Evaluation of Strength of Steel Fiber Reinforced Concrete Blended With Steel Slag

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Abstract - *Concrete assumes a fundamental part in the outline and development of the country's foundation. Practically forty percent of the volume of concrete consists of fine aggregates. These are acquired from common rocks furthermore river beds, accordingly debasing them gradually. Over a period of time, waste management has become one of the most unavoidable complex and difficult problem in the world which is affecting the environment. Steel slag is by product material which is gathered from cast iron manufacturing unit. Hence the idea of substitution of fine aggregate with steel slag appears to be encouraging.*
In this study the experimental investigation is done on the study of the Fibre reinforced concrete using steel slag as the replacement for fine aggregate. M30 grade of concrete was used. To this optimum replacement of slag material steel fibres are dispersed at different volume fractions. The steel fiber reinforced concrete containing fibers of 0.5%, 1.0% and 1.5% volume fraction of hooked end steel fibers of 60 aspect ratio were used. Tests of compressive strength, flexural resistance, split tensile strength and the Young's modulus tests are carried out on the specimens in which the steel fibres are dispersed in volume fractions of 0.5%, 1% and 1.5%. The cube size is 150mm x150mm x150 mm for testing the compressive strength of concrete. Flexural strength is checked by testing beams of size 700 mm x 150 mm x 150 mm beneath two points loading. From experiment the most optimum fiber and steel slag content that gives maximum compressive strength and flexural strength will be determined.

***Key Words*: Fiber reinforced concrete, Steel slag, fine aggregate, steel fibres, Aspect ratio.**

1. INTRODUCTION

Concrete possess much importance because of its property of being moulded into any desired shape. It is strong, inexpensive, plentiful and easy to make. It possesses the property of versatility. Concrete is friendly to the environment. It is virtually all natural. Concrete is an artificial conglomerate stone made with Portland cement, water and aggregates. Concrete has relatively high in compressive strength, but significantly low in tensile strength and are usually reinforced with the materials that are strong in tension. The elasticity of concrete is relatively constant at low stress levels but decreases at higher stress levels as matrix cracking develop. It has a very low coefficient in thermal expansion and as it matures concrete shrinks. Concrete subjected to long-duration forces is prone to creep.

Steel Slag: Steel slag is a by-product obtained either from conversion of iron into steel in a Basic Oxygen Furnace (BOF), or by the melting of the scrap to make steel in the Electric Arc Furnace (EAF). The molten liquid is an complex solution of silicates and oxides that solidifies on cooling and forms as steel slag. Steel slag is defined by the American Society for Testing and Materials as a non-metallic product, consisting essentially of calcium silicates and also ferrites combined with fused oxides of iron, aluminum, manganese, calcium and magnesium that are developed simultaneously with steel in basic oxygen and electric arc furnaces. The chemical composition and cooling of the molten steel slag have a great effect on the chemical and physical properties of solidified steel slag. In the Basic Oxygen Furnace (BOF), the hot liquid metal from blast furnace fluxes and scrap, which contains dolomite lime (CaO) and lime, are charged to a furnace .A lance is lowered into converter and then oxygen in injected with high pressure. The oxygen then combines with lime and removes the impurities as shown in Fig. 1.2(a). These impurities consist mainly of carbon in the form of gaseous carbon monoxide, silicon, , phosphorous, manganese and some iron as liquid oxides, which then combines withlime and dolomite lime to form steel slag. At the end of the refining stage, the steel which is in the liquid form is poured into the ladle while the slag is retained at the top of the vessel and has been removed in separate slag pot. This slag is now in molten state and is then processed to remove all the free metallic impurities with help of magnetic separation and then sized into construction aggregates. Unlike the Basic Oxygen Furnace (BOF) process, the Electric Arc Furnace (EAF) process does not use the hot metal, but uses the cold steel scraps. The Charged material is heated to form a liquid state by means of an electric current. The electricity has no electrochemical effect on the metal,but also helps in making it perfectly suited for melting scrap. During this melting process, other metals are also added to the steel to give the required chemical composition. Meanwhile oxygen is blown into the EAF to purify the steel. This slag which floats on the surface of molten steel is then poured off. Steel slag aggregates are used for soil stabilization or soil improvement material and for remediation of industrial waste water run-off.

Steel fibres: Fibers are usually used in concrete to control cracking due to plastic shrinkage and to drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact, abrasion, and shatter–resistance in concrete.

Generally fibers do not increase the flexural strength of concrete, and so cannot replace moment–resisting or structural steel reinforcement. Indeed, some fibers actually reduce the strength of concrete. The amount of fibers added to a concrete mix is expressed as a percentage of the total volume of the composite (concrete and fibers), termed "volume fraction" (Vf). Vf typically ranges from 0.1 to 3%. The aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter

Scope of present study: The original scope of this research was to investigate the properties of concrete with steel slag aggregates. The mechanical properties of concrete were tested with steel slag as replacement of coarse aggregates, In addition to this work steel fibres are added to the optimum replacement level and several tests were also carried out such as compressive strength and split tensile strength.

Thus replacing the natural aggregates in concrete applications with steel slag would lead to considerable environmental benefits and at the same time the strength properties of the concrete is increased and would be economical.

2. LITERATURE REVIEW

•**Aderibigbe and A. E. Ojobo:** Investigations conducted on the pozzolanic properties of a Steel slag revealed that on the basis of chemical constituents alone, the steel slag could be considered a pozzolana. Physical tests, however, showed that the steel slag exhibited little pozzolanic activity. An improvement in physical properties was obtained by calcining the slag at 700°C for 5 hr. Without sacrificing appreciable strength (e.g. a 13.5% reduction in strength), up to 20% replacement of Portland cement by steel slag is possible in the preparation of cement mortar. This results in appreciable cost savings in areas where cement is expensive and steel slag is considered a waste product.

•**A.M. Shende et.al.,** "Experimental Study on Steel Fiber Reinforced Concrete for M-40 Grade"The strength and durability of concrete can be changed by making appropriate changes in its ingredients like cemetitious material, aggregate and water and by adding some special ingredients. The presence of micro cracks in the mortar-aggregate interface is responsible for the inherent weakness of plain concrete. The weakness can be removed by inclusion of fibres in the mixture. Different types of fibers, such as those used in traditional composite materials can be introduced into the concrete mixture to increase its toughness, or ability to resist crack growth.

•**Joseph O. Afolayan and Stephan A. Alabi** The compressive strength of the concrete designed using steel slag as a coarse aggregate and partial replacement for cement was investigated. A series of experimental studies were conducted involve concrete production in two stages. The first stage comprised of normal aggregate concrete (NAC) produced with normal aggregates and 100% ordinary Portland cement (OPC). Meanwhile, the second stage involved production of concrete comprising of cupola furnace slag an aggregates with 100% ordinary Portland cement (OPC) and subsequently with 2%, 4%, 6%, 8% and 10% cementitious replacement with steel slag that had been grounded and milled to less than 75 μm diameter. The outcomes of compressive strength test conducted on the slag aggregate concrete (SAC) with and without granulated slag cementitious replacement were satisfactory compared to normal aggregate concretes (NAC).

•**P. Jyotsna Devi et.al.** in their work "A Study on the Flexural and Split Tensile Strengths of Steel Fibre Reinforced Concrete at High Temperatures "mixing with 1% volume of steelfibers to evaluate its performance at normal (M30) and at high strength concrete (M60).They introduced good results with that of steel fibres. By adding steel fibres flexural resistance can be increased. The test is carried out for 7, 28 and 91 days.

•**Mekala Prathap Reddy and Dr. K. Chandrasekhar Reddy** This paper investigation on M-30 grade of concrete with water cement ratio 0.45 to study the compressive strength, and tensile strength of steel fibers reinforced concrete (SFRC) containing fibers of an interval of 0.5%,1%,1.5% volume fraction of hook end steel fibers of aspect ratio 60 were used. The different percentage of one or more mineral admixtures with combination of steel fibers is used in this study. After curing this specimen were tested as per relevant codes of practice Bureau of Indian standard. A result data obtained has been analyzed as compared with a control specimen.

•**Girish Sharma** studied in his work "Beneficial effects of steel slag on concrete" with the aim of replacing steel slag of M35 gradewith aggregates(fine&coarse), the percentage from 0%to 55% and tested on its 7th and 28th day after curing. Their deep analysis concludes that there is constant increment when replaced with that of steel slag and can be used practically. Decrement is mentioned after 55% in case of coarse aggregate.

•**Ganeshan N et al,** „steel fibre reinforced high performance concrete for seismic resistant structure" Civil Engineering and construction. They had investigate a series of compression tests were conducted on 150mm x 150mm x 150mm cubes, 150mm x 300mm cylinders to find compressive strength, static and dynamic modulus of elasticity with and without steel fibers of volume fractions 0%, 0.5%, 1%, 1.5% of 0.5mm dia of aspect ratio 60 on PPC concrete. The weight density of concrete increasing with increasing of steel fibre content. Compressive strength and modulus of elasticity increased with addition of steel fibers. The compressive strength increased with the increase in silica fume with normal concrete. As a result the incorporation of steel fibers, silica fume and cement as produced a strong composite with superior crack resistance, improved ductility and strength behaviour prior to loading.

•**Bhikshma V, Ravande Kishor and Nitturkar"** Mechanical properties of fibre reinforced high strength concrete „Recent advances in concrete and construction tech. They had studied the effect of fibers on workability, compressive strength, split tensile strength, modulus of rupture of concrete and also studied the effect of fibers on impact and toughness of concrete. They investigated an experimental study were steel fibers added at the volume of 0.5%, 1%, 1.5%, 2%.. They draw the following conclusions: Due to high content of fibre, large surface area of fibers, fibers are sure to absorb more cement paste and increase of viscosity of mixture makes slump loss. The compressive strength increased from 6% to 17% with the increase of volume fraction of fibers. The split tensile strength increased from 18% to 47% with the increase of volume fraction of fibers. Flexural strength increased from 22% to 63% with the increase of volume fraction of fibers. Modulus of elasticity increased from 8% to 25% with the increase of volume fraction of fibers. Toughness increased by 19.27% with the increase of volume fraction of fibers when compared to plain concrete.

3. MATERIALS AND METODOLOGY

Cement
The cement used in this experimental work is 43 grades Ordinary Portland Cement. All properties of cement are tested by referring IS 12269 – 1987 Specification for 43 Grade Ordinary Portland cement.

Water
Potable water used for the experimentation.

Fine Aggregate
Locally available sand passed through 4.75mm IS sieve is used. The specific gravity value is 2.63

Table -1: Properties of FA and CA

Properties	Fine Aggregate (River Sand)	Coarse Aggregate (Crushed Stone)
Specific Gravity	2.63	2.68
Fineness Modulus	3.75	7.13
Loose Bulk Density (Kg/m^3)	1450	1350
Compacted Bulk Density (Kg/m^3)	1700	1610

Coarse Aggregate
Crushed aggregate available from local sources has been used. The coarse aggregates with a maximum size of 20mm having the specific gravity value of 2.68.

Steel fibers
Steel fibers are the most commonly used type of fibers. Steel has high modulus of elasticity. Use of steel fibers provides significant improvements in flexure, impact and fatigue strength of the concrete. Concrete containing hydraulic cement, water, aggregate, and discontinuous discrete fibers is called fiber reinforced concrete. The steel fiber used in the study is hooked end type MSH 5030 having aspect ratio 60. The length of fiber is 30mm and the diameter of fiber is 0.50mm.

Table -2: Properties of Steel Fiber

Mechanical Properties of Hooked End Steel Fiber	
Length	30mm
Diameter	0.50mm
Aspect ratio	60
Tensile Strength	1186Mpa
Tolerance for diameter and length	(+-) 10% (As per ASTM)

Steel slag:
The steel slag utilized here is an air cooled slag and is gathered from NELCAST INDUSTRIES located in Gudur town, Nellore city, Andhra Pradesh. Its properties were given in Table 3 and Table 4.

Table-3: Index Properties

Property	Value
Specific gravity	2.61
Loose density	1382 kg/m^3
Compacted density	1520 kg/m^3
Crushing strength	29.8%

Table- 4:
Chemical composition of Steel slag

Constituent	Composition(%)
Calcium oxide	40-52
Iron oxide	10-14
Magnesium oxide	5-10
Silica	30-35
Manganese oxide	5-8
Aluminium oxide	1-3
Phosphorous oxide	0.5-1
Water absorption	0-3

Fig -1: Steel Slag

Experimental program and Mix Design

The selection of suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible is termed the concrete mix design. The mix design of the concrete has been carried out based on IS 10262 – 2009. In this Experimental study we are using M-25 grade concrete. The factors affecting the strength of concrete at a given age and cured at prescribed temperature is the degree of compaction.

Cement – 380 kg/m^3
Sand – 691 kg/m^3
Coarse aggregate (20mm)- 1170 kg/m^3
Water -190 kg/m^3

From the literature review optimisation of the steel slag it was found that the
optimum level for the replacement of the steel slag was 50%. Keeping the optimum replacement level of steel slag as constant, the steel fibres are dispersed into the concrete at the volume fractions of 0.5% , 1% and 1.5%. The steel fibres that are used in here are of length 30mm and diameter 0.5mm with the L/d ratio of 60. The type of the steel fibres that are used are of crimped type steel fibres.

The dimension of the specimens are of cylenders of size 100mm X 200mm and 150mm X 300mm where the 100mm and 150mm are the diameters of the cylenders,The dimensions of the cube are 100mm X 100mm X 100mm,The dimensions of the prisms are 500mm X 100mm X 100mm.By adding the steel fibres into the concrete the specimens for the compressive strength, split tensile strength and the flexural strength were being casted at a grade of M25.The specimens were demoulded and kept in curing. The compression test is carried out for 7 days and 28 days and the remaining tests such as flexural strength, split tensile strength test were carried out for 28 days.

4. RESULTS AND DISCUSSIONS

All the tests have been performed in standard procedures and the results and load values obtained were tabulated and calculated in following sections.

4.1 Compressive Strength

Compressive strength tests were conducted on cured cube specimen at 7 days and 28 days age using a compression testing machine of 200 kN capacity. The cubes were fitted at center in compression testing machine and fixed to keep the cube in position. The load was then slowly applied to the tested cube until failure.

MIX	% OF STEEL SLAG	% VOL OF FIBERS	7 DAYS STRENGTH N/mm^2	28 DAYS STRENGTH N/mm^2
M1	0%	0.50%	17.04	28.4
M2	0%	1.0%	17.97	29.96
M3	0%	1.50%	18.94	31.4
M4	50%	0.50%	19.75	31.89
M5	50%	1.0%	20.44	32.4
M6	50%	1.50%	22.1	33.6

Table -4.1: Compressive Strength values

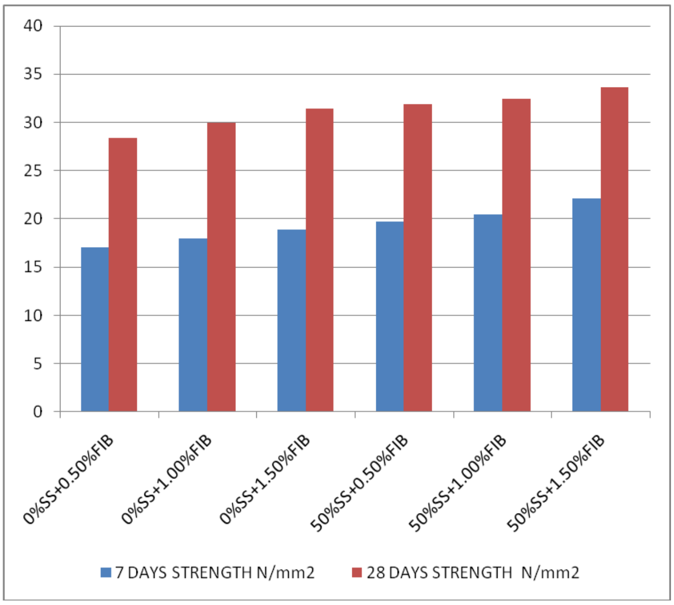

Chart -4.1: Compressive Strength

4.2 Split Tensile Strength

The split tensile test were conducted as per IS 5816:1999. The size of cylinder is 300mm length with 150mm diameter. The specimen were kept in water for curing for 7 days and 28 days and on removal were tested in wet condition by wiping water and grit present on the surface. The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine and the load is applied until failure of the cylinder along the vertical diameter.

MIX	% OF STEEL SLAG	% VOL OF FIBERS	7 DAYS STRENGTH N/mm^2	28 DAYS STRENGTH N/mm^2
M1	0%	0.50%	2.10	3.58
M2	0%	1.0%	2.16	3.61
M3	0%	1.50%	2.20	3.66
M4	50%	0.50%	2.22	3.7
M5	50%	1.0%	2.62	3.77
M6	50%	1.50%	2.3	3.83

Table -4.2: Split Tensile Strength values

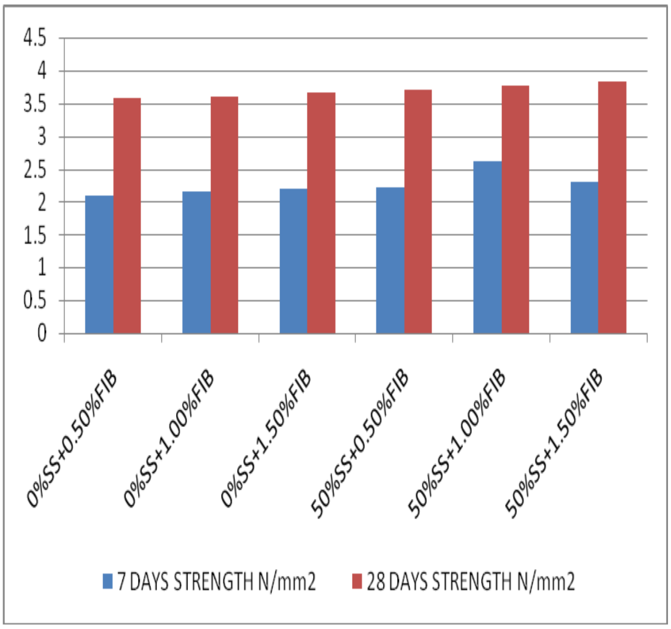

Chart -4.2: Split Tensile Strength

5. SUMMARY AND CONCLUSIONS

The main objective of this study was to study the behaviour of concrete and changes in the properties of concrete with steel slag aggregates by replacing the use of natural aggregates. Steel slag is a by-product and using it as aggregates in concrete will might prove an economical and environmentally friendly solution. A comparison was made between concrete having natural coarse aggregates and concrete with various percentages of steel slag aggregates replaced by volume. The results of this research were encouraging, since they show that using steel slag as coarse aggregates in concrete has no negative effects on the short term properties of hardened concrete.

1. From the literature review compressive strength findings optimum replacement level of the steel slag aggregate was found to be 50%.

2. When the steel fibres were added to the optimum replacement level of steel slag to produce steel slag aggregate concrete, it was observed that the compressive strength reached 33.6 MPa for SLA50%1.5%.

3. When steel slag was used as coarse aggregate replacement the compressive strength of the steel slag aggregate concrete was increased by 7%.

4. The slight improvement in strength may be due to shape, size and surface texture of steel slag aggregates, which provide better adhesion between the particles and cement matrix.

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