Compressive Strength of Fired Clay Bricks Incorporated with Ceramic Sludge Industry

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Abstract. Sludge is created during a variety of industrial processes, including industrial ceramics. Considering sludge waste is often disposed of in landfills, the expense of treating sludge waste is becoming uneconomical, and landfill area is diminishing. The industrial ceramics sludge has been identified as a potential alternative ingredient in making bricks. In this research, the optimum percentage of ceramic industry sludge incorporation with fired clay is determined according to its physical properties in order to improved compressive strength in fired clay brick. From the result shows that by incorporation of 30% of ceramic sludge into fired clay brick complied with the British Standard (BS) requirement and Eco-Labelling criteria in SIRIM ECO 023:2016 for building material usage. Therefore, ceramic sludge can be material for brick production with appropriate mix and design and as an alternative substitution of reasonable material that offers eco-friendly disposal method.

1 Introduction

Sludge is frequently linked with human waste from residential sludge; nevertheless, sludge is an accumulated material that includes industrial waste, hospital waste, wastewater treatment, street runoff, farming, and, in certain situations, landfill leachate. In general, sludge from residential areas is organic while Industrial sludge can be organic or inorganic. To prevent environmental pollution, the inorganic content of industrial sludge, such as heavy metals, should be treated specifically. In addition, industrial sludge, including ceramic sludge, becomes a serious problem because of public concern and the scarcity of available land [1].

Ceramics are chemically defined by whatever they're certainly without. Ceramics are non-metallic and inorganic solids (those that are neither metals or based on carbon molecules), according to most science textbooks and dictionaries.; in other words, ceramics are what's left upon we remove metals and organic materials (including wood, plastics,

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rubber, and anything that was once alive) [2]. Ceramic sludge is mostly composed of Silicon Oxide (SiO_2), Aluminium Oxide (Al_2O_3), and oxides of alkaline and alkaline earth metals, as well as oxides of heavy metals such as lead, cadmium, and chromium [3].

The aim of this research is incorporation of ceramic waste into clay bricks which usually results in lightweight bricks with better retention of acceptable compressive strength. The lightweight bricks will reduce transportation cost and manufacturing.

Additionally, by integrating waste, the fired clay bricks clay content is decreased, cutting the cost of production [4]. This encourages many researchers to conduct additional research on the potential sludge to be integrated into the brick. As a result, the goal of this research is to create fired clay brick with ceramic sludge.

2 Methods

2.1 Raw materials preparation

Sludge waste used in this study is sanitary wares ceramic sludge. The ceramic sludge was collected from the Saniton Ceramic(M) Sdn. Bhd., Johor Bahru, Johor. All the brick samples were made at the Research Center for Soft Soils (RECESS) of Laboratory and Mechanical Polymer Ceramic Laboratory. The brick properties were determined and tested at the Material Structure Laboratory. Compressive strength properties of fired clay brick incorporated with material sludge ceramic (1%, 5%, 10%, 20% and 30%).

2.2 Brick manufacturing

The clay soil and ceramic sludge were dried in the oven for 24 hours at 105°C. Both were manually ground and crushed, and sieved with sieve diameters ranging from 3mm to 5mm. All of this was carried out in the RECESS and Geotechnic laboratories. The clay soil and ceramic sludge were dried in the oven for 24 hours. The substance was then crushed and formed into pellets for examination in an X-ray fluorescence apparatus. While preparing raw materials, the raw materials were sieved using a 10 μm sieve after the drying process. The 16g sieved sample was then delivered to UTM for XRF analysis.

Then, two types of bricks produced: control bricks made of clay and bricks with ceramic sludge. The RECESS Laboratory produced control bricks (0%) and sludge bricks with varying percentages (1%, 5%, 10%, 20%, and 30%). All bricks shall be manufactured in accordance with BS3921:1985. Control brick was created by combining soil and water in a specific ratio in a mechanical mixer. After thoroughly mixing the soil, it was placed in a mould and manually compacted at 2500 psi. The brick was cured at ambient temperature for 24 hours before being placed in a 105°C oven for another 24 hours. After drying, the brick was burned in the furnace for another 24 hours at 0.7 °C/min till 1050°C. The ceramic sludge bricks were created using the same procedure and process, integrating ceramic sludge, clay soil, and water in varied percentages ratio by weight based on specific gravity and optimum moisture content, as may be seen in Table 1. According to the BS 3921:1985 standard, the brick qualities, which is compressive strength were evaluated.

Table 1. Ratio Mixture.

Mixture	Percentage of Ceramic Sludge (%)	Clay (g)	Sludge (g)	Water (mL)
Ceramic Sludge (BS)	0	3000	0	450
	1	2970	30	480
	5	2850	150	520
	10	2700	30	540
	20	2400	600	570
	30	2100	900	600

2.3 Compressive Strength

The maximum stress of a brick under crush loading is defined as its compressive strength. The compressive strength is calculated by dividing the greatest load by the control brick cross-sectional area.

The greatest force that a brick can bear after being crushed is known as its compressive strength. A brick compressive strength is calculated by dividing the highest load by the cross-sectional area at the beginning of the brick. The ability of bricks to sustain compaction pressures greater than tension is widely recognised. The strength of each kind of brick varies. Engineering bricks are divided into two classes (BS 3921:1985) and are robust and dense, as may be seen in Table 2:

Table 2. Compressive Strength (BS : 3921:1985).

Class	Compressive Strength
	N/mm²
Engineering A	≥70
Engineering B	≥50
Damp - proof course 1	≥5
Damp - proof course 2	≥5
All others	≥5

Note 1 : There is no direct relationship between compressive strength and water absorption as given in this table and durability.
Note 2 : Damp-proof course 1 bricks are recommended for use in buildings whilst damp-proof course 2 bricks are recommended for use in external works.

The compressive strength of the bricks was tested (Figure 1) to determine their strength until failure. According to the BS 3921:1985 test technique, the compressive strength must be between 28 and 42 N/mm^2. Bearing platens should be cleansed of any grime, and brick should also will be clean of any grit or other debris that will come into contact with the platens.

The loads were applied to the sampler without being shocked and increased at a convenient rate not exceeding 35.0 N/mm^2.min up to half the anticipated maximum loads. The loading rate was gradually reduced to 15.0 N/mm^2.min and held there till failure. During the test, the greatest changed load by the specimen will be recorded. Ten specimens were chosen at random to meet the BS3921:1985 standard. Each specimen's results will be divided by the area of the bed face (Equation 1)

$$\text{Compressive strength, } C = F/A \quad (1)$$

where:

C = Compressive strength

F = Maximum loads at failure (N)

A = Area of the bed face (mm^2)

Fig. 1. Compressive Strength Test.

2.4 Eco Label Sirim

When the brick were certified by SIRIM Eco-Labelling Scheme, it represent as environmentally beneficial product. As Malaysia's official national eco-labelling programme, the SIRIM Eco-Labelling Scheme has been acknowledged. The quality and safety aspects of the product shall comply with national standards such as MS 2282-3, BS EN 771-2, BS EN 1338 and MS 1380 or any other relevant international standards specifically on masonry units. The quantity of recycled content materials shall be significant in order to be recognised as being environmentally preferable. The recycled content material shall not be less than 20 %. The recycled content materials will be revised to be not less than 30 % in 2021.

3 Results and discussion

3.1 Classification of soil

The percentage of moisture content was between 12% to 24% which compliance with the British Standard 1377. The moisture content does affecting the properties of brick. Hence, it comply with the eco label criteria. Table 3 show the values of OMC in brick control and brick ceramic sludge with different percentages.

Table 3. Percentage of water.

Mixture Identification	Water (%)
Control Brick	15
Ceramic sludge brick (1%)	16
Ceramic sludge brick (5%)	17
Ceramic sludge brick (10%)	18
Ceramic sludge brick (20%)	19
Ceramic sludge brick (30%)	20

3.2 Chemical composition and concentration analysis

Chemical parameters were achieved by using XRF to generate the ceramic sludge characteristics as shown in Table 4. The results indicate that Silicon (Si) and Aluminium (Al), with respective concentrations of 43.387% and 19.22%, have the highest chemical contents in ceramic sludge which are within the required limits for the casting of burnt clay bricks; silica (SiO2) and alumina (Al2O3) are suggested to be present in clay in amounts ranging from 50 to 60% and 10 to 20%, respectively [7].

Table 4. Composition of heavy metals.

Heavy Metals	Formula	Ceramic Sludge
Silicon	Si	43.387
Aluminium	Al	19.222
Potassium	K	15.007
Iron	Fe	6.995
Calcium	Ca	4.244
Zirconium	Zr	3.553
Ttitanium	Ti	2.314
Phosphorus	P	1.775
Zinc	Zn	1.558
Sulfur	Si	0.611
Srontium	Sr	0.553
Vanadium	V	0.241
Rubidium	Rb	0.197
Copper	Cu	0.12
Yttrium	Y	0.07
Manganese	Mn	0.056
Lead	Pb	0.04
Gallium	Ga	0.033
Niobium	Nb	0.012
Thrium	Th	0.011

3.3 Compressive strength

The result of the evaluation of the compressive strength of Ceramic Sludge (CS) brick is shown in Figure 2. The CS brick (30%) had the maximum compressive strength, measuring 25.66 N/mm² followed by 20%, 10%, 5% and 1% with 22.89 N/mm², 22.05 N/mm², 21.76 N/mm² and 21.12 N/mm² discretely. The outcomes showed that the control brick had the lowest compressive strength compare to other samples, at 15.32 N/mm². Evidently, all of the tested bricks met the requirements of BS 3921:1985—between 7 N/mm² and 100 N/mm² although not sufficiently to qualify as engineering brick. However, it does comply to eco label criteria. This increase in strength could be attributed to the addition of ceramic sludge that was burned at high temperatures before being mixed with brick clay. The increased strength would have resulted from the use of previously sintered materials (such as ceramic sludge) rather than brick clay [8].

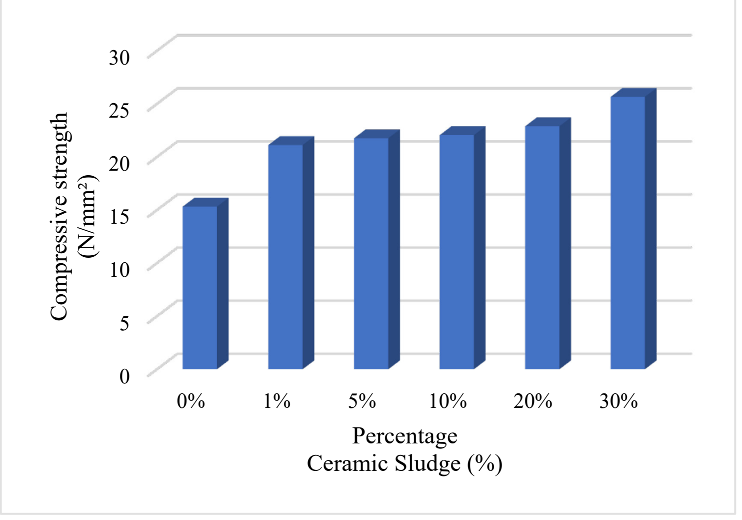

Fig. 2. Compressive strength between different percentage of sludge.

3.4 Overview Results

The result of the percentage of ceramic sludge that meets Standard BS 3291 :1985 which compliances with Eco Label Standard for compressive strength properties is shown in Table 5. Only 30% that compliances with British Standard and Eco Label Standard for compressive strength. This occurred when all compressive strength compliances with British Standards, but only 30% of the percentage ceramic sludge is fulfilled, since the Eco Label Standard requires the percentage of ceramic sludge to be 30% or higher.

Table 5. Percentage of Ceramic Sludge that meets Standard (AS/BS) and Eco Label Standard.

Percentage of Ceramic Sludge (%)	Compressive Strength (BS 3291:1985)	Eco Label Standard
0	x	x
1	x	x
5	x	x

10	x	x
20	x	x
30	/	/

4 Conclusion

As a conclusion, clay soil can be replaced as a raw material by ceramic sludge because they passed the standard (BS). The results revealed that full utilisation of ceramic sludge brick obtained the highest compressive strength up to 25 N/mm² and a low initial rate of absorption under the 8 g/mm² limit. Ceramic sludge could be used up to 5% in burned clay bricks for better physical properties that fulfil the specification. Nevertheless, up to 30% of ceramic sludge can be employed in burnt clay brick in order to satisfies the standard of eco-label standards.

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