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# UTILIZATION OF POLISHING SLUDGE (PS) AND BODY MILL SLUDGE (BS) INCORPORATED INTO FIRED CLAY BRICK

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## ABSTRACT

Brick manufactured from mosaic sludge waste and clay is investigated considering the huge volume that has been produced and the effect towards the environment. In this study, the research attempt to reuse two types of mosaic sludge from polishing (PS) and body mill (BS) process conducted in mosaic industries to be incorporated into fired clay brick. The mosaic sludge is used to replace the raw material which is clay up to 10%. In this investigation, the composition and concentration of heavy metals were determined by using X-Ray Fluorescence Spectrometer (XRF). Physical and mechanical properties test were conducted (compressive strength, shrinkage, density and initial rate of suction). The results show that PS brick (5%) and BS brick (5%) obtained the highest compressive strength, low density and less total shrinkage compared to other percentages. Nevertheless, all properties for all bricks incorporated with different percentages of mosaic sludge were complied with the British Standard 3291:1985. Both mosaic sludge (PS and BS) could be an alternative low cost material for brick and at the same time provide an environmental friendly disposal method for the waste.

**Keywords:** bricks, mosaic sludge, compressive strength, density, shrinkage, initial rate of suction.

## INTRODUCTION

Sludge often related with human waste from residential sludge, however sludge could also be the accumulated solid which consists of industrial waste, hospital waste, wastewater waste, run off water from the street, agricultural and some cases from landfill leachate generated. Generally sludge came from residential areas is in organic state. Human waste can cause less harmful and impact to the environment compared to industrial waste it is because industrial sludge could be in organic or inorganic form. Inorganic content of industrial sludge such as heavy metals should get the particular treatment to prevent environmental pollution. Furthermore, sludge from industrial also becomes a critical issue [1] as huge amount was disposed to the landfill and the limited availability of land is a major concern. Mosaic is a colored pieces of hard material in form of stone, tile or glass. Mosaic provided a durable form of ornament for walls and pavements. Mosaic was made by clay, sand, feldspar, quartz and water. Mosaic ingredients are mixed homogenously to formthebody slip of the mosaic. Body slip is used to be a base for coating. Drying and heating process will be carried out on body slip until it will turn into a powder and dry dust followed by dry pressing process. The different temperature usage will produce different durability for the tiles. Maximum temperature is 2500 degree Fahrenheit [2]. In mosaic manufacture process, it produces several of waste that may constitute of sludge, dust and solid waste. These wastes will further increasing the environmental pollutants. The majority of traditional ceramic products will produce oxides such as silica, alumina, lime, alkaline oxides and magnesium oxides [3]. Mosaic sludge content heavy metals from mosaic colouring substances process and need to be managed properly. Recently, many types of waste have turn into alternative low cost raw material in brick and this is due to high demand and flexibility of clay soil characteristics. Different types of waste have been successfully incorporated into fired clay brick especially sludge waste for example marble sludge, stone sludge, water treatment sludge, sewage sludge, desalination sludge, textile laundry sludge and ceramic sludge [4, 5, 6, 7, 8]. The utilization of these wastes in clay bricks usually has positive effects on the properties such as lightweight bricks with improved shrinkage, porosity, thermal properties, and strength [9]. The lightweight bricks will reduce the transportation and manufactured cost. Moreover, this replacement will reduce the content of clay soil in the fired clay brick that eventually reduce the manufacturing cost [10, 11]. This motivates many studies to investigate more on the potentialof different sludge to be incorporated into the brick. Therefore, the aim of this research is to examine the potential to manufacture fired clay brick incorporated with two types of mosaic sludge.

## MATERIAL AND METHODS

### Material

Mosaic sludge waste was collected at the mosaic manufacturer at Kluang, Johor. The mosaic sludge was collected in a semisolid condition. Clay soil was collected at the brick manufacturer at Sedenak, Johor. Both materials (clay soil and sludge mosaic) was kept properly in the box and been storage separately before been used.

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**Methods**

Mosaic sludge and clay soil were dried into the oven for 24 hours. Then, the mosaic sludge and clay soil were crushed and were prepared in pellet form before being tested for X- ray fluorescence (XRF) by using Philips software SemiQ machine.

In the brick manufacturing process, different percentages of sludge were mixed with clay soil using a mechanical mixer. Water content is an important factor affecting the quality of the brick; therefore, compaction test was conducted to determine the optimum moisture content (OMC). Using this OMC, the mixtures with various proportions of mosaic sludge and clay soil were prepared in brick manufacturing. The mixtures were then moulded into a brick mould. After being dried for 24 hours in room temperature followed by another 24 hours at105˚C in theoven, the moulded mixtures were fired into a furnace at 1050˚C for another 24 hours. As a requirement based on BS 3921:1985 standards, the brick properties including total shrinkage, density, compressive strength and initial rate of suction were determined.

## RESULT AND DISCUSSIONS

**X-ray Fluorescence (XRF)**

The composition of clay soil and mosaic sludge produced from both BS and PS process varies considerably depending on the type of raw material and the process that have been done during manufacturing. The result shows the highest percentage of clay was silicon dioxide ($SiO_2$) and aluminium oxide ($Al_2O_3$) (between 57.6% to 58.10% and 31.5% to 32.0% respectively). The mosaic sludge also shows that the highest percentage was demonstrated by silicon dioxide ($SiO_2$) and aluminium oxide ($Al_2O_3$) between 65.5% to 68% and 21.6% to 23.8% respectively. The concentrations of heavy metals for the clay soil and mosaic sludge (BS and PS) shown that high value of titanium (Ti), manganese (Mn), ferum (Fe), zinc (Zn), zirconium (Zr) and barium (Ba) and all these heavy metals were more than 100ppm.

**Total shrinkage**

The contracting of hardened mixture due to the loss of capillary water was defined as firing shrinkage [12]. Shrinkage depends upon several factors include the properties of the mechanisms, the proportion of the components, mixing manner, the amount of moisture, and dry environment. From Table 1, it shows that the 5% of BS brick obtained the lowest shrinkage with 0.34% followed by 1% and 0% of BS brick with 0.43% and 0.59% respectively. BS brick with 10% showed the highest among the other with 0.69%. Similarly PS brick (10%) also has shown the highest shrinkage value with 0.56% and followed by 1% and 5% of PS brick with 0.50% and 0.34%. Nevertheless, all manufactured bricks do not exceed 1% of shrinkage. Referring to the previous research, in order to yield a good quality brick the brick should not be more than 8%.

**Table-1.** Total shrinkage of the manufactured bricks.

| | **Control** | **BS** | | | **PS** | | |
|---|---|---|---|---|---|---|---|
| Percentage of mosaic sludge (%) | 0% | 1% | 5% | 10% | 1% | 5% | 10% |
| Drying shrinkage (%) | 0.15 | 0.15 | 0.26 | 0.26 | 0.15 | 0.26 | 0.26 |
| Firing shrinkage (%) | 0.69 | 0.46 | 0.31 | 0.56 | 0.47 | 0.31 | 0.56 |
| Total shrinkage (%) | 0.59 | 0.43 | 0.34 | 0.69 | 0.50 | 0.34 | 0.56 |

**Density**

Table-2 shows the density for BS brick and PS brick. BS brick (5%) shows the lowest with 1680kg/m$^3$ and the highest was control brick (0%) with 1690.81kg/m$^3$. Whilst, density value for BS brick 10% and 1% were 1683kg/m$^3$and 1688kg/m$^3$ respectively. On the other hand, density result for PS brick (5%) shows the lowest density with 1688kg/m$^3$, followed by 1% and 10% PS incorporation with 1690kg/m$^3$ and 1692kg/m$^3$, respectively. Common density for bricks were between 1500kg/m$^3$ to 2000kg/m$^3$ and density values of all brick samples falls within the range. Furthermore, transportation and manufactured cost will be reduce if the bricks arelightweight [13].

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**Table-2.** Density of the manufactured bricks.

| | Control | BS | | | PS | | |
|---|---|---|---|---|---|---|---|
| Percentage of mosaic sludge (%) | 0% | 1% | 5% | 10% | 1% | 5% | 10% |
| Density (kg/m$^3$) | 1691 | 1688 | 1680 | 1683 | 1690 | 1688 | 1692 |

**Compressive strength**

Table-3 shows the result of the compressive strength for BS brick. The highest compressive strength obtained was BS brick (5%) with 25.8 N/mm$^2$ and followed by BS brick (10%) with 24.5N/mm$^2$. BS brick for 1% with 16.40N/mm$^2$ was higher than control brick with 14.92N/mm$^2$. However, for the PS brick, the result on Table-3 shows that the highest compressive strength was obtained by PS brick (5%) with 18.76N/mm$^2$, followed by PS brick (10%) with 18.25N/mm$^2$. Nevertheless, PS brick (1%) with 14.06N/mm$^2$ shows lower compressive strength compared to the control brick with 14.92N/mm$^2$. Obviously, all the results obtained and all the tested bricks were comply with the standard BS 3921:1985 between 7N/mm$^2$ to 100N/mm$^2$ but not satisfied to be classified as engineering brick.

**Table-3.**Compressive strength of the manufactured bricks.

| | Control | BS | | | PS | | |
|---|---|---|---|---|---|---|---|
| Percentage of mosaic sludge (%) | 0% | 1% | 5% | 10% | 1% | 5% | 10% |
| Compressive strength (N/mm$^2$) | 14.92 | 16.4 | 25.8 | 24.5 | 14.06 | 18.76 | 18.25 |

**Initial rate of suction**

Based on Table-4, the graph shows the amount of initial rate of suction for BS brick slightly decreased with 1% to 10% of incorporation. The highest was determined by BS brick (1%) with 11.4 g/mm$^2$ and the lowest was BS brick (10%) with average 10.51g/mm$^2$. As for PS brick based on Table-4, the lowest IRS values obtained were PS brick (5%) with average 10.08g/mm$^2$ followed by PS brick (10%) with average of 10.77g/mm$^2$. The highest value was determined by PS brick (1%) with average 12.88 g/mm$^2$. Based on the classification of brick in terms of initial rate by BS 3921:1985, the water initial rate was unsatisfied to be classified as damp-proof course brick but can be classified as all other brick no limits.

**Table-4.** Initial rate of suction of the manufactured bricks.

| | Control | BS | | | PS | | |
|---|---|---|---|---|---|---|---|
| Percentage of mosaic sludge (%) | 0% | 1% | 5% | 10% | 1% | 5% | 10% |
| Initial rate of suction (g/mm$^2$) | 11.31 | 11.4 | 10.92 | 10.51 | 12.88 | 10.08 | 10.77 |

**CONCLUSIONS**

As a conclusion, all the characteristic, percentages of sludge, physical and mechanical properties incorporated with mosaic sludge waste (BS and PS) were determined. The characteristic that was found by XRF shows the chemical composition of raw material of clay soil and mosaic sludge were high with silicon dioxide ($SiO_2$) and aluminium oxide ($Al_2O_3$). Therefore, the same characteristic of mosaic sludge is adequate to replace clay soil as a raw material. The results showed 5% of BS brick and PS Brick obtained the highest compressive strength with 25.8N/mm$^2$ and 18.76N/mm$^2$, less total shrinkage with 0.34% respectively and lowest density with 1680kg/m$^3$ and 1688kg/m$^3$. Incorporation of 5% mosaic sludge was recommended due to its physical and mechanical properties. The density and shrinkage for all brick was satisfied with average mass (1600kg/m$^3$) and complied with the standard and shrinkage which is below 8% and not exceeed 1%. It also had shown all different percentage with different result. It could be happen due to the cohesion between the soil and mosaic sludge that has been incorporated with suitable percentages, as the mixture can be mix properly and balance with the suitability on the bond. Nevertheless, all the mosaic sludge brick comply with the British Standard. It can be concluded that mosaic sludge is suitable as an alternative low cost raw material to replace clay soil in brick manufacturing while providing a suitable waste disposal method.

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