C&D and inorganic waste as ARM in India's cement industry

Annual generation of construction and demolition (C&D) waste and industrial inorganic wastes in India is estimated to be 170Mt and >230Mt, respectively, and is projected to increase with growing urbanisation and economic development. Considering the continued expansion of the cement industry and its need to adopt sustainable practices, waste valorisation has emerged as a great opportunity for the sector.

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The physical, chemical and mineralogical characteristics of inorganic wastes suggest their potential to be used as alternative raw materials (ARMs) in cement manufacturing. In India more than 60 per cent of fly ash generated and almost all the granulated blastfurnace slag (GBS) is used by the Indian cement industry as blending materials. There is a considerable shortage of conventional building materials in India. All government construction and renovation projects involving demolition, even in the private sector, may be mandated to use at least 20 per cent of recycled construction and demolition (C&D) waste products.[1] The Bureau of Indian Standards (BIS) has prescribed standards for use of C&D waste as coarse and fine aggregates in concrete production,[2] fly ash and GBS as blending materials in cement manufacturing, and other inorganic wastes as performance improvers in cement production.

Recycled aggregates produced in a C&D waste recycling facility in Delhi, India

Construction and demolition waste

The treatment and processing of C&D waste in India is at a very nascent stage. There are a limited number of studies into the use of recycled concrete aggregate (RCA), mixed recycled aggregate (RA) and fines extracted from recycled concrete, as ARMs in cement manufacturing. Galbenis and Tsimas[3,4] investigated the use of RCA and RA with ordinary Portland cement (OPC) raw meal in different proportions. Currently, C&D waste is not used in the Indian cement industry.

As part of the Indo-Norwegian project on co-processing, the National Council for Cement and Building Materials (NCB) analysed the fines extracted from two samples of RCA and two samples of RA. As shown in Table 1, the results indicate that the fines extracted from both the RCA and RA are siliceous in nature. Their chemical composition and conformity with the composition of OPC raw meal indicates that these materials can be used as an additive in the production of clinker. Therefore, the use of C&D waste in the cement process should be studied on a case-to-case basis.

Table 1: chemical analysis of C&D waste fractions from Delhi conducted by NCB

Chemical compound	RCA-1 (%)	RCA-2 (%)	RA-1 (%)	RA-2 (%)
Silica	51.75	52.4	68.7	50.4
Iron oxide	9.93	4.22	3.69	5.25
Alumina	10.63	8.22	8.38	12.11
Calcium oxide	11.66	16.71	7.04	11.25
Loss on ignition	7.6	12.2	6.07	12.31

Other inorganic wastes

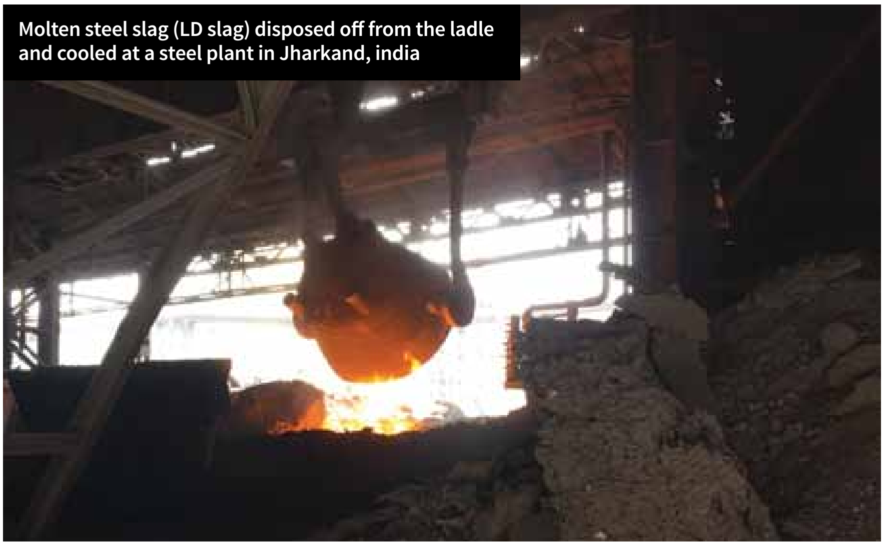
Furthermore, the NCB has explored the use of jarosite as a set controller replacing gypsum. Burnability studies showed the mineralising effect of jarosite in terms of rapid lime assimilation and improved clinker mineral phase formation, compared to a control mix prepared without jarosite.

The NCB and Sterlite Industries (I) Ltd have carried out a joint study that aims to use copper slag as a raw mix component in the manufacture of OPC and as a blending material for Portland slag cement (PSC). The outcome of the study was that copper slag up to 2.5 per cent can be used in a raw mix for OPC and up to 35 per cent in PSC production without any adverse effect on

Table 2: potential use of wastes as alternative raw materials in the cement industry and other uses

Wastes	Generation in India (Mta)	AR value	Potential utilisation as AR (% of raw mix)	Other uses	Limitations
C&D wastes	165-175	Silicon, calcium, iron, aluminium	Study under progress	Recycled aggregates (RA) and recycled concrete aggregates (RCA) in construction, blocks, tiles and bricks	Segregation of C&D wastes, C&D waste rules (2016) to accommodate use in cement production
Fly ash	169	Calcium, silicon	1-3	Pozzolan in cement, bricks, blocks, tiles, roads and embankments, reclamation of low-lying areas, agriculture, geo-polymeric cement	Revise standards for higher utilisation in cement and bricks production; possibility of high carbon content or heavy metals (Pb, Cr and Hg)
Red mud	13.7	Iron, aluminium	2-3	Bricks, tiles	High alkalinity, moisture
Spent pot liner (SPL)	0.04	Mineraliser, fluoride, carbon, sodium	2	Carbon fraction as alternative fuel in cement; trial undertaken in a cement plant in Chhattisgarh. Standard Operating Procedure[9] published by CPCB 9	Hardness and crushability, high sodium content, possible cyanide content, development of flammable gases during transport and storage, odour
Spent catalyst [10,11]	0.03	Silicon, alumina	RFCC-3.5 SAC-2.07	Asphalt filler, metal recovery, sand replacement	High content of silica and heavy metals (Pb, Zn, Mn)
Lime sludge	4.5	Calcium	>70% (dry basis)	In Portland limestone cement (PLC), cement replacement in mortar and concrete, bricks, lime, composite filler, FGD	Moisture
Carbide sludge	0.2	Calcium	30		Heavy metals (Pb, Zn, Mn)
Marble slurry/dust	5-6 (slurry)	Calcium, sulphur (gypsum)	5-15	Bricks, filler materials, production of gypsum, road construction, low-cost binder, mineral grinding	Moisture, local availability (only in Rajasthan)
Jarosite (Hindustan Zinc Ltd)	0.045-0.06	Sulphur (gypsum)	1.5	Set retarder, metal recovery	Heavy metals (Pb, ZN, Cd, Cr)
Blastfurnace slag	24	Calcium, mineraliser	10-15	Pozzolan in cement	Limited availability
Steel/LD slag	12	Calcium, iron corrective, silicon	15	Aggregate, road construction, ceramic tiles	Crushability (hardness); Content of pure iron (harm to equipment)
Lead-zinc slag [12]	1	Calcium, silicon, iron oxide, alumina	5-6	Bricks, tiles, road construction, aggregate, geo-polymeric cement. 0.4Mt sold to cement industries in Rajasthan	Heavy metals (Pb, Zn)
Copper slag	3	Iron, mineraliser, silicon	1.5-2.5	Sand substitute, filler materials, pozzolan in cement, recovery of iron, mine backfill	High-sulphur, heavy metals (Cu, Pb, Zn)

RFCC: Residual fluidised catalytic cracking – SAC: spent alumina catalyst – FGD: flue gas desulphurisation



Molten steel slag (LD slag) disposed off from the ladle and cooled at a steel plant in Jharkand, india

the performance. Leachability studies up to one month indicated that there was no leaching of copper.

Rajasthan state has 95 per cent of India's marble deposits generating 5-6Mta of slurry.[5] Few cement plants in Rajasthan are using 'Makrana' marbles slurry as a replacement for limestone because of the calcined nature of Makrana rock and low moisture percentage. The technical potential of converting marble powder to gypsum is being explored by the Centre for Development of Stones (CDOS), Jaipur.

The addition of red mud can improve the strength properties of cement and resistance to sulphate attack.[6,7] LD slag (steel slag from a basic oxygen furnace) contains calcium and iron, and can be used as ARM following proper size classification. The NCB has investigated the use of LD slag as a performance improver, as blending materials and as raw material in cement manufacture. Studies indicated that five per cent LD slag can be used as a performance improver, depending on the glass content, 10-15 per cent LD slag can be added as blending material while 4.25 per cent could be used as a raw material to replace iron-bearing additives. Further research in terms of durability is in progress.

Investigations by the NCB showed that spent pot liner (SPL) waste can be used as a mineraliser to up to 1.5 per cent in the cement raw mix, which reduces the clinkerisation temperature by 30-40˚C and results in good-quality clinker. The NCB also investigated the use of lead-zinc slag as a raw mix component (up to 5.5 per cent) in OPC clinker production in addition to other raw materials. Compared to GBS, the lower glass content (42 per cent) of used lead zinc slag restricted addition to 40 per cent only in the clinker sample in the manufacture of PSC at an optimised fineness of 350 ± 20m^2/kg Blaine.

The main sources of the lime sludge are sugar, paper, acetylene, fertiliser, sodium chromate and soda ash industries. The following sludges could be used as alternative raw materials in the cement manufacturing process:

- up to 74 per cent of lime sludge on dry basis from paper industry
- up to 30 per cent of carbide sludge
- approximately eight per cent of phosphor-chalk limited by P_2O_5, and SO_3
- up to five per cent of chrome sludge (as mineraliser) limited by chromium oxide.

The lime sludge from the paper industry has been found to be suitable as a blending material for manufacture of masonry cement in the proportion of up to 30 per cent conforming the Indian Standard specification of IS: 3466-1988.[8]

Conclusion

The origin of the wastes can help in qualifying the assessment of possible contamination of volatile organic compounds (VOCs), heavy metals (such as mercury and cadmium) and other critical elements (including chlorine, magnesium, phosphorus and alkalis). Feeding of the wastes in high quantities requires proper size classification, especially when used in the hot end of the kiln. If there is a risk of formation of VOCs, feeding of wastes through the cold end of the kiln (ie in the raw mill or kiln feed) should be avoided. The emission limits as prescribed by the Indian Ministry of Environment, Forests and Climate Change (MOEFCC) for the cement industry should be used as one of the decision-making criteria.

With India's construction sector growing exponentially, C&D waste recycling will be an important source of secondary raw materials, as a negligible amount is currently being processed and used. To enhance the use of inorganic wastes such as steel slag, lead-zinc slag, copper slag, jarosite, red mud and SPL by the Indian cement industry, the development of technical guidance is needed as is the determination of commercial viability on a case-to-case basis. ■

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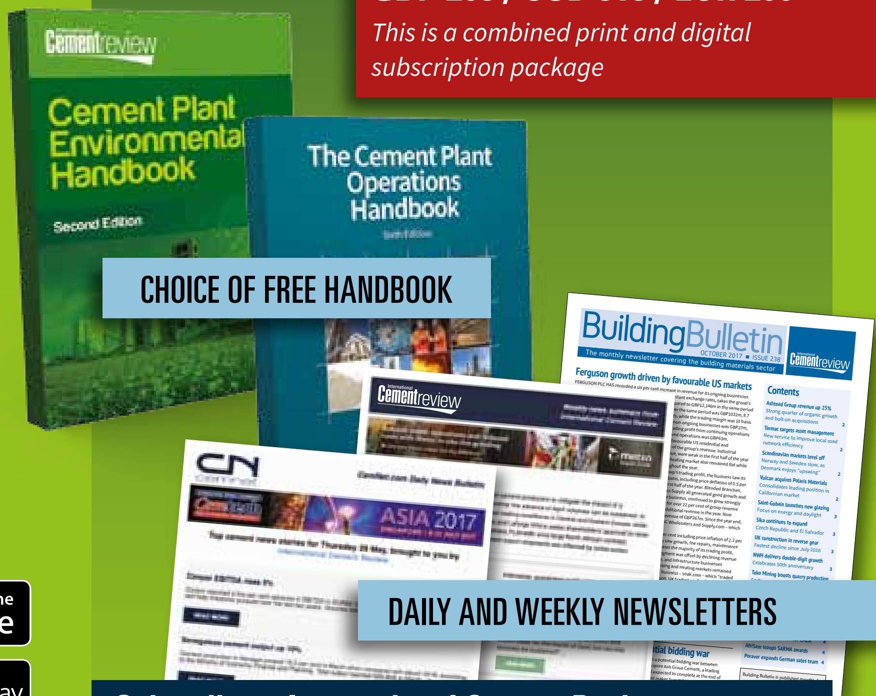

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