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Note from the field

Assessment of durability characteristics of cement concrete containing jarosite

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ABSTRACT

Jarosite, one of the by-product of zinc manufacturing industry has been of a major concern in this context because of its hazardous nature. The present study aims to assess the durability of cement concrete containing jarosite. Fine aggregates have been replaced by jarosite in different percentages. Equivalent volume of 25% cement has also been replaced by fly ash. Durability parameters like chloride diffusion and corrosion in jarosite were determined. Keeping the environmental suitability of concrete in mind, toxicity leaching characteristic potential test has been performed on raw jarosite and concrete samples. It was observed that the chloride diffusion in concrete and corrosion of reinforcement in jarosite added concrete has been less than control mixtures. The satisfactory performance of durability properties has been validated with the Scanning Electron Microscopy images and X-ray diffraction.

1. Introduction

Concrete industry need to be transformed into sustainable society from being consumption based society by lowering the pollution of natural environment and to prevent the exhaustion of natural resources (Pelisser et al., 2011, 2012; Gencel et al., 2012, 2013). The extraction of natural resources has caused impacts ranging from geographic and cultural displacement of indigenous communities to contamination of water, air and land with toxic by-products (Moran et al., 2014). Thus, use of industrial by-products as a raw material in concrete is becoming necessary to address sustainability of both, the concrete and the industrial growth (Tripathi et al., 2012; Thomas and Gupta, 2015). Also, an important way to achieve cleaner and sustainable production is process optimisation and improved waste management (Yong et al., 2016). The management of industrial waste or by-products can improve sustainability of environment too (Pacelli et al., 2015).

Jarosite, one of the by-product of zinc manufacturing industry has been of a major concern in this context because of its hazardous nature (Mehra et al, 2013). Along with jarosite as sand replacement material, fly ash has been incorporated into concrete as mineral admixture (25% of weight of cement). Fly ash, a type of industrial waste, has been widely applied in concrete materials. The use of fly ash as a partial replacement for cement in concrete has numerous benefits; it reduces greenhouse gas emissions, demonstrates good long term strength and durability, reduces the demand for water, consumes less energy and decreases the pressure on natural resources. Moreover, fly ash is economical, and there are numerous fly ash resources (Zong et al., 2014).

Jarosite recycle/reuse has been reported just few decades ago. Past studies indicate various researches on using jarosite as a raw material for developing different products. Along with industrial wastes like DFS and activator, jarosite has been processed to make different construction materials. The materials used as substitute of natural crushed stones, gravel and sand applicable as bases or sub-bases of roads, airfields and dams. Also bricks, tiles and similar items have been developed using jarosite (Mymrin and Vaamonde, 1999; Mymrin et al., 2005). Application of model (coupled process of diffusion and precipitation at the interface of two material layers) suggested the potential use to form a self-sealing layer in jarosite/fly ash co-disposal sites (Ding et al., 1998, 2002).

Solidification/stabilization technique was used to recover/recycle jarosite using fly ash and clay into value added materials

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like bricks etc. Studies confirmed that fly ash has got huge potential for immobilization of hazardous metals present in jarosite and its usefulness in developing non-hazardous materials for construction purposes (Ashokan et al., 2006, 2006b, 2007). Ochereous mine water along with jarosite residue had been mixed to form controlled low strength material. Investigating the different properties of prepared material approved the suitability of jarosite for sub surface applications (Bouzalako et al., 2008).

Utilization of industrial by-products, derived from mineral ore extraction has been encouraged in the recent years. The different by-products are Red Mud, Copper tailings, Copper slag, ISF slag and GGBS slag (Morrison et al., 2003; Liu, 2016; Bilir, 2012; Mithun and Narasimhan, 2016; Onuaguluchi et al., 2016, Tripathi and Chaudhary, 2016). Current study aims the proper utilization of jarosite as replacement for natural fine aggregates along with fly ash (25% cement replacement) in concrete (Mehra et al., 2016). Concrete mixtures have been prepared for three different w/c ratios (0.40, 0.45 & 0.50) and fine aggregates replacement by jarosite at different percentages (0, 5, 10, 15, 20 & 25%). The durability properties in terms of chloride diffusion and corrosion have been investigated. For environmental suitability of hazardous jarosite use in concrete, leaching of heavy metals has been evaluated. One of the main leaching procedure that has been utilized to analyze the potential of heavy metal leachability from the stabilized layers is toxicity characteristic leaching procedure (TCLP) test (Xue et al., 2009; Disfani et al., 2012). SEM images of jarosite added concrete has been analyzed in evident support for strength and durability studies. For knowing the predominating phases in jarosite concrete, the X ray diffraction has been performed on the concrete powder and studied.

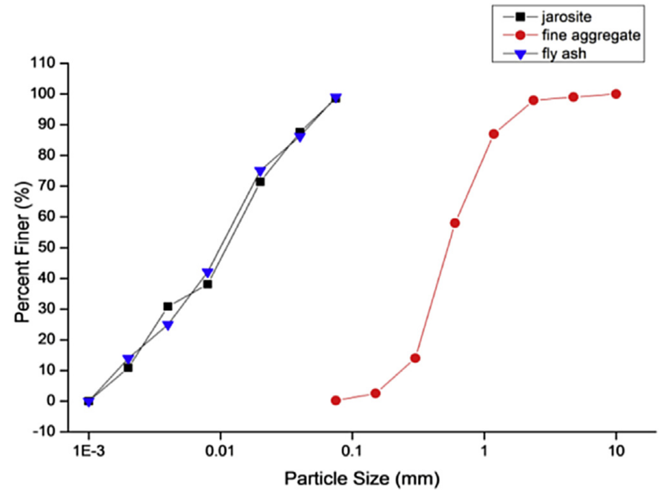

Fig. 1. Particle size of fly ash, fine aggregates and jarosite.

Table 1
Properties of raw materials.

Properties	Cement	Fine aggregate	Coarse Aggregate		Jarosite	Fly ash	Admixture
			10 mm	20 mm			
Specifications	OPC Grade 43	Zone II					
Specific gravity	3.14	2.65	2.66	2.66	2.85	2.10	1.10
Water absorption	–	0.28%	0.33%	0.32%	–		
pH	–	–	–	–	6.2		6.0

2. Material properties and preparation of test specimens

Jarosite and fly ash have been procured from Hindustan Zinc Limited, Debari, Udaipur, Rajasthan and Kota Super Thermal Power Station, Kota, Rajasthan respectively. Other raw materials for concrete such as aggregates, water, cement and chemical admixtures have been used as per the requirement for concrete mix design. Physical and chemical testing of materials carried out prior to casting of concrete samples has been tabulated in Table 1. Particle size of Cement, fly ash and jarosite has been graphed in Fig. 1.

Adopting w/c as 0.45, the concrete mix designing has been done as per IS: 10262-2009 for M25. Moreover, keeping cement content constant for other w/c (0.40 & 0.50), the amount of water has been reduced and increased respectively. Mixture proportions are given

Table 2
Mixture proportions of fresh concrete.

FA replacement %	Water–cement ratio	Water (kg)	Cement (kg)	Fly ash (Kg)	Fine aggregate (Kg)	10 mm (kg)	20 mm (kg)	Jarosite (Kg)	Admixture (gm)	Compacting factor
0	0.40	15.2	28.50	9.50	71.300	58.2	58.2	0	304	0.96
5	0.40	15.2	28.50	9.50	67.735	58.2	58.2	3.565	342	0.97
10	0.40	15.2	28.50	9.50	64.170	58.2	58.2	7.130	418	0.97
15	0.40	15.2	28.50	9.50	60.605	58.2	58.2	10.695	494	0.98
20	0.40	15.2	28.50	9.50	57.040	58.2	58.2	14.260	570	0.98
25	0.40	15.2	28.50	9.50	53.475	58.2	58.2	17.825	646	0.96
0	0.45	17.1	28.50	9.50	71.300	58.2	58.2	0	152	0.97
5	0.45	17.1	28.50	9.50	67.735	58.2	58.2	3.565	228	0.99
10	0.45	17.1	28.50	9.50	64.170	58.2	58.2	7.130	304	0.98
15	0.45	17.1	28.50	9.50	60.605	58.2	58.2	10.695	380	0.97
20	0.45	17.1	28.50	9.50	57.040	58.2	58.2	14.260	494	0.97
25	0.45	17.1	28.50	9.50	53.475	58.2	58.2	17.825	570	0.98
0	0.50	19.0	28.50	9.50	71.300	58.2	58.2	0	0	0.96
5	0.50	19.0	28.50	9.50	67.735	58.2	58.2	3.565	114	0.97
10	0.50	19.0	28.50	9.50	64.170	58.2	58.2	7.130	190	0.96
15	0.50	19.0	28.50	9.50	60.605	58.2	58.2	10.695	228	0.95
20	0.50	19.0	28.50	9.50	57.040	58.2	58.2	14.260	304	0.97
25	0.50	19.0	28.50	9.50	53.475	58.2	58.2	17.825	380	0.98