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Experimental Study on the Use of Low Carbon Silico Manganese Industry Waste as Coarse Aggregate in Concrete

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Abstract*— Concrete is one of the prime materials for construction and it is the most broadly utilized for different applications everywhere throughout the world. Aggregate makes 70% of its volume is the principal component material in concrete production and consumes globally 8–12million tonne of natural aggregate annually. The accumulated waste generated from industries severely affects environmental conditions. The reuse of industrial waste materials and by – products also decreases the need to produce new raw materials. The scarcity of raw materials required for construction is increasing day by day due to globalization. The main challenge for researchers and engineers is preventing the exhaustion of natural resources and increasing the usage of waste materials. The fact that materials that consider as waste from different industries are expanding and Increasing to cover the huge demand of construction materials and existing structure restoration, as the Engineers especially civil engineers has left a big impression throughout the history that consider an Ecological move via using new waste materials in the construction and development. Due to its mechanical strength, porosity, wear resistance and water absorption, steel slag is already being used as a fine and coarse aggregate for asphalt road mixes, as well as a raw material for clinker, as ballast for railways, and as a filling material in various excavations. Successful incorporation of steel slag as aggregates in construction products requires the consideration of certain issues. Firstly, as steel slag is an industrial by product until recently disposed in landfills, the question is whether it is suitable for use in construction. Then the technical characteristics of the material are examined because due to its physicochemical properties steel slag requires special care, but can also provide maximum value if used for specific applications. The utilization of a by-product in suitable applications mainly where it is advantageous compared to traditional materials, but also where it is most economical can give a higher added value to the product. Finally, there are a number of economy-related parameters that allow for a new product to enter the construction market like the situation of the local aggregate market or the need to communicate the efficiency of a new product through demonstration projects. This study aims to analyze the viability of the use of waste products (silico manganese slag) from low carbon silico manganese industry as coarse aggregate in concrete.

Index Terms*—. Concrete production, use of waste products, low carbon silico manganese industry waste as coarse aggregate in concret.

I. INTRODUCTION

Global warming and environmental degradation have become the one of the major issues in recent years. The scarcity of raw materials required for construction is increasing day by day due to globalization. The main challenge for the researchers and engineers is preventing the exhaustion of natural resources and increasing the usage of waste materials. The major by product from industry is slag. The metallurgical steel slag from industries creates great concern to the environment. These steel slags may be used as substitution of natural aggregate in the field of construction. The paper aims to study experimentally, the effect of replacement of coarse aggregate by silico manganese slag on mechanical properties and durability properties of concrete.

The consumption of Slag in concrete not only helps in reducing greenhouse gases but also helps in making environmentally friendly material. By using steel slag in the concrete influences both the mechanical & durability properties of concrete. In this present Investigation, an attempt is made by utilizing silico manganese slag as suitable substitutes for natural coarse aggregates in concrete.

A. Introduction to Silico Manganese Slag

Steel making slag may be a product resulting from the economic process distributed to supply first Fe and second steel silicomanganese slag is generated in the steel making processes resulting from the transformation of Fe to liquid steel.

1) Advantages of Silico Manganese Slag

- Greater hardness: Slag incorporates a greater resistance to wear. This can be a result of its mineral composition. The results are less wear, longer road lifetimes. Roads constructed using silico manganese slag demonstrates reduced rutting(potholes).
- Better adhesion: Silico manganese slag has micro pores and thus, it retains its own adhesiveness wear. In contrast, natural rock becomes smooth with wear its surface becomes polished and slippery. As a result, tires can grip better on surfaces constructed using silico manganese

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slag and this is often particularly important highways and in curves.

- Wear resistance: Silico manganese slag is hard and internally bound. Natural gravel doesn't have some stability and load bearing capacity. As slag is difficult and more compact than natural rock. Roads lasts longer. As there's less wear, particulate pollution is reduced. but this, slag is effectively employed in preparation of Asphalt

B. Objectives of the Study

- To check the workability of concrete with the use of manganese slag as coarse aggregate.
- To review the compressive strength of concrete with the use of manganese slag as coarse aggregate.
- To review the flexural strength of concrete with the use of manganese slag as coarse aggregate.
- To review the durability of concrete with the use of manganese slag as coarse aggregate

II. EXPERIMENTS ON MATERIAL PROPERTIES

The samples for the experiments are collected from INDSIL Hydro Power and Manganese Ltd (Palakkad, Kerala, India). The waste deposition at industry is as shown below in figure 1. And the physical properties, chemical composition, properties of cement and fine aggregate are shown in table 1,2,3,4

FIG 1. WASTE DEPOSITION AT INDUSTRY

III. TESTS ON AGGREGATE

Aggregates are used in concrete to provide economy in the cost of concrete.Aggregates act as filler only. These do not react with cement and water. But there are properties or characteristics of aggregate which influence the properties of resulting concrete mix. These are as follow.

Composition

Aggregates consisting of materials that can react with alkalies in cement and cause excessive expansion, cracking and deterioration of concrete mix should never be used. Therefore, it is required to test aggregates to know whether there is presence of any such constituents in aggregate or not.

Size and Shape

The size and shape of the aggregate particles greatly influence the quantity of cement required in concrete mix and hence ultimately economy of concrete. For the preparation of economical concrete mix on should use largest coarse aggregates feasible for the structure. IS-456 suggests following recommendation to decide the maximum size of coarse aggregate to be used in P.C.C & R.C.C mix.

Maximum size of aggregate should be less than

- One-fourth of the minimum dimension of the concrete member.
- One-fifth of the minimum dimension of the reinforced concrete member.
- The minimum clear spacing between reinforced bars or 5 mm less than the minimum cover between the reinforced bars and form, whichever is smaller for heavily reinforced concrete members such as the ribs of the main bars.Remember that the size & shape of aggregate particles influence the properties of freshly mixed concrete more as compared to those of hardened concrete.

Surface Texture

The development of hard bond strength between aggregate particles and cement paste depends upon the surface texture, surface roughness and surface porosity of the aggregate particles. If the surface is rough but porous, maximum bond strength develops. In porous surface aggregates, the bond strength increases due to setting of cement paste in the pores.

Specific Gravity

The ratio of weight of oven dried aggregates maintained for 24 hours at a temperature of 100 to 1100C, to the weight of equal volume of water displaced by saturated dry surface aggregate is known as specific gravity of aggregates.

Specific gravities are primarily of two types.

- Apparent specific gravity
- Bulk specific gravity

Specific gravity is a mean to decide the suitability of the aggregate. Low specific gravity generally indicates porous, weak and absorptive materials, whereas high specific gravity indicates materials of good quality. Specific gravity of major aggregates falls within the range of 2.6 to 2.9.Specific gravity values are also used while designing concrete mix.

Bulk Density

It is defined as the weight of the aggregate required to fill a container of unit volume. It is generally expressed in kg/litre.

Bulk density of aggregates depends upon the following 3 factors.

- Degree of compaction
- Grading of aggregates
- Shape of aggregate particles

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VOIDS

The empty spaces between the aggregate particles are known as voids. The volume of void equals the difference between the gross volume of the aggregate mass and the volume occupied by the particles alone.

Porosity and Absorption

The minute holes formed in rocks during solidification of the molten magma, due to air bubbles, are known as pores. Rocks containing pores are called porous rocks.Water absorption may be defined as the difference between the weight of very dry aggregates and the weight of the saturated aggregates with surface dry conditions.Depending upon the amount of moisture content in aggregates, it can exist in any of the 4 conditions.

- Very dry aggregate (having no moisture)
- Dry aggregate (contain some moisture in its pores)
- Saturated surface dry aggregate (pores completely filled with moisture but no moisture on surface)
- Moist or wet aggregates (pores are filled with moisture and also having moisture on surface)

Deleterious Materials

Aggregates should not contain any harmful material in such a quantity so as to affect the strength and durability of the concrete. Such harmful materials are called deleterious materials.

Crushing Value

The aggregates crushing value gives a relative measure of resistance of an aggregate to crushing under gradually applied compressive load. The aggregate crushing strength value is a useful factor to know the behaviour of aggregates when subjected to compressive loads.

Impact Value

The aggregate impact value gives a relative measure of the resistance of an aggregate to sudden shock or impact. The impact value of an aggregate is sometime used as an alternative to its crushing value.

Abrasion Value

The abrasion value gives a relative measure of resistance of an aggregate to wear when it is rotated in a cylinder along with some abrasive charge.

Tests on Cement

Different blends of cement used in construction are characterized by their physical properties. Some key parameters control the quality of cement. The physical properties of good cement are based on:

- Fineness of cement
- Consistency
- Setting time
- Bulk density
- Specific gravity (Relative density)

Table.1 Physical Properties of Low Carbon Silico Manganese Slag

PROPERTY	VALUE
Specific gravity	3.4
Water absorption	0.65%
Crushing value	29%
Impact value	17.3%
Bulk density	1999 Kg / cum
Abrasion value	28%
Volume of voids	0.245 %

Table.2 Chemical Composition of Low Carbon Silico Manganese Slag

CONSTITUENTS	COMPOSITION
Aluminium oxide	1-4 %
Calcium oxide	40-57%
Magnesium oxide	10-14%
Manganese oxide	5-10%
Silica	20-35%

Table.3 Properties of Cement

PROPERTIES	TEST RESULTS
Normal consistency	30%
Specific gravity	3.08
Initial setting time	30
Final setting time	240
Fineness of cement	4.44%

Table.4 Properties of Fine Aggregate

PROPERTIES	TEST RESULTS
Fineness modulus	2.89
Specific gravity	2.6
Bulk density	1.7

IV. CONCRETE MIX DESIGN

Concrete mix design is done as per IS 10262:2009. Chosen M30 grade concrete. Results obtained is shown in table 5.

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Table.5 Proportions of Various Materials

w/c ratio	Cement	FA	CA	Water
0.4	350 kg/cum	850kg/cum	1415 kg/cum	140kg/ cum

V. TEST RESULTS AND DISCUSSIONS

A. Workability Test

Generally, Slump values for M20 to M30 can be as low as 25 and as high as 75. Slump values for M30 to M40 can be as low as 50 and as high as 100.The slump value obtained is 5 cm. The slump is true slump.

B. Compressive Strength of Concrete

The M30 grade of concrete means the concrete mix which attains 28-day strength (characteristics) minimum as 30 MPa or 30 N/mm2.The compressive strength test on the specimens shows good results. An average compressive strength value on 7th day, 14th day and 28th day are 28.18 N/mm²,33.80 N/mm² and 35.02 N/mm² respectively. Figure 2 gives the result.

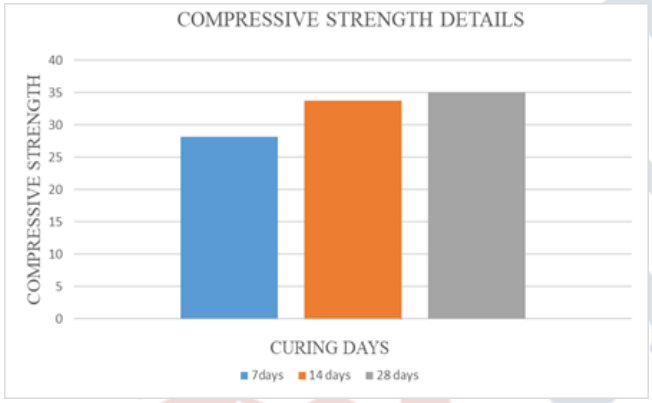

Fig 2. Compressive Strength Results

C. Splitting Tensile Strength of Concrete Cylinder

The split tensile strength test on the specimens shows good results. An average split tensile strength value on 7th day, 14th day and 28th day are 3.79 N/mm²,3.81 N/mm² and 4.05 N/mm² respectively. Test result is given in figure3

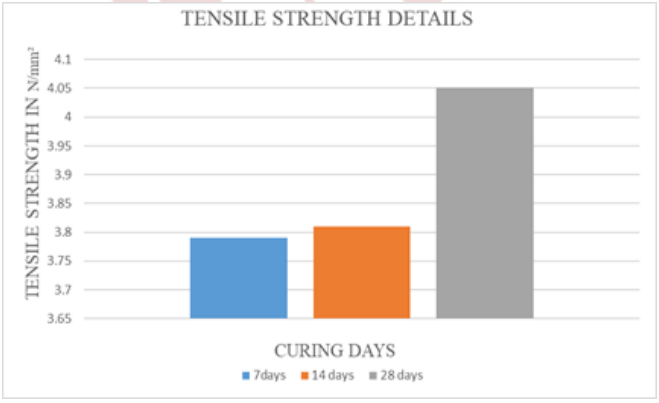

Fig 3. Tensile Strength Details

D. Durability Tests

When a concrete structure is prone to chemical actions its durability gets affected. The chemicals may cause cracking of concrete, volume change and deterioration of structure. The life of structure reduces and it can lead to failure of structures.

1) Acid Attack Test

The resistance of concrete to acid attack was found by the % loss of weight of specimen and the % loss of compressive strength on immersing concrete cubes in acid water. Results obtained are shown in table 6 below.

Table.6 Results of Compressive Strength after Immersing in Acid

SL NO	CURING PERIOD	LOAD IN kN	COMPRESSIVE STRENGTH N/mm²
1	28 days water curing and immersed in acid solution for 90 days	700	31.33
		705	
		710	

2) Alkaline Attack Test and Results

Alkali substances are present in cements used as a binder in concrete only in a minimum content. The most known process that alkali causes is the alkali-silica reaction. Results obtained are shown in table 7 below.

Table.7 Results of Compressive Strength after Immersing in Alkaline Water

SL NO	CURING PERIOD	LOAD IN kN	COMPRESSIVE STRENGTH N/mm²
1	28 days water curing and immersed in alkaline water for 90 days	702	31.33
		703	
		710	

3) Sulphate Attack Test

Sulphate Resisting Cement is a blended cement designed to improve the performance of concrete where the risk of sulphate attack may be present. It also provides improved durability for concrete in most aggressive environments, reducing the risk of deterioration of the structure and structural failure. Results obtained are shown in table 8 below.

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Table 8 Results of Compressive Strength after Immersing in Sulphate Water

SL NO	CURING PERIOD	LOAD IN kN	COMPRESSIVE STRENGTH N/mm²
1	28 days water curing and immersed sulphate in water for 90 days	705	31.31
		702	
		707	

1) Technical papers submitted for publication must advance the state of knowledge and must cite relevant prior work.
2) The length of a submitted paper should be commensurate with the importance, or appropriate to the complexity, of the work. For example, an obvious extension of previously published work might not be appropriate for publication or might be adequately treated in just a few pages.
3) Authors must convince both peer reviewers and the editors of the scientific and technical merit of a paper; the standards of proof are higher when extraordinary or unexpected results are reported.
4) Because replication is required for scientific progress, papers submitted for publication must provide sufficient information to allow readers to perform similar experiments or calculations and use the reported results. Although not everything need be disclosed, a paper must contain new, useable, and fully described information. For example, a specimen's chemical composition need not be reported if the main purpose of a paper is to introduce a new measurement technique. Authors should expect to be challenged by reviewers if the results are not supported by adequate data and critical details.

VI. CONCLUSION

The paper study experimentally, the effect of replacement of coarse aggregate by silico manganese slag on mechanical properties and durability properties of concrete. From the Physical properties and chemical composition of low carbon silico manganese slag it is very suitable to replace coarse aggregate in concrete. Hardness, better adhesion and wear resistance are the added advantages of slag.

The designed mix is also results to a true slump suitable for structural members. Compressive strength of an average 35.02 N/mm² is available after 28 days of curing and an average split tensile strength of 4.05 is resulting after 28 days of curing.

When comparing with the normal concrete with natural coarse aggregate the results obtained from workability test, compression test and split tensile strength are good acceptable.

Concrete should be durable as far as its strength and serviceability to the structure is concerned. It is now well recognized that concrete needs protection for longer durability. A concrete is said to be durable if it performs satisfactorily in the working environment during its anticipated exposure conditions during service. Durability of concrete is defined as its ability to resist weathering action, chemical attack, abrasion and any other process of deterioration. Durable concrete envisages limits for maximum water cement ratio, minimum cement content, cover thickness, type of cement used and presence of amount of chlorides and sulphates in concrete.

Durability tests are conducted in the phase II of the project to understand the properties of concrete. Acid attack, alkaline attack test and sulphate attack tests shows good results.

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