HEAT OPTIMIZATION IN INTERNAL CURING PROCESS OF GEOPOLYMER MORTAR BY USING STEEL DUST

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ABSTRACT

In conjunction with today competitive world, there was large amount of industrial wastes were produced with the rapid development of steel industry, which eventually lead to the disposal of these industrial waste in landfill and higher cost was required to reduce its impact on the environment. Among the industrial waste from steel industry, steel dust was one of the latest raw materials that has the ability to improve the geopolymer mortar performance on the mechanical properties due to its heat conductivity. It cannot be denied that the characteristic and mechanical properties of geopolymer mortar can be activated by elevated temperature of curing. But, the problem arose was the high temperature of curing can cause the shrinkage for geopolymer mortar and low durability. Meanwhile, low temperature curing cannot accelerate the strength improvement of geopolymer mortar. Owing to this, only few researches had been carried out to study the effect of steel dust as portion of fine aggregate replacement towards the heating optimization of internal curing process in geopolymer mortar. Thus, the experimental work presented here was aimed to study the effect of adding steel dust on the mechanical properties and water porosity of geopolymer mortar. In this study, steel dust was added to replace small proportion of fine aggregates in geopolymer mortar. Three different proportions of steel dust, which were 0%, 5% and 10% were added into the mortar with different curing temperatures of 50 ^{o}C and 60 ^{o}C. All cubes specimens were first oven cured for 1 day at 50 ^{o}C and 60 ^{o}C after the completion of casting in each mix. The specimens were then air cured for 1, 7 and 28 days at concrete laboratory before subjected to mechanical properties test. All cubes specimens were tested for its mechanical properties, which were compressive strength test and water porosity test. The results showed that addition of steel dust influenced the behavior of geopolymer mortar. Based on the laboratory test result, the geopolymer mortar with the addition of 10% steel dust and 50 ^{o}C curing temperature shows a conventional trend of high compressive strength with lower porosity, whereas for the addition of 10% steel dust and 60 ^{o}C curing temperature, it shows a non-conventional trend of high compressive strength, yet higher porosity as well. Conclusively, the results have validated the positive effect of steel dust addition into geopolymer mortar, particularly to the compressive strength enhancement. Geopolymer mortar with 10% steel dust addition as partial replacement for fine aggregates has appeared as the optimum proportion that contributed to the mechanical strength improvement of geopolymer mortar.

ABSTRAK

Bersempena dengan dunia yang penuh persaingan hari ini, terdapat sejumlah besar bahan buangan industri yang dihasilkan dengan perkembangan pesat industri keluli, yang akhirnya membawa kepada pelupusan sisa industri ini di tapak pelupusan dan kos yang lebih tinggi diperlukan untuk mengurangkan kesan terhadap alam sekitar. Antara bahan buangan industri daripada industri keluli, habuk besi adalah salah satu daripada bahan-bahan mentah terkini yang mempunyai keupayaan untuk meningkatkan prestasi Geopolimer mortar terhadap sifat mekanikal kerana kekonduksian haba. Ia tidak dapat dinafikan bahawa sifat-sifat dan mekanikal Geopolimer mortar boleh diaktifkan oleh suhu tinggi pengawetan. Tetapi, masalah yang timbul adalah suhu yang tinggi menyembuhkan boleh menyebabkan pengecutan mortar untuk Geopolimer dan ketahanan rendah. Sementara itu, pengawetan suhu rendah tidak boleh mempercepatkan peningkatan kekuatan daripada Geopolimer mortar. Disebabkan ini, hanya beberapa kajian telah dijalankan untuk mengkaji kesan debu keluli sebagai sebahagian penggantian agregat halus ke arah pengoptimuman pemanasan proses pengawetan dalaman Geopolimer mortar. Oleh itu, kerja-kerja eksperimen yang dibentangkan di sini adalah bertujuan untuk mengkaji kesan penambahan debu keluli pada sifat-sifat mekanikal dan keliangan air Geopolimer mortar. Dalam kajian ini, habuk besi ditambah untuk menggantikan sebahagian kecil agregat halus dalam Geopolimer mortar. Tiga perkadaran yang berbeza dari tanah keluli, yang 0%, 5% dan 10% telah ditambah ke dalam mortar dengan suhu pematangan yang berbeza 50 ^{o}C dan 60 ^{o}C. Semua kiub spesimen ketuhar pertama sembuh selama 1 hari pada 50 ^{o}C dan 60 ^{o}C selepas selesai pemutus dalam setiap campuran. Spesimen kemudiannya udara sembuh untuk 1, 7 dan 28 hari di makmal konkrit sebelum tertakluk kepada ciri-ciri ujian mekanikal. Semua kiub spesimen diuji untuk sifat-sifat mekanik, yang adalah ujian kekuatan mampatan dan ujian keliangan air. Hasil kajian menunjukkan bahawa penambahan debu keluli mempengaruhi tingkah laku Geopolimer mortar. Berdasarkan keputusan ujian makmal, mortar Geopolimer dengan penambahan 10% habuk besi dan 50 ^{o}C pengawetan suhu menunjukkan trend konvensional kekuatan mampatan tinggi dengan keliangan yang lebih rendah, manakala bagi penambahan 10% habuk besi dan 60 ^{o}C suhu pengawetan, ia menunjukkan trend bukan konvensional kekuatan mampatan yang tinggi, namun keliangan yang lebih tinggi juga. Muktamad, keputusan telah disahkan kesan positif samping debu keluli ke dalam Geopolimer mortar, terutamanya kepada tambahan kekuatan mampatan. Geopolimer mortar dengan 10% Selain debu keluli sebagai pengganti separa untuk agregat halus telah muncul sebagai bahagian yang optimum yang menyumbang kepada peningkatan kekuatan mekanik Geopolimer mortar.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

%	Percentage
mm	Millimeter
Kg/m^3	Kilogram per meter cube
g	Gram
kN	Kilo Newton
℃	Degree Celsius
Mpa	Mega pascal
∑	Sum
m^3	Meter cube
h	Hour
µm	Micrometer
d	Days
±	Plus-Minus

LIST OF ABBREVIATIONS

ASTM	American Society For Testing and Materials
EN	European Standards
MS	Malaysia Standard
GM	Geopolymer Mortar
CO_2	Carbon Dioxide
Class F	Class F Fly Ash
EAFD	Electric-Arc Furnace Dust
A	100% of Fine Aggregate At 50^0C
B	95% of Fine Aggregate + 5% Steel Dust At 50^0C
C	90% of Fine Aggregate + 10% Steel Dust At 50^0C
D	100% of Fine Aggregate At 60^0C
E	95% of Fine Aggregate + 5% Steel Dust At 60^0C
F	90% of Fine Aggregate + 10% Steel Dust At 60^0C
Na_2SiO_3	Sodium Silicate Solution
SiO_2	Silicon Oxide
Na_2O	Sodium Oxide
WEPA	World Environmental Protection Agency

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Concrete was widely used in the construction of building and infrastructure due to its excellent durability and cost effectiveness. The concrete was a composite construction material which produced by mixing cement, coarse and fine aggregates, water and also other admixture which was in right proportion. Changing in environmental condition and also the quantity and quality of raw materials used when mixing concrete will lead to the different in the properties of concrete. It cannot be denied that Ordinary Portland Cement (OPC) had been popular to use as one of the common binder during the mixing of concrete. (Sarker et al., 2014). However, there was high energy consumptions during the manufacturing of cement and indeed there was larger amount of the emission of greenhouse gases such as CO_2 into the atmosphere. Thus, the cement production industries had their responsibility to take care about the greenhouse gases emissions issues. (Ganesan et al., 2014).

Thus, many researches had been carried out to find out another new types of raw materials that can replace cement as the binder for the mixing of concrete. Then, after few years of researches, there was emerging of the new alternative binders called geopolymer mortar that can help to lower down the greenhouse gases emissions during manufacturing of concrete. (Sarker et al., 2014). Fly ash based geopolymer mortar was existed as new environmental friendly construction materials for sustainable development alternative to conventional concrete made from alkali activated aluminosilicate and aggregate. Accounting to the history of the geopolymer, geopolymer technology was first introduced by Davidovits that had the idea to provide an alternative low emission binding agent to Portland cement. Geopolymers were inorganic aluminosilicates which produced by alkali activation of waste materials such as low and high calcium fly ash, steel dust, metakaolin, blast furnace slag and also benite. The process of manufacturing geopolymer mortar was called geopolymerization in the presence of two kind of chemical solution which called sodium hydroxide and sodium silicate solution. The difference between the mechanical properties of geopolymer mortar compare to Portland cement were geopolymer mortar had high early strength, drying period was faster, low shrinkage, and also resistance to sulphate attack and corrosion (Ganesan et al., 2014). Even though geopolymer mortar can be produced by various sources of waste materials, but fly ash was the most effective geopolymer binders for the manufacturing of concrete.

Since geopolymer mortar was emerging as the effective and environmental friendly construction material, thus it was a need to do the research for the performance of geopolymer mortar in different building structures. One of these building structure was bricks that make up of geopolymer mortar with the addition of other raw materials to check for the heat optimization during the internal curing process.. (Sarker et al., 2014). The durability of the geopolymer mortar had the relationship with the heating efficiency during the internal curing process on the geopolymer motar. Concrete which act as the building materials were now widely used in the construction of building and infrastructure. Conventional concrete will caused the emission of greenhouse gases to the atmosphere. Thus in order to save our Earth, many researches had been done to explore new materials to replace conventional concrete. One of the latest and common technology was the geopolymerization process which produce geopolymer concrete from waste materials such as fly ash. Geopolymerization was the reaction undergone by aluminosilicates in a highly concentrated alkali hydroxide or silicate solution, forming a very stable material called geopolymer having amorphous polymeric structures with interconnected Si–O–Al–O–Si bonds .According to (Duxson et al. and Dimas et al.) the geopolymerization process took place when there was dissolution of solid aluminosilicate materials in a strong alkaline solution, formation of silica–alumina oligomers, polycondensation of the oligomeric species to form inorganic polymeric material, and bonding of un-dissolved solid particles in the final geopolymeric structure. (Ahmari & Zhang, 2012)

1.2 PROBLEM STATEMENT

Nowadays, concrete has been popular as the building materials in all the construction of building and infrastructures. But environmental issues continue to exist as the major problems in all over the world due to the higher percentage of emission of the greenhouse gases such as CO2 into the atmospheres during the production of concrete since it is high energy consumptions. Owing to this, geopolymer mortar that produced from geopolymerization process is produced in order to replace the usage of concrete since geopolymer concrete was more environmental friendly and cost effectiveness. It cannot be denied that the characteristic and mechanical properties of geopolymer mortar can be activated by elevated temperature of curing. But, the problem arose was the high temperature of curing can cause the shrinkage for geopolymer mortar and it was not economically. Meanwhile, low temperature curing cannot accelerate the strength improvement of geopolymer mortar. So, therefore this research was carried out to study about the effect of steel dust as internal heat distributor during the curing process for geopolymer mortar. The optimization of heating on internal curing process of geopolymer mortar can lead to the enhancement on the behavior of geopolymer mortar and its properties due to the adding of steel dust at low curing temperature. In order words, the strength improvement of geopolymer mortar for compressive strength can be achieved even at low curing temperature with the addition of steel dust. Thus in this project, in order to optimize the heating distributuion on internal curing process for the geopolymer mortar and also checked whether it would lead to the inclined or declined the compressive strength, steel dust had been added into during the casting of geopolymer mortar by replaced some portion of fine aggregates.

1.3 OBJECTIVES

The main objective of this research is:

- To determine the effect of steel dust as fine aggregate replacement towards the heating optimization of internal curing process in geopolymer mortar.

The sub-objectives of this research are:

- To determine the workability of geopolymer mortar during casting.
- To determine the compressive strength and water porosity of geopolymer mortar with the addition of steel dust to partially replace fine aggregate.

1.4 SCOPE

There were six different types of mixture that need to produce. First two type of mixture is act as control sample (do not contain any steel dust) that cured inside the oven with different temperature which were in 50 Celcius and 60 Celcius. Each type of mixture was consists of 9 geopolymer mortar cubes in which 7 of the geopolymer mortar cubes were used to test for the compressive strength whereas the 2 lefted had been used for the water porosity test. The third and fourth mixture contained 5% of steel dust as the replacement of fine aggregates proportion at 50 Celcius and 60 Celcius respectively. Whereas the last three mixtures which were the fifth, sixth and seventh mixture had 10% of steel dust which replace the fine aggregates proportion at 50 Celcius and 60 Celcius respectively.

There were total of 54 geopolymer mortar that had been casted in order to complete the research. Each of the geopolymer mortar cubes has the same dimension which is 50mm length x 50mm width x 50mm height . Before casting for the geopolymer mortar, there was a need to prepare and clean the cube moulds in order to fill in the geopolymer mortar during casting.

Fine aggregates were also one of the materials in this research to produce geopolymer mortar. Fine aggregates were prepared using 5mm sieve. Fly ash was also another waste materials used to produce geopolymer mortar in which it was prepared by using

150 micrometer sieve after put into the oven for drying purpose for 24 hours. Steel dust that obtained from the steel industry was also used to replace some proportion of fine aggregates.

For the compressive strength test, two geopolymer mortar cubes from each mixture will be tested for the compressive strength by using compressive machine at 1 and 7 days respectively. Whereas, there were 3 geopolymer mortar cubes would be tested on 28 days. While waiting to check for the compressive strength, all the geopolymer mortar cubes that had been casted were undergone curing at room temperature.

1.5 RESEARCH SIGNIFICANCE

The heating distribution of internal curing process on geopolymer mortar can be optimizing by adding waste materials which was steel dust as the replacement of small portion of fine aggregates. The usage of steel dust can help to reduce the wastage from the industry and indirectly can help to conserve the environment from the pollution. Besides, the usage of steel dust can also help to minimize the annually amount of landfill from the steel industry. In addition, after adding steel dust into the mix design proportion of geopolymer mortar, the geopolymer mortar can also access to higher compressive strength and became more durability as the steel was good conductor of heat and not easy to undergo corrosion and brittle.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter explained about the literature of the heat optimization of internal curing process on geopolymer mortar. This chapter was consisted of two sub-section which were involve heating optimization of internal curing process on geopolymer mortar cubes and also geopolymer mortar with added metal dust. Nowadays, many country in this world had promoted the ideas of conserving and protecting the environment. Thus many research had been done in order to increase the heating efficiency of buildings. One of the most significant method to improve the heating efficiency of buildings is to improve the thermal insulation properties of the buidings. This can be done by introducing pores on the bricks to become perforated brick and also can adding some raw materials into the bricks during the concrete mix design. Therefore, there are two different values for thermal conductivity in which the first involving the bulk material that constituting the walls, whereas another bricks which has large perforations of rectangular cross section will have equivalent thermal conductivity for whole structure of bricks. In this case, after making pores on the bricks , then burn it and micro-pores will emerging which has the function to reduce the thermal conductivity of the brick . (Sutcu, 2015).

From the research of (Sutcu, 2015), thermal conductivity of the clay bricks was approximately 1.0 ±0.4 W/mK depending on their type of raw materials used in the production of bricks and processing. These values can be minimize by addition of some raw materials or waste materials into the mixtures of concrete mixture before casting. When this is made into an extruded product with vertical perforations its thermal conductivity could be much lower as 0.08 W/mK. Examples of raw materials that are usually added into the mixture of concrete bricks are steel dust, blast furnace slag. Sawdust, wood slag and so on. (Sutcu, 2015).

2.2 GEOPOLYMER MORTAR

Recently, geopolymer had emerged as the replacement for Portland cement for making concrete due to its environmental friendly and high durability. For our knowledge, geopolymer mortar was mainly manufactured by utilising the industrial waste or by-product materials such as fly ash, blast furnace slag, steel dust and any other materials that contained aluminosilicate which was originated from geological sources. Since it produced low CO_2 emission in comparison to Portland cement concrete so it was classified as green environment or environmentally friendly. Geopolymer mortar was synthesised by mixing aluminosilicate materials with alkaline solutions which was then undergone process called polymerisation. The polymerisation was a process that involved the chemical reaction between the aluminosilicate materials and alkaline activators which were then lead to the formation of polymeric chain. (Nath & Sarker, 2015)

Due to the advancement and innovative of latest technology, some steel dust from iron industry had been introducing into the geopolymer mortar mix design. Steel dust act as the replacement for small proportion of fine aggregates in order to maximise the heating distribution of geopolymer mortar. Besides that, the adding of steel dust into the geopolymer mortar mix design also can boost the performance of geopolymer mortar by activating other specific characteristic of the geopolymer mortar. Thus, for this few decades, various researches and experimental work had been carried out to verify the performance of geopolymer mortar.

2.3 GEOPOLYMER MORTAR DURABILITY

The durability of geopolymer mortar was not only depend on the mix design proportion which was the mortar to water ratio, but also influenced by the compressive strength, water permeability or porosity and also the shrinkage characteristic of geopolymer mortar. In addition, the geopolymer mortar durability can also be affected by the addition of the raw materials, surrounding environment, inappropriate specification of design and also poor workmanship. (Moradi-Marani, et al,. 2010).

(Dunster, et al,.2002) due to the high hardness and high durability of steel dust, since it was unprofitable when acted as cement addition, so then many researches had been change and focused only the use of steel dust on the replacement in aggregates on geopolymer mortar.

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2.4 GEOPOLYMERIZATION

Nowadays, many researches had been done to use the geopolymerization technology to manufacture geopolymer mortar. Geopolymers were made up of inorganic polymer which formed by the chemical reaction between the highly concentrated alkali solution with aluminosilicate materials. The mixture was usually consists of water, sodium hydroxide and sodium silicate but other alkali metal or mixtures of different alkalis or any waste concentrated alkali can also be used. The binders that usually used were Class F flyash, steel dust, blast furnace slag and also any other materials with aluminosilicate content. Geopolymer which was a very stable material was formed which had amorphous polymer chain with interconnected Si-O-Al-O-Si bonds. (Ahmari & Zhang, 2012)

Geopolymerization was the reaction undergone by aluminosilicates in a highly concentrated alkali hydroxide or silicate solution, forming a very stable material called geopolymer having amorphous polymeric structures with interconnected Si–O–Al–O–Si bonds. According to (Duxson et al.2007) and (Dimas et al.2009), when there was dissolution of aluminosilicate materials with a strong alkaline solution, geopolymerization process was occurred together with the formation of silica–alumina oligomers in which the polycondensation of the oligomeric species to form inorganic polymeric material, and bonding of un-dissolved solid particles in the final geopolymeric structure. Freidin, 2007, had suggested to use geopolymerization of Class F fly ash to manufacture geopolymer mortar or called cementless concrete. During the research, Freidin, 2007, used water glass with a silica module of 2.3 as the alkali activator and applied different forming pressures to prepare the test specimens. The results showed that the geopolymer mortar that produced via geopolymerization process can fulfill the requirements of Israeli Standard for the production of conventional cement concrete blocks. (Diop and Grutzeck, 2008) had investigated the feasibility of using a tuffs that rich in aluminosilicate to produce geopolymer mortar via the geopolymerization technology. (Diop and Grutzeck, 2008) tested their specimens by compressed the tuff with the alkali activators which was sodium hydroxide in a cylinder with pressure approximately 10MPa. Then (Diop and Grutzeck, 2008) made analysis on the effect of both the concentration of sodium hydroxide in (4, 8, and 12 M) and also the curing temperature at (40, 80, and 120 ℃) respectively. The results that had studied had proved that the strength of the geopolymer mortar increased with the increasing in the concentration of sodium hydroxide solution and the curing temperature. Whereas (Mohsen and Mostafa, 2010) had been studied the usage of low kaolinitic clays such as red clay, white clay, and grey clay in the production of geopolymer mortar. Activation of the raw materials of clay by calcination is last for 2 hours at 700 Celcius and then an alumina ball mill will ground in and sieving the mixture using sieve less than 120 μm before used it to mix with the sodium hydroxide solution and sodium silicate solution which acted as alkali activator. Then the testing specimens were molded using special steel mold with pressure about 15MPa and then allowed the specimen to mature for 24 hour at room temperature. After cured at room temperature for 24 hour, then the specimens was cured at different temperature together with different time for 3 days at 75 ℃ before being tested. After that, the results showed that the performance of behavior of geopolymer mortar is influenced by the curing temperature and also the type of alkali activators used. (Ahmari & Zhang, 2012)

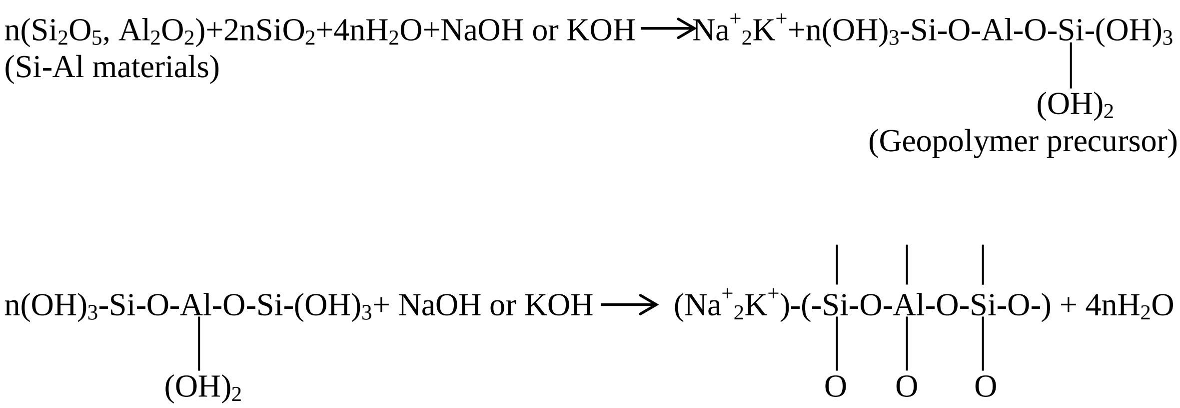

Figure 2.1 The chemical reaction for the polymerization (Sourav Kr. Das,et al,.2014)

2.5 INTERNAL CURING PROCESS

2.5.1 Effects Of Internal Curing Process

The concrete curing was a complicated process which was divided into external curing and internal curing in which its characteristics were depend on the water/cement ratio, type of materials used, temperature, air humidity and so on. During the curing process, evaporation of water and rea-arrangement of molecular among the mixtures had occurred and this lead to the decreasing in the concrete volume and development of internal strains. In addition, strength for the concrete also will increase due to cement hydration. Cracking of concrete occurred due to the internal strains at the early stages of concrete. (André,et al,. 2012)

External curing was one of the way to limit the concrete shrinkage. During external curing, the surfaces of concrete were exposed to moisture and keep wet with the surrounding air humidity. However, external curing was difficult to be carried out due to its accessibility and highly cost together with the unsufficient condition in which for the mixtures with low cement/water ratio and low water permeability. Thus, in order to make the curing of concrete become more efficiency, there was an alternative emerging which called internal curing which involve the internal water reservoirs into the concrete mixtures. In this method, before or during the mixing of concrete, the internal water reservoirs had absorbed some of the water and released the water gradually during the curing of concrete. With these, some porous lightweight aggregates and superabsorbent polymers had been used as the internal water reservoirs.(Lura, et al,.2014)

Internal curing process was usually to be used to reduce the shrinkage and prevent the early cracking of the concrete by providing additional water and increase the cement hydration materials for the concrete. (Lura, et al,.2014). From (Suzuki, et al,. 2009), internal curing was a process that supply additional curing water for the concrete via absorption of water in shale, clay or new type of materials for concrete mixtures called lightweight aggregates .

Hydration process that occur during concrete mixing will produced pores in the concrete which was then form stress that lead to the shrinkage of concrete. Then internal curing will supply additional water for the concrete and this can help to reduce the shrinkage of concrete at the early ages and lower down the water porosity of the concrete, which eventually cause the high early strength of concrete. (Suzuki, et al,. 2009).

Many researches also had been done on geopolymer mortar to prove that the internal curing process shown high performance when mixed with low calcium fly ash, slag and also steel dust when in larger dosage. This is because during the production of geopolymer mortar, it was high energy consumptions, thus indeed the water demand increased during the mixing process.

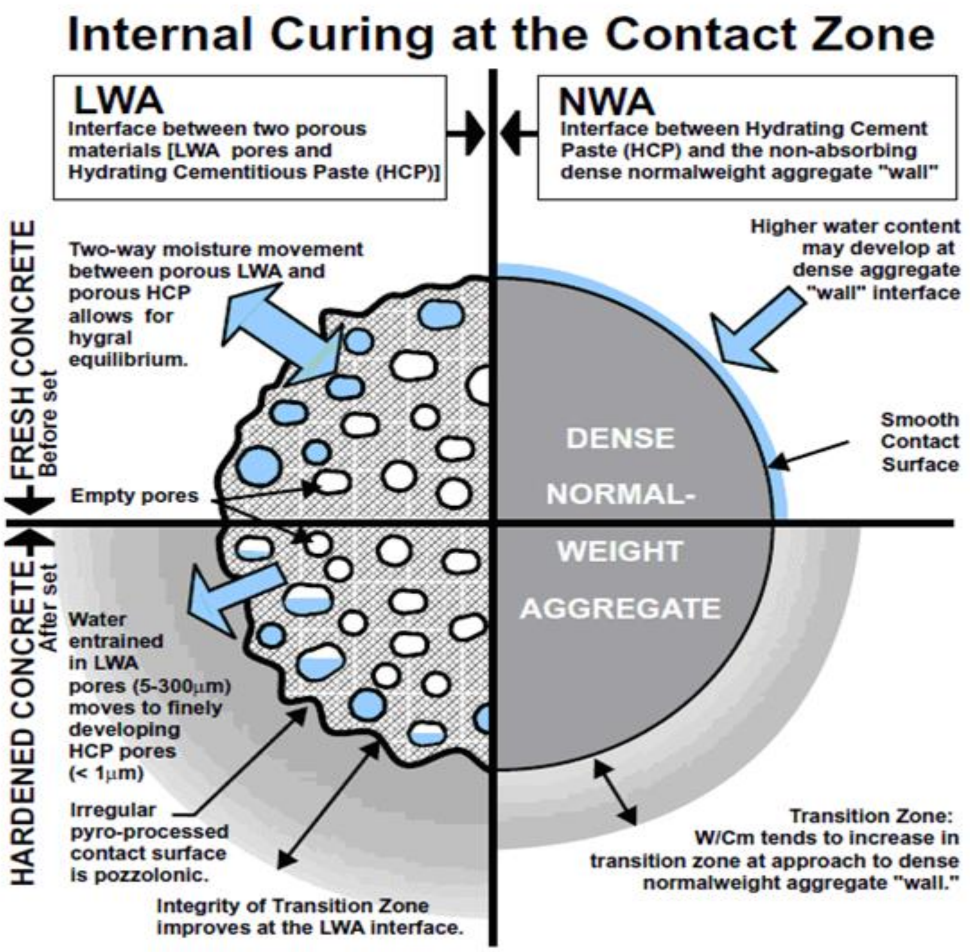

Figure 2.2: Internal Curing Process

(Suzuki, et al,. 2009).

2.5.2 Imporatnces Of Monitoring Internal Curing Process

The systematic monitoring of the curing process was significant to allow an improvement in material monitoring, which result in the ease for the construction management especially in huge and large infrastructures and building construction such as large dams, deep foundations, bridge, and so on. (André, et al,. 2012)

Other significant of internal curing process control was to make sure the safety of the construction process in which by meticulous planning and controlling of the formwork location and removal process. From the research, between year of 1998-2005 there was significant number of workers that have injuries during the construction that was caused by the collapse of buildings such as walls, scaffolding and roofs. (Suzuki, et al,. 2009).

The internal curing process monitoring was also need to take care when there was operations in adverse climatic conditions and in particular conditions, such as submerged or underground concreting of structural elements. (André, et al,. 2012)

During the curing of geopolymer mortar, special attention need to be taken to the concrete condition, in which make sure the surface of geopolmer mortar was always wet, prevent huge vibration nearby the curing concrete, prevent rapid change in surrounding temperature and so on. An inappropriate curing of concrete will bring side effects such as defects in the concrete after curing, reduced its lifetimes, durability of concrete also will be decreased and thus it make highly cost for maintenance. (André, et al,. 2012)

2.6 GEOPOLYMER MORTAR WITH ADDED METAL DUST

Researches had been done to use metal dust that obtained from the residue after the steel manufacturing process in steel industry to study about the heat efficiency on geopolymer mortar. Some examples of metal dust that usually used in the production of geopolymer mortar include recycling electric-arc furnace dust, granulated blast furnace slag and also the steel dust. Most of the researches done by using those recycling residue from steel industries showed positive results and analysis for their respective purposes.

Research that had been conducted on the use of electric-arc furnace dust (EAFD) in concrete have proved that by addition of EAFD into the concrete mix design will improved the behaviour of the fresh and hardened concrete in which the initial and final setting time of concrete with the addition of 2% EAFD was analyzed to be faster than that of concrete without addition of EAFD. Besides, there was also 15–30% increase for the compressive strength of concrete in the 7 and 28 days with the addition of EAFD. (Maslehuddinet al,. 2011).

2.6.1 Steel Dust

Recently, steel industries were blooming in Malaysia for this few decades, and it had become one the major industries in this country. Steel dust was produced as a by-product during steel moulding and cutting. It consisted mainly of fine powder form due to the cutting and bending of steel during the moulding of steel. The powder formed was deposit on the machines plates and it was collected by specially designed bag filters. Steel dust consists of approximately 50% of iron oxide and 21% of zinc oxide. Whereas other constituents include: calcium oxide, silicon oxide, magnesium oxide, nickel, chromium and so on. According to the statistics, the amount of steel dust produced is approximately 1% of the steel produced during steel moulding process. From the research, most of the steel dust that generated which was about 70% of steel dust was sent for land fill, while the remaining 30% were reused and processed again for another purposes. Steel dust was considered as hazardous materials by World Environmental Protection Agency (WEPA) due to the leachability of heavy metals to the environment and it need to be dispose immediately after reached its stabilization. By doing research, the leachability of the heavy metals will be minimized due to the chemical fixation of steel dust. One of the methods was by the addition of steel dust into the concrete production .It can help to stabilize the steel dust from any other hazardous reactions. In order to stabilize the steel dust for landfill or process it for other purposes, the steel industry from all over the worlds has spent approximately $50–250 per ton of steel dust.

2.6.2 Uses Of Steel Dust

(Sikaldis and Mitrakas, 2006) had done the research for the addition up to 20 % of EAFD at various temperatures which range from 850–1050 ℃ on the properties of extruded clay-based ceramic building products . (Sikaldis and Mitrakas, 2006) .The water absorption, firing shrinkage, apparent density, mechanical strength, colour, and leaching behavior of the ceramic specimens was reported to be within the acceptable limits. The addition of 7.5–15 .% EAFD was reported to improve the properties of the product, while addition up to 20 % EAFD was not beneficial for the product.

(Xuefeng and Yuhong, 1998) had evaluated the application of EAFD in the production of concrete due to its chemical composition and physical properties. From the research, it was dedicated that the quality of cement produced with the addition of EAFD had met the Chinese specifications and requirements for production of cement. Besides, it was also verified that there was more economically to use the EAFD in concrete compared to that the usage in iron ore.

(Sorlini et al.) had investigated the reuse of Waelz slag which was an modified EAFD as a replacement of either coarse and fine aggregate in concrete production. For this research, the Waelz process had convert EAFD with the 18–35% concentration of zinc concentration into an impure zinc oxide which contained 55–65% of zinc which name as Waelz oxide .EAFD and pellets were mixed with the reducing agent and other additives which was then continuously fed into the rotary kiln during the Waelz process with the furnace at temperature that ranges from 700–800 ℃, which was then allowed the occurrence of reduction , vaporization and oxidation of zinc and other volatile metals . Then the impure zinc oxide, which name as Waelz oxide was produced. From this research, it was proved that Waelz slag can be used as the replacement of aggregates for concrete mix design proportion.

2.7 MECHANICAL PROPERTIES OF GEOPOLYMER MORTAR

2.7.1 Compressive Strength

The compressive strength of geopolymer mortar was checked to ensure its applicability in construction and understanding the strength development of the geopolymer mortar. From the study of (Ahmari & Zhang, 2012) , (Ahmari & Zhang, 2012) proved that the concrete cubes that made from geopolymer mortar showed high early strength, may be due to the addition of steel dust into geopolymer mortar compare to conventional concrete.