International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

IJIEMR Transactions, online available on 20th Jan 2020. Link :http://www.ijiemr.org/downloads.php?vol=Volume-09&issue=ISSUE-01

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Volume 09, Issue 01, Pages: 65-75.

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International Journal for Innovative Engineering and Management Research
PEER REVIEWED OPEN ACCESS INTERNATIONAL JOURNAL
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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 10.48×10^{-5} centimeter/second to 3.69×10^{-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.

CHAPTER 1
INTRODUCTION
1.1 INTRODUCTION

Permeability, described as moment of liquid through a porous medium under an application of pressure head, is the most significant property of concrete

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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.

1.2 HIGH PERFORMANCE CONCRTE

Over the past two decades, High performance concrete (HPC) has been widely used in the field by the contractors. Even in marine construction engineering, the proportion of concrete was often characterized by low water-binder ratio, adequate mineral admixtures and super plasticizers to attain low chloride permeability and high frost resistance.

1.3 SUPPLEMENTARY CEMENTITIOUS MATERIALS

Severe ecological contamination controls and guidelines have prompted an expansion in utilization of industrial wastes and sub graded by-products like fly ash, silica fume, ground granulated blast furnace slag etc., as supplementary-cementitious materials (SCMs). The utilization of SCMs in concrete constructions not only counteracts to check the contaminatiom but also to improve the properties of concrete in fresh and solidified states.

These SCMs can be assigned into two grouping relying upon their sort of react: pressure driven and pozzolanic. Pressure driven materials reacts really with water to give cementitious compound like GGBS. Pozzolanic materials does not have any cementitious property yet when used with bond or lime react with (CaOH) to shape items having cementitious properties.

1. **MICRO SILICA**
2. **POZZOLANIC REACTIVITY**

1.4 FIBERS

Plain concrete have lesser elasticity, confined flexibility and little insurance from breaking. Interior micro cracks are basically present in the solid and its poor Rigidity is a result of to the spread of such micro cracks, at last inciting to Weak Crack of the concrete. In the past endeavors have been made for the improvement in malleable properties of Cement by using Traditional Strengthened Steel bars and moreover by applying Limiting strategies. Albeit both these systems give Rigidity to the Solid individuals, they regardless, don't expand the Inborn Elasticity of solid itself. It has been seen that the expansion of little firmly divided and reliably scattered strands to concrete would go about as split arrester and would improve its static and dynamic properties. Strands are essentially depicted by one long pivot with other two axes every now and again frequently roundabout or close round.

1.4.2 TYPES OF FIBERS

For the most part, the accompanying various kinds of Fibers in particular are,

a) **Silicon Carbide fiber**
b) **Carbon Fibers**
c) **Glass Fiber**
d) **Boron Fiber**

1.7 OBJECTIVES OF THE PRESENT WORK

Coming up next are the motivation behind the present examination:

- To evaluate the influence of various Percentages of Micro Silica on the Permeability of Concrete.
- To examine the influence of different proportions of Silica Fume in combination of various Percentages of Steel Fibers Fractions on Permeability of Concrete.
- To arrive at best combination of Silica Fume and Steel Fiber content for improved Durability.

Literature Review

2.0 GENERAL

As mentioned earlier in the Section 1.6, need for the present study is ascertained on the basis of research reports that are available on strength & durability characteristics of concrete containing admixtures like Micro Silica & Steel Fibers. In order to plan the experimental program and attain the objectives defined, a comprehensive literature survey is essential. Hence in the following text detailed literature review on strength & durability characteristics of concrete having different admixtures is presented.

2.1 INFLUENCE OF MICRO SILICA ON STRENGTH PROPERTIES OF CONCRETE

Prasad, B.K. have taken up an examination to explore the impact of replacement of cement with silica fume in the production of High Strength Concrete. The replacement levels chosen were 0% to 20% in the increment of 5%.Thus a total of four mixtures, two of controlled concrete with and rest of two specimens with Micro Silica concrete were used. The Compressive strength and Flexural strength were found. The results displayed that.

- Optimum replacement level of Micro Silica by 12% produced a 28 days compressive quality of 55.07Mpa.
- The Flexural strength of Micro Silica concrete has increased 15% to 20% when compared to that of controlled concrete.

Venkatesh Babu examined on mechanical properties of High Performance Concrete mixes, with various substitution levels of Ordinary Portland cement with Condensed micro silica of grade 960D. The Compressive strength, split Tensile strength and Flexural strengths of the mixes were examined according to IS specifications. The following interpretation were done by the authors.

- The most extreme 90 days Compressive quality of 89.25Megapascals with 7.5% replacement of Ordinary Portland Cement with condensed micro silica when compared to 75.7Megapascals with 55 substitution of Portland Pozzalana cement.
- When comparing with the compressive strength, the rate of

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increase in tensile strength was less.

Nilforoushan, Mohammed Reza completed an examination on the effect of 15% Micro Silica on the mechanical strength of concrete made with Sulphate resisting cement. For this a total of 150 cubes were cast, 75 cubes with sulpate resisting cement and rest 75 cubes with sulphate resisting cement and Micro Silica.

The compressive strength was observed at 14 days, 28days, 180days, and 360days. The results indicate that, Compressive Strength of specimens containing 15% Micro silica is much higher than specimens without Micro, silica. It was also observed that increment in Compressive strength is more at 28 days of curing.

Al Mutairi, Bufarsan has driven a trial examination to consider about the distinctive of different rates of Fine/Coarse Tire waste and silica rage at different temperatures on the Compressive Quality of concrete. The Compressive quality of concrete blends made with tire Elastic was surveyed with those of concrete containing silica fume and conventional concrete to get to the comfort of reusing elastic waste as a piece of concrete.

Test results certifies that the handling temperature of solid blocks sway the compressive quality qualities. Generally, the utilization of silica fume or Fine rubber blended with silica fume as total substitution of 5% by volume updated the Compressive Quality of concrete at a temperature of 150ºc.

EXPERIMENTAL PROGRAMME

3.1 MATERIALS USED

The materials utilized in the test program are Cement, Coarse Aggregates, Fine Aggregates, Water, Micro Silica, Steel Fibers, Super plasticizer.

3.1.1 CEMENT

Ordinary Portland Cement of 53 Grade confirming to IS: 12269 was used. It was tested for Physical properties. The detailed test results are given in Table 3.1

Table 3.1 Physical Properties of Ordinary Portland Cement

S.No.	Property	Test Method	Test Result
1.	Normal consistency	Vicat Apparatus	33 %
2.	Sp. Gravity	Specific gravity bottle	3.14
3.	Initial-setting time Final-setting time	Vicat Apparatus	75 min 200 min
4.	Fineness	Sieve test on Sieve No. 9	3.4 %

3.1.2 COARSE AGGREGATE

In this investigation Natural Aggregates of maximum size of 20mm were used with 60% of 10mm down size Aggregates and 40% of 20mm down size Aggregates. All the relevant tests were conducted on Coarse Aggregates to evaluate its Physical properties. The details are shown in Table 3.2 and Table 3.3

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Table 3.2 Properties of Fine Aggregate and Coarse Aggregate

S.No.	Property	Test Results for Fine Aggregate	Test Results for coarse Aggregate
1	Sp. Gravity	2.62	2.72
2.	Bulk density i) loose ii) compacted	1640 Kg/m³ 1775 Kg/m³	1452 kg/m³ 1579 kg/m³
3.	Fineness modulus	3.05	7.05

Total wt. of Coarse Aggregate sample = 5000 gms

Table 3.3 Sieve Analysis of Coarse Aggregate

IS Sieve No	Wt. of aggregate retained, (gm)	% wt, retained	Cumulative % retained	% passing
20 mm	278	5.56	5.56	94.44
10mm	4722	94.44	100.00	0.0
4.75mm	--	0.0	100.00	0.0
2.36 mm	--	0.0	100.00	0.0
1.18 mm	--	0.0	100.00	0.0
600 µ	--	0.0	100.00	0.0
300 µ	--	0.0	100.00	0.0
150 µ	--	0.0	100.00	0.0
			705.56	

Fineness modulus = 705.56 /100 = 7.05

3.1.3 FINE AGGREGATE

Locally accesible River Sand confirming to IS: 383 was utilized as Fine Aggregate. The Physical properties of Fine Aggregate were explored. The details are given on Table 3.2 and Table 3.4.

Total wt. of Fine Aggregate sample = 1000 grams

Dust particle = 1000-10 = 990 grams

Table 3.4 Sieve Analysis of Fine Aggregate

IS Sieve No	Wt. of aggregate retained, gm	%wt. retained	Cumulative % retained	% passing
4.75mm	20	2	2.0	98
2.36 mm	6.3	6.3	8.3	91.7
1.18 mm	32.5	32.5	40.8	59.2
600 µ	210	21.0	61.8	38.2
300 µ	320	32.0	93.8	6.2
150 µ	52	5.2	99.0	1
	990		305.7	

Fineness modulus = 305.7/100 = 3.05

3.1.4 WATER

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

3.1.5 MICRO SILICA

The Physical and Chemical Properties of Micro Silica are tabulated in Table 3.5and Table 3.6.

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Table 3.5 Physical Properties of Micro Silica as per Manufacturer's Literature

Average particle size, µm	Coarse Particles > 45 micron Max. 9% Coarse Particles < 45 micron Max. 91%
Specific surface area	202 cm/gm
Bulk density(kg/m³)	500-600
Physical Form	Grey colored powdered

Table 3.6 Chemical Properties of Micro Silica as per Manufacturer's Literature

Characteristics	Micro Silica (% wt)
Loss on Ignition at 750 ° C	Max. 4%
SiO2	85%
K2O	<1%
Na2O	<1%
Fe2O3	<1%
PH Value	8

3.1.6 STEEL FIBERS

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

3.1.7 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.

3.2 CONCRETE MIX DESIGN

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

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

The above mix proportions were used throughout the experiment.

3.3 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,

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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. Details of 13 mix cases containing Micro Silica, Steel Fibers, etc. are presented in Table3.

Table 3.7 Details of Mix Cases

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

3.4 CASTING AND CURING OF TEST SPECIMENS

Using the mix proportions and quantities of ingredients tabulated in Table3.8 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.

Table 3.8 Quantities of Concrete Ingredients for Three Cylinder Specimens

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
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
M1A1F1	1.205	1.175	3.382	60.25	31.3	6.7	501.96
M1A1F2	1.205	1.175	3.382	60.25	46.95	6.7	501.96
M1A1F3	1.205	1.175	3.382	60.25	62.6	6.7	501.96
M2A2F1	1.173	1.175	3.382	87.97	31.3	6.7	501.96
M2A2F2	1.173	1.175	3.382	87.97	46.93	6.7	501.96
M2A2F3	1.173	1.175	3.382	87.97	62.58	6.7	501.96
M3A3F1	1.143	1.175	3.382	114.3	31.2	6.7	501.96
M3A3F2	1.143	1.175	3.382	114.3	46.9	6.7	501.96
M3A3F3	1.143	1.175	3.382	114.3	62.5	6.7	501.96

TEST RESULTS

4.1.1 Variation of Coefficient of

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Permeability of Concrete for various proportions of Micro Silica and no Steel Fibers

Table 4.1 Results for Permeability Test

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

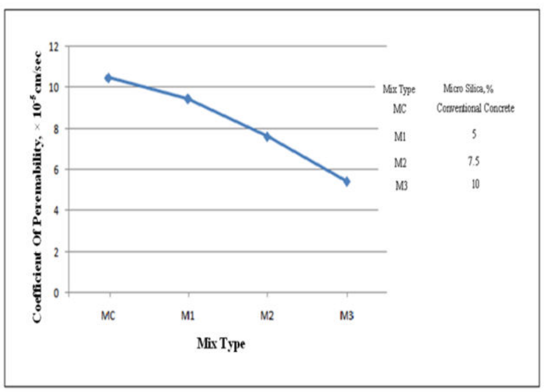

Figure 4.1 Variation of Coefficient of Permeability of Concrete with Various Percentages of Micro Silica

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

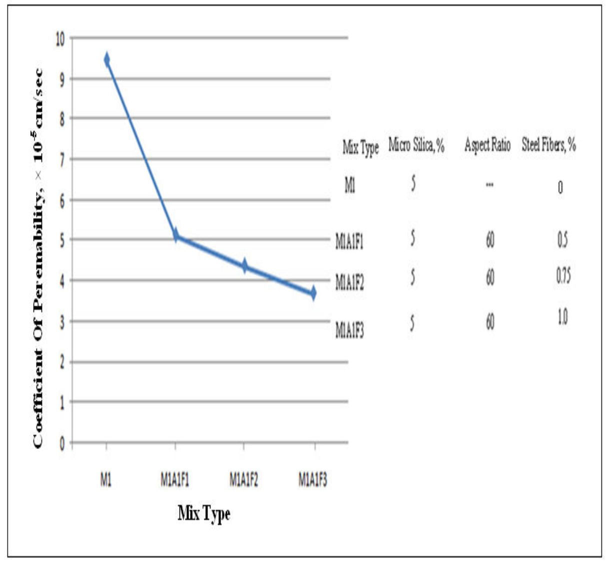

Figure 4.2 Variation of Coefficient of Permeability of Concrete with Various Percentage Fraction of Steel Fibers and 5% Micro Silica

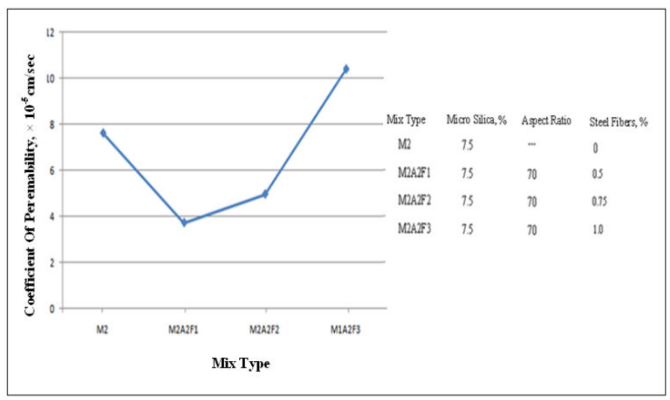

Figure 4.3 Variation of Coefficient of Permeability of Concrete with Various Percentage Fraction of Steel Fibers and 7.5% Micro Silica

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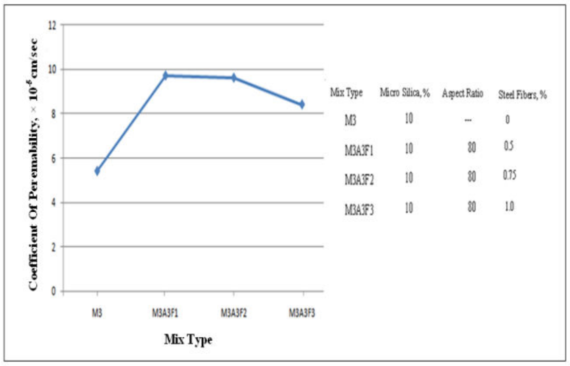

Figure 4.4 Variation of Coefficient of Permeability of Concrete with Various Percentage Fraction of Steel Fibers and 10% Micro Silica

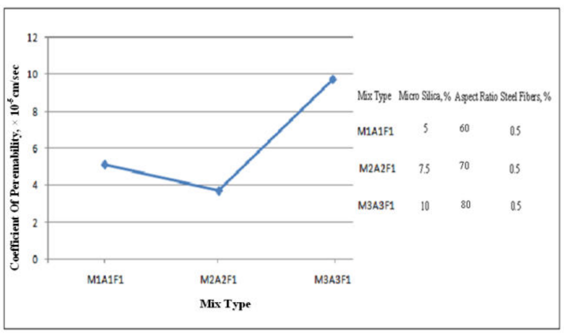

Figure 4.5 Variation of Coefficient of Permeability of Concrete with Various Percentages of Micro Silica for 0.5% Steel Fibers Fraction

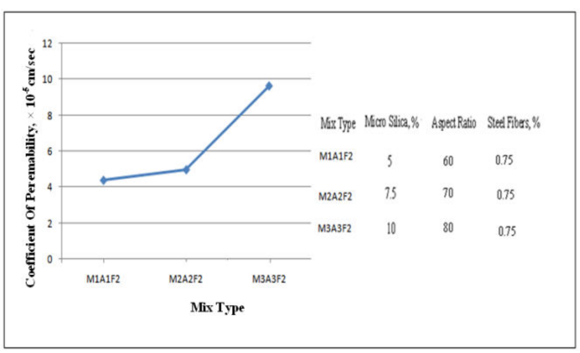

Figure 4.6 Variation of Coefficient of Permeability of Concrete with Various Percentages of Micro Silica for 0.75% Steel Fibers Fraction

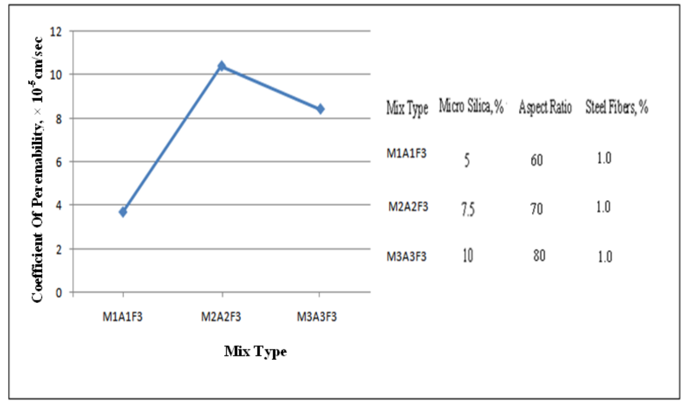

Figure 4.7 Variation of Coefficient of Permeability of Concrete with Various Percentages of Micro Silica for 1.0% Steel Fibers Fraction

4.1.3 Relative Coefficient of Permeability for Various Mix Cases

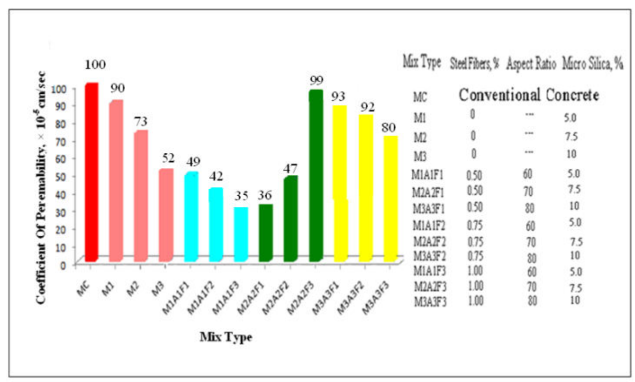

Figure 4.8 Relative Coefficient of Permeability for Various Mix Cases

5.4 CONCLUSIONS

These are the following Conclusions are given from the test outcomes and discussions.

- Addition of 5% Micro Silica reduces the Coefficient of Permeability to 9.46×10^{-5} cm/sec, when compared to 10.48×10^{-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 7.61×10^{-5} centimeter/second and 5.42×10^{-5} centimeter/second, respectively. The reduction is about 48%.

- Addition of 5% Micro Silica along with various percentages of volume fraction of Steel Fibers, the coefficient of Permeability reduces from 5.13×10^{-5} cm/sec to 4.37×10^{-5} centimeter/second, and 3.69×10^{-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.
- On addition of 7.5% Micro Silica and Steel Fibers having Aspect Ratio 70, the Coefficient of Permeability value decreases to 3.72×10^{-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 4.96×10^{-5} centimeter/second, 10.39×10^{-5} centimeter/second, respectively. This increase in permeability is due to Balling effect.
- 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 9.72×10^{-5} centimeter/second, 9.62×10^{-5} centimeter/second, 8.42×10^{-5} centimeter/second, when compared to 10.48×10^{-5} centimeter/second, for concrete specimen without Micro Silica and Steel Fibers.
- 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.
- 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.
- 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.

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