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Experimental Investigation Properties on Concrete by Using Steel Slag

Salla ArunTejadhar Reddy
Post Graduate Student,
Department of Civil Engineering,
Annamacharya Institute of Technology and Sciences,
Kadapa.

Dr. P. Sri Chandana, Ph.D
HoD,
Department of Civil Engineering,
Annamacharya institute of Technology and Sciences,
Kadapa.

Abstract:

Steel slag is the residue of steel production process and composed of silicates and oxides of unwanted elements in steel chemical composition. Fifty million tons per year of LD slag were produced as a residue from Basic Oxygen Process (BOP) in the world.

In order to use these slags in cement, its hydraulic properties should be known. Chemical composition is one of the important parameters determining the hydraulic properties of the slags. In general, it is assumed that the higher the alkalinity, the higher the hydraulic properties. If alkalinity is> 1.8, it should be considered as cementations material.
Investigations were carried out also on the usability of steel slag as construction material under laboratory and practical conditions. For this application, the required properties are high compression strength, wear strength and resistance to climatic conditions. The most important criterion is volume stability, in which free CaO and MgO contents of the slag play an important role.

The Experimental programmed was carried out in two stages
1. Sample cubes were casted for the determination of the optimum contentof fly ash and silica fume proportions
2. Experimental works were conducted on steel slag concrete mixes by using different binder mix modified with different percentages of silica fume and fly ash

1. INTRODUCTION

1.1 GENERAL:

Concrete is a mixture of cement, sand, coarse aggregate and water. Its success lies in its versatility as can be designed to withstand harshest environments while taking on the most inspirational forms. Engineers and scientists are further trying to increase its limits with the help of innovative chemical admixtures and various supplementary cementations materials SCMs.

Early SCMs consisted of natural, readily available materials like volcanic ash or diatomaceous earth. The engineering marvels like Roman aqueducts, the Coliseum are examples of this technique used by Greeks and Romans. Nowadays, most concrete mixture contains SCMs which are mainly byproducts or waste materials from other industrial processes.

1.2 SUPPLEMENTARY CEMENTITIOUS MATERIAL:

More recently, strict environmental – pollution controls and regulations have produced an increase in the industrial wastes and sub graded byproducts which can be used as SCMs such as fly ash, silica fume, ground granulated blast furnace slag etc. The use of SCMs in concrete constructions not only prevent these materials to check the pollution but also to enhance the properties of concrete in fresh and hydrated states.

2. MATERIALS AND METHODOLOGY

2.1. MATERIALS

2.1.1 Silica Fume

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Silica smoke is a result in the lessening of high-virtue quartz with coke in electric curve heaters in the generation of silicon and ferrosilicon composites. Silica smoke comprises of fine particles with a surface territory on the request of 215,280 ft^2/lb (20,000 m^2/kg) when measured by nitrogen adsorption strategies, with particles give or take one hundredth the extent of the normal concrete Because of its great fineness and high silica content, silica smoke is an extremely successful pozzolanic material molecule.

Silica smoke is added to Portland bond cement to enhance its properties, specifically its compressive quality, bond quality, and scraped spot resistance. These upgrades comes from both the mechanical changes coming about because of expansion of a fine powder to the bond glue blend and in addition from the pozzolanic responses between the silica smoke and free calcium hydroxide in the glue. Expansion of silica smoke additionally decreases the porousness of cement to chloride particles, which shields the fortifying steel of cement from consumption, particularly in chloride-rich situations, for example, seaside are when silica fume is incorporated, the rate of cement hydration increases at the early hours due to the release of OH ÿ ions and alkalis into the pore fluid. The increased rate of hydration may be attributable to the ability of silica fume to provide nucleating sites to precipitating hydration products like lime, C±S±H, and ettringite. It has been reported that the pozzolanic reaction of silica fume is very significant and the non-evaporable water content decreases between 90 and 550 days at low water /binder ratios with the addition of silica fume.

2.1.2 Steel Slag

Steel slag is the residue of steel production process and composed of silicates and oxides of unwanted elements in steel chemical composition. Fifty million tons per year of LD slag were produced as a residue from Basic Oxygen Process (BOP) in the world.

In order to use these slags in cement, its hydraulic properties should be known. Chemical composition is one of the important parameters determining the hydraulic properties of the slags. In general, it is assumed that the higher the alkalinity, the higher the hydraulic properties. If alkalinity is> 1.8, it should be considered as cementations material.
Investigations were carried out also on the usability of steel slag as construction material under laboratory and practical conditions. For this application, the required properties are high compression strength, wear strength and resistance to climatic conditions. The most important criterion is volume stability, in which free CaO and MgO contents of the slag play an important role. Both oxides can go into reaction with water. Hydration causes volume expansion and affects stability of volume. This is one reason why steel slag aggregate are not suitable for use in Portland cement concrete b. But at that moment, most steel slag being used as unbound aggregate for asphalt concrete pavement in many countries

3. TEST PROCEDURE:

The Experimental programmed was carried out in two stages

Stage 1: sample cubes were casted for the determination of the optimum contentof fly ash and silica fume proportions

Stage2: Experimental works were conducted on steel slag concrete mixes byusing different binder mix modified with different percentages of silica fume and fly ash.

Stage 3: This experimental investigation was carried out for three different proportions of fly ash replacements with Portland cement. Then optimum percentage replacement was found for fly ash replacement. Then again three proportions of silica fume is replaced in place of OPC, and optimum percentage is found. Finally these optimum replacements are combined and analyzed with the steel slag mixed concrete and results were tabulated.

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Stage 4: Here concrete is prepared with six different types of binder mix with silica fume and fly ash replacements and steel slag additions.

3.1 Determination Of Strength Of Concrete Of 1:1.274:2.99 Mix Proportion By Using Ordinary Portland Cement And Fly Ash,Silica Fume As Replacement And Steel Slag As Addition,Sand As Fine Aggregate And Kankar As Coarse Aggregates.

In this phase concrete of mix proportion 1 : 1.274 : 2.99 will be prepared by using OPC with optimum proportion of fly ash silica fume replacements and steel slag additions, sand as fine aggregate and kankar as coarse aggregate. The different samples are done. The concrete mixes will be tested for following strengths.

Compressive strength after 7 days,28 days, 90 days Split tensile strength after 7 days,28 days, 90 days. Flexural strength after 7 days,28 days, 90 days

3.2. LABORATORY TEST CONDUCTED:

3.2.1Compressive Strength Test

For each set nine standard cubes were cast to determine 7-days,28 day and 90 days compressive strength after curing. Also nine no. of cube was casted to know the compressive strength of concrete. The size of the cube is as per the IS 10086 – 1982.

3.2.2 Split tensile strength:

For each set 9 cylinders were casted and tested for 7 days, 28 days and 90 days for determining the split tensile strength for the optimum proportions of fly ash, silica fume replacements and steel slag additions.

3.2.3 Flexural Test:

It is the ability of a beam or slab to resist failure in bending. The flexural strength of concrete is 12 to 20 percent of compressive strength. Flexural strength is useful for field control and acceptance for pavement .but now a days flexural strength is not used to determine field control,only compressive strength is easy to judge the quality of concrete. To determine the flexural strength of concrete four numbers of prism were casting. Then it was cured properly.

Flexural strength = PL/BD2.
Where P is load
L= Length of Prism.
B = Breadth of Prism.
D = Breadth of Prism

3.3 CONCRETE MIXING:

Thorough mixing is essential for the production of uniform, high quality concrete. For this reason equipment and methods should be capable of effectively mixing concrete materials containing the largest specified aggregate to produce uniform mixtures of the lowest slump practical for the work.

Separate paste mixing has shown that the mixing of cement and water into a paste before combining these materials with aggregates can increase the compressive strength of the resulting concrete. The paste is generally mixed in a high-speed, shear-type mixer at aw/cm (water to cement ratio) of 0.30 to 0.45 by mass. The cement paste premix may include admixtures such as accelerators or retarders, super plasticizers, pigments, or silica fume. The premixed paste is then blended with aggregates and any remaining batch water and final mixing is completed in conventional concrete mixing equipment.

High-energy mixed (HEM) concrete is produced by means of high-speed mixing of cement, water and sand with net specific energy consumption of at least 5 kilojoules per kilogram of the mix. A plasticizer is then added to the activated mixture, which can later be mixed with aggregates in a conventional concrete mixer. In this process, sand provides dissipation of energy and creates high-shear conditions on the surface of cement particles. This results in the full volume of Water interacting with cement. The liquid activated mixture can be used by itself or foamed (expanded) for lightweight concrete. HEM concrete

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hardens in low and subzero temperature conditions and possesses an increased volume of gel, which drastically reduces capillarity in solid and porous materials.

3.4 WORKABILITY

Workability is the ability of a fresh (plastic) concrete mix to fill the form/mould properly with the desired work (vibration) and without reducing the concrete's quality. Workability depends on water content, aggregate (shape and size distribution), cementations content and age (level of hydration) and can be modified by adding chemical admixtures, like super plasticizer. Raising the water content or adding chemical admixtures increases concrete workability. Excessive water leads to increased bleeding (surface water) and/or segregation of aggregates (when the cement and aggregates start to separate), with the resulting concrete having reduced quality. The use of an aggregate with an undesirable gradation can result in a very harsh mix design with a very low slump, which cannot be readily made more workable by addition of reasonable amounts of water. Workability can be measured by the concrete slump test, a simplistic measure of the plasticity of a fresh batch of concrete following the ASTM C 143 or EN 12350-2 test standards. Slump is normally measured by filling an "Abrams cone" with a sample from a fresh batch of concrete.

3.5 CURING

In all but the least critical applications, care needs to be taken to properly cure concrete, to achieve best strength and hardness. This happens after the concrete has been placed. Cement requires a moist, controlled environment to gain strength and harden fully. The cement paste hardens over time, initially setting and becoming rigid though very weak and gaining in strength in the weeks following. In around 4 weeks, typically over 90% of the final strength is reached, though strengthening may continue for decades. The conversion of calcium hydroxide in the concrete into calcium carbonate from absorption of CO_2 over several decades further strengthen the concrete and making it more resilient to damage. However, this reaction, called carbonation, lowers the pH of the cement pore solution and can cause the reinforcement bars to corrode.

3.6 PRECAUTIONS:

Following precautions should be followed carefully while mixing and placing the concrete.

1. The plastic straws and sheets taking should be cut up to our requirements without errors.
2. The water for curing should be tested every 7 days and temperature of the water must be at 27±2°C.
3. The concrete moulds should be carefully removed from moulds, placed in water and taking to the tests without causing any failure.

4. EXPERIMENTAL RESULTS

Table4.1. Mix proportion

Water	Cement	Fine Agg	Coarse Agg
191.6 Lit	405 Kg	515 Kg	1210 Kg
0.50	1	1.274	2.99

Hence the Mix is 1:1.274:2.99 (Designed for M25)

4.2 Normal Consistency of Cement:

Trail No	Weight of Cement (gm)	% of Water Added	Depth of Penetration (mm)
1	400	28	15
2	400	30	10
3	400	32	7

Hence the Consistency of cement is 32%.

4.3 Final setting time of cement:

Weight of cement sample taken=400gms
Consistency of cement=32% as obtained above
Volume of water to be added =0.85*32/100*400=108.8m
Final setting time=458 minutes.

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4.4 Water absorption test:

Weight of oven dried aggregate= 500g
Weight of aggregate soaked in water for 24 hours= 501g
Percentage of water absorbed=(501-500)/100
=0.1%

4.5 Specific gravity of cement:

Weight of empty specific gravity bottle W1 =44.1 gm.
Weight of sp.gr. bottle + wt. of cement W2 = 70.00gm.
(1/3 rd to 2/3 rd of bottle full)
Weight of specific gravity bottle + cement + kerosene(W3)
= 106.20 gm
Weight of specific gravity bottle+ kerosene (W4) = 83.80 gm.
Specific gravity of kerosene = 0.79
Specific gravity of cement = (W2-W1)/{(W4-W1)-(W3-W2)}

4.6 Specific gravity of Coarse aggregates:

Weight of saturated aggregates A = 500gms
Weight of dry aggregates D = 490gms
Weight of pycnometer = 610gms
Weight of pycnometer + Water C = 1502.8gms
Weight of pycnometer + Water+ aggregates B = 1816.8gms
specific gravity =D/{A-(B-C)} = 2.6

4.7 Specific gravity of Fine aggregates:

Weight of empty pycnometer W1 = 610 gm.
Weight of pycnometer + fine aggregate W2 =1110 gm.
Weight of pycnometer + fine agg + water W3=1769.2 gm.
Weight of pycnometer + water W4 =1450 gm.
1) Dry weight of aggregate =W2-W1
2) Weight of equivalent volume of water = (W2-W1)-(W3-W4)
Specific gravity = (W2-W1)/(W2-W1)-(W3W4)
= 2.75

4.8 Table: compressive strength results for different fly ash proportions

Sl.no.	Percentage replacement	Compressive force bared by the specimen(kn)
1	5	650
2	10	760
3	15	700
4	20	640
5	30	595

Table 4.9: compressive strength results for various silica fume proportions

Sl.no.	Percentage replacement (fly ash+ silica fume)	Compressive force bared By the specimen(kn)
1	10+10	670
2	10+15	710
3	10+20	720
4	10+25	690
5	10+30	685

From the above values, we can conclude the optimum percentage of silica fume replacement with OPC is obtained at 20% replacement which has given the strength as 720 kn. So we can fix the 20% as optimum.

4.3 Optimum % of steel slag addition:

In order to determine the steel slag optimum content we are casted the six number of cubes for 7 and 28 days and with different proportions of addition

(5%,10%, 15%, 20%, 30%) of fly ash. And these casted cubes were tested and results were tabulated in the following table6.4.

Table4.10: compressive strength results for various steel slag proportions

Sl.no.	Percentage replacement (fly ash+ silica fume + steel slag)	Compressive force bared by the specimen(kn)
1	10+20+5	885
2	10+20+10	930
3	10+20+15	910
4	10+20+20	895
5	10+20+30	810

From the above values, we can conclude the optimum percentage of steel slag addition with OPC is obtained at 10% replacement which has given the strength as 930 kn. So we can fix the 10% as optimum.

4.4 Cube compressive strength results: These results are obtained by testingthe total 9 specimens for 7 days, 28 days and 90 days and by considering the average of the test results and that are tabulated in table6.5.

Table4.11compressive test results for optimum proportions for various curing days

	7 Days (MPa)	28 Days (MPa)	90 Days (MPa)
1	21.02	32.84	56.54
2	13.33	35.11	64.44
3	20.62	35.46	63.11
4	28.48	41.33	66.22

Where
1=Conventional mix concrete.
2=10% Fly ash replaced concrete.
3=10% FA and 20% SF replace concrete.
4=10%FA+20% SF replaced and 10% steel slag added concrete.

4.5 Split tensile strength results:

These results are obtained by testing the total 9 specimens for 7 days, 28 days and 90 days and by considering the average of the test results that are tabulated in table6.5.

Table4.12: Split tensile strength results

	7 Days (MPa)	28 Days (MPa)	90 Days (MPa)
1	1.54	2.05	3.90
2	1.18	2.40	4.34
3	1.58	2.086	4.22
4	1.938	2.57	4,45

Where
1=Conventional mix concrete. 2=10% Fly ash replaced concrete.
3=10% FA and 20% SF replace concrete.
4=10%FA+20% SF replaced and 10% steel slag added concrete.

4.6 Flexural strength results:

These results are obtained by testing the total 9specimens for 7 days, 28 days and 90 days and by considering the average of the test results that are tabulated in the table6.6.

Table 4.13: flexural strength results

	7 Days (MPa)	28 Days (MPa)	90 Days (MPa)
1	4.444	5.86	6.57
2	3.64	6.22	7.5
3	4.8	8	10.13
4	5.6	8.5	11.02

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Where
1=Conventional mix concrete.
2=10% Fly ash replaced concrete.
3=10% FA and 20% SF replace concrete.
4=10%FA+20% SF replaced and 10% steel slag added concrete.

5. CONCLUSIONS

Based on experimental investigation on the "strength of concrete" and considering the "environmental aspects" the following observations are made regarding of fly ash silica fume replaced and steel slag added concrete for compression members, tension members and flexural members.

By doing this project we are reduced the cement content by 30% than conventional concrete.

In compression members the incremental change in the strength was observed and it is more than 1.2585 times than conventional concrete.

In the split tensile strength aspect we observed the incremental change which is 1.2536 times more than the conventional concrete.

In flexural strength aspect we observed the drastically incremental change, which is 1.4505 times more than the actual conventional concrete

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Author Details

Salla ArunTejadhar Reddy
Post Graduate Student,
Department of Civil Engineering,
Annamacharya Institute of Technology and Sciences,
Kadapa.