International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 6 Issue 5, July-August 2022 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

An Experimental Study on Self-Compacting Concrete using Electric Arc Furnace Oxidizing Slag

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ABSTRACT

Compaction is not promising and also in dense reinforcement structural elements. The self-flow of fresh concrete is the mandatory requirement for SCC and hence the suitability of EAFOS as coarse aggregate in SCC has to be examined before using in SCC. However, the reports on the suitability of EAFOS as coarse aggregate in SCC are limited. Hence, the fresh concrete properties of SCC with EAFOS as aggregate such as flowing, filling and passing ability were examined. In addition, the hardened concrete properties of SCC with EAFOS such as density, compressive strength, flexural strength, modulus of elasticity and ultrasonic pulse velocity (UPV) were investigated and compared with the results of normal concrete. The relationship between the mechanical properties of concrete was arrived and also suitable models were developed for predicting the compressive strength of SCC using UPV results.

KEYWORDS: *compaction, coarse aggregate, compressive strength, investigated, concrete*

How to cite this paper: Veeru Kumar Gupta | Dr. Abhay Kumar Jha | Dr. Abhay Kumar Jha "An Experimental Study on Self-Compacting Concrete using Electric Arc Furnace Oxidizing Slag" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-6 | Issue-5, August 2022, pp.1426-1429, URL: www.ijtsrd.com/papers/ijtsrd50677.pdf

IJTSRD50677

I. INTRODUCTION

In order to preserve the natural resources, several investigations have been conducted by replacing the coarse aggregate in concrete with alternative materials such as Metallurgical slag, Ceramic scrap, Bottom ash and Construction debris. The steel slag can be made available from iron and steel industries in Tamil Nadu, South India. The basic mechanical properties of concrete made with steel slag were determined in previous investigations (Al-Zaid et al. 1997, Maslehuddin et al. 2004, Wang, 2010, Chunlin et al. 2011, Manso et al. 2011, Veerabathran and Murthi, 2014) and EAFOS (Papayianni, 2010 & 2011, Polanco et al. 2011, Kim et al. 2012, Abu-Eishah 2012 and Pellegrino et al. 2013). The durability studies of concrete with steel slag were also carried out by few authors (Qiang et al. 2013) and EAFOS (Beshr et al. 2003, Manso et al. 2006, Etxeberria et al. 2010). Almost all the literature evidences had shown the suitability of various by-products as aggregate in normal concrete. However the effect of making SCC is limited. In the current investigation, EAFOS is used as a replacement material to the coarse aggregate in SCC.

II. LITRATURE RIVEW

Pellegrino and Gaddo (2009) conducted an investigation to substitute the natural aggregates with oxidizing electric furnace slag in traditional concrete. The results mentioned that the concrete made with oxidizing electric furnace slag showed good strength characteristics and reported that the compressive strength increases up to 21% in the case of 100% substitution of slag as coarse aggregate and 50% of fine aggregate. However the slag should be stored and aged outdoors in advance and exposed to natural moisture for various weeks in order to achieve the chemical / physical stability for safe use in concrete.

Bosela et al. (2009) made an effort to quantify the influence of slag on the properties of fresh and hardened self-compacting concrete by conducting various tests such as slump flow test, V-funnel test, J-ring test, U- box test and sieve stability test alongwith the compressive strength test. The addition of optimum slag content of 15% seems to give good rheology of fresh SCC.

Wang (2010) expressed in a research publication that the steel slag contains oxides (CaO and MgO) that can be result in volumetric instability (expansion) that must be dealt with through steel slag aging and quality control to ensure its appropriate use in construction and care must be taken to prevent potential steel slag expansive behavior.

Cunlin et al. (2011) conducted a preliminary investigation using EAFOS as coarse aggregate and found a higher compressive strength and lower shrinkage. Zaki et al. (2011) reported the results on the flexural behaviour of reinforced concrete beam using EAFOS as aggregate in HPC concluded that encouraging results in mechanical properties were observed compared to dolomite aggregate concrete. EAFOS based concrete showed good ductility behaviour with tension reinforcement ratio up to 3.6% and the entire beam specimen tested provided ample warning to the imminenceof failure.

Papayianni (2011) carried out an investigation on the large amount of high calcium fly-ash and EAFOS in concrete and EAFOS produced a heavy concrete with a density of 2800 kg/m^3. The 28 days compressive strength increases by 20% when coarse EAFOS used as aggregate and the similar pattern was observed in spilt tensile and flexural strength and also showed significant increase in the elastic modulus. The increased strength properties with EAFOS aggregates could be attributed to the surface properties of EAFOS.

METHODOLOGY

Workability of normal concrete

The workability of fresh concrete was measured by slump test in accordance with ASTM: C143 - 90(a) and IS: 7320 - 1974. The slump cone was placed ona horizontal and non-absorbent surface and filled in three equal layers of fresh concrete. Each layer of concrete was tamped 25 times with a standard tamping rod. The top layer of concrete was levelled and the mould was lifted vertically without disturbing the concrete cone. The subsidence of concrete was measured for finding the workability of concrete. The details of experimental setup are shown in Figure 3.11.

Figure 1. Slump test in progress

Fresh concrete properties of SCC

Slump-flow test, V-funnel test, U-box test and L-box test were conducted on fresh concrete for determining the properties of SCC such as filling ability, passing ability as per the specifications of European Guidelines for self-Compacting Concrete prepared by Federation of National Trade Associations representing producers and applications of specialist building Products (EFNARC).

Slump flow test

The slump flow test was conducted to find the final diameter of concrete circle. The testing apparatus consists of a slump cone (Abram's cone) and a steel plate with dimensions of 900 x 900 mm as shown in Figure 3.12. The flow of SCC is shown in Figure 3.13. The slump flow had been measured in two directions perpendicular to each other as per EN 12350 - 8. The time for SCC to spread to 500 mm in diameter (T_{500}) and the final slump flow diameters (D2) in the two orthogonal directions can be measured.

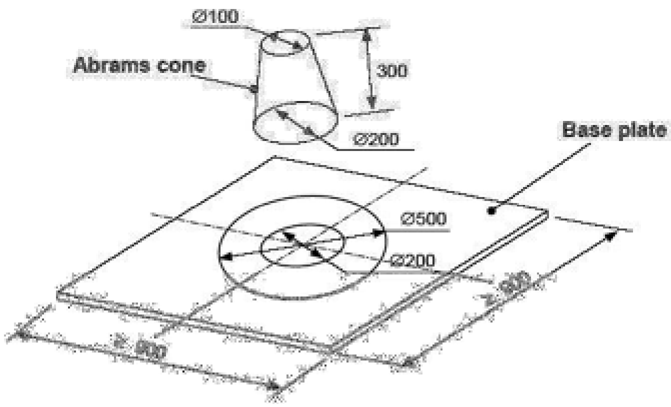

Figure 2. Schematic diagram of Slump flow test (source: EFNARC)

Figure 3. Slump flow of SCC

Compressive strength

The concrete cubes of 150 mm size were prepared and compacted with a table vibrator. After 24 hours of casting, the cube specimens were de- moulded properly and placed in a water tank for further curing. Precautions were taken during de-moulding to maintain the uniform edges and surfaces. Compressive strength tests were carried out on cube specimens after 7, 28, 90 days curing using electrically operated compression testing machine of 2000 kN capacityas per IS 516:1959 at the rate of 15 kN / cm^2 per minute . The compressive strength was calculated by dividing the load at which the specimen fails by the contact surface area of concrete cube. The experimental setup is shown in Figure 3.17.

Figure 4. Compressive strength test

Splitting Tensile strength

A 2000 kN electrically operated compression testing machine was used for conducting the splitting tensile strength of 150 mm diameter and 300 mm height specimen as per IS 5816:1999. The load was applied without any shock and increased constantly at the rate of 15kN/cm^2 per minute until the specimen fails as shown in Figure 3.18. The splitting tensile strength wascalculated using the following formula:

$$f_t = \frac{2P/}{\pi DL} \qquad (2.1)$$

Where,

f_t = Splitting tensile strength of the specimen in Mpa

P = Maximum load in N applied to the specimen

D = Measured diameter of the specimen in mm

L = Measured length of the specimen in mm

Figure 5. Splitting tensile strength test

Conclusion

- The 50% EAFOS based mix C designated M20, M30 and M40grade normal concrete specimens were resulted 28%, 17% and 10% higher than the respective control concrete and 100% EAFOS based mix D designated M20, M30 and M40 grade normal concrete specimens were also resulted 33%, 24% and 13% higher than the respective control concrete. The increase in compressive strength could be attributed to the strong bond between the EAFOS aggregate particles and mortar matrix due to the surface propertiesof EAFOS particles.
- The compressive strength of 28 days cured 50% EAFOS based mix C (CS20) specimens were 14% higher than the control concrete and 21% higher in 28 days cured 100% EAFOS based mix D (DS20) concrete specimens. The compressive strength of 90 days cured M20, M30 and M40 grade SCC specimens of mix C were 32%, 21% and 16% higher compressive strength than that of respective control concrete. It was observed in 100% EAFOS based M20, M30 and M40 grade mix D SCC specimens resulted 38%, 27% and 20% higher than the respective control concrete. The increase in the compressive strength of SCC with EAFOS could be ascribed to the strong bond between EAFOS aggregate particles and cement matrix due free flow of matrix in to the porous and rough surface of EAFOS aggregate particles.

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