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# Study of Optimum Replacement of Cement with Silica Fume on Various Method of Mix Proportioning

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**Abstract :** The effect of optimum replacement of cement with silica fume on various methods of mix proportioning is discussed in this paper. The optimum extent of replacement of cement with silica fume as reported in the previous module of work was taken as 13%[1]. The extent of replacement was applied to various methods of mix proportioning like Indian Method, Pumpable Concrete Method, American Method and British Method. This work is done to study the pattern of cube compressive strength and cylinder tensile strength when optimum replacement is adopted. Cubes and cylinders are casted to find the compressive strength and tensile strength for 0% and 13% replacement for all methods of mix proportioning mentioned above.
**Keywords :** Optimum Replacement, Silica Fume Concrete, Compressive Strength, Tensile Strength.

## 1.0 Introduction

The performance of concrete is constantly and continuously enhanced over a period of years by adoption of various methods of mix proportioning, varying the constituents of concrete, addition of supplementary cementitious materials / admixtures (chemical and mineral) etc. Any addition of supplementary cementitious material or admixture involves dosage and type of the material added. Researches are done in many parts of the world on optimizing the supplementary cementitious materials and admixtures. The results have a larger degree of variation and it is quite difficult to be adopted for any specific requirements.

Considering the wide range of optimization reported and with an intention to get a correct extent of replacement of cement with silica fume, trials were done in different modules (as defined in Table 1 given below). Finally the optimum replacement of cement with silica fume was reported in module 3 as 13% replacement[1] This work studies the pattern of behaviour of the cubes (compression and indirect tension) for different methods of mix proportioning like Indian Standard Method, Pumpable Concrete Method, American Method and British Method.

## 2.0 Literature survey

### 2.1 General

In this study, works done on optimizing the extent of replacement of cement with silica fume are given as reference for the work that was done.

## 2.2 Literature review

**Hunchate et al**[2] presented a paper on the mix design of high performance concrete using silica fume as admixture. The silica fume was used in concrete for various proportions and found that the compressive strength of concrete was maximum at 15% replacement of cement with silica fume.

**Alves et al**[3] presented a paper on the comparison of mix proportioning methods for high strength concrete. The results reported indicate the advantage of using specific proportioning methods for HSC, as for the same compressive strength at 28 days and savings up to 50% in the consumption of cement were achieved. **Singh et al**[4] made a comparative study between IS method and ACI method for absolute volume concrete mix design. It was reported that ISI methods performed well for low strength than higher strength and the design strengths 30 MPa and 40 MPa were obtained by ACI method. **Abo-El-Enien et al**[5] presented a paper on physico-mechanical properties of high performance concrete using different aggregates in the presence of silica fume. It was concluded that addition of 10% of silica fume to the cement content developed a stronger and a denser interfacial transition zone between concrete coarse particle and the cement matrix. **Amudhavalli et al**[6] studied the effect of silica fume on the strength and durability parameters of concrete. It was reported that the optimum compressive strength and flexural strength have been obtained in the range of 10-15% silica fume replacement level. **Duval et al**[7] studied the influence of silica fume on the workability and the compressive strength of high performance concretes. The cement replacement of 10% with silica fume was reported without impacting the workability and the compressive strength of the concrete. It reached the maximum compressive strength at 10% to 15% of cement replacement with silica fume.

## 3.0 Experimental Investigation

## 3.1 Materials used for work

The cement used for the experimental work is ordinary Portland cement of 53 grade conforming to IS 10262-1987 with a Specific gravity: 3.15. The fine aggregate used for the experimental work is locally available river sand, which belongs to zone II as per IS 456:2000. The physical properties of the fine aggregate used had a Specific Gravity of 2.64 and Water Absorption of 1%. The coarse aggregate used for the experimental work is locally available quarried and crushed blue broken granite of size 20mm. The physical properties of coarse aggregate are: (a) Specific Gravity: 2.9; (b) Water absorption: 1%. Water used for the experimental work is potable water free from any impurities with a pH value 7.62. Silica fume used for the experimental work was in dry densified form obtained from obtained from ELKEM INDIA (P) LTD., Mumbai, conforming to ASTM C-1240. The specific gravity of the silica fume was 2.4.

### 3.2 Experimental Procedure

This work is a continuation of modules done in previous years of investigation for finding the optimum replacement extent of cement with silica fume using IS method[1]. The modules conducted in the previous years for this purposes and the results obtained summarized as follows:

**Table 1 – Various Modules, the Extent of Replacement adopted and Optimum Results Achieved**

| Module # | % Replacement of cement with silica fume adopted | Highest cube compressive strength achieved in % |
|---|---|---|
| 1 | 5%, 10%, 15%, 20%, 25% | 15% |

| | | |
|---|---|---|
| 2 | 10%, 12.5%, 15%, 17.5%, 20% | 12.5% |
| 3 | 12%, 12.5%, 13%, 13.5% | 13% |

The result of cube compressive strength obtained in the last module (Module 3) is given below for reference:

**Table 2 – Experimental Results of Module 3**

| **S.F. replacement%** | **Cube Compressive strength** | |
|---|---|---|
| | **7th day** | **28th day** |
| **M20 Grade** | | |
| 0% | 15.76 | 31.12 |
| 12% | 16.96 | 31.76 |
| 12.50% | 17.4 | 32.18 |
| **13%** | **19.36** | **33.41** |
| 13.50% | 17.64 | 32.58 |
| **M25 Grade** | | |
| 0% | 19.2 | 40.05 |
| 12% | 21.12 | 42.5 |
| 12.50% | 22.91 | 44.64 |
| **13%** | **23.6** | **46.35** |
| 13.50% | 23.17 | 45.21 |
| **M30 Grade** | | |
| 0% | 22.15 | 43.75 |
| 12% | 26.35 | 44.2 |
| 12.50% | 28.61 | 45.6 |
| **13%** | **29.27** | **48.75** |
| 13.50% | 27.54 | 46.75 |

| **S.F. replacement%** | **Cube Compressive strength** | |
|---|---|---|
| | **7th day** | **28th day** |
| **M35 Grade** | | |
| 0% | 25.89 | 45.87 |

| | | |
|---|---|---|
| 12% | 27.8 | 47.62 |
| 12.50% | 29.97 | 48.51 |
| **13%** | **32.87** | **53.87** |
| 13.50% | 30.34 | 49.29 |
| **M40 Grade** | | |
| 0% | 27.45 | 46.15 |
| 12% | 31.72 | 48.25 |
| 12.50% | 32.92 | 50.31 |
| **13%** | **34.78** | **54.08** |
| 13.50% | 33.27 | 52.61 |

Hence it is found that an optimum percentage replacement of 13% of cement with silica fume is observed. In continuation with the above modules, we extended this optimum percentage to the following methods:

a. Indian Standard method;
b. Pumpable concrete method;
c. American method; and
d. British method.

Mix proportioning was done with the above mentioned methods for moderate conditions for M20, M25, M30, M35 and M40 grade of concrete. The extent of replacement of cement with silica fume adopted for this work were 0% and 13%. The cement content and water cement ratio varied with different methods and different grades. Cube compressive strength and cylinder tensile (split- tension) strength were studied at 7 days and 28 days.

## 4.0 Results

Result of the experiment for the work and few graphs of the result are shown below:

**Table 3 – Results of the experiments carried out for cubes**

| | | **Strength (MPa)** | | | |
|---|---|---|---|---|---|
| **Grades** | **M20** | **M25** | **M30** | **M35** | **M40** |
| | | | | | |
| **Methods** | **Cube Compressive strength at 7 days for 0% replacement of cement with silica fume** | | | | |
| IS | 15.87 | 19.05 | 22.37 | 26.41 | 27.63 |
| PC | 15.12 | 18.87 | 21.65 | 25.38 | 26.67 |
| AM | 13.93 | 16.27 | 19.5 | 23.45 | 26.6 |
| BR | 14.15 | 18.02 | 19.69 | 25.27 | 26.38 |
| Cube Compressive strength at 28 days for 0% replacement of cement with silica fume | | | | | |
| | | | | | |
| IS | 32.56 | 41.01 | 43.3 | 45.73 | 47.24 |
| PC | 24.93 | 29.85 | 33.53 | 38.64 | 41.78 |
| AM | 23.84 | 30.77 | 39.44 | 43.53 | 47.3 |
| BR | 27.17 | 32.43 | 35.04 | 39.04 | 43.42 |
| Cube Compressive strength at 7 days for 13% replacement of cement with silica fume | | | | | |
| | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| IS | 19.36 | 23.97 | 28.06 | 33.3 | 35.57 |
| PC | 18.28 | 21.97 | 26.3 | 28.3 | 34.3 |
| AM | 13.7 | 16.01 | 22.96 | 24.67 | 25.73 |
| BR | 14.16 | 19.04 | 23.26 | 22.31 | 25.79 |
| Cube Compressive strength at 28 days for 13% | | | | | |
| replacement of cement with silica fume | | | | | |
| | | | | | |
| IS | 35.87 | 45.9 | 49.24 | 52.77 | 55.1 |
| PC | 28.49 | 33.63 | 36.79 | 42.5 | 45.63 |
| AM | 25.99 | 32.43 | 34.52 | 36.74 | 38.27 |
| BR | 31.51 | 34.84 | 34.81 | 36.25 | 38.4 |

**Table 4 – Results of the experiments carried out for cylinder**

| | **Strength (MPa)** | | |
|---|---|---|---|
| **Grades** | **M30** | **M35** | **M40** |
| **Methods** | **Cylinder Tensile strength at 7 days of 0% replacement of cement with silica fume** | | |
| IS | 5.34 | 5.72 | 6.33 |
| | | | |
| PC | 5.56 | 6.73 | 7.12 |
| | | | |
| AM | 5.85 | 6.44 | 7.24 |
| | | | |
| BR | 5.02 | 5.79 | 7.17 |
| | | | |

Cylinder Tensile strength at 28 days for 0% replacement of cement with silica fume

| | | | |
|---|---|---|---|
| IS | 7.97 | 8.53 | 9.45 |
| | | | |
| PC | 8.3 | 10 | 10.62 |
| | | | |
| AM | 9.64 | 9.76 | 10.8 |
| | | | |
| BR | 7.53 | 8.68 | 10.74 |
| | | | |

Cylinder Tensile strength at 7 days for 13% replacement of cement with silica fume

| | | | |
|---|---|---|---|
| IS | 5.49 | 5.8 | 6.49 |
| | | | |
| PC | 5.13 | 5.59 | 6.22 |
| | | | |
| AM | 5.11 | 5.7 | 6.56 |
| | | | |
| BR | 5.45 | 5.81 | 6.5 |
| | | | |

Cylinder Tensile strength at 28 days for 13% replacement of cement with silica fume

| | | | |
|---|---|---|---|
| IS | 8.73 | 8.65 | 8.86 |
| PC | 7.66 | 8.3 | 9.29 |
| AM | 7.57 | 9 | 9.82 |
| BR | 8.18 | 8.7 | 9.1 |
| | | | |

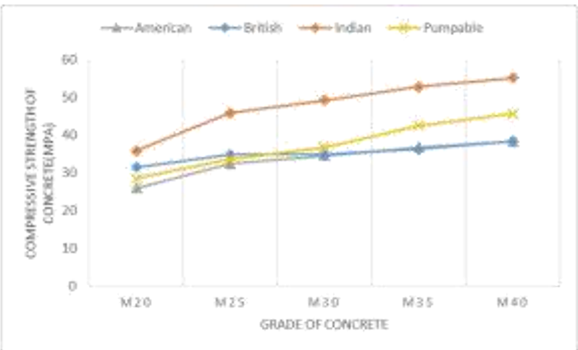


**Fig 1 – Cube Compressive Strength for 13% replacement for various grades of concrete at 7 days**

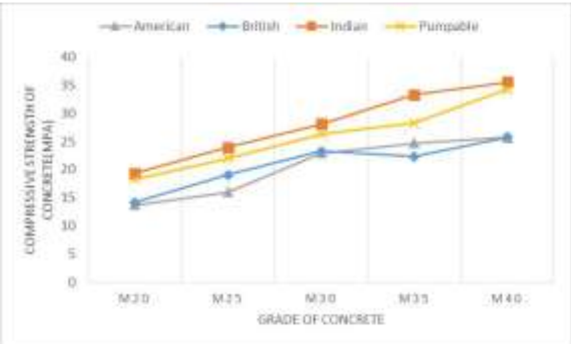


**Fig 2 – Cube Compressive Strength for 13% replacement for various grades of concrete at 28 days**

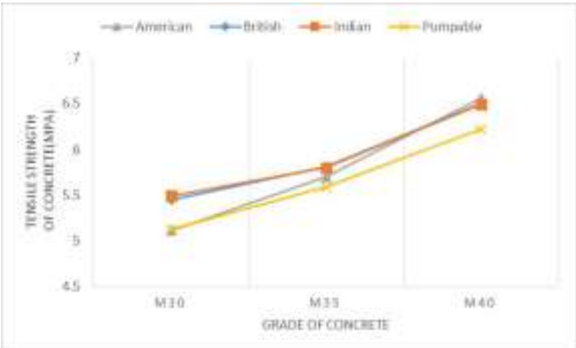


**Fig 3 – Cylinder Tensile Strength for 13% replacement for various grades of concrete at 7 days**

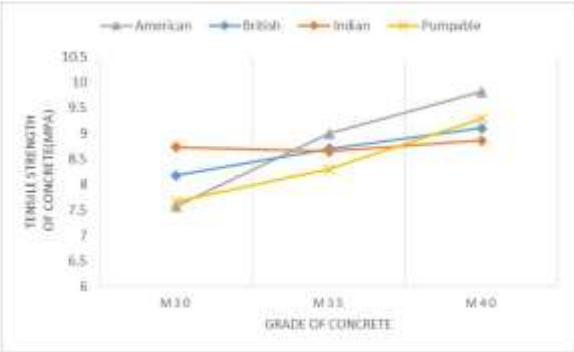


**Fig 4 – Cylinder Tensile Strength for 13% replacement for various grades of concrete at 28 days**

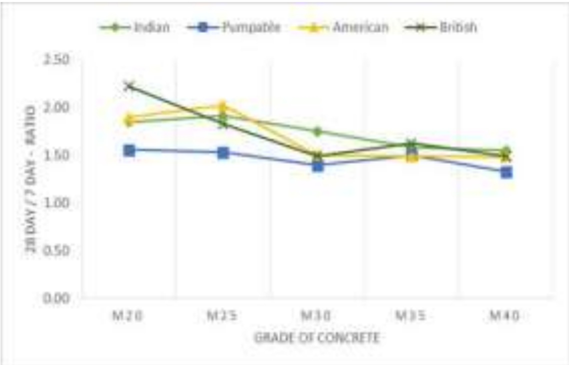


**Fig 5 – ó28cube/ ó7cube for various grades of concrete using various methods**

## 5.0 Discussion of Results:

From the results we can infer the following:

1. Fig.1 shows the cube compressive strength for 13% replacement for various grades of concrete at 7 days.

   (i) The cube compressive strength for 13% replacement for various grades of concrete at 7 days shows that, the strength achieved is over 90% of the grade of respective concrete. This shows with the addition of silica fume the early strength is more than the controlled concrete;
   (ii) IS method gives more compressive strength when compared to other methods under consideration.

2. Fig. 2 shows the cube compressive strength for 13% replacement for various grades of concrete at 28 days. The compressive strength for 13% replacement of cement with silica fume for various grades of concrete at 28 days shows that

   (i) The increase of compressive strength is over 70% for M20, M25, M30 grades of concrete and lesser as the grade moves higher to M35 and M40;
   (ii) The increase of 7days compressive strength ranges from 10% to 16.6% from M20 grade concrete over to 40% grade concrete
   (iii) Addition of silica fume results in lesser gain of strength beyond 7 days.

3. Fig. 3 shows the cylinder tensile strength for 13% replacement for various grades of concrete at 7 days. The cylinder tensile strength for 13% replacement of cement with silica fume for various grades of concrete at 7 days show that

   (i) The IS method gives higher tensile strength than the other 3 methods;
   (ii) The cylinder tensile strength gained at 7 days for all grades of concrete is around 20% of corresponding cube compressive strength.

4. Fig.4 shows the cylinder tensile strength for 13% replacement for various grades of concrete at 28 days. The cylinder tensile strength for 13% replacement of cement with silica fume for various grades of concrete at 28 days shows that

   (i) The gain in cylinder tensile strength at 28 days is at an average of 16% of cube compressive strength;
   (ii) The gain in cylinder tensile strength at 28 days when compared with 7 days cylinder tensile strength is around 33%
   (ii) The results of American methods is higher for higher grades of concrete. The cylinder tensile strength gained at 7 days for all grades of concrete is around 20% of corresponding cube compressive strength.

5. Fig. 5 shows the ó28-cube/ ó7- cube for various grades of concrete at 28 days. The ratio of $28^{th}$ day cube compressive strength and $7^{th}$ day cube compressive strength of various grades of concrete for various methods ranges from 1.30 to 2.23.

## 6.0 References

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