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BEARING STRENGTH OF SILICA FUME CONCRETE WITH AREA RATIO OF FIVE

N. Venkata Ramana

Associate professor, Civil Engineering Department, University B.D.T. College of Engineering, Davangere, Karnataka (State) India.

ABSTRACT

This article presents the bearing strength of silica fume concrete. The concrete mixes were prepared with mineral admixture of silica fume as partial replacement to cement and the crimpled steel fibres were also added to same mixes. In the mixes the silica fume was varying from 0 to 25% with increment of 5% and for the same the mixes the steel fibres were added in the volume proportion of 1 and 2%. In addition to those mixes the plane mix was used for comparison purpose. Cube compressive strengths were determined apart from the bearing strengths by testing the cube specimens. The results are compared with IS 456 and ACI318 codal provisions and also regression models were developed to estimate the bearing strengths.

KEY WORDS- Bearing strength, Compressive strength, Area Ratio 5, IS 456, ACI 318 and Regression Models.

INTROUDCTION

Cementations materials have been used by mankind for construction from time immemorial. The every rising functional requirement of the structures and the capacity to resist aggressive elements has necessitated developing new cementations materials and concrete composites to meet the higher performance and durability criteria. The environmental factors and pressure of utilizing waste materials from industry have also been the major contributory factors in new developments in the field of concrete technology. Concrete is an artificial material in which the aggregates both fine and coarse are bonded together by the cement when mixed with water. The concrete has become so popular and indispensable because of its inherent in concrete brought a revolution in applications of concrete. Concrete has unlimited opportunities for innovative applications, design and construction techniques. Its great versatility and relative economy in filling wide range of needs has made it very competitive building material. With the advancement of technology and increased field of applications of concrete and mortars, the fresh and harden concrete properties of the ordinary concrete need modifications to make it more suitable for a by situations. Added to this is the necessity to combat the increasing cost and scarcity of cement. Under these circumstances the use of admixtures is found to be an important alternative solution. Hence an attempt has been made in the present investigation to evaluate the compressive and bearing strength of fibre reinforced silica fume concrete.(replacement of cement by micro silica fume (0,5,10,15,20 and 25%) along with crimped steel fibers (0,1,2%)). In this regard brief literature is presenting here in to know the statue of work has been taken place in this area.

Carson and Chen [1] studied the influence of adding steel fibres on the bearing capacity and ductility of concrete through testing 150mm concrete cylinders. It was found that the bearing capacity was significantly higher than that of unreinforced materials. Niyogi[2] conducted extensive investigation on the bearing strength of concrete. The variables investigated were the geometry of specimens, the bearing area, mix proportions, strength of concrete, amount and form of reinforcement and nature of the bed. Wee et al.[3] also showed that silica fume, at replacement levels of 5 and 10%by mass of OPC plays a key role in resisting sodium sulphate attack, indicating nosigns of spalling after about 1 year of exposure in 5% sodium sulphate solution.Hekal et al.[4] reported that partial replacement of Portland cement by silica fume (10–15%) did not show a significant improvement in sulphate resistance of hardened cement pastes. Shannag and Shaia[5] prepared high-performance concrete mixes containing various proportions of natural pozzolan and silica fume (up to 15% by weight of cement). The results also showed that magnesium sulphates had a more damaging effect than sodium sulphates.Mazloom et al. [6] made high-performance concrete containing silica fume. The silica fume content was 0, 6, 10, and 15%, and water–cementitious ratio being0.35 and 100 ± 10 mm, respectively. Behnood and Ziari [7] designed concrete mixtures to evaluate the effect of silica fume on the compressive strength of the heated and unheated concrete specimens. González-Fonteboa and Martinez-Abella [8] studied the properties of concrete using recycled aggregates from Spanish demolition debris (RC mixes) and the impact of the addition of silica fume on the properties of recycled concrete. Kadri and Duval [9] investigated the influence of silica fume on the hydration heat of concrete. Portland cement was replaced by silica fume (10–30% by mass)in concrete with w/(c +sf) ratios varying between 0.25 and 0.45. Suksun horpibulsuk et.al.[10] investigated the performance of fully instrumented test wall reinforced with bearing reinforcement and suggested a method of designing BRE wall. You-Fu-Yang et. al [11] investigated behaviour of concrete filled double-skin tube (CFDST) subjected to local bearing forces. The results showed the CFDST specimens have a high bearing capacity and a good deformation resistant ability on subjecting to local bearing forces. The bearing capacities obtained are compared experimentally. Chao Hou et. al [12] studied behavior of circular concrete filled double skin tubes (CFDST) subjected to local bearing forces . A finite element analysis was conducted between full range behavior of CFDST & CFST under local bearing. Based on load- transfer mechanism analysis, simplified formulae for predicting the strength of CFDST under local bearing forces are presented. Reasonable agreement between the predicted and measured values is achieved. Ali. A.Sayadi et. al [13] took up galvanized steel strips as embedded components and foamed concrete as infill material to investigate the effectiveness of interlocking area and bearing area on bond behaviour. The result indicates increase in locking area results in higher tensile capacity along with greater displacement in initial stage. Based on experimental results equations were developed to analytically describe the bond slip behaviour, tensile capacity and bond strength. Omid sargazi and Ehsan seyedi Hosseininia [14] presented a study on bearing capacity of eccentrically loaded rough ring footings resting over cohesion less soil. Comparison between the results of numerical simulations with those of analytical solutions and experimental data indicates good agreement. Amir Hossein Arshian and Guido Morgenthal [15] concentrated to assess the ultimate load bearing capacity of laterally restrained RC slabs considering the contribution of compressive membrane action. The sensitivity studies, non-influential parameters are fixed at their mean values and probability of failure is estimated for investigated modelling strategies using full probabilistic approach.

From the above review of literature it is observed that no work has been carried out on bearing strength of concrete using steel fibres and silica fume as admixture. Hence, an attempt has been made in this investigation to study the behaviour of silica fume concrete. In the experimental work the cement replacement by the silica fume is in the proportion of 0, 5, 10, 15, 20&25%. In addition to this mixes, few more mixes were prepared with crimped steel fibres by volume 0, 1 & 2% in concrete. For all mixes cubes of standard size 150mmx150mmx150mm were cast and tested in the laboratory. Total 108 cubes were cast, out of total, 54 cubes were used for cube compressive strength and remaining 54 were used for bearing strength

OBJECTIVES AND EXPERIMENTAL PROGRAMME

The specific objectives of the present investigation are

1. To evaluate the compressive and bearing strengths of concrete

2. Applicability of IS456- 2000 and ACI318M-11 code provisions to estimate the strengths

3. Developing of Regression Modals to estimate the strengths

MATERIALS USED

Cement: Ordinary Portland cement of 53 grade confirming to IS 8112-1989 standards was used to cast the specimens. The specific gravity of cement was noticed as 3.1.
Silica Fume: The silica fume was obtained from Navabarath Ferro Alloy Plant at Palvancha of Badhardri kottoagudem (Dist) in Telangana (state), India (country).The specific gravity for silica fume was noticed as 2.1 and the silica content was 89%
Fine aggregate: River sand from local sources was used as fine aggregate. The specific gravity of sand is observed as 2.58 and it was conformed to zone II based on sieve analysis.
Natural Coarse Aggregate: Crushed natural granite aggregate from local crusher has been used and which has maximum size of 20mm .The specific gravity of coarse aggregate was observed as 2.66.

Water: Clean fresh water was used for mixing and curing the specimens.

Fibres: Steel Fibres are supplied by “Stewols India (P) Ltd, an ISO 9001: 2008 Company” at Nagpur. The most important parameter describing a fibre is its Aspect ratio. "Aspect ratio" is the length of fibre divided by an equivalent diameter of the fibre, where equivalent diameter is the diameter of the circle with an area equal to the cross sectional area of fibre. In the present investigation crimped round fibres were used with aspect ratio of 90 and the physical properties are presented Table 1 and the used fibres can viewed in Figure 1.

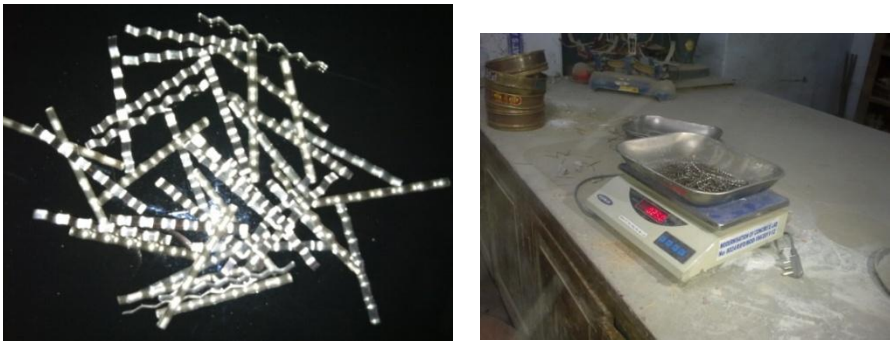

Fig.1: Crimped steel fibre

Table 1: Details of Crimple fibre

Length of Fiber	50 mm
Aspect ratio	90
Diameter (d)	0.55 mm)
Width (w)	2.5 mm
Tensile Strength	450MpaMpa
Physical form	Clear, bright and undulated along the length
Material Type	Low Carbon Drawn Flat Wire

CASTING

The cubes were cast in steel moulds with inner dimensions of 150 x 150 x 150mm.The cement, silica fume; sand, coarse aggregate and crimped steel fibres were mixed thoroughly manually. The mix proportion was adopted for all mixes as 1:1.63:3.12 and water cement ration was arrived as 0.5. (This was designed for M20 grade concrete) During mixing of concrete initially 25% of water required is added and mixed thoroughly till to obtain uniform mix. After that, the balance of 75% of water was added and mixed thoroughly with a view to obtain design mix. Care has to be taken in mixing to avoid balling effect.

For all test specimens, moulds were kept on table vibrator and the concrete was poured into the moulds in three layers and compaction was provided with tamping rod, in addition to this table vibrator was also provided.The moulds were removed after twenty four hours and the specimens were deployed to curing pond. After curing the specimens in water for a period of 28 days the specimens were taken out and allow drying under shade. Three cubes were cast for each mix as specified in test program.

TESTING

Compressive strength test

Compression test on cubes is conducted with 2000kN capacity of compression testing machine. The machine has a least count of 1kN. The cube was placed in the compression-testing machine and the load on the cube is applied at a constant rate till to failure of the specimen and the corresponding load is noted as ultimate load. Then cube compressive strength of the concrete mix is then computed by using standard formula and the obtained values are presented in the next section.

Bearing Strength test

The bearing strength test was conducted on cubes. To analogous the column and footing, a steel plate 67mm (breadth) x 67mm (width) x 25mm (thick) was placed on cubes and tested in cube compression machine. The size of the square plate (67x67mm) is prepared so as to achive the bearing area to the punching area is 5. A 2000 KN Compression testing machine was used for testing and the axial load is applied at a constant rate as laid down in IS: 516-1959. The obtained test resulted presented in the next section.

DISCUSSION OF TEST RESULTS

Compressive Strength

First crack (FC) stage

The compressive strengths for all mixes (for various replacements 0, 5, 10, 15, 20&25%) with 0%, 1% &2% fiber are presented in Table 2. From this, it can be observed that for 0% fiber the 28 days compressive strength increases with the increase in the percentage of silica fume up to 15%. For 15% replacement of silica fume there is increases in cube compressive strength by 24.07% over NC. For 25% replacement level, the compressive strength has decrease by 9.24% when compared with reference concrete. Verma Ajay et.al [16] has been presented in their experimental work as 15% silica fume is optimum.For 1% fiber the 28 days compressive strength increases with the increase in the percentage of silica fume up to 15%. For 15% replacement of silica fume there is increases in cube compressive strength by 21.06% over NC. For 25% replacement level, the compressive strength has decrease by 5.22% when compared with reference concrete. For 2% fiber the 28 days compressive strength increases with the increase in the percentage of silica fume up to 15%. For 15% replacement of silica fume there is increases in cube compressive strength by 17.16% over NC. For 25% replacement level, the compressive strength has decrease by 12.76% when compared with reference concrete or NC.

Table 2: Compressive strength at first crack

S.No	**Nomenclature**	**Compressive strength 0% fibre**	**Compressive strength 1% fibre**	**Compressive strength 2% fibre**
1.	NC	23.68	24.68	26.39
2.	SF5	25.00	26.18	26.57
3.	SF10	27.96	28.34	29.19
4.	SF15	29.38	29.88	30.92
5.	SF20	24.62	25.35	25.60
6.	SF25	21.49	23.39	23.02

Ultimate stage (US)

The compressive strengths for all mixes (for various replacements 0, 5,10,15,20 &25%) with 0%, 1% &2% fiber are presented in Table 3. From this, it can be observed that for 0% fiber the 28 days compressive strength increases with the increase in the percentage of silica fume up to 15%. For 15% replacement of silica fume there is increases in cube compressive strength by 23.39% over NC. For 25% replacement level, the compressive strength has decrease by 9.81% when compared with reference concrete. But Swamy BLP et al [17], K.Perumal and R.Sundararajan [18] has reported in their investigation as 10% is optimum. But in the present experimental investigation 15% is found to be optimum. The presence of micor silica fume in the concrete mass is decrease the voids i.e the final product makes as denser and it leads higher strength carrying capacity.For 1% fiber the 28 days compressive strength increases with the increase in the percentage of silica fume up to 15%. For 15% replacement of silica fume there is increases in cube compressive strength by 21.04% over OPC. For 25% replacement level, the compressive strength has decrease by 9.68% when compared with reference concrete.For 2% fiber the 28 days compressive strength increases with the increase in the percentage of silica fume up to 15%. For 15% replacement of silica fume there is increases in cube compressive strength by 22.31% over OPC. For 25% replacement level, the compressive strength has decrease by 11.01% when compared with reference concrete or NC. Pu-Woei et.al [19] has been presented in their experimental work as the percentage of carbon fiber increases in the mix the strengths were increases. Same types of observations were made in the present experimental work for steel fibers. Based on the rule of mixture the strengths were increased.

Table 3: Compressive strength values at ultimate stage

S.No	Nomenclature	Compressive strength 0% fibre	Compressive strength 1% fibre	Compressive strength 2% fibre
1.	NC	32.61	33.97	35.13
2.	SF5	34.26	35.38	36.82
3.	SF10	37.79	39.02	40.19
4.	SF15	40.24	41.12	42.97
5.	SF20	33.86	34.92	35.71
6.	SF25	29.41	30.68	31.26

Influence of silica fume on bearing strength

The allowable bearing stress depends on the bearing strength of concrete and this often controls the dimensions of the members. According to ACI 318 the ultimate stress under concentrated forces is called bearing strength. In reality this type of forces are encountered in the area of missiles, projectiles and explosions (S.P Ray and B.Venkateswarulu [20]). In the present experimental work the author is focused the bearing strength evaluation for pedestal purpose only.

Bearing strength for 67.1mm plate (Bearing ratio is 5)

First crack (FC) stage

The bearing strengths for all mixes (for various replacements 0, 5, 10, 15, 20&25%) with 0%, 1% &2% fiber are presented in Table 4. From this, it can be observed that for 0% fiber the 28 days bearing strength increases with the increase in the percentage of silica fume up to 15%. For 15% replacement of silica fume there is increases in cube bearing strength by 19.86% over NC. For 25% replacement level, the bearing strength has decreased by 13.48% when compared with reference concrete. For 1% fiber the 28 days bearing strength increases with the increase in the percentage of silica fume up to 15%. For 15% replacement of silica fume there is increases in cube bearing strength by 23.98% over NC. For 25% replacement level, the bearing strength has decrease by 9.98% when compared with reference concrete.For 2% fiber the 28 days bearing strength increases with the increase in the percentage of silica fume up to 15%. For 15% replacement of silica fume there is increases in cube bearing strength by 13.66% over NC. For 25% replacement level, the bearing strength has decrease by 13.77% when compared with reference concrete.

Table 4: Bearing strength values at first crack

S.No	Nomenclature	Bearing strength 0% fibre	Bearing strength 1% fibre	Bearing strength 2% fibre
1.	NC	48.87	51.36	56.35
2.	SF5	51.13	54.16	58.19
3.	SF10	56.16	61.01	62.25
4.	SF15	58.58	63.68	64.05
5.	SF20	49.80	53.19	54.44
6.	SF25	42.28	46.23	48.59

Ultimate stage (US)

The bearing strengths for all mixes (for various replacements 0,5,10,15,20&25%) with 0%,1% &2% fiber are presented in Table 5. From this, it can be observed that for 0% fiber the 28 days bearing strength increases with the increase in the percentage of silica fume up to

15%. For 15% replacement of silica fume there is increases in cube bearing strength by 19.39% over NC. For 25% replacement level, the bearing strength has decrease by 15.81% when compared with reference concrete. For 1% fiber the 28 days bearing strength increases with the increase in the percentage of silica fume up to 15%. For 15% replacement of silica fume there is increases in cube bearing strength by 23.27% over NC. For 25% replacement level, the bearing strength has decrease by 12.48% when compared with reference concrete. For 2% fiber the 28 days bearing strength increases with the increase in the percentage of silica fume up to 15%. For 15% replacement of silica fume there is increases in cube bearing strength by 13.08% over NC. For 25% replacement level, the bearing strength has decrease by 16.14% when compared with reference concrete.

Table 5: Bearing strength at ultimate stage

S.No	Nomenclature	Bearing strength 0% fibre	Bearing strength 1% fibre	Bearing strength 2% fibre
1.	NC	68.17	71.71	78.66
2.	SF5	70.72	74.92	80.47
3.	SF10	76.92	83.52	85.22
4.	SF15	81.39	88.40	88.95
5.	SF20	68.50	73.23	74.96
6.	SF25	57.39	62.76	65.96

Relationship between bearing and compressive strength

The bearing strength of concrete is most important parameter during the design of axially loaded elements. For normal concrete the IS 456-2000 and ACI 318M-11 recommended the following equations.

$f_b=0.45(f_{ck})\sqrt{(A1/A2)}$------------------------IS 456-2000

$f_b=0.85øf_c^1$------------------------------------ ACI318M-11

In the above expressions

f_{ck} = Characteristic compressive strength (N/mm^2)

f_c^1 = Specified compressive strength (N/mm^2) (here cube strength was taken as specified compressive strength)

ø = Strength reduction factor (taken as one unit)

The validity of the above equations was demonstrated in Table 6. From this table it is observed that the IS and ACI codes are underestimate the strength. Hence the author is felt that there is a necessity to develop a regression model (RM) to suit the experimental values for silica fume concrete. The author developed regression models with a correlation coefficient R^2=0.99 for all % of fibres.

fb= 6.93fck+0.043(%rep)-90.43--------------- for 0% fiber
fb=5.029fck-0.617(%rep)-0.7197-------------- for 1% fiber
fb=6.311fck-0.748(%rep)-17.75--------------- for 2% fiber

In the above expressions

f_b = Bearing strength (N/mm^2)

f_{ck} = Characteristic compressive strength (N/mm^2)

% rep= Percentage of replacement

The performance of the proposed model is presented in Table 7. From this table it is observed that the ration between EXP and RM is about 0.98 to 1.00. The ratio inferences the proposed model is best suited to the experimental values and also may concluded that it is better than IS and ACI code formulas.

Table 6: Applicability of IS456-2000 and ACI318M-11 Codes

% Fibre	% SF	IS456-2000	ACI 318-11	Exp	Exp/ACI318M-11	Exp/IS456-2000
0%	0	29.35	22.17	68.17	2.32	3.07
	5	30.83	23.29	70.72	2.29	3.03
	10	34.01	26.01	76.92	2.26	2.95
	15	36.21	27.36	81.39	2.24	2.97
	20	30.47	23.02	68.50	2.24	2.97

	25	26.46	17.99	57.39	2.16	3.19
1%	0	30.57	23.09	71.71	2.34	3.10
	5	31.84	24.05	74.92	2.35	3.11
	10	35.11	26.53	83.52	2.37	3.14
	15	37.00	27.96	88.40	2.38	3.16
	20	31.42	23.74	73.23	2.33	3.08
2%	25	27.61	20.86	62.76	2.27	3.00
	0	31.61	23.88	78.66	2.48	3.29
	5	33.13	25.03	80.47	2.42	3.21
	10	36.17	27.32	85.22	2.35	3.11
	15	38.67	29.21	88.95	2.30	3.04
	20	32.14	24.28	74.96	2.33	3.08
	25	28.13	21.25	65.96	2.34	3.10

Table 7: Performance of Regression Modal (RM)

Sl.No.	% of fibre	% of replacement	Exp. Bearing strength(N/mm^2)	Bearing strength (N/mm^2) as per RM	Exp/RM
1	0%	0	68.17	68.10	1.00
2		5	70.72	70.67	1.00
3		10	76.92	76.87	1.00
4		15	81.39	81.37	1.00
5		20	68.50	67.70	1.01
6		25	57.39	57.86	0.99
7	1%	0	71.71	71.68	1.00
8		5	74.92	74.88	1.00
9		10	83.52	83.48	1.00
10		15	88.40	88.38	1.00
11		20	73.23	73.24	0.99
12		25	62.76	62.75	1.06
13	2%	0	78.66	78.63	1.00

14		5	80.47	80.42	1.00
15		10	85.22	85.18	1.00
16		15	88.95	88.91	1.00
17		20	74.96	74.92	1.00
18		25	65.96	65.96	1.00

CONCLUSIONS

From the present experimental work the following conclusions were drawn.

1. The optimum dosage for silica fume is found to be 15%. At this stage compressive and bearing strengths were increased when compared with other replacements.

2. At first crack state and ultimate stages, the % of increase is about to 6 to 24% for 15% silica fume replacement when compared with reference concrete.

3. With incorporation of steel fibers (i.e., 1 and 2%) in the concrete mixes the compressive and bearing strengths were increased when compared with respective replacement of silica fume.

4. For bearing ratio of 5, at first crack and ultimate stages the % of increases about 5 to 20%for 15% replacement of silica fume when compared with reference concrete.

5. The IS and ACI codes underestimates the bearing strengths for different bearing ratios and for better estimation of bearing strengths, few regression models were evaluated and tested for experimental results and found that those are well matched.

6. Radial cracks were observed for all cubes in the bearing test.

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