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International
Journal
Of Modern Engineering Research (IJMER)

Health Monitoring of Reinforcement In Concrete Piers In A Barrage Project

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ABSTRACT: *Useful life of any barrage project depends on functional stability of the concrete piers. The piers are constructed using concrete of different grades. Its durability is dependent on various factors viz. speed of running water, its aggressively, temperatures fluctuations etc. The endurance capacity of these piers against these adverse conditions is goes on reducing with passage of time. Gradually permeability of concrete increases which causes corrosion of reinforcement thus weakening of concrete. Once such a 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 diagnose degree of corrosion of reinforcement in the piers of a barrage project using Half Cell Potentiometer.*

Keywords: *Corrosion, Half cell potentiometer, Piers, Rebar, Reinforcement.*

I. INTRODUCTION

Corrosion problems are very common in almost all aspects of technology resulting in cropping of variety of problems. Corrosion damage in the reinforcement is an enormous economic liability. In a barrage project piers are constructed using concrete of different grades. The permeated water causes corrosion of reinforcement leading to weakening of structure [1] and spalling of cover (Fig. 1.1).

Fig. 1.1 Exposed reinforcement in piers due to spalling of cover

Diagnosis of the intensity of corrosion and its constant monitoring will provide useful information for adopting suitable preventive measures [2]. In this paper effort has been made to diagnose degree of corrosion of reinforcement in the piers of a barrage project 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 [2, 3]. 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. 2.1.

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 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.

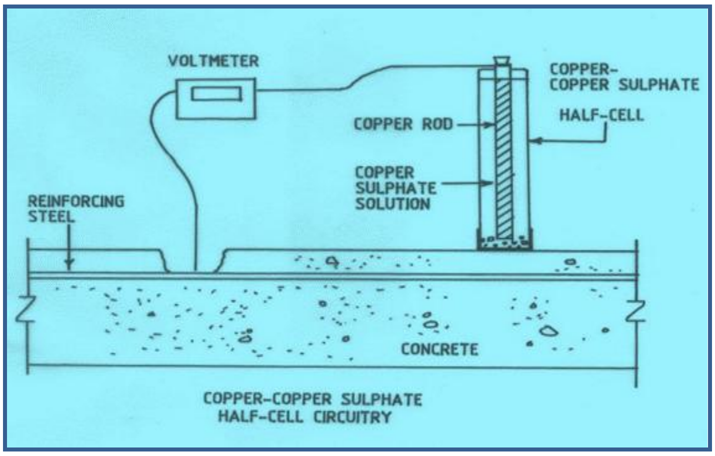

Fig 2.1 Copper- Copper Sulphate Half- Cell

Measurements are made in either a grid or random pattern. The potential risks of corrosion based on potential difference readings [3] are presented in Table I.

Table I: The potential risks of corrosion based on potential difference readings

Potential difference levels (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. 3.1)

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

Micro Cover Meter   Half Cell Surveyor

Fig 3.1. 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 [5]. 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, their interpretation is given in Table II.

Table II: 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. TEST LOCATIONS

Detailed location of different piers and grid patterns are given in Table III.

Table III: Details of locations for corrosion monitoring

Pier	Location	Grid pattern
1	D/S RHS FACE, 3.2m from gate.	10'x5' (column x row)
2	D/S RHS FACE, 2.5m inside from nose of the pier	10'x5' (column x row)
3	D/S RHS FACE	10'x5' (column x row)
4	D/S LHS FACE	10'x5' (column x row)
5	D/S RHS FACE	10'x5' (column x row)
6	D/S RHS FACE, mid of the face, 20.5m apart from gate, lower end of the grid ended at 10.3m from top.	10'x5' (column x row)
7	D/S RHS FACE, mid of the face, 19.5m apart from gate, 4.7m from top.	10'x5' (column x row)
8 A	D/S RHS, 10.7m from top, 1.0 m above water level, 29.0 m apart from gate	10'x5' (column x row)
8 B	D/S RHS, 10.9 m from top & 27.0 m apart from gate. 0 m above water level	10'x5' (column x row)
9	RHS, 11.55m from top and 1.0 m above water level, 23.4 m apart from gate	10'x5' (row x column)
10	LHS, 11.5m from top and 1.0 m above water level, 13.7 m apart from gate	20' x 10' (10 x 10)

V. OBSERVATIONS

The investigation work of corrosion monitoring of the identified concrete piers was restricted to the area which could be accessed using a boat (Table 3). The observed values for the tests done on different piers are presented in Fig. 6.1 to Fig. 6.22 in the form of contour map and pie chart [6, 7, 8].

VI. RESULTS AND DISCUSSION

6.1. Pier 1

Only 2% region falls in 'D' category depicting uncertain corrosion activity while remaining 98% (6% in 'E', 70% in 'F' and 22% in 'G') area falls in categories which are indicative of no noticeable corrosion activity in the scanned area of the pier.

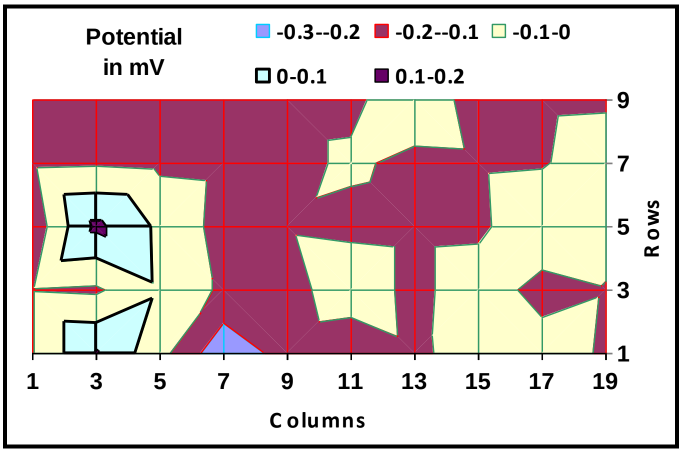

Fig. 6.1 Contour Map Showing Corrosion Status

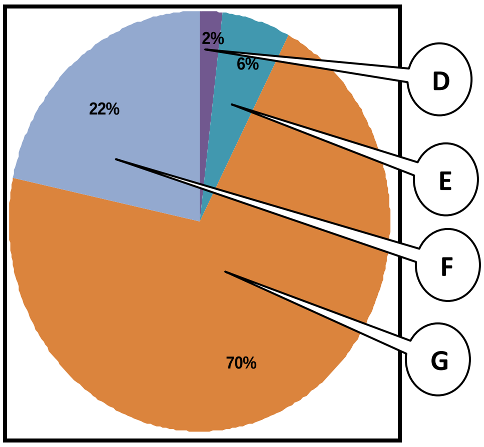

Fig. 6.2 Pie Chart of Scanned Area

6.2. Pier 2

Only 33% region falls in ‘D’ category depicting uncertain corrosion activity while remaining 67% (20% in ‘E’, 16% in ‘F’ and 31% in ‘G’) area falls in categories which are indicative of no noticeable corrosion activity in the scanned area of the pier.

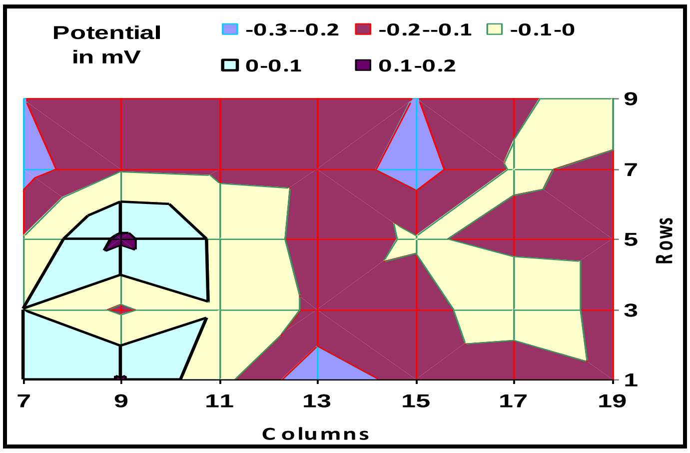

Fig. 6.3 Contour Map Showing Corrosion Status

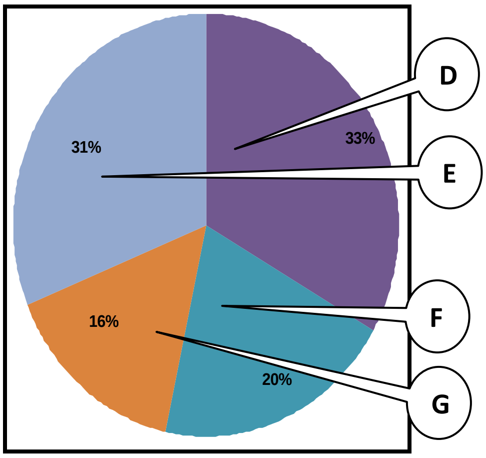

Fig. 6.4 Pie Chart of Scanned Area

6.3. Pier 3

Only 2% region falls in D category depicting uncertain corrosion activity while remaining 98% (6% in ‘E’ , 42% in ‘F’ and 50% in ‘G’) area falls in categories which are indicative of no noticeable corrosion activity in the scanned area of the pier.

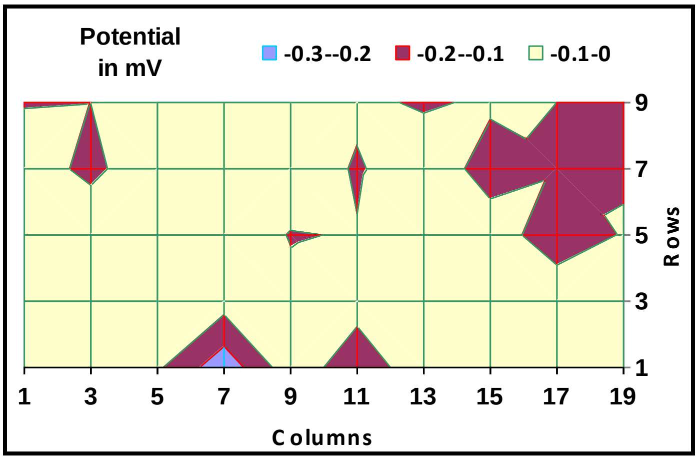

Fig. 6.5 Contour Map Showing Corrosion Status

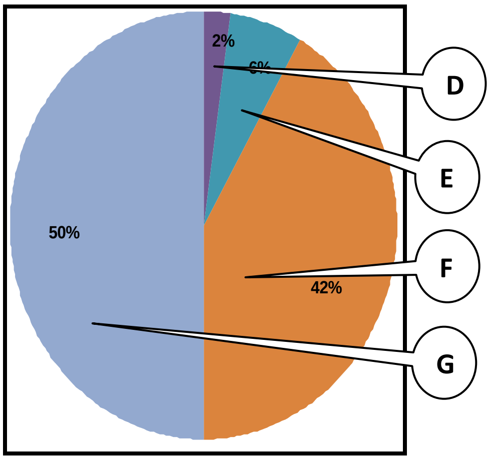

Fig. 6.6 Pie Chart of Scanned Area

6.4. Pier 4

100% area (43% in ‘F’ and 57% in ‘G’) falls in categories which are indicative of no noticeable corrosion activity in the scanned area of the pier.

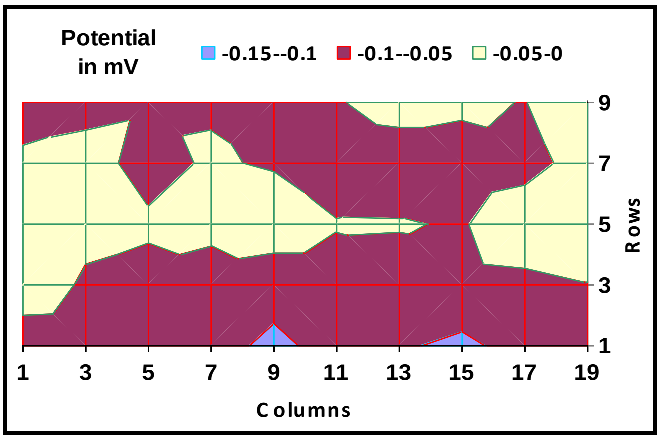

Fig. 6.7 Contour Map Showing Corrosion Status

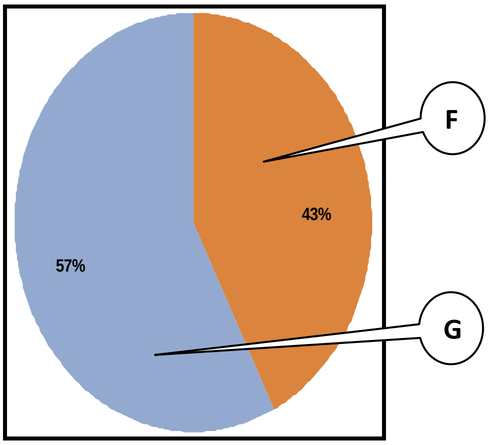

Fig. 6.8 Pie Chart of Scanned Area

6.5. Pier 5

100% area (18% in 'F' and 82% in 'G') falls in categories which are indicative of no noticeable corrosion activity in the scanned area of the pier.

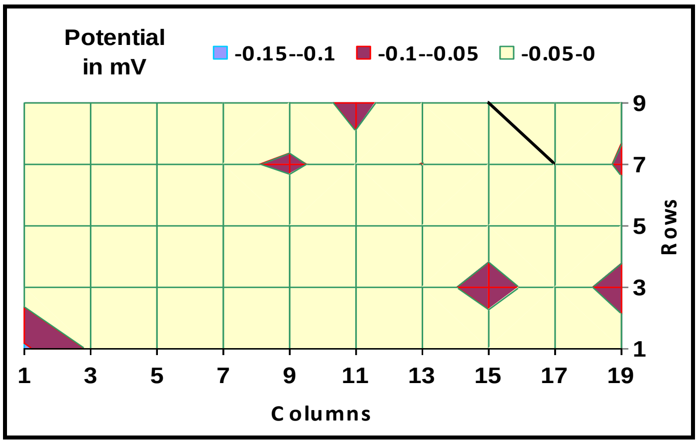

Fig. 6.9 Contour Map Showing Corrosion Status

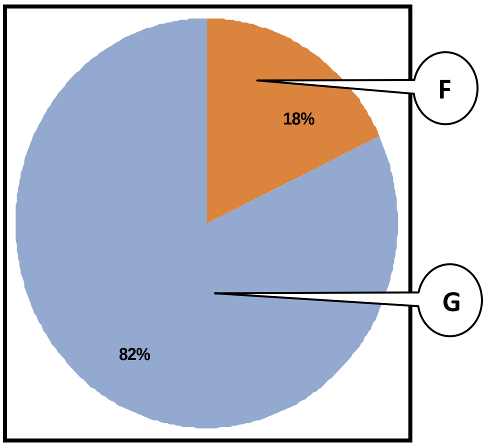

Fig. 6.10 Pie Chart of Scanned Area

6.6. Pier 6

Only 14% region (2% in 'C' and 12% in 'D' category) depicts uncertain corrosion activity while remaining 86% (46% in 'E' and 40% in 'F') area falls in categories which are indicatives of no noticeable corrosion activity in the scanned area of the pier.

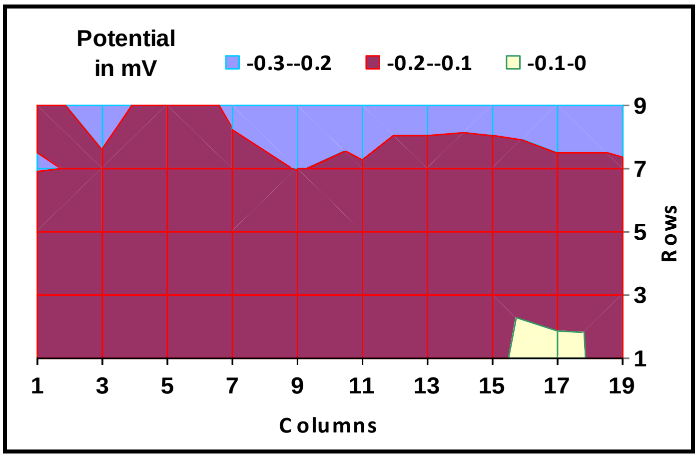

Fig. 6.11 Contour Map Showing Corrosion Status

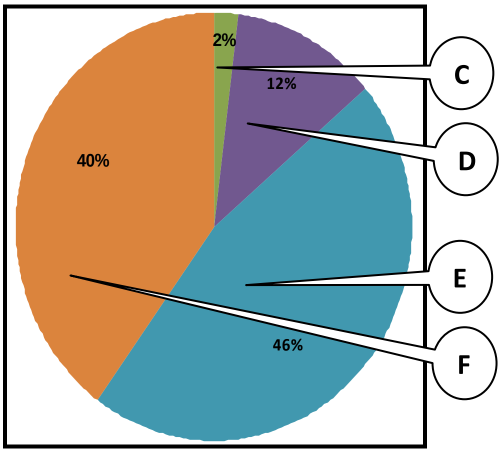

Fig. 6.12 Pie Chart of Scanned Area

6.7 Pier 7

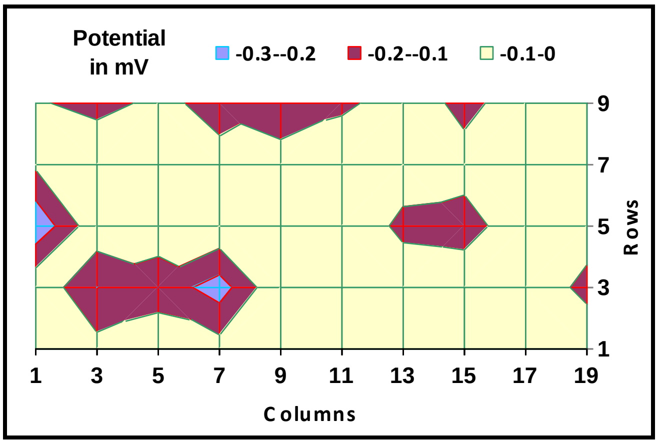

Fig. 6.13 Contour Map Showing Corrosion Status

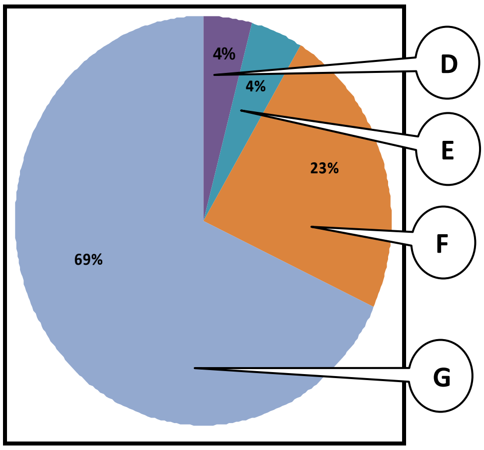

Fig. 6.14 Pie Chart of Scanned Area

Only 4% region falls in 'D' category depicting uncertain corrosion activity while remaining 96% (4% in 'E' , 23% in 'F' and 69% in 'G') area falls in categories which are indicatives of no noticeable corrosion activity in the scanned area of the pier.

6.8. Pier 8 A

100% area (28% in 'E', 56% in 'F' and 16% in 'G') falls in categories which are indicatives of no noticeable corrosion activity in the scanned area of the pier.

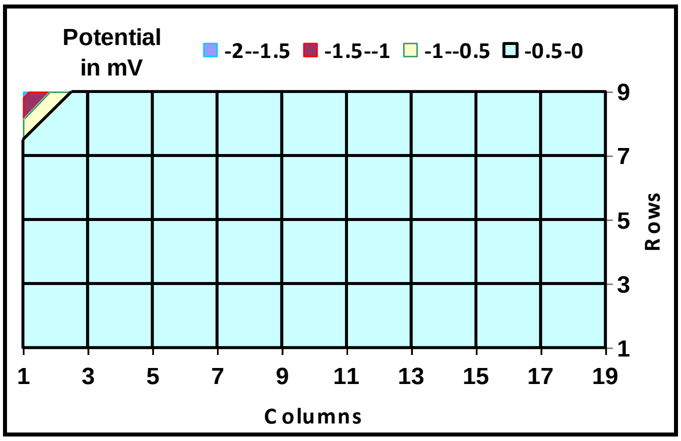

Fig. 6.15 Contour Map Showing Corrosion Status

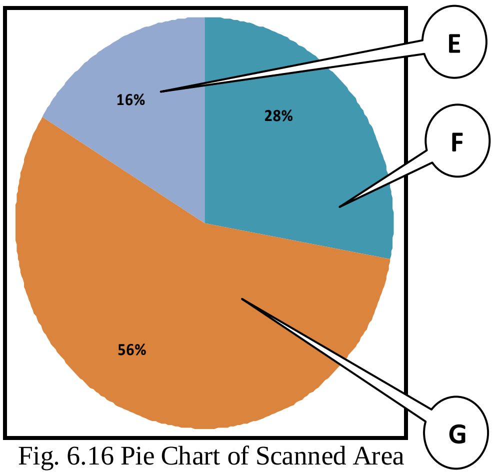

Fig. 6.16 Pie Chart of Scanned Area

6.9. Pier 8 B

100% area falls in 'G' category which indicates no noticeable corrosion activity in the scanned area of the pier.

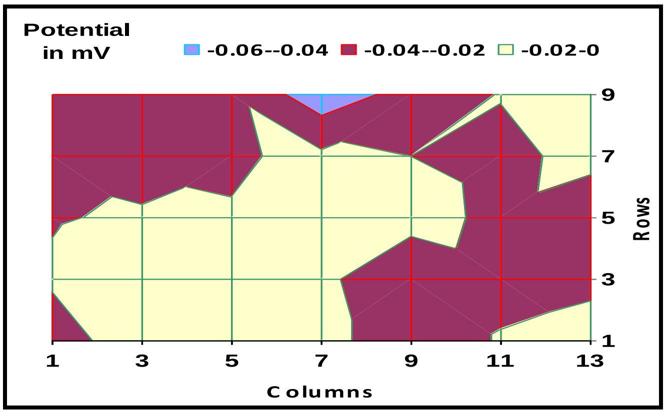

Fig. 6.17 Contour Map Showing Corrosion Status

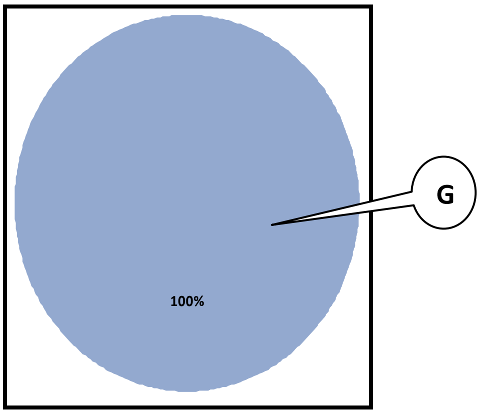

Fig. 6.18 Pie Chart of Scanned Area

6.10. Pier 9

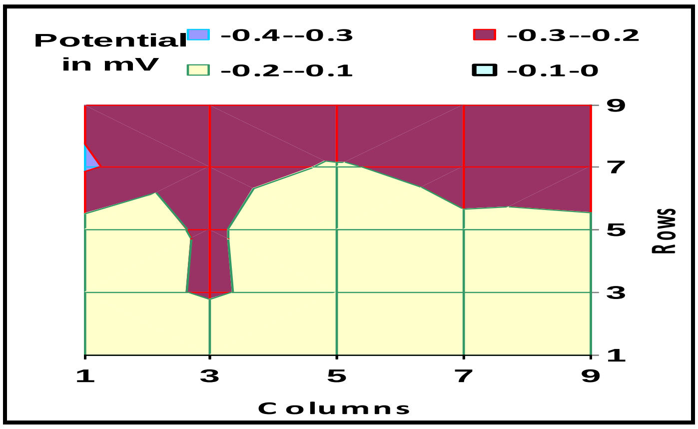

Fig. 6.19 Contour Map Showing Corrosion Status

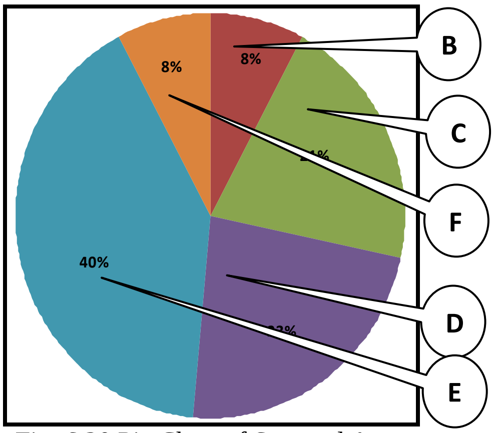

Fig. 6.20 Pie Chart of Scanned Area

6.11. Pier 10

5% scanned area fall under categories 'A' & 'B', depicting , 90% chance of corrosion is occurring in this area whereas 27% area fall under categories 'C' & 'D' showing uncertain corrosion activity. 68% area (49% in 'E', 16% in 'F' and 3% in 'G' categories) falls in area which are indicatives of no noticeable corrosion activity in the scanned area of the pier. The general look of exposed rebar shown in figure 1 is also evident of vigorous corrosion activities in the area.

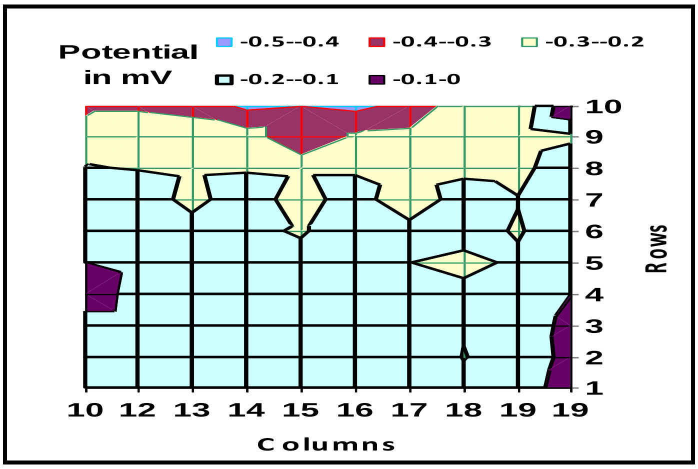

Fig. 6.21 Contour Map Showing Corrosion Status

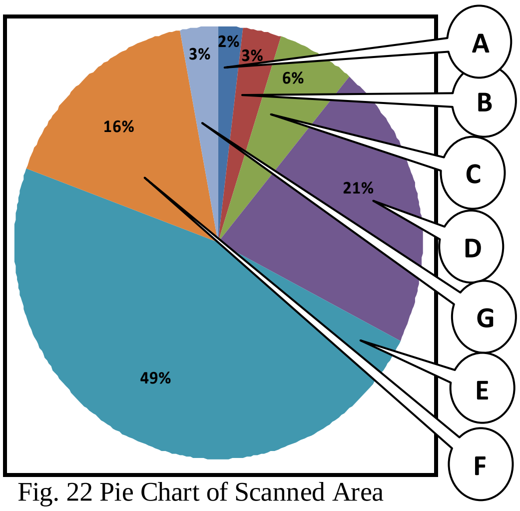

Fig. 22 Pie Chart of Scanned Area

VII. CONCLUSION

The Half Cell Potential Testing method is a technique, used for assessment of the durability of reinforced concrete and helps in diagnosing reinforcement corrosion. As per standard practices stated above, the test results shows that

- No corrosion activity is detected on pier no 4, 5, 8A and 8B.
- Corrosion activity has already initiated on the piers 1, 2, 3, 6, 7.
- Scanning result on pier no. 9 and 10 shows high degree of corrosion.

Since indications of deterioration of concrete and reinforcement have been observed a strict vigil through periodic monitoring of these piers should be kept using Non Destructive Tests.

Acknowledgements

The authors extend their sincere thanks to Director CSMRS for his constant inspiration. We also extend our sincere gratitude to Sh. Sohan Singh of CSMRS for his valuable efforts. We also extend our sincere gratitude to all the authors whose publications provided us directional information from time to time.

REFERENCES

[1] Diagnosis of Deterioration of Concrete Structures- Identification of Defects, Evaluation and Development of Remedial Actions, *Concrete Society Camberley, UK, Technical Report 54*, (2000)

[2] ASTM C 876-91 (Reapproved 1999), "Standard Test Method for Half-cell Potentials of Uncoated Reinforcing Steel in Concrete," *Annual Book of ASTM Standards, 03.02* (2006), 11-16.

[3] RILEM TC 154-EMC, "Electrochemical Techniques for Measuring Metallic Corrosion" Recommendations, "Half-cell potential measurements – Potential mapping on reinforced concrete structures," *Materials and Structures*. 36 August - September (2003), 461-471.

[4] Elsener, B. and Bohni, H., "Potential Mapping and Corrosion of Steel in Concrete," in "Corrosion Rates of Steel in Concrete," ASTM STP 1065, N.S. Berke, V. Chaker, D. Whiting eds. *American Society for Testing and Materials, Philadelphia* (1990), 143-156.

[5] Stratfull, R. F., Jurkovich, and W. J., Spellman, D. L., "Corrosion Testing of Bridge Decks," *Highway Research Record 539, Washington, D. C., Transportation Research Board* (1975).

[6] Clemena, G. G., "Benefits of Measuring Half-cell Potentials and Rebar Corrosion Rates in Condition Surveys of Concrete Bridge Decks," *Virginia Transportation Research Council* (1992).

[7] JSCE-E 601-2000, "Test Method for Half-cell Potentials of Uncoated Rebars in Concrete Structures," Standard Specifications for Concrete Structures – 2002, Test Methods andSpecifications, *Japan Society of Civil Engineers* (2002).

[8] Pankaj Sharma et al, "Corrosion Monitoring Of Reinforcement in Underground Galleries of Hydro Electric Project" *Int. Journal of Engineering Research and Application*, Vol. 3, Issue 5, Sep-Oct 2013, pp.1087-1090.