Utilization of Construction and Demolition (C&D) Waste and Industrial Inorganic Wastes in Cement Manufacturing

Parmanand Ojha, Pinky Pandey, Kåre Helge Karstensen and Palash Kumar Saha

Abstract Annual generation of C&D waste and industrial inorganic wastes in India is estimated to be 170 million tonnes and >300 million tonnes, respectively, which is projected to increase with the growing urbanization and economic development. Considering the constant expansion of the cement industry and its need to sustain, waste valourization has emerged as a great opportunity for the industry. Bureau of Indian Standard (BIS) has prescribed standards for use of C&D waste as coarse and fine aggregates, fly ash and granulated blast furnace slag (GBFS) as blending materials in cement manufacturing and other inorganic wastes as performance improvers in cement manufacturing. The physical, chemical and mineralogical characteristics of inorganic wastes suggest their potential to be utilized as alternative raw materials in cement manufacturing. The addition of red mud can improve the strength properties of cement and resistance to sulphate attack. Spent Pot Liner (SPL) can be gainfully utilized as a mineralizer in cement raw mix. NCCBM has explored use of Jarosite as set controller in place of gypsum, use of copper slag and lead–zinc slag as alternative raw materials and as blending materials in Portland Slag Cement (PSC) and use of marble dust as decarbonated raw material and as blending material in Portland Limestone Cement (PLC). There are, however, limited number of studies for use of recycled concrete aggregate (RCA), recycled masonry aggregate (RMA) and fines extracted from recycled concrete, as alternative raw materials in cement manufacturing. As a part of the Indo-Norwegian project on co-processing, NCCBM is currently exploring the possibility of utilization of fines extracted from recycled concrete aggregate and recycled aggregate as alternative raw materials in cement manufacturing. This paper contains potential utilization and further opportunities for increased utilization of C&D waste and industrial inorganic wastes in cement manufacturing process.

P. Ojha (✉) · P. Pandey
NCCBM, Ballabgarh, India
e-mail: pnojhaji@gmail.com

K. H. Karstensen
Asian Institute of Technology, Khlong Luang, Thailand

K. H. Karstensen · P. K. Saha
SINTEF, Trondheim, Norway
e-mail: palashkumar.saha@sintef.no

S. K. Ghosh (ed.), *Urban Mining and Sustainable Waste Management*,
https://doi.org/10.1007/978-981-15-0532-4_4

Keyword C&D waste · Fly ash · Slag · Red mud · Jarosite · Cement

1 Introduction

The rapidly growing economy, urbanization and industrialization are leading to the increasing generation of C&D wastes and industrial wastes. Estimated annual generation of C&D waste in India is in the range of 165–175 million tonnes (Mt) projected to increase further in coming years. Current generation of industrial inorganic wastes is more than 300 Mt. The major industrial inorganic wastes are coal combustion residues, red mud, Spent Pot Liner (SPL), spent catalyst, marble dust, soda ash, lime sludge, jarosite, slags (lead–zinc, copper, steel), etc. It is evident from the physical, chemical and mineralogical characteristics of these wastes, generated from different processes, that they have good potentials for recycling and gainful utilization in cement manufacturing process with 100% material recovery.

2 Construction and Demolition (C&D) Waste

C&D waste is the debris generated from construction, repair, renovation and demolition of structures. It is a non-hazardous solid waste comprising the range of materials, e.g. bricks, mortar, concrete, wood, steel, tiles, metal, masonry, asphalt, stone (marble, granite, sandstone), etc. After processing of C&D waste, generally two types of materials are obtained, i.e. recycled aggregate (RA) consisting of brick masonry, cement mortar, tiles, etc., and recycled concrete aggregate (RCA) consisting of concrete debris. Out of total C&D waste generation about 90–92% is RA and 8–10% is RCA. RA is being processed through wet process, and RCA is being processed through dry process. The treatment and processing of C&D waste in India are at a very nascent stage.

2.1 Current Generation of C&D Waste

The estimated C&D waste generation is in the range of 165–175 Mt/year (BMTPC 2016). Total C&D waste generation from megacities such as Mumbai, Delhi, Bangalore, Hyderabad, Chennai, Ahmedabad, Pune, Surat and Kolkata is 17,600 tonnes/day and in 1 million plus population cities is 4320 tonnes/day.

2.2 Current C&D Waste Processing Plants Operational in India

The processing and recycling of C&D waste in India are limited to four operational plants—three in Delhi located in Burari (IEISL 2017), East Kidwai Nagar (NBCC 2013) and Shastri Park and one in Ahmedabad with capacities of 500 tonnes/day, 150 tonnes/day, 500 tonnes/day and 100 tonnes/hour, respectively. The Municipal Corporations of Jaipur, Bengaluru, Pune and Bhopal are planning to set up processing plants of capacities in the range of 300–750 tonnes/day.

2.3 Current Utilization of C&D Waste in Construction Industry

The C&D waste is processed to produce usable building materials such as fine aggregate, coarse aggregate, bricks/blocks, tiles, paver blocks, kerbstones and prefab slabs. Based on the research conducted in India, BIS has allowed the usage of C&D waste in IS: 383-2016 as coarse and fine aggregates in concrete (BIS 2016). C&D waste may be used in RCA up to 25% in plain concrete, 20% in reinforced concrete of M25 or lower grade and up to 100% in lean concretes of grade less than M15. Liu and Wang (2013) have provided the model for calculating costs of disposal routes for CDW. They have found that on equal conditions, the costs of recycling and reuse are least (Liu and Wang 2013).

2.4 Utilization of C&D Waste in Cement Industry

Limited research has been conducted internationally (Galbenis and Tsimas 2004; Puertas et al. 2008; Gastaldi et al. 2015; Schoon et al. 2015; Kara et al. 2017; Galbenis and Tsimas 2006) and in India on use of C&D waste in the cement industry. Substitution of natural raw material by recycled concrete aggregates and rubbles obtained from C&D waste in clinker production was explored by Galbenis and Tsimas (2004); whereas, Puertas et al. (2008) used ceramic tiles in cement production. Gastaldi et al. (2015) used hydrated cement separated from C&D waste to replace 30% of raw material, while in some other study, Schoon et al. (2015) used C&D waste fines as alternate raw material. Kara et al. (2017) evaluated the suitability of C&D waste components, e.g. tiles, bricks, fire bricks, plaster and concrete as secondary raw material. Galbenis and Tsimas (2006) investigated the use of RCA and RMA with OPC raw meal in different proportions. Currently, C&D waste is not utilized in the Indian cement industry. National Council for Cement and Building Materials (NCCBM) analysed the fines extracted from two samples of RCA and two samples of RA. The results indicate that the fines extracted from RCA and RA are siliceous

Table 1 Chemical analysis of CDW fractions from Delhi conducted by NCCBM

Chemical composition (%)	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

in nature. Their chemical composition and their conformity with the composition of Ordinary Portland Cement (OPC) raw meal indicate that these materials can be used as an additive in the production of clinker. The use of C&D waste in cement process should be studied on a case to case basis. The analysis is given in Table 1.

3 Fly Ash

The thermal power plants in India are primarily dependent on the combustion of high ash bituminous coal in pulverized fuel-fired systems. Hence, the low-lime fly ash (like Class F of ASTM C 618) is the prime variety generated in India, although significantly smaller volumes of high-lime fly ash (comparable to ASTM Class C) are available in the country.

3.1 Fly Ash Generation Versus Utilization in India Including Cement Industry

As per the data from Central Electricity Authority (CEA), in 2016–17, 169.25 Mt of fly ash was generated in India from coal-fired power plants, almost 2.5 times compared to 1996–97 generation. The fly ash utilization stands at 107.1 Mt in 2016–17 (63.3% of generation) compared to 6.6 Mt in 1996–97. In 2016–17, 40.6 Mt was utilized by the Indian cement industry (CEA 2017).

NCCBM has conducted pioneering studies to enable standardization and commercialization of fly ash in the cement and construction sector. NCCBM has assisted in standardizing and commercializing composite cement recommending 15–35% fly ash and granulated blast furnace slag (GBFS) in the range 20–50% (IS 16415-2015) (BIS 2015a); whereas, Portland Pozzolana Cement (PPC) has already got lions share in the Indian cement market (BIS 2015b). NCCBM is currently investigating production of geo-polymeric bricks using chemically activated fly ash.

4 Red Mud

Red mud is a by-product of the production of alumina from bauxite in the Bayer process which involves reaction with NaOH at high temperature and pressure. Its composition, property and phase vary with the origin of the bauxite and the alumina production process.

4.1 Red Mud Generation and Composition

The total red mud generation in different industries, namely NALCO, HINDALCO, VEDANTA, UTKAL, RAYKAL, Aditya and JSW is 13.7 Mt/year (Samal et al. 2013).

Red mud is alkaline in nature and contains oxides and salts of iron (30–60% by weight), aluminium (10–20% by weight), silica (3–50% by weight), sodium (2–10% by weight) and calcium (2–8% by weight) and a variety of trace elements such as titanium (trace—25% by weight), potassium, chromium, vanadium, manganese, lead, zinc, phosphorus, fluorine, sulphur and arsenic. Mineralogical phases of red mud are haematite Fe_2O_3, goethite FeO(OH), gibbsite $AlOH_3$, diaspore, AlO(OH), quartz SiO_2, cancrinite $Na_6Ca_2[(CO_3)_2|Al_6Si_6O_{24}]\cdot 2H_2O$, kaolinite $Al_2Si_2O_5(OH)_4$ and calcite ($CaCO_3$) (Deelwal et al. 2014).

4.2 Red Mud Utilization and Ongoing R&D Work

Red mud and siliceous additive have been used together to make bricks (Mustafa 2000). CBRI Roorkee has produced clay bricks by partially replacing clay with red mud and fly ash. HINDALCO has sponsored projects for utilization of red mud as additive for production of special cement and mortar. Apart from construction applications, red mud can be used for glass ceramics, water treatment, as catalyst, as geo-technical material (Deelwal et al. 2014) and in recovery of metals from red mud. Red mud can be used as an alternative raw material in cement production (Mishra et al. 2011).

5 Spent Pot Liner

Spent Pot Liner (SPL) is a by-product generated when the carbon and refractory lining of aluminium electrolytic cell, known as a pot, reaches the end of its useful life. Life of aluminium smelter pot is 2500–3000 days, and the generation of SPL per pot is around 60–85 tonnes (Tiwari 2017). SPL has been classified as hazardous waste. SPL generation in India is estimated to be more than 45,000 tonnes/year @ 20 kg/tonnes of aluminium production.

5.1 Utilization of SPL

SPL could be used as an energy source (Parhi 2014) and as raw material component (Chaturvedi et al. 2011; Alka and Kumar 2011). A demonstration trial of SPL carbon fraction has been carried out in a cement plant in Chhattisgarh. SPL has also been used in captive power plants of HINDALCO. Central Pollution Control Board (CPCB) has published standard operating procedures and checklist of minimal requisite facilities for utilization of SPL generated from primary aluminium smelting industries (CPCB 2017).

5.2 Spent Catalyst

Spent catalysts are generated from the catalytic cracking process when catalysts are withdrawn regularly to maintain desired cracking and product yield. Annually, 32,000 tonne of spent catalyst is generated in India. NCCBM has investigated the utilization of spent catalysts as alternative raw material in cement manufacturing process. Spent catalyst has also been used as an asphalt filler. Lin et al. (2017) have also reported the use of 4% spent catalyst as cement raw material; whereas, Al Dhamri et al. (2011) have reported 3.5% use in Portland cement clinker.

6 Lime Sludges

The main sources of the lime sludge are sugar, paper, acetylene, fertilizer, sodium chromate and soda ash industries. It is estimated that approximately 4.5 Mt of lime sludges are generated in these industries (Sengupta 2014).

The following sludges could be used as alternative raw materials in cement manufacturing process: up to 74% of lime sludge on dry basis from paper industry, up to 30% of carbide sludge, approximately 8% of phosphor–chalk limited by P_2O_5, and SO_3; and up to 5% of chrome sludge (as mineralizer) limited by chromium oxide. The lime sludge from paper industry has been found suitable as a blending material for the manufacture of masonry cement in the proportion of up to 30% conforming the Indian Standard Specification of IS: 3466-1988.

7 Marble Dust/Slurry

Rajasthan state has 95% of India's marble deposits (Report on disposal options of marble slurry in Rajasthan 2011) generating 5–6 Mt of slurry every year. The marble dust and slurry from marble stone processing can be gainfully utilized as limestone substitute (up to 5–15%) in cement manufacturing process. However, the presence of MgO and moisture restricts the use of dolomitic marble slurry. Few cement plants in Rajasthan are using 'Makrana' marbles slurry as the replacement of limestone because of the calcined nature of Makrana rock and low moisture percentage.

The technical possibilities for converting marble powder to gypsum are being explored by Centre for Development of Stones (CDOS), Jaipur. Marble dust can be used in road construction, as filler materials and in brick manufacturing. The marble bricks with more than 80% marble slurry have compressive strength that is 2.5 times more than the traditional red bricks. Options for marble slurry management include use in—cement manufacturing, producing synthetic gypsum, road construction, preparing low-cost binder, brick manufacturing and mineral grinding plants (Indian minerals yearbook 2016).

8 Jarosite

Jarosite is a waste generated when iron sulphate from reaction of insoluble zinc ferrite ($ZnO.Fe_2O_3$) and sulphuric acid reacts with ammonium sulphate. Jarosite, due to higher SO_3 content (up to 30%) could act as a gypsum substitute. NCCBM has worked on 3% jarosite replacement for gypsum. Utilization up to 1.5% jarosite as raw mix component has also been reported by NCCBM.

The presence of mineral phases bearing iron, sulphur, sodium, potassium and zinc in jarosite showed its suitability for use as mineralizer in development of clinker mineral phases. Burnability studies showed the mineralizing effect of jarosite in terms of rapid lime assimilation and improved clinker mineral phase formation as compared to control mix prepared without using jarosite.

9 Steel Slag

During steel production, depending on the cooling process, three types of slags are generated, namely air-cooled slag, granulated slag and expanded slag (Ministry of Mines 2018). Steel slag, especially, GBFS is being used as performance improver in cement and as mineral admixture in mortar and concrete (Tiwari et al. 2016). LD slag has calcium and iron and can be used as AR after proper size classification and removal of the magnetic particles. NCCBM is investigating on the production of geo-polymeric cement from slag.

10 Copper Slag

Approximately 3 Mt of copper slag is generated in India; for every tonne of copper, 2.2 tonne of slag is generated. Copper slag is used by the Indian cement industry as a performance improver (IS 269: 2015). Copper slag as an alternative iron corrective reduces calcination temperature and therefore reduces the need for mineralizers. The use of copper slag as pozzolan and in mortar has been reported in many studies.

Up to 15% of copper slag can be used as a cement replacement with constant water: cement ratio of 0.4. This gives higher compressive strength than ordinary cement (Tixier et al. 1997). The dynamic compressive strength of copper slag reinforced concrete generally improved with the increase in amounts of copper slag used as a sand replacement up to 20%, compared with the control concrete (Wu et al. 2010). Since copper slag has higher shear strength and density, it can be used as backfill material in retaining walls to reduce seismic earth pressure (Sathya and Shanmugavalli 2014).

NCCBM and Sterlite Industries (I) Ltd have done joint study that aims to utilize the copper slag as raw mix component in the manufacture of Ordinary Portland Cement (OPC) and as a blending material for Portland Slag Cement (PSC). Leaching behaviour was also studied. The outcome of the study was that copper slag up to 2.5% can be used in raw mix for OPC and up to 35% in manufacture of PSC without any adverse effect on the performance.

11 Lead–Zinc Slag or Imperial Smelting Furnace (ISF) Slag

Imperial smelting furnace (ISF) slag or lead–zinc slag is produced during the pyrometallurgical refining of sulphide metal. Use of lead–zinc slag as a performance improver in OPC (IS: 269) has already been approved by Bureau of Indian Standards (Indian Standard 2015). Morrison et al. (2003) reported increase in density of concrete when sand was substituted with ISF slag due to high specific gravity of ISF slags.

Rajasthan State Pollution Control Board has given consent to Hindustan Zinc Limited for sale of lead–zinc slag for cement manufacturing, road construction, bricks and tiles manufacturing; more than 0.4 Mt of slag has been sold to cement industries in Rajasthan.

12 Conclusion

With the construction sector growing exponentially, C&D waste recycling and recovery will be an emerging sector to work for in India, as negligible amount is being

Table 2 Potential utilization of wastes as AR in cement industry and other uses

Wastes	Generation in India (Mt/year)	AR value	Potential utilization as AR (% of raw mix)	Other uses
C&D wastes	165–175	Iron, aluminium, calcium		Recycled aggregates (RA) and recycled concrete aggregates (RCA) in construction, blocks, tiles and bricks
Fly ash	169	Calcium, silica	1–3%,	Pozzolan in cement, bricks, blocks, tiles, roads and embankments, reclamation of low lying areas, agriculture, geo-polymeric cement
Red mud	13.7	Iron, aluminium	2–3%,	Bricks, tiles
Spent Pot Liner (SPL)	0.04	Mineralizer, fluoride, carbon, sodium	2%	Carbon fraction as alternative fuel in cement
Spent catalyst	0.03	Silica, alumina	RFCC-3.5%, SAC-2.07%	Asphalt filler, metal recovery, sand replacement
Lime sludge	.4.5	Calcium	>70% on dry basis	In Portland limestone cement, cement replacement in mortar and concrete, bricks, lime, composite filler, FGD
Carbide sludge	0.2	Calcium	30%	
Marble slurry/dust	5–6 (slurry)	Calcium, sulphur (gypsum)	5–15%	Bricks, filler materials, production of gypsum, road construction, low-cost binder, mineral grinding

(continued)

Table 2 (continued)

Wastes	Generation in India (Mt/year)	AR value	Potential utilization as AR (% of raw mix)	Other uses
Jarosite (Hindustan Zinc Ltd)	0.045–0.06	Sulphur (gypsum)	1.5%	Set retarder, metal recovery
Blast furnace slag	24	Calcium, mineralizer	10–15%	Pozzolan in cement
Steel/LD slag	12	Calcium, iron corrective, silica	15%	Aggregate, road construction, ceramic tiles
Lead–zinc slag	1	Calcium, silica, iron oxide, alumina	5–6%	Bricks, tiles, road construction, aggregate, Geo-polymeric cement
Copper slag	3	Iron, mineralizer, silica	1.5–2.5%	Sand substitute, filler materials, Pozzolan in cement, recovery of iron, mine backfill

RFCC: Resid Fluidized Catalytic Cracking; SAC: Spent Alumina Catalyst; FGD: Flue Gas Desulphurization

processed and utilized today. For enhancing the utilization of inorganic wastes such as steel slag, lead–zinc slag, copper slag, jarosite, red mud and SPL, by the Indian cement industry, technical guidance is required to be developed and commercial viability needs to be worked out on a case to case basis (Table 2).

References

AL-Dhamri, H., Melghit, K., Taha, R., & Ram, G. (2011) Utilization of by-product from petroleum refinery in Portland cement clinker and cement manufacturing. In *13th International Congress on the Chemistry of Cement*, Madrid, 3–8 July, 2011.

Singh A. K., Alka, M., & Kumar, S. (2011). Utilization of Spent Pot Liner (SPL) as a raw mix component in cement manufacturing. In *XIII ICCC, International Congress on the Chemistry of Cement*, Madrid, 3–8 July 2011.

BIS (Bureau of Indian Standards). (2015a). Composite cement—Specification, IS 16415: 2015.

BIS (Bureau of Indian Standards). (2015b). Portland Pozzolana cement—Specification, IS 1489 (Part 1): 2015.

BIS (Bureau of Indian Standards). (2016). Coarse and Fine Aggregate for Concrete, IS:383, New Delhi, January 2016.

BMTPC (Building Materials & Technological Promotion Council). (2016). Guideline for Utilization of C&D waste.

CEA (Central Electricity Authority). (2017). Report on fly ash generation at coal/lignite based thermal power stations and its utilization in the country for the year 2016–17, New Delhi, December 2017.

Chaturvedi, S. K., Yadav, D., Ali, M. M., Nanda, S., & Das, S. N. (2011). Potential of utilizing spent pot refractory lining waste from alumina smelter in cement manufacture. In *XIII ICCC, International Congress on the Chemistry of Cement*, Madrid, 3–8 July 2011.

CPCB. (2017). SOP and checklist of minimal requisite facilities for utilization of SPL generated from primary aluminium smelting industries. Ministry of Environment, Forest and Climate Change, Government of India, March 2017.

Deelwal, K., Dharavath, K., & Kulshreshtha, M. (2014). Evaluation of characteristic properties of red mud for possible use as a geo technical material in civil construction. *International Journal of Advances in Engineering and Technology*, *7*(3), 1053–1059.

Galbenis, C. T., & Tsimas, S. (2004). Applicability study of recycled aggregates as raw materials in cement clinker manufacturing. In *Advances in Mineral Resources Management and Environmental Geotechnology*, Hania, Greece.

Galbenis, C. T., & Tsimas, S. (2006). Use of construction and demolition wastes as raw materials in cement clinker production. *China Particuology, 04*(02), 83–85.

Gastaldi, D., Canonico, F., Capelli, L., Buzzi, L., Boccaleri, E., & Irico, S. (2015). An investigation on the recycling of hydrated cement from concrete demolition waste. *Cement and Concrete Composites*, (61), 29–35.

IEISL (IL&FS Environmental Infrastructure & Services Ltd.). (2017). C&D waste Project. Retrieved from http://www.cips.org.in. Accessed December 15, 2017.

Indian minerals yearbook. (2016). (Part III) Mineral Reviews 55th Edition, Marble, Govt. Of India, Ministry of Mines, Indian Bureau of Mines.

Indian Standard, Ordinary portland cement—Specification, IS 269: 2015.

Indian Standard, Specification for Masonry Cement, IS 3466: 1988.

Kara, M., Kilic, Y., & Erenoglu, T. (2017). An experimental study on construction and demolition waste usage as secondary raw material for cement production. *World Journal of Innovative Research, 2*(04), 01–07.

Lin, K. L., Lo, K.-W., Hung, M.-J., Cheng, T.-W., & Chang, Y.-M. (2017). Recycling of spent catalyst and waste sludge from industry to substitute raw materials in the preparation of Portland cement clinker. *Sustainable Environmental Research*, *27*, 251–257.

Liu, J., & Wang, Y. (2013). Cost analysis of construction and demolition waste management. *The Open Construction and Building Technology Journal*, 251–263.

Ministry of Mines. (2018). Indian Minerals Yearbook 2017 (Part—II: Metals & Alloys) (56th edn) Slag-Iron and Steel (Advance Release), Government of India, Indian Bureau of Mines, Indira Bhavan, Civil Lines, Nagpur-440 001, March 2018.

Mishra, C. R., Yadav, D., Sharma, P. S., & Ali, M. M. (2011). Production of Ordinary Portland Cement (OPC) from NALCO red mud. In Stephen J. Lindsay (Ed.), *Light Metals 2011*, *TMS* (*The Minerals, Metals & Materials Society*).

Morrison, C., Hooper, R., & Lardner, K. (2003). The use of ferro-silicate slag from ISF zinc production as a sand replacement in concrete. *Cement and Concrete Research*, *33*(12), 2085–2089.

Mustafa, K. (2000). BCR-from byproduct to brick: Using red mud waste as a construction material. Retrieved from https://www.ceramicindustry.com/articles/88630-bcr-from-byproduct-to-brick-using-red-mud-waste-as-a-construction-material. Accessed July 30, 2018.

NBCC (National Buildings Construction Corporation Limited). (2013). Press Release, May 3, 2013.

Parhi, S. S. (2014). *Gainful utilization of spent pot lining—A hazardous waste from aluminium industry* (M. Tech., thesis). Chem Engineering, NIT, Rourkela, Odisha, August 2014.

Puertas, F., Díaz, I. G., Barba, A., Gazulla, M. F., Palacios, M., Gómez, M. P., & Ramírez, S. M. (2008). Ceramic wastes as alternative raw materials for Portland cement clinker production. *Cement and Concrete Composites,* (30), 798–805.

Report on disposal options of marble slurry in Rajasthan, 2011–12, CPCB Zonal Office (Central) Bhopal.

Samal, S., Ray, A. K., & Bandopadhyay, A. (2013) Proposal for resources, utilization and processes of red mud in India—A review. *International Journal of Mineral Processing*, *118*, 43–55.

Sathya, M., & Shanmugavalli, B. (2014). Effect of using copper slag as a backfill in retaining wall. *International Journal of Research in Engineering and Technology*, *03*(09).

Schoon, J., Buysser, K. D., Driessche, V., & Belie, N. D. (2015). Fines extracted from recycled concrete as alternative raw material for Portland clinker production. *Cement and Concrete Composites*, *58*, 70–80.

Sengupta, B. (2014) Co-processing of waste in cement kilns, status and options to promote co processing for waste management. In *International Conference*, Wastech, 2014 organized by GSPCB at Mahatma Mandir, Gandhi Nagar on November 21, 2014.

Tiwari, N. K. (2017). Spent pot liner utilization in cement industry, presentation, BALCO, Korba, C.G. In *3rd International Conference on Alternate Fuel and Raw Material in Cement Industry*, New Delhi, March 23–24, 2017.

Tiwari, M. K., Bajpai, S., & Dewangan, U. K. (2016). Steel slag utilization—Overview in Indian perspective. *International Journal of Advanced Research, 4*(8), 2232–2246.

Tixier, R., Devaguptapu, R., & Mobasher, B. (1997). The effect of copper slag on the hydration and mechanical properties of cementitious mixtures. *Cement and Concrete Research*, *27*(10), 1569–1580.

Wu, W., Zhang, W., & Ma, G. (2010). Optimum content of copper slag as a fine aggregate in high strength concrete. *Materials & Design*, *31*(6), 2878–2883.