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Effects of Industrial Waste Water on Strength Parameters of Silica Fumed Concrete

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Abstract: With rapid growth in population and industrial production along with decline in average annual rainfall in many regions, quantity of fresh water available for human needs is falling in a hast. This causes scarcity of fresh water for purposes other than human consumption. Construction industry requires large amount of water for not only in mixing and curing of concrete but also in other phases of erection. Due to scarcity water, construction projects does not get required amount of fresh water which leads to slow pace of work and reduction in quality of construction which later leads to economical losses. To avoid this many alternatives to reduce the need water are being explored worldwide. But die to their high price and unavailability in semi-urban areas these alternatives are used only in large scale construction projects in urban cities. Industrial waste water is one of the alternatives which is stupid in this paper as it is freely available in many regions. Silica fume is used in concrete as a partial replacement of cement to balance the adverse effects of mildly acidic industrial waste water. It is observed that when we use the chemically untreated waste water with fresh water in a ratio of 1, upto 20% replacement of cement by silica fume tensile and compressive strength goes on increasing. While flexural strength goes on increasing as we increase the percentage of silica fume. All the tests results of concrete specimens which were cured for 28 days shows that industrial waste water can be added to silica fumed concrete for high performance.
Keywords: Industrial Waste Water, Silica Fume, Compressive Strength, Tensile Strength, Flexural Strength

I. INTRODUCTION

India has experienced very fast urbanisation during the past 50 years. Exponential and rapid rate of growth has resulted in increased use of water which has increased generation of sewage. Settlement of population and increased industrialisation has been along the rivers. Resulting wastewater is not being treated adequately thereby resulting in discharge of untreated waste water into these rivers thereby causing deterioration of quality of receiving water and disturbing the eco system.

Waste water management is completely neglected and it should be seen as a resource rather than a burden to be disposed of. Water should be carefully managed at every stage, from fresh abstraction, pre-treatment, distribution, use, collection and post-treatment By 2030, global demand for water is expected to grow by 50%. Most of this demand will be in cities and will require new approaches to waste water collection and management. So, reused waste water may help in addressing other challenges, including food production and industrial development.

Water, food and energy securities are emerging as increasingly important and vital issues for India and the world. Most of the river basins in India are closing or closed and experiencing moderate to severe water shortages, brought on by the simultaneous effects of agricultural growth, industrialisation and urbanisation. Current and future fresh water demand could be met by enhancing water use efficiency and demand management. Thus, wastewater/low quality water is emerging as potential source for demand management after essential treatment. only 60% of industrial waste water, mostly large scale industries, is treated. Performance of state owned sewage treatment plants, for treating municipal waste water, and common effluent treatment plants, for treating effluent from small scale industries, is also not complying with prescribed standards. Thus, effluent from the treatment plants, often, not suitable for household purpose and reuse of the waste water is mostly restricted to agricultural and industrial purposes. Wastewater- irrigated fields generate great employment opportunity for female and male agricultural labourers to cultivate crops, vegetables, flowers, fodders that can be sold in nearby markets or for use by their livestock. However, there are higher risk associated to human health and the environment on use of wastewater especially in developing countries, where rarely the wastewater is treated and large volumes of untreated wastewater are being used in agriculture.

In this research paper feasibility of use of chemically untreated industrial waste water discussed by mainly considering the strength parameters. As basic aim was to cater the need of vast areas including semi-urban and rural areas use of chemical admixtures and super-plasticizers was avoided.

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II. EXPERIMENTAL PROGRAMME

M20 grade of concrete have been considered in the present investigation with different percentage replacement of cement with silica fume. The principal properties of the materials used in concrete mix have been evaluated and given below:

A. Material Properties

Cement: Cement used was of Ultratech brand (OPC-53). Standard consistency: 28 %, Initial setting time: 40 minutes; Final setting time: 580 minutes; Specific Gravity: 3.15, Compressive strength at 28 days: 40 N/mm2.

Fine Aggregate: Specific Gravity: 2.735; Fineness Modulus: 3.14; Zone-II (IS 383: 1970) Coarse Aggregate: Nominal size: 20 mm; Specific gravity: 2.80

Silica Fume: 920D class micro silica has been used in concrete mixes to replace cement. Specific gravity= 2.24. The amount of various ingredients is: SiO_2 = 85%, Carbon= 3.5%.

Water : Industrial waste water in Nagpur was used in research. Samples were collected at random sites for entire week to get the most accurate chemical composition. Visible matters like organic particles, papers, plastics, rubber, wood was removed by screening and then it was tested for its chemical composition. Water was collected for samples only after that it was prepared in laboratory artificially. Water used in research had following properties.

Table - 1: Chemical Composition of Industrial Waste Water

pH value	3.43	Nitric Acid	54 ppm
Lead	30 ppm	Phosphate	139 ppm
Hydrochloric Acid	45 ppm	Sulpher	204 ppm
Boric Acid	34.6 ppm	Manganese	73.5 ppm
Hydrofluoric Acid	21.9 ppm	Starch	20 ppm

B. Mixture Proportion

The concrete mixes were proportioned following IS 10262: 1982. The mixes were prepared with the same type of aggregate. The concrete mixes (M20) were designed with various percentages of micro silica (10%, 15%, 20% and 25% respectively). Water cement ratio was considered as 0.44.

C. Preparation of Test Specimen

Under laboratory conditions 150mm X 150mm X 150mm concrete cubes were prepared. The mixing was done in a tilting type mixer machine; cubes were cast and compacted by using a vibrating rod. The slump was noted for each of the mixes. The concrete cubes, six for each type of mix, were cured in water. The cubes were tested under nominal conditions. Each water-cured cube was taken from water at each of the test age and then rubbed with a clean dry cloth until a saturated surface dry sample was obtained.

D. Test Conducted

Following tests were conducted on hardened concrete to examine the influence industrial waste water on concrete having cement replacement by silica fume.

1) Weight and Density of cubes
2) Compressive Strength Test
3) Split Tensile Strength Test
4) Flexural Strength Test

The weight was measured for cubes taken from curing platform, just prior to compressive strength test (surface dry condition). The value of weight of cubes obtained for normal concrete, silica fumed concrete and concrete prepared by adding waste water is determined.

The compressive strength of specimen with different mix proportion and water cement ratios were tested at the end of 28 days curing period. As large no. of variations in parameter are considered, only three specimen was casted for each proportion. Compressive test was conducted on cubes using compression testing machine of 2000KN capacity.

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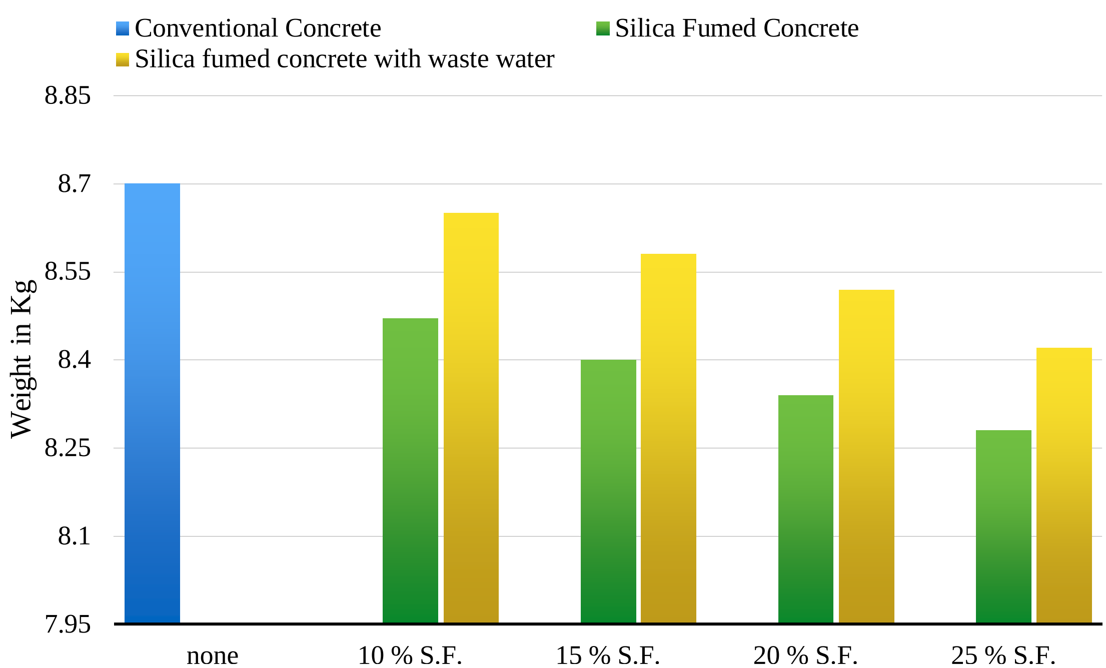
Split tensile strength test was performed on concrete specimen of size 300 mm length and 150 mm diameter. for testing, specimens were taken out of jute sheets and allowed to dry for one hour to get surface dry conditions. Centres of both planes were marked to ensure that both planes lies in same axis while testing the strength of specimen. After that specimen were loaded on machine and strength was calculated. The increase in strength of concrete specimen with respect to normal concrete was also calculated.
Flexural Strength test was performed on concrete species of size 150 mm X 150 mm X 500 mm.for testing, specimens were taken out of jute sheets and allowed to dry for one hour to get surface dry conditions. Centres of both planes were marked to ensure that both planes lies in same axis while testing the strength of specimen. After that specimen were loaded on machine and strength was calculated. The increase in strength of concrete specimen with respect to normal concrete was also calculated.

III. RESULTS

A. Weight and Density Test.

Table-2: Weight of Concrete Specimens

Conventional Concrete	% of Silica Fume	Weight of 28 days cured concrete cubes			
		Silica Fumed Concrete	Decrease	Concrete with waste water	Decrease
8.70 Kg	10%	8.47 Kg	2.64%	8.65 Kg	0.57%
	15%	8.40 Kg	3.45%	8.58 Kg	1.38%
	20%	8.34 Kg	4.13%	8.52 Kg	2.07%
	25%	8.28 Kg	4.82%	8.42 Kg	3.21%



Graph - 1: Comparative Weights of Concrete Specimens

From table 2 and graph 1 it can be seen that weight of concrete cubes decreases as percentage of silica fume increases. Basic reason behind this is weight of silica fume is less than weight of cement. Concrete cubes in which industrial waste water is added shows some higher weights but still it is less than normal concrete. This shows that industrial waste water can be added in concrete when light weight concrete is required to reduce the stresses and strains in structures.

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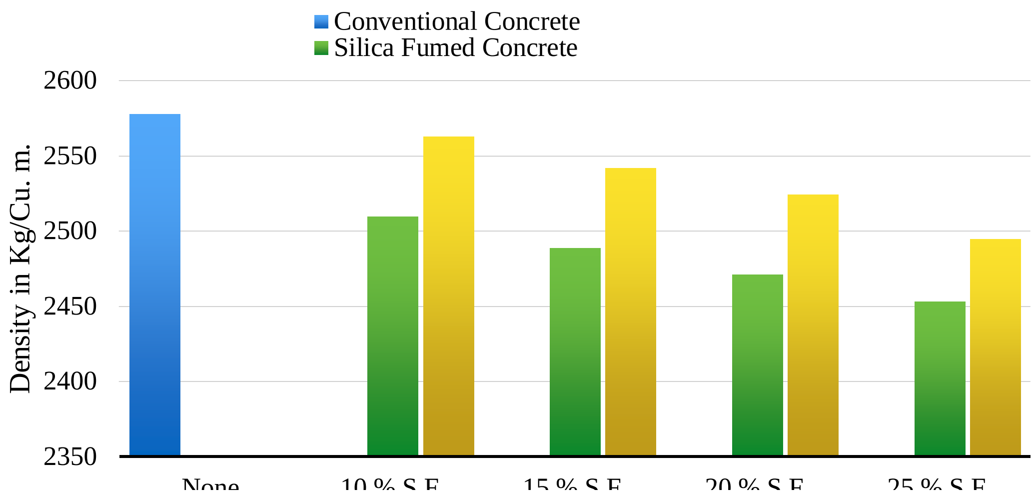
Table-3: Density of Concrete Specimens

Conventional Concrete	% of Silica Fume	Density of 28 days cured concrete cubes (Kg/cu.m)			
		Silica Fumed Concrete	Decrease	Concrete with waste water	Decrease
2577.777	10%	2509.62	2.64%	2562.96	0.57%
	15%	2488.88	3.45%	2542.22	1.38%
	20%	2471.11	4.13%	2524.44	2.07%
	25%	2453.33	4.82%	2494.81	3.21%



Graph - 2: Comparative Density of Concrete Specimens

Table 3 and graph 2 shows that same trend as of weight of cubes can be seen in density of cubes. As percentage of silica fume increases density of the concrete decreases. The density of silica fume concrete is lowest followed by concrete with waste water and normal concrete.

B. Compressive Strength of Concrete Specimens

The compressive strength of specimen with different mix proportion and water cement ratios were tested at the end of 28 days curing period. As large no. of variations in parameter are considered, only three specimen was casted for each proportion. Results of compressive strength test are shown in table 4.

Table-4: Comparative Compressive Strength of Concrete Specimens

Water Cement Ratio	Conventional Concrete	Compressive Strength in MPA				
		% of Silica Fume	Silica Fumed Concrete	% Increase	Concrete with SF & IWW	% Increase
0.44	46.4	10%	47.8	3.10	47.75	2.99
		15%	48.25	4.07	48.22	4.01
		20%	48.75	5.15	48.67	4.98
		25%	48.6	4.83	48.59	4.81

*SF = Silica Fume, IWW = Industrial Waste water

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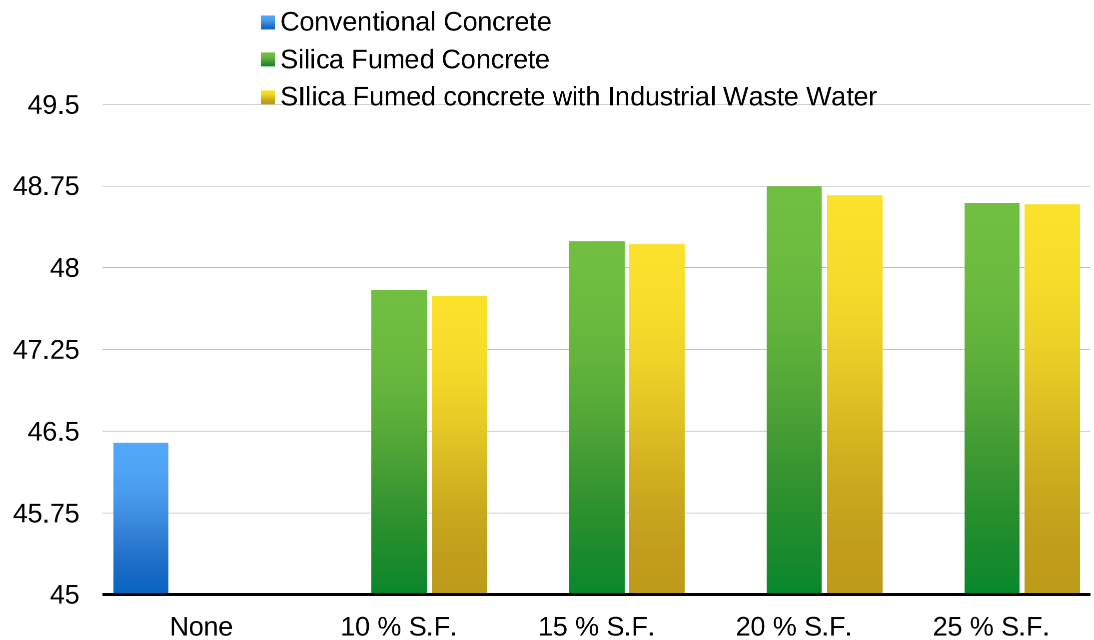

Graph - 3: Comparative Compressive Strength of Concrete Specimens

As we increase the percentages of silica fume replacement upto 20%, compressive strength increase and then it gradually decreases. Also it can be seen that concrete with industrial waste water shows slightly low strength than silica fume concrete. Though strength of concrete with industrial waste water is lower than silica fume concrete it is greater than normal concrete. This shows that when we add industrial waste water in silica fume concrete its strength decreases but it is still higher than normal concrete. When we need a optimisation of resources or when we take environmental issues in consideration it is advisable to add industrial waste water in concrete along with silica fume to enhance its strength.

C. Tensile Strength of Concrete Specimens

Split tensile strength test was performed on concrete specimen of size 300 mm length and 150 mm diameter. for testing, specimens were taken out of jute sheets and allowed to dry for one hour to get surface dry conditions. Centres of both planes were marked to ensure that both planes lies in same axis while testing the strength of specimen. After that specimen were loaded on machine and strength was calculated. The increase in strength of concrete specimen with respect to normal concrete was also calculated and shown in table below

Table-5: Comparative Tensile Strength of Concrete Specimens

Water Cement Ratio	Conventional Concrete	Tensile Strength in MPA				
		% of Silica Fume	Silica Fumed Concrete	% Increase	Concrete with SF & IWW	% Increase
0.44	5.17	10%	5.18	0.19	5.17	0
		15%	5.28	2.12	5.19	0.38
		20%	5.34	3.28	5.26	1.74
		25%	5.29	2.32	5.22	0.98

*SF = Silica Fume, IWW = Industrial Waste water

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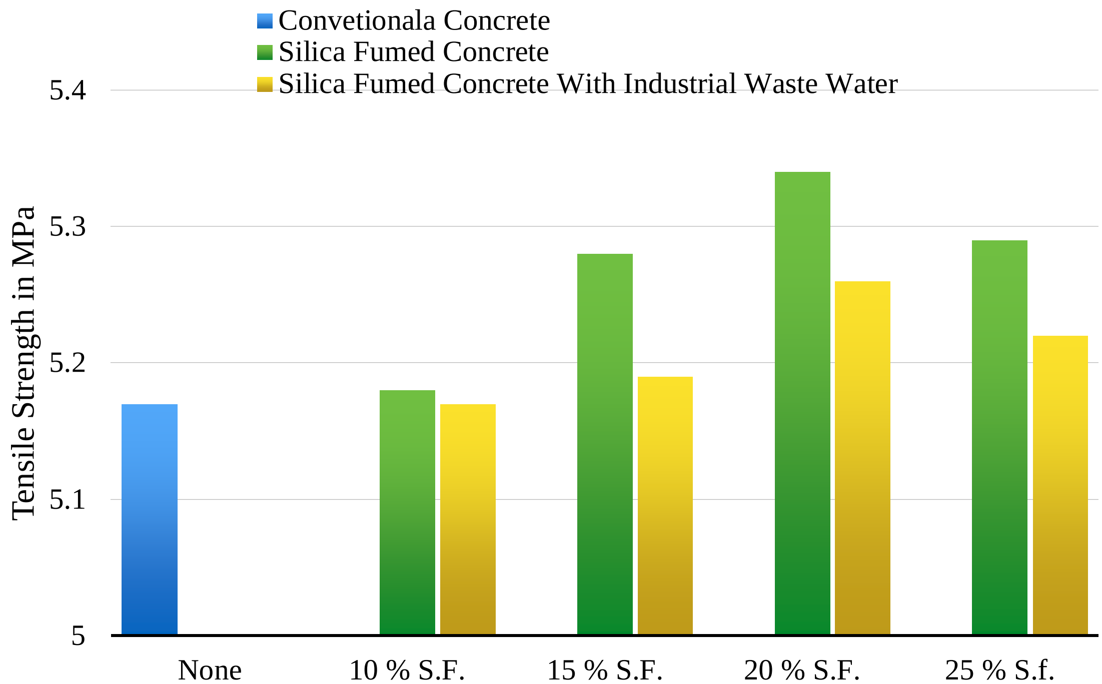


Graph - 4: Comparative Tensile Strength of Concrete Specimens

When we consider the silica fume replacement, we can observe that upto 20% replacement of cement by silica fume, strength of concrete increases but after that is decreases. Also a note should be taken that tensile strength follows the same pattern like compressive strength. As we can see that highest compressive strength can be achieved by adding 20% of silica fume at water cement ratio of 0.44, it should be considered as limits. From graph 8.4, it is also clear that concrete specimen having industrial waste water has lower strength than that of concrete specimen having only silica fume. But still strength of concrete specimen with industrial waste water is higher than normal concrete. This proves that though large quantity of waste water is hazardous for concrete but in limit it may be beneficial from environmental point of view.

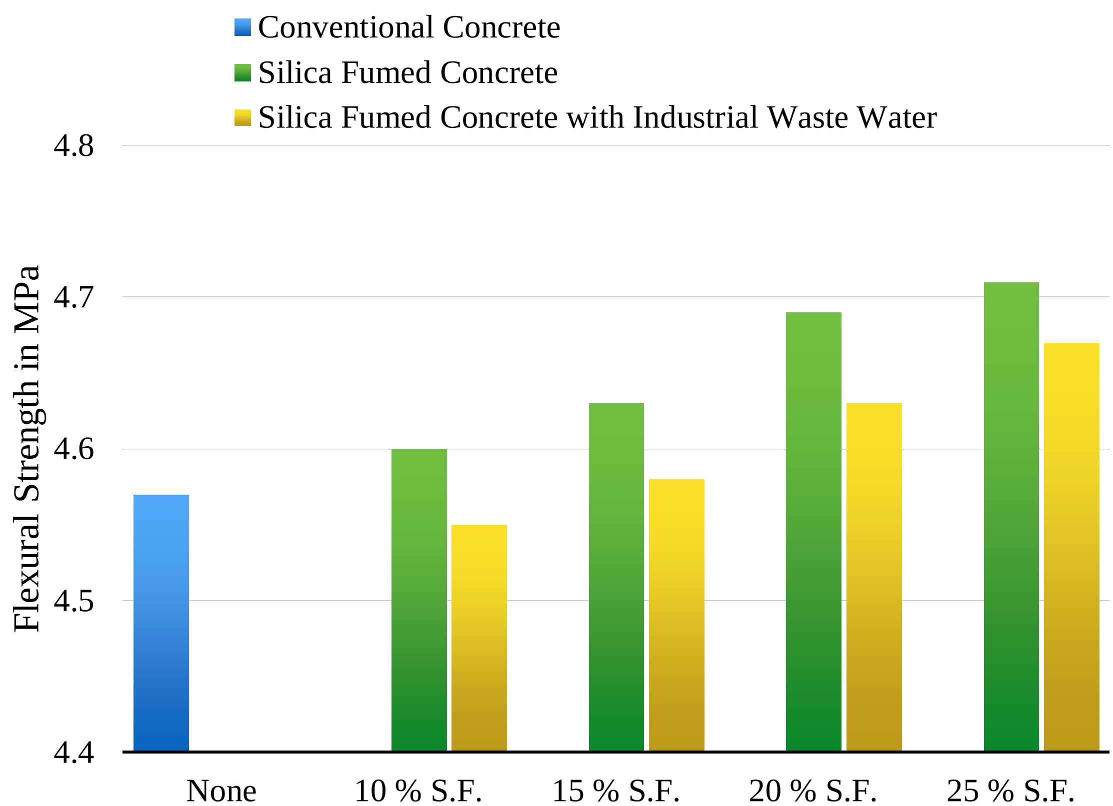
D. Flexural Strength of Concrete Specimens

Flexural Strength test was performed on concrete specimens of size 150 mm X 150 mm X 500 mm.for testing, specimens were taken out of jute sheets and allowed to dry for one hour to get surface dry conditions. Centres of both planes were marked to ensure that both planes lies in same axis while testing the strength of specimen. After that specimen were loaded on machine and strength was calculated. The increase in strength of concrete specimen with respect to normal concrete was also calculated and shown in table 5.

Table-6: Comparative Flexural Strength of Concrete Specimens

Water Cement Ratio	Conventional Concrete	Flexural Strength in MPa				
		% of Silica Fume	Silica Fumed Concrete	% Increase	Concrete with SF & IWW	% Increase
0.44	4.57	10%	4.60	0.65	4.55	-0.43
		15%	4.63	1.31	4.58	0.21
		20%	4.69	2.62	4.63	1.31
		25%	4.71	3.38	4.67	2.18

*SF = Silica Fume, IWW = Industrial Waste water



Graph - 5: Comparative Tensile Strength of Concrete Specimens

Unlike tensile and compressive strengths, Flexural strength continuously goes on increasing with water cement ratio and silica fume percentage. Flexural strength of silica fume concrete is higher than concrete with industrial waste water. Though concrete with industrial waste water is lower than silica fume concrete, it is higher than normal concrete. Though flexural strength increases with water cement ratio and silica fume percentages, both substitutes can not be used above their standard limits as prescribed in Indian Standard Codes.

IV. CONCLUSIONS

A. Weight of the concrete decreases with increase in percentages of silica fume. Concrete with industrial waste water and silica fume with shows slightly higher weight than that of the normal concrete. At 25% replacement of cement by silica fume we get lowest weight of concrete. It is 8.28 Kg (4.82% less) for silica fume concrete and 8.42 Kg (3.21% less) for concrete with silica fume and industrial waste water.

B. Density of the concrete decreases with increase in percentages of silica fume. Concrete with silica fume has lowest density followed by concrete with industrial waste water and normal concrete. Lowest density for silica fume concrete found at 25% replacement is 2453.33 Kg/m^3 (4.827% less) and for concrete with waste water it is 2494.81 Kg/m^3 (3.22% less). Concrete with silica fume and industrial waste water both can be used in structures requiring low density concrete.

C. Silica fume decreases bleeding significantly, because free water is used in wetting of the large surface area of the silica fume. In addition, silica fume blocks the pores in the fresh concrete and stops water from permeate the surface of the concrete.

D. For silica fume percentages it can be seen that upto 20 percentages of replacement of cement by silica fume compressive strength increases then it gradually decreases. For water cement ratio of 0.44 and silica fume replacement of 20% we get highest compressive strength for both type of concrete. For silica fume concrete, highest strength is 48.75 MPa (5.15% higher) and for concrete with waste water it is 48.67 MPa (4.98% higher)

E. Tensile strength follows the same trend as of compressive strength. Upto 20% replacement of cement by silica fume it shows increment and then it gradually goes on decreasing. For water cement ratio of 0.44 and silica fume percentage of 20 we get highest compressive strength. For silica fume concrete highest strength is 5.34 MPa (3.28% higher) and for concrete with waste water it is 5.26 MPa (1.74 % higher).

F. Flexural strength of silica fume concrete is highest followed by concrete with waste water and normal concrete. Highest flexural strength for silica fume concrete is 4.72 MPa (3.38% higher) at 25% replacement and W/C ratio of 0.44. For same ratio and replacement we get strength of 4.67 MPa (2.18% higher) for concrete with silica fume and waste water both.

G. The thermal conductivity can be reduced by the addition of untreated or silane treated silica fume due to the interface between silica fume particles and cement which act as an obstacle against heat conduction.

H. Concrete with industrial waste water and silica fume both can be used effectively in all types of superstructures safely. Additionally it has applications in High wear surface, Acid resistant structural elements.

I. Concrete which consist of silica fume and industrial waste water in optimum proportions can be used adequately in structures having large dynamic loads like bridges, underground tunnels etc.

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