Leachability of Quarry Dust Waste Incorporated into Fired Clay Brick using TCLP

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Abstract

Background/Objectives: Industrial waste is defined as waste generated by industrial processes, and one of these types of industrial waste are quarry dust. Currently, stockpiles approximately 60,000 tons of waste within the quarry compound and this amount has become bigger and create space problems. The criteria of the waste are very fine dust and formed from the process of producing premix using drum mix and dryer process. Therefore, this research focused on utilizing this waste in brick manufacturing as an alternative disposal method to the quarry dust as well as complies with the environmental regulations.

Methods/Statistical Analysis and Findings: This research has established that the 30% of quarry dust brick improved most properties if appropriately designed and prepared during brick manufacturing. By taking into account the effects of quarry dust to the environment, it found that incorporation of 30% quarry dust into fired clay bricks leached less heavy metal during the leachability test and complied with USEPA, EPAV, and WHO standard.

Application/Improvements: The comprehensive experimental testing in this research measured the possibility of incorporating quarry dust into clay bricks. Therefore, these results indicate that incorporation of quarry dust in fired clay bricks could minimize the potential of quarry dust environmental problems.

Keywords: Fired Clay Brick, Heavy Metal, Leachability, Quarry Dust

1. Introduction

Quarry dust wastes were produced during the production of aggregates through the crushing process of rocks for aggregates production. Year by year, a significant amount of quarry dust waste is thrown away into landfills. The primary source of air pollution is dust from quarry sites that depends on factors such as the local microclimate conditions, the size particles and concentration of dust particulate matter and also their chemical and physical properties. Environmental pollution caused by quarry dust waste and heavy metals has been a problem for many years in our world.

There are some areas of the Earth's crust, where the high concentration of heavy metals, leading to naturally high metal levels in the soils formed from them. There are several adverse effects quarrying activities have brought to bear on humans and the entire ecosystem. Therefore, the development of mining operations, such as quarrying, gives rise to a rapid increase in the number of the discharge of heavy metals and another dangerous constituent leaching into the environment could cause serious environmental and health problems.

Leaching is the process by which soluble components are dissolved from a solid material such as rock, soil, or waste into a fluid by percolation or diffusion. Furthermore, it can be described as the fluid extraction of a compound or element from a solid. It is a process in which both leachant and solid materials control the results. Characteristics of the constituent material that influence leaching including the particle size, shape, and surface area exposed to leaching. Besides that, the controlling factor such as the pH of the leachate and the
alkalinity/acidity of the solid is also influenced the leaching of the materials\(^4\). Therefore, to avoid these problems, many attempts have been made to fully utilize quarry dust waste as well as other wastes in construction or building materials\(^4\). The utilization of quarry waste is a solution to minimize the accumulation of unwanted material at the same time to maximize resource use and efficiency. In brick manufacturing, depending on the physical and chemical characteristics (of quarry fines, they may be used as filler, clay substitute, colorant, fluxing agent or even body fuels\(^3\)). For concrete production, by using quarry dust as the fine aggregate decreases the cost of its production regarding the partial replacement for natural river sand. It is an eco-friendly material to assured the environment through conservation of soil, reduction in carbon emissions and utilization of waste products\(^8\).

Table 1. Chemical composition of raw materials

| Oxides   | Clay soil Concentration (%) | Quarry dust Concentration (%) |
|----------|-----------------------------|-------------------------------|
| CaO      | 0.10                        | 2.35                          |
| K\(_2\)O | 0.22                        | 5.05                          |
| TiO\(_2\) | 1.05                        | 0.51                          |
| FeO\(_3\) | 5.41                        | 4.52                          |
| SO\(_3\) | 0.27                        | NA                            |
| SiO\(_2\) | 40.8                        | 53.0                          |
| MgO      | 0.36                        | 0.80                          |
| Al\(_2\)O\(_3\) | 38.70                  | 11.70                         |
| Na\(_2\)O | 0.47                        | 1.75                          |

The uses of quarry dust are desirable because of its benefits such as useful recycle of by-product. Substitution of clay will also reduce the usage of natural resources, and correct percentages in brick manufacturing will still provide adequate physical and mechanical properties. As such, the target of this research was to study the leaching characteristic and minimize contaminant from the quarry dust in brick.

3. Materials and Methods

3.1 Materials

Quarry dust wastes used in this research were collected and provided by Bina Kuari Sdn Bhd located in Kedah, Malaysia. The raw material such as clay soil was obtained from a brick producer located at Johor, Malaysia. Quarry dust waste and the soil were kept in the oven at 105\(^\circ\)C for 24 hours and preserved before mixing process.

3.2 Characterization of Raw Materials

Chemical composition and heavy metals characterization using X-Ray Fluorescence (XRF) has been widely used, and this method is fast, accurate and non-destructive with a minimum of sample preparation. Table 1 shows the results for chemical composition for clay soil and quarry dust. Meanwhile, results for heavy metals concentration for these materials were expressed in Table 2.

The major elements contained in clay soil and quarry dust by using XRF test are shown in Table 1. The result revealed that the highest composition of the clay soil is SiO\(_2\) with 40.8%. CaO with 0.10% recorded the lowest in clay soil. Similarly, observation for quarry dust shows that SiO\(_2\) also the highest element exist with 53%. Meanwhile, the least obtained in quarry dust is TiO\(_2\) with 0.51%.

Table 2. Heavy metals concentration in raw materials

| Heavy metals | Concentration (%) | Permissible limit |
|--------------|-------------------|------------------|
| Materials    | Quarry dust | Clay soil | USEPA* | FIN** | WHO*** |
| Cu           | 12              | 18        | 100    | 800   | 1      |
| Pb           | 62              | 16        | 5      | 4     | 0.05   |
| Zn           | 151             | 28        | 500    | 1200  | 5      |
| Mn           | 6               | 1         | 40     | NA    | 0.4    |
| V            | 43              | 68        | NA     | NA    | NA     |
| Ni           | 14              | 6         | 1.3    | 8     | NA     |
| Ba           | 389             | 197       | 100    | 280   | 0.7    |
2.3 Brick Manufacturing

Two types of brick sample were manufactured. One for clay brick with quarry dust waste with different percentages (10%, 20%, and 30%) and another one is clay brick used as brick control. The mixture samples were compressed into the mould with a pressure of 3000 psi. Next, the brick was dry naturally at room temperature and then at temperature 105°C both for 24 hours respectively. After that, the bricks were exposed and fired to temperature 1050°C using heating rate of 1°C/min in the furnace.

2.4 Leachability Test

The TCLP test was obtained by the USEPA in 1990 as the regulatory method for classifying wastes as hazardous based on toxicity. The concentrations of specific contaminants in the TCLP extract were compared to standards established which is from the USEPA itself, EPAV and the World Health Organization.

Therefore, TCLP test in this research was prepared in Wastewater Laboratory located at UTHM. The brick samples were divided into four parts and were crushed to obtain appropriate sample to conduct the test. Next, all samples were sieved through 9.5mm, and only 50g solid samples were poured in a 1L high-density polyethylene plastic bottle. The extraction fluid for 1L contained 5.7mL of glacial acetic acid with distilled water. The bottles were then agitated at 30 rpm for 18 hours in an end-over-end manner. The leachate collected was then filtered using 0.7 μm glass fiber filters, preserved the sample before being analyzed. Finally, the concentrations of leachate from raw materials and quarry dust waste brick was measured by Atomic Absorption Spectrometry (AAS).

3. Results and Discussion

Based on the results from XRF (Table 2), the high heavy metals values were selected to be tested on TCLP test. These heavy metals or elements are copper (Cu), Lead (Pb), zinc (Zn), manganese (Mn), vanadium (V), nickel (Ni), barium (Ba), chromium (Cr), ferum (Fe), cobalt (Co), arsenic (As) and cadmium (Cd). According to Table 3 below, it shows that there are insignificant concentrations of heavy metals leaching from the samples. The results were then compared to the regulatory levels. Further discussion on the results was explained accordingly from Figure 1.

![Table 3. Heavy metal leached](chart)

Figure 1 demonstrated the leaching reading for different percentages of quarry dust for fired clay brick. As for control clay (0%), quarry dust (10%) and also quarry dust (20%), Zn was recorded as the major heavy metal leached from those samples with 0.65 ppm, 0.40 ppm, and 0.30 ppm respectively. Meanwhile, the highest heavy metals from 30% quarry dust sample are Mn with 0.85 ppm. In contrast, the lowest concentration of heavy metals from quarry dust (0%) and quarry dust (20%) are Cr and Cd with 0.05 ppm. The results also found that as leached lower heavy metals in quarry dust (10%) with 0.01 ppm. V and As leached lower heavy metals in quarry dust (30%) with 0.04 ppm. According to the standard issued by USEPA and EPAV, all heavy metals did not exceed the limit for all types of fired clay brick. However, several heavy metals are exceeded WHO standard with Cd and Pb (control clay 0%, quarry dust 10%, quarry dust 20% and quarry dust 30%), As (control clay 0%, quarry dust 20%), and Mn (quarry dust 30%).
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Low concentration of heavy metals in fired clay brick might be connected to the firing temperature during firing process may change the composition of metals in the bricks to metal oxide\textsuperscript{13,14}. Therefore, these results indicate that incorporation of quarry dust in bricks could and efficiently reduce quarry dust contamination problems\textsuperscript{15}.

![Figure 1. Leachability of manufactured brick.](image)

4. Conclusion

The result presented useful information on the relation between different percentage uses of quarry dust. This research has established that incorporation 30% of quarry dust has improved most properties if appropriately designed during brick manufacturing. By taking into account the effects of quarry dust into the environment, it was found that incorporation 30% of quarry dust into fired clay brick had leached less heavy metals during leachability test. As a conclusion, these results indicate that incorporation of quarry dust could effectively minimize the potential contamination problem from these abundant wastes.

This research was financially supported by Vot U409-IGSP Grant under Public-Private Research Network (PPRN) from Ministry of Higher Education Malaysia and Universiti Tun Hussein Onn Malaysia.

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