Performance appraisal of industrial waste incineration bottom ash as controlled low-strength material

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Developing countries are witnessing tremendous growth in the production and manufacturing sectors. This leads to the accumulation and accelerating the output of industrial wastes. These wastes must be properly managed and disposed without causing any harmful environmental effects. Hence, civil engineers are left with the challenge of managing the industrial wastes. Research works are being undertaken to look into the aspect of managing, treatment, reuse, and disposal of thesewastes. The scheduled industrial waste generation in Malaysia in the year 2007 is 1,138,839 metric tonnes according to the Malaysia Environmental Quality Report 2007, Department of Environment, Malaysia. Around 120,000 metric tonnes of industrial wastes are treated by Kualiti Alam Sdn Bhd, Malaysia. Wastes with a Total Organic Carbon more than 10% are sent to incineration which produces around 14,000metric tonnes of bottom ash. The bottom ash is sent to secured landfills. But disposal by land filling is not a sustainable solution

Hence various methods of using the bottom ash and fly ash need to be developed. Incineration byproducts, if reused, will offer many advantages viz., ensures sustainability, reduces pollution and environmental degradation, generates revenue, and preservation of natural resources, etc.

One of the ways of using the incineration byproducts is to use them as controlled low-strength material (CLSM).

CLSM, in its simplest form, is a slurry made by mixing sand, cement, ash, and water. It is self compacting, flowable, and used primarily as replacement for soil and structural fillings. American Concrete Institute ACI committee 229 [1] defines CLSM as a material having a compressive strength of 8.3MPa or less. The CLSM is flowable, self compacting, and offers many advantages compared to conventional soil fills. Some advantages of CLSM over conventional back fills are easy placement with no vibration, less onsite labor requirements, ease of placing in intricate locations, no settlement problems, strong, durable, and flexibility to incorporate any locally available non-conventional materials.Waste materials like flue gas desulfurization material, foundry sand, wood fly ash, dry scrubber ash, glass cullets [2] are successfully tried in CLSM. However the reuse of industrial waste incineration bottom ash as CLSM has not been done yet. This is because of the worry of leaching of hazardous materials from the bottom ash and consequently refraining the researchers from thinking about the potentials of reusing the bottom ash. This paper aims to bring about a paradigm shift in the civil engineering fraternity to start investigating ways and means of reusing the industrial waste incineration bottom ash which are otherwise not utilized.

This paper presents the findings of a preliminary experimental investigation carried out on CLSM mixtures made using the industrial waste incineration bottom ash. CLSM mixes were made with the bottom ash, cement, and water. Various tests were conducted on the CLSM mixes in fresh and hardened states. The CLSM mixes were also tested for corrosivity and concentration of heavy metals and salts. The behaviour of CLSM under various curing environments with regard to strength has been discussed. The results from this investigation can be used on other industrial waste incineration bottom ash and the behaviour of CLSM incorporating such incineration bottom ash can be established.

Experimental methods

Materials

Ordinary Portland cement confirming to Malaysian Standard 522 part 1-2003 was used in this investigation. Bottom ash was obtained from the industrial waste incineration plant operated by Kualiti Alam Sdn Bhd, Malaysia. The bottom ash contains particles of various sizes from fine powder to 60mm. This was first dried in an oven at 105 ◦C until constant mass, and then sieved through a 10mm size sieve to eliminate particles larger than 10mm size. This is because more than 95% of the particles of the bottom ash is less than 10mm size, and, using <10mm size particles will enable the CLSM to more flowable and hence the need of using admixtures in order to make it flowable may be eliminated. The chemical compositions of cement and bottom ash are shown in Table 1. The grading curve for bottom ash is shown in Fig. 1. The fineness modulus of bottom ashwas 3.06, specific gravity 1.84, uncompacted bulk density 911 kg/m3, and the compacted bulk density 964 kg/m3. The percentage of particles of bottom ash finer than 75_mwas 12%. As per BS 882 [3], the grading of slag falls in the range of coarse and medium fine aggregate. Potable water is used in the investigation.

Mix proportions, and sample preparation

The mix formulations used in the investigation are shown in Table 2. The bottom ash, and cement were first placed in a tilting type mixer, and dry mixed for one minute. Sufficient quantity of water was then added and the contents mixed for two minutes.

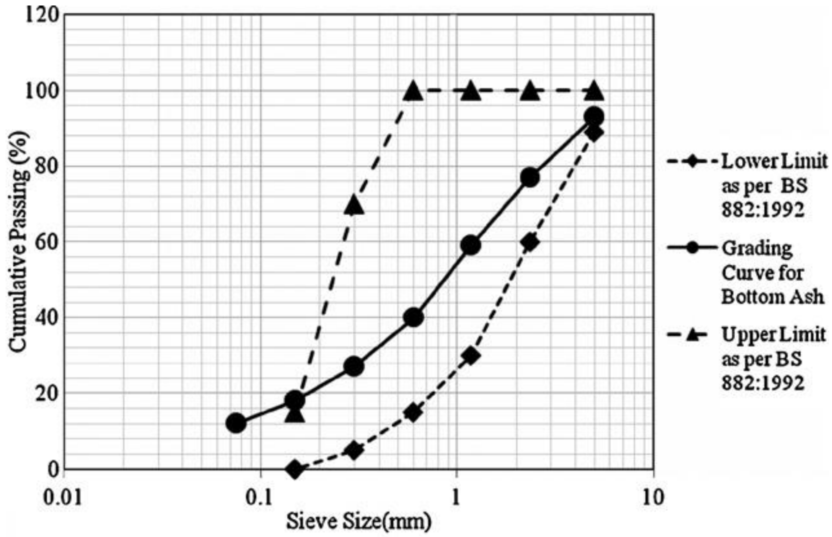

Fig. 1. Grading curve for bottom ash.

The sample was then tested for flow consistency as per ASTM D 6103 [4]. If the flow was less than 200mm, more water was added to get the flow more than 200mm. The contents were then mixed for another 2min. Resulting mix was then taken for further testing in fresh state, also filled in three numbers of 50mm 5 gang cube moulds. The cubes were kept covered with wet burlap over night, and then transferred to various curing environments in order to understand the behaviour of bottomash with regard tocompressive strength under these conditions. Any odd behaviour of bottom ash can be predicted from the results and the findings can be useful in the future course of investigation.

The curing environments in which the CLSM cubes were kept are as below:

a) NCDODT—Normal curing in plastic containers, demoulded on the day of test. Moulds were kept over water surface in closed plastic storage boxes. The boxes were kept in an air conditioned room. The temperature was 22 ◦C and the relative humidity within the box was more than 95%.

b) NCOE—Normal curing in plastic containers, demoulded 2–3 weeks earlier. The cubes were demoulded on seventh day and were kept in the same curing environment as in 1 above.

c) DC—Dry curing. The moulds were wrapped in plastic bags, and kept in a dry place in the laboratory environment. The demoulding was done on the day of testing.

d) DWC—Deionizedwater curing. Cubeswere kept as in 1 above for first one week. The cubes were then demoulded and immersed in deionized water and kept in air conditioned room at 22 ◦C until the day of testing.

Tests

Tests for compressive strength, stiffening time, fresh and hardened densities, bleeding, corrosivity, and leaching of heavy metals and salts were carried on the CLSM mixtures in this investigation.

The compressive strength of CLSMwasmeasured at 7, 14, and 28 days. The size of the cubes was 50mmwhich is five times the maximum size of the coarse material used. Universal testing machine of 100 kN capacity was used for the testing. The loading rate was kept low at 0.6 mm/min. The slow loading rate enables the test to be more accurate as it is a low-strength material. It took 4–8 min for failure of each specimen. Five cubes were tested on each day and average values reported.

Setting time test was done as per BS EN 13294 [5] on mortar sieved fromthe fresh CLSMusing a 5mmsieve. The containerswere then closed with a lid, and kept covered with wet burlap in the air conditioned room at 21 ◦C at a relative humidity of around 60% for the entire duration of testing. The penetration load was measured by a deflectometer with an accuracy of 0.002mmwhich is attached to a calibrated proving ring that is attached to the penetrometer. First reading was taken at two hours from the addition of water to CLSMmixtures. Subsequent readingswere taken at 30min intervals until the initial setting is reached. Duplicate readings were taken for each observation. The initial setting time is the time to get a penetration resistance of 0.5MPa starting from the time of water addition.

The density of CLSM at fresh state was measured by filling a 1.5 L copper container with CLSM and measuring the weight using a scale accurate to 5 g. The copper container was pre calibrated for its volume. Average of two observations was taken for the fresh density. Hardened density of CLSM was measured by measuring the weight of each 50mm cubes before testing for compressive strength. Average of 5 values was taken for the hardened density.

Test for bleeding of CLSM was done by filling about 800mL of fresh CLSM in 1000mL measuring jar. The jar was closed and kept in air conditioned room at 21 ◦C. After the CLSM was stabilized, the volume of CLSM, and the bleed that was accumulated above the CLSM were then recorded. The bleed is then expressed as a percentage of the initial volume of CLSM.

Corrosivity is a means to identify materials that are potentially a hazard to human health or the environment due to their ability to mobilize toxicmetals if discharged into the environment, to corrode handling, storage, transportation, and management equipment, or to destroy human or animal tissue in the event of inadvertent contact. Corrosion can occur when water or leachate water reacts with metal parts. A solid waste exhibits corrosivity if a representative sample of the waste has the property that is aqueous and has a pH less or equal to 2 or greater than or equal to 12.5 [6]. However, this range is not applicable to the corrosion or passivity of all materials. For example, higherpHvalues provide passivity to exposedsteel but may corrode glassy material. The corrosivity of CLSMwasmeasured as pH of bleed and leachate collected from the CLSM. Bleed water collected from the bleed test was used. The leachate was collected by placing three numbers of 50mm cubes in three liters of deionizedwater on day 7 in a plastic container (L/S = 8). The containerwas kept closed in air conditioned room at 21 ◦C. Cubes were removed from the container on 28th day, and the water in the container was used as leachate.

The toxicity of the CLSM was studied by measuring the concentration of heavy metals and salts in the bleed water and in the leachate. Samples that were used in pH tests were used in this study. Inductively coupled plasma optical emission spectrometer was used for these tests except mercury for which an atomic absorption spectrometer was used.

Full text available at :

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