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Gu, P.; Carter, P.; Beaudoin, J. J.

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Validation of half-cell potential data from bridge decks

Ping Gu*, Paul Carter +, J.J. Beaudoin* and M. Arnott* suggest that a little more effort may be necessary to provide assurances that conclusions drawn from such data are valid.

Introduction

Since the early 1980s, confidence in the use of half-cell potential measurements for identification of corrosion potential has evolved due to the success of bridge deck corrosion surveys[1,2] their simplicity and cost-effectiveness. The half-cell method is used for condition assessment of existing concrete structures. The data can be used to economically prioritize bridges for repair and to predict future infrastructure maintenance needs since the amount of corrosion usually increases in a predictable manner. An indication of the relative probability of corrosion activity is obtained empirically through measurement of the potential difference between a standard portable half-cell (a copper-copper sulfate standard reference cell is normally used for portable field readings) placed on the surface of the reinforced concrete deck and the reinforcing steel. The data analysis guideline described in ASTM C876, provides general principles for evaluation of reinforcing steel corrosion in concrete[3]. These are outlined in Table 1.

Problems with interpretation

A simple comparison of half-cell potential data with the above ASTM guideline may not tell the whole story. For instance, a more negative reading of potential in general is considered to indicate a higher probability of corrosion. This general 'rule' may only be valid in a comparison of data in the same bridge deck. Comparing electrical potential data from one bridge to another without validation with corrosion (current) rate measurements could possibly lead to misinterpretation. It was observed in a previous field survey that more negative potential readings usually occur in areas adjacent to expansion joints. These potential readings result from the anodic areas on the deck joint anchor straps near the strap to deck joint weld locations, where the cold joint between steel deck joint and concrete deck is intercepted by the anchor strap resulting in localized high exposure to chlorides and moisture. Therefore, these data may not accurately represent the corrosion state of the rebar below. This ambiguity can be easily avoided by validation of corrosion activity using linear polarization measurements. Moreover, the data analysis of half-cell potential measurements has become more complicated due to advances in the repair and protection technologies applied to bridges. Factors such as chloride or moisture content and temperature are known to have a significant influence on half-cell potential readings[1,2]. Steel fibre reinforcement, dense material overlays and concrete sealers tend to make the potential measurement more difficult and sometimes impossible. Cathodic protection systems and previous repair patches etc. can also cause interference. Therefore, confirmation with other non-destructive corrosion rate determination methods is necessary in evaluating half-cell potential results.

Table 1.

Half-cell potential reading, vs. $Cu/CuSO_4$	Expected corrosion activity
Less negative than -0.200V	90% probability of no corrosion
Between -0.200 V and -0.350V	An increasing probability of corrosion
More negative than -0.350V	90% probability of corrosion

Field study

A field study was recently conducted in Alberta to investigate the benefits of using linear polarization as a supplementary test to standard half-cell survey procedures. Half-cell potential data obtained from eight bridges were validated using a linear polarization technique by corrosion scientists from the Materials Laboratory, Institute for Research in Construction (IRC), National Research Council Canada (NRCC) and bridge engineers from Alberta Transportation and Utilities. This latter method is used to quantitatively measure the steel corrosion rate of reinforced concrete. Linear Polarization Instruments including Gecor 6 (GEOCISA) and Rp Monitor (Cortest Columbus Tech. Inc.) are based on the use of a 'guard ring' which confines the polarized area of rebar so that the corrosion rate in an identified location can be determined.

The effect of a previous deck repair patch on the half-cell potential readings is also of particular interest. The effect could be to increase or decrease the measured half-cell reading depending on the relative quality of the repair patch versus the adjacent concrete and the external environment within which the patch is exposed. The importance of supplementing the half-cell tests with additional corrosion rate measurements is illustrated in the two extreme cases described in the following sections.

Case I - a dense repair patch in a relatively poor concrete substrate

During a corrosion rate survey of a concrete bridge deck, it was noticed that the half-cell potential reading (-0.301V) on the patch was more negative than the area outside the patch (-0.190 V) (Figure 1). Visual inspection of the bridge deck noted that the concrete quality was relatively poor, since noticeable abrasive wear damage of the concrete surface was observed. By contrast, the repair patch appeared to be in a good shape. This bridge was not exposed to heavy traffic and de-icing salt was occasionally being applied.

* *Materials Lab., Institute for Research in Construction, National Research Council, Ottawa, Canada.*
+ *Bridge Engineering Branch, Alberta Transportation, Edmonton, Canada.*

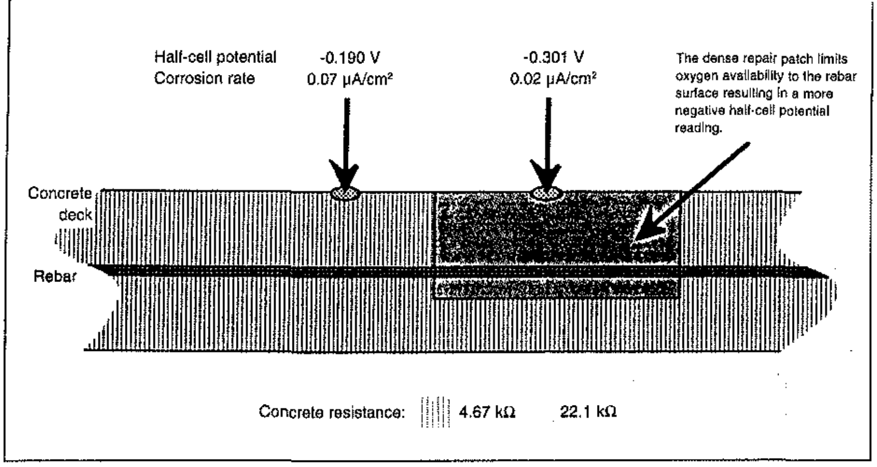

Figure 1. Dense repair patch in relatively poor concrete.

The more negative potential reading, in accordance with the general guideline for data interpretation, would suggest a high probability of corrosion activity underneath the patch material. However, a corrosion rate measurement using Gecor 6 indicated a slightly lower corrosion rate (0.02 μA/cm²) of the rebar underneath the patch than the corresponding rebar underneath the concrete outside the patch (0.07 μA/cm²). The corrosion rate measured on the patch is three times smaller even though a more negative half-cell potential reading (-0.301V) was measured on the patch surface compared to the reading on the surface outside the patch (-0.190).

A possible explanation of the half-cell potential difference is the lower oxygen concentration at the steel-patch interface compared with that in the existing concrete. The patch material is denser than the existing concrete and their electrical resistance values were measured at 22.1 kW and 4.67 kW respectively. The half-cell potential of the rebar is affected by the oxygen concentration at the rebar/concrete interface. High concrete resistance is associated with low permeability of oxygen resulting in a more negative half-cell potential as illustrated in Figure 2[4]. This explains the observation of a more negative potential reading recorded on the patch than that recorded on the surface of the adjacent concrete. This difference in the half-cell potential in the patch area versus the area outside the patch is not indicative of the extent of rebar corrosion.

Case II - a poor quality repair patch in relatively good quality concrete

This example was observed on a bridge with a heavy traffic load where de-icing salt was frequently used. The concrete deck had a surface membrane, where the aggregates had been sprinkled into the liquid polymer creating pinholes. This allowed the membrane to breathe making the half-cell potential measurement possible. The potential reading on the patch was -0.545 V which was slightly more negative than the area outside the patch, -0.509 V, (see, Figure 3). The Gecor 6 measurements, however, revealed that corrosion rate of rebar underneath the patch was 4.6 mA/cm², i.e. 20 times higher than the rate in the location outside the patch (0.16

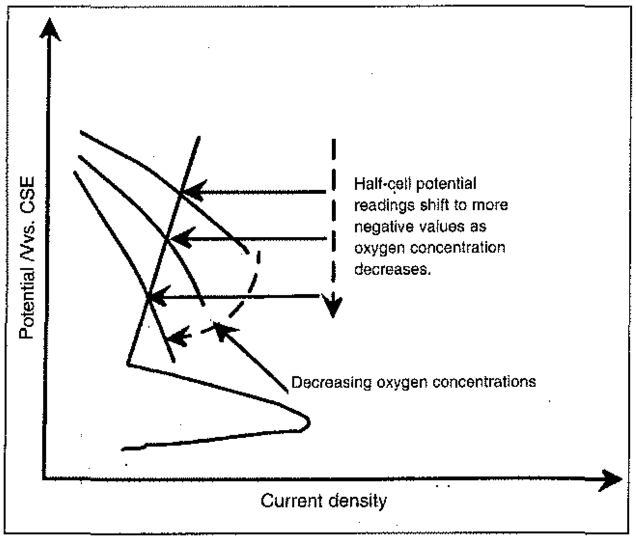

Figure 2. Evans diagram showing the effect of oxygen concentration on values of half-cell potential readings (redrawn from Reference 5.).

mA/cm²) regardless of the close values of half-cell potential. The patch material was more porous than the adjacent concrete with membrane. Their electrical resistance values are 1.0 kΩ and 2.5 kΩ respectively. The poor patching material allows chloride ion to diffuse to the rebar surface easily. Accumulation of chloride in the patch area makes the rebar embedded underneath a local 'anodic area' where rebar corrosion is preferential (Figure 3). The electrons produced at the anode are then consumed by oxygen reduction at local 'cathodic areas' i.e. most possibly on the surface of the rebar embedded outside the patch area. Low electrical resistance of the bridge deck may explain the small difference in half-cell potential between the patch area and the area outside the patch. The very negative half-cell potential reading (-0.509V) recorded outside

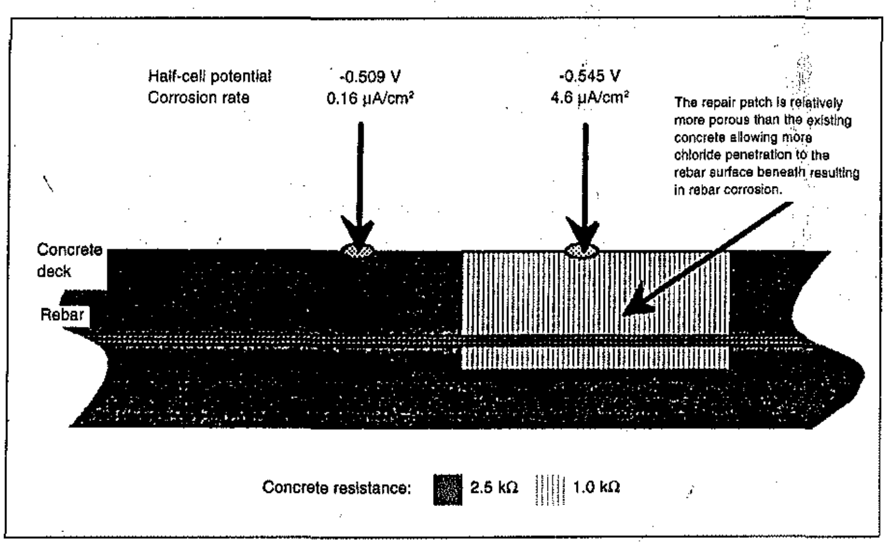

Figure 3. Poor repair patch in relatively good quality concrete.

the patch is mainly a result of signals from the corroded area (rebar beneath the patch) since the potential signals tend to spread out further when the concrete resistivity is relatively small as depicted in Figure 4.

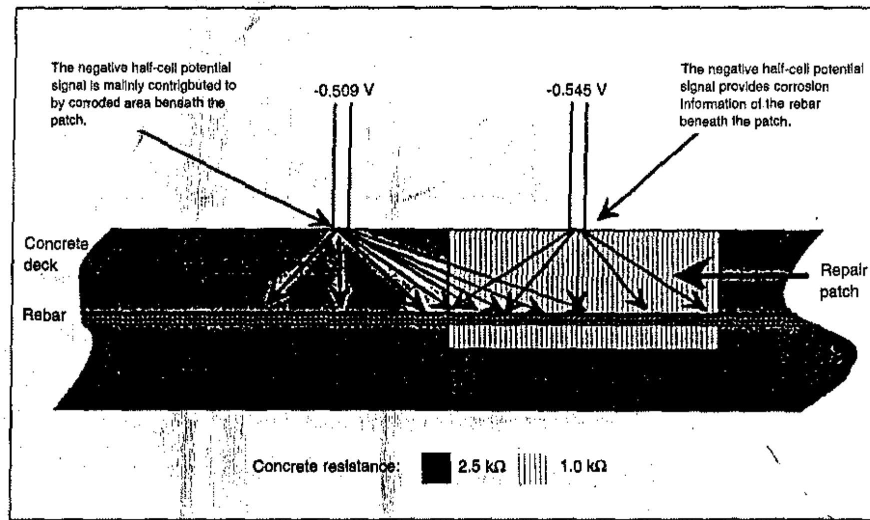

Figure 4. Half-cell potential measurement on low resistance concrete.

Summary

Rebar surface corrosion is complex. It is apparent that the uniformity of the repair mortar or concrete is one of the factors that affects rebar surface corrosion. In general, comparison of the differences in the half cell potential across a structure or an area of the bridge deck is more indicative of the level of corrosion activity than absolute values[5]. For example, a variation of 100 mV (from -150 mV to -250 mV) in half-cell potential reading may indicate more active rebar corrosion at a given deck location than another location with only a 30 mV variation (from -250 mV to -280 mV). Interpretation of rebar corrosion only from the 'absolute' half-cell potential guidelines may be misleading engineers and cause errors in judgment if other factors are not taken into account. Validation of the conclusions drawn from the half-cell potential data by corrosion rate measurements would appear prudent. A little more effort may be necessary to provide assurance that conclusions are valid.

References

1. SPELLMAN, D.L. and STRATFULL, R.F. *Concrete Variables and Corrosion Testing*, Highway Research Record 423, 1973.
2. STRATFULL, R.F. *Half-cell Potentials and the Corrosion of Steel in Concrete*, Highway Research Record 433, 1973.
3. Annual Book of ASTM Standards, C876-91, *Standard Test for Half-Cell Potentials of Uncoated Reinforcing Steel in Concrete*, Vol. 04.02, Philadelphia, 1992.
4. BOCKRIS, J. O'M. and REDDY, A.K.N. *Modern Electrochemistry*, Plenum Press, NY., 1970.
5. *Corrosion Detection in reinforced Concrete Bridge Structure*, User Manual, U.S. Department of Transportation, Federal Highway Administration, Demonstration project No. 84, March 1992..

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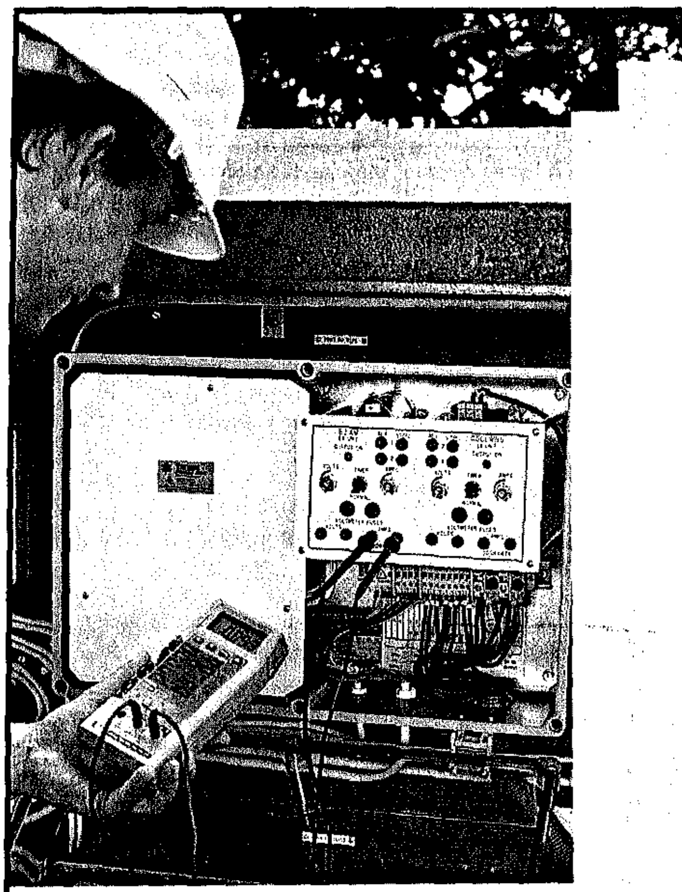

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