A STUDY ON THE EFFECT OF TYRE RUBBER WASTE POWDER AS PARTIAL SAND REPLACEMENT IN CEMENT MORTAR PROPERTIES

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Thesis submitted in fulfillment of the requirements
for the award of the
Bachelor Degree in Civil Engineering

Faculty of Civil Engineering and Earth Resources

UNIVERSITY MALAYSIA PAHANG

JANUARY 2019

ACKNOWLEDGEMENTS

First and foremost, I would like to express my sincere gratitude to God for everything that necessary in completing this thesis. I would like to express my very great appreciation to my dearest supervisor, Dr Doh Shu Ing for his valuable and constructive advice, suggestions, enthusiastic motivation and immense knowledge ever since the beginning of the thesis. His willingness to give his time to help me in completing this thesis has been very much appreciated. I wouldn’t have completed this thesis without his guidance for sure.

Besides that, I would like to extend my gratitude to the laboratory technicians of concrete laboratory for all guidance and assistance provided throughout my research. Next, I would like to express my very special appreciation to my friends, batch mates, seniors and juniors, especially Eric Jason and Nagatarshini whom helped, motivated and supported me in all aspects in completing this research.

Most importantly, none of this would have happen without this without the overwhelming love, continuous support and patience of my family. I would love to express my heartfelt appreciation and love to my parents, Mr Yathagan and Mrs Tamil Selvi who have been my pillar of strength of all time.

ABSTRAK

Simen mortar merupakan salah satu bahan yang penting yang digunakan secara luas dalam industri pembinaan. Pembuataan simen mortar mempunyai kesan negative yang besar untuk alam dan ekosistem. Banyak masalah berkaitan dengan alam semakin berleluasa terutamanya perlombongan pasir kerana pasir merupakan salah satu bahan utama dalam simen mortar. Tayar buangan juga merupakan salah satu pembuangan yang semakin hari semakin meningkat kerana industri otomobil semakin maju. Pelupusan pembuangan yang tidak betul mengundang masalah pencemaran dan kesihatan.. Oleh itu, penyelidikan ini telah dijalankan untuk membantu industri untuk mengurangkan bilangan pembuangan di tanah lupus dan juga mengurangkan pergantungan terhadap pasir semata-matanya bertujuan mengurangkan perlombongan pasir yang memberi kesan terhadap alam dan ekosistem. Penyelidikan ini adalah untuk mengkaji kesan sisa buangan tayar getah sebagai separa gantian untuk pasir dalam simen mortar dari segi kekuatan, kebolehkerjaan, dan kesan suhu terhadap kadar pengawetan. Peratusan sisa buangan tayar getah yang dikaji ialah 0% (kawalan), 5%, 10% dan 15%. Sebanyak lima ujian telah dijalankan; ujian kekuatan kemampatan, ujian kekuatan kelenturan, aliran ujian meja, ujian UPV dan ujian suhu. Prisma dengan saiz (40 x 40 x 160) mm digunakan untuk ujian kekuatan kelenturan manakala kiub dengan saiz (50 x 50 x 50) mm digunakan untuk ujian selebihnya. Ujian kekuatan kemampatan menunjukkan penurunan sekiranya peratusan sisa buangan tayar getah sebagai separa gantian menaik. Kekuatan kelenturan pula menunjukkan bahawa 10% sisa buangan tayar getah dalam simen mortar memiliki kekuatan awal paling tinggi pada hari ke-3 tetapi 5% memiliki kekuatan kelenturan tertinggi pada hari ke-28 jika dibandingkan dengan 10% dan 15%. Aliran ujian meja pula menunjukkan bahawa kebolehkerjaan simen mortar semakin naik sekiranya peratusan kandungan sisa buangan tayar geth dalam simen mortar meningkat. Ujian UPV menunjukkan bahawa semakin kurang peratusan kandungan sisa buangan tayar getah dalam simen mortar semakin kurang kandungan lubang dan retak dalam simen mortar. Ujian suhu menunjukkan bahawa penambahan sisa buangan tayar getah dalam simen mortar, semakin tinggi suhu simen mortar yang segar. Peratusan optimum kandungan sisa buangan tayar getah dalam penyelidikan ini ialah 5%.

ABSTRACT

Cement mortar is one of the most important materials widely used in construction industry. The production of cement mortar has a huge negative impact on nature and ecosystem. Many of nature based problems arises especially sand mining as sand is one of the main ingredient for cement mortar. Scrap tyres are also one of waste that drastically increasing day by day as the automobile industry progressing well. Improper disposal of waste tyre leads to pollutions and health issues. Hence, this research is carried out to help the industry to reduce the amount of waste at dump fill and also to reduce the dependency on sand solely in order to reduce sand mining which affects the nature and ecosystem. This research is basically to determine the effect of rubber waste powder content as partial sand replacement in cement mortar in terms of strength, workability and effect on temperature on rate of curing. The percentage of tyre rubber waste powder used to be tested were 0% (controlled), 5%, 10% and 15% .Total of five tests were conducted; compressive strength test, flexural test, flow table test, UPV test and temperature test. Prisms with size of (40 x 40 x 160) mm are used for flexural test and cube with the size of (50 x 50 x 50) mm used for the rest of the experiments. The compressive strength shows declination as the percentage of tyre rubber waste powder as sand replacement increases. The flexural test shows that 10% tyre rubber waste in cement mortar content has higher early strength on 3rd day but 5% has the highest flexural strength on 28th day has the highest compared to 10% and 15%. Flow table test indicates that the workability of the cement mortar increases as the percentage of tyre rubber waste increases in the cement mortar mix. UPV test shows that lesser the tyre rubber waste in cement mortar mix the lesser void and cracks exists. Temperature test shows that addition of tyre rubber waste powder increases the temperature of the fresh cement mortar. The optimum percentage of tyre rubber waste powder as sand replacement for the cement mortar in this research is 5%.

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LIST OF SYMBOLS

°C	Degree Celsius
mm	millimetre
MPa	Mega Pascal
Km/s	Kilometre per second

LIST OF ABBREVIATIONS

POFA	Palm Oil Fly Ash
UPV	Ultrasonic Pulse Velocity
OPC	Ordinary Portland Cement
kN	kilo Newton

CHAPTER 1

INTRODUCTION

1.1 Introduction

In this modern era of construction, cement mortar is a very essential and crucial material and widely used as construction material. Cement mortar is to be said as one of the oldest manufactured construction material used in construction of various structures around the world. Concrete is a mixture of aggregates like sand and stones combined with cement and water. The mixture is then allowed to dry and harden. Basically, cement mortar is the stone-like structure formed after this cement and other materials mixtures are hardened (cured). The cement is just a part of the cement mortar. Cement has been used as a binder of materiel. Early forms of cement used things like lime and pozzolana, a type of volcanic ash. The Romans were able to produce massive structures like the Pantheon and the Roman aqueducts based on this discovery. The growth rate of demands of cement mortar in construction industry increases drastically day by day. Cement mortar has a very high compressive strength but also high in terms of weight as the composition of the cement mortar is pure. In contrast, the production of cement mortar has a huge negative impact on nature and the ecosystem as well. Since fine aggregates are one of the main ingredients in production of cement mortar, sand mining in river became a very normal issue. This issue become serious when the demand for fine aggregate increases day by day.

Scrap tyres are one of the solid wastes that are produced drastically in this era. As the industry of automobile is progressing well, the production of tyre are increasing as well. The rate of the waste tyre also increases as the rate of car producing and usage of car on the road increases. These tyres usually dumped due to worn out condition or burst case and not safe to use anymore. These scrap tyres are often dumped in dump fill.

These kind of wastes are usually hard to disposed but will be reused by recycling it. Scrap tyres are referred as one of the solid waste classified under special solid wastage category. Thus, by using it in construction industry will bring.

1.2 Problem Statement

In this era of developing country and technology, many industries often forget to manage the sustainability of nature. The end products especially all these waste materials are often dumped uncontrollably in landfills. This dumping industrial waste problem is being a very serious issue where dump fill areas are getting out of control. Waste tyres are often used for landfills but this action has many negative effects to mankind and also nature. Improper disposal will cause water accumulation which will lead to breeding of mosquitoes, bacteria and etc. Besides that, if there is any fire accident, these tyres releases toxic gases which will cause serious health issues and severe pollutions (Dhir et al, 2001). In order to reduce all these negative impact on environment, few precaution steps need to be taken. The waste tyres can be reduced on land in a beneficial way which is through construction field (Po YW, 2004). Landfill disposal is normally used in construction in order to dump these tyre wastes but since European Union has set up new restrictions to reduce the usage of this method to introduce alternatives oriented towards material and recovery (Yung et al, 2013).

On the other side of this, researchers have revealed that concrete paving blocks containing tyre rubber crumb has improvised in terms of toughness and increase in ductility. Another research reported that addition of crumbs will increase the flexural impact on strength and toughness of hybrid concrete beams comprised of a rubberized concrete top layer increased. Therefore, this research is to investigate the effect of tyre rubber waste powder on cement mortar properties. The strength to withstand maximum load will be analysed.

The modulus of rupture is identified based on optimum amount of tyre powder to replace the fine aggregate. The effect of tyre rubber powder on temperature of cement mortar also tested to identify how it will affect the rate of curing. The Ultrasonic Pulse Velocity test will also be conducted to check whether the presence of tyre rubber will reduce the cracking and increase the flexibility of the cement mortar. In the end of this study, the proper percentage of tyre rubber replacing the sand will be identified to introduce this alternative in construction field for a better and developed future.

1.3 Objectives

The objectives of this research are:

i. To determine effect of rubber waste powder content as partial sand replacement on compressive and flexural strength of concrete.
ii. To investigate the effect of rubber waste powder as partial sand replacement on workability.
iii. To investigate the effect of tyre rubber waste powder as partial sand replacement on concrete temperature and rate of curing

1.4 Scope of Research

This research is all about investigating the effect of tyre rubber waste as partial cement replacement in cement mortar. The cement mortar properties will be identified through flexure test, compression test, flow table test, effect of temperature and. In this research, the content of the cement mortar are water, sand, Ordinary Portland Cement, and tyre rubber waste. The cement mortar is first mixed without tyre rubber waste powder to be kept as control mix which is used to compare with the tyre rubber mixed cement mortar to figure out the changes in properties of cement mortar. The sand is replaced by tyre rubber waste with 5%, 10%, and 15% of the sand mass.

Cement mortar cubes were casted in cube moulds of (50 x 50 x 50) mm^3 with 0%, 5%, 10% and 15% of tyre rubber waste of cement mass, 2 cubes for each percentage respectively. After removal of the cubes from the moulds are done, the temperature of a controlled cube and a tyre rubber waste mixed cube where taken precisely every 5 minutes from setting time until the first 2 hours and then every 1 hour until 17 hours of setting time. The cubes are let to be air cured. The following day, the cubes are immersed in water for water curing. The compression test, flow table and flexural test were conducted on 3^{rd}, $7^{th,}$ and 28^{th} days and the data were analysed. The test and experiments were conducted according to the existing standards.

1.5 Significance of Research

The main idea of the whole research is to minimise the industrial wastage on land and to reduce the effect of waste on environment. When we recycle wastes like used tyres or plastics into something we need in industries, we are not only reducing the usage of raw materials, in fact we are transfiguring waste materials into something useful. For instance, by replacing cement small amount of used tyre, we are reducing the amount of used tyre in landfill and save up the space for some other wastes. This will reduce the whole cost of construction with improvised strength as the usage of cement can be reduced. Besides that, we can produce a better and stronger cement mortar with some advantages like elasticity effect of tyre which can withstand more pressure and wear out slowly. This idea is applicable on road to reduce road surface wearing problems and reduce maintenance cost.

1.6 Layout of Thesis

This research consists of five chapters which are to give a rough idea or previous study on the research project, detailed explanation and findings from previous researches related to this research, method of carrying out the project, results obtained based on the experiments conducted, and lastly, a conclusion for the overall research. Chapter 1 is mainly to give an introduction to the main idea of the research. In this introduction, general explanation and related previous studies and input is discussed to bring up the objective of the research project. The general knowledge and explanation on concrete containing tyre rubber waste powder as partial replacement for cement. Therefore, the problem statement and objective of this research is proposed in this chapter. The scope of this research and the significance is also stressed in this chapter. Chapter 2 is mainly to explain the research project in detail and specifically. The methods and process that will be conducted throughout this research is also pictured clearly in this chapter. The literature review and briefing on issues to be investigated in using rubber waste powder as partial sand replacement. Other researches and journal were addressed and elaborated. This chapter is ended with the conclusion of literature review. Chapter 3 depicts the methodology of all the experiments carried out. The equipment, materials and apparatus needed for the experiments were listed to be prepared before the experiment is conducted. The standard operation process (SOP) was stated step by step with clear and precise instructions. Chapter 4 portrays all the detailed results obtained and to show all the formulae and calculations done to identify the proper properties of the effect of the tyre rubber waste powder as partial sand replacement in cement mortar. Chapter 5 concludes all the results obtained, analysed it together with the previous study and to prove whether the objectives are achieved.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Cement mortar is one of the most important materials that are essential in construction industry. A study shows that building operations consumes 40% of energy consumption. This contributes about 40% of emissions of greenhouse gas to the atmosphere (Lippiatt, 2007). More non-renewable natural material usage and the contribution of greenhouse gases to atmosphere which indicates the involvement of cement mortar and concrete in causing negative impact on natural environment. Besides that, waste materials dumped at landfills are being useless and also harmful for environment. Rather than keeping it as wastage, we can reuse the materials in helping the motive of bringing back the balance of nature without affecting the development of the country. This usage of waste materials needs a proper management to control and manage it properly in order to achieve the motive. An efficient management of all types of waste materials in using it for something useful will getting more consideration which helps to sustain the green construction concept.

Recycling the waste material will be helpful in reducing environmental pollution, reducing land filling activity and dispose waste in useful way while preserving natural resources (Thomas and Gupta, 2013). Every year many technological invention and mechanization produces massive amount of wastage from pre- and post-consumers product. Basically, the usage of non-renewable materials can be reduced in construction industry by replacing a certain amount of waste materials. Materials like coarse aggregate, fine aggregates, cement to be replaced with proper utilization of waste materials like tyre rubber waste powder, POFA, eggshells and so on. As there is a lot of nature based problems like river sand mining, excessive waste materials in dump fill, many researches need to be carried out for a better solution to this problem. This study is about finding the effects of tyre rubber waste powder used as partial sand replacement in cement mortar in terms of strength, flexibility, consistency and rate of curing is to bring in better alternatives in handling this problem.

2.2 Waste Dumping in Landfills

It is assumed that every year around 1000 million tyres will end their useful life and being disposed. Billions of tyres are disposed and buried in landfills all over the world which indicates a serious warning towards nature balance. It’s said that the number of tyres disposed per year will come up to 5000 million tyres (including stock piled) on regular basis. Excessive waste tyres will be breeding spot for various pests which will lead to health issues like Dengue. Besides that, some disposal of tyre involving burning of tyre causes serious fire hazards. So, in order to dispose the these tyre waste material in an effective and without affecting the nature is by replacing sand or aggregate in concrete or cement mortar in construction field (Thomas *et al*, 2014).

In another case study, it’s stated that waste tires generate a lot of toxic gases leads to severe pollution problem which is hazardous to health. Wu HH. (2001) reported that long-term buried waste tires will destroy the anti-leakage cover of the burial ground as it is said to often emerge from the burial ground. Based on Yeow (2015) report, these discarded tyres will usually be burnt as fuel in heat cement kiln and paper pulp factories because lack of alternatives of disposing it. Tyres were then being recycled to be reused as tyre and also other products as well. This will turn the tyre rubber waste into valuable material, zero pollution and leaves low-energy footprint.

2.3 Sand Mining

Sand is a granular material composed by rock and mineral particles due to influence of weathering and abrasion. Basavarajappa *et al*. (2014) stated that standard procedure of sand development is weathering which undergoes concoction, mechanical and organic procedure in breaking down of rock masses. Dynamic phenomenon is the accumulation of sand as layers in river courses. Sand normally forms layers and accumulate at riverbeds, streams, channels and shorelines. Sand is one of the important ingredients used in construction world especially in cement mortar and concrete.

Steinberger et al. (2010) stated that sand has a very high economic value where 47-59 billion tonnes of material is mined globally every year.

De Leeuw et al. (2010) discover that sand mining caused the Lake Poyang channel to get deeper and wider which increase the discharge of water into Yangtze River. This lowers lake’s water level badly in which it reaches the historically low level in 2008. Dubai city is one of the well-developed cities in the world with world’s amazing superstructures and architectural developments. Jan De Nul (2013) reported the Palm Jumeirah, the artificial sand island is constructed which required 186.5 million cubic meters of sand and 10 million cubic meters of rock that costs US$12 billion. Dubai’s own marine sand assets being depleted which forces them to import sand from Australia. Delestrac (2013) mentioned that Dubai imported sand from Australia for the construction of the highest building on planet Earth, Burj Khalifa tower (828 meters from sea level).

2.4 Sustainable Construction

A development of a country is sometimes judged based on the infrastructure in the nation. On verge of reaching the target of developed nation, the construction industries are used as one of the main catalyst for the company to reach the status. This target also has negative impact on nature and environment. Based on a study, by visualising the sustainable construction process, the industry must realise that construction industry not only focusing on development of buildings and structures alone, they also need to lessen the negative effects on environment as much as they can.

Through this the target can be achieved without damaging the nature and environment (Yoong *et al.,* 2014). Construction industry must make sure they have empowered the mankind to meet the requirement for shelter, fulfil the corporate destination without having no effects or minimal negative effect. If this environment issue is taken lightly, it will bring a huge negative impact on environment and mankind. As the building and construction materials are used widely in developing infrastructure in improving the quality of human life, natural resources are being used up. Sustainable construction doesn’t count cost and strength but also durability and environmental issues as equally important (Khatib 2009).

Disasters cause by construction such as soil erosion, sedimentation, flash flood and negative issues like depletion of natural resources will be out of control in which it will affect the human wellbeing badly (Yoong *et al*, 2014). This realization of importance of preserving the environment will helping developing a more dependable methodology which will pass all the requirements for improving the nation infrastructure without bringing negative effect to the nature and environment. The concept of sustainable construction must be the first priority as we can manage constrained assets of particular energy while minimize the impact on natural environment (Nazirah, 2009).

2.5 Cement Properties

The cement mortar or concrete must be in temperature range between 10°C to 29°C for a proper cement hydration process to avoid the risk for plastic shrinkage which will result in internal cracking due to stress. It has been identified that addition of rubber aggregates didn't cause the temperature to exceed the optimum temperature (Kardos and Durham, 2015). According to Stroh *et al*. (2016), it shows that C_4AF particles are the main reason for most of the Portland cement colour Cement mortar mixtures are consists of water, cement, fine aggregates, and any admixtures if needed. Different design can have different mechanical and durability properties in which it must satisfy the normal requirement.

Mechanical and durability properties are the ability of the cement mortar to resist load applied and other requirement where the desired engineering properties must be retained. Different mix of cement mortars will be casted based on the suitability of the strength and properties required. The proportion of ingredients, type of ingredients, adhesion between them, curing method and environment factor will determine the durability and life of the cement mortar.

Turatsinze *et al*. (2007) reported that addition of crumb rubber will enhance the strength of mortar by delaying crack initiation time of restrained shrinkage of mortar sample. It will also reduce the crack's length and width as the flexibility of the specimen increases as the amount of rubber tyre content in mixture increases. Studies show that tyre rubber waste in form of crumb can also be used as a partial replacement for natural fine aggregates in high strength cement concrete so we are going to find out whether tyre rubber waste powder, which is smaller than the crumbs size, will have any effects on the strength of cement mortar (Thomas *et al*, 2015). Mustafa *et al*. (2012) has discovered that sand replacement using fine crumb and crumb rubber has increased the fracture properties in all kind of proportions. It's also stated that the fracture properties in crumb rubber are higher compared to fine crumb rubber.

The use of scrap tires as alternative fuel in cement industry releases SO_2 and NO_x scrap tire in a more environmental friendly way. The influence of heat ratio of scrap tires on mass flow and concentration of these gases slightly reduces as stated in Chemsain K. (2011). Portland cement is the most used cement worldwide, where the other types of cement were used only when the concrete needs some special properties (Gyu et al, 2017).

2.6 Tyre Rubber Waste Powder

Studies show that high-carbon content fly ashes improvise the compressive strength of fly ashes and concrete mixtures. This shows that smaller particles compared to sand will fill in the voids between aggregate and make it denser and increases the compressive strength of the sample (Chen *et al*, 2009). Besides that, the density of the expanded–clay lightweight concrete is said to be increasing which causes compressive strength to increase. The compressive strength still increases even for the higher water/cement ratio. Due to exothermic effect, more heat is to be dissipated during the hydration of the cement which increases rate of curing. Thus, investigation need to be carried out whether will there be any effect of tyre rubber waste powder as partial sand replacement on temperature and rate of curing (Mačiulaitis *et al*, 2009).

In another research, it's shown that using tyre rubber waste as aggregate replacement in concrete reduces its compressive strength (Aiello M *et al*, 2010). Based on this, compressive strength of cement mortar should be analysed whether tyre rubber waste used as partial sand replacement has effect on it or not. Different study has stated that as the tyre rubber wastes content in the mixture increases, the compressive strength of the lightweight concrete or building materials reduces drastically (Azevedo F. *et al*, 2012). This is due to the poor adhesion performance between cement particles and rubber tyre particles which causes the bond to be weak which leads to lower compressive strength. Batayneh et al. (2008) also found the similar characteristics where the compressive strength, splitting tensile strength and flexural strength of concrete containing crumb rubber reduces compared to plain concrete. Observation shows that the loss in mechanical strengths is due to poor adhesion of scrap tire also.

Another research also mentioned that the addition of crumb rubber to concrete affects mechanical properties of the material. The compressive, splitting tensile strength and modulus of elasticity, toughness, flexural impact strength of hybrid concrete beams reduces comprised of rubberized concrete top layer content increases (Al-Tayeb *et al*, 2013). Turatsinze and Garros (2008) reported in terms of flexural loading, that samples containing tyre rubber aggregate will have higher strain capacity which will result minimized rate of crack propagation. Under the same research, it's said that the compressive strength and modulus of elasticity of concrete with scrap tire rubber as replacement material for natural aggregate will reduce as the content of the scrap tire rubber increase. This shows that the nature of rubber which has higher flexibility tend to increase the flexural strength of the material but reducing in compressive strength.

It is said that using of tyre rubber waste as partial sand replacement will enhance the durability of the structure due to self-compacting concrete. This is due to lesser voids in the concrete containing tyre rubber waste as the voids will be filled by these smaller particles (Yung *et al*, 2013). Another study also have proven that low rubber content which is less than 10% has a very good balance between toughness and strength. It also meets all the requirements for structural material properties (Li *et al*, 2014). A study had shown that the usage of waste tyre as aggregate replacement in concrete showing the rubber aggregates reduces the concrete workability (Guneyisi E *et al*, 2004). This information can be used in order to find whether the workability reduces if waste tyres are used as sand replacement.

In an investigation, it's proven that concrete composites containing tyre rubber waste has higher toughness in which it shows that tyre rubber waste has higher durability (Zheng L et al, 2008). When the content of crumb rubber content increases in concrete beam, it's discovered by Ho *et al.* (2012), that the ductility and slow crack propagation increases too.

2.7 Soil Stabilization

Amit *et al*. (2014) stated that the volume change potential of black cotton soil reduces when 30-50% of shredded tyre waste is added to the expansive black cotton soil. It's also discovered that shredded tyre waste reduces the shear strength of the soil.

Shredded tyre waste is suggested to be added in expansive black cotton soil only if the soil is used as backfill material of a retaining wall. It's said that it will help in reducing the backfill pressure. Besides that, it's also stated that the consolidation properties increase due to addition of shredded tyre waste which will increase the permeability of the mix. The compressibility properties of the mix also increase with the addition of shredded tyre.

Al-Bared *et al*, (2018) stated that different forms and sizes of tyre waster can be used to treat weak soils and also improvise the mechanical and physical properties of the soil. The negative impacts of the materials on environment will be reduced with the help of addition of tile and tyre rubber waste as soil improvement additives by reducing the amount of waste dumped in landfills or surrounding environment. These wastes also help in improve the workability of concrete. By using used shredded rubber tyre waste and fly ash as reinforcing agent and additive to soil, the strength of the cohesive of soil is improvised (Das and Singh, 2012).

2.8 Utilization of Waste Materials in Construction

Besides tyre rubber waste used in construction industry, there are few other waste products that can be used as sand, cement and aggregate replacement in order to reduce the problems like overload of waste in dump fills and environmental related problems. This is also essential in contributing towards sustainable construction.

2.8.1 Fly Ash

Fly ash is the product of the combustion of coal in electrical generation station. Taylor (2014) shows that excess calcium content is the reason of the self-cementing nature of the class C fly ash which act as the principal reactive phases for calcium hydroxide (CaOH) and anhydrite ($CaSO_4$). Mehta and Siddique (2007) stated that using fly ash improves the compressive strength of the concrete. This is due to the small size of the fly ash that fills in the voids which makes the concrete denser and compact compared with aggregates with larger size. Studies show that the early stage of hydration is disrupted but then accelerated at later stage due to usage of fly ash as cement replacement (Narmluk & Nawa, 2011). The usage of fly ash as cement or sand replacement helps in reducing waste disposal problems in landfill by channelling a certain amount into material and structure to be reused as a useful product. Based on

Fanghui *et al* (2015), about cement can be replaced by ground fly ash. The emission of carbon dioxide (CO_2) during hydration process of cement can be reduced due to additive of fly ash.

2.8.2 Seashells

Seashell is a disintegration of dead animals waste obtained near seashore area. Research shows that 90% of the composition of seashell contains calcium carbonate (Mosher et al, 2010). The seashells usually have higher densities and strength compared to limestone powder because of its crystal like structures that are composed by aragonite and calcite. The crushed seashells in concrete have a better permeation property compared to plain one. The addition of crushed sea shell is said to reduce the porosity of the concrete as it improvise the hydration process to produce more amount of C-S-H bond to fill in the void in concrete. The mixing of seashell into mortar mixtures didn't cause reduction in term of compressive strength (Safi *et al*, 2015). This is due to good adhesion between seashell and cement particles.

The seashell doesn't possess pozzolanic property. Since the modulus of fineness of seashell decreases, it tends to reduce the workability of concrete containing seashell. The early strength development of concrete may improve because of high level of calcium in seashell (Yang *et al*, 2005). Replacing coarse aggregate with cockle shell is able to produce good quality concrete due to its hardness property (Muthusamy and Sabri, 2012). The production of shell powder requires high energy for the grinding process to grind the shell into fine grain powder. This makes the usage of shell powder less popular in construction field. Sawdust also has a very high extent of surface porosity.

2.8.3 Limestone Powder

Limestone is the sedimentary rocks which made up of calcium carbonate. Limestone powder is normally used as filler in concrete that doesn't possess any pozzolanic properties. Research says that limestone-filled cements have been actively used in construction for more than 20 years (Livesey, 1991). Bobovetti *et al.* (2003) stated that the practice of using limestone filler is very common in the world because of its ability to improve the early strength and reduce content of cement in the mix. The addition of limestone powder im the concrete had improved in terms of strength. Chi *et* *al*. (2014) discovered that 15% of limestone in the material was the optimum percentage used to improve the mechanical properties of the concrete. Limestone powder addition is one of the most effective method in terms of cement cost where its substituted for gypsum as a set regulator. 15% of limestone powder able to increase the compressive strength up to 12% but Hameed and Sekar (2009) stated that limestone requires high cement content, as cement provides active silicon dioxide to react with the calcium hydroxide to from secondary calcium silicate hydrate gel (C-S-H). Limestone powder usage is able to reduce the initial and final setting time as well as the porosity of the cement mortar. This is because the limestone powder fills the voids between cement particles during hydration process due to formation of secondary C-S-H gel at early stage. This formation will speed up the setting time of cement paste (Heikal *et al*, 2000). The addition of limestone will also increase the heat of hydration. Addition of limestone powder is able to increase the permeability of the cement mortar which will reduce the rate of water absorption. 15% of limestone was the optimum percentage to reduce the rate of water absorption which is around 9.5% as stated by Benabed *et al* (2016). This addition of limestone powder has also improvised the permeability of cement mortar as it blocks the passage connecting capillary pores. Reduction of the usage of Portland cement production and carbon dioxide emission will provide economic and environmental advantages. Usage of limestone powder in construction industry can help reduce this problem. Addition of limestone powder also improves early and later strength development of cement mortar and concrete.

The use of limestone powder in the cement and concrete may provide economic and environmental advantages by reducing the Portland cement production and carbon dioxide emission. Thus, addition of limestone powder may improve the early and later strength development of the concrete.

2.8.4 Sawdust

Sawdust is the wood dust waste produce to due cutting and grinding of wood. Sawdust has a very high content of silicon dioxide and calcium oxide (Vassilev *et al*, 2014). Saw dust has higher surface area due to higher degree of irregularity in shape and porosity of the surface as the grinding and cutting process of wood is not uniform (Rajamma *et al*, 2009). Its stated that 10% of sawdust as partial cement replacement was the optimum percentage compared to other percentages (Raheem and Adenuga, 2013). The compressive strength of the concrete shows significant drop as the percentage beyond 10% of sawdust as partial cement replacement. A study justified that the mechanism of the sawdust particles that act like a filler material within the cement paste. This causes declination of the material strength as the surface area of filler materials to be bonded by decreasing the amount of cement (Udoeyo et al, 2016). This happens because of increased in sawdust amount which increased in surface area of the filler. Even though using sawdust in construction is one of the effective ways in order to reduce the quantity of waste in landfill, it's not advisable to do so because the mechanical properties of the sawdust material are not up to the requirement.

2.8.5 Palm Oil Fuel Ash (POFA)

A research on palm oil fuel ash (POFA) obtained from industrial waste from palm oil mill used as partial cement replacement in concrete mix (Munir et al, 2015). The role of POFA as the filler in foamed concrete explains how the voids between aggregates are filled in order to make it denser. Besides that, it's stated that POFA replacing cement in a concrete are able to reduce the weight of the concrete up to 50%. The strength of the concrete with addition of POFA reduces. Thus, POFA in foamed concrete can be used as light weight concrete which can be used as non-load bearing building structures material.

2.9 Summary

A lot of studies have been conducted to reduce depending solely on natural resources while not affecting the strength and quality of the cement mortar and concrete while practising sustainable construction. Researches had been conducted on effect of tyre rubber powder as partial sand replacement on cement mortar. This is to suggest an idea on how to reduce the amount of waste materials especially tyre rubber. Excessive tyre rubber on landfills causes a lot of issues. It causes more land to be used to dump these wastes. It also creates a habitat for pests which leads to health issues. This also is to reduce the dependency on natural resources especially sand which will lead to imbalance ecosystem and damage to natural environment. Despite all this issues, these wastes can be used as partial sand or cement replacement in order to reduce the amount on landfill. Thus, the compressive strength, flexural strength, workability, pulse velocity across the cube to identify the number of voids and cracks and effect of temperature on rate of curing had been identified and analysed to study the effect and compatibility of tyre rubber waste in construction in this research.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter depicts the specific detail of materials to be used, the characteristics of the materials, laboratory testing to be carried out, and the methodology of how the experiment to be carried out precisely. Expected data and results are also attached to be compared or set as a reference point. The tests conducted were compressive strength test, water absorption test, flexure test, and flow table. These tests were conducted to get enough data and results to support the study and to differentiate the difference of our study with the normal existing data and results. The procedure of each experiment were stated step by step and explained in detail with methodology 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.

3.2 Material Preparation

Materials used in Cement Mortar in this case study were Ordinary Portland Cement (OPC), sand, water and tyre rubber waste.

3.2.1 Ordinary Portland Cement

The main ingredient in Cement Mortar is the cement itself. Cement Mortar is produced when Portland cement form a paste together water which binds with sand to be harden. This OPC is used throughout this experiment.

3.2.2 Fine Aggregates

River sand which were mined in Sungai Panching, Kuantan, Pahang to be used as fine aggregates in UMP Laboratory. Fine sand is well graded fine aggregate. The modulus of fineness of the sand is 2.65.

Table 3.1 Modulus of Fineness

B.S sieve size (mm)	**Weight of the aggregate retained (g)**	**Cumulative weight of aggregate retained (g)**	**Cumulative weight of retained (%)**
10	0.01	0.010	0.00
5	2.40	2.410	0.48
2.16	24.75	27.160	5.43
1.18	89.27	116.430	23.27
0.6	166.21	282.640	56.48
0.3	146.51	429.150	85.75
0.15	50.98	480.130	95.94
pan	20.31	500.440	100.00

$$\text{Modulus of Fineness} = \frac{0.00 + 0.48+5.43+23.37+56.48+85.75+95.94}{100} = \frac{264.6}{100} = 2.65$$

3.2.3 Water

Water is one of the main substances used in mixing cement mortar. Water is very essential in this process called hydration process. Tap water was used for mixing and curing of cement mortar. A proper amount of water is used based on water cement ratio to get the optimum cement mortar mix. The water used from the UMP Structural Laboratory which is supplied by Jabatan Bekalan Air Pahang.

3.2.4 Tyre Rubber Waste Powder

Tyre rubber was the main reason this research is conducted. These tyre rubbers are used to replace the sand in the mix design in order to create the modified cement mortar 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 tyres were then cut into 5-8cm squares to form a smaller size using block cutter. These small squares were then crushed using broken rubber machine repeatedly to make it even smaller gradually. In this process, the iron wire and tyre rubbers were separated by using high-strength magnetic separation method. The particles were segregated through standard sieve screen to sort according to sizes and grades.

3.3 Mix Proportion

In this research, in order to identify the optimum mix design of cement mortar which uses tyre rubber waste as partial sand replacement, 4 trial mix design were used to compare the properties. The trial mix design were consists of 0%, 5%, 10% and 15% of tyre rubber waste replacing sand in the mix design. The water cement ratio used for the mixing is 0.4 (0.34 is identified through Vicat Penetration test but insufficient of water). Below is the mix design of the research.

Table 3.2 Mix Design for Cement Mortar

Element	**Weight (kg/ m3)**
Cement	400
Fine Aggregate	690
Water	1000

3.4 Preparation of Cement Mortar with Tyre Rubber Waste Powder

As per planned, four mixtures of cement mortar were produced for the purpose of testing the optimum amount of waste tyre powder to be replacing sand in the mixture. This research was also to compare tyre rubber contained cement mortar with the plain cement mortar to identify the advantages and disadvantages together with the suitability of usage of this mixture in industry. The first design consists of Ordinary Portland Cement, fine aggregates and water which was used as controlled sample (0% of Tyre rubber Powder as partial sand replacement). The other 3 mixtures were designed with the same ingredient as the controlled sample but with addition of tyre rubber powder replacing sand in 5%, 10%, and 15% proportion of the sand in the mixture.

3.4.1 Mixing the Cement Mortar

The materials were prepared earlier according to the mix design as per proposed. The sand, the cement, and the tyre rubber (except controlled sample) were added into cement mortar mixer and mixed slowly. Then, the water is added gradually until optimum mixture is achieved. Flow table test was carried out and the observations were recorded.

3.4.2 Casting Cement Mortar

Since the testing were about cement mortar, the size of mould used for this research were cube moulds (50 X 50 X 50) mm for compression test and flexural prism moulds (40 X 40 X 160) mm for flexural test. The mould’s surfaces were greased using oil before proceeding with casting of the cement mortar. This is to ensure the removal of mould process of the cubes and prisms to be easier. After mixing the cement mortar and the flow table test, the cement mortar were compacted into the greased mould layer by layer and compacted again using vibrating table. After removing the air bubbles, the moulded cement mortars were allowed to dry in open air for 24 hours.

3.4.3 Curing Method

After 24 hours of drying period, the dried cement mortar were removed from the mould and immersed in water tank for water curing. Water curing helps in completing the hydration process as it will consistently provide the required amount of water. This method is said to be the best curing method as it minimise the loss of water to the maximum. These cubes and prisms were water cured for 3, 7 and 28 days.

3.5 Laboratory Testing

For this research, few tests were conducted in laboratory to identify the properties and to compare the mixture to get the optimum amount of tyre rubber to replace sand. Based on the information obtained from these tests, the data were analysed and interpreted to see whether it satisfies the objective of this research stated in Chapter 1. The tests conducted were compressive test, flexural test, and flow table test. The effect of tyre rubber in temperature of cube from setting time till hardening time was observed.

Table 3.3 Tests that were conducted in this study

Category of Test	Type of Test
Compressive strength of hardened concrete	Compressive strength test
Flexural strength of hardened concrete	Flexural test
Workability of fresh concrete	Flow table test
Ultrasonic Pulse Velocity Test	UPV test
Effect on Temperature	Temperature test

3.5.1 Compressive strength test

Compressive strength test was carried out to determine the compression strength and maximum load the hardened cement mortar can withstand. The samples, with the size of (50 X 50 X 50) mm were prepared and casted. The samples were immersed in water for water curing for 28 days. The cubes were tested in compression machine by applying compression load which is added gradually until the specific load where it fails. All the procedures and rules were followed according to BS 1881:Part116:1983 and ASTM C 39-03. The moulds were greased in its inner layer to ease removal of mould process as the cement mortar can be removed easily from the mould without sticking to the mould. Cement mortar is casted in mould and compacted using vibrating table. For each mixture, two cubes were casted due to insufficient mould and shortage of time. Once the cement is dried and hard, it’s removed from the mould and immersed in water for water curing process. Compression strength test is conducted on 3rd, 7th and 28th.

Before the compression strength test to be conducted, the dimension and weight of the cube is observed and recorded. The most clean and smooth surface of the cube, both upper and bottom part were cleaned together. The compression machine is adjusted to a smaller height to ensure the cube enters just to its size and holds the cubes in position. The cube was then placed in the centre of the platform. The machine settings were adjusted to ensure the precision of data is correct. The compression machine is set to start to apply continuous load until the cube failed due to maximum load of compression. The data of ultimate load, stress and type of failure were observed and recorded.

3.5.2 Flexural Test

Flexural test was conducted to find out the Modulus of Rupture, also known as bending strength. The cement mortar samples of were tested by applying loads at the middle of beam until failure occurs. The highest stress within the cement mortar samples at its moment if yield represents the flexural sample of the cement mortar. The prism samples with size of (40 X 40x 160) mm were first prepared and kept in water for curing for 28 days. The prisms were tested in Flexural Testing Machine. In this test, load is applied at the centre of the prisms gradually until it fails and the maximum load needed to fail the prisms was recorded. The rules and procedures were followed according to BS 1881:Part118 and ASTM C 78-02. For the preparation of the prism, the moulds were greased before the cement mortars were casted. The fresh cement mortars were inserted in the mould in 3 layers and compacted using vibrating table. Four prisms were casted per mixture, where two prisms tested respectively on 3rd and 28th days. The data were observed and recorded for analysis.

3.5.3 Flow Table Test

Flow Table Test is a method to check the workability of cement mortar. Freshly casted cement mortars were normally used in this test. The fresh cement mortars were casted based on mix design. According to mix design, 4 mixtures were mixed with respective amount of tyre rubber powder replacing the sand by 0%, 5%, 10% and 15%. These fresh cement mortars were then tested by using a wet flow table. The flow table moisturized with water and the wet mould was filled with freshly casted cement mortar. The mixture then compacted in 3 layers by using tamping method by dropping the rod for 25 times. Once compacted, the mould was removed and the fresh cement mortar experienced drop for 25 times. The diameters of the fresh cement mortar were taken for 6 times and the average is calculated.

3.5.4 Ultrasonic Pulse Velocity Test

Ultrasonic Pulse Velocity test (UPV test), is a non-destructive test used to identify the cracks, segregation and compaction. Firstly, the ultrasonic testing equipment is prepared with pulse generating and pulse receiving transducer. The UPV testing equipment is calibrated with standardised material. The transducers were placed on opposite sides of the materials. The travelling time and pulse velocity readings were recorded and analysed. The test is carried out on 3^{rd}, 7^{th} and 28^{th} days.

3.5.5 Effect on Temperature on Rate of Curing

Temperature difference is measured to identify the effect of tyre rubber waste powder on fresh cement mortar on which needed to identify the suitability of the admixture in rate of curing of the cement mortar. The fresh cement mortars were casted based on mix design with respective amount of tyre rubber powder replacing the sand by 0%, 5%, 10% and 15%. Once the fresh cement mortar was placed in the mould and vibrated to remove the air bubbles, the thermometer was placed and the temperature was taken. The reading of temperature is taken from the setting time until the first 2 hours for every 5 minutes and every hour until 17^{th} hours. The readings were tabulated and the effect of adding tyre rubber waste powder is analysed.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this project, four cement mortar mixes were prepared, one mix was used as control and the other four mixes were cement mortar with 5%, 10% and 15% of tyre rubber waste powder as partial sand replacement. The results of the control cement mortar were used to be compared with the results obtained from cement mortar of other mixes to observe the effect on properties. All the cement mortar were tested and analysed for compressive strength, flexural strength, consistency, UPV test, and effect on curing temperature. This chapter discusses the results obtained from the research.

4.2 Compressive Strength test

The compressive strength test was conducted based on BS EN 12390-3:2009. Cube size of 50 mm x 50 mm x 50 mm was used for cement mortar testing. Four types of mixtures were prepared (0%, 5%, 10% and 15%) with two cubes per mixtures, the sample cubes were water cured after dried for one day. The compressive strength was tested on 3^{rd}, 7^{th} and 28^{th} days.

Figure 4.1 shows the compressive strength test results of cement mortar mixes containing different percentages of tyre rubber waste powder as partial sand replacement. It is proven that replacing the tyre rubber waste powder as partial sand replacement has effect the compressive strength of cement mortar. The strength of cement mortar increases continuously as the curing time increases.

The compressive strength of controlled sample has the highest for all three days among that 4 mixes. Among the different samples that containing tyre rubber waste powder, cement mortar containing 5% of the waste has the highest compressive strength followed by 10% and 15% sample.

The controlled sample compressive strength of cement mortar after 28 days of water curing is 43.70 MPa. The compressive strength of each mixture of 5%. 10% and 15% of tyre rubber waste powder as partial sand replacement are 35.47 MPa, 29.55 MPa and 26.37 MPa respectively in water curing of 28 days. The result shows that the compressive strength declines as the percentage of tyre rubber waste powder used as partial sand replacement increase. This declining in strength is due to lack of adhesion properties between cement and tyre rubber particles. Rubber basically is impermeable to water so it slows down the absorption of water which is essential for hydration of cement in cement mortar. The higher the content of tyre rubber waste powder, the weaker the bonding between particles which reduces adhesion force between particles in cement mortar. This causes the compressive strength in cement mortar with tyre rubber waste powder less compared the normal cement mortar because it can't hold greater force due to weak bonding between particles.

Table 4.1 Compressive Strength Test results

	PERCENTAGE		0%	5%	10%	15%
	DAY\READING		Average	Average	Average	Average
COMPRESSION TEST	DAY 3	MAX LOAD	70.2	58.25	56.35	36.85
		STRESS	28.08	23.31	22.54	14.74
	DAY 7	MAX LOAD	81.05	68.30	61.80	49.90
		STRESS	32.42	27.32	24.74	19.97
	DAY 28	MAX LOAD	109.25	88.70	73.85	65.95
		STRESS	43.70	35.47	29.55	26.37

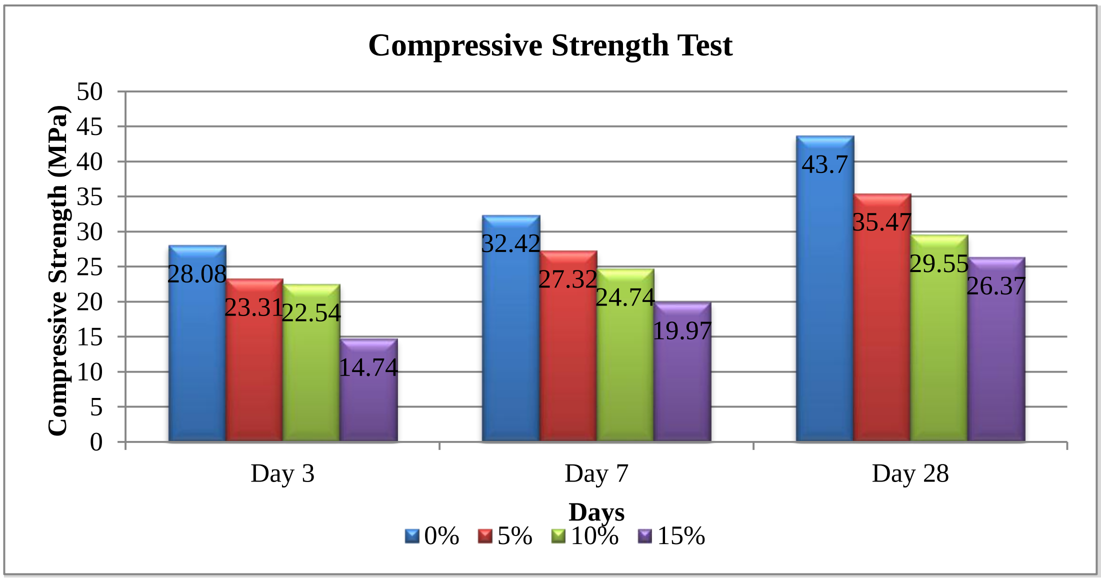

Figure 4.1 Compressive Strength Test result

4.3 Flexural Test

The flexural test is conducted to get the modulus of rupture of certain mixture. The test was carried out by following the specification as per in BS 1881:118 and ASTM C 78-02. Prism with size of 40 mm x 40 mm x 160 mm was used to test the cement mortar properties of flexural strength. Four types of mixtures were prepared (0%, 5%, 10% and 15%) with two prisms per mixtures, the sample cubes were water cured after dried for one day. The modulus of rupture was tested on 3^{rd} and 28^{th} days. The results of the Modulus of Rupture of each mixtures on 3^{rd} day shows that Flexural strength of prisms with 0% and 10% of tyre rubber waste powder as partial sand replacement in cement mortar prism has the same strength which is 5.93 MPa, where 5% and 15% of tyre rubber waste powder as partial sand replacement in cement mortar prism shows 3.74 MPa and 5.01 MPa respectively. This shows that replacing sand with tyre rubber waste powder has effect on early strength of the cement mortar. On 28^{th} day, the flexural strength of cement mortar declines as the percentage of tyre rubber waste powder increases in the mixture by replacing sand. The Modulus of Rupture of 0%, 5%, 10% and 15% of tyre rubber waste powder are 13.84 MPa, 9.90 MPa, 9.23 MPa and 7.56 MPa respectively. This overall result shows that the flexural strength of prisms reduces as the percentage of the tyre rubber waste increases in the mixture. This happens due to tyre rubber nature of being flexible but couldn't withstand high pressure compared to controlled sample which results reducing in term of strength.

Table 4.2 Flexural Test results

	PERCENTAGE		0%	5%	10%	15%
	DAY\READING		Average	Average	Average	Average
FLEXURAL TEST	DAY 3	MAX LOAD	2.53	1.59	2.53	2.14
		STRESS	5.93	3.74	5.93	5.01
	DAY 28	MAX LOAD	5.91	4.23	3.93	3.23
		STRESS	13.84	9.90	9.23	7.56

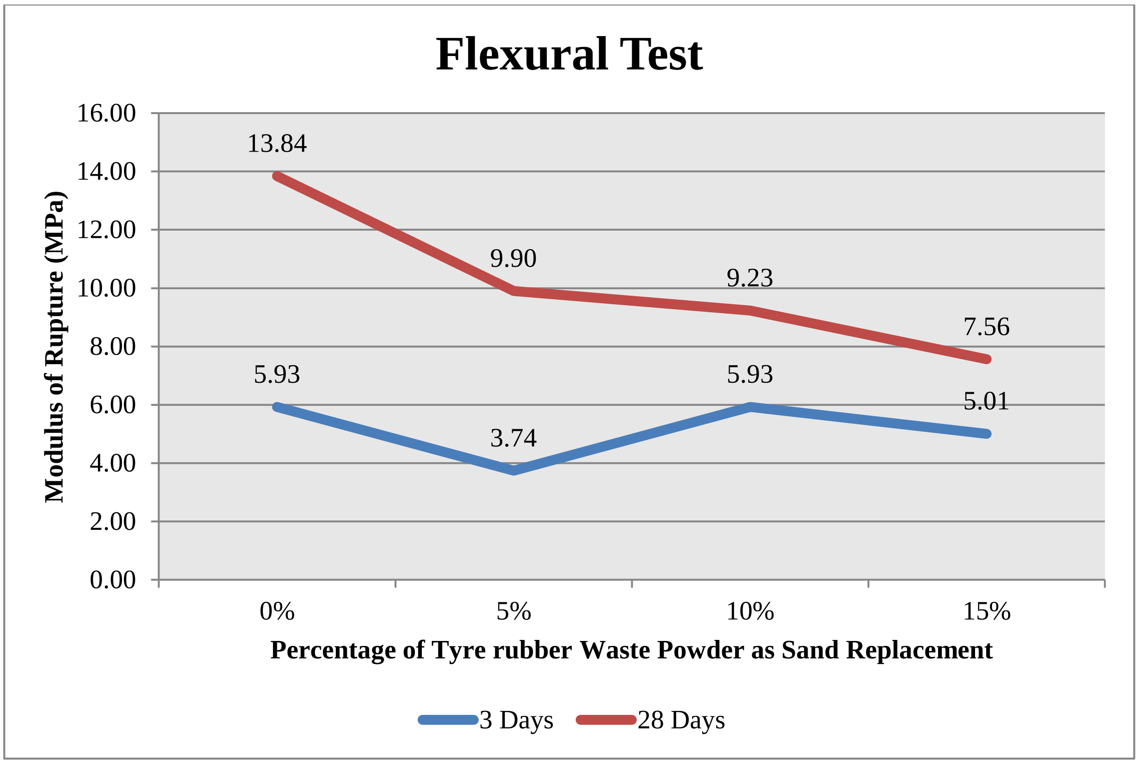

Figure 4.2 Flexural Test results

4.4 Flow Table Test

This test is mainly to measure the consistency of the cement mortar. The test is conducted once the fresh cement mortar is prepared. The result shows that the consistency increases as the content of the tyre rubber waste powder in the mixture increases as well. Data shows that 0% of tyre rubber waste powder has an average diameter of 159mm and 5% of tyre rubber waste powder as partial sand replacement has an average diameter of 173mm. The diameter of the fresh cement mortar with 10% of tyre rubber waste powder as partial sand replacement is 184mm and 15% of tyre rubber waste powder as partial sand replacement has 203mm diameter. This increase in diameter as the amount of tyre rubber waste replacing sand increasing proves that it increases the consistency of the cement mortar. This increases the workability of the cement mortar which shows that the ability of the cement mortar to be compacted and can be placed without segregation increases too. The lesser the workability of the cement mortar, the higher the strength of the cement mortar which is based on compressive strength test result.

Table 4.3 Flow Table Test results

0%		5%		10%		15%	
RDG	mm	RDG	mm	RDG	mm	RDG	mm
1	155	1	170	1	180	1	210
2	155	2	170	2	175	2	195
3	160	3	175	3	185	3	205
4	160	4	175	4	190	4	210
5	165	5	170	5	185	5	200
6	160	6	175	6	190	6	200
AVG	159	AVG	173	AVG	184	AVG	203

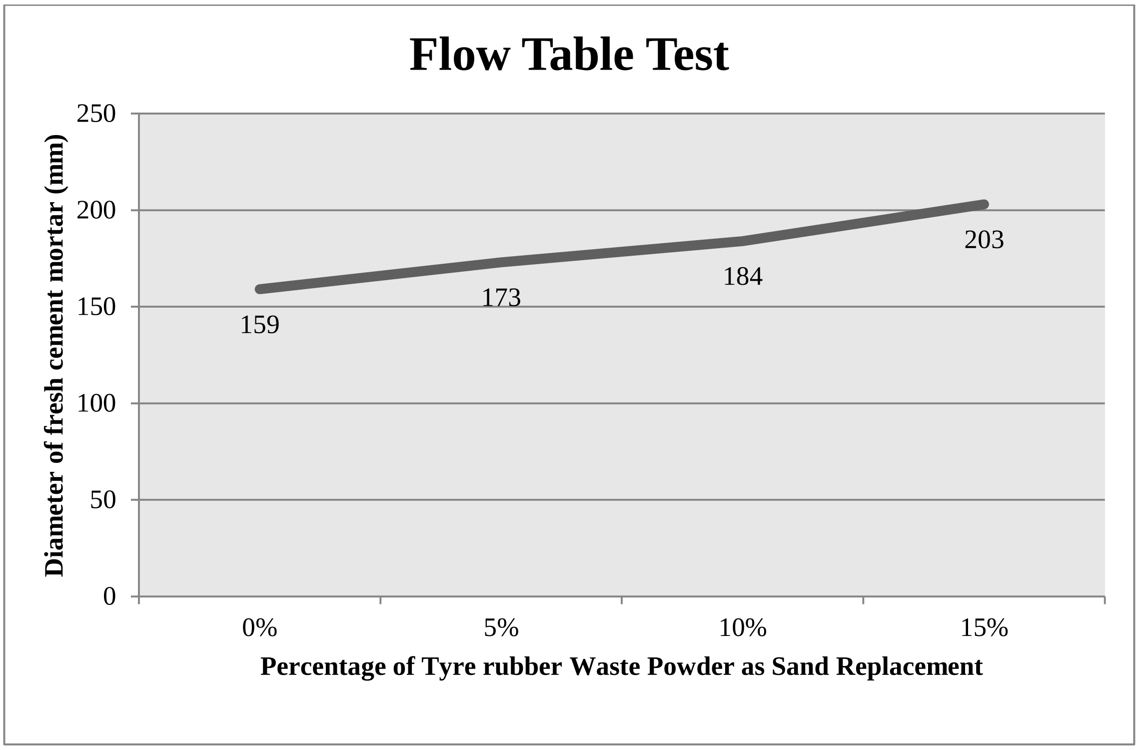

Figure 4.3 Flow Table Test results

4.5 Ultrasonic Pulse Velocity Test

The results of 10% and 15% of tyre rubber waste powder used as partial sand replacement in cement mortar were compared. It shows that for 10% of tyre rubber waste powder used as partial sand replacement in cement mortar the reading taken was 2.82 x10^{-6} km/s on 3^{rd} day,3.03 x10^{-6} km/s on 7^{th} day and 3.13 x10^{-6} km/s on 28^{th} day while 15% of tyre rubber waste powder used as partial sand replacement in cement mortar the reading taken was 2.80 x10^{-6} km/s on 3rd day, 2.95 x10^{-6} km/s on 7th day and 3.02 x10^{-6} km/s on 28th day. Based on this result, it shows that cement mortar with 10% of tyre rubber waste powder as partial sand replacement has less cracks and voids compared to cement mortar with 15% of tyre rubber waste powder as partial sand replacement. The faster the speed, the lesser the cracks and voids exist in the cement mortar. Lower percentage of tyre rubber waste powder has higher pulse velocity. This shows that lack of adhesion between cement and tyre particles that affect the strength of the cement mortar.

Table 4.4 Ultrasonic Pulse Velocity Test

Percentage	10%	15%
DAY 3		
Width(km)	0.00005	0.00005
Time(s)	17.7x10^{-6}	17.88x10^{-6}
Longitudinal Pulse(km/s)	2.82	2.8
DAY 7		
Width(km)	0.00005	0.00005
Time(s)	16.52x10^{-6}	16.94x10^{-6}
Longitudinal Pulse(km/s)	3.03	2.95
DAY 28		
Width(km)	0.00005	0.00005
Time(s)	15.97x10^{-6}	16.53x10^{-6}
Longitudinal Pulse(km/s)	3.13	3.02

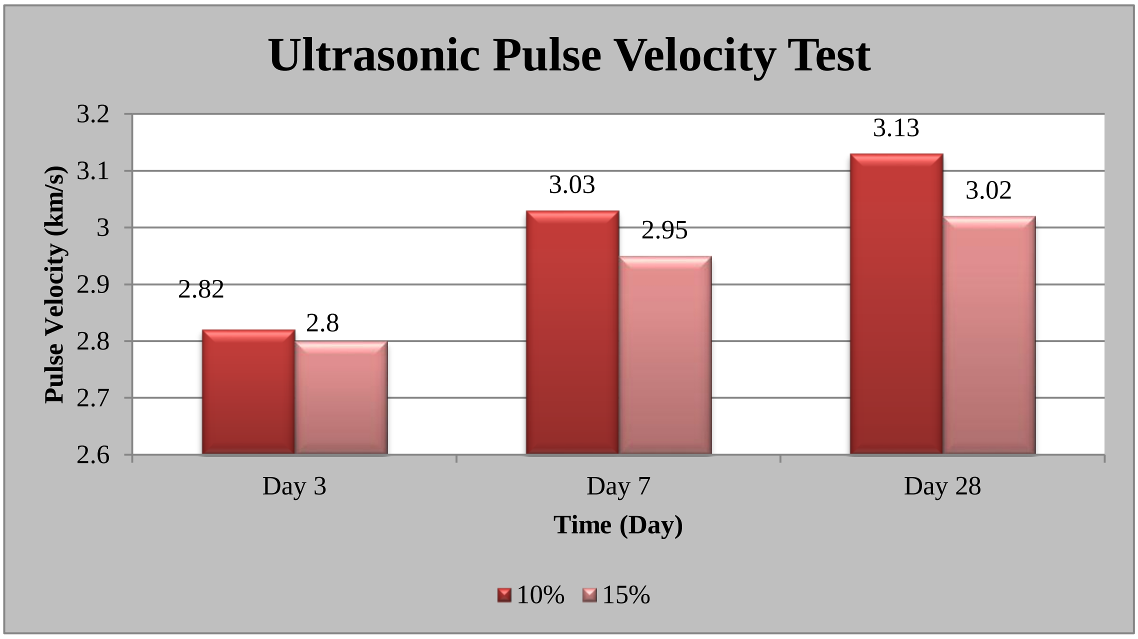

Figure 4.4 Ultrasonic Pulse Velocity test

4.6 Effect on Temperature on Rate of Curing

The temperature of fresh cement mortar is affected by the percentage of tyre rubber waste powder based on the results obtained. Based on the results obtained, there are slight changes in temperature of fresh cement mortar when tyre rubber waste powder is added in the mixture. The result shows that the more the percentage of tyre rubber waste powder used as sand replacing admixture, the higher the temperature of the mixture. Temperature will affect the rate of curing in early stages of the cement mortar cubes (Teixeira et al, 2016). The rate of curing is faster when the temperature is higher. 0% and 5% of tyre rubber waste powder replacing sand in the mixture has final temperature of 29.50°C while 10% and 15% of tyre rubber waste powder replacing sand in the mixture has final temperature of 32.10°C. The more the percentage of the tyre rubber waste powder added more drastic changes in temperature changes which will affect the rate of curing. The temperature should be optimum which is 29-30°C means really high temperature will have bad effects on rate of curing as it will undergo plastic shrinkage.

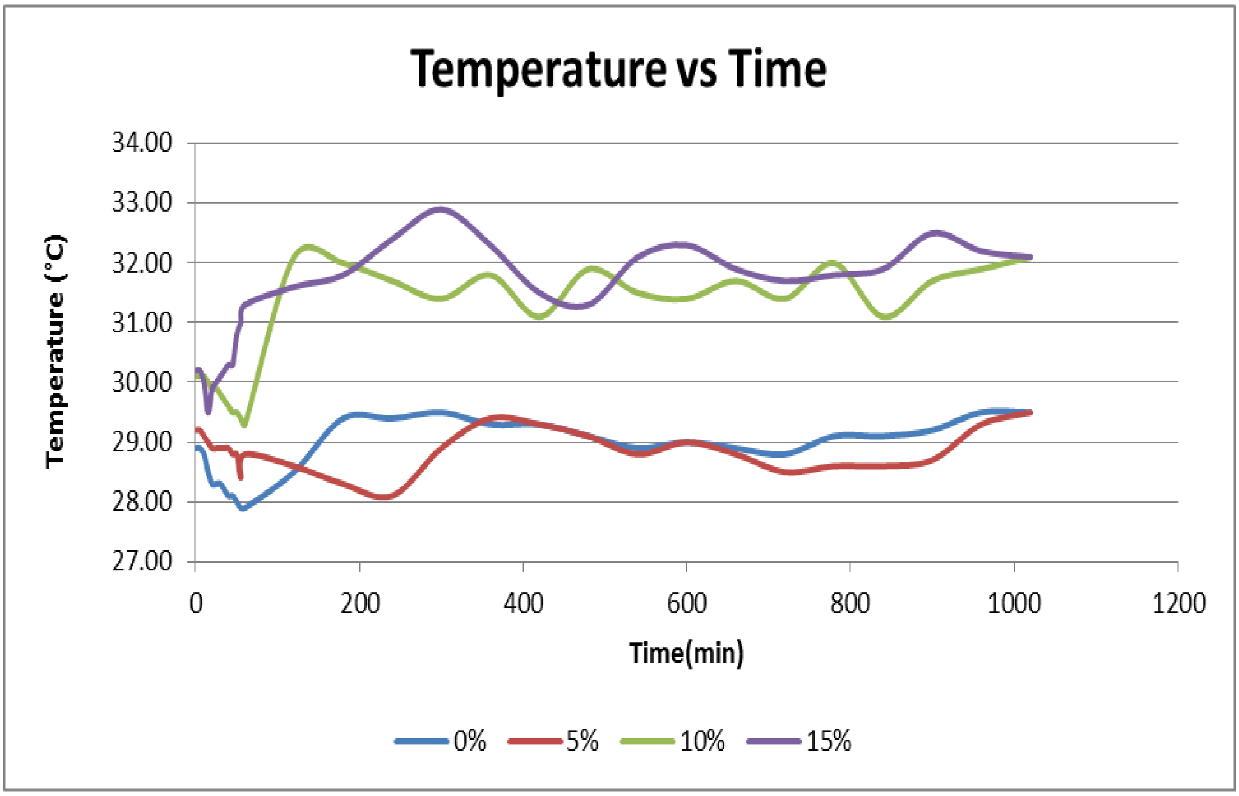

Figure 4.5 Temperature versus Time results

Table 4.5 Temperature reading for the first 17 hours

EFFECT OF TEMPERATURE				
Time\Percentage	0%	5%	10%	15%
Setting time	28.90	29.20	30.10	30.20
5 min	28.90	29.20	30.10	30.20
10	28.80	29.10	30.10	30.00
15	28.50	29.00	30.00	29.50
20	28.30	28.90	29.90	29.90
25	28.30	28.90	29.90	30.00
30	28.30	28.90	29.80	30.10
35	28.20	28.90	29.70	30.20
40	28.10	28.90	29.60	30.30
45	28.10	28.80	29.50	30.30
50	28.00	28.80	29.50	30.80
55	27.90	28.40	29.40	31.00
1 hour	27.90	28.80	29.30	31.30
2	28.50	28.60	32.10	31.60
3	29.40	28.30	32.00	31.80
4	29.40	28.10	31.70	32.40
5	29.50	28.90	31.40	32.90
6	29.30	29.40	31.80	32.30
7	29.30	29.30	31.10	31.50
8	29.10	29.10	31.90	31.30
9	28.90	28.80	31.50	32.10
10	29.00	29.00	31.40	32.30
11	28.90	28.80	31.70	31.90
12	28.80	28.50	31.40	31.70
13	29.10	28.60	32.00	31.80
14	29.10	28.60	31.10	31.90
15	29.20	28.70	31.70	32.50
16	29.50	29.30	31.90	32.20
17	29.50	29.50	32.10	32.10

CHAPTER 5

CONCLUSION

5.1 Introduction

The main purpose of this whole research is to identify the effect of the tyre rubber waste powder as partial sand replacement in cement mortar in terms of compressive strength, flexural strength, workability and effect on curing temperature. The following conclusions are drawn from the results obtained from the experiments conducted.

i. The cement mortar containing 5% of tyre rubber waste powder as partial sand replacement has the optimum strength which is 88.70MPa compared to other percentage of tyre rubber waste powder. It can be used for non-load bearing structures as it has lower strength compared to plain cement mortar.

ii. In term of flexural strength, 10% of tyre rubber waste powder as partial sand replacement has the higher early strength which is 5.93MPa but cement mortar containing 5% of tyre rubber has the highest among the samples containing tyre rubber waste powder which is 9.90MPa. So, we can use either cement mortar containing 5% or 10% tyre rubber waste as partial sand replacement if we need more durable surface or structure that will not wear out easily.

iii. The workability of the fresh cement mortar increases as the percentage of tyre rubber waste content in the mixture increases. This can be applied according to type of structure we need to construct. The lesser the workability, the stronger the cement mortar in terms of compressive strength. So based on necessity of the strength consideration and also the ability to place the cement mortar consideration, the proper percentage of tyre rubber waste powder is chosen. In this research, the optimum one would be 5% tyre rubber waste powder content cement mortar.

iv. The higher the content of tyre rubber waste powder in the mixture, the more the voids and cracks in the cement mortar. This is due to poor adhesion between tyre and cement particles.

v. The higher the content of tyre rubber waste powder in the mixture, the higher the temperature of the fresh cement mortar. The higher the temperature to a certain point, the temperature will help increasing in the rate of curing of the cement mortar.

vi. Based on overall results, observation and analysis, cement mortar containing 5% of tyre rubber waste powder is the most optimum amount and satisfies all the test criteria and the objective of the research.

vii. This research indicates that the tyre rubber waste powder have a very good potential in replacing sand in cement mortar in industry for low-cost building projects and for non-load bearing structures. The use of tyre rubber waste powder will reduce the consumption of sand from river and also reduce the volume of wastage disposed at landfill.

5.2 Recommendation

There are few recommendations I would like to suggest for further research in studying of cement mortar properties. The recommendations are:

i. To study the fire resistance of cement mortar containing tyre rubber waste powder as partial sand replacement.

ii. To investigate on different workability rate on strength on cement mortar containing tyre rubber waste powder as partial sand replacement.

iii. To study the durability of cement mortar containing tyre rubber waste powder as partial sand replacement in terms of acidic resistance.

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APPENDIX A

Figure 1 The moulds are cleaned before greased

Figure 2 Moulds are greased before the cement mortar is casted

Figure 3 The cement mortar is mixed using Grinding Machine

Figure 4 Well mixed fresh cement mortar

Figure 5 Freshly casted cement mortar

Figure 6 Temperature reading taken for the first 17 hours

Figure 7 Cube is undergoing compressive strength test

Figure 8 Compressive strength test result of cube

Figure 9 Prism undergoing Flexural Test

Figure 10 Result of flexural strength of the prism

Figure 11 UPV testing machine