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Fire Resistance of Lightweight Concrete Bricks Containing EPS and POFA: A Review

A.W. Norhayati[1], M. Zaulkafli[2], A. Suraya Hani[3*]

[1]*Politeknik Mukah, Sarawak,* [2]*Politeknik Tawau, Sabah,* [3]*Universiti Tun Hussein Onn Malaysia*

Abstract

To build environmentally sustainable structures, especially in developing countries, the possibility of using some agricultural wastes and industrial by-products from different industries as construction materials will be highly desirable and has several practical and economic advantages. Polystyrene (EPS) are widely using for many purpose including in construction industries. One of the major wastes in construction site is the polystyrene. Polystyrene are using as temporary block out of unfinished structure and architecture work such opening for slab, beam, wall and column. This phenomenon might lead to generate a lot of waste that can conclude as a material that not renewable. Malaysia also known as a country that produces palm oil, and this situation leads to generate a lot of agro-waste. Palm oil fuel ash (POFA) is an agro-waste resulting from the combustion of oil palm plant residue in palm oil industry. After the extraction of oil from oil palm fruit, both husks and shells are burnt resulting ash, known as POFA, is generally disposed of in open fields, thus creating environmental and health problems. Many researchers reported that properly processed POFA is adequately reactive and possesses good pozzolanic activity, and therefore can be used successfully as a supplementary cementing material for the production of concrete for building materials. Instead of just throw both of this wastes, it is better to study the potential of using both POFA and EPS to create a new sustainable, green material that will save our environment and also may lead to cost effective, time effective and energy saving in line with government target in eleventh plan. This paper provides a review of research on the capabilities of two materials namely EPS and POFA are used separately as substitutes in concrete and lightweight concrete bricks production. While in my study, this two materials were used according to the percentage to assess the effectiveness of POFA and EPS to be used in production of lightweight concrete brick converging on its mechanical properties and its workability as fire resistance.

Keynote : POFA,EPS, lightweight concrete brick, fire resistance

Introduction

In RMK 11 it was highlighted that Malaysia government will fostering the sustainable practices in construction in line with growing of need for green construction practice. This strategy will include inculcating green practices in the construction value chain and developing legislation that supports sustainable construction activities. The strategies taken is to increase productivity in the construction sector and will focus on increasing technology adoption and modernization of construction methods as well as reducing dependency on low-skilled labor due to the construction sector will become more important due to higher demand and it expected to grow at 10.3% annually with a contribution of RM327 billion by 2020. Application of new method of construction materials not only will contribute to the government aim, however it might lead to improve our country to fully utilize the sources that have in our country. Polystyrene (EPS) are widely using for many purpose including in construction industries. One of the major wastes in construction site is the polystyrene. Polystyrene are using in construction during construction stage in a various type of uses. with high thermal mass without considering the importance of thermal comfort zone in the houses. In accordance with ASHRAE Standard 55, thermal comfort is defined as “condition of mind which express satisfaction with the thermal environment and is assessed by subjective evaluation”.

This phenomenon might lead to generate a lot of waste that can conclude as a material that not renewable. During construction stage, there is several type of using polystyrene. It can be used as temporary block out of unfinished structure and architecture work such opening for slab, beam, wall and column. Beside polystyrene waste, Malaysia also known as a country that produces palm oil, and this situation leads to generate a lot of agro-waste. Palm oil fuel ash (POFA) is an agro-waste resulting from the combustion of oil palm plant residue in palm oil industry. After the extraction of oil from oil palm fruit, both husks and shells are burnt resulting ash, known as POFA, is generally disposed of in open fields, thus creating environmental and health problems.

According to the previous study for brick containing EPS it was highlighted that lesser percentage of polystyrene will lead to increase the fire resistance of the brick. The amount of cement and decrease percentage of EPS improves the fire resistance of polystyrene. Application of EPS beads will decrease the strength properties of the concrete. However, it may have potential to produce different strength-grades of concrete or product. EPS beads can be easily mix with any different contents in concrete to produce lightweight concrete with a wide range of densities. However, EPS normally will not be used in the structural lightweight concrete due to their mechanical properties of strength is poor, (Bin Chen, 2005). According to the Sadr Momtazi (2011), the strength of the EPS depends on the substitution of the EPS. As we know, Malaysia is a country that has a lot of producing of palm oil. This scenario leads to generate of a huge waste that become one of the major contributors that produce palm oil shell and palm oil fuel ashes. Increased agricultural production and the development of agro-based industries in many countries of the world have brought about the production of large quantities of agricultural wastes, most of which are not adequately managed and utilized. Nowadays, some of the agricultural wastes have been carried out in production of building materials due to depletion of traditional building materials (Ismail Demir, 2006).

Concrete Brick

Concrete brick is made from dry mix of cementitious materials, aggregates, water, and occasionally special admixtures. The material is molded and cured under controlled conditions to produce a strong, finished block that is suitable for use as a structural building element. Both the raw materials and the method of manufacture influence strength, appearance, and other mechanical properties of the brick. Concrete masonry manufacturing consists of six phases which is start by receiving and storing raw materials, followed by batching and mixing process, molding unit shapes, curing, cubing and storage, and finally delivery of finished units (see Figure 1). Autoclaved with high pressure steam was used during curing process. High-pressure steam curing enhances the quality and uniformity of concrete brick besides improve production rate and lowers cost of manufacturing.

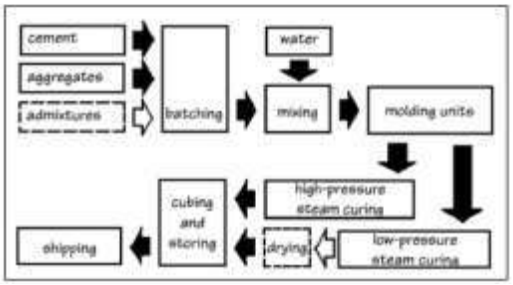

Figure 1: Concrete brick manufacturing process (Beall, 2004)

Polystrene

Polystyrene is a plastic that had been used to make a wide variety of consumer products. When combined with various colorants, additives or other plastics, polystyrene is used to make appliances, electronics, automobile parts, toys, gardening pots and equipment and more. Polystyrene also is made into a foam material, called expanded polystyrene (EPS) or extruded polystyrene (XPS), which is valued for its insulating and cushioning properties. Foam polystyrene can be more than 95% air and is widely used to make home and appliance insulation. Polystyrene is made by stringing together, or polymerizing, styrene, a building-block chemical used in the manufacture of many products. Polystyrene is highly stable and resistant to decomposition, largely due to the presence of phenyl groups and single C Cbonds. (Chaukura, 2015)

Expanded polystyrene (EPS)

EPS has been widely known as one of the most preferable lightweight materials used in the production of lightweight building materials. This is due to its properties which is extremely light which could contribute significant reduction of the structure weight. EPS also has good energy absorbing characteristic and good thermal insulator. Beside, EPS is safe to be use complies with all relevant technical environment standards.

Rigid and tough, closed-cell foam is a characteristic of expanded polystyrene (EPS). Normally in white color and was made of pre-expanded polystyrene beads. EPS widely using for many applications such as trays, plates, bowls and fish boxes. In construction it normally use for molded sheets for building insulation and packing building material Uses of polystyrene for construction is including to insulate ceilings, walls and floors (Chaukura, 2015). EPS beads can be easily mix with any different contents in concrete to produce lightweight concrete with a wide range of densities. However, EPS normally will not be used in the structural lightweight concrete due to their mechanical properties of strength is poor. (Bing Chen & Congqi Fang, 2011). According to Yi Xu & Lin Hua Jiang(2011), EPS bricks have obvious benefits of improving thermal insulation, absorbing sound characteristics and have a potential to reduce the loads of building walls. Thus, it can be considered that the EPS lightweight bricks were suitable for masonry walls due to it cost effective.

Palm Oil Fuel Ash (POFA)

Palm oil fuel ash (POFA) is a solid waste by-product of palm oil industry obtained from the burning of palm oil husk and palm kernel shell used as fuel in palm oil mill steam boiler. Abundance of research of POFA as cement replacement in the concrete mixture has been conducted. Based on the findings, it was found that POFA is one of the agricultural wastes which has similar characteristic of cement which it also can act as the binder in the concrete mixture through the pozzolanic reaction. In addition, it also found that POFA can increase the strength of the brick and enhance the fire resistance performance of brick. Palm oil fuel ash is a by-product produced in palm oil mill. After palm oil is extracted from the palm oil fruit, both palm oil husk and palm oil shell are burned as fuel in the boiler of palm oil mill. Generally, after combustion about *5%* palm oil fuel ash by weight of solid wastes is produced (Sata et al., 2004). The ash produced sometimes varies in tone of colour from whitish grey to darker shade based on the carbon content in it. In other words, the physical characteristic of POFA is very much influenced by the operating system in palm oil factory. In practice, POFA produced in Malaysian palm oil mill is dumped as waste without any profitable return (Sumadi & Hussin, 1995).

Palm oil fuel ash (POFA) is an agro-waste resulting from the combustion of oil palm plant residue in palm oil industry. Malaysia, Indonesia and Thailand are the main producers of palm oil, which is a leading agricultural cash crop in these tropical countries. After the extraction of oil from oil palm fruit, both husks and shells are burnt in boiler to produce steam for the turbine engine, which generates electricity for use in palm oil mills (Mahlia et al., 2001). After burning, the resulting ash, known as POFA, is generally disposed of in open fields, thus creating environmental and health problems (Tonnayopas et al., 2006). In order to find the solution to these problems, several studies were conducted to examine the feasibility of using POFA in construction materials. Starting from 1990, many researchers reported that properly processed POFA is adequately reactive and possesses good pozzolanic activity (Abdullah et al., 2006; Sata et al., 2004; Hussin and Awal, 1997), and therefore can be used successfully as a supplementary cementing material for the production of concrete.

Figure 2.1: Palm Oil Fuel Ash (POFA) and Expanded Polystyrene Beads (EPS)

POFA as an Ordinary Portland Cement (O.P.C) replacement

It had been proved that POFA is a cementitious that has good pozzolanic properties that can be replaced as a cement substitute in mortar and concrete mixes (Abdul Awal *et al.*2010). Tay (1990) used unground POFA to partially replace ordinary portland cement (OPC) and showed that unground POFA shall not be used with a content higher than 10% of cement by weight due to its low pozzolanic property. Hussin and Ishida (1999) used 20 – 40% ground POFA by weight of OPC in concrete. They found that the compressive strength, modulus of elasticity, Poisson's ratio, shrinkage and creep of concrete were comparable to that of OPC concrete up to 30% replacement of cement. In addition, Hussin and Awal (1996, 1997) has shown that it is possible to use 40% ground POFA without affecting the concrete strength. It was also shown that the POFA concrete is sufficiently durable in addition to having a good strength.

According to Sumadi and Hussin (1995), ground POFA can be used up to 20% cement replacement level with a durability factor at least comparable to that of OPC concrete. Ground POFA had shown good resistance to expansion due to sulfate attack (Awal and Hussin, 1997a; Jaturapitakkul et al., 2007) and alkali-silica reaction (Awal and Hussin, 1997b). POFA has been used not only in normal concrete but also in special concretes such as high-strength, high performance, and aerated concretes. Sata *et al*. (2004) made high-strength concrete with POFA and showed that the concrete containing up to 30% ground POFA provided a higher compressive strength than OPC concrete at later ages. Awal and Hussin (1999) used POFA to produce high performance concrete with reasonably a good durability. In addition, Abdullah et al. (2006), and Hussin and Abdullah (2009) used ground POFA in aerated concrete. Thus, the published literature shows that POFA has a good potential for the production of different types of concrete. The recent research studies show that POFA can also be used in other construction materials such as bricks and stone mastic asphalt (Ismail et al., 2010; Kamaluddin, 2008; Nasly and Yassin, 2009). Ismail et al. (2010) produced bricks with satisfactory compressive strength using POFA and paper sludge. Nasly and Yassin (2009) mentioned that POFA can be incorporated in interlocking blocks for use in sustainable housing. Besides, Kamaluddin (2008) used POFA as a filler material to produce stone mastic asphalt with enhanced stability, stiffness, and tensile strength. EPS and POFA are an agricultural solid waste in palm oil industry and can be an alternative material for production highly lightweight in the building environmentally sustainable structures. Results obtained from last researches the brick with maximum waste replacement at 25% POFA and 50% EPS gives the best result as it has highest waste content and it can achieve the lightweight, compressive strength requirement for a lightweight brick and low water absorption N.A. Kamarulzaman et. al (2018).

Fire Resistance

Fire resistance tests are intended to assess the performance of elements of construction for their load-bearing or fire separating properties usually termed their fire resistance for their regulated use in buildings. Fire resistance of beams, columns, doors, wall sections, etc., is determined by their performance in large furnaces (capable of holding specimens of 3 m long or of area 3 m × 3 m) against a standard temperature-time curve, typically rising from ambient to 850 °C over 20 minutes. These tests are designed for concrete, brick or steel (protected) elements T.R.Hull (2008)**.** In previous studies, cement sand brick has lower values of compressive strength, fire resistance and chemical-attack resistance (Abdullah, 2009). In this study, the fire resistance of lightweight bricks will be considered including other experiments as shown in Table 1.

Table 1: List of standards used to conduct the tests.

Laboratory Test	Standards	Review
Density of Samples	BS EN 12390-7 <1680kg/m³ (lightweight)	N.A.Kamarulzaman et.al, 2018
Compressive Strength	ASTM C109-07	N.A.Kamarulzaman et.al, 2018
Water Absorption	BS1881: Part 122	N.A.Kamarulzaman et.al, 2018
Fire Resistance	ASTM E 119	J.Gregg Borchelt & John Swink, 2013

ASTM E 119 was to evaluate the fire resistance rating of the specimens. This test method evaluates the duration for which the assembly tested will contain a fire, retain its structural integrity, or display both properties for a predetermined fire exposure time. For these tests a one-hour duration was established as the maximum time. E119 subjects the exposed face to a specified time-temperature curve, rapidly increasing in temperature initially and tapering off with time. If any component of the wall assembly begins to burn or contribute to the heat rise in the furnace the gas flow to the furnace is stopped until the temperature returns to the prescribed value.

CONCLUSION

Generation of solid waste is a serious problem and researchers have been trying to utilize the waste generated from various sectors in order to be more sustainable. According to the previous study for brick containing EPS it was highlighted that lesser percentage of polystyrene will lead to increase the fire resistance of the brick. This paper provides a review of research on the capabilities of two materials namely EPS and POFA are used separately as substitutes in concrete and lightweight concrete bricks production. While in my study, these two materials were used according to the percentage to assess the effectiveness of POFA and EPS to be used in production of lightweight concrete brick converging on its mechanical properties and its workability as fire resistance. Therefore, in the present study, an effort will be taken to develop a lightweight concrete brick which has a better performance than normal brick in term of low density, high compressive strength, low water absorption and fire resistance.

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