EXPERIMENTAL STUDY FOR INVESTIGATING PROPERTIES OF CONCRETE BY USING STEEL SLAG

BANOTHU RAVINDER[1]

[1]Site Engineer, Capital Engineering Services and Projects, Department of Civil Engineering

---***---

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 content of 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.

Key Words: Silica fume, Fly ash, Cement, Concrete, Steel slag, SCM.

1.INTRODUCTION

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 by products or waste materials from other industrial processes.

1.1 Supplementary Cementitious Material

1. Ground granulated blast furnace Slag: It is hydraulic type of SCM.
2. Fly ash: It is pozzalanic SC material.
3. Silica Fume: It is likewise a kind of pozzolanic material.
4. Steel slag

2. MATERIALS & PROPERTIES

2.1 Silica Fume

Table No.1:Physical Properties of silica fume

Material	Specific gravity
Silica Fume	2.27

Table No.2: Chemical Analysis of silica fume

Silica fume	**ASTM-C-1240**	**Actual Analysis**
SiO_2	85% min	86.7%
LOI	6% max	2.5%
Moisture	3%	0.7%
Pozz Activity Index	105% min	129%
Sp Surface Area	>15 m2/gm	22 m2/gm
Bulk Density	550 to 700	600
+45	10% max	0.7%

2.2 Steel Slag

2.2.1 Sieve Analysis of Steel slag

Table No. 3: Sieve Analysis of Steel slag

Sieve size	Weight Retained	Cum Weight Retained	% Cumulative weight Retained	% Passing
20 mm	270 gm	0.270 kg	5.4	94.6
12.5 mm	3522 gm	3.792 kg	75.84	21.16
10 mm	790 gm	4.582 kg	91.64	8.36
4.75 mm	334 gm	4.916 kg	98.62	1.68
Total	5000 gm			

No gradation was found from the above test.

2.2.2 Physical properties of Steel slag

Table No.4: Physical properties of Steel slag

Material	**Specific gravity**	**Water absorption in %**
Steel slag	3.35	1.1%

2.2.3 XRD Analysis of Steel slag

From XRD Analysis of steel slag we can find what type Alkalis present. These are tabulated in Table No 5.

Table No.5: XRD Analysis of Steel slag

Chemical Compound	**Visible**	**Ref-Code**	**Score**
Na_2O	Yes	03-1074	10
K_2O	Yes	77-2176	10

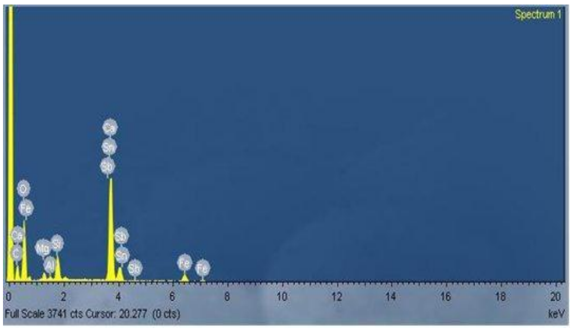


Figure 1. XRD Analysis of Steel Slag

2.3 Fly ash

Table No. 6 : Fly ash

Cement	**Consistency in %**	**Specific gravity**	**Initial setting time**	**Final setting time**
Fly ash cement	37.5	3	3 hour 50 min	11 hour 35 min

Chemical Analysis of Fly ash cement.

Table No 7: Chemical Analysis of Fly ash cement

Chemical Compound	**Fly Ash Cement in (%)**
Sio_2	6
Cao	49
MgO	0.66
Fe_2O_3	15
Al_2O_3	16

2.4 Ordinary Portland cement

Table No.8: Properties of Portland cement

SI.NO	**Constituent**	**Percentage**
1	Cao	64.00
2	Sio_2	22.00
3	Al_2o_3	4.10
4	Fe_2o_3	3.60
5	Mgo	1.53
6	So_3	1.90

2.5 SAND

2.5.1 Sieve Analysis of sand

Table No. 9 : Sieve Analysis of sand

Sieve size	**Weight Retained in gm**	**% passing**
4.75 mm	16 gm	98.4
2.36 mm	11 gm	97.3
1.18 mm	65 gm	90.8
600 micron	391 gm	51.6
300 micron	420 gm	9.4
150 micron	82 gm	1.2
Total	1000 gm	-

From the sieve analysis result, Sand falls under Zone II.

2.5.2 Physical properties of sand

Table no.10: Physical properties of sand

Fine aggregate	Specific gravity	Water absorption in %
Sand	2.65	0.6

3. EXPERIMENTAL INVESTIGATION

The Experimental programme was carried out in two stages

Stage1: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 1: This experimental investigation was carried out for three differentproportions 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.

Stage2: Here concrete is prepared with six different types of binder mix withsilica fume and fly ash replacements and steel slag addotions.

DETERMINATION OF STRENGTH OF CONCRETE OF 1:1.274:2.99 MIX PROPORTION BY USING ORDINARY PPORTLAND 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.

3.1 LABORATORY TEST CONDUCTED

3.1.1 Compressive StrengthTest
3.1.2 Split tensile strength
3.1.3 Flexural Test

Table 11 : Tested data for materials

Specific gravity of cement	3.14
Comp Strength of cement at 7 day =	Satisfies the requirement IS:269-1989
Specific gravity of Coarse aggregates	2.63
Specific gravity of Fine aggregates	2.75
Water absorption of Coarse aggregate	1%
Free moisture in CA & FA	: Nil

3.1.4 Mix proportion

Table 12: Mix proportion

Water	cement	Fine agg.	Coarse agg.
191.6 lit	405kg	515kg	1210kg
0.50	1	1.274	2.99
Hence the Mix is	**1:1.274:2.99**	(Designed for M25)	

5. RESULTS & DISCUSSION

5.1 Normal Consistency

Table 13: 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

5.2 Initial setting time of cement

Table 14 : Initial 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
Initial setting time obtained	53 minutes.

5.3 Final setting time of cement

Table 15 : 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
Initial setting time obtained	458 minutes.

5.4 Water absorption test

Table 16 : 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%

5.5 Specific gravity

Table 17 :Specific gravity

Cement	3.14
Coarse aggregates	2.6
Fine aggregates	2.75

5.6 Compressive Strength

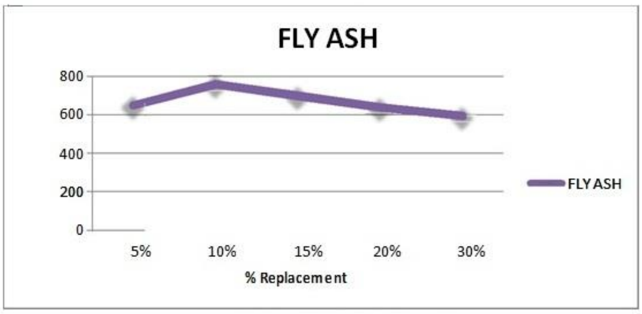
5.6.1. Fly Ash

Table 18 : 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

From the above values, we can conclude the optimum percentage of fly ash replacement with OPC is obtained at 10% replacement whch has given the strength as 760 kn. So we can fix the 10% as optimum.

The above results are represented in the graphical representation bellow.



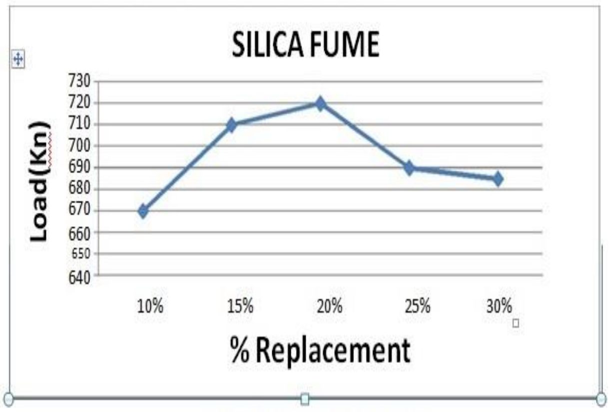
5.6.2. Optimum % of silica fumes replacement

Table 19 : 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.

The above results are represented in the graphical representation bellow.



5.6.3 Optimum % of steel slag addition

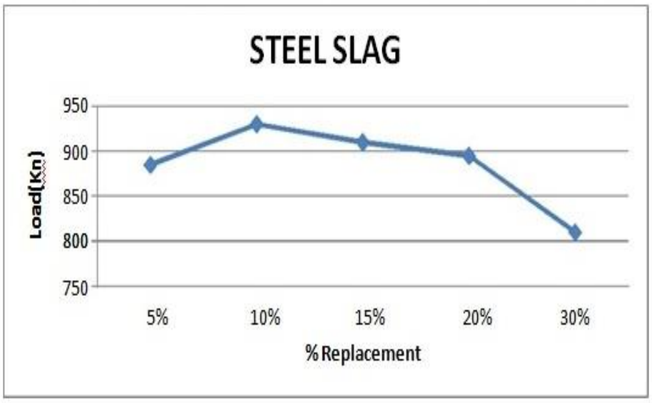
In order to determine the steel slag optimum content we are casted the six number of cubes for 7 and 28 days and with different proportions of addition (5%,10%, 15%, 20%, 30%) of fly ash. And these casted cubes were tested and results were tabulated in the following table 20.

Table 20 : 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

The above results are represented in the graphical representation bellow.



From the above three analysis we can conclude that the optimum percentages for fly ash and silica fume replacements and steel slag addition with OPC is 10%,20% and 10% respectively.

For these optimum proportions we are casted cubes, cylinders and prisms to determine the compressive strength, split tensile strength and flexural strength respectively. The results were recorded for 7 days, 28 days and 90 days and are shown bellow in sequential order.

5.6.4 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.

Table 21 compressive 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.

5.7 Split Tensile Strength

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 table 22

Table 22 : Split tensile strength

	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.

5.8 Flexural Strength

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 table 23

Table 23: 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

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.

5.9 Correlated Results In Graphical Representation

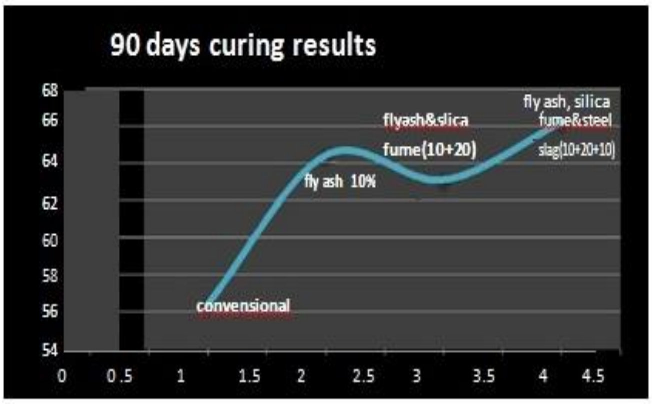


Fig 1 : 90 Days test results: Here the compression, s lit tensile and flexural strength results for 90 days are presented in sequential order.

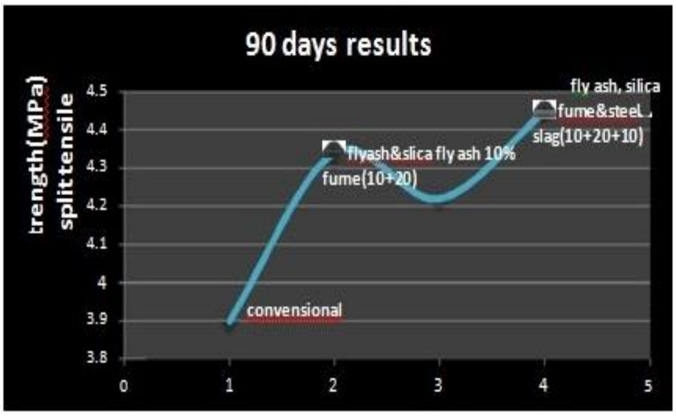


Fig 2 : 90 days split tensile strength results

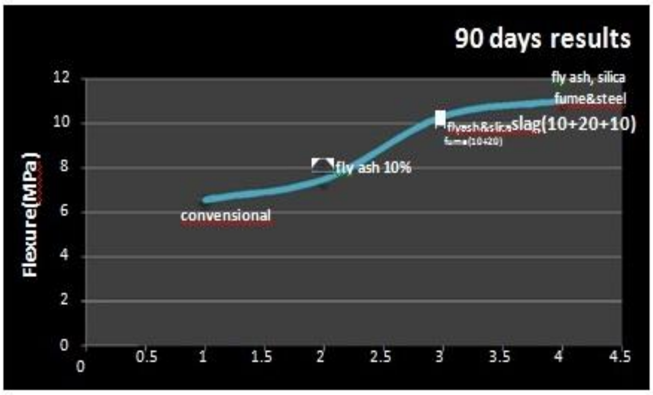


Fig 3 : 90 days flexural strength results

6. 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

REFERENCES

[1] Thanongsak, N., Watcharapong, W., and Chaipanich. A., (2009), "Utilization of fly ash with silica fume and properties of Portland cement–fly ash–silica fume concrete". Fuel, Volume 89, Issue 3, March 2010, Pages 768-774.

[2] Patel, A, Singh, S.P, Murmoo, M. (2009), "Evaluation of strength characteristics of steel slag hydrated matrix" Proceedings of Civil Engineering Conference-Innovation without limits (CEC-09), 18th - 19th September_2009.

[3] Li Yun-feng, Yao Yan, Wang Ling, "Recycling of industrial waste and performance of steel slag green concrete", J. Cent. South Univ. Technol.(2009) 16: 8–0773,DOI: 10.1007/s11771-009-0128-x.

[4] Velosa, A.L, and Cachim, P.B.," Hydraulic lime based concrete: Strength development using a pozzolanic addition and different curing conditions" ,Construction and Building Materials ,Vol.23,Issue5,May2009,pp.2107-2111.

[5] Barbhuiya S.A., Gbagbo, J.K., Russeli, M.I., Basheer, P.A.M. "Properties of fly ash concrete modified with hydrated lime and silica fume", aCentre for Built Environment Research, School of Planning, Architecture and Civil Engineering, Queen_s UniversityBelfast, Northern Ireland BT7 1NN, United Kingdom Received 28 January 2009; revised 1 June 2009; accepted 3 June 2009. Available online 15 July 2009.

[6] Gonen,T. and Yazicioglu,S. " The influence of mineral admixtures on the short and long term performances of concrete" department of construction education, Firat University, Elazig 23119, Turkey.2009.

BIOGRAPHIES

B. RAVINDER
Site Engineer
Capital Engineering Services and Projects
Department of Civil Engineering