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# Analysis of Corrosion Mechanism, Prevention and Repair measures of RCC Structures

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**ABSTRACT:** Corrosion in Reinforced Cement Concrete (RCC) structures is one of the most persistent and challenging durability issues encountered in the construction industry today. RCC, though known for its high strength and durability, becomes susceptible to degradation when environmental factors such as carbonation, chloride ingress, and moisture affect the passive film that protects the embedded steel reinforcement. Once corrosion initiates, it results in expansive rust formation that causes cracking, spalling of concrete cover, and ultimately a reduction in the structural strength and serviceability of the member. Through this integrated research approach, which combines theoretical understanding with field based experimental analysis, the project highlights the need for proactive corrosion detection and control methods in RCC structures. The inclusion of electrochemical testing in the project also provides insights into real time condition assessment practices that can be adapted on site for effective structural health monitoring. This project ultimately contributes to developing a comprehensive understanding of corrosion behaviour in RCC structures and promotes sustainable engineering practices by suggesting timely intervention measures that reduce maintenance costs and enhance structural reliability.

**KEYWORDS:** RCC Structures, Corrosion, Reinforcement Steel, Half Cell Potential, ASTM C876, Durability, Non-Destructive Testing, Electrochemical Evaluation, Structural Health Monitoring.

## I. INTRODUCTION

Corrosion of reinforcement in Reinforced Cement Concrete (RCC) structures is a widespread problem that threatens the safety, serviceability, and longevity of concrete infrastructure globally. The deterioration of steel reinforcement occurs due to factors such as chloride ingress, carbonation, environmental exposure, and moisture penetration, which lead to cracking, spalling, and eventually structural failure. The present project focuses on a detailed investigation of the corrosion mechanisms in RCC structures, the factors influencing corrosion initiation and progression, and effective strategies for corrosion prevention, monitoring, and repair. Beyond theoretical research, an experimental program has been designed in which nine RCC cubes embedded with reinforcement bars have been cast and tested using the half-cell potential technique as per ASTM C876 standards. This non-destructive method provides valuable insights into the corrosion activity within concrete and supports the theoretical understanding of corrosion phenomena.

## II. LITERATURE SURVEY

Kumar, A., & Singh, R. explored the application of half-cell potential mapping to assess corrosion in reinforced concrete members across various real time exposure conditions. Their study emphasized that the ASTM C876 method provides reliable qualitative corrosion estimates, particularly when combined with proper surface preparation and pre wetting. Testing was conducted on 36 RCC slabs aged between 1 to 15 years. It was observed that structures with higher exposure to water ingress and inadequate cover showed more negative potentials, indicating active corrosion. Their research concluded that even in partially accessible field locations, half-cell testing could be a dependable diagnostic tool for prioritizing repair interventions in deteriorating RCC infrastructure.

Desai, P., & Kulkarni, S. presented a comprehensive review of corrosion monitoring methods for RCC structures, emphasizing the relevance of electrochemical methods. Among all the approaches discussed resistivity mapping, chloride profiling, and linear polarization—the half-cell potential test stood out for its simplicity, cost efficiency, and

adaptability to field conditions. The paper presented case studies of bridge decks and water tanks where half-cell readings helped pinpoint high risk zones without damaging the concrete surface. They advocated for hybrid testing protocols combining half-cell potential and surface resistivity for a more accurate prediction model, especially in structures over 20 years old.

**Ravichandran, M., & Thomas, A.** evaluated the performance of corrosion detection techniques under marine exposure conditions, including half-cell potential, chloride ion diffusion, and Tazel extrapolation. Testing was performed on RCC columns exposed to tidal splashes over a span of 18 months. Half-cell potential values were recorded by monthly, and the study found clear patterns correlating high chloride penetration with potentials beyond 350 mV. The authors concluded that for marine infrastructure, half-cell potential testing could act as a frontline inspection method to detect early corrosion onset before structural distress becomes visible.

**Nair, R., & Bhandari, D.** addressed the challenge of detecting corrosion at very early stages, typically within days of concrete setting. Their research focused on using half-cell potential testing after just 7, 14, and 21 days of curing. Even with minimal curing, the test could detect variations in steel condition—especially when bars were intentionally pre rusted. The study also tested the sensitivity of readings to concrete moisture content and bar depth. Results showed a clear correlation between inadequate curing and lower (more negative) potentials. They concluded that half-cell testing could be an effective tool for on site quality control in fast-paced construction projects.

### Summary

The studies collectively highlight the effectiveness of **half-cell potential (HCP) testing** as a reliable, cost-effective, and adaptable method for detecting corrosion in RCC structures. Kumar and Singh validated its use in real-time conditions for repair prioritization, while Desai and Kulkarni emphasized its simplicity and recommended combining it with surface resistivity for better accuracy. Ravichandran and Thomas confirmed its usefulness in early corrosion detection under marine exposure. Nair and Bhandari demonstrated its potential for early-stage quality control during the initial curing phase in construction.

### Research Gap

Despite widespread support for half-cell potential testing across varied conditions and exposure scenarios, the following gaps remain. While hybrid methods (e.g., combining HCP with resistivity or chloride profiling) are recommended, no standardized or widely validated protocol exists. Most studies provide qualitative or semi-quantitative assessments. There's a need for robust quantitative models that link potential values with actual corrosion rates or structural damage severity. Nair & Bhandari explored early-stage detection, while others focus on aging structures. There's limited research on the longitudinal evolution of HCP values from early curing to advanced aging in the same structure. Marine, submerged, and urban environments affect results differently. A comparative multi-environment study using uniform methodology is lacking. Most HCP studies are manually conducted. There is a gap in exploring automated or continuous monitoring systems for HCP data collection

### Objectives

The major objectives that this project intends to accomplish are outlined as follows:

- To develop a clear understanding of the corrosion mechanisms affecting reinforcement bars embedded in RCC structures.
- To study and critically analyse various factors leading to corrosion initiation such as chloride ingress, carbonation, environmental exposure, and inadequate concrete cover.
- To explore and evaluate different corrosion prevention and control techniques, including material selection, protective coatings, corrosion inhibitors, and electrochemical methods like cathodic protection.
- To design and implement an experimental program by casting RCC cubes with reinforcement bars and subjecting them to half-cell potential testing for corrosion assessment.
- To interpret experimental results based on ASTM C876 guidelines and correlate findings with theoretical knowledge and environmental exposure conditions.
- To suggest practical recommendations for corrosion monitoring, maintenance, and repair in existing RCC structures.

- To promote sustainable construction practices by emphasizing early detection, preventive maintenance, and effective rehabilitation of corrosion affected structures.
- By achieving these aims, the project aspires to contribute to improving the durability and service life of RCC structures, ensuring their performance and safety over the long term.

### III. METHODOLOGY

The entire project was carried out in a systematic and phased manner to ensure accuracy and alignment with the testing standard (ASTM C876). From mix design to final result interpretation, each stage was planned and executed under academic and lab supervision.

The stepwise flow below outlines the process:

1. Collection of required materials including OPC 53 cement, fine and coarse aggregates, and 12 mm diameter reinforcement bars.
2. Preparation of M20 grade concrete mix using a nominal mix ratio of 1:1.5:3.
3. Casting of 9 RCC cubes in 3 separate batches to meet the targeted curing durations of 7, 21, and 28 days along with corroded and normal bars.
4. Initial setting for 24 hours inside moulds, followed by curing in water tanks.
5. Transportation of cured cubes to the lab on the common testing date
6. Preparation of  $\text{CuSO}_4$  solution and setup of copper sulphate electrode with sponge tip.
7. Connection of digital multimeter to reinforcement and electrode, and collection of potential readings from each cube.
8. Tabulation of results and interpretation using ASTM C876 corrosion probability chart.

#### 3.1 Testing Strategy

The test setup was designed to observe how curing duration and surface condition of reinforcement bars affected the corrosion activity within the concrete cubes.

- Total Cubes Tested: 9
- Reinforcement Type: 12 mm diameter bars, 30 cm long • Embedment: 15 cm inside the cube; 15 cm expose.
- Curing Periods:

- 1) 7 days curing (Batch 1) casted on 30/04/2025
- 2) 21 days curing (Batch 2) casted on 16/04/2025
- 3) 28 days curing (Batch 3) casted on 09/04/2025

- Testing Date: 06/05/2025
- Reference Electrode:  $\text{Cu}/\text{CuSO}_4$
- Measurement Device: MECO 9A06 Digital Multimeter
- Measurement Point: Top surface of cube, directly above embedded reinforcement
- Number of Readings per Cube: 1
- Moisture Condition: Surface wetted with  $\text{CuSO}_4$  solution prior to reading

Each reading was recorded after stabilization and reflects the half-cell potential in millivolts (mV).



Fig.3.1. Manufacturing of concrete (1)



Fig.3.2. Manufacturing of Concrete (2)



Fig.3.3. Testing Equipment Setup



Fig. 3.4 Acrylic Cylinder with sponge



Fig. 3.5 Copper Sulphate Powder

#### IV. EXPERIMENTAL INVESTIGATION

Half-cell potential testing was performed on nine reinforced concrete cube specimens, cured for 7, 21, and days, respectively. The measured potentials ranged from  $-44.0$  mV to  $-48.8$  mV, indicating a low probability of corrosion in all specimens, as per ASTM C876 guidelines.

Even the cubes with visibly corroded reinforcement (7-day curing batch) exhibited safe potential values, suggesting that the alkaline concrete environment provided sufficient initial passivation. The 21-day and 28-day cured specimens showed slightly more stable readings, highlighting the beneficial effect of extended curing on corrosion resistance.

Overall, the results validate the effectiveness of the half-cell potential method in early corrosion assessment and demonstrate that proper curing significantly enhances the protective qualities of concrete.

Table.4.1. HCPT Test Result

| Cube ID              | Curing Period | Half Cell Potential (mV) |
|----------------------|---------------|--------------------------|
| Cube 1               | 7 Days        | 44.0                     |
| Cube 2<br>(corroded) | 7 Days        | 48.7                     |
| Cube 3               | 7 Days        | 47.8                     |
| Cube 4<br>(corroded) | 21 Days       | 48.6                     |
| Cube 5               | 21 Days       | 48.8                     |
| Cube 6               | 21 Days       | 48.7                     |
| Cube 7               | 28 Days       | 48.7                     |
| Cube 8<br>(corroded) | 28 Days       | 48.8                     |
| Cube 9               | 28 Days       | 48.8                     |

## V. RESULTS AND DISCUSSION

Half-cell potential measurements on nine RCC cube specimens, conducted per **ASTM C876**, yielded values all more positive than  $-200$  mV, indicating a  $\leq 10\%$  likelihood of active corrosion. Notably, even the 7-day cured cubes—cast with visibly corroded bars—showed potentials between  $+44$  mV and  $-48.7$  mV, demonstrating that the fresh high-alkalinity concrete effectively passivated the reinforcement. Extended curing (21 and 28 days) produced even narrower and slightly more negative values (around  $-48.6$  to  $-48.8$  mV), reflecting the beneficial impact of prolonged hydration in reducing concrete permeability and limiting oxygen/moisture ingress. The tight potential range ( $-44.0$  to  $-48.8$  mV) across all specimens highlights uniform cover depth, quality casting, and consistent bar placement. Importantly, early-stage bar surface rust did not lead to active corrosion, underscoring that **environmental protection via quality concrete and curing** plays a more decisive role in early corrosion mitigation than the initial condition of the steel. These results validate the effectiveness of non-invasive half-cell testing under ASTM C876 and reinforce its practical value for early diagnostics—particularly in infrastructure exposed to moisture where hidden reinforcement corrosion is a concern.

Table 5.1. Corrosion Risk Classification (As per ASTM C876)

| Potential Value (mV) | Interpretation                                  |
|----------------------|-------------------------------------------------|
| > 200 mV             | 10% or less probability of corrosion (Low Risk) |
| 200 mV to 350 mV     | Uncertain 50% chance of corrosion               |
| < 350 mV             | 90% probability of active corrosion (High Risk) |

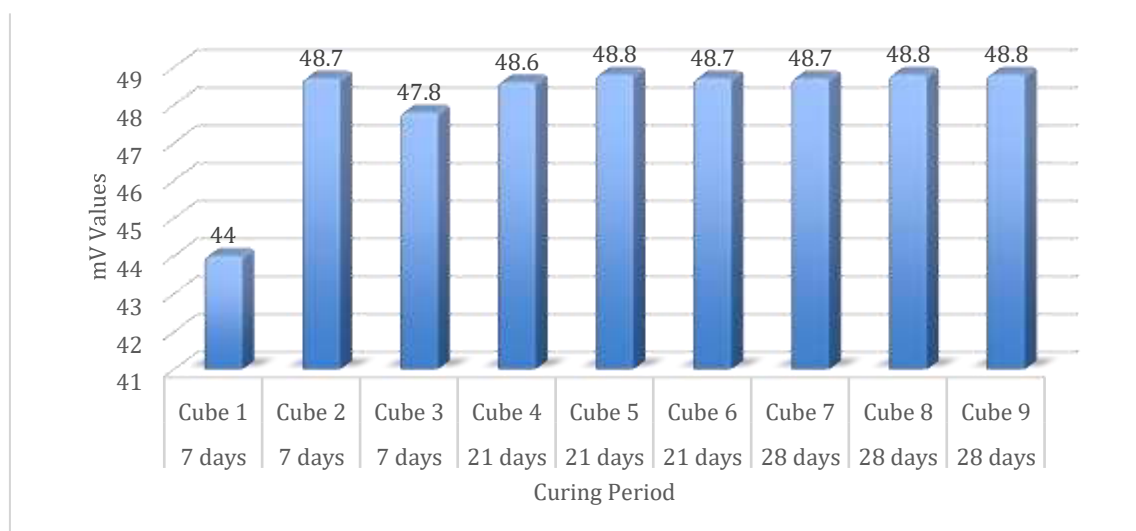


Fig.5.1. Graphical representation of Test Results

The bar graph above illustrates the half-cell potential values (in mV) recorded for each of the nine RCC cubes across different curing periods. It can be observed that all cubes, regardless of curing duration, recorded values greater than 200 mV, indicating a low probability of corrosion as per ASTM C876 standards. While the 7 days cured Cube 1 shows a slightly lower potential value (44 mV), the rest of the specimens consistently fall within a narrow range of 47.8 mV to 48.8 mV. This trend highlights the effectiveness of proper curing and concrete quality in maintaining the passivity of embedded reinforcement bars, even in cubes initially embedded with surface corroded steel

## VI. CONCLUSION

Our project aimed to explore the electrochemical assessment of corrosion activity in RCC specimens under controlled conditions. The study involved the casting of nine concrete cubes with embedded steel reinforcement bars, subjected to three different curing durations 7, 21, and 28 days. The specimens were tested using a Cu/CuSO<sub>4</sub> reference electrode, and the half-cell potentials were measured using a digital multimeter.

The results obtained from this experiment have been conclusive in demonstrating the effectiveness of curing, the influence of reinforcement condition, and the reliability of half-cell potential testing as a non-destructive method for corrosion detection.

### Summary of Key Findings

- All test results showed half-cell potentials greater than 200 mV, which, as per ASTM C876, indicates a 10% or lower probability of active corrosion.
- Even the cubes that used visibly corroded bars and were cured for only 7 days did not show high corrosion potential, reaffirming the protective role played by concrete cover and cement matrix.
- The consistency in readings across 21 days and 28 days cured cubes validated the effectiveness of extended curing in reducing corrosion risk.
- The testing procedure was practical, low cost, and easily implementable in both academic and professional settings.

### Emphasis on Corrosion Detection

Corrosion of reinforcement steel is a silent but destructive process that compromises structural durability, safety, and economic viability. Traditional methods of corrosion detection often require damaging the concrete or relying on visual signs that appear only in advanced stages. In contrast, the half-cell potential test:

- Detects corrosion risk before physical damage becomes visible
- Helps plan preventive maintenance and targeted repairs
- Minimizes structural downtime and repair costs
- Is suitable for both lab scale studies and real-world field applications

### Visualizing Corrosion Risk

The experiment allowed the visualization of corrosion risk levels through:

- Tabulated readings that classified each cube's corrosion probability
- A bar graph illustrating how all values remained in the low-risk zone
- Interpretation based on ASTM guidelines, simplifying decision making for field application

The visual results confirmed that the risk of corrosion was minimal across all specimens, highlighting how quality concrete, proper reinforcement placement, and effective curing together act as the first line of defence against reinforcement corrosion. The methodology proved to be practical, cost-effective, non-destructive, and suitable for both laboratory and field applications. Overall, the findings reinforce the value of quality material selection, proper curing, and standardized electrochemical testing for early corrosion detection—enabling targeted maintenance, minimizing structural damage, and optimizing repair strategies.

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