PERFORMANCE OF FLY ASH BASED [illegible] CONCRETE AT HIGH TEMPERATURE

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ABSTRACT

Nowadays the demand for cement concrete based on Portland cement as a construction material is on the increase day by day. The demand of concrete would increase in the future due to increase in infrastructure developments. The production of Portland cement will produce CO_2 gases that release to the atmosphere which causing the global warming of the earth. The new material that calls fly ash based geopolymer concrete which does not need Portland cement as a binder. The Portland cement is replaced by fly ash that rich with silica and alumina. Because the ceramic–like properties of the geopolymer it believed that can provide good fire resistance. This paper is show the result of study on the performance of fly ash based geopolymer concrete when expose to high temperature in term of compressive strength and their porosity. Sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) solution is act as an activator solution in the fly ash based geopolymer concrete. Concrete sample were cured in the oven at 60°C for 24 hours. After curing the sample were placed at room temperature until test on day 1 day 7 and day 28 for the control. For the research sample it will expose to the difference temperature (100°C, 200°C, 300°C, and 400°C) and difference time (15 minutes, 30 minutes, 45 minutes and 60 minutes) at day 28 before testing is conducted. From the research, sample geopolymer concrete was exposed to temperature have high compressive strength. Porosity result has shown the different trend from the usual result of porosity. The value of porosity is higher when exposed where the compressive strength also higher.

Keywords: Geopolymer, Fly ash, elevated temperature, strength, aggregate, concrete

ABSTRAK

Permintaan untuk konkrit simen berasaskan Simen Portland sebagai bahan pembinaan semakin meningkat, di sebabkan oleh peningkatan pembangunan. Penghasilan simen Portland akan menghasilkan gas CO_2 yang akan dilepaskan ke atmosfera dan mnyebabkan bumi semakin panas. Bahan baru yang dipanggil abu terbang berasaskan konkrit geopolymer yang tidak memerlukan simen Portland sebagai pengikat di perkenalkan. Simen Portland digantikan dengan abu terbang yang kaya dengan silika dan alumina. Karya ini menunjukkan hasil kajian mengenai prestasi abu terbang berasaskan konkrit geopolymer apabila terdedah kepada suhu yang tinggi dari segi kekuatan mampatan dan keliangan mereka. kajian ini di lakukan untuk mengetahui prestasi abu terbang berasakan konkrit geopolymer apabila ia terdedah pada suhu yang tinggi dari segi kekuatan mampatan dan juga keliangan. Larutan Sodium Silikat (Na_2SiO_3) dan Natrium Hidroksida (NaOH) adalah bertindak sebagai satu larutan pengaktif dalam abu terbang berasaskan konkrit geopolymer. Sampel konkrit ditempatkan di dalam ketuhar pada suhu 60°C selama 24 jam selepas ia mengeras didalam acuan. Selepas di tempatkan di dalam ketuhar selama 24 jam sampel konkrit diletakkan di tempat yang bersuhu bilik sehingga di lakukan ujian selepas 1 hari 7 hari dan juga 28 hari. Pada hari yang ke 28, sebelum ujian dijalankan sampel kajian akan di letakkan di dalam relau yang berlainan suhu bermula dari 100°C ,200°C ,300°C dan 400°C. Masa sampel berada di dalam relau untuk setiap suhu adalah 15minit 30minit 45 minit dan 60 minit. Daripada kajian yang dibuat sampel konkrit Geopolymer yang diletakkan di tempat suhu yang tinggi menunjukkan kekuantan mampatan yang tinggi. Selain itu ujian keliangan juga menunjukkan bahawa sampel konkrit geopolymer mempunyai nilai keliangan yang tinggi.ini dikatakan semakin tinggi kekuatan mampatan konkrit semakin tinggi nilai keliangan.

Kata kunci : Geopolymer, abu terbang, suhu menaik, kekuatan, aggregate konkrit

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CO_2	Carbon dioxide
OPC	Ordinary Portland cement
Na_2SiO_3	Sodium silicate
SiO_2	Silicon Dioxide
AL_2O_3	Aluminum Oxide
Fe_2O_3	Iron Oxide
CaO	Calcium Oxide
CSH- gel	Calcium silicate hydrate gel
KOH	Potassium hydroxide
NaOH	Sodium hydroxide
SEM	Scanning electron microscope

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Temperature representing one of the severe exposure condition. In any design building, it provides the suitable resistance at any type of temperature. So provision for resistance at high temperature that suitable for structural members are a main safety requirement for any design of building. Temperature in the structure must be determined in order to predict the endurance of the structure. At elevated temperature endurance of the structural member depending on the thermal and their mechanical properties.

Now a day the construction industry has expressed their interest in the utilization of various 'newer generation' concrete for their building material. This 'newer generation 'is likely to behave differently from the conventional concrete when the concrete exposed in high temperature. The physical and mechanical properties of concrete are affected due to exposure to heat .The element of the concrete could be interrupted. The surface of the concrete would spoil due to a buildup of pressure steam in the certain condition. Structure operation and safety can be affected by loss of structural integrity, thermally induced dimensional change, and release the moisture resulting from migration of free water. In the trusted design evaluation, the understanding of behavior of new concrete under long term of high temperature is very important.

The requirement for the cement concrete as the construction material is increasing .in the future is certainly that cement concrete will increase due to increasing infrastructure development.(Maholtra,1999) was estimated that the demand for cement concrete will increase from about 1.5 billion tons in year 1995 to 2.2 billion in the years 2010. One of the factors for global warming is the emission of greenhouse gases to the atmosphere by the human activity. One of the greenhouse gasses is CO_2 that contributed 65% of global warming. From the 6% CO_2 that release in the atmosphere is responsible by the cement industry because the production of a tone Portland cement will release approximately one tons of the CO_2 gases.

One of the important effort to produce environmentally friendly concrete,is the development of inorganic alumina-silica polymer that called Geoplolymer. Geopolymer are synthesizes from material of geological origin or by product materials such as metakaolin, fly ash ,silica fume and rice husk that are rich in silicon an aluminum. The word geopolymer is used to describe an environmentally friendly material which is possesses excellent strength and chemical properties

The geopolymer also displays ceramic like properties with superior endurance at high temperature. The raw material needs low energy for production and their inflammability at high temperature. In encapsulating hazardous waste for storage or disposal, geopolymer are attracting increasing interest as ecological friendly fireproof building material, sound and heat insulation and materials .Considerable promise for application in the concrete industry as an alternative binder to Portland cement was shown by the geopolymer technology that propose by Geopolymer technology can reduce the production of greenhouse gasses CO_2 and aggregate industries by 80 %.

Fly ash is one of the sources of geopolymer binder that's available abundantly worldwide, but today its utilization is limited. From 1998 estimation, production of fly ash is obtained more than 390 million tons annually, but the utilization is less than 15%.by the year of 2010.The production of fly ash was estimated about 780 million tons annually (Maholtra, 1999).

Accordingly, to make concrete more environmentally the efforts in using this product material in concrete are very important. When every tons of fly ash used to replace Portland cement than it will help to preserve one million tons of limestone, 0.25 million of coal and over 80 million units of power an also the reduction of 1.5 million tons of CO_2 to the atmosphere. The factor that why need use fly ash as main raw material in concrete are it is cheap and available in large amount. The concrete also need less water for the activation reaction to bind all the mixture and also it has high workability.

1.2 PROBLEM STATEMENT

We can realize from the current scenario that ordinary Portland cement is causing many of the environmental hazards such as large consumption of power for the manufacture of Ordinary Portland Cement (OPC), increasing greenhouse gases, and from the economic view which is the price of fly ash-based geopolymer concrete is predictable to be about 10 to 30 percent cheaper than that of Portland cement concrete. (B V Rangan)

So considering all above points there is a need to find some alternative material. Any material which contains silica and aluminum in amorphous state can be a source of binding material, and Fly ash which contains this is considered to be a waste product which can be utilized effectively to overcome the effects caused by Ordinary Portland Cement. Long term application of any material can be taken up only when it is tested for the drastic conditions, and one among the severe or extreme case is susceptible to high temperature.

When geopolymer concrete exposed to temperature, there is a decrease in their physical properties such as low in compressive strength, have cracking, high number of porosity values and also spalling of the concrete occurs.

An assessment of structural integrity must be made to determine whether a structure can be repaired rather than demolished after expose to temperature based on strength of fly ash based geopolymer concrete. Usually the evaluation damaged concrete by high temperature will start with a visual observation such as cracking change of color and. So there is need to find the evaluation of the Fly ash based Geopolymer concrete to extreme temperature for making the good structure building.

1.3 OBJECTIVE OF STUDY

The objective study for this research are:

I. To determine the compressive strength of fly ash based on geopolymer concrete when expose to high temperature.

II. To obtain the correlation between compressive strength and porosity of fly ash based geopolymer concrete when exopose to high temperature

1.4 SCOPE OF STUDY

This research was conducted to determine the compressive strength of fly ash based geopolymer concrete when exposed to high temperature. In this experimental work the main sources is fly ash that obtained from Manjung power station in Lumut Perak Malaysia used as base material to produced geopolymer concrete. The quantity of fly ash used is 350 (kg/m^3). The other material is fine aggregate and the quantity is 650 (kg/m^3) and also coarse aggregate with 1200 (kg/m^3). Sodium silicate (Na_2SiO_3) mixed with 6m of sodium hydroxide (NaOH) solution is used as alkaline activator in this research work. On the other hand this research also to studies the correlation between the strength and porosity of geopolymer concrete

The 54 molds (100mmX100mmX100mm) cube and 4 molds (50mmx50mmx50mm) cube are prepared by using the phenolic board. The mixtures are prepared by the mix of alkaline solution, aggregate and fly ash.

Then prepare the control. Geopolymer sample will be cured for 24 hours in the oven that the temperature is 60°C. The specimens will be tested on their porosity and compressive strength after 1, 7 and 28 days. The specimens will be exposed to the temperatures at 100°C, 200°C, 300°C, and 400°C and with different duration of 15 minutes, 30 minutes, 45 minutes and 60 minutes on day 28.

1.5 SIGNIFICANCES OF STUDY

This research was conducted to determine the compressive strength (density) of fly ash based geopolymer concrete after exposed to the high temperature for different time. The result of this research is important for engineers who are involved in planning the construction of a building. Other than that, from this research it is valuable in the future for the construction industry in producing a high compressive strength of concrete which more environmental friendly to replace the convectional concrete by using ordinary Portland cement (OPC).

CHAPTER 2

LITERATURE REVIEW

2.1 FLY ASH

Fly ash that was waste material from power station has been utilized as a mineral admixture component blended cement called pozzolans for about 60 years ago. This, the largest use of fly ash, consumes about 10 percent of fly ash produced throughout the world. Another 10-15 percent is used for construction, building materials and beneficiation applications. Remaining 75-80 percent is disposed of as waste

From American concrete institute (ACI) Committee, they describe that fly ash as 'The finely divided residue that results from the combustion of ground or powdered coal and that is transported by flue gasses from the combustion zone to the particle removal system' (ACI Committee 232 2004)'.

By using mechanical or electrostatic, fly ash removed from the combustion gases from the process of dust collection before the fly ash discharged to atmosphere. The size of fly ash is finer than OPC and lime and also the physical appearance is spherical in shape. The diameter of fly ash is only in the range 1μm to 150μm.

The chemical composition of fly ash is mainly a combination of the oxides of Silicon (SiO_2), Aluminum (AL_2O_3), Iron (Fe_2O_3) and Calcium (CaO) whereas Magnesium, Potassium, Sodium, Titanium and Sulfur are also present in the fly ash. The major for influence on the fly ash chemical composition is come from the type of coal (Malhotra and Ramezanianpour 1994).

2.2 USES OF FLY-ASH IN CONCRETE

Fly ash is one of an artificial pozzolan. The silicon dioxide in the fly ash reacts with the calcium hydroxide from the process of hydration of cement to form the calcium silicate hydrate (CSH- gel). Workability of the fresh concrete is improved because the size fly ash which is very small and the sizes plays as a filler of void in the concrete. So that the concrete produced more dense and durable. The development of high volume of fly ash concrete was successfully replaced the use of Portland cement in concrete up to 6o % is the most important achievement in the concrete industry. High volume fly ash concrete was proved that it is better in term of durability and resources more efficient than Portland cement.

2.3 GEOPOLYMER

French Professor Davidovitis in 1978 was form the name of geopolymer to present a board range of materials that was characterized by networks of inorganic molecule (Geopolymer Institute 2010).geopolymer the geopolymer is depend on thermally activated natural materials like industrial by product or metakaolinte.

Fly ash and slag is the example of the industrial byproduct that has provided the source of silicon (Si) and Aluminum (Al). The silicon and the aluminum were dissolved in the alkaline activating solution. From the mixing they will polymerizes into the molecular chains and they will bind with it.

Professor B. Vijaya Rangan (2008) state that "the polymerization process involves a substantially fast chemical reaction under alkaline conditions on silicon-aluminum minerals that results in a three-dimensional polymeric chain and ring structure". The ratio of Si to Al (SI: Al) is influencing the structure of the geopolymer.

Three dimensional polymeric chain and the ring structure consisting of Si-O_Al-O bond is formed by the reaction of Sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) in aqueous solution with fly ash.

The schematic diagram for the formation of geopolymer material can be shown in below equation

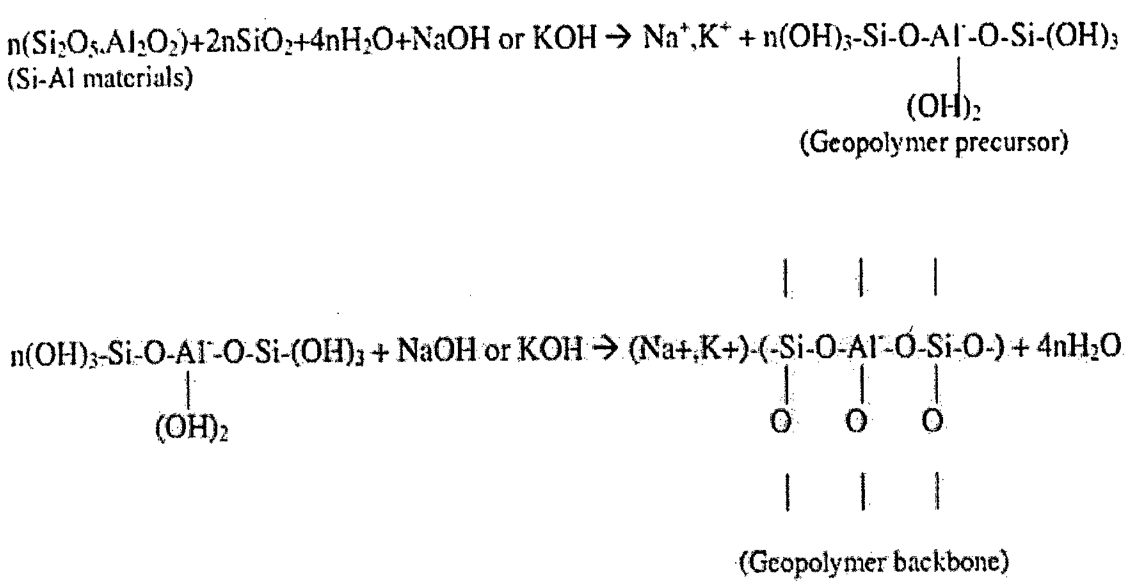

Figure 2.1: Equation of formation of geopolymer
(D.Hardjito and B.V.Rangan 2005)

Water is expelled during curing and subsequent so that water is not much involved in the chemical reaction of the geopolymer concrete. In the reaction of Portland cement it produces the primary hydration product that is a calcium silicate hydrate and calcium hydroxide. This formation is different compared to the concrete based geopolymer. Mechanical and chemical properties of the resulting geopolymer were affected by the difference in the reaction. This also reduces it to be more resistant to water ingress, alkali-aggregate reactivity, heat and other types of chemical attack.

The role of the calcium in thegeopolymer made from fly,the system is very important because its presence can be result in flash setting and therefore it must be controlled very carefully. The source of material is actually mixed with an activating solution that is providing the alkalinity (sodium hydroxide or potassium hydroxide) needed to liberate the Si and Al and possibly with an additional source of silica (sodium silicate).

The most important part is the temperature during curing. Heat often must be applied to facilitate polymerization depend upon their source material and activating solution. Although some of the system has been developed that are designed to be cured at room temperature

2.4 ALKALINE SOLUTION

The combination between potassium hydroxide (KOH) or sodium hydroxide (NaOH) with the potassium silicate or sodium silicate are the most common alkaline liquid was used in the geopolymerisation (Palomo et al. 1999)

(Palomo et al. 1999) was concluded the important role in the polymerization process is the type of alkaline liquid. The reaction occurs at high rates when the alkaline liquid contains soluble silicate either potassium or sodium silicate .The result is different when use of only alkaline hydroxide the reaction occurs at low rates.

Sodium silicate solution was added to the sodium hydroxide solution as an alkaline liquid to make sure the improvement of the reaction occurs between the source material and the solution. Furthermore the NaOH solution was produced a higher extent of disintegration of the material if compared to KOH solution after the study of the geopolymerization of the sixteen AL-Si minerals. (Xu, 2000)

2.5 WORKABILITY OF FRESH GEOPOLYMER CONCRETE

(Chindaprasirt et al 2007) stated that the concentration of sodium hydroxide NaOH and the proportion of Sodium silicate to NaOH ratio were affecting the workability of the geopolymer concrete. In the general increasing the concentration of the NaOH and the amount of sodium silicate solution it will make the workability of the mixes decrease. The viscosity of the solution mixture was increased due to the increase of the NaOH concentration then the flow of concrete will be reduced. The flow of concrete also reduces when sodium silicate was increased in amount .This is because the sodium silicate itself were very high viscosity

Addition of water or superplasticizer were making improvement in the workability of the mortar. However the improvement of the workability of the mortar is found better when uses extra water if compared to addition of superplaticizer.

2.6 CURING OF GEOPOLYMER CONCRETE

As we know, the process of curing for the fly ash based geopolymer concrete in the ambient condition, it is generally recommended for curing by a heat process. Heat curing can help that chemical reaction occurs in the geopolymer concrete. The compressive strength of geopolymer concrete will affected by the curing time and also curing temperature.

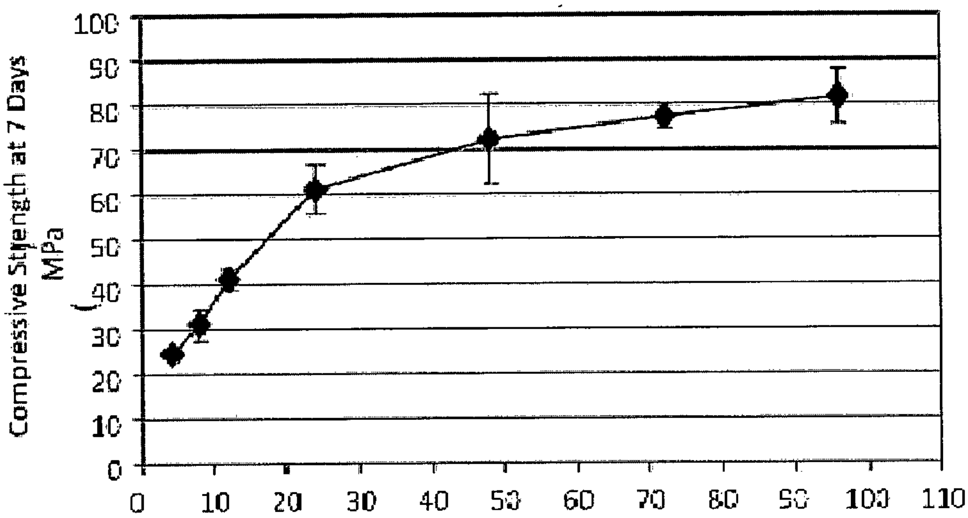

Figure 2.2: Effect of the curing time on compressive strength of geopolymer concrete (Hardjito and Rangan 2005)

Figure 2.2 shows that the effect of curing time by (Hardjito and Rangan 2005). Specimens are tested where (100 x 200) mm cylinders have heat cured at 60 °C in the oven. The curing time was varies that from 4 hours to 96 hours (4 days).The polymerization process was improved due to longer curing time, then it give higher number of compressive strength. The increasing of the compressive strength was rapidly up to 24 hours of the curing time. The increasing in strength was only moderate for the past 24 hours. So that conclusion is the heat-curing time need to be more than 24 hours in the practical application.

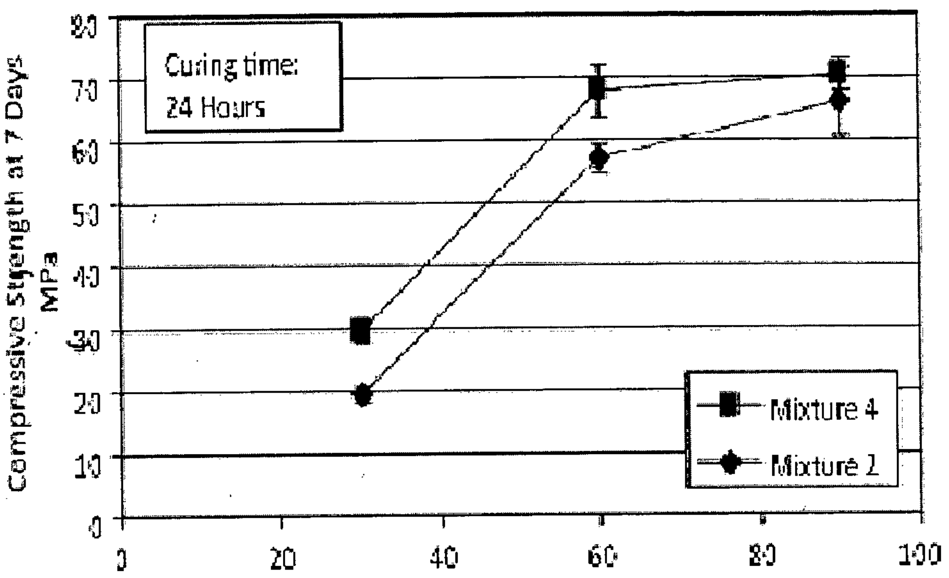

Figure 2.3: Effect of the curing temperature on compressive strength of geopolymer concrete (Hardjito and Rangan 2005)

The effect of curing temperature on the compressive strength of geopolymer concrete (Hardjiti and Rangan) was shown in the figure 2.3. Specimens test were (100 x 200) mm cylinders was cured for 24 hours in the oven. The compressive strength result will be greater due to higher curing temperature. From the graph, we can consider increasing the curing temperature above 60°C did not change the compressive strength significantly. Based on the result, a curing temperature is about 60°C is recommended in application.

2.7 BEHAVIOR OF GEOPOLYMER AT ELEVATED TEMPERATURE

The fire resistance of the concrete was one of the important properties that are all the time measured due to the user safety. Kong and Sanjayan (2008) stated that the proportion of fly ash to alkaline solution would involve the general strength and fire resistance of geopolymer. The fly ash-based geopolymer shown an increase in strength after temperature exposure. Kong and Sanjayan (2010) was observed that the size of aggregates will be affected the behavior of geopolymer concrete under elevated temperature. The aggregate with size less than 10 mm could give wide cracking of geopolymer but the aggregate with size larger than 10 mm were more stable.

However, the thermal incompatibility between the geopolymer matrix and its aggregate components was the most likely cause of strength loss in geopolymer concrete specimens at elevated temperatures. This can be demonstrated by comparison between geopolymer concretes made two different aggregates with definitely different thermal expansion characteristics. The higher of strength loss during elevated temperature was due to geopolymer concrete with greater incompatibility Thus, the extension aggregate with respect to temperature was a factor that controls the performance of geopolymer.

Bakharev (2006) observed that the result would be quite low and significant changes in the microstructure when the thermal stability of the geopolymer materials prepared with sodium containing activator. At 800°C, the number of pore size increased because amorphous structures were replaced by the crystalline Na-feldspars. This condition will be caused the strength of the concrete would be reduced.

When we use the potassium silicate where it has highest silica as activator it can remain generally amorphous up to 1200°C. The pore would be reduce after the material was firing and it improved the compressive strength of geopolymer. Geopolymer concrete prepared using class F fly ash with sodium and potassium silicate shows that the shrinkage was high and it led to large changes in compressive strength with increasing temperature in the range of 800 to 1200°C (Bakharev, 2006)

2.8 ECONOMIC BENEFIT OF GEOPOLYMER CONCRETE

If compared to Portland cement the heat cured fly ash based geopolymer concrete offer several economic benefits to the people using it and also to the world. The cost of one tone Portland cement is double or more the price of one tone fly ash. Even when we estimate the cost of production of geopolymer concrete after plus all the material, the estimation is around 10 to 30 percent cheaper than Portland cement concrete.

In addition the suitable use of one ton of fly ash it will receive approximately one carbon - credit that has significant redemption value. Three cubic meters of high quality fly ash based geopolymer concrete can be manufactured by utilizing one ton of fly ash. Geopolymer concrete performs better compared to Portland cement in terms of resistance to corrosion and fire up to 2400°F. This geopolymer concrete also has high compressive and tensile strengths, the most benefit is it can gain strength in early time.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter explained about the research that conducted and explaining the study that has been carried through. This chapter also describes the materials used, the preparation of the test specimens and the test procedures. Also, the sample or concrete mixture proportions were listed down in this section out conclusion.

For this study, the materials used are Fly Ash, Sodium Hydroxide (NaOH), Sodium Silicate (Na_2SiO3), coarse aggregate and fine aggregate. After casting and curing are done, all specimens will be tested. Tests including slump test, compressive strength test, and porosity test.

3.2 RESEARCH PLANNING

This research was started from September 2012 until June 2013. There were planning as a guideline to ensure this research will run smoothly. This research planning also helps to monitor the progress of the research. Figure 3.1 shows the flow chart of research methodology.

In the first phase reading material was prepared in other to done the literature review. The reading materials were referenced book and journal from past researcher. At this phase also all the materials that needed were prepared for this research. In the second phase, trial mixture was conducted.

Two sets of mixture were made. First of the mixture for control and another mixture for the experiment. Three tests will be conducted in the third phase. For the fresh concrete, slump test must do first, if the test fails need to do again the mixture with different proportion. After the concrete harden compressive strength test and porosity test will be conducted.

In the fourth phase data will be collected after testing is done and record the data obtain. After that analysis of the result and then making discussion depend on the data obtain. Then the last is making a conclusion and show whether this research achieve the objective or not.

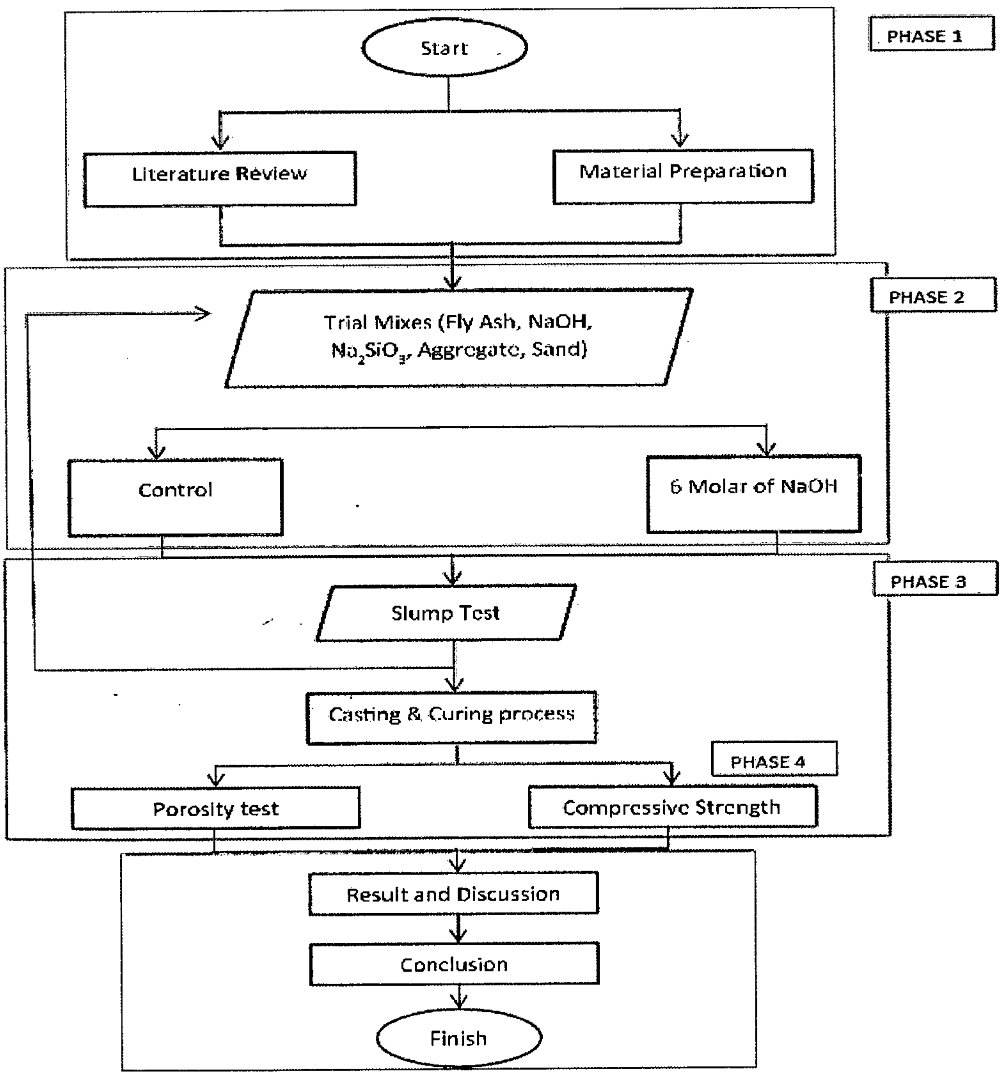

Figure 3.1: Research methodology flow chart