SUITABILITY OF PET AS AN ALTERNATIVE FOR PARTIAL COARSE AGGREGATE REPLACEMENT

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ABSTRACT

This research is conducted to determined suitability of PET as an alternative for partial coarse aggregate replacement. In the past decade, the environmental issues have been strongly emphasized as the environmental problem is getting more severe each day. Plastic waste deserves special attention due to non-biodegradable property which makes a lot of problems in the environment. Therefore, we suggested PET as alternative for coarse aggregate replacement in order to minimize environmental problem. At the end of this research we will able to determine the suitability of PET plastic bottle as alternative coarse aggregate in concrete production, attain the structural and mechanical behaviour of PET concrete and identify the optimum strength of PET concrete as compared to conventional concrete. The tests which are used to achieve the objectives are slump test, compressive strength test, flexural strength test, and water penetration test. Different percentage of PET proportion in the concrete which are 2.5%, 5.0%, 7.5% and 10.0% was mixed out and the results of the test were compared with the conventional concrete with 0% of PET proportion. Outcomes from the test conducted shows the most suitable percentage for PET as partial replacement are 2.5% which it will gives more strength, durability and acceptable workability and water penetration depth. The reduction of the concrete strength is closely related with reduction of present of coarse aggregate in concrete mixing.

ABSTRAK

Kajian ini dijalankan untuk mengenalpasti potensi kesesuaian PET sebagai bahan alternatif untuk penggantian sebahagian agregat kasar. Dalam dekad yang lalu, isu-isu alam sekitar telah ditekankan sebagai masalah alam sekitar yang semakin teruk setiap hari. Sisa plastik memerlukan perhatian khas kerana plastik adalah bahan bukan biodegradasi yang menyebabkan timbulnya banyak masalah dalam alam sekitar. Oleh itu, kami mencadangkan PET sebagai alternatif untuk penggantian agregat kasar untuk mengurangkan masalah alam sekitar. Pada akhir kajian ini kita akan dapat menentukan kesesuaian botol plastik PET sebagai agregat kasar alternatif dalam pengeluaran konkrit, mencapai tingkah laku struktur dan mekanikal PET konkrit dan mengenal pasti kekuatan optimum PET konkrit berbanding konkrit konvensional. Ujian yang digunakan untuk mencapai objektif adalah ujian kemerosotan, ujian kekuatan mampatan, ujian kekuatan lenturan, dan ujian penembusan air. Peratusan bahagian PET yang berbeza-beza digunakan dalam konkrit iaitu 2.5%, 5.0%, 7.5% dan 10.0% dan keputusan ujian dibandingkan dengan konkrit konvensional dengan 0% daripada bahagian PET. Hasil dari ujian yang dijalankan menunjukkan peratusan yang paling sesuai untuk PET sebagai pengganti separa adalah 2.5% dimana ia akan memberikan lebih kekuatan, ketahanan dan kebolehkerjaan boleh diterima dan kedalaman penembusan air. Pengurangan kekuatan konkrit berkait rapat dengan pengurangan agregat kasar dalam pencampuran konkrit.

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σ	Stress
σ_{max}	Maximum stress

LIST OF ABBREVIATION

PET	Polyethylene terephthalate
CO_2	Carbon Dioxide
B.C	Before Century
HSC	High Strength Concrete
HPC	High Performance Concrete
UPV	Ultrasonic Pulse Velocity
PVC	Polyvinyl Chloride
HDPE	High-Density Polyethylene
LDPE	Low-Density Grade
BS	British Standard
PSM	Projek Sarjana Muda
ASTM	American Standard Test Method
DOE	Department Of Environment
MR	Modulus of Rupture

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

In the past decade, the environmental issues have been strongly emphasized as the environmental problem is getting more severe each day (Musfon et. al, 2013). One of the factors came from waste product such as paper, glass, construction waste, plastic and others. Among different waste fractions, plastic waste deserves special attention due to non-biodegradable property which makes a lot of problems in the environment (Ramadevi, 2012). Plastic contains one or more organic polymers of large molecular weight, and make themdurable and degrade very slowly, the chemical bonds that existin plastic properties make it equally resistant to natural processes of degradation. Plastics can be categorized in two major categories: thermoses and thermoplastics (Chavan et. al, 2013) Polyethylene terephthalate (PET) is one of the most common consumerplastics used especially for mineral water or soft drink use and it is widely produced by the industries due to high demanding (Savoikar, 2011).

In 2007, a world's annual consumption is reported PET drink covers of approximately 10 million tons, which presents about 250 milliards bottles. This number rise about up to 15% every year (Frigione et. al, 2011). Consequently, the number of recycled or returned bottles is very low and it will gives bad impact in environmental terminology. Among the environmental implication of these PET is its biodegradable behaviour which can remain unchanged as long as 4500 years (Chavan et. al, 2013). In the same time, disposal of this PET will affect a landfilling.In United States miles of bottles sent to landfills monthly is about 8,854.26 miles (Plastic Bottle Statistics Sources, 2008). That is shown how serious landfilling occurs due to plastic bottle. According to Howard (2012), PET also cannot be burning because emission of hazardous gaseous like Carbon Dioxide (CO_2) that will give a negative impact to the air pollution,therefore one of effective ways to handle this PET plastic bottle is by reuse this material as alternative of coarse aggregate replacement in concrete production. Concrete is most widely material used in construction as the production in over 2 billion tonne quantities per year (The Concrete Conundrum, 2008).

Therefore, it will need a large amount of PET reuse if the material is proved as an effective constituent for coarse aggregate replacement. Coarse aggregate is designation given to the larger aggregate sizes by 4.75mm retained no 4 sieve (Nmai, 1999). Approximately aggregate contains about 75% in concrete mixture (Siddique et. al, 2002). In the same time it is approximately same in size with the PET plastic bottle and seems suitable as alternative for coarse aggregate replacement.

1.2 PROBLEM STATEMENT

In recent years, industrialization has increase vigorously especially in developing countries such as Malaysia. Rapid urbanization result major problem in environmental pollution due to increasing generation of domestic and industrial waste (Olivia et. al, 2011). The major problem in township area is disposal of waste especially disposal of PET from mineral water or soft drink use. PET has cause a lot of waste as the production of it also very high in quantity. PET has created a lot of problems to environmental. PET which contains polyethylene and plastic as constituent is non biodegradable. It take a very long time to dispose. According to Chavan et. al (2013) PET take about 4500 years before completely dispose. In the other hand, burning the PET also not one of a smart action because emission of hazardous gases escape to the air that will endanger the human health. Therefore,the only suitable ways to dispose PET is by use an incinerator. However, the problem during disposed activity is PET use a big space in landfilling. It will become no space for landfilling in long term and this problem must be concerned and need an effective solution immediately before it become unsolved problem later. Therefore, this is a challenge for civil engineers to convert the PET to useful building and construction material. In the other hand, in construction work there is scarcity of good quality of coarse aggregate. In addition, quarrying activity has increasing to fulfill the needs from construction. It is feared, when one day quarrying activity also cannot satisfied for aggregate production as the construction activity in Malaysia has developed rapidly in last decade. Before this happened we need to introduce an alternative for coarse aggregate replacement. Meanwhile,there is a problem on PET disposal, it is smart idea to introduce and suggested PET as alternative for coarse aggregate replacement. Besides, it can reduce landfilling and quarrying activity it also can give more healthy air to the human population as production of PET is pollute the air. In order to suggested PET as an alternative,we need to study how effective PET towards concrete production in term of durability, strength, cost, aesthetic and many more.

1.3 OBJECTIVES

The aim of this study is to investigate the use of PET plastic bottle as coarse aggregate replacement in concrete production. PET are crushed and broken into aggregate size ranging from 4.75 mm to 10 mm. Three objectives has been identified as shown below in order to achieve the aim of this study:

- To determine the suitability of PET plastic bottle as alternative coarse aggregate in concrete production
- To attain the structural and mechanical behaviour of PET concrete.
- To identify the optimum strength of PET concrete as compared to conventional concrete

1.4 SCOPE AND LIMITATION

In order to get how effective PET as an alternative of coarse aggregate replacement there is a test required to be done such as compressive strength test, flexural strength test, water penetration test. The test is conduct to know the PET concrete performance in term of strength, durability and limitation compared to conventional concrete.

Compressive Strength Test

This test is conduct by breaking cube concrete specimens in compression testing machine and the reading is measured to get compression strength. The compressive strength is calculated from failure load divided by cross sectional area resisting the load. This test is conduct to PET concrete cube and conventional concrete cube to differentiate which sample give higher compression strength

Flexural Strength Test

Flexural strength test is one measure of the tensile strength of the concrete. In this test a beam need to be cast for PET concrete and conventional concrete. This is important to identified mechanical behaviour of the concrete as measure of unreinforced concrete beam to resist failure in bending.

Water Penetration Test

The permeability test gives a measure of porosity level in concrete and resistance of concrete against the penetration of water exerting pressure. It is normally carried out for the concrete age 28 days.

Meanwhile, limitation of this research are curing is limited from 2-3 days and the laboratory test is conducted on 7,14 and 28 days after concrete hardened.

1.5 SIGNIFICANCE OF STUDIES

Concrete the most widely used construction materials in the world. Concrete is second most utilized material in the world as water is number one. Many modifications, research and developments have been made to place industrial waste such as PET plastic bottle in building construction. Utilization of waste materials for construction shall not only solve waste problems, but also provide a new source for construction purposes. The introduction of PET as coarse aggregate replacement materials in concrete seems to be successful recently. The use of PET as a substitute for coarse aggregates in concrete mix is one option that can alleviate the sludge disposal problem.

Research and development to convert PET into useful application such as a construction material will provide more alternatives for the engineer to select the most suitable concrete replacement material for different environments. In this case, studies are needed to study the performance of concrete using PET as coarse aggregate as replacement materials. In addition, the use of PET as coarse aggregate replacement materials in concrete is not common in the Malaysian construction sector. This study will be able to enhance the understanding of the suitability of PET as coarse aggregate replacement material.

1.6 CONTRIBUTION OF RESEARCH

Expected contribution of this research is to reduce or minimize the environmental issue that we need to concerned nowadays because its getting worse by the day. Among the environmental issue are landfilling, air pollution and quarrying activity. With the use of PET as a partial coarse aggregate replacement indirectly an environmental issue as stated in problem statement can be minimized. Others, is to minimize percentage usage of aggregates in concrete mixing. It is important to find an alternative for coarse aggregate started nowadays because natural aggregate used is non renewable aggregate. It is feared when one day, natural aggregate cannot fulfill the needs of construction. Therefore one of an effective solution to handle this problem is by studies about aggregate alternatives.

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

Land filling problem due to solid waste disposal become serious nowadays. Incineration process is no longer relevant to prevent this problem because it needs a high cost of management and maintenance and also needs high technology expert. Therefore, recycling is one of the effective ways that contribute to overcome some of the solid waste problem caused by the Polyethylene terephthalate (PET) plastic bottle. Then, a lot of studies involving on this topic have been conducted in order to identify the suitability of PET as alternative of coarse aggregate and also to increase the quality of existing conventional concrete. This chapter will explain about concrete, cement, aggregate, plastic, behaviour of the concrete and also it's characteristic accordingly to the previous research as guidance.

2.1 CONCRETE DEVELOPMENT

After series of continuous research about concrete, concrete has through an evolution phase since the past decade. Evolution of concrete is very important in term of construction because concrete is the most important material in the construction world. Concrete is one of the most construction material used in the construction industry, therefore it is needed to develop or make an evolution of concrete. There are many developments that we can do such as properties of the concrete, material on the concrete, production of the concrete, strength of the concrete, development of concrete from waste and much more. Below is the example of the concrete development that had been done by the researcher. Its development is related with its purposes and hope to the concrete. Concrete long history is beginning at 12000000 B.C that discovered in Israel (Poppelreiter, 2013). Concrete is actually a phenomenon of nature.

Naturally deposited of cement compound is occurs by spontaneous combustion due to reactions between limestone and oil shale. The development and evolution of concrete continuously occur. In 1796 James Parker from England has introduced hydraulic cement, in 1904 precast concrete has been introduced and the evolution is continuous and the latest is introduce of concrete jacket that can resist corrosion for the remaining 100-year life expectancy of the bridge. Entering 20^{th} century technological changes in concrete construction grow rapidly (Schaeffer, 1992; Steiger et. al, 2005). Among the innovation occurs are advances in formwork, mixing of concrete, techniques for pumping, and types of admixtures to improve quality. All of them contribute to the improvement of concrete quality. Meanwhile, in the past century concrete mechanical and chemical properties have made great advances. Many of these were developed and have been used since the first half of the twentieth century, but are valid for today's applications and further improvements (Malinwski et. al, 1991; Ali et. al, 2001; Oss, 2005).

2.2 CONCRETE

Concrete is one of the most important construction materials in the last few decades. In general, concrete can be defined as paste of water and cement that binds with the aggregate to form a hardened material due to chemical reaction of cement and water. The basic materials used in concrete production are mainly water, cement, coarse aggregate and fine aggregate. The strength and performance of concrete are very much dependent on the quality of the material used, mix design, water cement ratio and etc. Conventionally, higher cement water ratio will reduce the strength of the concrete. Concrete with the minimum compressive strength 25kN/mm2 and above is suitable for structural use such as a beam; column, shear wall and slab, meanwhile concrete, which has a compressive strength less than 25kN/mm^2, are only suitable for non-structural use. Three types of concrete, widely used are lightweight concrete, High Strength Concrete (HSC), High Performance Concrete (HPC). (Collard-Wexler et. al, 2007)

Among the production of concrete are:

- Normal concrete

Normal compressive strength is between 10kN/mm^2-40kN/mm^2. The development of strength started after 7 days casting. Attain 70% to 85% strength after 28 days. The strength becomes 95% in 90 days. Its slump varies from 1-4 inches. It's strong in compression but weak in tension. It's not durable against severe conditions such as thawing and freezing.

- High strength concrete

Normally has low water cement ratio w/c about 0.35 or lower. Silica Fume is added in order to avoid reduction of strength in cement aggregate bond. Only good and strong aggregate is used during the concrete making as weaker aggregate may not be strong enough to resist the load imposed. Among the properties of the concrete are high strength, high workability, early age, strength and long term mechanical properties.

- Air entrained concrete

Air entrained concrete is one of the greatest achievements in concrete development. This concrete is resist to freezing and thawing action. It is prepared by adding air entrained admixtures. Normal concrete cannot sustain 3-4 cycle freezing and thawing action; whereas air entrained concrete can sustain about 100 cycle freezing and thawing. However, it has low strength compared to normal concrete.

- Lightweight concrete

Lightweight concrete has lower per unit volume compared to normal concrete. Normally the aggregate used is lighter in weight. Density of lightweight concrete is in the range 240 kg /m^3 -1850 kg/m^3. Sometimes air entrained admixture is added in order to resist thawing and freezing action. It was normally used to minimize the dead load.

2.2.1 Cement

Cement can be defined as a material with adhesive and cohesive properties. Cement is a major material in concrete composition. Not only concrete, which goes through development and evolution, cement also gone the same process. Further research and studies has made cement presents in various types with various characteristics and properties. The function of cement is to bind fine and coarse aggregate together, to fill any voids in between fine and coarse aggregate particle and to form a compact mass. There are two types of cement, hydraulic cement and non-hydraulic cement.

Hydraulic cement is any cement that can be hardens after mixed with water. Meanwhile, non hydraulic cement is the cement with the slower hardens process, although after mixing with the water. Most common hydraulic cement is known as Portland cement (Hydravler et. al, 2012).

Cement can be classified into three types;

- Natural cement

  This cement has various properties because the content of clay cannot be ensured in the range 20 to 40%. Normally brown in colour and react quickly with water

- Artificial cement

  This cement has controlled quantities of lime and clay mixed in order to ensure a product is in homogenous composition and known the properties. Among examples of the artificial cement are Ordinary Portland Cement, Portland Pozzolana Cement, Super Sulphate Cement, Rapid Hardening or High Early Strength Cement and many more.

- Special cement

  This cement serve with some specific function or purposes such as altering the setting or hardening behaviour of a concrete, modified water retention and plasticity to mortars, producing different colours for architectural purposes, and resisting the penetration of water in the walls. (Malish, 1980)

2.2.1.1 Cement Production

Cement has long production making. It is started from quarrying work until dispatch and transportation of the cement. The figure below shows flow diagram of the concrete making.

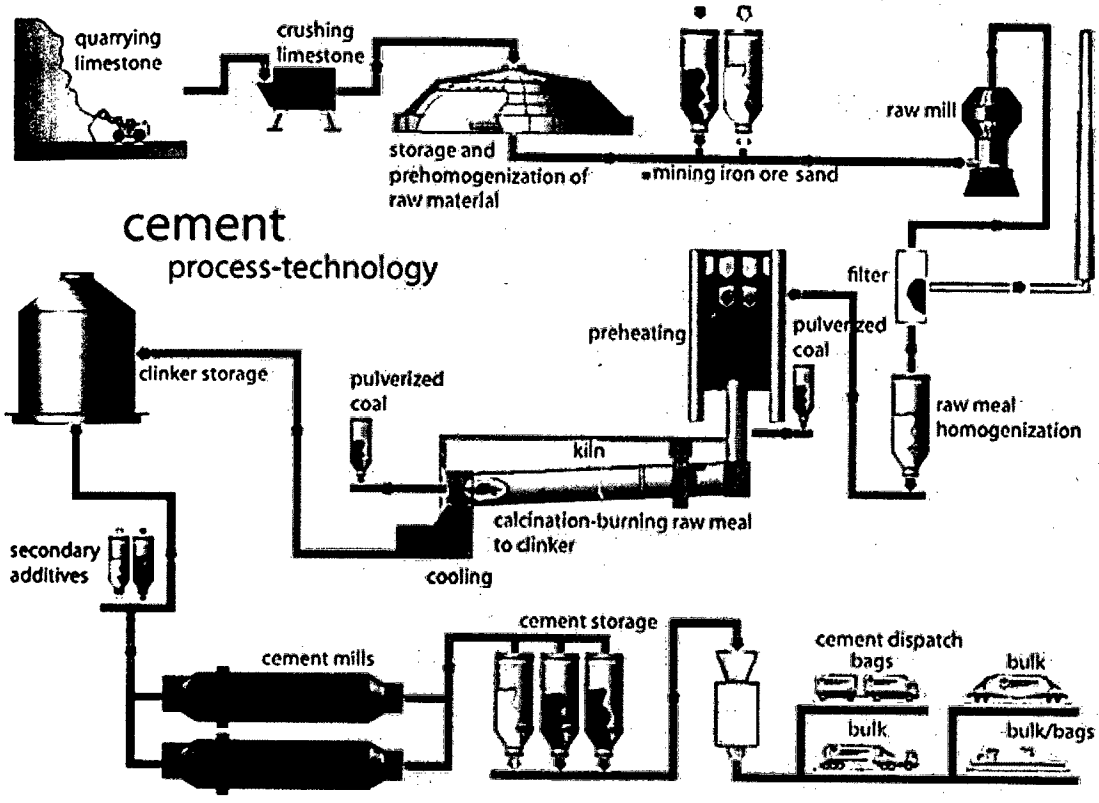

Figure 2.1: Flow Diagram of the Concrete Making

Quarrying, Dredging, and Digging

Quarrying process is by using explosives to blast the rock in order to gain limestone shale. After blasting, limestone and shale are transported to the nearby cement plant by using dump trucks or small railroad cars.

Grinding

Limestone and shale will be crushed into smaller pieces. When some of the pieces, are quite large, the pieces are then dumped into primary crushers that is reduce them to the size of a softball. The pieces are carried by conveyors to secondary crushers which crush the rocks into fragments usually no larger than 3/4 inch across.

Blending

Plant chemists will determine mineral content rock and raw materials. The proportions of each raw material also determined in order to obtain a uniform cement product. The various raw materials are then mixed in proper proportions and prepared for fine grinding.

Fine Grinding

After the raw materials have been blended, it must be ground into a fine powder form. This can be done by one of two methods:

- Wet process, or
- Dry process

Burning

Burning the blended materials is the key in the process of making cement. The wet or dry mix is fed into the kiln. As the kiln revolves, the materials roll and slide downward for approximately four hours. In the burning zone, where the heat can reach 3,000 degrees Fahrenheit, the materials become incandescent and change in colour from purple to violet to orange. Here, the gases are driven from the raw materials, which actually change the properties of the raw materials. What emerges is "clinker" which is round, marble-sized, glass-hard balls which are harder than the quarried rock. The clinker is then fed into a cooler where it is cooled for storage.