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Corrosion Monitoring Of Reinforcement in Underground Galleries of Hydro Electric Project

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ABSTRACT
The hydro projects in Himalayan region in India are constructed in head reaches of river basins. These projects envisage a concrete or masonry or rockfill or even an earthen dam. The underground inspection galleries and drainage gallery of these dams are constructed using concrete linings of different grades. Its durability is determined by various factors viz. aggressivity of surrounding water, temperatures fluctuations etc. The water in Himalayan Rivers is generally soft which is injurious to the useful life of concrete structures as it leads to leaching of lime. Leaching is a phenomenon that is caused by water migrating through the permeable concrete. The reduced alkalinity and permeated water causes corrosion of reinforcement leading to weakening of structure. Once such phenomenon is observed in any such structures a vigilant periodic monitoring approach becomes mandatory. The suitable remedial measure to be adopted will depend on the observed degree of deterioration. In this paper effort has been made to assess degree of corrosion of reinforcement in the gallery of one of the projects in Himalayan region using Half Cell Potentiometer which is a technique, used for assessment of the durability of reinforced concrete and helps in diagnosing reinforcement corrosion
Keywords **-** Corrosion, galleries, half cell potentiometer, reinforcement, rebar.

I. INTRODUCTION

Corrosion problems are very common in almost all aspects of technology resulting in cropping of variety of problems. Post construction corrosion damage in the reinforcement is an enormous economic liability. The underground inspection galleries and drainage gallery of dams are constructed using concrete linings of different grades. The water in Himalayan Rivers is generally soft which causes leaching of lime (Fig. 1, 2).

Figure 1 White Leachate Deposit in the Concrete gallery

Figure 2 White Leachate Deposit in the Concrete gallery

The continuous leaching of lime reduces the alkalinity of concrete [3] thus passivation of reinforcement is destroyed and permeated water leads to corrosion of reinforcement leading to weakening of structure. Diagnosis of the intensity of corrosion and its constant monitoring using Non Destructive Test (NDT) [1] will provide useful information for adopting suitable preventive measures. In this paper effort has been made to assess degree of corrosion of reinforcement in the gallery of one of the projects in Himalayan region using Half Cell Potentiometer.

II. Method Adopted

2.1 Half – Cell Electrical Potential Method to Measure Corrosion of Reinforcement in Concrete (ASTM C 876-91)

The Half Cell Potential Testing method is a technique, used for assessment of the durability of

reinforced concrete and helps in diagnosing reinforcement corrosion[1, 6]. The method of half cell potential measurements normally involves measuring the potential of an embedded reinforcing bar relative to a reference half cell placed on the concrete surface. The half cell is usually Copper/ Copper Sulphate or Silver/ Silver Chloride cell but other combinations are used. The concrete functions as an electrolyte and the risk of corrosion of reinforcement in immediate region of the test location may be related empirically to the measured potential difference. The typical layout of the equipment is shown fig. 3.

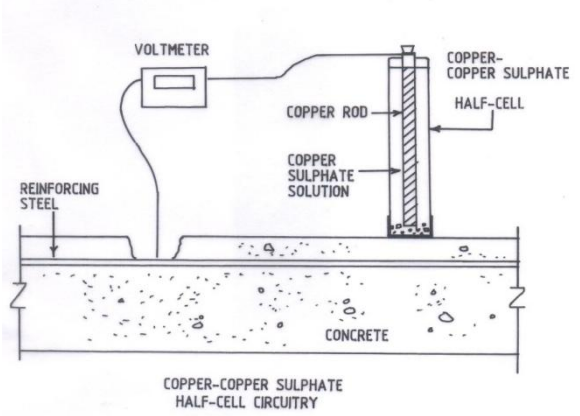


Figure 3 Copper- Copper Sulphate Half- Cell

The half cell consist a rigid tube composed of dielectric material that is non-reactive with copper or copper sulphate, a porous wooden or plastic plug that remains wet by capillary action, and a copper rod that is immersed within the tube in a saturated solution of copper sulphate. The solution is prepared using reagent grade copper sulphate dissolved to saturation in a distilled or deionized water. An electrical junction device is used to provide a low electrical resistance liquid bridge between the surface and the half cell, is normally a sponge. Electrical contact solution is made from normal house hold detergent. Measurements are made in either a grid or random pattern. The potential risks of corrosion based on potential difference readings [6] are presented in Table 1.

Table 1 The potential risks of corrosion based on potential difference readings

Potential difference (mv)	Chance of re-bar being corroded
less than -500mv	Visible evidence of Corrosion
-350 to -500 mv	95%
-200 to -350 mv	50%
More than -200 mv	5%

III. Equipment Used

Following equipments were deployed for the corrosion monitoring of reinforcement in concrete (Fig. 4)

- Micro cover meter- R Meter MKIII
- Half Cell Surveyor- CORMAP II

Micro Cover Meter

Half Cell Surveyor

Figure 4. Equipments Deployed for Investigation

The micro cover meter has been used to locate the rebar [4]**.** The concrete surface was examined for the exposed rebars/or got exposed to get a reference point. Surface was made wet and observation locations were marked on the surface [7]. The pre -activated Cu-$CuSO_4$ Half Cell was used to take observation.

The test results are categorized in 7 categories from A to G category in the typical map recorded on CORMAP II.

Table 2 Categories of Corrosion activity

A = - 0.420, B = - 0.350	A & B – 90% chance corrosion is occurring in this area
C = - 0.280 D = - 0.210	C & D – Corrosion activity over this area is uncertain
E = - 0.140 F = - 0.070 G= - 0.00	E –G – 90% chance that no corrosion activity is present over this area

IV. Location of Scanned area

The corrosion monitoring tests were carried out at 5 selected locations in the underground gallery Area where heavy leaching was observed were selected for scanning/mapping. The details of these locations is presented in Table 2.

Table 2 Locations for corrosion monitoring at Dam Foundation Gallery

Sl No.	Map No.	Location	Grid pattern (Column x Row)
1	1	L 1	12' x 6'
2	2	L 2	12' x 6'
3	3	L 3	12' x 6'
4	4	L 4	12' x 6'
5	5	L 5	12' x 6'

V. Observations

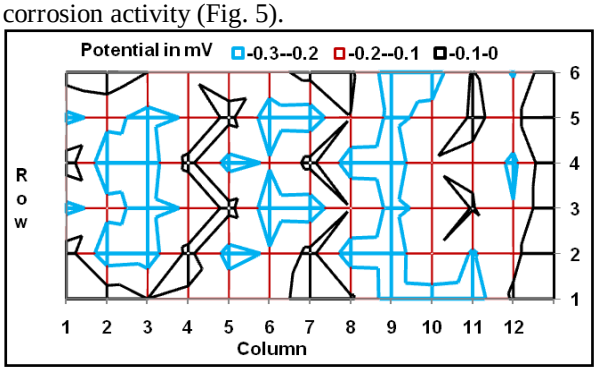
Micro cover meter/Rebar locator was employed to outline the scanning area. Scanning was conducted along the wall of drainage galleries by making a grid of 12 x 6 ft (column x row) pattern. Corrosion monitoring was done with the help of Half Cell Surveyor an equipment based on Electrochemical phenomena.

VI. Result and Discussion

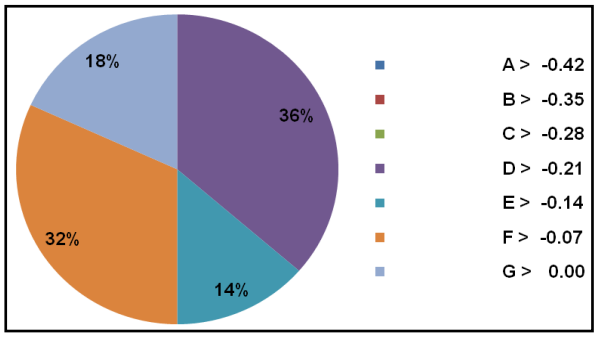
The results of the scanned locations are presented as contour Maps and Pie graphs (Fig. 5-9) which clearly illustrates degree of corrosion [2, 5].

6.1 Location L 1

36 % area falls under the **D** category indicating initiation of mild corrosion. Remaining area (64%) falls under E to G categories indicating no corrosion activity (Fig. 5).



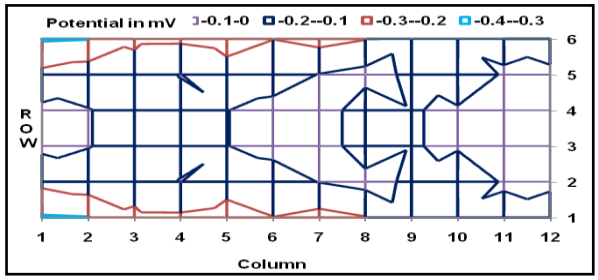
Contour Map



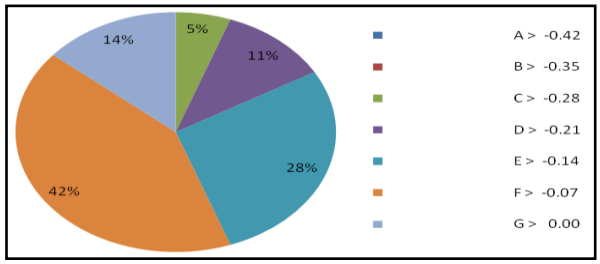
Pie Graph Showing Percent area under different Corrosion Categories

Figure 5 Corrosion Status of Location L 1

6.2 Location L 2



Contour Map



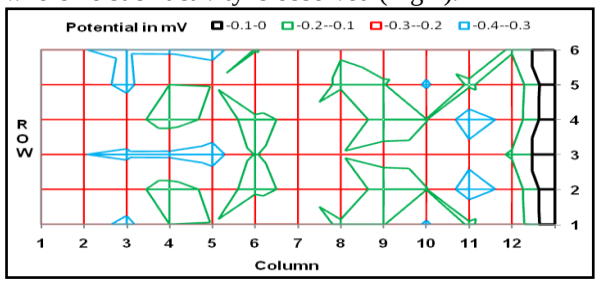
Pie Graph Showing Percent area under different Corrosion Categories

Figure 6 Corrosion Status of Location L 2

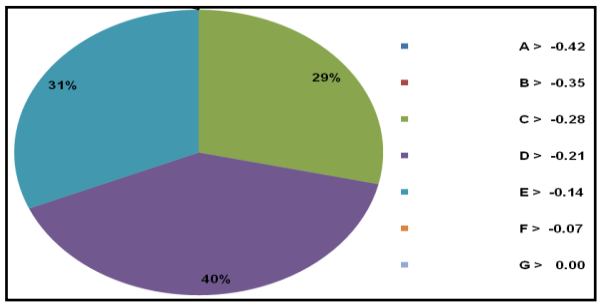
11% falls under D category showing mild corrosion activities. However, remaining area falls under E to G categories indicating no corrosion activity present in this area. As maximum area falls under category E to G it indicating no corrosion activity at present (Fig 6).

6.3 Location L 3

69 % of the area is under the C and D categories indicating initiation of mild corrosion activities while in rest of 31 % area is under category E where no such activity is observed (Fig 7).



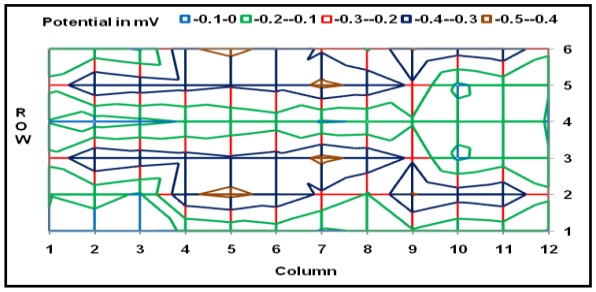
Contour Map



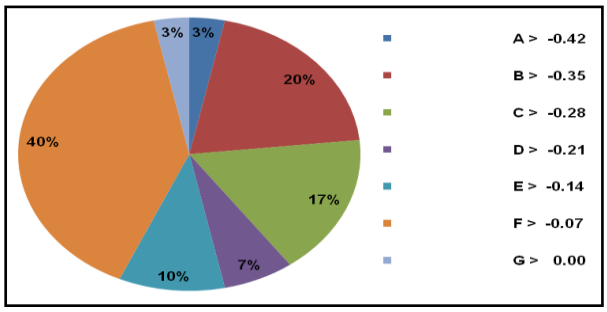
Pie Graph Showing Percent area under different Corrosion Categories

Figure 7 Corrosion Status of Location L 3

6.4 Location L 4



Contour Map

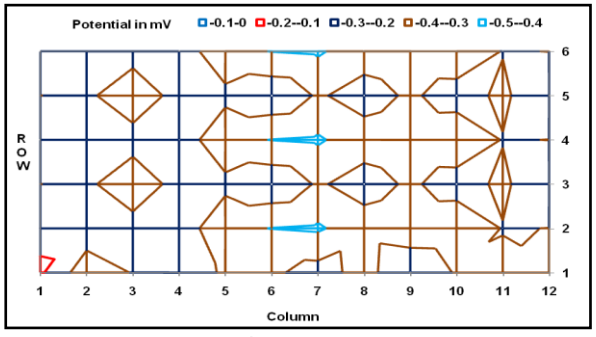


Pie Graph Showing Percent area underdifferent Corrosion Categories

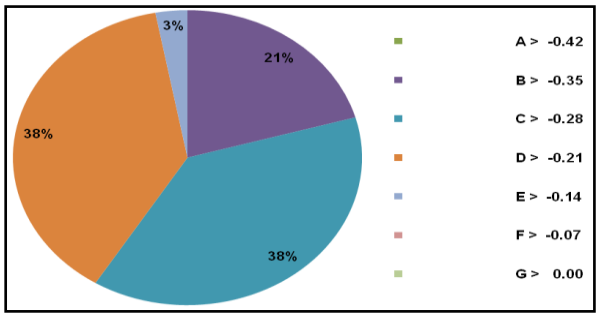
Figure 8 Corrosion Status of Location L 4

23% area is observed to be under the category A & B which indicate chances of corrosion of reinforcement24% area falls under C & D categories showing initiation of mild corrosion activities. Rest 53% area fall under E to G categories indicating no corrosion activity (Fig 8).

6.5 Location L 5



Contour Map



Pie Graph Showing Percent area under different Corrosion Categories

Figure 9 Corrosion Status of Location L 5

20% area is under the B category showing the chances of corrosion of reinforcement. 74% area fall under C & D categories showing initiation of mild corrosion activity. Only 3% area falls under E category indicating no corrosion activity (Fig 9).

VII. CONCLUSIONS

The Half Cell Potential Testing method is a technique, used for assessment of the durability of reinforced concrete and helps in diagnosing reinforcement corrosion. The detailed scanning of different areas by preparing a proper grid pattern indicated the corrosion process has already initiated at Location L 4 and L 5 while mild corrosion activity is observed at other three locations.

VIII. ACKNOWLEDGEMENT

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