

Physical and Mechanical Properties of Bodymill Sludge (BS) Incorporated Into Fired Clay Brick

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Abstract. The huge volume of mosaic sludge that has been produced and the effect towards the environment had lead to the investigation of incorporating mosaic sludge into fired clay brick. In this study, the research attempt to reuse bodymill sludge (BS) from mosaic manufacturing process. The mosaic sludge is used to replace the raw material of clay up to 30%. In this investigation, the composition and concentration of heavy metal were determined by using X-Ray Fluorescence Spectrometer (XRF). Physical and mechanical properties test were also conducted such as compressive strength, shrinkage, density and initial rate of suction. Scanning Electron microscope was carried out to determine surface changes of the manufactured sludge brick. From the results, it shows that brick with 5% of BS sludge obtained the highest compressive strength and lower total shrinkage compared to other percentages. Nevertheless, all the other properties for all bricks incorporated with different percentages of mosaic sludge were complied with the standard (BS 3291:1985). Thus, mosaic sludge 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, SEM.

Introduction

In general, sludge is one of the waste that has been produced in liquid and semisolid. Few different industrial sludge such as textile laundry (Herek et al, 2012; Jahagirdar et, 2013; Mary and Sreeja, 2014; Swarna and Venkatakrishnaiah, 2014; Baskar et al, 2006), waste water treatment (Victoria, 2013; Hegazy et al, 2012; Saijun, 2011; Ramadan et al, 2008; Weng et al, 2003), petroleum treatment plant (Sengupta et al, 2002) were successful incorporated into clay brick. Industrial sludge could be in organic or inorganic form. Inorganic content of industrial sludge such as heavy metals should get the specific treatment to prevent environmental pollution (Abdul Kadir *et al*, 2014). Furthermore, heavy metal has effected in the environment appealed concerned amongst ecologist around the world (Lokhande et al, 2011; Zhao et al, 2015), also huge amount of waste was disposed to the landfill and the limited availability of land is a major concern (Abdul Latif, et al, 2012). Moreover, huge quantities of industrial sludge been disposed to landfill for a long time may release hazardous substances and may infiltrate into soil and groundwater (Abdul Rahim & Kadir, 2014; Swierk et al, 2007). Mosaic is



pieces of hard material that has made and known as stone, tile or glass. Mosaic or tiles was made from quarts, feldspar, clay, sand and water, it was used for decoration walls and pavement, also provides a durable surface. These materials are mixed homogenously to form body slip of the mosaic. Mosaic body slip is used to be a base for topping. Drying and heating process was carried out on body slip until it turns into powder and dry dust and then followed by dry pressing process. Higher temperature use will produce stronger tiles and can allowing chemical bonds between the flakes (Jones, 2008). Maximum temperature is 2500 degree Fahrenheit (Molly, 2008). In mosaic fabrication 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 (Segadaes et al, 2005). Mosaic sludge content chemicals from mosaic colouring substances and need to be managed properly. This is also supported by Vallette (2014) in his research on a healthy choice for ceramic tiles. Recently, many types of sludge waste have become alternative low cost raw material in brick and this is due to high demand and flexibility of brick. 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 (Agrawal *et al.* 2014; Kadir *et al.*, 2014; Abdul Kadir and Mohajerani, 2011). The lightweight bricks will reduce the transportation and manufactured cost. Moreover, this incorporation will reduce clay content in the fired clay brick that eventually reduce the manufacturing cost (Abdul Kadir and Sarani, 2015; Abdul Kadir and Mohajerani, 2015). This motivates many researches to investigate more on the potential of different sludge waste to be incorporated into the brick. Therefore, this research is to investigate the potential to manufacture fired clay brick incorporated with mosaic sludge.

Material and Method

Material. Mosaic sludge waste was collected in semisolid form at one of the local mosaic manufacture in Kluang, Johor. Clay soil was collected from brick manufacturer at Sedenak, Johor. Both of the materials, clay soil and sludge mosaic was kept properly in a closed container and been storage individually.

Method. Pellet shape was made before being tested with X- ray fluorescence (XRF) machine by using model S4-Pioneer Bruker-AXS (Germany). Crush samples for every brick percentage were scanned for scanning electron microscope (SEM) by using model ZEISS EVO LS10 (Germany). All raw materials (mosaic sludge and clay soil) were dried in the oven for 24 hours. After that the mosaic sludge and clay soil were crushed with suitable tools and being weighed with suitable ratio. In the brick moulding process, different percentages of sludge were mixed with clay soil using a mixer machine. 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. Control brick with 0% of sludge were also made for comparison purposes. After 24 hours drying in room temperature followed by another 24 hours at 105°C oven-dry period, the moulded mixtures were fired into a furnace at temperature 1050°C for another 24 hours. As a requirement by BS 3921:1985 standard, the brick properties including firing shrinkage, density, compressive strength and initial rate of suction were determined.

Result and Discussion

X-ray Fluorescence (XRF). The composition of clay soil and mosaic sludge produced from BS process. The properties vary considerably depending on the type of raw material and the process that have been done during the manufacturing. The results shown the highest percentage of clay was silica dioxide (SiO_2) and aluminium oxide (Al_2O_3) which is 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 silica dioxide (SiO_2) and aluminium oxide (Al_2O_3) between 65.5% to 68% and 21.6% to 23.8% respectively.

The concentration of heavy metals for the mosaic sludge and clay soil shows that the clay soil and mosaic sludge (BS) contain high value of titanium (Ti), manganese oxide (Mn), iron (Fe), zinc (Zn), zirconium (Zr) and barium (Ba) and all these heavy metals were more than 100ppm. This was due to the process of the sludge that the amount of heavy metals was higher because of the processing of colouring and glazing of the mosaic.

Scanning Electron Microscope (SEM). Scanning Electron microscope (SEM) test was conducted at Analytical environment laboratory (Faculty of Civil and Environmental Engineering). Samples were analysed by using SEM to determine the shape and sizes of pores development in the bricks as well as to examine the brick texture (Cultrone et al, 2004).

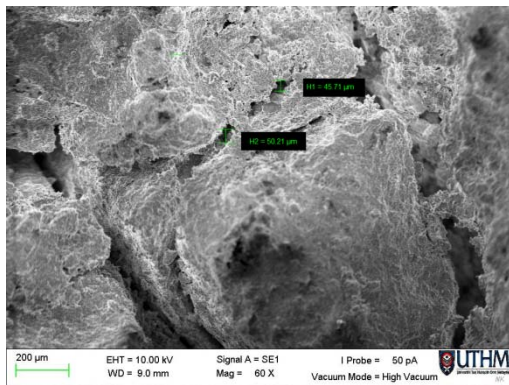


Figure 1a: Control Brick

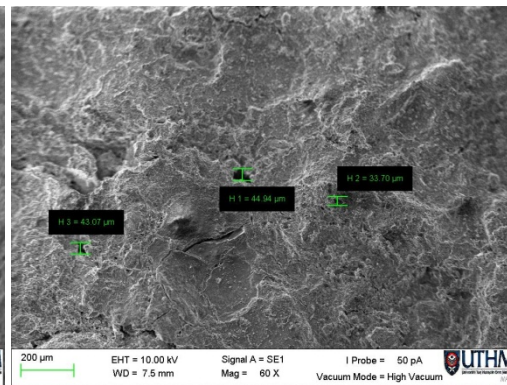


Figure 1b: BS Brick 1%

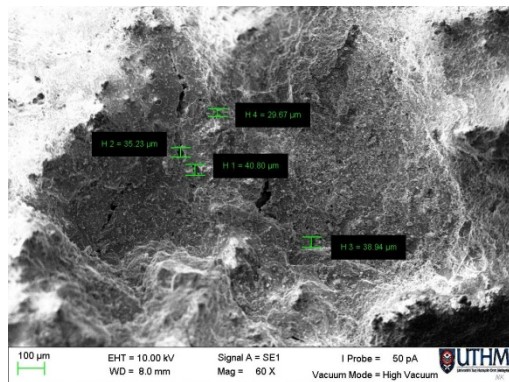


Figure 1c: BS Brick 5%

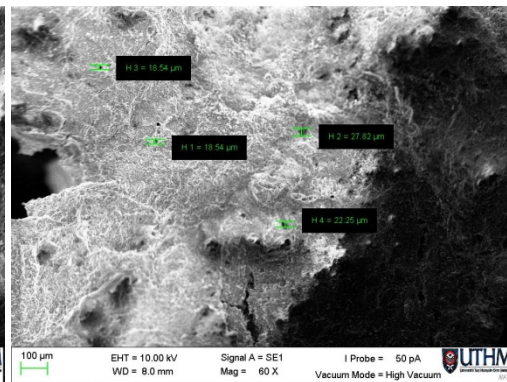


Figure 1d: BS Brick 10%

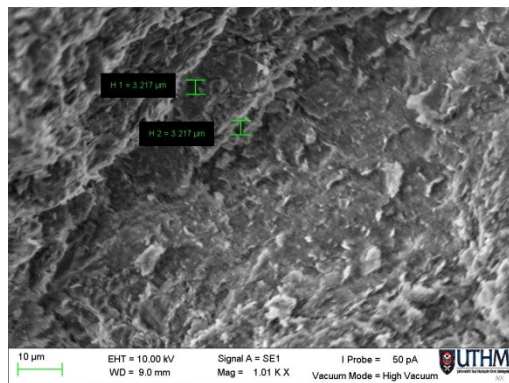


Figure 1e: BS Brick 20%

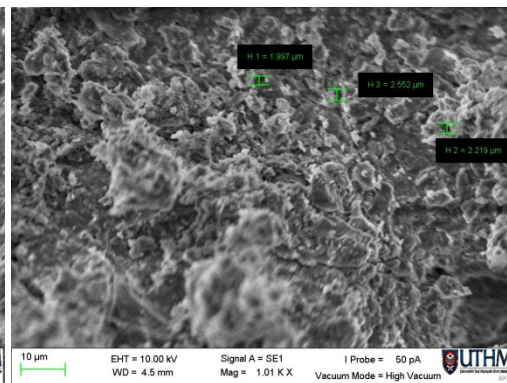


Figure 1f: BS Brick 30%

SEM were conducted in order to get a better understanding about microstructure in terms of porosity, Figure 1a to Figure 1f show SEM images of control brick and BS brick. The figures show that the surface structure appearances of the brick incorporated with mosaic sludge are finer compared to control brick. Furthermore, the images illustrate more coarse surface of brick with 0%, 1%, 5% and 10% compared to brick with 20% and 30%. The control brick shows the pore size was between $45\mu\text{m}$ to $50\mu\text{m}$. The BS brick shown 1% to 10% pore sizes samples were between $18\mu\text{m}$ to $44\mu\text{m}$. Meanwhile, for 20% and 30% it shows the pore sizes were between $1.9\mu\text{m}$ to $3\mu\text{m}$. This was due to the texture of mosaic sludge powder which is more fine compared to clay soil and this enable the mosaic sludge to cover and fill the gaps between the clay soil in the mixture. At this state, mosaic sludge brick (20% and 30%) gave smooth surface but the texture is more and less cohesion between the soils. According to Babu and Ramana (2013), addition of sludge may be attributed to changes in plasticity characteristic and filler action of sludge. Furthermore, BS up to 40% was visibly affected and it was supported by Ingunza et al. (2011) he also reported that the brick manufactured sludge up to 35% were very brittle and fractured as they were removed.

Physical and Mechanical Properties

Total Shrinkage. Firing shrinkage is defined as the contracting of hardened mixture due to the loss of capillary water (Koratic, 2009) Shrinkage depends upon several factors. These factors include the properties of the components, the proportion of the components, mixing manner, the amount of moisture, and dry environment. Furthermore, Rouf and Hossain (2003) claimed that drying and firing of the brick influences shrinkage behaviors. From Table 1 and Figure 2, it shows that the 5% of BS brick obtained the lowest shrinkage with 0.34% followed by 1%, 20%, 30% and 0% of BS brick with 0.43%, 0.56%, 0.57% and 0.59% respectively. On the other hand, BS brick (10%) showed the highest values with 0.69%. Nevertheless, all manufactured bricks do not exceed 1% of shrinkage and far from the good quality requirement by previous researcher that should less than 8% (ASTM, 1998; Weng *et al*, 2003; Baskar *et al*, 2006).

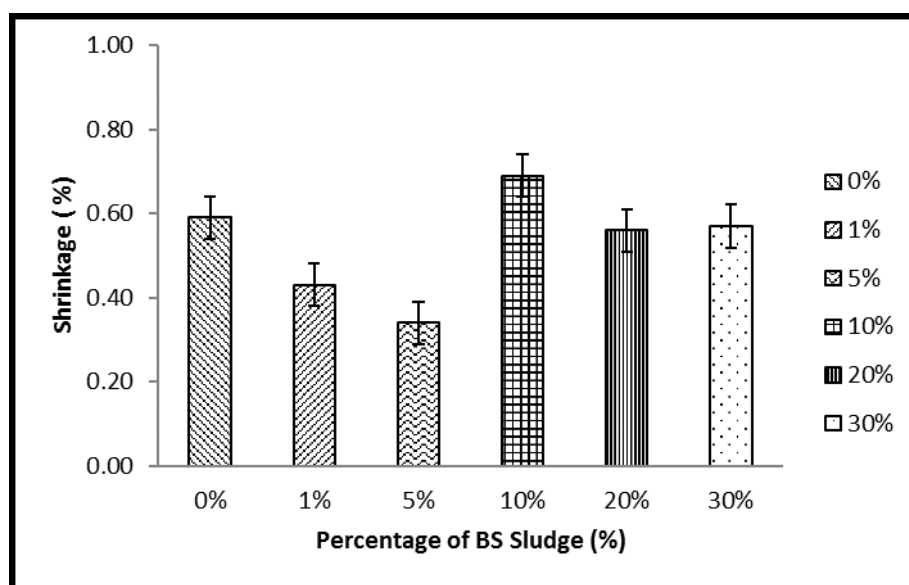


Figure 2. Shrinkage between different percentages of BS brick

Table 1. Total shrinkage of the manufactured bricks

	Control			BS		
Percentage of mosaic sludge (%)	0%	1%	5%	10%	20%	30%
Drying Shrinkage (%)	0.15	0.15	0.26	0.26	0.22	0.22
Firing Shrinkage (%)	0.69	0.46	0.31	0.56	0.52	0.67
Total Shrinkage (%)	0.59	0.43	0.34	0.69	0.56	0.57

Density. Table 2 and Figure 3 show the density of BS brick. BS brick (30%) shows the lowest density with 1665.24kg/m^3 and the value slightly increase from 20%, 10%, 5%, 1% and 0% with 1677.43kg/m^3 , 1679.89kg/m^3 , 1683.28kg/m^3 , 1688.06kg/m^3 and 1698.24 kg/m^3 respectively. Furthermore, BS brick shows trend with increasing the percentages of sludge into fired clay brick was decreased the density value. In general, based on the other resources (Riza et al, 2010), density values are generally between 1500kg/m^3 to 2000kg/m^3 . Therefore, the bricks are in the range and complied with common brick weight. According to Abdul Kadir et al. (2011), lighter bricks are feasible and the lightweight bricks will reduce the transportation and manufactured cost.

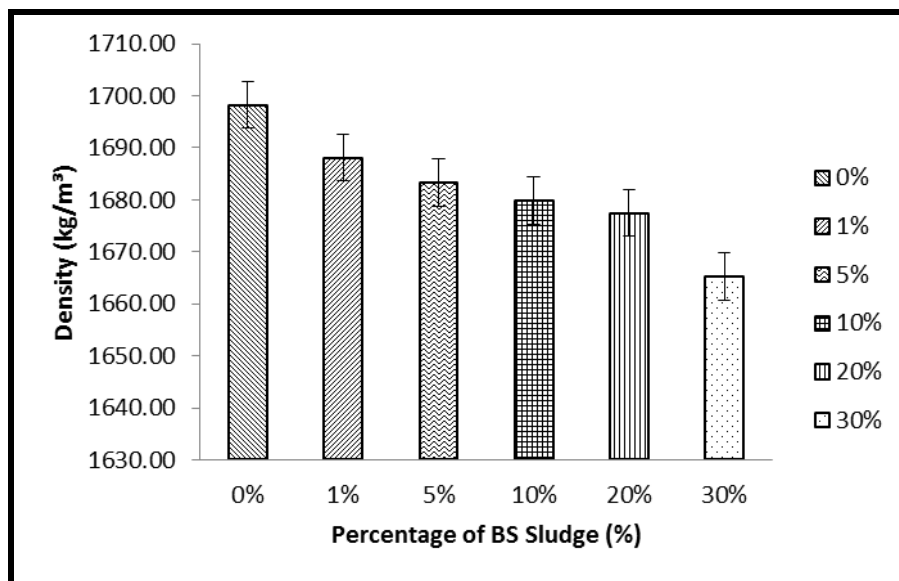


Figure 3. Density between different percentages of BS brick

Table 2. Density of the manufactured bricks

	Control			BS		
Percentage of mosaic sludge (%)	0%	1%	5%	10%	20%	30%
Density (kg/m^3)	1698.24	1688.06	1683.28	1679.89	1677.43	1665.24

Compressive Strength. Table 3 and Figure 4 show the result of the compressive strength of BS brick. The highest compressive strength obtained was BS brick (30%) with 26.58 N/mm^2 and followed by 20%, 10%, 5% and 1% BS brick with 26.17 N/mm^2 , 25.81 N/mm^2 , 24.80 N/mm^2 and 17.91 N/mm^2 correspondingly. The results determined control brick was the lowest among the other samples with 15.32 N/mm^2 . The reason for these was, clay soil was a more organic matter that burns and weak inter-particulate (Jahagirdar et al., 2013; Johari et al., 2010). Apparently, all results obtained and all the tested bricks are comply with the standard (BS 3921:1985) which is between 7 N/mm^2 to 100 N/mm^2 but not satisfied to be classified as engineering brick.

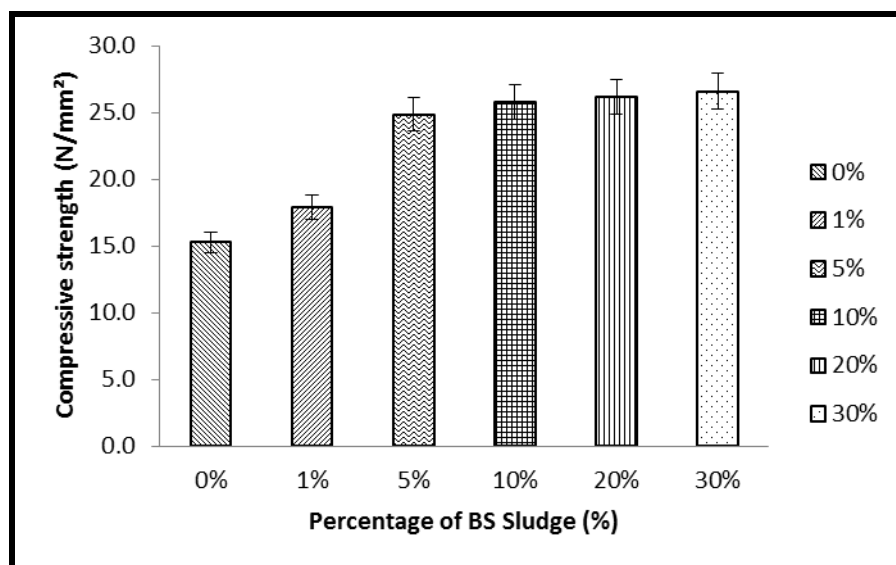


Figure 4. Compressive strength between different percentages of BS brick

Table 3. Compressive strength of the manufactured bricks

	Control		BS			
Percentage of mosaic sludge (%)	0%	1%	5%	10%	20%	30%
Compressive strength (N/mm ²)	15.32	17.91	24.80	25.81	26.17	26.58

Initial Rate of Suction. Based on Table 4 and Figure 5, its shows the amount of the initial rate of suction for BS brick slightly decreased from the 0% to 30% of sludge wastes. The highest was determined by BS brick (1%) with 12.65 g/mm^2 and the lowest was BS brick (30%) with average 3.94 g/mm^2 . The results obtained for control brick shows the highest with 12.96 g/mm^2 . Based on the classification of brick in terms of the initial rate by BS 3921:1985. The water initial rate for control brick and BS brick for 1% to 10% was unsatisfied to be classified as damp-proof course brick but can be categories as all other bricks (no limits). Otherwise, for BS brick 20% and 30% can be classified as damp-proof course brick course because do not exceed more than 5 g/mm^2 .

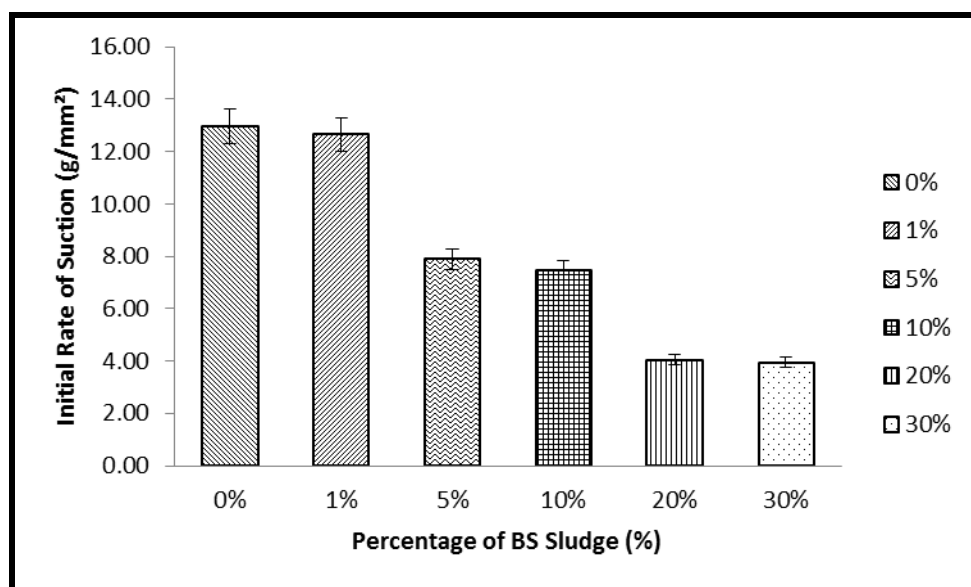


Figure 5. Initial rate of suction between different percentages of BS brick

Table 4. Initial rate of suction of the manufactured bricks

	Control			BS		
Percentage of mosaic sludge (%)	0%	1%	5%	10%	20%	30%
Initial rate of suction (g/mm ²)	12.96	12.65	7.90	7.47	4.03	3.94

Conclusion

As a conclusion, physical and mechanical properties incorporated with bodymill mosaic sludge waste were determined. The characteristic that was obtained by XRF shows the chemical composition of raw material of clay soil and mosaic sludge were high with silica dioxide (SiO_2) and aluminium oxide (Al_2O_3). Therefore, with the same characteristic, mosaic sludge is suitable to replace clay soil as a raw material. The properties of fired clay brick were significantly affected by different percentages of incorporated BS sludge. The results showed fully utilization of mosaic sludge brick obtained the highest compressive strength up to 25N/mm^2 and low initial rate of suction under the limit of 5g/mm^2 . Increasing the sludge ratio in general will decreases the macropores develop and thus increases the compressive strength value of the samples. On the other hand, the brick with higher pore size will absorb more water compared to the brick with low porosity. SEM result shows the surface structure appearances of the brick incorporated with mosaic sludge are finer compared to control brick. This was due to the texture of mosaic sludge powder which is finer compared to clay soil and this enable the mosaic sludge to cover and fill the gaps between the clay soils in the mixture and decreases the IRS. Furthermore, 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 standard. It can be concluded that mosaic sludge is suitable an alternative raw material in brick manufacturing while providing a suitable waste disposed method.

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