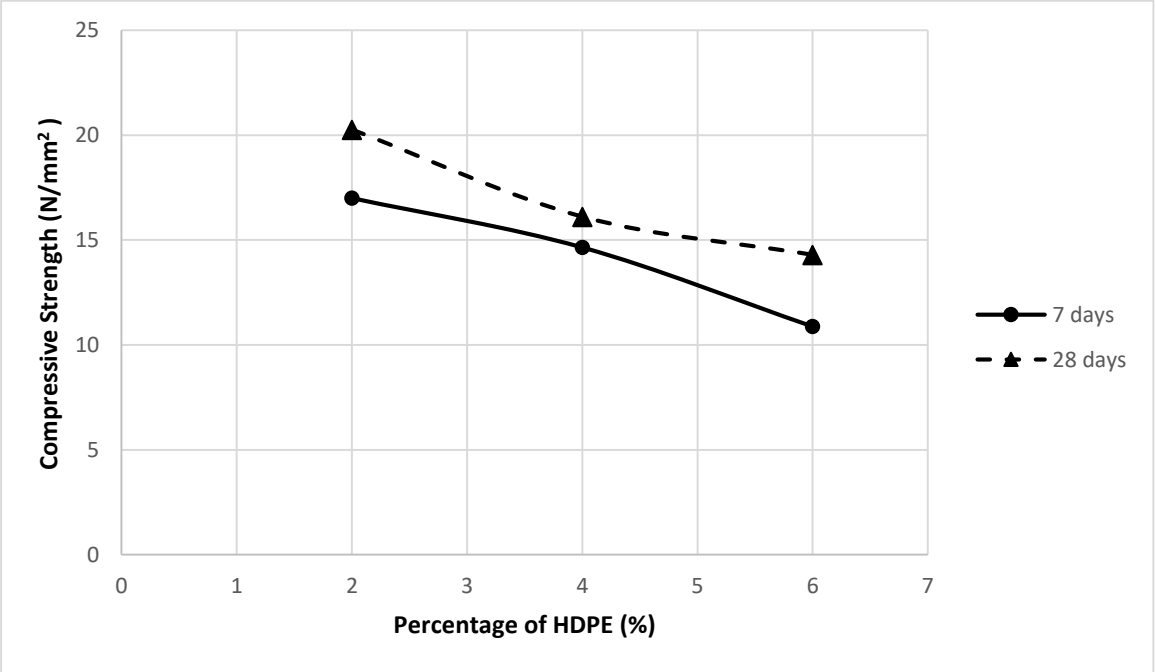

Figure 1: Compressive Strength against Percentage of HDPE

Figure 1 shows the relationship of compressive strength and the percentage of HDPE in plastic concrete mix. As the percentage of HDPE increase, the compressive strength of concrete decline. The

curve in the figure decline gradually. The reduce in compressive strength is cause by the HDPE. The weaker bond between the cement paste due to the addition of HDPE reduce the compressive strength of the concrete sample [6].

3.2 Thermal Conductivity

The thermal conductivity of plastic concrete samples is determined via Guarded Hot-plate method. Table 2 shows the thermal conductivity of plastic concrete sample.

Table 2: Thermal Conductivity of plastic concrete sample

No	HDPE Percentage	Thermal Conductivity (W/m ^{0}C)
1	0% (control)	0.479
2	2%	0.432
3	4%	0.417
4	6%	0.426

Based on the table, the control sample had thermal conductivity of 0.479 W/m °C. The common range of thermal conductivity for conventional concrete is range 0.4 to 0.7 W/m °C. The thermal conductivity of 2.00 % and 6.00 % HDPE samples acquired 0.434 W/m °C and 0.430 W/m °C respectively. The difference in thermal conductivity is relatively small. However, the 4.00 % HDPE sample had the lowest thermal conductivity of 0.421 W/m °C. The highest reduction in thermal conductivity is about 12.00 %.

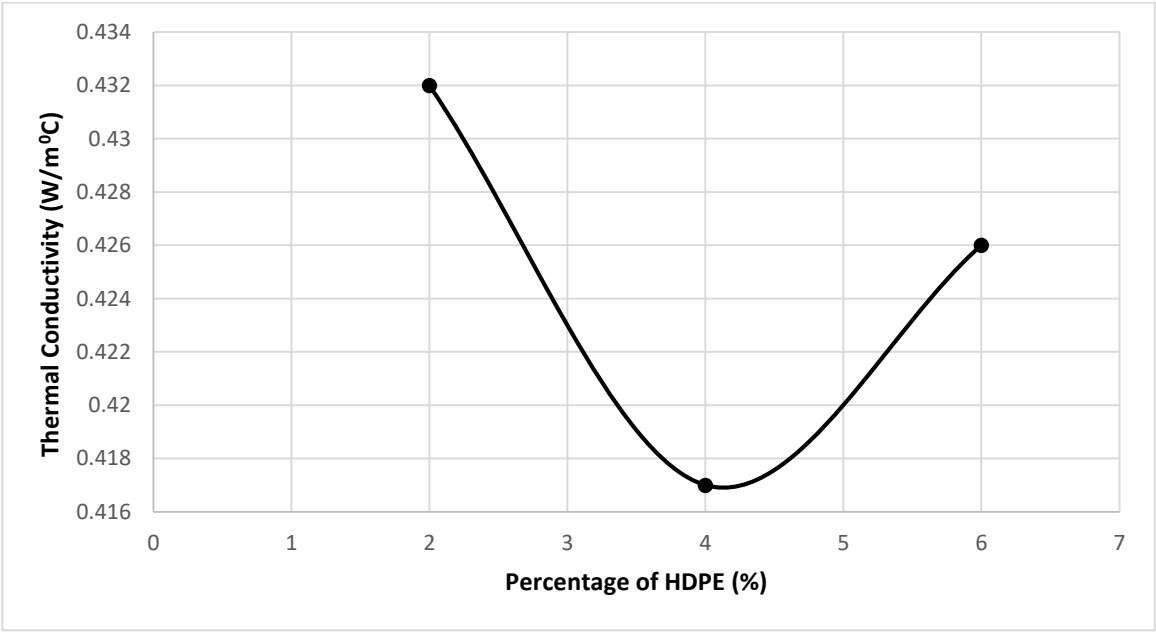

Figure 2: Thermal Conductivity against Percentage of HDPE

Figure 2 shows the relationship of thermal conductivity with the percentage of HDPE in the concrete sample. As the increase in plastic-cement percentage, the thermal conductivity of the concrete sample reduced. The trend of the curve showed a slight increase in thermal conductivity after the 4.00 % HPDE sample. The rise of thermal conductivity is considered to be minor. The lowest thermal conductivity was achieved by the 4.00 % HDPE sample. The position and alignment of the HPDE plastic in the plastic concrete sample is the cause of the inconsistency of the thermal conductivity value. Based on the data, the addition of HPDE in plastic concrete sample showed the ability to resist heat transfer. The HPDE in the plastic concrete sample act as an insulator against heat transfer [7].

3.3 Water absorption

Water absorption is an important property of concrete in flat roof design. The result of water absorption is shows in Table 3.

Table 3: Water Absorption of plastic concrete sample

No	HDPE Percentage	Dry Density (g/cm^3)	Water Absorption Percentage (%)
1	0% (control)	2.035	3.87
2	2%	1.878	4.65
3	4%	1.887	4.87
4	6%	1.782	4.88

Based on the table, the control sample achieved water absorption percentage of 3.87 %. Concrete sample with 2.00 % and 4.00 % HDPE achieved 4.65 % and 4.87 % of water absorption percentage. The 6.00 % HDPE sample scored the highest water absorption percentage of 4.88 %. The control sample recorded dry density of 2.035 g/cm^3. The concrete sample with addition of HDPE shows a drop in the dry density in general. Sample with 6.00 % HDPE percentage had the lowest average dry density of 1.782 g/cm^3. Sample of 2.00 % and 4.00 % HDPE recorded average dry density of 1.878 g/cm^3 and 1.887 g/cm^3 respectively. Figure 2 shows the graph of water absorption percentage against percentage of HDPE in the concrete sample.

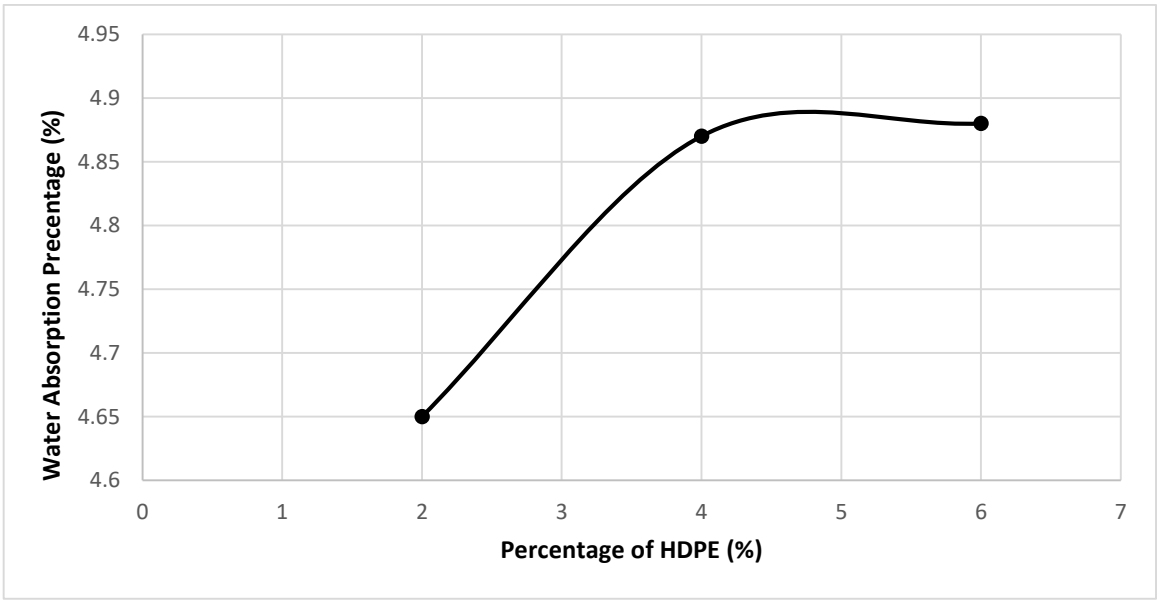

Figure 2: Water Absorption Percentage against Percentage of HDPE

From the figure, the curve shows an increasing trend of water absorption percentage as the HDPE percentage increases. The curve comes to a stable incline after 4.00 % of HDPE percentage. The plastic concrete sample have a lower dry density and higher void content. Void content in the concrete sample contribute to the water absorption rate of the concrete [8]. Water trap in the void of the concrete sample resulting a greater water absorption rate.

4. Conclusion

In summary, the study found that the compressive strength of the plastic concrete reduces as the HDPE percentage increase. Sample of 2.00 % HDPE percentage is the only plastic concrete mix passed the requirement of compressive strength for 7 days 28 days. The lowest thermal conductivity was

recorded by 4.00 % plastic-cement percentage sample of 0.421 W/m °C which is about 12.00 % reduction from the control sample. Water absorption had an incline trend as the HDPE percentage rise.

Lastly, the 2.00 % HDPE plastic concrete mix is proposed to be the design mix for flat roof construction based on this study. The properties of 2.00 % HPDE plastic concrete mix exhibit the criteria requirement for flat roof concrete. The 2.00 % HDPE plastic concrete mix is adequate without compromise on other properties.

Characterization of the plastic sample is recommended to perform before conducting laboratory test. Material characterization provide valuable data on the sample behavior. Potential research can study on the effect of performance for different plastic polymer in concrete mix.

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