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Studiu comparativ privind coroziunea în timp a electrozilor în sol, Partea 1 – Introducere

Comparative study regarding corrosion in time of the ground electrodes, Part 1 - Introduction

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Rezumat*:Obiectivul lucrării este de a prezenta, aspecte referitoare la: coroziunea metalelor acoperite şi neacoperite cu zinc în solul oraşului Timişoara (electrozi de împământare a Instalaţiei de Legare la Pamânt aferentă Instalaţiilor Electrice din Construcţii), analiza parametrilor de sol, prototipuri de electrozi, măsurători electrice, microbiologice şi analiza de prognoză-predicţie matematică, materiale şi dicţionare de termeni aferenţi. Un alt aspect prezentat în acest material este efectuarea de măsurători ale spectrului câmpului elecromagnetic oscilografiat al elementelor de metal acoperite şi neacoperite cu zinc din sol.*

Cuvinte cheie*: coroziune, electrod de împământare, sol, legare la pământ, microbiologia solului*

Abstract: *The objective of this paper is to present aspects related to: corrosion of metals covered, and not covered with zinc in the soil of Timişoara (grounding electrodes of a grounding installation related to Electrical Installations of Constructions), analysis of soil parameters, prototype electrodes, electrical, microbiological measurements and mathematical prognosis analysis-prediction, materials, and dictionaries of related terms. Another aspect presented in this material are the measurements related to the spectrum of the oscillograph electromagnetic field of the grounding electrodes, which are covered, and not covered with zinc.*

Key words*: corrosion, ground electrode, soil, grounding, soil microbiology*

1. Introduction

1.1 Corrosion regulations

National and international regulations in the field of earthing installations of electrical installations for constructions are known, but the problem is the corrosion (and not only) represents an important aspect to be researched and permanently topical. The simpliest corrosion definition is: [1] *The reaction between a material, usually a metal*, and the environment. In the U.S. Corrosion Society. respectively NACE International Technical Committees, constituted to reduce the loss of billions of dollars due to corrosion, activates the T-10 underground corrosion control committee with subcommittee G01.10, corrosion in soils. Thus, this subcommittee has developed several standards (recommendations) including: [2] G51-18 Standard test method for measuring the soil pH for use in corrosion testing; G57-06 (2012) Standard test method for measuring the soil resistance field using the Wenner method with four electrodes; G97-18 Standard test method for the laboratory evaluation of magnesium sacrifice anode test samples for underground applications; G158-98 (2016) Standard guide for three methods for evaluating buried steel tanks; G162-18 standard practice for performing and evaluating laboratory corrosion tests in soils; G165-99 (2017) Standard practice for determining rail-to-ground resistance; G187-18 Standard test method for measuring soil resistivity using the two-electrode ground box method; G200-09 (2014) Standard test method for measuring soil oxidation reduction potential (ORP); Standard guide G218-19 for external corrosion protection of ductile iron pipes using polyethylene coating supplemented with cathodic protection, etc. The Romanian norms related to corrosion also include the following documents: [3] Norm for the protection against corrosion of buried metal constructions Indicative I 14-76 replaces I 14-65. Chapter 9 Measurements on the ground and buried metal constructions; pct.9.1. In order to ensure the corrosion danger of buried metal constructions and to establish the appropriate corrosion protection measures, the following measurements shall be performed:

- determining the aggressiveness of the soil and groundwater, on the route of the buried metal construction;
- establishing the existence in the area of dispersion currents;
- performing measurements of the potential and intensity of the protection current in the buried metal construction;
- performing measurements on electric traction installations in direct current, according to STAS 833-72 “Requirements for reducing stray currents,,.

The measurement method must be chosen in such a way that through the auxiliary works (excavations for access to constructions, installation of electrodes, etc.), the natural state of the soil is modified as less as possible. Pct. 9.10.: The beneficiaries of buried metal constructions or of electric traction installations in direct current are obliged to keep a record of the values resulting from the measurements provided in art. 9.1 and 9.2. [4]

Protection of equipment and steel pipes against corrosion / Technical standard; Cap. XI, art. 263. In order to ensure the electrical safety of the pipes and related installations and to carry out the corrosion status determinations, the steel pipes belonging to SD and, as the case may be, outdoor installations for the use of natural gas made of steel shall be provided with: a) stations for measuring specific parameters (potential, current, resistance, etc.) which are mounted on the pipe in accordance with the technical regulations in effect; b) electrical insulating parts. Another important aspect is the corrosion rate and the corrosion of metallic elements covered and not covered with zinc under the influence of soil microorganisms.

2. Materials, equipment and measuring apparatus

Table 1

Materials, equipment and measuring apparatus

No.	
1	Sample of carbon steel of predetermined size, not covered with zinc layer
2	Sample of carbon steel coverd with a layer (default thickness *n*) of zinc
3	Sample of carbon steel coverd with a layer (default thickness *nx2*) of zinc
4	Electric conductor MYF-0.5mm^2
5	Apparatus for measuring the thickness of the coating on ferrous and non-ferrous materials
6	Measuring apparatus *FLUKE 287 True RMS Multimeter*
7	Temperature and humidity sensor for floor mounting
8	Above ground temperature and humidity sensor
9	Junction box
10	PVC tube of preset size
11	PVC Guaina copex flexible tube
12	Oscilloscope DSO-X 3054 A
13	Rectifier transformer
14	Wooden ruler
15	Wireless mode relay with remote control
16	Raspberry Pi microcontroller with HDMI port
17	Router
19	*Petri* plates
20	Microscope

21	Portable multichannel X-ray fluorescence analyzer - FRX, model Thermo Scientific NITON XL3t
22	Measuring apparatus *Metrel snuff ground*
23	Automatic colony counter Yul Flash & Go
24	Digital analyzer catv *Signal Analyzer Telemann 1730*

3. Soil characteristics and properties

The measurements were performed in the ground, in the city of Timişoara, Timiş County, Romania, with the following coordinates:

- Latitude: 45.7241;
- Longitude: 21.2339;
- Elevation: 88.

The soil lot on which the measurements related to the study of corrosion of metals coated and not covered with zinc, respectively of earthing electrodes, comprises an area of 48 m2 and is predominantly made of dusty clay according to the geotechnical study [5]. The main characteristics and properties of the soil with the above mentioned coordinates are presented in the Table *2÷6*:

Table 2

Soil characteristics, drilled depth, layer thickness

Characterization of the soil in the conformal layer SR EN ISO 14688-1 and SR EN ISO 14688-2	Stratification column	Drilled depth, layer thickness		Sample	
		Depth [m]	Thickness [m]	No.sample	Nozzle depth [m]
Vegetal soil		-0.30	-0.30		
Dusty, brown, hard clay		-0.70	-0.40	1N	-0.50
Dusty clay, sandy brown, plasticizer		-1.40	-0.70	2N	-1.20
Dusty clay, sandy black, plasticizer		-4.00	-2.60	3N	-2.00

Table 3

Characteristics of the soil column stratification, granularity

Characterization of the soil in the conformal layer SR EN ISO 14688-1 and SR EN ISO 14688-2	Stratification column	Granulosity		
		Sand 0.002...2 mm %	Dust 0.005...0.005mm %	Clay 0.005mm %
Vegetal soil		-	-	-
Dusty, brown, hard clay		21	52	27
Dusty clay, sandy brown, plasticizer		25	46	29
Dusty clay, sandy black, plasticizer		32	46	22

Table 4

Soil characteristics, volumetric weight, pore index, porosity, natural humidity

Characterization of the soil in the conformal layer SR EN ISO 14688-1 şi SR EN ISO 14688-2	Stratification column	Volumetric weight γ kN/mc	Pore indexe -	Porosity n %	Natural humidity w %
Vegetal Soil		-	-	-	-
Dusty, brown, hard clay		17.2	0.86	46.3	21.9
Dusty, sandy brown, plastic clay		17.7	0.84	45.6	23.8
Dusty, sandy, black, plastic clay		18.6	0.86	46.3	33.1

Table 5

Soil characteristics, lower and upper limit, index of plasticity and consistency

Characterization of the soil in the conformal layer SR EN ISO 14688-1 şi SR EN ISO 14688-2	Stratification column	Upper limit of plasticity W_L %	Lower limit of plasticity W_P %	Indix of plasticity I_P %	Indix of consistency I_C
Vegetal Soil		-	-	-	-
Dusty, brown, hard clay		42	23.5	18.5	1.09
Dusty, sandy brown, plastic clay		52.9	23.5	29.4	0.99
Dusty, sandy, black, plastic clay		47.4	29.3	18.1	0.79

Table 6

Soil characteristics, edometric mode, friction angle, specific cohesion

Characterization of the soil in the conformal layer SR EN ISO 14688-1 şi SR EN ISO 14688-2	Stratification column	Edometric mode M_{2-3} kPa	int. friction angl Φ grad	Specific cohesion c kPa
Vegetal Soil		-	-	-
Dusty, brown, hard clay		7937	21.7	33.9
Dusty, sandy brown, plastic clay		7407	15.7	16.9
Dusty, sandy, black, plastic clay		5333	23.3	8.1

The porosity of the soil n [%] between 45.6 ÷ 46.3 and the natural humidity w [%] between 21.9 ÷ 33.1, determine:

- Intense biological activity;
- Higher air capacity in the soil;
- The proportion between the soil pores determines and influences the relationship of the soil with water;
- Higher porosity implies higher permeability for water and air, so that air and aeration increase from clayey to sandy soil.

The IC Consistency Index of the soil from the lot on which the measurements were made, indicates a decrease (1.09 ÷ 0.75) over the area -0.70 ÷ -4m, so that the dusty clay, brown, hard, sandy brown, plastic and black sandy clay, has a structure that promotes water infiltration, retention and preservation. The IC Consistency Index justifies the forces that take place between the particles and the micro and macro aggregates in the soil implicitly the biologically intense activity. On the scale of 0.75 ÷ 1, the consistency of the clay soil is considered rigid, hard and compact and on the scale of 0.5 ÷ 0.75 the consistency of the clay soil is considered firm and stable. The specific cohesive strength of clay soil in [kPa] has a decrease from 33.9 ÷ 8.1 over the depth zone from -0.70 ÷ -4m, which justifies a higher presence of water percentage in the soil.

4. Photographic images with stages of prototype assembly for monitoring the corrosion of zinc coated and non-zinc coated metal elements

Table 7 presents the legend of the photo images and includes the following: the stage of drilling in the soil, the collection of soil samples and the assembly of metal samples covered and not covered with zinc in the soil for the study of corrosion.

Table 7

The legend of photographic images

Foto nr.	Legend
1	Equipment for drilling in the ground
2	Drilling operation in the ground with a drill
3	Dusty, sandy, black, plastic clay
4	Dusty, sandy brown, plastic clay Dusty, sandy, black, plastic clay
5	Soil test
6	Zinc coated and uncovered metal samples fitted with sensors
7	Installation of samples in the soil
8	Row of soil samples
9	Row of soil samples

Photographic images with stages of assembly of the metal samples (earthing electrodes) in soil and collection of soil samples for analysis

Fig. 1 Drilling equipment

Fig. 2 Drilling operation in the ground

Fig. 3 Dusty, sandy, black, plastic clay

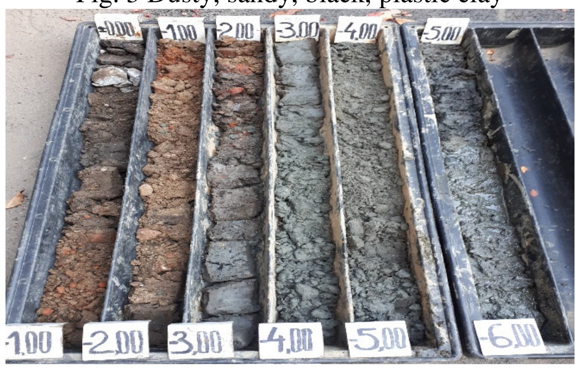

Fig. 4 Collected soil samples

Fig. 5 Non-galvanized and galvanized metal samples with senzors

Fig. 6 Installation of the samples in the soil

Fig. 7 The row of samples

Fig. 8 The row of samples

5. The metal analysis from soil

A pedological drill was used to take soil samples.

The analysis of the metals was performed with the portable multichannel X-ray fluorescence analyzer - FRX, Thermo Scientific NITON XL3t model.

The evaluation and interpretation of the obtained results was performed by reference to the reference values established for the soils of sensitive use, respectively Order 756/1997 for the approval of the Regulation on the assessment of environmental pollution with subsequent amendments and completions.

Table 9

Results of soil metal analysis

Determined chemical element	Sampling depth h= -1.5 m	Sampling depth h= -2.3 m	Alert limit cf Ord. 756 / 1997 actualized
Ca	17 ± 1 mg/kg s.u.	9 ± 1 mg/kg s.u.	-
K	9 ± 1 mg/kg s.u.	9 ± 1 mg/kg s.u.	-

Zn	287 ± 10 mg/kg s.u.	103 ± 10 mg/kg s.u.	300 mg/kg s.u.
Cu	48 ± 10 mg/kg s.u.	39 ± 10 mg/kg s.u.	100 mg/kg s.u.
Fe	35 ± 1 mg/kg s.u.	32 ± 1 mg/kg s.u.	-
Mn	860 ± 50 mg/kg s.u.	560 ± 50 mg/kg s.u.	1500 mg/kg s.u.
Zr	178 ± 5 mg/kg s.u.	224 ± 5 mg/kg s.u.	-
Sr	100 ± 3 mg/kg s.u.	96 ± 3 mg/kg s.u.	
Pb	48 ± 5 mg/kg s.u.	13 ± 4 mg/kg s.u.	50 mg/kg s.u.
As	4.4 ± 4 mg/kg s.u.	5 ± 3 mg/kg s.u.	15 mg/kg s.u.
Cr total	< 100 mg/kg s.u.	< 100 mg/kg s.u.	100 mg/kg s.u.
Ni	< 20 mg/kg s.u.	< 20 mg/kg s.u.	75 mg/kg s.u.

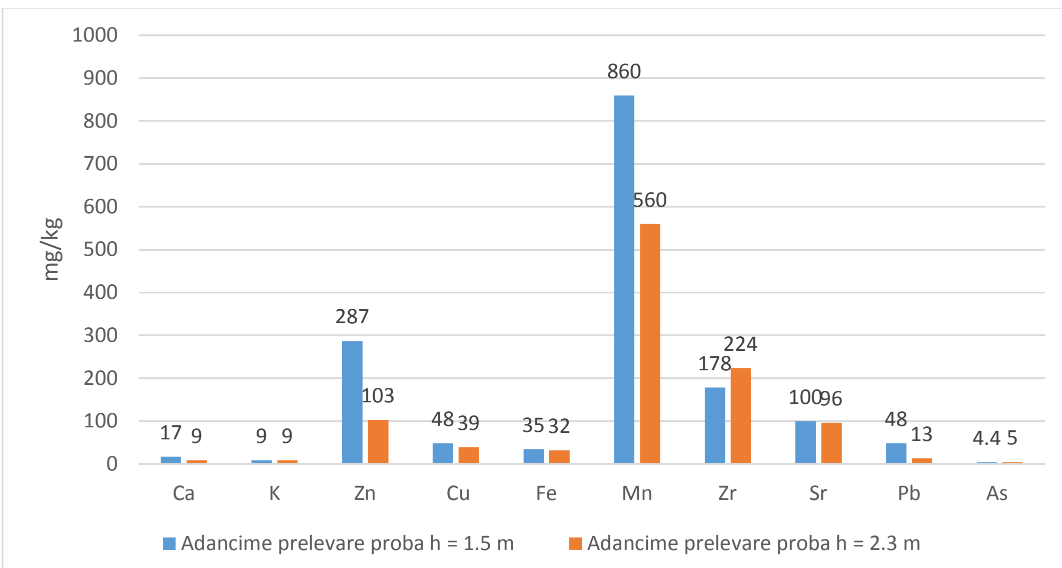

Fig. 9 The metals determined from the soil samples at 1.5 m and 2.3 m

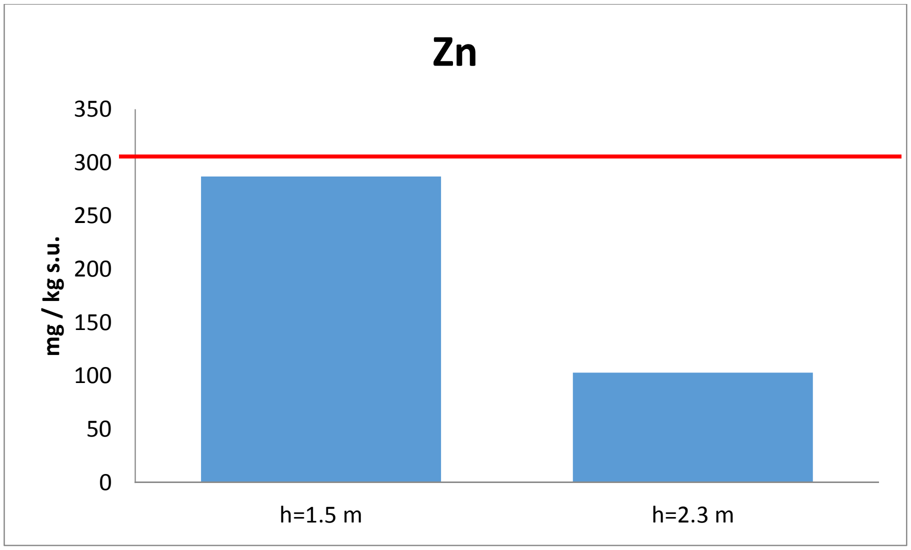

Fig. 10 Graphical representation of zinc in the soil samples

The analyzed element Zn, whose alert threshold, according to O 756/1997 is 300 mg / kg s.u, the value determined at a depth of 1.5 m is very close to this threshold value. This is justified by the fact that the soil is mixed with filler.

References

[1] https://www.asminternational.org/;
[2] https://www.astm.org/COMMIT/SUBCOMMIT/G0110.htm;
[3]https://www.academia.edu/9159953/NORMATIV_PENTRU_PROTEC%C5%A2IA_CONTRA_COROZIUNII_A_CONSTRUC%C5%A2IILOR_METALICE_%C3%8ENGROPATE_Indicativ_I_14-76_%C3%8Enlocuie%C5%9Fte_I_14-65;
[4]https://lege5.ro/Gratuit/gi4dgnbvgazq/protectia-echipamentelor-si-a-conductelor-din-otel-impotriva-coroziunii-norma-tehnica?dp=gi3damjwgqzdimi
[5] Analiza de sol conform fişei de foraj nr. 1 din 25.06.2018 eliberată de *S.C. CARA SRL, str.Filaret Barbu, nr. 2, codul poştal 300193, Timişoara]*