Study on Characteristic Compressive Strength of Concrete by Partial Replacement of Fine Aggregate by Steel Slag

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***Abstract*—T Due to growing environmental awareness, as well as stricter regulations on managing industrial waste, the world is increasingly turning to researching properties of industrial waste and finding solution on using its valuable component parts so that those might be used as secondary raw material in other industrial branches.Although iron and steel slag is still today considered waste and its categorized in industrial waste catalogues in most countries in world, it is most definitely not waste, neither by its physical and chemical properties nor according to data on its use as valuable material for different purpose. Moreover , since the earliest times of the discovery and development of processes on iron and other metals production, slag as by-product is used for satisfying diverse human needs, from the production medicines and agro-technical agent to production of cement and construction element. Considering the specificity of physical and chemical properties of metallurgical slags and s series of possibility for their use in other industrial branches and in the field of civil construction , this report demonstrates the possibility of using iron slag as partial replacement of sand in concrete.Iron and steel making slag are by-product of the iron and steel making processes. To date, these types of slag have been widely used in cement and as aggregate for civil works. The report presents an investigation of mechanical concrete by adding iron slag as replacement of sand in various percentages. The results show that the strength properties of concrete increase significantly when sand is partially replaced by steel slag .**

Keywords—Steel Slag,Coarse Aggreagte,Fine Aggregate

INTRODUCTION

The history of the use of Iron and Steel slag dates back a long way. European slag Association (2006) has reported about the earliest reports on the use of slag, where in it is mentioned that Aristotle used slag as medicament as early as 350 B.C. All through history use of slag has ranged from the novel to the usual including Cast cannon balls in Germany (1852), wharf buildings in England (1652), Slag cement in Germany (1892),Slag wool in Wales (1840) Armored concrete in Germany (1892) slag bricks made from granulated slag and lime in Japan (1901) according to Iron and Steel (2007).In the past, the application of Steel slag was not noticeable because enormous volumes of blast furnace slag were available. Through awareness of environmental consideration and more recently the concept of sustainable development extensive research and development has transformed slag into modern industrial product which is effective and beneficial.

The American Society of Testing and Materials (ASTM)(1999) defines blast furnace slag as “the non-metallic product consisting essentially of Calcium Silicates and other bases that is developed in a molten condition at the same time with Iron in a blast furnace”. Slag was considered to be essential in the production of Iron, but once it serve its purpose in refining the metal, it was strictly a nuisance with little or no use. The usefulness of slags was realized with the first ore smelting process. The use of slags became a common practice in Europe at the turn of the 19 th century, where the incentive to make all possible use of industrial by-products was strong and storage space for by-products was lacking. Shortly after, many markets for slag opened in Europe, the US, and elsewhere in the world. Slag is a by-product during manufacturing of pig iron and steel. It is produced by action of various fluxes upon gangue materials within the iron ore during the process of pig Iron making in blast furnace and steel manufacturing in Steel melting shop. Primarily, the slag consist of Calcium, Magnesium, Magnesium and Aluminum Silicates in various combinations. The cooling process of slag is responsible for generating different type of slag required for various end-use consumers. Although, the chemical composition of slag may remain unchanged, physical properties vary widely with the changing process of cooling.

The Blast furnace (BF) is changed with Iron ore, fluxing agents (usually limestone and dolomite) and coke as fuel and the reducing agent in the production of Iron. The iron ore is a mixture of Iron oxides, Silica and Alumina. From this and the added fluxing agents, Alkaline earth Carbonates, molten slag andiron are formed. Oxygen in the preheated air blown into the furnace combines with the Carbon of the coke of produce the needed heat and Carbon-monoxide. At the same time, the iron ore is reduced to iron, mainly through the dioxide. The oxides of Calcium and Magnesium combined with Silica and Alumina to form slag. The reaction of the Carbon-monoxide with the iron oxide yields Carbon-dioxide and metallic iron. The fluxing agents dissociate into Calcium and Magnesium oxides and Carbon dioxides. The oxides of calcium and magnesium combine with silica and alumina to form slag. Depending on the cooling method, three types of BF slag are produced: air cooled, expanded and granulated. Allowing the molten slag to cool slowly in air in an open pit produces the air cooled slag. Air cooled BF slag is defined in ASTM standard C-125 (American society for Testing and Materials, 1999) as "the material resulting from solidification of molten BF slag under atmospheric condition. Subsequent cooling may be accelerated by application of water to the solidified surface." The solidified slag has a vesicular structure with closed pores. The rough vesicular texture of slag gives it a greater surface area than smoother aggregates of equal volume and provides an excellent bond with Portland cement, as well as high stability in Asphalt mixture. Expanded slag is formed through controlled rapid cooling of molten slag in water or in water with combination of steam and compressed air. Steam and other gases enhance the porosity and vesicular nature of the slag, resulting in a light weight aggregate suitable for use in concrete. Quenching the molten slag into glass granules by using high pressure water jets produces granulated slag.

Quenching prevents the crystallization of minerals constituting the slag composition, thus resulting in a granular, glassy aggregate. This slag is crushed, pulverized, and screener for use in various applications, particularly in cement production, because of its Pozzolonic (Hydraulic cementation) characteristics. slags are co-products of steel making processes.

Production of steel calls for the removal of excess Silicon by mineralization and of Carbon by oxidation from pig or crude iron. Steel slag is a hard, dense material somewhat similar to air-hardness, which make it particularly suitable as a road construction aggregate. Slag is transported to processing plants, where it undergoes crushing, grinding and screening operations to meet various use specifications. Processed slag is either shipped to its buyer for immediate use or, in slack seasons, stored.

OBJECTIVES OF RESEARCH WORK

The objective of the present work is to study the partial replacement of one of the slags viz. Iron slag. It is proposed to partially replace fine aggregate with Iron slag and find its effect on the strength characteristics of concrete. Five percentage levels of replacement i.e., 10, 20 ,30,40 and 50% are considered for partially replacing sand with Steel slag. M20 concrete grade is initially designed without replacement and subsequently sand is partially replaced with Steel slag.

MATERIAL AND DESIGN

A. Portland Cement

Although all material that go into concrete mix are essential, cement is very often the most important because it is usually the delicate link in the chain. The function of cement is first of all to bind the stone and sand together and second to fill up the voids in between sand and stone particles to form a compact mass . It constitutes only about 20% of the total volume of concrete mix;it is the active portion of binding medium and is the only scientifically controlled ingredient of concrete. Any variation in it is quantity affect the compressive strength of concrete mix. Portland cement refere as (Ordinary Portland Cement) is the most important type of cement and is a fine powder by grinding Portland cement clinker. The OPC is classified into three grades namely 33 grade, 43 grade, 53 grade depending upon the strength of 28 days. Generally use of high cement offers many advantages for making strong concrete.

SI.NO	CHARACTERISTICS	VALUES OBTAINED EXPERIMENTALLY
1	Specific Gravity	3.12
2	Initial Setting Time	32 min
3	Final Setting Time	10.03 hours
4	Consistency	28%
5	Fineness	7.31%

Properties of OPC

B. Coarse Aggregate

The aggregate which is retained over IS sieve 4.75 mm is termed as coarse aggregate. The coarse aggregate may be of following types

Crushed gravels or stones obtained by crushing of gravels or hard stone.

Uncrushed gravels or stones resulting from the natural disintegration of rocks.

Partially crushed gravel obtained as a product of blending of above two types.

The normal maximum size is gradually 10 to 20 mm; however particles size up to 40mm or more have been used in self compacting concrete. Locally available coarse aggregate having the maximum size of 20 mm was used in this work. The aggregates were washed to remove dust and dirt and were dirt to surface condition. The aggregates were tested as IS383-1970. Specific gravity and other properties of coarse aggregate are given in the table below.

SI.NO	CHARACTERISTICS	VALUES OBTAINED EXPERIMENTALLY
1	Maximum size	20 mm
2	Specific gravity	2.65
3	Water absorption ratio	0.51%
4	Shape test(Elongation Index)	11.38%
5	Shape test(Flakiness Index)	16.10%
6	Crushing value	21.33%
7	Impact value	10.94%
8.	Finess Modulus	6.97

Properties of Coarse Aggregate

C. Fine Aggreagte

The aggregates most of which passes through 4.75mm IS sieve are termed as Fine aggregate. The Fine aggregate may be of following types,

Natural sand that is fine aggregate resulting from natural disintegration' of rocks.

Crushed stone and sand that is Fine aggregate produced by crushing hard stone.

Crushed gravel sand that is Fine aggregate produced by crushing natural gravel .

According to size, the fine aggregate may be described as coarse, medium and fine sand. Depending upon the particles size distribution IS 383-1970 has divided the fine aggregate into 4 grading zones (grad I to IV). The grading zones become progressively finer form grading zones I to IV. Sieve analysis and physical properties of fine aggregate are tested as per IS 383-1970 and results are shown

SI.NO	CHARACTERISTICS	VALUES OBTAINED EXPERIMENTALLY
1	Maximum size	>4.75
2	Specific gravity	2.6
3	Fineness modulus	2.62 Conforming Zone III

Properties of Fine Aggregate

D. Water

Generally, water is that is suitable for drinking is satisfactory for use in concrete. When water is obtained from source like stream and lake, no sampling is necessary. When it is suspected the water may contain sewage, main water or wastes from industrial plants or canneries, it should not be used in concrete unless test indicated that it is satisfactory. The portable water is generally considered satisfactory for mixing and curing of concrete. Portable was free from any detrimental contaminants and was good.

E. Steel Slag

In this work taken from the "Agni Steel Industry" located at Ingur, Tamil Nadu. It is brown in color as shown in figure.

SI.NO	CHARACTERISTICS	VALUES OBTAINED EXPERIMENTALLY
1	Maximum size	>4.75
2	Specific gravity	2.2
3	Fineness modulus	2.5

Properties of Steel Slag

MIXDESIGN

The determination of relative quantity of materials like cement, fine aggregate, coarse aggregate and water is called mix design of concrete. Proportions for concrete should be selected to make the most economical use of available materials to produce concrete of required quality. Many methods have been recommended for mix proportioning of concrete all over the world. Among those methods, INDIAN STANDARD method was selected. The design of mix used for the present work by IS method is given below.

Water(W) Kg/m³	Cement (C) Kg/m³	Fine Aggregate(FA) Kg/m³	Coarse Aggregate(CA) Kg/m³	Steel Slag (IS) Kg/m³
180	360	573.86	1233.54	0
180	360	516.48	1233.54	57.38
180	360	459.088	1233.54	114.772
180	360	401.702	1233.54	172.158
180	360	344.34	1233.54	229.52
180	360	286.96	1233.54	286.9

Proportion of Concrete Mixes

RESULTS AND DISCUSSION

This chapter deals with the presentation of results obtained from various tests conducted on concrete specimens cast with and without iron slag. The main objective of the research program was to understand the strength and durability aspects of concrete obtained using iron slag as partial replacement for sand. In order to achieve the objective of present study, an experimental program was planned to investigate the effect of iron slag on compressive strength of concrete. The experimental program consists of casting and testing of controlled and iron slag concrete specimen at different ages.

A.Compressive Strength

In most structural application s, concrete is employed primarily to resist compressive stresses. When a plain concrete member is subjected to compression, the failure of the member takes place in its vertical plane along the diagonal. The vertical crack occurs due to lateral tensile strains. A flow in concrete which is in the form of micro crack along the vertical axis of the member will take place on the application of axial compressive load and propagate further due to the lateral tensile strains.

B.Slump Test

The slump test is used to measure the workability of concrete and to determine the amount of water for water cement ratio. This method is commonly used to measure the consistency of concrete. This method is not suitable for very wet or very dry concrete. A metallic mould in the form of frustum cone apparatus is used for this test. The result obtained from the slump test is tabulated below,

SI.NO	% REPLACEMENT OF STEEL SLAG	W/C RATIO	SLUMP(mm)
1	0	0.50	30
2	10	0.55	30
3	20	0.60	27.5
4	30	0.65	24
5	40	0.70	23.25
6	50	0.75	22

Slump Test on Concrete

C

MIX	COMPRESSIVE STRENGTH (N/mm²)			AVERAGE COMPRESSIVE STRENGTH(N/mm²)		
	7 days	14 days	28 days	7 days	14 days	28 days
CM	10.58	16.97	20.08	11.42	17.00	19.65
	12.35	17.29	19.77			
	11.33	17.09	19.02			
10%	13.37	20.08	22.20	12.90	19.62	23.13
	12.75	19.77	24.04			
	12.59	19.02	23.15			
20%	16.8	22.00	24.96	16.00	22.83	25.3
	16.26	22.01	25.91			
	14.96	24.05	25.06			
30%	16.96	22.94	23.95	17.05	24.38	20.73
	16.24	23.82	19.33			
	17.97	26.4	18.93			
40%	14.48	23.83	17.15	15.7	22.02	17.58
	16.8	22.06	18.00			
	15.8	20.17	17.06			
50%	15.56	11.02	15.37	14.55	15.23	17.07
	12.71	14.51	14.44			
	15.39	20.17	21.42			

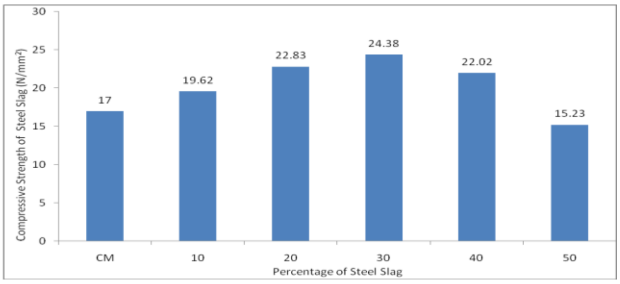
Test Procedure and Results

Test specimens of size 150X150X150mm were prepared for testing of the compressive strength concrete. The concrete mixes with varying percentages

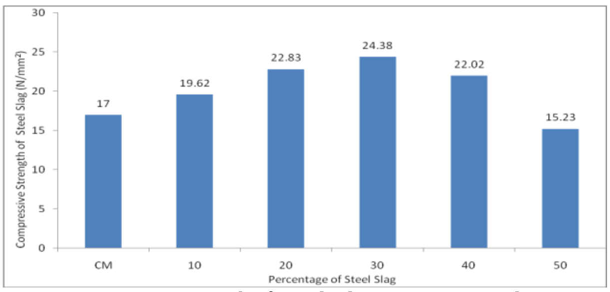
(0%,10%,20%,30%,40%,50%) of steel slag as partial replacement of the aggregate (sand) were cast into cubes and cylinders for subsequent testing.

In this study, to make concrete and fine aggregate were first mixed dry to uniform colour and then coarse aggregate was added and mixed with the mixture of cement and fine aggregates. Water was then added and the whole mass mixed. The interior surface moulds and the base plate were oiled before concrete was placed. After 24 hours the specimen were removed from the moulds and placed in clean fresh water at a temperature of 27+2 C. The specimen so cast was tested after 7, 14 and 28 days of curing measured from the time water is added to the dry mix. For resulting in compressive, no cushioning material was placed between the specimen and the plates of machine. The load was applied axially without shock till the specimen was crushed. Results of the compressive strength test on concrete with varying proportions of iron slag replacement at the age of 7,14 and 28 days are given in the Table above. The cube strength results of concrete are also show graphically in figure below. The compressive strength increases as compared to control mix as the percentage of steel slag is increased after adding 10% steel slag in the mix, there is an a increase of 26% after 7 days, 50% increase after 14 days and 43% increase after 28 days as compared to the control mix . by adding 20 % and 30 % steel slag ,there is large amount of increase in percentage that is 68%,91%,78% and 61% ,93%,80% after 7,14 and 28 days respectively . By adding 40% and 50% steel slag , there is large amount of increase in percentage i.e. 22%,33%,31% and 20%,32%,28% after 7,14 and 28 days respectively.

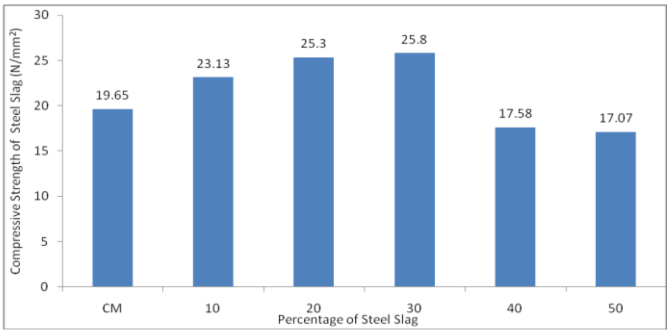
Figure shows the variation of percentage increase in compressive strength with replacement percentage of steel slag. The results also indicate that early age strength gain that is at 7 and 28 days , is higher when compared to the control mix if 50% of fine aggregate is replaced by steel slag.



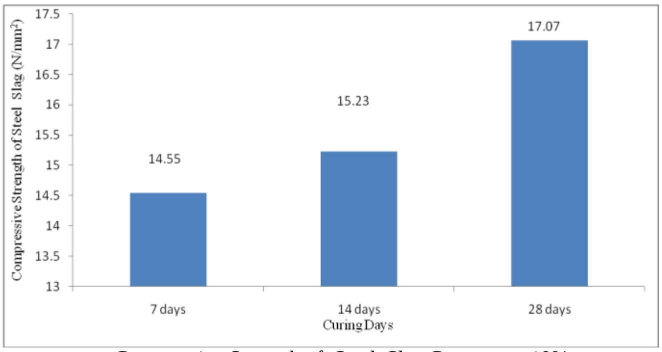
Compressive Strength of Steel Slag Concrete at 7 days



Compressive Strength of Steel Slag Concrete at 14 days



Compressive Strength of Steel Slag Concrete at 28 days



Compressive Strength of Steel Slag Concrete at 10%

CONCLUSION

After adding 10% steel slag in the mix, there is an increase of 26% after 7 days, 50% increase after 14 days and 43% increase after 28 days as compared to the control mix. By adding 20% and 30% steel slag , there is large amount of increase in percentage i.e. 68%,91%,78% and 61%,93%,80% after 7,14 and 28 days respectively. By adding 40% and 50% steel slag , there is large amount of increase in percentage i.e. 22%,33%,31% and 20%,32%,28% after 7,14 and 28 days respectively.

- The Compressive strength tends to increase with increase percentages of steel slag in the mix.
- The early age strength gain is higher as compared to later ages if 50% of fine aggregate is replaced by steel slag.

RECOMMENDATION

- As Steel Slag was considered as waste in Steel Industry, it can be used for the replacement of fine aggregate.
- Since the Steel Slag was replaced up to 50% and the Compressive Strength had increased upto 30% and further percentage is decreased ,so upto 30% can be used.
- High Strength concrete can also be used.

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