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Compressive Strength of Concrete by Replacing Cement with Silicafume for M20 Grade

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Abstract: ***Cement is the back bone for global infrastructure development. It was estimated that global production of cement is about 1.3 billion tonnes in 1996. Production of every ton of cement emits carbon dioxide to the tune of about 0.87 ton. It can be said that 7% of the world's carbon dioxide emission is attributable to Portland cement industry. Silica Fume is a very fine powder consisting mainly of spherical particles or microspheres of mean diameter about 0.15 microns, with a very high specific surface area (15,000-25,000 m2/kg). To fulfil the objective various properties of concrete using silica fume have been evaluated. Further to determine the optimum replacement percentage comparison between the regular concrete and concrete containing silica fume is done. It has been seen that when cement is replaced by silica fume compressive strength increases up to certain percentage (10% replacement of cement by silica fume). But higher replacement of cement by silica fume gives lower strength.***

Keywords: Definition, Mix design, compressive strength of cube, cylinder (by replacing silica), results

1. Introduction

Silica fume Definition: Very fine non crystalline silica produced in electric are furnaces as a byproduct of alloys of containing silicon; also known as condensed silica fume or micro silica.

Metals that produce silica fume: Silicon metal – typically greater 40 to 90% silicon alloyed with ironically greater than 97% and ferrosilicon alloys -ranging from 40 to 90% silicon alloyed with iron.

Mix Design: **By using Bureau of Indian Standards method As per IS 10262:2009(Revised)**
Stipulation of proportioning: Grade designation= M-20, type of cement = OPC 53 grade, maximum nominal size of aggregates = 20mm, S water/cement ratio = 0.53 (mild-M25)

Target mean strength for mix proportioning
[f' ck = f ck + k.s]
1) target mean strength = 20+1.65 x 4=26.6N/mm^2
2) characteristics strength at 28 days = 20Mpa

The standard deviations (σ) are:
M10-M15: 3.5 MPa; M20-M20: 4.0 MPa
M30-M50: 5.0 MPa

Selection of water content
1) Max. water content = 186lts(at 50mm slump)
2) corrected water content = 186+(186 x 6/100)
W=197lts.

Calculation of cement content
1) Water/cement ratio = 0.53
2) Cement content = 197lts/0.53
C=371.69 kg/m^3

Calculation of coarse and fine aggregate
From zone one and coarse (20mm) at w/c ratio 0.5
Volume of coarse aggregate = 0.6

Corrected Volume = 0.01/0.05 x 0.02=0.004@ 0.6+0.004
Coarse aggregate = 0.604m^3 ;Fine aggregate = 1-0.604=0.396m^3

Calculations:
Volume of concrete = 1m^3 ; absolute vol.0f cement = 372/3.10 x 1/1000
= 0.12m^3
volume of water = 197 x 10^-3 = 0.197m3
volume of materials (except aggregates)= 0.12+0.197 = 0.317m3
absolute total aggregates = 1-0.317 = 0.683m3
weight of coarse aggregate= 0.683 x 0.604x 2.63x 1000= 1085 kg/m3
weight of fine aggregate= 0.683 x 0.396 x 2.64x 1000= 714.035 kg/m3
total density = cement + coarse aggregate + fine aggregate +water=2368kg/m3

Table: For 1m^3, the proportions are:

Cement	Fine aggregate	Coarse aggregate	Water
372	714	1085	197
1	1.91	2.9	0.53

Calculation for cubes :
Volume of cube = 0.15*0.15*0.15 = 0.00375 m3
For 0.00375 m^3
Cement content = 0.00375*372 = 1.395 kg
Coarse aggregate content = 0.00375*1078 = 4.044 kg
Fine aggregate content = 0.00375* 723.5 kg =2.7131 kg
Water content = 0.00375*194 = 0.7275 liters
Replacement of cement with 0% silica fume:
Silica fume content = 0 kg ; Cement content= 1.2555 kg
Replacement of cement with 5% silica fume:
Silica fume content = 0.05kg ; Cement content= 1.2055kg
Replacement of cement with 15% silica fume:
Silica fume content = 0.15 kg;Cement content = 1.1055 kg
Replacement of cement with 25% silica fume:

Silica fume content = 0.25 kg ;Cement content= 1.0055 kg

Replacement of cement with 35% silica fume:

Silica fume content = 0.35 kg ;Cement content= 0.9055 kg

Compression Test

Apparatus:

Testing Machine:'Avery' testing machine.

Rubber Cap:400mm long ruler to measure the height of specimen.

Figure: Apparatus and Test Procedure of Compression Test

Balance: To measure the weight of the concrete specimens.

Vernier Caliper: To measure the diameter of the concrete specimens

Test Procedure

1) The testing for the specimens should be carried out as soon as possible after took out from the curing room. The specimens need to get the measurements before the testing.
2) The diameter and height of the specimens were measured and recorded. The weight of each specimenwas measured and recorded too.
3) The planets of the testing machine were cleaned with a clean rag.
4) Cleaned the uncapped surface of the specimen and place the specimen in the testing machine. The axis of the specimen was aligned with the centre of the thrust spherically seated platen.
5) Carefully placed the rubber cap on the specimen.
6) The planet was lowered to the tuber cap until the uniform bearing was obtained.
7) The force was applied and increased continuously at a rate equivalent to 20MPa compressive stress per minute until the specimen failed.
8) Recorded the maximum force from the testing machine.

Figure: setup for tensile strength

Figure: Making silica fume concrete in the laboratory

2. Concrete Cube Casting, Testing

Compressive strength of concrete

Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. For cube test two types of specimens either cubes of 15 cm X 15 cm X 15 cm or 10cm X 10 cm x 10 cm depending upon the size of aggregate are used. For most of the works cubical moulds of size 15 cm x 15cm x 15 cm are commonly used.

Cubecasting:

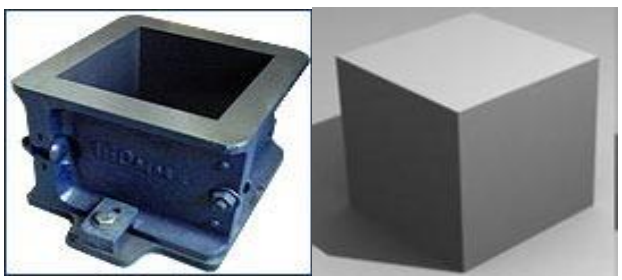


Figure: Cubecasting

3. Procedure for Compressive strength test of Concrete Cubes:

Apparatus
Compression testing machine

Precautions
The water for curing should be tested every 7days and the temperature of water must be at 27+-2oC.

Procedure
1) Remove the specimen from water after specified curing time and wipe out excess water from the surface and Take the dimension of the specimen to the nearest 0.2m.
2) Clean the bearing surface of the testing machine.
3) Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.
4) Align the specimen centrally on the base plate of the machine.
5) Rotate the movable portion gently by hand so that it touches the top surface of the specimen.
6) Apply the load gradually without shock and continuously at the rate of 140kg/cm2/minute till the specimen fails.
7) Record the maximum load and note any unusual features in the type of failure.

Split Tensile strength of concrete
Another method for testing of strength is split tensile strength which is tested by a cylinders. For cylinderspecimen of 15 X 30cm size is used..

Figure: Cylinder

Apparatus
Besides the conventual testing machine, supplementary bearing bar or plate and bearing strips made of plywood are necessary to perform the test.

Specimens
6 cylinders of 15 X 30cm size

PRECAUTIONS:
The water for curing should be tested every same7days and the temperature of water must be at 27+-2^{o}C

Procedure
Diametrical lines shall be drawn on each of the specimen and the diameter shall be measured accurately. One of the plywood strips shall be centred along the centre of the lower bearing block. The specimen shall be placed on the plywood strip.

The load is applied continuously and without shock, at a constant rate within the range 100 to 200 psi/min splitting tensile stress until failure of the specimen. The maximum applied load indicated by the machine at failure is recorded together with the type of failure and appearance of the concrete.

Calculation
The splitting tensile strength shall be calculated as follows:$\frac{2P}{}$
$T = \pi dl$
where; T = splitting tensile strength, psi ;
P = maximum applied load, lb
l = length, in; d = diameter,

4. Compressive Strength of Cubes, Cylinders Result & Analysis

Replacement of cement with silica fume by 0% by weight of cement with water/cement ratio 0.5

The mix is 0.52:1:1.944:2.89
The quantity of materials are worked out as below for 9 cubes casting,6 cylinders
(1) Cement =23.1055 kg
(2) Sand =44.93 kg
(3) Coarse aggregate =66.99 kg
(4) Water =12.043 lit

Compressive strength of cubes

Table

S. No	7-day compressive Strength (mpa)	14-day compressive strength(mpa)	28-day compressive strength(mpa)
1.	22.9	28.8	34.2
2.	23.1	28.7	34
3.	23	28.5	34.5
Average	**23**	**28.66**	**34.233**

Tensile strength of cylinders

Table

S. No	7 days Tensile strength(mpa)	28daysTensile strength(mpa)
1	1.948	2.5
2	2.061	2.603
3	1.953	2.525
Average	**1.987**	**2.542**

Replacement of cement with silica fume by 5% by weight of cement with water/cement ratio 0.5

The mix is 0.521:1:1.944:2.89
The quantity of materials are worked out as below for 9 cubes 6 cylinders casting
(1) Cement= 22.3563 kg;
(2) Silica fume =0.75 kg;
(3) Sand =44.932 kg
(4) Coarse aggregate=66.99 kg;
(5) Water=12.0432 lit

Compressive strength of cubes

Table

S. No	7-daycompressive strength(mpa)	14-daycompressive strength(mpa)	28-daycompressive strength(mpa)
1.	20.2	31.2	42.6
2.	20.4	31.2	42.9
3.	20.4	31.5	42.3
Average	**20.33**	**31.3**	**42.6**

Tensile strength of cylinders

Table

S. No	7-day tensile strength(mpa)	28-day Tensile strength(mpa)
1.	2.06	2.863
2.	1.895	2.406
3.	1.860	2.994
Average	**1.938**	**2.754**

Replacement of cement with silica fume by 15% by weight of cement with water/cement ratio 0.5

The mix is 0.521:1:1.944:2.89

The quantity of materials are worked out as below for 10 cubes casting

(1) Cement=20.856 kg;
(2) Silica fume=2.251 kg;
(3) Sand =44.9328 kg
(4) Coarse aggregate=66.99 kg:
(5) Water=12.043 lit

Compressive strength of cubes

Table

S. No	7-daycompressive strength(mpa)	14-daycompressive strength(mpa)	28-daycompressive strength(mpa)
1.	21.5	26.2	38.9
2.	19.5	24.5	40.2
3.	20	27.6	35.9
Average	20.3	26.1	38.3

Tensile strength of cylinders

Table

S.No	7-day Tensile strength(mpa)	28-day Tensile strength(mpa)
1.	21.3	31.7
2.	21.6	32.5
3.	21.8	31.5
Average	**21.566**	**31.9**

Replacement of cement with silica fume by 25% by weight of cement with water/cement ratio 0.5

Themix is0.521:1:1.944:2.89

The quantity of materials are worked out as below for 10 cubes casting

(1) Cement =19.356 kg;
(2) Silica fume =3.75kg;
(3) Sand =44.932 kg
(4) Coarse aggregate=66.99 kg;
(5) Water =12.0432 lit

Compressive strength of cubes

Table

S. No	7-day compressive strength(mpa)	21-day compressive strength(mpa)	28-day compressive strength(mpa)
1.	20.6	30.1	35.2
2.	20.3	30	35.1
3.	21.1	30	34.8
Average	**20.66**	**30.033**	**35.033**

Tensile strength of cylinders

Table

S. No	7-day Tensile strength (mpa)	28-day Tensile strength (mpa)
1	1.649	2.33
2	1.645	2.20
3	1.642	2.412
Average	**1.645**	**2.314**

Compression Test Result & Analysis

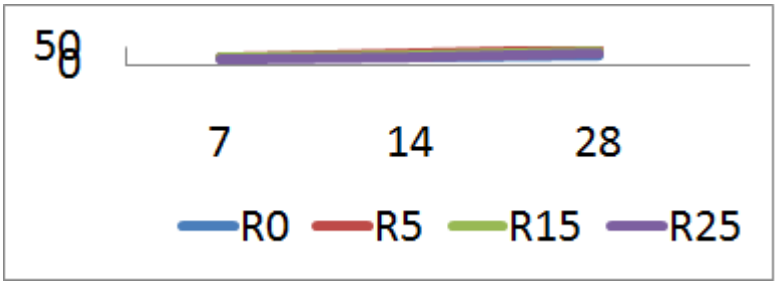
The compression test indicates that an increasing trend of compressive strength of each age of concrete. The graphical representation of variation of compressive strength at different concrete ages.

Table:

	Compressive strength(mpa)		
% replacement by silica fume	7-days	14-days	28-days
0%	23	28.66	34.233
5%	20.33	31.3	42.6
15%	21.566	31.9	48.166
25%	20.66	30.033	35.033
35%	18.966	26.8	28.3

Variation of compressive strength with age (Graph)

From the above information we can conclude that with replacement of 15% of the silica fume we get the good results and we can happily replace the silica fume till this percentage in the constructions.

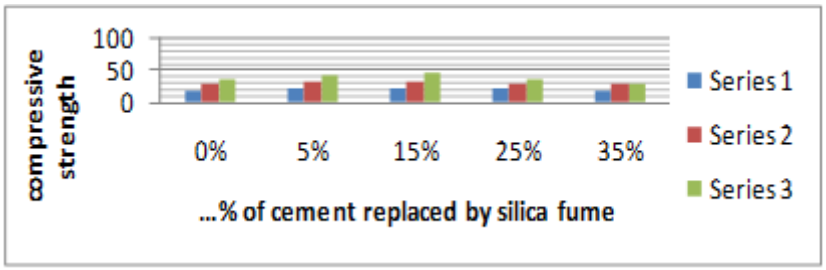


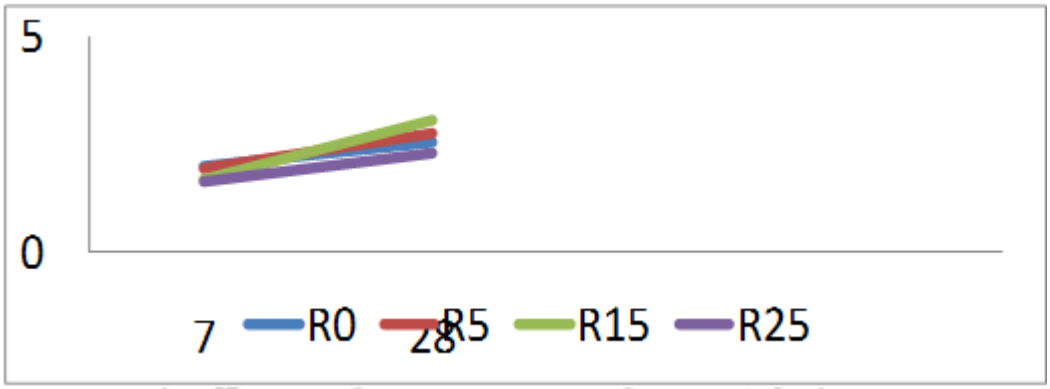
Tensile test result & analysis

The tensile test indicates that an increasing trend of tensile strength of each age of concrete. The graphical representation of variation of tensile strength at different concrete ages

Table

	Concrete age (days)	
(% R-replacement of Silica fume)	14-days	28-days
R0	2.52	2.78
R10	2.20	2.44
R20	2.46	3.32
R30	2.16	2.85





Graph

From the above information we can conclude that with replacement of 20% of the silica fume we get the good results and we can happily replace the silica fume till this percentage in the constructions.

5. Conclusion

- SILICA FUME is a well established, quality controlled highly pozzo anic material suitable for use in concrete. Its properties are closely controlled against ASTM and BS EN standards.
- SILICA FUME concrete is particularly effective where high resistances to abrasion, impact or chemical attack are required.
- High strength concretes (> 60 N/mm2) can readily be produced using SILICA FUME
- SILICA FUME is an industrial by-product and its use in concrete offers environmental benefits. Appropriate use of silica fume in ready-mixed and site-mixed fresh improves the fresh concrete properties, which lead to easier placement, faster construction and finishing, reduces permeability and improves strength and durability. Extremely high quality surface finishes can also be used

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