LIGHTWEIGHT CONCRETE WITH HDPE AND FLY ASH ADDITIVE

Sinatu Sadiah Shapie[1], Hussein Md Zan[2]

[1] Civil Engineering Department,
Politeknik Melaka

[2] Mechanical Engineering Department,
Politeknik Melaka

sinatusadiahshapie@yahoo.com, hussein@polimelaka.edu.my

Abstract

The purpose of this study is to develop a lightweight concrete by admixing with High Density Polyethylene (HDPE) and fly ash. The characteristic of HDPE which can sustain load, make it very useful to replace the portion aggregate in concrete mixture. The main specialties of lightweight concrete are its low density where it advantages are it has reduction in dead load, faster building rates in construction and handling costs. The concrete is designed to get a 28-day compressive strength of not less than 20 Mpa and density of less than 2000 kg/m3 to fulfil criteria as lightweight concrete. The control group concrete for this study have compressive strength at 20Mpa. The HDPE were then used to replace the aggregate at 20, 30 and 40 % by mass resulting in concrete strength more than the target with 38Mpa. It was found that the density from compressive strength control group with 20 to 40% of the aggregate replace with HDPE and fly ash reduced the density from 2479 kg/m3 to 1750 – 1896 kg/m3. The compressive strength also reduced from 84.2Mpa to 25.86 – 37.28Mpa.

Keywords: High Density Polyethylene, Fly Ash, Lightweight concrete, Strength, Density

1.0 Introduction

Concrete building components such as columns, beams and footings normally being built large and bulky sizes in order to support the load especially high-rise buildings. It designed to carry high density of concrete at about 2400kg/m^3 (SCG Cement, 2008). During the evolution process of the concrete, codes and standards for quality control of concrete has been developed by the several organisations including America Concrete institute (ACI), Society for Testing and Materials (ASTM) and also British Standard (BS).

Economic benefit of lightweight concrete were it low-heat conductivity and density (Topcu,1999). Lightweight property of concrete has been desirable in constructional elements (Yalgin,1983). Due to the growing of lightweight concrete use, many studied have been conducted to improve the quality and characteristic of these concrete. Additionally, the main purpose studied for reducing costs in manufactured are still being done. Architects, engineers, and contractors has recognized the inherent economies and advantages offered by this material, as evidence by the many impressive lightweight concrete structures found today around the world (ACI, 1987).

Furthermore, aggregate value in market is also increase due to high demand on construction. This issue can be resolved by using residual waste as it is more economical alternative. One of the residual wasted that researcher believe can be use are High Density Polyethylene (HDPE) combined with Fly Ash. HDPE is waste material that has no particular commercial value. Researcher believes that this material was very suitable to replace coarse aggregate in concrete. It is because it has strong strength. Therefore, in this study, the aggregate will be replace with a percentage of HDPE to obtain the optimum strength in concrete.

Generally, mineral admixtures such as silica fume and fly ash has been used in concrete mixtures to improve mechanical properties such hydration, alkali silica reaction, and permeability (Demirboga *et al.*, 2001).

The objective of this study is to investigate the use of HDPE in making lightweight concrete of reasonable compressive strength. The concrete is to have a target density of less than 2000kg/m^3 and target 28-day compressive strength of not less than 20Mpa.

2. 0 Literature Review

Structural lightweight concrete solves weight and durability problems in buildings and exposed structures. Lightweight concrete has strength comparable to normal weight concrete, typically 25% to 35% lighter (ACI, 1987).

2.1 Lightweight concrete

Conventional concrete is very heavy and requires high costs for due to their non-renewable materials used in it. Coarse aggregate is the main materials in concrete development. As a high demand in construction sector is increase, these aggregate constantly reduced by the time over, and lastly it will be fully utilized. In addition, rock mining activities can also lead to disturbed ecosystems in the quarry.

Lightweight concrete is made to facilitate employment due to low density without compromising the strength of the concrete, even it stronger than conventional concrete. Cement, sand and aggregate and water are the basic materials used to produce concrete. (Leslie S & Jonathan, 2006). According to ACI 213 (ACI,1987), structural lightweight aggregate concrete made with lightweight aggregate; the air-dried unit weight at 28 days is usually at the range of 1440kg/m^3 to 1850kg/m^3 and the compressive strength is more than 17.2Mpa. However, in ACI 213, the definitions like this is not a specification, the job speciafications may, at times allow unit weights up to 1900kg/m^3. In terms of classification of Lightweight concrete, the density must be specified less than 2200kg/m^3 consisting of or containing a proportion of artificial or natural lightweight aggregates are having a density of less than 2000 kg/m3.(George.R,2002). Lightweight concrete also use the same material, differences are the content or type of material that needs to be added to obtain a low density without affecting their strength.

Cement used in construction is characterized as hydraulic or non-hydraulic. Hydraulic cement (e.g Porland Cement) harden because of hydration, chemical reactions that occur independently of the mixture's mixture water content; they can be harden even underwater or when constantly exposed to wet weather.

In Malaysia, the use of Light Weight Concrete is not very common, thus may due to large amount of gravel aggregate still available in the market. Lightweight concrete may not popular due to more expensive cost, less knowledge and experience, not having enough the skill worker, the

machinery and appliance to construct the Lightweight Concrete is not enough.(Mohammad Shazli F.2008).

Malaysia imports lightweight aggregates from France and Germany and this type of aggregate were not in Malaysia. Producing lightweight aggregates mostly came from materials such as clay, shale, or slate. However, a blast furnace slag, natural pumice, vermiculite, and perlite also can be used as substitutes. To produce a lightweight aggregate, the raw material (excluding pumice) is expanded to about twice the original volume of the raw material. (John P.R et.al 2006). The expanded material has properties similar to natural aggregate, but is less dense and therefore yields a lighter concrete product.

Difficulty of sources and manufacturing made these lightweight aggregates have higher cost compare with conventional aggregates. This factors influence construction industry to choose conventional aggregates in their construction project. However this source is decreasing and people already have awareness about environmental care. To control fly ash and dust hovering in the atmosphere, recipients electrostatics was built and used for trapping 99 % of ash and dust. From the burning process of coal, 80% of product will become fly ash and remain 20% of product is bottom ash. (Atika et.al, 2012).

Therefore, study that related for reducing the use of aggregate in concrete have to be carried out. Study of the optimum percentage of HDPE , which can replace the coarse aggregate in concrete mixture will be done to resolved this issue. (Aticin & Pierre-Claude ,2000). Evaluation of use of HDPE and fly ash will be made based on research with a variety of concrete composition attempt to be provided with aggregates while fly ash is used as an additive to concrete with different ratios.

In concrete structure, there is open voids formation in the interstitial cement and aggregate that allows distribution water, thereby reducing stress. To overcome these drawbacks, the use of additives was fly ash. Evaluation of fly ash where possible to increase the strength of concrete and reduce the pores between cement and aggregate.

2.2 High Density Polyethylene

High Density Polyethylene (HDPE) or polyethylene high-density (PEHD) is a polythelene thermoplastic made from petroleum. HDPE is commonly recycled and has the number 2 as its recycling symbol (John P, 2009). HDPE plastic-type material possesses a stronger, harder and more resistant to high temperatures. HDPE waste will usually be found in the form of pallets, drums and bottles. In addition to plastic lumber and recycled plastic furniture, recycled HDPE is used to manufacture lawn and garden products, buckets, crates, office products and automobile parts (Andriana G, 2008).

HDPE has a good chemical resistances, it is used for packaging many household, industrial chemical such as detergents, bleach, and acids (John P, 2009). HDPE plastic has several properties that make it ideal as packaging and manufactured product. HDPE density were 0.95 – 0.97 g/cm^3 higher than Low Density Polyethylene (LDPE). Characteristic of HDPE, which can sustain load, makes researchers believe it very useful to replace the portion aggregate in concrete mixture.

2.3 Fly Ash

Fly ash has physical properties which are very fine-grained, even finer compare to Portland cement. Fly ash chemically reacts with the by-product calcium hydroxide released by the chemical reaction

between cement and water to form additional bonding properties, it also as a reinforced material in concrete. (Jimmy A.2006). The use of fly ash concrete has recently ained popularity as a resource-efficient, durable, cost0effective, sustainable option for many types of Portland Cement concrete applications (Crouch L.K et, al.(2007)

Fly ash is a pozzolanic siliceous or alumina siliceous material that, in finely divided form and in the presence of moisture, chemically reacts with the calcium hydroxide released by the hydration of Portland Cement to form additional calcium silicate hydrate and other cement compounds. Thus, concrete containing Fly Ash can become denser, stronger and generally more durable long term as these admixtures can enhance and some cases can boost in early strength becomes apparent, and increase in late strength occurs (Toutanji et al., 2004).

Fly ash offers environmental advantages; it is also improve the performances and quality of concrete. Fly ash is a by-product and therefore less expensive than Portland cement; it is also known to improve workability and reduce thermal temperatures (Mindess, S et.al.2003) .Fly ash is collected from the exhaust gases by electrostatic precipitators or bag filters (Kim D. Basham, et al, 2008). Fly ash affects the plastic properties of concrete by improving workability, reducing water demand, reducing segregation and bleeding and lowering heat of hydration. This material can increases the strength, reduce permeability, reduces corrosions of reinforcing steel, increases sulphate resistances, and reduces alkali-aggregate reaction. The techniques for working with this type of concrete are standards for the industry and will not impact the budget of a job. Fly ash particles provide a great workability of the powder portion of the concrete mixture which results a greater workability and lowering of water requirement for the same concrete consistency (Thomson C, 2010).

3.0 Methodology

2.1 Material

Material used in this study consisted of Portland cement, Quarry dust replacing the fine sand, HDPE, fly ash, water and super plasticizer. HDPE are taken from Recovery Victory Sdn.Bhd with average size of 2.54 cm to 5.08cm shredded to be smaller sizes. Meanwhile, the fly ash taken from Jimah O&M Sdn. Bhd situated at Port Dickson.

The study covers only on laboratory tests by determining the compressive strength of concrete to be tested by method of preparation of a cube. HDPE are taken from Recovery Victory Sdn.Bhd with permission and support. Experiment were conducted in Laboratory of Civil engineering at Polytechnic Malacca with Compressive Strength Test

Since the samples taken from recycles, the characteristic of HDPE obtained did not resemble all the HDPE in this country. Nevertheless, since that was too much uses of HDPE in industry manufacture and factory, the HDPE that have been recycle will probably have some difference characteristics.

2.1 Experimental Design

The control group concrete designed to have compressive strength at 20Mpa. To vary the density, aggregate was replaced by HDPE at 20,30 and 40% by mass, designed as P1, P2 and P3 respectively. A sufficient amount of concrete of each group was mixed using concrete mixer. For each group, 6 samples were prepared for each cube of the ratio of concrete mix. After casting for 24h, the concrete samples were removed from the moulds and cured in water at room temperature for 7,14 and 28 days.

Tests carried out for concrete slump test and cube test. Sizes of mould were 500 mm x 500x 100mm. For comparison and analysis, the ratio of cement –sand 1:3 and 1:2 are available to make comparison of samples of different materials besides percent in the mixer. (George.R,2002).

Testing was done carefully in a laboratory off-site. The only work done on-site is to make a concrete cylinder for the compression test. The strength is measured in Mega Pascal (Mpa) and is commonly specified as a characteristic strength of concrete measured at 28 days after mixing. The compressive strength is a measure of the concrete's ability to resist load, which tend to crush it.

4.0 Discussion

Comparison between strength of these three portion shows as in Table 4. Laboratory test with moulds size if 500 mm x 500 mm x 100 mm , reveals that the strength of HDPE concrete reached at least 25 Mpa after 7 days. After 28 days, the strength is almost 38 Mpa. Each data point was average strength of 2 samples.

Table 4 : Comparison Between Strength (N/mm^2).

Time (days)	Strength (N/mm^2)		
	Portion 1 (1 ½:2:2)	Portion 2 (1 ½:2:3)	Portion 3 (1:2:4)
7	25.48	22.00	15.52
14	30.32	24.67	18.12
28	37.28	30.11	25.86

The compressive strength and normalized compressive strength of concrete containing HDPE with the control concrete are shown in Figure 1. Overall, all mix shows higher compressive strength at the beginning 7 days with the first mix the highest with 25.48 Mpa to 37.28 Mpa at 28 days or increased from 7 days about 46.3%. In the second mix, the compressive strengths of sample varied from 22 Mpa at 7 days to 30.11 Mpa at 28 days or increased from 7 days with 36.8%. in the third mix, the compressive strength of sample varied from 15.52 at 7 days to 25.86 Mpa or increased from 7 days with 66.6%.

As shown in Figure 1, using 40% of HDPE in concrete mixture can cause larger improvement in the compressive strength than that caused by using 20 and 30%. However, the first mix with 20% HDPE shows the higher compressive strength may probably due to uses of 15% of fly ash that influenced by *pozzolanic* properties of fly ash resulting in long-term strengths.

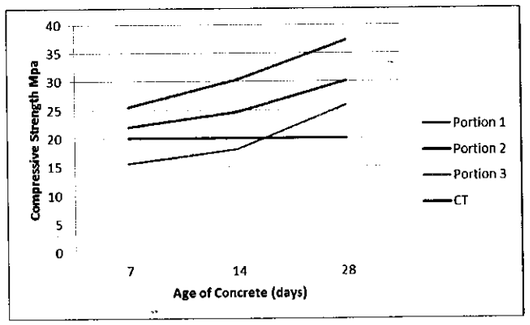

Figure 1: Relationship between compressive strength of concrete and age.

Density plays an important role in create a new lightweight concrete mixture. In this research, density of this concrete need to be less than 2000 kg/m^3. For first portion, the average density observed as 1750 kg/m3, while the second portion average density were 1896 kg/m3 and third portion with 1755 kg/m^3.

Observed from Table 5, that densities of samples in first portion are lower density than samples of the second and the third portion. This may due to the lowest use of HDPE, which are 20 percent in the first portion. Meanwhile the second portion it may have higher density due to uses of Quarry Dust in the mixture. The differences density between first mix with second mix are 8.3% and third mix are only 0.28%.

Table 5 : Comparison density between three portion.

Sample	Density kg/m)		
	Portion 1	Portion 2	Portion 3
1	1688.89	1896.30	1754.07
2	1659.26	1896.30	1748.15
3	1629.63	1896.30	1748.15
4	1718.52	1896.30	1748.15
5	1629.63	1896.30	1762.92
6	1748.15	1956.56	1754.07
Average	**1750**	**1896**	**1755**

5.0 Conclusion

Lightweight concrete must have dry densities between 400kg/m3 for aerated and 2000kg/m3 for structural lightweight concrete. While the density for normal concrete are within the range of 2000kg/m3 to 2600kg/m3. Advantages of this research by using recycled HDPE and fly ash lightweight concrete hence promote sustainable concept in construction industry. Nevertheless, as density trend rising, but it still in the range which is below of 2000kg/m3 and the result shows that the strength increase rapidly.

Fly ash has a plasticizer characteristic that can make concrete have high compressive strength. In this research, researcher had compared the strength of concrete with and without addition fly ash. It is proven that concrete cube contain fly ash has a higher strength. High density polyethylene (HDPE) has lighter weight and low density; as usual researcher choose a low density material to create innovation of new lightweight concrete. The first trial conducted, with addition of coarse aggregate and HDPE, shows that the mixture cannot be bond even with addition of fly ash. Due to the low strength achieved from the trials, researcher decided to produce lightweight aggregate concrete without usage of coarse aggregate. HDPE were used as replacement to coarse aggregate as it has advantages in terms of lightness and low density.

Based on the observation and tests have been made, researcher found that HDPE has potential to be used as a lightweight aggregate and fly ash to be used as a filler on concrete as both of these materials has resulting in higher long –term compressive strength.

At the end, researcher believe that the uses of HDPE and Fly Ash as material in the mixture of lightweight can be enlarge in new way. Hopefully there are parties that interested in this research so it can make a new move for further research with conscientious and detail. More detail of study can

be make of behaviour of HDPE and fly ash in the concrete, the aging of HDPE in concrete mixture, and the creep behaviour of HDPE in concrete structure their modulus elasticity .From observation, researches can conclude that HDPE have a high potential and can be commercial as concrete mixture that have been known by people out there.

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