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STUDY ON BEHAVOUR OF GRANULATED STEEL SLAG IN M30 CONCRETE

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ABSTRACT

Environmental destruction have become the major issue in recent years. Use of more and more environmental friendly materials in any Industry in general and construction industry in particular, is of paramount importance. Steel slag is a waste product generated during the production of steel. The world steel industry produces about 800 Mt of crude steel and an average of about 450 Kg of solid by products is generated in the steel industry per tons of crude steel These wastes are disposed in the form of landfills, caused an enormous amount of land pollution. It becomes necessary to protect the environment from these wastes.

To solve the problem of greenhouse gas emission from industries we can reuse the wastes from industries and help environment by steel slag as a fine aggregate. This will solve the problem of waste disposal side by side preserving our natural resources.. In this experiment, the replacement was done with fine aggregate by steel slag for different proportions of 5%, 10%,20% for M30 grade of concrete. The result data obtained will be analyzed and compared with a control specimen of 0% steel Slag or plain M-30 concrete for effective study of variation of compressive strength and split tensile strength of Concrete with respect to the change in steel Slag content. Workability of concrete gradually decreases, as the percentage of replacement increases, which is found using slump test .The proposed mix design method was found to be satisfactory for producing concrete with replacement of fine aggregates with steel slag.

To investigate the fresh concrete properties, the slump test was conducted for every batch of various percentage of waste steel slag. While for hardened concrete properties, compressive strength test and splitting tensile strength test were conducted. The results indicate that the concrete added with steel slag reduces compressive strength of concrete and the mechanical properties and durability properties of concrete. However, for splitting tensile strength test, it showed a strength development of concrete when added by Iron slag.

Keywords*: Granulated Steel Slag: M30 Grade concrete: slump Test, Compressive strength: Split tensile strength.*

I. INTRODUCTION

Concrete: Concrete's versatility, durability, sustainability, and economy have made it the world's most widely used construction material. The term concrete refers to a mixture of aggregates, usually sand, and either gravel or crushed stone, held together by a binder of cementations' paste. . The made up of Portland cement and water and may also contain supplementary cementing materials (SCMs), such as fly ash and chemical admixtures. Concrete materials are mixed in specific proportions to obtain the required strength. Strength of mix is specified as M5, M10, M15, M20, M25, M30 etc., where M signifies Mix and 5, 10, 15 etc. as their strength in kN/m^2.

Different properties of concrete:

1. Grades (M20, M25, and M30 etc.)

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2. Creep
3. Durability
4. Strength
5. Shrinkage

Granulated steel slag: Slag is the glass-like by-product left over after a desired metal has been separated (i.e., smelted) from its raw ore. Slag is usually a mixture of metal oxides and silicon dioxide. The slag occurs as a molten liquid melt and is a complex solution of silicates and oxides that solidifies upon cooling. Steel Furnace Slag or simply Steel Slag is produced in a furnace as its name suggests. It actually is produced in two types of furnaces namely BOF and EAF.

Uses of steel slag in civil engineering

- Steel slag instead of natural aggregates avoids the natural footprint of quarrying and also prevents deforestation
- Use of Steel Slag in Road Applications Steel slags have been utilized successfully both as bound and unbound layers of pavement structures.
- Steel slag is used as aggregate either in bound surface layers of pavements or in unbound sub-base or base layers of roads.

II. LITERATURE REVIEW

1. **Anil Singh, Arjun Kumar, Sulekha and Harsimran 2016** Singh in their **research "Study of Partial Replacement of Fine Aggregate by Iron Slag".** This study shows the possibilities of using iron slag as partial replacement of fine aggregate (sand) by iron slag. Iron slag was used to replace 25% to 30% of sand by weight at increment of 5% for both cube and cylinder. The strength of concrete increases rapidly with increase the iron slag content and the optimum value of compressive strength is obtained at 30% replacement. After 30% replacement the strength decreases. Similarly in the case of split tensile strength, the strength increases with the increase in iron slag content and the optimum value of split tensile strength is obtained at 30%. The uniform load conditions for compressive strength and split tensile strength are 4KN and 2KN respectively. In this study, the compressive strength of the iron slag concrete was studied. The results confirm that the use of iron slag overcome the pollution problems in the environment. The results shows that the iron slag added to the concrete had greater strength than the plain concrete.

   The strength characteristics of concrete mixtures have been computed in the present work by replacing 25%, 30% and 35% iron slag with the sand. On the basis of present study, following conclusions are drawn.
2. **Devinder Sharma1, Naveen Singh** (2017) in their research "**EFFECT OF WASTE STEEL SLAG AND SILICA FUME ON MECHANICAL PROPERTIES OF HIGH STRENGTH CONCRETE**" compare the properties of Self-compacting high strength concrete made with and without steel slag and silica fume, used as supplementary cementing material. Concrete samples of M60 grade using water/binder ratio 0.32, with varying percentage of steel slag (0 to 40%) in the interval of 10% and with optimum percentage of silica fume(10%) were casted and tested for mechanical and durability properties at the age of 7, 28 and 56 days. Replacement of fine aggregates with steel slag.

   1) Test results reported that there is rise in compressive strength, splitting tensile strength and flexural strength for M60 grade of concrete mix with inclusion of slag up to 40% replacement and 10% silica fume in addition to PPC.

   2) Compressive strength, splitting tensile strength and flexural strength of all concrete mixes showed a normal progression in strength with increase in curing age.
3. **Chetan Khajuria and Rafat Siddique** in 6, June 2014 in their study **Use of Iron Slag as Partial Replacement of Sand to Concrete** The environment problems are very common in India due to generation of industrial by-products. Due to industrialization enormous by-products are produced and to utilize these by-products is the main challenge faced in India. Iron slag is one of the industrial by-products from the iron and steel making industries. In this paper, the compressive strength of the iron slag concrete

was studied. The results confirm that the use of iron slag overcome the pollution problems in the environment. The results shows that the iron slag added to the concrete had greater strength than the plain concrete

The strength characteristics of concrete mixtures had been computed in the present work by replacing 10%, 20% and 30% iron slag with the sand. On the basis of recent testing, subsequent conclusions were drawn

After adding 10% iron slag in the mix, there was an increase of 26% after 7 days, 50% increase after 28 days and 43% increase after 56 days as compared to the control mix. By adding 20% and 30% iron slag , there was large amount of increase in percentage i.e. 68%, 91%, 78% and 125%, 113% , 87% after 7, 28 and 56 days respectively.

III. OBJECTIVE OF THE STUDY

The objective of the study is to investigate the properties of granulated steel slag with partially replacement of fine aggregates by iron slag in different percentage (5% by weight of fine aggregate, 10% by weight of fine aggregate and 20% by weight of fine aggregate by partially replacement of Granulated steel slag). To investigate the property such as compressive strength and split tensile strength of M30 grade of concrete having mix proportion 1:1:2 with water cement ratio 0.45. The environment problems are very common in India due to generation of industrial byproducts. Due to industrialization enormous byproducts are produced and to utilize these byproducts is the main challenge faced in India. So the usage of these wastes materials helping in dual role by minimizing the usage of raw material of concrete and by using the waste materials that are affecting the environment.
Different tests are conducted during the study

- Compressive strength
- Split tensile strength
- Flexural strength
- workability

IV. SCOPE OF THE STUDY

The main scope of this project work is to arrive the mix proportion of M30 concrete made up of replacing some percentage of fine aggregates with steel slag. Flexural strength for various trial mixes of slag and fine proportioned concrete element is to be found out.

Steel slag is one of the materials that can be considered as a waste material which could have a promising future in construction industry as a partial substitute in fine aggregates. It is an industrial by product material produced during manufacturing of steel. Proper handling of waste material resulting from the industries has recently become environmental concern besides resource management. The effluent from the steel making manufacturing industry is terms as slag. . The first preference of today's engineering is to minimize the adverse effects of whatever they build on environment. To achieve these objectives researchers focused their study on cement that was causing most adverse effect on the environment by emitting CO_2 and by usage of fossil fuels during burning process. To minimize these researchers focused on the usage of waste materials that were also adversely affecting the environment. Some of these are already in use such as fly ash; silica fume etc. and many others are under research. So the usage of these wastes materials helping in dual role by minimizing the usage of raw material of concrete and by using the waste materials that are affecting the environment. The other advantage of using these waste materials is that they are helping in improving the properties of concrete.

The original scope of this research is to investigate the properties of concrete with steel slag. The fresh and hardened properties of concrete were tested with steel slag. The free thaw resistance of concrete with steel slag was studied and the expansion of the concrete specimen was also examined. In addition to this research several tests were also included such as compressive strength and split tensile with steel slag.

V. RESEARCH METHODOLOGY

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The effect of granulated steel Slag on the strength of concrete for M30 grade can be studied by varying the percentage of steel Slag in concrete by replacing it with sand. Steel Slag content is varied by 5%, 10%, and 20%, of volume of concrete. Cubes of size 150mm X 150mm X150mm according to IS Code 5816-1999 are casted to check the compressive strength. All the specimens were cured for the period of 7, 14 and 28 days before crushing and thus compression test is performed. Size of cylinder use for split tensile strength 150mm X 300mm according to IS Code 5816-1970 to check the tensile strength of concrete.

Materials used in research

- Ordinary Portland Cement of 53 grade confirming to IS 8112-1995.
- Fine Aggregates: Natural River Sand confirming to Zone II of IS 383-1970.
- Coarse Aggregates: Natural crushed stone of size between 10-30mm confirming to IS 383-1970.
- Granulated Iron Slag.
- Water: normal tap water
- Sand

Ordinary Portland Cement of 53 grade confirming to IS 456-2000

Portland cement referred as (ordinary Portland cement) is the most important type of cement and a fine powder produced by grinding Portland cement clinker. Ordinary Portland cement (OPC) of 53 Grade was used throughout the course of the investigation. It was fresh and without any lamps. The physical properties of the cement are determined from various tests conforming to Indian standard IS 12269:1987 the cement is carefully stored to prevent deterioration in its properties due to contact with the moisture.

Fine Aggregates: Natural River Sand confirming to Zone II of IS 383-1970. When the aggregate is sieved through 4.75mm sieve, the aggregate passed through it called as fine aggregate. Natural sand is generally used as fine aggregate, silt and clay are also come under this category. The soft deposit consisting of sand, silt and clay is termed as loam. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent.

Coarse aggregate When the aggregate is sieved through 4.75mm sieve, the aggregate retained is called coarse aggregate. Gravel, cobble and boulders come under this category. The maximum size aggregate used may be dependent upon some conditions. In general, 40mm size aggregate used for normal strengths and 20mm size is used for high strength concrete

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Figure (1) Fine and coarse aggregates

Granulated Steel Slag: Blast furnace slag is recovered by melting separation from blast furnaces that produce molten pig iron. It consists of non-ferrous components contained in the iron ore together with limestone as an auxiliary materials and ash from coke. Approximately 290 kg of slag is generated for each ton of pig iron. When it is ejected from a blast furnace, the slag is molten at a temperature of approximately 1,500℃. Depending on the cooling method used, it is classified either as air-cooled slag or granulated slag.

Figure (2) Granulated Iron Slag

Sieve analysis

Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. In this we use different sieves as standardized by the IS code and then pass aggregates through them and thus collect different sized particles left over different sieves.

Coarse aggregate

Coarse aggregate means the aggregate which retained on 4.75mm sieve when it is sieved through 4.75mm. In sieve analysis of coarse aggregate the material is passes through sieves size of 80mm, 40mm, 20mm, 10mm, 4.75mm,

2.36mm, 1.18mm, 0.6mm, 0.3mm, and 0.15mm. In this process the average size of particle is known when we counted from lower order sieves size to higher order sieves.

Fine aggregate

The other type of aggregates are those particles passing the 9.5 mm (3/8 in.) sieve, almost entirely passing the 4.75 mm (No. 4) sieve, and predominantly retained on the 75 µm (No. 200) sieve are called fine aggregate. For increased workability and for economy as reflected by use of less cement, the fine aggregate should have a rounded shape. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent.

Table (1) Sieve Analysis Fine Aggregate

IS sieve size	Weight of fine aggregate retained				Percent retained	Cumulative percent retained	Percent passing
	I.	II.	III.	Avg			
1	2	3	4	5	6	7	8
10mm	0	1	5	2	0.2	0.2	99.8
4.75mm	11	11	15	12.33	1.23	1.43	98.57
2.36mm	37	32	21	30	3.0	4.43	95.57
1.18mm	313	320	331	321.33	32.13	36.56	63.44
600 mic	213	120	225	186	18.6	55.16	44.84
300 mic	270	288	265	274.33	27.43	82.59	17.41
150 mm	112	100	111	107.66	10.76	93.35	6.65
75 mm	23	28	15	25.33	2.53	95.88	4.12
Pan at the bottom	21	30	12	21	2.1	97.98	2.02
From the analysis result of sieves the sand is falls under zone II							

Figure (3) Coarse and fine sieves

Specific gravity: Specific gravity refers to the ratio of the mass of a substance to the mass of a reference substance at the same volume. Furthermore, apparent SG refers to the ratio of the weight of the volume of a substance to the weight of an equal volume of the reference substance. Here we use fine aggregate: natural river sand
Zone II (IS: 383)

Specific gravity of fine aggregate =D/[C-(A-B)]

SG = D/[C-(A-B)]
= 496/500-(1826-1514)
=2.64

Specific gravity of coarse aggregate = D/[C-(A-B)]

SG = 982/[990-(3372-2754)]
=2.64

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VI. TESTING AND RESULT

Compressive Strength on concrete cubes

The compressive strength of any material is defined as the resistance to failure under the action of compressive forces. Especially for concrete, compressive strength is an important parameter to determine the performance of the material during service conditions. Concrete mix can be designed to obtain the required engineering properties and durability. Some of the engineering properties of hardened concrete includes Elastic Modulus, Tensile Strength, Creep coefficients, density, coefficient of thermal expansion etc.

The formula for calculating compressive strength is

CS = F / A

Concrete gains maximum strength at 28days. Since in construction sector great amount of capital is at stake, so instead of checking strength at 28 days we can check strength in terms of concrete strength psi at 7 and 14 days to predict the target strength of construction work.

From the below table it is clear that, Concrete gains 16 % of its strength within 24 hrs., whereas concrete gains 65% of the target strength by the time of 7 days of its casting. In 14 days concrete gains 90% of the target strength and there after the gain of strength after 28 days is 99%.

Figure (4) Compression test

Result of tested cubes

Compressive strength of cubes after 7 days

weight before compaction = 8.13 kg

Load = 702 KN

=702/150 x150mm^2

=31.2 N /mm^2

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Table (2) Result of Compressive strength of concrete (cubes)

S. NO	Grade of concrete	Percentage of Iron slag Replacing sand	Avg. Compressive strength of cubes after 7days ($N/mm^{2)}$	Avg. compressive strength of cubes after 14days (N/mm^2)	Avg. compressive strength of cubes after 28days (N/mm^2)
1	M30	0%	31.2	35.2	39.5
2	M30	5%	32.4	36.2	39.6
3	M30	10%	32.5	35.4	39.56
4	M30	20%	32.3	35.6	40.21

Split tensile strength test on concrete cylinders

Split tensile strength test is a method of determining the tensile strength of concrete using a cylinder which splits across the vertical diameter. It is an indirect method of testing tensile strength of concrete.

The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack.

Figure (5) Split tensile test

The split tensile strength at which failure occurs is the tensile strength of concrete. In this Investigation the test is carried out on cylinder by splitting along its middle plane parallel to the edges by applying the compressive load to opposite edgesas per IS: 516-1959...The split tensile strength of cylinder is calculated by the following formula.

Ft= 2P/3.14DL

Table (3) Result of split tensile strength of cylinder moulds

S. NO.	Grade of concrete	Percentage of Iron Slag	Avg. Tensile strength of cylinder after 7days (N/mm^2)	Avg. tensile strength of cylinder after 14days (N/mm^2)	Avg. tensile strength of cylinder after 28 days (N/mm^2)
1	M30	0%	2.1	3.05	3.98
2	M30	5%	2.12	3.2	4.3
3	M30	10%	2.25	3.25	4.6
4	M30	20%	2.35	3.4	4.5

VII. CONCLUSION

1. The use of granulated steel slag in concrete. Replaces fine aggregate and reduces the cost of making concrete
2. Steel slag powder used as a mineral admixture could improve the fluidity of paste, which is beneficial for the workability of concrete
3. Compressive strength of concrete with partial replacement of fine aggregate by Granulated steel slag increased at 7 days, 14 days, and also 28 days up to 20% of slag.
4. The split tensile strength of concrete increased with partial replacement of fine aggregate by Granulated steelup to 20% .
5. A comparison was made between concrete having natural coarse aggregates and concrete with various percentages of steel slag aggregates replaced by weight. The results of this research were encouraging, since they show that using granulated steel slag as fine aggregates in concrete has no negative effects on the short term properties of hardened concrete.

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