COMPARISON STUDY OF USING DIFFERENT CURING CONDITION OF TIRE POWDER RUBBER IN CONCRETE

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ABSTRACT

Motorcar waste tyre has a steady increase in its generation annually in Malaysia. The number of motorcar waste tyres generated annually in the country was estimated to be 8.2 million or approximately 57,391 tons in the year 2006. In addition to this, 60% of the waste tyres are disposed via unknown routes. Waste tyres in Malaysia are neither categorized as solid waste or hazardous waste. Currently it is just generalized as trade waste. Since there isn't any law or regulation which governs waste tyre management, we have decided to use this material. From the previvors studied it shows that Tire waste is non-environmentally friendly which consist of a complex structure. A structure that is unbreakable by nature normal reaction and unable to be recycled. This work determines the mechanical properties of concrete after partial sand replacement and compare the effect of using two types of concrete curing which are water curing and salt curing in compressive strength and flexural strength. The tyre waste used in this research is grinded into powder form and then used partially to replace sand in a concrete mix design to find its suitable percentage to be used to gain the optimum strength. The concrete cubes tested in this research are sized at (150mm x 150mm x 150mm) each and tested at different percentage of sand replacement. The cubes are casted at a 0% (controlled cube), 5% and 10%. Each percentage had 9 identical cubes casted to get an average data that was tested on the 7th and 28th day since it was casted. Moreover, for flexural test, 18 beams size 500mm x 100mm x 100mm Flexural strength decreased with increasing tyre rubber replacement. Eearly strength shows that salt curing produced concrete with higher compressive and flexural strength and the best result go for control.

ABSTRAK

Tayar sampah bermotor mempunyai peningkatan yang mantap dalam penjanaannya setiap tahun di Malaysia. Bilangan tayar sisa kenderaan tahunan yang dihasilkan di negara ini dianggarkan berjumlah 8.2 juta atau kira-kira 57,391 tan pada tahun 2006. Tambahan pula, 60% tayar buangan dibuang melalui laluan tidak diketahui. Tayar sisa di Malaysia tidak dikategorikan sebagai sisa pepejal atau sisa berbahaya. Pada masa ini ia hanya menjadi umum sebagai sisa perdagangan. Oleh kerana tidak ada undang-undang atau peraturan yang mentadbir pengurusan tayar sampah, kami telah memutuskan untuk menggunakan bahan ini. Daripada pencahayaan yang dikaji ia menunjukkan bahawa sisa Tirus tidak bersifat mesra alam yang terdiri daripada struktur yang kompleks. Struktur yang tidak dapat dipisahkan oleh tindak balas normal semula jadi dan tidak dapat dikitar semula. Kerja ini menentukan sifat mekanik konkrit selepas penggantian pasir separa dan membandingkan kesan menggunakan dua jenis pengawetan konkrit iaitu pengawetan air dan pengawetan garam dalam kekuatan mampatan dan kekuatan lenturan. Sisa tayar yang digunakan dalam penyelidikan ini digali ke dalam bentuk serbuk dan kemudian digunakan sebahagiannya untuk menggantikan pasir dalam reka bentuk campuran konkrit untuk mencari peratusan yang sesuai untuk digunakan untuk mendapatkan kekuatan optimum. Kukuk konkrit yang diuji dalam kajian ini bersaiz pada (150mm x 150mm x 150mm) masing-masing dan diuji pada peratusan yang berlainan penggantian pasir. K kubus dilemparkan pada 0% (kiub terkawal), 5% dan 10%. Setiap peratusan mempunyai 9 kiub yang sama yang dicoret untuk mendapatkan data purata yang diuji pada hari ke-7 dan ke-28 sejak ia dipecat. Selain itu, untuk ujian lenturan, 18 saiz rasuk 500mm x 100mm x 100mm Kekuatan fleksibel menurun dengan penggantian getah tayar yang semakin meningkat. Kekuatan yang kuat menunjukkan bahawa pengawetan garam dihasilkan konkrit dengan kekuatan mampatan dan lenturan yang lebih tinggi dan hasil yang terbaik dapat dikendalikan..

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LIST OF SYMBOLS

SBPWM	Simple Boost Pulse Width Modulation
˚C	Degree Celsius
%	Percentage
Δ	Tolerance to Accommodate fixing precision
G	Grade

LIST OF ABBREVIATIONS

SBPWM	Simple Boost Pulse Width Modulation
OPC	Ordinary Portland cement
ASTM	American Society for Testing and Materials
FKASA	Fakulti Kejuruteraan Awam dan Sumber Alam
UTM	Universal Testing Machine
UMP	Universiti Malaysia Pahang
US	United State
w/c	Water-Cement ratio
L	Lit
cm2/g	Centimeter square per gram
s/c	Sand-Cement ratio
H	Hour
Mm	Milimeter
Kg/m3	Kilogram per meter cube
CSH	Calcium Silicate Hydrate
CH	Calcium Hydroxide
CO2	Carbon Dioxide
SO3	Sulphur Trioxide
MgO	Magnesium Oxide
kN	kilo Newton
kN/s	kilo Newton per second
kPa	kilo Pascal
ºC	Degree Celcius
Mw	Saturated Weight
N	Newton

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The management of waste material is a problem worldwide. In the developing countries, waste management is becoming an acute problem and in Malaysia there are many waste materials being generated daily that demands immediate attention. This has to be taken into serious consideration by the authorities and management because Malaysia is categorized as an emerging industrialized country among countries like China and South Korea (Von Lina Lau, 2004). Tyre dealers face considerable pressure when the waste tyres produced accumulates at their premises, often causing improper place of disposal of the tyre waste. These tyre dealers usually don’t have any assistance from their principals or authorities for proper management and disposal of waste tyres Von Lina Lau (2004).

In the past, tires were burned to avoid this accumulation in stockpiles. The tire fires were difficult to extinguish and would release harmful chemicals into the environment resulting in regulations making it illegal to do so in many countries. With approximately 3663 thousand metric tons of tires generated in 2015 in the United States alone, it is critical to continue finding innovative ways to use this waste material (TMA (U.S. Tire Management Association) 2017).

Ultimately, the purpose of this study was to assess the use of recycled tyre particles as a replacement of fine aggregate which is sand with tyre waste powder or crumbs. The effects of replacement on fresh and hardened concrete properties were determined. In each instance, the fine aggregate, sand, was replaced volumetrically in 5% increments up to the maximum of 10%.

Through this study, we will be working on determining concrete strength on each cube, type of failure on each cube All the cubes at different sand replacement percentage will be tested to compare the concrete strength of the cubes. The type of crack on the cubes will be determined. Therefore, in the end of this study, the feasibility of using rubber tyre waste as partial replacement of fine aggregate in concrete will be verified.

1.2 Problem Statement

Daily, there are tons of tire waste being produced worldwide and even in Malaysia. These tire wastes are stored and doesn't have proper disposal methods. With the rapid usage of automobile in Malaysia the number of cars has increased substantially in the last decade and reached over 120 million in 2016. The weight of waste rubber from tyre wastes is about 15 million tons at present which is very big concern to the authorities. Waste rubber disposal is a major environmental concern in Malaysia, mainly due to this material being a non-decaying material. Stockpiling of these materials is very dangerous because it presents a fire hazard and provides breeding ground for rats, mice and mosquitoes (Liu Rixin, and Lei Zhang, 2015).

The question of suitability of tyre waste material being used as sand replacement is asked because of the properties of tyre waste being an aggregate in concrete. The effects of tyre waste in concrete have been tested in previous studies but not till an extend of knowing its suitability in using tyre waste as sand replacement in concrete for construction purposes.

The vehicle tires which are disposed to landfills constitute one important part of solid waste. Stockpiled tires also present many types of, health, environmental and economic risks through air, water and soil pollution. The tires store water for a long period because of its particular shape and impermeable nature providing a breeding habitat for mosquitoes and various pests. Tire burning, which was the easiest and cheapest method of disposal, causes serious fire hazards. Once ignited, it is very difficult to extinguish as the 75% free space can store lot of free oxygen. In addition, the residue powder left after burning pollutes the soil. The oil that is generated from the melting of tires can also pollute soil and water. An estimated 1000 million tires reach the end of their useful lives every year. At present enormous quantities of tires are already stockpiled (whole tire) or landfilled (shredded tire), 3000 million inside EU and 1000 million in the US. By the year 2030 the number of tires from motor vehicles is expecting to reach 1200 million representing almost 5000 million tires to be discarded in a regular basis. Tire landfilling is responsible for a serious ecological threat. Mainly waste tires disposal areas contribute to the reduction of biodiversity also the tires hold toxic and soluble components. Secondly although waste tires are difficult to ignite this risk is always present. Once tires start to burn down due to accidental cause's high temperature take place and toxic fumes are generated besides the high temperature causes tires to melt, thus producing oil that will contaminate soil and water.

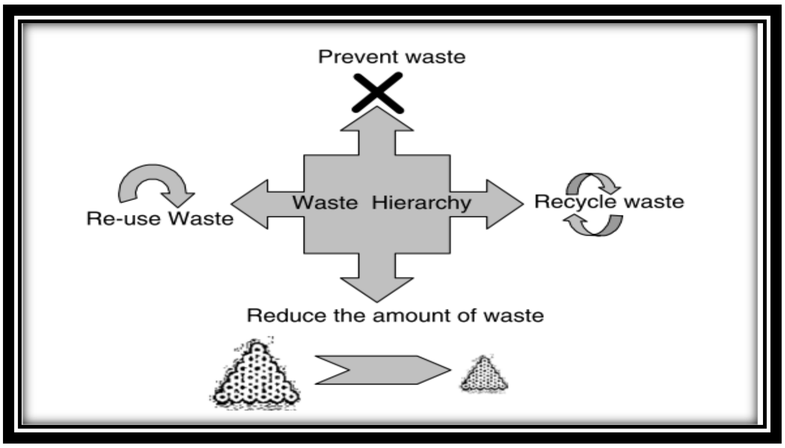

Figure 1. 1: Waste Hierarchy

1.3 Objective of Study

i. To identify the suitability of tier waste in concert production.
ii. To compare the effect of using two types of concrete curing which are water curing and salt curing in compressive strength.
iii. To compare the effect of using two types of concrete curing which are water curing and salt curing in flexural strength.

1.4 Scope of Research

This investigation focuses on the mechanical properties of tier waste powder in concert production. In this study there is one size of the powder are used to replace fine aggregate in concrete with 5% and 10% of replacement. Two types of curing process are used which are water curing and salt curing. This study aimed to investigate the compressive and flexural strength of concrete. Slump test was conduct for each mix of fresh concrete.

1.5 Significance of Research

The main motive of this research is to reduce the environmental pollution that is caused by the accumulation of waste tyre in many parts of Malaysia. Besides that, we can also save the space that is used in storing these waste tyres and transforming the waste into fortune. This can be made possible if waste tyres are recycled and used in the industry for other purposes such as replacing sand partially in concrete. This will eventually reduce the usage of river sand in the construction industry and subsequently save the environment.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

After water, concrete is the most broadly utilized construction material on the earth Gambhir (2004), with a worldwide consumption rate of around 25 x 109 metric tons per year. In generating concrete, the materials used are basically by mining Earth's resources and what better way of saving the environment than to recycle waste materials. There are probably many ways of a cleaner and more proficient management of different types of waste generation is getting more consideration in order to keep up sustainability in green construction.

In this chapter, all information's regarding this research and study are briefly discussed, explained and supported with several reviews from various sources of journals, reference books and articles. The question of if these tyre wastes are properly managed, if replacing tyre waste partially with sand will be suitable and the optimum mix design of tyre waste modified concrete will be discussed in detail in this chapter.

2.2 Tyre Waste Generation

2.2.1 Tyre Waste Generation Globally

In recent years, waste rubber disposal has been a major environmental concern and waste rubber has become one of the most difficult components of the waste stream to manage. In the US alone, approximately 273 million scrap tires are generated annually. In addition, approximately 3 billion used tires are currently stockpiled throughout the country Rixin Liu & Lei Zhang, (2015). Millions of waste tyres are produced each year around the world. In the USA, Zaiton (2014) estimates that 200 million tyres accumulate annually. With that tyre waste can be re-treated to prolong their useful life they are eventually scrapped. Only a very small fraction of finely divided scrap tyre can be used in the manufacture of new tyres. Tyres have been stockpiled in massive land dumps where they pose a serious fire risk. This is a worldwide problem. Once alight they are often impossible to extinguish, generating vast quantities of smoke, toxic fumes, oils and liquids. In warmer climates there is an additional disease risk from mosquitoes breeding in rain-water pools in tyres. Mandal, A., & Rooby, J. (2016).

2.2.2 Tyre Waste generation in Malaysia

Malaysia, like most of the developing countries, is facing an increase of the generation of waste and of accompanying problems with the disposal of this waste. Overall, the local communities generate 16,000 tons of domestic waste per day and the amounts per capita vary from 0.45 to 1.44 kg per day depending on the economic status of the areas concerned. In an average in Malaysia, the waste generated is about 1 kg per capita per day. Waste is usually grouped into three groups, which are solid waste, medical waste and hazardous waste Von Lina Lau (2004). Tyre wastes in Malaysia are not categorized in any of these three groups of waste but it’s more likely to be known as business or trade waste where there isn’t any law or regulation that governs tyre waste management.

Tyre dealers or workshops face a huge problem in disposing these wastes as they don’t have a proper way of actually disposing it other than piling it up at an open landfill or somewhere around their premises until a proper use of these used tyres come into place. This will eventually lead these dealers into receiving summons or penalties from local authorities for not being able to dispose these used tyres in a proper manner. They eventually lack guidance and assistance for proper management or disposal of waste tyres.

There are some public waste collectors that actually collects these tyres at a certain price, but it is still unknown to what extend these tyre wastes are actually being taken care of in an environmentally friendly and legal way. Gateway fees at landfill for disposing tyre wastes are very expensive as many private rubbish collectors have complained about the unattractive landfill gateway fees Sandra Kumar (2006).

2.3 Tyre Waste Rubber in Concrete

Concrete is one of the most commonly used construction materials in India because of its high compressive strength, long service life, and low cost. Concrete requires 3 essentials ingredients - cement (the binder), aggregates (ranging in size from fine to coarse) and water. Concrete's constituent materials are available naturally in all parts of the world. With the increasing requirement of concrete, these materials are getting deficient. It is thus a matter of serious concern for the civil engineers and they are searching for suitable materials which can fully or partially replace these materials. Keeping in view the disposal issues of plastic waste, and increasing demand for concrete, its utility in concrete has been studied and investigated by various researchers. Properties of concrete are affected by inclusion of plastic waste.

Workability of concrete with plastic waste decreases gradually with increasing plastic waste percentage. Similar observations of decrease in workability have been reported by Kumar et al. (2006) who used plastic bags in fibre form to replace cement concrete. However, Ghataora, G. S., & Dirar, S. (2015) reported slight improvement in workability with recycled plastic bag waste as replacement of sand in concrete. Systematic reduction in compressive strength has been observed with the increase in plastic waste content in concrete by some researchers. Borg et al. used PET fibres in concrete and reported that the PET fibres lead to a reduction in compressive strength with increasing fibre volume fractions. However, Al-Hadithi and Hilal (2016) carried out an experimental study using waste plastic fibres in self compacting concrete and reported the increase in compressive strength with increasing amount of waste plastic.

Flexural strength of plastic concrete is also influenced by the inclusion of plastic waste. It has been reported in the literature that flexural strength decreases with the increase of plastic waste content. However, Ramadevi and Manju (2012) reported that flexural strength of the specimens containing PET waste increased gradually with increase in the replacement percentage. Detailed studies have also been carried out for finding the effect of addition of plastic waste on modulus of elasticity of concrete and it was shown that modulus of elasticity decreased with the increase in plastic waste content. Yang et al. (2015) used recycled polypropylene waste in self-compacting concrete to replace sand and reported the decrease in elastic modulus with an increase in plastic content. However, Haneefa, K. M. (2019) reported slight increase in elastic modulus on using recycled high-density polyethylene plastic fibres in structural concrete. It is evident from the work reported that though a number of studies are available on utilization of plastic waste in concrete, most of studies are limited to mechanical properties of concrete containing plastic waste. Effects on properties of concrete like abrasion resistance, water permeability and dynamic modulus of elasticity has not been reported comprehensively. This study focuses on the mechanical properties of tier waste powder in concert production. In this study there is one size of the powder are used to replace fine aggregate with 5% and 10% replacement in concrete. Two types of curing process are used which are water curing and salt curing. This study aimed to investigate the compressive and flexural strength of concrete. Slump test was conduct for each mix of fresh concrete.

2.3.1 Effect of Tyre Waste Rubber in Concrete

During the last 20 years, significant research work has been carried out to recycle the used tyres by grinding them into small particles rubber aggregates and also by obtaining steel fibres, and to use them in cement-based materials like concrete by Hernández et al., (2018).

Results of various research studies indicate that mechanical properties (such as compressive, splitting tensile and flexural strength) of concrete are degraded in the presence of rubber aggregates. In opposite to that strain capacity of cement-based materials is significantly increased by the addition of rubber aggregates Turatsinze et al., (2012). confirmed that rubber aggregate incorporation improves the strain capacity of concrete before macro-crack localization.

In the present state of knowledge, information about fundamental fracture properties of rubberized concrete is limited. The addition of rubber aggregates in the concrete, brittleness index (BI) increases while compressive strength and toughness decrease. When resistance to the cracking due to imposed deformation is a priority, use of rubber aggregates should be considered as a suitable solution to improve durability in order to reduce maintenance expenses and an opportunity to recycle used rubber tyres.

Bompa & Elghazouli (2019) have investigated the creep response and long-term strength properties of unconfined and FRP confined concrete materials incorporating relatively high proportions of recycled tyre rubber particles. FRP-confined rubberized concrete materials provided with relatively high rubber content, as well as of high-strength conventional concrete from which the rubberized concrete was derived. A full account of creep tests carried out under sustained axial compression, and of material tests focusing on the complete constitutive response of the materials investigated, was given. The key observations are outlined below. The compressive strength of the considered rubberized concrete material with 60% volumetric rubber replacement was about one-tenth of the reference conventional concrete from which it was derived, yet it exhibited enhanced energy dissipation and comparatively ductile response. External confinement measures by means of FRP recovered a significant proportion of the strength lost due to the presence of rubber and enhanced the deformation characteristics further. The compressive strength-time curves for both unconfined rubberized concrete and its reference concrete followed similar logarithmic trend lines, with 18% and 10% increase in strength over one year after casting, respectively. For confined elements, along with inherent experimental variations, the hardening of the epoxy resin may have increased the stiffness of the jacket with time, allowing less dilation under axial loading leading to a reduction in strength and deformation. For two layers of FRP-confinement, the confined-to-unconfined compressive strength ratio of the rubberized concrete with 60% rubber replacement was 4.9 at 28 days. After a year from casting, these ratios were 4.0

for non-loaded control specimens and 3.5 for specimens subjected to an axial load ratio of 20%. At stress-to-strength ratios within the linear creep range, about a year after loading, the creep strains of the high-strength conventional concrete were 35% lower than that of the rubberized concrete elements. For the same stress-to-strength ratio, creep strains of FRP-confined rubberized concrete were higher than those of unconfined rubberized concrete by a factor of 2.80.

Although the stress-to-confined strength ratio was 0.20, for the FRP-confined concrete, the applied stress corresponded to a strain level within the crushing and non-linear creep ranges of the unconfined material, leading to an unstable crushing propagation throughout the concrete core, which increased the creep strains for the confined elements. Comparative assessment indicated that Eurocode 2 offers relatively conservative estimates of the creep coefficient for stress-to-strength ratios within the linear creep range for high-strength conventional concrete and confined rubberized concrete. However, it provides overly-conservative estimates for rubberized concrete, particularly since its concrete strength is outside of the codified model ranges.

2.3.2 Effect of Tyre Rubber as Replacement on Concrete

Research conducted by Siringi et al (2013) showed that an incorporation of a fine rubber content of 15% (as replacement for crushed sand by volume) would improve the workability of concrete slightly. Results by Sgobba et al (2010) for concrete with rubber ash also found good workability values and a high quantity of entrapped air.

Moreover, Sgobba et al (2010) found that concrete with 100% natural aggregate replacement with both fine and coarse rubber aggregate had an appreciable water requirement, attributed to the low specific gravity of the concrete and a high specific surface area of the rubber particles.

Wakchaure & Chava (2014) note in their literature review that research “conducted by Ki sang son et al gives slightly lower compressive strength and modulus of elasticity. But energy absorption capacity and ductility increase. Therefore, this type of concrete is suitable for seismic application. Wakchaure & Chava (2014) further point out that research conducted that using rubber aggregates concrete has ameliorative effects on the sound absorption, heat transfer and weight of concrete.

The incorporation of fine rubber aggregates into concrete yields concrete enhanced ductility as noted by Issa and Salem (2013), which is advantageous for use in highway barriers and other similar shock resting elements. However, the authors go on to remark that the rubberized “material is unpredictable, with its failure stress strain relationship not following a fixed pattern in experiments at some point. Compressive strength results comparable to the control cubes were recorded for fine rubber content lower than 25% in replacement of crushed sand.

Contrary to the results obtained by most authors, the research conducted by Siringi et al (2013) found that a 15% replacement in fine content of concrete with fine rubber crumbs would yield a 5% increase in the compressive strength of concrete compared to control results. Albeit noting a decrease in the splitting tensile strength and modulus of rupture (by an average of 12%) with an increase in rubber.

content. Siringi et al (2013) further remark that increased strain at failure, good energy absorption, improved modulus of toughness, and ductility are observed in rubberized concrete. With Typical concrete brittle failure not being observed in rubberized concrete.

Antil (2014) has conducted an experimental study on rubberized concrete. The test results of this study indicate that there is great potential for the utilization of waste tyres in concrete mixes in several percentages, ranging from 5% to 20%. Based on present study, the following can be concluded that the strength of modified concrete is reduced with an increase in the rubber content; however lower unit weight meets the criteria of light weight concrete that fulfill the strength requirements as per given in table 5.9 by Neville in 1995. Concrete with higher percentage of crumb rubber possess high toughness the slump of the modified concrete increases about 1.08%, with the use of 1 to 10% of crumb rubber. Stress strain shows that concrete with a higher percentage of crumb rubber possess high toughness, since the generated energy is mainly plastic. Failure of plain and rubberized concrete in compression and split tension shows that rubberized concrete has higher toughness. The split tensile strength of the concrete decreases about 30% when 20% sand is replaced by crumb rubber. The flexural strength of the concrete decreases about 69% when 20% sand is replaced by crumb rubber. The compressive strength of the concrete decreases about 37% when 20% sand is replaced by crumb rubber. For large percentage of crumb rubber, the compressive strength gain rate is lower than that of plain concrete.

There are numerous researches reports available on the mechanical and chemical properties of cement concrete. However, the research works carried out for the rubberized cement concrete are found to be limited. The available results indicate that the influence of the size, proportion and surface texture of rubber particle on the strength of concrete contaminating tyre rubber is significant. Zheng et al. (2008) worked on rubberized concrete and replaced the coarse aggregate in normal concrete with ground and crushed scrap tyre in various volume ratios. Ground rubber powder and the crushed tyre chips particles range in size from about 15 to 4 mm were used. The effect of rubber type and rubber content on strength, modulus of elasticity was tested and studied. The stress – strain hysteresis loops were obtained by loading, unloading and reloading of specimens. Brittleness index values were calculated by hysteresis loops. Studies showed that compressive strength and modulus of elasticity of crushed rubberized concrete were lower than the ground rubberized concrete. Taha et al. (2008) used chipped tyre rubber and crumb tyre rubber to replace the coarse and fine aggregate respectively in the concrete at replacement levels of 25%, 50%, 75%, and 100% by volume. The tyre rubber was chipped in two groups of size 5 to 10 mm and 10 to 20 mm. the crumb tyre rubber of size 1 to 5 mm was used. These were mixed with a ratio of 1:1. Salem (2013) determined the hardened properties of concrete using different types of tyre rubber particle as a replacement of aggregate in concrete. The different types of rubber particles used were tyre chips, crumb rubber and combination of tyre chips and crumb rubber. These particles were used to replace 12.5%, 25%, 37.5%, and 50% of the total mineral aggregate by volume. The results showed that the fresh rubberized concrete had lower unit weight and workability compared to plain concrete.

Fernández-Ruiz et al. (2018) the effect of using epoxy resin and ground tyre rubber replacement for cement in concrete. Compressive behavior and durability properties has studied Concrete mixtures with different percentages of replacement of cement have been produced. They have concluded that using of ground tyre rubber as cement replacement leads to a reduction of the strength and durability properties of the resultant concrete. Concrete with ground tyre rubber presents a flatter post-peak branch in the stress-strain and a larger ultimate strain. These properties make these mixtures potentially interesting for seismic design.

The addition of epoxy resin with and without hardener and ground tyre rubber instead of cement increases the ultimate strain with respect to conventional concrete. In addition to this, a change on the descending part of the stress-strain curve is observed, showing a better ductility. The compressive and flexural strength of each polymer cement concrete considered in this work are lower than the one obtained for traditional concrete. Epoxy without hardener as cement replacement has shown worse mechanical characteristics than its counterpart epoxy with hardener. Conversely, concrete mixtures with epoxy without hardener as cement replacement has shown the highest durability against chloride penetration. Colorimetric methods based on AgNO3 solutions can be used for the determination of chloride ingress into all the polymer cement concretes considered (chloride-free and affected zones were clearly visible). The replacement of 15% of cement with epoxy with hardener is recommended to achieve a higher resistance to chloride ingress and a slightly higher toughness with respect to traditional concrete. Furthermore, the concrete compressive and flexural strength are acceptably reduced.

Hernandez-Oliveres (2002) studied the effect of the addition of crumbed tyre rubber volume fractions up to 5% in a cement matrix does not imply a significant variation of the concrete mechanical features, either maximum stresses or elastic modulus. Analysing the variations on the modules experimentally obtained either under static or dynamic load, it can be observed that they increase with age and decrease as the fibre content or temperature increases. It can be concluded that the elastic branch of the plot stress–strain refers to the concrete matrix. In fact, the inclusion of fibre implies defects in the internal structure of the composite material, producing a reduction of strength and a decrease of stiffness. But when maximum strength is overcome, fibre collaborates with concrete, avoiding the opening of the cracks and therefore increasing the energy absorbed by strain (tough-ness) and the breaking of concrete. This feature of the composite can be assigned to the stiffness difference (modulus of elasticity) of the compounds (30 GPa for the concrete matrix and 10 times less for the rubber).

The microscopic study about the rubber–cement inter-face shows the crystallization of calcium compounds on the surface of the rubber fibre. The spectrum records a high concentration of calcium oxides on the surface coming from hydration products of cement (rubber has no calcium in its composition). Therefore, it can be said that hydrated cement reacts with the rubber fibre exterior surface and a diffusion of the hydrated products happens, especially the ones with high calcium oxides content.

2.4 Tyre Rubber

accumulated waste tyres have become a problem of interest because of its non-biodegradable nature Malladi (2004). Most of the waste tyre rubbers are used a fuel in many of the industries such as thermal power plant, cement kilns and brick kilns etc. unfortunately, this kind of usage is not environment friendly and requires high cost. Thus, the use of scrap tyre rubber in the preparation of concrete has been thought as an alternative disposal of such waste to protect the environment. It has been observed that the rubberized concrete may be used in places where desired deformability or toughness is more important than strength like the road foundations and bridge barriers. Apart from these the rubberized concrete having the reversible elasticity properties may also be used as a material with tolerable damping properties to reduce or to minimize the structural vibration under impact effects Siddique et al. (2004).

2.4.1 Civil Engineering Applications of Recycled Rubber from Scrap Tires

Scrap tire chips and their granular counterpart, crumb rubber, have been successfully used in a number of civil engineering applications. Tire chips consist of tire pieces that are roughly shredded into 2.5 to 30 cm lengths. They often contain fabric and steel belts that are exposed at the cut edge of the tire chip. Tire chips have been researched extensively as lightweight fill for embankments and retaining walls (Humphrey and Manion 1992) but have also been used as drainage layers for roads and in septic tank leach fields Kopasakis, K. (2002). According to Kopasakis, K. (2002), some of the advantageous properties of tire chips in civil engineering applications include low material density, high bulk permeability, high thermal insulation, high durability, and high bulk compressibility. In many cases, scrap tire chips may also represent the least expensive alternative to other fill materials. Crumb rubber is a finely ground tire rubber from which the fabric and steel belts have been removed. It has a granular texture and ranges in size from very fine powder to sand-sized particles. Crumb rubber has been successfully used as an alternative aggregate source in both asphalt concrete and PCC.

This waste material has been used in several engineering structures like highway. Few experiences have been recorded any utilization or management of this waste material, on the contrary, several cases of fatal and hazardous conditions occur on daily bases as a result of ignorance and bad handling of this waste material. It is important to note that the generation of this material on daily basis locally and worldwide is beyond tolerated level, which makes it an urgent and a standing issue to deal with.

2.4.2 Life-Span of Tyres

Tires are an advanced form of the wheel, before they get discarded and end up as waste, tires are used in various modes transport. Once the tire casing gets worn out, they are either rethreaded or if the tires are beyond rethreading, they are disposed of as waste. What extremely happens to discarded tires is of constitutes to this research. Figure 2.1 depicts the life - span of a ty for its roadworthy state to a stage where it gets discarded as waste.

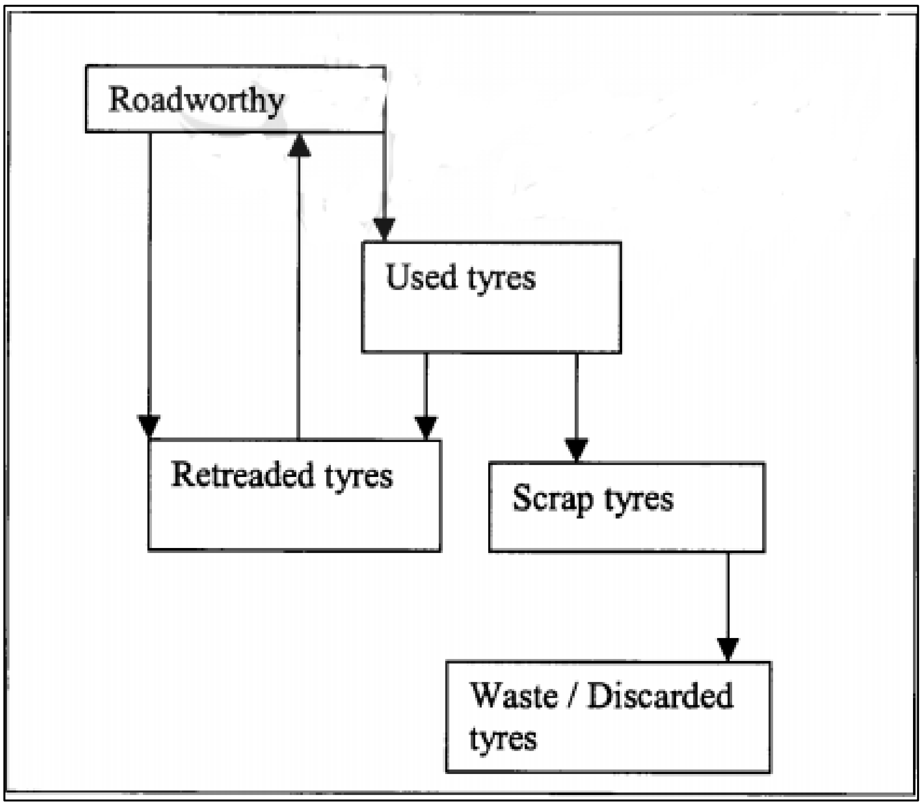

Figure 2. 1: Schematic representation of the life-span of tyres.

The diagram indicates that tyres ultimately end up as waste and waste has to properly disposed of. Waste that is not properly disposed of adds to various other environmental problems, a matter that is besides the focus of this research.

2.5 Concrete with Salt Curing

Salt like NaCl do not damage concrete, but the effects of salt can such as corrosion impact to embedded rebars and its behaviour during freezing and thawing process. Concrete produced using water with dissolved salt has better compressive strength (Wegian, 2010; Taylor & Kuwairi, 1978). Sodium chloride (NaCl) solution in concrete has accelerating effects on concrete compressive strength but is not sustained Wegian, (2010). Chloride Penetration As the concrete with RHA ages, chloride penetration improves. An average of 21.4% reduction was observed between the 7-day and 14-day penetration data. This suggests that rebars are more protected in concrete with RHA.

According to Wegian, 2010 concretes mixed and cured in seawater have higher compressive, tensile, flexural and bond strengths than concretes mixed and cured in fresh water in the early ages at 7 and 14 days. The strengths after 28 and 90 days for concrete mixes mixed and cured in fresh water increase in a gradual manner. Cement content in concrete mixes has a great effect on concrete strengths and durability. Higher cement content produces strength five times higher, especially for low water–cement ratios. Strengths are also affected by the aggregate type and properties and cement type, age and curing conditions but with a lower rate than the effect of cement content. The use of SRCs may help resist damage of concrete exposed to seawater. The increase of cement content and the use of SRC in concrete improve the resistance of concrete for deterioration against seawater and salty solutions. Care should be taken in the manufacturing of concrete to produce impermeable dense concrete in order to resist the attack of seawater. A meaningful test method is needed for evaluating the effect of seawater under continuous and alternating exposures.

Aaeios & Bermudez (2010) have done Series of experiment were conducted on M40 grade of concrete by this project work, the effect of sea water on compressive strength, flexural strength and split tensile strength of concrete was investigated. There is lower in the strength of concrete specimen cast & cured with salt water as compared to those of cast & cured in fresh water. The attained ph value is 11.96, hardness value is 190 ppm, minimum ph value in sea water must lie between 7.2 - 8.0 and hardness must lie between 90-180 ppm. When the sea water's ph and hardness value comes under minimum requirement then those sea water can be used in concrete construction. The rate of the strength gain in salt v water cubes is slow as compared with salt water. From the above finding we can conclude that there is reduction in the strength if we use salt water casting & curing the concrete. From the outcomes obviously, there was a minimal increment in the solid 3D shapes which were threw and cured with ocean water in seventh day test to 28th day test yet the quality picks up in 28th day trial of ocean water is low when contrasted with crisp water concrete. Although, the compressive strength of the concrete cubes which were casted using sea water shows slightly acceptable. The surface of cubes casted and cured using sea water has salts in it. From the above research, we can conclude that if the water contains fewer amounts of hardness, PH and salts then there is no reduction in strength. Hence, this water can be used for casting. If reinforcement is needed to be provided, then the structures should be provided with proper admixtures to protect it from corrosion.

Guo et al. (2018) investigated on four different grades of concrete made with fresh and sea water, cured in fresh water as well sea water over a period of 90 days for compressive strength have been analysed. They concluded that Sea water affects the gain in strength of concrete when used for mixing and curing. It shows some increases at the early strength but ultimately decrease the strength.

Concrete specimens made with fresh water and cured with sea water shows a loss in strength of around 7% whereas concrete specimens made and cured with sea water showed loss in strength of around 15% as compared to the similar concrete specimens made and cured with fresh water at age 90 days. Among the four grades of concrete studied, the higher-grade concrete B showed around 9% higher strength loss as compared to the other grades of concrete A, C and D when used sea water for mixing and curing concrete. And the higher strength concrete showed poorer resistance against strength deterioration as compared to the lower strength when used sea water for curing.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter gives a better understanding on the specific detail of materials to be used, the characteristics of the materials, laboratory testings' to be carried out, and the methodology of how the experiment to be carried out precisely. Besides that, the expected data and results are also attached to be compared or set as a reference point before all the tests are conducted. The tests conducted for this research were compressive strength test, slump test and the flexural strength test. These tests were conducted to get enough data and results to support the research and to differentiate our study with the normal existing data and results. The procedure of each experiment was stated step by step and explained in detail with methodology a chart. This chapter is to ensure the experiments and tests are conducted with minimal error as we understand the progress and purpose of the experiment more clearly beforehand.

3.2 Materials for Concrete Preparation

3.2.1 Ordinary Portland Cement

Portland cement is the most common type of cement in general use around the world as a basic ingredient of concrete, mortar, stucco, and non-specialty grout. It was developed from other types of hydraulic lime in England in the mid-19th century, and usually originates from limestone. It is a fine powder, produced by heating limestone and clay minerals in a kiln to form clinker, grinding the clinker, and adding 2 to 3 percent of gypsum. It is a compound of lime (CaO), silica (SiO_2), alumina (Al_2O_3), iron (Fe_2O_3) and

Sulphur trioxide (SO_3). Portland Cement is a grey coloured dust. When mixed with water, it hardens into the material used for concrete construction.

Figure 3. 1: YTL Portland Cement

3.2.2 Fine Aggregate

River sand which were mined in Sungai Panching, Kuantan, Pahang to be used as fine aggregates in UMP Laboratory. The sand is classified as well graded sand by the laboratory itself. Fine aggregate was supplied by a general aggregate provider from Kuantan, Pahang.

Figure 3. 2: Fine Aggregate

3.2.3 Coarse Aggregate

The type of coarse aggregate used in this study was granite. Granite aggregates have a maximum size of 20 mm and a minimum of 5 mm. Granite is Used as gravel or aggregate. It is almost huge and hard. The good properties of granite Cheaper than the cement, put into the mix as much as possible and Higher volume stability and better durability than the cement paste alone because of this it became one of the most popular materials.

Figure 3. 3: Coarse Aggregate

3.2.4 Water

Water is used in concrete to initiate the reaction. without water the chemical compounds are inert to any mixture. once the water is added the chemicals in cement starts to react, which in turn produces 'Bogue compounds' (chemical compounds responsible for early strength, setting time & Ultimate strength of concrete). Without water there will never be a reaction unless any other specific admixtures are used for initiating the reaction, whichever however is costly when compared to the cost of water. also, one more important role of water is, it plays a major role in complementing binding properties of the mix. however, it does not mean that water is the only responsible matter for binding.

3.2.5 Rubber Tire Waste Powder

Rubber tire was the main reason this research is conducted. The rubber tyre waste powder is used to replace the sand in the mix design in order to create the modified concrete and the design is tested to check whether the mix design can be applicable in construction line. Firstly, the used tyres were recycled and sorted out according to condition. The size of particle is 0.425 mm.

Figure 3. 4: Rubber Tire Waste Powder

3.2.6 Superplasticizer

Water reducers, retarders, and superplasticizers are admixtures for concrete, which are added to reduce the water content in a mixture or to slow the setting rate of the concrete while retaining the flowing properties of a concrete mixture. Admixtures are used to modify the properties of concrete or mortar to make them more suitable to work by hand or for other purposes such as saving mechanical energy. Many important characteristics of concrete are influenced by the ratio (by weight) of water to cementitious materials (w/cm) used in the mixture. By reducing the amount of water, the cement paste will have higher density, which results in higher paste quality. An increase in paste quality will yield higher compressive and flexural strength, lower permeability, increase resistance to weathering, improve the bond of concrete and reinforcement, reduce the volume change from drying and wetting, and reduce shrinkage cracking tendencies.

Figure 3. 5: Superplasticizer

3.3 Mix Design

In this research, in order to conduct the experiments and determine the optimum mix design of concrete with tyre waste rubber powder as partial sand replacement, 4 different mixes were done with 0%,5%,10% and 15% sand to be replaced. Figure 3.1 shows the details of the density of materials used. The water-cement ratio used in this research was 0.52 for all the mixes.

Table 3. 1: Materials used and its respective densities

Material	Density (kg/m^3)
Cement	320
Coarse Aggregate	1280
Fine Aggregate	640
Water	128

3.4 Experimental Programme

In this study, the tire concrete was produced to investigation the compressive strength and flexural strength using different percentage of tire as fine aggregate replacement. The percentage of tire as fine aggregate replacement by total weight of fine aggregate such as 0%, 5% and 10%. Tire were mixed with cement, cores aggregate, water and superplasticizer. The design of compressive strength for tire concrete must be obtained is 40 MPa. The tire concrete without fine aggregate replacement were design as a control mix. 27 cubes concrete were prepared to be test for compressive strength and 18 beam concrete to be test for flexural strength. Minimum three samples will be prepared for each parameter for 0%, 5%, and 10%. For cubes and beam have the dimension of 150 mm x 150 mm x 150 mm and 500 mm x 100 mm x 100 mm respectively. All the specimens were tested after expose to water curing at 3, 7, 28 days. The number of samples prepared as shown in Tables 3.2 and 3.3.

Table 3. 2: Numbers of cube specimens needed for compressive test

Type of Test	3 Days of Water Curing		7 Days of Water Curing		28 Days of Water Curing		Total Samples
Compressive Strength Test	0%	3 Samples	0%	3 Samples	0%	3 Samples	27(Cubes)For each curing
	5%	3 Samples	5%	3 Samples	5%	3 Samples	
	10%	3 Samples	10%	3 Samples	10%	3 Samples	

Table 3. 3: Numbers of beam specimens needed for flexural test

Type of Test	7 Days of Water Curing		28 Days of Water Curing		Total Samples
	0%	3 Samples	0%	3 Samples	
Flexure Strength Test	5%	3 Samples	5%	3 Samples	18 (Beams) For each curing
	10%	3 Samples	10%	3 Samples	

3.4.1 Concrete Mixing, Slump Test and Casting

Concretes were mixed in the mixer as normal where the coarse and fine aggregate was added in followed by cement and water gradually being added to ensure the mix was well mixed. As for the modified concrete mix with tyre waste, the tyre waste powder material was added gradually after the cement before water was added into the mix. The slump test was conducted immediately, and the slump measurements were taken before casting was done. The type of slump was determined based on Figure 3.7. All these concrete mixes were poured into cube moulds sized 150mm x 150mm x150mm and beam moulds sized 500mm x 100mm x100mm at 3 cubes and 3 beams per mix. The insides of the moulds were applied with oil before casting to ensure an easy removal of cubes and beams for curing.

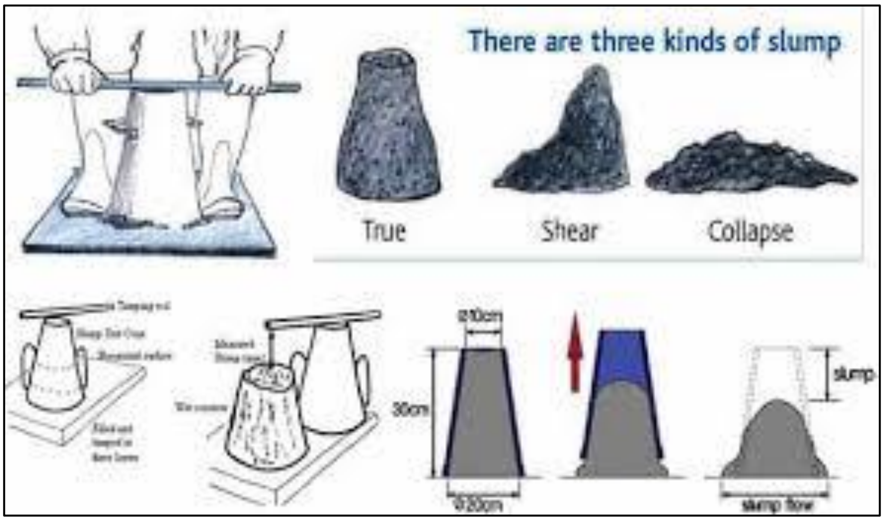

Figure 3. 6: Types of slump (BS 1881 Part 102: 1983)

3.4.2 Water Curing & Salt Curing

After 24hours or 1Day from the time the cubes are casted, the concrete will become dry. It is then removed from its respective moulds, marked with a industrial marker based on its respective test dates and immersed in a curing tank or water tank till its test dates are up. As for this research, concrete cubes were left for curing for 3, 7 and 28 days and concrete beams were left for 7 and 28 days. The salt water is prepared with 35mg/L of salt.

3.5 Concrete Preparation

In this research, three tests were conducted to study the suitability of tyre waste material as partial sand replacement in concrete. These tests were conducted to identify the basic mechanical properties and to compare the modified concrete with a normal concrete and get the optimum tyre waste percentage to replace sand. The tests were conducted, and the data was analysed to satisfy the objectives mentioned in Chapter 1. Tests that were conducted are the Slump test to identify concrete workability, compression test to identify concrete strength and Flexure strength test to identify concrete strength.

3.6 Testing procedure

3.6.1 Slump Test

Slump test is important in determining the workability of fresh concrete. Workability is determined through the amount of slump measured. It is carried out once concrete is mixed, before concrete even being placed into the cube mould. The procedures of carrying slump test are accordingly to BS 1881 Part 102 (1983). Figure3.8 shows the apparatus is used for carrying out the slump test.

Figure 3. 7: Apparatus used in slump test

First, mould of slump test is prepared and placed in a smooth, rigid and non-absorbent surface. The internal face of the mould is wetted to reduce friction of concrete with the face of mould. Concrete then is added into the mould for 3 layers and each layer is one-third of the height of the mould. For each layer, the concrete is tamped 25 strokes using tamping rod. For the last layer, level the concrete surface using the tamping rod. Then lift the mould upward from the concrete slowly and carefully. After that, the slump is measured. Generally, there are three possibilities of slump. The types of slump are true slump, shear slump and collapse slump as shown in Figure 3.7. Only true slump is accepted. If shear slump and collapse slump occurred, another sample has to be collected and the same procedures being repeated to obtain the amount of slump BS 1881 Part 102 (1983).

3.6.2 Compressive Strength Test

Compression test of moist-cured specimen is conducted immediately after the removal of specimens from moist storage or curing tank, with three hardened concrete specimens shall be used in the measurement of concrete strength at the designed age. In compression test, concrete specimens are subjected to the compression load at the specified rate. The specimen is tested to its failure and the maximum load achieved is 30 considered as the ultimate load for future strength calculation. The standard used for this experiment are BS 1881: Part116 (1983).

The compressive strength is given by the equation (3.1)

$$fc = \frac{P}{A} \quad \ldots\ldots (3.1)$$

where

fc = compressive strength, in MPa ($N/m\,m^2$)
P = maximum load at failure, in N
A = cross-sectional area of the specimen on which the compressive force acts, in mm^2
The compressive strength shall be expressed to the nearest 0.1 MPa (N/mm^2)

3.6.3 Flexural Strength Test

Flexural test of moist-cured specimen is conducted immediately after the removal of specimens from moist storage or curing tank. The concrete specimen is a plain (unreinforced) concrete beam that is subjected to the loading at the specified rate until failure occurs. The flexural strength (modulus of rupture) is theoretically derived from the elastic beam theory, where the stress-strain relation is assumed to be linear. The standards used for this experiment are BS 1881: Part 118 (1983).

The flexural strength is calculated by following equation:

i. If the fracture initiates in the tension surface within the middle third of the span length, calculate the flexural strength using equation (3.2).

$$R = \frac{PL}{bd^2} \ldots \ldots (3.2)$$

Where

$R =$ modulus of rupture (N/mm^2 or MPa)

$P =$ maximum load carried by the specimen during testing (N)

$L =$ span length (mm)

$b =$ average width of specimen at the fracture (mm)

$d =$ average depth of specimen at the fracture (mm)

ii. If the fracture occurs in the tension surface outside of the middle third of the span length by not more than 5% of the span length, calculate the flexural strength using equation (3.3).

$$R = \frac{3pa}{bd^2} \quad \ldots\ldots\ldots (3.3)$$

Where

$a =$ average distance between line of fracture and the nearest support measured on the tension surface of the beam (mm)

iii. If the fracture occurs in the tension surface outside of the middle third of the span length by more than 5% of the span length, discard the results of the test.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this research, 3 concrete mixes were prepared where one mix was used as the control mix and 2 others containing the 2 different percentage of tyre waste powder. The results of the tyre waste modified concrete were compared with the controlled mix to see its performance as a new concrete aggregate. All the concretes were tested and observed for workability, compressive strength, and flexural strength. Thus, this chapter represents the results and discussion from the respective lab tests done on the concrete.

4.2 Slump Test

Slump test is a test conducted immediately after the concrete is mixed and casted before it is poured in the mould. The results from the slump test are shown below in Figure 4.1Based on the results obtained from all three different mixes, it can be concluded that the concrete mixed has adequate workability according to standards. The mix with 0% sand replacement shows that the slump distance is 78mm, whereas for the 5% and 10% sand replaced cubes, shows 67mm and 58mm respectively. Since the data collected is ranged between 60mm-90mm, all the 3 mixes are considered having good workability.

Figure 4. 1: Slump Test reading for sand replacement

Table 4. 1: Slump Test results for 4 different mixes

Cube with percentage of sand replaced (%)	Slump Distance (mm)
0	78
5	67
10	58

4.3 Compressive Strength

Compressive strength test also known as the compression test was conducted on the concrete cubes according to BS EN 12390-3:2009. The size of the concrete cubes used was 150mm x 150mm x 150mm each. After casting and moulding it, the cubes were left for curing till the 3th, 7th and 28th day for all the 3 different mixes. Figure 4.2 and 4.3 shows the results obtained from the compressive strength test of the controlled mix and all the 2 different mixes containing different percentages of tyre wastes as partial sand replacement. Based on the results, we can conclude that the tyre waste does effect or influence the concrete strength. It is estimated that the concrete has its highest strength at the 28th day and with the concrete mix that has 0% sand replacement for salt curing and water curing.

The early strength of salt curing specimens showed higher strength in compressive than specimens with water curing. The strength at 28 days of curing showed a gradually increasing in strength of water curing compared to salt curing. The increasing of early strength of salt curing at the earlier stage can be reasoned by the effect of chloride which increase and accelerate the strength and bonding between cement paste materials.

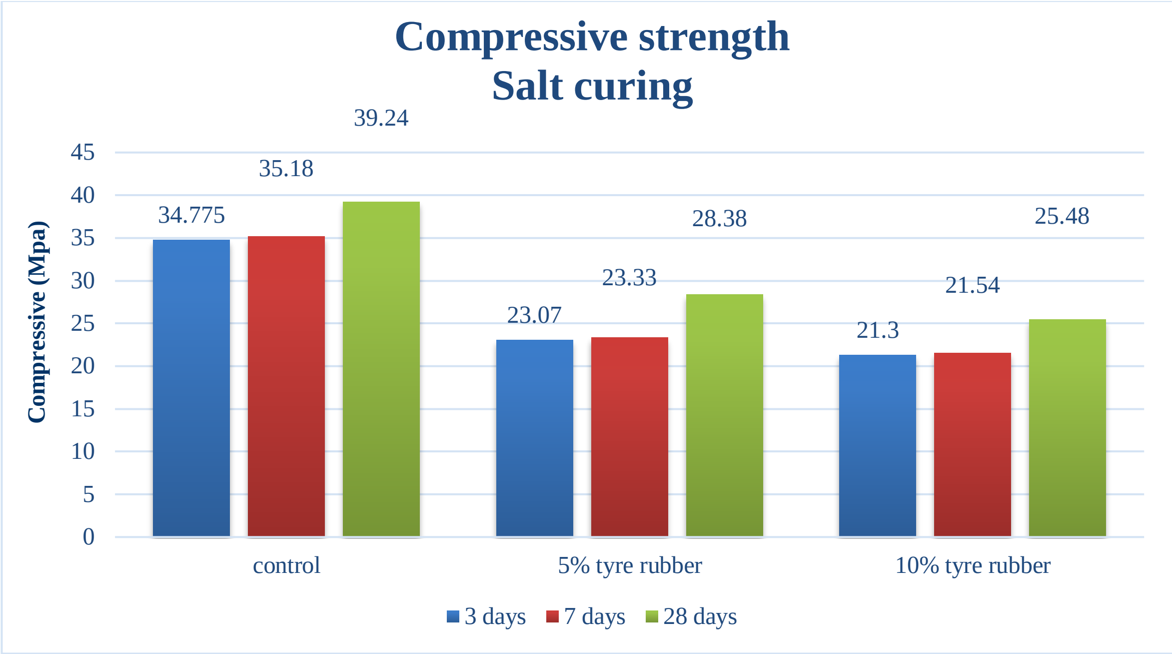

Figure 4. 2: Compressive Strength of Cubes (Salt Curing)

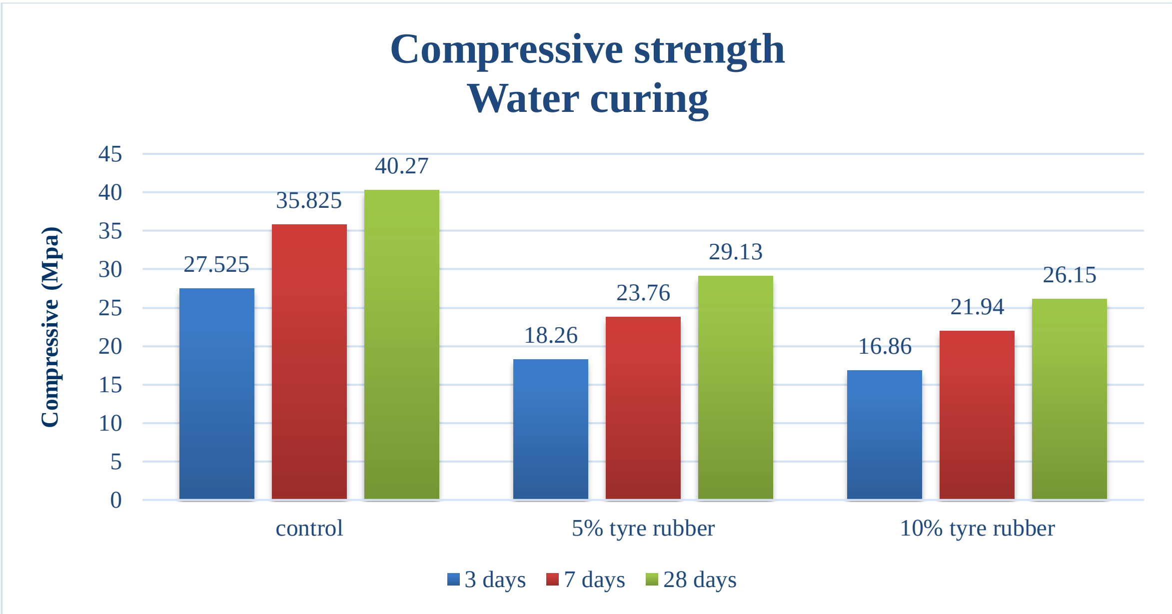

Figure 4. 3: Compressive Strength of Cubes (Water Curing)

Table 4. 2: Compressive strength results for 3,7 and 28-days testing

Salt curing	**0%**	**5%**	**10%**
Days	Compressive Strength (N/mm^2)	Compressive Strength (N/mm^2)	Compressive Strength (N/mm^2)
3	34.775	23.07	21.3
7	35.18	23.33	21.54
28	39.24	28.38	22.63
Water curing	**0%**	**5%**	**10%**
Days	Compressive Strength (N/mm^2)	Compressive Strength (N/mm^2)	Compressive Strength (N/mm^2)
3	27.525	18.26	16.86
7	35.825	23.76	21.94
28	40.27	29.13	26.15

4.4 Flexural strength test

Figures and table down showed the result of salt and water curing flexural strength of specimens after 7 and 28 days of curing. Results showed a reduction of flexural strength of specimens containing tyre rubber compared to control specimens and the reduction increase with increasing the percentage of tyre rubber replacement. The early strength of specimens with salt curing showed increasing more than water curing specimens. At 28 days water curing specimens showed gradually increasing in flexural strength compared to salt curing. The highest flexural strength 6.24N/mm^2 achieved by salt curing specimens with 5% tyre rubber at 28 days of salt curing, while water curing was 5.056 N/mm^2.

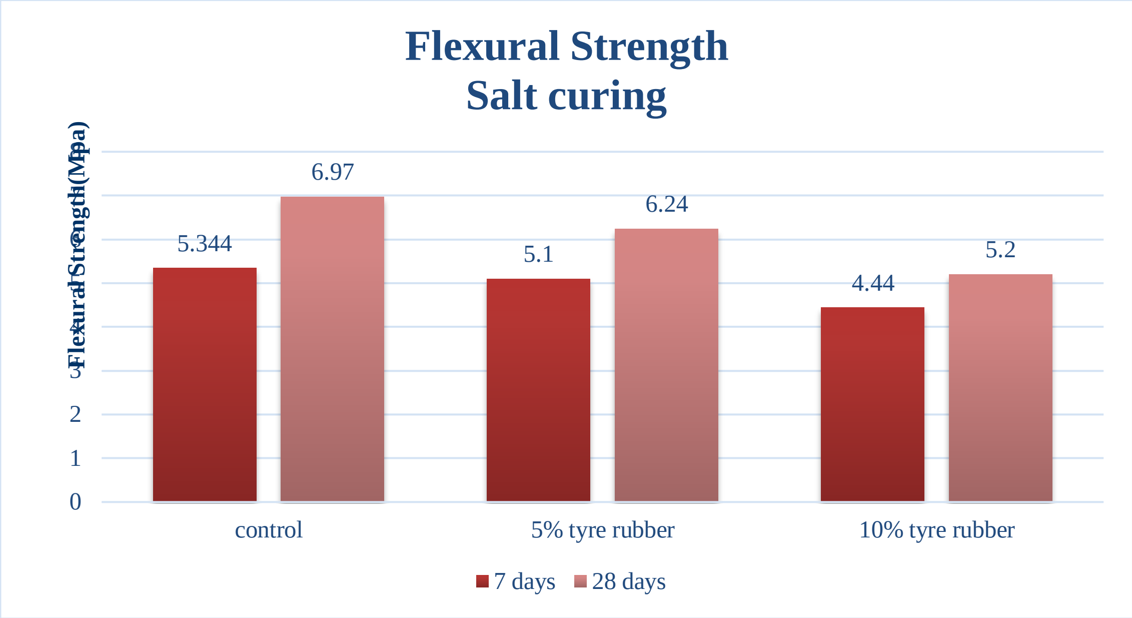

Figure 4. 4: Flexural strength of Beams (Salt Curing)

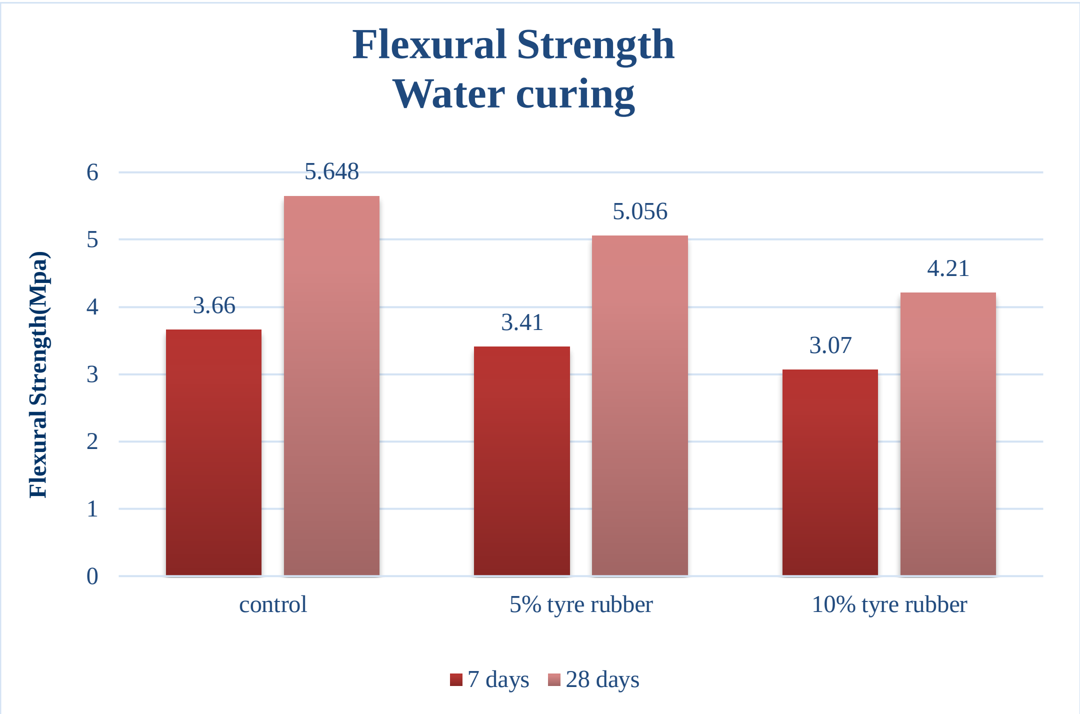

Figure 4. 5: Flexural strength of Beams (Water Curing)

Table 4. 3: Flexural strength results for 7 and 28-days testing

Salt curing	0%	5%	10%
Days	Flexural Strength (N/mm^2)	Flexural Strength (N/mm^2)	Flexural Strength (N/mm^2)
7	5.344	5.1	4.44
28	6.97	6.24	5.2
Water curing	0%	5%	10%
Days	Flexural Strength (N/mm^2)	Flexural Strength (N/mm^2)	Flexural Strength (N/mm^2)
7	3.66	3.41	3.07
28	5.648	5.056	4.21

CHAPTER 5

CONCLUSION

5.1 Introduction

The control specimens exhibited brittle failure while the rubberized concrete did not show brittle failure under compression loading. Horizontal cracks were observed for the specimens with rubber and inclined cracks were observed in the control specimens. The loss in mechanical properties of rubberized concrete was supported by the results obtained by various researchers. The reasons for the decrease in flexural strength of the rubberized concrete.

i. The aggregate would be surrounded by the cement paste containing rubber particles. This cement paste would be much softer than that without rubber. This results in rapid development of cracks around the rubber particles while loading and this leads to quick failure of specimens.

ii. There would be lack of proper bonding between rubber particles and cement paste, as compared to cement paste and natural aggregate. This can lead to cracks due to non-uniform distribution of applied stresses.

iii. The compressive strength depends on the physical and mechanical properties of the constituent materials. If part of the materials is replaced by rubber, reduction in strength will occur.

iv. Due to low specific gravity of rubber and lack of bonding of rubber with other concrete ingredients, there is a tendency for rubber to move upwards during vibration leading to higher rubber concentration at the top layer. Such a non-homogeneous concrete sample leads to reduced strengths.

5.2 Recommendations

There are few recommendations that I would like to suggest for further study for the development of this concrete material.

i. To study the durability of concrete containing tyre waste powder as partial sand replacement.
ii. To study and determine the extent of tyre waste being used as partial sand replacement in a much more specific percentage of replacement of sand.
iii. To study the fire resistance of concrete containing tyre waste rubber as sand replacement and determine the structural performance of concrete.

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