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Study on Effect of Silica Fume on Mechanical Properties of Concrete

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Abstract:
With increased environmental awareness and its potential hazardous effects, utilization of industrial by products has become an attractive alternative to disposal. Silica fume(SF), which is by product of the smelting process in the silicon and ferrosilicon industry.This paper presents the results of an experimental investigations carried out to find the suitability of silica fume in concrete. An experimental investigation has been carried out by partially with the replacement with micro silica in varying percentage i.e. by weight of OPC cement. Further to it, the comparison is made within various grades of concrete (M40, M45 & M50) and two type of cements (OPC & PPC- Fly Ash Base). 150mm x 150mm x150mm cubes were cast for respective designs of concrete and concretes of designated micro silica replacement as per the said percentage. Testing of the specimens were executed on compressive strength testing machine after ponding curing of 7days, 14 days and 28 days. The finding of the test is if a limited percentage of micro silica be replaced by cement then the blended cement concrete has substantial positive effects on the compressive strength of concrete, but there was a higher demand of super plasticizer. Its use will lead to a reduction in cement quantity required for construction purposes and hence sustainability in the construction industry as well as economic construction..

I. INTRODUCTION

Silica fume can be used either as a densified or undensified powder, a slurry, as a combination at the concrete mixer, or part of a factory-blended cement. The Report provides detailed information and references for further reading, on the effect of these materials on the fresh and hardened properties of concrete. Concrete is a most widely used construction material which is a mixture of cement, fine aggregate, coarse aggregate and water. It can be used for construction of multistory buildings, dams, road pavement, tanks, offshore structures, canal lining and many more. The process of selecting suitable ingredients of concrete and determining their relative amount with the objective of producing a concrete of the required strength durability and workability as economically as possible is termed the concrete mix design. The compressive strength of hardened concrete is generally considered to be an index of its other properties depends upon many.Earlier engineers, architects and builders were not been always energy conscious or concerned with the preservation and protection of the environment or conservation of resources. Portland cement is a relatively expensive material in terms of energy spent in its production. The use of industrial by-products or waste materials can result in major saving of energy and raw materials more so when these by-products have only scrap value in order to prove they say " waste is not waste, rather a resource out of site". In addition, by utilizing the industrial wastes in useful manner the environmental pollution also is reduced to a great extent

II. EXPERIMENTAL INVESTIGATION

A. The Experimental Programme was designed to compare the mechanical properties of M40, M45 & M50 grade of concrete with different replacement levels of ordinary Portland cement 53 grade with silica fume. The replacement levels of cement by silicafume are selected as 2%,4%, 6%, 8%,10%, 12%, 14%, 16%.The specimens of Cube specimen of size 150 x 150 x 150 mm were prepared with and without silica fume.

B. Materials Used are Cement, Fine aggregate, Coarse aggregate, Silica Fume, super plasticizer, Non shrinkage grout powder, water.

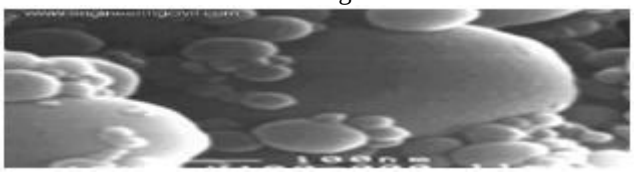
Properties of the material:

Ordinary Portland cement of 53 Grade was used and the specific gravity of cement was found to be 3.15.

No.	Particulars	Chemical Formula	Avg. %	Range
1	Lime	Cao	63	62 to 67
2	Silica	Sio_2	22	17 to 25
3	Alumina	Al_2O_3	05	3 to 8
4	Calcium Sulphate	$CaSO_4$	03	3 to 4
5	Iron Oxide	Fe_2O_3	03	3 to 4
6	Magnesia	MgO	02	0.1 to 3
7	Sulphur	SO_3	01	1 to 3
8	Alkalies		01	0.2 to 1
	Total		100	

(Source: Saurashtra Cement ltd. Technical division publication 2007)

– micro silica 920 D conforming to ASTM C1240.



	Unit	Micro-silica
SiO2	%	90 – 98
CaO	%	0.2 - 0.7
Al2O3	%	0.4 - 0.9
Fe_2O_3	%	1 – 2
Other	%	2 – 3
S.G	Kg/m^3	2200
Bulk density	Kg/m^3	550 – 650
Surface area	m2/kg	20,000

Description of Hind Super Plast SCA: Hind Plast Super SCA is a new generation Super plasticizer for concrete based on Polycarboxylic Ether Polymer with long lateral chains. Hind Plast Super SCA gets the cement to be dispersed to a greater extent and combines the properties to produce self-compacting non-shrinkable concrete with high range water reduction and workability retentions. It is also helpful for the production of high performance concrete with high workability. It conforms to IS: 9103: 1999 (Reaffirmed 2004) Edition 2.2 (2007-08), ASTM C494, Type F & G and IS: 2645: 2003.

Description of Fosroc CEBEX – 100 Grout Powder
It is an Expanding Grout Admixture for pressure injection grouting of cement milk into concrete and can also be admixed with cement used for concreting to prevent shrinkage of cement. It can also be added to cement sand mortar to compensate the drying shrinkage of cement. Cebex 100, a plasticised expanding grout admixture is supplied as a powder. The material is a combination of a plasticizing agent and a gas producing expansion medium. The plastisicing agent allows the use of a reduced water/cement ratio with consequent increased strengths and durability. The expansive medium counteracts the natural settlement and plastic shrinkage of the grout and aids stability and cohesion. Cebex 100 is a suitable pressure grouting admixture complying with BS: 8110 Part 1-1985, Section 8.9.4.6.

Followings are the specifications of aggregates.

Sl No	Test carried on for	Name of the Test Conducted	Procedural Compliance as per codal reference	UOM	Required	Achieved	Remarks
1	Fine Aggregate	Bulk Density Test	IS : 383 : 1970	g/cc		1.630	
3		Specific Gravity Test		g/cc		2.633	
5		Water Absorption Test		%	< 2	0.862	
		Fineness Modulus			2 - 3.5		
7		Silt		%	3	1.3	Deleterious Content
9		Clay Lumps		%	1	Bleow Detection Level	
11		Light Weight Particles		%	1		
13		Soft Particles		%	###		
15		Organic Impurities			Nil	Nil	No harmful organic matter to be present.
17		Reduction of Alkalies		mmol/L		128	Potential Alkali Reactivity
19		Silica				8.1	
21		Soundness with Na_2So_4	MoRTH	%	Max. 12	7.3	Soundness test
23		Soundness with $MgSo_4$			Max 18	8.1	

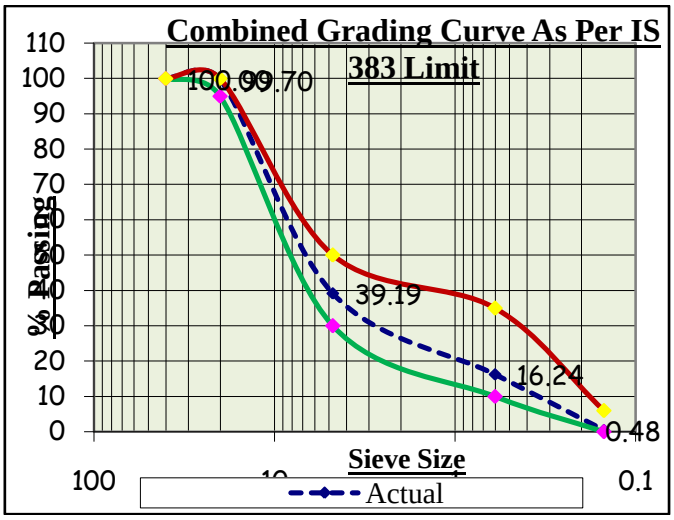
Table No - 3.4 Test report of Fine Aggregate

As the actual grading satisfy the limit of all in aggregate table, hence the proportion of aggregates may be taken for designing the concrete mix.

4.6.5.2 All in Aggregate Gradation tabulated with 15.025%, 45.075%, 39.900% cobmination as per IS:383 Table- 4.6

I.S. Sieve Size in mm	Percentage contribution in design mix concrete				Combined Grading in percentage	Combined Grading Limits in percentageas Per IS-383	
	15.025%	45.075%	39.900%	0.000%			
	20 mm CA Passing %	12.5 mm CA Passing %	Fine Aggregate Passing %	Crushed Sand Passing %		Min	Max
40	100.00	100.00	100.00	0.00	100.00	100	100
20	98.02	100.00	100.00	0.00	99.70	95	100
4.75	0.03	0.26	98.4	0.00	39.38	30	50
0.600	0.00	0.00	40.9	0.00	16.32	10	35
0.150	0.00	0.00	1.2	0.00	0.48	0	6

Combined Grading Curve As Per IS:383 Limit



C. The Casting and curing of Test specimens:
The specimen of standard cube were used to determine the compressive strength Split tensile and flexural strength of concrete. Three specimens were tested for 7, 14 & 28 days with each proportion of Silica fume replacement. For each measured quantities of coarse aggregate and fine aggregate was spread in a pan, the ordinary Portland cement (53 Grade) and silica fume were spread out over it, water was measured by considering the water binder ratio as 0.32 and weight of super plasticizer was estimated as 1.2 % of weight of binder. The exact quantity of water and super plasticizer was added. The concrete was thoroughly mixed until it achieved homogeneous and uniform consistency. The fresh concrete was cast in cube moulds, and was compacted by table vibrator.All freshly cast specimens were left in the moulds for 24 hours before being de moulded. The de moulded specimens were cured in water for 7,14&28 days, were air dried and then tested for its compressive strength as per Indian standards.

III.RESULTS

A. Compressive strength of concrete: The test was carried out conforming to IS 516-1959 to obtain compressive strength of concrete at the age of 7, 14 and 28 days. The cubes were

tested using Compression Testing Machine (CTM) of capacity 2000KN.

Sl No.	Ingredients of Design Mix	UOM	Design mix of Concrete with Different combinations by weight													
			Without Micro Silica						With Micro Silica Replacement							
			OPC Cement			PPC Cement			OPC-M 40 grade design taken as Base for replacement							
			M 40	M 45	M50	M 40	M 45	M50	2%	4%	6%	8%	10%	12%	14%	16%
1	Cement-Ambuja Cement - OPC - 53 Grade	kg/m^3	411	427	450	-	-	-	402.8	394.6	386.3	378.1	369.9	361.7	353.5	345.2
2	Cement-Ambuja Cement - PPC - Fly Ash Base	kg/m^3	-	-	-	422	438	450	-	-	-	-	-	-	-	-
3	Portable Water	kg/m^3	154	160	162	158	162	162	154	154	154	154	154	154	154	154
4	Micro Silica - Hind Silica M	kg/m^3	-	-	-	-	-	-	8.22	16.44	24.66	32.88	41.10	49.32	57.54	65.76
5	Chemical Admixture - Superplasticiser - Hind Plast Super SCA	kg/m^3	3.083	3.416	3.825	3.165	3.504	3.825	3.083	3.083	3.083	3.083	3.083	3.083	3.083	3.083
6	Plasticised expanding grout admixture - Foscroc - CEBEX 100	kg/m^3	-	-	-	-	-	2.025	-	-	-	-	-	-	-	-
7	Fine Aggregate	kg/m^3	751	739	723	728	716	708	751	751	751	751	751	751	751	751
8	Aggregate-20 mm	kg/m^3	298	293	291	289	285	285	298	298	298	298	298	298	298	298
9	Aggregate-12.5 mm	kg/m^3	891	877	869	865	854	851	891	891	891	891	891	891	891	891
10	Water Cement Ratio		0.375	0.375	0.360	0.375	0.370	0.360	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375
11	Total Weight of mix	kg/m^3	**2,508**	**2,499**	**2,499**	**2,465**	**2,459**	**2,462**	**2,508**	**2,508**	**2,508**	**2,508**	**2,508**	**2,508**	**2,508**	**2,508**

Table No 4.61 - Ingredient compositions by weight

4.8.2 Comparative Statement of ingredients of concrete design mix by volume shown in percentage

Sl No.	Ingredients of Design Mix	UOM	Design mix of Concrete with Different combinations by Percentage													
			Without Micro Silica						With Micro Silica Replacement							
			OPC Cement			PPC Cement			OPC-M 40 grade design taken as Base for replacement							
			M 40	M 45	M50	M 40	M 45	M50	2%	4%	6%	8%	10%	12%	14%	16%
1	Cement-Ambuja Cement - OPC - 53 Grade	%	16.39	17.08	18.01	-	-	-	16.06	15.73	15.40	15.08	14.75	14.42	14.09	13.77
2	Cement-Ambuja Cement - PPC - Fly Ash Base	%	-	-	-	####	####	####	-	-	-	-	-	-	-	-
3	Portable Water	%	6.140	6.401	6.483	6.409	6.589	6.580	6.140	6.140	6.140	6.140	6.140	6.140	6.140	6.140
4	Micro Silica - Hind Silica M	%	-	-	-	-	-	-	0.328	0.655	0.983	1.311	1.639	1.966	2.294	2.622
5	Chemical Admixture - Superplasticiser - Hind Plast Super SCA	%	0.123	0.137	0.153	0.128	0.143	0.155	0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.123
6	Plasticised expanding grout admixture - Foscroc - CEBEX 100	%	-	-	-	-	-	0.082	-	-	-	-	-	-	-	-
7	Fine Aggregate	%	29.94	29.57	28.93	29.53	29.12	28.76	29.94	29.94	29.94	29.94	29.94	29.94	29.94	29.94
8	Aggregate-20 mm	%	11.88	11.72	11.65	11.72	11.59	11.58	11.88	11.88	11.88	11.88	11.88	11.88	11.88	11.88
9	Aggregate-12.5 mm	%	35.53	35.09	34.78	35.09	34.74	34.57	35.53	35.53	35.53	35.53	35.53	35.53	35.53	35.53
10	Water Cement Ratio		0.375	0.375	0.360	0.375	0.370	0.360	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375
11	Total Weight of mix	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table No 4.62 - Ingredient compositions by volume shown in percentage

4.8.3 Comparative Statement of characteristic strength of concete of all design mixes

Sl No.	Compressive Strenght of Concrete at durations	UOM	Design mix of Concrete with Different combinations by Percentage													
			Without Micro Silica						With Micro Silica Replacement							
			OPC Cement			PPC Cement			OPC-M 40 grade design taken as Base for replacement							
			M 40	M 45	M50	M 40	M 45	M50	2%	4%	6%	8%	10%	12%	14%	16%
1	Compressice Strength of Cube at **7 Days**	N/mm^2	38.22	40.15	44.30	37.63	40.29	45.18	37.33	40.15	39.85	40.15	44.89	42.22	40.59	38.52
2	Compressice Strength of Cube at **14 Days**	kg/m^3	46.82	49.78	52.89	44.45	49.04	52.74	45.19	48.29	48.44	48.30	52.30	48.89	46.37	43.11
3	Compressice Strength of Cube at **28 Days**	kg/m^3	52.15	54.96	60.15	50.22	53.78	59.11	51.70	55.71	56.44	57.63	59.11	37.33	53.18	48.59

Table No 4.63 - Characteristic strength of all design mixes of concrete

IV.CONCLUSIONS

Result of 16% replacement is lower compared to 10%, 12%, 14 % replacement results. The results are even lesser than the base esults. Since, further replacement is to be restricted here. Silica fume is a material which may be a reason of Air Pollution this is a byproduct of some Industries use of micro-silica with concrete decrease the air pollution. Silica fume also decrease the voids in concrete. Addition of silica fume reduces capillary. Absorption and porosity because fine particles of silica fume reacts with lime present in cement. Mineral admixture such as micro silica is an ideal constituent for high performance concrete as it has the inherent ability to contribute to continued strength development through their pozzolanic reactivity and to enhance durability and chemical resistance through their pore refinement and reduced sorptivity characteristics.

Resultant conclusions are:

• Cement replacement up to 10% with silica fume leads to increase in compressive strength, for M40 grade of concrete with OPC cement

• From 12% there is a decrease in compressive strength for 3, 7, 14 and 28 days curing period.

•It was observed that the compressive strength of M40 grade of concrete with 6% replacement of micro silica satisfy the compressive strength criteria of M45 Grade.

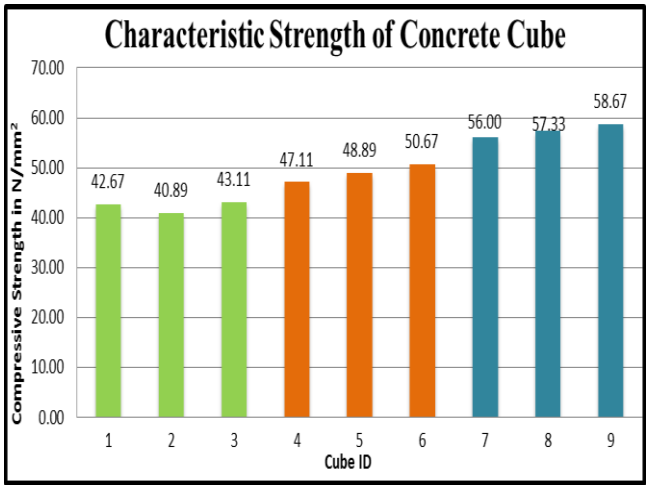
• The maximum replacement level of silica fume is10% for M40 grade of concrete.

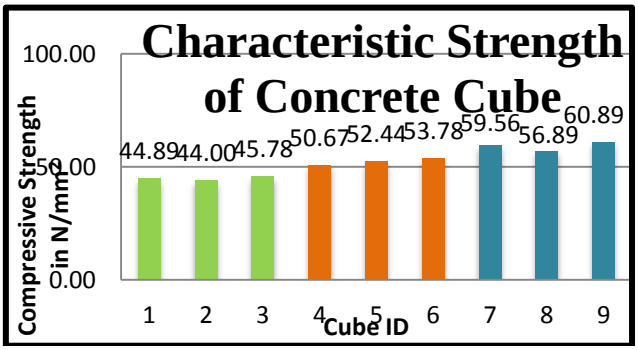
• At 10% replacement of micro silica, M40 grade concrete behaves fully satisfactory the strength parameter of M50 grade concrete.

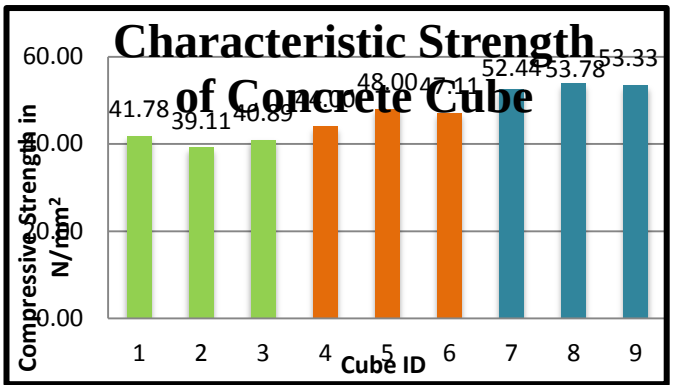
• The use of micro silica in high strength concrete leads to economical and faster construction.

• Use of Micro Silica, reduces CO2 emission from structures.

• Due to use of the micro silica in a OPC concrete the life of that concrete is increase 4-5 times than the OPC concrete.







Dry mix Proportion with 16% Micro silica replacement to design of section - 4.7.1

Ingredients	Quantity	UOM
Cement-OPC	345.24	kg/m^3
Water	154.0	kg/m^3
Chemical Admixture	3.083	kg/m^3
Micro Silica (16%)	65.760	kg/m^3
Fine Aggregate	751.000	kg/m^3
Aggregate-20 mm	298.00	kg/m^3
Aggregate-12.5 mm	891.00	kg/m^3
Water Cement Ratio	0.375	
Total Weight of mix	2508.00	kg/m^3

Table No - 4.57 - 16% micro silica replacement by weight of cement

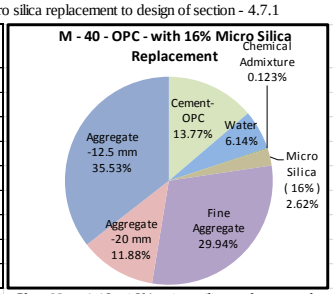
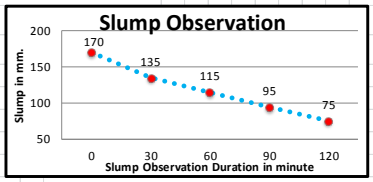


Chart No - 4.46 - 16% micro silica replacement by weight of cement in percentage

4.7.14.2 Workability Observation (Slump Reports)

Time lapse in minute	Slump In mm.	Remarks
0	170	
30	135	
60	115	Acceptable
90	95	
120	75	

Table No - 4.58 Slump for the design with 16% replacement of Micro Silica



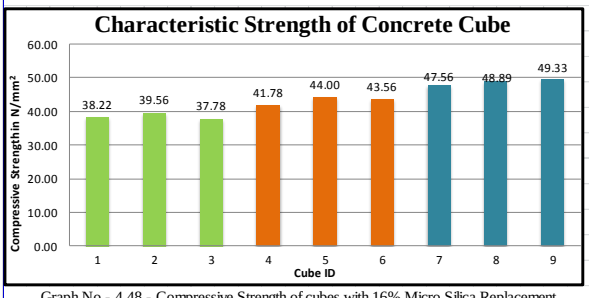
Graph No - 4.47 - Slump for the design with 16% replacement of Micro Silica

4.7.14.3 COMPRESSIVE STRENGTH OF CONCRETE CUBES (with 16% Micro Silica)

Cubes test Result achieved in laboratory for the trial mix as per IS:516 : 1999 test method.

Date of casting	Date Of testing	Cube age in days	Cube ID	Wt. of Cube in gms	Density of Cube in gm/cc	Failure load in kN	Compressive strength in N/mm^2	Average Compressive Strength in N/mm^2
08/02/18	15/02/18	7 Days	1	8628	2.556	860	38.22	38.52
08/02/18	15/02/18		2	8619	2.554	890	39.56	
08/02/18	15/02/18		3	8631	2.557	850	37.78	
08/02/18	22/02/18	14 Days	4	8633	2.558	940	41.78	43.11
08/02/18	22/02/18		5	8621	2.554	990	44.00	
08/02/18	22/02/18		6	8643	2.561	980	43.56	
08/02/18	08/03/18	28 Days	7	8635	2.559	1070	47.56	48.59
08/02/18	08/03/18		8	8629	2.557	1100	48.89	
08/02/18	08/03/18		9	8648	2.562	1110	49.33	

Table No - 4.59 Compressive Strength of cubes with 16% Micro Silica Replacement



Graph No - 4.48 - Compressive Strength of cubes with 16% Micro Silica Replacement

4.7.14.4 A Comparative Statement between M - 40 OPC design of Section 4.7.1 with 16% Micro Silica Replaced by weight of cement to that same design

Average Characteristic Strength of Concrete (Mpa)	M- 40 of Section 4.7.1		16% MS Replacement
In 7 Day	38.22	V S	38.52
In 14 Day	46.82		43.11
In 28 Day	52.15		48.59

Table No - 4.60- A comparison between strength of M-40 OPC Vs. 16% MS replacement

Note: Result of 16% replacement is lower compared to 10%, 12%, 14% replacement results. The results are even lesser than the base results. Since, further replacement is to be restricted here.

4.8 Consolidated Statements of Design Mixes of Concrete

4.8.1 Comparative Statement of ingredients of concrete design mix by weight

Sl No.	Ingredients of Design Mix	UOM	Design mix of Concrete with Different combinations by weight													
			Without Micro Silica						With Micro Silica Replacement							
			OPC Cement			PPC Cement			OPC-M 40 grade design taken as Base for replacement							
			M 40	M 45	M50	M 40	M 45	M50	2%	4%	6%	8%	10%	12%	14%	16%
1	Cement-Ambuja Cement - OPC - 53 Grade	kg/m^3	411	427	450	-	-	-	402.8	394.6	386.3	378.1	369.9	361.7	353.5	345.2
2	Cement-Ambuja Cement - PPC - Fly Ash Base	kg/m^3	-	-	-	422	438	450	-	-	-	-	-	-	-	-
3	Portable Water	kg/m^3	154	160	162	158	162	162	154	154	154	154	154	154	154	154
4	Micro Silica - Hind Silica M	kg/m^3	-	-	-	-	-	-	8.22	16.44	24.66	32.88	41.10	49.32	57.54	65.76
5	Chemical Admixture - Superplasticiser - Hind Plast Super SCA	kg/m^3	3.083	3.416	3.825	3.165	3.504	3.825	3.083	3.083	3.083	3.083	3.083	3.083	3.083	3.083
6	Plasticised expanding grout admixture - Foscroc - CEBEX 100	kg/m^3	-	-	-	-	-	2.025	-	-	-	-	-	-	-	-
7	Fine Aggregate	kg/m^3	751	739	723	728	716	708	751	751	751	751	751	751	751	751
8	Aggregate-20 mm	kg/m^3	298	293	291	289	285	285	298	298	298	298	298	298	298	298
9	Aggregate-12.5 mm	kg/m^3	891	877	869	865	854	851	891	891	891	891	891	891	891	891
10	Water Cement Ratio		0.375	0.375	0.360	0.375	0.370	0.360	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375
11	Total Weight of mix	kg/m^3	**2,508**	**2,499**	**2,499**	**2,465**	**2,459**	**2,462**	**2,508**	**2,508**	**2,508**	**2,508**	**2,508**	**2,508**	**2,508**	**2,508**

Table No 4.61 - Ingredient compositions by weight

4.8.2 Comparative Statement of ingredients of concrete design mix by volume shown in percentage

Sl No.	Ingredients of Design Mix	UOM	Design mix of Concrete with Different combinations by Percentage													
			Without Micro Silica						With Micro Silica Replacement							
			OPC Cement			PPC Cement			OPC-M 40 grade design taken as Base for replacement							
			M 40	M 45	M50	M 40	M 45	M50	2%	4%	6%	8%	10%	12%	14%	16%
1	Cement-Ambuja Cement - OPC - 53 Grade	%	16.39	17.08	18.01	-	-	-	16.06	15.73	15.40	15.08	14.75	14.42	14.09	13.77
2	Cement-Ambuja Cement - PPC - Fly Ash Base	%	-	-	-	####	####	####	-	-	-	-	-	-	-	-
3	Portable Water	%	6.140	6.401	6.483	6.409	6.589	6.580	6.140	6.140	6.140	6.140	6.140	6.140	6.140	6.140
4	Micro Silica - Hind Silica M	%	-	-	-	-	-	-	0.328	0.655	0.983	1.311	1.639	1.966	2.294	2.622
5	Chemical Admixture - Superplasticiser - Hind Plast Super SCA	%	0.123	0.137	0.153	0.128	0.143	0.155	0.123	0.123	0.123	0.123	0.123	0.123	0.123	0.123
6	Plasticised expanding grout admixture - Foscroc - CEBEX 100	%	-	-	-	-	-	0.082	-	-	-	-	-	-	-	-
7	Fine Aggregate	%	29.94	29.57	28.93	29.53	29.12	28.76	29.94	29.94	29.94	29.94	29.94	29.94	29.94	29.94
8	Aggregate-20 mm	%	11.88	11.72	11.65	11.72	11.59	11.58	11.88	11.88	11.88	11.88	11.88	11.88	11.88	11.88
9	Aggregate-12.5 mm	%	35.53	35.09	34.78	35.09	34.74	34.57	35.53	35.53	35.53	35.53	35.53	35.53	35.53	35.53
10	Water Cement Ratio		0.375	0.375	0.360	0.375	0.370	0.360	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375
11	Total Weight of mix	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table No 4.62 - Ingredient compositions by volume shown in percentage

4.8.3 Comparative Statement of characteristic strength of concete of all design mixes

Sl No.	Compressive Strenght of Concrete at durations	UOM	Design mix of Concrete with Different combinations by Percentage													
			Without Micro Silica						With Micro Silica Replacement							
			OPC Cement			PPC Cement			OPC-M 40 grade design taken as Base for replacement							
			M 40	M 45	M50	M 40	M 45	M50	2%	4%	6%	8%	10%	12%	14%	16%
1	Compressice Strength of Cube at **7 Days**	N/mm^2	38.22	40.15	44.30	37.63	40.29	45.18	37.33	40.15	39.85	40.15	44.89	42.22	40.59	38.52
2	Compressice Strength of Cube at **14 Days**	kg/m^3	46.82	49.78	52.89	44.45	49.04	52.74	45.19	48.29	48.44	48.30	52.30	48.89	46.37	43.11
3	Compressice Strength of Cube at **28 Days**	kg/m^3	52.15	54.96	60.15	50.22	53.78	59.11	51.70	55.71	56.44	57.63	59.11	37.33	53.18	48.59

Table No 4.63 - Characteristic strength of all design mixes of concrete

V.REFERENCES

[1]. Verma Ajay, ChandakRajeec and Yadav R.K. "Effect of micro silica on the strength of concrete with ordinary Portland cement" Reaserch journal of Engineering Science ISSN 2278-9472 vol.1(3), 1-4, sept (2012).

[2]. Dilip Kumar Singha Roy "Effect of Partial Replacement of Cement by Silica Fume on Hardened Concrete". International journal of engineering Technology and Advanced Engineering (ISSN 2250-2459, volume 2, issue 8, August 2012)

[3]. T. Shanmugapriya, Dr. R. N. Uma "Experimental Investigation on silica Fume as partial replacement of Cement in High Performance Concrete". (IJES) 2013

[4]. IS 456-2000, "Indian Standard Code of Practice for plain and reinforced concrete" Fourth revision, BIS, New Delhi.

[5]. IS 383-1970, "Indian Standard Specification for coarse and fine aggregate from natural source for concrete," 2nd Edition, BIS, New Delhi.

[6]. IS 2386-1963, "Indian Standard Methods of tests for aggregate" BIS, New Delhi.

[7]. IS: 12269-1987, "Indian Standard Ordinary Portland Cement 53 grade Specification" BIS, New Delhi.

[8]. IS: 10262-1982, "Recommended guidelines for concrete mix design, "BIS, New Delhi.

[9]. Behnood and H. Ziari, Effects of Silica Fume Addition and Water to Cement Ratio on the Properties of High-Strength Concrete after Exposure to High Temperatures (2007).

[10]. Bashir et al., Study of Permeability and Compressive Strength of Silica Fume Concrete (2014).

[11]. N. K. Amudhavalli and J. Mathew, Effect of Silica Fume on Strength and Durability Parameters of Concrete (2012).