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EXPERIMENTAL STUDY ON STEEL SLAG INSTEAD OF CORASE AGGREGATE WITH PARTIAL REPLACEMENT OF FLY ASH IN CONCRETE

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ABSTRACT

In this Experimental study, steel slag is used as coarse aggregate replacement Material up to 100% and Fly ash is used as Partial replacement for cement up to 30%. Class C Fly ash is used as partial cement replacement material. The steel Slag aggregate percentage replacement is 100% and fly Ash replacement percentage are 10%, 20%, 30% by weight of cement. Tests are conducted in cubes, cylinders and prisms to find out the compressive strength, split tensile strength and flexural strength for both Ordinary concrete and steel slag concrete with partial replacement of fly ash. This project report summarizes the experimental program to investigate the significance of steel slag aggregate & partial replacement of fly ash in concrete. Finally suggestions were made for the use of steel slag with partial replacement of fly ash for cement to increase the strength of concrete.

KEYWORDS: Steel Slag, Fly Ash, Nominal Concrete, Steel Slag Concrete.

Concrete is the most widely used material on earth in construction industry. Concrete is prepared by mixing various materials like cement, fine aggregate, coarse aggregate, portable water, etc. which are economically available. It is designed specifically for civil engineering projects. Concrete is a composite material composed of granular materials like coarse aggregates bound together with cement or binder which fills the space between the particles and glues them together. In the future, it is becoming a more challenging task to find suitable alternatives of natural aggregates for preparing concrete. Steel slag aggregates can be used in concrete by replacing the natural aggregates is a most promising concept. Slag is a co-product of the iron and steel.

Steel Slag

Steel slag is a by-product of steel, which is produced during the separation from the molten steel, in steel-making furnaces from impurities. It is a non-metallic ceramic material formed from the reaction of flux such as calcium oxide with the inorganic non-metallic components present in the steel scrap. In NSL Chemicals Ltd, steel slag is processed into a constructional material through a proprietary treatment method in Singapore and Malaysia plants (NSL Chemicals Ltd (Road stone) and RST TeknologiSdnBhd respectively).

Figure 1: Steel slags

Fly ash

Fly ash is one of the residues generated in the combustion of coal. Fly ash is generally captured from the chimneys of coal-fired power plants, and is one of two types of ash that jointly are known as coal ash, Fly ash is classified as Class F and Class C types.

The replacement of Portland cement with fly ash is considered to reduce the greenhouse gas "footprint" of concrete, as the production of one ton of Portland cement produces approximately one ton of CO_2 as compared to zero CO_2 being produced using existing fly ash.

Class C Fly Ash

Fly ash produced from the burning of younger lignite or sub bituminous coal, in addition having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash will harden and gain strength over time. Class C fly ash generally contains more than 20Percent lime CaO.

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Alkali and sulphate SO4 contents are generally higher in Class C fly ashes.

Class F Fly Ash

The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 10Percent lime CaO.

Figure 2: Class C Fly Ash

Figure 3: Class F Fly Ash

LITERATURE REVIEW

In this journal he looked at the physical properties of blast furnace slag and steel slag and concluded that both materials were suitable to replace natural stone aggregates in base and sub base road layers, as long as the steel slag was adequately weathered. The study also mixed various slag together and determined that a mixture of ACBF slag (50%),steel slag(20%), granulate blast furnace slag (20%), fly ash (6%), and lime (4%) would self-stabilize over time and form an adequate bound base or sub base road layer. They have got that the concrete containing above these material provided better corrosion resistances **(**Mathur et al., 1999).

In this journal author had studied on the performance of steel making slag and granulated blast furnace slag (GGBFS). Availability of natural sand is decreasing year by year, for this serious problem they have used ground granulated slag (GGBS) which is named as BF slag sand or Sandy-S. In concrete they used as fine aggregate in place of natural sand. Their result shows that the strength, after curing for 91 days is approximately 1.3 times greater than that of 28 days and the strength also continues to increase after 91 days, showing a long term strength increase than conventional concrete (Tatsuhito.TandYabuta. K (2002). .

This study was conducted to evaluate the mechanical properties and durability characteristics of steel slag aggregate concrete in comparison with the crushed limestone aggregate concrete. The durability performance of both steel slag and crushed limestone aggregate concretes was evaluated by assessing by water permeability, pulse velocity, dimensional stability and reinforcement corrosion. The results indicated that the durability and characteristics of steel slag cement concretes were better than those of crushed limestone aggregate concrete Maslehuddi M. et al. (2003).

TakshiFujii ,ToshikiAyanond and Kenji Sakta have developed the concrete using steel making slag which is reducing environmental load. They have made the concrete Using Ground granulated blast furnace slag (GGBS), lime dust (LD), steel making slag (SS), high range water reducing admixture (HRWRA) and Air entraining agent (AE).Their result indicted that low resistance to freezing and thawing of the steel making slag concrete was due to small amount entrained air by the agent and adequate quantity of fly ash is necessary to consume calcium hydroxide around the aggregate TakshiFujii, ToshikiAyanond and Kenji Sakta (2007).

MATERIALS AND METHODS

Ordinary Portland Cement of 43 Grade cement with a specific gravity of 3.158 and fineness 1.2 percent is used as the major binding material in concrete. To increase the mechanical and durability property it is partially replaced with mineral admixture like Fly ash, obtained from Thermal power Plant at Mettur. The fly ash is found to have a specific gravity of 2.2 and comes under class C type. River sand procured from local suppliers having a specific gravity of 2.7, water absorption of 2.2% and free surface moisture of 0.5% is used as conventional fine aggregate in the study. Slag obtained from Cast iron foundry is crushed and conformed to maximum gauge size of 20mm is used as a 100% alternative for coarse aggregate in trial concrete mix adopted in this study. The crushed slag has a specific gravity of 2.6 and water absorption as 0.8%.

Mix Proportions

Concrete mix design is a process of selecting relative proportions of the various raw materials of high performance concrete are determined with an aim to achieve a certain minimum strength, as economically as possible. M30 grade of concrete were designed as per IS 10262 : 2009, to yield an average compressive strength of 30 MPa for 3 ,7, 14 and 28 days with the water binder ratio of 0.40 Mix ratio of 1:1.005:2.43

Table 2 Mix Proportion

Cement Kg/m^3	Fine aggregate Kg/m^3	Control slag aggregate Kg/m^3
1	1.005	2.43
479	487.17	1165.5

Experimental Methodology

Compressive Strength

Methodology: This test is carried out in cube specimens. The cube specimens of size 150mm x 150mm x 150mm is used for the study. Specimens are tested for compressive strength at the end of 7, 14 and 28 days curing using compressive testing machine. At least three specimens preferably from different batches shall be made for testing at each selected age. The bearing surface of the testing machine in such a manner that loads is applied to opposite side of the cubes cast. The compression strength is calculated using the equation, Compression strength =P/A in N/mm^2

P- Compressive load on cube at failure in N, A- Cross sectional area of specimen in mm^2

The spherically seated block is brought to bear on the specimen and the load is applied continuously without shock. The rate of loading applied shall be 140 $kg/cm^2/min$. The maximum load applied to the specimen until failure is recorded.

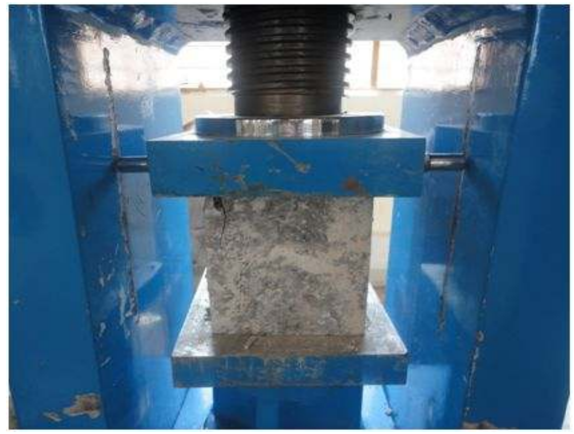

Figure 4: Compressive strength test

Split Tensile Strength

Methodology: This test is carried out in cylindrical specimens. The cylindrical specimens of size 150mm dia and 300mm Height are used for the study. Specimens are tested for split tensile strength at the end of 7, 14, 28 days curing using compressive testing machine. At least three specimens preferably from different batches shall be made for testing at each selected age. Specimen stored in water are tested immediately on removal from water and while they are still in wet condition. The bearing surface of the testing machine in such a manner that loads is applied to opposite side of the cubes cast. The axis of the specimen is carefully aligned with the centre of thrust of the spherically seated platesThe Split tensile strength is calculated using the equation, Split Tensile Strength = $2P/\pi LD$, P = Compressive Strength (N/mm^2); L = length of the Cylinder (mm); D = Diameter of the Cylinder (mm)

Figure 5: Split Tensile Test

Flexural Strength

Methodology: This test is carried out in beam specimens. The beam specimens of size 700mm x

150mm x 150mm is used for the study. Specimens are tested for Flexural strength at the end of 7, 14, 28 days curing using flexural testing machine. At least two specimens preferably from different batches shall be made for testing at each selected age. The bearing surface of the testing machine in such a manner that loads is applied to opposite side of the cubes cast. The axis of the specimen is carefully aligned with the centre of thrust of the spherically seated plates. The Flexural strength is calculated using the equation.

Figure 6: Flexural Strength Test

Conditions: If, a> 13.3 cm, formula 1 is used. If 11 < a < 13.3 cm, formula 2 is used.

Formula:

$$F_b = \frac{P\,x\,l}{b\,x\,d^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1 \quad \text{and} \quad F_b = \frac{3P\,x\,a}{b\,x\,d^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

TEST RESULTS AND CONCLUSION

Compressive Strength Test Results

Cubes are casted by varying the percentage replacement of cement with Fly ash from 0% to 30% as mineral admixture at 10% increment, the below table shows the compressive strength results for 7, 14 and 28 days.

Table 3: Compressive strength (7, 14, 28 days)

Mix	Description	7days (N/mm^2)	14 days (N/mm^2)	28 days (N/mm^2)
CC	Conventional concrete	23.03	32.46	43.11
SC	Control Slag Concrete	23.55	35.14	44.58
SC1	10% Fly ash	24.58	36.33	47.10
SC2	20% Fly ash	24.73	37.30	48.44
SC3	30%Fly ash	22.22	36.31	47.84

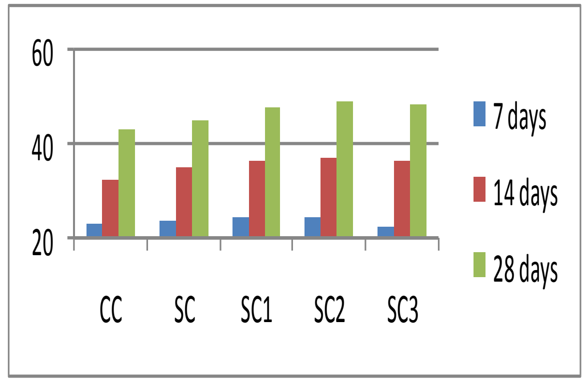

Figure 7: Compressive strength (7, 14, 28 days)

Split Tensile Strength Test Results

Cylinders are casted by varying the percentage replacement of cement with Fly ash from 0% to 30% as mineral admixture at 10% increment. The 7, 14 and 28days cylinder split tensile test results of slag concrete are shown in Tables

Table 4: Split tensile strength test results-7, 14, 28 days

Mix	Description	7 days (N/mm^2)	14 days (N/mm^2)	28 days (N/mm^2)
CC	Conventional concrete	1.49	1.82	2.33
SC	Control Slag Concrete	1.17	1.58	2.26
SC1	10% Fly ash	1.58	1.77	2.34
SC2	20% Fly ash	1.97	2.22	2.89
SC3	30%Fly ash	1.95	2.07	2.82

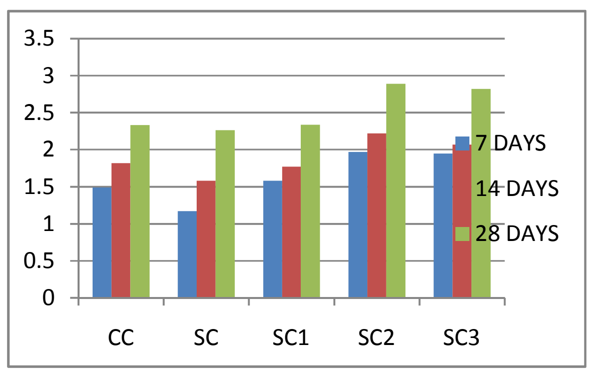

Figure 8: Split tensile strength test results-7, 14, 28 days

Flexural Strength Test Results

Prisms are casted by varying the percentage replacement of cement with Fly ash from 0% to 30% as mineral admixture at 10% increment. The 7, 14 and 28days flexural strength test results of slag concrete are shown in Tables.

Table 5: Flexural strength test results-7, 14, 28 days

Mix	Description	7 days (N/mm^2)	14 days (N/mm^2)	28 days (N/mm^2)
CC	Conventional concrete	2.07	3.05	4.71
SC	Control Slag Concrete	1.97	3.90	5.02
SC1	10% Fly ash	2.07	3.95	4.97
SC2	20% Fly ash	3.00	4.72	5.49
SC3	30%Fly ash	2.58	4.51	5.28

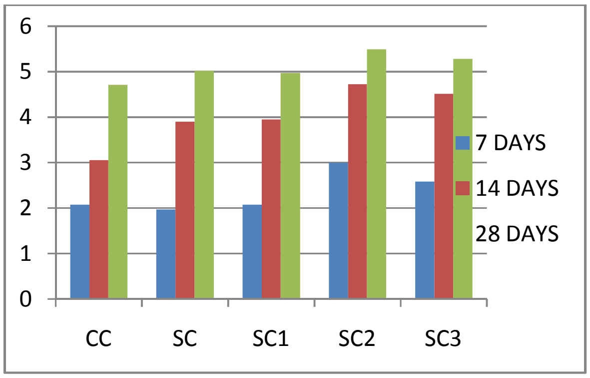

Figure 9: Flexural strength test results-7, 14, 28 days

CONCLUSION

Concrete with good strength can be produced using Electric Arc Furnace slag from cast iron foundry as an alternative material for aggregate, while using steel slag the experimental results shows that the mechanical properties of concrete attains more strength than conventional concrete in compressive and flexural strength (7, 14 & 28days), for cement replacement with Fly Ash by 20% will shows better results in which the strength gradually increases when comparing with other percentage of fly ash like 10% and 30% .

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