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Research paper

Mechanical and durability aspects of concrete incorporating secondary aluminium slag

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Abstract

The environmental impact can be minimised by making use of many industrial wastes in a sustainable manner. Recycling and reutilisation of industrial waste and by-products is of paramount importance in cement and concrete industry. In view of rapid infrastructure growth, there is an emerging need for development of cementitious materials or fillers either to replace cement or fine aggregate for stable growth. One of the industrial wastes is secondary aluminium dross. In this paper, an attempt has been made to study the mechanical and durability aspects of concrete incorporated with secondary aluminium dross. Cement has been partially replaced by secondary aluminium dross in different proportions to study the mechanical and durability aspects. Various properties such as compressive strength, split tensile strength, flexural strength, sorptivity, water absorption, rapid chloride penetration have been studied for the usefulness of secondary aluminium dross as construction material. It is observed that up to 15% replacement of cement by secondary aluminium dross, the responses are comparable with the conventional concrete. Studies have also been carried out by adding other supplementary cementitious materials such as fly ash and silica fume in various proportions along with secondary aluminium dross and found the improved mechanical and durability properties. From the overall study, it can be concluded that the concrete incorporated with secondary aluminium dross can be used for making paver blocks, refractory bricks and for normal concrete strength applications.

Keywords: Secondary aluminium slag; Industrial waste; Compressive strength; Flexural strength; Split tensile strength; Durability

1. Introduction

With the rapid increase of population, the type and quantity of waste generation from industries, factories, companies, and housing sector have increased significantly. The waste material can be broadly categorised into two types, namely, biodegradable and non-biodegradable. Most of non-biodegradable or non-decaying waste materials will not decay or degrade and will remain in the environment for several years. The non-decaying waste materials or non-biodegradable waste materials cause waste disposal problems, thereby contributing to the environmental issues. However, the environmental impact can be minimised by making use of many wastes in a sustainable manner. One of the main themes of sustainability include reduce, reuse and recycle waste. Fig. 1 presents the triple bottom line concept applicable to any industry for longer sustainability keeping in view of environmental aspects, energy conservation, profit and other considerations [1].

Recycling and reutilisation of industrial waste and by-products is a subject of great importance today in cement and concrete technology also. Traditional industrial by-products used in cement and concrete manufacture include fly ash, granulated blast furnace slags, silica fume etc. Similarly, aluminium refining industries generate different solid wastes. Disposal and recycling of dross produced during aluminium melting is a worldwide issue. Majority of dross is being disposed off in landfill sites, which is likely to result in leaching of toxic metal ions into groundwater causing serious pollution problems [2]. When secondary aluminium dross contacts with water, it is observed that it emits less amounts of harmful/toxic gases. The gases include NH_3, CH_4, PH_3, H_2, H_2S, etc. [2]. It is mentioned that recycling aluminium uses about 5% of the energy required to produce aluminium from bauxite which is significant. Recycling results in significant cost savings over the production of primary new aluminium even when the costs of collection, separation and recycling are taken into

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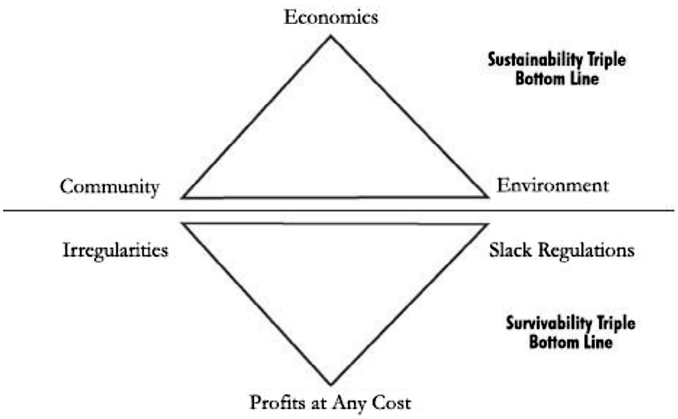


Fig. 1. Typical sustainability concept.

consideration. Considering all the factors, it appears that if the dross could be used as an engineered product, most of the sustainability issues can be addressed.

Petavratzi and Wilson [3] used aluminium dross as filler in production of non-aerated concrete, concrete bricks and concrete roof tiles. Ewais et al. [4] carried out investigations towards manufacture of calcium aluminate cement by using aluminium sludge and aluminium slag (dross) wastes as a source of CaO and Al_2O_3, respectively with some addition of alumina. Elinwa and Mbadike [5] used aluminium waste for concrete production by replacing the cement in different percentages. It was found from their experiments that the compressive and flexural strengths of concrete with 10–15% replacement of cement by aluminium waste are comparable with control concrete. It was also found that the concrete made with aluminium waste retards setting times of concrete, which is beneficial for hot weather concrete conditions. Adeosun et al. [6] evaluated the mechanical properties of polypropylene (PP) by adding aluminium dross in different proportions for particle size range between 53 µm and 150 µm. It was found that the ultimate tensile strength improved by 68% (at 15 wt% Al-dross addition), density increased by 54% (at 50 wt% Al-dross addition), and water absorption by 500% (at 8 wt% Al-dross addition) compared to conventional PP. Interestingly, the impact resistance of the composite was found to be the same (68J) as that of conventional PP at 15 wt% Al dross. Kazjonovs and Korjakins [7] produced expanded light weight aggregate by using aluminium scrap and municipal solid waste container glass. Adeosun et al. [8] studied the physio-mechanical behaviour of brick made up of aluminium dross and bentonite in different proportions and found that 106 µm particle size brick can serve as acid refractory due to its properties. Ozerkan et al. [9] evaluated the mechanical and corrosion properties of aluminium dross incorporated concrete. From their study, it was suggested that aluminium dross can be used as an ingredient in the range of certain limits to improve expanded concrete/mortar and to improve the corrosion resistivity of concrete/mortar.

It is mentioned in the open source that in India, the production of dross from various sectors is about 120,000 tons. Effective utilisation of this dross will result significantly in

1 reduction of environmental impact
2 reduction of cost of concrete
3 reduction of carbon print

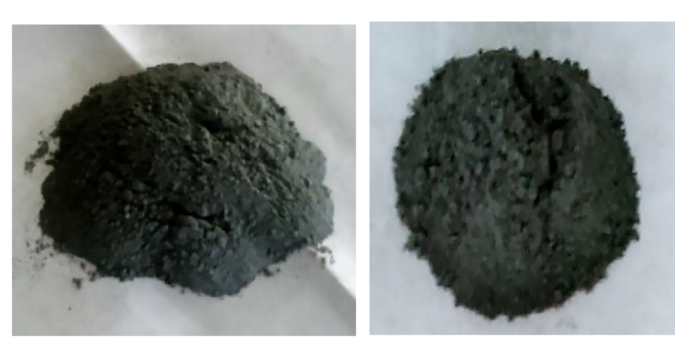
The studies carried out on concrete incorporated with secondary aluminium dross for possible utilisation as construction/building material are observed to be scanty [10–14]. In the present study, mechanical and durability properties of concrete incorporated with secondary aluminium dross and other supplementary cementitious materials such as fly ash and silica fume are investigated for possible utilisation in construction sector.

2. Experimental studies

For the present investigation, the sample of secondary aluminium dross is obtained from M/s VakkalImpex (P) Ltd, Hindupur, Andhra Pradesh, India. The wastes are irregular in shape, black in colour and contain lumps and small particles of aluminium produced by burning aluminium scraps (raw material) in a furnace at about 1900 °C. Before using the waste in concrete it was ground and sieved using sieve size of 90 µm. The collected samples were treated with water. Local sand with size of around 400 µm was used as fine aggregate which conforms to Zone II. The specific gravity of sand is 2.7 and bulking of sand is 4. Fineness modulus of fine aggregate is 3.12. The size of coarse aggregate is 20 mm. The specific gravity and fineness modulus of coarse aggregate are 2.8 and 8.47 respectively. The chemical composition of secondary aluminium dross after water wash treatment and cement obtained through XRF analysis are given in Table 1. Fig. 2 shows the typical aluminium dross sample.

Table 1
Composition of secondary aluminium dross/slag and cement.

Chemical composition	OPC	Secondary aluminium dross
Al_2O_3 (%)	5.7	87.2
SiO_2 (%)	18.3	2.7
P_2O_5 (%)	–	0.57
SO_3 (%)	4.3	1.37
Cl^- (%)	0.2	2.2
CaO (%)	65.3	2.0
TiO_2 (%)	0.5	2.0



(a) Untreated secondary aluminium dross (b) Treated secondary aluminium dross

Fig. 2. Typical aluminium dross.