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Microstructural investigation and durability performance of high volume industrial by-products-based masonry mortars

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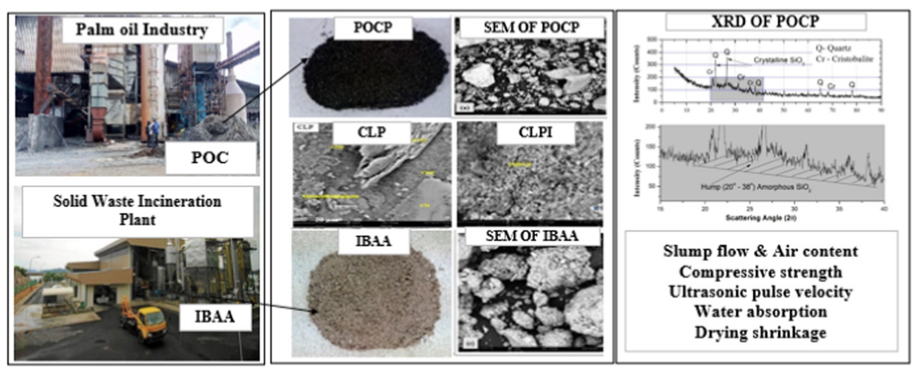
HIGHLIGHTS

- Influence of POCP and IBAA in masonry mortar investigated.
- Microstructural behaviour assessed using SEM and XRD techniques.
- Use of 40% POCP produced better durability performance.
- Use of IBAA up to 50% produced requisite strength in masonry mortar and sustainable.

GRAPHICAL ABSTRACT



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ABSTRACT

The use of eco-efficient building materials in construction has become a trend in regard to the effort of mitigating the effect of global warming which include CO_2 emission, energy demand, and natural resources depletion that lead to negative environmental impacts. The present study was attempts to investigate the microstructure behaviour and durability performance of masonry mortars. In this context, palm oil clinker powder (POCP) was utilised to replace cement up to 80%, while the incinerated bottom ash aggregates (IBAA) was utilised to replace mining sand up to 100%. Eventually, further investigation was carried out on the durability performance through water absorption, sorptivity, sulphate attack, and electrical resistivity on the ideal mixtures of 40% of POCP (CLP) and IBAA with 50% (CLPI50) & 100% (CLPI) mixtures. As a result, irregular shape of POCP particles in SEM and the presence of high silica in POCP were observed to produce the peaks of portlandite as well as early occurrence of calcite. In this case, IBAA particles have angular, while porous microstructure in SEM and the XRD results showed high peaks of quartz and calcite. The final mixes containing CLP, CLPI50, and CLPI respectively obtained 51, 56, and 61% of 28-day compressive strength of control mix (CL) that was greater than the requisite 12.4 MPa. On another note, the mix- CLP showed better durability performance (6% water absorption, 84 mm/100 cm^2 of IRA) compared to CLPI50 (7%, 89 mm/100 cm^2), while the drying shrinkage performance of CLP possessed similar trend to that of the CL (0.064%). Finally, the mix CLP managed to produce extremely good electrical resistivity.

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1. Introduction

The rapid growth in the production of industrial waste in different parts of the world has caused more harmful environmental effects including landfilling disposal; hence, the use of industrial waste in the composition of building materials has gained its momentum because it is in line with the sustainable development goals. The palm oil industry tends to produce a huge amount of wastes in the shape of empty fruit brunches, fibres, oil palm shell (OPS), palm oil fuel ash (POFA), and palm oil clinker (POC) [1,2] considering that it is one of the most recognized industrial by-products in the ASEAN region, particularly in Malaysia. Generally, Malaysia is widely known for palm oil production and it is the second largest producing country in the world after Indonesia which annually generates about 2.6 million tonnes of solid waste consisting of high amount of POC and OPS [3]. In regard to this matter, there had been numerous researches carried out on OPS as coarse aggregate replacement, but recently it has also been used as blast resistant aggregate [4,5]. On the other hand, the interest on the usage of POC as potential construction material has gained considerable attention [6,1,7,8]. Moreover, it is important to note that POC causes environmental problems because it is normally stored in open fields, in which the surrounding is often polluted due to that landfilling occurring in the vicinity of palm oil industries. However, POC is regarded as a potential waste by-product that can be converted into building materials in diverse forms such as coarse, fine aggregates as well as cement replacement materials in concrete or mortar.

On a similar note, another solid waste that must be of concern to the environment is municipal solid waste that tends to generate an approximate total of about 1.7 to 1.9 billion metric tonnes annually [9], thus posing a serious threat to the environment considering that they are disposed as landfill [10]. Hence, government regulatory bodies have been enforcing the related companies to dispose-off these wastes safely, including the effort shown by the governing research funding bodies and companies in conducting research projects that can help to figure out a way to convert the wastes into potential building material [11,12]. For example, environmental policies in advanced countries alike Singapore and Japan emphasize the need to pare landfill disposals as much as possible due to the scarce amount of land as well as tight environmental controls, whereby approximately 80% of the wastes are incinerated and then recycled and reused in different ways [13,14]. However, greater than 80% of waste in China ends up as compost production and landfilling. In relation to this, it is crucial to acknowledge that the recycling and reusing is the best management strategy for waste [15]. Therefore, it can be seen that most developed countries have opted for the recycling method known as the incineration process which are further separated into three different parts. The schematic diagram that depicts the common municipal solid waste incineration process is shown in Fig. 1.

On the contrary, the ground clinker as well as clinker that is produced from the burning of raw materials of limestone and other materials in kiln are the primary raw materials for production of Portland cement. Moreover, this process consumes about 1.7 tonnes of raw materials of limestone per tonne of clinker produced. Apart from that, approximately 3.2–6.3 GJ of energy are required to process these materials for every tonne of clinker produced [17]. In addition, it should be noted that clinker production is often accompanied by a significant amount of emission that contributes to 5–8% of CO_2 greenhouse gas emission [17–19]. Correspondingly, the impact of carbon footprint of cement – lime mortar on the environment is deemed as an indicative due to the conflict of cement-based mortars with old materials. Furthermore, the proportion of cement and aggregates in the ratio of 30:70% for mortar application tend to form a major portion of the mortar volume. Hence, the value of fine aggregates in mortar is very important considering the occurrence of recent flooding coupled with receding of ground water in many countries that projected the seriousness of infiltration of ground water as well as the crucial need for sand deposits to be preserved for the purpose of maintaining ecological balance. On another note, the exploitation of natural aggregates is quite alarming with an estimated amount of 8–12 billion tonnes are used annually [20]. Apart from cement, the aggregates and minerals from virgin sources have been used quite extensively in traditional construction [21].

The durability performance of materials available as by-products waste has to be examined and reported, which can be

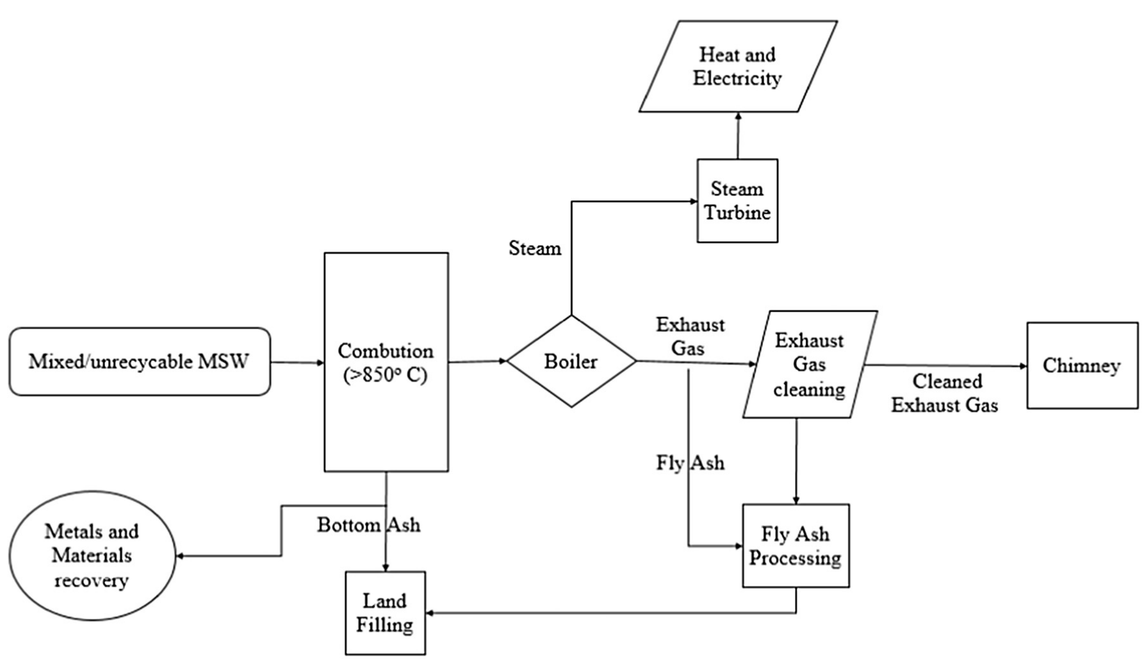

Fig. 1. Schematic diagram of depicting the common municipal solid waste incineration process (Source: adopted [16]).