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Study on feasibility of reutilizing textile effluent sludge for producing concrete blocks

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ABSTRACT

With an increasing interest in recycling and reusing waste, there is a need to carry out research on exploring ways to transform industrial wastes into construction materials. This paper attempts to explore the feasibility of reutilizing textile effluent sludge (TES) for producing concrete blocks with a pretreatment step. The lime-based pretreatment process was adopted to remove ammonia in TES which had been found to lead to bad odor and strength loss of the concrete blocks. The concrete blocks were prepared with an aggregate to cement ratio of 12, 10 and 6. The pretreated TES was adopted to replace the fine aggregate at a mass ratio ranging from 0% to 30%. The compressive strength and drying shrinkage values were determined to evaluate the performance of concrete blocks containing TES. The results indicated that the lime-based pretreatment process can lower the ammonia concentration in TES significantly. The concrete blocks with a lower TES content and lower ammonia concentration had higher compressive strength and better volume stability. When the TES content in the concrete blocks was about 10%, the concrete blocks with an aggregate to cement ratio of 10 can satisfy the minimum strength requirement for non-load bearing applications. Meanwhile, the result of leaching test indicated that the toxic trace metals present in textile effluent sludge could be stabilized/solidified and metal leaching from the concrete blocks is not a concern.

1. Introduction

Textile industry involves processing or converting raw material/fabric into finished clothing materials via several processes which consume large amount of water and produces polluting waste effluents (Karthikeyan and Mohan, 1999) containing non-biodegradable and toxic dissolved substances (Khatri et al., 2014). Previous studies confirmed that the levels of pollutants in textile effluent were considerably higher than the discharge limits stipulated by local regulations (Noorjahan, 2011; Paul et al., 2012). Therefore, treatment of the textile effluent before discharge is almost mandatory leading to the production of huge volumes of textile effluent sludge. Besides landfill disposal of the sludge, there are growing interests in trying to re-utilize the sludge.

Currently, cement based binders are extensively adopted for treating industrial solid waste containing radioactive or hazardous substances to prevent the leaching of contaminants to the environment (Batchelor, 2006). Stabilization of hydrocarbons in petroleum solid waste was also investigated with cement-based S/S process (Karamalidis and Voudrias, 2007). It was found that inclusion of cement blended with pozzolanic materials increased the leachability of most polycyclic aromatic hydrocarbons in solidified sludge samples. Sewage sludge from have been studied for fired bricks production, but high content of this sludge resulted in a degradation of mechanical strength and absorption of fired bricks (Ingunza et al., 2011).

Several kinds of waste are also reused in combination with cement for producing concrete products, including waste marble (Gencel et al., 2012), ferrochromium slag (Gencel et al., 2013) and CRT funnel glass (Ling and Poon, 2014). Recently, reutilization of sewage sludge ash (SSA) was reported to manufacture blocks with best performance by replacing 10% sand with SSA (Francisco et al., 2014). Even another study assessed the potential feasibility of reusing lime-dried sludge as a replacement of limestone material for clinker production (Xu et al., 2015). Rala et al. (2015) have explored the feasibility of reuse the marble slurry to partially replace cement for concrete production. They found that 10% of cement replaced by marble slurry was the optimum content to produce concrete with the requisite strength and enhanced durability.

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As early as 1980s, sludge from wastewater treatment plants had been studied and reused for producing fired clay bricks, and the results indicated that the compressive strength was acceptable while the texture and finish on the surface of bricks were rather poor (Tay, 1987). The reuse potential of textile effluent sludge for the production of cement-sludge bricks was also confirmed in previous study (Hema and Suneel, 2009), and the compressive strength of the product could even meet the requirement of structural application as described in the India standard. However, the density and compressive strength of the cement brick decreased with increasing amounts of sludge in the brick. The negative effects of textile effluent sludge on properties of concrete block were also demonstrated in some other studies. Herek et al. (2012) suggested that incorporating no more than 20% by mass of sludge could lead to good quality concrete bricks in terms of mechanical characteristics; leaching and solubilization tests proved the sludge brick were inert. Balasubramanian et al. (2006) also reported an investigation on replacing 10%, 20% and 30% of cement with textile effluent sludge to produce flooring tiles, pavement blocks, hollow blocks, solid blocks and burnt clay bricks. It was concluded that a maximum of 30% substitution for cement with textile effluent sludge may be possible in fabrication of non-load bearing building materials.

Few studies gave a valid explanation for the adverse effects of textile effluent sludge on properties of cement-sludge mixtures. It was speculated that the presence of chloride and sulfates in sludge resulted in decline in strength (Raghunathan et al., 2010); Pandey et al. (2011) inferred that Zn and Pb salts in the sludge caused precipitation of protective coatings around cement grains during cement hydration, leading to a decrease in compressive strength.

In this paper, an investigation of assessing the feasibility of reutilizing a textile effluent sludge (TES) with high concentrations of ammonia is reported. Pretreating processes for the TES were attempted in order to alleviate the deleterious effects of TES on the properties of cement-sludge mixtures. Then, the pretreated sludge was used as a partial replacement of fine aggregate to produce concrete blocks. The evaluation of the concrete blocks was conducted in terms of compressive strength and drying shrinkage.

2. Materials and experimental program

2.1. Characteristics of textile effluent sludge

The textile effluent sludge (TES) was obtained from a bleaching and dyeing factory which is located in Guangdong Province of Chinese mainland. The sludge collected (as shown in Fig. 1) was generated from the wastewater treatment process of the factory. A series of physical and chemical tests were conducted to characterize the sludge. The analysis results of the TES are shown in Table 1.

2.2. Pretreatment methods

Considering the high concentration of ammonia (NH_4–N) in the sludge, it was necessary to remove the ammonia salts in TES for two main reasons. First, ammonia is a strong odors compound which would be unacceptable to the workers handling the TES, and the ultimate users of TES related products. Moreover, a previous study on reusing ammonia contaminated fly ash in cement mortar and concrete demonstrated that the presence of ammonia can inhibit cement hydration and thus lower the compressive strength (Kim et al., 2007). In this study, anhydrous lime (CaO) was chosen to remove ammonia from TES as it is the cheapest source of alkali to produce hydroxide ions (OH^-), which can convert ammonium ions in the sludge to ammonia gas (released).

Fig. 1. Raw textile effluent sludge.

Several pre-treatment methods listed below had been tried:

Method A: The as received sludge were pre-dried at 105°C for 24 h, and then ground manually to fine particles smaller than 5 mm in size (Fig. 2). The particle size distribution was determined and the results are presented in Table 2. The prepared TES was used for making the blocks similar to the reference sample;

Method B: The prepared TES from process A was mixed with lime before concrete blocks casting. Before mixing with cement and aggregates, the TES was mixed with lime and water for 5 min using a planetary mixer, with a proportion of TES: lime: water = 1: 0.25: 0.6;

Method C: The prepared TES from process A was mixed with lime for 5 min with a proportion of TES: lime: water = 1: 0.25: 0.6; and then the mixture were aged for 24 h in the laboratory (23 ± 2 °C, 65 ± 10%RH) before concrete blocks casting;

Method D: The as received TES was mixed with lime for 5 min with a proportion of TES: lime = 1: 0.07, and then the mixture were aged for 24 h in the laboratory environment (23 ± 2 °C, 65 ± 10%RH) before concrete blocks casting.

The basic route for the all pretreatment methods is sketched in Fig. 3. After the pretreatment process, the NH_4–N concentrations of the pretreated sludge were also determined using the HACH Method 8155 (Hach Company, 2003).

2.3. Concrete block casting

2.3.1. Mix proportions of concrete blocks

Four series (A, B, C and D) of concrete block mixes were designed to reuse the sludge corresponding to the four pretreating method of TES mentioned above.

The cement used was ASTM Type I Portland cement. Crushed fine granite passing 5 mm sieve was used as the fine aggregate, while the crushed granite with a nominal size of 10 mm was used as the coarse aggregate. Aggregate to cement ratios (A/C) of 6, 10 and 12 were adopted. The pretreated sludge was used to replace the fine aggregate with different mass ratios. The amount of water added varied slightly with the different mixes, and was dependent on the amount of pretreated sludge (normally the pre-treated TES had a higher water demand than natural aggregates) used. The details of mix proportions for concrete blocks are presented in Table 3.

2.3.2. Fabrication of concrete blocks

The experimental procedure of concrete blocks casting is illustrated in Fig. 4. Specimens with dimensions of 70 mm × 70 mm × 70 mm, and 25 mm × 25 mm × 285 mm were