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UTILIZATION OF FLY ASH WASTE AS CONSTRUCTION MATERIAL

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Abstract

In Malaysia there are six coal fired electric power station for the time being. These power stations usually can produce a high amount of electric power of more than 2400 MW. In peninsular Malaysia, there are four coal fired electric power station that produced at least 1400 MW of electric power. Coal fired electric power station is one of the cheapest electric production compared to the amount of power that can be produced. These power stations are still not enough to cater demand due to future development. Fly ash is a waste byproduct of electric power plants which use coal as their fuel source. Previously, a coal based power station disposed the waste amounts out of their equipment by burying it in landfills or returning it to strip mines. The growth in power plants that use coal as the source of fuel has produced hundreds of millions of tons of ash every year. With the advancement of technology and the economic crisis in Malaysia, the development of infrastructure in the use of new structural materials has been promoted but overall with unsatisfactory results in terms of cost savings. However, this problem can be solved by using waste industrial waste such as fly ash as a source to replace the existing building materials which is cost effective. The main aspect of waste management is to prevent the production of waste through minimizing the waste produced and also re-use of waste materials through recycling. The paper will be discussing the potential of managing waste of fly ash by utilizing it as construction materials.

Keywords: *Fly ash; Waste management; Concrete; Pollozan materials.*

Introduction

The Waste Management Association of Malaysia (WMAM) is a non-profit, technical and educational organization which provides a forum to discuss all matters regarding waste management. It aims to establish and maintain contact with organizations related to waste management field either local or international [1]. The waste collection and disposal is the basis for the local authorities in order to regulate the disposal of waste in Malaysia [2]. The collection, transportation and disposal of waste were not properly addressed. These include restriction on dumping procedures and improper locations for the waste disposal.

Fly ash is characterized as one of the residues created in burning chamber from the coal in electrical power plant, and contains the fine particles that rise with the flue gases. Fly ash is a spherical fine glass powder with a particles size estimated in a range from 0.5 to 100 μm. Fly ash can be classified into two types: class F and class C. Fly ash is classified based on the chemical composition of the fly ash itself. The first one is fly ash class F, made from anthracite and bituminous coal while the other one is fly ash class C that is made from burning lignite or sub-bituminous coal. Moreover, according to Manas, fly ash has the ability to self-cementing [3].

Geopolymers are the cementitious materials used to replace cement produced by adding pozzolanic compound or mineral rich alumino silicate (Si- Al) catalysts, including composition ofsodium silicate solution (Na_2SiO_3) and sodium hydroxide (NaOH) [4]. A material made essentially of a mixture of sodium hydroxide and sodium silicate solution which, when combined with powdered materials such as fly ash, forms a material with properties similar to cement and in the same range as Portland cement paste [5].

Although these three components can vary a lot, from the concentration of sodium hydroxide and sodium silicate to the ratio of the two solutions in the composition of fly ash, there is a general consensus in producing geopolymers in the form of polymerization reactions [6-7]. Curing process is the most important and plays an important role in the reaction of geopolymerization as water and moisture content have an impact on the performance and properties of geopolymers [8]. This paper will be discussing the potential of managing waste of fly ash by utilizing it as a construction material.

Fly Ash

Fly ash is byproduct of coal combustion used in order to generate electricity, which is widely available worldwide and lead to waste management proposal. Thus, geopolymer concrete produced by using fly ash is an excellent alternative to overcome the abundant fly ash byproduct. Fly ash is a pozzolanic material which is being used as a supplement material in the production of Portland cement concrete due to its cementations properties [9]. The physical, mineralogical and chemical properties of fly ash will strongly affect the performance of fly ash. The use of high fineness and low carbon content of fly ash will reduces the water demand of concrete which allow the production of concrete at lower water content when compared to a Portland cement concrete of the same workability [9].

Table 1. The production and reuse of fly ash in the United States, 2012 [15]

Items	Fly Ash Production (Tons)	Fly Ash Reuse (Tons)	Fly Ash Reuse in Cement (Tons)
Fly Ash	52,100,000	23,205,204	2,281,211

The amount of waste produced depends on a lot of factors, such as air pollution control system technology, production process, incinerator technology and operation, and feed waste composition. Table 2 shows typical amount of some waste produced.

Table 2. Typical amounts of incinerated waste produced [10]

Byproduct	Quantity (kg/ton)
Fly ash	10 - 30
Bottom ash	250 - 420
Boiler ash	2 - 12
Grate siftings	5
Economizer ash	Small

Fly ash can be disposed in two types of condition which is dry condition or wet condition. Based on previous studies, fly ash in wet condition does not prevent the metal from transferring into the soil. Heavy metals cannot be degraded biologically into harmless products like other organic waste [11]. Previous studies also show that coal ash which is a non-hazardous materials comply the criteria for landfill disposal [13]. Fly ash can be considered as a byproduct rather than waste. Table 3 shows the thermal power generation, ash generation and coal consumption of fly ash.

Table 3. Thermal power generation, ash generation and coal consumption in India [10]

Year	Thermal power generation (mW)	Ash generation (mt)	Coal consumption (mt)
1995	54 000	75	200
2000	70 000	90	250
2010	98 000	110	300
2020	137 000	140	350

Characterization of Fly Ash

The fly ash used for the characterization was from Sultan Abdul Aziz Power Station in Kapar, Selangor. The fly ash was classified as Class F fly ash accordance to ASTM. The composition of fly ash was analyzed by using X-ray Fluorescence (XRF), as shown in Table 4. The composition of fly ash shows that the SiO_2 and Al_2SiO_3 content in fly ash is very similar to Portland cement which makes fly ash suitable to be used in construction materials.

Figure 1 shows the microstructure of fly ash determined by means of SEM. The morphology of fly ash consists mostly of a glassy, hollow, spherical particle, which is a cenosphere (thin-walled, hollow spheres); which is supported by Davidovits [12].

Table 4. XRF analysis data of fly ash composition

Composition	Percentage
SiO_2	52.11 %
Al_2O_3	23.59 %
Fe_2O_3	7.39 %
TiO_2	0.88 %
CaO	2.61 %
MgO	0.78 %
Na_2O	0.42 %
K_2O	0.80 %
P_2O_5	1.31 %
SO_3	0.49 %
MnO	0.03 %

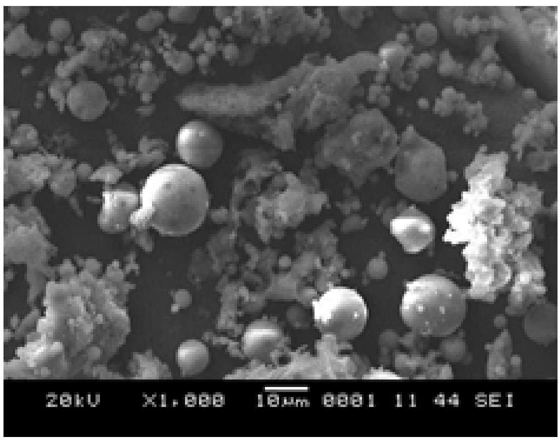

Fig. 1. Morphology of fly ash

Effect of Fly Ash on Properties of Concrete

Fly ash is suitable for utilization as pozzolanic material. It reacts chemically with calcium hydroxide at room temperature to form compounds that have cementation properties in the presence of moisture. Fly ash comprises of a high amount of reactive silica and alumina. These reactive elements complete the hydration chemistry of cement. On hydration, cement produces C–S–H gel and free lime such as $CaOH_2$, which binds and reinforces the concrete. Water, sulphates and CO_2 that exist in the environment attack the free lime causing the deterioration of the concrete. However, cement technologists observed that the reactive elements present in fly ash resolves the free lime problem of the cement and turn the concrete from deteriorate into durable. The distinction between fly ash and OPC becomes apparent under optical microscope. The morphological properties of fly ash make the fly ash to flow and blend freely in mixtures. This property makes fly ash a good admixture for brick production [7]. The addition of fly ash in concrete will give various affect to the properties of concrete. Table 5 summaries the effect of fly ash addition to the properties of concrete accordance to type of property.

Table 5. The Effect of Fly Ash on the Properties of Concrete [14]

Property	Effect of Fly Ash
Fresh concrete	• Improved workability • Reduced water demand for most fly ashes. • Produced concrete with more cohesive and segregates less-improved pump ability. • Reduced bleeding especially at high replacement level.
Set time	• Extended-especially in cold water. • Can increased or retarded the setting time for certain combinations of fly ash, cement and chemical admixtures.
Heat of hydration	• Reduced for Class F fly ash at normal levels of replacement, Class C fly ashes have to be used at higher levels of replacement to reduce heat (for example ≥ 50%). • Increased in reduction by using high levels of replacement, low total cementitious contents, and low concrete placing temperature.
Early age strength	• Reduced the early strength of concrete especially at first day. • Class F will have a greater reduction and for higher replacement levels of fly ash.
Long term strength	• Improved long term strength. • Strength improved with the increment of replacement level of fly ash.
Permeability and chloride resistance	• Reduced by time.
Expansion (alkali-silica reaction)	• Reduced. • Sufficient levels of replacement can completely suppressed deleterious.
Sulfate resistance	• Increased for class F fly ash. • Resistance to cyclic immersion in sodium sulphate solution and drying has been shown to be relatively unaffected by up to 40% fly ash.
Resistance to carbonation	• Decreased. • Significant decreases when high levels of fly ash are used in poorly-cured, low-strength (high w/cm) concrete.

Potential of Fly Ash

For as far back as some decades, the utilization of fly ash in building development had a great track record. The performance benefits that fly ash provides to mechanical and toughness properties of brick have been decently inquired and recorded in real structures. Presently, fly ash is utilized as part of more than half of all prepared mixed brick put in the United States, and many design experts proceed to remain overly restrictive with regards to utilizing fly ash as a part of construction materials [10]. Hence, many studies have been conducted on cement and concrete applications which were authorized and federally approved. Table 6 shows the potential of fly ash application.

Table 6. Potential areas for fly ash utilization

The usage of Fly Ash	Description
Fly ash in Geopolymer	Geopolymer concrete with fly ash produced a concrete with high compressive strength, low creep, good acid resistance and low shrinkage. The role of binder in concrete is replaced by fly ash based geopolymer paste which also possesses pozzolanic properties as OPC and high alumina and silicate content.
Fly ash bricks	Fly ash bricks have a number of advantages over the conventional clay bricks and concrete brick in term of its properties. Fly ash can also produce unglazed tiles for use on footpaths.
Fly ash in manufacture of cement	Fly ash is suitable for use as pozzolanic materials. In the presence of moisture, it reacts chemically with calcium hydroxide at room temperature to form compounds possessing cementitious properties. Fly ash has a high amount of silica and alumina in reactive form which complements the hydration chemistry of cement. This property makes fly ash an excellent admixture for producing concrete.
Fly ash in ceramics	A process to produce ceramics from fly ash having superior resistance to abrasion had been developed.
Fly ash in road construction	Fly ash can be used to stabilize the soil for sub based in road construction.

Conclusions

A pozzolanic property from a fly ash shows a good potential of fly ash to be managed as construction materials. There remains significant room for improvement in the quantity and quality of these products recovered from fly ash. Fly ash may improve the characteristics of the concrete for application in cement and concrete products. However, further efforts need to be done on recovery of products from fly ashes with a wide range of characteristics.

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