

Assessment of Corrosion Risk of Reinforcement in Drainage Gallery of Power Station Using Half-Cell Potential Meter

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ABSTRACT

Half-cell potential measurements are quick, low-cost, and virtually non-destructive techniques to assess the corrosion risk of steel reinforcement in concrete. This study presents a practical application of CORMAP II half-cell potential measurements on existing reinforced concrete (RCC) blocks of the drainage gallery of the power station. The blocks show no signs of deterioration on the concrete surface.

Temperature, reference electrode type, and pre-wetting period are some variables that affect the measured values of the half-cell potential. On the equipotential contour map, however, the negative potential area is related to localized corrosion. The numerical criteria disagree with the corrosion condition of steels. Therefore, even if there are no visible indicators of corrosion-related deterioration on the concrete surface, the equipotential contour map is a more reliable technique for detecting localized corrosion than the numerical criterion.

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I. Introduction

For concrete constructions, steel corrosion in concrete is a common thing. Rusting, cracking, and spalling are frequently apparent signs of deterioration on the surface of the concrete as steel corrodes. However, if these signs of corrosion appear, it might be too late to make repairs to stop further degradation. These results suggest that repairs should start even before corrosion of the concrete surface is apparent. Additionally, regularly checking the risk of steel corrosion in concrete is vital.

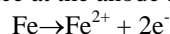
Measuring half-cell potential is a rapid, inexpensive, and generally non-destructive method for evaluating the corrosion risk of steel in concrete. Examining existing concrete structures can predict steel corrosion risk even without apparent concrete corrosion symptoms.

There are various half-cell potential measurement standards available from different organizations. The numerical specifications recommended by ASTM C 876 and IS 516 (Part 5/Sec 2) for assessing the corrosion risk of steels using a half-cell potential survey. RILEM TC 153-EMC advises using numerical criteria and focusing on the gradient or difference of the potential rather than the observed potential. This paper demonstrates the use of half-cell potential measurements in an existing drainage gallery of power station. Based on these findings, the interpretation of half-cell potential measurements and their use for assessing the corrosion risk of steels are discussed.

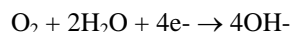
II. Principles of concrete steel corrosion:

Corrosion is an electrochemical process consists of two reactions, one producing electrons (anode process) and the other consuming electrons (cathode process). Anode and cathode, respectively, are the names of the corresponding regions on the metal. Both the anode and cathode processes occur at different potentials that are primarily influenced by the constituent materials and the concentration of the species (Fe²⁺, OH⁻, O₂, Cl⁻). The corrosion process involves an anode, cathode, electrolytic connection (ionic current), and Metallic connection (electronic current).

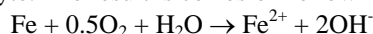
An oxidation (production of electrons) takes place at the anode and iron (steel) dissolves:



A reduction (consumption of electrons) takes place at the cathode, which is the driving force in the corrosion process. The cathodic process is usually a reduction of oxygen according to the reaction:



This cathodic reaction implies that corrosion depends on oxygen and water availability. Then a galvanic cell is formed, in which electrons pass through the reinforcement from anodic to cathodic sites and the electrical charge is passed as ions in the electrolyte. The result is corrosion following the overall reaction:



Corrosion of reinforcing steel follows the same principles and occurs with the same reactions as other corrosion processes. The electrolyte is the only particular factor in reinforcing steel corrosion. While the electrolyte in a “normal” corrosion process is water or salt solutions in water the electrolyte in the corrosion of reinforcing steel is the porous concrete, particularly the interconnected pore liquid system. The electrical resistivity of the concrete is much higher than in aqueous solutions. Consequently, resistivity is considered a controlling factor for the corrosion rate. The concrete resistance may also express the ease of chloride penetration into the concrete.

The most critical parameters to the onset and development of steel corrosion in concrete are permeability of the concrete, electrical resistance, humidity level, oxygen availability, chloride content, depth of carbonation, and temperature. The temperature has a general accelerating effect on all degradation processes. The concrete density primarily affects the initiation phase, mostly associated with chloride ingress and indirectly with resistivity. Of these parameters, the humidity level is by far the most critical parameter.

The humidity in the concrete affects all of the essential factors for corrosion, such as carbonation, chloride penetration, critical chloride content, oxygen supply, and electrical resistance of the concrete. Concrete humidity governs both the initiation of corrosion and the propagation of corrosion. In some instances, the carbonation depth may be considered a measure of the humidity front, and chloride penetration is very much dependent on the humidity, perhaps most of all the capillary movement of water.

III. Experimental Methodology

Step 1: Preparation of a new reference electrode: After loosening the top cap, 1/3 of the new electrode should be filled with Cu/CuSO₄ crystals. Now add antifreeze solution and distilled water, and tighten the top cap. Make sure that there are some undissolved copper sulphate crystals in the tube by shaking the electrodes for a few minutes. If not, you should reopen the top cap of the electrode and add more crystals. It is advised to wait until the electrode is ready to use before removing the plastic protective cap from the porous plug assembly on the bottom of the electrode. One day before the scheduled testing, prepare the Cu/CuSO₄ solution. This will allow the copper sulphate solution to saturate the ceramic porous plug thoroughly.

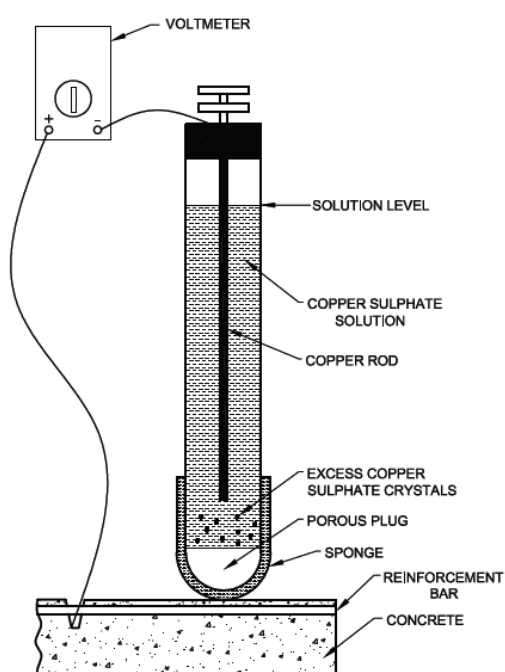


Figure 1: Copper- Copper Sulphate Half- Cell

Step 2: Sponge with a wet bottom: Unscrew the bottom reservoir of the COR MAP II test probe and fill the container with about 3/4 of the electric contact solution.

Step 3: Use the power key on the logger unit to turn it on now. Press the same button again to turn it off.

Step 4: Set up a new map: Users can evaluate or set up a new map using the James instrument COR MAP II. Once the device is turned on, a menu screen with different options will appear. Highlight "INSTALL A NEW MAP" using the up and down arrow keys, as indicated in the Figure 2.

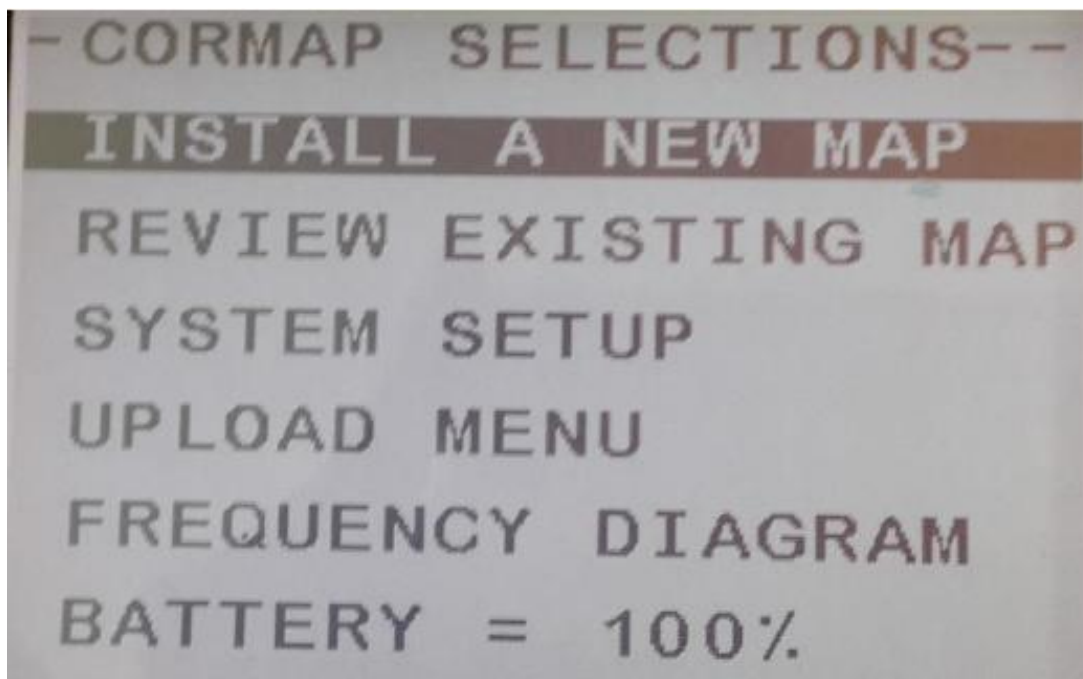


Figure 2: Set up a new map

When you hit enter, a new map menu sub screen will show up. The up and down arrow keys are used to select the desired values. You can select a minimum and maximum value for each column.

- New Columns = minimum 20 and maximum 4740
- New Rows: minimum 10, maximum 1180
- New Frames: maximum 250

Step 5: Attach the Cu/CuSO₄ probe to the 6-pin connector data logger. Connect the exposed rebar, reel, and ground connector on the COR MAP II, as illustrated in the Figure 3, using the supply reel and an alligator clip.



Figure 3: Half Cell Potential Test Equipment for Corrosion Assessment

Step6: As in the image above, use a Cu/CuSO₄ probe to take readings. The voltage will be shown by the data logger device and converted into the seven letter categories in the table below. The display pointer can be moved to the following grid point on the data logger by using the arrow keys. Enter the value into the COR MAP II data logging device by pressing the enter key. The internal high impedance voltmeter readings from the COR MAP II have been organized into 7 categories. The comprehensive examination of voltages is permitted for these 7 groups. From A to G, different categories make up the categories. Corrosion risk is greatest for category A. the voltages for each category are listed below in

Table 1: Criteria for corrosion of reinforced concrete (Reference electrode (Volts) Cu/CuSO₄)

IS 516 Part 5 Section 2 Criteria (Volts)	ASTM C 876 Criteria (Volts)	COR MAP Criteria (Volts)	Probability of corrosion of reinforcement
-0.000 to -0.200	-0.000 to -0.200	G = -0.000 F = -0.070 E = -0.140	Low (90% chance that no corrosion activity is present over this area)
-0.200 to -0.350	-0.200 to -0.350	D = -0.210 C = -0.280	Corrosion activity over this area is uncertain
-0.350 to -0.500	-0.350 to -0.500	B = -0.350 A = -0.420	High (90% chance that corrosion is occurring in this area)
More than -0.500	-	-	Severe corrosion

IV. Results and Discussion

Corrosion tests were conducted in Block No. 1, 2, 3, 4, 5, 6, 7 & 8 in the drainage gallery of the power station by using Half Cell Potential meter at 25 test points (5 rows & 5 columns) in each block. The equipotential mapping of each block is present in Figures 1 to 8. The potential of eight blocks is mainly falling in the range of no corrosion to uncertain as per IS 516 Part 5 Section 2 and ASTM C 876. Out of the eight blocks, block-5 falls into a minimum of 16% of test location falling under uncertain and a maximum of 96% at block-8. Block-5 falls into a minimum of 16% of test locations falling under uncertain and a maximum of 96% at block-8. The details of potential falling in the criteria as per IS 516 Part 5 Section 2 and ASTM C 876 of each block are presented in Figure 9.

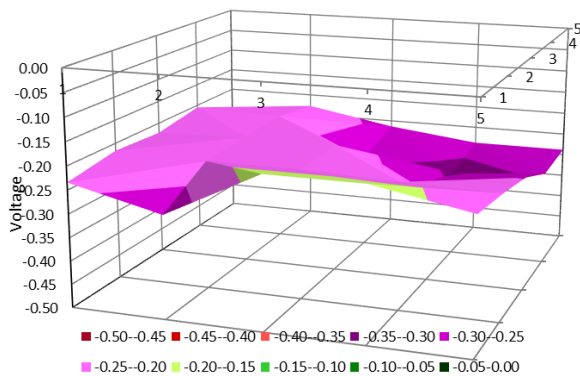


Figure 1: Drainage Gallery, Block 1

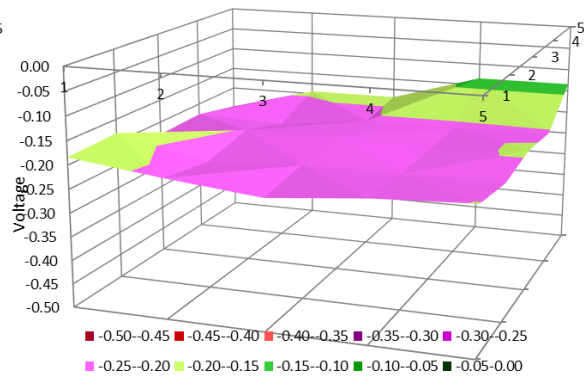


Figure 2: Drainage Gallery, Block 2

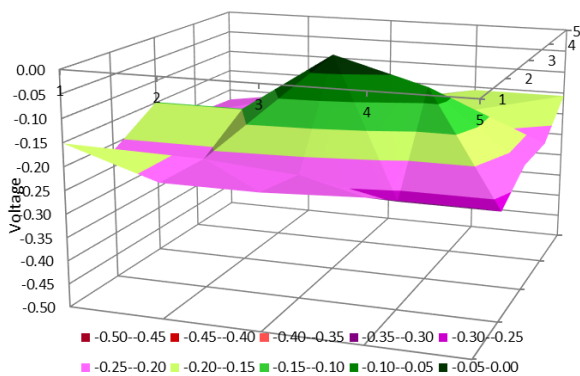


Figure 3: Drainage Gallery, Block 3

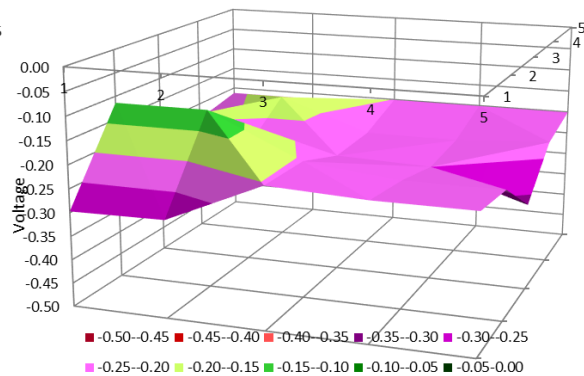


Figure 4: Drainage Gallery, Block 4

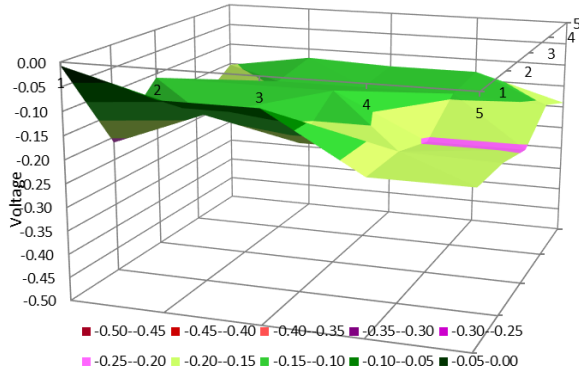


Figure 5: Drainage Gallery, Block 5

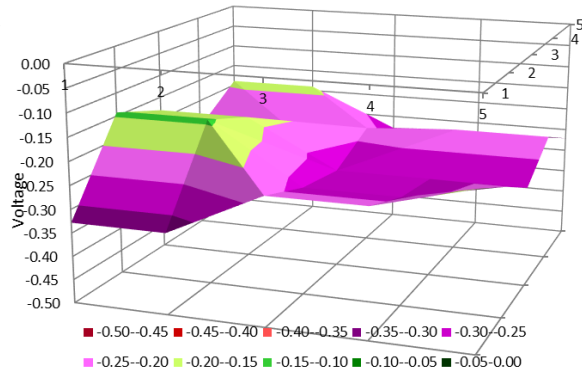


Figure 6: Drainage Gallery, Block 6

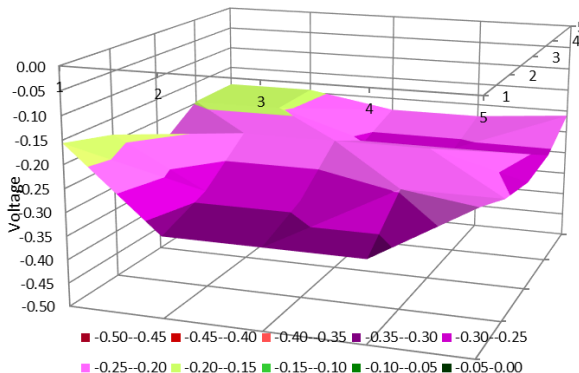


Figure 7: Drainage Gallery, Block 7

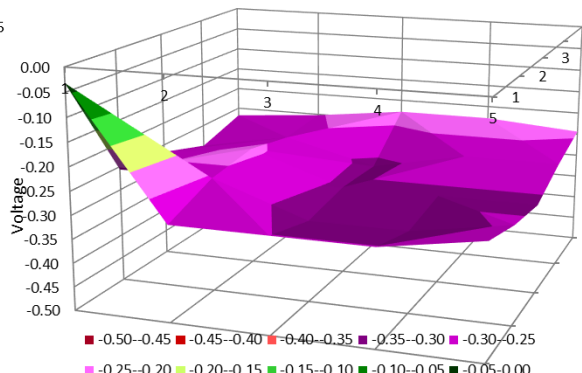


Figure 8: Drainage Gallery, Block 8

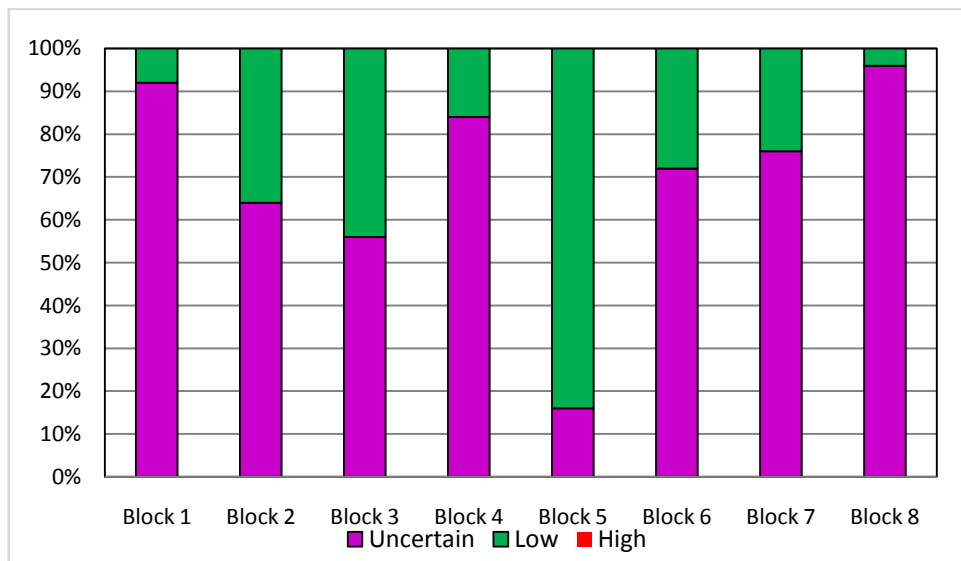


Figure 9: Block wise Test Results

V. Conclusion

Based on the present field investigation, the following conclusions can be drawn regarding the application of half-cell potential measurement to assess the corrosion risk of the existing RCC drainage gallery:

- The areas of localized corrosion correspond to the area with the highest negative potential on the equipotential contour map. If there are no symptoms of corrosion on the concrete surface, the potential gradient is a helpful indicator for choosing the location for more destructive tests.
- The temperature and pre-wetting are only a few aspects that may lead to differences in the measured values of the half-cell potential. However, the potential gradient follows the same pattern on the entire structure.

- The numerical criteria for assessing the corrosion risk of existing concrete structures are not particularly suitable. The equipotential contour map is a more reliable method for locating localized corrosion and selecting the location for additional destructive tests.

Acknowledgments

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