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Micro and mechanical behaviour of Treated Used Foundry Sand concrete

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HIGHLIGHTS

- To minimize the iron content; the Used Foundry Sand (UFS) was treated with acid.
- By treating, silica in sand enriched is called as Treated Used Foundry Sand (TUFS).
- To assess properties of concrete; fine aggregate was partially replaced with TUFS.
- TUFS shows enhanced properties in mechanical and micro studies.

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ABSTRACT

Used Foundry Sand (UFS) is the high quality silica sand by-product from the production of both ferrous and nonferrous metal casting industry. The UFS from ferrous metal casting industry contains more iron content. Inclusion of UFS without proper treatment in concrete will reduce the binding and strength properties. In order to minimize the iron content, the UFS was treated with acid. While treating with acid, the silica in foundry sand has been enriched. This is called as Treated Used Foundry Sand (TUFS). This paper presents the results of experimental investigation carried out to evaluate the microstructural and mechanical properties of concrete mixtures in which fine aggregate (river sand) was partially replaced with TUFS. Test results indicated a marginal increase in the strength properties and good microstructural properties of plain concrete by the inclusion of TUFS as partial replacement of fine aggregate (sand). This will pave the way for making good quality concrete and disposing the Used Foundry Sand safely without disturbing the environment.

1. Introduction

Concrete is the most widely and popularly used construction material in construction industry. Slightly more than a ton of concrete is being produced every year for every human being on the planet. Over past several decades, the demand for concrete has been increasing rapidly due to infrastructure development. The concrete constitutes various ingredients like cement, fine aggregate and coarse aggregate. Out of these, river sand is used as a fine aggregate in concrete production for several decades. The demand for river sand is increased due to depletion of sand. At present, many researches are being carried out to overcome the stress and demand for river sand by using alternative materials like foundry sand, fly ash, bottom ash and slag which can result in significant improvement in overall energy efficiency and environmental performance.

Foundry industry produces a large amount of by-product material during casting process [1] which is a high quality silica sand. It is a by-product of ferrous and nonferrous metal casting industries. Foundry industries reuse the sand many times and after many cycle it is removed and disposed to nearby sites. This waste sand from foundry is termed as Used Foundry Sand (UFS). The physical and chemical characteristics of foundry sand depend on the type of casting process and the nature of industry from which it originates. The automotive industries are the major generators of foundry sand.

Like many waste products, foundry sand also has some valuable applications to other industries. In Tamilnadu, approximately 200 tons of sand is used in the production annually of which 20 tons are discarded and are available to be recycled into other products [3]. Many foundries dump the waste in nearby vacant area which causes pollution and environmental degradation.

Hence various researches are in progress to effectively utilize the Used Foundry Sand in concrete. Siddique et al. [1] investigated abrasion and strength properties of concrete containing

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Waste Foundry Sand (WFS) in which sand was replaced with 0%, 5%, 10%, 15% and 20% of WFS by mass. Mechanical and abrasion properties were studied. Test results indicated that abrasion strongly correlated with mechanical properties irrespective of WFS content and age. They found optimum percentage was 15% for making concrete. In another study Siddique et al. [4] investigated the strength, durability and micro properties of concrete made with UFS. The results reported that concrete with foundry sand showed good resistance to carbonation and rapid chloride penetration resistance. Khatib and Ellis [5] evaluated the properties of concrete containing foundry sand. Three types of sand used in foundry were considered and the replacement for river sand was in 0%, 25%, 50%, 75% and 100%. They concluded that increase in replacement level of foundry sand decreased the strength of concrete. Also based on shrinkage test, they concluded that length change of concrete increased as the replacement level of standard sand with foundry sand increased. The findings Siddique et al. [6] revealed that when fine aggregate was replaced with Foundry Sand (FS) in 10%, 20% and 30%, a marginal increase in strength properties like compressive, split tensile, flexural and modulus of elasticity was noted. Bakis et al. [9] studied the use of waste foundry sand in asphalt concrete. Mixes were prepared with 0%, 4%, 7%, 10%, 14%, 17% and 20% replacement of fine aggregate with Waste Foundry Sand (WFS). Flow value and Marshal Stability were studied and the results suggested that WFS replacement of 10% was most suitable for asphalt concrete mixtures. The foundry sand from non-ferrous metal casting industry can directly be used in concrete. This has been proved by many researchers [2–7]. There is not much work reported on UFS from ferrous metal casting industry. These industries discard foundry sand containing more iron content when it can no longer be reused. If it is directly used as a partial replacement for sand, it will affect the binding properties and decrease the strength. After the removal of iron content, UFS from ferrous metal casting industries can be used in concrete and the UFS so used is called as Treated Used Foundry Sand.

This investigation was made to assess the impact of using TUFS as partial replacement for fine aggregates in concrete properties, such as compressive strength, split tensile strength and flexural strength along with microstructural analysis using SEM.

2. Experimental investigation

2.1. Materials

The cement used was Ordinary Portland Cement 53 grade. It was tested as per the Indian Standard Specifications BIS: 12269-1987 [10]. Fine aggregate was natural sand conforming to zone II of BIS: 383-1970 [11] passing through 4.75 mm size sieve and having specific gravity 2.69 with fineness modulus 2.74. Natural aggregate having size 20 mm, specific gravity 2.72 and fineness modulus 6.17 was used as coarse aggregate. Modified melamine formaldehyde chemical based admixture was used to increase the workability. It has a relative density of 1.20 kg/l. The dosage was uniform for all mix at 0.3% by weight of cement. The UFS was collected from ferrous metal casting industry near Ganapati, Coimbatore, India. The UFS had the specific gravity 2.32 and fineness modulus 1.72. The investigation was made to determine the chemical composition of UFS by EDX test and is shown in Fig. 1. From EDX test report, it was observed that there was a presence of 10.85% iron content in UFS sample. The presence of iron content will decrease the binding property and also increase the rate of corrosion. To remove the iron content, chemical treatment of UFS was carried out.

2.2. Treatment of Used Foundry Sand

UFS was treated with various strength of Hydrochloric acid as 2.5%, 5% and 10%. To treat with 2.5% HCl concentration solution, 100 g of UFS was added to 487.5 ml of distilled water and 12.5 ml of HCl. Similarly for preparing 5% HCl strength, 100 g of UFS was added to 475 ml of distilled water and 25 ml of HCl acid and for 10% HCl strength, 100 g of UFS was added to 450 ml distilled water and 50 ml of HCl. The above prepared samples were then stirred with magnetic stirrer for 24 h as adopted by Monosi, et al. [12]. After 24 h, the solution was separated by centrifugation, filtered with 0.2 µm filter paper and the collected UFS was washed with distilled water thoroughly and dried for 24 h. The above sample was considered as Treated Used Foundry Sand. To analyze the chemical composition of the treated samples Energy-Dispersive X-ray spectroscopy (EDX) test was conducted and the results are presented in Figs. 2–4.

Test results revealed that the UFS subjected to acidic treatment with 2.5% concentration contained 75% silica and 9% iron; with 5% concentration, contained 80% silica and 2% iron content. Similarly samples subjected to acid treatment with 10% concentration contained 73% silica and 0.5% iron content. By comparing the test results of TUFS, it was found that there was an increase in silica content and decrease in iron content in UFS treated with 5% HCl. Moreover, the chloride content present in the TUFS was brought down due to acid treatment from 1.57% to 0.45% by washing it in water thus bring the chloride level less than the allowable limit of 1% as per ACI 318-95 Standard [17]. The water used for washing can be sent to the treatment plant available in the industrial unit and can be reused for other purposes after treatment.

2.3. Mix proportions

Control Concrete (CC) was proportioned to have target 28-day compressive strength of 27.7 MPa according to BIS: 10262-2009 [13]. The concrete mix proportion was1:1.6:2.92; 1 part cement, 1.6 part fine aggregates, and 2.92 part coarse aggregates with a water cement ratio of 0.5. Four additional concrete mixtures (R10, R20, R30 and R40) were proportioned where sand (fine aggregate) was replaced with 10%, 20%, 30% and 40% TUFS by mass respectively. A constant water-to-cement ratio of 0.5 was used in the preparation of all concrete mix.

2.4. Fresh concrete properties

To have a clear picture on workability of fresh concrete with TUFS incorporation, tests were conducted to evaluate the slump, compaction factor and Vee-Bee time in accordance with test procedure described in Indian Standard Specification BIS 1199-1959 [14]. The mix proportion and the properties of fresh concrete are tabulated and shown in Table 1. All the tests on fresh concrete shows almost same workability irrespective of the replacement of sand with TUFS indicating that TUFS will not adversely affect the workability of concrete though a slight reduction was noticed. Moreover, while preparing the concrete, no visible difference was noticed among the control concrete and concrete with TUFS in terms of workability and colour of the mix.

2.5. Specimen preparation and casting

150 mm concrete cubes were cast for compressive strength, 150 mm diameter $\times$ 300 mm high cylinders for splitting tensile strength and 100 mm $\times$ 100 mm $\times$ 500 mm beams for flexural strength. All the specimens were prepared in accordance with BIS: 1199-1959 [14]. Soon after casting, test specimens were left in the casting room for 24 h at a temperature of about 27 ± 1 °C.