Effect of Fly Ash and HDPE on Concrete Strength

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Abstract
Rapid development in construction industry needs innovative elements to ensure concrete emphasize application of green construction. These present study covered the use of recycled plastics as replacement of coarse aggregates in concrete and fly ash as a replacement of cement. The main aim of the study is to investigate the change in mechanical properties of concrete with the addition of plastics and fly ash in concrete. Along with the compressive strength, water absorption of the resultant concrete is also studied. It is found that the use of plastic aggregates and fly ash results in the strength of the concrete. The compressive of concrete reduces with the introduction of plastics. Average compressive strength at 28 days showed for M2 (contained 10% plastic HDPE) is 25.64 N/mm^2 while M3 (15% plastic HDPE) is 23.37 N/mm^2 and M4 is 22.45 N/mm^2 (10% plastic HDPE). Test results show that, inclusion of fly ash generally contributes the improvement of concrete properties.
Keywords : Fly Ash, Compressive strength, partial replacement

1.0 Introduction

Waste utilization has been one of the considerations in the construction industry towards sustainability. With the growing demand in the construction industry, excessive materials are being manufactured, and along with it, are the waste products that are being produced. Big attention is being focused on the environment and safeguarding of natural resources and recycling of wastes materials. Actually many industries are producing a significant number of products which incorporate scrap (residues). In the last 20 years, a lot of works concerning the use of several kinds of urban wastes in building materials industrials process have been published. Many researches have been extended to study new kinds of wastes to investigate deeply particular aspects (Parvesh Kumar,2013). Production of solid waste in Malaysia is 1 kg/person per day. In average, approximately 26 million people in the country produce 26 million kilos of solid waste every single day. Plastic waste is the most common solid waste that generate in the country accounting for 7-12 percent by weight and 18-30 percent by volume of the total residential waste generated (Mojtaba *et.al* ,2013).

Research conducted in this paper utilizes HDPE plastic and fly ash. HDPE is a waste material that has no particular commercial value. It is made from petroleum and has the number 2 as its recycling symbol. HDPE is also known for its large strength to density ratio as polyethylene is much lighter than conventional concrete materials. Besides, it is non-toxic materials which make it environmentally safe. HDPE is also very tough, ductile and also withstand higher temperatures (120°C for short

period,110°C continuously). But, at the same time, they are non-degraded and cause environmental problems (retrieved April 20,2017 from https://en.wikipedia.org/wiki/Bottle_wall) . Due to the relatively low value of the material and the required processing costs, much plastic ends up in aggregate where there is no environmental benefit (Wan Noor Atimmi ,2010).

Energy is the main backbone of modern civilization of the world over, and the electric power from thermal power stations is a major source of energy, in the form of electricity. In Malaysia, over 90 percent of electricity generated is by coal-fired plants. Fly ash is the solid residues produced from coal combustion process and disposed every year. Fly ash is an industrial by-product that is normally consigned to landfills and the reuse of it as cement extenders provides an immediate benefit for the environment. The continuous reduction of natural resources and the environmental hazards posed by the disposal of coal ash has reach alarming proportion such that the use of coal ash in concrete manufacture is a necessity than a desire.

The compressive strength is the most common performance measure used by engineers in designing structures. The use of fly ash as a partial replacement in concrete has been proven to reduce the early strength up to 28 days, but improves the ultimate strength (after more than a year) due to the pozzolanic reaction. In their study (Parvesh Kumar et.al,2013) found that the high volume fly ash (HVFA) concrete mixtures containing 50-60% fly ash can be designed to fulfil the requirement of strength and workability suitable for concrete construction.

The use of HDPE, fly ash in the production of green concrete is a new dimension in concrete mix design and if applied on large scale would revolutionize the construction industry, by economizing the construction cost and decreasing the wastes materials from entering the landfill. The productive use of waste materials is one of the ways to alleviate some of the problems of solid waste management. There are several benefits of using waste materials. It helps people save and sustain industrial resources for which it is impossible to renew, as well as having an effect on decreasing the environmental pollution. Because of the environmental and economic reasons, currently there has been a growing trend for the use of the industrial wastes or the by-products as supplementary materials or as an admixture in the production of composite cement and concrete. Using industrial by-products in concrete will lead us to have sustainable concrete design and a greener environment.

2.0 Objectives of Study

i. To determine the optimum percentage of HDPE, and fly ash content to replace the aggregates without affecting the strength of concrete.
ii. To determine the strength of concrete by replacing HDPE and fly ash.

3.0 Literature Review

In engineering, materials are employed to design and build structures, develop and produce new products. In the other way, the strength of concrete is largely dependent upon three key criteria which is firstly the engineering rationale incorporated into the design of the structure, then the

physical characteristics of the materials used in the construction of the structure and the quality of the construction used in assembling these components (National Concrete Masonry Association, 2011).

HDPE is a semi-crystalline thermoplastic polymer, which belongs to the polyolefin group and is manufactured through the polymerization of ethylene, with the help of catalysts. HDPE is one of the most important plastics (Mandelkern L, 1964). In 2007, the global HDPE market reached a volume of more than 30 million tons, whereby the packaging and construction industries were particularly responsible for driving growth. HDPE is the polyethylene grade with the highest rigidity and the least amount of flexibility. It is well suited for a wide range of applications, like trash canisters, and a multitude of everyday household goods, such as small bottles and clothespins. This light-weight, non-toxic material is easily recyclable and serves increasingly as an alternative for less environmentally friendly substances. Commercial grade HDPE materials have subtle characteristic differences, caused by variations in polymerization technologies, catalyst residues, molecular structures of the polymer chain, and utilized additives. Understanding of these differences and use of the best characteristics makes optimization for specific applications possible.

4.0 Methodology

The methodology is explained on the test procedures that have been used to achieve the objectives. In addition, it describes the procedures for laboratory work carried out to obtain the desired results. Figure 1 below shows how the research mixes design using sand cement at 1:6 proportional mixes. The concrete have being poured into the mould, measuring by 150 x 150 x 150 mm. The specimen formed cured with water through sprinkling [14]. Curing ages are 7, 14 and 28 days. Then it subjected for water absorption testing and compressive strength test. The ratio 1:2:4 were used in concrete mixture which 1 for cement, 2 for sand and 4 for aggregate with the water cement ratio of 0.55 by mass.

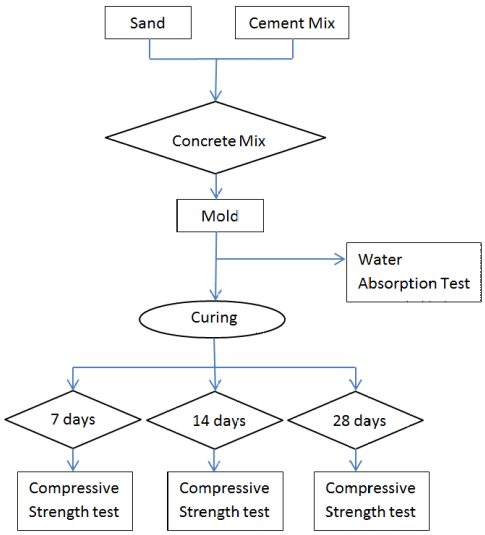


Figure 1: Conceptual Framework

4.1 Materials

The materials used in this study are cement, sand, HDPE, fly ash aggregates and water. All the material should be in good condition and quality before uniformly mix in the concrete mixture.

4.1.1 Cement

The type of cement used in this research is Ordinary Portland Cement. This is because this type of cement is abundant in the market and suitable for normal use. Cement is certified and meets the standards set by SIRIM.

4.1.2 Aggregates

The sand used has regular shape and cleans from any dirt. The aggregate gives volume to the concrete since this occupies maximum space in the total volume concrete. The aggregate firstly will run sieves analysis as per ASTM C33-03 Standard Specification for Concrete Aggregates for grading it. The aggregate was air dried in room temperature to obtain saturated surface dry condition to ensure that water cement ratio is not affected.

4.1.3 Fly Ash

Fly ash was obtained from Jimah Power Plant, Mukim Jimah port Dickson. Fly ash is defined in Cement and Concrete Terminology as the finely divided residue resulting from the combustion of ground or powdered coal, which is transported from the firebox through the boiler by flue gases.

4.1.4 HDPE

HDPE is one type of plastic which material properties have a stronger, harder, and more resistant to high temperatures. HDPE waste will usually take from pallets, drums, and bottles. It is commonly used for milk bottles, Tupperware, gallons of drinking water, folding chairs and others. HDPE was obtained from Victory Recovery Resources Sdn. Bhd and crushed in average size 4.75 cm to 10.00 cm.

4.2. Curing

Curing was employed to maintain satisfactory moisture content and allow proper hydration and hardening of the sand concrete blocks. The blocks were cured for the whole period of the 28 days during which water is sprinkled on them for two weeks during curing (Odeyemi, et.al,2015). Sufficient curing is essential for a concrete to provide its potential performance .Then they were tested for their compressive strengths (Henry,2004).

4.3 Compressive Strength

Compressive strength test was performed to obtain a sample of the panel. This test is performed by BS 5628 : Part 1 :1992. Maximum strengths described in N/mm2 are obtained by proper mixing of suitable material and arrangement also by proper compacting and curing (Sadek Debounch et.al,2010). In this research sample the concrete has reached

age 7,14 and 28 days are tested for compressive strength using Universal Testing Machine (UTM) .
The compressive strength of each cube was calculated, by dividing the load causing failure of the specimen by the cross-sectional area as follow (Tomas U. Ganiron Jr ,2013):

$$\text{Compressive strength (N/mm}^2\text{)} = \frac{\text{Load at failure (N)}}{\text{Cross sectional Area (mm}^2\text{)}}$$

There are 45 sample tested for compacting. The concrete placed on the platform of the machine and the platform ensured clean and no impurities such as traces of broken concrete. The sample tested using UTM machine which is the easier way to identify strength of material.

4.4 Water Absorption Test

Water absorption test is one test used to determine the percentage of water absorption on the concrete. This test should be done carefully and follow the correct procedures so that there is no error that would affect the results of the readings taken. Furthermore, durability of concrete is mainly dependent on the capacity of a fluid to penetrate the concrete's microstructure, which was called permeability (Sina Safinia et. al, 2016).

The concrete cube weighted before immersed. The through pores allow air to escape in the 24 hour absorption test (BS 3921). The 24 hours immersion test allows water to be absorbed in pores which are easily filled under cold condition. The effects of concrete absorption property is due to variable raw materials used (Sadek Debounch et. al, 2010). Furthermore, the high surface water absorption only decreased compressive strength of cover concrete. The whole strength of concrete depends on both surface and internal structures. So, strength of concrete cannot be evaluated by water absorption (Shilpi Saxena et al, 2013). The water absorption by immersion gives an estimation of the total (reachable) pore volume of the concrete, but gives no indication on the concrete permeability, which is more important with regard to durability. Table 1 indicates the average of water absorption for concrete.

Table 1: Average of Water Absorption for concrete w/c 0.55

Type of mix	Water Absorption (%)
0% (control)	0.62
10%	0.76
15%	0.88
20%	0.95

4.5 Slump Test

The results of the slump test of concrete containing difference proportion of HDPE are shown in Table 2. Referring to the table below, the slump value is increase with the increasing of the HDPE ratio. That means the HDPE will reduce the workability of the concrete when replaced in

higher percentage such as 30 % of aggregate weight. The values of slump are 12 mm, 14 mm, and 16mm for 10 %, 15 %, and 20 % of HDPE, respectively.

Table 2: Slump Test

Type of mix	Slump Test (mm)
10%	90
15%	80
20%	65

5.0 Result and Discussion

Concrete test is conducted to determine the characteristics and behavior of the concrete. The compressive strength is measured by breaking cube concrete specimen in a compression testing machine. In concrete, strength related to the stress required causing failure and it is defined as the maximum stress the concrete sample can withstand. Testing the specimens is classified according to the curing age and water content of the concrete as on the 7, 14 and 28 days. Under the compressive strength test the specimens were cracked and reach ultimate strength recorded by machine as shown in Table 3. The data shown in the Table 3 reveal that, at all ages the strength of control concrete were higher than the corresponding concrete containing HDPE plastic. The strength of concrete is decreasing linearly with the increasing of HDPE plastic volume in the concrete mixture.

Table 3: Average of Compressive strength for concrete w/c 0.55

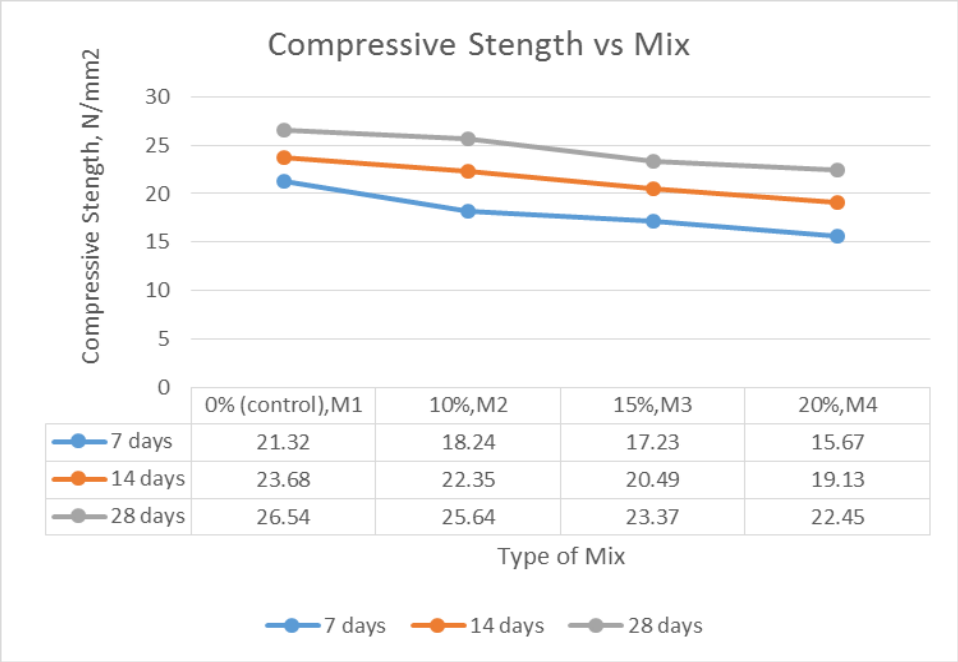
Type of mix	Average Compressive Strength (N/mm^2)		
	7 days	14 days	28 days
0% (control),M1	21.32	23.68	26.54
10%,M2	18.24	22.35	25.64
15%,M3	17.23	20.49	23.37
20%,M4	15.67	19.13	22.45

The various aspects studied include:

i. The effect of mix proportion towards water absorption
ii. Compressive strength in varying percentages as a partial replacement of aggregates.

5.1 The Effect of Mix Proportion Towards Water Absorption

From the result, it is observed that the water absorption of concrete decreased with the increased fly ash and HDPE contents as shown in Figure 2.



	0% (control),M1	10%,M2	15%,M3	20%,M4
7 days	21.32	18.24	17.23	15.67
14 days	23.68	22.35	20.49	19.13
28 days	26.54	25.64	23.37	22.45

Figure 2 Graph Compressive Strength vs curing period

5.2 Compressive Strength In Varying Percentages as a Partial Replacement of Aggregates

Figure 2 shows that on addition of plastic aggregate there was a gradual decrease in 7 day, 14 day and 28 day compressive strength of cube. The drop in compressive strength due to the addition of HDPE as aggregates may be attributed to lower bond between the cement paste and HDPE in concrete. The higher compressive strength means the good bond between materials in concrete. Less HDPE volume in concrete give good bond between materials in concrete than more HDPE. This is because HDPE has a smooth and shiny surface that is difficult to bind with other materials in concrete. This show that it is better to substitute the HDPE plastic substituent in a lower quantity to ensure the concrete can achieve higher strength.

6.0 Discussion and Conclusion

From the above findings, it can be concluded that concrete using HDPE are suitable to be used as a partial of replacement for area in concrete mix. At the same time, by used waste material such fly ash as a replacement of cement in this research enables the large utilization of waste products.

From the result, it also showed that concrete grade 20 can be archived for this invention. Average compressive strength at 28 days for M2 is 25.64 N/mm^2 while M3 is 23.37 N/mm^2 and M4 is 22.45 N/mm^2. Compressive strength, for all the samples is continued to increase with age for all the mix proportions. Compressive strength of all mixes is acceptable for most structural applications since the observed compressive strength is more than 20MPa at 28 days. Fly ash used as cement replacement enables the large utilization of waste products.

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