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EFFECT OF PARTIAL REPLACEMENT OF SAND BY IRON SLAG ON STRENGTH CHARACTERISTICS OF CONCRETE

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ABSTRACT

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 solutions 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 is categorized in industrial waste catalogues in most countries in the 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 purposes. Moreover, since the earliest times of the discovery and development of processes of iron and other metals production, slag as by-product is used for satisfying diverse human needs, from the production of medicines and agro-technical agents to production of cement and construction elements.

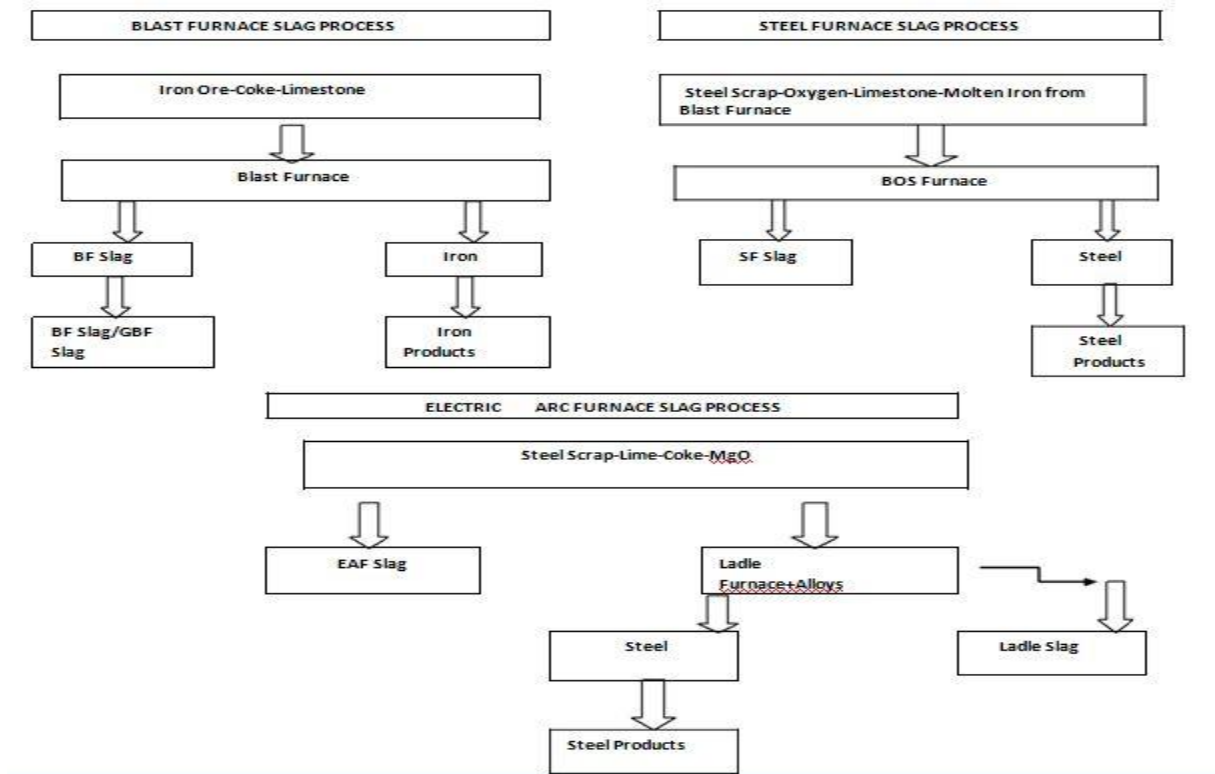
Considering the specificity of physical and chemical properties of metallurgical slags and a series of possibilities for their use in other industrial branches and in the field of civil constructions, this report demonstrates the possibilities of using iron slag as partial replacement of sand in concrete.

Iron and steel making slag are by products of the iron making and steelmaking 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 and durability properties of concrete by adding iron slag as replacement of sand in various percentages. The X-ray diffraction analysis carried out in this paper gives a deeper insight in the mineralogical constitution and behavior of such slags when used for construction purposes. The results show that the strength properties of concrete increase significantly when sand is partially replaced by iron slag.



International Journal of Engineering Researches and Management Studies

Comparison Of Slag Formation Processes



1. INTRODUCTION

Slag is a by-product generated 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 consists of calcium, magnesium, manganese and aluminium silicates in various combinations. The cooling process of slag is responsible mainly for generating different types of slags 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 charged 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, and iron are formed. Oxygen in the preheated air blown into the furnace combines with the carbon of the coke to 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 combine with silica and alumina to form slag. The reaction of the carbon monoxide with the iron oxide yields carbon dioxide (CO₂) and metallic iron. The fluxing agents dissociate into calcium and magnesium oxides and carbon dioxide. The oxides of calcium and magnesium combine with silica and alumina to form slag.



International Journal of Engineering Researches and Management Studies

2. CONSTITUENT MATERIALS USED

Portland cement

Although all materials 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 sand and stone together and second to fill up the voids in between sand and stone particles to form a compact mass. It constitutes only about 20 percent 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 its quantity affects the compressive strength of the concrete mix. Portland cement referred as (Ordinary Portland Cement) is the most important type of cement and is a fine powder produced 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.

Fine aggregate

In this experimental program, fine aggregate was locally procured and conformed to Indian Standard Specifications IS: 383-1970. The sand was sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm and conforming to grading zone II. It was coarse sand light brown in color.

Coarse aggregate

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 dried to surface dry condition. The aggregates were tested as per IS: 383-1970.

Iron Slag

In this work, the Iron Slag is taken from the Dhiman Iron and Steel industry located at Mandi Gobindgarh, Punjab. It is black in color as shown in figure. The sieve analysis of iron slag is shown in Table 3.6.



Magnesium Sulphate

The Powder form of Magnesium Sulphate was obtained from Swindra Instruments Corporation, Anand Pura, Patiala. It was white in color. The solution of strength 50g/l as per ASTM C1012 was made by adding it to water and used for sulphate resistance test.



International Journal of Engineering Researches and Management Studies

3. MIX DESIGN (M20)

Mix Designation	Water (W) kg/m ³	Cement (C) kg/m ³	Fine Aggregates(FA) kg/m ³	Iron Slag (IS) kg/m ³	Coarse Aggregates (CA) kg/m ³	Ratio of W:C:FA:IS:CA
M20	180	360	573.86	0.00	1233.54	0.5:1:1.59:0:3.42
M20	180	360	516.48	57.38	1233.54	0.5:1:1.43:0.15:3.42
M20	180	360	459.088	114.772	1233.54	0.5:1:1.27:0.31:3.42
M20	180	360	401.702	172.158	1233.54	0.5:1:1.11:0.47:3.42

4. TEST METHODS

The procedure of methods used for testing cement, coarse aggregates, fine aggregate and concrete are given below:

Specific Gravity

Sieve Analysis for Coarse and Fine Aggregates as per IS: 2386 (Part I) – 1963

Compressive Strength of Concrete

Cube specimens of size 150 mm x 150 mm x 150 mm were taken out from the curing tank at the ages of 7, 28 and 56 days and tested immediately on removal from the water (while they were still in the wet condition). Surface water was wiped off, the specimens were tested. The position of cube when tested was at right angle to that as cast. The load was applied gradually without shock till the failure of the specimen occurs and thus the compressive strength was found.

Split Tensile Strength of Concrete

The split tensile strength of concrete is determined by casting cylinders of size 150 mm X 300mm. The cylinders were tested by placing them uniformly. Specimens were taken out from curing tank at age of 7, 28 and 56 days of moist curing and tested after surface water dipped down from specimens. This test was performed on Universal Testing Machine (UTM)

Sulphate Resistance Test

Tests performed for checking the sulphate resistance of concrete, produced using iron slag as partial replacement for sand, in this work are compressive strength test after immersing the cube specimen in 50g/l of magnesium sulphate solution(as per per ASTM C1012) for 7, 28 and 56 days. Before immersing them in sulphate solution, specimens are cured for 28 days in water under normal temperature.

Cube specimens of size 150 mm x 150 mm x 150 mm were taken out from the magnesium sulphate solution at the ages of 7, 28 and 56 days and tested immediately on removal from the solution (while they were still in the wet condition). Surface solution was wiped off before testing the specimens for compressive strength. The position of cube when tested was at right angle to that as cast. The load was applied gradually without shock till the failure of the specimen occurs and thus the compressive strength was found.



International Journal of Engineering Researches and Management Studies

5. X-RAY DIFFRACTION

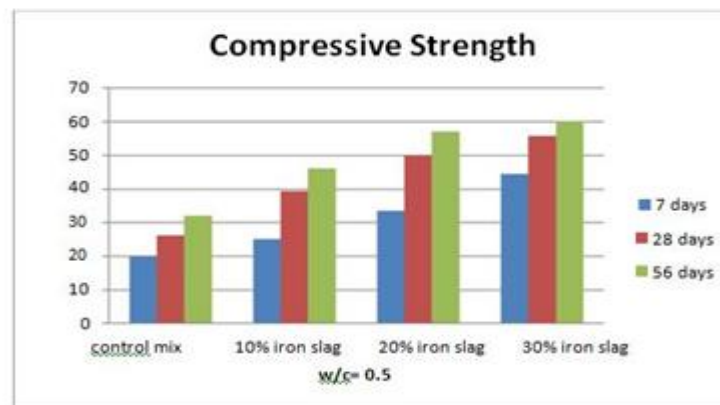
X-ray diffraction is one of the most powerful tools for identifying unknown crystalline phases. By comparing the positions and intensities of the diffraction peaks against a library of known crystalline materials, the target material can be recognized. In addition, multiple phases in a sample can be identified and quantified. Even if one of the phases is amorphous, x-ray diffraction can find out the relative amount of every phase.

Samples Testing

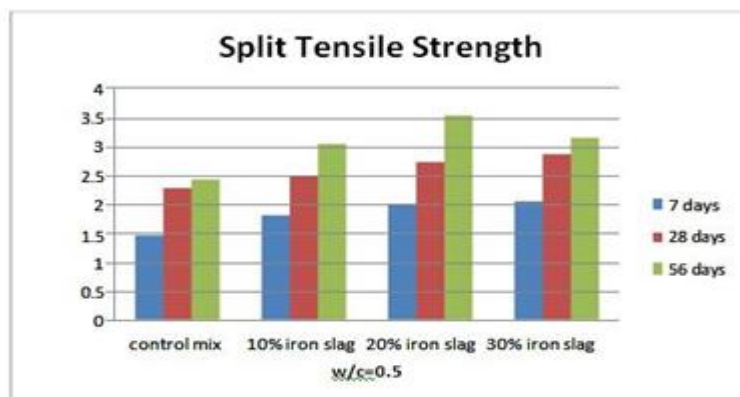
In carrying out the X-ray diffraction, the concrete samples are first grinded into powder form. The sample size is normally 0.002mm to 0.005 mm and then they are put into the small packets. X-ray diffraction (XRD) data for grind samples were tested on Panalytical's X'Pert Pro with Cu radiation at IIT Ropar, Punjab. The samples are scanned in the range of $2\theta = 5 - 60^\circ$ at the scanning speed of $2^\circ/\text{min}$.

6. RESULT ANALYSIS

Compressive strength of concrete mixes of specimen size $150 \times 150 \times 150$ with iron slag



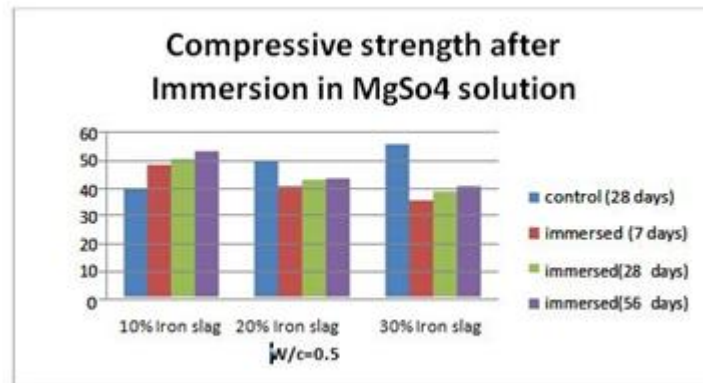
Splitting tensile strength of concrete mixes with iron slag





International Journal of Engineering Researches and Management Studies

Compressive strength of concrete mixes after immersion in 50gm/liter of MgSo4



7. CONCLUSIONS

Compressive Strength

After adding 10% iron slag in the mix, there is 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 is large amount of increase in percentage i.e. 68%, 91%, 78% and 125%, 113%, 87% after 7, 28 and 56 days respectively.

Split Tensile Strength

After adding 10% iron slag in the mix, there is increase of 24% after 7 days, 9% increase after 28 days and 25% increase after 56 days. By adding 20% and 30% iron slag, there is large amount of increase in percentage 37%, 19%, 46% and 40%, 25%, 29% after 7, 28 and 56 days respectively.

Sulphate Resistance

The compressive strength of 10% iron slag specimens when immersed in 50g/l MgSo4 solution gives more strength than standard mix value when immersed in water at 7, 28 and 56 days. But when the percentage of iron slag increase to 20% and 30%, the compressive strength of the mix tends to decrease when compared with the compressive strength of specimen cured in water at same age.

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International Journal of Engineering Researches and Management Studies

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