PHYSICAL, MECHANICAL AND DURABLE CHARACTERISTICS OF CONCRETE INCORPORATING POLYETHYLENE TEREPTHALATE FIBER FROM BOTTLE WASTE

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To my beloved parents: “Jawed Ahmad Usmani & Shahla Faizan”

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ABSTRACT

High consumption of plastic based products especially polyethylene terephthalate (PET) bottles had increased the volume of polymeric waste which in turn causing environmental problems. With the increase of awareness in sustainable development, researchers have come out with an idea of utilizing plastic waste fiber which is believed to offer some benefits such as waste reduction and resource conservation. In this research an attempt has been made to investigate the physical, mechanical and durability characteristics of concrete incorporating PET fibers from recycled bottle wastes and was exposed to acid and sulphate attack At the first stage, fiber length of 10mm, 20mm and 30mm with 0.5% of fiber content was included into the concrete matrix to find out the optimum length of fiber to be used. Once the typical best length was determined, the fresh and hardened properties of concrete including workability, density, compressive strength, splitting tensile and flexural strength are determined with fiber volume range of 0.5% - 1.5%. The results revealed that the presence of PET fiber in concrete noticeably decreased the density and workability of concrete. Although a small amount of fibers increased the compressive strength, higher amount caused a reduction in compressive strength. However, the splitting tensile and flexural strength as well as the ductility of concrete were greatly enhanced. The concrete exposed to acid attack showed characteristic yellowish colour and for sulphate it combines with C-S-H or concrete paste and destroys the paste. Out of this study, the optimum length and fiber volume determined were 20mm and 0.5% fiber volume fraction respectively. In conclusion, the PET fibers in concrete provided satisfactory performance showing good potential in concrete construction.

ABSTRAK

Konfigurasi Penggunaan produk plastik yang tinggi terutamanya botol polyethylene terephthalate (PET) telah menyumbang kepada peningkatkan jumlah sisa polimer, seterusnya menyebabkan pencemaran alam sekitar. Selaras dengan peningkatan kesedaran dalam pembangunan lestari, para penyelidik telah menyumbangkan idea dalam memanfaatkan penggunaan gentian sisa plastik yang dipercayai mendatangkan pelbagai faedah seperti pengurangan sisa dan pemulihan sumber. Dalam kajian ini satu percubaan telah dibuat untuk menyiasat sifat-sifat fizikal dan mekanikal konkrit segar dan keras dengan menggabungkan PET serat daripada bahan buangan botol ke dalam campuran konkrit. Pada peringkat pertama, panjang gentian daripada 10mm, 20mm dan 30mm dengan 0.5% kandungan gentian telah dimasukkan ke dalam matriks konkrit untuk mengetahui panjang optimum serat yang akan digunakan. Setelah panjang tipikal serat telah ditentukan, sifat-sifat segar dan keras konkrit yang terdiri daripada kebolehkerjaan, ketumpatan, kekuatan mampatan, tegangan membelah dan kekuatan lenturan dikaji dengan pelbagai kanduangan gentian dari 0.5%-1.5%. Hasil kajian menunjukkan bahawa kehadiran gentian PET dalam konkrit nyata mengurangkan ketumpatan dan kebolehkerjaan konkrit. Kandungan gentian konkrit yang sedikit meningkatkan kekuatan mampatan, namun kenaikan selanjutnya menyebabkan pengurangan dalam kekuatan mampatan. Walau bagaimanapun, tegangan membelah dan kekuatan lenturan serta kemuluran konkrit telah banyak dipertingkatkan. Daripada kajian ini, panjang dan peratusan gentian yang optimum adalah 20mm dengan 0.5% kanduan gentian. Kesimpulannya, serat PET dalam konkrit memberikan prestasi yang memuaskan serta mempunyai potensi yang baik dalam industri konkrit.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

FRC	-	Fiber reinforced concrete
PET	-	Polyethylene Terephthalate
M30	-	Concrete grade of 30N/mm^2
PC	-	Plain concrete
PET-FRC	-	Fiber reinforced concrete with polyethylene terephthalate fiber
PET-FRC10	-	Fiber reinforced concrete with 10mm long polyethylene terephthalate fibers
PET-FRC20	-	Fiber reinforced concrete with 20mm long polyethylene terephthalate fibers
PET-FRC30	-	Fiber reinforced concrete with 30mm long polyethylene terephthalate fibers
PET-FRC0.5	-	Fiber reinforced concrete with 0.5% polyethylene terephthalate fibers
PET-FRC1.0	-	Fiber reinforced concrete with 1.0% polyethylene terephthalate fibers
PET-FRC1.5	-	Fiber reinforced concrete with 1.5% polyethylene terephthalate fibers

APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background Information

Concrete is a composite material, primarily consists of three basic elements which are cement, aggregate and water. Concrete is relatively good in compression but weak in tension. Concrete tends to fail in a brittle manner due to its low tension resistance. To overcome some of the bitter properties of the concrete, reinforced concrete was introduced. Steel reinforcement bars are added into the concrete as an improvement to the tensile strength and made it more ductile. However, steel reinforcement prone to experience corrosion which greatly reduces the strength and durability of concrete. Thus, the attempts to improve the properties of concrete have never stopped. Besides steel reinforced concrete, a new invention of construction material called fiber reinforced concrete (FRC) has been introduced as well. In FRC, discrete fibers are added into a cement base matrix with an ordered or random distribution manner. In construction technology, there are many types of fibers like steel, carbon, aluminum, wood, glass, and others that can be introduced into concrete mix. Such type of concrete has wide varieties of applications in civil engineering field.

Polyethylene terephthalate (PET) is a member of the polyester family of polymers and it play an important role as synthetic fiber in industrial production. PET gains its population due to its physical characteristics which are lightweight,

colourless in natural state, semi-crystalline resin, excellent water and moisture barrier and impact-resistant where it is less breakable than other materials. Due to these characteristics, PET had become increasingly paramount among the manufacturers and consumers. The world's PET production rate is relatively high, resulted in high volume of waste production in which its annual consumption rate represents more than 300,000 million units and most of the waste is discarded to landfill. PET waste is a non-biodegradable material which do not undergo decay process, remained in nature for hundreds of years (Irwan *et al*., 2013). This issue has become a big headache for environmentalists. Since then it had drawn tremendous interest among the researches. Efforts and attempts have been made to explore their potential in concrete whether it can improve the mechanical properties of the concrete. Although the development of recycled PET fibre in concrete is considered relatively new invention but it is believe to benefit both construction and PET recycling industries if the utilization of PET fibre is being verified.

1.2 Problem Statement

Concrete is a composite material, primarily consists of three basic elements which are cement, aggregate and water. In the field of civil engineering, concrete is considered as a miraculous man made material which widely use in developed and developing country. Concrete is the backbone of the whole world's infrastructural development (Nibudey *et al.*, 2014). Concrete possesses a lot of good properties such as relatively high compressive strength, durability, low coefficient of thermal expansion, versatility and impermeable. However, there is an inherent weakness found in the concrete that is low tensile strength. Concrete tends to experience a sudden failure in brittle manner due to its inherent low tension resistance. Such kind of failure is extremely unfavorable in structural design as it does not indicate any prior sign of failure. Crack and creep also tend to form when it is subjected to shrinkage or tension and long-duration of applied forces.

Consumption of plastics had become an integral part of humans' lives now a day. YIN Shi *et al*. (2013), has stated that considerable growth in the world population in the last few decades has led to significant demand for low cost living and turn out to huge plastics production and consumption. According to Plastics Europe (2013), the plastic industry had experienced a growth with a year on year expansion of 8.7% in 50 years starting from1950 to 2012. Although the properties of plastic such as relatively cheap, durable and versatile material which have brought benefits to society in terms of economic, however, plastic waste do impose negative environmental impacts. Generally, the increase in plastics production rate has contributed to the high volume of waste generation which in turn may affect the human health, wildlife and ecosystem.

Waste plastic is being the most prominent among the significant amount of non-biodegradable solid waste. Among all different form of plastics, PET is a well-known materials used in food and beverage packing products and mostly majority of these products end up discarded to the landfill. These PET products such as PET bottles will not decay and remain in the environment for a very long duration of time which may trigger air watered ground pollution. Besides, to destroy it, treatment method through incineration can be carried out because plastic has low melting point. Nevertheless, by mean of incineration, the moment the plastic is exposed to heat; toxic gases will be emitted and could be highly dangerous to human health.

As a result of environmental impact associated with the increase in the general awareness of waste management, the construction industry is encouraging the use of recycled waste materials to be added as a supplement to increase the desire properties of concrete. Researches are putting much efforts and attempts to investigate the utilization of waste fibers into the concrete mass in order to sustain and protect the ecosystem. The addition of recycled PET fiber reinforced concrete has attracted widespread attention. The development of new PET fiber construction materials in concrete is still considerably new and is in doubt as the physical and mechanical properties are still under preliminary study. It is still a major challenge to produce recycled plastic reinforced concrete with sufficient mechanical properties.

As such, the use of recycled PET as short fibers reinforcement in structural concrete is ought to be further investigated.

1.3 Objectives of Research

The aim of this research is to study the physical, mechanical and durability properties. The objectives of this research are as follow:

1. To study the fresh properties in terms of workability of concrete.
2. To study mechanical properties in terms of density, compressive strength, tensile strength and flexural strength.
3. To study the durability behavior in terms of resistance to chloride, sulphate and acid attack of concrete containing PET fibers.

1.4 Scope of Research

To achieve the objectives of the study, it needs to conduct some laboratory works. This research will be carried out in Structure and Materials laboratory of the Faculty of Civil Engineering, University Teknologi Malaysia. The duration of this research is set to be completed in 90 days by immersing in different solutions. The concrete grade used in this research is M30 and without any additional of chemical admixtures. All the specimens were tested for 7, 14 and 28 days of curing. This research focuses on the following:

1. The effect of different PET fibers volume fraction range from 0.5%-1.5% towards the fresh properties of concrete. The property studied is workability.
2. The influence of different percentage of PET fibers range from 0.5% - 1.5% towards the hardened state properties of concrete. The properties studied

include density, compressive strength, flexural strength and splitting tensile strength.

1.5 Significance of Research

PET is one of the most prominent forms of plastic in which its production rate is kept on increasing and resulted in a large amount of plastic waste discarded to the landfill, creating a serious problem to our future ecosystem. Hence, the idea of using recycled PET fiber as short fibers reinforcement in concrete will be an effective contribution to the preservation of the environment. Besides, it is believe to benefit the construction industries as well. The idea of using recycle PET fiber not only aims in reducing the PET waste disposal to the environment and reuse it as useful material, but also aims to increase the mechanical properties of concrete by adding PET fiber in concrete. PET fibers will help in energy absorption and delaying the propagation of micro cracks in the concrete during loading. In addition, as PET fibers are abundantly available, cheaper and lighter, hence the construction cost will be much economical and conservational in resources. In addition, the inclusion of PET fiber in concrete will not trigger any corrosion problem as steel does. Apart from that, the findings of this research can also help in promoting environmental awareness, creating a more sustainable construction in the construction industry.

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