Potential Use of Municipal Solid Waste Ash (MSWA) As Sustainable Construction Bricks
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ABSTRACT
Uncontrolled infrastructure development may produce excessive carbon emission and scarcity of natural resources, that exploited for the mean of development. The reuse of waste materials will promote material ecology and the cradle to cradle concept. This study utilizes Municipal Solid Waste Ash (MSWA) as a potential target material in replacing laterite soil that is nonrenewable natural resources. Mix design, compositions were established for industrial trial of brick making. Laterite soil on its own (100%) and in combination with MSWA, (50:50) stabilized with PC and Lime at 20% and 30% were used to produce bricks. The bricks were then air dried. Two engineering properties, compressive strength and water absorption were studied. The investigation results show that compressive strength and water absorption of laterite soil combine with MSWA at (50:50) recorded higher strength compared to when laterite soil were used alone. This suggests viability and feasibility of using waste material in brick making.

Keywords: Municipal Solid Waste Ash, Compressive Strength, Water Absorption.

1. INTRODUCTION
Bricks are common materials used in construction, particularly clay bricks. Clay is non renewable resources which the industry should think about the alternative materials available. Previous researches have been done to find the substitute materials for clay bricks [1]–[12]. Producing bricks from natural and nonrenewable resources is equally challenging to ensure that natural resources will possibly be sustain for another decade. An alternative resource should be explored before the scarcity of these non-renewable resource arises. This experiment attempts to use the waste from industry, which is Municipal Solid Waste Ash (MSWA) as an alternating resource. This research study on the possibilities of utilising municipal solid waste ash as the promising alternative materials for laterite clay. The objectives of this study is to identify compressive strength and water absorption of Municipal Solid Waste Ash (MSWA) bricks. X-ray Fluorescence (XRF) carried out to identify the oxide composition. Laterite soil is unstable and needs Hydrated lime and Ordinary Portland Cement as binder to stabilise and solidify the soils.

Malaysia National Green policy objectives encourage the sustainable economy at the same time conserve the environment. Greater extent capability and capacity of Green Technology innovation as such to increase Malaysian competitiveness globally. Utilising waste for production of construction material such as brick becoming demanding in the academia world[7], [13], [14]. This proves that instead of discarding waste or by-products into the landfill, it is becoming more valuable if the waste turn into valuable products. Even though in Malaysia capacity of incinerator plant not as many as in China [5] yet it is worth to try recycle MSWA into the production of construction components. In Malaysia about four (4) active incinerator which are located in Langkawi Island, Pangkor Island, Tioman Island and Cameron Highland. Past researches used MSWA as alternative materials for cement [5], [9] and the result indicated slightly improvement were achieved compare to ordinary portland cement. Zhang [7] developed solid waste incinerator fly ash in ceramic bricks which found that the municipal solid waste incinerator ash successfully stabilised the heavy metal contents. Foremost all the exploration on utilising solid waste incinerator for construction components or co-product such as cement that need heat treatment throughout the process. Heat treatment involving the emission of carbon dioxide to the environment which we
know contribute to the Green House Gas to the atmosphere. Criteria of green product should have zero or low green house gas emission.

2. METHODOLOGY

Bricks were pressed in the soil laboratory, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, Shah Alam. This experiment was conducted according to BS EN 772-1:2011 determination of compressive strength. Three main materials used in this research were laterite clay, MSWA and sand. Laterite soil was gathered from construction site around Shah Alam. This laterite clay normally were disposed or used for filing work. Meanwhile the binder used are Ordinary Portland Cement and Hydrated Lime. All pressed bricks were air cured in the laboratory environment, which no direct sunlight to avoid rapid hydration.

2.1. Materials and composition

Municipal Solid Waste (MSW) ash, particularly Bottom Ash was collected from Pangkor Island Incinerator Plant. The plant processes solid waste up to 30 tonnes per day. In this research bottom ash were utilised as the target materials. The grain size of MSW bottom ash are 5mm to 0.06mm. The X-ray fluorescent (XRF) was carried to identify the oxide composition in the MWSA, laterite, Hydrated Lime and Ordinary Portland Cement (OPC). Table 2.1 illustrated the chemical composition of oxide content in the MSWA.

Table 2.1: Oxide Composition of Target Materials and binder

| NO | OXIDE CONSTITUENTS          | WT (%) | MSWA | LATERITE | HL | OPC |
|----|-----------------------------|--------|------|----------|----|-----|
| 1  | Silicon Dioxide             | SiO₂   | 5.845| 26.518   | 0.221| 6.723|
| 2  | Aluminium Oxide             | Al₂O₃  | 4.721| 33.267   | 0.384| 3.269|
| 3  | Calcium Oxide               | CaO    | 7.412| 0.033    | 51.75| 34.320|
| 4  | Magnesium Oxide             | MgO    | 3.603| 1.137    | 2.939| 5.372|
| 5  | Ferric Oxide                | Fe₂O₃  | 9.937| 21.569   | 19.315| 17.577|
| 6  | Titanium Oxide              | TiO₂   | 0.343| 0.793    | 0.061| 0.117|
| 7  | Sulphur Trioxide            | SO₃    | 1.238| 0.058    | 0.027| 1.483|
| 8  | Diphophorus Penta Oxide     | P₂O₅   | 1.084| 0.030    | 0.014| 0.040|
| 9  | Sodium Oxide                | Na₂O   | 4.785| 0.218    | 0.171| 0.345|
| 10 | Potassium Oxide             | K₂O    | 0.711| 0.698    | 0.025| 0.252|
| 11 | Chromium Oxide              | Cr₂O₃  | 2.205|          |      |      |

Table 2.2: Design Mix Composition

| Label | Laterite % | MSWA % | Sand % | Cement (OPC) | Hydrated Lime (HL) |
|-------|------------|--------|--------|---------------|------------------|
| LCC   | 60         | 10     | 23     |               |                  |
| LCC:MSW | 30       | 30     | 10     | 23            |                  |
| MSWC  | 60         | 10     | 23     |               |                  |
The composition used for control specimen was 60% laterite, 10% sand, binder 23% and water 7% of the total weight of all dry materials. Two types of binder were tested in this research which were ordinary Portland cement and hydrated lime. Laterite clay with cement labelled as LCC and Laterite clay with hydrated Lime labelled as LCCL which all this were control sample. Mix composition with 50% of MSWA and 50% of laterite clay labelled as MSW:LCC used cement as binder and MSW:LCL with hydrated lime as binder. MSWA 100% content with cement and hydrated lime as binder were labelled MSWC and MSWL respectively. Table 2.2 shows the percentage of materials used for this experiment.

### 2.2. Procedure

All materials were air dried before thoroughly mix using a lab scale rotating mixer. Bricks were pressed in the laboratory with the industry scale size of (225mm x 102.5mm x 65mm) mould (Figure 2.1). Thirteen (13) numbers of bricks were prepared for each design mix which designated for water absorption and compressive strength for 7 days, 28 days and 60 days curing. In total about 78 nos of bricks were manually pressed at average pressure of 300 psi.

All pressed bricks were wrapped with plastic film as to avoid rapid hydration during the air curing process. 3 nos of bricks were tested for compressive strength test. Testing for compressive strength follows the BS EN772-1: 2011 [15]. Compression rate with loading of 0.5N/mm² per second as stipulated in the standard. Water absorption test was conducted after the brick has undergo curing for 28 days (Figure 2.2). Bricks were oven dried for 24 hours before immersed in the water for 24 hours. Readings were recorded for calculation of absorption percentage. The formula for water absorption (Ws) calculation as follows

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Ws = \frac{Mw - Md}{Md} \times 100
\]
Figure 2.2: Water Absorption Test

3. RESULT AND DISCUSSION

3.1 Compressive Strength

Laterite clay naturally is weak and need to stabilise to be more effectively used as construction components. Figure 3.1 shows the result of laterite clay bricks and MSWA bricks using OPC as a stabiliser and Figure 3.2 shows laterite clay brick and MSWA bricks using Hydrated Lime as the stabiliser. Compressive strength of MSWA with laterite clay (LCC:MSW) indicated the highest value (8.2 kN/m$^2$ for 7 days, 10.32 kN/m$^2$ for 28 days and 12.8kN/m$^2$ for 60 days) if compared to control brick (LCC) and 100% MSWA brick (MSWC). All this sample used OPC as a binder. The compressive strength developed starting from 7 days, 28 days and 60 days of curing period. LCC which the control samples had a compressive strength of 5.30kN/m$^2$ at day 7, 6.8kN/m$^2$ at day 28 and maintain at day 60. The samples with 100% of MSWA which labelled as MSWC had achieved the compressive strength of 5.9kN/m$^2$ at day 7, 7.9kN/m$^2$ at day 28 and slightly increased at 8.4kN/m$^2$ in 60 days.

Hydrated lime adds as binder gives different result if compared to OPC as a binder. Even it was an increased in compressive strength, but the increase was very minimal. The control sample (LCL) has the compressive strength at 7 days curing, 28 days and 60 days respectively were 4.4kN/m$^2$, 4.6kN/m$^2$ and 4kN/m$^2$. Sample with equal weight of MSWA and laterite clay (LCL:MSW) had the compressive strength of 4.9kN/m$^2$ at 7 days, 5kN/m$^2$ at 28 days and 4.3kN/m$^2$ at 60 days of curing. MSWL bricks which contain 100% of MSWA with hydrated lime shown steady strength between day 7 and 28 which was 4.8kN/m$^2$ and at 60 day curing period the strength decreased at 4.25kN/m$^2$. Hydrated lime may need to add with other binders to increase the strength such as Ground Granulated Blast Slag.
Generally, adding of MSWA slightly increased the compressive strength value for both with OPC and hydrated lime as binder. But when using MSWA only as target materials the compressive strength was lessened, either for OPC or hydrated lime as the binder. Adding laterite clay with MSWA provide a potential recycle of waste that added value for a sustainable brick without involving any firing process. Muntahar [16] also found that adding clay and sand with waste materials could contribute better strength for unfired bricks.

3.2 Water Absorption

The low rate of water absorption indicated, the materials could sustain when immersed in water. Figure 3.3 illustrated the water absorption test result. In this research the control sample LCC and LCL had equally the same rate of absorption about 1% increased after 24 hours immersion. Bricks with combination of laterite clay and MSWA with cement (LCC:MSW) had low absorption compared to hydrated lime (LCL:MSW) as binder. This means cement is a better binder for laterite bricks with MSWA. Meanwhile, for 100% MSWA bricks with cement as binder (MSWC) had the highest absorption rate compared to MSWA bricks with hydrated lime (MSWL). In this research it found that by adding MSWA could reduce the percentage rate absorption laterite clay bricks. Theoretically higher percentage of water absorption gives low the compressive strength. As in the previous study by Muntahar [16] found that equal ratio of lime and waste ash give the optimum result. Oti [17] add another waste which Ground Granulated Blast Slag to activate lime as a potential soil stabilisation in construction component development. The optimum design mix, composition needs to add laterite clay as silicious materials and cement as a binder.

Figure 3.2 - Compressive Strength for Control Bricks and MSWA with HL as a binder

Figure 3.3 – Rate of Absorption (%) of all samples
4. CONCLUSION

The following conclusion achieved throughout this research.

• MSWA mix equally with laterite clay and ordinary Portland cement as binder developed a compressive strength of 10.32kN/m$^2$ at 28 days of curing.

• Hydrated Lime as binder does not contribute much in accelerating the compressive strength. Hydrated lime may add with other substance materials such as GGBS to develop better engineering properties.

• Steady and low water absorption rate for bricks with composition of laterite clay and MSWA and cement as the binder. The highest changes of the rate of absorption were bricks with MSWA 100% and cement as a binder.

As conclusion MSWA potentially can be utilised with laterite soil and binder proposed is Ordinary Portland cement. This research will be extended to explore more optional binder and stabilizer that more sustainable. Reduction of cement as a binder could explore more.

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