P: ISSN No. 0976-8602 RNI No.UPENG/2012/42622 VOL.-IV, ISSUE-III, July-2015
E: ISSN No. 2349 - 9443
Asian Resonance

# Effect of Micro Silica on Concrete Mixes

**Abstract**

Concrete plays a vital role in Infrastructure development of a country and Concrete is the world's largest consuming material in the field of construction. The replacement of cement through some admixtures or other additives to increase the strength is in trend. Micro silica, a very fine non-crystalline material is very good as filler material to provide good strength. An attempt has been made to increase the strength of concrete by replacing cement with 0%,5%,10%,15% and 20% of Micro silica in a design mix of M35 and M40.The materials are taken from the locally available sources in the North Eastern region. It is observed that an optimum replacement of 15% of Micro silica to that of cement (by weight) increases the strength of concrete upto 30%.Further addition of micro silica shows a decreasing trend.

**Keywords :** Compressive Strength, Design Mix, Micro Silica, North East India

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## Introduction

The word "concrete" comes from the latin word concretus (meaning compact or condensed). This name was chosen due to the fact that this material grows together, due to the process of hydration, from a visco elastic, moldable liquid into a hard, rigid, solid, rocklike substance. The romans first invented hydraulic cement based concrete or simply concrete. They built numerous concrete structures including the 43.3 meterdiameter concrete dome, the Pantheon,which is now over 2000 years old but still in use.Structural concrete is used extensively in various kinds of civil engineering structures. It is the most commonly used construction material consumed at a rate of approximately one ton for every living human being.

Concrete is a composite material which essentially consists of cement, coarse aggregate (CA), fine aggregate (FA) and water. Coarse aggregate gives the volume to the concrete and fine aggregate makes the concrete denser by filling the voids of coarse aggregate. Water hydrates and sets the cement which thus acts as a binder for all the ingredient particles of concrete. Concrete is the most important engineering material and the addition of some other materials may change the properties of concrete. With increase in trend towards the wider use of concrete for pre stressed concrete and high rise buildings there is a growing demand of concrete with higher compressive strength. The ultimate properties of concrete in terms of its strength, durability and economy depend not only on the various properties of its ingredients but also on the mix design standards, method of preparation, handling and curing conditions. Characteristic strength of concrete depends on its quality control and the extent of quality control is often an economical compromise and depends on the size and type of job. Economization is nowadays done by replacing cement with cheap, waste and recycled products. Concrete admixture is a material other than water, aggregates, hydraulic cement and fiber reinforcement used as an ingredient of a cementitious mixture to modify its freshly mixed, setting or hardened properties and that is added to the batch before or during mixing. The major reasons for using admixtures are reduced cost, to achieve certain properties in concrete more effectively and to maintain the quality of concrete during the stages of mixing, transporting, placing curing in adversed weather conditions.

The use of micro-silica as a pozzolan in concrete was originated in Scandinavia during the early 1950's and was introduced to the United States in 1984. Micro-silica is a by-product from the silicon carbide and metallic industries where it is recovered from exhausts of electric furnaces. Silica fume is an ultrafine airborne material with spherical particles less than 1 μm in diameter, the average being about 0.1 μm. It is approximately a hundred times finer than Portland cement. When it is used in concrete, it acts as a filler and as a cementitious material. The small silica fume particles fill spaces between cement particles and between the cement paste matrix and aggregate particles. The silica fume also combines with calcium hydroxide to form additional calcium hydrate through the pozzolanic reaction. Both of these actions result in a denser, stronger and less permeable material.

**Literature Review**

Verma[7] found that Silica fume increases the strength of concrete more 25%. Silica fume is much cheaper than cement therefore it is very important form economical point of view. Silica fume also decrease the voids in concrete. Pandit4 concluded that addition of micro silica to concrete increases thestrength more than 17% due to their pozzolanic properties and reduces the permeability of concrete. Ghutke2 found that Silica fume has been recognized as a pozzolanic admixture that is effective in enhancing the mechanical properties to a great extent. Addition of silica fume to concrete improves the durability of concrete and also in protecting the embedded steel from corrosion. When fine pozzolana particles are dispersed in the paste, they generate a large number of nucleation sites for the precipitation of the hydration products. Therefore, this mechanism makes the paste more homogeneous and dense as for the distribution of the fine pores. This is due to the reaction between the amorphous silica of the pozzolanic and the calcium hydroxide produced by the cement hydration reactions. Because of its chemical and physical properties, it is a very reactive pozzolana. Aginam[1] concluded that, there is a relationship between the aggregate size and quantity to the final strength of concrete. The study revealed a decrease in strength with increase in aggregate quantity and a decrease in strength with decrease in aggregate sizes. Pradhan[5] states a higher compressive strength resembles the concrete incorporating silica fume gives high strength concrete as per IS code recommendations. Improved pore structures at transitionzone for silica fume concrete resembles that it may be led to as high performance concrete. Zakaria[8] found the effect of different influencing parameters on concrete characteristics (at the givenworkability) considering four design methods (A.C.I, D.O.E, Murdock, the Basics).

**Methodology**

**Materials**

All the materials used for the experiment is locally available in North Eastern India.

**Micro silica**

Silica fume, also known as micro silica, is an amorphous (non-crystalline) polymorph of silicon dioxide as shown in Fig1. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm.

**Table I. Physical Properties of Micro Silica**

| Sl no | categories | Description |
|---|---|---|
| 1 | Size | Less than 1 µm |
| 2 | Shape | Spherical |

**Table II. Chemical Properties**

| Sl no | Ingredients | Percentage |
|---|---|---|
| 1 | Silica | 99.886% |
| 2 | Alumina | 0.043% |
| 3 | Ferric oxide | 0.040% |
| 4 | Calcium oxide | 0.001% |
| 5 | Titanium oxide | 0.001% |
| 6 | Potassium oxide | 0.001% |
| 7 | Sodium oxide | 0.003% |

**Working Phenomena of Micro Silica in Concrete**: Improvisation of concrete occurs through two mechanisms-

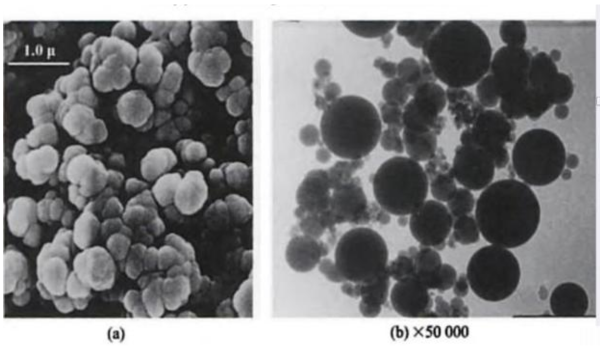


**Fig1: Photo of Micro Silica**

**Pozzolanic Effect**

When water is added to OPC (ordinary Portland cement), hydration occur forming two products, as shown below:

$$OPC + H_2O \rightarrow CSH \text{ (Calcium silicate hydrate) } + Ca(OH)_2$$

In the presence of micro-silica, the silicon dioxide from the micro-silica will react with the calcium hydroxide to produce more aggregate binding CSH as follows:

$$Ca(OH)_2 + SiO_2 \rightarrow H_2O + CSH$$

The reaction reduces the amount of calcium hydroxide in the concrete. The weaker calcium hydroxide does not contribute to strength. When combines with carbon dioxide, it forms a soluble salt which will leach through the concrete causing efflorescence, a familiar architectural problem. Concrete is also more vulnerable to sulphate attack, chemical attack and adverse alkali-aggregate reactions when high amounts of calcium hydroxide is present in concrete.

**Micro Filler Effect**

Micro-silica is an extremely fine material, with an average diameter 100 times finer than cement. At a typical dosage of 8% by weight of cement, approximately 100,000 particles for each grain of cement will fill the water spaces in fresh concrete. This eliminates bleed and the weak transition zone between aggregate and paste found in normal concrete. This micro-filler effect will greatly reduce permeability and improve the paste to aggregate bond of silica fume concrete compared to conventional concrete. The silica react rapidly providing high early age strength and durability. The efficiency of micro-silica is 3-5 times that of OPC and

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consequently vastly improved concrete performance can be obtained.

**Cement**

Ordinary Portland cement of 43 grade conforming to IS 8112: 2013 is used.

**Fine Aggregate**

Zone-II sand is used for the entire experiment as per IS 383:1970 specifications.

**Coarse Aggregate**

As per IS 383:1970 specifications the coarse aggregate is used.

**Water**

Portable water for drinking purpose was used for the Experiment.

**B.Mix Design Proportions**

Mix proportioning of grade M35 and M40 was performed as per IS 10262 and for each case the cement is replaced by 5%, 10%, 15% and 20% of silica fume.

**Table III. Mix Proportions by Weight**

| Sl no | Mix Design | w/c | Cement | F.A | C.A |
|---|---|---|---|---|---|
| 1 | M35 | 0.43 | 1 | 1.52 | 2.59 |
| 2 | M40 | 0.41 | 1 | 1.48 | 2.45 |

**Figures and Tables**

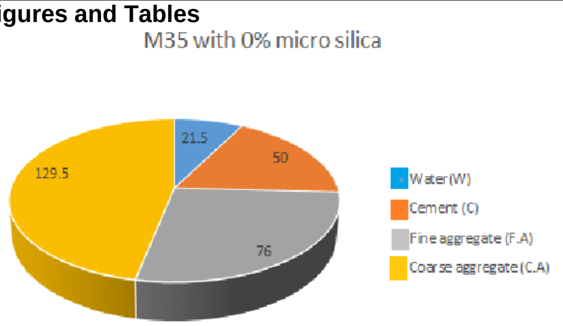


**Fig2: Composition of M35 With 0% Micro Silica**

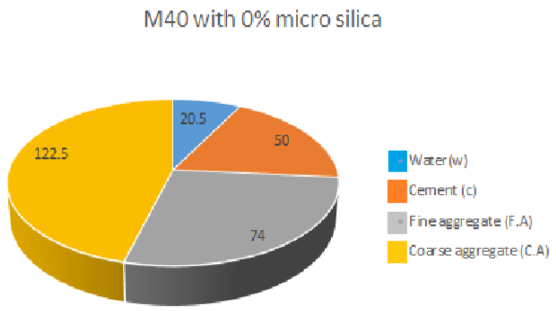


**Fig3: Composition of M40 With 0% Micro Silica**

**Table IV. Proportions of M35& M40 Per Bag of Cement**

| Ingredients | Weights (kg) | |
|---|---|---|
| | M35 | M40 |
| Water(W) | 21.5 | 20.5 |
| Cement (C) | 50 | 50 |
| Fine aggregate (F.A) | 76 | 74 |
| Coarse aggregate (C.A) | 129.5 | 122.5 |

**Tests**

The routine tests were performed for fine aggregate(source- Kanaighat) and coarse aggregates (Source- Sarupathar)and results are listed in table V.

**Table V. Test Results**

| Sl no | Materials | Test | Results |
|---|---|---|---|
| 1 | Sand | Sieve analysis | Zone II |
| 2 | Sand C.A | Specific Gravity | C.A-2.69, F.A- 2.62 |
| 3 | Cement | Standard Consistency | 33% |
| 4 | C.A | Aggregate Impact value | 18% |
| 5 | C.A | Los-Angeles Abrasion value | 18.6% |
| 6 | C.A | Flakiness | 13.5 % |
| 7 | C.A | Elongation | 11.5% |

**Fig4: During Compression Test of the Cubes**

**TableVI: Sieve Analysis of Fine Aggregate**

| Particle Size (mm) | Percentage Finer |
|---|---|
| 4.75 | 97.79 |
| 2.36 | 96.59 |
| 1.18 | 76.71 |
| 0.6 | 44.18 |
| 0.3 | 10.65 |
| 0.15 | 3.82 |

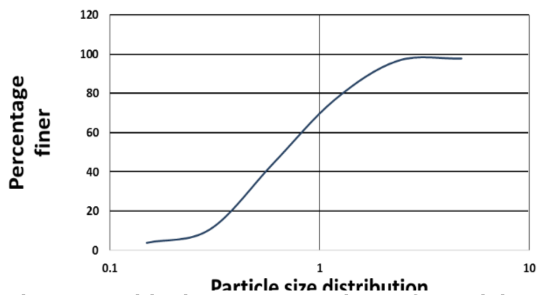


**Fig5: Graphical Representation of Particle Size Distribution.**

**Results**

Concrete cubes were cast with mix proportion of M35 and M40 with varying proportion of micro silica – 0%,5%,10%,15% and 20%. During casting the cubes are mechanically vibrated and then cured and tested for compressive strength of 3, 7, 28, 45 and 60 days.

**Table VII: Results of M35 and M40 for 7 days**

| Percentage of Micro silica | Compressive strength in N/mm$^2$ with no micro silica | |
|---|---|---|
| | M35 | M40 |
| 0% | 29.4 | 31.22 |

| | | |
|---|---|---|
| 5% | 32.63 | 34.67 |
| 10% | 37.63 | 39.2 |
| 15% | 38.51 | 42.74 |
| 20% | 38.22 | 40.44 |

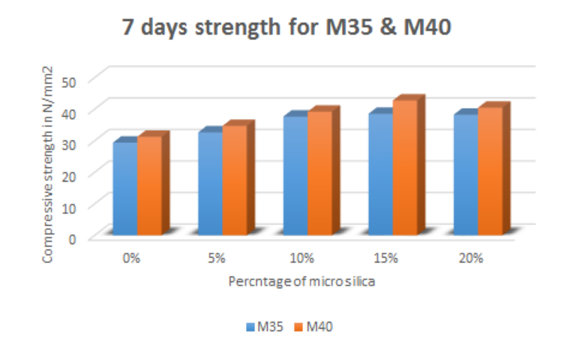


**Fig6: 7 Days Compressive Strength of M35& M40 with Varying Percentage of Micro Silica.**

**Table VIII. Results of 28 days Compressive Strength**

| Percentage of Micro silica | Compressive strength in N/mm$^2$ | |
|---|---|---|
| | M35 | M40 |
| 0% | 42.2 | 46.80 |
| 5% | 45.5 | 51.01 |
| 10% | 51.4 | 56.16 |
| 15% | 54.02 | 58.97 |
| 20% | 53.17 | 57.1 |

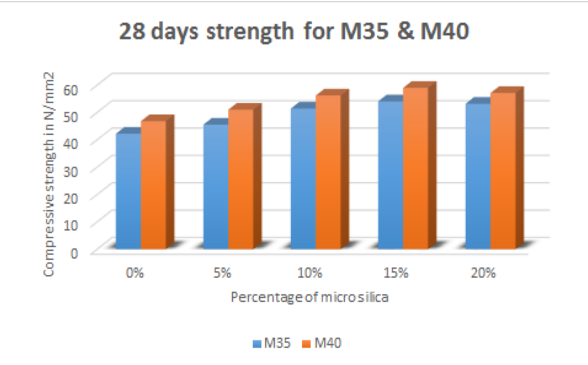


**Fig7: 28 Days Compressive strength of M35 & M40 with Varying pPercentage of Micro Silica.**

**Table IX. Results of 45 days Compressive Strength**

| Percentage of Micro silica | Compressive strength in N/mm$^2$ | |
|---|---|---|
| | M35 | M40 |
| 0% | 47.56 | 51.48 |
| 5% | 53.23 | 54.62 |
| 10% | 57.2 | 58.11 |
| 15% | 60.12 | 61.23 |
| 20% | 58.5 | 59.56 |

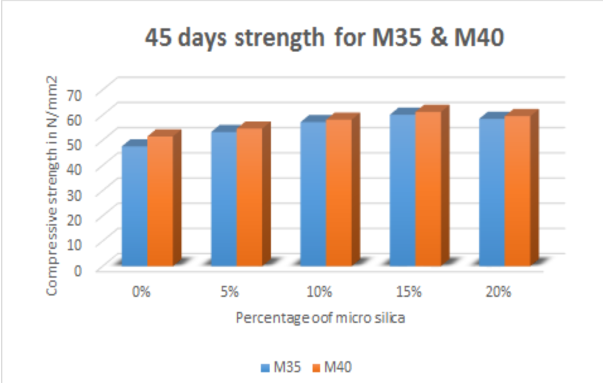


**Fig 8: 45 Days Compressive Strength of M35 with Varying Percentage Oof Micro Silica**

**Table X. Results of 60 Days Compressive Strength**

| Percentage of Micro silica | Compressive strength in N/mm$^2$ | |
|---|---|---|
| | M35 | M40 |
| 0% | 48.98 | 51.9 |
| 5% | 54.83 | 55.22 |
| 10% | 58.91 | 60.23 |
| 15% | 61.92 | 63.00 |
| 20% | 60.25 | 61.10 |

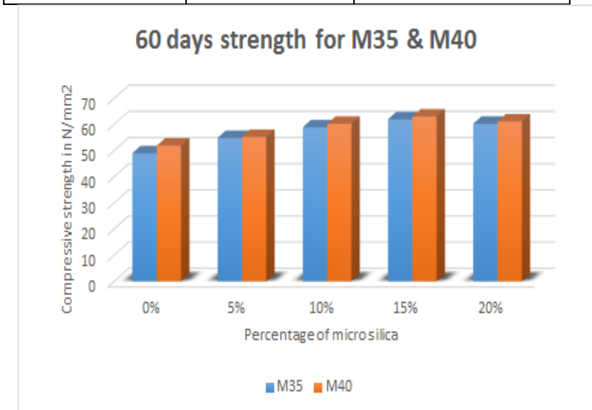


**Fig9: 60 Days Compressive Strength of M35 & M40 with Varying Percentage of Micro Silica**

**Table XI: Change in Compressive Strength with Varying Percentage of Micro Silica fFor M35**

| Description | Compressive strength in N/mm$^2$ w.r.t days | | | | |
|---|---|---|---|---|---|
| | 3 | 7 | 28 | 45 | 60 |
| M-35/0% | 18.2 | 29.4 | 42.2 | 47.56 | 48.98 |
| M-35/5% | 19.86 | 32.63 | 45.5 | 53.23 | 54.83 |
| M-35/10% | 21.62 | 37.63 | 51.48 | 57.20 | 58.91 |
| M-35/15% | 24.85 | 38.51 | 54.02 | 60.12 | 61.92 |
| M-35/20% | 23.02 | 38.22 | 53.17 | 58.5 | 60.25 |

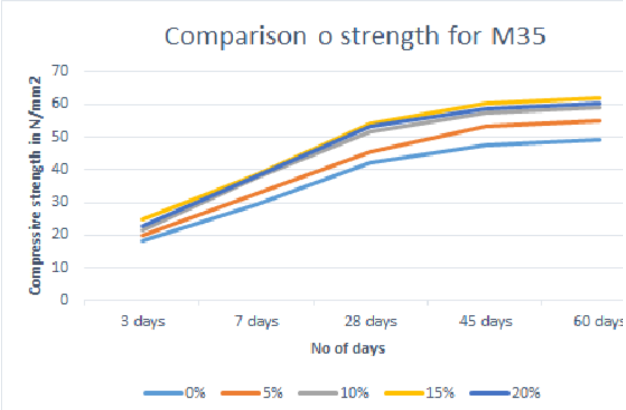


**Fig10: Comparison of Strength of 3, 7, 28, 45 and 60 Days with Varying Percentage of Micro Silica for M35**

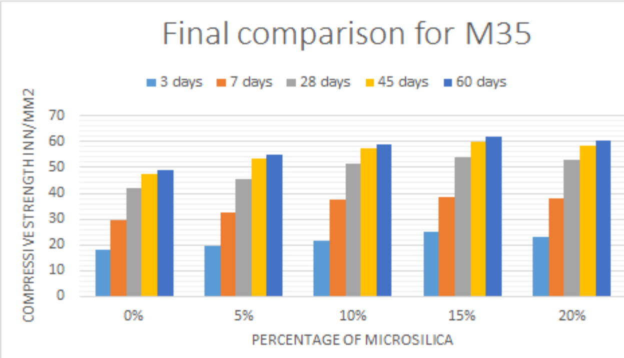


**Fig11: Comparison of Strength of 3, 7, 28, 45 and 60 Days With Varying Percentage of Micro Silica For M35**

**Table XII: Change in Compressive Strength With Varying Percentage Of Micro Silica For M40**

| Description | Compressive strength in N/mm$^2$ w.r.t days | | | | |
|---|---|---|---|---|---|
| | 3 | 7 | 28 | 45 | 60 |
| M-40/0% | 19.67 | 31.22 | 46.8 | 51.48 | 51.9 |
| M-40/5% | 20.91 | 34.67 | 51.01 | 54.62 | 55.22 |
| M-40/10% | 24.71 | 39.2 | 56.16 | 58.11 | 60.23 |
| M-40/15% | 25.95 | 42.74 | 58.9 | 61.23 | 63.00 |
| M-40/20% | 24.67 | 40.44 | 57.1 | 59.56 | 61.1 |

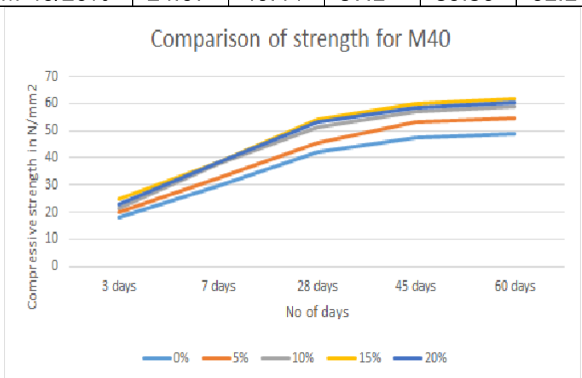


**Fig12: Comparison of Strength of 3, 7, 28, 45 and 60 days with Varying percentage of micro silica for M40**

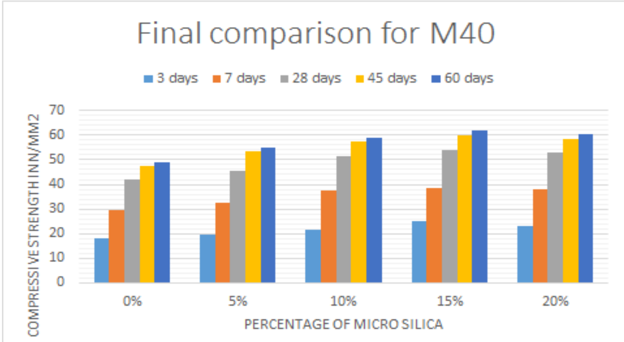


**Fig13: Comparison of Strength of 3, 7, 28, 45 and 60 days with varying Percentage of Micro Silica for M40.**

**Discussion**

From comparative study, it was observed that replacement of cement by 15% of microsilica shows maximum increase in the compressive strength for all durations such as 28, 45 and 60 days with locally available fine and coarse aggregates of North-Eastern Region.

**Conclusion**

At first mix design for M35 and M40 was performed as per IS 10262. The total cement content in the above cases were first calculated out. Then fraction of the total cement consumption was substituted by different percentages (5%, 10%, 15% and 20%)of microsilica as mentioned earlier.For both of cases (M35 and M40), the beneficial effect of micro silica is observed. In all cases locally available materials in north eastern region was used. Concrete acquired a better packing of its constituents due to extremely small particles of micro silica and becomes more impermeable with strong transition zone between aggregate and cement paste and as a result in all observation addition of micro silica gives more compressive strength. It is observed from the test results that corresponding to 15% replacement of cement by micro silica gives the best results and this trend was similar for both M35 as well as M40 concretes. The corresponding water cement ratios were 43 % for M35 and 41% for M40. . Minimum 6 cubes were cast for each proportion and the average values of compressive strength have been presented.

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