High Strength Waterproof Concrete using Various Admixtures

Atul Singhal[1] Srushti Jariwala[2] Kajal Patel[3] Nishit Ramshawala[4] Shyam Doshi[5]
[1,2,3,4]B.E. Students [5]Assistant Professor
[1,2,3,4,5]Department of Civil Engineering
[1,2,3,4,5]Bhagwan Mahavir College of Engineering & Technology, Gujarat, India

Abstract— The use of silica fume had major impact on industries, ability to routinely and commercially produce silica fume modified concrete of flow able in nature but yet remain cohesive, which in turn produces high early and later age strength including resistant to aggressive environments. This study is an experiment on the nature of silica fume and its influences with waterproofing admixture on the properties of fresh concrete. As after adding waterproofing admixtures in the concrete, it reduces the compressive strength of the concrete. After partial replacement of cement by silica fume with an addition of waterproofing admixture the strength parameters of concrete have been studied. First the strength parameters of concrete without any partial replacement were studied then strength parameters by partial replacement with silica fume have been studied by placing cube on compression testing machine (CTM). Silica fume were used to replace 0% to 15% of cement by weight. The results showed that partial replacement of cement with silica fume had significant effect on the compressive strength of cube, Durability and Split Tensile Strength. The strength of concrete increases rapidly as we increases the silica fume content and the optimum value of compressive strength is obtained at 10% replacement. After 10% it starts decreasing under uniform load condition of 4 KN.

Key words: Cement, Concrete, Compressive Strength, Silica Fume, Waterproofing Admixtures

I. INTRODUCTION

In today's generation, we have to look at a way to reduce the cost of building materials, especially cement without increasing the cost. Nowadays, cement is so costly that only rich people & government can afford. This study is carried out to investigate the possibility of utilizing materials as partial replacement materials for cement in the production of concrete. This study also investigates the strength properties of micro silica concrete and dampness in concrete is also a major problem nowadays but adding waterproofing admixtures has a great impact on the strength and durability of the concrete so we have to find out a way that will give us a strong waterproof / damp proof concrete at a lower cost. Thus adding silica fume and waterproofing admixtures simultaneously in the concrete can solve the problem.

II. EXPERIMENTAL INVESTIGATION

A. Materials

1) Cement

Ordinary Portland Cement of 53 grade was used in the present study which surpasses Specifications (IS 8112-1989) on compressive strength levels.

2) Fine Aggregate

Natural sand as per IS: 383-1970 was used. Locally available River sand having bulk density 2610 kg/m^3 was used. The properties of fine aggregate are shown in Table 1

Sr. No	Property	Result
1	Specific Gravity	2.61
2	Fineness modulus	3.10
3	Grading zone	II

Table 1: Properties of fine aggregate

3) Coarse Aggregate

Crushed aggregate confirming to IS 383:1970 was used. Aggregates of size 10 mm of specific gravity 2.83 and fineness modulus 6.28 were used.

4) Water

Generally, water that is suitable for drinking is satisfactory for use in concrete. The portable water is generally considered satisfactory for use in concrete.

5) Silica Fume

Micro silica is a byproduct of some industries so it becomes cheaper than cement. It is also known as silica fume, condensed silica fume and silica dust too. It is powder based product having color as white or grey. Its specific gravity is 2.2 to 2.3. The size of micro silica is lesser than 1 µm.

6) Waterprrofing Admixture (Hydraproof Combination)

Hydraproof combination is a unique composition of the present need. Hydraproof Combination is a ready to use liquid highly effective super plasticiser for cement concrete. It is primarily based on Sodium salt, Naphthalene Formaldehyde sulphonate condensate. Immediately it mixes with water on addition. It acts as a triple function additive for producing free flowing concrete. It has a powerful deflocculating and dispersing effect on the cement particles results into concrete with zero slump/collapse slump, literally a flowing concrete. The concrete results with low permeability and fine surfacefinish.

III. MIX PROPORTIONING

Concrete mix design in this experiment was designed as per the guidelines specified in I.S. 10262-1982. But some restriction is imposed by restricting the amount of cementations material content is equal to 450 Kg/m^3. The Table 2 shows mix proportion of concrete (Kg/m^3):

w/c ratio	Cement	F.A	C.A	Water
0.5	1.293	2.703	3.671	0.646

Table 2: Mix Proportion of M25 grade

w/c ratio	Cement	F.A	C.A	Water
0.45	1.327	2.544	3.814	0.642

Table 3: Mix Proportion of M30 grade

IV. METHODOLOGY

The first testing of silica fume in Portland-cement-based concretes was carried out in 1952. The biggest drawback to exploring the properties of silica fume was a lack of material with which to experiment. Early research used an expensive additive called fumed silica, an amorphous form of silica made by combustion of silicon tetrachloride in a hydrogenoxygen flame. Silica fume on the other hand, is a very fine pozzolanic, amorphous material, a by-product of the production of elemental silicon or ferrosilicon alloys in electric arc furnaces. Before the late 1960s in Europe and the mid-1970s in the United States, silica fumes were simply vented into the atmosphere.

With the implementation of tougher environmental laws during the mid-1970s, silicon smelters began to collect the silica fume and search for its applications. The early work done in Norway received most of the attention, since it had shown that Portland cement-based-concretes containing silica fumes had very high strengths and low porosities. Since then the research and development of silica fume made it one of the world's most valuable and versatile admixtures for concrete and cementitous products.

No.	Categories	Description
1	Size	≤ 1μmm
2	Shape	Spherical

Table 4 Physical properties of silica fume

No.	Test Parameters	Results
1	Loss of ignition	0.08%
2	Silica (SiO_2)	99.67%
3	Iron (Fe_2O_3)	0.015%
4	Alumina (AbO_3)	0.07%
5	Calcium (CaO)	0.04%
6	Magnesium (Mg)	0.02%
7	Sodium (Na_2O)	0.05%
8	Potassium (K_2O)	0.01%

Table 5 Chemical properties of silica fume

A. *Compressive Strength Test:*

In most structural applications, concrete is employed primarily to resist compressive stresses. When a plain concrete member is subjected to compression, the failure of the member takes place, in its vertical plane along the diagonal. The vertical crack occurs due to lateral tensile strains. A flow in the concrete, which is in the form of micro crack along the vertical axis of the member will take place on the application of axial compression load and propagate further due to the lateral tensile strains.The load was applied axially without shock till the specimen was crushed. Results of the compressive strength test on concrete with and without varying proportions (0%, 3%, 5%, 10% and 15%) of silica fume replacement at the age of 7days, 14 days and 28 days were noted. The cubes were tested using compression testing machine (CTM).

$$P/A = \text{Compressive stress.}$$

Where, P = Load (N) and A = Area (mm^2)

B. *Split Tensile Strength Test:*

Split tensile strength test was carried out conforming to IS 516-1959 to obtain tensile strength of concrete at the age of 28 days. The cylinders of size 100mm in diameter and 200mm in length were tested using compression testing machine (CTM). The uniform applied loading of 2KN is given to sample in compression testing machine (CTM). The split tensile strength of concrete is most often evaluated using a split cylinder test, in which a cylindrical specimen is placed on its side and loaded in diametrical compression, so to induce transverse tension.

Practically, the load applied on the cylindrical concrete specimen induce tensile stresses on the plane containing the load and relatively high compressive stresses on the plane containing the load and high compressive stresses in the area immediately around it. The split tensile strength obtained by formula given below:

$$T = 0.637P/DL$$

Where,
T= split tensile strength in MPa.
P = Applied load.
D = Diameter of concrete cylinder sample in mm.
L = length of concrete cylinder sample in mm.

C. *Durability Test:*

Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties.

D. Resistance to Sulfate Attack:

High amounts of sulfates in soil or water can attack and destroy a concrete that is not properly designed. Sulfates (for example calcium sulfate, sodium sulfate, and magnesium sulfate) can attack concrete by reacting with hydrated compounds in the hardened cement paste. These reactions can induce sufficient pressure to slowly cause disintegration of the concrete. Like natural rock such as limestone, porous concrete (generally with a high water-cementitious ratio) is susceptible to weathering caused by salt crystallization.

Examples of salts known to cause weathering of concrete include sodium carbonate and sodium sulfate. Sulfate attack and salt crystallization are more severe at locations where the concrete is exposed to wetting and drying cycles, than continuously wet cycles. For the best defense against external sulfate attack, concrete with a low water to cementitious material ratio (w/cm) (less than 0.45 for moderate sulfate environments and less than 0.40 for more severe environments) should be used along with cements or cementitious material combinations specially formulated for sulfate environments

E. *Resistance to Sea Water:*

The durability of concrete is regarded as its ability to resists the effects and influences of the environment while performing its desired functions. Over the year it has become very necessary and imperative to ascertain the qualities of properties of coastal structures (oil platform, sea wall, buck head etc) in contact with sea water as they tend to perform their functions during the period of their design life. The properties of concrete structures such as strength, durability, stability, resistance to frost & thaw action etc require thorough investigation. The effect of seawater on concrete has remained a major problem associated with structures either built in sea water or cast or cured with sea water. The presence of sodium chloride in sea water accelerates the attack on other compounds on the concrete. The chemical action of seawater on concrete is mainly due to attack by Magnesium sulphate ($MgSO_4$). This attack is by crystallization. It has been established that potassium and magnesium sulphates (K_2SO_4 & $MgSO_4$) present in seawater can cause sulphate attack in concrete as a result of initial reaction with calcium hydroxide [$Ca(OH)_2$] which present in set cement and form by hydration of C_3S & C_2S.

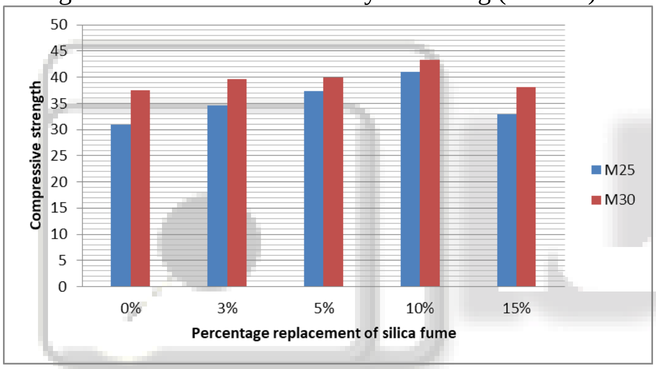
Seawater tends to increase the risk of corrosion of embedded steel reinforcement when the structure is duely exposed to air. The most damaging effect of seawater on concrete structures arises from the attack of chlorides on the steel reinforcement and salt build up. The increase in the risk of corrosion of steel limits the use of seawater in steel reinforced structures, if prior preventive measures are not put in place. Preventive measures include the coating of reinforcement steel with cement slurry mixed with fresh water.

V. RESULTS AND DISCUSSION

A. *Compressive Strength:*

MS	CEMENT	M25	M30
0%	100%	30.93	37.42
3%	97%	34.58	39.67
5%	95%	37.34	39.93
10%	90%	40.95	43.23
15%	85%	32.90	38.06

Table 6: Compressive strength results of M25 and M30 grade of concrete after 28 days of curing (N/mm2)

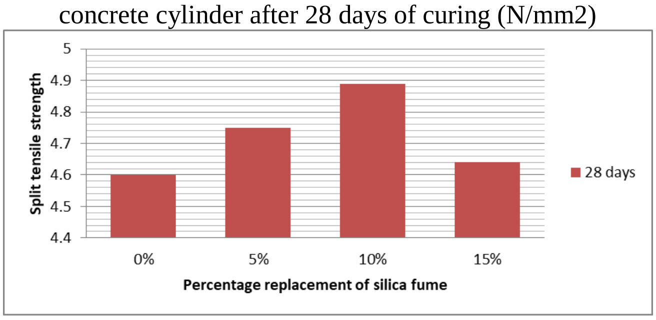


Graph 1: Graphical representation of compressive strength results of M25 and M30 grade of concrete cube after days of curing (N/mm^2)

B. *Split Tensile Strength:*

Mix (%)	STS (N/mm^2)		Avg. STS(28days)
	Specimen1	Specimen2	
0	4.46	4.75	4.60
5	4.82	4.67	4.75
10	4.91	4.88	4.89
15	4.72	4.55	4.64

Table 7: Split tensile strength results of M30 grade of concrete cylinder after 28 days of curing (N/mm2)

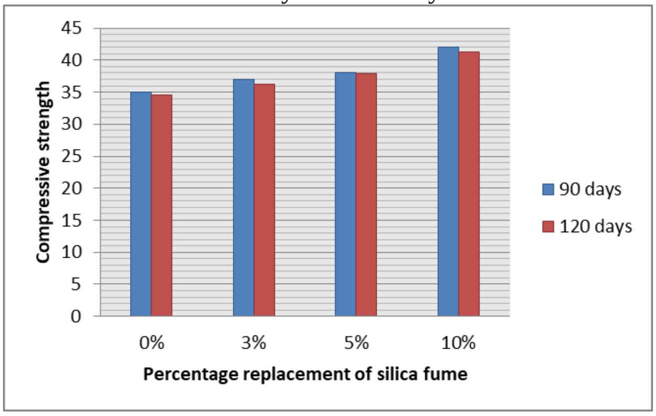


Graph 2: split tensile strength results of M30 grade of concrete cylinder after 28 days of curing (N/mm^2)

C. *Durability Test Results:*

MS%	Avg. C.S. (N/mm^2)		Average weight (kg)			
	90 Days	120 Days	Before curing		After curing	
			90 day	120 day	90 day	120 day
0	35.03	34.52	9.23	9.17	7.82	7.70
3	36.93	36.17	9.71	9.68	7.96	7.81
5	38.12	37.91	9.77	9.75	8.15	8.07
10	41.97	41.29	10.0	9.98	8.63	8.24

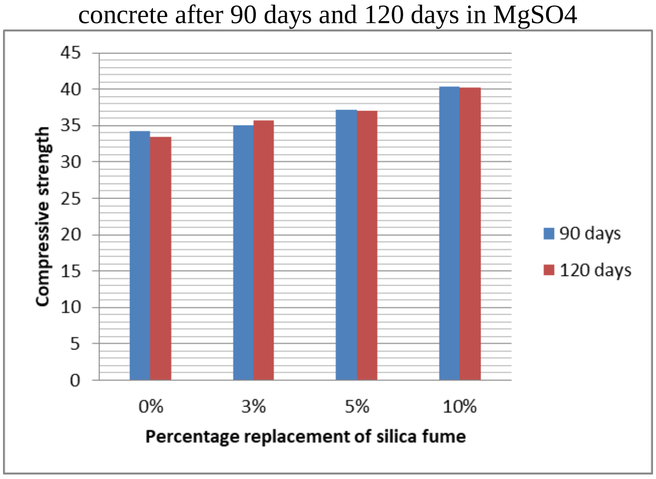
Table 8: compressive strength results of M30 grade of concrete after 90 days and 120 days in sea water



Graph 3: compressive strength results of M30 grade of concrete after 90 days and 120 days in sea water

MS%	Avg. C.S. (N/mm^2)		Average weight (kg)			
	90 Days	120 Days	Before curing		After curing	
			90 day	120day	90 day	120 day
0	34.21	33.41	9.33	9.31	7.71	7.52
3	35.09	35.72	9.82	9.79	7.83	7.67
5	37.17	37.01	9.87	9.85	8.19	8.05
10	40.31	40.21	9.94	9.90	8.77	8.69

Table 9: compressive strength results of M30 grade of concrete after 90 days and 120 days in MgSO4



Graph 4: compressive strength results of M30 grade of concrete after 90 days and 120 days in $MgSO_4$

VI. CONCLUSION

It may be concluded that use of silica fume is a necessity in production of not only for high strength concrete but also for low/medium strength concrete as this material facilitate the adoption of lower water - cement material ratio and better hydration of cement particles including strong bonding amongst the particles. From the study it has been observed that maximum compressive strength is noted for 10% replacement of cement with silica fume and the values are higher than those of the normal concrete cube whereas split tensile strength of the SF concrete is increased respectively as compared to the normal concrete when 10% of cement is replaced by SF. As the SF concrete is more compact and thereby more durable in nature and hence with some degree of quality control, it may be used in places of construction where there is a chance of chemical attack, frost action etc. Lastly with good quality control, high early strength can be achieved in SF concrete which may be useful in various structural constructions such as high-rise buildings, bridges, chimneys, machine foundations, run ways etc., wherein, the timeframe of completion vis-à-vis the economy is an important driven factor for the targeted purpose as well as for the contractors and owners alike as this concrete will provides quick stage by stage or floor to floor construction.

ACKNOWLEDGMENT

We thank you for giving us the opportunity to develop the project. Then our humble thanks to all professors and all staff members of our college for the co-operation and keep interest extended by them throughout our B.E. course. It is the base that they have built, which sustains such good job. We deeply owe our gratitude to my project guide Mr. Shyam K. Doshi, who inspires us to undertake this project. His dynamic guidance and continuous interest kept us going inspite of all the difficulties. We would also like to admit thanks to the person who helped us as well as my friends throughout our Bachelor’s Study. We would also like to thanks him to be our external guide for helping us lot through the beginning.We would also thank all the staff members of civil department for their kind support at various stages of the work. It is beyond the reach of our language to express our sincere gratitude to our parents for their infinite inspiration and sacrifices for the benefit of our academic career.

REFERENCES

[1] Ray, I, De, A and Chakraborty, Fifth Conference on Concrete Technology for High Slump Concrete, Vol 1, p.p 86-93
[2] Joshi, N. G. Bandra – Worli Sea Link: Evolution of HPC mixes containing Silica Fume, Indian Concrete Journal, (Oct. 2001), pp. 627-633
[3] Saini, S, Dhuri, S. S, Kanhere, D. K, Momin, S. S. High Performances concrete for an urban viaduct in Mumbai, Indian Concrete Journal, (Oct. 2001) , pp. 656-664.
[4] Basu, P. C. : NPP containment structures Indian experience in Silica Fume –based HPC, Indian Concrete Journal, (Oct. 2001), pp. 656- 664.
[5] Thomas, M D. A. Using Silica Fume to Combat ASR in Concrete, Indian Concrete Journal, (Oct. 2001), pp 656-664
[6] Lewis, R. C. ,Hasbi, S. A. : Use of Silica Fume concrete :Selective case studies, Indian Concrete Journal, (Oct. 2001), pp. 645-652.
[7] Roncero, J., Gettu, R., Agullo, L. , Vazquez, E. : Flow behaviour of superplasticised cement pastes : Influence of Silica Fume, Indian Concrete Journal, (Jan. 2002), pp. 31-35.
[8] Vishnoi, R. K. , Gopalakrishnan, M. : Tehri Dam Project : Silica Fume in High Performance Concrete for Ensuring Abrasion Erosion Resistance, Proceedings organised by Indian Society for Construction Materials and Structures, (February 2003), pp. 28-40.
[9] Kanstad, T, Biontegaard, O, Sellevold, E. J, Hammer, T. A. and Fidjestol, P. Effect of Silica Fume on Crack Sensivity, Concrete International, (Dec. 2001), pp 53-59
[10] AbhinavShyam, Abdullah Anwar, Syed Aqeel Ahmad (2016). Experimental Investigation on Properties of Silica Fumes as a Partial Replacement ofCement.
[11] N.K. Amudhavalli& J. Mathew (2012). Effect of silica fume on strength and durability parameters of concrete.
[12] S. Sudhakar, K. G. Raveendran, V. Rameshkumar, M. Sravanan, P. Kanmani (2015). Performance of silica fume on strength and Durability of Concrete.
[13] V. S. Ghutke& P. S. Bhandari (2014). Influence of silica fume on concrete.
[14] D. Pradhan, & D. Dutta (2013). Effects of Silica Fume in Conventional Concrete.
[15] Lakhbir Singh, Arjun Kumar, Anil Singh (2016). Study of partial replacement of cement by silica fume.
[16] Referred Book – Concrete Technology (Theory and Practice) By M. S.Shetty
[17] IS 12269:2013 Ordinary Portland Cement 53 Grade Specification
[18] IS 383:1970 Specifications For Coarse And Fine Aggregates from Natural Sources forConcrete
[19] IS 456:2000 Plain and Reinforced Concrete - Code of Practice
[20] IS 2386:1963 Method Of Test For Aggregates Of Concrete
[21] IS 516:1959 Methods For Test Of Strength Of Concrete
[22] IS 5816-1999 Split tensile strength of concrete-method of test

