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Behaviour of the Steel Slag Blended Concrete by Determination of Its Elastic Properties

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Abstract: The behavior of the steel slag blended concrete is experimented, by partially replacing Coarse aggregate by steel slagto study the mechanical properties by experimenting the cylinder compressive strength (CCSHH), the modulus of elasticity (MEY) and modulus of rupture (MRE). The steel slag is used as a supplementary material in the concrete. The partial replacement for the coarse aggregate replacement was done up to 8% and partial replacement of fine aggregate with steel slag was done up to 30% and the test procedure for determining the mechanical properties of concrete was confined to ASTM STP 169D, ACI :318 and IS 516 - 1959 codal regulations. The Comparison was done with the conventional concrete and the steel slag replaced concrete in terms of strength and economy for replacement mixes. Further modeling of the relationships between the mechanical properties of CCSHH, MEY and MRE of the replacement mixes was done and validated with NZS: 3101-New Zealand Standard code 3101, AS: 3600-Australian Standard code 3600) and ACI: 318-American Concrete Institute code 318)

Index Terms: Enterkey about five words or phrases in alphabetical order, separated by commas. For a list of suggested keywords see: https://ieee-tmi.org/tmi-keywords.asp?s=author

I. INTRODUCTION

In India for most of the construction activities concrete is one of the most abundantly used structural element [1]. The present research studies aiming in reducing the cost and in term the pollution in the production of the concrete, since the carbon-di-oxide emission on the production of cement is second largest in the world [2]. Alternate pozzolanic materials are tried to replace the coarse and fine aggregate in concrete [3]. The present study focuses on effective utilization of the steel slag as a replacement of both fine and coarse aggregate with inclusion of binary replacement. In addition to the strength characteristic studies the elastic in terms of CCSHH, MEY and modulus of ruptureMRE are also to be validated confining to the various International Standards.

II. EXPERIMENTAL PROGRAMME

A. Materials for the Preparation of Concrete

Steel Slag is a byproduct of metal smelting, and several tons are produced every year around the world in the process ofproduction of metals and alloys.

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Cement of OPC 53 grade was used. Six numbers of Concrete cylinders (150/300mm)and beams (100/100/500mm) for each mix including the conventional concrete and were casted following the recommendations given as per Indian Standards and tested for each percentage of replacement. The Cylinder of size 150/300 mm are usually used for all compressive strengths due to its reliability in the test results [4]. Then optimum percentage was found by testing the specimens the individual replacements was done and tested for compression, split tensile and flexural test.

The specimens for compression strength and flexural on the concrete were prepared by casting fresh concrete in cast iron steel moulds. The raw materials used for making concrete are weighed with correct proportions. Mixer machine are used for concreting by skilled labourand needle vibration is done to achieve a high quality of compacting as shown in figure 2.2. After 24 hours, the specimens were de-moulded and placed into curing tank till the period of testing. For developing the desired properties of the concrete, curing should be properly done by maintain moisture content through the duration of curing [5]

Fig 1. Preparation of Concrete

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III. TEST PROCEDURES

Six Beams of size were casted for each mix for flexural strength after 7 days and 28 days curing. The average value of these 3 numbers was taken for further study. Similarly, six cylinders for each mix were casted in order to find out the poisons ratio by determining the lateral and longitudinal strain by CCSH at the age of 7 days and 28 days as displayed in figure 2.3. The testing machine of 2000kN capacity as per IS: 516-1959 code was used for all the mixes.Load was applied gradually with the help of hydraulic pumps until the specimen fails (ultimate load of specimen)

For the test on CCSH, the linear and lateral deflect meters are placed in the cylinder to measure the strain laterally and longitudinally as shown in figure 2.3. Due to the Poisson's effect cylinder specimen undergo lateral expansion. The load is applied 0.15 to 0.35 Mpa/s (ASTM C 1077) and the deflection is noted on the corresponding longitudinal and lateral deflectometersuntil the first appearance of crack on the specimen. After the initial crack, the deflect meters are removed and further rate of loading is increased till failure of the specimen.

Table 1 Mixes and Mix ID

Mixes	Mix ID
Nominal Mix	NM
4% 6% and 8% Fine Aggregate Replacement	CA1 CA 2 CA3
10% 20 % and 30 %Coarse Aggregate Replacement	FA1 FA2 FA3
4% Fine Aggregate Replacement +10% /20%/30%Coarse Aggregate Replacement	CF1CF2CF3
6% Fine Aggregate Replacement +10% /20%/30%Coarse Aggregate Replacement	CF4CF5CF6
8% Fine Aggregate Replacement +10% /20%/30%Coarse Aggregate Replacement	CF7CF8CF9

IV. DISCUSSIONS

A. Predicted Modulus of Rupture

Concrete beams were casted for each concrete mix including nominal mix for all the percentages of replacement mix flexural strength is determined after 28 days for appropriate results. From the CCSHH, Concrete design principles have suggested equations to predict the MR of concrete. The predicted equation generation should always be compatible with the experimental results (Philippe Geyskens, 1998)

The equations codified by International organizations like the Australian, American and New Zealand standards were taken into account to predict From the CCSHH,Concrete design principles have suggested equations to predict the MRE of concrete. The CA, FA and CF mixes are compared with the experimentally results. The MRE (ffc) at 28 days is determined using Eq. (1) as codified by AS (Australian Standard) 3600 and NZS: (New Zealand Standards) Code 3101 by using the value ofCCSHH (fc) at 28 days. $f_{fc}=0.6\sqrt{f_c}$ ….. (1)

ACI (American Concrete Institute) code 318-14, codifies Eq. (2) to be the relationship between the MRE and the CCSHH at 28 days.

$f_{fc}=0.62\sqrt{f_c}$ ….. (2)

From the experimental data of MRE and CCSHH, a relationship confining to Eq. (1) and Eq. (2) was developed by 0.5 power law regression analysis.

$f_{fc}=0.6070\sqrt{f_c}$ ….. (3)

$f_{fc}=0.6458\sqrt{f_c}$ ….. (4)

$f_{fc}=0.7351\sqrt{f_c}$ ….. (5)

B. Predicted Modulus of Elasticity

The modulus of elasticity is taken as a tool or parameter to study the inclusion of supplementary materials for developing a sustainable concrete and validating its properties [7]. The strength of the concrete is dependent on the modulus of elasticity [8], to check the compatibility of concrete design principles for MEY from CCSH,the MEY obtained by experimental results are compared with MEY obtained from concrete design principles like ACI-318, AS-3600 and NZS:-3101 are tabulated in table 6.The modulus of elasticity can be studied by various statistical tool, which is an vital parameter to study the properties of the concrete.[9]The modulus of elasticity can be studied by various statistical tool, which is an vital parameter to study the properties of the concrete [4].The international codes ACI-318 and AS-3600 [Eq. (5)] and NZS:-3101 [Eq. (6)] codifies the relationship between MEY and CCSHH of concrete as follows.

$E_c=\rho^{1.5}\ [0.043\sqrt{(f_c)}]$ ….. (5)

$E_c=3320\sqrt{f_c}+6900$ ….. (6)

Ec – Modulus of Elasticity (N/mm2)

fc – CCSH (N/mm2)

ρ – Density of concrete (kg/m3)

The equation has been modelled with respect to the experimental value and the values codified by the international codes namely the NS, ACI and AS.

$E_c=3548\sqrt{(f_c)}+5595$ ….. (7)

$E_c=3495\sqrt{(f_c)}+5909$ ….. (8)

$E_c=3559\sqrt{(f_c)}+5595$ ….. (9)

The proposed equation for CA, CF and FA concrete mixes with including the density of concrete are determined by 0.5 power regression analysis

$E_c=\rho^{1.5}\ [0.03542\sqrt{(f_c)}]$ ….. (10)

$E_c=\rho^{1.5}\ [0.03522\sqrt{(f_c)}]$ ….. (11)

$E_c=\rho^{1.5}\ [0.03752\sqrt{(f_c)}]$ ….. (12)

To validate the MEY of the experimental value with that of the International codes; ratio between the test values and the value obtained as per the code is determined and from the reference value of unity, representing the 100% is inferred with all the mixes. And from the results it can be depicted that most of the mixes are nearly 98% accuracy with the test results when compared with the values calculated by the international codes. The most results form the best fit the minimum best fit is 0.95 and the maximum best fit value is unity. Hence from the values it can be concluded that the test results match with that of the international code equations.

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V. RELATIONSHIP BETWEEN MODULUS OF RUPTURE AND MODULUS OF ELASTICITY

The properties of concrete without taking a Compressive strength as a parameter is of limited study [5], hence from the Eq.(1) and Eq. (3) relationship between the MRE and MEY is determined. With density of concrete based on the codal provision of AS:

3600for conventional concrete as follows

$E_c=0.0717 \rho^{1.5} f_{fc}$ ….. (13)

$f_{fc}=[E_C/\rho^{1.5}]\, 13.953$ ….. (14)

Based on NZS: 3101, without considering the density from Eq. (1) and Eq. (3), the relationship between MRE and MEY is derived for conventional concrete as follows

$E_c=5533 f_{fc}+6900$ ….. (15)

$f_{fc}=0.000181 E_c-1.247$ ….. (16)

Similarly, as per ACI: 318 318code from the Eq. (1) and Eq. (3), the MRE and MEY is related by considering the density for conventional concrete as

$E_c=0.0693 \rho^{1.5} f_{fc}$ ….. (17)

$f_{fc}=[E_C/\rho^{1.5}]14.419$ ….. (18)

Similarly by considering the density values by Eq 3, Eq4 and Eq5, the proposed MRE and proposed MEY for CA, FA and CF concrete is related without density as

$E_c=0.06494 \rho^{1.5} f_{fc}$

$E_c=0.05621 \rho^{1.5} f_{fc}$

$E_c=0.05348 \rho^{1.5} f_{fc}$

$f_{fc}=[E_C/\rho^{1.5}]15.3983$

$f_{fc}=[E_C/\rho^{1.5}]17.7906$

$f_{fc}=[E_C/\rho^{1.5}]18.7001$

From Eq. 4 Eq 8 and Eq 9 for CA, FA and CF concrete

$E_c=5831.96.57 f_{fc}+5900$

$E_c=5391.76 f_{fc}+5900$

$E_c=4848.32 f_{fc}+5900$

VI. CONCLUSIONS

The replacement of Steel slag for Fine aggregate (30 %) and coarse aggregate (8%) in the concrete mix was done. From the testing for the mechanical properties with the elastic constants the following conclusions are drawn

- Cylinder compressive strength was determined for the nominal and the replacement mixes and was found that the steel slag of the fine aggregate of 30% and 6% inclusion of the coarse aggregate shows the optimum strength
- Equation was developed based on the MRE and CCSHH values for individual as well as combination mix of the CA, FA and CF series respectively; also the validation of the results are also compared with the international standards and accuracy was found to be around 98.9%
- Based on the MEY and the test results the equation is established according to the various international standards and authenticated with the linear power regression analysis with an accuracy of 99% minimum
- Relations were recognized between MRE and MEY based on ACI, NZS and IS codes and confirmed with the test outcomes, by considering with and without density parameter.

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