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A Study on Efficiency Factor of Silica Fume

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ABSTRACT

The mineral admixtures are generally industrial by products and their use can provide a major economic and environmental benefit.The relative performance of various supplementary cementitious material can be compared with that of Portland cement using the practical concept of efficiency factor 'k'. The utilization of supplementary cementitious material is well accepted because of the several improvements possible in the concrete composites, the present study is an effort to quantify the strength of silica fume at various replacement levels and evaluate their efficiencies in concrete. This study reports the results of an experimental study, conducted to evaluate the strength and strength efficiency factor of hardened concrete, by partial replacing the cement by 5%, 10%, 15%, 20%, 25% of silica fume for M50 grade concrete at ages of 7days, 14days, 28days, 90days. The overall efficiency of silica fumes depending upon percentage replacement of silica fume and age of concrete. The optimum of silica fumes replacement as cementitious material characterized by high compressive strength and low heat of hydration. From this study we concluded that the grain size of silica fume is less than cement, and highly reactive properties causes improve the early strength over short period.

KEYWORDS: *Silica fume, High Compressive strength.*

I. INTRODUCTION

1.1 General

Rapid industrial development causes serious problems all over the world such as depletion of natural aggregate and creates enormous of waste materials from the construction and demolition activities .one of the ways to reduce this problem is to utilize the wastes. Portland cement can be partially replaced by cementitious and Pozzolanic materials especially those of industry such as fly ash, GGBS, silica fume, ceramic waste powder and metamorphic rock dust from stone cutting industry. Hence this research is to find the efficiency factor for Different mineral admixtures like silica fume (SF) Replacement levels so that according to the target strength, the corresponding Mineral Admixtures can be replaced to get High Performance Concrete using Bolomey equation was used.

1.2 Development of Silica Fume Concrete

Owing to liberalization, privatization and globalization, the construction of important infrastructure projects like express ways, airports, and nuclear plants etc.., are increasing year after year in India .such development activities consume large quantities of precious natural resources .this leads to depletion of natural resources on one side and manifold increase in cost of construction of structure on other side, which is a major problem in construction sector today. The following are the main reasons for the development of concrete using silica fume as partial replacing for cement.

- Depletion of natural resources can be prevented to some extent.
- Disposal of waste in barren land can be reduced.
- Use of silica fume as a partial replacement for cement in concrete id effective in reducing both cost and environmental pollution.
- The concrete with mineral admixtures provides lower permeability
- Reduced heat of hydration, reduced alkali-aggregate reaction
- High strength and Chemical attack.

1.3 Material Used

Cement:- Ordinary Portland cement of 53 grade jaypee cements conforming to IS: 8112 – 1989 was used for the present experimental investigation. Cement was tested as per the procedure given in IS: 4031 and IS: 4032.

Fine Aggregate:- Natural river sand with fraction passing through 4.75 mm sieve and retained on 600 μm sieve was Used and tested as per IS: 2386.

Coarse Aggregate:- Crushed granite coarse aggregates of particle shape "average and cubic" was used for the present Investigation .The coarse aggregates were tested as per the procedure given in IS: 2386.20mm and 10mm size coarse aggregate are used.

Water:- Potable tap water available in the laboratory with pH value of 7.0±1 and confirming to the Requirements of IS: 456 - 2000 was used for mixing concrete and curing the specimens as well.

Mineral Admixture:- Silica fume is a by - product resulting from the reduction of high purity quartz with coal in electric arc furnaces in the manufacture of silicon and ferrosilicon alloys. The fume has a high content of amorphous silicon dioxide from the gases escaping from the furnace.

Chemical Admixture:- In this investigation, super plasticizer Conplast SP 430, based on sulphonated naphthalene polymers complies with IS 9103- 1999, BS: 5075 part 3 and ASTM C – 494, Type F was used.

1.4 Object

The main objective of the work is studying the effect on strength on partial replacement of cement with silica fume. In this work we study the comparison between strength variation on NCC and silica fume concrete. From this study we find out how much economy can be attained on a using silica fume as partial replacement for cement .the objectives of the work are follows

- Determine the ways to utilize industrial wastes in most effective and ecologically, environmentally, socially and finally responsible manner.
- Develop industrial waste management methods.
- Develop to mitigate and ultimately avoid the industrial waste materials.
- Develop ways to use industrial waste as raw material for making construction material.
- To develop environmental friendly method of construction.
- To make the best use of the industrial means of construction.
- To overcome the problem of waste disposal crisis caused to industries.

1.5 Scope

The aim of this research is to find out efficiency of silica fume so as to develop a mix design procedure by considering the efficiency factor for silica fume, with different replacement levels at 7,14,28 and 90 days. Hence, according to the target strength, the test specimens such as standard 150 mm cubes were cast using steel moulds and care was taken to see that the moulds were filled with concrete in three equal layers and were compacted well using a table vibrator. The specimens were remoulded after 24 hours and cured in water. The mechanical properties of hardened concrete, such as compressive strength and split tensile strength were evaluated in accordance with IS: 516 -1959.

After required mix proportion is achieved, cement is replaced with silica fume by 5%,10%,15%,20%,25%.in incase cubes were casted and tests were conducted. The effect of strength of mix is determined for corresponding increment of percentage silica fume replacement by observing the compressive strength test. The comparisons between the strength of conventional concrete that are casted on the mix design are proposed.

II. LITERATURE REVIEW

H.S. Wong, H. Abdul Razak, Efficiency of calcined kaolin and silica fume as cement replacement material for strength performance.

In this paper, a relative strength-based method to obtain efficiency values for strength performance is used. The first mixture is the OPC control mixture, while the second is a blended mixture containing a Pozzolanic material as a partial replacement for cement. The total cementitious materials content and other mixture characteristics, such as water and aggregate contents, are the same for both mixtures. In addition, both mixtures are subjected to similar curing history. Therefore, strength development for the control is principally dependent on the rate of cement hydration, while for the blended mixture, is dependent on the combination of cement hydration and Pozzolanic reaction. By observing the relative strength, which is defined as ratio of strengths of the blended mixture to the control, an understanding of the rates of reaction in a blended Pozzolanic system relative to the control system can be achieved. If the Pozzolanic contributes positively to strength development at a certain age, then the resulting relative strength value will be greater than unity.

Michele Valente, Michele vigneri, Marcom Bressan, Alessandro Pasqualini, and Use of fly ash in concrete: efficiency factors of the supplementary cementing materials.

The use of the Pozzolanic activity index characteristic the efficiency of fly ash. Although the factor of efficiency can be defined for any concrete property, this study will reference specifically the compressive strength and the permeability to chlorides. The use of laboratory tests on concrete enables this study to verify the relationship between the efficiency factors. **Conclusion:** the effect of fly ash on the concrete's properties was described using the efficiency factor .in this study the fly ash efficiency factor was referred to very important properties: compressive strength and permeability to chlorides. The variability of aforesaid experimental data obtained in this study show much lower values at 56 days and 90days concrete.

III. SILICA FUME HISTORY

Silica fume (SF) is a by-product of the smelting process in the silicon and ferrosilicon industry. The reduction of high-purity quartz to silicon at temperatures up to 2,000^{0}C produces SiO_2 vapours, which oxidizes and condense in the low temperature zone to tiny particles consisting of non-crystalline silica. By-products of the production of silicon metal and the ferrosilicon alloys having silicon contents of 75% or more contain 85–95% non-crystalline silica.

Silica fume has been recognized as a Pozzolanic admixture that is effective in improves the mechanical properties to a great extent. By using silica fume along with super plasticizers, it is relatively easier to obtain compressive strengths of order of 100–150 MPa in laboratory. Using Addition of silica fume to concrete improves the durability of concrete through reduction in the permeability, refined pore structure, leading to a reduction in the diffusion of harmful ions, reduces calcium hydroxide content which results in a higher resistance to sulphate attack. Improvement in durability will also improve the ability of silica fume concrete in protecting the embedded steel from corrosion.

Physical properties of silica fume

property	value
Particle size (typical)	1 lm
Bulk density As-produced	130–430 kg/m^3
Surface area (BET)	13,000–30,000 m^2/kg
Specific gravity	2.22
Densified	480–720 kg/m^3
Slurry	1,320–1,440 kg/m^3

Chemical composition of silica fume

Chemical component	% by weight
Sio_2	90-96
Al_2o_3	0.-0.8
Fe_2o_3	0.2-0.8
MgO	0.5-1.5
Cao	0.1-0.5
Na_2o	0.2-0.7
K_2o	0.4-1.0
C	0.5-1.4
S	0.1-0.4
Loss of ignition	0.7-2.5

IV. EXPERIMENTAL PROGRAM

Tests on Cement:-

- Standard consistency of 53 grade of jaypee cement is found 30%.
- Initial setting time 77 minutes

- Final setting time 220 minutes
- Specific gravity of cement 3.076
- Compressive strength of Cement for 53 Grade

Days	Compressive strength in N/mm^2
3 Days	26.32
7 days	37.11
28 days	53.39

Tests on Fine Aggregate

SI.NO	Test conducted	Values
1	Specific gravity	2.63
2	Uncompact bulk density	1.1%
3	Compacted bulk density	1496.29kg/m^3
4	Water absorption	1614.81kg/m^3
5	Fineness modulus	2.82

Tests on Coarse Aggregate

SI.NO	Test conducted	Values
1	Specific gravity	2.7
2	Un compacted bulk density	1.1%
3	Compacted bulk density	1496.29kg/m^3
4	Water absorption	1377.78skg/m^3
5	Fineness modulus	6.29

Mix Design for M50 Grade Concrete

Cement: Fine Aggregate: Coarse Aggregate = 1: 1.35: 2.59 & Water Cement Ration = 0.37

Table quantities of material used for normal mix and silica fume mix:

Materials used	Normal concrete	5% of silica fume	10% of silica fume	15% of silica fume	10% of silica fume	25% of silica fume
Cement kg/m^3	460	437	411	398	368	345
Silica fume kg/m^3	0	23	46	69	92	115
Fine aggregate kg/m^3	625	625	625	625	625	625
Coarse aggregate kg/m^3	1191.64	1191.64	1191.64	1191.64	1191.64	1191.64
Super plasticizer kg/m^3	4.6	4.6	4.6	4.6	4.6	4.6
Water kg/m^3	170	170	170	170	170	170

V. RESULTS AND DISCUSSION

Compressive strength test is the most common test conducted on hardened concrete this is because, it is an easy to perform and most of desirable characteristic properties concrete are quality related to its compressive strength.

Compressive test is conducted on 150x150x150mm cubes. Concrete cube specimen are removed from curing tank and wiped clean and allowed to dry from some time .the test is conducted in UTM of capacity 300T.

The compression tests were carried out at 7, 14, 28, and 90 days.

Cube compressive strength =load/ area of cross section of cube.

Fig1: compressive strength test of cube

Table Compressive strength of concrete for Different days

Mix No	Silica fume Replacement	Compressive Strength(MPa)			
		7days	14days	28days	90days
A-1	0	44.44	46.667	53.7	54
A-2	5	45.33	47.55	55.11	56
A-3	10	47.11	48.89	57.77	59
A-4	15	49.77	52	64	65.22
A-5	20	48	51.55	60	60
A-6	25	47.11	49.77	57.77	58.22

From the above Table it has been observed that the compressive strength increased 0% to 15% and then decreased 20% to 25% of silica fume replacement. The optimum percentage of silica fume replaced by 15% and corresponding compressive strength is 64 MPa.

Fig 1: 7 days compressive strength at different percentage levels:

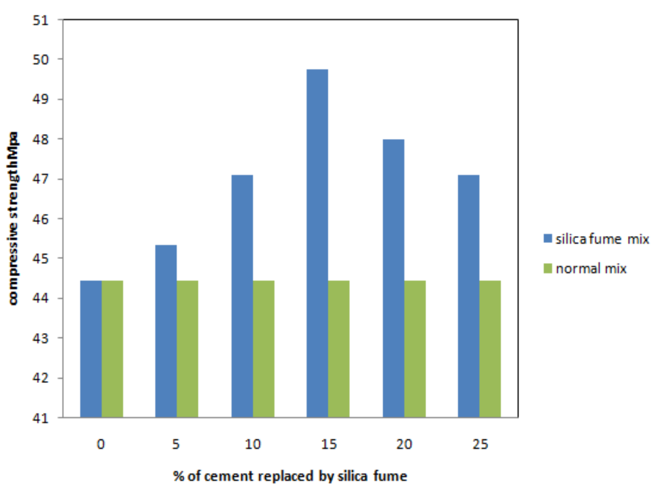

Fig 1 shows the variation of compressive strength with silica fume replacement percentage. There is a significant improvement in the compressive strength of concrete because of the high Pozzolanic nature of the silica fume and void filling ability. The compressive strength with replacement of cement by silica fume was increased 0% to 15% and then decreased. Hence the optimum silica fume was 15%. Optimum compressive strength for 7 days is 49.77 Mpa.

Fig 2: 14 days compressive strength at different replacement level

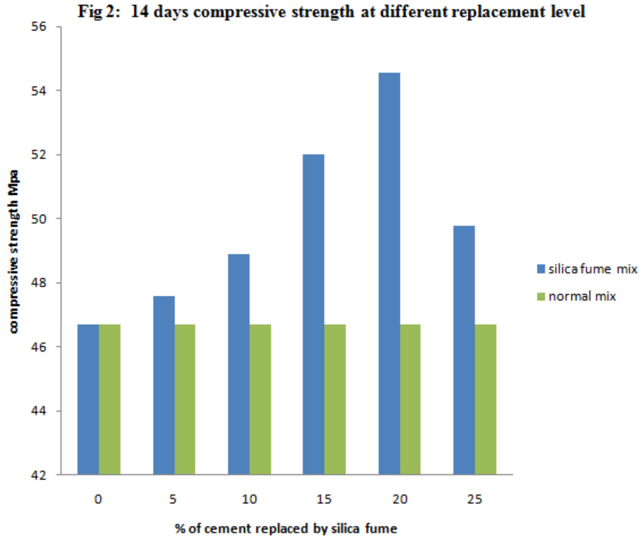

Fig 2 shows the variation of compressive strength with silica fume replacement percentage. There is a significant improvement in the compressive strength of concrete because of the high Pozzolanic nature of the silica fume and void filling ability. The compressive strength with replacement of cement by silica fume was increased 0% to 15% and then decreased. Hence the optimum silica fume was 15%. The optimum silica fume replacement percentage for obtaining maximum 14 day strength of concrete ranged from 5% to 15%.[10] The maximum value of compressive strength was obtained as 52 MPa at 15% replacement of silica fume.

Fig 3 28 days compressive strength at different replacement level

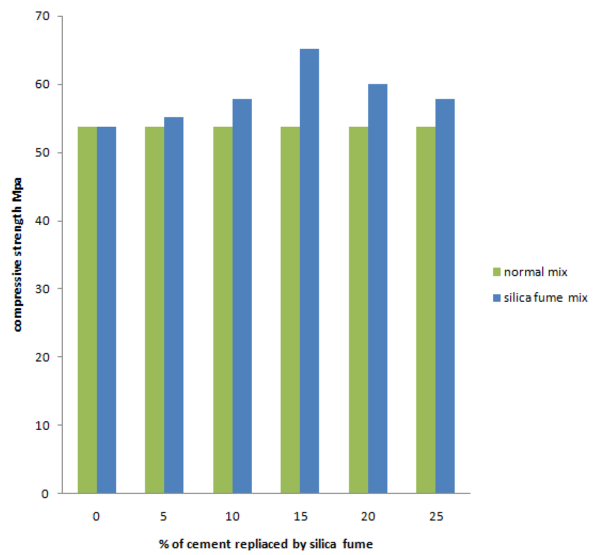

Fig 3 shows the variation of compressive strength with silica fume replacement percentage. There is a significant improvement in the compressive strength of concrete because of the high Pozzolanic nature of the silica fume and void filling ability. The compressive strength with replacement of cement by silica fume was increased 0% to 15% and then decreased. Hence the optimum silica fume was 15%. The optimum silica fume replacement percentage for obtaining maximum 28-day strength of concrete ranged from 5% to 15%. The maximum value of compressive strength was obtained as 64MPa at 15% replacement of silica fume.

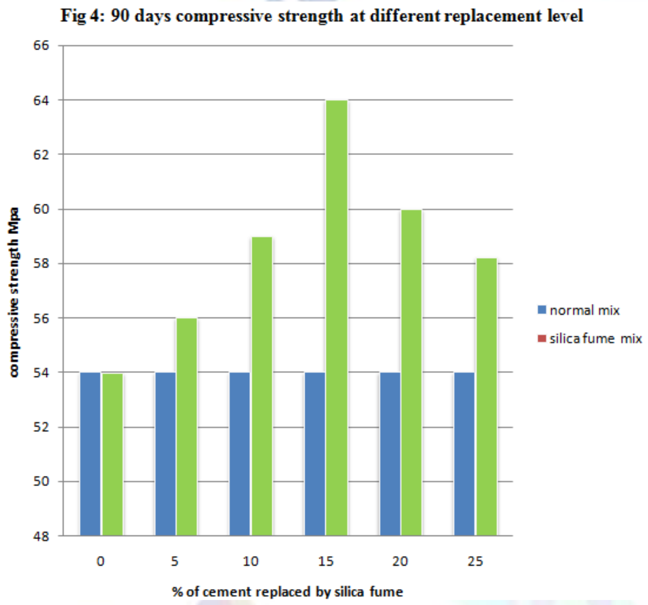

Fig 4 shows the variation of compressive strength with silica fume replacement percentage. There is a significant improvement in the compressive strength of concrete because of the high Pozzolanic nature of the silica fume and void filling ability. The compressive strength with replacement of cement by silica fume was increased 0% to 15% and then decreased. Hence the optimum silica fume was15%. The optimum silica fume replacement percentage for obtaining maximum 90-day strength of concrete ranged from 5% to 25%. [10] The maximum value of compressive strength was obtained as 65.22Mpa at 15% replacement of silica fume.

VI. EFFICIENCY FACTOR OF SILICA FUME

The cementing efficiency factor, '*k*' of a Pozzolanic material is defined as the number of parts of cement in a concrete mixture that could be replaced by one part of Pozzolanic material without changing the property being investigated, which is usually the compressive strength[Babe and Rao (1996)].the efficiency factor for strength performance of a Pozzolanic material is calculated on the basis of comparison between concrete strength and the w/c ratio for a non-blended mixture and between concrete strength and w/b ratio for a blended mixture[Wong and Razak (2005)]. a way that the strength to water cement ratio relation for normal concrete is also valid for fly ash concrete considering the effective water cement ratio, as given by [$w/(c + kf)$], where w is the weight of water in kg/m3, c is the weight of cement in kg/m3, f is the weight of Pozzolanic material in kg/m3 and 'k' is the efficiency factor of Pozzolanic material in concrete. He found that the strength and workability of the fly ash concrete with effective w/b ratio [$w/(c + kf)$], is comparable to that of the conventional concrete without fly ash having same water content and w/b ratio. The suggested a value of 0.25 for this cementing efficiency, 'k' of fly ash for replacements up to 25% [Babu and Rao (1996)].

For calculating the efficiency of silica fume, an equation has been proposed by author based on the principle of Bolomey's equation

$$S = A\,[(C/W) - 0.5] \text{ -------- } (4)$$

In above equation the constant is calculated by using normal mix compressive strength, and then we determine the efficiency factor of silica fume mixes for various replacement levels Compute Bolomey's Coefficient 'A' value from the equation (5) by substituting values for S, C and W at 0% replacement for M $_{50}$at 7,14and 28 and 90 days. Using computed 'A' value, the strength efficiency factors 'k' at all ages for all percentage replacement levels of silica fume mix concrete.

Table: Bolomey's constant (A) value for normal mix concrete

Curing period	Bolomey's constant A
7days	20.24
14days	21.25
28days	24.46
90days	24.59

EFFICIENCY OF SILICA FUME:

The contribution of silica fume ability to any property of hardened silica fume concrete may be expressed in terms of efficiency factor, k. For compressive strength of silica fume mix , k is in the range of 1.18 to 1.98for m50 concrete mix with 0.371 water/cement ratios at 7,14,28and 90 days, which means that in a given concrete, 1 kg of silica fume, may replace 1.18 to 2 kg of cement without impairing the compressive strength.

When the efficiency factor 'k' of silica fume at optimum % of replacement in normal mix concrete. It is evident that strength efficiency in silica fume concrete is increased by 18.5%.and in my investigation I was observed that the efficiency factor was decreasing with increase the silica fume content after optimum % replacement level.

Table: compressive strength and efficiency factor of silica fume for different age at different replacement levels

Mix No	Silica fume Replacement	Compressive Strength(Mpa)				Efficiency Factor (K)			
		7days	14days	28days	90days	7days	14days	28days	90days
A-1	0%	44.44	46.667	53.7	54	–	–	–	–
A-2	5%	45.33	47.55	55.11	56	1.249	1.23	1.35	1.52
A-3	10%	47.11	48.89	57.77	59	1.51	1.41	1.64	1.78
A-4	15%	49.77	52	65.22	64	1.62	1.64	1.832	1.977
A-5	20%	48	51.55	60	60	1.30	1.41	1.456	1.43
A-6	25%	47.11	49.77	57.77	58.22	1.179	1.20	1.36	1.24

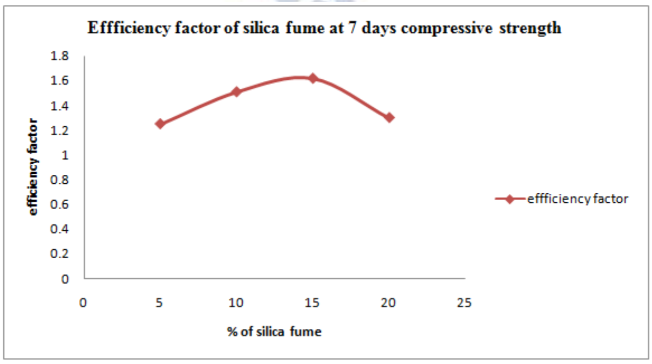

Fig 1: 7days efficiency factor for different replacement levels of silica fume

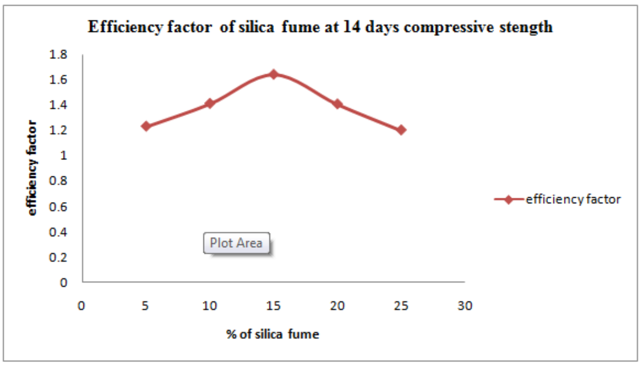

Fig 2:14 day's efficiency factor for different replacement levels of silica fume

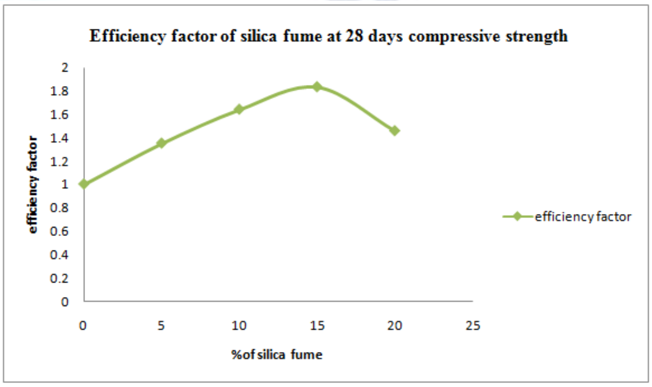

Fig 3: 28days efficiency factor for different replacement levels of silica fume

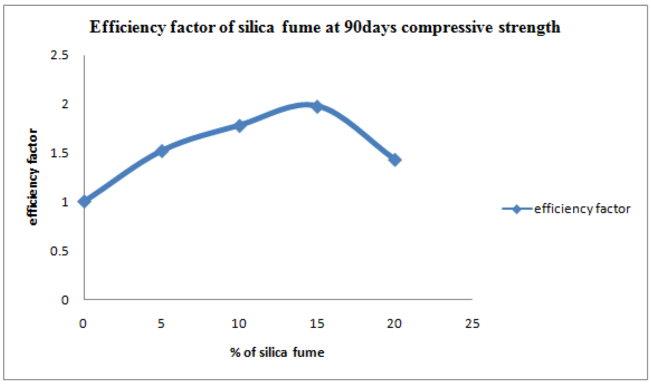

Fig 4:90days efficiency factor for different replacement levels of silica fume

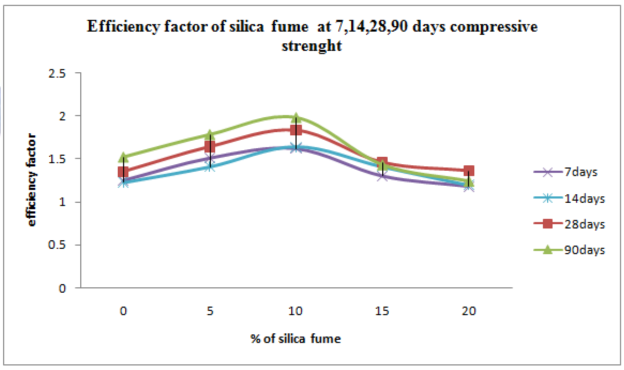

Fig 5**:** comparison of efficiency factor for silica fumes at 7, 14, 28, and 90 days compressive strength.

Fig 5 show that the efficiency factor of silica fume is increased up to 15 % of silica fume replacement and then decreased 20 to 25%.The contribution of silica fume ability to any property of hardened silica fume concrete may be expressed in terms of efficiency factor, k. For compressive strength of silica fume mix , k is in the range of 1.18 to 1.98for m50 concrete mix with 0.371 water/cement ratios at 7,14, 28and 90 days, which means that in a given concrete, 1 kg of silica fume, may replace 1.18 to 2 kg of cement without impairing the compressive strength.

VII. CONCLUSION

1. Silica fume is a Pozzolanic cementitious materials, it can be used as cement replacement material.
2. Using silica fume waste in concrete can solve several environmental problems.
3. Silica fume surface area is more than the cement surface area so, the silica fumes absorb the water content in concrete mix when replaced, and causes decrease in the slump values.
4. The compressive strength for silica fume replaced concrete mixes show increasing trend as the replacement level is increased up to 15% and then decreasing trend.
5. The maximum value of compressive strength obtained was 49.77MPa at 15% replacement of silica fume at 7days and increased to 11.9% compared with conventional concrete.
6. The maximum value of compressive strength obtained was 52MPa at 15% replacement of silica fume at 14days and increased to 11.9% compared with conventional concrete.
7. The maximum value of compressive strength obtained was 64MPa at 15% replacement of silica fume at 28days and increased to 19.1% compared with conventional concrete.
8. The maximum value of compressive strength obtained was 65.22MPa at 15% replacement of silica fume at 90days and increased to 20% compared with conventional concrete.
9. The efficiency factor for silica fume replaced concrete mixes show increasing trend, as the replacement level is increased up to 15% and then decreasing trend.
10. Efficiency factor increases with age which shows the activation of Pozzolanic activity of Mineral admixtures with time.
11. It is evident that strength efficiency in silica fume concrete is increased by 18.5%.and the efficiency factor was decreasing with increase the silica fume content after optimum15% replacement level.
12. It is evident that1 kg of silica fume, may replace 1.18 to 2 kg of cement without impairing the compressive strength.

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