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Assessing Rapid Chloride Penetration in Concrete with Aluminium Powder: Effects of Saline Water Curing

Sandip Maruti Kale, Anand Dattatray Shinde, SahirAyub Shaikh, Vikas Laxman Suryawanshi, Omkar Kalidas More

[1]*Assistant Professor,S.B. Patil College of Engineering, Pune.*
[2,3,4,5]*Student,S.B. Patil College of Engineering, Pune.*

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ABSTRACT: In order to assess the resistance of concrete to the penetration of chloride ions, we employed Electrical resistivity techniques to determine the relative permeability of the material. The commonly used method for this purpose is the ASTM C 1202, also known as the rapid chloride permeability test (RCPT), which provides an electrical indication of concrete's ability to resist the penetration of chloride ions.One of the key components in concrete that aids in its gas liberation is aluminium powder. When aluminium reacts with calcium hydroxide, it releases hydrogen, leading to the formation of pores within the concrete ranging in size from 0.1 to 1.0 mm. Consequently, this increases the overall porosity of the concrete. By increasing the quantity of aluminium powder, the porosity is further elevated, thereby rendering the concrete more susceptible to corrosion.It is worth noting that concrete mixes containing aluminium powder, when subjected to curing in saline water, exhibit a higher susceptibility to corrosion.

KEYWORDS: Rapid Chloride Penetration Test (RCPT), Corrosion, Aluminium powder.

I. INTRODUCTION

Chloride ingress causes corrosion in concrete structures. Chlorides enter concrete through various mechanisms, primarily diffusion. When chloride concentration outside the concrete exceeds the inside, chloride ions move through to the rebar, leading to corrosion in the presence of oxygen and wetting/drying cycles. The rate of chloride ingress depends on the internal pore structure, influenced by factors like mix design, curing, and construction practices. The Rapid Chloride Permeability Test (RCPT) is used to evaluate concrete's resistance to chloride penetration and predict its service life. It measures the concrete's electrical conductance, indicating its resistance to chloride ions. Higher Coulomb values indicate higher permeability. RCPT is essential for quality control and assessing concrete improvements uses corrosion in concrete structures. Chlorides enter concrete through various mechanisms, primarily diffusion. When chloride concentration outside the concrete exceeds the inside, chloride ions move through to the rebar, leading to corrosion in the presence of oxygen and wetting/drying cycles. The rate of chloride ingress depends on the internal pore structure, influenced by factors like mix design, curing, and construction practices. The Rapid Chloride Permeability Test (RCPT) is used to evaluate concrete's resistance to chloride penetration and predict its service life. It measures the concrete's electrical conductance, indicating its resistance to chloride ions. Higher Coulomb values indicate higher permeability. RCPT is essential for quality control and assessing concrete improvements.

II. LIITERATURE REVIEW

In a comprehensive study conducted by Prakash Joshi et al., detailed information about the RCPT method was provided. The researchers applied the RCPT technique to a rapid-setting repair grout that incorporated a corrosion-inhibiting chemical. The obtained low coulombs-passed value of 177 indicated that the repair grout possesses suitable characteristics for structural repairs in various applications.The permeability of concrete is influenced by its internal pore structure, which, in turn, is affected by factors such as hydration and curing conditions. The study demonstrated that as the concrete ages and the water-cementitious material ratio decreases, there is a reduction in

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chloride permeability. To validate this finding, concrete samples from a bridge deck rehabilitation project were tested. Initially, these samples did not meet the specified coulombs passed value at 28 days. However, they achieved the required level at later ages, underscoring the importance of proper moist curing. Furthermore, the results revealed a significant decrease in chloride permeability as the concrete aged, emphasizing the beneficial effects of concrete age on permeability. Notably, after 90 days, the chloride permeability among the different tested mixes was almost identical.

According to M. T. Bassuoni et al., durability refers to the ability of concrete to resist physical or chemical deterioration caused by environmental factors or internal interactions between its constituents. A durable concrete ensures the corrosion resistance of embedded steel, leading to a longer lifespan for the overall structure. Coastal areas pose a particular challenge due to the detrimental effects of high chloride concentration in seawater, which can accelerate chemical deterioration. In such cases, lower chloride permeability indicates better concrete durability.To address the expensive nature of standard chloride permeability tests, an experiment was conducted using a cost-effective improvised apparatus made from easily accessible materials. The Rapid Chloride Permeability Test (RCPT) performed with this simplified method revealed significant variations in chloride permeability among different concrete qualities. The improvised setup requires less than 10 percent of the cost of other available apparatus, while maintaining reliability and accuracy. Although a direct comparison with sophisticated instruments is yet to be made, there are compelling reasons to believe that this method can achieve comparable precision.In order to ensure the long-term performance of reinforced concrete structures in aggressive environments, cost-effective quality control measures and methods are necessary. Such measures can serve as a basis for job specifications and on-site quality control. Therefore, this economical method offers a viable alternative.

III. METHODOLOGY

A. Materials:

We designed M40 concrete mix using OPC Grade 53 cement, fine aggregate, normal river sand with specific gravity 2.71 and coarse aggregate with specific gravity 2.84.

Property	Value
Normal Consistency of Cement	30-35%
Specific Gravity of Cement	<=3.15
Initial Setting Time of Cement	>30 min
Final Setting Time of Cement	<600min
Fineness of Cement of Cement	10%
Specific Gravity of Fine Aggregate	2.71
Specific Gravity of Coarse Aggregate	2.84

B. Mix Design (IS 10262:2019)

For experimental analysis, we made concrete of M40 grade (IS 10262:2019), we found ingredient proportion i.e., ratio of mix is 1:1.57:2.81 with water-cement ratio taken as 0.40. We replaced cement by Aluminium powder (2%) and prepared 2 samples. First sample was cured in normal potable water, while the other sample was cured in saline water (33-35% NaCl).

IV. EXPERIMENTAL ANALYSIS

A. Rapid Chloride Penetration Test (RCPT):

The Rapid Chloride Permeability Test (RCPT) is an electrical method employed to evaluate the resistance of concrete against chloride ion penetration, which is essential for determining its durability and lifespan. By subjecting a concrete sample to a constant 60V voltage for 6 hours and measuring the resulting current, the RCPT offers insights into the concrete's electrical conductance and its ability to withstand chloride ions. The standardized procedures for RCPT can be found in ASTM C 1202.

The RCPT quantifies the coulombs of charge that pass through the concrete specimen during a specific time period. Coulombs represent the amount of electrical charge, with one coulomb equal to one ampere-second. A higher coulomb value indicates greater permeability of the concrete to chloride ions, indicating lower resistance. The test necessitates specialized equipment for the Rapid Chloride Permeability Test, including two reservoirs containing NaCl and NaOH solutions, as well as a concrete specimen with defined dimensions.

To conduct the test, a concrete specimen with a diameter of 100 mm and thickness of 50 mm is cast and saturated. It is then placed between the two reservoirs, creating a single cell. The cell is connected to a DC power supply, which applies a 60V voltage to the concrete specimen for a duration of 6 hours. The current passing through the concrete at different time intervals is measured

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and displayed on an LCD screen linked to the cell. This test offers valuable information for quality control, assessing the impermeability of concrete to chloride ions, and evaluating the effectiveness of concrete property enhancements.

B. Aluminium Powder:

Aluminium powder is commonly used in concrete as a gas-liberating agent. It reacts with calcium hydroxide, releasing hydrogen and forming pores in the concrete within the 0.1-1.0 mm range. This increases the porosity and lowers the dry thermal conductivity. Increasing the amount of aluminium powder raises porosity, reduces density. lowers modulus of elasticity, and typically decreases compressive strength. However, there are variations in compressive strength depending on the aluminium content, with some studies observing an initial increase, followed by a decrease, and then another increase. These changes may be linked to pore shape and orientation, particularly elliptical pores resulting from hydrogen evolution, leading to mechanical anisotropy.

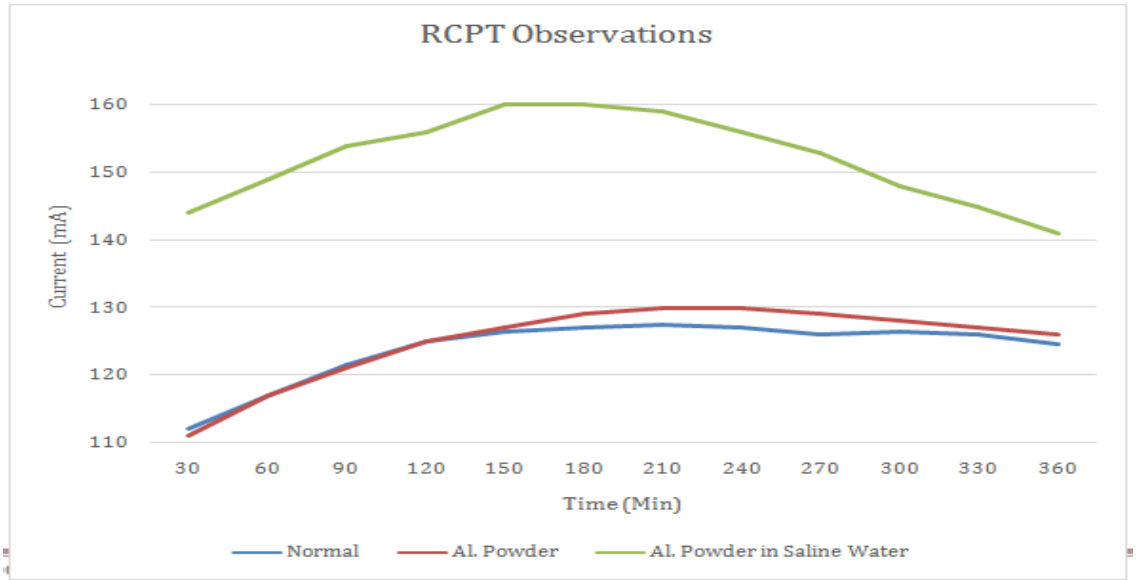
Performing RCPT

Charge Passed (C)	Penetrability of Chloride Ion
>4,000	High
2,000-4,000	Medium
1,000-2,000	Low
100-1,000	Very Low
<100	Negligible

Concrete mix samples are tested for RCPT. The observations are taken at 30 minutes time interval and the test is performed for 6 hours, as per ASTM C1202.

Time (min)	Concrete Mix		
	Normal	Aluminium Powder	Aluminium Powder Cured in Saline Water
30	112	111	144
60	117	117	149
90	121.5	121	154
120	125	125	156
150	126.5	127	160
180	127	129	160
210	127.5	130	159
240	127	130	156
270	126	129	153
300	126.5	128	148
330	126	127	145
360	124.5	126	141

As per ASTM C1202,
Q_0 = 2462.85 C, Q_1 =2486.7 C, Q_2 = 3028.5 C



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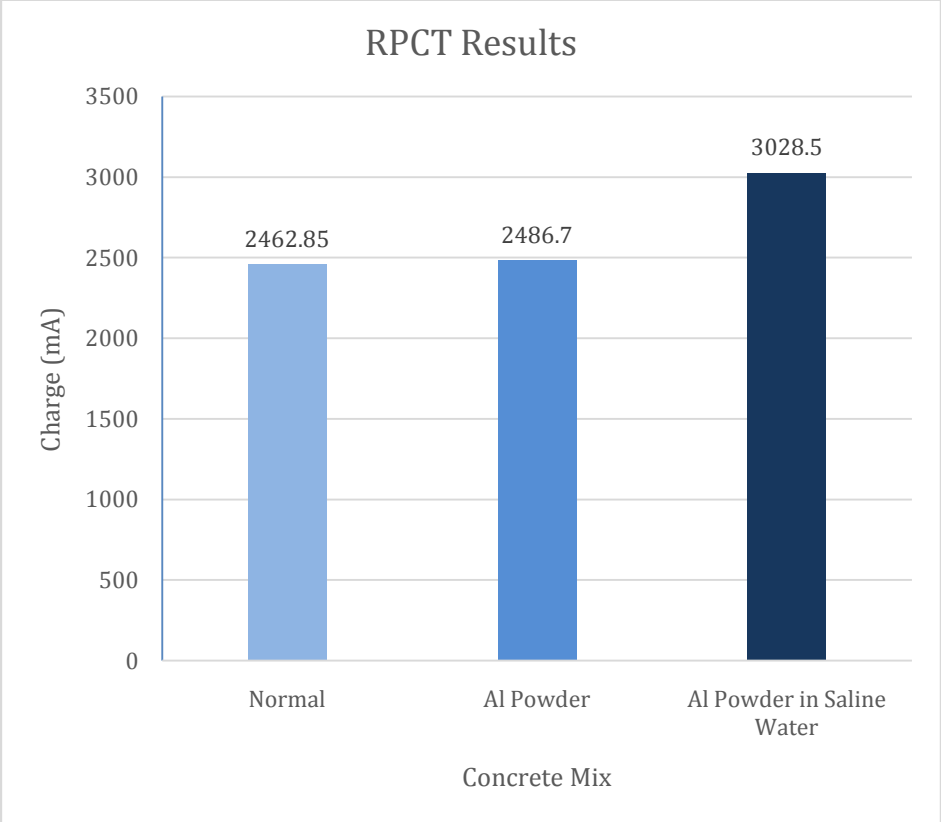

Concrete mixed with aluminium powder exhibits a slightly higher charge transfer value compared to normal concrete. Furthermore, when concrete mixed with aluminium powder is cured in saline water, it shows a higher charge transfer value compared to the corresponding value of normal concrete.

V. CONCLUSION

Based on the experimental investigation, normal concrete exhibits a lower charge transfer value, indicating a medium susceptibility to chloride ion penetration. On the other hand, concrete containing aluminium powder shows a slightly higher charge transfer value compared to normal concrete, placing it within the range of medium susceptibility.

However, concrete that incorporates aluminium powder and undergoes curing in saline water (33-35% NaCl) displays a charge transfer value that exceeds 25% compared to normal concrete. This signifies a significantly higher susceptibility to chloride ion penetration.

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