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Comparative Study of Rapid Chloride Penetration Test (RPCT) on Self Compacting Concrete (SCC)

Sandip Kale[1], Anand Shinde[2], Sahir Shaikh[3], Vikas Suryawanshi[4], Omkar More[5]
[1, 2, 3, 4, 5]*Department of Civil Engineering, SPPU*

Abstract: ***To check resistance to chloride ions penetration, we used Electrical resistivity techniques to give an indication of the relative permeability of concrete. The ASTM C 1202 (Standard Test Method for Electrical Indication of concrete's ability to resist chloride Ion Penetration), more commonly known as the rapid chloride permeability test (RCPT). Self-compacting concrete (SCC) is a very fluid concrete and a homogeneous mixture. In this research work, M40 grade of concrete mixes were made using IS 10262:2019 method. The fresh and harden properties of SCC was taken at the ages of 3,7 and 28 days. After experimental investigation, we can conclude that SCC was more workable than the normal concrete and it did not show any major reduction in compressive strength up to 2% replacement of Super plasticizer. The RCPT is performed on Normal & SCC mix after 28th days and SCC mix showed less values of charges passed than that for the normal concrete mix. Hence, SCC has more resistance to chloride ions penetration.***

Keywords: Self-Compacting Concrete (SCC), Rapid Chloride Penetration Test (RCPT), Corrosion, Workability, Compressive Strength.

I. INTRODUCTION

Concrete is vital in construction but faces challenges like harsh environments and the need for compaction. Engineers are experimenting with additives and materials to enhance concrete quality. Self-compacting concrete (SCC) is a recent innovation that doesn't require vibration. It flows under its weight, filling formwork and compacting even with dense reinforcement. SCC is dense, homogeneous, and durable like traditional concrete, but it's faster to place and requires less labour. SCC's fluidity, homogeneity, and resistance to segregation allow for superior finish and durability. Following production and placement guidelines are crucial for SCC's success.

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. LITERATURE REVIEW

In their study, R. Jeya et al. assessed the suitability of Self-Compacting Concrete (SCC) for construction. They found that SCC, a highly fluid and homogeneous mixture, resolves issues with traditional concrete. Through experiments, they evaluated its filling ability, passing ability, segregation resistance, workability, and strength. They also examined the chloride penetrability of SCC. SCC is defined as concrete that doesn't require compaction, making it ideal for structures with congested reinforcement or limited access. They achieved optimal results for filling ability, passing ability, segregation resistance, and compressive and tensile strength with a specific SCC mix (SCC5) containing 1% superplasticizer and 0.4% viscosity modifying admixtures. The study confirmed SCC's superior resistance to chloride permeability compared to conventional concrete.

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In another study by Prakash Joshi et al., the RCPT method was explained in detail. They conducted RCPT on a rapid-setting repair grout containing a corrosion-inhibiting chemical. A low coulombs-passed value of 177 indicated that the repair grout is suitable for structural repairs in various applications. The permeability of concrete is influenced by its internal pore structure, which is affected by factors like hydration and curing conditions. The study demonstrated a reduction in chloride permeability with age and lower water-cementitious material ratio. Concrete samples from a bridge deck rehabilitation project were tested, and while they didn't initially meet the specified coulombs passed at 28 days, they achieved the requirement at later ages. The results highlighted the importance of proper moist curing and showed that chloride permeability decreases significantly with concrete age. After 90 days, the chloride permeability among the different mixes tested was nearly the same.

III. METHODOLOGY

A. *Materials*

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

Superplasticizer, also known as also known as high-range water reducers, are additive used in making high strength concrete. Plasticizers are chemical compounds that enable the production of concrete with approximately 15% less water content. Superplasticizers allow a 30% or more reduction in water content. We used Sundanda polytancrete NGT super plasticising concrete admixture. Polytancrete NGT is water-miscible polymeric liquid admixture. It is to be added to the gauging water to be blended withinside the concrete/mortar. It will increase all strengths and improves numerous houses like finish-ability, workability and finished appearance.

Table I
Characteristics of Materials

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. Along with the normal mixes, we also designed SCC by 1%, 1.5% and 2% replacement of cement by Super plasticizer.

IV. EXPERIMENTAL ANALYSIS

A. *Slump Cone Test*

The concrete slump test is conducted to determine the workability and consistency of a concrete mix. It is performed in the laboratory or at the construction site to ensure uniform quality throughout the construction process. While the concrete slump value primarily indicates the workability and water-cement ratio, other factors such as material properties, mixing methods, dosage, and admixtures can also influence the results.

Following Table 2 shows the results of slump cone test and Fig 1 shows slump value of different mix samples.

TABLE III
SLUMP CONE TEST RESULTS OF SCC

Sample	Slump Value (mm)
0%	55
1%	75
1.5%	85
2%	115

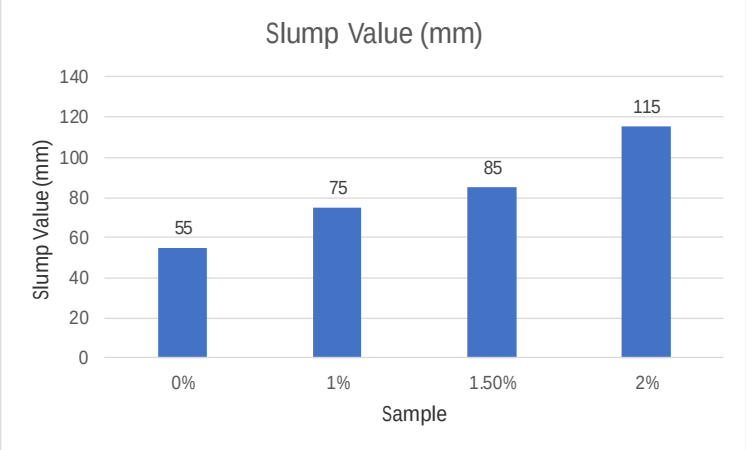


Fig. 1: Slump Cone Test Results

It can be seen that the workability of the concrete mix increases with the increase in the addition of chemical admixture, Superplasticizer. Normal concrete is not very workable, but the increase in the dosage of super plasticizer increases the workability of the concrete.

B. Compression Test

The compressive strength of concrete is measured using 150 mm size cubes tested at 28 days, according to Indian Standards (ACI standards use cylinders with a diameter of 150 mm and height of 300 mm). The characteristic strength refers to the concrete strength below which no more than 5% of test results are expected to fall. It is determined by casting and testing concrete specimens as per the specified code of practice, and the cubes should have a minimum strength value that 95% of them should exceed after being cured for 28 days. Concrete mixes will be tested at 3,7 and 28 days for their respective compressive strength.

Concrete mix samples are tested for compressive strength on 3^{rd},7^{th} and 28^{th} day to ensure the mix design is as per calculations.

TABLE IIIII

COMPRESSIVE STRENGTH TEST OBSERVATIONS

Mix	Replacement (%) of Super plasticizer	Compressive Strength (MPa) at Various Days		
		3 Day (N/mm^2)	7 Day (N/mm^2)	28 Day (N/mm^2)
M1	0%	19.5	33.9	49.25
M2	1%	19.85	35.3	50.20
M3	1.5%	20.10	35.1	50.75
M4	2%	19	33.4	49.15

All the four samples gave results as required for their target strength of 48 MPa. SCC mixes did not show any major reduction in compressive strength up to the replacement of 2% superplasticizer. The compressive strength of the SCC mixes is nearly same as that of the normal concrete mix. M3 mix (1.5% replacement of super plasticizer) gave the maximum compressive strength of 50.75 MPa, followed by M2 with 50.2 MPa compressive strength. M4 mix showed a small reduction in the compressive strength (49.15 MPa) as compared to the normal concrete mix (49.25 MPa).



Fig. 3: Performing Compressive Strength Test

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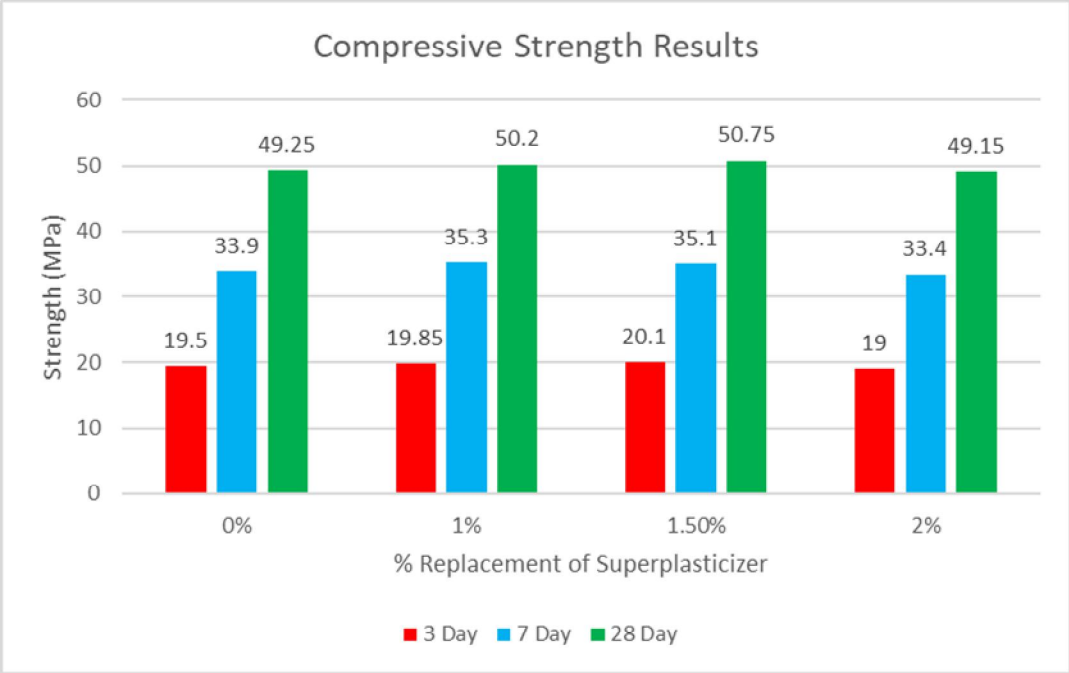


Fig.2: Results of Compressive Strength Test

C. Rapid Chloride Penetration Test (RCPT)

The Rapid Chloride Permeability Test (RCPT) is an electrical method used to assess a concrete's resistance to chloride ion penetration, which is crucial for determining its durability and service life. By applying a constant voltage 60V to a concrete specimen for 6 hours and measuring the current passing through it, the test provides an indication of the concrete's electrical conductance and its ability to resist chloride ions. Standardized procedures for RCPT can be found in ASTM C 1202.

RCPT measures the coulombs of charge passed through the concrete specimen over a specific time period. Coulombs represent the quantity of electrical charge, with one coulomb equivalent to one ampere-second. The higher the coulomb value, the greater the permeability of the concrete to chloride ions, indicating lower resistance. This test is conducted using specialized equipment for the Rapid Chloride Permeability Test, involving two reservoirs containing NaCl and NaOH solutions, and a concrete specimen with specific dimensions.



Fig. 4: Performing RCPT

The concrete specimen, with a diameter of 100 mm and thickness of 50 mm, is cast and saturated before being placed between the two reservoirs, forming a single cell. The cell is connected to a DC power supply, applying a voltage of 60V to the concrete specimen for 6 hours. The current passing through the concrete at various time intervals is measured and displayed on an LCD screen connected to the cell. This test provides valuable information for quality control and assessing the impermeability of concrete to chloride ions, as well as evaluating the effectiveness of improvements in concrete properties.

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TABLE IVV
RCPT RATINGS (ASTM C1202)

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.

TABLE V
RCPT COMBINED RESULTS

Time (min)	Current (mA) in Concrete Mix			
	0% Replacement	1% Replacement	1.5% Replacement	2% Replacement
30	112	88	98	88.5
60	117	93.5	100	91.5
90	121.5	98	102.5	94.5
120	125	101.5	105	97.5
150	126.5	103.5	106	99
180	127	104.5	106	99.5
210	127.5	105.5	106	99
240	127	106	105.5	99
270	126	105	105.5	98
300	126.5	105	105	98.5
330	126	105	105	98
360	124.5	104.5	104	97.5

As per ASTM C1202,
Q_0 = 2462.85 C, Q_1 = 2022.75 C, $Q_{1.5}$ =2065.5 C, Q_2 = 2011.5 C

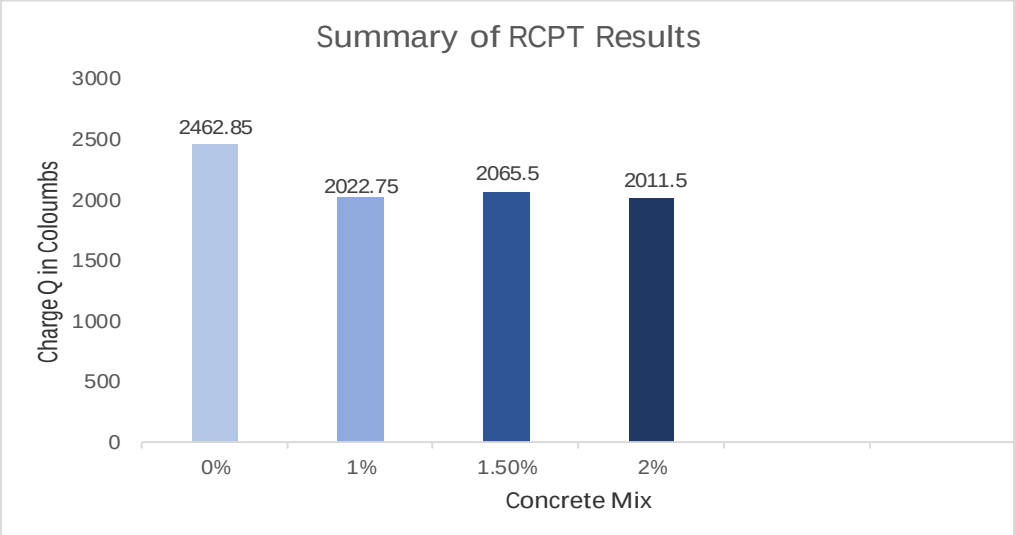


Fig5: Summary of RCPT Results

Normal concrete mix transferred 2462.85 C and SCC samples shows less respective values. SCC mixes have more resistance to penetration of chloride ions. In general, the addition of the super-plasticizer reduces chloride ion penetration in the concrete.

V. CONCLUSIONS

Self-Compacting Concrete (SCC) is more workable than the normal concrete and does not show any major reduction in the compressive strength up to 2% replacement of super plasticizer. Super plasticizer reduces the chloride ion penetrability as well. The chloride ion penetrability decreases with the increase in the super plasticizer. Hence, Self-Compacting Concrete has more resistivity for the chloride ion penetration.

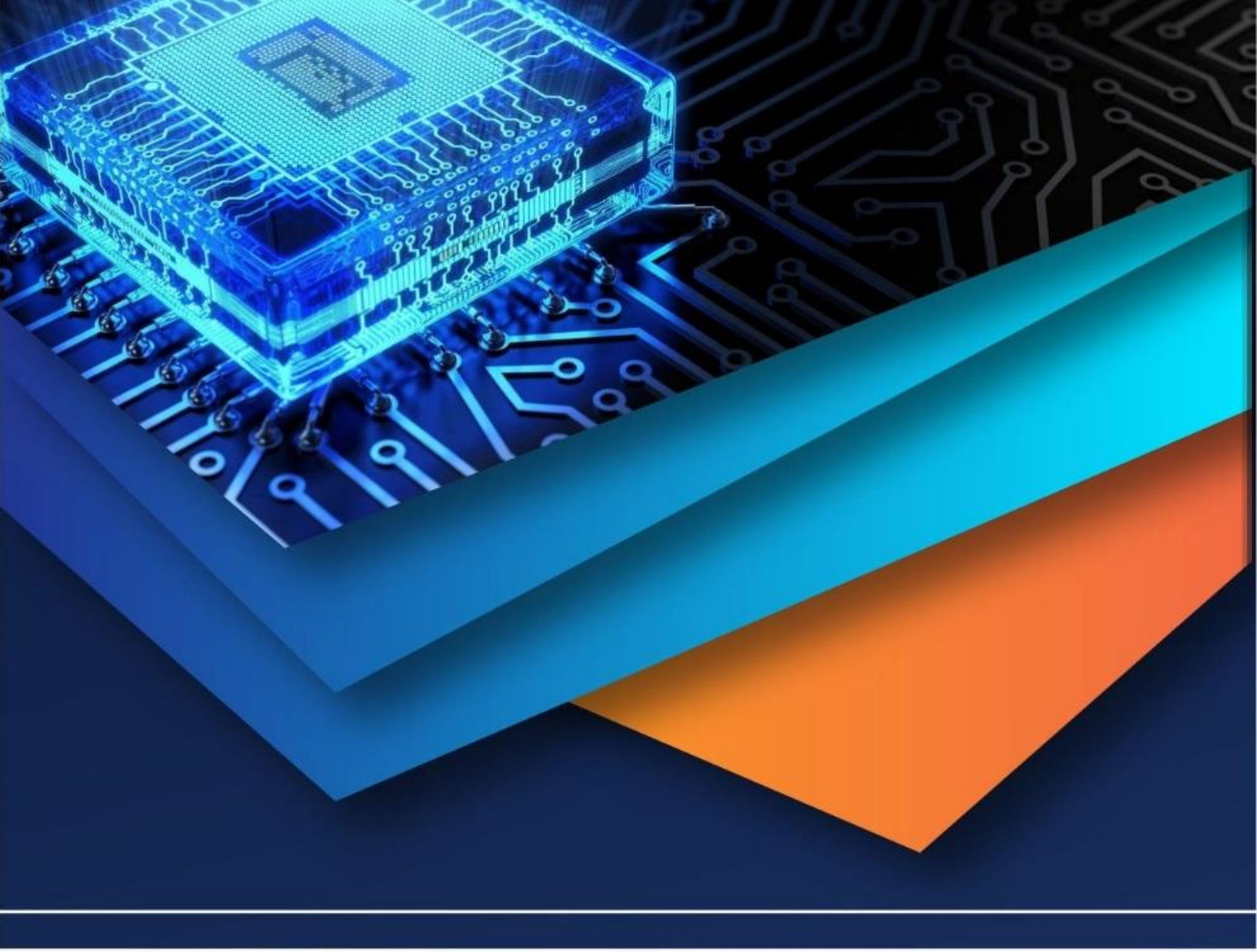
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