Utilization Oil Based Industrial Sludge as Potential Construction Components

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ABSTRACT

The aim of this study is to investigate the potential of using Wastewater Treatment sludge (WWTs) from oil-based industry as a target material for sustainable construction component. Intensive laboratory investigations were carried out to establish the best mix design for brick composition. WWTs were blended with Laterite Clay (LC) at 50:50 ratio to produce unfired bricks. These target material were stabilised using Hydrated Lime (HL), Portland cement (PC) on its own and combination of Ground granulated blast-furnace slag (GGBS), waste from metal industry, HL: GGBS and PC: GGBS both (50:50 and 70:30 ratio) at 10%, 20% and 30% stabilizer dosage. The influence of the waste addition on the compressive strength and water absorption test was investigated on brick specimens. The unfired brick were fabricated in the factory environment. The bricks that casted were wrapped in cling film and air cured for 7 and 28 days before testing. The results obtained show that the measured strength properties and water absorption of the stabilized WWTs are comparable to conventional bricks. The results suggest there is a potential of using sludge from oil based industry in view of economic and environmental concern.

Keywords: Construction component, industrial scheduled waste, wastewater treatment sludge, ground granulated blast furnace slag.

1. INTRODUCTION

The concept of vision 2020 is to make Malaysia as fully industrialized and developed country by the year 2020. Supported by former Prime Minister, Tun Mahathir Mohamed, stated that formulation of industrial policy in Malaysia is more geared towards enhancing the contribution and performance of the industrial sector of the country. The policy towards an industrialized country by the year 2020, will promote to the growth of many industries and increased demand from the infrastructure to meet the target economic of the country [1]. Due to the growth of many industries problems arised on the accumulation of industrial waste and/or by-products particularly from Wastewater Treatment sludge (WWTs) plants. Some are dangerous and classified as scheduled waste by the Department of Environment (DOE). Disposal and treatment of these wastes could not cope with mass quantity of sludge [2].

Alternative sustainable technology is urgently needed to address this problem. In line with the increase in population, rapid industrial development and the problems of waste disposal new approach is needed to recycle the industrial wastewater into a green construction component. By developing new technology of recycling industrial waste into green, sustainable construction component would be a preventative to environmental degradation, climate change and carbon constraints in the future.

In Malaysia, this industrial sludge is sent to landfill, hoards of land and converting sludge as composite fertilizer. A method of converting sludge into fertilizer composite is not very practical for all water treatment plants for different organic matter content [3]. However, these methods are becoming less efficient due to the rising operational costs. Method of landfill and hoards require space of land which is very costly.

Therefore, intensive research need to be carried out to discover alternatives to address this issues. Some researchers have proven that the sludge can be used as components in building structure. For example, sludge can be mixed with clay to produce bricks. Sludge that mixed with limestone can produce mortar with the same properties of PC mortar. The use of sludge in
construction component can reduce the operating costs other than increasing the productivity of the construction industry to reduce the use of cement and lime [4]. Dust sludge and sludge mixed with clay can produce bricks [5]. In addition, the study also showed that sludge not only can be used in the production of bricks, but also as lightweight aggregate and synthetic materials such as cement [6]. Although there are many previous researches investigate the use of WWTs in construction industry, however research on WWTs from oil based industry has not been given as much attention [7]. Thus, this research was designed to address the following objective which is to investigate the potential of using WWTs from oil based industry as a target material for sustainable construction components and to evaluate the engineering and environmental properties of the product specimen.

2. MATERIALS AND METHOD

2.1 Materials

The materials used for experimental research consisted of LC and WWTs as target material and HL, PC and GGBS as binder. The basic materials characterization was carried out in accordance with the British Standards (BS) and American Society for Testing and Material (ASTM) and other accepted engineering standards.

i. Laterite Clay (LC)

A fine-grained soil with high clay content (LC) has been used in this study. It was supplied by a construction site located in Puchong, Kuala Lumpur. LC possesses a great amount of iron and aluminum oxides. Iron oxides, existing mainly in the amorphous and crystalline inorganic forms, are one of the major components in many soil orders. The analysis from the chemical and XRD test of LC, gave a mineralogical composition of quartz, zircon, oxides of titanium, iron, tin, aluminum and manganese.

ii. Wastewater Treatment sludge (WWTs)

WWTs were supplied by Lam Soon Edibles Oil Sdn Bhd, located in Telok Panglima Garang, Klang. This company specializes in the process of cooking oils and detergent. During the process of manufacturing, about 52,723 tonnes of WWTs was produced per annum. The WWTs will go through pH coagulation tank and flocculation tank before clarifier. Once this process was done, the sludge undergone the anaerobic reactor and bio tank before filter press to remove the water.

iii. Hydrated Lime (HL) and Portland Cement (PC)

Lime in the form of quick lime (calcium oxide-CaO), HL (Calcium hydroxide-Ca(OH) 2), or lime slurry can be used to treat soils. Most lime used for soil treatment is “high calcium” lime, which contains no more than 5% magnesium oxide or hydroxide. In this research, HL was used because it formed when quick lime chemically reacts with water. HL reacts with clay particles and permanently transforms them into a strong cementitious matrix and contains no more than 5% magnesium oxide. HL was supplied by MCB Industry Sdn. Bhd. PC was supplied by YTL Sdn Bhd. This PC was manufactured by Malaysia Standards MS 522: Part 1: 1989.

iv. Ground Granulated Blast Furnace-Slag (GGBS)

GGBS was used in this research was obtained from YTL Sdn. Bhd factory, in Pelabuhan Klang, Selangor. GGBS is a by-product from blast-furnaces used to make iron. The manufacturing of GGBS is accordance with the Malaysia Standards MS 522: Part 2: 2005.

The physical and chemical properties of target material and binders are shown in Table 1 and 2 respectively. The mix design composition for brick specimens are shown in Table 3 respectively.
2.2 Preparation of Brick Specimens

The brick specimens were fabricated at Majpadu Bricks Sdn. Bhd., Jalan Kebun, Klang, Selangor. All materials were prepared at soil laboratory, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA before taken to the factory.

All of the materials were weighed in accordance with the mix design composition before mixing. The dry materials were mixed thoroughly for 5 min to ensure that all materials have been dispersed evenly in the mixture. Then the pre-calculated water was introduced into the dry material and the mixture was thoroughly mixed until homogeneous. It was then poured into the brick fabrication machine with a mould size of 213mm length, 101mm width and 63mm depth. The pressure used for pressing bricks is 9kN/in². After pressing, the bricks were stacked on wooden pallets and marked in accordance with the percentage of mixed composition. The bricks were then stored in an open area and air cured for 7 and 28 days before testing.

![Figure 1](a) The automatic hydraulic press used for brick making in Majpadu Brick factories. (b) The sample of unfired bricks specimen.

2.3 Laboratory testing

The compressive strength of test specimen was determined by its failure load using a compressive strength test machine. The compression load was applied continuously at a stable rate of 0.1 (N/mm²)/s until failure in accordance with BS EN 772-1:2011 (see Figure 4a).

To verify the resistance of the test specimens in wet environments, they are subjected to immersion in a water tank (see Figure 4b). After 24 h, the specimens were removed from the tank, the surface water on the specimens wiped off with a cloth, and the water absorption recorded in accordance with BS EN 772-21:2011, every 24 hours for 20 days. The following is the formula to calculate the rate of water absorption in the bricks.

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\text{Rate of water absorption (Ww)} = \frac{\text{Mw} - \text{MD}}{\text{MD}} \times 100\%
\]

Notations:
- MD: mass of the specimens after drying.
- Mw: wet mass of the specimens after being removed from the water tank.
Table 1 Physical properties of the Laterite clay, WWTs, HL, PC and GGBS

| Physical properties | Laterite clay | Waste Water Treatment sludge (WWTs) | Hydrated Lime (HL) | Portland Cement (PC) | Ground Granulated Blast-furnace Slag (GGBS) |
|--------------------|---------------|-------------------------------------|-------------------|----------------------|---------------------------------|
| Specific gravity   | 2.66          | 1.03                                | 2.2-2.3           | 3.15                 | 2.9                             |
| Liquid limit (%)   | 63            | 28                                  | -                 | -                    | -                               |
| Plastic limit (%)  | 32            | 25                                  | -                 | -                    | -                               |
| Plasticity index (%) | 31        | 3                                   | -                 | -                    | -                               |
| Activity coefficient | 80         | 1.00-1.03                           | 77                | -                    | 50                              |
| Clay (%)           | 16            | -                                   | -                 | -                    | -                               |
| Silt (%)           | 37            | -                                   | -                 | -                    | -                               |
| Fine sand (%)      | 56            | 5                                   | -                 | -                    | -                               |
| Coarse sand (%)    | 6             | 79                                  | -                 | -                    | -                               |
| Moisture content (%) | 24       | 70                                  | 6                 | Varying from 1 to more | 0.71                        |
| Colour             | Yellow        | Grey                                | White             | Grey                  | Off-white                       |

Table 2 Chemical properties of the Laterite Clay, WWTs, HL, PC and GGBS

| Oxides | Laterite Clay | Waste Water Treatment sludge (WWTs) | Hydrated Lime (HL) | Portland Cement (PC) | Ground Granulated Blast-furnace Slag (GGBS) |
|--------|---------------|-------------------------------------|-------------------|----------------------|---------------------------------|
| CaO    | 0.13          | 2.75                                | 51.75             | 34.32                | 20.80                           |
| CO₂    | 17.87         | 69.35                               | 25.09             | 30.50                | 18.82                           |
| MgO    | 3.45          | 0.84                                | 2.94              | 5.37                 | 15.44                           |
| Al₂O₃  | 25            | 15.38                               | 0.38              | 3.27                 | 14.10                           |
| SiO₂   | 38.73         | 1.34                                | 0.22              | 6.72                 | 17.14                           |
| Fe₂O₃  | 12.19         | 4.24                                | 19.32             | 17.58                | 10.54                           |

Table 3 Mix design composition for specimens fabrication

| Target Material (%) | Stabiliser | Ratio (%) | Dosage (%) | OMC (%) |
|--------------------|------------|-----------|------------|---------|
| LC (100%)          | HL         | 100       | 30         | 25      |
|                    | PC         | 100       | 30         | 20      |
|                    | GGBS:HL    | 70:30     | 30         | 25      |
|                    | GGBS:HL    | 50:50     | 30         | 25      |
|                    | GGBS:PC    | 70:30     | 30         | 20      |
|                    | GGBS:PC    | 50:50     | 30         | 20      |
| LC:WWTs (50:50)    | HL         | 100       | 10         | 15      |
|                    | PC         | 100       | 30         | 15      |
|                    | GGBS:HL    | 70:30     | 20         | 15      |
|                    | GGBS:HL    | 50:50     | 30         | 15      |
|                    | GGBS:PC    | 70:30     | 30         | 15      |
|                    | GGBS:PC    | 50:50     | 30         | 15      |

3. RESULTS AND DISCUSSION

The results and discussion on this paper represent two testing methods conducted which is compressive strength and water absorption test in accordance with the BS for clay brick.
3.1. Compressive Strength

The compressive strength is important to determine the load that the brick could sustain before failure. Figure 2 illustrates the compressive strength results of LC mixed with WWTs (50:50) stabilized with 10, 20 and 30% stabilizer at 15% moisture content. The PC-based stabilizer (either when use alone or combined with GGBS) recorded higher compressive strength values compared with lime-based stabilizer throughout 7 and 28 days of curing. The highest 28 days strength recorded when PC and GGBS:PC (50:50) were used as stabilizers. The above results support the finding that the properties of LC and WWTs give more strength to the brick. This suggests that the contribution of silica oxide (SiO$_2$) and alumina oxides (Al$_2$O$_3$) present in WWTs when combined with PC and GGBS enhanced pozzolanic reaction from the lime Ca(OH)$_2$ enter into reaction of alumina cement. When the HL was used on its own as stabilizers or combined with GGBS, strength results are lower than in PC as binder. The results also show that the optimum percentage of using HL to stabilize WWTs is 10%. Increment of HL in the system will reduce the compressive strength.

![Figure 2: The compressive strength development of the LC:WWTs (50:50) mixed with stabilizers at 7 and 28 day curing period.](image)

3.2. Water Absorption

The water absorption test was carried out to determine the permeability of bricks. The water absorption of bricks was tested after 28 days of curing. The test was regulated according to the BS 3921: 1985 guideline which that water absorption shall not be more than 20% by weight up to class 125 and 15% by weight for higher class. The specimens were placed in the curing tank and reading were taken every 24 hours for 20 days. The ratio of the water content to the dry mass of bricks determines the quantity of water absorption of the specimens. The amount of water absorbed by the bricks composites depend on their void volume and the amount of materials that are present. Both these parameters have an effect on the density. In Figure 3, illustrates the mix that contains 10% HL, 30% GGBS:PC (70:30) ratio and 20% GGBS:HL (50:50) ratio, collapsed when soaked under water. It was only the test specimen with 30% PC, 20% GGBS:HL (70:30) ratio and 30% GGBS:PC (50:50) ratio can withstand the water pressure at the end of testing age. The maximum percentage of water absorption of this system range from 11%-$\cdot$14%. It shows some of the rapid water absorption during the earlier days of soaking. Water absorption rates become stable after 5
days of curing. Increased moisture content reduces strength associated with porosity of the materials. Lin & Weng support the fact that the less water infiltrates into brick, the more durability of the brick and resistance to the natural environment are expected [8].

Figure 3: Water absorption of the LC:WWTs (50:50) mixed with stabilisers at different curing age.

Figure 4 (a): Compressive strength test machine for bricks. Figure 4 (b): Bricks in a water tank during the water absorption test.

4. CONCLUSION

The conclusion that can be drawn from the results and discussion above, brick produced with LC, and then combined WWTs mixed with stabilizers (PC) had a beneficial effect on compressive strength of bricks. There is potential in using WWTs as replacement of LC for unfired brick production. The strength resistance and water absorption value is reflecting each other. The strength characteristics of the test specimens have been increased by the presence of combined action of PC are strongly bound to the soil and WWTs particles. The results obtained show that there is the potential use of binder mixed for the manufacture of unfired clay materials and for various stabilized soil applications. The following conclusions are therefore derived from the trials:
a. The addition of 50% WWTs in LC are comparable with conventional bricks for acceptance in making good compressed building components.

b. The sample made with PC and WWTs combined with LC tends to achieve higher strength values when compared to a mixture of HL. PC mixed with WWTs and LC offers other benefits due to the characteristics of PC which is cohesive and adhesive which enable it to bind its component materials.

c. The sample made from a combination of LC and WWTs mixed with stabilizers (PC) is suitable for use in wet areas but not where the environment is continuously wet. However, the sample made from a combination of LC and WWTs mixed with stabilizer (HL) are not suitable for use in wet environments and are therefore recommended for use in dry environments.

d. The additional admixtures need to use in the sample made with WWTs and LC because the strength is very lower compared with brick control that achieve acceptable limits for masonry units.

e. Waste materials that use of bio-energy as WWTs is recommended, especially when the materials add the advantages of environmental benefits.

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