

Half-cell potential test from the upper-side and the lower-side of reinforced concrete slabs: a comparative study.

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Abstract

This article describes an experimental investigation on a reinforced concrete bridge deck to compare half-cell potential measurements carried out from the under-side to those obtained from the upper-side of the deck. It was noted that the results are similar but are not identical. This particular situation is caused by the physical conditions of the upper-side and lower-side of the decks which, sometimes, can be similar.

Résumé

Cet article concerne une investigation expérimentale sur une dalle de tablier de pont pour comparer les mesures de potentiel de corrosion obtenues par l'intrados et par l'extrados. Il a été constaté que les résultats sont similaires mais ne sont pas identiques. Cette situation est attribuée aux conditions physiques de l'intrados et de l'extrados qui, parfois, peuvent être similaires.

Keywords

Reinforced concrete, corrosion, evaluation, half-cell potential, upper-side, lower-side.

1 Introduction

Bridge decks are generally made up of concrete slabs which are reinforced with two mats of steel rebars. In the province of Québec (Canada), the corrosion of steel rebars is the principal cause of degradation of bridge decks. Bridge engineers frequently use the half-cell potential (HCP) test to evaluate the corrosion activity of the reinforcements, its extent and its severity. This test is carried out from the upper-side of the decks and requires the closing of the lanes to collect the data. This is obviously very problematic in the great urban centres such as the towns of Montreal or Quebec.

One of the ways of proceeding to avoid this problem would be to collect the half-cell potential data from the lower-side of the bridge decks. However, the adequate evaluation of the corrosion activity of the upper rebars from the HCP measurements carried out from the lower-side of the decks requires the knowledge of the difference between the measurements collected from the lower and upper sides.

This article presents the results of an investigation carried out on a concrete bridge deck to determine the possible correlations between the HCP measurements collected from the lower-side to those collected from the upper-side of the decks.

2 The Half-cell potential test

Basically, the half-cell potential (HCP) test assesses the condition of the steel embedded in concrete with regard to corrosion activity [1, 2]. In this method, the electrical potential difference between the upper steel rebars and a standard portable reference electrode in contact with the

concrete surface is measured. Figure 1a illustrates the basics for such a measurement. The reference electrode is connected to the negative end of the voltmeter and the steel reinforcement to the positive. A grid pattern is used to identify locations where the half-cell is to be placed to obtain potential measurements. The HCP values are then plotted on schematic diagram of the structure investigated as an equipotential contour map. The ASTM standard C876 [3] provides general guidelines for the interpretation of the HCP data. According to these guidelines, the probability of corrosion of the rebars is less than 10% if the potential is greater than -200 mV, whereas potential values lower than -350 mV indicate a high probability (> 90%) that corrosion is active. The HCP values between these limits indicate areas where the corrosion activity is uncertain.

3 Description of the HCP tests

The half-cell potential tests were carried out on a concrete bridge deck which was built in 1963. Its length is 38.5 m and its width is 9.16 m. This bridge deck consists of a thin concrete slab located on the Western side, and of a thick concrete slab located on the Eastern side. Table 1 shows the main characteristics of these slabs.

Table 1. Characteristics of the concrete slabs of the deck

Slab	Length (m)	Thickness (m)	Average cover of upper rebar mesh (m)	Average cover of lower rebar mesh (m)	Distance between rebars (m)
Thin slab	27,6	0,17	0,038	0,045	0,19
Thick slab	10,9	0,53	0,067	0,028	0,30

The covers of the upper and lower rebars indicated in Table 1 were obtained from three corings made in the thin slab at different locations and two corings in the thick slab. These corings were done to check the electrical continuity of the reinforcements. For this purpose, the measurement of electrical resistance was done: (a) between the rebars of the upper mesh, (b) between the rebars of the lower mesh and (c) between the rebars of the upper and lower meshes. In all cases, the electrical resistance was low indicating that the electrical continuity between the rebars was good in the thin slab as well as in the thick slab.

The HCP measurements were carried out with a copper-copper sulphate reference electrode according to nine lines in the longitudinal direction of the bridge. The distance between these lines as well as the distance between the points of measurements on each line was equal to 1 m. The HCP measurements were done in 243 locations in the thin slab and in 90 locations in the thick slab. For each location, the measurements were done:

- from the upper-side of the slabs, while taking as reference the upper rebar mesh and then the lower rebar mesh (Figure 1a and 1b),
- from the lower-side of the slabs, while taking as reference the upper rebar mesh and then the lower rebar mesh (Figure 1c and 1d).

4 Results of the HCP tests

Figures 2 and 3 give the HCP results concerning the thin slab. These results are given in the form of grey scale maps indicating the probability of corrosion of the reinforcements:

- the white zones correspond to areas where the probability of corrosion is lower than 10%,
- the gray zones correspond to areas where the probability of corrosion is 50%,
- the black zones correspond to areas where the probability of corrosion is > 90%.

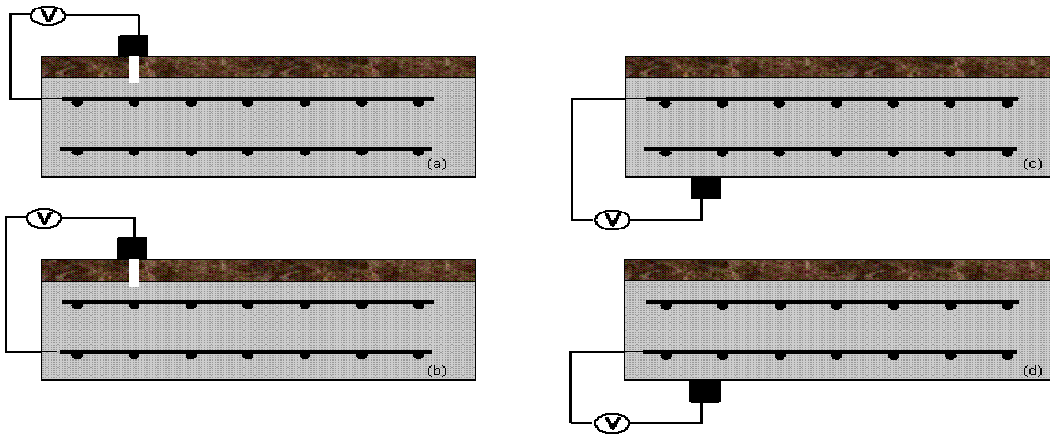


Figure 1: HCP measurements carried out on the slabs

Figure 2a relates to the measurements taken from the upper side of the deck according to the configurations in Fig. 1a. This figure shows that the probability of corrosion of the reinforcements is weak along the northern and southern edges of the deck and is uncertain in the center of the deck. The probability of corrosion is high in four areas in this slab.

Figure 2b relates to the measurements taken from the upper side of the deck according to the configuration in Fig. 1b. Figure 2b is identical to Fig. 2a. This result is foreseeable because when the rebars of the upper mesh are connected electrically to those of the lower mesh, the voltmeter measures the potential difference between the reference electrode and the nearest rebar to the electrode. Thus, Fig. 2a and 2b relates both to the corrosion activity of the upper rebar mesh.

Figure 3 relates to the measurements taken from the lower-side according to the configuration indicated in figures 1c. This figure describes the corrosion activity of the rebars near the bottom of the slab. The HCP map obtained from the lower side according to figure 1d is not given here because it is identical to Fig. 3.

The HCP maps relating to the thick slab are given in Fig. 4. Figure 4a relates to the HCP measurements taken from the upper side according to the configuration of measurements in Fig. 1a. The corrosion activity is uncertain in a large area of the slab. The probability of corrosion is high in a region located at the West of the slab and in a small portion of the slab located at the east. The HCP map also shows a region at the North of the slab where the probability of corrosion is low. The HCP map obtained using the configuration in Fig. 1b is not shown here because it is identical to that in Fig. 4a.

5 Discussion of the HCP results

The HCP map of the upper rebar mesh (Fig. 2a and 2b) resembles to that of the lower rebar mesh (Fig. 3). In particular, the four zones in Fig. 2a (and 2b) where the probability of corrosion of the reinforcements is high are also present in the cartography of the corrosion activity of the lower reinforcements. This result can be explained by the infiltration in these places, of water and ions chloride through the full thickness of the slab. The visual inspection of the lower-side of the slab confirmed these facts (Fig. 5).

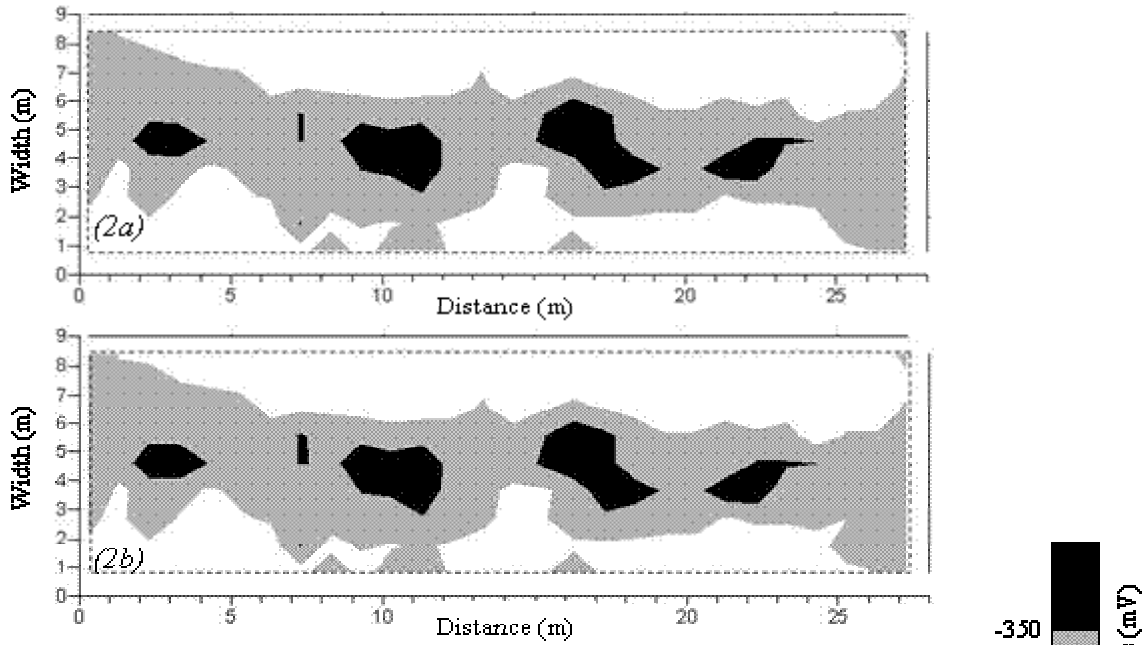


Figure 2 : Results of the HCP measurements from the upper-side

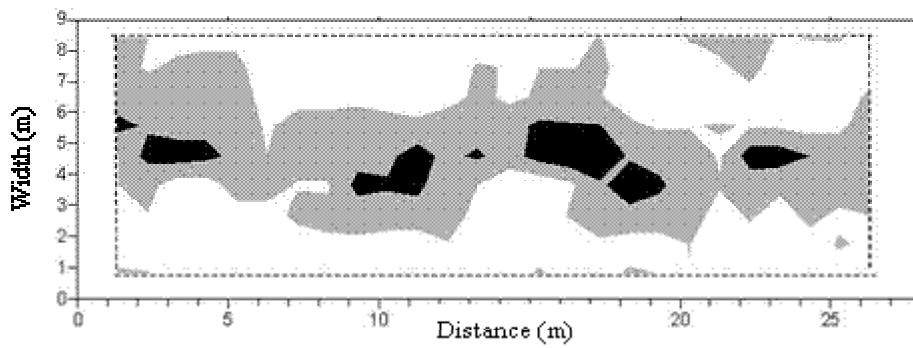


Figure 3 : Results of the HCP measurements from the lower-side

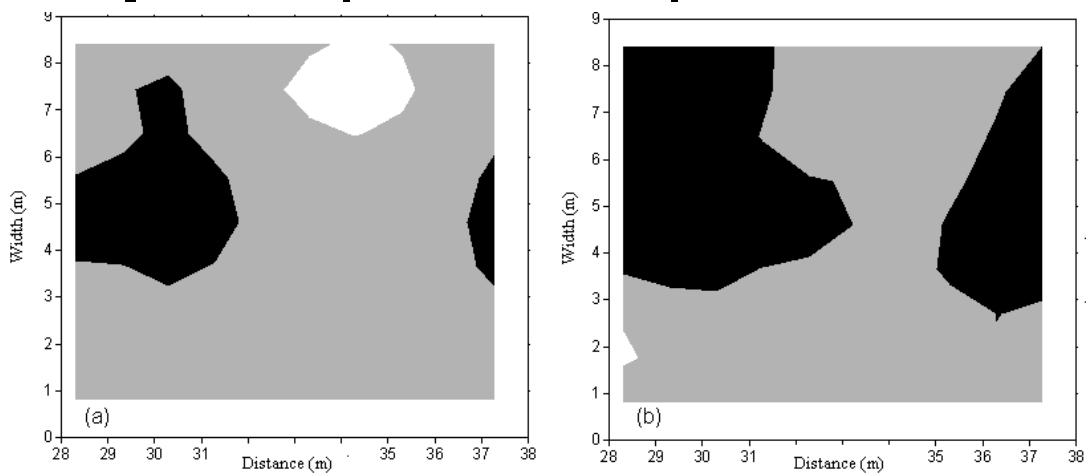


Figure 4: Results of the HCP on the thick slab
(a) HCP measurements from the upper-side
(b) HCP measurements from the lower-side

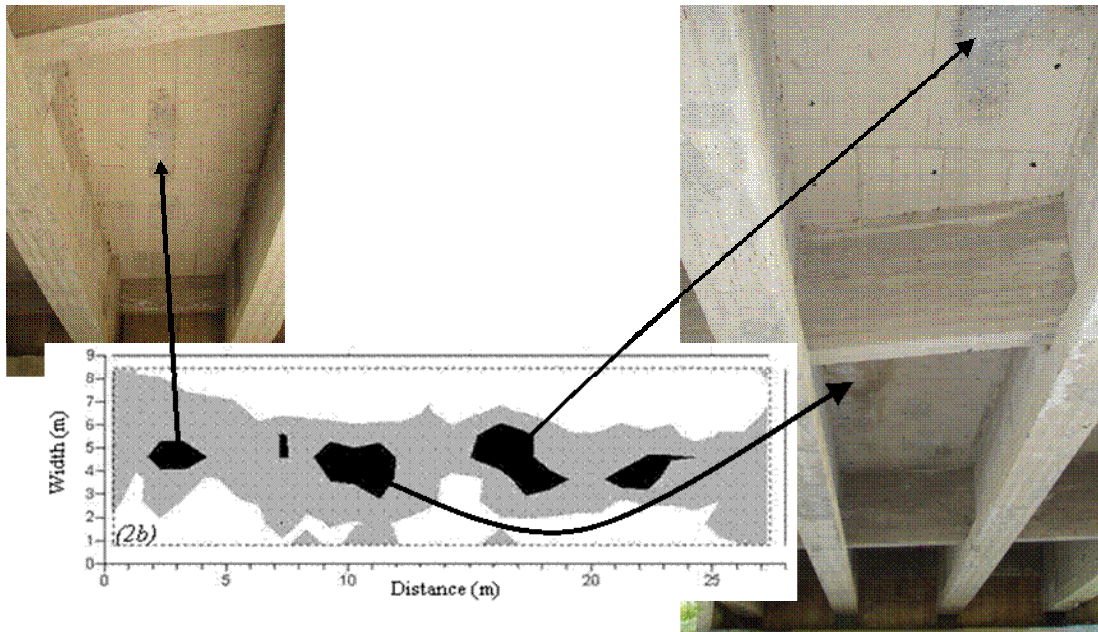


Figure 5 : Correlation between the HCP results and the humidity on the lower-side of the slab

The resemblance between the HCP results relating to the upper and the lower sides in the case of the thick slab (Fig 4a and 4b) is also caused by the infiltration of water and ions chloride through the full thickness of the slab.

Figure 2 and Fig. 3 are similar but they are not identical. Figure 6 gives the HCP values obtained from the upper side versus those obtained from the lower side. It shows that the relation tends towards a linear relation, but the dispersion of the results is not negligible. This result was also obtained in the case of the thick slab.

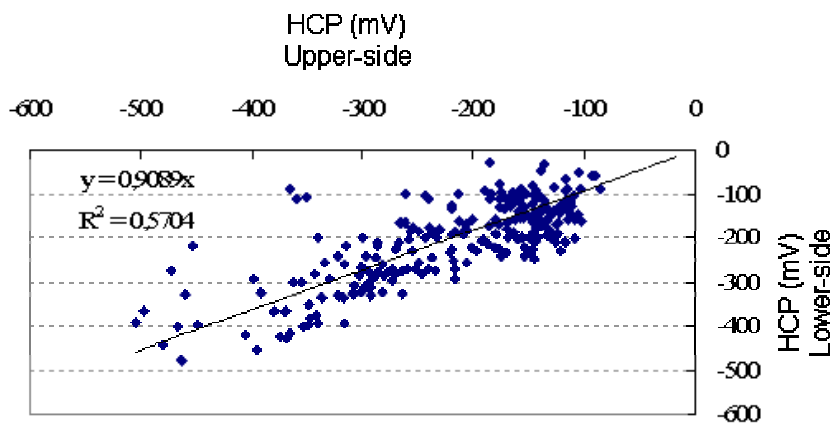


Figure 6: HPC data of the upper-side versus HCP data of the lower-side

Finally, Table 2 gives the statistical distribution of the HCP data for the thin slab as well as for the thick slab. In the case of the thin slab, the percentage of the data corresponding to high probability of corrosion (potential < -350 mV) is about the same for the measurements from the upper

side and the lower side. However, for the thick slab, this percentage is 2,6 times greater for the tests carried out from the lower side (42 % comparatively to 16 %).

Usually, bridge engineers use HCP measurements from the upper side to determine the top surface of concrete bridge decks to repair and to estimate the cost of the repair. The top surface to repair expressed as a percentage of the total surface of the deck is taken equal to the percentage of the HCP data corresponding to high probability of corrosion of the rebars. Thus, if we consider the HCP data collected from the lower side to determine the top surface of the deck to repair, then this surface will be over-estimated in the case of the thick slab.

Table 2: Statistical distribution of the HCP data

Hal-cell Potential	Thin slab		Thick slab	
	Higher side	Lower side	Higher side	Lower side
> -200 mV	50 %	56 %	5 %	1 %
-200 mV to -350 mV	41 %	36 %	79 %	57 %
< -350 mV	9 %	8 %	16 %	42 %

6 Conclusions

The experimental investigations reported herein show that the HCP values collected from the lower-side of a concrete bridge deck can be similar to those collected from the upper side when the physical conditions of the lower and the upper sides of the deck are similar. Laboratory investigations are in progress on a set of reinforced concrete slabs to study in detail the correlation between the HCP data from the upper and lower sides of these slabs in the case where the upper and the lower rebars are connected or not to each others.

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