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STRENGTH AND PERMEABILITY CHARACTERISTICS OF FIBRE REINFORCED CONCRETE

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ABSTRACT

Corrosion of reinforcing steel due to chloride ingress is one of the most common environmental attacks that lead to the deterioration of concrete structures. Corrosion related damage to concrete structures is a major problem. This durability problem has received widespread attention in recent years because of its frequent occurrence and the associated high cost of repairs. The rate of chloride ion ingress into concrete is primarily dependent on the internal pore structure. The pore structure in turn depends on other factors such as the mix design, degree of hydration, curing conditions, use of supplementary cementitious materials, and construction practices. Researchers all over the world are attempting to develop high performance concretes by using fibres and other admixtures in concrete upto certain proportions. The present study concentrates the behaviour of fibre reinforced concrete with varying concrete strength (M25 & M50) and different percentages of fibre additions (0.5, 1, 1.5%).

The present study concentrates the behaviour of fibre reinforced concrete with two different concrete strength (M25 & M50) and different percentages of fibre additions (0.5, 1, 1.5%). The permeability index values get reduced due to addition of glass fibre. The addition of glass fibre in concrete will have better effect on high grade of concrete for permeability and lower grade of concrete for compression test due to quantity of cement content, water-cement ratio and the ratio of fine aggregate to coarse aggregate.

Keywords: chloride, porosity, permeability, voids, glass fiber reinforced concrete.

INTRODUCTION

Concrete is a rigid material with high compressive strength and weak in tensile strength. Reinforcing bars are used to improve the tensile strength. In addition to that fibres can make the concrete more homogenous and can improve the tensile response, particularly the ductility. The various types of fibres added to concrete are steel, glass, carbon, hemp fibre.

Reinforced concrete structures are exposed to harsh environments yet is often expected to last with little or no repair or maintenance for long periods of time (often 100 years or more). To do this, a durable structure needs to be produced. For reinforced concrete bridges, one of the major forms of environmental attack is chloride ingress, which leads to corrosion of the reinforcing steel and a subsequent reduction in the strength, serviceability and aesthetics of the structure. This may lead to early repair or premature replacement of the structure. A common method of preventing such deterioration is to prevent chlorides from penetrating the structure to the level of the reinforcing steel bar by using relatively impenetrable concrete. The ability of chloride ions to penetrate the concrete must then be known for design as well as quality control purposes. The penetration of the concrete by chloride ions, however, is a slow process. It cannot be determined directly in a time frame that would be useful as a quality control measure. Therefore, in order to assess chloride penetration, a test method that accelerates the process is needed, to allow the determination of diffusion values in a reasonable time.

Fibre reinforced concrete (FRC) is concrete made primarily of hydraulic cements, aggregates and discrete reinforcing fibres. FRC is a relatively new material. This is a composite material consisting of a matrix containing a random distribution or dispersion of small fibres, either natural or artificial, having a high tensile strength. Due to the presence of these uniformly dispersed fibers, the cracking strength of concrete is increased, the fibres acting as "Crack arresters".

Effect of fibres in concrete

Fibres are usually used in concrete to control cracking due to both plastic shrinkage and drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibres produce greater impact, abrasion and shatter resistance in concrete.

Fibres with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the modulus of elasticity of the fibre is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. Increase in the aspect ratio of the fibre usually segments the flexural strength and toughness of the matrix. However, fibres which are too long tend to "ball" in the mix and create workability problems.

Objectives of the study

The objectives of the current research work to study the durability properties of:

- M25 and M50 grade of concrete with varying percentages of addition of glass fibres 0, 0.5, 1 and 1.5% at 28 days
- Comparing each grade with their percentage of addition of glass fibres.

Permeability studies

Permeability of cement mortar or concrete is of particular significance in structures which are intended to retain water or which come into contact with water. Besides functional considerations, permeability is also intimately related to the durability of concrete, specially its resistance against progressive deterioration under exposure to severe climate, and leaching due to prolonged seepage of water, particularly when it contains aggressive gases or minerals in solution. The determination of the permeability characteristics of mortar and concrete, therefore, assumes considerable importance. For fibre reinforced concrete permeability test cylinder of size as 150mm x 300mm will be used.

MATERIALS AND METHODS

The concrete consists of Portland cement, water and sand used for construction. After the ingredients were well mixed according to the construction requirements, the mixture was placed into a PVC cylindrical mold with a release membrane between the cylinder and the mixture. After a hardening period of 48 h, the specimens were demolded. Then the specimens were cured in saturated limewater for 28 days. Materials are taken as per IS: 456: 2000 and tested as per the codal provisions. The trail mixes are prepared as per the IS code.

The properties of the selected materials for this experimental study are reported in Table 1

Table 1 physical property of materials

Property	***Specific gravity***	***Loose bulk density: kg/m³***	***Compacted bulk density: kg/m³***	***Fineness modulus***
Cement	3.15	2.6	----	----
Fine aggregate	2.6	1410.1	1671.18	3.12
Coarse aggregate	2.83	1491.5	1715.25	5.95

Cement

The minimum grade of cement to be used IS 15658-2006 in paver blocks is ordinary Portland cement of grade 33. In this study the ordinary Portland cement of 53 grade conforming to Indian standard IS 12269-1987 (BIS, 1987b), with physical properties as given in Table 1, has been used in this experimental study.

Coarse aggregate

Locally available crushed stone conforming to graded aggregate of nominal size 10 mm as per IS 383-1970 was used in this experimental work. Its physical properties are dealt with in Table 1**.**

Sand

Locally available river sand conforming to grading zone I of IS 383-1970 (BIS, 1970) was used in this experimental work. For sand test has been carried out and conforming to IS 2386 (part I)-1963. Its physical properties are dealt with in Table 1.

Glass fibre

Glass fiber is made up from 200-400 individual filaments which are lightly bonded to make up a stand. These stands can be chopped into various lengths, or combined to make cloth mat or tape. Using the conventional mixing techniques for normal concrete it is not possible to mix more than about 2% (by volume) of fibers of a length of 25mm.

The major appliance of glass fiber has been in reinforcing the cement or mortar matrices used in the production of thin-sheet products. The commonly used verities of glass fibers are e-glass used. In the reinforced of plastics & AR glass E-glass has inadequate resistance to alkalis present in Portland cement where AR-glass has improved alkali resistant characteristics. Sometimes polymers are also added in the mixes to improve some physical properties such as moisture movement. The properties of the selected glass fibre are reported in Table 2.

Table 2 physical property of glass fibre

Name	***Value***	***Unit***
Type	E-Glass fibre	-
Young's modulus	73000	MPa
Tensile strength	1900-2600	MPa
Elongation	0-3.2	%
Density	2600	kg/m³
Length	25	Mm

Water

The Water used for mixing concrete should be portable drinking water having pH value of 7 and the water is free from organic matter and the solid contents should be within the permissible limits as per IS 456-2000 & and conforming to IS 3025.1964.

Mix proportions

The concrete consists of Portland cement, water and sand used for construction. After the ingredients were well mixed according to the construction requirements, the mixture was placed into a PVC cylindrical mold with a release membrane between the cylinder and the mixture. After a hardening period of 48 h, the specimens were demolded. Then the specimens were cured in saturated limewater for 28 days. Fibre reinforced concrete with varying concrete strength (M25 & M50) and different percentages of fibre additions (0.5, 1, 1.5%). The proportions are taken as per the design mix of IS 10262:2009. The slump of the concrete is calculated using slump cone. The specimens were tested for permeability value as per IS 3085:1997.

Casting

The concrete mix shall be cast in split moulds of the required size, with a removable collar of about half the height set on the top. The material shall be compacted either by hand rodding or vibration, as proposed to be done during construction. The collar shall then be removed and the mould shall be struck off level with a straight-edge using a sawing motion without further travelling or finishing, which might raise the fines to the surface. The specimen shall be cured for 28 days.

Another consequence of poor workability is non-uniform distribution of the fibers. Generally, the workability and compaction standard of the mix is improved through increased water/ cement ratio or by the use of some kind of water reducing admixtures. Addition of fibre quantity can affect the workability of concrete, the workability variations are given in the Fig 1.

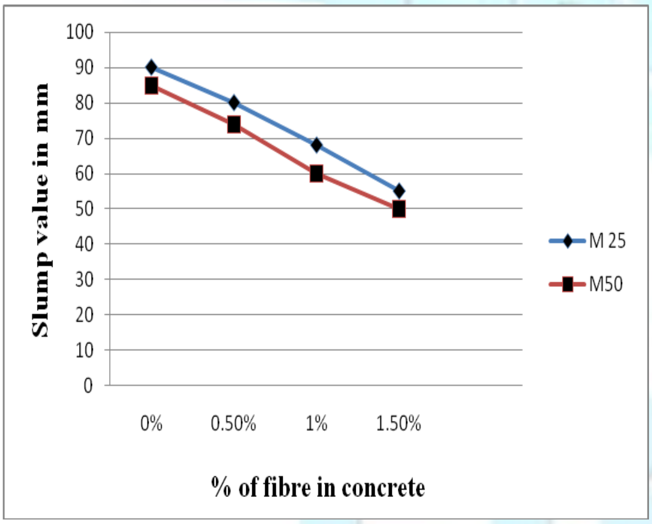

Fig 1 Slump value for fibre reinforced concrete

PERMEABILITY TEST

Permeability of cement mortar or concrete is of particular significance in structures which are intended to retain water or which come into contact with water. Besides functional considerations, permeability is also intimately related to the durability of concrete, specially its resistance against progressive deterioration under exposure to severe climate, and leaching due to prolonged seepage of water, particularly when it contains aggressive gases or minerals in solution.

The test shall preferably be carried out at a temperature of $27^0 \pm 2°C$. In case arrangements are not available for maintaining the above temperature, a record shall be maintained of the actual temperature. An approximate correction may be made on the basis that each 5°C increase of temperature above the standard temperature, results in 10 percent increase in the coefficient of permeability and vice versa. The specimens were tested for permeability value as per IS 3085:1997.

The test setup for permeability testing of the cylinder is shown in Fig 2 and the testing of specimen in fig 3

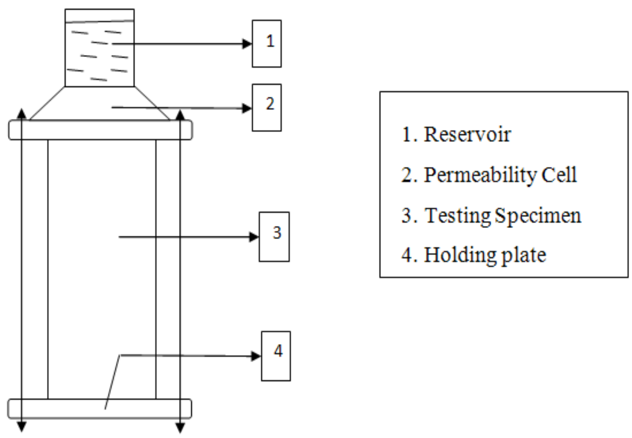

Fig 2 *Arrangement of permeability test*

Permeability Cell

The permeability cell shall consist of a metal cylinder with a ledge at the bottom for retaining the specimen, a flange at the top, a removable cover plate and a sheet metal funnel which can be securely bolted to the cell. Gunmetal, aluminium or other suitable corrosion-resistant metal shall be used for fabrication of the cell and cover plate, which shall be designed to safely withstand the maximum test pressure. A rubber or neoprene O-ring or other suitable gasket, seated in matching grooves, shall be used between the cell and the covet plate to render the joint water-tight. Typical details of the permeability cell together with pertinent dimensions for use with test specimens of various sizes.

Calculation

To measure the coefficient of water permeability by flow, the DARCY'S Law can be applied as the flow is continuous. The coefficient of permeability shall be calculated as follows:

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

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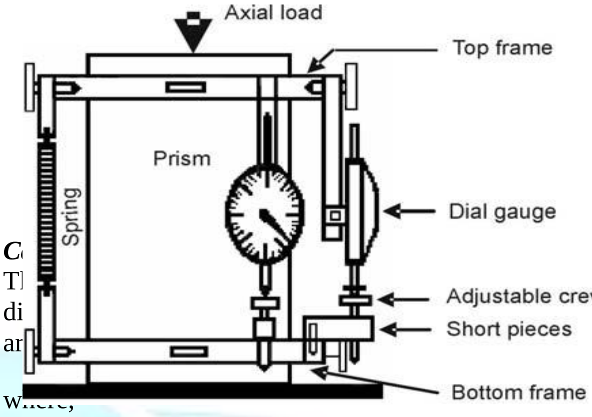
Where
K = coefficient of permeability in cm/set
Q = quantity of water in milliliters percolating over the entire period of test after the steady state has been reached
A = area of the specimen face in cm
T = time in seconds over which Q is measured
H/L = ratio of the pressure head to thickness of specimen, both expressed in the same units.

Fig 3 permeability tests on cylinder specimen

COMPRESSIVE TEST

The compression test is used to determine the hardness of cubical and cylindrical specimens of concrete. The strength of a specimen depends upon cement, aggregate, bond, w/c ratio, curing temperature, and age and size of specimen.

Mix design is the major factor controlling the strength of concrete. Cubes of size 15cm X 15cm X 15cm or cylinder of size 15cm X 30cm should be cast. The specimen should be given sufficient time for hardening and then it should be cured for 28 days. After 28 days, it should be loaded in the compression testing machine and tested for maximum load. Compressive strength should be calculated by dividing maximum load by the cross-sectional area. The test setup for compression testing of the cylinder is shown in Fig 4 and the permeability index graph is shown in Fig 5 and 6.



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where,
f_c = ultimate compressive strength, in psi.
P = ultimate compressive axial load, in lbs.
D = diameter of cylinder specimen, in mm.

RESULTS AND DISCUSSIONS

Generally in the cases of a concrete as a composite high porosity does not necessary mean high permeability. Indeed only the interconnected of these pores is significant for permeability. The results given in this paper are average values obtained from three specimens per mix and were derived from penetration measurements. Compared to the M25 concrete M50 concrete shows better control of water percolation. This was due to the quantity of cement content, water-cement ratio and the ratio of fine aggregate to coarse aggregate. In addition fibre reinforced concrete (FRC) shows higher permeability index. This is mainly fibres, which complete arrest the water penetration to a certain level.

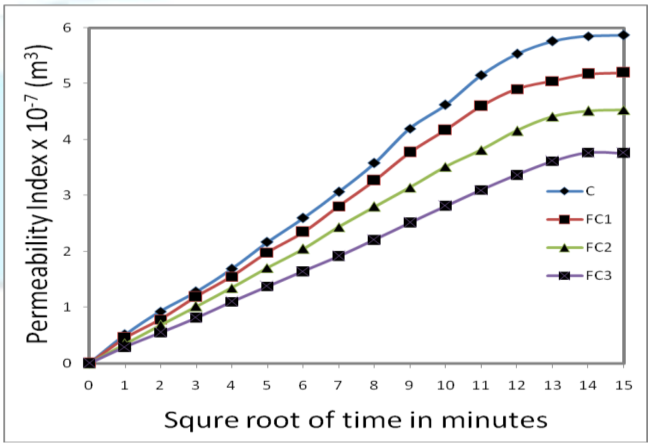

Fig 5 Permeability Index of M25 concrete

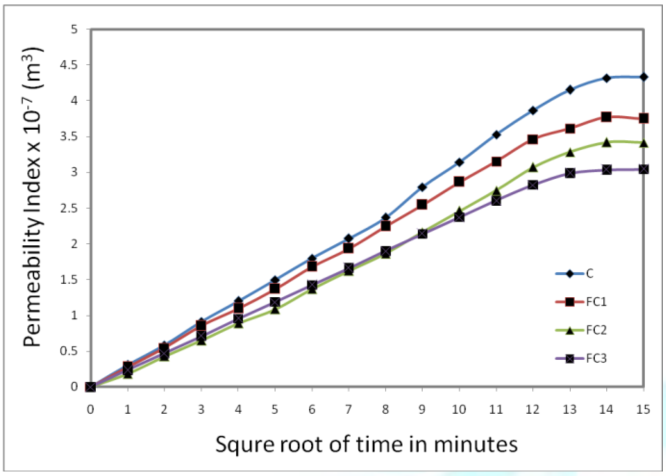

Fig 6 Permeability Index of M50 concrete

***Effect of glass fibre on permeability of glass fibre concrete*:** On the basis of the Experimental study it was observed that the addition of glass fibres gives a reduction in bleeding. From the test results it is found that the permeability value is decreased at 28 days due to the addition of glass fibre in concrete.

Compressive test was carried out on M25 and M50 concrete cylinders and the test carried out based on standard procedures and stress strain pattern is shown in Fig 7 and 8. Combinations of various percentages of fibre of 0%, 0.5%, 1% and 1.5% cement. From these results it was found that there is an increase in compressive strength due to the addition of glass fibre in to concrete. Glass fibre addition to concrete can increase the compressive strength whatever the fibre amount.

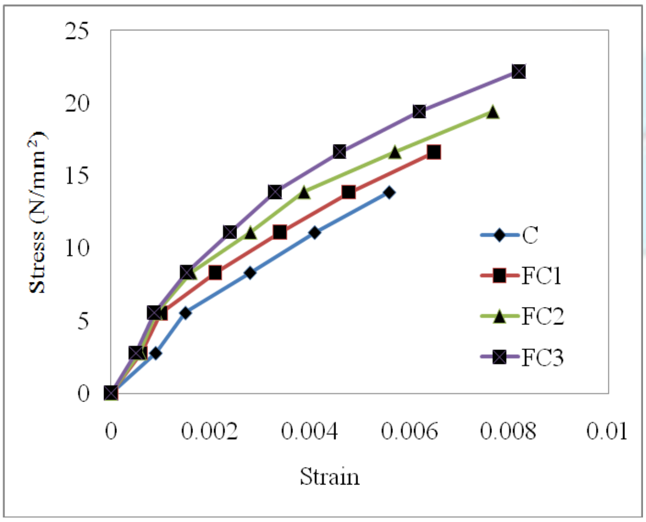

Fig 7 Stress strain pattern for M25 concrete

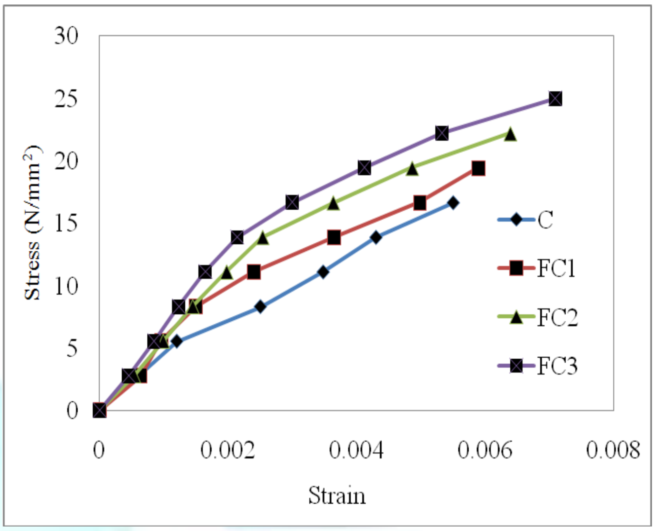

Fig 8 Stress strain pattern for M50 concrete

Comparision between compressive strength and permeability index value

The compressive strengths obtained from fibre reinforced concrete was carried out on M25 and M50 concrete cylinders with different percentage of glass fibre (0, 0.5, 1, 1.5%) in concrete. The permeability index value obtained by testing such concrete and an exponential equation is developed for different strength of concrete and permeability index value is shown in Fig 9.

Exponential equation $Y = 5.213e^{-0.75X}$

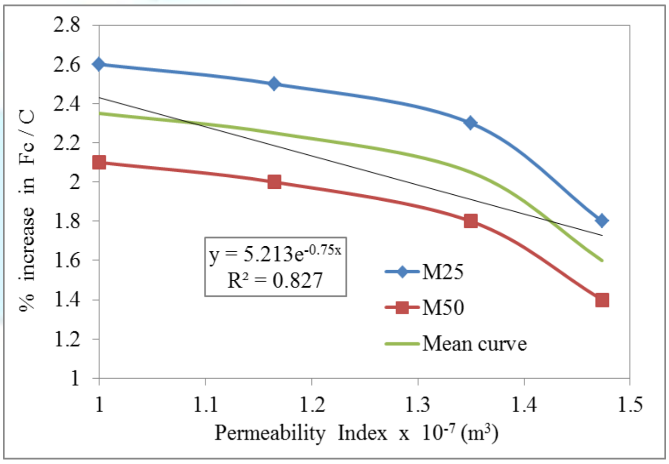

Fig 9 Exponential equation for strength of concrete and Permeability Index value

SUMMARY AND CONCLUSIONS

The addition of glass fibre in concrete offers a holistic solution to the problem of permeability in concrete, increase the concrete strength and at the same time reducing the environmental impact. The following salient conclusions are drawn from the present investigations

- The permeability index value get reduced due to addition of glass fibre, it is about 6.4% by the addition of 0.5%, 12.6% by the addition of 1% and 26.3% by the addition of 1.5% of glass fibre in M25 concrete when compared to control concrete.

- Similarly for M50 concrete, the permeability value is about 8.7% by addition of 0.5% of glass fibre, 15% by addition of 1% of glass fibre and 30.1% by addition of glass fibre to that of control concrete.

- The compressive strength increased by about 16.4% by the addition of 0.5%, 24.7% by the addition of 1% and 47.3% by the addition of 1.5% of glass fibre in M25 concrete when compared to 0% of glass fibre in concrete.

- Similarly for M50 concrete, the permeability value is about 14.3% by addition of 0.5% of glass fibre, 22.3% by addition of 1% of glass fibre and 43.5% by addition of glass fibre to that of 0% glass fibre in concrete.

- The addition of glass fibre in concrete will have better effect on high grade of concrete for permeability and lower grade of concrete for compression test due to quantity of cement content, water-cement ratio and the ratio of fine aggregate to coarse aggregate.

- Based upon the experiment results a regression analysis was done to formulate an exponential equation, the present equation can able to calculate the permeability index for the required concrete strength more accurately.

Further studies are recommended to confirm these results and to establish a relationship between porosity and permeability of glass fibre reinforced concrete. The various other types of fibres are involved in concrete mix the permeability index and compressive stress value are to be calculated on different strength of concrete.

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