OPTIMIZATION ON THE GEOPOLYMER BRICK PRODUCTION FROM DESIGN AND STRENGTH PROPERTIES POINT OF VIEW.

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ABSTRACT

This study focuses on the use of fly ash (fly ash) as a key ingredient to replace ordinary Portland cement (OPC) to produce geopolymer brick. The use of fly ash is also a great choice because it can conserve natural resources, preserve the environment and thereby reduce environmental pollution. Geopolymer concrete is low cementations of CO_2. Therefore, this study was undertaken to distinguish the workability of geopolymer bricks using different sodium silicate. There are five types of samples. The difference in this sample only as sodium silicate density 90 kg/m^3, 85 kg/m^3, 80 kg/m^3, 75 kg/m^3, 70 kg/m^3. Three tests were conducted in this study to obtain the engineering properties of geopolymer brick. Several tests are tests of compressive strength, porosity test and water absorption test. For the curing process, all samples will be placed in the chamber for the cure with the same conditions until the day of the test is 3 days, 28 days, 56 days. The chamber is placed in the open to make sure the chamber is getting enough heat from solar. Compression tests conducted at 3.28 and 56 days. The results of the compression tests showed that the curing conditions have a significant effect on the mechanical properties of the brick.

Keywords:Fly ash, OPC , Concrete, Workability , Curing process.

ABSTRAK

Kajian ini memberi tumpuan kepada penggunaan abu terbang (fly ash) sebagai bahan utama untuk menggantikan simen Portland biasa (OPC) bagi menghasilkan bata geopolymer. Penggunaaan abu terbang juga merupakan satu pilihan yang terbaik kerana ia dapat memulihara sumber asli, mengekalkan persekitaran dan sekali gus mengurangkan pencemaran alam sekitar. Konkrit geopolymer adalah bahan cementations rendah CO_2. Oleh itu , kajian ini dijalankan untuk membezakan kebolehkerjaan bata geopolymer dengan menggunakan natrium silikat yang berbeza . Terdapat lima jenis sampel. Perbezaan dalam sampel ini hanya sebagai ketumpatan natrium silikat yang 90 kg/m^3, 85 kg/m^3, 80 kg/m^3, 75 kg/m^3, 70 kg/m^3. Tiga ujian telah dijalankan dalam kajian ini bagi mendapatkan sifat kejuruteraan bagi bata geopolymer. Antara ujian yang dijalankan adalah ujian kekuatan mampatan, ujian keliangan dan ujian serapan air. Bagi proses pengawetan ,semua sampel akan ditempatkan di dalam kebuk itu untuk proses menyembuhkan dengan keadaan yang sama sehingga hari ujian yang 3 hari , 28 hari, 56 hari. Kebuk itu akan diletakkan di tempat terbuka untuk memastikan kebuk itu mendapat haba yang cukup dari solar. Ujian mampatan dijalankan pada 3,28 dan 56 hari. Hasil daripada ujian mampatan menunjukan bahawa keadaan pengawetan memberi kesan yang ketara pada sifat-sifat mekanik bata tersebut.

Kata kunci : Abu terbang, OPC, konkrit, kebolehkerjaan, proses pengawetan

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LIST OF ABBREVIATIONS

OPS	Ordinary Portland Cement
ASTM	American Society for Testing and Material
BS	British Standard
CO_2	Carbon Dioxide
Na OH	Sodium Hydroxide
$Na_2 SiO_3$	Sodium Silicate
KOH	Potassium Hydroxide

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND STUDY

In this study, the specimen that used is fly ash brick. Fly ash brick is used geopolymer as a major material to replace Ordinary Portland Cement (OPC). Geopolymer has emerged as a new cement alternative in the field of construction materials. The used fly ash to replace the cement is because the production of cement was emitted the carbon dioxide CO_2 gas to the atmosphere. The cement industry is held responsible for some of the CO_2 emission, because the production of one tonne of Portland cement emits approximately one ton of carbon dioxide CO_2 gas into the atmosphere (Davidovits, 1994; McCaffery, 2002).

The effect of Global warming due to the emission of greenhouse gasses CO_2 will increase. Among the greenhouse gasses, CO_2 contributes about 65% of Global Warming (McCaffery, 2002). The major material in this specimen has a best potential to reduce CO_2 (Habert et al., 2011). This material of brick could give high strength to brick itself and high temperature resistance. The brick also a high temperature resistance

and good chemical resistance (Barbosa et al., 2002). Hence, the material has been used in the production of brick masonry construction to support sustainability. It also contributed to the development of civil engineering in terms of reducing the use of natural resources. In other words, geopolymers are inorganic binders that function as the better-known Portland cement. Over the last decade, much research has been conducted on the chemical, mechanical and micro structural aspects of geopolymers. But inadequate research focus is given to the study of the interactions between aggregates and geopolymeric binders (G.Saravanan, .2012)

Geopolymers also have excellent properties such as abundant raw resource, little CO_2 emission, less energy consumption, low production cost, high early strength and fast setting. These properties make geopolymer find great applications in civil engineering. Heat-cured low-calcium fly ash-based geopolymer concrete exhibit excellent resistance to sulphate attack, undergoes low creep, and suffers very little drying shrinkage (Radhakrishna,.2008). The elastic properties are comparable with Portland cement concrete.

Though Ordinary Portland Concrete (OPC) is widely used in the concrete industry for many Decades it releases greenhouse gas, i.e. carbon dioxide (CO_2), into the atmosphere while manufacturing it. Geopolymer technology is one of the recent technologies applied to reduce the use of Portland cement in concrete. Fly ash reacts with alkaline solutions to form a cementations material, fly ash based geopolymer does not emit carbon dioxide.

Materials for fly ash mixture are the main ingredient, sand, sodium silicate and water. These materials are mixed in the mix design. The differences sample density sodium silicate 90 kg/m^3, 85 kg/m^3, 80 kg/m^3, 75 kg/m^3, 70 kg/m^3. The dimension for this specimen brick 65mm x 95mm x 225mm for all samples.

1.2 PROBLEM STATEMENT

Nowadays, most of the brick manufacturing industry had just discovered a new product such as fly ash brick that can produce quality products. Therefore, the research carried out to investigate the workability of geopolymer bricks using different sodium silicate. Fly ash brick is used geopolymer as a major material to replace Ordinary Portland Cement (OPC). To replace OPC with fly ash is the best choice in the manufacture of brick because it makes the brick achieve high strength for the compression test. The geopolymer concrete is a low-CO_2 cementations material. Thus, this process can save CO_2 emissions caused by the cement industries. Therefore, comparing to the Portland cement with the production of geopolymer concrete has a relatively higher strength, stability and better durability.

1.3 OBJECTIVE OF STUDY

The general objective of this study is to investigate the compressive strength of geopolymer brick as cementations to produce high strength concrete with different content sodium silicate. The specific objectives on this study were:

1. To determine the workability and strength of geopolymer bricks using different sodium silicate.

2. To determine the porosity and water absorption of fly ash based geopolymer brick.

1.4 SCOPE OF STUDY

This study is to determine the optimal on the geopolymer brick production from design and strength properties point of view and test on compression as well as flexural. There are five types of sample. The difference in this sample is just as the density of sodium silicate which is 90 kg/m^3, 85 kg/m^3, 80 kg/m^3, 75 kg/m^3, 70 kg/m^3. A total of 60 cubes with each mixture has same dimension which is 65mm x 95mm x 225mm.This all mixture has same test for concrete which is compressive strength and porosity test. All samples was been placed in the chamber for curing process with the same condition until the testing day which is 1 days, 28 days, 56 days. The chamber will be placed at open place to make sure the chamber gets enough heat from solar.

1.5 SIGNIFICANT OF STUDY

The outcome of the study would provide information on the performance the compressive strength of geopolymer brick as cementations to produce high strength concrete with different content sodium silicate. Furthermore, the finding from the research would be useful knowledge on the geopolymer industry for producing concrete possessing enhanced strength and durability in comparison to ordinary OPC. For the fly ash brick, the utilization of fly ash in brick production brings economic benefits because it is usually a low-cost material and it can be used to replace higher cost materials.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this chapter is to study and analyse the previous study that has been done earlier by using journal, thesis, research paper and also article. This chapter will review more detail regarding geopolymer brick.

2.2 INTRODUCTION TO BRICKS

Bricks has been using for a very long time ago as construction are used for building and pavement all throughout the world. The invention of brick is believed to have arisen in about the third millennium Before Century somewhere in Middle East (James W., 2003). During ancient times, the bricks are believed were made from mud left after the area flooded. The bricks were moulded by hand and left in the sun to dry (Cowan, Henry J,. 1977). The manufacturing of brick still uses traditional methods to produce it. But now days there are advanced technologies in brick making and brick production. Brick still used until today because of its own characteristic which is more resistance and primarily used as building material in construction wall. Cement brick is one of brick types made with a blend of fine-grain sand, a cementations material such as Portland cement and water (S.E. Smith, 2003).

Process for making brick can be providing into four steps which is clay preparation, moulding, drying and burning. Zhihong Zhang say energy that use in the brick production process happen in the second last steps that is drying and burning green brick. Thus, energy uses become a critical apprehension due to industrial development. In these modern days, industries have found a renewable energy source such as wind, biomass, solar, hydropower and wave energy that free from CO_2 as an alternative (Schnitzer H et al., 2007; Ernest F Bazen et al., 2009). Besides that, the public awareness of advantages of uses renewable energy, only 15% of these sources were demand in 2006. The estimation at 2030, the trend is increase to 1.8%. The table shows a world industrial energy usage for various sources for the year 2006 and 2030 (Abdelaziz Ea., Saidur R., Mekhilef S., 2011).

Table 2.1: World industrial energy usage for various sources

Sources of energy	2006	2030
Liquids	34.6	28.6
Natural gas	24.1	25.6
Coal	24.8	24.3
Electricity	14.9	19.7
Renewable	1.5	1.8

Source: (Abdelaziz Ea., Saidur R., Mekhilef S., 2011)

In general, size of brick should be such that the core is easily burnt and the weight should be such that the mason is able to place the brick conveniently with one hand (Syed Danish Hassan, 2008). Brick can be made in various sizes. According to H.Bailey and D.W.Hancock (1979), brick can be defined brick as one unit that has a dimension that not less 337.5mm long, 225mm width and 112.5mm height. But based on BS 3921:1985, British Standard, 1 unit of brick must have at least 215mm long, 102.5mm width and 65mm height.

There are a few of characteristic of bricks. First is Common burnt clay bricks are formed by pressing in moulds. Then these bricks are dried and fired in a kiln. Common burnt clay bricks are used in general work with no special attractive appearances. When these bricks are used in walls, they require plastering or rendering. Then, second is Sand lime bricks are made by mixing sand, fly ash and lime followed by a chemical process during wet mixing. The mix is then moulded under pressure forming the brick. These bricks can offer advantages over clay a brick such as their colour appearance is grey instead of the regular reddish colour and their shape are uniform and present a smoother finish that doesn't require plastering. It also offers excellent strength as a long bearing member.

There are types of bricks were us in construction. Clay brick in Malaysia are commonly used in construction industry based on the BS 3921. Clay brick are small, rectangular blocks made of fired clay (Michael S.Mamlouk, 2006). Making clay for brick is varying widely in composition from one place to another. Bricks mostly use for different purpose, including building, facing and aesthetic, floor making, wall and paving. Other brick types of brick are concrete brick. Concrete brick normally is the admixture of cement, water and aggregate. It has been compressed to produce a better and durable brick. This concrete also has more benefits than its striking visual qualities. They deaden exterior noise, giving a better insulator from traffic noise, airplanes flying overhead and other various disruptions. Another benefit of concrete brick is fire protection. Lastly, as we know concrete brick walls can improve the thermal mass quality of exterior walls.

2.3 TYPE OF BRICK.

2.3.1 Clay brick

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2.3.2 Concrete brick

Concrete brick normally is the admixture of aggregate, cement and water. It has been compressed to produce better and durable brick. The concrete brick also has more benefits than its striking visual qualities. They deaden exterior noise, giving a better insulator from traffic noise, airplanes flying overhead and other various disruptions. Another benefit of concrete brick is fire protection. Concrete brick walls can improve the thermal mass qualities of exterior walls.

2.3.3 Calcium –silicate brick

The raw material for calcium silicate brick include lime mixed with quartz, crushed flint or crushed siliceous rock together with mineral colorants. The material are mixed and left until the lime (5%-10% is completely hydrated together with 1:8 (lime: sand) the mixture is then pressed into moulds and cured in an autoclave for two or three hours to speed the chemical hardening. The finished bricks are very accurate and uniform, although the sharp arises need careful handling to void damage to brick(and brick-layer) the brick can be made in a variety of colours, white is a common but pastel shade can be achieved.

2.4 MATERIALS TO PRODUCE GEOPOLYMER BRICK.

The main compound of the geopolymer brick is the fly ash, sand, and sodium silicate. The use of fly ash for the replacement of cement OPC so the production of brick can be more environmental friendly and get good strength.

2.4.1 Geopolymers

Polymer is a class of materials made from large molecules that are composed of a large number of repeating units (monomers). The molecular structure of the unit that makes up the large molecules controls the properties of the material. The noncrystalline

or amorphous state is the state when the regularity of atomic packing is 10 completely absent. The most familiar kind of an amorphous solid is glass (Young Mindness et al. 1998).

Geopolymers are a member of the family of inorganic polymers, and are a chain structures formed on a backbone of Al and Si ions. The chemical composition of this geopolymer material is similar to natural zeolitic materials, but they have amorphous microstructure instead of crystalline (Palomo, Grutzeck et al. 1999; Xu and van Deventer 2000). The polymerisation process involves a substantially fast chemical reaction under highly alkaline condition on Si-Al minerals, that results in a three dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds, as follows (Davidovits 1999):

$$Mn\ [-(SiO_2)\ z–AlO_2]\ n\ .\ wH_2O$$

Where: M = the alkaline element or caption such as potassium, sodium or calcium; the symbol – indicates the presence of a bond, n is the degree of polycondensation or polymerisation; z is1,2,3, or higher, up to 32.

2.4.2 Fly Ash

In this paper, the synthesis of high-strength geopolymer using fly ash was studied. Arsenic, mercury and antimony have also been reported, and the mineralogical structure of the ash is a key variable determining reactivity (R.S.Iyer, J.A.Scott.2001 217-228). Fly ash are considered as pozzolans (substances containing silica and alumina) where in the silica reacts to produce calcium silicate hydrate (Nonavinakere and Reed, 1995). There are mainly two types of fly ash ,there are types F and types C. Types F is produced when anthracites, bituminous or sub-bituminous coal is burned and is low in lime (B7%) and contains more silica, alumina and iron oxide. Type C comes from lignite coal and contains more lime (15-30%) (Fischer et al., 1978). Most of the fly ash available globally is low calcium fly ash formed as a by-product of burning anthracite or bituminous coal. Low calcium fly ash has been successfully used to

manufacture geopolymer concrete when the silicon and aluminium oxides constituted about 80% by mass, with the Si to Al ratio of to (B.V.Rangan 2008). As conclusion, fly ash is relatively inexpensive and widely available by product that can be used for partial for geopolymer brick to meet huge demand for concrete needed for infrastructure and housing in a cost- effective and environmental friendly manner.

A higher proportion of silica (SiO_2) and or the sum of silica (SiO_2), alumina (Al_2O_3) and iron (Fe_2O_3) is needed to ensure that sufficient potential reactive glassy constituent is present in FA. When fly ash is activated in an acidic or basic environment, the effect of a high calcium concentration typically leads to the acceleration of the rate of reaction. In a pozzolanic reaction between fly ash and $Ca(OH)_2$ or calcium silicate phases in cement paste, the early reaction may be so rapid that it will be unsuitable for applications that require longer workability or setting time. Therefore, Class F fly ash is much preferred in cement and geopolymer applications due to the high content of amorphous alumino silicate phases and greater workability (Sindhunata, 2006).

The effect of fineness of fly ash on the setting time of geopolymer paste, workability, strength development, and drying shrinkage of geopolymer mortars made from classified fine high-calcium fly ash was investigated. The heat-cured geopolymers were activated with sodium hydroxide (NaOH) and sodium silicate. A small amount of water was incorporated for workability. The results indicate that the setting time of paste decreases with an increase in fly-ash fineness. The flow, strength, and drying-shrinkage characteristics of mortars were improved using fine fly ash. Geopolymer mortars with high 28-day compressive strength of 86.0 Mpa were obtained (Hatanaka, S., and Cao, T. (2011). The primary components of power station fly ash are silica (SiO_2), alumina (A1203) and iron oxides (Fe_2O_3), with varying amounts of carbon, calcium (as lime or gypsum), magnesium and sulphur (sulphides or sulphates). The annual production of fly ash in Thailand alone has reached nearly 3 million tons (Wijeyewickrema et al., 2000). Ahmaruzzaman (2009) identifies that a substantial amount of ash is still disposed of in landfills and lagoons at a substantial cost to the utilizing companies and thus to the consumers.

2.4.3 Sodium Silicate

Sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) were both procured from local market. Laboratory grade (97% pure) sodium hydroxide was in the form of pellets (3mm approximately) with specific density of 2.13 g/cm3. The chemical composition of sodium silicate solution was Na_2O=15.23% by mass, SiO_2=35.67% by mass and remaining water. The Molar Ratio (SiO_2/Na_2O) was found to be 2.34. The density of sodium silicate solution was found to be 1.53 g/cm3 (Bennet Jose Mathew, Sudhakar M, Dr. C Natarajan).

In cement, hydration process is main process to form the bond that is C-S-H gel. In the geopolymer concrete/mortar, the bond was produced by the geopolymerisation process which is form by the reaction between source material like fly ash and the alkaline liquid. The alkaline liquids are from soluble alkali metals that are usually Sodium or Potassium based. The most common alkaline liquid used for geopolymerisation is a combination of Sodium Hydroxide (NaOH) or Potassium Hydroxide (KOH) and Sodium Silicate or Potassium Silicate (B.V. Rangan 2008).

2.4.4 Water

Water is needed in concrete mixture, the water must been clean from excess impurities because it will effect to hardness process, volume stabilization, durability and discolouration. Suitable water is water containing dissolved solids less than 2000-ppm. Therefore, the water supplied in the water supply system can be used because it contains dissolved solids less than 2000-ppm (Mehta, 1991). Water is added to sodium silicate to produce alkaline solution.

2.5 SOLAR ENERGY

Use of solar energy for drying crops saves conventional fuels and also offers the advantage of less pollution. Experiments conducted in many countries have clearly shown that solar energy can effectively be used to dry agricultural crops. Solar dryers with normal collectors generally provide low-grade heat and, thus, are good for

agricultural crop drying purposes as it meets the requirement of high airflow rate with small temperature rise. Sodha et al. describe that the dryers using conventional solar air heaters with lifespan of 10 or more years are economical when compared with those using wood, oil or electricity. (P.N.Sarsavadia, 2006) Solar mean something about the sun and solar energy are the energy that relevant with the sun. This solar energy source is more environmental friendly from fossil energy sources and can reduce the problem like a greenhouse and nature pollution from the fossil energy source usage.

2.6 LOW TEMPERATURE DRYERS

In low temperature drying systems, the moisture content of the product is usually brought in equilibrium with the drying air by constant ventilation. Thus, they do tolerate intermittent or variable heat input. Low temperature drying enables crops to be dried in bulk and is most suited also for long term storage systems. Thus, they are usually known as bulk or storage dryers (McLean KA., 1980). Their ability to accommodate intermittent heat input makes low temperature drying most appropriate for solar-energy applications. Thus, some conventional dryers and most practically-realised designs of solar-energy dryers are of the low temperature type.

2.7 SOLAR DRYER TYPE

Solar dryer fall into two broad categories: active and passive. Passive dryer can be further divided into direct and indirect models .A direct (passive) dryer is one in which the food is directly exposed to the sun's rays. In an indirect dryer, the sun's rays do not strike the food to be dried. A small solar dryer can dry up to 300 pounds of food per month; a large dryer can dry up to 6,000 pounds a month; and a very large system can dry as much as 10,000 or more pounds a month. Passive dryer use only the natural movement of heated air. They can be constructed easily with inexpensive, locally available materials. Direct passive dryers are best used for drying small batches of foodstuffs.Indirect dryers vary in size from small home dryers to large-scale commercial unit"s. Active dryers require an external means, like fans or pumps, for moving the solar energy in the form of heated air from the collector area to the drying

beds. These dryers can be built in almost any size, from very small to very large, but the larger systems are the most economical.(VITA Volunteer Roger G.Gregoire, P.E. 1984)

2.7.1 Indirect Dryer

An indirect dryer is one in which the sun's rays do not strike the food/herb to be dried. In this system, drying is achieved indirectly by using an air collector that channels hot air into a separate drying chamber. Within the chamber, the food/herb is placed on mesh trays that are stacked vertically so that the air flows through each one. shows an indirect passive dryer. The solar collector can be of any size and should be tilted toward the sun to optimize collection. By increasing the collector size, more heat energy can be added to the air to improve overall efficiency. Larger collector areas are helpful in places with little solar energy, cool or cold climates, and humid regions. Tilting the collectors ismore effective than placing them horizontally, for two reasons. First, more solar energy can be collected when the collector surface is more nearly perpendicular to the sun's rays. Second, by tilting the collectors, the warmer, less dense air rises naturally into the drying chamber. The drying chamber should be placed on support legs, but it should not be raised so high above the ground that it becomes difficult to work with. (VITAVolunteer Roger G. Gregoire, P.E.)

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter will discuss about the experimental procedure, the material that being used, preparation of material, apparatus and method that being perform and explaining about the test has been carried out to produce geopolymer brick. This research planning and design mix for specimens also describe in this chapter. All the process will be performed at the concrete Laboratory of Faculty of Civil Engineering, University Malaysia Pahang (UMP).

This survey is to determine the efficiency of the chamber to bring around the geopolymer brick. To find out the efficiency of the chamber, three different curing conditions were used in the study were in the chamber, the room temperature in an oven. To carry out this study, the specimen is fly ash, sodium silicate, sand and water. These materials are mixed in the mix design. To determine the curing method is not successful, a compression test will be performed. In addition, porosity test was also conducted for brick mixed geopolymer to determine the better.

3.2 RESEARCH PLANNING

The research planning is the main step in doing this research because it is important for researchers to recognize the scope of work to be executed. Figure 3.1 shows the flow chart for the research methodology. In the flow chart, there are several steps to complete the research.

The first step before starting the study is to find the article and journals of other research related to the topic and achieve its objectives. At the same time, the material that's going to be used should be well prepared in term of the quantity, the quantity and the types of material. There are five mixes design for the specimen with difference sample density of sodium silicate which is 90 kg/m^3, 85 kg/m^3, 80 kg/m^3, 75 kg/m^3, 70 kg/m^3. Ingredients for this mix are fly ash, sodium silicate, sand and water. Each mix in this study would use 30% of water only.

Next step, casting and curing process would be done. In the curing process, we used chamber for the curing conditions. All specimens will be tested for compressive and porosity. This test will be conducted on 1, 28, 56 days. The result of specimen would be used to do the discussion, if the specimen past the testing. Trial mixes must be done again, if not past. The conclusion and discussions made will be done after have a result of the test.