International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Email:editorijoer@gmail.com http://www.ijoer.in ISSN: 2321-7758

Vol.4., Issue.5., 2016
(Sept.-Oct.)

RESEARCH ARTICLE

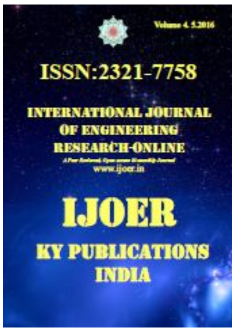
ISSN: 2321-7758

STUDY ON THE FIBRE REINFORCED CONCRETE USING STEEL SLAG AS THE COARSE AGGREGATE REPLACEMENT

MALLAVARAPU RAMA HARSHITHA[1], G.GANESH NAIDU[2]

[1]M.Tech student, IV semester, PACE Institute of technology and sciences, Ongole

[2]Assistant Professor and Head , Department of Civil Engineering, PACE Institute of technology and sciences, Ongole.



ABSTRACT

Concrete plays a vital role in the design and construction of the nation's infrastructure. Almost three quarters of the volume of the concrete is composed of aggregates. These are obtained from natural rocks and river beds, thus degrading the rocks slowly. This issue of environmental degradation, and need for aggregates today demands for the usage of any other alternative source. Thus the concept of replacement of coarse aggregate with steel slag seems to be promising one. In this study an attempt is to be made to use steel slag, a by-product from the steel industry used as a replacement for coarse aggregate in concrete and find the optimum replacement level of steel slag as coarse aggregate and also add steel fibres to the optimum mix at different volume fractions. M25 grade of concrete was used. Possible optimum replacement of slag material was found to be 50%.Tests on Compressive strength, Flexural strength, Split tensile strength, Young's modulus and ultimate load carrying capacity were conducted on specimens. It was concluded that replacing some percentage of coarse aggregate with the steel slag enhances the strength. The results showed that replacing about 50 percent of steel slag aggregates for coarse aggregate and addition of steel fibres at volume fraction of 1.5% increases the strength of the concrete when compared to the control concrete mix.

Keywords: steel slag, flexural strength, crack patterns of RC beams of steel slag coarse aggregate, workability and compressive strength

1. INTRODUCTION

Concrete is the most widely used material for construction all over the globe because of its superior specialty of being mould to any desirable shape. It is a material with strength and durability has emerged as the dominant construction material for today's infrastructures. Around five billion tons of concrete have been used around the world wide every year, in terms of cost it is equivalent to 25 to 30% of the nation budget.. India has taken a decision on developing the infrastructural development in 21st century such as high ways, airports, ports, power projects and tourism projects. In every construction aspects it requires concrete, hence concrete plays a vital role in present scenario of construction industries. and the consequent energy requirement for this processing has a serious economic impact. More over in the alluvial plain area, where there is no availability of virgin aggregates, such as debris and the rubble particles are recycled and make it into use for new structural applications with variable and effective economy in these days.

The concept of using fibers as reinforcement is not a new one . They have been used as reinforcement since ancient times. Historically, horse-hair was used in straw and mortar in mud bricks. In 1900s, asbestos fibers were used in concrete. In the 1950s, the concept of composite materials was came and fiber-reinforced concrete was one of the interesting topic . Once the health risks due to asbestos were discovered, there must be a need to find a replacement for the substance in concrete and other building materials. By 1960s, steel, glass (GFRC), and synthetic fibers such as polypropylene fibers were used in concrete. Research for new fiber-reinforced concretes continues today.

1.1.1 Importance of Concrete: 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. It is recyclable

1.1.2 Properties of Concrete: 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.

1.2 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.

1.3.Substitution with Steel Slag (iron slag) aggregate: The word "Iron slag" was in since 1918", who as NSA has promoted the use of Blast furnace and steel furnace slag. Blast furnace slag has been called "All-purpose Aggregates" as it can be used in all construction applications as either a normal weight or light weight (expanded or pelletized)aggregates depending on how it was formed and processed. Blast furnace slag is also quickly quenched by water or air to produce granulated Blast furnace slag.

1.4. 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" (V_f). V_f typically ranges from 0.1 to 3%. The aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter

1.5. 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, split tensile strength, Young‟s modulus. The flexural properties are also determined for the beams with reinforcement. For this experimentation the percentage of the volume of natural aggregates normally used in concrete was replaced by steel slag. This replacement was done in 10% increments until all natural. To that optimum mix the steel fibres are added at volume fractions of 0.50%, 1.00% and 1.50%.

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.

1.6. Objective of the present study: To determine the mechanical properties of the fibre reinforced concrete using steel slag as a coarse aggregate replacement such as,

- Compressive strength of the slag aggregate concrete
- Flexural strength of the slag aggregate concrete
- Split tensile strength of the slag aggregate concrete
- Young‟s modulus of slag aggregate concrete
- To determine the initial crack load and Ultimate load carrying capacity in RC beams

2.0 MATERIALS USED

This chapter provides the overview of materials used for this research. All the materials used during the research program remained the same and only the proportions were varied. The water-cement ratio of 0.5 was maintained constant during the course of the research program.

Raw materials required for the concrete in the present work are:

- Cement
- Fine aggregates
- Natural coarse aggregates
- Steel slag aggregates
- Steel fibre (SF)
- Water

2.1 Cement : Ordinary Portland cement 53 grade conforming to IS:12269 has been used in this experimental study. The physical properties and chemical properties of the cement are shown in table 2.1(a) and 2.1(b)

Table: 2.1(a) Chemical properties of cement

Constituent	Composition (%)
Lime (CaO)	60 to 67%
Silica (SiO_2)	17 to 25%
Alumina (Al_2O_3)	3 to 8%

Iron oxide (Fe_2O_3)	0.5 to 6%
Magnesia (MgO)	0.1 to 4%
Sulphur trioxide (SO_3)	1 to 3%
Soda and/or Potash (Na_2O+K_2O)	0.5 to 1.3%

Grade of cement	**53 Grade**
Minimum Compressive Strength, N/mm^2	
3 day	27
7 day	37
28 day	53
Initial setting time	92 minutes
Final setting time	195 minutes

Table 2.1(b) Physical properties of fine aggregate

S. No	**Property**	**Value**
1	Specific gravity	2.74
2	Fineness modulus	8.83
3	Nominal maximum size	20 mm

2.2. Fine Aggregates: The size of the fine aggregate is below 4.75mm. Fine aggregates can be natural or manufactured. The grade of the aggregates must be same throughout the work. The fine aggregate shall consist of natural sand or other inert materials with similar characteristics, or combinations having hard, strong, durable particles. The use of concrete is being constrained by urbanization, zoning regulations, increased cost and environmental concern.

Locally available sand conforming to grading as zone-II of table 4 according to the IS: 383-1970 has been used as fine aggregate in this experimentation.

2.3 Coarse aggregates

2.3.1 Natural coarse aggregates: The material whose particles are of size are retained on IS sieve of size 4.75mm is termed as coarse aggregate and containing only so much finer material as is permitted for the various types described in IS: 383-1970 is considered as coarse aggregate. The properties of aggregate greatly affect the durability and structural performance of concrete. Aggregate was originally viewed as an inert material dispersed throughout the cement paste largely for economic reasons. It is possible, however, to take an opposite view and to look on aggregate as a building material connected in to a cohesive whole by means of the cement paste, in a manner similar to masonry construction.

The coarse aggregates that are used in this experimental investigation are of 20mm size, crushed and angular in shape. Crushed aggregate available from local sources has been used.

Table 2.3.1: Physical properties of Natural Coarse Aggregate

S. No	**Property**	**Value**
1	Specific gravity	2.57
2	Fineness modulus	2.46
4	Grading	Zone-II

2.3.2 Steel Slag aggregates: Slag is a co-product of the iron and steel making process. Iron cannot be prepared in the blast furnace without the production of its co-product, blast furnace slag. Similarly, steel cannot be prepared in the basic oxygen furnace (BOF) or in an electric arc furnace (EAF) without making its co-product, steel slag. The use of steel slag aggregates in concrete by replacing natural aggregates is a most promising concept. Steel slag aggregates are already being used as aggregates in asphalt paving road mixes due to their mechanical strength, stiffness, porosity, wear resistance and water absorption capacity.

. Steel slag is currently used in bituminous asphalt paving, the manufacture of Portland cement, and in roadway construction as a base course, along with some agricultural applications. The only potential problem with steel slag aggregate is its expansive characteristics and undesirable reactions between slag and components of concrete. This might be a perception, but most of the information is anecdotal in nature rather than documented in published research studies. The chemical and physical properties of the steel slag are given in the below tables 2.4.2(a) and 2.4.2(b)

Steel slag aggregates

Table: 2.3.2(a) Chemical Composition of steel slag:

Constituent	Composition (%)
CaO	40 – 52
SiO_2	10 -19
FeO	10 – 40
(70 - 80% FeO, 20 - 30%	
Fe_2O_3)	
MnO	5 – 8
MgO	5 -10
Fe	0 - 5
Al_2O_3	1 – 3
P_2O_5	0.5 - 1
S	< 1

Table: 2.3.2(b) Chemical Composition of steel slag:

Property	Steel Slag
Specific gravity	3.1
Crushing strength	29.8%
Impact strength	26.8%

2.4.Steel Fibres: The dimensions of the steel fibres are of length 30mm and diameter of 0.5mm with the L\d ratio of 60 and are of crimped type. The steel fibers are used at different volume fractions such as 0.5% , 1% and 1.5%. Steel fibres are added to the optimum replacement mix in the slag aggregate concrete to determine the strength properties of the slag aggregate concrete.

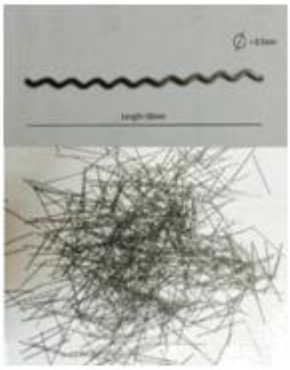


Fig: 2.4. Steel fibres

The properties of the steel fibres used in this study are given in the table

Table: 2.5 Properties of steel fibres

Properties	Description
Diameter(mm)	0.5
Length(mm)	30
Aspect ratio	60
Ultimate tensile strength (MPa)	900
Elastic modulus (GPa)	210
Density	7850(kg/m^3)
Cross section	Crimped

2.6 Water: Water is required for the purpose of hydration of cement and to give workability during mixing and furthermore setting of concrete. For this study convenient water with pH7 and adjusting to the determinations of IS456-2000 is utilized for cementing and additionally curing of the specimens. Portable water available in laboratory is used in this study.

3.Experimental program

3.1 Overview: The main objective of this research was to utilize the steel slag aggregate in theconcrete mixture and identify the mechanical and flexural properties of the mixture. The experimental study started by replacing the percentage of the volume of natural aggregates, normally used in the manufacture of concrete , with steel slag in increments of 10% until all the natural aggregates were replaced by the steel slag to find the possible optimum replacement level for the steel slag in concrete. And to that possible optimum replacement level the steel fibres are added at different volume fractions such as 0.50% , 1.00% and 1.50% and identify the strength properties of the concrete.

Table showing the results of workability of SSAC

S. No	Mix ID	% Replacement steel slag	Slump value (mm)
1	CC	0	160
2	SLA20%	20	150
3	SLA40%	40	140
4	SLA60%	60	135
5	SLA80%	80	120
6	SLA100%	100	115

hours before the specimens were demoulded and placed in curing tank. The specimens with and without fiber were cured in the tank for 7 and 28days

3.2. Concrete mix proportions for samples: From the above concrete mix proportions the ideal mix is to be known after conducting the compression test on the cube specimens for 7 days and 28 days.

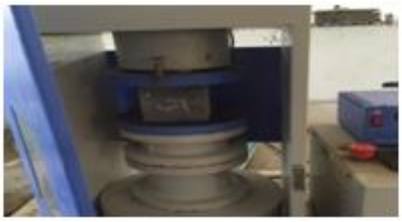
Mixture	Fine aggregate(Kg/m^3)	Coarse aggregate (Kg/m^3)	Steel slag aggregate(Kg/m^3)	Cement content(Kg/m^3)	W/C ratio
CCM	691	1170	0	380	0.5
SLA10 %	691	1053	117	380	0.5
SLA20 %	691	936	234	380	0.5
SLA30 %	691	819	351	380	0.5
SLA40 %	691	702	468	380	0.5
SLA50 %	691	585	585	380	0.5
SLA60 %	691	468	702	380	0.5
SLA70 %	691	351	819	380	0.5
SLA80 %	691	234	936	380	0.5
SLA90 %	691	117	1053	380	0.5
SLA10 0%	691	0	1170	380	0.5

3.4 Casting: Mix proportion of 1: 1.82: 3.1 is chosen according to its ingredients i.e, cement, fine aggregate, coarse aggregates and the water cement ratio is 0.50. For every mix, 6 cubes are prepared to test, each 3 cubes for 7 days and 28 days after curing. Mix the cement and sand with trowel on non-porous plate until uniform colour is achieved. Place the coarse aggregate in the flat surface and place the cement sand mix upon the aggregates and mix the entire materials thoroughly. Then add water to the mixture. The water/cement ratio used in this mix is 0.50. Natural aggregate is replaced by steel slag accordingly in proportion of 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100% respectively. The time of mixing shall be in any case not less than 3 to 5 minutes. Mixing time is the time elapsed between the water is added to the mix and casting of cubes.

4.0 Compressive strength test for the Optimisation of Steel slag aggregate:

Fig: Compressive strength testing machine

Curing of concrete specimens



Flexural strength testing machine

Table 4.1 : Compressive strength at 7 days

Mix ID	% Replacement of steel slag	Compressive strength (Mpa)
CC	0	27.9
SLA10%	10	31.4
SLA20%	20	33.8
SLA30%	30	32.1
SLA40%	40	33.8
SLA50%	50	38.5
SLA60%	60	26.9
SLA70%	70	24.2
SLA80%	80	21.8
SLA90%	90	19.9
SLA100%	100	19.2

Table 4.2: Compressive strength at 28 days

Mix ID	% Replacement of steel slag	compressive strength (Mpa)
CC	0	38.1
SLA10%	10	33.6
SLA20%	20	34.1
SLA30%	30	34.3
SLA40%	40	36.4
SLA50%	50	40.3
SLA60%	60	33.1
SLA70%	70	31.6
SLA80%	80	26.9
SLA90%	90	23.7
SLA100%	100	21.6

Table 4.3: Compressive strength of steel slag aggregate concrete at 7 & 28 days

S. No	Mix ID	7 days	28 days
1	SLA50%SF0.5%	42.4	47.3
2	SLA50%SF1.0%	43.6	50.1
3	SLA50%SF1.5%	49.7	53.6

Table 4.4: Split tensile strength of slag aggregate concrete at different volume fractions of steel fibres at 28days

S. No	Mix ID	Split tensile strength
1	SLA50%SF0.5%	4.15
2	SLA50%SF1.0%	5.22
3	SLA50%SF1.5%	5.98

Table 4.5: Flexural strength of slag aggregate concrete at different volume fractions of steel fibres at 28days:

S. No	Mix ID	Flexural strength(Mpa)
1	SLA50%SF0.5%	6.29
2	SLA50%SF1.0%	7.41
3	SLA50%SF1.5%	7.62

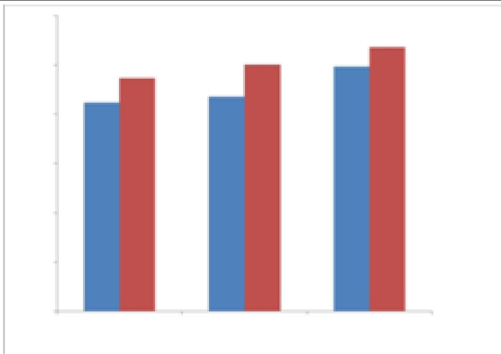
Table 4.6: Young's modulus of slag aggregate concrete at different volume fractions of steel fibres for 28days:

S. No	Mix ID	Young"s modulus (Gpa)
1	SLA50%SF0.5%	26.21
2	SLA50%SF1.0%	27.18
3	SLA50%SF1.5%	28.36

Table 4.7: Load and Deflection values for RCC beams at different volume fractions of steel fibres:

Load (KN)	Deflections (MM)			
	CC	SLA50% SF0.5%	SLA50%SF 1.0%	SLA50% SF1.5%
5	0.22	0.06	0.16	0
10	0.26	0.06	0.28	0
15	0.3	0.12	0.32	0.15
20	0.38	0.25	0.5	0.22

25	0.48	0.46	0.72	0.39
30	0.6	0.69	0.96	0.54
35	0.8	0.96	1.1	0.78
40	1.1	1.24	1.42	1.04
45	1.2	1.56	1.68	1.28
50	-	1.69	1.92	1.59
55	-	1.82	2.1	1.95
60	-	-	2.56	2.7



The flexural strength of specimen expressed as the modulus of rupture (f_b)

$f_b = 3Pa / bd^2$

If crack falls outside the load point

$f_b = PL / bd^2$

a = distance between the line of fracture and the nearer support. P = applied load b = width of the specimen. d = depth of the specimen.L = clear span of the specimen.

Table4.8:Compressive strength of steel slag aggregate concrete at 7 & 28 days

S. No	Mix ID	7 days	28 days
1	SLA50%SF0.5%	42.4	47.3
2	SLA50%SF1.0%	43.6	50.1

Table 4.9:Split tensile strength of slag aggregate concrete at different volume fractionsof steel fibres at 28days:

S. No	Mix ID	Split tensile strength
1	SLA50%SF0.5%	4.15
2	SLA50%SF1.0%	5.22
3	SLA50%SF1.5%	5.98

SLA50%SF0.5%SLA50%SF1.0% SLA50%SF1.5%

Split tensile strength of SSAC at 28 days

Table5.1 : Flexural strength of slag aggregate concrete at different volume fractions ofsteel fibres at 28days:

S. No	Mix ID	Flexural strength(Mpa)
1	SLA50%SF0.5%	6.29
2	SLA50%SF1.0%	7.41

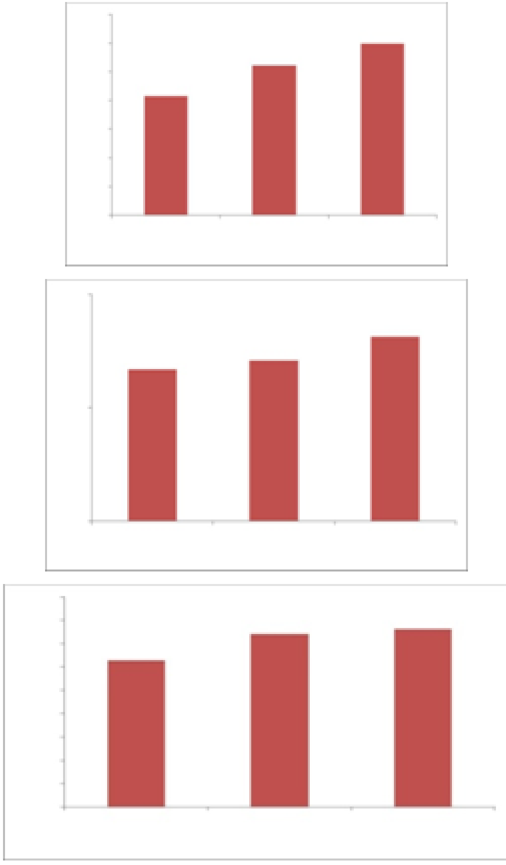


Fig: Flexural strength

Table:5.2 Young's modulus of slag aggregate concrete at different volume fractions of steel fibres for 28days:

S. No	Mix ID	Young‟s modulus (Gpa)
1	SLA50%SF0.5%	26.21
2	SLA50%SF1.0%	27.18
3	SLA50%SF1.5%	28.36

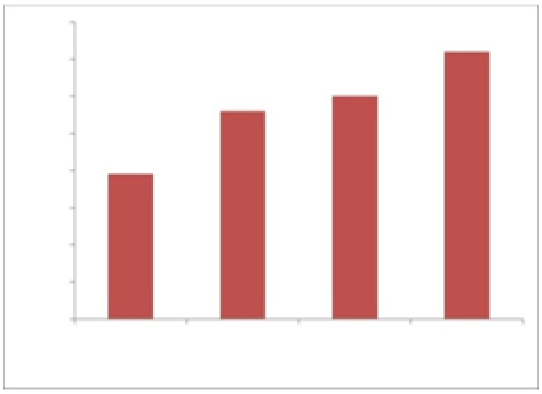
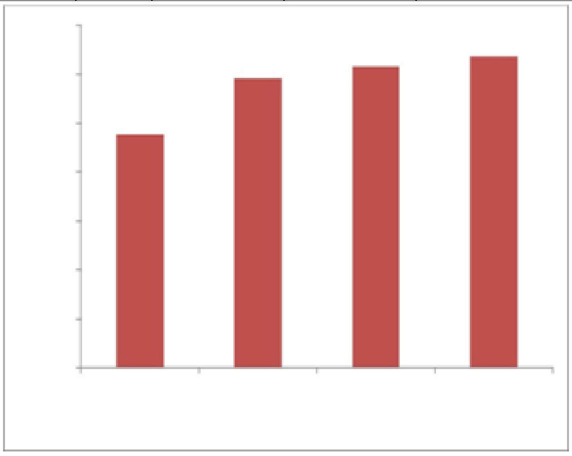


Figure : Young's modulus of the SSAC at 28 days

Table : Load and Deflection values for RCC beams at different volume fractions of steel fibres:

Load (KN)	Deflections (MM)			
	CC	SLA50%SF0.5%	SLA50%SF1.0%	SLA50%SF1.5%
5	0.22	0.06	0.16	0
10	0.26	0.06	0.28	0
15	0.3	0.12	0.32	0.15
20	0.38	0.25	0.5	0.22
25	0.48	0.46	0.72	0.39
30	0.6	0.69	0.96	0.54
35	0.8	0.96	1.1	0.78
40	1.1	1.24	1.42	1.04
45	1.2	1.56	1.68	1.28
50	-	1.69	1.92	1.59
55	-	1.82	2.1	1.95
60	-	-	2.56	2.7



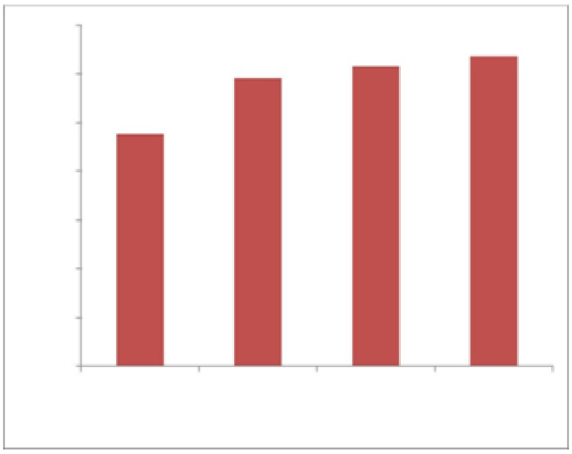


Figure : Initial cracking load of RC beams Mix ID

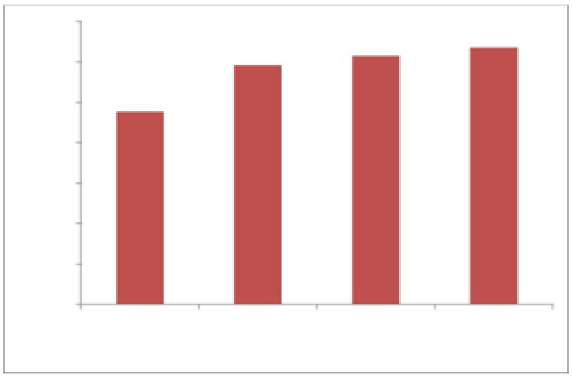
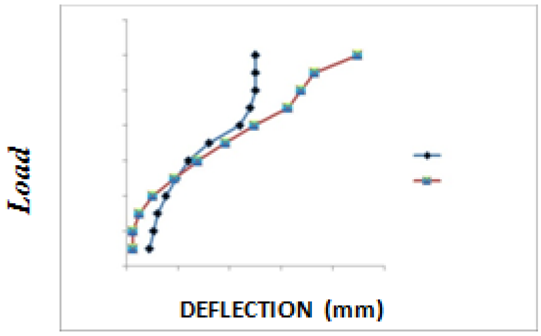


Figure : Ultimate load bearing capacity of RC beams



Ultimate load bearing capacity of RCC beams

Type of fibre	Mix ID	Initial Cracking	Ultimate
		Load (KN)	Load (KN)
Normal	CC	19.6	47.7
Concrete			
Steel fibres	SLA50%SF0.5%	28	59.1
	SLA50%SF1.0%	30	61.5
	SLA50%1.5%	36	63.5

CONCLUSIONS

Summary

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.

RESULT

THE FINAL RESULTS OF THE RESEARCH PROGRAM CAN BE SUMMARIZED AS FOLLOWS:

1. From the compressive strength findings optimum replacement level of the steel slag aggregate was found to be 50%.
2. Steel slag aggregate concrete attains the maximum compressive strength of 40.3 MPa which was slightly higher than the control concrete.
3. When steel slag was used as coarse aggregate replacement the compressive strength of the steel slag aggregate concrete was increased by 6% when compared to control concrete.
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.
5. 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 52.1MPa for SLA50%1.5%.

SCOPE OF FUTURE WORK

A much more extensive field study on a concrete structure made with steel slag aggregates used in the mixture should be conducted and changes in durability and mechanical properties should be investigated.

Further investigation on resistance of concrete with steel slag aggregates to attack by sulphates, alkali silica reactions, carbonation, sea water attack, harmful chemicals and resistance to high temperatures are needed.

The behaviour of steel slag aggregate concrete under corrosive environments and its fire resistance capacity should also be investigated. The results of such studies would directly benefit the construction industry and broader use of steel slag inconcrete would improveoverall properties and cost effective solution.

REFERENCES

[1]. Abdulaziz I. Al-Negheismish, Faisal H. Al-Sugair and Rajeh Z. Al-Zaid (1996),

[2]. ”Utilization of Local Steel making Slag in concrete”, Journal of Environmental science of sustainable society,Vol.1, pp. 39-55.

[3]. Caballero-Morrison.K.E, J.L. Bonet , Juan Navarro-Gregori, J.R. Martí-Vargas , ” Behaviour of steel-fibre-reinforced normal-strength concrete slender columns under cyclic loading” Engineering Structures 39 (2012) 162–175

[4]. Chinnaraju.K, V. R.Rramkumar, K. Lineesh, S. Nithya, V. Athish‟s “study on concrete using steel slag as coarse aggregate replacement and ecosand as fine aggregate replacement”, international journal of research in engineering & advanced technology, volume 1, issue 3, june-july, 2013 pp 2320 – 8791

[5]. Ditao Niu, Lei Jiang , Min Bai, Yuanyao Miao, “Study of the performance of steel

fiber reinforced concrete to water and salt freezing condition" Materials and Design 44 (2013) 267–273

[6]. Eray Baran, Tolga Akis , Seda Yesilmen, " Pull-out behavior of prestressing strands in steel fiber reinforced concrete" Construction and Building Materials 28 (2012) 362–371

[7]. Erhan Guneyisi , Mehmet Gesog˘lu, Suleyman _Ipek , "Effect of steel fiber addition and aspect ratio on bond strength of cold-bonded fly ash lightweight aggregate concretes"

[8]. Construction and Building Materials 47 (2013) 358–365

[9]. Huang Yi, Guoping Xu, Huigao Cheng, Junshi Wang, Yinfeng Wan, Hui Chen , " An overview of utilization of steel slag" Procedia Environmental Sciences 16 (2012) 791 – 801

[10]. IS 12269 (1987): 53 grade ordinary Portland cement [CED 2: Cement and Concrete]