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Solidification- Stabilization Technique for Metal bearing Solid Waste from Zinc Industry –A case study

A.K.Vyas

Professor & Head

Department of Civil Engineering, Malaviya National Institute of Technology, Jaipur, INDIA

Abstract. Disposal of solid and hazardous wastes has become a major issue in all industrialized countries. In the present study the Jarosite waste from Hindustan Zinc Limited (HZL) was solidified/stabilized with different combinations of binder/waste ratio in cement concrete mixed in the ratio of 1:2:4. Sand was replaced by Jarosite in the following percentages: 20%, 40%, 60%, 80%, and 100% in fine aggregate. Ordinary Portland Cement (OPC), Sulphate Resistant Portland Cement (SRPC) and their combinations were used as binders in cement concrete mixes. The cement concrete thus prepared, were tested for compressive strength and Toxicity Characteristics Leaching Procedure (TCLP) after 28 days. The results showed that concrete with 40% OPC and 60% SRPC and replacement of 60% of sand by Jarosite waste proved to be the most optimum combination. Leaching tests indicated that solidification and stabilization technique was effective in terms of restraining of leaching of heavy metal ions like Zn , Cd and Pb to the tune of 93%, 90% and 87% , respectively.

Key words: Stabilization/Solidification, Hazardous waste, Jarosite.

1. Introduction

Industrialization and Development of a country go together. Where there are industries indeed there are pollution problems. The need to treat and handle air, water, and wastewater pollutants has resulted in the formation of sludge and solid waste. The waste may be hazardous or non-hazardous consisting of organic and/or inorganic materials. The danger to human health and stringent regulations on land disposal of hazardous waste have resulted in development of advanced technologies for hazardous waste management such as secured landfill sites, Stabilization/Solidification techniques etc. In recent years, solidification and stabilization techniques have emerged as viable alternatives for waste disposal. It is therefore important that all the industries not only take care of the process of manufacture but also safe disposal of the pollutants generated in the form of solids, liquids or gaseous wastes. Amongst the heavy and toxic metals, arsenic, cadmium, chromium, nickel, lead, copper, mercury and zinc are considered deleterious to the environment, when their concentrations are more than the stipulated limits. The major environmental degradation is caused by copper, lead and zinc industries (A.Agrawal et al 2004).

2. Wastes from Zinc industries

Nearly 80% of zinc mineral resources are treated by hydro-metallurgical methods. During this hydro-metallurgical process of zinc extraction Jarosite waste is generated. Jarosite waste, originating from the zinc industry using hydro-metallurgical processing routes, is considered hazardous. Metals such as zinc, cadmium and copper are present in an environmentally mobile form, thus the jarosite waste is usually stored in lined ponds. The another process/method of zinc extraction is Pyro-metallurgical method which generates slag.

Corresponding author: Tel +91 141 2529085 Fax: +91 141 2529029
E mail : ashokkvyas@rediffmail.com

The Imperial smelter furnace (ISF) slag generated at Chanderia unit of Hindustan zinc Limited (HZL) is stored in a separate dump yard with minor commercial disposal (A.Agrawal et al 2004). Though the slag is vitreous in nature the toxic constituents are in sufficient amount and may prove to be hazardous due to mobility of the ions by weathering. Mymrin and Vaamonde (1999) described the possibility of using jarosite waste processing as one of the components of new construction materials. The materials consist only of industrial wastes, but a small change in the composition of the materials made by adding 1-4% of CaO or Portland Cement, gives rise to strengthening of the samples very early. The statistically designed experimental trials revealed that the density, water absorption capacity and compressive strength of fired jarosite bricks are 1.51 gm/cm^3, 17.46% and 43.4 kg/cm^2 respectively with jarosite sand mixture in the ratio of 3: 1 indicating the potentials in developing building materials (Asokan Pappua et al 2000).

The utilization of hazardous and polluting industrial wastes is a challenge for environmental protection. This paper presents one of the most promising ways of solving the problem through the use of some materials prepared exclusively from industrial wastes, demonstrating that it is possible to take advantage of their useful properties and to neutralize their harmful characteristics thereby obtaining valuable materials.

3. Experimental Studies

3.1. Replacement/Substitution of sand by Jarosite in cement concrete

3.2. Properties of Jarosite

Jarosite is an insoluble basic iron sulphate mineral of approximate formula $(NH_4)_2Fe_6(OH)_{12}$ and since it was first recognised at Jaroso in Spain, it was given the name Jarosite. Jarosite is the major waste generated at HZL, Debari during Hydro-metallurgical extraction of Zinc. The jarosite cake from the vacuum filter is acidic with pH of 3.9. The physico-chemical characteristics of vacuum filter jarosite are presented in Table-1.

Table-1 Physico-chemical characteristics of vacuum filter jarosite

Sr.No.	Parameter	Unit	Jarosite Cake
1	pH	-	3.55
2	colour	-	Light yellow
3	Electrical conductivity	µv/cm	2100
4	Bulk density	gm/cc	1.36
5	Moisture	%	47.5
6	Alkalinity	mg/l	70.0
7	Sulphate as SO4	%	45.0
8	Organic matter	%	0.75
9	Nitrogen as N	mg/kg	505
10	Phosphorous as P	mg/kg	289
11	Potassium as K	mg/kg	254
12	Calcium as Ca	gm/kg	54.05
13	Magnesium as Mg	mg/kg	553
14	Lead as Pb	%	4.61
15	Zinc as Zn	%	3.22
16	Mercury as Hg	µg/kg	22
17	Arsenic as As	mg/kg	6.6
18	Antimony as Sb	mg/kg	9.0
19	Cadmium as Cd	mg/kg	256.36
20	Iron	%	21.56
21	Copper	mg/kg	500.28
22	Al2O3	%	4.4
23	Acid insoluble matter	%	12.68
24	Bismuth as Bi	mg/kg	12.0
25	SiO2	%	4.0

3.3. Methodology

The Jarosite waste from Hindustan Zinc Limited (HZL) was solidified/stabilized with different combinations of binder/waste ratio in cement concrete blocks mixed in the ratio of 1:2:4. Sand was replaced by jarosite in the following percentages: 20%, 40%, 60%, 80%, and 100%, respectively in concrete mixes. OPC(Ordinary Portland Cement), SRPC (Sulphate Resistant Portland Cement) and their combinations were used as the waste contained lots of sulfates. SRPC was used due to its less C_3A (0-5%) content to resist sulphate attack. The cement concrete cube specimens, thus prepared, were tested for compressive strength at 28 days and for leaching of heavy metal ions after 28 days.

4. Results & Discussion

4.1. Phase I

OPC was used as binder in cement concrete mixes in phase I. The Unconfined compressive strength (UCS) test results are tabulated in Table 2.

Table 2 : Compressive Strength of Concrete mixes using OPC as binder

Sr.No.	Cement OPC (Kg)	Fine aggregate		Coarse Aggregate (Kg)	Total Weight (Kg)	UCS, (28 days curing) in Kg / cm^2	Comparative st in Kg / cm^2
		Sand (Kg)	Jarosite (Kg)				
1	1.0	2.00	0.00	4.0	7.0	170	100
2	1.0	1.60	0.40	4.0	7.0	155	91.18
3	1.0	1.20	0.80	4.0	7.0	140	82.35
4	1.0	0.80	1.20	4.0	7.0	125	73.53
5	1.0	0.40	1.60	4.0	7.0	100	58.82
6	1.0	0.00	2.00	4.0	7.0	65	38.24

The percentage of jarosite was increased to 20% in each trial mixand average compressive strength was recorded after 28 days. This strength was compared with that of control mix.

4.2. Phase II

SRPC was used as binder in cement concrete mixes in phase II. Sand was replaced by jarositein the similar way done in phase I. UCS tests were conducted after 28 days of curing. The results of tests are given in Table 3.

Table 3 : Compressive Strength of Concrete mixes using SRPC as binder

Sr.No.	Cement SRPC (Kg)	Fine aggregate		Coarse Aggregate (Kg)	Total Weight (Kg)	UCS, (28 days curing) in Kg / cm^2	Comparative str in Kg / cm^2
		Sand (Kg)	Jarosite (Kg)				
1	1.0	2.00	0.00	4.0	7.0	180	100
2	1.0	1.60	0.40	4.0	7.0	170	94.44
3	1.0	1.20	0.80	4.0	7.0	160	88.88
4	1.0	0.80	1.20	4.0	7.0	150	83.33
5	1.0	0.40	1.60	4.0	7.0	135	75.00
6	1.0	0.00	2.00	4.0	7.0	100	55.50

It can be seen that average compressive strength in all the mixes increased by using SRPC as binder in place of OPC. The Comparative strengths of these mixes also have shown remarkable improvement.

4.3. Phase III

SRPC was replaced with OPC by 40% to make the process cost effective. The UCS results are tabulated in Table 4.

Table 4: Compressive Strength of Concrete mixes using OPC and SRPC as binder

Sr.No	Cement		Fine aggregate		Coarse Aggregate (Kg)	Total Weight (Kg)	UCS, (28 days curing) in Kg / cm^2	Comparative st in Kg / cm^2
	SRPC (Kg)	OPC (Kg)	Sand (Kg)	Jarosite (Kg)				
1	0.6	0.4	2.00	0.00	4.0	7.0	170	100
2	0.6	0.4	1.60	0.40	4.0	7.0	160	94.12
3	0.6	0.4	1.20	0.80	4.0	7.0	155	91.76
4	0.6	0.4	0.80	1.20	4.0	7.0	150	88.24
5	0.6	0.4	0.40	1.60	4.0	7.0	120	70.59
6	0.6	0.4	0.00	2.00	4.0	7.0	80	47.06

It can be seen that comparative strength was further improved as compared with test results of phase II. The improvement was noticed up to jarosite content of 60% in fine aggregate content. The comparative strength reduced with further increase in jarosite content in the mixes.

The unconfined compressive strength variations with changes in percentages of Jarosite for three phases are shown in the graph given below. It can be seen from Figure 1 that fall in comparative strength was rapid with increased content of jarosite in ement concrete mixes with OPC as binder (phase I). The tests results improved a little with SRPC as binder in phase II of the study. The slope of the compressive strength curve flattened indicating insignificant impact of jarosite in binder consisting of mix of 60% SRPC and 40% OPC as seen in phase III part of the study.

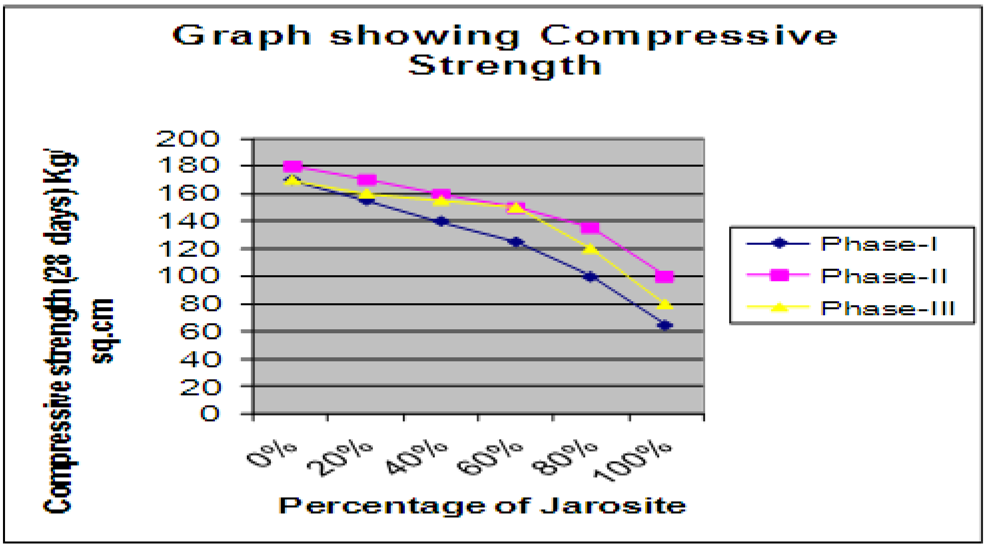

Fig 1: Graph showing variation of Compressive Strength with Jarosite content

5. Toxicity characteristics leaching procedure (TCLP)

The performance of stabilised waste is generally measured in terms of leaching and extraction test. Leaching test measures potential of stabilised waste to release contaminants to the environment. The TCLP is suitable for determining the mobility of organic and inorganic compounds present in liquid, solid and multiphasic wastes. Treatment effectiveness in terms of contaminant-Zn, Cd, Pb not leached due to S/S for Phase I, II, III are tabulated in Table 5.

Table-5 Treatment effectiveness in terms of contaminants

Percentage of Jarosite	Treatment effectiveness after 28 days of curing (%)								
	Phase - I			Phase - II			Phase - III		
	Zn	Cd	Pb	Zn	Cd	Pb	Zn	Cd	Pb

20%	94.57	91.5	87.79	95	92.11	83.3	95	91.75	88.02
40%	94.5	91.4	87.64	94.61	91.89	88.27	94.39	91.64	87.87
60%	93.89	91.4	87.53	94.2	91.57	88.15	93.97	91.4	87.67
80%	93.54	90.73	87.52	93.98	91.54	88.77	93.79	91.05	87.71
100%	93.24	89.57	87.17	93.98	89.97	88.77	93.6	89.67	87.17

The results in Table 5 show that the effectiveness treatment in terms of % of contaminant Zn, Cd and Pb not leached after 28 days was observed above 93%, 90% and 87%, respectively.

6. Conclusions

The application of S/S technique for Jarosite waste indicated that all samples satisfy 50 pounds per square inch (psi) after 28 days of curing which is recommended for land filling as per the US EPA 1996 guidelines. As the binder to waste ratio decreases there is decrease in UCS. According to IS 456-2000 concrete mix 1:2:4 have a min compressive strength of 150 Kg / cm^2. Hence concrete cubes which have compressive strength more than 150 Kg / cm^2 can be used for reinforced concrete beams, slabs, walls, columns, roads. Cement concrete mixes with compressive strength between 140 - 100Kg / cm^2 can be used as foundation bed for buildings, mass concrete work. Cement concrete blocks with compressive strength less than 100 Kg / cm^2 can be used for mass concrete work only. Treatment effectiveness in terms of percentage of contaminant zinc, lead, and cadmium not leached due to S/S decreases as jarosite content increases. Further it is anticipated that cement concrete mixes when subjected to immersion procedure test would give much favourable leachability results and practically these can be used successfully as civil engineering materials.

The review suggests that partial replacement of sand with ISF slag in concrete was not significantly detrimental to the compressive strength of the concrete after 1 month. The initial results on properties of slag have indicated a good promise for its use for road applications; however, only after detailed mix-design and TCLP experiments, the feasibility of replacement of slag as road aggregate would be decided from both engineering and environmental points of view.

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