International Journal of Civil Engineering and Technology (IJCIET)
Volume 10, Issue 03, March 2019, pp. 1961–1967, Article ID: IJCIET_10_03_195
Available online at http://iaeme.com/Home/issue/IJCIET?Volume=10&Issue=3
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

INFLUENCE OF INDUSTRIAL BY-PRODUCTS ON THE BEHAVIOR OF HIGH-PERFORMANCE CONCRETE

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ABSTRACT

The by-products obtained from industries such as Silica Fume (SF) and Fly Ash (FA) can be utilized to improve the strength and durability of High-Performance Concrete (HPC). The application of these industrial by-products is becoming common all over the world because of the reduction of their potentially dangerous effects on the environment. This paper investigates the behavior of Silica Fume as a fractional replacement to Ordinary Portland Cement (OPC) on the parameters such as water permeability, compressive strength, split tensile strength and flexural tensile strength of High-Performance Concrete (HPC). HPC mixes with silica fume contents of 0 %, 5%, 7.5%, and 10% and a constant proportion of 10% fly ash was adopted in the trial mixes. Superplasticizer in optimum dosage was added to achieve required workability. Tests were conducted to determine the optimum proportion of Silica fume which yields appreciable Fresh and hardened state properties.

Key words: High-performance concrete, workability, flyash, Silica fume, Superplasticizers, Split tensile strength, Flexural strength., Compressive Strength, Partial replacement.

Cite this Article: Kannan. S.U., Raja. M. A., Nalanth. N., Shalini. J, Influence of Industrial By-Products on the Behavior of High-Performance Concrete, *International Journal of Civil Engineering and Technology* 10(3), 2019, pp. 1961–1967.
http://iaeme.com/Home/issue/IJCIET?Volume=10&Issue=3

1. INTRODUCTION

High-Performance Concrete (HPC) is now extensively used globally for the reason that it exhibits high workability, high compactness with a high modulus of elasticity, high dimensional stability with moderate abrasion and impact resistance, high strength and penetration resistance. As per American Concrete Institute (ACI), High-Performance Concrete is well-defined as, "concrete that meets distinct combinations of performance and homogeneity requirements that cannot always be accomplished routinely using conventional ingredients and regular mixing, placing, and curing practices."(I. B. Muhit et al. 2013)

HPC always has a low water/cement ratio in the range of 0.20 to 0.45 (Kosmatka et al2003). The use of high range water reducing admixtures in HPC is essential to attain enhanced workability. It is also found that the use of silica fume (SF) as a supplementary cementitious material (SCM) in HPC is vital if the desired high strength is to be achieved. Fly ash (FA) is another SCM used optionally in HPC, mainly to enhance its workability and durability (Muhit, I. B. et al. 2013). The large amount of CO_2 emissions generated during the production of OPC is a major contributor to global warming and the greenhouse effect. Hence regarding sustainability, the minimum use of OPC for the production of any concrete is desirable. One potential option in this regard is to use SCMs appropriately. As discussed, SF and FA are commonly used in HPC. If the optimum usage of these SCMs can be identified, it can have a positive impact on sustainability. Many investigations have been carried out to examine the behavior of concrete with either SF or FA. There are also mix proportioning guidelines available in this regard. However, a few studies have studied the combined use of these two SCMs. This study, therefore, investigates, through experimental research, the optimum combined use of silica fume & flyash in the production of HPC. An experimental series comprised of HPC mixes in which SF & FA contents were each varied from 0%, 5%, 7.5%, and 10 % was conducted.

2. MATERIALS AND PROPORTION

Normally HPC is composed of following components Ordinary Portland cement, fine aggregate, coarse aggregate, mineral admixture, chemical admixture, superplasticizer, and water. Ordinary Portland Cement of grade 43 conforming the IS 12269 – 1987 has been used for this investigation. River sand accessible in the local area was used as a fine aggregate which conforms the IS383 –1970 and comes under the grading Zone II. Crushed blue stones of size 20 mm conforming to IS: 383 – 1970 was used as a coarse aggregate. FA generated from the thermal power plant was used as a mineral admixture in powdered dry form. Silica fume conforming to IS15388:2003 was used as a mineral admixture in a densely powdered form. Superplasticizer was used as a chemical admixture which aids to reduce the water content in the concrete and also used to reach the required workability of the HPC. A commercially available polycarboxylate based superplasticizer was used in this investigation (R.M. Karthikeyan et al. 2017). Replacement or partial replacement of the cement by SF and FA enhance the properties of the HPC. In this investigation, different proportion of SF and FA has been used to form the HPC, and the strength is calculated through the Compressive strength test, split tensile strength, flexural strength test, and water absorption test. Properties of OPC are listed in the following Table 1.

Table 1 Properties of 43 grade OPC

Test particulars	Result obtained	Requirements as per IS:8112-1989
Specific gravity	3.15	3.10-3.15
Normal consistency (%)	31	30-35
Initial setting time (min)	29	30 max
Final setting time (min)	540	600 max
Compressive strength (MPa)		
a) 3 days	26	23
b)7 days	35	33
c) 28 days	47	43

3. MIX PROPORTIONING

In this investigation, different mixtures are considered for the study. M1, M2, M3, M4 are the mixtures obtained by replacing cement by 0, 5, 7.5, 10 percent of SF and the mixtures M5, M6, M7 are obtained by the same percent of SF mentioned above with the 10% of fly ash. The proportion mixes are mentioned in Table 2. FA is manufactured from the combustion of ground or powdered coal. Increased strength with lower permeability is achieved by hardened FA concrete resulting in a higher resistance towards aggressive admixtures. Also, partial replacement of cement with FA decreases the production cost of concrete due to the lower price of FA compared to cement. (Visnu et al. 2017). SF is a very fine non-crystalline SiO_2, which is a by-product of the glass industry. It is made at a temperature of approximately 2000° C, and its size is about 0.1μm. SF acts as an excellent pore-filling material. It can be used in proportions of 5 – 10% of cement content in a mix. SF of its extreme fineness and high silica content is a high silica content is a highly effective pozzolanic material. Silica fume reacts pozzolanically with the calcium hydroxide during the hydration of cement to form the stable cementitious compound calcium silicate hydrate(C-S-H)gel.

Table 2 Mix Proportions Quantities in kg/m^3

Mix	Cement kg/m^3	SF kg/m^3	FA kg/m^3	Fine Aggregate kg/m^3	Coarse Aggregate kg/m^3	SP Lit/m^3
M1	571.57	0	0	610.27	1171.8	6.97
M2	542.99	28.58	0	599.81	1171.8	8.83
M3	528.7	42.87	0	594.58	1171.8	9.23
M4	514.41	57.16	0	589.35	1171.8	9.75
M5	485.83	28.58	57.16	577.28	1171.8	16.72
M6	471.55	42.87	57.16	572.05	1171.8	17.19
M7	457.26	57.16	57.16	566.82	1171.8	17.19

4. EXPERIMENTAL PROCEDURE

In this investigation, the mixes M1-M7 were tested to evaluate the properties of the HPC. Compressive strength test, split tensile strength, flexural strength test and water absorption test were conducted based on which the optimum mix is identified.

4.1. Compressive Strength Test

The capability of the concrete to carry the loads without any cracking or deflection is called compressive strength. Factors influencing

Compressive strength is water absorption rate, the ratio of water to cement, quality of concrete material and quality control during concrete production. This test was performed based on IS: 516-1959. 10x10x10 cm cube was taken for the test. After the curing process, the specimen was subjected to test in a compression testing machine of the capacity of 2000KN, and the results are given in Table 6., From the table it is evident that the mix M3 containing 7.5% of silica fume attained the maximum compressive strength of 60 MPa.

Table 3 Description of Mixes

MIX	% silica fume	% of fly ash
M1	0	0
M2	5	0
M3	7.5	0
M4	10	0
M5	5	10
M6	7.5	10
M7	10	10

4.2. Split tensile strength test

Split tensile strength test was conducted based on the IS:5816- 1999. Tensile strength is a measure of maximum load at which the concrete may crack. Cylindrical specimens of age 28 days were subjected to testing as shown in shown in Figure.3. Split tensile strength is directly correlated with the compressive strength (Manu S. Nadesan and Dhinakar 2017). From the tabulation given below, it is clear that the mix M3 gives the highest tensile strength. Here the SF percentage is 7.5 this value is compared with the control mix tensile strength value. The strength of M3 is 17.06% greater than the normal concrete mix.

Table 4 Split tensile strength test

Mix	SF (%)	FA (%)	28 days (MPa)
M1	0	0	4.98
M2	5	0	5.03
M3	7.5	0	5.83
M4	10	0	5.09
M5	5	10	5.62
M6	7.5	10	5.19
M7	10	10	5.01

Table 5 Cube Compressive Strength

Mix	Silica Fume (%)	Flyash (%)	7 days (MPa)	28 days (MPa)	90 days (MPa)
M1	0	0	42.33	54.67	66.67
M2	5	0	40.67	55.00	67.67
M3	7.5	0	44.67	61.33	76.33
M4	10	0	40.33	56.33	71.67
M5	5	10	42.33	58.67	74.33
M6	7.5	10	41	57.33	73.67
M7	10	10	39.33	55.33	67.33

4.3. Flexural strength

Flexural strength was conducted in accordance with IS 516-1959. The test was carried out on 100mm x100mm x500mm size concrete prism. Universal Testing Machine of 400kN capacity was used to conduct the test, where two-point loading was adopted. The load was applied to the uppermost surface, along two lines spaced 13.3 cm apart. The load was gradually increased until the specimen failed and the values were recorded.

Table 6 Flexural Strength Result Mix

Mix	Silica fume (%)	Flyash (%)	28 Days (MPa)
M1	0	0	4.59
M2	5	0	5.13
M3	7.5	0	5.96
M4	10	0	5.23
M5	5	10	5.71
M6	7.5	10	5.36
M7	10	10	5.09

Above table shows water absorption value is reduced when the mix proportion of silica fume and flyash was increased. Pozzolanic material added in higher proportion reduces the water absorption property. With the help of two mineral admixtures, FA and SF the mechanical properties and the pozzolanic reactions of the mix results in the strongest and durable concrete.(B. Karthikeyan and G. Dhinakaran 2017

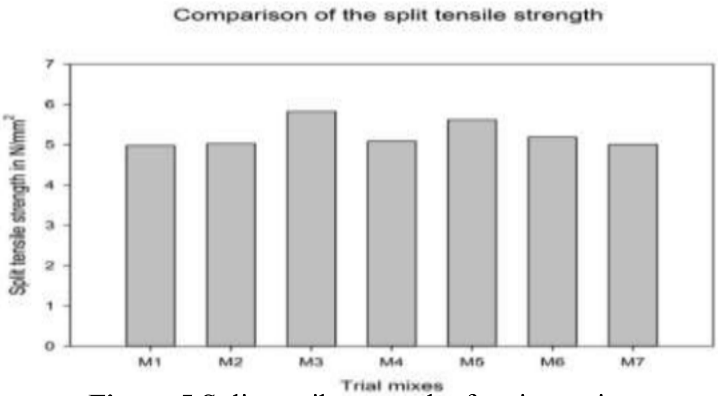

Figure 5 Split tensile strength of various mixes

5. RESULT AND DISCUSSION

SF has strong effects in compressive strength of concrete at 7, 28 and 90days of age. The difference of compressive strength for dissimilar replacement levels of OPC by silica fume is shown in Table 6 It is clear that maximum compressive strength can be obtained by the replacement of 7.5% OPC with silica fume. An increase in compressive strength of about 12.56% was observed.

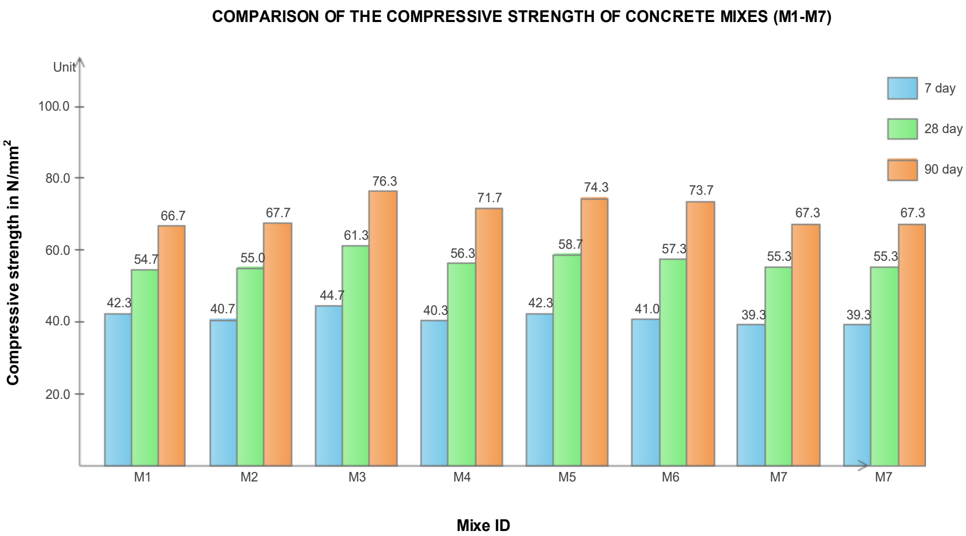

Figure 4 Compressive strength at 7, 28 and 90 days

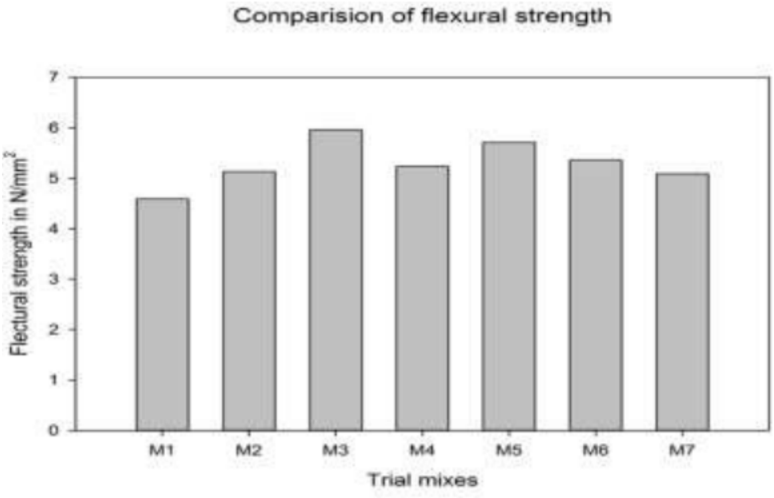

Figure 6 Flexural Strength of various mixes

Like SF, FA has strong effects in compressive strength of concrete. The difference of compressive strength for dissimilar replacement levels of OPC by Fly Ash at 7, 28 and 90 days are shown in Figure 4.So, it can be concluded that maximum compressive strength can be obtained by replacing 10% OPC with fly ash.

Optimum level of SF can play a great role in increasing the split tensile strength. Split tensile strength for different replacement level of OPC by silica fume for28days aged concrete are shown in Table 4. Ultimately it can be decided that the partial replacement of 7.5% OPC by silica fume was found to be optimum and 14.57% split tensile strength was increased from control mix (SF-I) at 28 days. Optimum level of FA can play a significant role in increasing the split tensile strength of concrete. Split tensile strength for different replacement level of OPC by fly ash for 28days aged concrete are shown in Table 4. It is decided that the partial replacement of 10% OPC by fly ash was found to be optimum and more than 28% split tensile strength was increased from control mix (FA-I) at 28 days. Flexural tensile strength for different replacement levels of OPC by silica fume are shown in Table 7. Eventually it can be decided that the partial replacement of 7.5% silica fume was found to be optimum and an increase of 22.98% flexural tensile strength was attained by (M3) at 28 days. Fly Ash has strong effects on the flexural tensile strength of concrete. The variation of flexural tensile strength for different replacement levels of OPC by fly ash for given in Table 7 Ultimately it can be decided that the partial replacement of 10% fly ash was found to be optimum

6. CONCLUSIONS

The superplasticizer demand of concrete containing fly ash and silica fume increases with increasing amount of fly ash and silica fume. The increase is primarily due to the high surface area of the fly ash and silica fume. Fresh concrete containing fly ash and silica fume is more cohesive and less prone to segregation. From the experimental results, it is evident that the compressive strength of high-performance concrete containing 7.5% of silica fume is 12.18% higher than the normal concrete. The split tensile strength of high-performance concrete containing 7.5% of silica fume is 17.06% higher than the normal concrete. Also, the flexural strength of high-performance concrete containing 7.5% of silica fume is 29.8 % higher than the normal concrete. It is found that as the age of concrete increases, the compressive strength also increases. Silica fume concrete attains high strength than silica fume with fly ash concrete. Durability test indicates that when more pozzolanic material is added to concrete, the Water Absorption will reduce.

REFERENCES

[1] SudarsanaRao.Hunchate Sashidhar.n Chandupalle, Vaishali.G.Ghorpode and Venkata Reddy.T.C4 Mix Design of High-Performance Concrete Using Silica Fume and Superplasticizer, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 3, Issue 3, March 2014, Pages 10735-10742

[2] I. B. Muhit1, S. S. Ahmed2, M. M. Amin1 and M. T. Raihan1 Effects of Silica Fume and Fly Ash as Partial Replacement of Cement on Water Permeability and Strength of High-Performance Concrete Association of Civil and Environmental Engineers, 2013, Pages - 109-115

[3] Manu S. Nadesan, P. Dinakar, Structural concrete using sintered fly ash lightweight aggregate: A review, Construction and Building Materials, Volume 154, 2017, Pages 928-944

[4] Kosmatka, S., Kerkhoff, B. and Panarese, W,"Design and Control of Concrete Mixtures," 1sted. Skokie: Portland Cement Association., 2003.

[5] R.M.D.M. Sanjeewa, P.S.K. Pathirana, and H.D. Yapa, Mix Design Aspects of High-Performance Concrete Comprised of Silica Fume and Fly Ash ENGINEER - Vol. L, No. 04, pp. [23-29], 2017

[6] EN, B., 2001. 206-1: 2000 Concrete. Specification, Performance, Production, and Conformity BSI.

[7] R.M.Karthikeyan1, K.M.Ramkumar2*, D Jayalin3, Experimental Study on High-Performance Concrete and High Volume Flyash Concrete using Polypropylene Fibre, International Journal of Chem Tech Research, Vol.10 No.8, pp 276-283, 2017

[8] S.V.V.K.Babu, N.Ch.Anjaneyulu, V.SrinivasaRao Experimental Investigation on High-Performance Concrete with Partial Replacement of Cement by Fly Ash and Fully Replacement of Sand by Stone Dust, International Journal of Constructive Research in Civil Engineering (ICRC) Volume 1, Issue 1, June 2015, PP 8-13

[9] V.Visnu R.M.Karthikeyan Dr. G. Prince Arulraj, Experimental Investigation on High-Performance Concrete with Partial Replacements of Fine Aggregate by M-Sand and Cement by Fly Ash, International Journal On Engineering Technology and Sciences – IJETS ISSN (P): 2349-3968, ISSN (O): 2349-3976 Volume 2 Issue 2, February 2015

[10] B. Karthikeyan, G. Dhinakaran, Influence of ultrafine TiO2 and silica fume on the performance of unreinforced and fiber reinforced concrete, Construction, and Building Materials, Volume 161, 2018, Pages 570-576

[11] Ankit Kumar 1 , N Kisku 2 Effect of Silica Fume and Fly Ash as Partial Replacement of Cement on the strength of Concrete International Journal of Innovative Research in Science, Engineering and Technology, Vol. 5, Issue 10, October 2016