THE EFFECT OF BOTTOM A... EPLACEMENT ON
CONCRETE COMP... KABILITY

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ABSTRACT

Coal combustion by-product has been around since people understood that burning coal can generates electricity, and its utilization in concrete production for nearly a century. Malaysia facing an increasing production using by-products called coal bottom ash from thermal power plants, running into method of disposal where no other commercial usage. A significant amount of research has been conducted somewhere on coal bottom ash to ascertain its pozzolanic activity, compressive strength in concrete and mortar, durability and water absorption characteristics in order to ensure its usage as a construction material. This paper presents the experimental investigations carried out to study the effect of bottom ash as partial sand replacement on concrete compressive strength and workability. The various properties was studied consist of compressive strength, workability and water absorption of the concrete at the various percentage of replacement. The strength development for various percentages varies from 0%, 10%, 20%, 30%, 40% and 50% replacement of fine aggregates with bottom ash can easily be equated to the strength development of normal concrete at various ages. The results of compressive strength at 7, 28, 60 and 90 days curing are presented. The results showed that for a grade 30 concrete with a combination of coal bottom ash can produce 28 day strength similar to normal concrete.

ABSTRAK

Pembakaran arang batu telah wujud semenjak manusia memahami bahawa pembakaran arang batu boleh menjana elektrik dan penggunaannya dalam pengeluaran konkrit menghampiri satu abad. Malaysia menghadapi penggunaan yang semakin meningkat menggunakan produk arang batu dari loji jana kuasa di mana ianya melalui kaedah pelupusan di mana tiada kegunaan komersial yang lain. Sejumlah kajian telah dilakukan di sesebuah lokasi mengenai abu arang batu untuk memastikan pozzolanik aktiviti, kekuatan mampatan dalam konkrit dan mortar, ketahanan dan ciri-ciri penyerapan air bagi memastikan penggunnaannya sebagai bahan dalam pembinaan. Kertas kerja ini dijalankan untuk mengkaji kesan abu arang batu sebagai sebahagian daripada penggantian penggunaan pasir terhadap kekuatan mampatan konkrit dan kebolehkerjaan. Kekuatan meningkat untuk pelbagai peratusan dari 0%, 10%, 20%, 30%, 40% dan 50% penggantian pasir halus dengan abu arang batu dan ianya menghampiri kekuatan konkrit biasa di pelbagai peringkat umur. Keputusan kekuatan mampatan konkrit pada 7, 28, 60 dan 90 hari dicatatkan. Hasil kajian menunjukkan bahawa bagi konkrit gred 30 dengan gabungan daripada abu arang batu boleh menghasilkan kekuatan pada 28 hari menghampiri kekutan konkrit biasa.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Concrete is a mixture of various materials liked cement, fine aggregate, coarse aggregate and water where it is dominant construction material for the infrastructural and building needs. Waste material has attracted attention among researchers to use it as a replacement to natural aggregate or cement in concrete making.

Bottom ash (BA) is a solid waste from the combustion coal where contains several toxic elements such as lead (Pb), zinc (Zn), cadmium (Cd) and copper and the needs of bottom ash has to be ground to increase the pozzolanic activity and as a replacement of Portland cement. It is produces as by-products from electric power plant in the develop country such as China, Malaysia and other countries where limiting in landfill damped. In the Peninsula Malaysia, Perak, Johor, Selangor and Negeri Sembilan are the 4 famous electric power plants used a coal to generate the electricity. The capacity of TNB's electric power plant in Perak consist of 2100 MW (3 X 700 MW).The bottom ash is physically coarse, porous, glassy, granular, greyish and incombustible materials where it is collected from the bottom of furnaces which producing 80% of fly ash and 20% of bottom ash in the burning process.

1.2 PROBLEM STATEMENT

The growing demand for electricity resulted in the construction of many coal fired power plants. Bottom ash from electric power plant is estimated because of the increasing in the develop country such as China, Malaysia and other countries where landfill for damped is limited. Perak, Selangor, Johor and Negeri Sembilan are 4 famous electric power plants in peninsula Malaysia that use a coal as a power material for generates electricity. 80% of the product from the burning process will become fly ash and the remains 20% of product will be bottom ash. According to 2006 statistics, 45% bottom ash is used in transportation applications which is asphalt concrete aggregate, road base material, embankment or backfill material and structural fill (American Coal Ash Association (ACAA, 2006). Bottom ash is used as fine aggregate in producing lightweight concrete masonry and as cement replacement in structural masonry purpose (Saikea et al, 2008), (Berg, 1998), (Jaturapitakkul and Cheerarot, 2003).

1.3 OBJECTIVE OF STUDY

The objectives of the study are:

i. To determine the effect of bottom ash as a partial replacement of sand toward compressive strength of concrete.

ii. To determine the effect of bottom ash as a partial replacement of sand toward workability of concrete.

iii. To determine the effect of bottom ash as a partial replacement of sand toward water absorptionof concrete.

1.4 SCOPE OF STUDY

Scopes of this study include the following procedures:

i. The study focus on the compressive strength, workability and water absorption test of bottom ash
ii. The methods of testing are accordance to BS1881:Part 119:1983.
iii. The study will consist 4 sets of different percentage of bottom ash, 10% of weight of the fine aggregate, 20% of weight of the fine aggregate, 30% of weight of the fine aggregate, 40% of weight of the fine aggregate and 50% of weight of the fine aggregate.
iv. The bottom ash is generated from combustion of coal process at Kapar Power Plant, Selangor.
v. The specimens are cured for the 7, 28, 60 and 90 days.
vi. The test involved in this study will be conducted at FKASA Lab, UMP.

1.5 SIGNIFICANT OF STUDY

The study will serve at the good understanding on the effectiveness of the bottom ash as a partial cement replacement towards compressive strength, workability and water absorption of concrete. In addition, this study will be best solution in preserving good environment which helps to reduce pollution from bottom ash as the concrete will be used in construction industry.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The composition of bottom ash and fly ash is bottom ash is forms up to 25% of the total ash while the fly ash forms the remaining 75%. Published literature describe that there is a strongly possibility of coal bottom ash is being used as a partial replacement of fine aggregate. Effect of coal bottom ash on the properties of concrete such as workability, compressive strength and water absorption are presented.

The desired workability of concrete based on water demand can be achieve depends on the number of fines and properties of fine aggregate in it. Natural river sand particles are dense and the surface becomes smooth due to weathering affects. The number of particles size of bottom ash is smaller than 75μm compared to the natural river sand. Ghafoori and Bulcholc (1997) examined the effect of high calcium bottom ash as natural sand replacement on the properties of fresh concrete mixtures of proportions of 3000psi, 4000psi, 5000psi and 6000psi of 28 days strength. According to the Aramraks (2006), he examined the water requirement of concrete mixes is 50% and 100% of bottom ash as sand replacement. He observed that the mixes using bottom ash required approximately 25-50% of more mixing water content of normal concrete in order to obtain suitable workability. On the other side, aggarwal et al. (2007) found that the workability of concrete is measured in terms of compaction factor where workability decreases with the increase of the replacement level of the fine aggregates with the bottom ash. However, there is some of the contrast data in the published literature which does not support the above concept of decreased workability of the used bottom ash as sand replacement in concrete. Bai et al. (2005) observed that the slump increased with increase in bottom ash content as fixed water cement ratios of 0.45 and 0.55 and cement content of 382 kg/m^3. According to the Shi-Cong and Chi-Sun (2009), the effect of bottom ash as sand replacement at levels of 0%, 25%, 50%, 75% and 100% where the cement water ratio of 0.53.

Porosity of hydrate paste which is controlled by water ratio and the presence of bond cracks at the interface of aggregate and hydrated paste is a factor of the strength development of concrete. The investigation shows that bottom ash particles are more porous and weak than natural sand particles where increased in demand of mixing water in concrete as sand replacement. Ghafoori and Bucholc (1997) found that compressive strength of combine bottom ash and sand mix lower than the control of concrete where the average differences in compressive strength at the age 3 days and 7 days were 12% and 14.5% respectively. According to the Andrade et al.(2007), he observed that concrete mixed preparation with addition of bottom ash as equivalent volume replacement where correcting in quantities of bottom as according to the moisture content showed very significant loss in compressive strength. However, in case of concrete mixed preparation with the addition of bottom ash as nonequivalent volume replacement, the compressive strength of bottom ash concrete was similar to the reference concrete according to the moisture content without correcting bottom ash quantities.

In the context of Aggarwal et al. (2007), he investigated that the effect of bottom ash with varying levels from 20% and 50% as sand replacement on properties of concrete and observed the compressive strength of bottom ash concrete specimens was lower than control specimens at all the ages. The strength is difference between bottom ash concrete specimens and control concrete specimens less distinct after 28days. Chun et al. (2008) noticed that the strength of concrete differed by the context of pond-ash collected from each disposal site where the increase in content of pond-ash will be greater increase in compressive strength compared to normal concrete and it might be consequence of decreased in water ratio or cement ratio induced by the absorption of mixing water. According to the Richardson (2002), a 20% replacement level is ideal level for the best performance of concrete brick where for normal concretes, 20% replacement is an optimum ratio with regard to the test for the ratio of 10%, 20%, 30%, 40% and 50% of bottom ash.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

The experimental and implementations of the research were carried out to determine the effectiveness of the bottom ash as a partial replacement of sand for concrete cube. To determine the optimum mix and mechanical behavior of concrete by using bottom ash, two types of testing were carried out. The test was compressive strength test and water absorption test.

A flow chart is done to arrange and explain all the main activities which will be carried out throughout the research starting with deciding the research title and ends with the presentation in figure 3.1 to shows the flow chart of research methodology

For a lab work, it started by preparing the material to be used. This is also including the Sieve Analysis Test for the fine and course aggregates, and Chemical Composition Analysis of bottom ash for classification of pozzolanic material based on ASTM C618. After all the material is prepared, the concreting work is done. The sample consist of 100 x 100mm cube of plain concrete, 10% ,20%, 30%, 50% and 100% partial replacement of bottom ash. The concrete will be cure for the duration 7, 28, 60 and 90 days. All the related testing will be conducted at FKASA Concrete Lab, UMP after the curing process is completed.

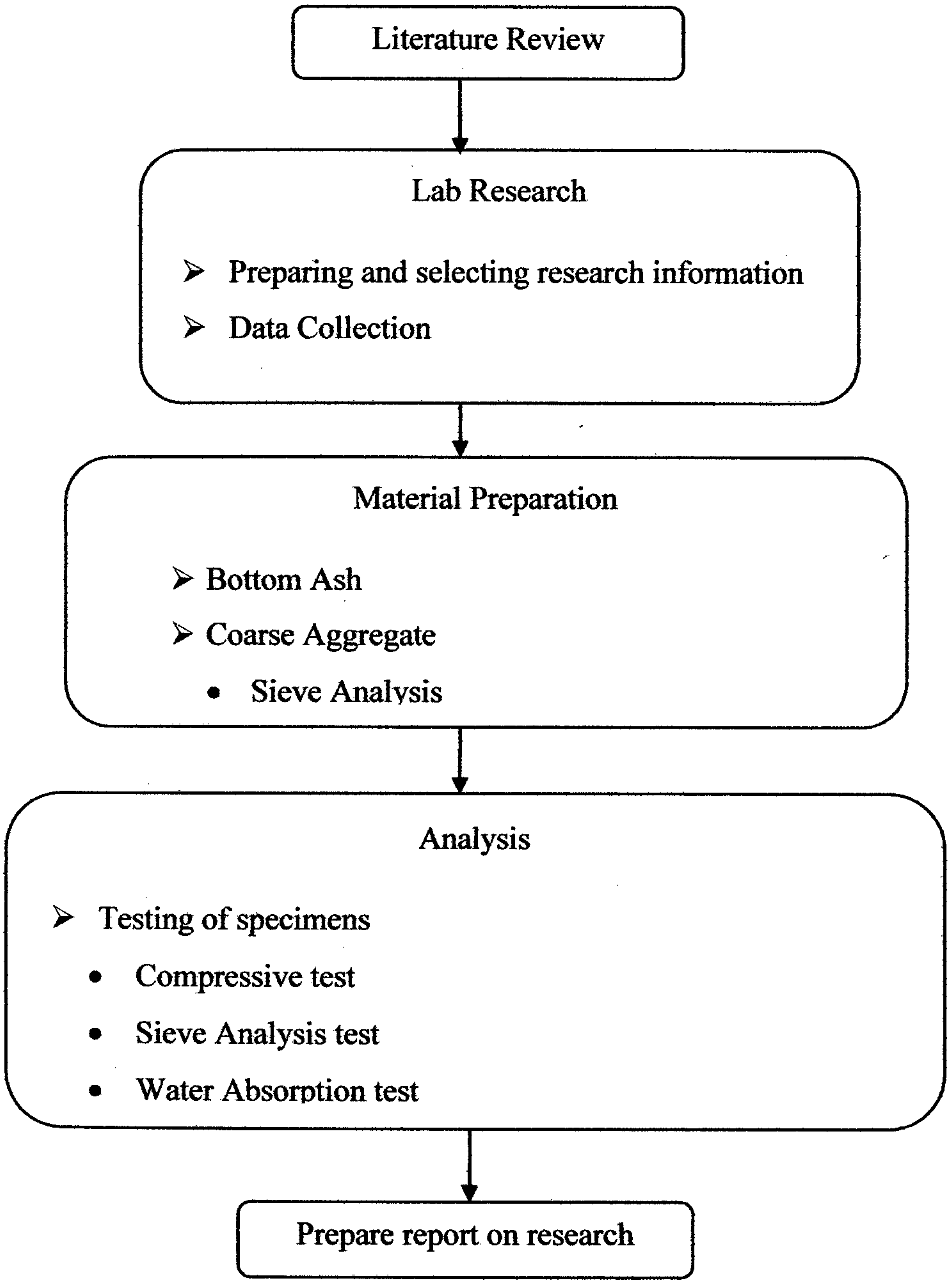

Figure 3.1: Research methodology flow chart

3.2 MATERIAL QUANTITY CALCULATION

3.2.1 Mix Design

The characteristics strength of 30 N/mm^2 at 28 days was used in this study. The 120 cubes were prepared for this study in six sets of sample. The first set was a control mix that 0% replacement with w/c ratio is 0.58 and 30-60mm in slump. All sets of mix were prepared with constant w/c ratio of 0. With slump test between 30-60mm and bottom ash replacement is 10%, 20%, 30%, 40% and 50%. For compressive strength test sets are 18 cubes with size 100mm x 100mm x 100mm each. Meanwhile, a set for porosity test are 4 cubes of 100mm x 100mm x 100mm. Table 3.3 shows the summary of mix proportion of concrete per meter cubes.

Table 3.1: Summary of mix proportion of concrete per meter cubes

Mix type	w/c ratio	Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	Bottom Ash (kg)	Water (kg)	Slump (mm)
Control	0.58	10.41	21.05	31.62	-	5.75	30-60
Bottom ash (10%)	0.58	10.41	18.95	31.62	2.10	5.75	30-60
Bottom ash (20%)	0.58	10.41	16.85	31.62	4.20	5.75	30-60
Bottom ash (30%)	0.58	10.41	14.75	31.62	6.30	5.75	30-60
Bottom ash (40%)	0.58	10.41	12.65	31.62	8.40	5.75	30-60
Bottom ash (50%)	0.58	10.41	10.55	31.62	10.5	5.75	30-60

3.3 PREPARATION OF MATERIALS

3.3.1 Preparation of Mould

The size of mould used in this research is 100 mm x 100 mm x 100 mm and before the samples is being prepared, the mold must be setup and check for the cleanliness and proper assembling of joints. Before the concrete is poured into the mould, it must be coated with a thin layer of oil inside the mould surface.

3.3.2 Bottom ash

Bottom ash is collected from electrical power plant in Kapar Energy Venture located in Selangor. There are physically coarse, porous, grassy, granular, grayish and incombustible materials that are collected from the bottom furnaces. Figure below shows the bottom ash particle and the sieve analysis for the bottom ash.

Figure 3.2: Sample of Kapar bottom ash

3.3.3 Ordinary Portland cement

The ASTM has designed five types of Portland cement which is Types I until V. These types of cement are physically and chemically differ primarily in their content of C3A and in their fineness. In terms of performance, primarily, it is differ in the rate of early hydration and in their ability to resist sulfate attack. The figure below is cement type used in the research.

3.3.4 Water

Water is an important constituent in concrete and it is chemically reacts with cement (hydration) to produce the desired properties of concrete. Mixing water is the quantity of water that comes in contact with cement, gives impacts to the slump of concrete and is used to determine the water to cementitious materials ratio (w/c) of the concrete mixture. Strength and durability of concrete is controlled to large extent by its water-cement ratio.

3.3.5 Fine aggregate

Fine aggregate is the inert or chemically inactive material; passing through a 4.75mm IS sieve and contains not more than five per cent coarse material. The purpose of fine aggregates is to fill all the open spaces in between the coarse particles. Thus, it reduces the porosity of the final mass and increases its strength. Usually, natural river sand is used as fine aggregate. The fine aggregate size used in this research is passing 200mm sieve size.

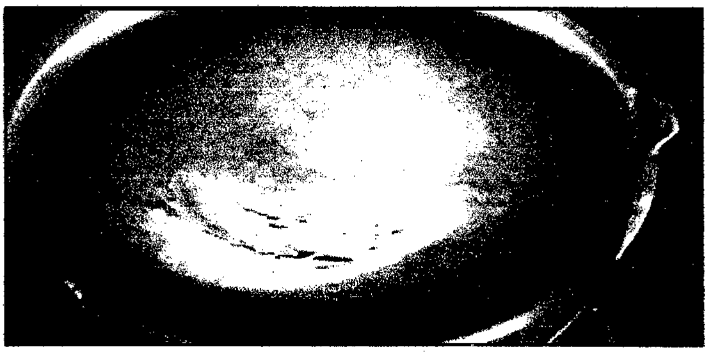

Figure 3.3: Sample of fine aggregate

3.3.6 Coarse aggregate

Coarse aggregates are particles greater than 4.75mm. Generally, the range sizes between 9.5mm to 37.5mm in diameter. They can either be from primary, secondary or recycled sources and gravels constitute the majority of coarse aggregate used in concrete with crushed stone making up most of the remainder. The aggregate size used in the research is 5mm in diameter.

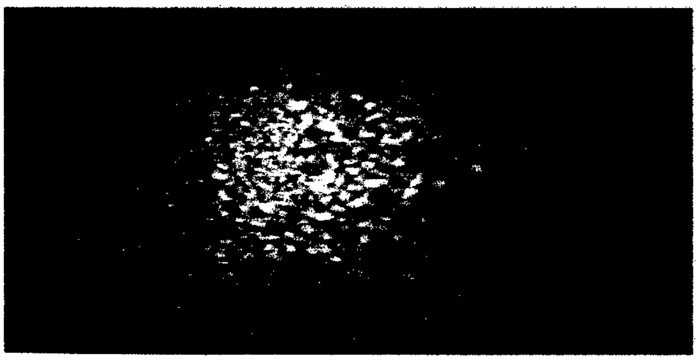

Figure 3.4: Sample of coarse aggregate

3.4 SAMPLE PREPARATION

3.4.1 Sieve Analysis

Sieve analysis test was primary used to determine the grading of materials for being used as aggregates. It is used to determine the compliance of the particle size distribution with applicable specification requirements. The results by using bottom ash and sand will be compared.

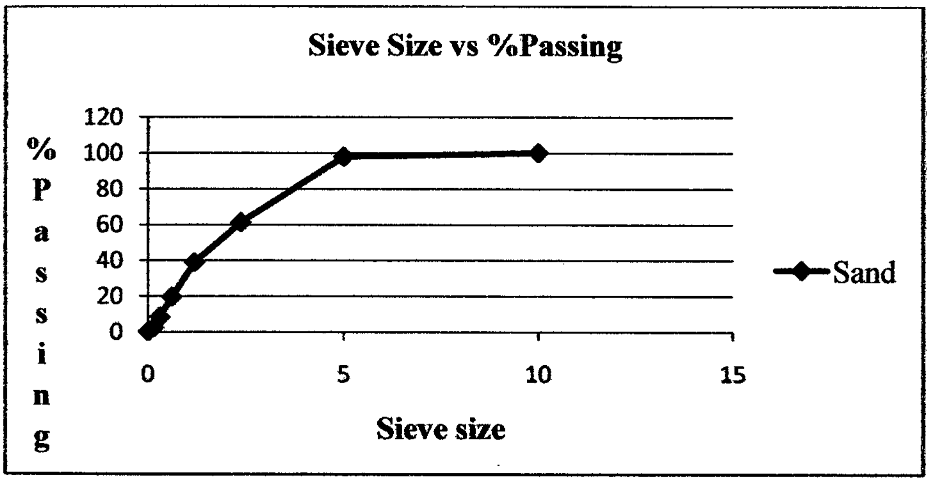

Figure 3.5: Sieve analysis for sand

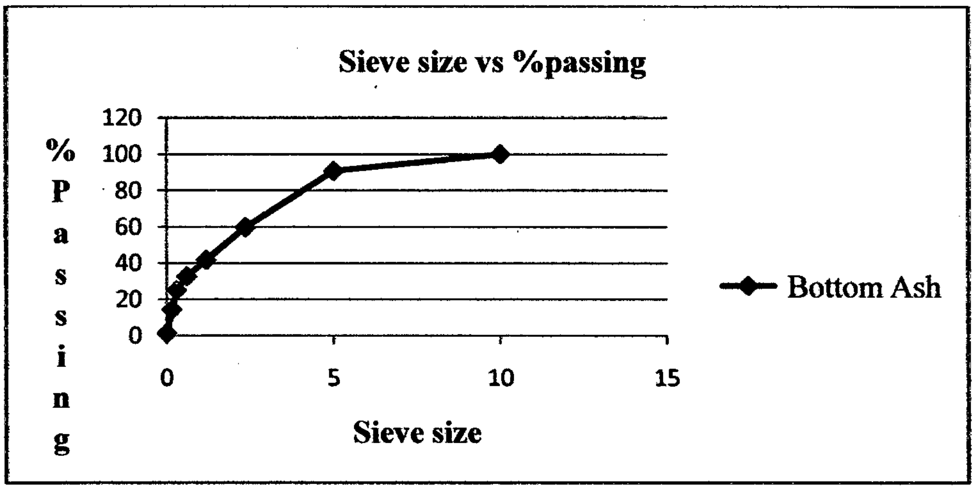

Figure 3.6: Sieve analysis for bottom ash

3.4.2 Mixing

The process of mixing was done by the machine. The sample will be added into the mixer in the following sequence with fine aggregate, cement, coarse aggregate and water. The water will be added after the all material already mixes together. When the mix is ready, the workability test was performed on the concrete. The mixing process will be continue with the percentage of 10%, 20%, 30%, 40% and 50% of fine aggregate replacement.

3.4.3 Curing Process

The process of curing is concrete specimen will be placed into water tank for a certain period. The purpose of curing is to make sure the concrete have a proper process of hardened and to make sure the cement in concrete are fully reacts with water and have a good bonding. The duration of being cured is 7, 28, 60 and 90 days. The testing will be done after the curing process.

3.5 TESTS ON CONCRETE

3.5.1 Sieve Analysis

Sieve analysis test is primaly used to determine the grading of materials for being used as aggregates. It is used to determine the compliance of the particle size distribution with applicable specification requirements. The gradation data may be used to identify relationships between various aggregates, to check the compliance with such blends and to predict trends during production by plotting gradation curves graphically. A suitable gradation of aggregate in Portland cement concrete mixture is desirable in order to secure workability of the concrete mix. For asphalt concrete, the gradation will affect significantly to the strength, stability, resistance to aging and other important properties.

A known weight of material is obtained. The amount is determined by the largest size of the aggregate to the smallest size of aggregate. The sieve pan are assembled from the top to bottom starting from 10mm, 5mm, 2.36mm, 1.18mm, 600Mm, 300 Mm, 150 Mm and 75 Mm. The material is sieve in the mechanical shaker for a certain period, about 10 to 15 minutes. The materials retained on each sieve are weighted. The results are tabulated