Effects of Micro-Silica on Strength of Concrete Structures.

[1]Dr. Sanjeev Chaudhari, [2]Vaibhv P Karnik, [3]Zaid Mistry, [4]Abhishek Gurav, [5]Divyesh Maiyani.

[1]Associate Professor,[2]Undergraduate Student,[3]Undergraduate Student, [4]Undergraduate Student,[5]Undergraduate Student.
[1]Department of Civil Engineering,
[1]Thakur College of Engineering and Technology, Mumbai, India.

Abstract: In the modern age, concrete can be deduced as the most used building material, as it's been in use since a long time now and it seems very difficult to find an alternative to concrete itself. However, an alternative would not be necessary if its strength and other properties could be enhanced to suit the exponentially increasing demand of higher strengths. Taking only India into consideration, the population has been increasing at a booming rate. Therefore, to compensate on the increasing population leading to increased loads and stresses concrete has to be made stronger and more capable in order to sustain the loads and provide safe habitable conditions. As a result, this research paper conveys the scope of a new modified type of concrete known as Micro-Concrete, and in what ways it can successfully replace the conventional concrete.

Index Term – Micro-Silica, Concrete, Flow Test, Compressive Test.

I. INTRODUCTION

Concrete is made up of numerous materials, out of which cement is the most important. Cement is the material which gives concrete its binding and flexural ability, therefore to understand the trend of strength in different forms of concrete, the behavior of cement in the same would be needed to study too. The major lookout for cement in concrete would be to observe the hydration of cement. At present various materials are added to the mix like, fly ash, blast furnace slag, and bacteria etc, which show increase in strength. However, Micro Technology shows the most significant results and has the best potential for the future

1.1. Contents and Hydration of Cement

Cement by definition is the combination of calcium silicates and other calcium compounds in the crystalline form and is what inhibits concrete with the strength. Out of all the calcium compounds in cement C_3S (Tri-Calcium Silicate) and C_2S (Di-Calcium Silicate) are the major constituents (about 70% composition of cement) which give the strength after reacting with water. This reaction of the Calcium compounds with water is called as the "Hydration Reaction". These reactions are exothermic reactions and along with heat they give 2 major end products namely C-S-H gel and Calcium Hydroxide (Ca $(OH)_2$. Out of the two products C-S-H gel (Calcium Silicate Hydrates) has comparatively a larger surface area and takes up more than half of the volume of cement. The larger surface area of C-S-H allows itself to form a matrix-fibrous structure which has the unique ability to attract and bind various entities of cement making it a firmly bond unit. (Shetty, 1987)

1.2. Production of Micro-Silica

MicroSilica is a by-product formed in the electric reduction furnaces during the production of ferrosilicon and silicon. SiO2 is reduced with a carbon reducing agent to give ferrosilicon or silicon. In the reaction zone gaseous SiO is formed as an intermediate product. As gas moves upwards, a part of it is condensed in the cooler placed above reaction zone. The gas which escapes is transformed into amorphous SiO2 by quickly cooling and oxidizing it with the air which is supplied to the furnace. Now with the help of filters the particulate SiO2 is taken out of the furnace in the off-gas. The MicroSilica obtained in this way is generally spherical in shape and the size varies between 0.02 to 0.05 microns.

1.3. Micro-Silica in Concrete (Article)

The unique selling point of Micro-technology is its extra minuscule size which allows its Micro-particles to have increased surface area. So when these particles come together they are able to form fiber matrices of larger surface area as it's Microstructure pack particles closer than normal and would fill the natural voids. The exothermic reactions which take place in concrete are dependent on the amount of area available to carry out the reaction, therefore larger the surface area, faster will be the rate of reaction. Which means that in a small amount of cement, in comparison with ordinary concrete more strength can be obtained due to accelerated rate of reactions. As the rate of pozzolanic reactions increases more amount of C- S-H gel is formed which increases the density of the matrix structure. In turn, this phenomenon helps to increase the strength and durability of concrete overall, strength is improved in several aspects such as compression, flexure, tension and shear.

1.4. Benefits of Micro-Silica

- Significantly increases the durability of concrete
- MicroSilica reduces the permeability.
- Increases ultimate strength gain.

- Beneficial in all types of High Strength Concrete.
- Improves bond strength to steel.
- Improves freeze/thaw durability of concrete.
- Provides excellent resistance to sulphate or seawater attack.
- Reduces the corrosion of steel.
- Significantly reduces alkali silica reactivity.

II. PROPERTIES OF MATERIALS

For the design mix of M25, the materials used are Cement, Sand, Coarse aggregate, Water and MicroSilica. The various properties of these materials are illustrated below.

2.1. Cement Properties

Ordinary Portland Cement of grade 53 is used in agreement with (IS: 12269–1987) for the production of concrete samples. The properties of cement are given in table 1.

Table 1: Properties of Cement (Shetty, 1987)

Specific gravity	Fineness (m^2/kg)	Soundness (mm)	Setting Time (min)	Consistency
3.15	225	10	IST – 30 FST - 600	28%

2.2 Coarse and Fine Aggregate Properties

Table 2: Properties of Coarse and Fine Aggregates. (Parida, 2015)

Property	Coarse Aggregate	Fine Aggregate
Specific Gravity	2.72	2.65
Bulk Density (KG/L)	1.408	-
Bulk Density (KG/L)	1.25	-
Water Absorption (%)	4.469	0.0651
Impact Factor	26.91	-
Crushing Value	26.541	-
Fineness Modulus	3.38	-

Table 3: Properties of Micro-Silica (Mr. Arihant S. Baid, 2013)

Compound	% by weight
SiO2	86-90
SiC	0.1-0.4
Fe_2O_3	0.2-0.9
TiO	0.02-0.06
Al_2O_3	0.2-0.6
MgO	2.5-3.5
Cao	0.2-0.5

Fig. 1: Micro-Silica sample while mixing.

III. PROCEDURE

- Cement- 450kg
- Fine aggregates- 705kg
- Coarse Aggregates- 1085kg
- Water- 170kg
- Superplasticizers- 5kg (0.7% - 0.8%)
- The final proportion of concrete is 1: 1.56 : 2.41 : 0.38

3.1. Flow Table Test

This is laboratory test which gives the manifestation of the peculiarity of concrete with respect to consistency and cohesiveness. In flow test, the mass of concrete is subjected to vibration. The spread or flow of the concrete is deliberated and this flow is associated to workability. The apparatus essentially consists of flow table 76cm in diameter over which concentric circles are indicated. A mould is made up of smooth casting metal which is in the form of frustum of cone and its dimensions are given as follows;

- Bottom surface- 25cm diameter
- Top surface- 17cm diameter
- Height of cone- 12cm

1. First of all, the top surface of the table is cleaned of all the granular materials and it is wetted. Then, the mould is placed on the centre of the table stiffly held and concrete is poured in two layers.
2. The top layer is rodded constantly and the excess of concrete which has overflowed is then removed from the mould.
3. The mould is lifted in vertically upward direction with one continuous motion and concrete is allowed to stand on its own weight without any support.
4. The table is then raised and dropped down by 12.5mm fifteen times in about 15 seconds.
5. The diameter of the spread concrete is measured in about six symmetrical directions to the nearest of 5mm and then, the average spread is noted down. (Shetty, 1987)

3.2. Compressive Strength

Cement concrete is a mixture of cement, fine aggregates, coarse aggregates and water in a certain proportion which has always been meant to resist compressive stresses more efficaciously. Hence the strength of concrete is nothing but the compressive strength. The size of mould used in compressive strength of concrete is 150mm x 150mm x 150mm as per I.S. code. Compressive strength of concrete is inversely proportional to the size of specimen. Compressive strength of concrete depends upon the various parameters;

- Water Cement Ratio
- Cement types
- Aggregates texture
- Curing of concrete
- Temperature at which concrete is hardened
- Hardening time

The steps to be followed are:

1. Firstly, select a suitable proportion of cement, sand and aggregates (For example 1:1:2 means 1 part of cement 1 part of sand and 2 parts of aggregates)
2. Mix it in a dry state followed by adding MicroSilica in varying percentage and water cement ratio as per the flow table test.
3. The moulds are cleaned and oil is applied on the internal surface.
4. Concrete is then filled in these moulds in 3 layers 50mm each by tamping each layer 25 times with tamping rod and then they are placed on vibration table to evict air and voids from the concrete.
5. The moulds are then removed from the vibration table and the top surface is levelled and the date of casting is impregnated on the cubes.
6. Then the cubes are kept for curing (i.e. for 3 days, 7 days and 28 days)
7. At the time of testing, excess water is made to drain and then the cube is placed in the compression testing machine.
8. Load is gradually applied till the failure occurs. Peak load and peak stresses are noted down. (Shetty, 1987)

Table 4: Standard Compressive Strength of Ordinary Concrete

Grades of concrete	Compressive strength at the end of 7 days (N/mm^2)	Compressive strength at the end of 28 days (N/mm^2)
M10	7	10
M15	10	15
M20	13.5	20
M25	17	25
M30	20	30
M35	23.5	35
M40	27	40

IV. Results and Discussions

4.1. Flow Test Results

Table 5: For 6.4% Micro-Silica

Time of flow	Flow Diameter
Initial	630
1-hour flow	600
2-hour flow	480

Table 6: For 5.6% Micro-Silica

Time of flow	Flow Diameter
Initial	650
1-hour flow	615
2-hour flow	500

Table 7: For 4.8% Micro-Silica

Time of Flow	Flow Diameter
Initial	670
1-hour flow	620
2-hour flow	520

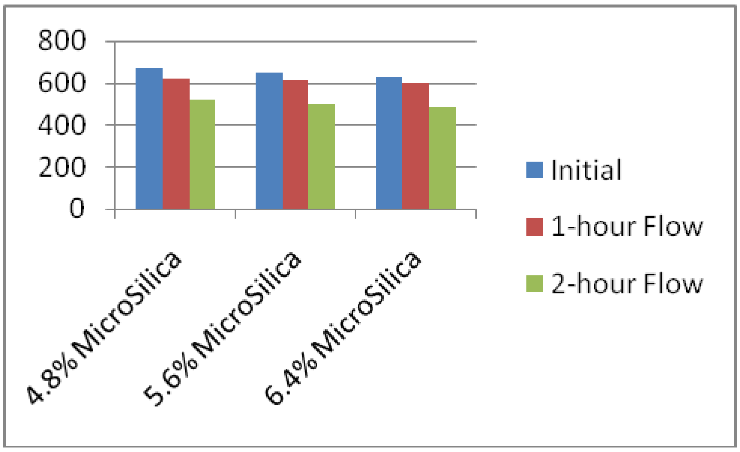

Fig.2: Flow test graph

From the graph, it has been observed that as the percentage of MicroSilica increases, flow of concrete decreases up to certain percentage. After flow table test, optimum water cement ratio was found to be 0.38%.

4.2 Compression Test Results

Table 8: For 6.4% Micro-Silica

Days	Strength (MPa)			Average Strength (MPa)
3	43.4	42.8	43.2	43.13
7	57.9	57.2	57.6	57.56
28	72.4	72.9	72.6	72.63

Table 9: For 5.6% Micro-Silica

Days	Strength (Mpa)			Average Strength (MPa)
3	42	42.5	42.3	40.24
7	55.8	55.6	55.4	55.6
28	70.6	70.1	70.8	70.5

Table 10: For 4.8% Micro-Silica

Days	Strength (Mpa)			Average Strength (MPa)
3	40.5	40.6	40.4	40.5
7	53.6	53.8	53.9	53.8
28	67.5	67.4	67.6	67.5

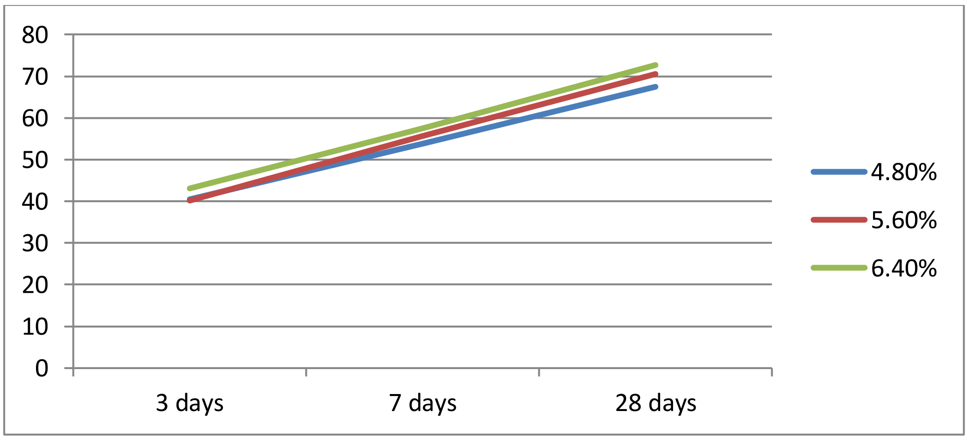

Fig. 3: Graph of Compressive test results.

From the graph, we can conclude that as the percentage of MicroSilica increases, the strength of concrete also increases upto a certain limit. The maximum increase in the compressive strength is observed for 6.40% of MicroSilica. The design factors shall be taken into consideration with 6.4% of MicroSilica.

V. CONCLUSION

Application of MicroSilica in Concrete yields to enhanced properties of the same grade of concrete. It is to become one of the most commonly used products because it reduces the proportion of cement to be used and at the same time also imparts increased strength to the concrete, which enables the designers to make the design of the structural components more economical. MicroSilica is able to inhibit Concrete with such advantages because of the increased surface area it provides for the pozzolanic reactions taking place between the cement and water. Therefore, as the rate of reaction is directly proportional to the amount of surface area, the rate of the hydration reactions increases. Along with imparting high initial strength to Concrete, MicroSilica would also make the Concrete more durable in the long term as the durability tests suggest.

This study depicted that the strength of Concrete increases with increasing MicroSilica content up to a certain optimum percentage. Beyond the optimum value the strength is observed to be decreasing. The optimum percentage for the addition of MicroSilica is considering both flow properties and strength properties of concrete.

The results obtained from the experimental observation of the Effect of MicroSilica on strength of Concrete Structures definitely verify that:

- The mixing of MicroSilica in the Concrete mix makes the Concrete more homogenous and reduces the extent of its segregation, bleeding compared to the ordinary Concrete.
- With increasing percentage of MicroSilica the workability also increases up to an optimum value.
- Concrete obtained from the MicroSilica mix is seen to be more intact and crack free.
- The Characteristic compressive strength results speak for themselves as a considerable increase has been observed.

VI. REFERENCES

[1] Mr. Arihant S. Baid (2013) Effect of partial replacement of cement by silica fumes (MicroSilica).
[2] Paramita Mondal (2010) Effects of adding silica fume and Nanosilica to concrete and provides a better understanding of the changes in the concrete nanostructure.
[3] MS Shetty (1987) Concrete Technology.
[4] Concrete Construction Article.