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DEVELOPMENT OF HALFCELL POTENTIOMETER FOR MEASURING CORROSION

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ABSTRACT
Traditional corrosion measurement techniques often lack the required precision and sensitivity for real-time monitoring, hindering effective preventive measures. The newly developed half-cell potentiometer addresses these limitations by incorporating effective electrochemical principles and technology [1]. The device enables precise potential difference measurements between a reference electrode and a corroding metal surface, yielding valuable insights into corrosion rates and mechanisms.
Innovation in corrosion measurement is critical for industries such as infrastructure, energy, and manufacturing, where the detrimental effects of corrosion lead to substantial economic losses and safety concerns. The newly developed half-cell potentiometer bridges the gap between traditional measurement techniques and contemporary demands for precision and efficiency [2]. By enabling timely and accurate corrosion monitoring, this advancement promises to revolutionize corrosion control strategies and contribute to the longevity and sustainability of various systems and structures [3].
KEY WORDS: Half-cell potentiometer, Corrosion measurement, Electrochemical process, Corrosion monitoring techniques, Precision, sustainability

1. Introduction

The half-cell potentiometer is a laboratory instrument used for measuring electrode potentials. It was first developed in the late 19th century by the German chemist Walther Nernst.
The potential difference between the two electrodes causes a current to flow through the circuit, which can be measured by the galvanometer. By adjusting the resistance of the calibrated resistor, Nernst was able to balance the current in the circuit to zero, and the potential difference between the two electrodes could be read off the calibrated resistor.
The half-cell potentiometer quickly became an essential tool for electrochemists, allowing them to measure electrode potentials accurately and with great precision. It was particularly useful in the study of redox reactions and has been instrumental in the development of modern electrochemistry.
Measurements of the half-cell potential can be carried out on buildings with either standard or stainless-steel reinforcement. A similar methodology may be utilized to evaluate corrosion of reinforcing steel in concrete. It is not possible to evaluate the presence of pre-stressing steel in the ducts of post tensioned cables.
Plastic ducts separate the strands from the concrete surface, whereas metallic ducts hide the strands from the concrete surface. Epoxy coated steel is not considered for treatment in this advice due to the fact that EP coated bars are often electrically insulated from one another and so cannot be assessed the same method may be used to measure galvanized steel, however different criteria will be utilized.
The use of half-cell potential measurements is recommended primarily for reinforced concrete constructions that are open to the environment No matter the depth of the concrete cover or the size

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or details of the rebar, the procedure (measuring and interpreting) may be used to evaluate the structure.
Measurements of the half-cell potential will reveal corroded rebar not just in the most superficial layers of reinforcement that are next to the reference electrode, but also farther into the structure over the lifetime of construction as well as in any sort of environment The measurements of the half-cell potential should only be performed on a free concrete surface The existence of isolating layers, such as asphalt, organic coatings or paints, etc., may cause the results to be inaccurate or even impossible to perform

2.MATERIALS AND METHODOLOGY

2.1 MATERIALS USED

A copper-copper sulphate half-cell consists of a rigid tube or container made of a dielectric material that does not react with copper or copper sulphate, a porous wooden or plastic plug that keeps it moist by capillary action, and a copper rod. It has been constructed. Tube in a saturated solution of copper sulphate. Solutions should be prepared using reagent grade copper sulphate crystals dissolved in distilled or deionized water. A solution is considered saturated when there are excess (undissolved) crystals at the bottom of the solution. Rigid pipes or containers must have an inside diameter of at least 1 inch (25 mm). The porous plug diameter must be 1/2 inch (13 mm) or larger. The diameter of the immersion copper rod should not be greater than 1/4 inch. (6 mm), not less than 2 inches (50 mm) in length. A current standard based on the $Cu \rightarrow Cu^{++} + 2e$ half-cell reaction indicates that the potential of a saturated copper-copper sulphate half-cell relative to the hydrogen electrode is -0.316 V at 72 °F (22.2 °C) The materials used in a half-cell potentiometer play a crucial role in ensuring accurate and reliable corrosion measurements. These materials are selected based on their compatibility with the electrochemical processes involved in corrosion and their ability to provide stable and consistent measurement conditions.

- Mini LCD digital thermometer

A thermometer is an instrument used to measure temperature. It works by measuring changes in the physical properties of a material, such as expansion or contraction, as the temperature changes.

- Palm size voltmeter

A voltmeter is an instrument used to measure electrical potential difference between two points in an electrical circuit. It is an essential tool for electricians, engineers, and scientists, and is widely used in a variety of applications, from testing batteries and power supplies to troubleshooting electrical faults. Voltmeters can be either analog or digital, and can measure voltage in a variety of units, including volts, millivolts, and microvolts.

An analog voltmeter works by using a needle to indicate the voltage level on a scale, like a speedometer in a car. The voltage being measured is applied to a set of coils, which produce a magnetic field that deflects the needle. The position of the needle corresponds to the voltage level and can be read directly from the scale. Digital voltmeters, on the other hand, use a microprocessor to convert the voltage level into a digital signal, which is then displayed on an LCD screen. Digital voltmeters are generally more accurate and easier to read than analog voltmeters and can also measure voltage in a wider range of units.

- Connectors

In a half-cell potentiometer, connectors are used to connect the reference electrode and working electrode to the potentiometer. The reference electrode is connected to the reference electrode terminal, while the working electrode is connected to the working electrode terminal. The connectors used in a half-cell potentiometer must be made of materials that are inert to the electrolyte solution, to prevent any interference with the electrode potential. Common materials used for connectors in half-cell potentiometers include platinum, gold, silver, and graphite. Proper selection and use of connectors are crucial to ensure accurate and reliable measurements in half-cell potentiometer.

- 5mm thick craft board

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It is a simple box that we can use to store all the equipment's from being exposed to the environmental conditions and store all the equipment's.

- 0.5 Sq. single core copper wire

A 0.5 Sq. single core copper wire is a type of electrical wire that consists of a single copper conductor with a cross-sectional area of 0.5 square millimeters. It is commonly used in low voltage applications, such as household wiring, and is also used for wiring small electrical devices, such as lamps and radios.

This type of wire is highly flexible and easy to work with, making it a popular choice for both professional electricians and DIY enthusiasts. Its small size and lightweight also make it ideal for use in tight spaces or for applications where space is at a premium. The copper conductor offers excellent electrical conductivity and low resistance, allowing for efficient power transmission and reduced energy loss.

- Battery Clamp

Battery clamps, also known as jumper cables, are used to connect a discharged battery to a charged battery in order to jumpstart a component. These clamps have positive and negative terminals that are connected to the corresponding terminals of the batteries, allowing the charged battery to transfer power to the discharged battery.

- Copper Sulphate Crystal

Copper sulphate crystals are commonly used in potentiometers as an electrolyte to facilitate the flow of current between the reference electrode and the working electrode. The crystals dissolve in water to create a conductive solution that can be used to measure electrochemical potentials.

All the various parts of the potentiometer are shown in the figure 2.1

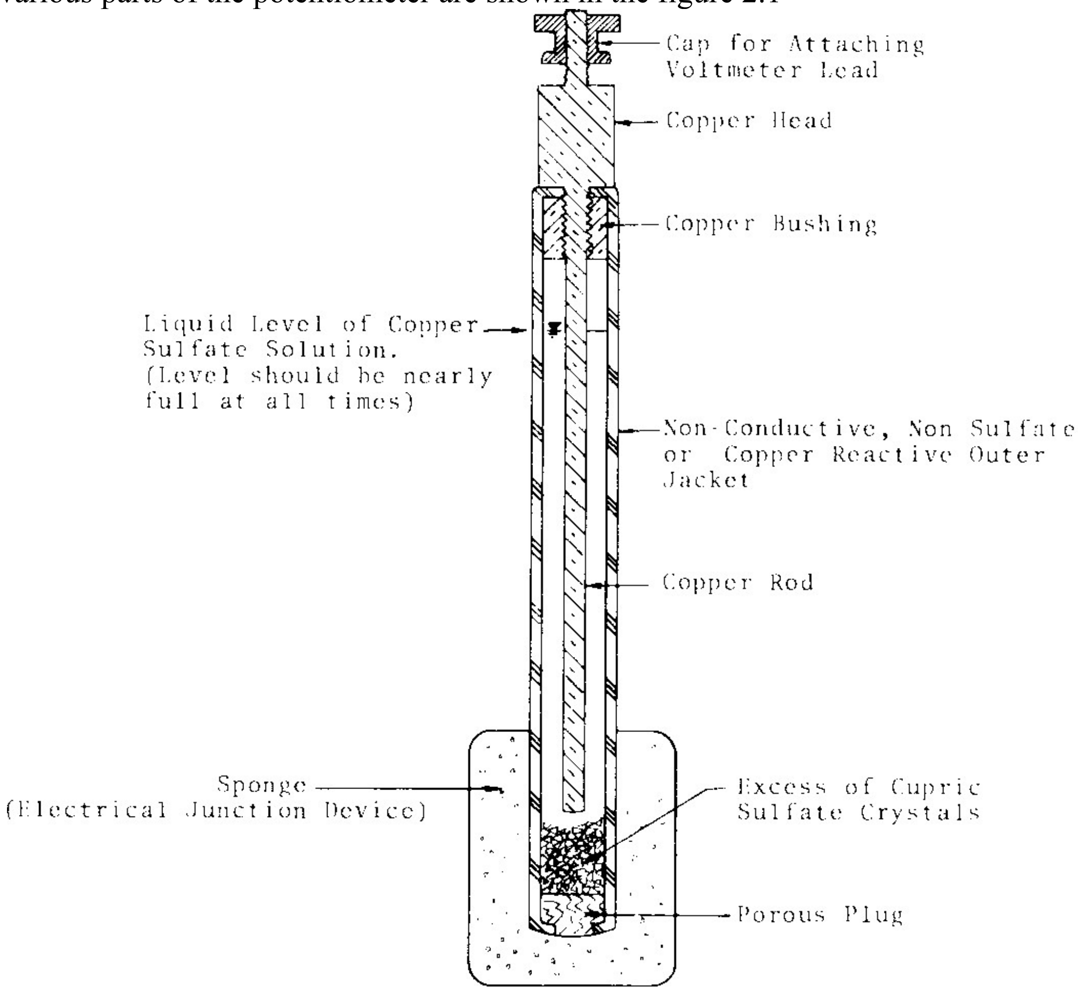

Figure 2.1 standard parts of half cell potentiometer

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2.2 METHODOLOGY

In reinforced concrete structures, there is a natural protective film that forms on the surface and prevents the bar from corroding. With time, chlorides (from de-icing salts or marine exposure) and/or CO2 penetrate the concrete and breakdown that protective layer. Chlorides destabilize the passive film leading to its localized breakdown, while CO2 lowers the pH of the concrete below the level of stability of the passive film. In the presence of oxygen and water, an electrochemical reaction initiates the process of corrosion.

Corrosion can be illustrated as shown in Figure 1, where the metal (rebar) reacts in the solution (available in the concrete pores) and gives away electrons from the anode (where oxidization occurs) to the cathode (where reduction occurs). The positive ions formed at the surface of the anode will react and create corrosion by-products. This electrochemical reaction creates a potential difference, and consequently a corrosion current, between the anodic and cathodic areas at the surface of the steel reinforcement. This current, or the potential distribution on the reinforcement surface, is what is of interest when measuring half-cell potential.

The test provides valuable information on the likelihood of corrosion and helps in the quality assurance of concrete repair and rehabilitation. Several standard associations have standardized the test procedure including ASTM C 876, UNI 10174 and RILEM TC 154. Depending on the measured half-cell corrosion potential value, the probability of active corrosion is determined using the Table 2.2

Table 2.2 Half-cell determination

Half-Cell Potential Measurement (mV, CSE)	Likelihood of active corrosion (%)
if the reading is less then- 200	There is a greater than 90 % probability that no reinforcing steel corrosion is occurring in that area at the time of measurement
-200 to -350	uncertain
If the reading is greater than -350	, There is a greater than 90 % probability that reinforcing steel corrosion is occurring in that area at the time of measurement.
Electrode used	CSE: Copper Sulphate Reference

When the half-cell potential measurement is less than -350 mV (CSE electrode), then the chance of having active corrosion is more than 90%. When the measured value is more positive than -200 mV, the chance of active corrosion is less than 10%. For potential values between -200 mV and -350 mV, there is uncertainty in interpreting the test results.

3.RESULTS AND DISCUSSION

In this chapter a brief outlook into the tests that were conducted using the developed half-cell potentiometer are shown and table 3.1 gives us a systematic understanding of the condition of the reinforcement during the testing. The following results and conclusions are drawn based on the ASTM standards: Table.

Table 3.1: - describing the variation of readings of Standard device and Developed device.

Standard device						
Ground Floor						
Column Location	**Column Middle Out Side Column 01**					**average**
Half Cell	41	46	40	54	57	47.6

Developed device						
Ground Floor						
Column Location	**Column Middle Out Side Column 01**					**average**
Half Cell	51	56	50	46	44	49.4

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	<10 % Probability Corrosion					
Beam Location	**Internal Side**					
Half Cell	89	92	85	79	88	86.6
Slab Location	**Internal Side**					
Half Cell	75	77	82	86	71	78.2

	<10 % Probability Corrosion					
Beam Location	**Internal Side**					
Half Cell	72	85	92	71	105	85
Slab Location	**Internal Side**					
Half Cell	92	105	101	99	86	96.6

Ground Floor Column 02						
Column Location	**Column 02**					
Half Cell	38	49	48	43	52	46
Inference	<10 % Probability Corrosion					

Ground Floor Column 02						
Column Location	**Column 02**					
Half Cell	41	62	78	54	65	96.6
Inference	<10 % Probability Corrosion					

Ground floor						
Column Location	**Column 03**					
Half Cell	21	35	47	29	33	33
Inference	<10 % Probability Corrosion					

Ground floor						
Column Location	**Column 03**					
Half Cell	43	56	45	59	76	55.8
Inference	<10 % Probability Corrosion					

Ground Floor						
Column Location	**Column 04**					
Half Cell	41	45	50	31	22	37.8
Inference	<10 % Probability Corrosion					

Ground Floor						
Column Location	**Column 04**					
Half Cell	72	86	82	73	88	80.2
Inference	<10 % Probability Corrosion					

Ground Floor						
Column Location	**Column 05**					
Half Cell	58	67	28	14	53	44
Inference	<10 % Probability Corrosion					

Ground Floor						
Column Location	**Column 05**					
Half Cell	65	75	38	45	76	59.8
Inference	<10 % Probability Corrosion					

Ground Floor						
Column Location	**Column 06**					
Half Cell	53	13	36	61	38	40.2
Inference	<10 % Probability Corrosion					

Ground Floor						
Column Location	**Column 06**					
Half Cell	86	96	84	74	68	81.6
Inference	<10 % Probability Corrosion					

Ground Floor						
Column Location	**Column 07**					
Half Cell	54	42	53	28	53	36
Inference	<10 % Probability Corrosion					

Ground Floor						
Column Location	**Column 07**					
Half Cell	26	69	78	85	88	69.2
Inference	<10 % Probability Corrosion					

Ground Floor

Ground Floor

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Column Location	**Column 08**					
Half Cell	33	14	42	51	52	57
Inference	<10 % Probability Corrosion					

Column Location	**Column 08**					
Half Cell	55	65	78	75	62	67
Inference	<10 % Probability Corrosion					

Ground Floor						
Column Location	**Column 09**					
Half Cell	145	185	165	180	142	143
Inference	Upto 50% Probability Corrosion					

Ground Floor						
Column Location	**Column 09**					
Half Cell	162	192	177	162	179	174.4
Inference	Upto 50% Probability Corrosion					

Ground Floor						
Column Location	**Column 10**					
Half Cell	237	247	242	230	234	242
Inference	>50% Probability of Corrosion					

Ground Floor						
Column Location	**Column 10**					
Half Cell	242	256	268	289	298	270.6
Inference	>50% Probability of Corrosion					

Ground Floor						
Column Location	**Column 11**					
Half Cell	34	42	17	19	56	18
Inference	<10 % Probability Corrosion					

Ground Floor						
Column Location	**Column 11**					
Half Cell	46	78	85	84	64	71.4
Inference	<10 % Probability Corrosion					

Ground Floor						
Column Location	**Column 12**					
Half Cell	45	47	63	37	56	38
Inference	<10 % Probability Corrosion					

Ground Floor						
Column Location	**Column 12**					
Half Cell	56	85	75	85	64	73
Inference	<10 % Probability Corrosion					

First Floor						
Column Location	**Column 01**					
Half Cell	19	47	17	18	34	23
Inference	<10 % Probability Corrosion					

First Floor						
Column Location	**Column 01**					
Half Cell	31	54	17	18	34	30.8
Inference	<10 % Probability Corrosion					

First Floor						
Column Location	**Adjacent C2**					
Half Cell	56	37	48	19	17	18
Inference	<10 % Probability Corrosion					

First Floor						
Column Location	**Adjacent C2**					
Half Cell	56	37	48	19	17	39.5
Inference	<10 % Probability Corrosion					

First Floor

First Floor

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Column Location	Column 03					
Half Cell	58	28	18	12	16	19
Inference	<10 % Probability Corrosion					

Column Location	Column 03					
Half Cell	56	85	75	32	21	53.8
Inference	<10 % Probability Corrosion					

First Floor						
Column Location	Adjacent C4					
Half Cell	238	243	218	232	246	219
Inference	>50% Probability of Corrosion					

First Floor						
Column Location	Adjacent C4					
Half Cell	245	265	287	249	259	261
Inference	>50% Probability of Corrosion					

First Floor						
Column Location	Adjacent C5					
Half Cell	23	26	24	48	19	17
Inference	<10 % Probability Corrosion					

First Floor						
Column Location	Adjacent C5					
Half Cell	32	38	39	62	25	39.2
Inference	<10 % Probability Corrosion					

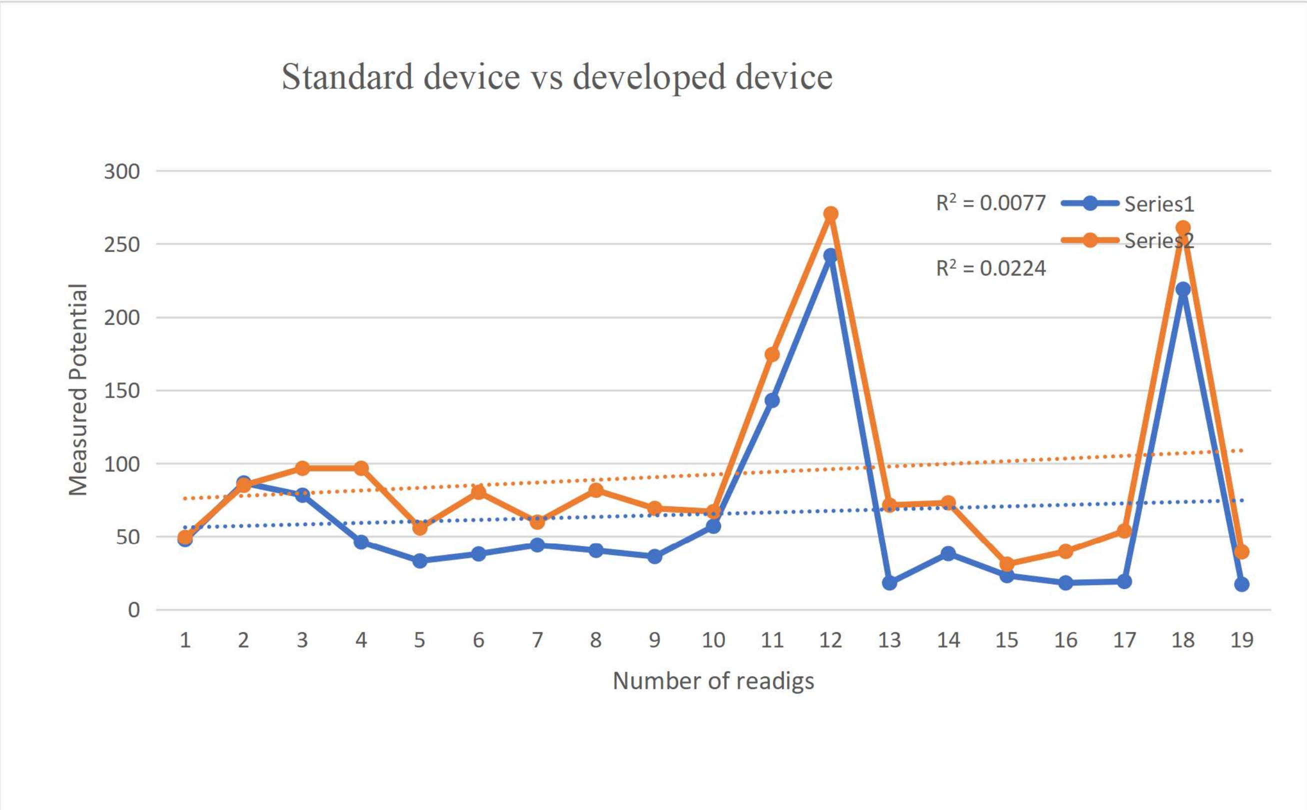

Figure 3.1 graph describing standard versus developed device.

Figure 3. Shows variation between standard and developed device as seen in the graph there is not much variation in the readings and also the R^2 equation shown in the graph.

CONCLUSIONS

During the project moisture sensors, temperature sensors, copper sulphate crystals, half-cell were used, and the following are the conclusions drawn.

1. The device is very economical due to the assembly and usage of locally available products.
2. The process of assembly when compared to the commercially available device is relatively easier.

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3. The accuracy is almost similar to the standard commercially available device.
4. The made in India initiative is also invoked as all the parts of the device are manufactured in India.

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