Properties of controlled low-strength material made using industrial waste incineration bottom ash and quarry dust

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The scheduled industrial waste generation in Malaysia in the year 2009 is 1,705,308 metric tonnes [1], major components of the wastes are from dross, slag, clinker, ash, gypsum, oil and hydrocarbon. These wastes must be properly managed and disposed without causing any harmful environmental effects. Around 126,288 metric tonnes of industrial wastes are treated by Kualiti Alam Sdn Bhd, Malaysia. Incineration of these wastes produces around 25,000 tonnes of bottom ash (BA) which are sent to secured landfills. But disposal by land filling is not a sustainable solution.

Hence various methods of using the bottom ash need to be developed. Incineration bottom ash, if reused, will ensure sustainability, reduce pollution and environmental degradation, generate revenue, and preserve the natural virgin resources [2]. One of the ways of using the industrial waste incineration bottom ash is to use them as controlled low-strength material (CLSM). CLSM, in its simplest form, is slurry made by mixing sand, cement, ash, and water. ACI committee 229 [3] defines CLSM as a material having a compressive strength of 8.3 MPa or less. It is self compacting, flowable, and used primarily as replacement for soil and structural fillings like bridge abutment, pipeline bedding, tilt-up construction, foundation backfill, filling abandoned mines, under slab voids, and sequential excavations in contaminated soil. Many waste materials have been successfully employed in CLSM applications. Dry scrubber ash, fly ash, clean coal ash, high-fines limestone screenings, recycled glass are to name a few [4]. Materials like scrap tyre rubber [5], fluidized bed combustion ashes [6], and recycled concrete aggregate [7] were also used in CLSM applications. Tests done by the authors earlier on the use of incineration bottom ash as CLSM showed promising results [8,9], and there were minor problems like stability. Quarry dust (QD) is crushed dust, produced during the breaking of stone boulders in stone crushers for producing coarse aggregates. The quarry dust consists of excess fines and is considered as a waste material which is normally dumped in bulk quantities around the quarry plants and causes environmental pollution. Quarry dust has been used successfully in concrete, pavement

construction, and in CLSM [10–13]. Use of quarry dust in bulk quantities will greatly mitigate the environmental problems caused by dumping of quarry dust in open lands.

The combination of industrial waste incineration bottom ash and quarry dust in CLSM application has not been carried out before. Quarry dust, being fine material, is supposed to enhance the performance of CLSM made using the bottom ash. The objective of this paper is to study various engineering properties of CLSM made using industrial waste incineration bottom ash and quarry dust. Various mix proportions of CLSM were developed using bottom ash, quarry dust, cement and water. Tests were done on CLSM mixtures in fresh and hardened states and the results discussed. The significance of this research is the attempt of using quarry dust and industrial waste incineration bottom ash to develop CLSM. Both are waste materials and hence will contribute to sustainability.

Experimental methods

Materials used

Ordinary Portland cement conforming to Malaysian Standard MS 522 Part 1 2003 [14] was used in this investigation. Bottom ash was obtained from the industrial waste incineration plant operated by Kualiti Alam Sdn Bhd, Malaysia. The raw materials that are incinerated include chemical wastes, wastes from electrical, electronic, and metal industries. The bottom ash contains particles of various sizes from fine powder to 60 mm. The bottom ash was first dried in an oven at 105 _C until constant mass, and then sieved through a 10 mm sieve to eliminate unsuitable material and particles larger than 10 mm size. Quarry dust was also prepared in the same manner like the bottom ash for use in this investigation. The physical properties of bottom ash and quarry dust are given in Table 1 and the chemical composition of cement, quarry dust, and bottom ash is shown in Table 2. The specific gravity of bottom ash is 1.83 and the specific gravity of quarry dust is 2.59. The quarry dust is denser and heavier than bottom ash. The grading curves for bottom ash and quarry dust are given in Fig. 1. It is indicated that the grading of both materials fall within the ranges given in BS 882:1992 [15].

Mix proportions and sample preparation

The mix proportions used in the investigation are shown in Table 3. The formulations were calculated by mass and volume on solid materials at oven-dry condition using a back calculation procedure based on measurements made on the fresh mixture for density, density values of raw materials, and the water content needed for flowability requirements. The bottom ash, quarry dust, 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. The sample was then tested for flow consistency as per ASTM D 6103 [16] standard test method for flow consistency of CLSM. According to ACI 229R [3], the CLSM is considered flowable if the spread diameter is at least 200 mm. Hence the spread diameter for all the CLSM mixtures was kept constant at 200 ± 20 mm. Water content was then adjusted until the flow was 200 ± 20 mm. The contents were then mixed for another 2 min. CLSM was then filled in 70.7 mm cube moulds, and about 450 ml in a 500 ml plastic measuring jar for stability measure ments. The moulds were not subjected to vibration, but tapped at the sides to remove entrapped air. Cubes were kept covered with wet burlap in the laboratory environment for one day, and then transferred to the curing environment which is maintained at 22 _C and 95% relative humidity. The cubes were removed from the moulds on the day of testing.