INFLUENCE OF BOTTOM ASH FROM COAL FIRE BOILER IN CEMENT BRICK TOWARD MECHANICAL PROPERTIES

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ABSTRACT

Recycling is the act of processing the used material for use in creating new product. The usage of natural aggregate is getting more and more intense with the advanced development in infrastructure area. In order to reduce the usage of natural aggregate, recycled aggregate can be used as a replacement materials. In Malaysia the used of bottom ash from coal fire boiler power plant become one of the serious environmental problems facing now. Therefore, new alternative needed to recycle and reuse them to avoid those problem from become more serious environmental problem. Several researches have been developed for its reuse and it was found that the use of disposal bottom ash in the cement brick is a possible form of its to improve certain of properties of cement brick, such as better compression performance, ductility, and lightweight. In this study "Bottom Ash" were use to determine the mechanical characteristics of recycled aggregate concrete. Test that has been done with different replacement percentage of "Bottom Ash" based on weight of the fine aggregate (0%, 25%, 50% and 100%). At the end of the study, it can observe that the replacement of "Bottom Ash" reduce the performance of cement brick in side of strength, but it produces more ductile and lightweight concrete with high workability of mixture which is suitable for application of structures that are more resistant to high impact and able to sustain failure mode longer compared to the ordinary concrete.

ABSTRAK

Kitar semula merupakan pemprosesan bahan terpakai untuk dijadikan produk baru. Penggunaan aggregat semulajadi semakin hari semakin pesat dengan kemajuan di dalam bidang pembangunan insfrastuktur. Untuk mengurangkan penggunaan aggregat semulajadi, aggregat terbuang boleh digunakan sebagai bahan gantian. Di Malaysia, sisa dari arang batu loji janakuasa terutamanya abu dasar relau adalah salah satu masalah serius kepada alam sekitar yang dihadapi sekarang .Oleh itu, alternatif baru diperlukan bagi mengitar dan menggunakan semula abu dasar relau bagi mengelakkan ianya menjadi masalah alam sekitar yang lebih teruk. Beberapa penyelidikan telah dijalankan untuk mengkaji penggunaan semula dan telah dijumpai bahawa penggunaan abu dasar relau dalam batu bata adalah satu kemungkinan ianya dapat memperbaiki ciri-ciri kejuruteraan bata seperti meningkatkan sifat lelasan dan mampatan. Dalam kajian ini abu dasar relau digunakan sebagai penggantian agregat untuk mengkaji sifat mekanikal konkrit yang dihasilkan. Ujian yang dilakukan adalah dengan penggantian peratusan abu dasar relau yang berbeza berdasarkan berat agregat halus (0%, 25%, 50% dan 100%). Diakhir kajian, dapat dilihat bahawa penggantian abu dasar relau telah mengurangkan prestasi konkrit dari segi kekuatan konkrit, tetapi ianya menghasilkan konkrit yang lebih anjal dan ringan dengan campuran yang mempunyai kebolehkerjaan tinggi sesuai bagi aplikasi untuk struktur-struktur bukan utama yang lebih tahan untuk hentaman tinggi dan berupaya untuk menampung mod kegagalan lebih lama berbanding bata biasa.

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CHAPTER 1

INTRODUCTION

1.1 General

Coal was introduced as a raw material for power generation since 1988 in Malaysia. The existing coal-fired power plants in Malaysia are Kapar (1,600MW) commissioned in 1988-1999 and TNB Jana Manjung (2,100MW) commissioned in 2003. Looking at the electricity generation mix, the percentage of coal remains stable at an average of 8.6 percent from 1993-2000 and increased slightly to 12 and 14.1 percent in 2001 and 2002 respectively. However, in 2003 the percentage increased tremendously from 14.1 percent to 24.6 percent of coal in the electricity generation mix due the commissioning of Jana Manjung power plant. According to Joseph, 2005 with the two more new constructed IPP coal-fired power plants, Jimah and Tanjung Bin coal consumption is expected to increase from 10 million tons to 19 million tons in year 2010.

Bottom ash has been categorized as solid garbage. Bottom ash possess properties that give them several productive uses as construction material, yet more than 70 percent of the ash remains unused (ACAA 1998). The majority of unused coal ash is disposed of in landfills or mined out areas of coal mines prior to their reclamation. Basically, its applications and potential applications that cement and concrete industries, production of synthetic aggregates, and backfill and embankment material for highway construction, stabilization of engineered soils for construction purpose.

1.2 Problem of statement

The growing demand for electricity resulted in the construction of many coal-fired power plants. As the consumption of coal by power plants increases, so does the production of coal ash. While the use of coal increase, waste issue associated with coal production are tempted more and more thoughtfulness. Malaysia is very serious about environmental issue and it is going to be very stringent about the emission standards on the new project for coal power (Joseph, 2005). Even though there is no report about the producing of coal ash annually in Malaysia, but basically there is about 10% of total weight of the coal burned produces ash (Huang, 1990). Disposal of unused coal ash is costly and places a considerable burden on the power industry and finally transferred to the electricity consumer. In addition, the disposing of ash in landfills contributes to the ongoing problem of diminishing landfill space in the Malaysia. Ash disposal also may pose an environmental hazard.

Tanjung Bin power plant consumed enormous quantities of coal each year. This produces a substantial amount of unused coal ash. The majority of ash is disposed in mines prior to the reclamation. Besides that, there are many areas of the Malaysia are faced with a shortage of conventional construction materials. In addition, zoning restrictions and environmental regulation often remove acceptable material from availability. Normally these same city areas are served by power station that produces large quantities of ash. Obviously, a favorable combination of circumstances is created for utilization of power plant ash as a partial of full substitute for conventional aggregate in various applications. The successful use of bottom ash in civil engineering construction would provide significant economic savings. Therefore, it is the intension of this final year project to determining the mechanical behavior of cement brick by using bottom ash from Tanjung Bin power plant in construction industry.

Figure 1.1: Tanjung Bin power plant

1.3 Objective

The purpose of this project is to study the bottom ash an aggregate in cement brick. Thus the objectives of the study are:

i. To design optimum mix of cement brick by using bottom ash
ii. To determine the effectiveness of bottom ash as a sand/aggregate replacement mixes in cement brick
iii. To study mechanical (compressive strength) behavior of cement brick by using bottom ash

1.4 Scope of research

This study concentrated on investigation of mechanical behavior and performance by using namely compressive strength and water absorption test of Bottom Ash (BA). The block specimen's dimensions for compressive strength test are 110 mm x 220 mm x 65 mm. The methods of testing are accordance to BS1881: Part 119: 1983. The experiment and testing were run and analyzed in the concrete laboratory FKASA, UMP.

A sample of bottom ash was prepared in the laboratory to determine the optimum mix and mechanical behavior of the cement brick. Three series of concrete mix design with BA were casting and one control mix for comparison. The amount percentage of BA were added comprises of 25%, 50% and 100% from the total weight of fine aggregate use in cement brick. The hardened mortar brick was taken out from the mould after 24 hours after casting and it was cured in the curing tank and control room for curing period of 7, 28, 60 and 90 days for all mixes. The tests were conduct after 7, 28, 60 and 90 days of curing period.

1.5 Significant of the research

An environmental issue is a major problem in many countries. They are seriously taken this problem with technology and enforcement by law to reduce this pollution. In Malaysia, the way in handling the pollution on coal ash is by using conventional method which is the waste were stored in manmade pond. This study might contribute to solve some of the coal waste problems and reduce the pollution. The experimental study conducted is a step towards the new design of cement brick by used bottom ash as a replacement for some of the fine aggregate of cement brick. As the brick will be used in construction industry and this will create a new environment which helps to solve pollution from bottom ash and it will be a 'new home' for this waste.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Coal ash has been dumped for many years on free land and has also partially been deposited in landfill sites. The waste been generated in vastly increasing amounts as the demand for electricity, heat and energy has progressed. From the literature search it is found that research on fly ash behavior had widely been made but it is quite scarce for bottom ash also known as pond ash. In Malaysia, there limited research works on studying the behavior of bottom ash and the usage of bottom ash in application to civil engineering construction.

2.2 Bottom ash

Bottom ash is formed when ash adheres as hot particles to the boiler walls, agglomerates and then falls to the base of the furnace at a temperature around 12000 Celsius (Kim et al., 2006). Hence the term "Bottom Ash" is coarse, with grain sizes spanning from sand to gravel, granular, incombustible by-product, and solid mineral residue. Depending on the boiler furnace types, the bottom ash collected is classified into two types: dry bottom ash and wet bottom ash (more commonly referred to as boiler slag). The incombustible mineral elements stick together until they are heavy enough causes them to removed from the bottom of the furnaces either in a wet or dry condition and is transported to handling areas by conveyor or pipe. It is angular in shape and ranges in color from a medium brown or medium gray to almost black. Bottom ash is much coarser and more highly fused than fly ash, but has a similar chemical composition to fly ash. It does not have any cementations properties due to its larger sizes.

2.3 Utilization of bottom ash

Disposal in landfills and surface impoundments is most commonly used coal combustion residues management option. However, there are many alternative uses, such as the use of fly ash in cement. Table 2.1 shows the various applications of coal combustion residues in the United States. The utilization of coal combustion residues in these productive alternatives has been increasing steadily. The cumulative coal combustion residues utilization rate increased from 24.8 percent in 1995 (ACAA, 1998) to 38.1 percent in 2003 (ACAA, 2005a) as markets for coal combustion residues increased. Figure 2.1 illustrates the steadily increasing amounts of coal combustion residues products in the United States that are being utilized for purposes other than disposal.

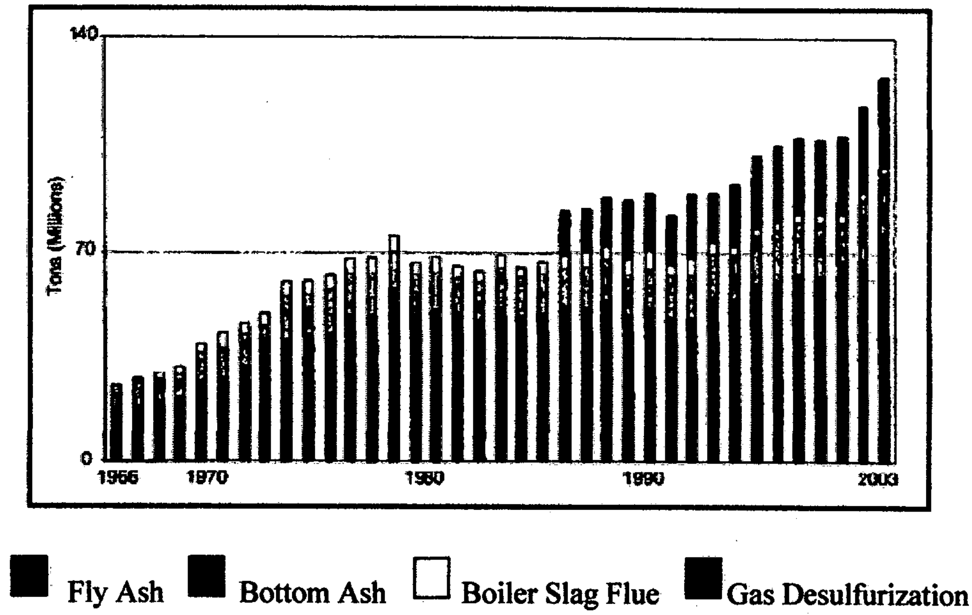


Figure 2.1: Generation of fly ash, bottom ash, boiler slag and flue gas desulfurization (FGD) by utilities (1966-2003) (ACAA, 2005).

Alternative uses of CCRs may help to conserve resources by reducing the consumption of virgin materials like gypsum can use for wallboard production (National research council, 2006). According to the recent statistics report on CCRs utilization, 30.3 percent of all bottom ash and 93.3 percent of all boiler slag produced in 1996 were used (National research council, 2006). Structural fill and road base/sub-base applications are major bottom ash uses.

About 65% of bottom ash is used in road base/sub-base, structural fill, and snow and ice control (Figure 2.2). Minor uses include concrete, mining applications, and cement clinker raw feed. Bottom ash also can be used as fine aggregate in asphalt paving mixtures. Some bottom ash is sufficiently well graded that pavements containing bottom ash can meet gradation requirements. Bottom ash containing pyrites or porous particles is not suitable for use in hot mix asphalt mixtures, where strict gradation requirements exist. It is used more commonly in cold-mix emulsified asphalt mixtures, where gradation requirements and durability are not critical as in hot mix surface mixtures (National research council, 2006).

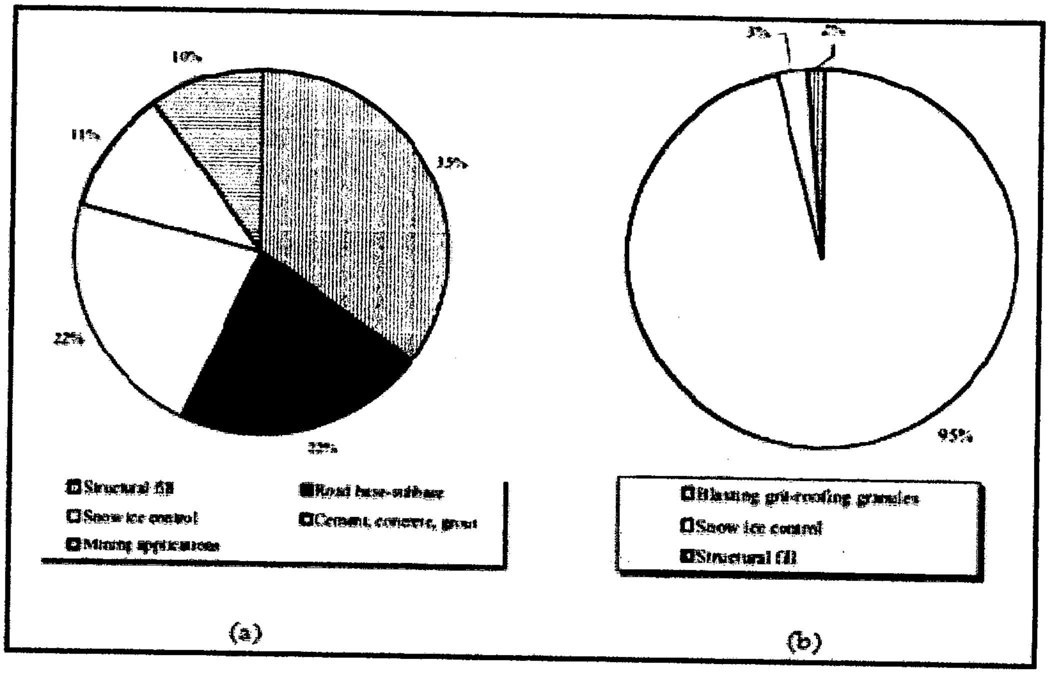


Figure 2.2: (a) Leading bottom ash uses (ACAA, 1998)
(b) Leading boiler slag uses (ACAA, 1998)

Boiler slag is used almost exclusively in the manufacture of blasting grit due to its abrasive properties. Use as roofing granules is also a significant market area. Blasting grit and roofing granules make up almost 90% of boiler slag applications (Figure 2.2). Boiler slag can also be used as fine aggregate, especially in hot mix asphalt owing to its superior hardness, affinity for asphalt, and its dust free surface, which aids in asphalt adhesion and resistance to stripping. Since boiler slag exhibits a uniform particles size, it is commonly blended with other aggregate for use in asphalt mixtures (National research council, 2006).

Table 2.1: Total coal combustion product production and use (ACAA, 1998).

(Thousand metric tons)

	Fly ash	Bottom ash	Boiler slag	FGD material 1/	Total CCPs
Production	42,600	9,420	756	18,400	71,200
Use:					
Agriculture	13	4	--	66	83
Blasting grit-roofing granules	--	102	610	--	712
Cement clinker raw feed	818	142	--	--	960
Concrete-grout	9,240	276	--	317	9,830
Flowable fill	274	10	--	1	285
Mineral filler	106	51	11	(2/)	168
Mining applications	682	258	--	164	1,100
Roadbase-subbase	1,070	508	--	85	1,660
Snow and ice control	3	489	12	--	504
Soil modification	71	22	--	--	93
Structural fills	2,320	483	32	496	3,330
Wallboard	--	--	--	2,160	2,160
Waste stabilization-solidification	1,800	27	--	19	1,850
Other	68	336	28	170	602
Total	16,500	2,710	693	3,480	19,900
Individual use percentage	38.60	28.70	91.70	19.00	NA
Cumulative use percentage	38.60	36.80	37.60	32.80	NA

NA Not available. -- Zero.
1/ FGD: flue gas desulfurization.
2/ Less than 1/2 unit.

2.4 Problem of coal ash

The value of coal is absolutely opposite by the environmental issues. The negative aspects of mining operation can lead to confirmations among citizen group, government agencies and the mining industry. The conflicts tend to be centered on the following issue:

i. Destruction of landscape
ii. Destruction of agriculture and forest lands
iii. Dust
iv. Sedimentation erosion

2.5 Properties of bottom ash

Information regarding the physical, chemical, and engineering properties of coal combustion residues is required before these materials can be safely effectively utilized. The physical and engineering properties, in particular, are important parameters affecting the behavior of coal combustion residues in various engineering applications. Information concerning the chemical composition is important for addressing the potential environmental impacts associated with coal combustion residues utilization and disposal (Abbas, 2002). Most of the researchers (Seals et al., 1972; Moulton, 1973; Majidzadeh et al., 1977) has accentuated that bottom ash has quite alterable physical, chemical, and engineering characteristics. It is not only varying from one plant to another, but also from day to day production within a single plant over time.

Therefore, these characteristics reported by researchers just can be taken as references and not absolutes. Power plant's operating parameters play an important role in the validation on the characteristics of bottom ash from a given source. As long as it remains constant, laboratory data tested on these bottom ashes can be recognized as valid. It is important to insure that the samples obtained are representative of the entire supply (National research council, 2006). There are two different types of bottom ash: dry bottom ash and wet bottom ash (boiler slag). Basically, wet bottom ash tends to have more regular characteristics than dry bottom ash because of wet bottom ash is solidified from the molten slag while dry bottom ash is the straightforward product of flaming process.

2.6 Application of bottom ash

Previously, Sanjeev, 2006 reported about a study to optimize the concrete composite mix design for the project, constructing and using concrete composites made with bottom ash. Bottom ash significant can increase the strength of the mixes concrete. The ash is mainly used in cement industry and the remainder is still directly dumped into ash pond or landfills (Jabolonski & Tyron 1998).

2.7 Sand

According to the. Selvaraju., and Pushpavanam (2000) Sand and brick used for construction activity in the Indian Institute of Technology Madras was taken without any chemical treatment. The bricks were broken down to increase the surface area. The sand and brick particles were sieved with mechanical sieves and the fraction containing particle size less than 710 um was used for experiments.

The desired fraction was then washed withwater and then decanted. After settling, the water was poured out and the sand was taken for drying. After drying at 85 ◦C, the solid particles were ready for use as the adsorbent. Analysis of the physical characteristics of sand included specific surface area, pore specific volume and pore size distribution.

2.8 Brick

Brick have their own characteristics. It included compressive behavior, water absorption behavior and also durability behavior (BS3921, 1985)

2.8.1 Compressive characteristics of brick

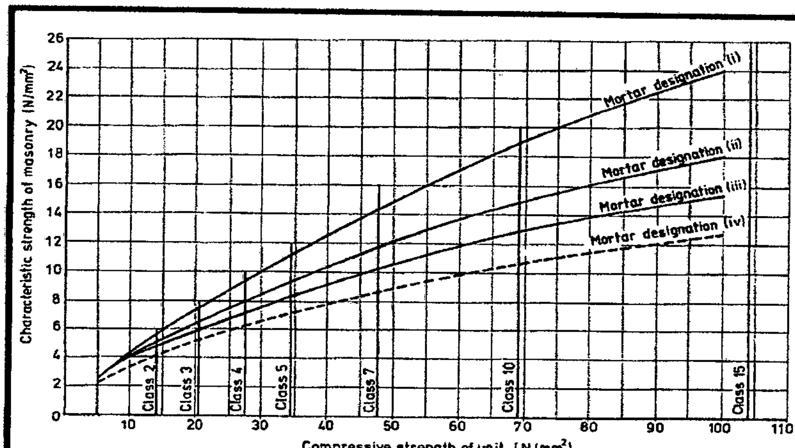
The compressive strength of perforated bricks and hollow blocks is determined by dividing the ultimate load by the gross plan area of the unit, as if it were solid. This compressive strength should therefore be used in obtaining the value of compressive strength, *f*k from Table 2.1. Table 2.1 shows application of masonry to build with standard format bricks complying with the requirements of BS 187, BS 6073-1 or BS 3921.

For normally bonded masonry can be defined in terms of the shape and compressive strength of the structural units and the designation of the mortar. The values given in Table 2 inclusive may be taken to be the characteristic compressive strength, *f*k, of walls constructed under laboratory conditions tested at an age of 28 days under axial compression in such a manner that the effects of slenderness may be neglected (Cavalieri, 2000).

Table 2.2: Characteristic compressive strength of brick masonry, *fk*,

(a) Constructed with standard format bricks									
Mortar designation	Compressive strength of unit (N/mm^2)								
	5	10	15	20	27.5	35	50	70	100
(i)	2.5	4.4	6.0	7.4	9.2	11.4	15.0	19.2	24.0
(ii)	2.5	4.2	5.3	6.4	7.9	9.4	12.2	15.1	18.2
(iii)	2.5	4.1	5.0	5.8	7.1	8.5	10.6	13.1	15.5
(iv)	2.2	3.5	4.4	5.2	6.2	7.3	9.0	10.8	12.7
(b) Constructed with blocks having a ratio of height to least horizontal dimension of 0.6									

Source: BS5628-1, 1992



Interpolation for classes of loadbearing bricks not shown on the graph may be used for average crushing strengths intermediate between those given on the graph, as described in clause 10 of BS 3921 : 1974 and clause 7 of BS 187 : 1978.

Figure 2.3: Characteristic compressive strength of brick masonry, *fk*

Source: (Cavalieri, 2000)

2.8.2 Water absorption characteristics of brick

The method for the determination of water absorption specified in this standard is the 5 h boiling test. Methods of test by 24 h cold immersion and absorption under vacuum are also used as works control tests only. The results obtained from these tests are generally lower than, and are not proportional to, those obtained using the method given in this standard, nor are they equivalent to each other.

Characteristic of water absorption give an effect towards durability of brick. Absorption is the total of water contain in a small aperture of the air that can be found in unit brick. Brick has a small aperture known as through pores and cul-de-sac or closed pores. Through pores can help to trap the air during 24 hour of water absorption. However, the water was not allowed to pass through in water absorption test. So that, vacuum test or boiled the sample (brick) for 5 hours will be done using BS standard (BS 3921:1985). Percentage of water absorption to dry weight of brick was calculated – normally the range is 3 -30%.

Table 2.3: Classification of bricks by compressive strength and water absorption in N/mm²

Class	Compressive strength (see 2.1)	Water absorption (see 2.2)
	N/mm^2	% by mass
Engineering A	≥ 70	≤ 4.5
Engineering B	≥ 50	≤ 7.0
Damp-proof course 1	≥ 5	≤ 4.5
Damp-proof course 2	≥ 5	≤ 7.0
All others	≥ 5	No limits
NOTE 1 There is no direct relationship between compressive strength and water absorption as given in this table and durability.		
NOTE 2 Damp-proof course 1 bricks are recommended for use in buildings whilst damp-proof course 2 bricks are recommended for use in external works (see Table 13 of BS 5628-3:1985).		

Source: BS5628-1, 1992