Assessment of Water Permeability Test on Polypropylene based Self-Compacted Fibre Reinforced Concrete (PSCFRC)

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ABSTRACT. An investigation conducted to study the effect of water permeability and strength characteristics such as compressive strength of Polypropylene self-compacted fibre reinforced concrete (PSCFRC) is presented. Polypropylene fibres of lengths, 35 mm with a diameter of 0.44 mm, were systematically combined in different mix proportions to combinations of 0.2%, 0.4%, and 0.6% Polypropylene fibre volume fraction. For comparison, a concrete mix with no fibres was also mixed. A total of 72 cube specimens of 150 mm were tested, 36 each for compressive strength and water permeability at 28 and 56 days of curing. According to the findings of this study, a fibre combination of SCFRC 0.6 percent is the most acceptable fibre composition to use in Polypropylene self-compacted fibre reinforced concrete (PSCFRC) for maximum performance in terms of compressive strength and water permeability requirements together.

Keyword: Permeability, Fibre, PSCFRC, Compressive strength, SCC

1. INTRODUCTION

The subject of concrete structure durability has been a hot topic of discussion for several years. The durability of concrete plays a critical role in controlling its serviceability. It is defined as the ability of concrete to resist weathering actions, chemical attack and abrasion while maintaining its desired properties. It usually refers to the duration of trouble-free performance. Different concrete requires different degrees of durability depending upon the exposure environment [1, 2].

Furthermore, the ability of a fluid to permeate the microstructure of concrete, known as permeability, is crucial to its long-term durability. High permeability allowed molecules to enter the system, causing them to react and lose their chemical stability. Moreover, concrete’s low permeability can improve water penetration, sulphate ions, chloride ions, alkali ions, and other harmful substances that caused the chemical attack. Concrete is durable if it is made with graded aggregates that are strong and inert; also, it should have entrained air to resist the freeze-thaw cycle under extreme conditions. Therefore, durability is increased by using self-compacted concrete in place of conventional concrete (plain concrete). The ability to transmit fluids or gases into the internal microstructure of concrete is referred to as permeability.

The experimental results showed that the water permeability was significantly lower in the FRC than in the NSC under cyclic and static load [3]. One of the critical segments of special SCC is self-compacting fibre reinforced concrete (SCFRC). The combination of self-compacting concrete (SCC) and fibre reinforced concrete (FRC) in several applications is showed interesting and advantageous also. Besides (additional) structural reinforcement, the fibres can reduce the effects of plastic shrinkage with improved distribution of micro cracking. SCFRC is particularly effective in applications where these features are best displayed, and the fibres can replace traditional reinforcement. Some examples are applications in industrial floors, covering tunnels, sewage pipes, beams and etcetera. However, the uses of fibre reinforced concrete (FRC) mostly emphasise on refining the mechanical properties of the hardened concrete, fresh concrete, particularly in self-compacting concrete (SCC), requires some consideration. Fibres change the workability of the fresh concrete and can influence the self-compacting properties of the concrete.
Self-compacting concrete cuts construction time and labor expenses in half. It does away with the necessity for vibration. It decreases noise pollution while also increasing the ability of highly congested structural members to fill. Self-compacting fibre reinforced concrete combines self-compacted concrete and fibre reinforced concrete, which enhance the durability and ease of construction. Fibres in self-compacted concrete improve the post cracking properties of concrete and increase the ductile behaviour. Polypropylene fibres influence flexural and tensile strength; toughness; impact, spalling, freeze-thaw, and resistance to abrasion; water absorption; porosity; permeability; and durability of concrete [4-10, 14-26, 34]. The addition of Polypropylene fibre reduced the length of water permeability of concrete. Similarly, the samples with the fibres had lower permeability than samples without fibres [11]. It is important to note that cracks are not detrimental to the construction or serviceability if they do not surpass a particular size. When concrete transforms from a plastic to a solid-state and the modulus of elasticity of concrete exceeds the modulus of elasticity of the fibres, micro-Polypropylene fibres not showing to play a significant role. [12, 13]. For a newly developing material like SCC, studies on durability are developing rapidly. According to the literature, some research on the durability of SCC and others studied durability of fibre reinforced concrete. SCFRC does not have a full study that includes durability factors like permeability [13]. As an outcome, to replace a gap in the literature, an attempt was made to research and evaluated the permeability of self-compacted fibre reinforced concrete.

2. PROBLEM FORMULATION AND OBJECTIVES

2.1 Problem formulation

Water is present in all concrete durability issues. The water tightness or permeability of concrete is intimately connected to its durability. The permeability of water into concrete expand its volume and lead to the formation of cracks. Water permeability of concrete causes disintegration of concrete thus damages the inner quality of structures. In addition, it causes critical deterioration of steel reinforcement to lead to severe degradation of the structure quality. In coastal regions, problems related to the durability of structures are mainly due to high water penetration.

2.2 Objectives

- To determine the compressive strength of self-compacting fibre reinforced concrete (PSCFRC).
- To determine the permeability of self-compacting fibre reinforced concrete (PSCFRC).
- This research objective to study the relationship between self-compacting fibre reinforced concrete compressive strength and permeability.

3. MATERIALS AND METHOD

The mix parameters employed in the experimental programme were three weight fractions of fibres: 0.2%, 0.4% and 0.6%. The cement employed was regular Portland cement of grade 53, with starting and ultimate setting times of 35 and 460 minutes, respectively, and after three and seven days, the compressive strengths were 23.4 MPa and 35 MPa, respectively. The modulus of fineness of the coarse and fine aggregates was 7.24 and 3.49, respectively. The cement and aggregates were tested to fulfill IS: 12269-2013 [35] and IS 383-2016[36]. Polypropylene fibres of different percentage were prepared from a diameter of 0.44 mm. In a drum pan mixer, all batches were blended in the same way. The weighted coarse aggregate and fine aggregate were placed in the mixer and mixed for 30 seconds. After that, the cementitious elements were added, and mixing proceeded for almost 3 minutes. The consistency and workability of concrete mixes was evaluated using slump test. 12 cubes of size 150×150×150mm were prepared and compacted...
using a compacting rod. The concrete specimens were demoulded after 24 hours and kept in the water curing tank until the testing age.

A SCC mix with 29% coarse aggregate content of concrete volume with a paste volume of 388 liter/m³ have been designed for water/binder ratio 0.36 (by weight). Cement has been replaced with 35% fly ash and fly ash combinations by total weight of cementitious material. Coarse aggregate of sizes 12.5mm with coarse aggregate blending weight of total aggregate are used in this mix. High performance super plasticizer cum retarder is used. All the material properties and input parameters are shown in Table 3.1, 3.2 and Table 3.3. Air content assumed as 2% of concrete volume.

Table 3.1. Material specification

| Sr. No. | Material               | Specification                |
|---------|------------------------|------------------------------|
| 1       | Coarse Aggregate       | 10mm                         |
| 2       | Fine Aggregate         | Less than 4.75mm             |
| 3       | Cement                 | M53                          |
| 4       | Polypropylene Fibre    | Length 35 mm, Dia.0.44mm     |

Table 3.2. Test on Aggregate (IS 2386-3, 1963)

| Sr. No. | Test                | Fine Aggregate | Coarse Aggregate |
|---------|---------------------|----------------|------------------|
| 1       | Fineness modulus    | 3.49           | 7.24             |
| 2       | Specific gravity    | 3.03           | 3.00             |
| 3       | Bulk density:       |                |                  |
|         | (1) Compacted weight| 1883.33 kg/m³  | 1831.97 kg/m³    |
|         | (2) Loose weight    | 1706.67 kg/m³  | 1644.92 kg/m³    |

Table 3.3. Properties of polypropylene fibre

| Sr. No. | Properties         | Specification |
|---------|--------------------|---------------|
| 1       | Elastic Modulus    | 3000-30000 MPa|
| 2       | Tensile Strength   | 300-700 MPa   |
| 3       | Specific gravity   | 0.91          |
| 4       | Diameter           | 0.44mm        |
| 5       | Surface            | Smooth        |
| 6       | L/d ratio          | 80            |
| 7       | Design Even Length | 35mm          |
| 8       | Cross-section      | Circular      |

4. EXPERIMENTAL INVESTIGATION

Fresh properties of SCC determined by filling ability by slump flow, passing ability by L-box test. In this investigation, 72-cubes tested to investigate concrete compressive strength and water permeability of SCC with the combination of fly ash and different proportioning of polypropylene fibre with the replacement of 0.2, 0.4 and 0.6 %. All test specimens of the cube with 150 mm size.
4.1 Casting of PSCFRC

All batches were mixed using the same procedure in a drum pan mixer. The mixing sequence was placing the weighted coarse aggregate and fine aggregate in the mixer and mixed for 30 sec. The cementitious materials were then added with fibres by 0.2%, 0.4% and 0.6% and mixing continued for 3 min more. Super plasticizer was the mix. The flow ability and consistency of concrete mixes were evaluated using slump flow test, L-Box test, J-Ring test and T-50 test. 72 cubes of size 150×150×150mm were prepared. The concrete specimens were demoulded after 24 hours and kept in the water curing tank until the testing age.

4.2 Fresh Properties of SCC

SCC is defined by three key characteristics: filling ability, passage ability, and stability or resistance to segregation [27], all of which are governed by the rheology of the fresh mix, with yield stress and plastic viscosity being the governing rheological parameters [28-31]. As a result, table 4.1 lists the fresh properties of Self Compacted Concrete (SCC).

| Sr. No | Testing Methods | Unit | Permissible limits | Workability Value |
|--------|-----------------|------|--------------------|-------------------|
| 1.     | Slump Flow(Diameter) | mm   | 650-800            | 657               |
| 2.     | Slump Flow(Time)  | Sec  | 2-5                | 3.5               |
| 3.     | L-Box           | -    | 0.8-1.0            | 0.94              |
| 4.     | J-Ring          | mm   | 0-10               | 7                 |

4.3 Hardened Properties of SCC

4.3.1 Compressive Strength Test

Compressive strength test were conducted on cured cube specimen at 28 and 56 days of age using a Compression Testing Machine (CTM) OF 200 tons capacity. In a compression testing machine, the cubes were inserted in the centre and a minimal load was given to maintain the cube in place. After then, the load was gradually given to the tested cube until it failed.
4.3.2 Water Permeability test

The permeability of water is determined by performing a permeability test in accordance with DIN: 1048(part 5)-1991 [32]. The equipment was set up on a levelled surface. The compressor used in the test has a capacity of 5 bars. The 150 mm air-dried concrete cubes were set on the table with appropriate rubber gaskets beneath them. The 150 mm air-dried concrete cubes were placed on the table with rubber gaskets underneath. Before testing, the surface was roughened with a wire brush for roughly 100 mm indiameter. The M.S. Plate was retained on the cube, and the cube's bolt was tightened. For 72 hours, a pressure of 5 bars was maintained. The pressure was released after the compressor was turned off. All of the cubes were split using a splitting device included with the equipment beneath a concrete testing machine, and the maximum and minimum water penetration levels were measured. Table 4.5, 4.6, 4.7, 4.8 shows how the average value was determined.
Figure 7. Splitting of cube in CTM

Figure 8. Penetration of Water in Cube

Table 4.2. Compressive Strength of Conventional Concrete

| Age of Concrete | Identification Mark | Compressive Strength MPa |
|-----------------|----------------------|--------------------------|
| 28 Days         | CC 1-28              | 52.62                    |
|                 | CC 2-28              | 53.01                    |
|                 | CC 3-28              | 52.83                    |
| 56 Days         | CC 1-56              | 54.64                    |
|                 | CC 2-56              | 54.53                    |
|                 | CC 3-56              | 53.73                    |

Table 4.3. Compressive Strength of PSCFRC 0.2%

| Age of Concrete | Identification Mark | Compressive Strength MPa |
|-----------------|----------------------|--------------------------|
| 28 Days         | SCFRC021-28          | 55.22                    |
|                 | SCFRC022-28          | 56.31                    |
|                 | SCFRC023-28          | 55.54                    |
| 56 Days         | SCFRC021-56          | 56.41                    |
|                 | SCFRC022-56          | 57.21                    |
|                 | SCFRC023-56          | 56.92                    |

Table 4.4. Compressive Strength of PSCFRC 0.4%

| Age of Concrete | Identification Mark | Compressive Strength MPa |
|-----------------|----------------------|--------------------------|
| 28 Days         | SCFRC041-28          | 58.22                    |
|                 | SCFRC042-28          | 58.31                    |
|                 | SCFRC043-28          | 57.94                    |
| 56 Days         | SCFRC041-56          | 58.51                    |
|                 | SCFRC042-56          | 58.61                    |
|                 | SCFRC043-56          | 58.72                    |
### Table 4.5. Compressive Strength of PSCFRC 0.6%

| Age of Concrete | Identification Mark | Compressive Strength MPa |
|-----------------|----------------------|--------------------------|
| 28 Days         | SCFRC061-28          | 58.31                    |
|                 | SCFRC062-28          | 58.58                    |
|                 | SCFRC063-28          | 58.63                    |
| 56 Days         | SCFRC061-56          | 58.62                    |
|                 | SCFRC062-56          | 58.84                    |
|                 | SCFRC063-56          | 58.92                    |

### Table 4.6. Permeability of Conventional Concrete

| Age of Concrete | Identification Mark | Permeability mm/sec |
|-----------------|----------------------|---------------------|
| 28 Days         | CC 1-28              | 0.0000964           |
|                 | CC 2-28              | 0.000104            |
|                 | CC 3-28              | 0.0000926           |
| 56 Days         | CC 1-56              | 0.0000849           |
|                 | CC 2-56              | 0.0000887           |
|                 | CC 3-56              | 0.000081            |

### Table 4.7. Permeability of PSCFRC 0.2%

| Age of Concrete | Identification Mark | Permeability mm/sec |
|-----------------|----------------------|---------------------|
| 28 Days         | SCFRC021-28          | 0.0000617           |
|                 | SCFRC022-28          | 0.0000694           |
|                 | SCFRC023-28          | 0.000073            |
| 56 Days         | SCFRC021-56          | 0.000054            |
|                 | SCFRC022-56          | 0.0000578           |
|                 | SCFRC023-56          | 0.0000463           |

### Table 4.8. Permeability of PSCFRC 0.4%

| Age of Concrete | Identification Mark | Permeability mm/sec |
|-----------------|----------------------|---------------------|
| 28 Days         | SCFRC041-28          | 0.0000385           |
|                 | SCFRC042-28          | 0.0000347           |
|                 | SCFRC043-28          | 0.0000385           |
| 56 Days         | SCFRC041-56          | 0.00003086          |
|                 | SCFRC042-56          | 0.000027            |
|                 | SCFRC043-56          | 0.0000347           |

### Table 4.9. Permeability of PSCFRC 0.6%

| Age of Concrete | Identification Mark | Permeability mm/sec |
|-----------------|----------------------|---------------------|
| 28 Days         | SCFRC061-28          | 0.0000255           |
|                 | SCFRC062-28          | 0.0000267           |
|                 | SCFRC063-28          | 0.0000254           |
| 56 Days         | SCFRC061-56          | 0.0000238           |
|                 | SCFRC062-56          | 0.0000245           |
|                 | SCFRC063-56          | 0.0000242           |
Figure 9. Relation between Compressive strength and water permeability of SCFRC for 28 days

Figure 10. Relation between Compressive strength and water permeability of SCFRC for 56 days

5. CONCLUSION

From the experiment and results we can conclude that the behaviour of self compacted fibre reinforced concrete mainly depends on quantity, quality, types and proportions of fibre used. To achieve desired strength and durability good quality of material should be used.

1) The significant improvement in compressive strengths is observed with inclusion of polypropylene fibre in self compacted concrete.

2) The compressive strengths increase with increase in fibre content.

3) Using polypropylene fibre in self compacted concrete increases durability of concrete by reducing the permeability of concrete compared to plain concrete.

4) Permeability of concrete is reduced due to addition of polypropylene fibre in self compacted concrete.

5) Permeability of self compacted concrete is reduces with increase in fibre content.

6) Water permeability of PSCFRC is linearly related to the compressive strength of PSCFRC for 28 and 56 days of PSCFRC. R-squared values obtain for 28 days of PSCFRC and 56 days of PSCFRC as 0.948 and 0.938, respectively.

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