DEVELOPMENT OF GREEN COMPOSITE BINDER MATERIAL FROM INDUSTRIAL WASTE STABILISATION

By

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Dissertation submitted in partial fulfillment of
the requirements for the
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CERTIFICATION OF APPROVAL

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Approved by,

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(Dr. Asna Mohd Zain)

Date: 15th August 2013

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

JAN 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I, Dahnaraj Lachemykanden (I/C No: 901012-10-5597), am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ABSTRACT

Creating a ‘green composite binder material from industrial waste stabilization’ is a method to provide a greener environment for future generation. Binder that used for construction were usually consist of Portland cement type 1, water, and sand. Sometimes, there will be admixture and aggregates to enhance the quality of the binder in various factors. Therefore, this project is mainly adding industrial waste stabilization as an admixture to replace sand for stabilizing the Portland cement. The main objective involve in this individual final year project are to produce a green composite binder using suitable industrial waste stabilization, creating a cost effective binder, and create light weight and stronger binder using waste materials. The main problem statement of this project is to review the best combination of industrial waste stabilization in order to produce a light weight and strong composite binder. The production of new green composite binder are able to increase the green building index rating. This government organization advice contractor to design a building which save energy and resource, recycle materials and minimize the emission of toxic substances throughout its life cycle. This invention will help the environment to go greener in future and help reduce industrial waste stabilization. Producing different sample using these wastes with allocated ratio will enable it to undergo various tests. According to the methodology and result, it is conclude that solidified FPM industrial waste in Portland cement produce better cement complex with giving 56.7kN in air curing and meet the requirement of soundness test and blaine air permeability test.

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CHAPTER 1: INTRODUCTION

1.1 Background of Study

Now world has been considering more on reusing material since it is vital to build a better place for future generation. Most of the material that can be reuse for further utilization commonly known as environment friendly products. It's our responsible as an engineering student to create a greener environment which practice more recycling and reusing methods. These methods are emphasis more in this project in order to invent an environment friendly product.

Industrial sector always facing enormous problem in disposing their industrial waste. As we know, industrial waste need to be treated by environmental waste management agencies before it go to the dumping place. A new dumping area for dispose the industrial waste will a hustle and space wasting especially in small countries. It is very important to utilize the waste to the maximum to reduce the land pollution creating by the industrial sector. Relating to the current problem, this project is focusing on developing a green composite binder material from industrial waste.

In civil engineering field, a binder is commonly refers to cement where it's a substance that react and hardens independently, and can bind other materials together. By using the industrial waste as an ingredient together with binder and it is expected to reduce the sand and cement mining which affecting the natural habitat and ecosystem. This project have high prospect to create a green composite binder to provide a greener environment for future generation.

Binder is a one of the very important material in current building construction. Modifying the norm of cement mixing by including selected industrial waste will impact a lot in construction sector. This project will subsequently reduce the cost of binder since the selected industrial waste can replace the binder.

Although many research and experiment was carried out to invent a green composite binder, creating binder material using industrial waste will be an eye opener project where it will solve many environment related problems. According to green building organization, a green building focuses more on increasing the efficiency of reusing the available resources in order to reduce the building impact on human health and the environment during building's lifecycle.

For the selection part of perfect and suitable industrial waste, it required careful study about the waste and its impact to the environment. The waste should be stabilize as first before included into binder mixing. This will ensure the industrial waste retain its properties until the building cycle ends. Past study shows that 'lignen' type or accurately explain as sticky type of material will be the perfect ingredient for binder mixing. Hence, it's important to evaluate the industrial waste characteristic before entering the 'try and error' phase.

Cement mixing task is a less complicated process where a perfectly mixed slump need a total of 28 days to fully gain its strength and to totally dry. Slump that used for construction were usually consist of Portland cement type 1 (OPC), water and sand. Sometimes, there will be admixture or aggregates to enhance the quality of the slump in various factor. In civil sector admixture are often refer to as ingredients in concrete other than OPC, water and sand that are added to the mix immediately during mixing. The mixture may be varied to certain level according to its accepted (PAC, 2013). However an aggregate can be define as an inert granular material such as gravel and stone which provide extra strength to concrete. Since, this project is to develop a green composite binder material, hence the aggregate will be substitute with the selected industrial waste.

In a nut shell, it's important to develop a green composite binder material which in high in strength, lighter weight and lower in cost. This study will also assure that reusing industrial waste material can be done and it has high prospect in substituting the sand which is a common aggregate in cement mixing task. It also gives a good approach to reduce the environmental problem and solid waste problem in the world.

1.2 Problem Statement

Industrial waste are being produce day by day causing environmental pollution with rapid industrialization in this country. Commercial and domestic solid waste is a great practical problem for many local government. Industrial wastes are usually much smaller in volume but are more likely to contain hazardous materials, such as toxic chemicals, flammable liquids and asbestos (Ping, 2011). The disposal of hazardous industrial waste has been a greater concern because of the perceived hazard to health and the risk of environmental contamination. As an effort to reduce the industrial waste in disposal area, these industrial waste will be analyzed and used when mixing cement in order to create green composite binder.

Binders are usually manufactured from many mining material such as cement and sand. Mining of natural resource created a lot of problem in ecosystem and destroyed many natural habitat. By using industrial waste in preparation of composite binder material, the amount of cement and sand usage can be reduce effectively. It is important to practice to utilize as much of recycle material to avoid any pollution.

What modification can be done in order to make a green composite binder using industrial waste? In order to answer the problem above, every selected industrial waste will be carefully analyzed for hazard and apply in experiment.

1.2.1 Significance of project

The aim of the project is to produce a green composite binder material using industrial waste stabilization, many criteria was questioned and discussed with my supervisor madam Dr.Asna bt M Zain. It has been decided to produce a binder from industrial waste stabilization with aim to reduce waste management by utilizing material like glass, plastic, petrochemical waste, car automotive residue and wood residue according to its ability. As an alternative for just throwing away those recyclable materials and industrial waste, these can be utilize in many ways. The major significant of this project also can be said to reduce the cement and sand mining which imbalance the ecosystem directly.

1.3 Objective of the project

The objective of the project is reviewed based on the problem statement above so that the problem can be solved. These objectives can be a guideline in order to complete this valuable project. The main objectives involve in this individual final year project are as follows:

1. **To study the effect of various type of industrial waste with OPC in order to produce a green composite binder.**

   Normal slump is produced by adding Portland cement type 1, water and sand which increase the cement and sand mining day to day. To avoid this act, some useful industrial waste stabilization will be determined and use as component in order to reduce the amount of sand and cement content. By adding these components, the waste also can be reduced from all kind of industrial area. Using a recycle material or waste material as a component in cement mixture will categories as green composite binder. These materials can be obtain from various industrial plant.

2. **To design a cost effective binder which is cheaper than the normal commercial binder in market.**

   Using waste material as the component in binder, it will indirectly reduce the price of the binder. Moreover the price of the industrial waste will be very less, in some plant they willing to give away their waste for free. This will reduce their work to dispose the waste and indirectly help the world to invent an eco-friendly material. There will not be burden especially for those who are not rich enough to build a good house. As we use waste material, it can reduce the cost in making this green composite binder.

3. **To study the effect of additive in order to produce a light weight and stronger binder using industrial waste residue.**

   Aim of this product is to produce a bricks that less in weight but stronger. The criteria of industrial waste should be a strong polymer like waste so that it has the strong bond between the cement and the waste. To increase the strength of the material, it is important to use the aggregate such as rice husk ash (RHA), silica fume and certain type of acid. The new compositions of the binders have to hold the strong forces for example when there is a land slide.

1.4 Relevance of the Study

This project will focus on the topic of cement technology where we need to study the chemical and physical process of cement slurry. These topics are related to the course of civil engineering. Moreover, these projects also have deep contact with Fluid Mechanics, where chapter flow of slurry is applied. Later after the sample is prepared all kind of various tests should be done according to chemical analysis subject which explain about the procedure and suitable equipment to use. The first step in this project will be getting an introduction to the related topics by reading books, journals and research papers. Research will be done in order to better understand green composite binder. A study was done according to the modified Shearbrook method. This project is the best project to introduce to world where it can be used for future generation.

1.4.1 Feasibility of the project within the scope and time frame

This project select suitable industrial waste from polymer plant. The plant waste is recycled to become resin and selling in large amount in Pengkalan, Lahat which is very near to our university. Moreover, the virgin Portland cement type 1 can be obtained from Bota, Perak which is also nearer to our university. The rice husk ash (RHA) can be obtained in our university in Blok J-2. This project is achievable and the cost for buying the material is within RM 50- RM 100. Truly this project will be an achievable project within the time range given.

1.4.2 Scope of Study

The main scope of study which is the main pillars is to produce a green composite binder material using industrial waste stabilization. These samples will have different type of waste including different ratios of cement to waste. The successful sample of mortar will be put under some various tests such as compressible test, Le Chatelier test, Blaine air permeability test and much more.

CHAPTER 2: LITERATURE REVIEW

2.1 Past research on the green composite

All over the world, engineers and scientist are really working in to green composite binder. There are many projects and journal which can be taken as reference to proceed with this project. Journal by Hiroyuki Kinoshita is the best stepping stone for this project where he develop a green composite binder consist of woodchips, bamboo fibers and biodegradable adhesive. This journal was published online on 18 April 2009 where the date is telling the origin research age of this project. This journal gave an idea where woodchips and sawdust also can be mixed with binder in order to produce green composite binder. Although wood have natural gum structure it will have not enough strength to hold the binders. Small amount of stress will able to damage the whole structure of binder material (K.Kinoshita, 2009).

Many green composite which consist of natural fibres as reinforcements and a biodegradable resin as a matrix material are proposed. Natural fibres such as bamboo, hemp and kenaf are light, strong, renewable and inexpensive. In Malaysia, there are a lot of natural fibres as well as industrial waste. Biopolymers have the high capability to become a substitute component for green composite binder. This country is one of biggest export in oil palm production and rubber production. While looking at to high profit in these export but a very few know that the waste of this oil palm and rubber is giving big problem in this country. It is important to reuse and recycle all this waste stabilization to create a greener environment. Bamboo is basically the highest growing and high production natural resource and construction material available in this world. In one article, it was stated that bamboo and woodchip cement composite are have quite high strength and other than that it is also eco-friendly nature and provide most economically viable product (R.Sudin, 2004)

Before investigate deeply about green composite binder, the research have to initiate with the normal controlled cement binders. “Portland cement is a dosely chemical combination of calcium, silicon, aluminium, iron and small amounts of other compounds, to which gypsum are added in the final grinding process to regulate the setting time of the concrete. The term ‘Portland’ in Portland cement originated in 1824 when an English mason obtained a patent for his product; which he named Portland cement". As referring to Concrete Pipe Handbook page 2-2, American Concrete Pipe Association, 1988, there are 8 type of Portland cement. Here were going to investigate about Portland cement type 1. Type 1 is a general purpose Portland cement suitable for all uses where the special properties of other types are not required. It is used where cement or concrete is not subject to specific exposures, such as sulphate attack from soil or water, or to an objectionable temperature rise due to heat generated by hydration. Its uses include pavement and sidewalk, reinforced concrete building, bridges railway structure, tanks, reservoirs, culverts, sewer, water pipes and masonry units. U.S Bureau of Reclamation, Concrete Manual, 1975, has mention that sulphate attack can be negligible on Type 1 Portland cement (Rinker, 1988).

Table 1: Relative Degree of Sulphate Attack

Relative Degree of Sulfate Attack	Percentage Water-Soluble Sulfate (as SO_4) in Soil Samples	Sulfate (as SO_4) in Water Samples, Ppm	Cement Type
Negligible	0.00 to 0.10	0 to 150	I
Positive	0.10 to 0.20	150 to 1500	II
Severe	0.20 to 2.00	1500 to 10,000	V*
Very Severe	2.00 or more	10,000 or more	V plus pozzolan **

Material safety and data sheet (MSDS) of this Portland cement type 1 was obtained from ASH GROVE Portland Cement Company. The main health and safety handling method for Portland cement is to wear safety personal protective equipment such as protective clothing, both, rubber gloves, dust mask, eye safety glasses. The basic physical data is given as below as stated in material safety and data sheet.

Table 2: MSDS of OPC type

Section III. Physical Data			
Boiling Point:	NA	Specific Gravity (Water = 1):	3.1-3.4
Vapor Pressure (mmHg.):	NA	% Volatile by Volume (%):	0
Vapor Density (Air = 1):	NA	Evaporation Rate:	NA
Solubility in Water:	Slight		
Appearance/Odor:	Sanded powder; No odor		

Section IV. Fire & Explosion Hazard Data	
Flash Point:	Non-Flammable
Flammable Limits – UEL (%):	NA
– LEL (%):	NA
Extinguishing Media:	NA
Special Firefighting:	None required
Unusual Fire and Explosion Hazards:	None

Some information about the binder which consisting of Portland cement type 1, sand, gravel and water is obtained from lecture note from Concrete Technology subject (EVB 3022) prepared by Noor Amila Wan Abdullah Zawawi, lecturer in Unversity Teknology

Petronas. The process from mixer of slump to its finally compacted shape is called workability. Along the workability of this cement technology, there are a lot of considerations which have to glance through. About 28 days need to dry the slurry 100% at room temperature. In order to determine a perfect water-cement ratio there is a formula for calculate water cement ratio formulate by Duff A. Abrams in 1918 with a promising experiment.

$$\text{water/cement ratio} = \frac{\text{weight of water in kg/m3}}{\text{weight of cement in kg/m3}} \quad (1)$$

The 1997 Uniform Building Code specifies a maximum 0.50 water-to-cement ration (1:2) when concrete is exposed to freezing and thawing in a moist condition or to de-icing chemical, and a maximum 0.45 water to cement ration for concrete in severe or very severe sulphate condition (PCA, 2013).

An experiment was conducted in Japan using woodchips and bamboo fibres along with some biodegradable adhesive to make bricks. “We used woodchips of 200µm, bamboo fibres of 10mm in length and Landy CP-100 adhesive for this brick making process. Landy CP-100 adhesive is an aqueous dispersion of starch fatty acid ester (CORNPOL resin) made from the cornstarch. The proposed green composite have small quantity of biodegradable resin is used and the matrix consist of the woodchips impregnated slightly with the biodegradable resin. The biodegradable resin is used to coat the woodchip and bamboo for water resistivity and is also functioned as to strengthen the adhesion of woodchip. The following tables are the mechanical properties of each material and its reasoning” (Kaizu, 2009).

Table 3: Mechanical properties of specimen

Mechanical properties of wood and bamboo fiber used as ingredients for specimen.

Tensile strength of wood (Japanese cedar)	55 MPa
Compressive strength of wood	28 MPa
Bending strength of wood	90 MPa
Impact energy of wood	3.6 J/cm^2
Tensile strength of bamboo fiber	290 MPa

Mechanical properties of Landy CP-100.

Properties	Landy CP-100
Density (g/cm^3)	1.13
Grass transition temperature (°C)	−60
Softening temperature (°C)	39
Young's Modulus (MPa)	540
Tensile strength (MPa)	25
Total elongation (%)	110
Absorption (%)	5.0
Adhesive strength (MPa)	
Temperature of adhesive	
80 °C	1.0
100 °C	1.5
120 °C	4.0
140 °C	3.5
160 °C	2.0

This journal highly recommends, choosing high strength biopolymer or empty fruit bunch (EFB) which generally has high content of fiber. The woodchips are selected as the main ingredient in this experiment because wood store a binding agent chemical which called as lignin. Lignin is a natural chemical which act as a gum.

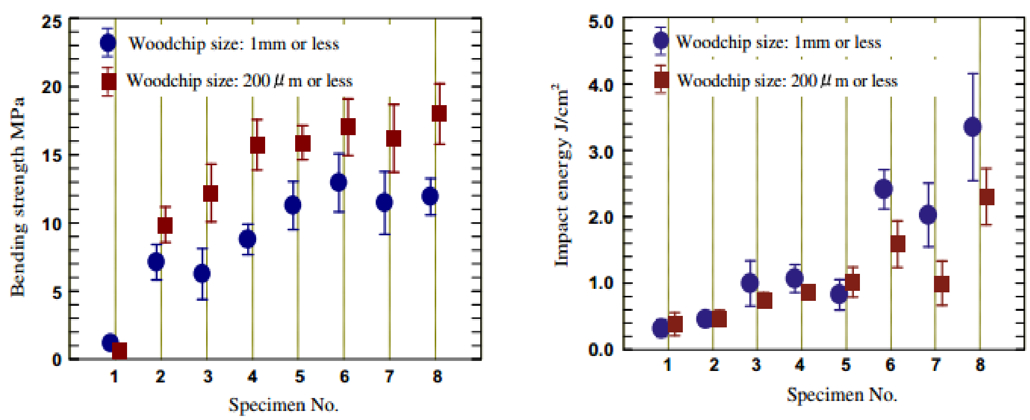


Figure 1: Bending strength and Impact energy of specimen

Another recent journal which publish on October 2012, have proven that a eco-friendly binder can be produce using metakaolin, fly ash, lime and anhydrous gypsum. The binder used in this mortar was developed by the reaction of inorganic minerals fly ash (FA), lime (L) and activated kaolin clay, which is rich in silica and alumina. The Metakaolin (MK) was prepared by thermal activation of kaolin clay for 3 h at 750 °C. The ratio of FA: MK: L was 30:40:30 mass%. Anhydrous gypsum was added as a chemical activator in varying proportions of 0, 2.5, 5, 7.5 and 10% by weight of the binder. The mortar was prepared using a binder: sand ratio was of 1:1.5 mass% and a water/binder ratio of 0.50. The mortar specimens were cured at 20 °C for 24 h in their moulds and then demoulded. The demoulded mortar specimens were cured at room temperature up to 28 days (Morsy, 2012).

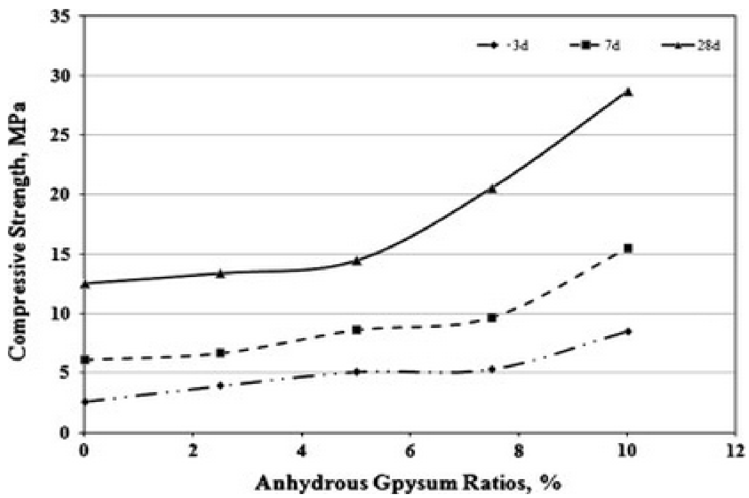


Figure 2: Compressive strength vs. Gypsum ratios

Another project which close enough to make it reference for my project is creation of binder using fly ash, flurogypsum and Portland cement. It used mainly fly ash and fluorogypsum, two industrial by-products; thus, it is an energy-saving and environmentally friendly binder with a satisfactory developing prospect. It has some faults, such as long initial setting time and low early strength (Yan, 1998) . Alum was added to the binder as an activator to improve its properties. The microstructure and properties of the binders cured in different conditions were investigated.

Table 3. Strength (MPa) of mortars with binder-to-sand ratio of 1

	Cured in air								Cured under water	
	Flexural strength				Compressive strength					
									Flexural strength(28 days)	Compressive strength(28 days)
	3 days	7 days	28 days	91 days	3 days	7 days	28 days	91 days		
G	3.31	4.48	8.81	10.48	15.8	24.8	54.6	69.4	6.64	59.0
GH	6.67	8.51	9.17	10.71	40.3	44.5	58.6	71.1	9.33	58.8
GA1	3.34	5.96	8.98	9.64	18.0	34.0	55.5	60.7	8.08	55.8
GA2	2.31	3.95	7.03	8.69	10.7	23.8	37.8	54.3	5.67	41.1
GA2H	3.38	5.18	7.90	9.45	13.8	26.8	43.4	60.9	7.06	46.3

Figure 3: Strength of the samples

A research was done in Riga Technical University in Latvia about obtaining composition of alkali activated binders from local industrial wastes. This research was done in January 2010. This geo-polymer composition are mainly industrial waste from the by-product of the reaction which taken from local heating plant furnace. Wood bottom ash and barley bottom ash are the industrial waste from the furnace.

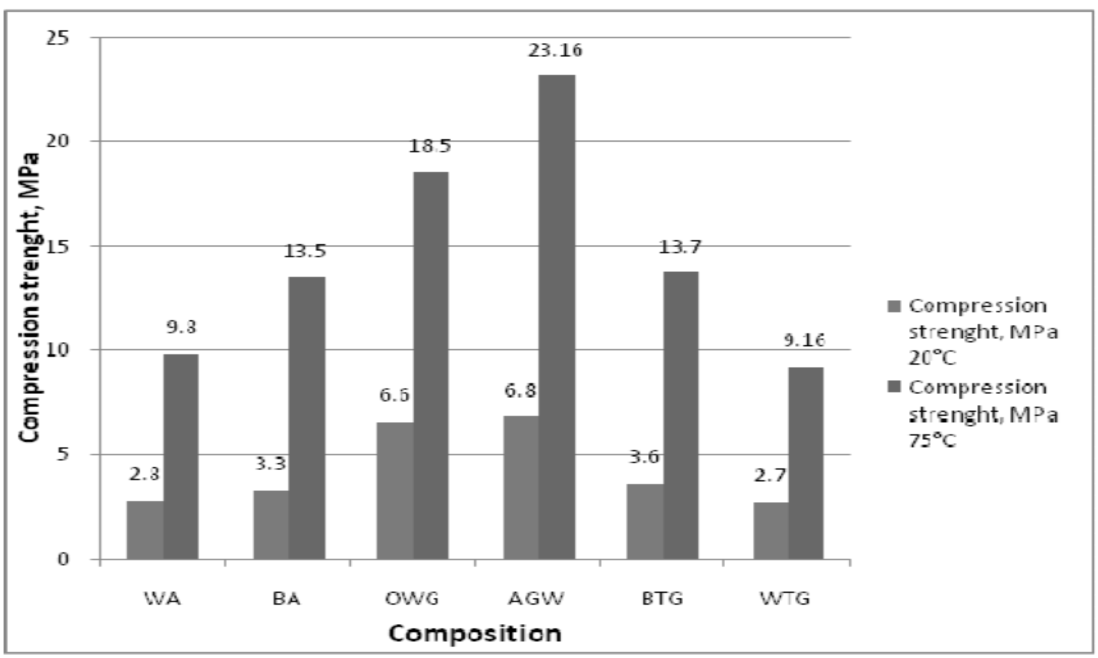


Figure 4: Compressible strength according to the mixture

The samples are created with different mixture combination such as wood ash (WA), barley ash (BA), additionally ground waste glass (AGW), barley and wood ash (BTG), calcined clay wood ash (WTG) and rough ground glass (OWG) (Diana Bajare, 2010).

An old research which has been took at 1997, the cementations binder was produced by blending an equal proportion of calcined phosphogypsum with the ground fly ash and 10 percent each of OPC and lime. This binder was tested for compressive strength, water absorption, soundness and porosity (Singh, 1997).

Table 4: Properties of cementations binder

Table 2 – Properties of cementitious binder

Property studied	Results
Fineness, cm^2/g	3200
Consistency, %	34.0
Setting time, minutes Initial Final	 10 50
Compressive strength, N/mm^2 (28 days)	8.78
Bulk density, g/cc	1.92
Cold expansion, mm	1.80

The industrial waste stabilization give a big impact on creating this mortar. After doing some research, it is assumed that polymer type industrial waste will give a strong strength to the cement paste and mortar. This is because polymer have a natural covalent bond which strong and rigid. Lotte Chemical Titan (M) Sdn. Bhd has provide their material safety and data sheet about their industrial waste which consist of health hazard, flammability hazard, reactivity hazard and it's physical and chemical properties. This is the industrial waste of low density polyethylene plant.

Figure 5: Hazard information of industrial waste

III. HAZARDS IDENTIFICATION

These products should not be considered as hazardous materials as our own interpretation of the U.S. Occupational Safety and Health Act and Regulations, including the Hazard Communication Standard 29 CFR 1910.1200 dated November 25, 1983.

Hazardous Material Identification System	Rating
Health Hazard:	0 Minimal
Flammability hazard	1 Slight
Reactivity hazard	0 Minimal

Table 5: MSDS of Industrial Waste

IX. PHYSICAL AND CHEMICAL PROPERTIES			
Physical state:	Solid pellets	% volatile (vol.):	<0.4
Molecular formula:	$(C_2H_4)x$	Melting point:	> 100°C
Boiling point:	N/A*	Solubility in water:	Negligible
Vapor pressure @ 20°C:	N/A*	Specific gravity:	0.900 – 0.935
Vapor density:	N/A*	pH:	N/A*
		Evaporation rate:	N/A*
*N/A: not applicable			

Rice husk ash (RHA) is used as aggregate which increase the strength of the cement mortar. The production of RHA is carried in University Teknologi PETRONAS itself in block J-2. The RHA which used in this project is burnt from a range of 700-800 °C in a special oven and will be crushed in an agitator. The physical and chemical properties are listed as below:-

Table 6: MSDS of RHA

TECHNICAL SPECIFICATIONS :	
SiO2 – Silica	85 % minimum
Humidity	2 % maximum
Particle size	25 microns
Colour	Grey
Loss on ignition at 800°C	4 % maximum
pH value	8

Green Building Index (GBI) is a government organization which acts as tool to evaluate the sustainable aspects of building that are commercial, institutional and industrial in nature. There are six criteria which that make up GBI rating which carries of total 100%. This project is falls under Materials and Resources (MR) criteria where carries 8 points. There are few divisions in these MR criteria which are:-

- Recycled content materials 2 points
- Regional Materials 1 point
- Sustainable Timber 1 point
- Storage and collection of recyclable 1 point
- Construction waste management 2 points
- Refrigerants and clean agents 1 point

This invention will help the environment to go greener in future and help reduce industrial waste stabilization (Wee, 2012) .

2.2 Review on other related researches

The latest finding is tabulated in table 7 below.

Table 7: Summary of latest finding

No	Author	Year	Objectives	Findings
1	K.Kinoshita	2009	Study the effect of various type of industrial waste to produce green composite binder	1. Develop green composite binder using woodchip and sawdust 2. Wood have natural gum like polymer call lignin
2	R.sudin	2004		1. Develop green composite binder using biodegradable resin and bamboo fiber 2. Resin used to coat the fiber to allow water resistance and increase strength
3	Kaizu	2009		1. Develop green composite binder using bamboo fiber and resin called Landy with woodchips 2. Landy increase the strength
4	Morsy	2012	To study the effect of additive in order to produce light and stronger binder.	1. Develop green composite binder using Metakaolin, fly ash, and lime 2. The ratio is 40:30:30
5	Yan	1998		1. Develop green composite binder using fly ash and flurogypsum. 2. Adding both enough to increase the strength

6	Diana	2010		1. Produce geopoymer using plant furnace industrial waste. 2. Maximum attain peak load around 20-30kN
7	Singh	1997		1. Develop green composite binder using phospogypsum, lime and OPC
8	Rinker	1988	To study the current and future potential and basic studies of binders	1. Optimum 28 days to dry 2. MSDS of OPC 3. Water cement ratio optimum is 0.5

2.1.4 Research Gap

Most of the researches that have been done previously are focusing on green composite binder using organic substance. However, there are also a few researches done to investigate the project using industrial waste.

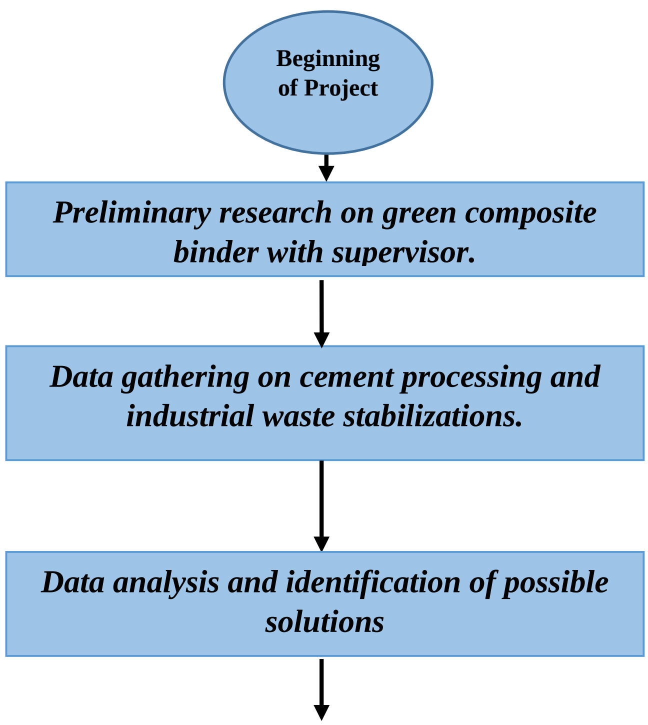
CHAPTER 3: Methodology

3.1 Research Methodology

In order to do further studies and research two type of research methodology have to be done as stated below:-

- Quantitative
- Qualitative

Quantitative data is best explained as data that has numerical significant and where by qualitative is subjective, meaning it is open to interpretation. Both methods are can be used in this project in order to get the best possible reasoning for this problem. Example of quantitative methods are such as calculations, tabulations, graphs, chemical equation and hazard codes which explained well in result and discussion session in Chapter 4. Where else, example of qualitative methods are such as survey, quotations, interview, flowchart, Gantt chart and meeting. All this methods are used to success the project activities with the help of supervisor. The research flowchart is shown in Figure 6.



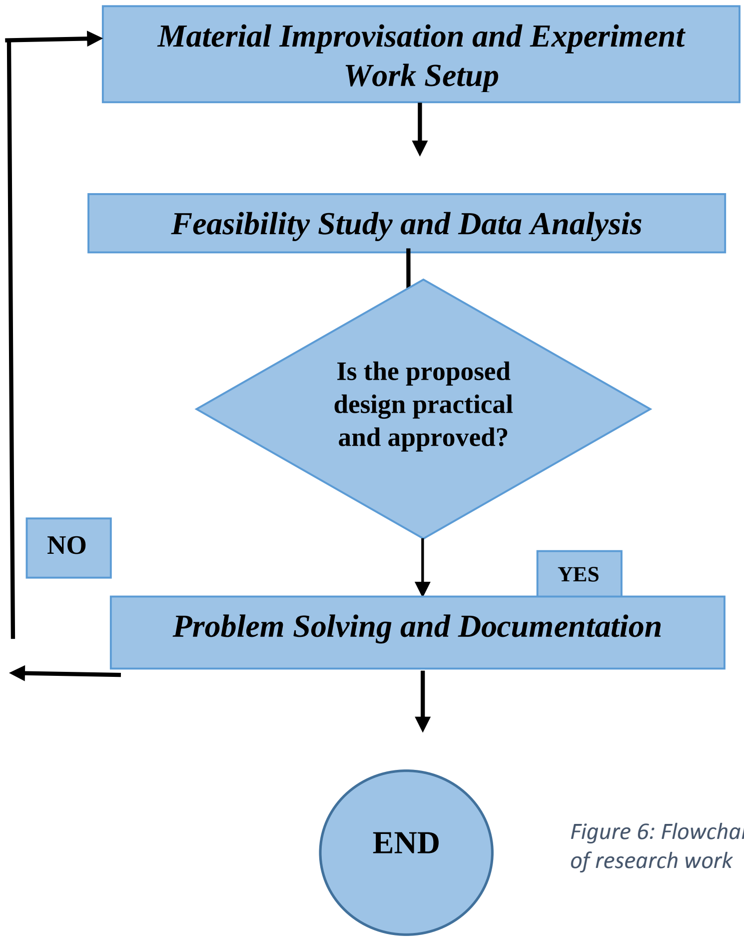


Figure 6: Flowchart of research work

3.1.1 Preliminary Research

After begin the project, the preliminary research was done on green composite binder material. The findings are stated in chapter 2 which is literature review. A lot of industrial waste can be applied in this project considering its characteristic. From conducting the literature review on current research, only polymer-like characteristic industrial waste can be able to give higher strength when mixed with binder. Similar case study was analyzed in order to have a better understanding about the project topic. Meeting was frequently conduct with supervisor in order to update the progress and to have better understanding on experimental setup.

3.1.2 Data Gathering

All the criteria is set in order to choose the best industrial waste candidate to be mixed in binder. After discuss with civil lab technician and supervisor, it is finalize that a polymer like industrial waste will be perfect because it has the natural rubber characteristic. Although woodchip and sawdust have lignin which natural glue in organic, the main problem statement of this project is to reduce the land pollution causing by the industrial waste. Sawdust and woodchip is industrial waste which have less harm than a chemical plant industrial waste. Survey was conduct on few industrial waste as well as Portland cement Type 1 in order to understand the benefits and advantages of the material.

Moreover, interview was done face to face to the chemical plant representative to know more about the material. Survey result was created and tabulated as below in Table 8. Other than that, material safety and data sheet (MSDS) was requested to analyze the hazard code of the materials.

Table 8: Information about materials

Materials	Quantity	Price	Area
Portland Cement Type 1	50 Kg	RM 17	Bota,Perak
Titan Waste Stabilisation	15 Kg	RM50	Lahat, Pengkalan
FPM Waste Stabilization	15 Kg	Free	Johor
Rice Husk Ash (RHA)	10 Kg	Free	Blok J-2,UTP

The important raw was identified as shown in Table 8 which is Portland cement type 1, rice husk ash (RHA), and different type of industrial waste. Most importantly, item such as store drum and scoop need to buy in order to store the raw material. The lab session and the mould (50mm x 50mm x 50mm) was booked early for 1 month usage. After all the material and data is collected and segregated, data was analysed and the type of experiment was identified. It is important to identify the experiment work and type of testing to be done. This will ensure a constant flow of project progress. The experiment work and type of testing is explain further in next research methodology.

3.1.3 Data analysis and possible solution to carry out experiment

For data analysis, all the industrial waste was send for lab in order to identify the hazard identification. This is the most important task in this whole project because the material which created have to be save and stable. The stabilization of industrial waste is crucial because the building which will be construct using this green composite binder material should not release harmful effect after few years. The standard building have a life span of 99 years, so it important to this material to at least stable for 99 years and above. The both industrial waste is analysed and the result is as stated below in Table 9. The procedure for the test is conduct according to U.S Occupational Safety and Health Act and Regulations, including the Hazard Communication Standard 29 CFR 1910.1200.

Table 9: Hazard identification

Industrial Waste	Plant	Hazard identification	Rating
Titan Industrial Waste	Ethylene-Based Homopolymer	Health Hazard	0 Minimal
		Flammability Hazard	1 Slight
		Reactivity Hazard	0 Minimal
FPM industrial Waste	Hexane-Butene Copolymer	Health Hazard	0 Minimal
		Flammability Hazard	1 Slight
		Reactivity Hazard	0 Minimal

The materials is always keep away from sparks and open flame because it has a slight possible to produce flame. Both material have to be store away from strong oxidising agents and store in a condition where the temperature have to be below 250 ^{o}C. These products also will not produce a hazardous polymerization.

The RHA and the OPC is classified safe to use with using proper personal protective equipment (PPE). Both also identified as alkaline base material where no reactivity hazard. The mask should be wear all time of experiment because the particle size is near to 25 microns and it is very easy to enter the respiratory system.

The main three experiment are identified in this project in order to obtain the result. This three experiment will be carried out in sequence and the list is shown below:-

- Experiment 1
  - Characterisation of material and different ratio combination to identification
- Experiment 2
  - Sample development using different curing method
- Experiment 3
  - Characterisation study of sample using different testing machine.

There are listing of testing which carried out after obtain the sample. These testing will show the quality of the sample which created. Below table is shows the list of test which carried out and its explanation.

Table 10: Type of testing with explanation

Type of Testing	**Explanation**
Slump Test	Method to characterize the workability of fresh slump
Making and Curing cubes	Method to have satisfactory moisture content and temperature
Compressive strength	Method to identify the peak load
Blain Air Permeability	Method to determine fineness of cement
Le Chatelier Test	Method to detect presence of uncombined lime and magnesia which cause the expansion of cement.

After identify the list of experiment and the type of testing, the experiment will be conducted to obtain the samples.

3.1.4 Experiment Work Setup

Adding RHA is the cement paste as aggregate is a must to increase the strength and increase the water resistance ability. 22% of the weight of paddy is received as husk. This husk contain about 75% organic volatile matter and the balance 25% of the weight of this husk is converted into ash during the firing process. This RHA commonly contain about 85% - 90% of amorphous silica. The first step in order to make this RHA, we need to burn the husk in a special oven in over 700^{o}C.

Figure 7: Oven for burn RHA

After the process of burning finish it will remove of the oven and put inside an agitator which will crush the husk into powder. It will use 9 metal ball to crush the burnt husk and need 999 second for the crushing process.

Figure 9: Burnt RHA

Figure 8: RHA Crusher

Preparation of Mould

There will be 3 type of moulds need for this project to undergo different test in order to identify its quantitative characteristic. The cube, rectangle and cylinder type of mould is needed to be fabricate from outsource as well as a curing cabinet. A curing cabinet is important in this project because it will successfully maintain the moisture content in the mortar, set and slowly hardens the mortar. Usually the moisture content in a mortar should be 8-9 %. For the initial part of project 50mm X 50mm mould is used to create samples as shown in Figure 10.

Figure 10: 50mm x 50mm mould

Before pour the sample into the mould, there are some preparation has to be made in order to smoothen the moulding process. The mould have to be cleaned (Figure 11) before use for next moulding and the mould will be coated with diesel so that the sample can be obtain without sticking directly into mould (Figure 12).

Figure 12: Cleaning of mould

Figure 11: Diesel Coating

After the mould is prepared in stand-by condition, the ingredients are prepared according to the ratio using the sludge/cement mixing calculation which explained further in below session. Every material which use in this project is carefully weight using weighing machine (Figure 13) and mixed using mixing tray rather than using mixer since the amount is too little. After the mix all the material, we use the vibrator machine in order fill the mixture in the mould in a compact manner as shown in Figure 14.

Figure 13: Weighing the cement amount

Figure 14: Vibration table

After the sample is created according to its ration and waste stabilization, a template of Microsoft excel is created in order to key in the data according to the test it undergoes. It will put under various test in various equipment such as **compressible strength test** which situated at cement lab in block 13, **permeability test** equipment at block 15, **Humidity test** equipment at block 4, **slump test** at block 13 and many more. The data will be collected on 7^{th}, 14^{th}, and 28^{th} day during the mortar's drying period.

Calculation for the Experiment

In order to calculate the cement to industrial waste to RHA to water ratio, it is important to understand and identify the moisture content of industrial waste. In order to identify the humidity content of industrial waste, the sample was weigh and put in to oven which the temperature set at 100^{o}C.

1. The mass of a small container is measured
2. 100g of industrial waste is measured and fill into the container

3. The sample is dried in oven for 1 day in a 100 – 105^{o}C oven
4. The sample is reweigh and equation 2 is used to calculate the moisture content.

$$Mn = \frac{(Ww - Wd)}{Wd} \times 100$$

(2)

In which M_n = moisture content (%) of material, W_w = wet weight of the sample and W_d = weight of the sample after drying. The calculation is showed in appendix part. After the test carried out, it is known that the moisture content is only about 1.522%. After identify the moisture content, the ratio of mixing can be identified using sludge mixing calculation. The formulas are showed below and the calculation is attached in Appendix.

Mass of the industrial waste

Waste type: Polyethylene Waste Product (Resin Form)

Density: 0.915 x 10^3 = 915 kg/m^3 (According to MSDS)

Sample: 4 mould x 3 cubes per mould = 12 samples

Total Volume = $1.5x10^{-3}m^3$

Mass of the waste to use (using density formula) = 1.3725kg

Mass of dry sludge = Mass of waste – (Mass of waste x Moisture content)

= **1.3525Kg**

Mass of the cement

Advised ratio of cement to waste = 4:1

Mass of cement = **5.41Kg**

Mass of the water

According to the literature review, ratio of water to cement = 0.5:1

Mass of water = 2.705 Kg

Since 1kg=1L, there will a usage of **2.705 L** of water.

Mass of Rice Husk Ash (RHA)

Since there is variation in using RHA, for the first part of experiment we used 0.15:1 cement to RHA ratio to see the different compared to the controlled sample.

Mass of RHA = **0.8115Kg**

All this material is mixed in mixing tray. After it all material is mixed well, it was pour into mould and dry for 1 day before remove from the mould and continue dry it for 28 days as illustrated in Figure 16 and Figure 15.

Figure 16: Demoulded Sample

Figure 15: Cured Samples

It was cured in a curing cabinet to stabilize the industrial waste. In curing cabinet, we can also adjust the humidity at our desire. The sample tabulation on how data is insert is attached in Appendix.

3.1.5 Testing Procedure

Slump Test

The slump test is one of the method to characterize the workability of fresh concrete. It measure consistency of fresh paste which is a capability of fresh paste to being handled. The height of the paste mix after being placed in the slump cone fifer form one sample to another.

Sample with lower height are the true slump. For slump between 0 -175 mm it is called true slump, while if more than 175mm it is called collapse slump. Figure 17 and Figure 18 shows the slump test measurement.

Figure 18: Measuring height of cement paste

Figure 17: Performing slump test

Compressive strength Test

This test is to determine the compressive strength of cement mortar according to BS 1881: Part 116:1983. This test is done to know the details of the physical response of cement mortar to compressive load as shown in Figure 18. This test will be done on 7th day, 14th day, 21st day and 28th day.

Condition of compressible strength test is:-

- 3 days: 40% of max compressive strength is developed
- 7 days: 70% of max compressive strength is developed
- 28 days: 100% of max compressive strength is developed

Figure 19: Compressible test unit

Blain Air Permeability

This test is to determine the fineness of cement in terms of specific surface. This method uses a small glass manometer to apply suction to the powder bed. The Blaine method is now by far the most commonly used, mainly because of the ease of maintenance. The specific surface is calculate using special formula as shown below in equation 3:-

$$Specific\ Surface\ value, S = \frac{S_S\sqrt{T}}{\sqrt{T_s}} \qquad (3)$$

Where:-

S_s = 377.4 m^2/Kg (constant)

T_s = 92.2 s

Start the timer when the bottom of the meniscus of the liquid reaches the second mark from the top and stop the timer when the bottom of the meniscus reaches the third mark. Record the time, T to nearest second. The standard value which will pass the test is when S_s is around 300 – 450 m^2/Kg.

Le Chatelier (Soundness) Test

This test is to detect the possible risk of the late expansion due to uncombined lime in cement hydration process. This condition will determine the cement quality and its suitability to use in cement making. The calculation involve is the final gap – initial gap. If the gap exceed 2.5mm, it failed the soundness test. Lower the value of expansion, the cement is good. Soundness test is illustrated in Figure 20.

Figure 20: Soundness test

3.2 Key milestone

Key milestone of the research work is listed in table 11.

Table 11: Key milestone

Key milestone	Week
Finalization of project title	4
Decide problem statement and objective	6
Submission of Extended Proposal Report	6
Enquiry about experiment with lab technician	7
Proposal Defense	9
Purchasing industrial waste and cement	11
Submission Of Interim Draft Report	12
Submission Of Interim Report	13
Submission Of Progress Report	21
Conducting Experiments and test	14
Discussion with supervisor about result	22
Pre-SEDEX	25
Submission of Draft Report	25
Submission of Dissertation	26
Submission of Technical paper	26
Oral Presentation	28
Submission Project Dissertation	28

3.3 Tools Used

Software

- Microsoft Excel: - this tool is used for create tables and graphs to represent the data of the result and discussion.
- Microsoft Word: - for the preparation of document such as extended proposal, interim report and progress report.
- Microsoft Power Point: -for the usage of presentation purpose.

Tools

- Mechanic and Civil Tools: - use spade, mixer, and compressible test equipment for prepare and test the sample.
- Store drums: - use to store raw materials such as rice husk ash (RHA), Portland cement type 1, and the selective industrial waste stabilization.
- Equipment for testing purpose: -need to test the sample that produce to quality its ability of its strength, permeability and much more.

3.4 Gantt Chart

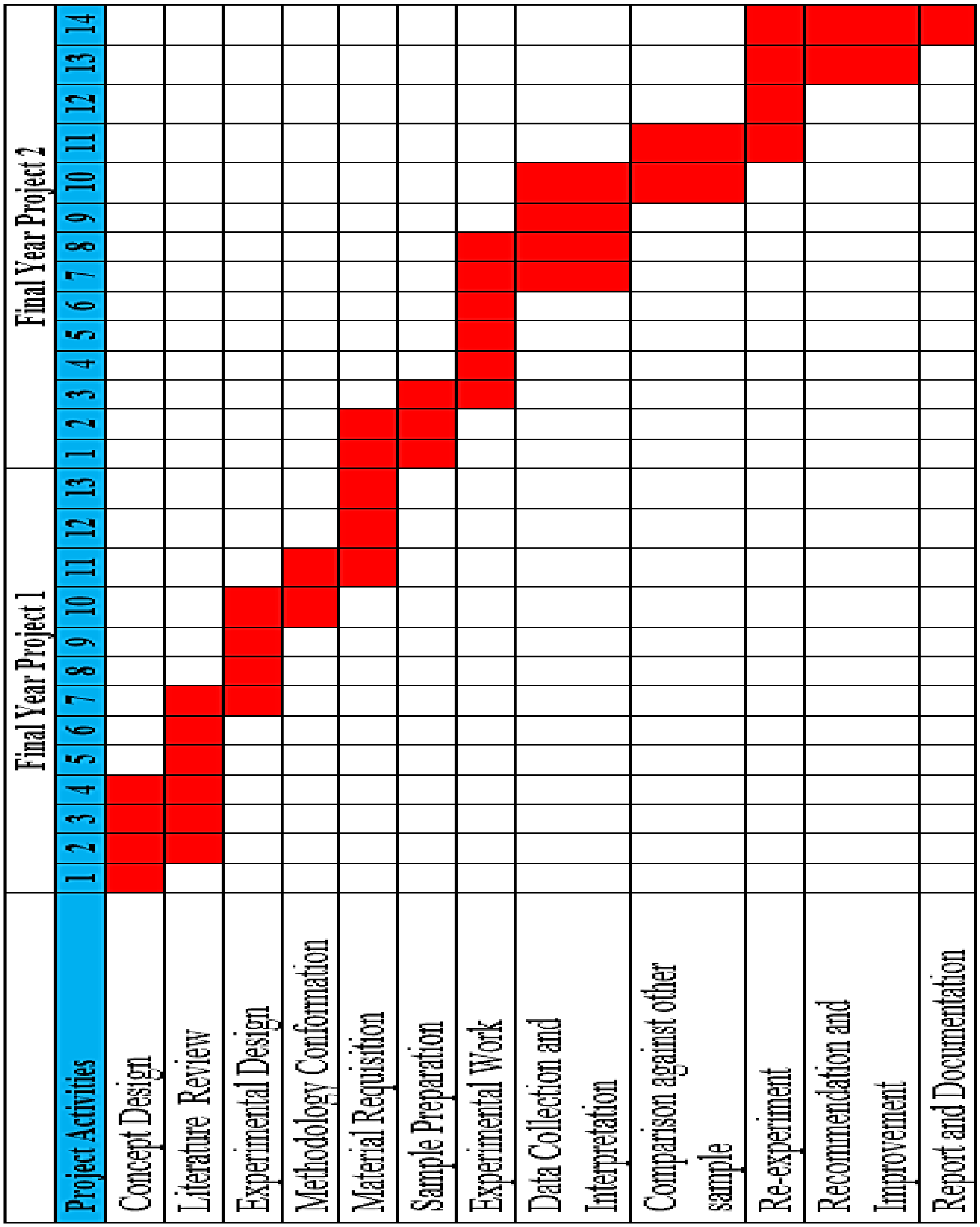


Figure 21: Gantt chart of the research work

CHAPTER 4: RESULT AND DISCUSSION

4.1 Different ratio combination identification

There are several sub experiment which carried out in order to identify the best ratio combination between:-

- Water and cement
- RHA and cement

4.1.1 Water and cement Ratio Identification

The optimum water to cement ratio is 0.5. In order to identify the best ratio a range 0.4 to 0.5 is taken. The result of the experiment is shown in figure 22.

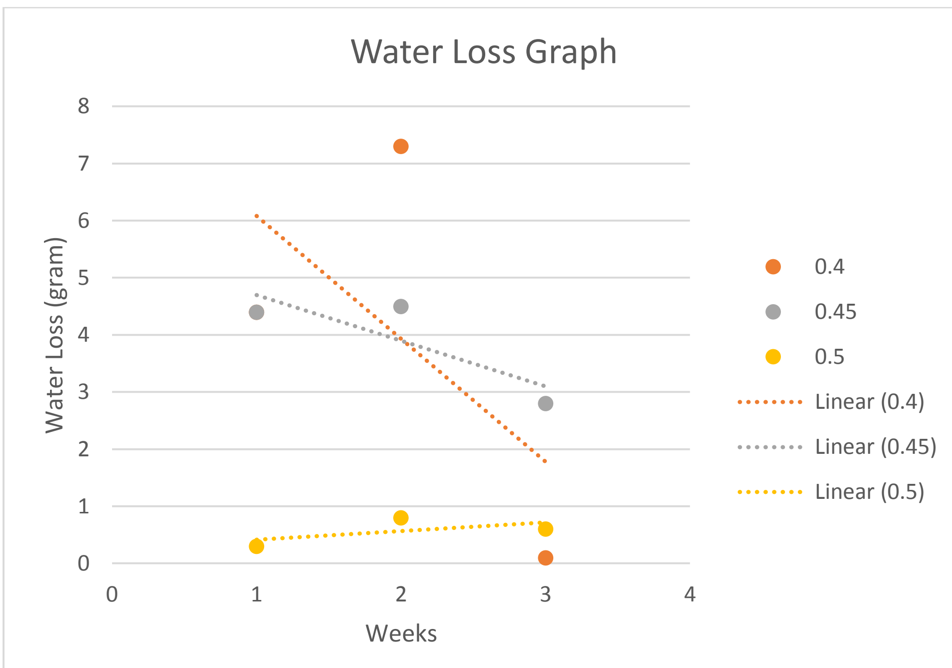


Figure 22: Water loss Graph

As seen in figure 22, 0.45 water to cement ratio have an optimum water loss compared to other to ratios. 0.4 Ratio is ignored since the water loss is higher hence the sample will have the least compressible strength. 0.5 Ratio have minimum water loss which cause water bleeding in the sample and cause the sample wont attain a maximum strength. The confirmation in choosing the ratio will be finalise by looking at figure 23.

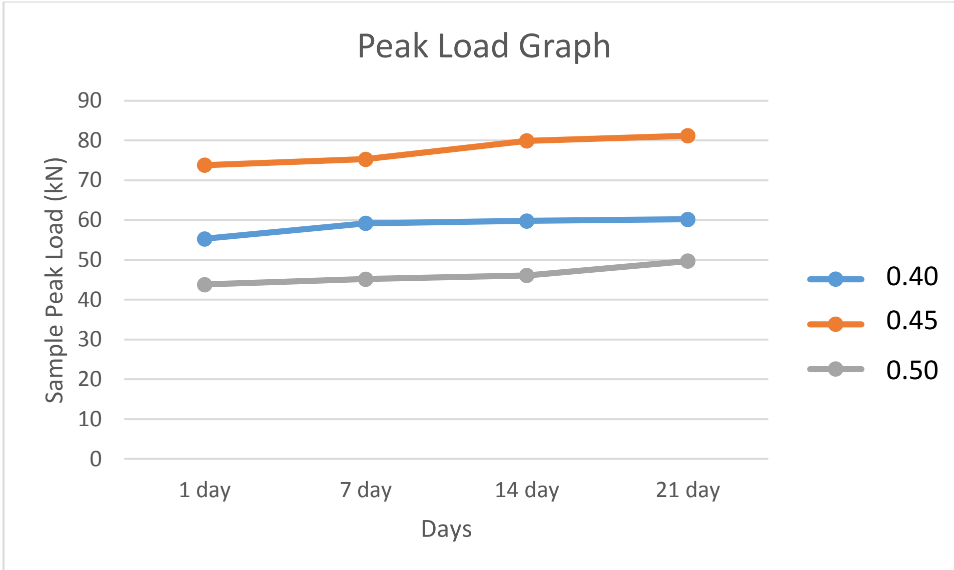


Figure 23: Peak Load Graph

Here the confirmation can be done where it is observe that 0.45 Ratio have the highest peak load. This ratio describe that it undergoing optimum water loss and attain maximum peak load strength as days goes. As a conclusion 0.45 Ratio was chosen.

4.1.2 RHA and cement Ratio Identification

The optimum ratio mixing for RHA to cement is 0.15. A range of 0.1 to 0.15 is taken into consideration in order to identify the best ratio combination between RHA and cement. The result in form of graph is shown in figure 24.

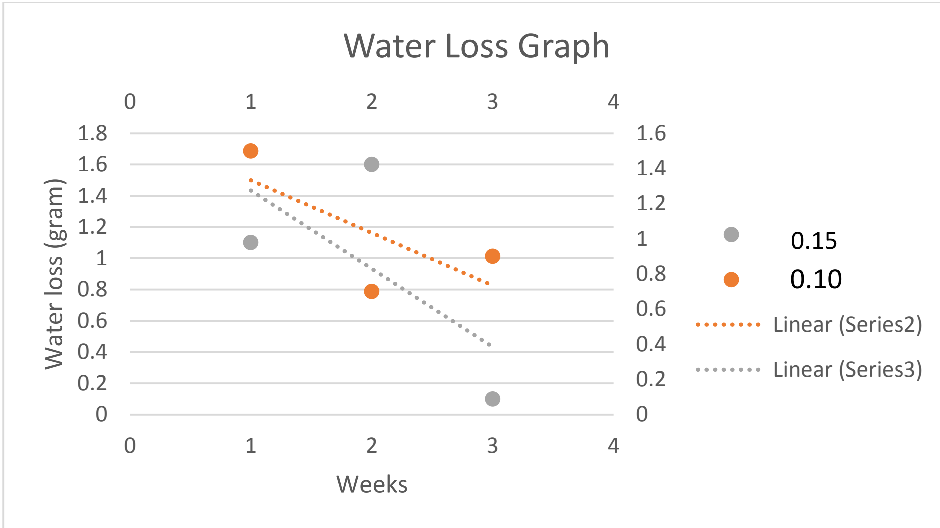


Figure 24: Water Loss Graph

As seen in figure 25, 0.15 RHA to cement ratio have an optimum water loss compared to other to ratios. 0.1 Ratio has high water loss and it won't able to give a high peak load strength. The confirmation in choosing the ratio will be finalise by looking at figure 25.

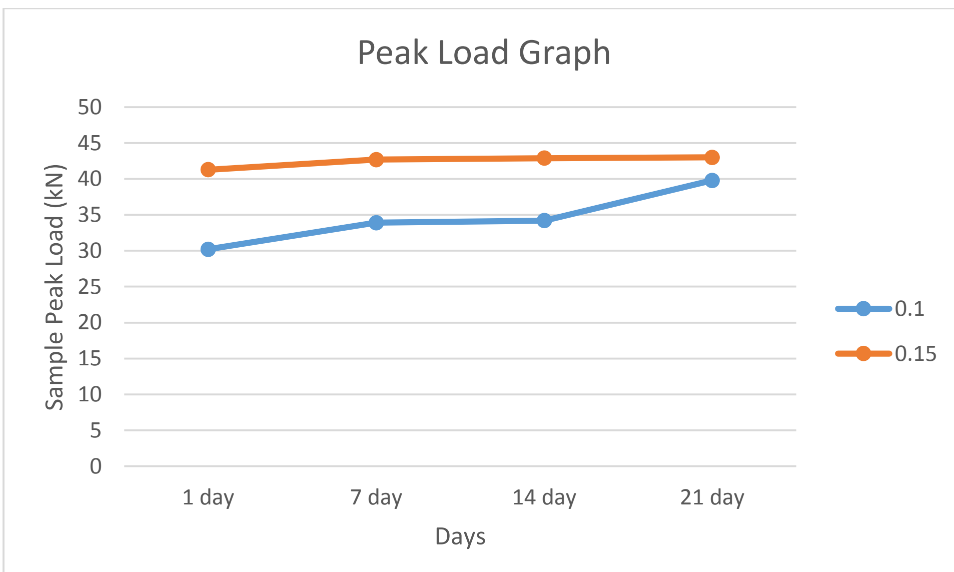


Figure 25: Peak Load Graph

Here the conclusion can be made that 0.15 RHA to cement ratio giving a high compressible peak load strength. As a conclusion, 0.15 ratio is chosen in order to proceed with the experiment using industrial waste. The amount of industrial waste use in the mixing is calculated and the calculation is shown in Appendix. The formula and the method is also included in Chapter 3 which is methodology.

4.2 Study the characteristic using different curing method

There are 2 type of curing methods used in this project. There are:-

- Air curing
- Water curing

4.2.1 Air curing method for Titan industrial waste without RHA

The sample was initial experimented with Titan industrial waste without using RHA and the result was shown in Figure 26.

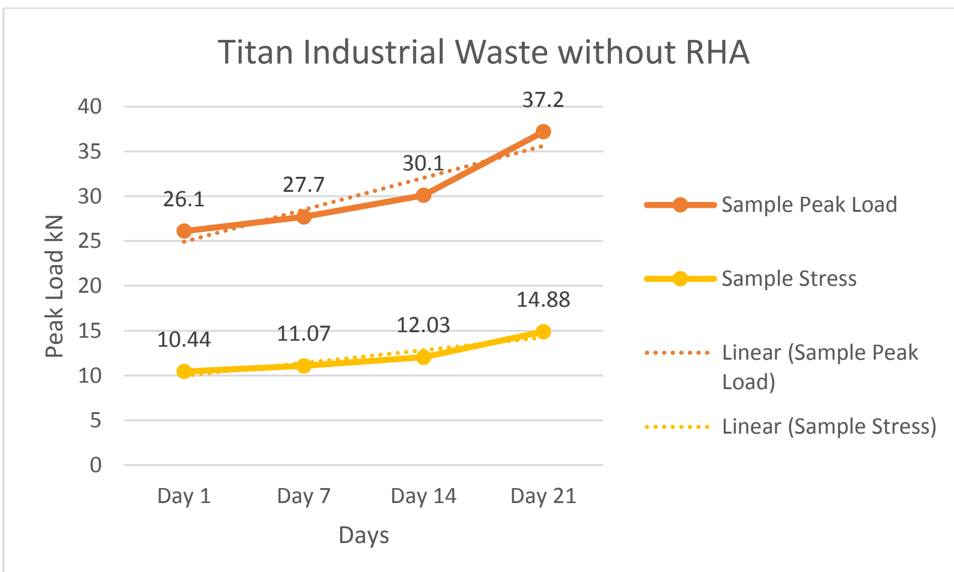


Figure 26: Titan Industrial waste without RHA

The strength for the sample is 37.2kN, which is higher than the normal cement sample compressible strength. Although the sample is high in strength, the load can be increase by using RHA in the mixture. Figure 27 shows that Titan industrial waste composite binder material using RHA. RHA is admixture which can increase the strength of the sample by 5kN to 10kN. The result shows as below.

4.2.2 Air curing method for Titan industrial waste with RHA

The sample was cured in air stored in specific place in room temperature. The result of the compressible peak load strength is shown in figure 27.

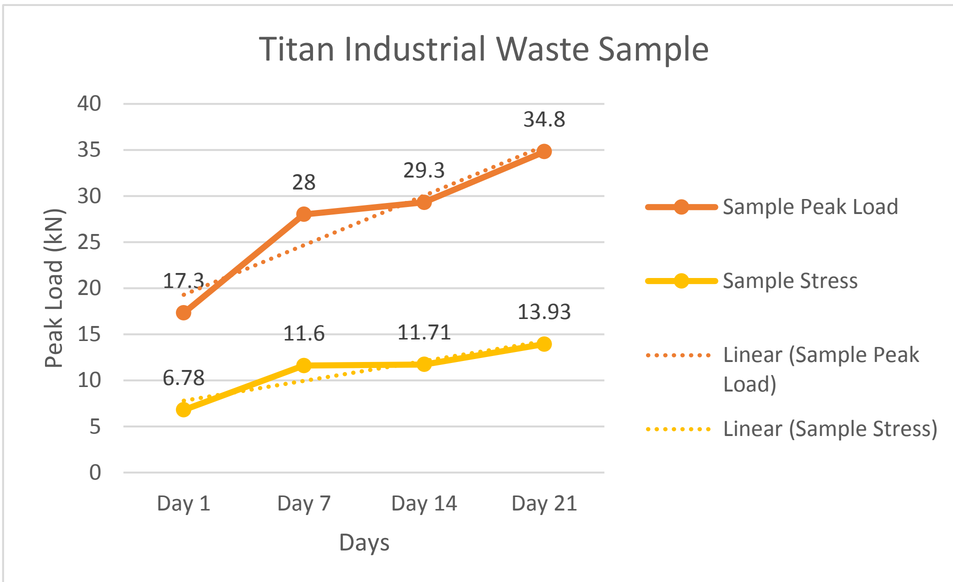


Figure 27: Titan Industrial waste sample

It is observed that as the days goes the strength of the sample is increasing. From the figure 28, we can conclude that a maximum of 45kN is achieved after 21 days. The normal cement sample can be reach a maximum 30kN to 40kN. Although the peak load is just slight increase from the normal, it can be reach higher if different waste used. The Figure 28 shows that compressible peak load strength from FPM industrial waste.

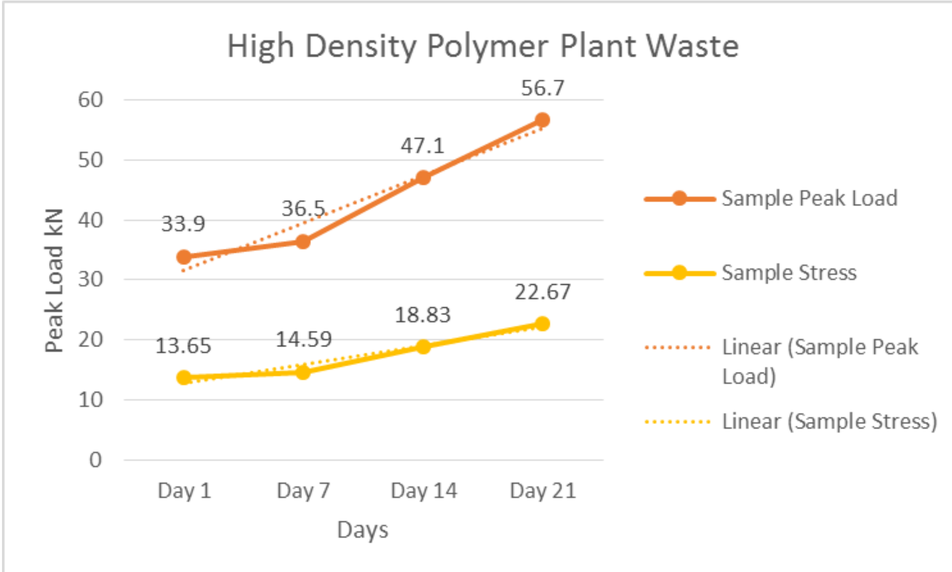


Figure 28: FPM industrial waste

Using this industrial waste clearly shows that this strength is more than the normal cement and it is increase rapidly with a steep gradient. This industrial waste provide 10kN more than the Titan industrial waste. As a conclusion FPM industrial waste giving a high strength which is 56.7 kN and it shows that industrial waste can be useful in some areas. In testing the sample, only FPM industrial waste is chosen because the cost to test the sample are expensive and time consuming. It is vital to know the characteristic of the suitable green composite binder material. The testing result are shown in table below.

4.2.3 Water Curing method for Titan industrial waste using RHA

Water curing method is definitely bad method for cure the industrial waste binder material. The Figure 29 shows that the progress to attain the maximum strength is slow and the strength is just 34.8 kN. Water curing slows down the strengthen process.

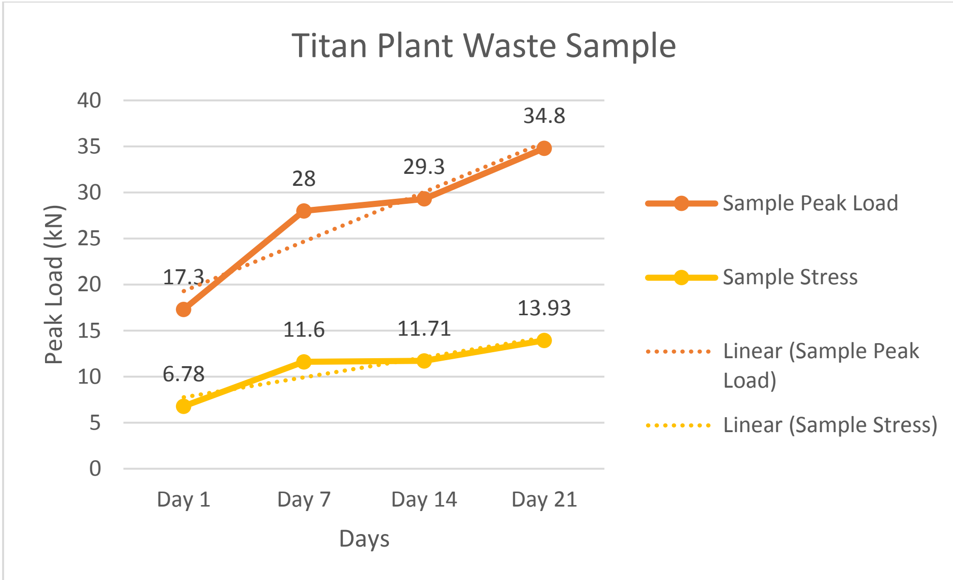


Figure 29: Water Curing for Titan industrial waste

4.2.4 Water Curing method for FPM industrial waste using RHA

Similar to above case, the water curing is also not functioning well to FPM industrial waste. Figure 30 explain that the progress is slow down compare to air curing. As a conclusion, hereby the experiment conclude that air curing is better in curing the industrial waste compared to water curing which normally used in cement sample curing. The sample is just obtaining a maximum of 47.3kN which very low compared to the FPM industrial waste which obtain about 56.7kN. The Figure 30 shows the result of the experiment.

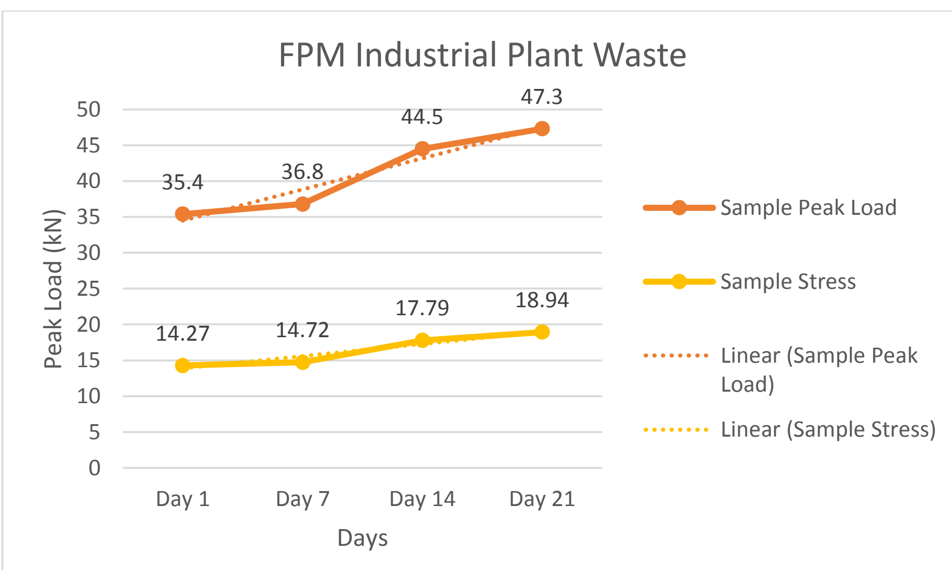


Figure 30: Water Curing of FPM Industrial Waste

4.3 Characterisation Study of the chosen sample

There are few test done on the FPM industrial waste binder material in order to test other criteria and safety aspect. A total of 3 tests (other than compressive strength and curing test) were done which:-

- Slump test
- Blaine air permeability test
- Le Chatelier (Soundness Test)

4.3.1 Slump Test

The slump test gave an excellent result of 165mm or near to 6.5 inches which in the range from 0 – 175mm. This slump is called as valid slump which means the medium workability in mixture. This test is done to measure the consistency of the slump. So this mixture is accepted. The methodology on this test is explain in chapter 3.

4.3.2 Blaine air Permeability test

Blaine air permeability test is to determine the fineness of sample in terms of specific surface expressed as total surface area in square meters per kg of cement. The result for this test is 327.85 m^2/kg which is in the range of standard value which is from 300 – 450 m^2/kg.

4.3.3 Le Chatelier (soundness) test

The expension test was done in order to consider the swelling, cracking or disintegration resulting from expansive chemical reaction such as the hydration of free lime (CaO) in cement paste. The distance between indicators shows 0.42cm, which resulted in difference about 0.02cm. The result is explain that, lower the value of expansion, the cement is pass the soundness test. In order to pass the test, the difference expansion can’t exceed 2.5mm.

4.4 Costing

Normal cement sample cost (for 100 samples) = RM 156

Industrial waste cement sample cost (for 100 samples) = RM 50, since the industrial waste was obtained in a free basis.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The effort in produce the perfect green composite binder material is completed by choosing the best industrial waste. The design to produce a cost effective binder is achieved by spending only RM 50, which more than half cut down. Finally, light weight and stronger binder is created using industrial waste residue with RHA. The weight of the industrial waste cement sample is 188.5 g which is lighter than the normal cement sample which is 226.9 g. The experiment also shows that the maximum strength which is 56.7kN is achieved from FPM industrial waste with air cured compared to 30kN of strength in normal cement sample. All the test such as Blaine air permeability test, Le Chatellier test, Slump test, compressive strength test and curing test showing a positive and valid result. This project is very important in order to reduce the pollution in future and can be commercialise in order to save the environment. The FPM industrial waste was selected and recommended to creating green composite binder material.

5.2 Recommendation

This project will give an excellent result if the industrial waste can be grind to be particle as same as the size of cement particle which is around 20 microns. The miscible mixing will ensure the even mixing. Moreover, soda lime admixture is better than RHA. Since this project is concentrate on cheap samples, RHA become the main attraction. In order to get a better result soda lime will be a better choice indeed. It is also better to have cement like industrial waste where we also can reduce the amount of OPC used in this project. This will reduce the costing even more. Moreover, other suitable industrial waste also can be used as a substitution for current industrial waste.

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APPENDIX

1. Moisture Content of industrial waste.

$$Mn = \frac{(Ww - Wd)}{Wd} \times 100$$

$$1.522\% = \frac{(100 - 98.5)}{98.5} \times 100$$

2. Sludge to cement calculation

Mass of the industrial waste

Waste type: Polyethylene Waste Product (Resin Form)

Specific gravity: 0.915 (According to MSDS)

Density: 0.915 x 10^3 = 915 kg/m^3

Sample: 4 mould x 3 cubes per mould = 12 samples

Cubes volume = (50mm x 50mm x 50mm) =125,000mm

Total Volume = cube volume x 12 samples = 1.5x$10^{-3}$$m^3$

Mass of the waste to use (using density formula) = 1.3725kg

Mass of dry sludge = Mass of waste – (Mass of waste x Moisture content)

= 1.3725 – (1.3725 x 0.01522)

= **1.3525Kg**

Mass of the cement

Advised ratio of cement to waste = 4:1

Mass of cement = **5.41Kg**

Mass of the water

According to the literature review, ratio of water to cement = 0.5:1

Mass of water = 2.705 Kg

Since 1kg=1L, there will a usage of **2.705 L** of water.

Mass of Rice Husk Ash (RHA)

Since there is variation in using RHA, for the first part of experiment we used 0.15:1 cement to RHA ratio to see the different compared to the controlled sample.

Mass of RHA = **0.8115Kg**

3.

Experiment 1: To Identify best Combination Mixing Ratio

A. Water/Cement Ratio

Water/Cement ratio which range from 0.4-0.5 is took to identify which is the best combination ratio. The result of the experiment is shown below.

Sample(0.40)	Mass	Compressible value		
Day(s)	(gram)	Sample Peak Load	Sample Stress	Pace Rate
Day 1	210.1	55.3	22.85	0.9
Day 7	205.7	59.2	23.67	0.9
Day 14	198.4	59.8	23.92	0.9
Day 21	198.3	60.2	23.98	0.9

Sample(0.45)	Mass	Compressible value		
Day(s)	(gram)	Sample Peak Load	Sample Stress	Pace Rate
Day 1	225.8	73.8	35.43	0.9
Day 7	221.4	75.3	37.54	0.9
Day 14	216.9	79.9	37.89	0.9
Day 21	214.1	81.2	39.45	0.9

Sample(0.50)	Mass	Compressible value		
Day(s)	(gram)	Sample Peak Load	Sample Stress	Pace Rate
Day 1	205.2	43.8	15.14	0.9
Day 7	204.9	45.2	16.11	0.9
Day 14	204.1	46.1	16.78	0.9
Day 21	203.5	49.7	17.12	0.9

As a conclusion, water to cement (0.5 ratio) was choosen.

4.

B. Cement to RHA ratio (water to cement ratio keep to 0.45)
RHA/Cement ratio which range from 0.1-0.2 is took to identify which is the best combination ratio. The result of the experiment is shown below.

Sample(0.10)	Mass	Compressible value		
Day(s)	(gram)	Sample Peak Load	Sample Stress	Pace Rate
Day 1	195.4	30.2	9.83	0.9
Day 7	193.9	33.9	11.45	0.9
Day 14	193.2	34.2	11.88	0.9
Day 21	192.3	39.8	12.59	0.9

Sample(0.15)	Mass	Compressible value		
Day(s)	(gram)	Sample Peak Load	Sample Stress	Pace Rate
Day 1	198.2	41.3	13.65	0.9
Day 7	197.1	42.7	13.99	0.9
Day 14	195.5	42.9	14.76	0.9
Day 21	195.4	43	15.14	0.9

Since there is no different in peak load when coming to 0.15 ratio, the experiment didn't further with 0.2

5.

Experiment 3: Testing of Designed Sample with Industrial Waste

A. Industrial Waste from Polyethylene Plant (Resin Form)
This expermient was performed with and without RHA.

A.1. [Water + Cement + Industrial Waste]
Mass of dry sludge = 1.325 Kg (Using 4:1 ratio cement to sludge)
Mass of cement = 5.41 Kg (using 0.45:1 ratio cement to water)
Mass of water = 2.43 Kg, which is 2.43 L

Sample[A.1]	Mass	Compressible value		
Day(s)	(gram)	Sample Peak Load	Sample Stress	Pace Rate
Day 1	190.4	26.1	10.44	0.9
Day 7	189.7	27.7	11.07	0.9
Day 14	189.2	30.1	12.03	0.9
Day 21	185.9	37.2	14.88	0.9

The study still be continue for another 1 week.

6. A.2 [Water + Cement + Industrial Waste + RHA]

Mass of dry sludge = 1.325 Kg (Using 4:1 ratio cement to sludge)

Mass of cement = 5.41 Kg (using 0.45:1 ratio cement to water)

Mass of water = 2.43 Kg, which is 2.43 L

Mass of RHA = 0.811 Kg (Using 0.15:1 ratio cement to RHA)

Sample[A.2]	Mass	Compressible value		
Day(s)	(gram)	Sample Peak Load	Sample Stress	Pace Rate
Day 1	193.7	33.6	13.46	0.9
Day 7	192.1	37.8	15.14	0.9
Day 14	187.4	42.8	17.12	0.9
Day 21	184	45	18.01	0.9

The study still be continue for another 1 week.

B.1 [Water + Cement + Industrial Waste Type 2 + RHA]

Mass of dry sludge = 1.000 Kg (Using 4:1 ratio cement to sludge)

Mass of cement = 4.00 Kg (using 0.45:1 ratio cement to water)

Mass of water = 1.8 Kg, which is 1.8 L

Mass of RHA = 0.6 Kg (Using 0.15:1 ratio cement to RHA)

Sample[B.1]	Mass	Compressible value		
Day(s)	(gram)	Sample Peak Load	Sample Stress	Pace Rate
Day 1	213	33.9	13.65	0.9
Day 7	201.2	36.5	14.59	0.9
Day 14	199	47.1	18.83	0.9
Day 21	198.4	56.7	22.67	0.9

The study still be continue for another 1 week.