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Durability assurance of production-scale high-performance concrete using surface resistivity

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A B S T R A C T

As India advances towards performance-based specifications for reinforced concrete, there is a need for field-relevant durability performance indicators that can be rapidly verified during construction and linked to long-term service life requirements. Conventional durability tests such as water permeability and rapid chloride penetration test (RCPT), while informative, are laboratory intensive, time-consuming, and not well suited for real-time quality assurance in large-scale construction. This study reports surface electrical resistivity measurements obtained from production-scale high-performance concrete used in nine infrastructure projects across India with mixing volumes ranging from 22 m^3 to 420 m^3, all produced under stringent quality control regimes. Using the Wenner 4-probe method on saturated surface-dry uncarbonated specimens, resistivity measurements were obtained from 60 concrete cubes of M30-M60 grades incorporating supplementary cementitious materials (SCMs) and other admixtures, cast alongside actual structural elements. The compressive strength, charge passed and water penetration depth were also recorded for applicable cases. Based on approximately 400 measurements in total, average resistivity values ranged from 3.6 kΩ.cm to 153.7 kΩ.cm, RCPT results ranged from 118 C to 1666 C, and water penetration depths varied from 3 mm to 10 mm. Higher resistivity values, especially as observed in concretes with SCMs, were consistently associated with lower charge passage, while trends in water penetration depth were more scattered. The results provide a pan-India field database showing how surface resistivity varies across production concrete used under site conditions.

Keywords: *Performance-based specifications; durability; field quality assurance; service life.*

1 Value of the data

- The dataset provides a large collection of surface electrical resistivity measurements obtained from production-scale concrete used in major infrastructure projects. Such field-based datasets are limited in literature and offer valuable reference information on the range of resistivity values observed under real casting and curing conditions.
- The dataset can be reused for benchmarking resistivity values across concrete grades and constituents, supporting comparison between laboratory measurements and in-situ performance of large-batch mixed concrete for durability related quality control and specification development.
- The dataset reflects concrete produced using raw materials sourced from locations across projects in India, enabling reuse for examining variability in durability indicators associated with material sourcing under field conditions.

2 Background

As India transitions toward performance-based specifications for reinforced concrete, there is a growing need for durability performance indicators that can be verified during construction and linked to target service life requirements. Conventional durability tests such as the rapid chloride penetration test (RCPT) and water permeability test, while informative, are laboratory-intensive, time-consuming, and unsuitable for rapid or in-situ quality assurance during large-scale concreting operations. Moreover, their direct use for field acceptance and service-life-oriented decision-making remains limited.

Surface electrical resistivity testing [1]-[3] is a rapid, reliable, and non-destructive method that is increasingly adopted worldwide for the durability assessment of concrete. Agencies such as the Federal Highway Administration (FHWA), USA, have noted that several state departments, including those in Florida and Louisiana, now permit or use surface resistivity as a cost-effective alternative to the RCPT in durability specifications [4]. The test can be performed both on laboratory specimens at construction sites and directly on in-situ structural elements, making it particularly suitable for quality control during construction. For new structures, a minimum specified target resistivity value that correlates with the expected service life could be verified on site through multiple measurements, enabling rapid, performance-based acceptance checks aligned with durability objectives.

While numerous laboratory studies exist, there remains limited published evidence based on production concrete placed under real construction conditions in India. The present study addresses this gap by establishing a pan-India, field-based database of surface electrical

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resistivity measurements obtained from production concrete and benchmarking selected values against conventional durability indicators. The objective is to support standardization and specification-level adoption, rather than to establish mechanistic cause-effect relationships.

3 Data description

All measurements were obtained from concrete produced and cured under routine site quality-control conditions, and not from laboratory trial batches. The complete dataset is presented within this manuscript and organized in Tables 1-3, which together document the raw data, processed values, and relevant metadata.

4 Experimental design, materials and methods

4.1 Field projects and concrete mixes

The database was developed from nine infrastructure projects distributed across India (refer Figure 1), representing diverse geographic regions and construction conditions. The map also indicates clusters of specimen ID ranges corresponding to projects that used similar sources of ground granulated blast furnace slag, GGBS, reflecting realistic field procurement practices. A total of 20 concrete mixes were investigated, with individual placement volumes ranging from approximately 22 m³ to 420 m³. The mixes predominantly belonged to medium- to high-strength grades (M45-M60), with selected M30-M40 concretes included for comparison.

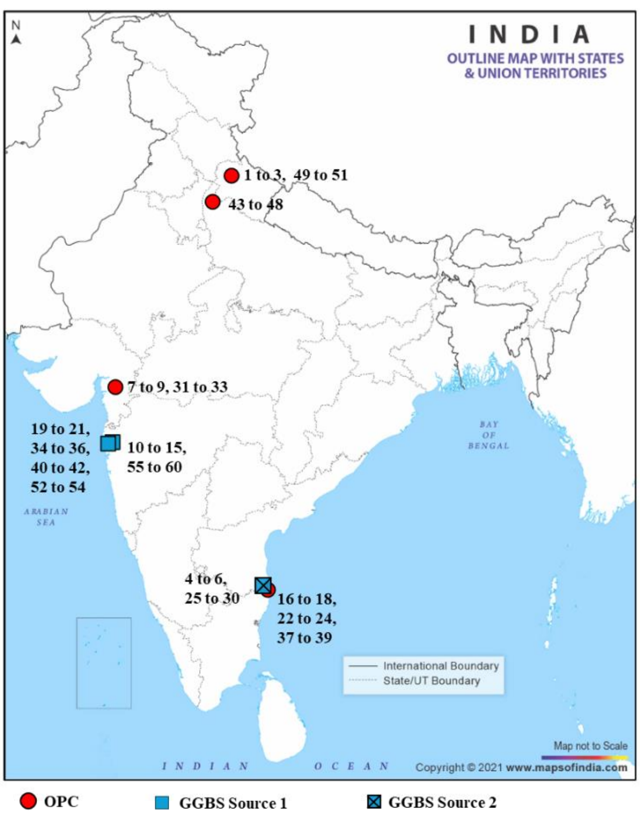

Figure 1 Spatial distribution of the field study locations where concrete data was collected

The concretes were produced using Ordinary Portland Cement (OPC) with varying proportions of supplementary cementitious materials (SCMs), including GGBS, and ultrafine materials such as microsilica (MS). Polycarboxylate ether (PCE)- and sulphonated naphthalene formaldehyde (SNF)-based superplasticizers were used. Selected mixes incorporated corrosion inhibiting admixtures, polymer fibres, and permeability-reducing admixtures as part of project-specific durability strategies. Concrete cubes were cast alongside actual structural elements and cured as per site quality control practices. The details of the concrete mixes (arranged in the ascending order of concrete grade) are given in Table 1 and Table 2.

4.2 Surface electrical resistivity testing

Surface electrical resistivity measurements were carried out using the Wenner four-probe method following the procedures described in RILEM recommendations and EN 12390-19:2023 [3] at 28 days on cube specimens in a saturated surface-dry (SSD) condition. Indicative interpretation ranges reported in AASHTO T 358 [1] were subsequently used only for comparative analysis. Cube specimens were selected as they are routinely cast and tested for quality control at construction sites in India. Furthermore, EN 12390-19:2023 allows surface resistivity measurements on cubes, cylinders, and prisms. In this study, one specimen geometry was used throughout to maintain consistency across all projects.

Figure 2 Measurement of surface resistivity at the field quality control laboratory

4.3 Other tests

Compressive strength at 28 days was determined as per IS 516 (Part 1) using the same specimens following the resistivity measurement [5]. RCPT was conducted following ASTM C1202 [6], and water penetration depth under pressure was measured in accordance with DIN EN 12390-8 [7]. These tests were used to benchmark resistivity trends and were not intended for mechanistic interpretation.

4.4 Summary of the dataset

The test results are presented in Table 1. Surface electrical resistivity values across the field database range from 3.6 to 153.7 kΩ.cm, indicating substantial variability in transport resistance under production conditions. Corresponding rapid chloride penetration test (RCPT) results range from 118 C to 1666 C, spanning low to very low chloride penetrability classes as defined in ASTM C1202. Measured depths of water penetration under pressure vary between 3 mm and about 10 mm, exhibiting comparatively greater scatter. Based on available project-level records, the observed standard deviation for RCPT results ranged between approximately 52 and 72 C, while the standard deviation for water penetration depth ranged between 0.7 and 1.5 mm.

Concretes with very low resistivity (<10 kΩ.cm) are predominantly associated with low to very low chloride penetrability, with RCPT charge passed typically in the range of 600-1666 C. All concretes exhibiting RCPT values exceeding 1000 C fall within this resistivity range. In contrast, concretes with higher resistivity (>50 kΩ.cm) consistently correspond to very low chloride penetrability, with RCPT values generally below 700 C and the minimum recorded value (118 C) occurring exclusively in this range. No concrete in the dataset exhibits the combination of high resistivity (>50 kΩ.cm) and RCPT charge passed exceeding 1000 C. Concretes with intermediate resistivity (10-50 kΩ.cm) largely fall within the low chloride penetrability class, providing a transitional performance range. The numerical separation between lower and higher resistivity values is consistently observed across projects and mix designs included in the dataset. Table 3 groups the measured surface resistivity values into indicative ranges to highlight trends across the mixes studied.

The relationship between compressive strength and average 28-day compressive strengths for different concrete mixes is shown in Figure 3. The horizontal dashed line at resistivity of 20 kΩ.cm indicates the threshold for durability classification, above which concrete is commonly associated with low permeability and high durability.

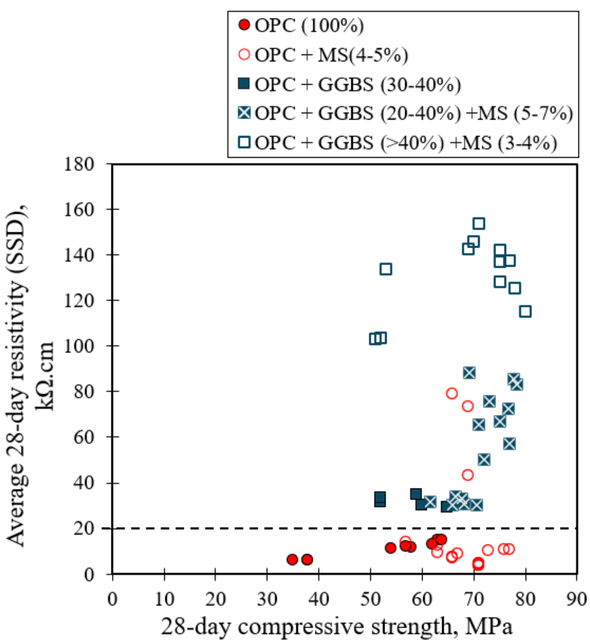

Figure 3 Relationship between 28-day compressive strength and average 28-day surface resistivity (SSD) of concrete cube specimens at construction sites.

It can be observed that high compressive strength does not always correspond to high resistivity. Furthermore, the incorporation of SCMs at adequate dosages can significantly improve the resistivity and consequently, the durability of the concrete. Therefore, surface resistivity is a promising quality control parameter that, when measured alongside compressive strength in the field, can provide an indication of concrete durability.

5 Limitations

The experimental program was not designed to isolate the influence of individual mix parameters such as SCM content, water-binder ratio, or chemical admixtures. Accordingly, field-scale associations can be made from the dataset rather than deterministic cause-effect relationships.

6 Ethics statement

This study does not involve human participants, animal experiments or social media data. Hence, ethical approval is not required.

7 Data accessibility

[Durability Assurance of Production-Scale High-Performance Concrete using Surface Resistivity]

8 Credit author statement

Poongothai Arunachalam - Data collection and data curation;
Srinivasan Thalaimalaisamy - Data curation;
Dyana Joseline - Conceptualization and writing.

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10 Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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