ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 4, Special Issue 22, December 2017

Chloride Ion Permeability Studies on Fibre Based High Performance Concrete

Maruthachalam D[1], Boobalan S C[2], Vishnuram B G[3]

Professor, Department of Civil Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, India [1]

Assistant Professor, Department of Civil Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, India [2]

Principal, Department of Civil Engineering, Ahalia School of Engineering and Technology, Palakkad, India [3]

Abstract**:** The purpose of this study is to investigate Chloride Permeability study on High Performance Concrete with addition of Polyolefin Macro Monofilament Fibre (PMMF). The Concrete was produced by partial replacement of Ordinary Portland cement with mineral admixtures fly ash and metakaolin 10% each, with addition of PMMF at the various dosages of 0.1, 0.2 and 0.3 percentage by volume fraction. The M60 grade concrete was designed as per ACI 211.4R-08 "Guide for selecting proportions for high strength concrete with Portland cement and other cementitious materials". This investigation clearly explains the effect of PMMF dosage through measurement of Chloride ions by Rapid Chloride Permeability Test (RCPT). The results indicate that the concrete with 10% fly ash and 10% Metakaolin replacement with 0.3% of PMMF shows the better performance on above studies when compared with other samples. With addition of 0.3% fibres the weight loss percentage and charges passed decreases for rapid chloride penetration test when compared to the control mix. The investigation shows that addition of PMMF makes the concrete more durable along with the mineral admixtures.

Keywords: Chloride Permeability, Fly ash, Metakaolin, Rapid Chloride Penetration Test

I. Introduction

Concrete is most widely used construction material in the world. It has been in use for centuries in various types of structures due to its versatile nature. Increase in demand and decreases in supply of aggregates for the production of concrete result in the need to identify the new source of aggregates**.** High Performance Concrete (HPC) is a composite material consisting of hydraulic cement, sand, silica fume, fly ash, coarse aggregates, water and fibres. HPC results from the addition of either short discrete fibers or continuous long fibers to the cement based matrix. In this composite material, short discrete fibres are randomly distributed throughout the concrete mass. The recent developments in the field of high-performance concrete represent a giant step toward making concrete a high-tech material with enhanced characteristics and durability. These developments have even led to it being a more ecological material in the sense that the components admixtures, aggregates, and water are used to their full potential to produce a material with a longer life cycle.

In this present investigation, we have done experimentation on rapid chloride measurement test with addition of fibres to check the durability of concrete.

Capillary absorption, hydrostatic pressure, and diffusion are the means by which chloride ions can penetrate concrete. The most familiar method is diffusion, the movement of chloride ions under a concentration gradient. For this to occur the concrete must have a continuous liquid phase and there must be a chloride ion concentration gradient. A second mechanism for chloride ingress is permeation, driven by pressure gradients. If there is an applied hydraulic head on one face of the concrete and chlorides are present, they may permeate into the concrete.

Vaishali et al. (2011) investigated effect of metakaolin on compressive strength and chloride ion permeability test. The Chloride ion permeability test has been conducted as per ASTM C1202 on various metakaolin based HPC mixes attained by absolute volume method. They found that with the increase in metakaolin content from 0 to 10%, there is a marginal increase in compressive strength beyond which it decreased. The experimental results indicate that metakaolin has the ability to considerably reduce the permeability of high performance concrete [4]. Chandramouli et al. (2010) studied the Durability on Concrete using RCPT for Different Grades of Concrete by addition of various percentages of

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glass fibres. They concluded that with increasing percentage replacement of fibre of 0-10%, there was a consistent reduction in permeability. Since the pores are arrested by glass fibres and chloride permeability of glass fibre reinforced concrete shows less permeability of chlorides for higher grades of concrete. The results show that addition of glass fibres improves that durability performance appreciably [5]. [7] presented a book, this book makes students to expose themselves to basic electronic devices, be familiar with the theory, construction, and operation of Basic electronic devices.

II. Experimental Layout

A. Materials

- Cement: The Ordinary Portland Cement of 53 Grade was used in this study. The specific gravity, initial and final setting of OPC 53 grade were 3.15, 28 and 600 minutes respectively.
- Fine Aggregates: Locally available river sand conforming to grading zone II of IS 383 –1970. Sand passing through IS 4.75mm Sieve will be used with the specific gravity of 2.67.
- Coarse Aggregates: Crushed granite aggregates with specific gravity of 2.7 and passing through 20 mm sieve and retained on 10 mm will be used for casting all specimens.
- Metakaolin: To make the Concrete as a High Performance Concrete, Metakaolin is used by replacing cement by 5% & 10% (Different Mixes). High-Reactivity Metakaolin (HRM) as mineral admixture in dry dense form conforming to ASTM C 618 class N Pozzolana.
- Fly ash: Flyash is the best known and one of the most commonly used “pozzolans”. Class F is generally low in lime, usually under 5 per cent and contains a greater combination of silica, alumina and iron (greater than 70 per cent) than class C flyash. Flyash (Class-F) was obtained from Mettur Thermal Power Plant (MTTP).
- Water: Casting and curing of specimens were done with the potable water that is available in the college premises.
- Superplasticizer: A commercially availible Sulphonated Napthalene Formaldehyde based Superplasticizer (Conplast SP 430) was used as chemical admixture to enhance the workability of the concrete.
- Polyolefin macro monofilament fiber: This fibre is from the material of Virgin Homopolymer Polypropylene. Its length is 38 mm with a tensile strength of 620-758 MPa.

B. Mix Proportions

In this study, control mix was designed as per ACI 211.4R-08 to achieve M60 grade of concrete. Fly ash and Metakaolin was used to replace Ordinary Portland Cement at constant level of 10% and the PMM fibre of 0%, 0.1%, 0.2% & 0.3% were used. The mix proportions of different mixes are shown in Table I.

TABLE I
MIX PROPORTIONS (GRADE M60)

Mix Description	Cement (kg/m^3)	Fly Ash (kg/m^3)	Metakaolin (kg/m^3)	Fibre (kg/m^3)	Fine Agg. (kg/m^3)	Coarse Agg. (kg/m^3)	Water (Lit/m^3)	SP (Lit/m^3)
CM	615.2	-	-	-	511.4	1102	181	-
FMHPC0	492.2	61.5	61.5	-	511.4	1102	181	4.8
FMHPC1	492.2	61.5	61.5	0.9	511.4	1102	181	4.8
FMHPC2	492.2	61.5	61.5	1.8	511.4	1102	181	4.8
FMHPC3	492.2	61.5	61.5	2.7	511.4	1102	181	4.8

C. Casting and Testing of Specimens

In the present study , the rapid chloride penetration test (RCPT) was performed as per ASTM C1202 to determine the electrical conductance of HPC trial mixes of M60 grade at the age of 28, 56 and 90 days curing and to provide a rapid indication of its resistance to the penetration of chloride ions. The test method consists of monitoring the amount of electrical current passing through a water-saturated 50 mm thick and 100 mm diameter concrete specimen as shown in figure 1, which is subjected to a 60 V applied DC voltage for 6 hours. The RCPT apparatus consists of two reservoirs as shown in figure 2. The fixed specimen was between two reservoirs using an epoxy bonding agent to make the setup to be leak proof as shown in figure 3 & 4. In one reservoir is a 2.4N NaCl solution which is connected to negative terminal of DC source and in the other reservoir is a 0.3 M NaOH solution connected to positive terminal of DC source. A DC of 60 V was applied across the specimen using two stainless steel electrodes (meshes) and the current across the specimen was recorded at 30 minutes interval for the duration of 6 hours.

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Mix	Charge passed as per ASTM equivalent (coulombs)			Degree of Chloride ion Penetrability based on charge passed		
	28 Days	56 Days	90 Days	28 Days	56 Days	90 Days
CM	3639.9	2325	1697.1	Moderate	Moderate	Low
FC 0	3141.9	1449	1018.5	Moderate	Low	Low
FC 1	2343.3	1077.9	677.7	Moderate	Low	Very Low
FC 2	1767.3	704.4	322.2	Low	Very Low	Very Low
FC 3	1170.6	307.5	241.5	Low	Very Low	Very Low

The total charge passed during this period was calculated in terms of coulombs using the trapezoidal rule as given in the ASTM C 1202,

$$Q = 900\,(I_0 + 2\,I_{30} + 2\,I_{60} + \ldots\ldots\ldots\ldots + 2\,I_{330} + I_{360}) \quad \text{- - - (i)}$$

Where

Q = charge passed (coulombs)

I_0 = current (amperes) immediately after voltage is applied

I_t = current (amperes) at 't' minutes after voltage is applied.

Fig. 1. Test Specimens

Fig. 2. RCPT Test Setup

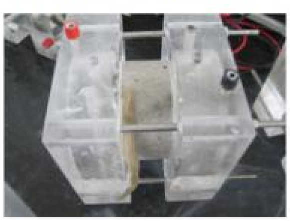

Fig. 3. Sealing the Specimen

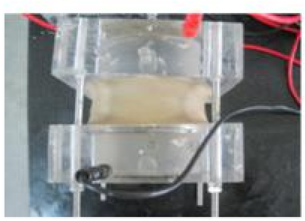

Fig. 4. Sealed Specimen

III. RESULTS AND DISCUSSION

A. *Rapid Chloride Penetration Test Results*

The results of the rapid chloride penetration tests of the HPC mix containing control mix and fly ash, metakaolin replaced concrete with fibre dosage 0%, o.1%,0.2% and 0.3% for 28,56 and 90 days of curing are given in Table II.

TABLE II
RAPID CHLORIDE PENETRATION TEST

From the test results, it is observed that the lowest value charge passed is for the mix having fibre dosage as 0.3%. It is also noted that the addition of pozzolanic material such as fly ash and metakaolin increases the penetration resistance of concrete when compared to control mix. It is also noted that as the curing period increases the penetration resistance increases due to the depletion of calcium ions in the gel pore fluids and subsequent reduction of pH and the development of constricted discontinuous and tortuous pore structure. As a result of pore structure becoming relatively more refined due to the pozzolanic reactions, the high conductivity path or the least resistive paths for the ions will be decreased. The variation of charge passed for different mixes for various curing periods are shown in the Fig. 5

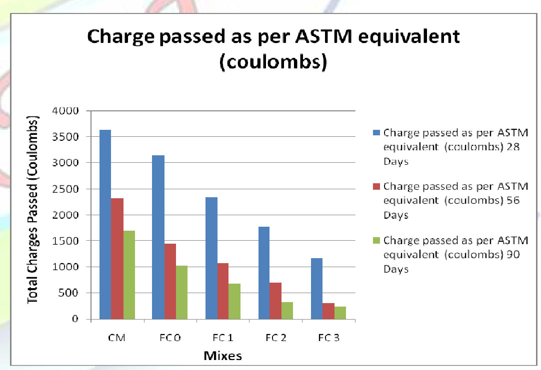

Fig. 5. Variation of charge passed for different fibre dosage for various curing periods

B. *Diffusion Co-efficient for Mixes*

The diffusion co-efficient for the HPC mix containing control mix and fly ash, metakaolin replaced concrete with fibre dosage 0%, o.1%,0.2% and 0.3% are given in Table III.

TABLE III
DIFFUSION CO-EFFICIENT FOR MIXES

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From the results it is indicated that the diffusion co-efficient value decreases as the fibre dosage increases and also as the curing period increases. The decrease in diffusion co-efficient value indicates that the concrete exhibits increased penetration resistance. The fibres used provide excellent resistance to the salts. The variations of diffusion co-efficient for different mixes for various curing periods are shown in the fig. 6.

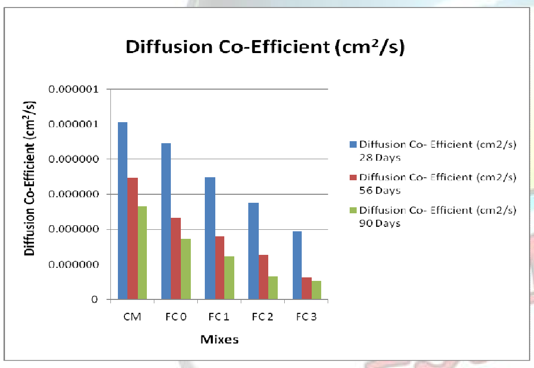

Fig. 6 Variation of diffusion co-efficient for different fibre dosages for various curing periods

IV. Conclusion

The following conclusions were drawn from the present investigation,

- Rapid chloride Penetration test conducted in the laboratory gives a good result for HPC with 10% Fly ash and 10% Metakaolin than that of control mix concrete. The permeability of HPC was lower than control mix concrete.
- The increase in fibre dosage shows reduction in the charges passed in HPC mixes. Also the increase in curing period reduces the charges passed (low, very low) indicating that there is higher penetration resistance as the fibre dosage and curing period increases.
- The diffusion co-efficient value decreases as the fibre dosage increases and also as the curing period increases.

Mix	Diffusion Co- Efficient (cm^2/s)		
	28 Days	56 Days	90 Days
CM	1.00961E-06	6.93E-07	5.32E-07
FC 0	8.92234E-07	4.66E-07	3.46E-07
FC 1	6.97417E-07	3.63E-07	2.46E-07
FC 2	5.50273E-07	2.54E-07	1.32E-07
FC 3	3.89314E-07	1.27E-07	1.03E-07

- The decrease in diffusion co-efficient value indicates that the concrete exhibits increased penetration resistance.

Thus from the above conclusions the performance of HPC using mineral admixtures such as Metakaolin and fly ash with polyolefin macro monofilament fibres are good and far better than control mix concrete (OPC).

ACKNOWLEDGMENT

The authors of the present work wish to acknowledge "NINA Concrete Systems Pvt. Ltd., for sponsoring the Polyolefin Macro-Mono fibre for the study. We appreciate the support from the "English India Clays Limited", Thiruvananthapuram for providing Metakaolin for the experimental investigation. The authors would also like to acknowledge the facilities provided by Sri Krishna College of Engineering and Technology for the project, a special thanks to all the students for their great help in experimental investigation.

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Vol. 4, Special Issue 22, December 2017

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