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A Study of Micro-Silica as a Partial Replacement of Cement in Concrete

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Abstract - *Concrete is widely used material in the field of construction and also replacement or by doing addition of other material may change the properties of concrete. Now a days use of concrete is increased for high rise building and due to that there is increase in demand of concrete with higher compressive strength, also one of expensive ingredient in concrete is cement and to make the concrete mix economical it should be replaced with any other cheap material hence in this experiment we are going to do partial replacement of cement with the cheap material like condensed silica fume to increase the compressive strength and workability of concrete. In this experiment we will take various proportion, 5%,10%,15% of adding micro silica by the mass of cement in concrete in mix design of M25, M30 and M35 grade of concrete as per IS code.*

***Key Words*: Condensed silica fume/ micro silica/ silica fume, Compressive strength, Concrete mix.**

1.INTRODUCTION

The concrete is mostly used material for construction any structure for example dams, roads pavements, tanks etc. Concrete mixture is consist of cement, sand, coarse aggregate and water. The process of selecting suitable ingredients of concrete and determining their relative amount with objective of producing a concrete of required strength durability and workability as economically as possible is termed as concrete mix design. In the concrete mix design cement is the costly material so it should be replaced by any other cheap material.

While replacing the cement the care should be taken that the strength of concrete is not reduced. The micro silica also known as silica fume or condensed silica fume is the good replacement of cement in the concrete mix design. The silica fume is a by product of silicon and ferrosilicon alloy production. It is an ultra fine powder.

Hence when it is used in concrete to fill the spaces between the cement particles and between the cement paste matrix and aggregate particles and it act as a filler and cementitious material. Hence by using silica fume is concrete the voids are also reduced. For replacement of cement generally cheaper materials are selected. According to that micro silica is cheaper than the cement hence it is a very good replacement. And also by doing the replacement of cement with micro silica the strength of concrete is also increased.

2.LITERATURE REVIEW

Ghutke and Bhandari (2014)

The influence of micro silica on concrete was examined in this study. The result showed that micro silica is a good for partial replacement of cement. The strength was increased when cement was replaced with micro silica. Concrete reduces its workability as percentage of micro silica is increased. The optimum compressive strength can be obtained in 10% replacement of micro silica. As strength of 15% replacement of cement by micro silica is more than normal concrete. The optimum cement replacement percentage by micro silica varies from 10% to 15 %.

Hanumesh, Varun and Harish (2015)

In this study it is observed the mechanical properties of concrete when partial replacement of cement is done with micro silica. The main aim of this work is to study mechanical properties of M20 grade concrete when cement is replaced with silica fume at different percentages (5,10,15 and 20). The results showed that strength of concrete is increased when 10% replacement of cement is done with micro silica. Above 10% replacement of cement with silica fume it is observed that there is decrease in compressive strength. Hence, optimum percentage of replacement of cement by silica fume is 10% for M20 grade of concrete.

3.METHODOLOGY

The main objective of mix design is to decide the properties of material which we are going to use in concrete so that concrete will be produced of required properties. Another objective of mix design is to achieve the desired workability of fresh concrete and also to obtain minimum strength at the hardened stage. Mix design is also used to produced concrete economically so that wastage will be avoided.

Material used for mix design

1. **Cement** - Ambuja brand cement was used of PPC 53 grade.
2. **Coarse aggregate** - 20 mm and 12.5 mm size of coarse aggregate was used in this experiment.
3. **Fine aggregate** - Sand passing through 2.36 mm of IS sieve was used in this mix design.
4. **Micro-Silica** - Black coloured micro-silica was used in this experiment. Spherical partical of micro-silica was less than 1mm in diameter. Specific gravity of micro-silica was 2.36.
5. **Admixture** - Conplast SP430 which is free from chloride was used. According to brouchre SP430 0.5-2% by weight of cement can be added in mix design.
6. **Water** - Clean, Potable water was used in mix design.

4.CONCRETE MIX DESIGN

- **Test data for materials**

Design of M25 (5% of micro silica)

1. Cement used – PPC 53 grade
   Specific gravity of cement – 3.15
2. Micro silica – mineral admixture
3. Specific gravity of micro silica – 2.26
4. Chemical admixture – Superplasticizer
5. Specific gravity of
   1. coarse aggregate – 2.76
   2. fine aggregate – 2.69
   3. chemical admixture – 1.2
6. Degree of supervision – Good
7. Sieve analysis- Zone

- **Target strength for mix proportion**

F'ck = fck+1.65SO
F'ck = 25+1.65 * 4 ……
(From IS 10262-2019 table 2)
F'ck= 31.6 N/sq.mm
OR
F'ck = fck+1.65X
F'ck=25+1.65*5.5 …….
(From IS 10262-2019 table1)
F'ck=34.075N/sq.mm
Which ever is higher
Therefore, F'ck=34.075N/sq.mm

- **Selection of water cement ratio**

From IS 456- 2000 table 5
For M25 w/c ratio is 0.45

- **Water content selection**

For 20mm aggregate,
Maximum water content=186Kg
(IS 10262-2019, table 4)
Increasing 3% water content for every 25mm slump
Water content for 75mm slump
= 186+3/100 *186
= 191.57 kg/cu.m
Assuming 18% water reduction by adding chemical admixture
= 191.57*0.82
=157.0875 Kg/ cu.m

- **Calculation of cement content**

W/C ratio =0.45
Cement content=157.0875/0.45 = 349.08
Approximately, 350 Kg/cu.m
Adding micro silica @ 5% of cementitious material = 350*5/100 = 17.5 kg/ cu.m
Cement = 350-17.5 = 332.5 kg/ cu.m
Min. cementations material should be 320 Kg/cu.m
332.5 Kg/cu.m >320 Kg/cu.m
…….(Hence ok)
Therefore, Cement= 333Kg/ cu.m

- **Proportioning of volume of coarse aggregate and fine aggregate content**

According to IS 10262-2019 table 3
Volume of CA corresponding to 20mm size aggregate and FA of zone 2 and after applying correction
Volume of coarse aggregate = 0.63
Volume of fine aggregate = 0.37

- **Mix calculation**

a) Volume of concrete= 1 cu.m
b) Volume of entrapped air= 0.01 cu.m
c) Volume of cement = (Mass of cement/Specific gravity of cement) * (1/1000)
= (332.5/3.15)*(1/1000)
= 0.1057 cu.m
d) Volume of micro silica = (Mass of micro silica/specific gravity of micro silica)*(1/1000)
= (17.5/2.26) *(1/1000)
= 0.00774 cu.m
e) Volume of water = (Mass of water/specific gravity of water)*(1/1000)
= (157.0875/1)*(1/1000)
= 0.158 cu.m
f) Volume of admixture (Mass of admixture is1.2% of cement)

= (Mass of admixture/specific gravity of admixture)*(1/1000)
= (4/1.25)*(1/1000)
= 0.0032 cu.m

g) Volume of all in one aggregate
= {(a-b)-(c+d+e+f)}
= {(1-0.01)-(0.1057+0.00774+0.158+0.0032)}
= 0.71536 cu.m

h) Mass of coarse aggregate
= g*voume of CA*specific gravity of CA *1000
= 0.71536*0.63*2.76*1000
= 1243.86 Kg/cu.

i) Mass of fine aggregate
= g* volume of FA*Specific gravity of FA *1000
= 0.71536*0.37*2.69*1000
= 711.99 Kg/cu.m

- **After applying moisture content correction in water final mix proportion**
  For 1cu.m
  I. Cement =169 Kg/cu.m
  II. Fine aggregate=707.19Kg/cu.m
  III. Coarse aggregate = 1235.96Kg/cu.m
  IV. Micro silica=17.5Kg/cu.m
  V. Admixture =4Kg/cu.m
  VI. Water = 169.78Kg/cu.m

- **In this way, similarly mix design for**
  M25(10%,15% replacement of micro silica)
  M30(5%,10%,15% replacement of micro silica)
  M35(5%,10%,15% replacement of micro silica)
  IS DONE.

FOR M25

Use of MicroSilica	Cement (Kg/m³)	Fine Aggregate (Kg/m³)	Coarse Aggregate (Kg/cu.m)	Micro-Silica (Kg/m³)	Chemical Admixture (Kg/cu.m)	Water (Kg/m³)
5%	169	707.19	1235.96	17.50	4.00	169.78
10%	315	705.88	1233.58	35.00	3.78	169.92
15%	300	703.11	1228.73	50.00	3.60	169.88

FOR M30

Use of MicroSilica	Cement (Kg/m³)	Fine Aggregate (Kg/m³)	Coarse Aggregate (Kg/m³)	Micro Silica (Kg/m³)	Chemical admixture (Kg/m³)	Water (Kg/m³)
5%	373.92	693.56	1212.02	19.68	4.49	169.68
10%	354.24	691.35	1208.16	39.36	4.25	169.65
15%	334.56	689.08	1204.20	59.04	4.01	169.6

FOR M35

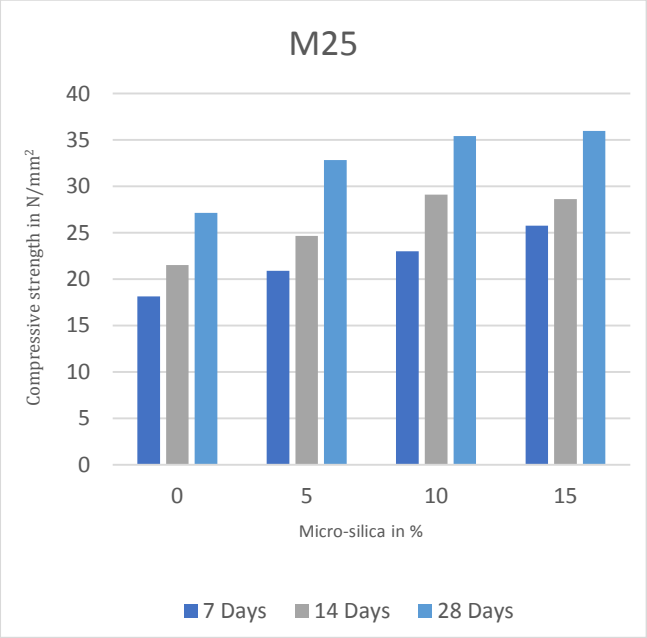
Use of MicroSilica	Cement (Kg/m³)	Fine Aggregate (Kg/m³)	Coarse Aggregate (Kg/m³)	Micro Silica (Kg/m³)	Chemical Admixture (Kg/m³)	Water (Kg/m³)
5%	392.73	687.05	1200.65	20.66	4.71	169.57
10%	372.06	684.68	1196.51	41.33	4.46	169.54
15%	351.39	682.31	1192.46	62.00	4.21	169.50

5.RESULTS

The compressive strength of concrete for M25, M30 and M35 grade was tested at 7 days, 14 days and 28 days curing period. The results are given below.

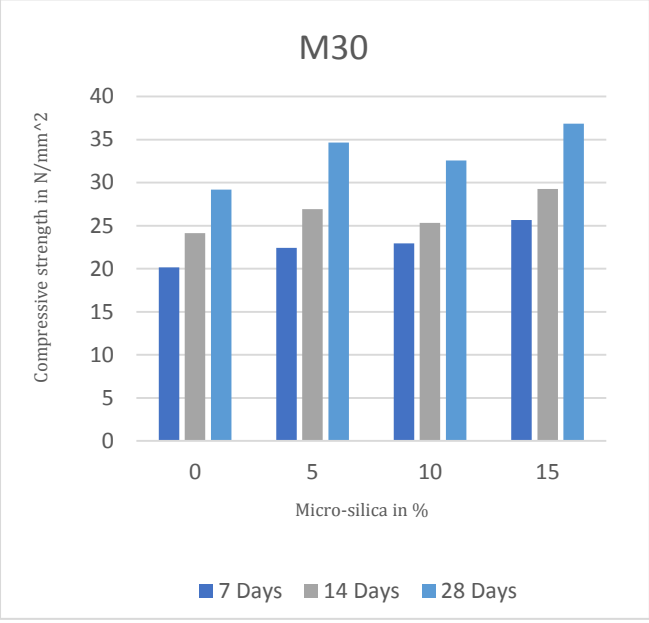
- **Compressive strength For M25 Grade**

Sr.No.	Micro-Silica used (%)	Compressive Strength (N/mm^2)		
		7 Days	14 Days	28 Days
1	0	18.13	21.51	27.14
2	5	20.88	24.65	32.85
3	10	23.01	29.11	35.42
4	15	25.76	28.62	35.98



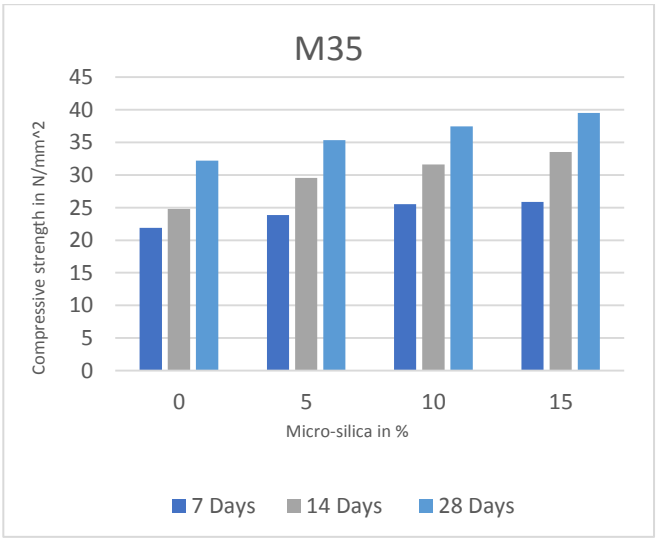
- **Compressive strength For M30 Grade**

Sr.No.	Micro-Silica used (%)	Compressive Strength (N/mm^2)		
		7 Days	14 Days	28 Days
1	0	20.17	24.12	29.21
2	5	22.43	26.91	34.64
3	10	22.96	25.33	32.56
4	15	25.67	29.26	36.84



- **Compressive strength For M35 Grade**

Sr.No.	Micro-Silica used (%)	Compressive Strength (N/mm^2)		
		7 Days	14 Days	28 Days
1	0	21.92	24.78	32.22
2	5	23.87	29.57	35.36
3	10	25.52	31.64	37.48
4	15	25.89	33.55	39.52



6.CONCLUSION

The compressive strength of concrete is increased For M25, M30 and M35 grades of concrete when replacement of cement with micro silica is done up to 15% further addition of micro silica resulted in decrease in strength.

Addition of micro silica helped in proper bonding of ingredients present in concrete due which voids in the concrete was less and dense concrete structure was achieved. The workability of concrete is also improved due to addition of silica fume in concrete.

Partial replacement of cement with micro silica can be economical as it is a waste product of industry and thus it can help in reduction of CO2 emission.

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