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Research paper

Investigation of concrete produced using recycled aluminium dross for hot weather concreting conditions

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Abstract

Aluminium dross is a by-product obtained from the aluminium smelting process. Currently, this dross is processed in rotary kilns to recover the residual aluminium, and the resultant salt cake is sent to landfills. The present study investigates the utilization of recycled aluminium dross in producing concrete, which is suitable for hot weather concreting condition. The primary objectives of the experimental study are to examine the feasibility of using concrete blended with recycled aluminium dross under hot weather concreting situations and then to evaluate the strength and durability aspects of the produced concrete. From the experimental results it is observed that the initial setting time of the recycled aluminium dross concrete extended by about 30 minutes at 20% replacement level. This property of recycled aluminium dross concrete renders it to be suitable for hot weather concreting conditions. Based on the results obtained, the replacement of cement with 20% of Al dross yields superior mechanical and durability characteristics.

Keywords: Hot weather concrete; Recycled aluminium dross; Durability of concrete

1. Introduction

The hot weather is considered to be any combination of high air temperature, low relative humidity and increased wind velocity [1]. Concrete applications may be considered as hot weather concrete at temperatures above 40 °C depending on the site specific application as per IS:7861 (Part 1)-1975 [2]. The actual temperature of the concrete mix as conveyed to the site is effected by the temperature of the ingredient materials used in the mix, the temperature of the equipment used to batch and transport the concrete, the cementitious content of the mixture, and finally by the ambient temperature and conditions at the project site. Ideal conditions for placing concrete occur when temperature ranges between 68 °F and 72 °F (20 °C and 22 °C), the relative humidity is 50 percent or higher and the near surface wind velocity is low [3]. As a general rule of thumb, an increase of 20 °F will reduce the setting time of a concrete mixture by as much as 50 percent [4]. Some of the effects of hot weather concreting include accelerated setting time of concrete; increased tendency for plastic shrinkage; potential strength reduction due to high water demand and high curing temperatures; and stiffening of the mix prematurely, preventing it from being well compacted and finished properly.

Nowadays, there is an intense need to come out with novel technologies to convert various wastes into serviceable feedstock cost-effectively. Currently, various kinds of pozzolanic materials are blended along with cement during the production of concrete for modifying the strength and durability properties of conventional concrete. Indeed, the use of pozzolanic materials existed before the discovery of contemporary ordinary Portland cement (OPC) nearly about 2000 years ago itself [5]. Most of the pozzolanic materials are nothing but the by-products procured from industries, for instance, coal fly ash, blast furnace slag, rice husk ash, silica fume, etc. Intrinsically, there has been not much research done with respect to manufacturing, engineered and optimized pozzolanic materials, which are purposely explored for usage along with Portland cement.

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Aluminium dross is a by-product obtained from the aluminium smelting process. Currently, this dross is processed in rotary kilns to recover the residual Al, and the resultant salt cake is sent to landfills. The composition of recycled aluminium dross is typically variable and unique to the plant generating the waste [6]. The recycled aluminium dross contains some volume fraction of toxic materials and land filling of these toxic substances is not ecologically fair. So, in the present study an effort has been put forth to utilize recycled aluminium dross as an admixture, while producing concrete suitable for hot weather concreting conditions.

There are relatively few successful applications employing recycled aluminium dross in concrete technology. Puertas et al. [7] researched on using PAVAL™ (a high alumina content waste) generated from aluminium refining industries for application as a partial replacement of fine aggregates in producing cement mortar. Their main finding was that the PAVAL™ waste had a high specific surface area which resulted in requirement of higher quantity of mixing water. They also observed that there was a considerable increase of the total porosity and decrease of the mechanical strengths when compared to that of conventional silica sand mortar. The aluminium dross was found to retard the hydration reactions in cement mortar during the calorimetric study. The initial and final setting time was found to be extended for more than 2 hours. On the other hand, a decrease in the average size of the pores was seen, which had a progressive influence on the durability characteristics of the final material. Ewais et al. [8] investigated on calcium aluminate cement mixes. They used both aluminium sludge and aluminium slag in their study. Aluminium sludge was the source of both CaO and Al_2O_3 whilst the aluminium slag had only aluminium oxide with certain supplements of pure alumina. The cement mixes manufactured from 37.50 to 41.25% of aluminium slag (dross), 45–50% of aluminium sludge and 12.50–13.75% of alumina were observed to be the ideal mix for manufacturing calcium aluminate cement. Elinwa and Mbadike [9] examined the applicability of using aluminium wastes to manufacture concrete samples. They carried out tests on the setting time, flexural and compressive strengths at 5, 10, 20, 30 and 40% cement replacement levels. They conclude that under hot weather concreting, the aluminium wastes serve as a retarder. The optimum substitution level for the better flexural and compressive strengths was found to be at 10% by weight of cement. Arimanwa et al. [10] examined the characteristics of concrete produced using aluminium waste (an auxiliary cementitious element) and proposed a prediction model based on Scheffe's theory for the prediction of the compressive strength of aluminium waste-cement concrete. The residue produced from aluminium extrusion plants was employed as a partial substitute for cement in different mix ratios. The initial and final setting times of concrete decreased due to the addition of aluminium waste. The partial replacement of cement with aluminium waste did not modify the density of the resulting concrete significantly. One of the important findings was that the aluminium waste absorbed water from the design mix and thereby degraded the workability of the concrete. Mbadike [11] reports the influence of integration of aluminium waste for producing concrete matrix of diverse water-to-cementitious ratio and mix proportions. By varying water to cement ratio, cubes of various mix proportions were cast. The 7, 14 and 28 days strength of the cube samples were tested. A standard 1:2:4:0.55 mix with 5% aluminium waste resulted in an increase of compression strength from 26.07 N/mm^2 to 28.47 N/mm^2, thereby exhibiting a rise of 9.21% of the compressive strength. For 1:2:4 mix proportion of aluminium waste concrete, the slump of concrete ranged from 4 to 20 mm, while that for 1:3:6 mix proportion ranged from 7 to 14 mm.

Weather conditions can have a remarkable influence on the setting time, concrete placing and finishing. Hot weather concrete problems normally arise during the period of the summer season. Thermal shrinkage is more critical during autumn and spring (temperature differential) [12]. It is highly significant to study the consequences of the environmental factors which impact over the characteristics of fresh and hardened concrete and thereby formulate precautionary measures needed to prevent the damages occurring to the concrete. In hot weather concreting, with the use of conventional concrete, the water content present in it evaporates at a faster rate, thereby accelerating the initial and final setting times [13]. Since the concrete produced using aluminium wastes retards the initial and final setting times, it proves to be beneficial under hot weather concreting conditions. Additionally the aluminium waste serves as a supplementary cementitious material and can be substituted with cement.

Due to hot weather conditions, problems arise in mixing, placing, and curing of concrete, which invariably affect the durability and serviceability properties of the concrete. The reason for these problems may be the increased hydration rate of concrete and evaporation of moisture from fresh concrete. The factors which affect the hydration rate of concrete are its on-site temperature, composition, cement fineness and the type of admixtures employed. Since India is a tropical country and most of the regions here lie in the tropical zone, it is necessary for engineers to be aware of tackling problems encountered during production and placement of concrete in hot weather conditions. Hence the main objective of the present study is to examine the feasibility of using recycled aluminium dross in concrete as a partial replacement to cement and evaluating its strength and durability aspects under hot weather conditions. The properties of concrete like compressive, tensile and flexural strengths are investigated for recycled aluminium dross concrete mixes that are produced under hot weather conditions. Additionally, durability properties like water absorption and acid resistance of recycled aluminium dross concrete are tested.

2. Materials and methodology

CEMENT: In ordinary Portland cement (OPC), more or less 3/4th of the mixture is one or the other forms of calcium silicate which is responsible for the bonding/gluing process. The OPC when mixed with water undergoes chemical reaction leading to the solidification of the cement material and this process is the so-called "hydration of cement". Some of the vital aspects/properties, which play an active role in the choice