An Experimental Study on the Strength of Concrete by Partial Replacement of Cement with Silica Fume and Coarse Aggregate with Steel Slag

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Abstract – This study presents an evaluation of steel slag aggregate concrete with and without adding silica fume in comparison with the conventional natural aggregate concrete. Hardened concrete consist of more than 70% aggregate due to the high demand in building construction and the increase of the amount of disposing waste material, suppliers and researchers are exploring the use of alternative materials which could preserve natural sources and save the environment. Steel slag was used as an aggregate replacement in conventional concrete mixes. Steel slag which is mainly consists of calcium carbonate is produced as a by-product during the oxidation process in the steel industry. Steel slag was selected due to its characteristics, which are almost similar to conventional aggregates and the fact that it is easily obtainable as a by-product of the steel industry. As a result, utilization of steel slag will save natural resources and clean environment. Particle packing analysis is made to optimize the gradation of coarse aggregate which would decrease the cement requirement and increase the density of packing which would result in its improved performance in terms of strength and other parameters. Silica fume is a by-product of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive Pozzolanic. Concrete containing silica fume can have very high strength and can be very durable. Silica fume is non-metallic and non-hazardous waste industries. It is suitable for concrete mix and improves the properties of concrete i.e. compressive strength etc.

Index Terms – SCM, steel slag concrete, steel slag, silica fume.

1. INTRODUCTION

1.1. Genaral

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 cementitious materials SCM's. Early SCM's 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 the Greeks and Romans. Nowadays,the most concrete mixture contains SCM's which are mainly by-products or waste materials from other industrial processes.

1.2 Scope and Objective

- The scope and objective of this present project investigation is to increase the strength of concrete by using silica fume & steel slag.
- To increase the strength of concrete by partial replacement of coarse aggregate with steel slag which is a waste material produced from steel industries.
- The main objective of this project is to get high strength by using normal mix proportions with partial replacement of silica fume in cement and steel slag in coarse aggregate.

2. EXPERIMENTAL PROGRAM

2.1. Materials Used

The different materials used in this investigation are:

1. Cement
2. Fine aggregates
3. Coarse aggregates
4. Mineral admixtures - silica fume
5. Steel slag
6. Water

2.1.1 Cement

Cement is a binding material, which is the combination of two raw materials called calcareous and argillaceous materials. Zuari-53 grade ordinary Portland cement conforming to IS: 12269 were used.

Serial No	Physical tests	Obtained results
1	Fineness	6.8%
2	Standard consistency	31%
3	Initial setting time	40 min
4	Final setting time	290 min
5	Specific gravity	3.15
6	Compressive strength	221.7Kg/cm^2

TABLE – 2.1: Shows the results of physical tests on ordinary Portland cement of 53 grades

2.1.2 Fine Aggregate:

The standard sand used in this investigation was obtained from Pennar river, Nellore. The standard sand shall be of quartz, light gray or whitish variety and shall be free from silt. The sand grains shall be angular, the shape of the grains approximating to the spherical form elongated and flattened grains being present only in very small or negligible quantities. The standard sand shall (100 percent) pass through 2-mm IS sieve and shall be (100 percent) retained on 90-micron IS Sieve and the sieves shall conform to IS 460 (Part: 1): 1985.

Serial no	Test	Obtained results
1	Bulking of sand	3.57%
2	Specific gravity of sand	2.65
3	Sieve analysis of sand	ZONE- III as per IS:383-1980

TABLE – 2.2: Shows the results of physical tests on fine aggregate

2.1.3 COARSE AGGREGATES:

According to IS 383: 1970, coarse aggregate may be described as crushed gravel or stone when it results from crushing of gravel or hard stone. The coarse aggregate procured from the quarry was sieved through the sieved of sizes 20 mm and 10 mm respectively. The aggregate passing through 20 mm IS sieve and retained on 10 mm IS sieve was taken. The Specific gravity of the coarse aggregate is 2.64.

Serial no	Tests	Obtained results
1	Impact test	18.31%
2	Crushing test	24.58%
3	Specific gravity	2.71
4	Water absorption	1%
5	Flakiness index	17.02%
6	Elongation index	21.40%

TABLE – 2.3: Shows the results of physical tests on coarse aggregates

2.1.4 Silica Fume:

Silica fume is a by-product of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses for silica fume is in concrete. Because of its chemical and physical properties, it is a very reactive Pozzolanic. Concrete containing silica fume can have very high strength and can be very durable. Silica fume is available from suppliers of concrete admixtures and, when specified, is simply added during concrete production. Placing, finishing, and curing silica-fume concrete requires special attention on the part of the concrete contractor.

The physical properties and chemical composition of silica fume values are listed as per the manufacturer's manual in the below tables:

PHYSICAL PROPERTIES	RESULTS
PHYSICAL STATE	Micronized Powder
ODOUR	Odourless
APPEARANCE	White Colour Powder
COLOUR	White
PACK DENSITY	0.76 gm/cc
PH of 5% SOLUTION	6.90
SPECIFIC GFRAVITY	2.63
MOISTURE	0.058%

OIL ABSORPTION	55 ml / 100 gms

TABLE –2.4**:** shows the physical properties of silica fume

2.1.5 Steel Slag

Serial no	Tests	Obtained results
1	Impact test	17.65%
2	Crushing test	23.86%
3	Specific gravity	3.42
4	Water absorption	1.5%
5	Flakiness index	15.81%
6	Elongation index	19.92%

TABLE – 2.5**:** Shows the results of physical tests on coarse aggregates (steel slag)

2.1.6 Water:

Portable water was used in the experimental work for both preparing and curing. The pH value of water taken is not less than 6.

3. MIX DESIGN

3.1 Mix Proportion:

Designed to mix proportions for M_{20} grade concrete is mentioned below table.

Cement	**Fine aggregates**	**Coarse aggregates**	**Water**
387	568	1207	191.6
1	1.467	3.118	0.49

TABLE – 3.1: shows the designed mix proportion values for the M_{20} grade concrete mix.

3.2. Calculation of Materials Quantity:

We required 8.1 kg of materials for making one M20 grade concrete cube of size 150 mm X 150 mm X 150 mm. As per the mix design, materials required for making of one M20grade concrete cube of size 150 mm X 150 mm X 150 mm cube are shown below table for various mix proportions.

S. No	Mix proportion in %	Cement in grams	Silica fume in grams	Fine aggregate in grams	Coarse aggregate in grams
1	0	1450	0	2127	4522
2	10	1305	145	2127	4522
3	20	1160	290	2127	4522
4	30	1015	435	2127	4522
5	40	870	580	2127	4522
6	50	725	725	2127	4522

TABLE – 3.2**:** shows the materials required for making of one M_{20} grade concrete cube with various mix proportions of silica fume

S. No	Mix proportion in %	Cement in grams	Fine aggregate in grams	Coarse aggregate in grams	Steel slag in grams
1	0	1450	2127	4522	0
2	10	1450	2127	4070	452
3	20	1450	2127	3617	905
4	30	1450	2127	3165	1357
5	40	1450	2127	2713	1809
6	50	1450	2127	2261	2261

TABLE – 3.3**:** shows the materials required for making of one M_{20}grade concrete cube with various mix proportions of steel slag

Sno	Mix proportion in %	Cement in grams	Silica fume in grams	Fine aggregate in grams	Coarse aggregate in grams	Steel slag in grams
1	20	1160	290	2127	3617	905

TABLE – 3.4**:** shows the materials required for making of one M_{20}grade concrete cube with mix proportions using both silica fume and steel slag

4. TESTS ON CONCRETE

Tests conducted on fresh concrete in the lab as well as site for quality controls are

1. Slump test
2. Compaction factor test

4.1 Slump Test

The fresh concrete would vertically settle when the lateral supports are removed. This settlement is called a slump and various values of the slump are preferred for various constructions. The Slump is the measure indicating the consistency or workability of cement concrete and gives the w/c ratio needed for mixing concrete for different works.

Fig no: 4.1 - SLUMP test apparatus

Mix proportion in %	**Slump in cm**
0	1
10	0
20	1
30	2
40	0
50	1

TABLE – 4.1.1: shows the slump values of various mix proportions using silica fume

Mix proportion in %	**Slump in cm**
0	1
10	1
20	0
30	1
40	0
50	2

TABLE – 4.1.2**:** shows the slump values of various mix proportions using steel slag.

4.2 Compaction Factor Test (Reference: IS: 1199 – 1959):

This test is adopted to find out the workability of concrete, where nominal size of the aggregate does not exceed 40 mm. This test is based upon the definition that workability is the amount of work done to bring the concrete to full compaction.

The workability of the concrete mix has been observed by conducting the compaction factor test.

Fig no: 4.1 - Compaction factor test apparatus

MIX PROPORTION IN %	**COMPACTION FACTOR TEST**
0%	0.87
10%	0.85
20%	0.84
30%	0.82
40%	0.81
50%	0.80

TABLE – 4.2.1**:** shows the compaction factor values for various mix proportions using silica fume

Mix proportion in %	**Compaction factor test**
0%	0.87
10%	0.89
20%	0.88
30%	0.85
40%	0.83
50%	0.81

TABLE – 4.2.2: shows the compaction factor values for various mix proportions using silica fume.

4.3 Compressive Strength Test

Representative samples of concrete shall be taken and used for casting cubes 15 cm x 15 cm x 15 cm. The Compressive strength is calculated by using the following formula:

Compressive strength (kg/cm^2) = W_f / A_p

Where

W_f = Maximum applied load just before the load, (kg)

A_p = Plan area of cube mould, (mm^2)

Fig no: 4.2-Concrete Cube testing

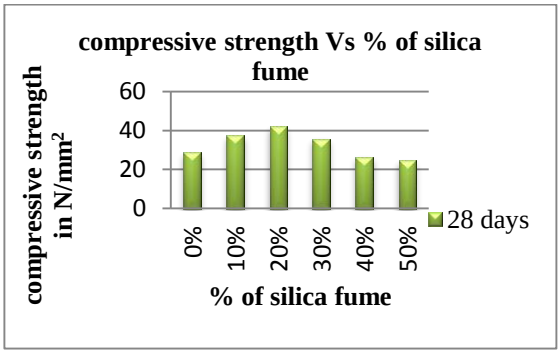
5. RESULTS AND DISCUSSIONS

5.1 Compressive Strength

% in silica fume	Compressive strength in Mpa			Avg. Compressive strength in Mpa
	Sample I	Sample II	Sample III	
0%	27.96	30.03	28.62	28.87
10%	37.62	38.96	36.08	37.55
20%	40.55	42.96	42.40	**41.97**
30%	35.11	37.87	33.98	35.65
40%	26.42	25.08	27.81	26.43
50%	23.09	24.76	25.82	24.55

TABLE: 5.1.1: Shows the characteristic compressive strength of the cubes for different percentages of silica fume of concrete cubes at the 28 days strength

Based on the results and discussion, it is clear that there is no advantage of using silica fume above 20% in concrete. However, 20% of silica fume replacement in concrete can be taken as optimum dosage.

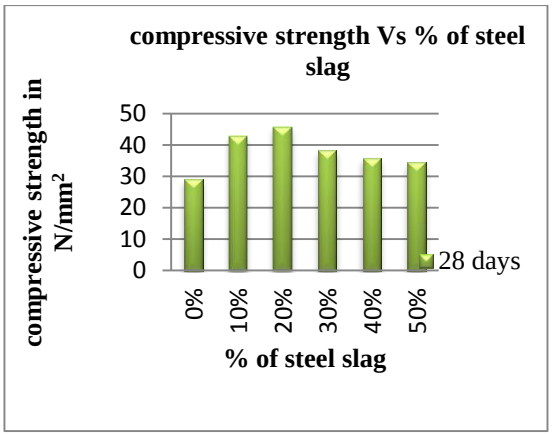


BAR CHART – 5.1.1: shows the compressive strength V/s % of Silica Fume

% of steel slag	Compressive strength in Mpa			Avg. compressive strength in Mpa
	Sample I	Sample II	Sample III	
0%	27.96	30.03	28.62	28.87
10%	43.06	42.61	41.70	42.65
20%	46.52	45.68	44.96	**45.72**
30%	38.22	38.46	37.87	38.18
40%	34.30	37.02	35.69	35.67
50%	35.96	33.36	34.15	34.49

TABLE: 5.1.2**:** Shows the characteristic compressive strength of the cubes for different percentages of steel slag 28 days strength.

Based on the results and discussion, it is clear that there is no advantage of using steel slag above 20% in concrete. However, 20% of steel slag replacement in concrete can be taken as optimum dosage.



BAR CHART–5.1.2**:** shows the compressive strength V/s % of steel slag.

Based on the results and discussion, it is clear that there is an increase in strength of concrete and it advantageous. It has been observed using 20% of silica fume in concrete increases strength and 20% of steel slag increases strength individually.

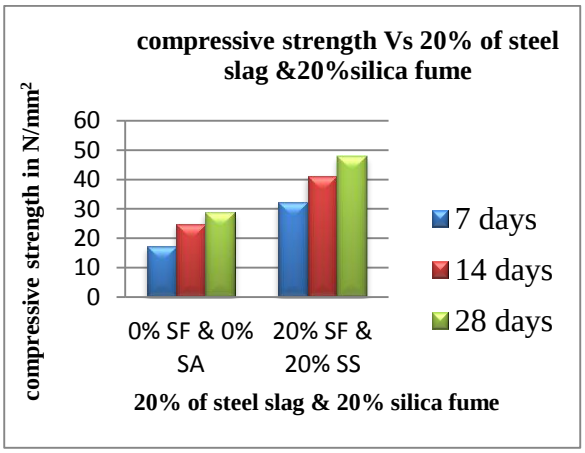
Since 20% silica fume with replacement of cement increases the strength and 20% steel slag with replacement of coarse aggregate increases the strength

We have casted cubes for testing combination with 20% of silica fume in replacement of cement and 20% steel slag in replacement of coarse aggregate and the results are below in Table 5.1.3.

% of silica fume added replaced in cement in concrete mix	% of steel slag added replaced in CA in concrete mix	Age in days	Avg. compressive strength in Mpa
0%	0%	7 days	17.23
		14 days	24.89
		28 days	**28.87**
20%	20%	7 days	32.26
		14 days	41.15
		28 days	**47.97**

TABLE: 5.1.3: Shows the characteristic compressive strength of the cubes for 20% of steel slag and 20%

- The compressive strength of designed M_{20} grade mix proportion with 20% steel slag and 20% silica fume is **47.97**N/mm^2



BAR CHART–5.1.3**:** shows the compressive strength V/s 20% of steel slag and 20% of silica fume

6. CONCLUSIONS

Based on the work carried out the following conclusion have been mentioned below:

1. The partial replacement of cement with silica fume and the partial replacement of coarse aggregate with steel slag in the M_{20}grade mix proportion concrete results in increase of compressive strength.
2. The partial replacement of cement with silica fume and the partial replacement of coarse aggregate with steel slag in the M20 grade mix proportion concrete results in increase of compressive strength.
3. Partial replacement of cement with silica fume and the partial replacement of coarse aggregate with steel slag in M20 grade mix proportion concrete results in the increase of compressive strength at 10%, 20% and 30% of silica fume and steel slag proportions.
4. At 40% and 50% of silica fume and At 40% and 50% of steel slag proportions results in reduction in the compressive strength of concrete.
5. Partial replacement of cement with silica fume and the partial replacement of coarse aggregate with steel slag in M20 grade mix proportion concrete results in increase of compressive strength at 10%, 20% and 30% of silica fume proportions.
6. Availability of silica fume is slightly difficult but cost of silica fume is economical.
7. Availability of steel slag is in places where there is steel manufacture companies but it is reusing in concrete increases strength and decreases the usage of coarse aggregate which is economical and eco-friendly

Final conclusion is the 20% steel slag and 20% silica fume has high compressive strength in concrete.

REFERENCES

[1] Influence of silica fume on concrete by Prof. Vishal & S. Ghutke & Prof. Pranita & S.Bhandari (IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e -ISSN: 2278-1684, p-ISSN: 2320-334X PP 44-47).

[2] Effect of silica fume on strength and durability Parameters of concrete by N. K. Amudhavalli, Jeena Mathew (International Journal of Engineering Sciences & Emerging Technologies, August 2012.ISSN: 2231 – 6604 Volume 3, Issue 1, pp: 28-35).

[3] Effect of Silica Fume in Concrete by Vikas Srivastava, Alvin Harison, P. K. Mehta, Atul and Rakesh Kumar(International Journal of Innovative Research in Science, Engineering and Technology. An ISO 3297: 2007 Certified Organization Volume 3, Special Issue 4, March 2014)

[4] Mechanical Properties Of Concrete Using Steel Slag Aggregate by J. Saravanan and N.Suganya

[5] Sustainable Replacement Of Steel Slag As Coarse Aggregate In Concrete P. Murthi , S. Alan , C. Chakkaravarthi , N. Raguraman , P. Seenivasan

[6] Utilization Of Industrial Waste Slag As Aggregate In Concrete Applications By Adopting Taguchi's Approach For Optimization Mohammed Nadeem, Arun D. Pofale

[7] Strength and durability of concrete using steel slag as a partial replacement of coarse aggregate in concrete by K.Thangaselvi (International Journal Of Advanced Research Trends In Engineering And Technology(IJARTET) Vol.2,Isssue7,July 2015)

[8] Study On Concrete Using Steel Slag As Coarse Aggregate Replacement And Ecosand As Fine Aggregate Replacement by Dr.k.Chinnaraju1, V.R.Ramkumar2, K.Lineesh3, S.Nithya4, V.Sathish5((International Journal of Research in Engineering & Advanced Technology,Volume1,Issue3,June-July,2013(IJREAT)ISSN:2320-8791) www.ijreat.org

[9] Experimental Investigation on Replacement of Steel Slag as Coarse Aggregate in Concrete by Ravikumar H1, Dr. J.K. Dattatreya2, Dr. K.P Shivananda3 (Journal of Civil Engineering and Environmental

Technology ISSN : 2349-8404; Online ISSN : 2349-879X; Volume 2, Number 11; April – June, 2015 pp 58 – 63)
[10] Experimental Investigation Of Silica Fume And Steel Slag In Concrete by Mr. Mohammed thariq (international Journal of Advanced Science and Engineering Research www.ijaser.in Volume: 1, Issue: 1, June 2016 ISSN: 2455-9288)
[11] Effect Of Silica Fume On Different Strength Parameter Of Steel Slag Concrete by Sanjay Kumar Athya1, Miss Ragini Mishra2 (International Journal Of Innovation In Engineering Research & Management Issn :2348-4918)
[12] Effect Of Silica Fume On Steel Slag Concrete Kunda Sindhu Priya Reddy1, A.V.S Sai Kumar2 (International Journal Of Scientific Engineering And Technology Research Issn 2319-8885 Vol.04,Issue.50, December-2015, Pages:10761-10765 Www.Ijsetr.Com)
[13] A Study On Effect Of Silica Fume On The Mechanical Properties Of Steel Slag Aggregate Concrete by Devaraj P Kumbar1 and V D Gundakalle2(International journal of structural and civil engineering research)
[14] Experimental Study On Effect Of Silica Fume On Steel Slag Concrete by Ajay1, Nikhil Jain2 (International Journal of All Research Education and Scientific Methods (IJARESM) ISSN: 2455-6211, Volume 4, Issue 7, July- 2016, Impact Factor: 2.287)
[15] Effect of Silica Fume and Slag on Compressive Strength and Abrasion Resistance of HVFA Concrete by Alaa M. Rashad, Hosam El-Din H. Seleem, and Amr F. Shaheen (International Journal of Concrete Structures and Materials Vol.8, No.1, pp.69–81, March 2014)
[16] Experimental Investigation of Silica Fume and Steel Slag in Concrete by D. Karthik1, J. Doraikkannan2 (International Journal Of Modern Engineering Research (IJMER))
[17] Strength Modification Of Steel Slag Concrete Due To Silica Fume by Sumeet Thakur1 by SSRG (International Journal of Civil Engineering (SSRG-IJCE) – EFES April 2015)
[18] Concrete technology by M.S. Shetty – S Chand & co; 2004
[19] Concrete technology by A.M. Neville – Pearson publication
[20] Certificate analyses of silica fume (Micro silica) properties by ASTRAA CHEMICALS, Chennai.
[21] Influence of silica fume on concrete by Prof. Vishal & S. Ghutke & Prof. Pranita & S.Bhandari (IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e -ISSN: 2278-1684, p-ISSN: 2320-334X PP 44-47).
[22] Effect of silica fume on strength and durability Parameters of concrete by N. K. Amudhavalli, Jeena Mathew(International Journal of Engineering Sciences & Emerging Technologies,August 2012.ISSN: 2231 – 6604 Volume 3, Issue 1, pp: 28-35).
[23] Effect of Silica Fume in Concrete by Vikas Srivastava, Alvin Harison, P. K. Mehta, Atul and Rakesh Kumar(International Journal of Innovative Research in Science, Engineering and Technology. An ISO 3297: 2007 Certified Organization Volume 3, Special Issue 4, March 2014)
[24] I.S: 10262 – 2009 : Recommended guide lines for concrete mix design
[25] I.S: 2386 – 1963 : Test procedures of aggregates
[26] I.S: 383 – 1970 : specification for coarse and fine aggregate from natural resources
[27] I.S: 516 – 1959 : Methods of tests for strength of concrete.
[28] I.S: 4031 – 1996(part – 1) : Determination of fineness by dry sieving.
[29] I.S: 4031 – 1968 : Test procedures of cement
[30] I.S: 269- 1976 : Test procedures of cement
[31] I.S: 1199 – 1959 : Test procedures for fresh concrete
[32] WWW.GOOGLE.COM

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