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CONDITION MONITORING OF THE REINFORCEMENT'S CORROSION IN STRUCTURAL ELEMENTS

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Abstract: *Knowing the status of the steel reinforcements in existing structural elements, represents an important issue in building rehabilitation and long-time behaviour. A quick non-destructive method of pin pointing areas, where active corrosion of re-bars is taking place on reinforced concrete structures can be done by use of half-cell measurements, using the M.C. Miller Concrete Corrosion Mapping System. The exchange of energy which is the nature of corrosion in different sections of steel reinforcing, can be measured by potential. Half-cell potential measurements allow a comprehensive survey of bridge deck/structures to be performed in a relative short period of time.*

Key words: *condition monitoring of reinforcement, non-destructive method, Half-cell potentiometer.*

1. Introduction

The periodical condition monitoring of the concrete reinforcement corrosion in the existing structures it is mandatory. The suitable consolidation and strengthening of the damaged concrete elements it is based on the non-destructive tests as well as visual observations made by experts. The assessments of structural concrete elements depends on factors such as: the experience of the assessor, the time available for the assessment and the data available, and does not always reflect the hidden defects produced by corrosion, de bonding of reinforcements due to atmospheric conditions, etc. For these reasons there is a need for a reliable, safe, accurate and cost effective method of assessing concrete's reinforcements integrity [7].

Inside a reinforced concrete element, or a pre-stressed concrete element, steel reinforcements are protected against the corrosion process, by the concrete coating layer existent due to the hydration of the cement; that means there exists a dense layer containing calcium hydroxide-Ca(OH)2-a basic compound [2].

This steel bar protecting layer can be affected by external factors, so that along the reinforced concrete bars appears a differential potential electric which leads to the possibility of an electrochemical corrosion of steel. From the technical literature the degradation process of an element can be described as the initial time period before the corrosion appears together with the corrosion time period.

In a reinforced or pre-stressed concrete element a so-called passivated layer is formed on the surface of reinforcing bars; it is a thin but very dense layer of $Ca(OH)_2$ which prevents further corrosion.

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This film may, however, be attached by the surrounding concrete environment so that electrical potential differences may develop along the bars: electrochemical corrosion will then take place. The progression of deterioration of an element with time is described by; initial period and corrosion process period [2].

a) *The initial period* occurs in two different ways: carbonation of the concrete surrounding the reinforcement and presence of chloride.

The process of carbonation consists of several stages. First, gaseous, CO_2 penetrates the surfaces of concrete, generally through the capillary pores. Second the carbon dioxide reacts with the calcium hydroxide. As a result, the alkalinity of the concrete is lowered and the passivated can no longer be preserved, so that the corrosion of the reinforcement is then possible. This neutralization process continues as further CO_2 enters the pore system.

The mechanism of concrete carbonation is very similar with chloride ingress because the main factors of influence are the same. Main factors influencing carbonation and chloride ingress are: carbon dioxide and chloride concentration.

b) *Corrosion process period*

After disruption of the passivated layer-whether by carbonation or by chloride attack-corrosion of the reinforcing steel may occur, due to the presence of water and oxygen.

The corrosion products take up a considerably larger volume than the original iron (8 times), which may result in fracturing of the concrete by expansive pressure. Parallel cracks with reinforcing steel bars and spilling of the concrete cover will take place.

Chloride based salts provide serious risks for local pit corrosion of the bas when the chlorides reach the reinforcement.

In order to assess the service life of a member or a structure it is necessary to know the factors that affect it. Safety and durability of reinforced concrete structures are affected by the corrosion process, which leads to cross section degradation and also affects the steel-concrete bond [3,4].

2. Reinforcement Corrosion M by Use of Half-cell Potentiometer

Energy differences which appear in cross section of steel reinforcement because of the corrosion process can be quantified using the Half -cell potentiometer. Relative energy levels can be determined using a baseline electrode with a stable electrochemical potential. A high impedance voltmeter is connected between the baseline reinforcement and the reference electrode located on the tested concrete surface. The potential recordings at the voltmeter represents the electrical-energetically levels - the corrosion process - of the steel reinforcement nearby reference half-cell.

For a better accuracy of the test results, must be considered the following: an electrical bond with the steel reinforcement (if there are no reinforcements out of the concrete, at least one must be uncovered).
The testing process follows next steps [8], [9]:

1. Adding the concentrated $CuSO_4$ on the concrete surface, with a pre-wetting of the machine sponge and an appropriate packing with electrical contact solution.
2. Tracing a grid on the concrete surface and highlighting the hubs where are made the potential readings.
3. Connecting the reference cell to the baseline reinforcement.
4. Attaching the sponge to a network point.
5. Measuring a recording of the potential differences between reference cell and reinforcement.

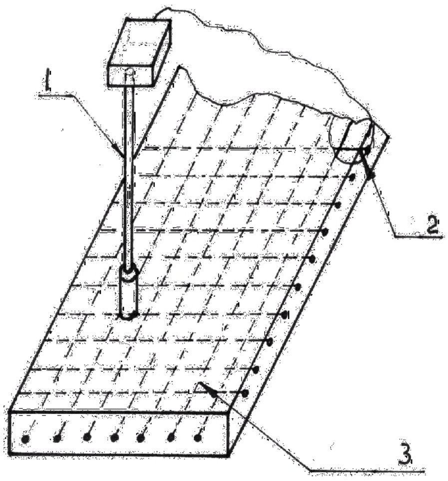
Using the same reference reinforcement, the steps 4 and 5 should be repeated for all the network hubs.

The tested concrete surface should be free of any insulation or asphalt materials in all the network hubs where the potential measurements will be made; the concrete has to be dried.

For an accurate determination the network mesh should be done having an eye dimension no greater than 2 m^2.

The half-cell potentiometer results are influenced by oxygen content of the reinforcement. If the out outcome potential measured is greater than 0.20V than there is no corrosion in the tested steel reinforcement. Possible obtained results when the test it is done:

1. Smaller potential (absolute value) than – 0.20V: 90% or a bigger probability of the corrosion absence in the cross section;
2. Potentials inside the [– 0.20V, – 0.35V] area: inconclusive;
3. Potentials greater (absolute values) than 0.35V: 90% or a bigger probability of corrosion existence in the cross section;
4. Potentials with positive values: not taken into account because indicates that the concrete is not dried enough.



1. Half -cell potentiometer; 2. Reference re-bar; 3. Tested element

Fig. 1. *Half -cell potential circuit*

2.1. Experimental Control Miniaturization of Reinforcement Corrosion

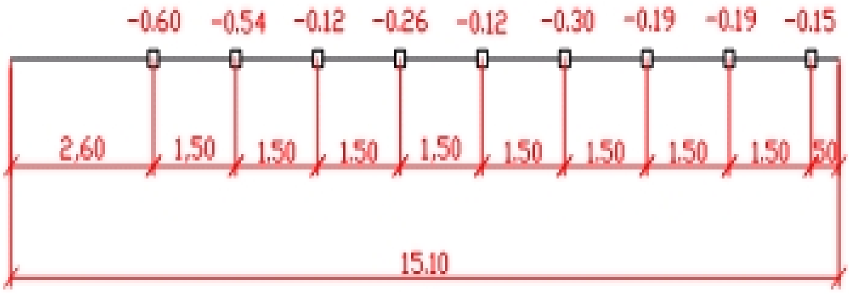
Two pre-stressed concrete beams (Fig.2) were tested to determine the corrosion stage of the reinforcement, using the Half - cell potentiometer – M.C. MILLER, made in New Jersey, SUA. The tested beams were placed in the yard of Civil Engineering Faculty of Timisoara, each beams have 15.1 meters length [5], [6].

(a) Half – cell potentiometer

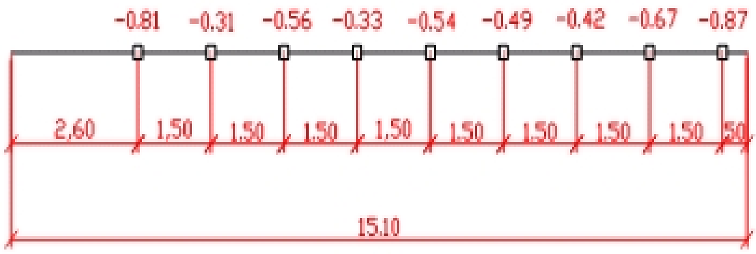
(b) Reference reinforcement

Fig. 2 (a, b). *Using a Half -cell potentiometer*

The chosen network for the determinations, in both cases, has the grid dimensions of 1.5 meters between the lines (fig. 3 (a), (b)). In the network hubs, $CuSO_4$ was applied with a bonding role. Each of the two beams has a pre-cleaned reinforced zone, considered as being the reference steel bar.



(a) Beam no.1: pre-stressed concrete



(b) Beam no.2: pre-stressed concrete

Fig. 3 (a, b). *Potentials obtained using a Half-cell potentiometer*

After the measurements were made, the following conclusions were drawn by the research team:

1) The pre-stressed concrete beam no.1, presents reinforcement corrosion to the left side, on a 5 meters zone.

2) The pre-stressed concrete beam no.2, presents reinforcement corrosion on the entire length, with increased defects towards beam's edges.

3) The Half -cell potentiometer can successfully be used for:

- identifying the risk of corrosion (process that it is not apparent at the surface);
- identifying the extent of corrosion (partially observable process at the surface of the concrete elements);
- assessing the integrity of a concrete structure which may have experienced corrosion [10].

4) The concrete functions as an electrolyte and the risk of corrosion of the reinforcement in the test region may be empirically related to the measured potential difference [10].

5) Measurement of the potentials & magnitude of corrosion current flow may enable assessment of existing & future corrosion behaviour to be made [10].

The obtained data are graphically represented in the Fig. 4.

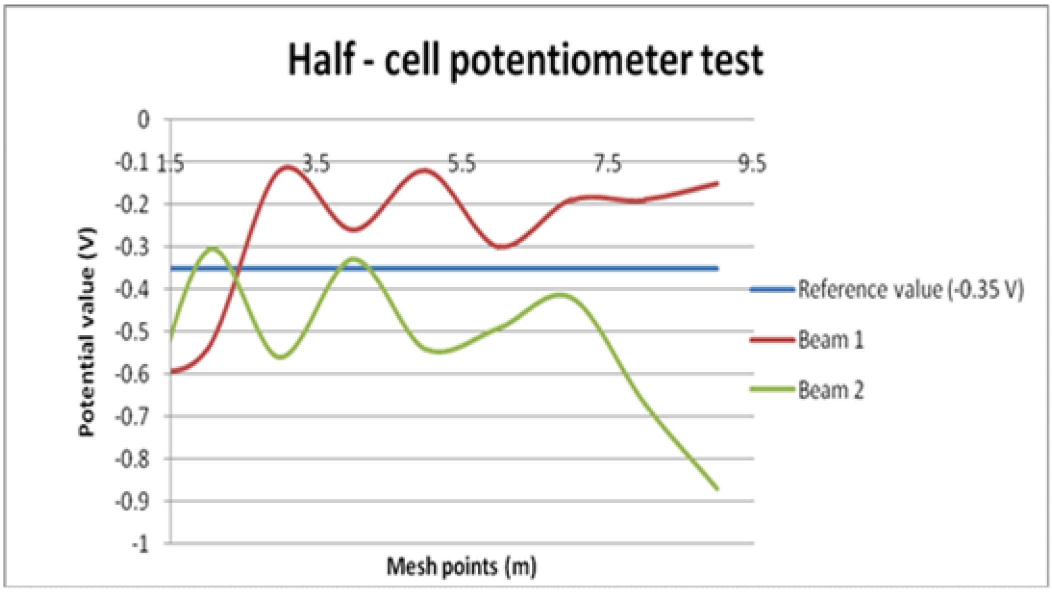


Fig. 4. *Beams corrosion results*

3. Conclusions

The main problem of steel reinforcement is their corrosion in time due to environmental conditions.

Corrosion of reinforcing steel and other embedded metals is the leading cause of deterioration in concrete. When steel corrodes, the resulting rust occupies a greater volume than the steel. This expansion creates tensile stresses in the concrete, which can eventually cause cracking and de-lamination[1]. This leads to a big economical issue. Non-destructive test will provide good and accurate information for choosing the suitable repearing method.

Knowing that corrosion it is an electrochemical process that it is produced by the flow of charges (electrons and ions), that being the case of reinforced concrete elements [1], the Half -cell potentiometer testing method, based on a detailed scanning of different electrical potential values obtained on areas tested on the both pre-stressed concrete beams tested, lead to the following observations:

1) The testing apparatus consists of half-cell, electrical junction device, electrical contact solution, voltmeter and electrical lead wires. Electrochemical Half – cell potentiometer test provides a relatively quick method of assessing reinforcement corrosion over a wide area without the need of wholesale removal of the concrete cover.

2) Quantitative measurements are made so that a structure can be monitored over a period of time and deterioration can be noted. Areas of usage include marine structures, bridge decks, and abutments and so on. [11]

3) The collected data reveals the fact that the second pre-stressed beam tested has an active corrosion in its steel reinforcement.

4) The measurements made using the Half – cell potentiometer can be performed in almost any exterior conditions, in a relative short time and the results obtained are very accurate if the concrete surface is well previously wet using $CuSO_4$ solution as a bond material.

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