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RAPID CHLORIDE PERMEABILITY TEST FOR DURABILITY STUDIES ON GLASS 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. Chlorides penetrate crack-free concrete by a variety of mechanisms: capillary absorption, hydrostatic pressure, diffusion, and evaporative transport. Of these, diffusion is predominant. Diffusion occurs when the concentration of chloride on the outside of the concrete member is greater than on the inside. This results in chloride ions moving through the concrete to the level of the rebar. When this occurs in combination with wetting and drying cycles and in the presence of oxygen, conditions are right for reinforcement corrosion. 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. Therefore, wherever there is a potential risk of chloride-induced corrosion, the concrete should be evaluated for chloride permeability. Researchers all over the world are attempting to develop high performance concretes by using fibres and other admixtures in concrete upto certain proportions. In the view of the global sustainable developments, it is imperative that fibres like glass, carbon, aramid and polypropylene fibers provide improvements in tensile strength. Research in GFRC (Glass fibre reinforced concrete) resulted in the development of an alkali resistance fibre (AR Glass fibres High Dispersion) that provided improved long term durability. In the present experimental investigation cylinders of 100mm x 150mm of M20 grade concrete were cast with varying percentage of addition of 0.03%, 0.06% and 0.1% of glass fibre. The rapid chloride permeability tests were conducted for a period of 90, 180, 365 and 720 days. The test results show that the addition of glass fibres exhibit better performance.

Keywords: glass fibre reinforced concrete, rapid chloride permeability test, durability.

INTRODUCTION

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.

Many of the current applications of fibre reinforced concrete involve the use of fibres ranging around 0.1 percent. Recent attempts made it possible to incorporate relatively large volumes of steel, glass and synthetic fibres in concrete. Results of tensile tests done on concretes with glass, polypropylene and steel fibres, indicate that with such large volume of aligned fibres in concrete, there is substantial enhancement of the tensile load carrying capacity of the matrix. This may be attributed to the fact fibres suppress the localization of micro-cracks into macro cracks and consequently the apparent tensile strength of the matrix increases.

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". Fibres suitable of reinforcing concrete having been produced from steel, glass and organic polymers.

Types and properties of glass fibres

Glass fibre is available in continuous or chopped lengths. Fibre lengths of up to 35 mm are used in spray applications and 25 mm lengths in premix applications. Glass fibre has high tensile strength (2-4 GPa) and elastic modulus (70-80 GPa) but has brittle stress-strain characteristics (2.5-4.8% elongation at break) and low creep at room temperature. Glass fibres are usually round and straight with diameters of 0.005 to 0.015 mm (0.0002 to 0.0006 in.). They could also be bonded together to produce glass fibre bundles with bundle diameters of up to 1.3 mm (0.050 in.). The glass fibres used in the present experimental investigation is High Dispersion Cem-FIL AR fibres. Anti-crack fibres do not protrude from the surface and require no further finishing. The dispersion property of the fibre is very rapid into mono-filament reinforcement with 212 millions of filaments per kg. It is very effective at low dosages and easy and safe to handle. It controls and prevents early age cracking in concrete. The major draw back of glass fibre is its high vulnerability in the alkaline cementitious environment, which affects the long-term performance characteristics of the composite adversely. Alkali-resistant glass fibres can, however, be used to overcome this problem.

The penetrability of concrete is obviously related to the pore structure of the cement paste matrix. This will be influenced by the water-cement ratio of the concrete, the inclusion of supplementary cementing materials which serve to subdivide the pore structure [McGrath, 1996] and the degree of hydration of the concrete. The older the concrete, the greater amount of hydration that has occurred and thus the more highly developed will be the pore structure. This is especially true for concrete containing slower reacting supplementary cementing materials such as fly ash require a longer time to hydrate [Tang and Nilsson, 1992; Bamforth, 1995].

Another influence on the pore structure is the temperature that is experienced at the time of casting. High-temperature curing accelerates the curing process so that at young concrete ages, a high-temperature cured concrete will be more mature and thus have a better resistance to chloride ion penetration than a normally-cured, otherwise identical, concrete at the same at age. However, at later ages when the normally-cured concrete has a change to hydrate more fully, it will have a lower chloride ion diffusion coefficient than the high-temperature-cured concrete [Detwiler, *et al*., 1991; Cao and Detwiler, 1996].

The inclusion of supplementary cementing materials affects binding, though the exact influence is unclear [Byfors, 1986; Rasheeduzafar, *et al*., 1992; Sandberg and Larrson, 1993; Thomas, *et al*., 1995]. Also, the content of the cement influences its binding capacity, with increased C_3A content leading to increased binding [Holden, *et al*., 1983; Midgely and Illston, 1984; Hansson and Soreson, 1990].

Objectives of the study

The objectives of the current research work to study the durability properties of M20 grade of concrete with varying percentages of addition of glass fibres 0.03%, 0.06 % and 0.1% at 90, 180, 365 and 720 days and compare with 0% at 90, 180, 365 and 720 days.

Research significance

GFRC provides an ideal system for achieving the durability requirements of new constructions. This research study investigated the characteristics of GFRC with varying percentage of addition to M20 grade of concrete.

MATERIALS AND METHODS

Materials

Cement

Ordinary Portland cement of 53 grades available in local market is used in the investigation. The cement used has been tested for various proportions as per IS 4031-1988 and found to be confirming to various specifications of are IS 12269-1987. The specific gravity was 2.96 and fineness was 3200cm^2/gm.

Coarse aggregate

Crushed angular granite metal of 20 mm size from a local source was used as coarse aggregate. The specific gravity of 2.71 and fineness modulus 7.13 was used.

Fine aggregate

River sand was used as fine aggregate. The specific gravity of 2.60 and fineness modulus 3.25 was used in the investigation.

Glass fibres

The Glass Fibres are of Cem-FIL Anti - Crack HD with modulus of elasticity 72 GPa, Filament diameter 14 microns. Specific Gravity 2.68, length 12 mm and having the aspect ratio of 857.1. The number of fibres per 1 kg is 212 million.

Rapid chloride permeability test

According to ASTM C1202 test, a water-saturated, 50 mm thick, 100 mm thick diameter concrete specimen is subjected to a 60 v applied DC voltage for 6 hours using the apparatus and the cell arrangement is shown in Figure-1. In one reservoir is a 3.0% NaC1 solution and in the other reservoir is a 0.3 M NaOH solution. The total charge passed is determined and this is used to rate the concrete according to the criteria included as Table-1.

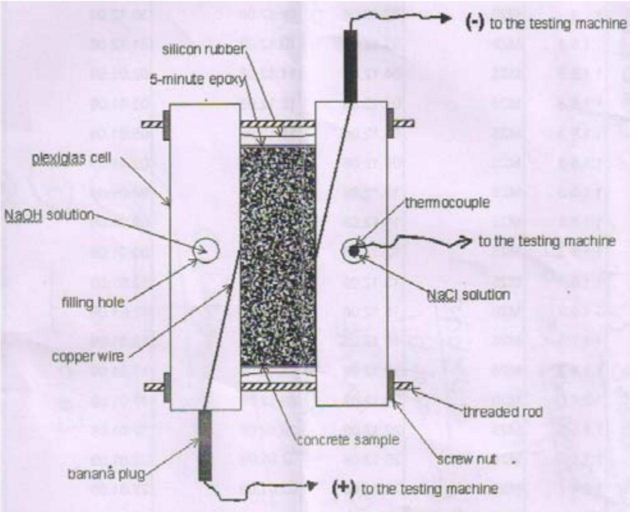

Figure-1. ASTM C1202 test setup.

Table-1. RCPT ratings (per ASTM C1202).

Charge passed (coulombs)	**Chloride Ion penetrability**
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very low
<100	Negligible

Specimens

The specimens cast (Figure-2) were cut according to the ASTM 1202 as shown in Figure-3.

Figure-2. Typical M20 grade specimen with varying % of GFRC.

Figure-3. Cutting of the specimen.

The detailed test set up is shown in Figure-4.

Figure-4 Test set up.

The details of the values after testing using RCPT specimen are presented in Table-2 and Figure-5.

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Table-2. Rapid chloride permeability test for ordinary concrete and glass fibre reinforced cement concrete.

Grade of concrete	% of glass fibers	Charge passed (Coulombs)				Chloride permeability as per ASTM C 1202			
		90	180	365	720	90	180	365	720
M20	0.00	3450	3165	2912	2810	Moderate	Moderate	Moderate	Moderate
M20	0.03	3100	2512	2478	2462	Moderate	Moderate	Moderate	Moderate
M20	0.06	2972	2413	2172	2163	Moderate	Moderate	Moderate	Moderate
M20	0.10	2843	2212	2115	2085	Moderate	Moderate	Moderate	Moderate

Testing of specimens

The specimens were fit in the chamber with the required brass as well as rubber oaring. The record time is set as 30 minutes and also the log time as 6 hours and 30 minutes and the current of 60V is passed continuously. The data logger records the readings of corresponding cells at the every record time with its initial readings. At the end of log time, the system halts after taking the final reading.

Average current flowing through one cell is calculated by,

I = 900 * 2 * I Cummulative coulombs.

$I_{CUMMULATIVE} = I_0 + I_{30} + I_{60} + I_{90} + I_{120} + I_{150} + I_{180} + I_{210} + I_{240} + I_{270} + I_{300} + I_{330} + I_{360}$

Where

I_0 = Initial current reading in mA.
I_{30} = Current reading at 30 minutes in mA.
I_{60} = Current reading at 60 minutes in mA.
I_{90} = Current reading at 90 inutes in mA.
I_{120} = Current reading at 120 minutes in mA.
I_{150} = Current reading at 150 minutes in mA.
I_{180} = Current reading at 180 minutes in mA.
I_{210} = Current reading at 210 minutes in mA.
I_{240} = Current reading at 240 minutes in mA.
I_{270} = Current reading at 270 minutes in mA.
I_{300} = Current reading at 300 minutes in mA.
I_{330} = Current reading at 330 minutes in mA.
I_{360} = Current reading at 360 minutes in mA.

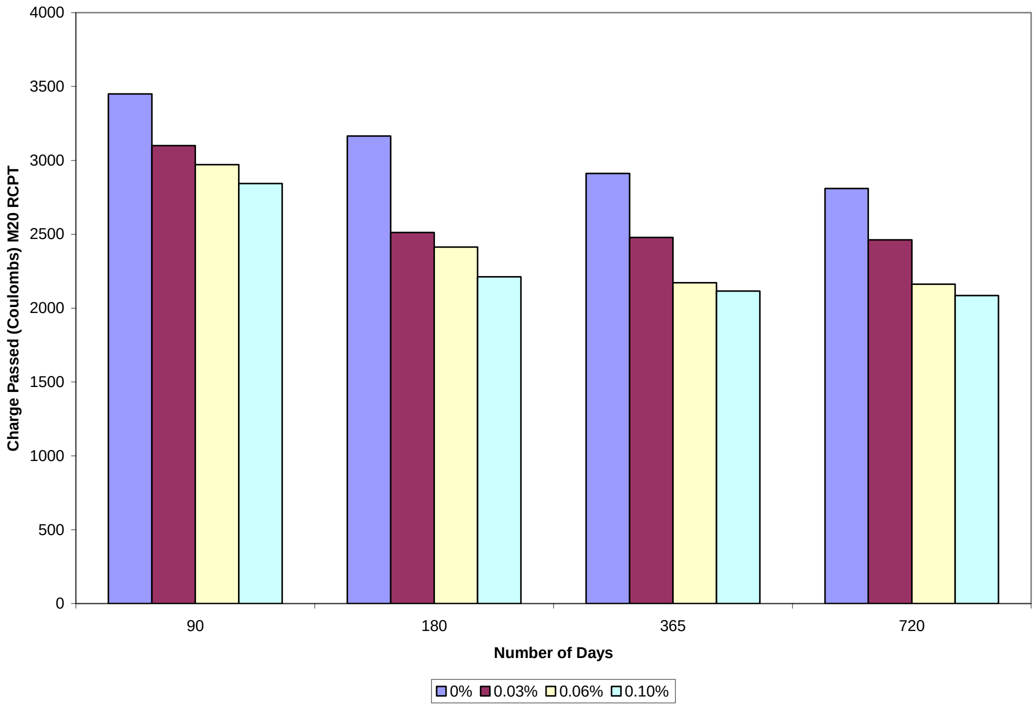

Figure-5. RCPT value for M20 grade at different ages of concrete.

CONCLUSIONS

The performance of GFRC increased with regard to durability. The following salient conclusions are drawn from the present investigations:

a) Chloride permeability of glass fibre reinforced concrete shows less permeability of chlorides into concrete when compared with 0% of GFRC;
b) The GFRC reduces the cracks causing interconnecting voids to be minimum;

c) Due to the addition of 0.1% of glass fibres there is decrease of permeability by 17.59% at 90 days; and
d) When the specimen tested at 720 days the value is 25.80%.

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