EFFECT OF EPOXY RESIN AS PARTIAL CEMENT REPLACEMENT ON COMPRESSIVE STRENGTH AND TENSILE STRENGTH WITH THE FIXED PROPORTION OF SILICA SAND AS PARTIAL SAND REPLACEMENT

GAN SHANG WEI

B. ENG(HONS.) CIVIL ENGINEERING

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

DECLARATION OF THESIS AND COPYRIGHT

Author's Full Name : GAN SHANG WEI

Date of Birth : 28 AUGUST 1994

Title : EFFECT OF EPOXY RESIN AS PARTIAL CEMETN REPLACEMENT ON COMPRESSIVE STRENGTH AND TENSILE STRENGTH WITH THE FIXED PROPORTION OF SILICA SAND AS PARTIAL SAND REPLACEMENT

Academic Session : 2017/2018

I declare that this thesis is classified as:

- ☐ CONFIDENTIAL (Contains confidential information under the Official Secret Act 1997)*
- ☐ RESTRICTED (Contains restricted information as specified by the organization where research was done)*
- ☑ OPEN ACCESS I agree that my thesis to be published as online open access (Full Text)

I acknowledge that Universiti Malaysia Pahang reserves the following rights:

1. The Thesis is the Property of Universiti Malaysia Pahang
2. The Library of Universiti Malaysia Pahang has the right to make copies of the thesis for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified by:

_______________________	_______________________
(Student's Signature)	(Supervisor's Signature)
940828-04-5293	DR GUL AHMED JOKHIO
New IC/Passport Number	Name of Supervisor
Date: 08 JUNE 2018	Date: 08 JUNE 2018

NOTE : * If the thesis is CONFIDENTIAL or RESTRICTED, please attach a thesis declaration letter.

SUPERVISOR'S DECLARATION

I/We* hereby declare that I/We* have checked this thesis/project* and in my/our* opinion, this thesis/project* is adequate in terms of scope and quality for the award of the Bachelor Degree of Civil Engineering

____

(Supervisor's Signature)

Full Name : DR GUL AHMED JOKHIO

Position : SENIOR LECTURER

Date : 08 JUNE 2017

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

____

(Student's Signature)

Full Name : GAN SHANG WEI

ID Number : AA14103

Date : 08 JUNE 2018

EFFECT OF EPOXY RESIN AS PARTIAL CEMENT REPLACEMENT ON COMPRESSIVE STRENGTH AND TENSILE STRENGTH WITH THE FIXED PROPORTION OF SILICA SAND AS PARTIAL SAND REPLACEMENT

GAN SHANG WEI

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

Faculty of Civil Engineering and Earth Resources

UNIVERSITI MALAYSIA PAHANG

JUNE 2018

ACKNOWLEDGEMENTS

First of all, I would like to express my gratitude to my supervisor, Dr Gul Ahmed Jokhio for the continuous guidance, advice, support, and assisting me in making this research possible. His knowledge and opinion in this field of study has helped me to complete my research and thesis.

I would like to thanks to the staffs help me in all the technical problem during my laboratory works in Concrete and Heavy Structure Laboratory of the Faculty of Civil Engineering and Earth Resources.

Last but not least, I wish to thanks my family for encouraging me with their best wishes and also to all who are involved directly or indirectly in the process of complete my research.

ABSTAK

Struktur adalah elemen yang dapat dijumpai di setiap negara. Kebanyakan struktur disokong oleh unsur-unsur yang dibuat oleh konkrit seperti rasuk, lajur, papak dan asas. Ia memainkan peranan penting dalam menahan beban dari elemen atas yang meningkatkan kestabilan dan ketahanan struktur. Bahan utama yang digunakan dalam campuran untuk menghasilkan konkrit adalah simen. Karbon dioksida telah dikeluarkan dalam proses pengeluaran simen. Apabila pembangunan negara meningkat, liputan kawasan bandar meningkat dan penggunaan simen telah meningkat. Oleh itu, usaha untuk mengkaji kesan resin epoksi sebagai pengganti simen separa dalam konkrit pada kekuatan mampatan dann kekuatan tegangan adalah amat penting. 30 bilangan sampel konkrit telah disediakan untuk tujuan kerja makmal. Ujian kekuatan manpatan dan ujian kekuatan tegangan digunakan untuk menentukan kekuatan mampatan dan tegangan bagi setiap sempel untuk mendapatkan peratus optimum simen boleh digantikan dengan resin epoksi untuk menghasilkan kekuatan optimum. Dalam kajian ini, 30% simen yang digantikan dengan resin epoksi memberikan kekuatan mampatan optimum serta kekuatan tegangan berbanding 10% dan 20% sampel. Keputusan kekuatan mampatan yang direkodkan dari kajian ini berbeza dari 5.96 hingga 2917 MPa manakala hasil kekuatan tegangan yang direkodkan berubah dari 1.26 hingga 2.23 MPa. Hasil keseluruhan sampel menunjukkan berkadar terus apabila peratusan resin epoksi meningkat.

ABSTRACT

Structures are the elements that can be found in every country. Most of the structures are supported by the elements that made by concrete such as beam, column, slab and foundation. It play an important roles in withstand the loads from the upper elements which increase the stability and durability of the structures. The main material used in the mixtures to produce concrete is cement. The carbon dioxide was emitted in the process of cement production. As the development of the country increased, the coverage of urban area was increased. Hence, the usage of cement was increased. Therefore, making an effort to study the effect of the epoxy resin as the partial cement replacement in concrete on compressive strength and tensile strength is crucial. 30 numbers of concrete samples were prepared for the purpose of laboratory works. Compressive strength test and tensile strength test were used to determine the Compressive Strength and tensile strength of each sample in order to observe the optimum percentage of cement can be replace by epoxy resin to produce optimum strength. In this research, the 30% of cement was replaced by the epoxy resin gave the optimum compressive strength as well as tensile strength compare to 10% and 20% of the samples. The results of compressive strength recorded from this research varied from 5.96 to 29.17 MPa while the results of tensile strength recorded were varied from 1.26 to 2.23 MPa. The overall results of the samples show directly proportional when the percentage of the epoxy resin increased.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

MPa	Mega Pascal
mm	Millimetre
KN	Kilonewton
m	metre
Kg	Kilogram
g	Gram
M^3	Metre Cube
g/mol	Gram per moles
°C	Degree Calcius

LIST OF ABBREVIATIONS

ASTM	American Section of the International Association for Testing Materials
PIC	Polymer Impregnated Concrete
PMC	Polymer Modified Concrete
PC	Polymer Concrete
IPCC	Intergovernmental Panel on Climate Change
CAS	Chemical Abstract Service
UTM	Universal Testing Machine

CHAPTER 1

INTRODUCTION

1.1 Background of study

Nowadays, concrete has been widely used in the field of construction as supporting material to transfer the load of the building. Therefore, concrete is an important material in construction project. As we know that concrete is the combination of cement, coarse and fine aggregates. Cement act as the binder that bind the aggregate to produce significant strength. However, cement brings negative impact to the environment. The manufacturing of cement is not environmental friendly due to the emission of carbon dioxide, nitrogen monoxide, sulphur dioxide, volatile organic compounds and others especially during the production of clinker in calcination process. The emission can also be in form of dust, noise and vibration during the operation of machineries. Although many machinery has been invented to overcome the problems of emission however the elimination of harmful substance due to emission still cannot be totally prevented. Other than that, there is another weakness of concrete is it is with poor tensile and flexural strength, high porosity and low resistant toward the chemicals substance.

As a result, polymer cement concrete is under research for the replacement of cement. In polymer cement concrete, polymer act as the binder between the aggregate instead of cement in order to improve its properties. The polymer cement concrete has more excellent properties compare to the concrete. Besides that, it is much more environmental friendly compare to cement. The environment pollution cause by the manufacturing of cement can be solved with the replacement of cement with epoxy resin to act as the aggregate binder. There are various polymers that can choose to replace cement as the binder in the concrete. Epoxy resins are one of the syntactic polymers that can replace cement as the binder and it has better properties than the cement. In the addition, epoxy modified concrete has good resistance toward heat, strong resistance to the acid, organic solvents.

Epoxy resin manufacture from the petroleum derived and some plant derived sources also can produce the resin. For this research, Epoxy resins are purchased from the supplier. Cured Epoxy has excellent properties which are high resistance to acids, alkali and heat. The fine aggregate of the polymer concrete also replace by the silica sand which is almost same size with the sand. This is to reduce the void ratio during the mixing process. By using silica sand as the fine aggregate the minimum void ratio between the epoxy, cement and aggregate is decrease and this can improve the strength of the concrete.

Due to the advantages of epoxy resin instead of the cement and replacement by the silica powder instead of sand as the fine aggregates, thus in this research the different proportion ratio of epoxy resin studied to examine the compressive strength and the best model also been determined.

1.2 Problem Statement

In this twenty-first century, all the countries are in the state of development which means that the ratio of the building to the natural has been increase. The emission of air pollutants will increase while those countries are in the developing process. Global warming is one of the most serious problems that concern by the public and government. This is because the global warming can cause negative effect to our next generation if global warming is more serious sea level will also increase. The main air pollutant which causes global warming is greenhouse gas which also called carbon dioxide. In our knowledge, plants inhale in carbon dioxide and manufacture their food under the process of photosynthesis and thus in the same time this action has kept the planet cool. However, by increasing the manufacturing of concrete of combination of cement, course and fine aggregates will cause rising of carbon dioxide level which will then turn the cooling system down. According to research study of ("Carbon dioxide's effects on plants increase global warming, study finds -- ScienceDaily",

2010) global warming cause by the greenhouse gas and the increase of carbon dioxide would cause significant warming to the planet which then will cause the melting of the iceberg, the climatic change and flash flood.

All of us know that concrete is the common component use in civil engineering construction field as the support element to transfer the load to earth. Meanwhile, cement is the main component to act as the binder between the aggregate to form concrete. However, the manufacture process of cement will emit large amount of carbon dioxide gas and significant amount of solid waste materials that will cause environment pollution. Furthermore, according to the Earth Institute of Columbia University the industries which produce a material so ubiquitous and invisible is cement which caused global warming (Ebnesajjad, 2016). https://chemical-materials.elsevier.com/new-materials-applications/global-warming-carbon-dioxide-buildings-and-clt/ Thus, in this research, different portion of the epoxy resin to replace cement with the fix portion of sand replace with the silica sand is investigated to determine the optimum portion which can achieve the largest strength. By doing so, the best portion of epoxy resin can be found and in same time help to reduce the use of cement in the construction field and cut down the side effect toward environment.

1.3 Objective

The main aim of this research is to investigate the optimum proportion of cement can replace by the epoxy resin in order to increase the mechanical properties of concrete. The objectives of this study are:

1. To study the effect of the epoxy resin as the partial cement replacement in concrete on compressive strength with the optimum proportion of silica sand as the partial sand replacement.
2. To study the effect of the epoxy resin as the partial cement replacement in concrete on tensile strength with the optimum proportion of silica sand as the partial sand replacement.

1.4 Scope of study

The scopes of this research involve identify the maximum percentage of cement can be replaced by epoxy resin in order to produce the concrete with excellent compressive strength and tensile strength. The proportion of sand will also replace by the silica sand which is similar size with sand but the proportion of silica replacement is fixed at the optimum percentage that can produce highest compressive and tensile strength. Research found that the silica can act as the fillet in order to reduce the void ratio between aggregate (Golestaneh,et.al., 2010).

The grade of normal concrete use to compare the strength polymer concrete is G25 which will have 25N/mm compressive strength. Civil Engineering Laboratory Manual book 3rd Edition as the guideline to calculate the proportion of materials for mix design in order to standardize the design for all portion of materials.

In this research, four concretes with different percentage of cement replace by epoxy resin will be made to find out the most suitable proportion that will result highest compressive and tensile strength. The tests will carry out by using universal test machine same as the procedure of testing the normal concrete. The compressive strength test and tensile splitting test are used to test the specimen for 3 day, 7 day and 28 day for each percentage of epoxy resin as the cement replacement. Three specimens are used to test on each day in the test and there are nine specimens are used to test in one test for one percentage of epoxy resin as the cement replacement. The total number of specimens made in this research is seventy two for two tests. This research will take one and half month to obtain the results and the location to carry out the test on concrete is the concrete laboratory at University. This duration of study include the process of mix design, curing of concrete and test the mechanical properties of concretes.

1.5 Significance of Study

Public health is one of the main topics discuss and concern not only by government agencies and the global agencies. Many actions had taken by the agencies in order to overcome or solve the phenomenon that will bring negative effect to public health and environment. Global warming is one of the most common and serious phenomenon that rising nowadays during hot season. One of the parameters that cause the phenomenon is carbon dioxide gas. Intergovernmental Panel on Climate Change, or IPCC was formed by a group of scientist from United Nations. IPCC found that carbon dioxide is the gas responsible for the most warming that happen on earth. (“Global Warming and Climate Change Causes,” 2017).

During the production of clinker which is a component of cement, the carbon dioxide is released (Gibbs, 2000). This research found a way that can reduce the use of cement to make concrete by replace it with epoxy resin. As the need of cement decease, the production of cement will reduce. Hence, the emission of carbon dioxide will decrease significantly. This research will benefit to the public and have a big improvement in the construction field when it is success. Since the emission of carbon dioxide can be reduced, global warming can be solve in the future.

In this research, the fixed proportion of sand will also replace with silica sand. The process of making concrete will also require large amount of sand. Sand and coarse aggregate mixtures contain different size in granules and gravels form to ensure there are uniform voids between the aggregate particles in concrete mixture (Tim Plaehn, n.d.). The production of sands required mining process from beach and lake which will bring the negative effect to the environment. Water quality of the river will be affected if the instream sand mining activities take place(MATTEO BARABINO, 2017) . Hence, the decrease on use of sand in the construction filed will also help to improve the condition of environment. This also can bring the benefit toward the public when the water quality is good condition.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter covers the introduction about the epoxy resins that used in this study. The properties and chemical compound of epoxy resins are discussed in this chapter. The histories about the contribution of polymer concrete are given to get to know more about the function and advantages of polymer concrete. The type of polymers are introduce in this chapter to give more understanding about the fundamental of polymer in concrete This chapter also cover the previous research that study about the epoxy resin as the cement replacement and the silica sand as the sand replacement.

2.1 History of polymer in concrete

The polymer concrete had been published over 25 year and there are many research was study about the sustainability of polymer concrete in the future toward the construction field. There were few type of polymer in concrete which is polymer concrete (PC), polymer modified concrete (PMC) and polymer impregnated concrete (PIC). PC and PMC was start used in the 1950s, although the uses were very limited and the knowledge on the polymer in concrete is very less. After 20 year, the PIC was developed that the concrete-polymer is publish widely. The first International Congress on Polymer in Concrete (ICPIC) was held in London after the American Concrete Institute Committee 548, Polymer in Concrete was formed. The concrete-polymer materials become household words in the construction industry with the help of regular ICPIC conferences.

In 1960s, the researchers have performed extensive research on the material about the polymer impregnated concrete (PIC) in Brookhaven National Laboratory and the bureau of Reclamation in United Stated, the PIC has become widely known by the people. Although there are other researchers already invented it earlier. PIC was produced by inject the low viscosity monomer into the hydrated Portland cement concrete. The compressive strengths of the PIC normally three to four times greater than the concrete from which it was made and same goes to the tensile and flexural strength. PIC also had high resistant toward the acid and alkali due to the low permeability in the structure of itself. Since the PIC can produce outstanding properties, many structures are using the PIC as the support part including bridge deck, pipes, building cladding and post-tensioned beams and slabs. (Fowler, 1999)

Polymer concrete (PC) was establish and used in 1958 at United Stated to produce the cladding of building. Polymer concrete is the mixture of aggregate, polymer binder and hardened if necessary. There are no Portland cement or water found in PC. The polymers used as the binder are polyester-styrene, acrylics and epoxies but also the vinyl ester, furan and urethane also been used. Sulphur is also used as the polymer to make the sulphur concrete which can withstand high acid attack. Normally, PC used as the repair material for concrete due to the rapid curing time and excellent bonding with concrete and steel reinforcement. The applications of the PC were used as the drains, underground boxed, acid tank and cells which need the strong resistance toward the acid and alkali. (Fowler, 1999)

Polymer modified concrete (PMC) using the latexes mix with the Portland cement since the 1950s. PMC made with the combination of Portland cement concrete with a polymer modifier like ethylene vinyl acetate, polyvinyl acetate and etc. The amount of the polymer used as the Portland cement binder is in the range of 10-20% of cement. The applications of the PMC were widely used in floor and bridge overlays with the minimum thickness usually about 30mm. PMC can produce higher flexural strength, low permeability of concrete and excellent bonding strength with concrete. PMC can be enhanced by adding the fibres to the mixture to improve tensile strength and reduce cracking in the service life of PMC. PMC required less cost compare to PC because less polymers are used in PMC.

2.2 Epoxy Resin

2.2.1 Fundamental of Epoxy Resin

The raw material used in production of epoxy resin is epichlorohydrin which is known as cycloaliphatic resins. The other common name of epoxy resin called as polyepoxides which is the reactive polymers that contain epoxide group. The term “resin” describes a board class polymer which can be cured into a usable harden plastic. Epoxies have excellent performance compare to other resin types in term of resistance toward degradation and mechanical properties. Epoxies are been widely used as the construction material for binding material. (Boyle et al., 2001)

The epoxy resin is thermosetting resins that contain the three-membered ring which consisting of two carbon atoms and one oxygen atom as shown in the Figure 2.1. Epoxy resin are higher molecular weight polymers or low molecular weight pre-polymers which consist at least two epoxide functional groups. The other name of epoxide functional groups is oxirane functional groups or glycidyl. One of the IUPAC Name of epoxy resin are 2-(chloromethyl)oxirane. The identifier of epoxy using CAS number is 37625-93-7. The standard molecular formula of epoxy resin is $C_{21}H_{25}ClO_5$ with the molecular weight of 983.876 g/mol. (PubChem, n.d.)

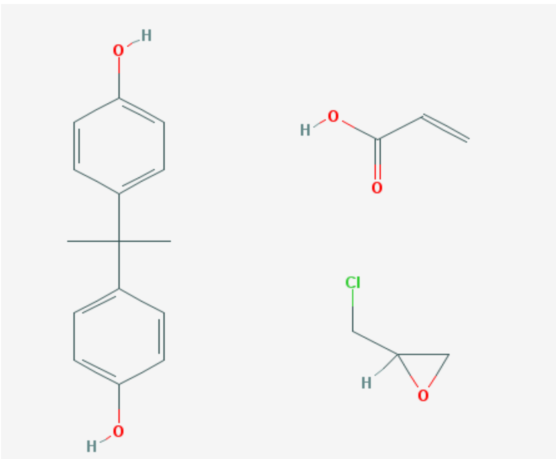

Figure 2. 1: Structural Formula of Epoxy Resin

2.2.2 Properties of Epoxy Resin

Epoxy resin is a colourless liquid as shown in Figure 2.2 and there are many colour of epoxy resin available in market which added dye for commercial purpose. Epoxy resin has low viscosity and easy cure at room temperature to 150 ℃ mix with the curing agent. One of the most excellent properties of epoxy resin is low shrinkage during the curing process because it chemical reaction occur without evolving volatile by-products. In addition, epoxy resin has high adhesive strength because the presence of polar hydroxyl and ether groups. This is one of the reason epoxy resin has been used as the binder material in construction field as the repair materials. (Takeichi and Furukawa, 2012)

Epoxy resin has excellent resistance toward alkali and acid after cured, it strength of resistance depend on the curing agent used. The cured epoxy resin can produce high mechanical properties and it usually surpasses other type of cured resin.(Jin, 2017) The tensile strength of the thermosets of epoxy resin can be exceeding 80MPa which is double of it compressive strength. The most common type of epoxy resin used in daily life is bisphenol A. As the molecular weight increase, the epoxide content are less and the material behaves like thermoplastic.(Gibson, 2017)

Figure 2. 2: Colourless epoxy resin and it hardener

2.2.3 Advantages of Epoxy Resin as Replacement of Cement

The materials that use epoxy resin as a binder in an aggregate matrix formed exhibit very favourable properties. These properties include resistant toward the acid and alkali, heat, fast rate of curing and excellent strength and bonding between particles(Kumar and Rakesh, 2016). Epoxy resins are used as the concrete repair material due to the high adhesives properties of epoxy resin. Therefore, Epoxy resin has been used as the cement replacement in the polymer concrete and polymer-impregnated concrete (Samanta, 2006). With the use of epoxy resin, the concrete will have excellent moisture resistance.

The epoxy resins are easy cure in any temperature between 5 ℃ and 150 ℃ depend on the curing agent used. There is no heat required during curing process and the curing can be added simultaneously with the epoxy resin. Unlike the curing process of furan resin, the resin cannot mix simultaneously with curing agent because explosion will occur. Besides that, Epoxy resins have low shrinkage during hardening compare to other resin such as furan resin, polyester resin and etc (Fink, 2013). Furthermore, the epoxy resin helps to reduce the void ratio in the concrete after curing, this can increase the mechanical properties of the concrete produce and the porosity of concrete also reduced.(Jin, 2017) Hence, the durability of concrete work life can be increased. (Alkhaleefi, 2001)

2.3 Silica Sand

2.3.1 Fundamental of Silica Sand

The common state of silica is in crystalline state and very rare in an amorphous state. The Silica sand consists of particles of mineral and rock fragments and small grains. The sands contain high silica particle level that is referred to as silica sand. Silica sand is the combination of silicon and oxygen in the given chemical formula SiO_2 as shown in the figure 2.3. The silica is hard, inert toward chemical and has very high melting point as the normal sand. The production of silica sand is from unconsolidated sands and crushed sandstones.

The crystalline silica sands were used to manufacture the glass in three to five thousand year BC. It has continued to contribute in the world being a raw material in the development of industrial especially in the ceramics and foundry industries. The silica sands also used in making the sand moulds for the foundry industry.

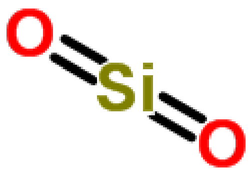

Figure 2. 3: Chemical Formula of Silica

2.3.2 Properties of Silica Sand

There are three major forms of crystalline silica which are quartz, cristobalite and tridymite. There are two types of quartz which is alpha and beta quartz. When the alpha quartz is heated under atmospheric pressure it became beta quartz at 573 ℃. The tridymite is formed when silica is heat up to 870 ℃ and the cristobalite is formed at 1470 ℃. Silica sand is melted under 1610 ℃ which is high melting point compare to metal such as copper and aluminium. The crystalline structure of quartz is the combination of large amount silica dioxide. Four oxygen atoms linked with the silica atom at the centre to form a three-dimensional shape named as tetrahedron shape. The giant size of tetrahedrons is form by joined together by share one electron from the oxygen to other silicon.

The colour of quartz is usually white or colourless but most of the time it will colour by the iron and other impurities. Quartz is relatively inert and does not react with the dilute acid because the bond in the giant tetrahedrons structure is strong enough to resist the dilute acid. The silica sand that can easily obtain in daily life are alpha quartz which is most stable form of silica sand. The crystalline tetrahedron structure of silica sand is shown as in figure 2.4.

Figure 2. 4: Tetrahedron Shape of Silica

2.3.3 Advantages of silica sand as river sand replacement

The silica sands are more environmental friendly compare to the river sand. With the silica sand as the replacement of river sand, the sand mining can be reduce and the ecosystem can be protected. The silica sand is cheaper compare to the river sand due to it is easily available. The micro-filling effect of silica sands help to reduce the pores between aggregate in concrete.(Manohara, 2018) Hence, the mechanical properties of the concrete can be increase and it can provide better moisture resistivity. The concrete made by using the silica sand can provide smooth surface texture benefit workability and reduce the water required in the mixture. (Radhakrishnan Kuttoor, 2011) .Silica sand can also obtain from the cement manufacture process which can use to increases the efficiency in the concrete. The silica sand has micro-filling effect and more consistent grading than many extracted aggregates. Silica sand also has light weight compare to river sand which can reduce the weight of concrete produced. (VishnumanoharA, 2014)

2.4 Curing Agent of Epoxy Resin

The curing grade of epoxy resin used in this research is room temperature curing grade. The curing agent is needed in transform the liquid state of epoxy resin to hard thermoset solids which is the hardening process of epoxy resin (Takeichi and Furukawa, 2012). Aliphatic amines are the most often curing agent used with epoxy resin. The ratio of curing agent and epoxy resin must be calculate before add them together because the ratio of mixture will affect the properties of cured resin. The ratio between curing agent normally is 1:1 or 1:2 depend on the curing agent used. Curing agent can reduce the temperature required to cure the epoxy resin and the bond can be break without heat because the chemical reaction between curing agent and epoxy resin is exothermic reaction.

The type of curing in this research called cold curing which is the epoxy resin can be cured under room temperature. The epoxy ring can be attacked by either active hydrogen or available ions but even amines. In this research, amine is used as the curing agent. The primary amine group react with the epoxide group to form the secondary amine groups. After that, the secondary amine groups react with the other epoxide groups and form the tertiary amine group. The chemical reaction of between hardener and epoxide group are shown in Figure2.5. The primary and secondary amine groups act as the hardener and tertiary amine groups as the catalytic hardeners (Takeichi and Furukawa, 2012). The product form after the curing process is very stable and high resistance toward chemical.

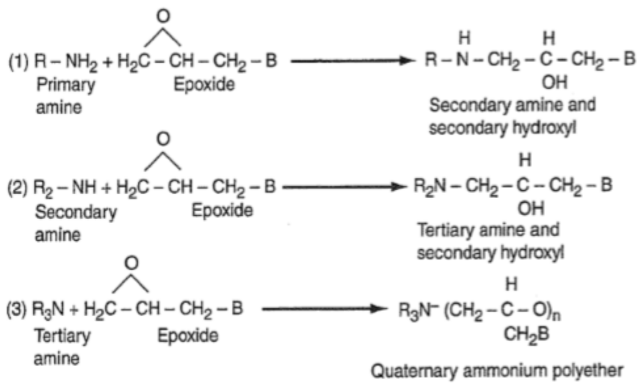

Figure 2. 5: Chemical Reaction of amine with epoxide group

Source: (Boyle et al., 2001)

2.5 Cube Test

The concrete has excellent compressive strength properties and that is the reason it used as the support element in construction field. With the use of epoxy resin as the cement replacement and the silica as the sand replacement, the compressive strength of concrete can be increase. The cube test is carry out to test the compressive properties of concrete with applied the vertical load on the cube continuously without shock until the crack observe on specimen. The maximum load carried by specimen before the crack being observe is recorded. The portion of cement replaced by epoxy resin and the portion of sand replaced by the silica sand will directly affect the compressive strength that produce by concrete. The optimum proportion of cement replace by epoxy resin and the portion of sand replace by the silica can produce the concrete with highest compressive strength.

In the research carry by others, it was investigate that with the increase percentage of cement replace by epoxy, the mechanical properties increase (Paper, 2005). The another research found that the optimum proportion of silica sand as the fine aggregate replacement was 50% of the portion of sand used in the process. This portion of sand replace by the silica sand will produce the slightly higher compressive strength compare to other portion.(Jignesh, 2015). The concrete with no replacement of epoxy resin and silica sand was produced for the comparison purpose. Basically, the polymer concretes are fast curing rate compare to the plain concrete. It will achieve the maximum compressive strength in the early stage. That is the different in term of curing rate between the polymer concrete and plain concrete. The test was carry out after the specimen curing about 3 days, 7 days and 28 days to determine the time for concrete to achieve it optimum strength.

Figure 2. 6: Experiment Set Up for Cube Test

Source: (Paper, 2005)

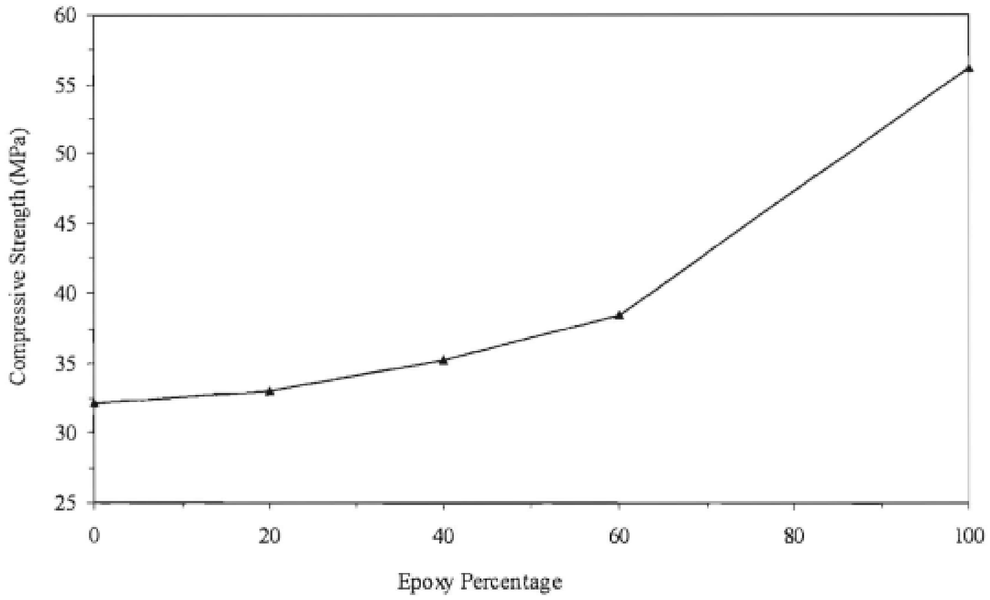

Table2. 1: Compressive Strength Epoxy Polymer Concrete versus percentage of Epoxy resin in concrete

Source: (Paper, 2005)

2.6 Tensile Splitting Test

Tensile strength is one of the mechanical properties of concrete structure but the plain concrete has weak tensile properties. Split tensile strength test is the test to determine the tensile strength of concrete. The shape of specimens used in this test is cylinder. The procedure of tensile splitting test is almost same with the cube test but a wood with same length with specimen was place on the specimen to make sure the uniform load are applied on it. The reading of the tensile strength test will smaller than the cube test because the concrete will subject to tensile failure rather than compressive failure.

Tensile strength is an important property that needed to determine because concrete structure are easily crack when subjected to the tensile forces. This is because of the various kinds of factor and applied loading itself. Concrete has high compressive strength than the tensile strength. Besides that, determination of the tensile strength is important that can help the designer to identify the length of reinforcement should be provided to the concrete in order to reduce the potential of cracking occur. The tensile splitting test can carry out for same type can also be used for compressive strength test and it is simple to perform and give uniform results than the other tension tests such as double punch test.

Basically, the tensile strength of polymer concrete is higher than the plain concrete which is double of tensile strength of plain concrete. (Horton lowel, 1983). In the research, it found that the optimum dosage of polymer in concrete from 0-25% which can produce the highest compressive strength and tensile strength (Kardon, 1997).

Figure 2. 7: Position of Specimen for Tensile Splitting Test

Source: (Paper, 2005)

2.7 Summary

This chapter presented a general concept of cement replaced by the epoxy resin from previous researchers study. The history of polymer in concrete had been reviewed in section 2.1. In this section, the advantages of the polymer concrete had been compared and discussed. In the next section, the basic properties of several type of epoxy resin had been introduced in section 2.2. The properties of silica sand also been discussed in the next section which is section 2.3. Next, the curing agent for the epoxy resin had been reviewed in section 2.4. Lastly, the standard of cube test and tensile splitting test had been explained in section 2.5 and 2.6.

CHAPTER 3

METHODOLOGY

3.0 Introduction

The research methodology for this research has two phases; (i) material preparation phase and (ii) mechanical properties testing of the samples. The material preparation phase includes preparing the materials needed for this research mix design which are cements, coarse and fine aggregate, epoxy resin and silica sand. Four different percentage of cement which used to make concrete are replaced with the epoxy resin and a fixed percentage of silica sand is replace the sand to reduce the void ratio between particles. Phase two involves testing the mechanical properties (Compressive and Tensile) of the sample in accordance with ASTM standards to understand effectiveness of the replace of cement with epoxy resin.

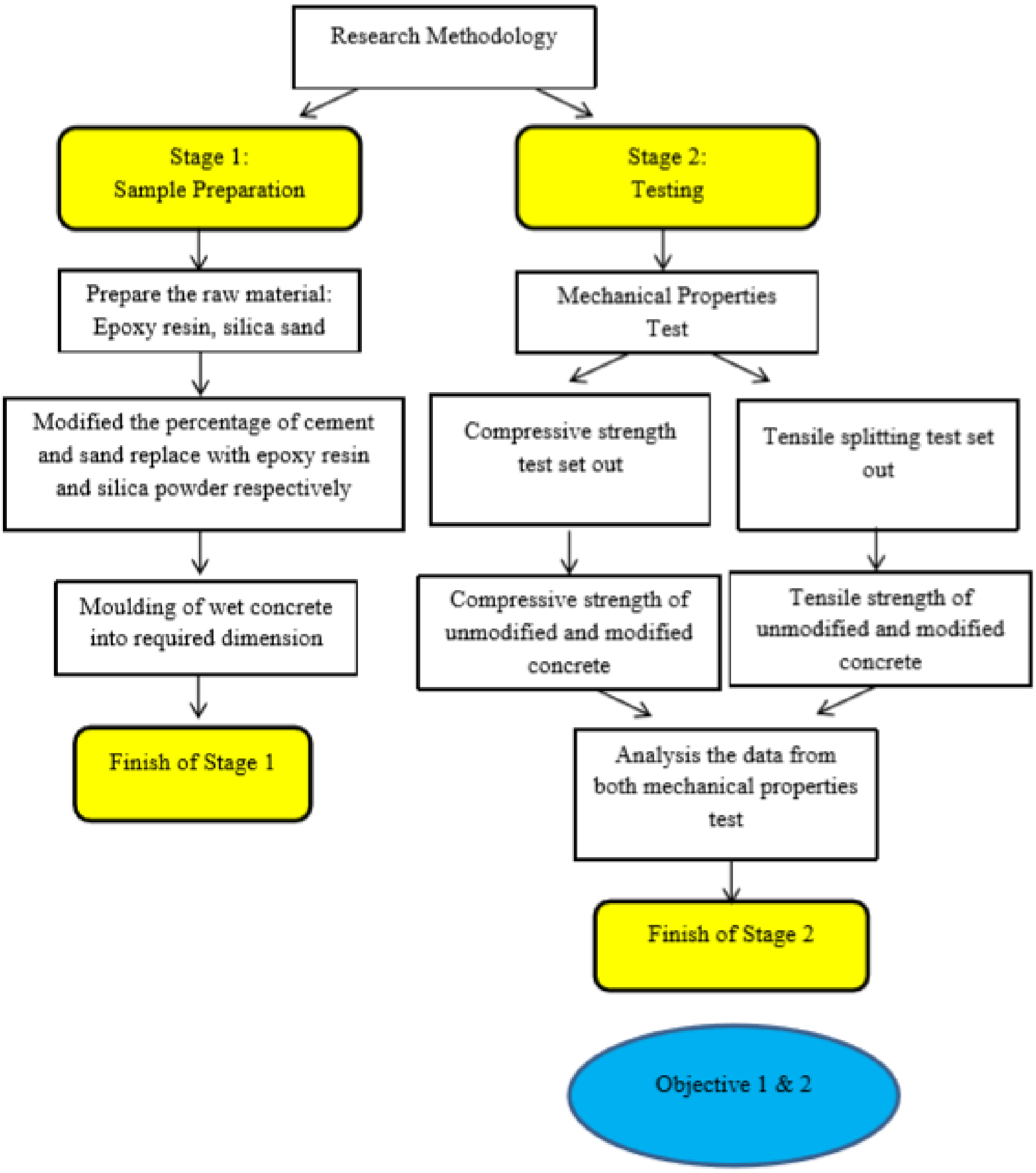

Figure 3. 1: The overall procedure of research

3.1 Material Preparation

The flow for the material preparation of this research is shown in Figure 3.1. The epoxy resin and silica sand is purchase from the supplier. Four sample with different percentage of cement replace with epoxy resin and fix percentage of sand replace with silica sand is calculated to proceed with the mix design. The dimension of samples will be moulded according to standard size of tensile test and compressive test.

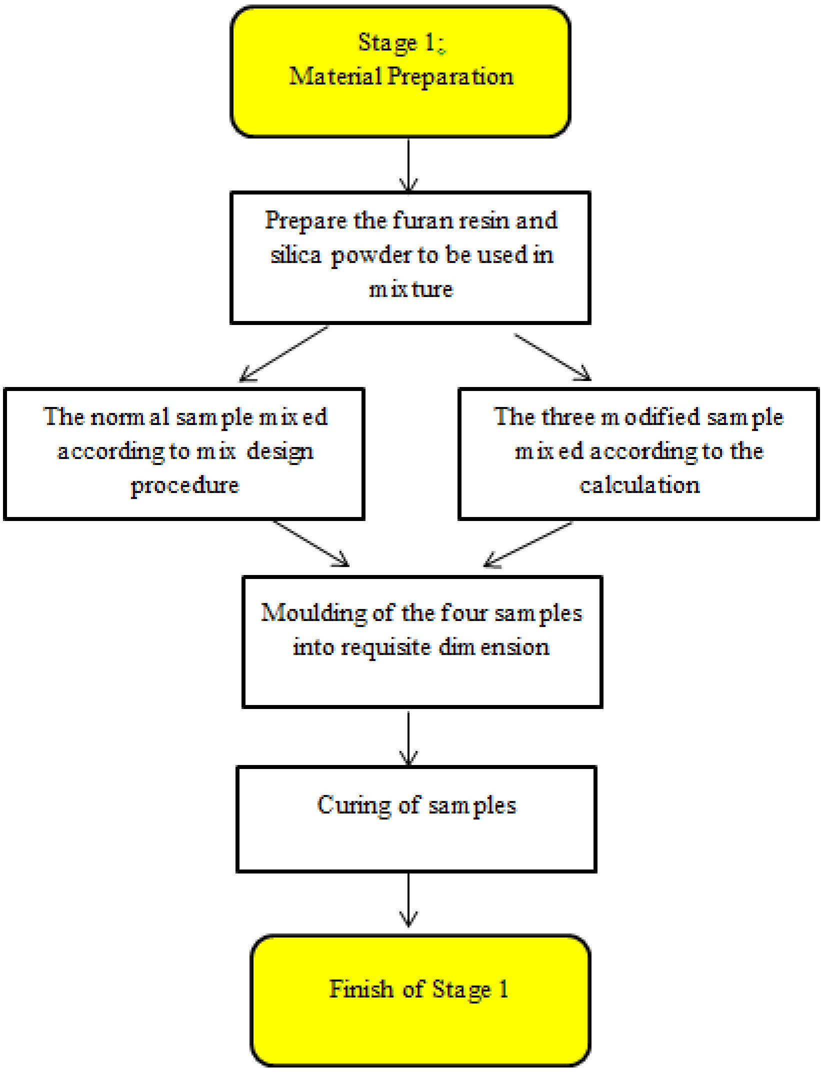

Figure 3. 2: The process involve in Stage 1

3.1.1 Sample Preparation

In this research, there is four samples with different percentage of cement replace with epoxy resin and a fixed percentage of sand replace with silica sand. The percentage of cement will be replace by epoxy resin are 0%, 10%, 20% and 30%. The percentage of sand replace with silica sand is 10% for four samples. The size of coarse aggregate is sieved according to the size needed in mix design which is 10mm and 20mm. There are two type of sample which is cube and cylinder shape. For the unmodified concrete in cube shape, the weight of cement, water, sand and course aggregate of size 10mm and 20mm are 0.32kg, 0.205kg, 0.801kg, 0.337kg and 0.673kg respectively. For the unmodified concrete in cylinder shape, the weight of cement, water, sand, and course aggregate of size 10mm and 20mm are 0.512kg, 0.328kg, 1.283kg, 0.539kg and 1.077kg. However, the weight of epoxy resin and cement are different with the unmodified concrete but the weight for water, sand, silica sand and course aggregate are the same. For the modified cube concrete with 10%, 20% and 30% of cement replace with epoxy resin, the weight of epoxy resin and cements are 0.032kg and 0.288kg, 0.062kg and 0.256kg, 0.096kg and 0.224kg respectively. For the modified cylinder concrete with 10%, 20% and 30% of cement replace with epoxy resin, the weight of epoxy resin and cement are 0.0512kg and 0.461kg, 0.102kg and 0.410kg, 0.154kg and 0.358kg respectively. The sample with different percentage are prepare separately.

After that, the materials are pour into the container and strip it for 20 mint to make sure the material are mix uniformly. The mixtures are pours in to the mold and the mold are vibrates using the vibration table. Thus, the mold is rest for one day and demold after 24 hour. The samples are put into the curing tank for 3 day, 7day and 28day.

Figure 3. 3 : Cylinder Sample had mould in to the cylinder mould

Figure 3. 4 : Prepare the mould for cube samples

Figure 3. 5 : The samples are left for one day in the mould and move to curing tank

Figure 3. 6 : The samples were placed in the curing tank until the day for tested

3.2 Material Testing

There are two test will be conduct to test the samples mechanical properties. The machine use to carry out the tests is Universal Test Machine and the load capacity is 50kN. The mechanical properties tests consist of the compressive test (ASTM C39) and tensile test (ASTM C496). All the cured sample have to be readied and labelled before the carry out the test. The process of material testing in stage 2 is illustrated in Figure 3.3

.

Figure 3. 7 : Samples were dried before determine its weight

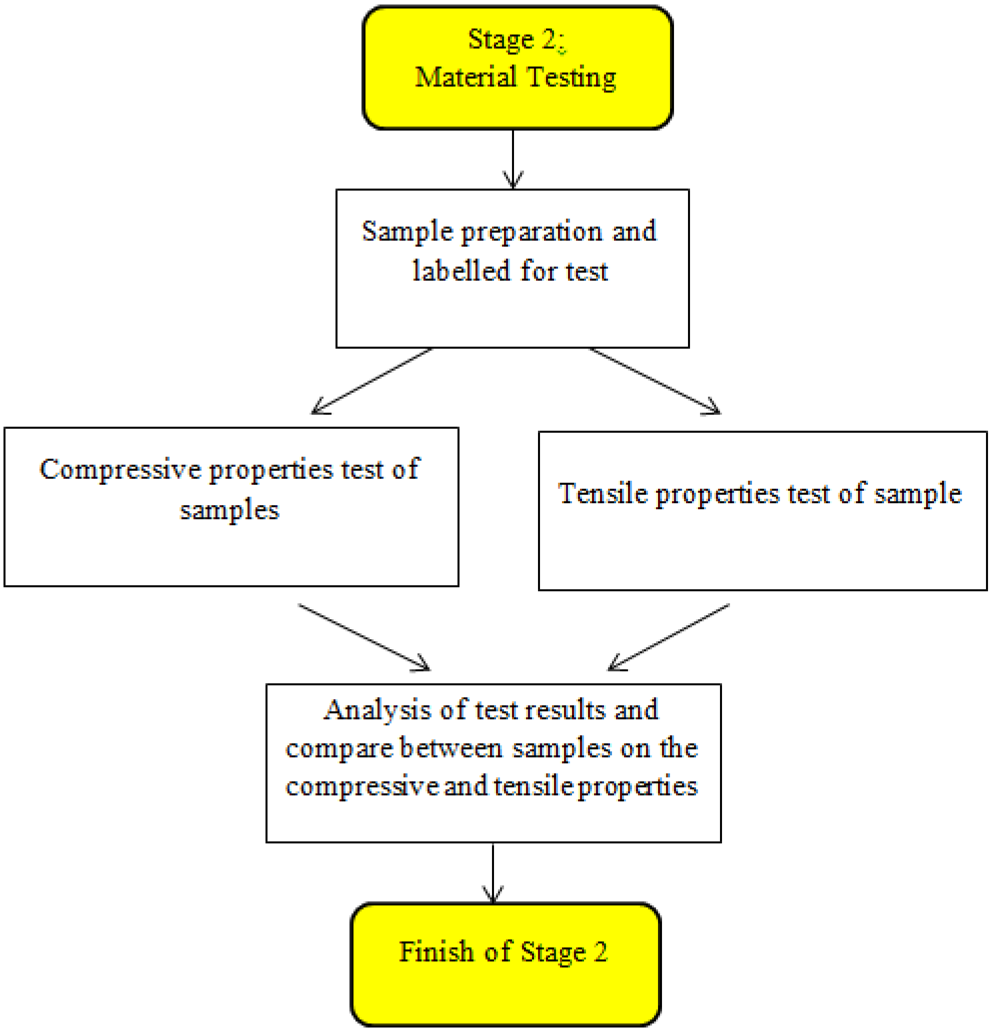

Figure 3. 8 : The process involve in stage 2

3.2.1 Mechanical Properties Test

The mechanical properties of concrete samples that will be tested in this research are compressive properties and tensile properties. Both tests are conducted using the UTM that available in the concrete laboratory. Each test required 3 samples to test for 3 day, 7 day and 28 days. Through the mechanical properties testing on the samples, a basic comparison between the compressive strength and tensile strength can be observed after the test.

The compressive test of samples is done accordance with ASTM C39 standards which is the standard test method for compressive strength. The compressive axial load of 50kN is applying to the cube samples at a rate until the failure occurs. The rate of movement of load at 0.25 $\pm$0.05 MPA/s shall be applied on the samples. (American Society for Testing and Materials, 2016) The samples are to be in the cube shape with dimension of 0.1x0.1x0.1m (width x breadth x length). The shape of each sample must be same and not more than 2%. The compression tests of cured samples must be made as soon as practicable after remove from the curing tank. The test is done when the load reading on load indicator is decreasing steadily and a well-defined fracture pattern show on samples. The result of maximum load carried by the samples show on the load indicator is recorded. After the test of all sample are done, the reading of each samples are compare and find out the largest compressive strength among the samples. Hence, a simple conclusion about the compressive properties can be made from the test result by analysis the compressive strength result.

Figure 3. 9 : Cube Samples placed into the Machine for Compressive Strength Test

Splitting tensile test in this study is to be done in accordance with ASTM C469 standard which is the guideline of standard splitting tensile strength test method for cylindrical concrete. The dimension of cylinder shape samples required in this test is 0.1m diameter and 0.2m height. The diametral compressive loads are applying to the length of cylindrical concrete samples at a constant rate until the failure occurs. The load must apply continuously and without shock at constant rate about 0.7 to 1.4 MPA/min splitting tensile stress and the test is stop when the failure occurs.(American Society for Testing and Materials, 2011) The Maximum applied load at failure show on load indicator is recorded for the analysis. During applying the load to samples, plywood bearing strips are used to ensure the load applied along the cylinder is uniform. The maximum load recorded is divided by appropriate geometrical factor for each sample to obtain the tensile splitting strength.

Figure 3. 10 Cylinder Samples placed into the Splitting Mould for Tensile Strength Test

Figure 3. 11 : Reading after the Tests were recorded and analysed the Results

3.2.2 Analysis of Data

The data recorded from both testing are arrange according to it category for the comparison purpose. There are two methods used in this research to analysis the data from the test which are comparison of data using graphical representation and ANOVA: Single factor methods to determine the significance of the data obtain from the experiment.

Firstly, ANOVA: Single Factor method is used to determine the statistically significant of the data for different percentage of cement replace by the epoxy resin which obtain from the test. This method is conduct using Microsoft Excel application. The data is key in at the excel sheet according to their category. After that, select the data and analysis the data using ANOVA: Single Factor method. The ANOVA table are produced in the sheet that shown the P-value and F-critical. The data is consider statistically significant if the P-value is less than 5% and the F-critical is less than the F-value obtain from the ANOVA table.

Besides that, the experimental data are arrange according to it category and calculate the average of the data in order to increase the accuracy of data. There are three specimens for each day of testing in a percentage of epoxy resin as cement replacement and there are three data of the strength obtain from testing. The data need to total up and divide by three to get the average of the data. After that, the data of four different percentage of cement replace by epoxy resin are put in a same graph to figure out the optimum percentage of cement replace by epoxy resin can produce the highest strength. For example, the specimens tested on 3 day after moulding for compressive strength. The data of specimen with 0%, 10%, 20% and 30% of cement replace by the epoxy resin are arrange in the same histogram graph to find out the highest compressive strength among the four specimens. Though the graphical representation method, the simple conclusion can be made which is the optimum percentage of cement can be replace by the epoxy resin can be found.

3.3 Summary

This chapter presented the whole idea to conduct the laboratory works of this research. The process of the preparation of material had been explained in section 3.1. The amount of the material to be used in the mix design had been calculated and listed in section 3.1.1. Next, procedure of the laboratory test for the samples had been outlined in section 3.2. In this section, the detail of material test included the rate of load and the method of testing for samples. After that, the method of measure the significance of data had been discussed and explained in section 3.2.2.

CHAPTER 4

RESULT AND DISCUSSION

4.0 Introduction

In this study, the epoxy resin is used as a replacement material to cement in concrete with the fixed proportion of sand replaced by the silica sand in order to determine the strength of the concrete. However, the results obtain from the laboratory works were analyzed to obtain the optimum proportion. In this chapter, the results were gone through the ANOVA: Single Factor to determine the significance of the data obtained. After that, the results obtained are listed in table and plotted in graph to clearly observe the optimum proportion of cement that can replace by the epoxy resin to produce the highest compressive and tensile strength. The discussion for the variety of the data was made in this chapter.

4.1 ANOVA: Single Factor Analysis

The main purpose of this analysis is to determine the significance of data in different percentages of samples. The null hypothesis for ANOVA is that the mean is the same for all different percentages of samples. The alternative hypothesis is that the average is not the same for all groups. The ANOVA table for all the samples were listed as below with different curing days.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	
0	3	44.317	14.77233	3.402184	1.844501
0.1	3	10.593	3.531	0.239121	0.489
0.2	3	7.996	2.665333	0.044965	0.21205
0.3	3	46.089	15.363	0.001267	0.035595

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	431.4542	3	143.8181	156.0044	1.95E-07	4.066181
Within Groups	7.375075	8	0.921884			
Total	438.8293	11				

Table 4. 1 : ANOVA table for the compressive strength result of the samples cured in 3 day

The data obtained from the laboratory were significance because the P-value of the samples is 1.95E-07 which is smaller than 5% and the F value also bigger than F critical

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance	
0	3	56.7	18.9	1.729225	1.315
0.1	3	13.871	4.623667	0.24454	0.49451
0.2	3	11.346	3.782	0.000529	0.023
0.3	3	52.59	17.53	0.001444	0.038

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	592.9004	3	197.6335	400.1207	4.72E-09	4.066181
Within Groups	3.951477	8	0.493935			
Total	596.8519	11				

Table 4. 2 : ANOVA table for the compressive strength result of samples cured in 7 day

The data obtained from the laboratory for samples cured in 7 day were significance because the P-value of the samples is 4.72E-09 which is smaller than 5% and the F value also bigger than F critical.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance	
0	3	87.507	29.169	0.315844	0.562
0.1	3	14.614	4.871333	0.002352	0.048501
0.2	3	11.07	3.69	0.0361	0.19
0.3	3	56.49	18.83	0.0025	0.05

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1328.933	3	442.9776	4966.168	2.04E-13	4.066181
Within Groups	0.713593	8	0.089199			
Total	1329.646	11				

Table 4. 3 : ANOVA table for the compressive strength result of samples cured in 28 day

The compressive strength data obtained from the laboratory for samples cured in 28 day were significance because the P-value of the samples is 2.04E-13 which is smaller than 5% and the F value also bigger than F critical.

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*	
0	3	2.719	0.906333	0.001722	0.041501
0.1	3	0.141	0.047	6.4E-05	0.008
0.2	3	0.453	0.151	0.0016	0.04
0.3	3	3.336	1.112	0.000121	0.011

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.564882	3	0.854961	975.055	1.36E-10	4.066181
Within Groups	0.007015	8	0.000877			
Total	2.571897	11				

Table 4. 4 : ANOVA table for the tensile strength result of samples cured in 3 day

The tensile strength data obtained from the experiment for samples cured in 3 day were significance because the P-value of the samples is 1.36E-10 which is smaller than 5% and the F value also bigger than F critical.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance	
0	3	4.098	1.366	0.000484	0.022
0.1	3	0.5921	0.197367	0.006344	0.07965
0.2	3	0.747	0.249	0.000001	0.001
0.3	3	4.695	1.565	0.006561	0.081

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4.693453	3	1.564484	467.3547	2.54E-09	4.066181
Within Groups	0.02678	8	0.003348			
Total	4.720233	11				

Table 4. 5 : ANOVA table for the tensile strength result of samples cured in 7 day

The tensile strength data obtained from the experiment for samples cured in 7 day were significance because the P-value of the samples is 2.54E-09 which is smaller than 5% and the F value also bigger than F critical.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance	
0	3	6.69	2.23	0.000484	0.022
0.1	3	1.665	0.555	0.000961	0.031
0.2	3	2.002	0.667333	0.000306	0.017502
0.3	3	7.005	2.335	2.5E-05	0.005

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8.415531	3	2.805177	6316.781	7.8E-14	4.066181
Within Groups	0.003553	8	0.000444			
Total	8.419084	11				

Table 4. 6 : ANOVA table for the tensile strength result of samples cured in 28 day

The tensile strength data obtained from the experiment for samples cured in 28 day were significance because the P-value of the samples is 7.8E-04 which is smaller than 5% and the F value also bigger than F critical.

4.2 Compressive Strength Test

Percentages of Cement Replaced by Epoxy Resin	Compressive Strength (MPa)				
	Sample 1	Sample 2	Sample 3	Average	Standard Deviation
0%	12.929	16.618	14.77	14.7735	1.845
10%	4.020	3.042	3.531	3.531	0.489
20%	2.456	2.880	2.660	2.668	0.212
30%	15.329	15.400	15.36	15.3645	0.036

Table 4. 7 : The Results of Compressive Strength Test for 3 day of curing

Percentages of Cement Replaced by Epoxy Resin	Compressive Strength (MPa)				
	Sample 1	Sample 2	Sample 3	Average	Standard Deviation
0%	20.215	17.585	18.900	18.900	1.315
10%	4.131	5.120	4.620	4.626	0.495
20%	3.805	3.759	3.782	3.782	0.023
30%	17.492	17.568	17.53	17.530	0.038

Table 4. 8 : The Results of Compressive Strength Test for 7 day of curing

Percentages of Cement Replaced by Epoxy Resin	Compressive Strength (MPa)				
	Sample 1	Sample 2	Sample 3	Average	Standard Deviation
0%	28.607	29.731	29.169	29.169	0.562
10%	4.823	4.920	4.871	4.8715	0.049
20%	3.880	3.500	3.690	3.690	0.190
30%	18.780	18.880	18.830	18.830	0.050

Table 4. 9 : The Results of Compressive Strength Test for 28 day of curing

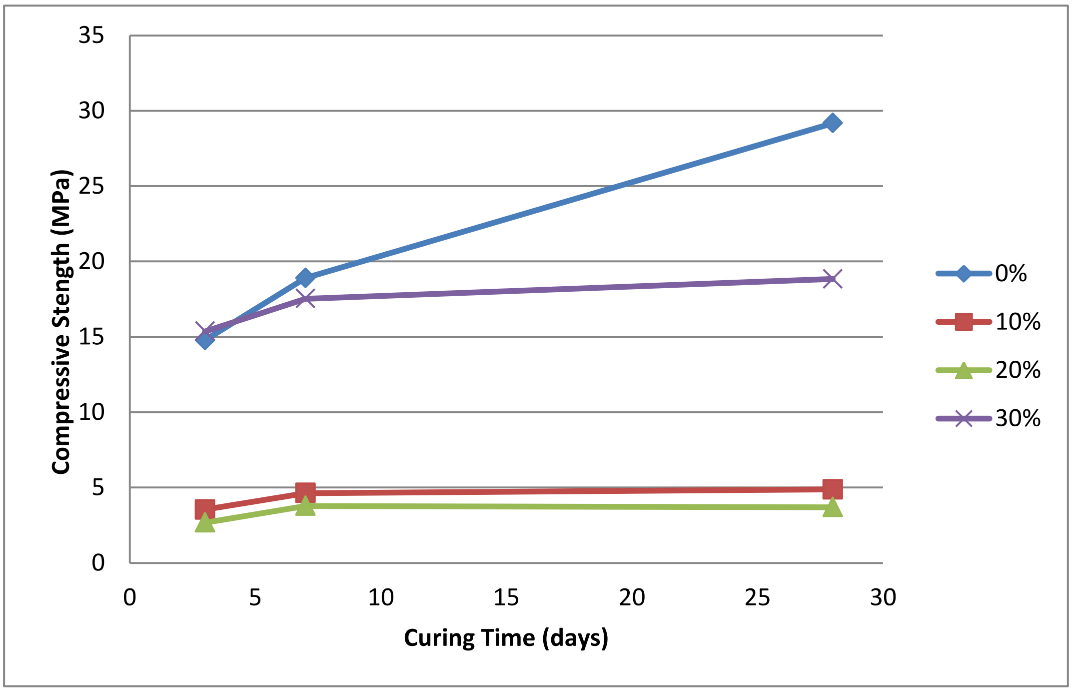

Figure 4. 1 : Variety in the Compressive Strength of 0%, 10%, 20% and 30% of Cement Replaced by Epoxy Resin

In the results of compressive strength obtained from the experiment, the 0% samples shown the highest compressive strength compare to others because the behaviour of 0% samples is actually almost similar with the plain concrete. The concrete design grade was C25 which can produce at least 25 MPa theoretically but the 0% samples produced 29 MPa which is higher than the theoretical strength.. The samples with 10% of cement replaced by epoxy resin produce the lowest compressive strength among the others percentages in three curing days. The compressive strength produced by 0% shown the highest which is 14.774 MPa in 3 days of curing; it increased to 18.900 MPa in 7 day of curing and increased significantly to 29.169 MPa in 28 days of curing. For 10% samples, the compressive strength produced was 3.531 MPa in 3 days of curing; it increased to 4.626 MPa in 7 days of curing and increased again to 4.872 MPa in 28 days of curing. For 20% samples, the compressive strength produced was 2.668 MPa in 3 days of curing; it increased to 3.782 MPa in 7 days of curing and increased again to 3.690 MPa. For the 30% samples, the compressive strength produced was 15.365 MPa in 3 days of curing; it increased to 17.530 MPa in 7 days of curing and increased again to 18.830 MPa in 28 days of curing.

The 30% samples shown the second higher compressive strength but lower than the 0% samples because the cement grout on the surface of samples was absorbed by the oil type of hardener used. Hence, the surface of the 10%, 20% and 30% was not bind by the cement grout. It is one of the reasons of the samples produce lower compressive strength compare to the 0% samples. The another reasons of the epoxy resin samples produce lower compressive strength compare to 0% samples are when the samples are cured in the water for long time. The strength of samples was decreased from the observation. However, all the samples have higher compressive strength when the curing day increased

Figure 4. 2 : The pattern of the samples after compressive test

4.3 Tensile Splitting Test

Percentages of Cement Replaced by Epoxy Resin	Tensile Strength (MPa)				
	Sample 1	Sample 2	Sample 3	Average	Standard Deviation
0%	0.865	0.948	0.906	0.907	0.042
10%	0.039	0.055	0.047	0.047	0.008
20%	0.111	0.191	0.151	0.151	0.040
30%	1.101	1.123	1.112	1.112	0.011

Table 4. 10 : The Results of Tensile Splitting Test for 3 day of curing

Percentages of Cement Replaced by Epoxy Resin	Tensile Strength (MPa)				
	Sample 1	Sample 2	Sample 3	Average	Standard Deviation
0%	1.388	1.344	1.366	1.366	0.022
10%	0.118	0.277	0.197	0.197	0.080
20%	0.248	0.25	0.249	0.249	0.001
30%	1.646	1.484	1.565	1.565	0.081

Table 4. 11 : The Results of Tensile Splitting Test for 7 day of curing

Percentages of Cement Replaced by Epoxy Resin	Tensile Strength (MPa)				
	Sample 1	Sample 2	Sample 3	Average	Standard Deviation
0%	2.252	2.208	2.230	2.230	0.022
10%	0.524	0.586	0.555	0.555	0.031
20%	0.650	0.685	0.667	0.668	0.018
30%	2.330	2.340	2.335	2.335	0.005

Table 4. 12 : The Results of Tensile Splitting Test for 28 day of curing

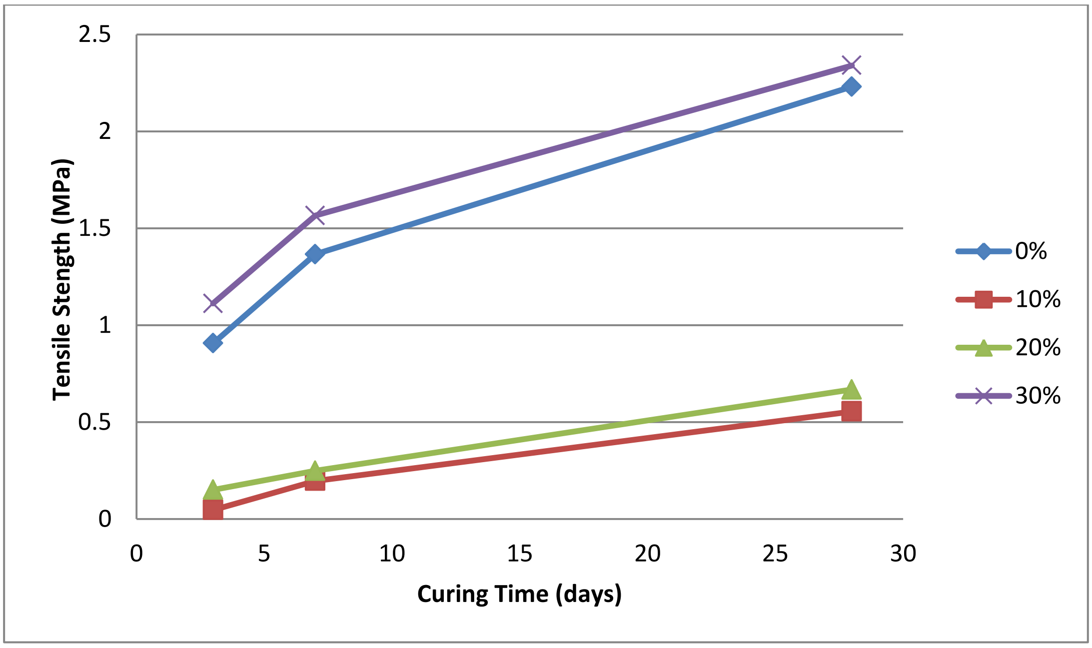

Figure 4. 3 : Variety in the Tensile Strength of 0%, 10%, 20% and 30% of Cement Replaced by Epoxy Resin

In the result of tensile strength, 30% samples produced the highest tensile strength which is 2.335 MPa in 28 day of curing and almost same with 0% samples which is 2.230 MPa. However, 10% samples give the lowest tensile strength which is 0.555 MPa and almost near to the 20% samples with the value of 0.668 MPa. All the samples show the increasing when the number of curing time increasing. This can be explain that the samples are undergoes the process of keeping the hardened concrete moist so that the samples are continue to gain strength. The 0% and 30% samples show the significant increase in the tensile strength compare to the other two percentages of samples especially from 7 day of curing to the 28 day of curing. The tensile strength produced by the 0% samples were 0.907 MPa in 3 days of curing; it increased to 1.366 MPa in 7 day of curing and increased again to 2.230 MPa in 28 day of curing. For the 10% samples, the tensile strength produced was 0.047 MPa in 3 days of curing; it increased to 0.197 MPa in 7 days of curing and increased again to 0.555 MPa in 28 days of curing. For the 20% samples, the tensile strength produced was 0.151 MPa in 3 days of curing; it increased to 0.249MPa in 7 days of curing and increased again to 0.668 MPa in 28 days of curing. For the 30% samples, the tensile strength produced was 1.112 MPa in 3 days of curing; it increased to 1.565 MPa in 7 days of curing and increased again to 2.335 MPa in 28 days of curing.

Figure 4. 4 : Pattern of the cylinder samples after tensile splitting test

Figure 4. 5 : Structure of the 30% Samples after Tensile Splitting Test

Figure 4. 6 : Structure of 0% Samples after Tensile Splitting Test

4.4 Summary

This chapter presented the outcome of the thesis to achieve objectives. The ANOVA table had been listed in section 4.1. In this section, the average compressive strength and tensile strength can be obtained from the tables. Next, the table of the compressive strength for each sample and it average and standard deviation had been shown in section 4.2. The table of the tensile strength for each sample are listed in section 4.3. Three values of compressive strength and tensile strength were considered and used for calculation of average of compressive strength and same with the value of tensile strength. The compressive strength achieved by the samples were varies from 3.690 MPa to 29.169 MPa and the tensile strength achieved by the samples were 0.555 MPa to 2.335 MPa.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the outcome of this research, 72 concrete samples were prepared with several percentages of cement replaced by epoxy resin and the fixed proportion of sand replaced by silica sand for each samples. Two tests were carried out to measure the optimum percentages of cement can be replaced by epoxy resin in order to produce the optimum compressive strength and tensile strength. The first test was compressive strength test and the compressive properties of samples were determined from the test. The mix design of concrete samples in this research was calculated based on the mix design of concrete grade 25. Normally, the grade 25 concrete can produce 25 MPa of compressive strength and it tensile strength are varies between 1/8 to 1/12 of cube compressive strength which is around 3.125 MPa to 2.083 MPa.(Neville, 1995) From the results of this research, the compressive strength achieved by the samples were varies from 3.690 MPa to 29.169 MPa and the tensile strength achieved by the samples were 0.555 MPa to 2.335 MPa. Compressive strength of samples was achieved by the 0% samples which are 29.169 MPa more than the designed strength. However, the 30% samples also produced the compressive strength that near to the design strength which is 18.930 MPa. The other percentage of samples produced very big different with the design strength. Tensile strength of samples was achieved by the 0% and 30% samples which are 2.230 MPa and 2.335 MPa respectively. The tensile strength of samples was fall in the range of designed strength from 3.125 MPa to 2.083 MPa. The 10% and 20% samples produced the lowest tensile strength which is 0.555 MPa and 0.668 MPa respectively. The effect of different type of curing method and different type of hardener used on the strength produced should be investigated.

5.2 Recommendation

Based on this study, there is some elements can be improved in order to have comprehensive study on the research which are:

1. Investigate the effect of different type of curing method on the compressive strength and tensile strength produced.

2. Investigate the effect of type of hardener used to mix with the epoxy resin on the compressive strength and tensile strength produced.

3. Increase various percentage of cement replaced by epoxy resin to obtain the optimum percentages that can produce highest strength.

REFERENCES

Aggarwal, L.K., Thapliyal, P.C. and Karade, S.R. (2007), "Properties of polymer-modified mortars using epoxy and acrylic emulsions", *Construction and Building Materials*, Vol. 21 No. 2, pp. 379–383.

Alkhaleefi, A. (2001), "Epoxy modified Portland Cement Concrete at elevated temperatures".

American Society for Testing and Materials. (2016), "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens", *American Society for Testing and Materials*, pp. 1–7.

American Society for Testing and Materials. (2011), "Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens, C496/C496M-11", No. C, pp. 1–5.

Ariffin, N.F., Hussin, M.W., Sam, A.R.M., Bhutta, M.A.R., Abd Khalid, N.H. and Mirza, J. (2015), "Strength properties and molecular composition of epoxy-modified mortars", *Construction and Building Materials*, Vol. 94, pp. 315–322.

Boyle, M. a., Martin, C.J. and Neuner, J.. (2001), "Epoxy Resins", *ASM Handbook Volume 21*.

Danish District heating association. (2018), "Weblet Importer", *Solarheatdata.eu*.

Fernández-Ruiz, M.A., Gil-Martín, L.M., Carbonell-Márquez, J.F. and Hernández-Montes, E. (2018), "Epoxy resin and ground tyre rubber replacement for cement in concrete: Compressive behaviour and durability properties", *Construction and Building Materials*, Vol. 173, pp. 49–57.

Fink, J.K. (2013), *Epoxy Resins*, *Reactive Polymers Fundamentals and Applications*, available at:https://doi.org/10.1016/B978-1-4557-3149-7.00003-6.

Fowler, D.W. (1999), "Polymers in concrete: A vision for the 21st century", *Cement and Concrete Composites*, Vol. 21 No. 5–6, pp. 449–452.

Gibbs, M.J., Soyka, P. and Conneely, D. (2000), "CO2 Emissions from Cement Production", *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, pp. 175–182.

Gibson, G. (2017), "Epoxy Resins", *Brydson's Plastics Materials*, pp. 773–797.

Golestaneh, M., Amini, G., Najafpour, G.D. and Beygi, M. a. (2010), “Evaluation of Mechanical Strength of Epoxy Polymer Concrete with Silica Powder as Filler”, *Applied Sciences*, Vol. 9 No. 2, pp. 216–220.

Hyun surk kim, kyu yeol park, dai gil lee. (1995), “Materials Processing Technology”, Vol. 60, pp. 219–224.

Islam, M.A., Rahman, M.M. and Ahme, M. (2011), “Polymer-modified concrete: World experience and potential for Bangladesh”, *Indian Concrete Journal*, Vol. 85 No. 1, pp. 55–63.

Jiang, J., Lu, Z., Niu, Y. and Li, J. (2017), “Investigation of the properties of high-porosity cement foams containing epoxy resin”, *Construction and Building Materials*, Vol. 154, pp. 115–122.

Jignesh, K. (2015), “Effect of use of Silica Sand as Fine Material in Concrete”, Vol. 2 No. 1, pp. 266–271.

Jin, N.J., Seung, I., Choi, Y.S. and Yeon, J. (2017), “Prediction of early-age compressive strength of epoxy resin concrete using the maturity method”, *Construction and Building Materials*, Vol. 152, pp. 990–998.

Jin, N.J., Yeon, J., Seung, I. and Yeon, K.S. (2017), “Effects of curing temperature and hardener type on the mechanical properties of bisphenol F-type epoxy resin concrete”, *Construction and Building Materials*, Vol. 156, pp. 933–943.

Kardon, B.J.B. (1997), “Polymer-Modified Concrete : Review”, *American Society of Civil Engineers*, Vol. 9 No. MAY, pp. 85–92.

Kumar, R. and Rakesh. (2016), “A Review on Epoxy and Polyester Based Polymer Concrete and Exploration of Polyfurfuryl Alcohol as Polymer Concrete”, *Journal of Polymers*, Hindawi, Vol. 2016, pp. 1–13.

Manoharan, T., Laksmanan, D., Mylsamy, K., Sivakumar, P. and Sircar, A. (2018), “Engineering properties of concrete with partial utilization of used foundry sand”, *Waste Management*, Vol. 71, pp. 454–460.

Muthukumar, M. and Mohan, D. (2004), “Studies on polymer concretes based on optimized aggregate mix proportion”, *European Polymer Journal*, Vol. 40 No. 9, pp. 2167–2177.

Muthukumar, M. and Mohan, D. (2005), “Studies on furan polymer concrete”, *Journal of Polymer Research*, Vol. 12 No. 3, pp. 231–241.

Neville, A. (1995), *Properties of Concrete., 4th Ed. UK: Addison Wesley Longman Limited;*, available at: https://theconstructor.org/concrete/properties-of-concrete-3/1692/ (accessed 20 May 2018).

Payne, G.H. (1966), “The effect of epoxy resins on the durability and unconfined compressive strength of an A-1B soil”.

PubChem. (n.d.). “Epoxy resin | C21H25ClO5 - PubChem”, available at: https://pubchem.ncbi.nlm.nih.gov/compound/169944#section=Top (accessed 5 December 2017).

Radhakrishnan Kuttoor. (2011), “Can silica sand work a magic in construction? - The Hindu”, available at: http://www.thehindu.com/news/national/kerala/Can-silica-sand-work-a-magic-in-construction/article15458420.ece (accessed 28 November 2017).

Samanta, B.C., Maity, T., Dalai, S. and Banthia, A.K. (2006), “Mechanical properties of modified epoxy: effect of chain length”, *Pigment & Resin Technology*, Emerald Group Publishing Limited, Vol. 35 No. 4, pp. 216–223.

Sivaramanan, S. (2015), “Global Warming and Climate change , causes , impacts and mitigation”, *ResearchGate*, No. DOI: 10.13140/RG.2.1.4889.7128, p. 1.

Takeichi, T. and Furukawa, N. (2012), *Epoxy Resins and Phenol-Formaldehyde Resins, Polymer Science: A Comprehensive Reference, 10 Volume Set*, Vol. 5, Elsevier B.V., available at:https://doi.org/10.1016/B978-0-444-53349-4.00157-6.

Tim Plaehn. (n.d.). “The Importance of Sand in Concrete”, available at: https://www.hunker.com/13425130/the-importance-of-sand-in-concrete (accessed 7 November 2017).

VishnumanoharA. (2014), “Performance of Normal Concrete with Eco Sand (Finely Graded Silica) As Fine Aggregate”, *International Journal of Engineering Science Invention ISSN (Online*, Vol. 3 No. 5, pp. 2319–6734.

Wang, R., Zheng, S. and Zheng, Y. (2011), *Polymer Matrix Composites and Technology*, Woodhead Pub., available at: https://books.google.com.my/books?id=uHhwAgAAQBAJ&pg=PA166&lpg=PA166&dq=chemical+reaction+between+curing+agent+and+furan+resin&source=bl&ots=a9Bzge4DiZ&sig=YkfK5IBNUZl0DVylcM-nd8VdHh0&hl=en&sa=X&ved=0ahUKEwjEuKidwubXAhUBYo8KHZ5wA4EQ6AEIUzAD#v=onepage&q=ch (accessed 30 November 2017).

Technical Data Sheet. (2005), *Mancuso Chemicals Ltd*, Vol. 26.

“Carbon dioxide’s effects on plants increase global warming, study finds -- ScienceDaily”. (2010), *Carnegie Institution*, available at: https://www.sciencedaily.com/releases/2010/05/100503161435.htm (accessed 3 November 2017).

APPENDIX A

TECHNICAL DATA SHEET OF EPOXY RESIN AND HARDERNER

TECHNICAL DATA SHEET

E-110I / H-9

E-110I/H-9 is a two component, non-volatile liquid high gloss epoxy resin that forms hard enamel like finish. It is specially formulated for maximum durability and aesthetic appeal. It exhibits several outstanding features as follow:

Advantages:

1. Non-toxic, non-volatile and colorless.
2. Low viscosity and long pot life provide easy application.
3. Tenacious adhesion to variety of substrates including wood, plate metals, plastic etc...
4. The coated transparent surface is very smooth and glossy as well as more attractive and eye-catching.
5. Excellent resistance to brushing and scratching.
6. Can be cured either at room temperature or elevated temperature.

Typical Properties

	E-110I	H-9
Appearance	**Clear liquid** (Color paste can be provided)	**Clear liquid** (Color paste can be provided)
Viscosity (CPS)	3,500 – 4,500 cps	100 – 150 cps
Mixing Ratio (by weight)	2 : 1	
Pot Life	60 minutes	
Shelf Life	6 months	
Cure Condition	R. T. : *14 – 16 hrs : 70°C : *70 – 80 mins	
Compression Strength	728 kg/cm²	
Flexural Strength	297 kg/cm²	
Tensile Strength	136 kg/cm²	
Flash Point	> 300°C	> 150°C

Technical Data Sheet
E-110I / H-9

Applications Data

1. Use proper container and mixing rod.

2. To minimize wastage, accurate the ratio 2 : 1 of resin & hardener on each application by weight.

3. Mix thoroughly, scraped the edge of the container and mixed uniformly.

4. Complete preparation and apply it within the pot life period.

Cautions

1. For storage, once the pack has been opened the cap must be properly sealed and store in cool conditions, preferably away from sunlight or excessive heat.

2. Precaution must be taken to prevent E-110I and H-9 contaminating each other during operation to ensure longer storage life.

Safety Precaution

1. Provide adequate ventilation when mixing the Resin and Hardener.

2. It may cause skin irritation in sensitive individuals. Keep material and solvent off skin with protective gloves.

3. In case of eye contact, flush with clean, running water for at least 15 minutes then seek medical attention.