A review on use of municipal solid waste ash in concrete

M.R. Lavanya, M. Ibrahim Bathusha and B. Sugumaran

As landfill space for the disposal of ash from Municipal Solid Waste Incineration (MSWI) becomes scarce, it becomes more attractive to reduce the volume of materials being disposed there. Recycling is one approach, waste minimization is the second, and combustion for energy production is the third, and the best one. Ash from municipal solid waste combustors can have less than 10% of the original volume entering the facility. A further reduction in land filling, though, can be realized by developing a beneficial use for the ash. One of the possibilities is to use Municipal Solid Waste Incineration (MSWI) ashes in concrete production, as it is done with coal combustion products. The bottom ash features the most convenient composition for this purpose, and it is available in highest amounts among the MSWI ashes. Untreated bottom ash was used as partial replacement of sand in concrete; strength was not negatively affected up to 30% percentage of replacement and the prepared concrete had sufficient durability. This has the additional advantage of replacing sand and gravel, which must be mined sometimes from environmentally sensitive areas. The appropriate utilization of MSWI residues is a topic studied around the world in the last few decades. In this review, we discuss the current status of research on the use of MSWI ashes in concrete.

INTRODUCTION

Several researches have studied the possibility of recycling fly and bottom ashes in the cement and concrete manufacturing, as aggregates and/or mineral additions. Industrial processes have been developed to use these residues as raw materials for the production of Portland cement clinker [Kikuchi.R (2001), Shimoda.T, Yoloyama. S (1999)]. Aubert.J et al., (2003). Paine K.A et al., (2000) have shown the reactivity of the ashes with lime or clinker. Bottom ashes have been used as aggregates in concrete. But reactions that cause expansion, often related to the presence of metallic aluminium and/or aluminium compounds, have been reported to progressively damage the concrete. Several treatments have been proposed to reduce this phenomenon [Pera J et al., (1997)]. From mechanical (physical) and durability points of view, the bottom ash incorporated in the concrete behaves like ordinary sand. The leaching tests carried out on the concrete confirm that it is possible to obtain the ash materials without major risks for the environment. In addition, these results, as a whole, suggest that the use of waste in concrete constitutes a potential means of adding value and at the same time reduce green house gases. Attempts at using large amounts of ash in cement clinker have been developed in Japan: this is known as ecocement.

Another process, known as the Co-combustion process, initially uses the energy from MSW incineration to calcine limestone to lime in Portland cement production and then uses a blend of fly ash and bottom ash as part of the clinker raw meal feed.

MSWI ASH AS MINERAL ADDITION IN CONCRETE

MSWI bottom ash is potentially attractive as mineral addition for the production of concrete, provided that the risk of entrapment of hydrogen bubbles produced by corrosion of aluminium metallic particles in the fresh concrete is prevented. This could be achieved by wet grinding the bottom ash so that reactions leading to gas development are exhausted within the slurry before this slurry is added to the concrete mixture. However, by considering bottom ashes from different incinerators, a large variability was observed in the times required to complete the hydrogen gas production. Nevertheless, when the hydrogen development in the fresh concrete could be avoided, wet ground MSWI bottom ash showed a good pozzolanic behavior and proved to provide significant contribution to the development of the strength and impermeability of concrete [Luca Bertolini et al., (2004)]. The concrete with the addition of dry ground MSWI bottom ash did not show any workability problem and its fresh density was comparable with that of the other normal concretes. As far as properties of hardened concrete are concerned, the 28-day compressive strength of concrete with 30% wet ground MSWI bottom ash was similar to that of the concrete with 100% Portland cement. MSWI bottom ash from Udine may act as a true cementitious material able to increase the strength and the durability of concrete, provided that the bottom ash is ground in the presence of water and its fineness is comparable to that of typical cement. Accordingly, bottom ash from MSWI treated by a wet grinding process can be advantageously used as an additional ingredient in the production of cement mixes with improved properties of strength, elastic modulus, and resistance to aggressive agents, and to water penetration. The water used for wet grinding is introduced in the concrete mix as part of the mixing water and thus no residues are produced.

PARTIAL REPLACEMENT OF CEMENT RAW MATERIALS WITH MUNICIPAL SOLID WASTE ASHES AND CALCIUM CARBIDE WASTE

Cement raw meals were replaced by 5% and 10% of MSWI and CCW to study the properties of the laboratory produced MSWI and CCW cements. Chemical composition, setting times, compressive strength and expansion in sulfate solution of these pastes and mortars were tested and compared with those made of conventional cement. It was found that the chemical compositions of MSWI and CCW cements were similar to that of the control cement. However, SiO2 content of MSWI cements was higher than that of the control cement, whereas CaO content was lower. Setting times of cement pastes were slightly more when MSWI or CCW were used to replace a part of raw meal in cement production. The longer setting times of these cement pastes were observed due to the lower C3S but higher C2S content than those in the control cement. Compressive strength of CCW cement mortars was close to that of the control cement. However, compressive strength of the mortars produced from MSWI cements was lower than that of the control cement mortar, especially when the percentage of MSWI in the raw meal was increased. When compared to the control cement, the performance of MSWI cement and CCW cement in sodium sulfate solution was superior due to the lower C3S and C3A. [P. Krammart et al., (2004)].

MUNICIPAL SOLID WASTE FLY ASH AS A BLENDED CEMENT MATERIAL

Laboratory tests were carried out to characterize the properties of municipal fly ash MFA samples collected from an incineration plant over a period of 12 months. The laboratory test results show that the major elements present in all MFA samples are Ca, K, Na, Si, Al, and Mg. The specific gravity of the ash samples lies in the range of 2.12–2.58, generally lower than the value of 3.2 for ordinary Portland cement (OPC). The Brunauer-Emmett-

Teller (BET) Surface area of the (MFA) was found to be 6.03 m^2/g, about six times higher than OPC, which has a BET surface area of 1.03 m^2/g. In the investigation on the use of MFA as a blended cement material, 50-mm mortar cubes were cast with various percentages of the OPC replaced by an equivalent amount of MFA. Compressive strength results indicate that up to 10% by weight of OPC could be replaced by MFA. In these cases, higher mortar strengths than in the control cubes were achieved. A seven-day strength activity index of 123.6% was achieved by the MFA, which is almost 50% higher than the requirement of 75%, which shows the contribution of MFA toward the strength development of the blended cements. Mercury porosimetry performed on hardened cement pastes indicated a reduction in the average pore diameter with an increasing percentage of cement replacement, indicating a pore refining capability of MFA particles. [Chia-Chia Goh et al., (2003)].

MUNICIPAL SOLID WASTE BOTTOM ASH AS AN AGGREGATE SUBSTITUTE UTILIZED FOR ASPHALT CONCRETE

An attempt was made to analyze the physical and environmental properties of asphalt mixtures containing different amounts of MSW-BA used as an aggregate substitute. The Marshall mix design method, water sensitivity, and wheel track rutting tests were conducted on MSW-BA asphalt mixtures to evaluate the engineering properties of the mix. Leach tests were performed to measure the concentration of heavy metals. The MSW-BA asphalt mixture had relatively lower rutting resistance when compared with the conventional one. The results of the water sensitivity test showed that the MSW-BA asphalt mixtures had a lower tensile strength ratio compared with the conventional asphalt mixtures. The test results obtained from the toxicity characteristic leaching procedure testing indicated that, after being mixed with asphalt binder, the concentration of heavy metals and the levels of toxicity were significantly reduced. The concentrations of MSW-BA all along were below regulation limits. [Jian-Shiuh Chen et al., (2008)]. If the percentage of MSW-BA introduced into an asphalt mix remains less than 20%, the tensile strength ratio could be controlled within 75%. The MSW-BA asphalt mixtures also showed relatively higher rutting depth from the results of the wheel tracking test. . It is recommended that the use of the MSW-BA ash in asphalt concrete mixtures be limited to be 20% ash, by total weight of the mix, in binder or base course and 10% in surface mix to ensure satisfactory pavement performance.

RECYCLING OF MUNICIPAL SOLID WASTE INCINERATOR ASH IN HOT-MIX ASPHALT CONCRETE

Physical tests were performed on the incinerator ash to determine its gradation and specific gravity, as well as chemical composition of the Leachate from the ash. MSW ash was used in the mixture of hot-mix asphalt with a percentage of up to 40% by total aggregate weight. Optimum mixtures were evaluated for moisture susceptibility and raveling potential. The results indicate the potential use of the MSW ash in asphalt concrete mixtures for surface and base course mixtures with percentages of 15 and 20 ash substitutions, respectively [Hossam F. Hassan (2004)]. Therefore, it is recommended to use up to 15% MSW ash replacement of the aggregate for bituminous surface course. Twenty percent of ash replacement can be used for bituminous base course. Higher percentages of ash replacement should be avoided for surface or base course. Their use in other applications such as low volume roads would need to be evaluated.

CONCLUSION

It could be a possible replacement of raw material in Portland cement production. R. Kikuchi has shown that the addition of MSWI ash for clinker production will shorten the setting time and decrease workability; he suggested that a delaying agent like gypsum should be added. Cement production consumes huge quantities of energy and emits large amounts of carbon dioxide, which is the major cause of global warming. One of the advantages of using MSWI ash as raw material for cement is the reduction in carbon dioxide emissions, thus minimizing the global warming effect. Due to the fact that MSWI bottom ash and fly ash are composed of lime instead of calcium carbonate, use of them in cement production can reduce the carbon dioxide emission. There are several technical problems discouraging this application; the high chloride content will affect the product quality, and the cycling effect in the cement kilns will cause rapid clogging and corrosion inside the heat exchangers. Pre-treatment of fly ash is recommended to remove the chloride and heavy metals content, also the quantities of MSWI ash added to the process should be carefully controlled in order to ensure the process safety as well as product quality.

It is possible to use MSWI bottom ash as concrete aggregate. The results show that treated (immersion in sodium hydroxide for 15 days) bottom ash can replace up to 50% of gravel in concrete without affecting the durability. Cracking and swelling occur if the ash is not treated, due to the reaction between metallic aluminum and cement. MSWI fly ash could also be used as lightweight concrete aggregate by processing into pellets. This could be suitable for non-structural applications such as interior walls for insulating purposes. Also, the use of cement-solidified MSWI fly ash has been proved to be suitable for safe reuse as artificial aggregate in Portland cement mortars. It showed low leaching rates of heavy metals, high compressive strengths (up to 36 N/mm^2 after 90 days of curing) without delay in mechanical strength development. Water washing treatment can enhance the reuse of MSW fly ash as a concrete aggregate, under the condition of a compact pressure of 28 N/mm^2 and sintering temperature of 1,140^oC for 60 minutes. The leaching problem is the major environmental concern of this application. Although many results show that the heavy metal leaching is not significant, unexpected heavy metal leaching may occur when the structure is demolished or comes in contact with rain.

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M.R. Lavanya received her BE in Civil Engineering; ME in Infrastructure Engineering; pursuing her PhD on use of municipal solid waste ash in concrete. She is an Assistant Professor in the Department of Civil Engineering, Dr. Mahalingam College of Engineering and Technology, Pollachi, Coimbatore, Tamil Nadu. She has around five years of experience in academic teaching, consultancy and research works.

Dr. M. Ibrahim Bathusha holds a BE in Civil Engineering; ME in Environmental Engineering; PhD on GIS applications in water quality monitoring and solid waste management. He is an Associate Professor in the Department of Civil Engineering, PSG College of Technology, Coimbatore. He is having 23 years of experience in academic teaching, consultancy and research works. He has carried out many consultancy works in water quality assessment, waste water treatment and his field of research is waste management and reuse of waste sludge.

Mr. B. Sugumaran received his BE in Civil Engineering; ME in Construction Engineering and Management; pursuing his PhD in fibre reinforced self compacting concrete. He is an Assistant Professor (SG) in the Department of Civil Engineering, Sri Eshwar College of Engineering, Coimbatore. He has more than 5 years experience in academic teaching, consultancy and research works.