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# INVESTIGATION OF PERMEABILITY PROPERTIES OF HIGH PERFORMANCE FIBER REINFORCED CONCRETE

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**Abstract :** Degradation of Concrete by the acid attack, the occurrence of reinforcement corrosion and associated damage of Concrete because of water intrusion is progressively being recognized as some of the threatening Durability problems in Reinforced Concrete Structures. High Performance Concrete (HPC) is a novel construction material with improved properties like Higher Strength, Durability, Higher Constructability, etc. In the present investigation an exertion has been made to inquire about the joint impact of addition of silica fume and Steel Fibers on the Durability of SFR-HPC with regard to Impermeability of Concrete. A HPC of M40 grade was considered and Permeability test were performed to find the persistence of Steel Fiber Reinforced High Performance Concrete. The main variables considered in this study are. Four various proportions of Micro Silica viz. 0%, 5%, 7.5%, 10% by weight of Cement. Three different Aspect Ratios of Steel Fibers i.e. 60, 70, 80. Three different Volume Fractions of Fibers i.e. 0.5%, 0.75%, 1.0%. A total of 39 numbers of Concrete specimens were cast with and without Micro Silica and Steel Fibers and tested as per IS: 3085 specification for Permeability. An average of 3 specimens was taken for each mix and Coefficient of Permeability was determined. Test results indicate that by adding of Micro-Silica to Plain Concrete up to 10% decreases its Permeability by about 52%.Further, addition of Micro Silica 5% and Steel Fibers fraction of 1.0%, reduces its Coefficient of Permeability from $10.48\times10^{-5}$ centimeter/second to $3.69\times10^{-5}$ centimeter/second. The reduction is about 35%. It is also noted that addition of 7.5% Micro Silica and Steel Fibers above 0.75% fraction, results indicate in increase in Coefficient of Permeability value. Further experimental results reveals that addition of 10% Micro Silica along with Steel Fibers do not reduce the value of Coefficient of Permeability of Concrete. In all, the results of present investigation gave an insight on possible way of improving impermeability of Concrete by making use of mineral admixtures like Micro Silica in combination with Steel Fibers.

***Keywords*** *- High Performance Concrete (HPC), Micro-Silica, Steel Fibers, Coefficient of Permeability, workability, compressive strength, Flexural strength and Tensile strength.*

## 1.INTRODUCTION

Concrete production exists around the world as a leading material in construction for our infrastructure and essentially today, this man-made stone has risen as a most versatile and universally recognized tool to build with. The durability of concrete is characterized as the capacity of the material to stay workable for in any event the required lifetime of the structure. Likewise, its durability is fundamental in safeguarding the infrastructure of society. Amongst the different strategies to improve the Durability of Concrete, and to accomplish High Performance Concrete, the utilization of Micro Silica is a newly approach. In many situations, the durability of concrete is likewise legitimately identifies with its permeability which again depends a great deal upon its protection from entrance of dampness. The dampness which goes into the concrete can prompt to disintegration of steel reinforcement and diminishes the life of the structures radically. Accordingly, the durability of concrete depends to great extent upon the penetrability of concrete which is characterized as the simplicity with which it enables the liquids to go through it. Moreover, it is by reducing the permeability, the time is known to be extended so as to prevent any aggressive chemical to get into the concrete where it can do its damage. Consequently, a significant proportion of improving concrete impermeability is to initially improve the capacity of opposing shrinkage and arresting crack. In the past, several examination have demonstrated that addition of Mineral Admixtures and fiber steel is an proficient technique to improve the mechanical performance of weak networks as mortars and concretes by preventing cracking. Additionally, it is very much popular to increase fracture durability given by fiber spanning on the primary crack plane prior to crack augmentation. Debonding, sliding and hauling-out of the filaments have been featured as the nearby systems that control the bridging action. From long term, Bond-based materials for example concrete have been utilized for the development of civil frameworks. Regardless, the breaking down of common foundation wherever all through the world, has incited the affirmation that bond based materials must be improved similar to their building property and sturdiness. Furthermore, strategic infrastructure investments require strict quality control and assurance measures on the production and durability of concrete, from which usually a 100-year service life, without any major repair work, is expected. The use of pozzolanic materials in optimum proportion reduces the permeability of concrete. This is evident because of the conversion of (CaOH), otherwise soluble and leachable, into cementitious product.

## A. PERMEABILITY OF CONCRETE

Permeability, described as moment of liquid through a porous medium under an application of pressure head, is the most significant property of concrete administrating its long-term strength. Permeability of concrete, thus, is affected by two essential components: inter-connected porosity in cement paste and thinline cracks in the concrete. Porosity in the paste of cement and the level of its interconnectivity are overseen for most of the part by water-cementatious (w/c) ratio, level of compaction and level of hydration. Density and Area of interfacial micro cracks, then again, are controlled by level of connected pressure of distortion, outside or inside, experienced by the concrete.

## B. NEED FOR PRESENT STUDY

The durability of concrete depends a great deal upon its protection from entrance of dampness. The dampness which goes inside the concrete can prompt erosion of steel reinforcement and decrease the life of the structure definitely. Regardless of the way that, the durability of concrete relies on the porousness of concrete which is portrayed as the straightforwardness with which it empowers the fluid to experience in it. Despite the fact that the durability is a key factor influencing the life span of concrete structure, just few examinations were completed to explore the impact of expansion of micro silica on the Durability

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of Normal and High Performance Concrete. Utilization of Micro Silica diminishes the Permeability of Concrete. Usage of Steel Fibers increases the tensile strength present in the structure. A literature survey shows that while so many researchers considered the individual impact of adding of either Micro Silica or Steel Fibers on Durability of Normal Concrete, very few reports are available on the influence of presence of both Micro Silica and Steel Fibers on the Permeability of Concrete. Hence an attempt has been made to consider the joint impact of Micro Silica and Steel Fibers on the Durability of High Performance Concrete (HPC) with respect to Permeability

## 2. OBJECTIVE

a. To evaluate the influence of various Percentages of Micro Silica on the Permeability of Concrete.

b. To examine the influence of different proportions of Silica Fume in combination of various Percentages of Steel Fibers Fractions on Permeability of Concrete.

c. To arrive at best combination of Silica Fume and Steel Fiber content for improved Durability.

## 3. MATERIALS USED

Cement:

Cement used in the investigation was found to be Ordinary Portland Cement(53 grade) confirming to IS : 12269 – 1987.

Fine Aggregate:

The fine aggregate used was obtained from a near by river course. The fine aggregate confirming to zone – II according to Is 383-1970 was used..

Coarse aggregate:

The coarse aggregate used is from a local crushing unit having 20mm nominal size. The coarse aggregate confirming to 20mm well-graded according to IS:383-1970 is used in this investigation.

| property | Test result |
|---|---|
| Normal consistency | 33% |
| Specific gravity | 3.14 |
| Initial setting time | 75 |
| Final setting time | 200 |
| fineness | 3.4% |

Table.1 Physical properties of cement

WATER:

Portable Water free from salts and natural pollutants and was used for mixing and curing of Concrete.

MICRO SILICA:

The Physical and Chemical Properties of Micro Silica are tabulated in below table

| | |
|---|---|
| Average particle size, µm | Coarse Particles > 45 micron Max. 9%<br><br>Coarse Particles < 45 micron Max. 91% |
| Specific surface area | 202 cm/gm |

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| | |
|---|---|
| Bulk density(kg/m³) | 500-600 |
| Physical Form | Grey colored powdered |

Table.2 Physical Properties of Micro Silica as per Manufacturer's Literature

STEEL FIBERS:

Straight Galvanized iron Steel Fibers chopped in three different sizes with Aspect Ratio viz. 60, 70, 80, was used.

SUPER PLASTICIZER:

Super plasticizer Conplast SP-337 Manufactured by Fosroc Chemicals (India) Limited, Bangalore, was utilized as water reducing agent to achieve the required Workability.

## 4. EXPERIMENTAL WORK

Using the Properties of Cement and Aggregates, Concrete mix design of M40 grade was designed as per IS 10262**.** The mix design procedure and calculations are shown in Appendix A. The following proportions by weight were obtained.

| Cement | Fine aggregate | Coarse aggregate | Water-Content | W/C Ratio |
|---|---|---|---|---|
| 450 kg/m³ | 412.12 kg/m³ | 1340.14 kg/m³ | 186.5 kg/m³ | 0.41 |

Table.3: Designed Values of Materials

By using these proportions, a Trial mix was carried out and Compressive strength was determined. It was found that compressive strength for 7 days was very high with these proportions. So, again by doing trials with different water content, final proportions satisfying the strength requirements were obtained. The final proportions are as given below.

| Cement | Fine aggregate | Coarse aggregate | Water-Content | W/C Ratio |
|---|---|---|---|---|
| 450 kg/m³ | 417 kg/m³ | 1356 kg/m³ | 178 kg/m³ | 0.39 |

Table.4: Designed Values of Materials

The above mix proportions were used throughout the experiment.

A. CONCRETE MIX CASES

As stated earlier, the present investigation aims at understanding the impact of Micro Silica and Steel Fibers on Coefficient of Permeability of Various grades of Concrete. Accordingly, a total of 13 mix cases including one controlled concrete mix were designed by considering Micro Silica in various percentages viz.5%, 7.5%, 10%, combined with Steel Fibers having three different Aspect Ratios i.e. 60, 70, 80. Various percentage fractions of Fibers were also varied from 0.5% to 1.0% for each Aspect Ratio of Fibers to understand its importance on Permeability of concrete.

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Details of 13 mix cases containing Micro Silica, Steel Fibers, etc. are presented in below table.

| Mix ID | Micro Silica in Concrete, (% by weight of cement) | Aspect Ratio of Steel Fibers | Fraction of Fibers, (% by total wt. of concrete ingredients) |
|---|---|---|---|
| MC | 0 | -- | -- |
| M1 | 5 | -- | -- |
| M2 | 7.5 | -- | -- |
| M3 | 10 | -- | -- |
| M1A1F1 | 5 | 60 | 0.5 |
| M1A1F2 | 5 | 60 | 0.75 |
| M1A1F3 | 5 | 60 | 1.0 |
| M2A2F1 | 7.5 | 70 | 0.5 |
| M2A2F2 | 7.5 | 70 | 0.75 |
| M2A2F3 | 7.5 | 70 | 1.0 |
| M3A3F1 | 10 | 80 | 0.5 |
| M3A3F2 | 10 | 80 | 0.75 |
| M3A3F3 | 10 | 80 | 1.0 |

Table.5 Details of Mix Cases

CASTING AND CURING OF TEST SPECIMENS:

Using the mix proportions and quantities of ingredients tabulated in Table.6 for various mix cases, concrete of desired grade is produced and specimens for Permeability test are cast. In all 39 cylinders of size 100millimeter Ø x 100millimeter ht. are cast. The detailed procedure of concrete mixings, casting and testing is described in the following text.

| Mix Type | Cement (kg) | Fine Aggregates (kg) | Coarse Aggregate (kg) | Micro Silica (gm) | Steel Fibers (gm) | Super Plasticizer (ml) | Water (ml) |
|---|---|---|---|---|---|---|---|
| MC | 1.269 | 1.175 | 3.382 | --- | --- | 6.7 | 501.96 |
| M1 | 1.205 | 1.175 | 3.382 | 60.25 | --- | 6.7 | 501.96 |

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| M2 | 1.173 | 1.175 | 3.382 | 87.97 | --- | 6.7 | 501.96 |
| M3 | 1.143 | 1.175 | 3.382 | 114.3 | --- | 6.7 | 501.96 |
| M1 A1F 1 | 1.205 | 1.175 | 3.382 | 60.25 | 31.3 | 6.7 | 501.96 |
| M1 A1F 2 | 1.205 | 1.175 | 3.382 | 60.25 | 46.95 | 6.7 | 501.96 |
| M1 A1F 3 | 1.205 | 1.175 | 3.382 | 60.25 | 62.6 | 6.7 | 501.96 |
| M2 A2F 1 | 1.173 | 1.175 | 3.382 | 87.97 | 31.3 | 6.7 | 501.96 |
| M2 A2F 2 | 1.173 | 1.175 | 3.382 | 87.97 | 46.93 | 6.7 | 501.96 |
| M2 A2F 3 | 1.173 | 1.175 | 3.382 | 87.97 | 62.58 | 6.7 | 501.96 |
| M3 A3F 1 | 1.143 | 1.175 | 3.382 | 114.3 | 31.2 | 6.7 | 501.96 |
| M3 A3F 2 | 1.143 | 1.175 | 3.382 | 114.3 | 46.9 | 6.7 | 501.96 |
| M3 A3F 3 | 1.143 | 1.175 | 3.382 | 114.3 | 62.5 | 6.7 | 501.96 |

Table.6 Quantities of Concrete Ingredients for Three Cylinder Specimens

MIXING OF MATERIALS:

Various constituents of concrete mixtures were weigh batched accurately as tabulated in Table 3.8. Cement, Fine Aggregate, Coarse Aggregate, Micro Silica was mix thoroughly. Fibers are then added to the mix in required proportions. After through dry mixing, little quantity of water from a required quantity was added to the mix. After mixing, remaining quantity of water along with Super Plasticizer was added and it is then overturned and mixes well till a homogeneous mix was obtained. This homogeneous concrete was used for casting of specimens.

CASTING OF SPECIMENS:

The homogeneous mix obtained was used to cast the cylinder specimen of size 100mm diameter×100mm height which meets the requirements of Cement Mortar and Concrete Permeability Apparatus as per IS 3085-1965. The wet mix was filled into the moulds in layers. Table vibrator was used for doing the compaction of concrete.

CURING:

After 24 hours of casting, the specimens were demoulded and labeling was done as per the mix cases and immersed in the water tank for curing.

B .PERMEABILITY TEST PREPARATION OF SPECIMEN:

Once the curing is done for 28 days, the specimens were removed from the curing tank and it was kept for drying for few hours. The surface was cleaned and dust particles and deposits were removed. The sharp edges of the cylinders at the joints were smoothened. Care had been taken to

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smoothen the edges to round shape. After drying the thread was wound around the specimen densely to fit it in the Permeability apparatus cell with no gaps. However, to ensure that gap between the specimen and cells are closely air tight, molten sealing compound was poured. The whole set up was tested for water leakage through the gaps between specimen and cell walls by pounding water over one of the surface of the specimen. After it ensures that no leakage is taking place, the cell is capped with cover plate and tightened properly to ensure no leakages from the sides. The whole set up of Permeability cell with specimen is ready for running the Permeability test.

TESTING OF SPECIMENS:

The permeability cell with specimen made ready as stated above is placed in the permeability test set up and water pipe was attached to a water reservoir of Permeability test setup. The water reservoir of Permeability test setup was loaded with distilled water and the standard test pressure of 10kilogram/centimeter-square was maintained in the water reservoir. This may anyway can be decreased as much as 5 kilogram/centimeter-square in case of more Penetrable Specimens, and may be increased up to 1515kilogram/centimeter-square for less Permeable Specimens.

RUNNING THE TEST:

After testing the seal, the desired test pressure was applied and in the mean time, a clean collecting bottle was placed in position and the water percolating through the specimen was recorded. This test was proceeded for 24 hours till the steady state flow was reached. The out flow was considered as an average of all the out flows measured during 24 hours. This test was done at a temperature of 27˚c ± 2˚c. Any increase or decrease of 5˚ctemperature results for coefficient of permeability value to be increased or decreased by 10%.

## 5. RESULTS & DISCUSSIONS

### A. PERMEABILITY TEST RESULTS

The permeability test was done on different Mix Cases of Micro Silica and Steel Fibers as describe in Table 6. To determine the Coefficient of Permeability, the quantity of water percolating, Area of Specimen, time for which permeability test was done, pressure head and thickness of specimen were observed.

The Coefficient of Permeability is calculated using the following formula.

$$K = \frac{Q}{A \times T \times \frac{H}{L}}$$

In which,
K = Coeff. of Permeability in centimeter/second.

Q = Qty. of Water in milliliters permeating over the whole time of test after the Steady State has been reached

A =Area of the specimen in centimeter²

T = Time in seconds over which Q is measured; and

H/L= Proportion of the Pressure Head to Thickness of Sample, both indicated in similar units.

Calculated values of Coeff. of Permeability are presented in Table 7.

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For better understanding and discussion, the Penetrability outcomes test results are exhibited in the graphical form. These graphs will reveal the impact of silica fume and Steel filaments on performance of various grades of concrete in terms of Permeability.

B. Variation of Coefficient of Permeability of Concrete for various proportions of Micro Silica and no Steel Fibers A graph (Fig.1) is drawn between concrete mix types without Steel Fibers and Coefficient of Permeability to depict the trend of change in Coefficient of Permeability of Concrete containing various proportion of Micro Silica.

| MIX ID | Coefficient of Permeability, x $10^{-5}$( cm/sec) |
|---|---|
| MC | 10.48 |
| M1 | 9.46 |
| M2 | 7.61 |
| M3 | 5.42 |
| M1A1F1 | 5.13 |
| M1A1F2 | 4.37 |
| M1A1F3 | 3.69 |
| M2A2F1 | 3.72 |
| M2A2F2 | 4.96 |
| M2A2F3 | 10.39 |
| M3A3F1 | 9.72 |
| M3A3F2 | 9.62 |
| M3A3F3 | 8.42 |

Table.7 Results for Permeability Test

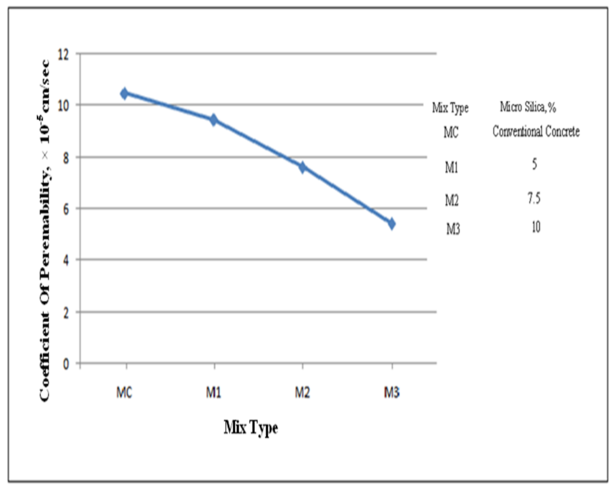


Fig .1 Variation of Coefficient of Permeability of Concrete with Various Percentages of Micro Silica

C. Variation of Coefficient of Permeability of Concrete for various proportions of Micro Silica and Steel Fibers

(a) To comprehend the impact of variation of Steel strands division viz. 0.5%, 0.75%, and 1.0% with constant percentages of Micro Silica, graphs are drawn. For 5% Micro Silica content in a concrete mixture, the relationship is shown in Figure.2. For 7.5% silica fume content, the variation is shown in Figure.3, and for 10% Micro Silica the trend is shown in Figure.4.

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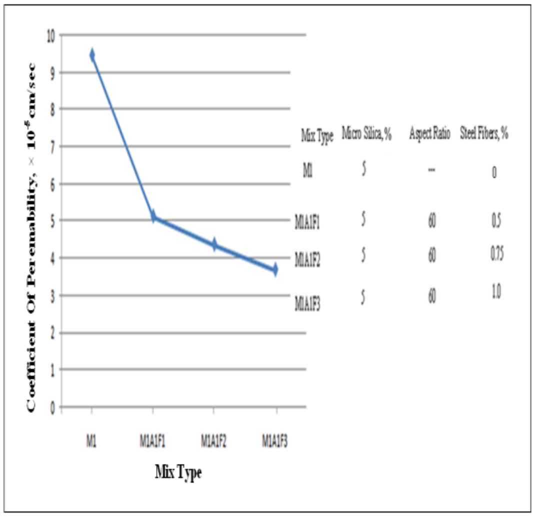


Fig .2 Variation of Coefficient of Permeability of Concrete with Various Percentage Fraction of Steel Fibers and 5% Micro Silica

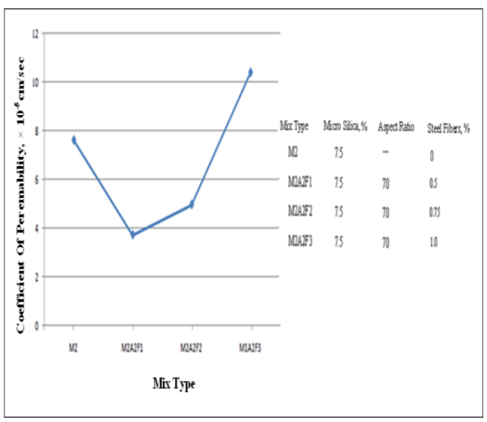


Fig.3 Variation of Coefficient of Permeability of Concrete with Various Percentage Fraction of Steel Fibers and 7.5% Micro Silica

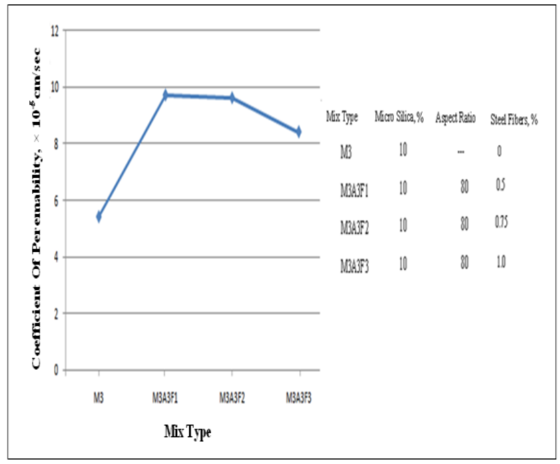


Figure.4 Variation of Coefficient of Permeability of Concrete with Various Percentage Fraction of Steel Fibers and 10% Micro Silica

(b) Graphs are drawn to indicate the influence of variation of Micro Silica viz. 5%, 7.5%, 10% and constant percentage fraction of Steel Fibers on Coefficient of Permeability of Concrete. For 0.5% Steel Fibers content and with 60 as Aspect Ratio in Concrete mixture, the variation is shown in Figure.5. For 0.755 Steel Fibers content and Aspect Ratio of 70, the relationship is shown in Figure.6. For 1.0% Steel strand content and with 80 as Aspect Ratio of in Concrete mixture, the trend is shown in Figure .7.

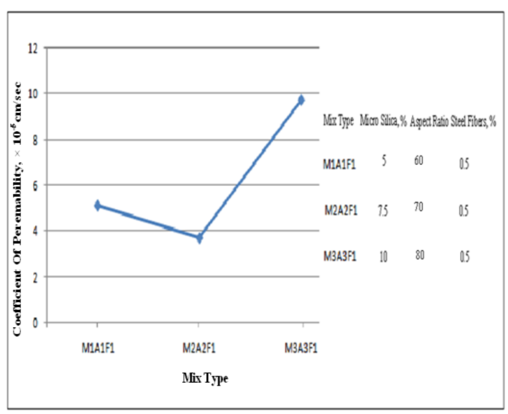

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Fig.5 Variation of Coefficient of Permeability of Concrete with Various Percentages of Micro Silica for 0.5% Steel Fibers Fraction

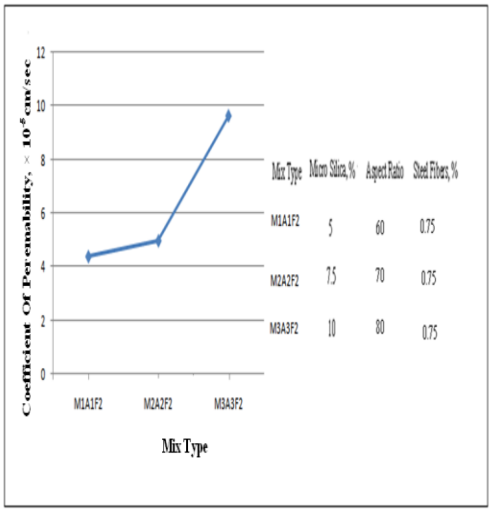


Fig.6 Variation of Coefficient of Permeability of Concrete with Various Percentages of Micro Silica for 0.75% Steel Fibers Fraction

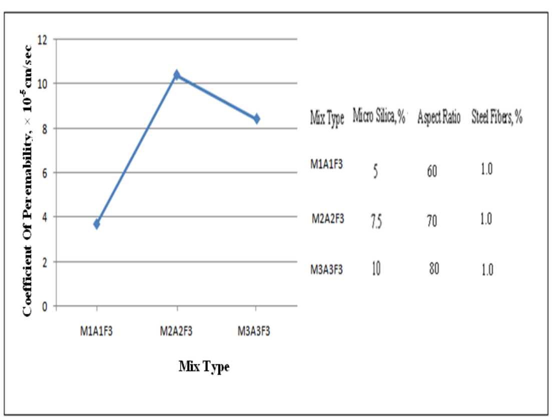


Fig.7 Variation of Coefficient of Permeability of Concrete with Various Percentages of Micro Silica for 1.0% Steel Fibers Fraction

D. Relative Coefficient of Permeability for Various Mix Cases

To have a reasonable picture of performance of different concrete blends containing micro Silica and Steel Strands in the Standard Conventional Concrete mixture, Relative values of Coefficient of Permeability of 13 Concrete mix cases are presented in the form of Bar charts shown in Figure.8.

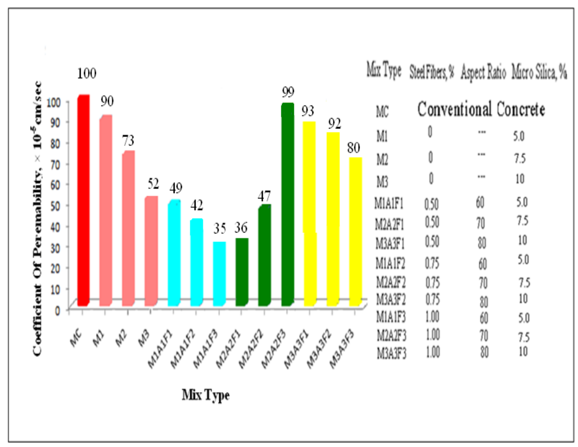


Fig.8 Relative Coefficient of Permeability for Various Mix Cases

## 6. CONCLUSION

**a.** Addition of 5% Micro Silica reduces the Coefficient of Permeability to $9.46\times10^{-5}$ cm/sec, when compared to $10.48\times10^{-5}$ cm/sec for sample without silica fume. As the addition of silica fume increases to 7.5% and 10%, the coefficient of Permeability reduces to $7.61\times10^{-5}$ centimeter/second and $5.42\times10^{-5}$ centimeter/second, respectively. The reduction is about 48%.

b. Addition of 5% Micro Silica along with various percentages of volume fraction of Steel Fibers, the coefficient of Permeability reduces from $5.13\times10^{-5}$ cm/sec to $4.37\times10^{-5}$ centimeter/second, and $3.69\times10^{-5}$ centimeter/second, for 0.5%,0.75%,1.0% Volume fraction of Steel Fibers respectively. The reduction is about 65% with compared to specimen without Micro Silica and Steel Fibers.

**c.** On addition of 7.5% Micro Silica and Steel Fibers having Aspect Ratio 70, the Coefficient of Permeability value decreases to $3.72\times10^{-5}$ cm/sec, for Steel Fiber volume 0.5%. Further increment in Volume part of Fibers to 0.75% and 1.0%, the Penetrability value increments to $4.96\times10^{-5}$ centimeter/second, $10.39\times10^{-5}$ centimeter/second, respectively. This increase in permeability is due to Balling effect.

d. Adding of 10% silica fume and Steel strands having Aspect Ratio of 80 does not have much effect on Permeability of Concrete. The value slightly reduces to $9.72\times10^{-5}$ centimeter/second, $9.62\times10^{-5}$ centimeter/second, $8.42\times10^{-5}$ centimeter/second, when compared to $10.48\times10^{-5}$ centimeter/second, for concrete specimen without Micro Silica and Steel Fibers.

e. Steel Fibers Aspect Ratio also affects the Coefficient of Permeability value. Steel fibers having Aspect Ratio 60 and 5% Micro Silica, the permeability value decreases. But further adding of Micro Silica 7.5%, 10% and Steel Fibers having Aspect Ratio 70 and 80, the Permeability value increases respectively.

f. For a given Aspect Ratio of Steel Fiber, Permeability of Steel Fiber Reinforced Concrete composites decrements as the Volume portion of strand increments. The rate of decrease of Permeability however decreases with the incrimination of Fiber content.

g. The best combination obtained from the test results is with the addition of 5% Micro Silica and Fibers volume fraction 1.0% and having Aspect ratio 60.

## 7. FUTURE SCOPE

Further studies on durability of Concrete in terms of Permeability to verify the influence of other mineral admixtures with or without Fibers. Studies on Performance of Concrete in terms of improving impermeability of Concrete can be carried out by using other type of Fibers in combination of mineral admixtures. Investigation on durability of Concrete in terms of Coefficient of permeability may be extended to wide range of various grades of Concrete containing mineral admixtures and Fibers.

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