Strength and Durability Study on Concrete Using Silica Fume and Iron Slag

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Abstract - *In the current situate, the demand for reducing over-exploitation of the natural aggregate and the disposal problem of Industrial by-products has become an environmental issue due to the pollution caused. This paper gives an idea on replacements in concrete made out of various Industrial by-products like Silica Fume and Iron Slag in concrete. The main objective of this study is to investigate the feasibility of using Iron Slag as filler material and Silica Fume as an admixture in concrete and to determine the optimum value of Iron Slag replacement in concrete. According to the earlier studies done by the researchers, it was decided to determine combined replacement of admixture in concrete and fine aggregate by Silica Fume in 15% and Iron Slag in 30%, 40%, 50%, and 60%. This paper presents a detailed experimental study on Compressive Strength, Split Tensile Strength and Flexural Strength determined at age of 7, 14 and 28 days. Mix design is done for M_{25} grade and the results were compared with the conventional concrete and summary is presented. The present study investigates the potential use of Silica Fume and optimum usage of Iron Slag in the production of concrete. Iron Slag is more economical than other Industrial waste and it is harmless and cost-effective.*

Key Words: Strength, Durability, Iron Slag, Silica Fume, Partial Replacement – Cement and Fine Aggregate.

1. INTRODUCTION

Concrete is the most important ingredient used for construction works in the world. It is essentially made from materials such as fine and coarse aggregate, cement and water at the required mixing ratio. Cement is the main ingredient of concrete to use for the binding purpose. During the hydration, the binder material is produced large heat that is very harmful to the environmental changes. Because it is emitting carbon dioxide. River sand is used another important component of concrete. It was used the most important choice for the fine aggregate component of concrete in the early periods. In the current situation, the river sand has increase concomitant price, because of the depletion of securable river sand and more use of river sand. So there is a need for research to find the eco-friendly, cheap and easily available alternative material to use for concrete. At the same time, the abolition of a large number of industrial waste is increased in every year and the disposal created by environmental problems. To overcome the crisis, the industrial waste is used for construction works. The concrete components are replaced by industrial waste products of iron slag and silica fume.

2. MATERIALS

2.1 Cement

An Ordinary Portland Cement (Ultra tech) is used for this experimental work. OPC is best suited for use in general concrete construction. Generally, Ordinary Portland cement is a binder material in the concrete mix which forms a solid matrix. These consist primarily of Silicates and Aluminates of lime obtained from Limestone and Clay. The 53 grade of Ordinary Portland Cement is tested as per IS 4036-1988.

Table - 1: Basic Properties of Cement

Properties	Cement
Specific gravity	3.15
Standard consistency	31%
Initial setting time	34min
Final setting time	480min
Fineness	5.32%

2.2 Silica Fume

Silica fume is a by-product obtained from the manufacture of silicon metal and ferrosilicon alloys. The Silica Fume is a finely – divided mineral admixture, composed of submicron particles of amorphous silicon dioxide. Silica fume is 100 to 150 times smaller than a cement particle. It is acting as the filler and improves the physical structure by finishing the voids between the cement particles and as a "pozzolan" reacting chemically to impart far greater strength and durability to concrete. Until a few years ago, concrete was considered to be the high strength of 6,000 psi. Nowadays, using silica fume for concrete with compressive strength in excess of 15,000 psi can be readily produced. . In this work, the silica fume is taken from the moon traders located at Madurai, Tamil Nadu. It is grey in colour as shown in Figure.

Table - 2: Properties of Silica Fume

Properties	Silica Fume
Specific gravity	2.2
Specific surface area	20,000 m^2/Kg
Particle size	Less than 1μm

2.3 Fine Aggregate

An important function of the fine aggregate is provide for workability and uniformity in the mixture and also helps the cement paste to hold the coarse aggregate particle in suspension. River sand used was found to be within the range prescribed for zone II class fine aggregates in IS 383-1970. Fine aggregate for this study has been bought from a local quarry located near Trichy.

Table - 3: Properties of Fine Aggregate

Properties	River Sand
Specific gravity	2.62
Water content	1.2%

2.4 Iron Slag

Iron slag is an industrial by-product generated during manufacturing of pig iron. Iron slag is produced by the blend of down-to-earth constituents of iron ore with limestone flux. The Iron slag is reducing the environmental pollution to a greater extent. It can be used as fine aggregate major constituents as they have greater sand properties. In this work, the Iron Slag is taken from the Government Metal Industry located at Trichy, Tamil Nadu. It is black in colour as shown in Figure.

Fig 1: Iron Slag

Table - 4: Properties of Iron Slag

Properties	Iron Slag
Specific gravity	2.63
Water content	0.93 %

2.4 Coarse Aggregate

The crushed aggregate is the strongest and least porous components of concrete. Presence of coarse aggregate reduces the drying shrinkage and the other dimensioned changes occurring on account of the movement of moisture. Coarse aggregate shall comply with the requirement of IS 383-1970. Size of coarse aggregate used in this project is 20mm. Coarse aggregate for this study has been bought from a local quarry located near Trichy.

Table - 5: Properties of Coarse Aggregate

Properties	Coarse Aggregate
Specific gravity	2.70
Water content	0.8 %

2.5 Water

An ordinary potable water is suitable for drinking purpose. In the present investigation, potable water was used as conforming to IS 456-2000 for the plain and Reinforcement.

3. MIX DESIGN

Mix design for an amount of materials are is designed as per IS 10262: 2009. The replacement percentage is deducted from the conventional materials. The fixed quantity of silica fume 15% and the optimal dosage selection of iron slag 30%, 40%, 50%, 60% are calculated for a cubic meter. For casting specimens the mix proportion is used of M25 grade concrete and the water-cement ratio of 0.45 for batching materials.

SF- Silica Fume

FA- Fine Aggregate

CA- Coarse Aggregate

INS- Iron Slag

Table -6: Quantity of Materials for Mix Design

Mixes	Cement Kg/m^3	SF Kg/m^3	FA Kg/m^3	INS Kg/m^3	CA Kg/m^3
M0	426.66	0	550.80	0	966.16
M1	362.66	64	385.56	165.24	966.16
M2	362.66	64	330.48	220.32	966.16
M3	362.66	64	275.40	275.40	966.16
M4	362.66	64	220.32	330.48	966.16

4. EXPERIMENTAL WORKS

4.1 Slump Test

In this teat is referred slump value to find out workability of concrete, which indicates water-cement ratio. Slump cone test, the mould shape in the frustum of a cone having top diameter 100mm, bottom diameter 200mm and height 300mm. the concrete is poured in place 3 or 4 layers at the cone. Each layer is tempered in 25 times with use the steel temper rod 16mm diameter and 600mm long of a bullet end. After 5 – 10 seconds lift the cone vertically up for measure slump values.

Fig 2: Slump Cone Test

4.2 Compressive Strength Test

The Compressive Strength Test is helped to find out the hardness of a cube specimen. The M25 concrete grade of cubes (150mm x 150mm x 150mm) that are to be tested was taken out from curing tank for 7, 14 and 28 days respectively wiped and left to dry in sunlight, then shifted to the place in Compression Testing Machine. The load has applied the cube in maximum capacity (3000 KN) of CTM. Before testing the calibrate to set zero, the dial gradually rises for increasing in load and stop at failure load, that time reading is noted. Finally, the load is calculated by the formula, Compressive Strength = Load / Area.

Table -7: Compressive Strength Test Results

Mixes	Mix Designation	Compressive Strength N/mm²		
		7 Days	14 Days	28 Days
Mix 0	SF 0% + INS 0%	10.29	15.8	30.08
Mix 1	SF 15% + INS 30%	10.80	16.82	31.36
Mix 2	SF 15% + INS 40%	11.25	17.63	32.21
Mix 3	SF 15% + INS 50%	11.96	20.15	34.7
Mix 4	SF 15% + INS 60%	10.02	14.98	29.03

Observation - The 15% Silica Fume and 50% Iron Slag partial replacement of concrete show 34.73 N/mm² very higher compressive strength than 30.08 N/mm² (conventional concrete) for 28 days curing. When compared to conventional concrete, Mix 4 shows 29.03 N/mm² lesser compressive strength for 28 days curing. The Compression Strength gradually increases Mix 1 to Mix 3 for 7.7% and mix4 is reducing 2% of Concrete.

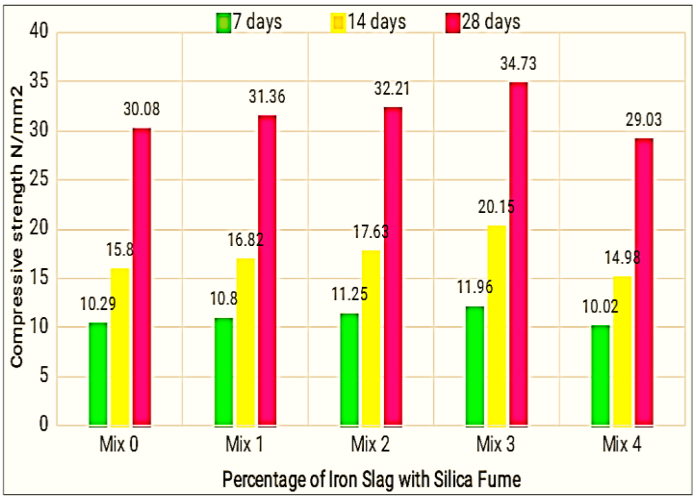

Chart -1: Compressive Strength Test Results

4.3 Split Tensile Strength Test

The test of concrete is determined by the indirect method of Split cylinder test. The concrete is the week in tension due to brittle nature and is not expected to resist the direct tension. When a tensile force is applied to develop cracks in concrete. So need test in the M25 grade concrete of cylindrical specimen (150mm diameter and 300mm length) that are to be tested were taken out from curing tank for 7, 14 and 28 days. respectively wiped and left to dry in sunlight, then the placed horizontally in CTM. After the test is finished and taken readings as calculated by the formula, Split Tensile Strength = 2P / πDL.

Fig 3: Split Tensile Strength Test in CTM

Table -8: Split Tensile Strength Test Results

Mixes	Mix Designation	Split Tensile Strength N/mm²		
		7 Days	14 Days	28 Days
Mix 0	SF 0% + INS 0%	1.24	2.46	5.08
Mix 1	SF 15% + INS 30%	1.31	2.59	5.48
Mix 2	SF 15% + INS 40%	1.39	2.77	5.62
Mix 3	SF 15% + INS 50%	1.42	2.81	5.69
Mix 4	SF 15% + INS 60%	1.13	2.10	4.86

Observation - Mix which has the application of two results combined shows greater strength than the mix taken under study. They are Mix 2 (5.62 N/mm²) and Mix 3 (5.69 N/mm²). The Split Tensile Strength gradually increases Mix 1 to Mix 3 for 0.7%. The Mix4 has a lesser strength of 0.25% compared to conventional concrete for 28 days curing.

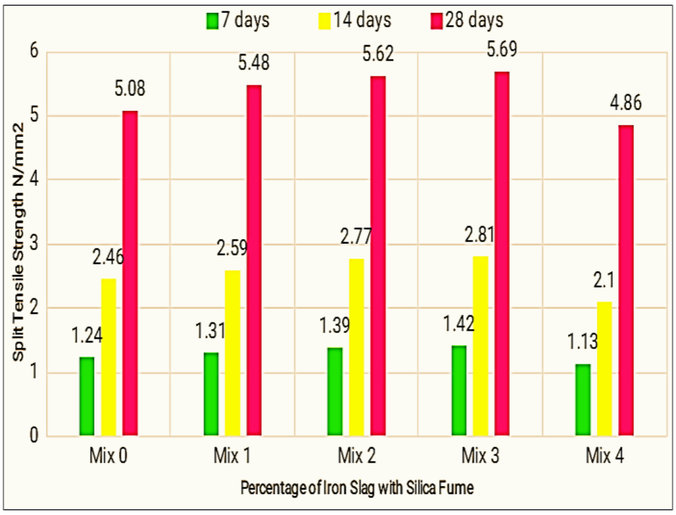

Chart -2: Split Tensile Strength Test Result

5. CONCLUSION

The inclusion of Silica fume in concrete helps to increase the Iron Slag partial replacement content in concrete due to it is workability and strength property.

The Mix 3 has the highest slump to compare conventional Mix 0 and the Mix 3 concrete becomes less workable, but there is good bonding among the materials as compared to conventional concrete.

The Compressive strength gradually increases Mix 1 to Mix 3 for 7.7% and Mix 4 is reduced 2% of concrete for 28 days.

The Split Tensile strength also gradually increase Mix 1 to Mix 3 for 0.7% and Mix 4 is reduced 0.25% compared to conventional concrete for 28 days curing.

From all results, the optimum effective partial replacement of concrete has found in Mix 3 ie, 15% of Silica fume and 50% of Iron slag.

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