THE EFFECTIVE ... SH (POFA) TO RESIST CHLORIDE ION IN CONCRETE

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A thesis submitted in fulfillment of the requirements for the award of the degree of Bachelor of Civil Engineering

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JUNE 2013

ABSTRACT

In nowadays construction, the demand for high performance and high durability of concrete is highly required to be used in reinforced concrete structure. The use of new material to product concrete with good quality has encouraged this study to be conducted. Corrosion of reinforcement is one of the most crucial problems for most of reinforced concrete structure because the corrosion can reduce the strength of the structure. A new by-product from palm oil mill that is POFA is used in this scope of study. POFA was found as pozzolanic material which is can replace cement in concrete production. The pozzolanic reaction that occurs can help to strengthen the concrete and enhance the concrete durability. In this study, cement has been replaced with 10%, 20% and 30% of POFA as cement replacement material. Specimens have been tested to measure the effect of POFA toward compressive strength test, impressive voltage test, half-cell test and acid soluble test. From the result of the laboratory testing, it is prove that concrete with 20% of replacement of POFA is the best composition from all the four compositions. In matter of strength, corrosion resistance and chloride diffusion, the results show that composition of 20% of POFA was produced the best result while compare to the control sample give the lowest result. As conclusion, POFA can be used as cement replacement which can produce good durability to the concrete with better corrosion resistance due to lower the penetration of ion chloride and slow the rate of corrosion inside the concrete.

ABSTRAK

Dalam bahagian pembinaan pada masa kini, permintaan terhadap konkrit yang berkualiti tinggi dan tahan lasak adalah sangat tinggi untuk digunakan dalam struktur konkrit. Penggunaan bahan baru untuk menghasilkan konkrit dengan kualiti yang bagus telah mendorong kajian ini untuk dijalankan. Proses pengaratan besi adalah salah satu masalah yang sangat banyak dihadapi bagi kebanyakan struktur konkrit kerana hakisan boleh mengurangkan kekuatan struktur. Satu produk baru telah dihasilkan dari kilang minyak sawit iaitu POFA telah digunakan dalan kajian ini. POFA didapati adalah bahan pozzolanic yang boleh menggantikan simen dalam pembuatan konkrit. Reaksi pozzolanic yang berlaku boleh membantu dalam mengukuhkan konkrit dan meningkatkan ketahanan konkrit. Di dalam kajian ini, simen telah digantikan dengan 10%, 20% dan 30% POFA untuk menggantikan simen. Dari hasil ujian makmal, ia membuktikan bahawa konkrit dengan 20% daripada penggantian POFA adalah komposisi yang terbaik dari semua empat komposisi. Dalam hal kekuatan, ketahanan kakisan dan penyebaran klorida, keputusan menunjukkan bahawa komposisi 20% POFA dihasilkan hasil yang terbaik manakala berbanding dengan sampel kawalan memberikan hasil yang paling rendah. Sebagai kesimpulan, POFA boleh digunakan sebagai pengganti simen yang boleh menghasilkan ketahanan yang baik untuk konkrit dengan rintangan kakisan yang lebih baik disebabkan oleh penembusan ion klorida dan perlahan kadar hakisan di dalam konkrit.

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POFA Palm Oil Fuel Ash

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Concrete with compressive strength of more than 50 MPa has become one of the most important construction materials. However, it can be misleading to automatically assume that such concrete would also possess high performance qualities in different service situations. Ranking high among such situations is that of reinforcement corrosion. While the aspects of steel corrosion in reinforced concrete have been extensively studied and documented, the extent of such aspects in high strength concrete is not evident. Corrosion of steel in concrete occurs only if certain species are efficiently transported to the vicinity of the reinforcement. The presence of aggressive agents such as chlorides can cause passivation of the reinforcing steel. Severe corrosion is known to be initiated by the ingress of chloride ions. This can happen in concrete even when the surrounding pH is as high as 12.5. This type of corrosion deterioration in concrete structures has proven to be the most disastrous and costly. The property of diffusion of chloride ions in concrete appears to be the dominant factor in this type of corrosion. Again, this property depends to a large extent on the pore size distribution in the concrete matrix and whether the pore system is continuous.

Early in situ testing was suggested so as to alert the possibility of corrosion being active in a structure. Most popular of such testing is the determination of half-cell potential values as described by the ASTM C876. According to this standard, if the half-cell potential in a certain area is more negative than) 350 mV copper–copper sulphate electrodes (CSE), then there is a more than 90% probability that corrosion has initiated in that area. These guidelines were based on extensive research as that of Van Daveer. The ASTMstandard however, alerts the users that the test is only indicative of possible corrosion. Whether actual corrosion is taking place can only be confirmed by corrosion current measurement.

Research workers have endeavoured to establish a certain value of chloride ion concentration that would be considered as ''threshold'' value for corrosion initiation. Glass and Buenfeld have reviewed threshold values suggested by many research workers and have shown total chloride values ranging from 0.17% to 2.2% by mass of cement. Kayyali and Haque attached greater importance to the ratio of free chloride to hydroxyl ion concentrations in the pore solution. Concrete standards have suggested certain limits for chloride ion content in the vicinity of the reinforcement. A value of 0.4% total chloride by mass of cement has been specified by the British Standard BS 8110 as the maximum limit for total chloride content. ACI 318 specifies a water-soluble chloride content of 0.15% while ACI 222 specifies acid-soluble chloride content of 0.20%. The limit set by the Australian Standards is 0.8 kg/m3 of concrete. For a typical concrete this works out to be 0.235% by mass of cement.

The limits on chloride concentration and half-cell potential values have been concluded after studies conducted mainly on conventional concrete. That is concrete prepared with natural aggregates, ordinary portland cement and water. Such limits and indicative values might not be correct when the structure is prepared with concrete that has twice the strength and essentially different matrix. Much research is needed to establish such values. So in relatively short term testing is important in order to establish bases of comparison.

There are several methods for increasing the service life of concrete structures and most of these methods depend on reducing the ingress of aggressive substances into concrete. For reinforced concrete structures in marine environment, the chloride penetration should be reduced in order to increase the service life of structures and one of the effective ways of minimizing the chloride diffusion of concrete is to substitute ordinary Portland cement by mineral additives . The mineral admixtures, or pozzolans, are finely divided materials and can react with calcium hydroxide at ordinary temperatures to form calcium silicate hydrates. Fresh and hardened concrete properties can be improved by using pozzolanic materials. The most widely used mineral admixtures are fly ash and granulated blast-furnace slag which are industrial by-products.

By reducing the clinker amount used, more economical mixtures can also be obtained. Utilization of such by products in cement and concrete technology has also important environmental benefits.

Pure Portland cements are the dominating type of cement in many countries. However, due to economic and environmental constraints, it is expected that the production of blended cements are bound to increase in the years to come . Blended cements are produced by replacing parts of the Portland cement by various types of pozzolanic materials. For many years, special cements such as granulated blast-furnace slag cements have proved to give a very high resistance of concrete against chloride penetration compared to that of pure Portland cements . In recent years, however, more optimized, high-performance cements and combinations of cements with pozzolanic materials have been used for improved durability of concrete structures in severe chloride containing environments. The main objective of the present project is to provide more data on the effect of various types of cements on the resistance of concrete against chloride penetration. In the experimental program five types of binders were used to produce concretes in the same compressive strength classes. Sulfate resisting cements or Portland cements are specified for almost all the projects in which the concretes exposed to a marine environment.

However, the performance of the sulfate resisting cements against chloride transport is not taken into account. Thus, two types of slag cements, an ordinary Portland cement and a sulfate resisting cement were used in this study. A series of fly ash concretes were also produced in which Portland cement was partially replaced by 25% fly ash.

1.2 PROBLEM STATEMENT

Nowadays, construction is one of the main things and the main material used for this purpose is cement. But, there is some common problems that can give negative effect with the using of this material that it can emitted carbon dioxide into air. This problem should be overcome by find some other material that can replace the using of cement to save our environment.

According to the UK Department of Transport, the annual cost to repair concrete structures damaged by reinforcement corrosion is estimated £755 million(Watford, UK: Building Research Establishment; 2001). By using some other material as the replacement that can help the concrete to increase their durability to resist corrosion, this losing cost can be reduced a lot and can save money in construction.

The using of agriculture waste now is receiving a lot of attention where the uses really can improve the characteristics of the concrete by acting as pozzolans and also can reduce environmental problems at the same time. and Palm Oil Fuel Ash is one of the pozzolanic material that can be used for this purposed of research.

1.3 OBJECTIVES OF THE STUDY

The objectives of this study are:

i. To determine the effect of POFA to resist the iron chloride.
ii. To investigate the corrosion rate towards POFA concrete.
iii. To investigate the percentage of chloride present in concrete.
iv. To determine the effect of POFA to the strength of concrete.

1.4 SCOPE OF THE STUDY

On progress to complete the study, it has to be done by using specific ways. It has to be done correctly to make sure the objectives stated can be achieved. There are scope of work to be followed:

a) Site location

For this study, the location selected is at UMP Pekan. This location is selected because the surrounding is suitable with the case study. The building is placed near the beach where the air n soil condition contain chloride ion. The strength of the concrete must be affected by the chloride content.

b) Sample preparation and testing

To study the effect of chloride on concrete structure, the sample of concrete is produced in laboratory to be tested with the chloride solution. After the curing test is done, the sample will be tested for compressive strength test. It is to determine the strength of the sample structure. Other than compressive strength test, compacting factor and hach-test also applied in this study.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Malaysia being the largest palm oil producing country generates millions of tons of solid wastes known as palm oil fuel ash (POFA) which disposed annually by palm oil mills all over the country. POFA which is generated in the form of coarse and larger size than OPC (Hussin et al., 2008) is a by-product obtained from burning the remaining of extracted palm oil fibers and shells in the palm oil mill. It varies in tone of colour from whitish grey to shade depending on the operating system in the palm oil factory. This ash which does not have sufficient nutrients to be used as fertilizer is dumped in open fields in the vicinity of the palm oil mills (Tay and Show, 1995). Similarly, POFA produced in Malaysian palm oil mill also dumped as waste without any profitable return (Salihuddin and Hussin, 1995) thus became one of the pollutants to environment. This has initiated Malaysian researcher to conduct studies on exploring the possibility of using this ash to produce a new construction material.

The continuous research carried out was rewarded at the end of 20th century, when Salihuddin and Hussin (1993) found this ash has high potential to be used as a cement replacement material. This revelation has lead Abdul Awal and Hussin (1997) and Hussin and Abdullah (2009) attempts to produce blended cement concrete and lightweight concrete respectively integrating POFA as one of the ingredient, which eventually results in innovation a new agro cement based concrete performing better in terms of strength and durability compared to normal concrete. Since then, within the past twenty years of studies in POFA utilization in concrete making, researchers (Sata et al., 2004; Mat Yahaya, 2003; Hussin et al., 2008) agrees that only certain percentage of POFA can be added as mineral admixture.

The rate of chloride penetration into concrete is affected by the chloride binding capacity of the concrete. Concrete is not inert relative to the chlorides in the pore solution. A portion of the chloride ions reacts with the concrete matrix becoming either chemically or physically bound, and this binding reduces the rate of diffusion. However, if the diffusion coefficient is measured after steady-state conditions have been reached, then all the binding can be presumed to have taken place and this effect will not then be observed. If a steady state condition has not been reached, then not all the binding will have occurred and this will affect the results. The chloride binding capacity is controlled by the cementing materials used in the concrete. The inclusion of supplementary cementing materials affects binding, though the exact influence is unclear [Byfors, 1986; Rasheeduzafar, et al., 1992; Sandberg and Larrson, 1993; Thomas, et al., 1995].

Also, the C3A content of the cement influences its binding capacity, with increased C3A content leading to increased binding [Holden, et al., 1983; Midgely and Illston, 1984; Hansson and Sorenson, 1990]. The rate of chloride penetration into concrete is affected by the chloride binding capacity of the concrete. Concrete is not inert relative to the chlorides in the pore solution. A portion of the chloride ions reacts with the concrete matrix becoming either chemically or physically bound, and this binding reduces the rate of diffusion. However, if the diffusion coefficient is measured after steady-state conditions have been reached, then all the binding can be presumed to have taken place and this effect will not then be observed. If a steady state condition has not been reached, then not all the binding will have occurred and this will affect the results. The chloride binding capacity is controlled by the cementing materials used in the concrete. The inclusion of supplementary cementing materials affects binding, though the exact influence is unclear [Byfors, 1986; Rasheeduzafar, et al., 1992; Sandberg and Larrson, 1993; Thomas, et al., 1995]. Also, the C3A content of the cement influences its binding capacity, with increased C3A content leading to increased binding [Holden, et al., 1983; Midgely and Illston, 1984; Hansson and Sorenson, 1990].

2.2 PALM OIL FUEL ASH (POFA)

POFA is a waste product that was generated from the burning of the palm oil mill. These waste products has fine size just like cement, but will not set at all (unless a Class C ash, which is contain substantial calcareous material) when mixed with water. This particle usually are finer than cement and has a rounded shape, including some partly broken hollow spheres known as a cenospheres and is low density (SG usually 1.9 to 2.4 compared to cement that is 3.15).

In a research to test the behaviour of POFA as a potential pozzolanic material concrete construction, their research had carried out to determine the properties of POFA to compare it with the ordinary Portland Cement (OPC). From the chemical analysis reveals that in general, POFA can satisfies the requirement to be pozzolanic and can be classified into Class C pozzolana as specified in ASTM C618-92.

In most cases, the chemical elements of oil palm ash are found to be silicon dioxide, aluminium oxide, iron oxide, calcium oxide, magnesium oxide, sodium oxide, potassium oxide and sulphur trioxide, fluctuating upon the varieties of proportion of irrigated area, geographical condition, fertilizers used, climatic variation, soil chemistry, timeliness of production and agronomic practices in the oil palm growth process.

2.3 POZZOLANIC REACTION IN CEMENT

Pozzolanic reaction occur when a pozzolans react in the presence of water with lime (calcium hydroxide). Pozzolans does not possess cementitious property in itself so that's why it needs the present of lime water to react. This reaction will occur at normal temperature to form compounds of low solubility to have cementitious properties. [M.L Gambhir 2004].

When pozzolanic reaction occurs in the mixture, the lime is produced during the C_3S and C_2S hydration is transformed into calcium silicate hydrate. In terms of mechanical properties and durability, this reaction can be considered as the weakest hydration products of portland cement. With the pozzolanic reaction, it can improve the quality of the cement paste [Massaza 1998]. With the mixture of the material that can produce hydration reaction significantly can improve the strength and durability of the concrete.

2.4 Effect of Agriculture Ash in Concrete

Mixture of agriculture ash in concrete can bring to some effects to the concrete such as:

i. Physical effects
ii. Chemical effects
ii. Surface chemistry effects

2.4.1 Physical effects

The fly ash particles are similar in size and shape so that can entrained air bubbles and have similar effect that is :

i. Reduced bleeding
ii. Water reduction
iii. Reduced slump lost
iv. Improved cohesion and plasticity

Fly ashes are very fine particles and very valuable as pore-blockers which mean it can reduced the permeability and also can harden the concrete in the same time. Permeability of POFA concrete will reduces when the age increase. The pore sample that contained 30% of ashes are denser than the control sample as shown by mercury porosity analysis. As the conclusion, the reduction in permeability is because of the formation of additional gel that exist from the pozzolanic activity.

2.4.2 Chemical Effects

Free lime will be released when the cement hydrates. When the fly ash combines chemically with the free lime, it will form compounds that similar to those that produced by the rest of the cement. This reaction is a bit slow and also generates heat during the setting process. This heat process is good for hot climates and for mass concrete. Fly ash is effectively reactive silica because this is very material causing problems in coarse aggregates through alkali aggregates reaction.

2.4.3 Surface Chemistry Effects

Fly ash can act as a catalyst to the cement reaction or can be said as a starting point for the growth of the catalyst in the cement paste. From the formation of the catalyst it will result on smaller strength reduction at the early age than chemical effect alone.

A work on roller compacted and other concrete with 50 – 60 % of fly ash substitution have been done. Good result are obtained with using of high fly ash in either earth dry concrete (roller compacted) or by using normal slump attain through using superplastisizers. In the other case, poor results are obtained with high fly ash at normal water contents. It can be said that the water cement ration is important to have a good strength in case of fly ash compared to the case of cement.

2.5 CORROSION

Corrosion of the steel rebar in reinforced concrete occurs when the iron atoms combine with oxygen or chloride atoms to form a new compound. This is an electrochemical reaction that depends on the presence of water in the pores to act as an electrolyte. Initially, the rusting of steel in a normal environment, without the presence of concrete, will be discussed. There are three distinct chemical reactions that occur:

Fe + ~ e ~ +   + 2 ë   (2- 1)

0 2 + 4 e - + 2 H 2 0 + 4 0 H '   (2-2)

2 ~ e ~ '   +1/2 O2 + 4 OH- -+ 2 FeO.OH + H20 (2-3)

Each of these reactions occurs at a different location in the chemical system. The iron disassociates at the anode (The oxygen and water react in the electrolyte. These then react at the cathode to form corrosion products at the cathode. Reaction 2-3 is one typical cathodic reaction, but there are other possibilities. This is a normal course for corrosion reactions of any metal,(P. Schiessl,).

Once concrete is involved, there are some differences. The concrete initially prevents corrosion by creating a basic environment. This passivates the steel by changing the form of corrosion products. Instead of producing the loose product FeO.OH, the FeOz and FeOs are produced. These substances adhere more closely to the surface of the bar. The progress of corrosion is thus limited by restricting oxygen access.(Schiessl,).

Various factors affect the rate of corrosion in concrete. These include the concrete quality, the thickness of cover, any cracking that may exist, the water and oxygen content of the pore system and either the chloride concentration or the depth of carbonation; depending upon what is causing corrosion. The concrete quality affects corrosion rate by limiting the access of any deleterious substances as well as oxygen. The quality can be improved by both reducing the water-cernent ratio and the inclusion of supplementary cementing materials. Increasing the concrete cover thickness has a similar effect of reducing the amount of aggressive substances that c menter. Cracks increase the amount of corrosion by providing pathways for deleterious chemicals and oxygen or water. The oxygen content and water content of the concrete are important as corrosion is an electrochemical process requiring the presence of both these substances to occur. If either of these substances are not present, then corrosion cannot occur.

2.6 CORROSION IN CONCRETE REINFORCEMENT

The corrosion of the reinforcing steel is mainly because of the reaction with the chloride ions. Because of the corrosion that happen in concrete, it will affect the mechanical properties and durability of the concrete which it may reduce it and this will bring harm to the construction [T. Meng, et.al.2006].

The other cause of the corrosion is carbonation. This reaction not only occurs in marine environment structure because the concrete carbonation due to reaction of hydrated cements compounds with atmospheric CO_2 can develop the corrosion process. The carbonation process will reduce the pH of the concrete pore solution thus develop uniform corrosion in the reinforcing steel. This uniform carbonation-induced corrosion accelerates the crack formation and will cut life span of the concrete structures.

Atmosphere conditions could encourage the carbon dioxide aggressiveness. Although the actual carbonation rate is depend on factors like type of cement, porosity of material and type of pozzolanic, the natural environment also could tribute to the carbonation process like the humidity and the surrounding temperature. This natural environment could be the worst when the structures is placed near the sea where the wind, rain and also the soil could be the transportation agents for the chloride ion.

2.7 REINFORCEMENT -CONCRETE BOND

The bond between reinforcing steel and concrete is not fully understood, though a good working theory has been produced. Most of the main concepts are agreed upon, though some of the details are still being discussed. The reason for this is that the force transfer called bond is a complicated, rnultipart phenornenon. (R.A. Treece, and J. O. Jirsa,1989).

A good summary of the major influences on bond is contained in Nawy .(Edward G. Nawy) The major factors are, according to Nawy:

1. Adhesion between the concrete and the reinforcing elements.
2. Gripping effect resulting fiom the drying shrinkage of the surrounding concrete

3. Frictional resistance to sliding and interlock on the reinforcing elements subjected to tensile stress.
4. Effect of concrete quality and strength in tension and compression.
5. Mechanical anchorage effects of the ends of the bars through the development length, splicing, hooks and crossbars.
6. Diameter, shape and spacing of reinforcement as they affect crack development.

Another variable that affects bond and has not been discussed so far is concrete confinement. Increasing the confinement around a bar increases its bond strength (K. Leet, Ed. McGraw-Hill Inc, Toronto, 1996).

2.8 MECHANISMS OF CHLORIDE ION TRANSPORT

Capillary absorption, hydrostatic pressure, and diffusion are the means by which chloride ions can penetrate concrete. The most familiar method is diffusion, the movement of chloride ions under a concentration gradient. For this to occur, the concrete must have a continuous liquid phase and there must be a chloride ion concentration gradient. A second mechanism for chloride ingress is permeation, driven by pressure gradients. If there is an applied hydraulic head on one face of the concrete and chlorides are present, they may permeate into the concrete. A more common transport method is absorption. As a concrete surface is exposed to the environment, it will undergo wetting and drying cycles.

When water (possibly containing chlorides) encounters a dry surface, it will be drawn into the pore structure though capillary suction. Absorption is driven by moisture gradients. Typically, the depth of drying is small, however, and this transport mechanism will not, by itself, bring chlorides to the level of the reinforcing steel unless the concrete is of extremely poor quality and the reinforcing steel is shallow. It does serve to quickly bring chlorides to some depth in the concrete and reduce the distance that they must diffuse to reach the rebar [Thomas, et al., 1995].

2.9 PROPERTIES OF THE CONCRETE THAT AFFECT THE CHLORIDE PENETRATION RATE

The rate of ingress of chlorides into concrete depends on the pore structure of the concrete, which is affected by factors including materials, construction practices, and age. The penetrability of concrete is obviously related to the pore structure of the cement paste matrix. This will be influenced by the water-cement ratio of the concrete, the inclusion of supplementary cementing materials which serve to subdivide the pore structure [McGrath, 1996], and the degree of hydration of the concrete.

The older the concrete, the greater amount of hydration that has occurred and thus the more highly developed will be the pore structure. This is especially true for concrete containing slower reacting supplementary cementing materials such as fly ash that require a longer time to hydrate [Tang and Nilsson, 1992; Bamforth, 1995].

Another influence on the pore structure is the temperature that is experienced at the time of casting. High-temperature curing accelerates the curing process so that at young concrete ages, a high temperature cured concrete will be more mature and thus have a better resistance to chloride ion penetration than a normally-cured, otherwise identical, concrete at the same at age. However, at later ages when the normally-cured concrete has a chance to hydrate more fully, it will have a lower chloride ion diffusion coefficient than the high-temperature-cured concrete [Detwiler, et al., 1991; Cao and Detwiler, 1996].

The rate of chloride penetration into concrete is affected by the chloride binding capacity of the concrete. Concrete is not inert relative to the chlorides in the pore solution. A portion of the chloride ions reacts with the concrete matrix becoming either chemically or physically bound, and this binding reduces the rate of diffusion. However, if the diffusion coefficient is measured after steady-state conditions have been reached, then all the binding can be presumed to have taken place and this effect will not then be observed. If a steady state condition has not been reached, then not all the binding will have occurred and this will affect the results. The chloride binding capacity is controlled by the cementing materials used in the concrete. The inclusion of supplementary cementing materials affects binding, though the exact influence is unclear [Byfors, 1986; Rasheeduzafar, et al., 1992; Sandberg and Larrson, 1993; Thomas, et al., 1995]. Also, the C3A content of the cement influences its binding capacity, with increased C3A content leading to increased binding [Holden, et al., 1983; Midgely and Illston, 1984; Hansson and Sorenson, 1990].

2.10 EFFECT OF CURRENT ON BOND STRENGTH.

The uses of current can give effect to the bonding between steel and concrete. A studied has been done towards the effects of impressed cathodic current that approximately $0.03A/m^2$ of the steel surface area on the bond strength for 5 years of time. The result after 2 years shows that there are significant loss in strength and bond after 2 years period compared to control specimen. The bond was found to have reduction after 4 years when the sample was treated with approximately $1200Ah/m^2$.[Locke, 1983]. A researched found that 33% decrease in bond strength for $5426Ah/m^2$ of charge of steel surface in studies involving deformed steel bars.

The bond strength decrease because the changes in composition in the hardened cement matrix such as accumulation of alkali hydroxide around the cathode which may soften the binder matrix.

CHAPTER 3

RESEARCH METHODOLOGY

To complete the objectives of this study, they are certain method that has to be followed in order to have the information and result. All the testing is being conducted in laboratory.

3.1 MATERIAL USED

3.1.1 Portland cement

For this study, the cement that used for the mix was Ordinary Portland Cement (OPC) which is meet the standard with ASTM Type 1. This cement is kept in a dry place and in air-tight container to avoid the properties of the cement broke.

Figure 3.1 Portland Cement

3.1.2 Sand

Sand that used in this research is properly graded river sand. The sand not need to be filtered because the size of the sand is already fine for the mixture.

Figure 3.2 Sand

3.1.3 Water

The water used for this research is only used tap water. The water should be clean from any substances which can effects the composition of mixture.

3.1.4 Aggregates

Aggregates used for this research also graded aggregates where it not to be sieve to have the fine size of the aggregates. The size of the aggregates is 10mm.