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METHODOLOGY REGARDING THE ASSESMENT IN TIME OF SOME CONCRETES MECHANICAL CHARACTERISTICS SUBJECTED ON DISSOLVING – LEVIGATION CORROSION

BY

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Abstract. The paper presents a methodology regarding the evaluatin in time of some concretes characteristics subjected to dissolving – levigation corrosion. The accelerated corrosion realization method, the utilised experimental program and the results of some mechanical testing effectuated on the samples subjected to this corrosion type are presented.

Key words: concrete; dissolving-levigation processes; mechanical characteristics.

1. Introduction

The last years produced important changes regarding the reinforced concrete structures design and realization.

Exclusively taking into account of the strengths and stability requirements in reinforced concrete elements and structures represents an outdated conception at international level, the behavior in time and buildings sustainability being more and more actual issues due to the multiple technical, economical, ecological etc. aspects, which this approach is generating.

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From the strength's point of view the concrete is characterized by its compression strength class, the other characteristics being linked by this characteristic. The concrete's class choosing is assessed tacking into account, for first the concrete elements and structures strength requirements.

In the last period many concerns at international level are existing regarding the establishing of the reinforced concrete structures degradation causes and processes and to adopt of a strategy on the treatment of these situations (CEB 183, 1992).

The researchers concern are focused on the describing of the deterioration processes, aiming to elaborate in this sense more or less simple models of the deterioration causes and mechanism and of the generating factors. Finally, by synthesizing of the fundamental knowledge and experience in concrete's sustainability, rules and recommendations can be enounced on the design, execution and maintenance (Neville, 2001).

In present, due to the complex nature of the ambient environment's effects on the concrete structure and their specific answer, the ensuring of a concrete building performance needs a construction materials improvement, corresponding design, correct execution and inspection and preventing measures for deterioration risks (Georgescu, 2001; Portand Cement Association, 2003).

In the case of the concrete elements supposed on soft or completely unhardened waters attack, the visible degradations are appearing after a long period of time, almost 20 years. In all this time, the dissolving – levigation processes of the calcium hydroxide from the cement stone produced important changes at microstructural level, allowing the corrosive agents infiltration in concrete's structure, that by specific mechanisms are leading to the concrete's matrix's deterioration.

If on this chemical attack the repeatedly frez – thaw effect is overlapping the appearing degradations are significant and can lead, due to the leak of some efficient structural rehabilitation measures, even to the exposed structures collapse (Ilinoiu, 2001).

Due to the relative great time period after, degradations in the concrete's structure are observed, when the corrosion processes are advanced and the rehabilitation solutions are enough expensive, the study of this corrosion type on some concrete's characteristics appeared as a necessity.

2. Methodology Regarding the Evolution in Time of Some Mechanical Characteristics of the Concretes Supposed on Dissolving – Levigation Corrosion

Studying the evolution in time of some concrete's mechanical characteristics subjcted on dissolving – levigation corrosion, for example strength decreasing or permeability modification can be appreciated for a long term.

To realize a database for this evaluation an apprehension of a dissolving – levigation corrosion's acceleration method was necessary. This method is reproducing the temperature, humidity and chemical composition of the water that is actioning on some of the cooling towers type structures.

The methodology regarding the evolution in time of some mechanical characteristics of the concretes subjected on dissolving – levigation corrosion involves the following steps:

2.1. Establishing of the Accelerated Corrosion Method Achievement

The method presented in this paper suppose to maintain of some concrete samples into a steaming chamber, where are supjected to the dissolving – levigation corrosion. By this way the concrete was supposed on dissolving – levigation attack under an action of a soft water liquid phase (soft water) and a high temperature.

At significant time periods (3, 6, 12, 18, 24, 30, 36 months) the samples are subjected to some determination to study the variation in time of some characteristics. These are referring to volumic mass, permeability and compression strengths determinations.

2.2. Experimental Program's Describing

Utilized materials:

Aiming to reproduce as real the situations that are met in practice and as a consequence of some preliminary studies, it was choose to realize a study to observe the control of the behaviour in time of a concrete having the following composition presented in Table 1.

Table 1
Recipe for 1 m^3 of Concrete

Mixture	Cement	Water	Aggregate 1982 kg						
			0...0.25	0.25...0.5	0.5...1	1...2	2...4	4...8	8...16
	260	130	160	240	240	201	279	392	470

The concrete mixture was realized according to the actual standards requirements (NE 012-1:2007; NE 012/2-2010; SR EN 206-1/2014), respecting the quality conditions for the component materials.

a. Cement

A CEM I 42,5 R type was utilized.

The CEM I 42,5 R represents a Portland cement with high initial strength. The main constituents are the Portland clinkers (K) (95,...,100%) and the minor constituents (0,...,5%) (SR EN 197-1/2011).

b. Mineral aggregates

An washed and sorted pit aggregate was used. The heavy weight aggregates used to the concretes preparation perform operations and analysis to determine the quality requirements an the main characteristics according to the SFS-EN 12620:2003 Standard.

c. No additives were used for concrete's preparation.

d. The water that is introduced in the mixtures is potable water according to the SFS-EN 1008 Standard's requirements.

2.3. Preparation Steps of the Concrete

The cement's and aggregates sorts dosages were realized by weighting and for the water was effectuated by a volumetric dosage (gradated cylinder).

In the concrete mixer the granular and powder materials were introduced one at a time performing a dry mixing followed by the water's adding and by a remixing to realize of a required homogeneity.

2.4. Fresh Concrete Testing

a. Workability determination

The workability testings were realized on the fresh concrete by the slump test.

According to this method the slump is given by the difference between the tronconic vessel's heights (h_{initial}) and the slumped concrete's bulk's heights (h_{final}).

The slump:

$$t = h_{\text{initial}} - h_{\text{final}}, \text{ [mm]}. \quad (1)$$

For the realized mixture a 120 mm slump was obtained, corresponding to a S3 slump class (according to NE 012: 2007).

b. Determination of the fresh concrete's volumic mass

The fresh concrete's volumic mass was determined.

The moulds were weighted by an 0.1 accuracy electronic scale and than filled with concrete and compacted on the vibration table. There were reweighted after the corresponding compacting.

The volumic mass is computed with the formula:

$$\rho = \frac{m_{\text{filledmould}} - m_{\text{emptymould}}}{V_{\text{mould}}}, \text{ [kg/m}^3\text{]}. \quad (2)$$

The results are synthetized in Table2.

Table 2
Determination of the Fresh Concrete's Volumic Mass

Sample	Mould's volume cm^3	Mould's mass		Volumic mass kg/m^3
		Empty, [g]	Filled, [g]	
1	8,520	2,863	8,526.7	2,344
2	8,523	2,863	8,529.8	2,375
3	8,518	2,863	8,524.6	2,305
4	8,524	2,863	8,531.0	2,445
5	8,520	2,863	8,526.9	2,400
6	8,519	2,863	8,525.4	2,235
Average				2,350

2.5. Samples manufacturing

Metallic moulds having a 142 mm side were used that were greased with Decofrol.

The moulds were filled with concrete, followed by compacting on the vibrating table.

Each series is composed by a 6 samples number, totally being manufactured 42 probes.

Finally the concrete moulds were labeled, mentioning the preparation date and the concrete mixture type.

After 24 hours the concrete cubes were demoulded and were introduced in a water tank at a 20ºC temperature, where were maintained for 28 days.

A samples series were considered as witnesses, the other were introduced into the steaming device.

2.6. Steaming Device's Description

The device is composed by a cylindrical reservoir type chamber made of steel sheet treated at the interior by primer and painting.

The device's dimensions allow disposing the samples on three grills made of welded mesh.

On the lateral wall, at a half of the heights a visiting door is provided that allows an easy access to the three equidistance grills were the samples are disposed. The device is realizing a continuous pulverisation on the sample's surface of a water or steam jet function of the selected temperature.

The water is continuously recirculated being taken at the inferior part of the chamber added by an aspiration pump and sent through an exterior circuit (rubber hose) to the superior part of the device. From there, by a extremely fine pulverisation system it is dispersed in the interior, all the samples coming into contact with the water, respective with the steam. The water's heating is realized by a resistance fixed in the interior in the collecting water tank's area. The device has a thermostat which allows setting the desired temperature, 65ºC in this case.

In the water tank's area there is a temperature sensor that is actioning the thermostat, so the resistance comes into operation automatically to maintain the water at the desire temperature.

The operating of the entire device is automatic being controlled by an electronic system (control panel) because the continuous working regime made impossible its permanent surveillance by an operator.

The water used in this experimental study represents an unhardened soft water that has almost the same chemical composition with the water utilized in the cooling towers.

2.7. Mechanical Testing

At the default testing terms 3, 6, 9, 12, 24 and 36 months the concrete samples were take of from the steaming device and determinations of the volumic mass, permeability and compression strength were effectuated, those being parameters taken into account for studying the behaviour in time of the designed concrete mixture.

a. Determination of the hardened concrete volumic mass

It is necessary verify the series homogeneity. If on samples from the same series are obtained much different values it can be concluded that a series unhomogeneity exists due to some samples preparation deficiencies.

The concrete samples were dried at constant mass in an oven.

The concrete samples were measured with the vernier calipper and weighted on a electronic scale to obtain a superior accuracy. The volume of each sample was computed.

The volumic mass is determibed with the following formula:

$$\rho = \frac{m}{V}, \ [\text{kg/m}^3], \tag{3}$$

where: m is the samples mass in dry at constant mass state; V – volume of the sample computed by the dimensions

$$V = a \times b \times c, \tag{4}$$

The results are presented in Table 3.

Table 3

Volumic mass kg/m^3	Testing terms (months)						
	0	3	6	9	12	24	36
	2,380	2,380	2,378	2,375	2,374	2,372	2,370

b. Determination of the water permeability

The hardened concrete permeability is expressed by the impermeability degree.

The impermeability degree (P_n^x) represents the water pressure (*n* expressed in barrs) when it is penetrating the concrete structure on at most a maxim allowed depth (*x*, in cm).

The impermeability classes are: P_4 ; P_8 ; P_{10}.

Supplementary, for the hydrotechnical concretes the P_2; P_6; P_{10}; P_{16} classes are added.

The testing for the impermeability degree determination are execute on cubic or cylindrical concrete samples after at least 28 days from the preparation moment (SR EN 12390-8:2005).

The testing is effectuated with a device called permeabilimeter. The samples are strongly fixed with rubber gaskets on the device's cells and subjected to the water action that is exerciting a 2 barrs pressure in the first 48 hours. The water pressure is increasing according to the impermeability scale at each 24 hours.

On the entire time of the testing the upper face of the sample is analyzed to observe that wetting spots are appearing. In the case when the prescribed pressure was reached and maintained for 24 hours without the appearing on the opposite face to the water pressure exerciting due to the wetting, the sample will be splitted by its heights and the distance *X* of the wet zone is measured. If it is less than the allowed limit the imposed impermeability class is realized.

For this case the P_8^{10} class was imposed.

The results are presented in Table 3.

Table 4

Water penetration depth	Testing terms (months)						
	0	3	6	9	12	24	36
	10.3	–	–	10.1	–	10.1	10.1

c. Determination of the compression strength

In this experimental program cubic samples having 142 mm sides were subjected to compression testing.

The testing was realized with a hydraulic testing machine determining the load that is determining the samples destroying (STAS 1275-88).

The computing formula is:

$$R_c = \frac{F}{A}, \text{[N/mm}^2\text{]}, \quad (3)$$

where: *F* is the fracture load, [N]; *A* – fracture area, [mm^2].

Table 5
Centralizated Results

Compression strength	Testing terms (months)						
	0	3	6	9	12	24	36
	32.5	31.6	31.2	29.6	25.5	24.7	24.4

3. Interpretation of the Results Obtained from the Experimental Program

Analyzing the obtained results from the compression strength determination a slow decrease of the value in the first 9 months from 32.5 N/mm^2 to 29.6 N/mm^2 can be noticed (Fig. 1). Then, a more accentuated strength decrease is occurring as a result of the calcium hydroxide from the cement stone dissolving. After this moment the obtained values are showing a decrease tendency of the compression strength, but more slow, that might mean to reach an equilibrium between the two phases, respectively the dissolving and levigation of the calcium hydroxide.

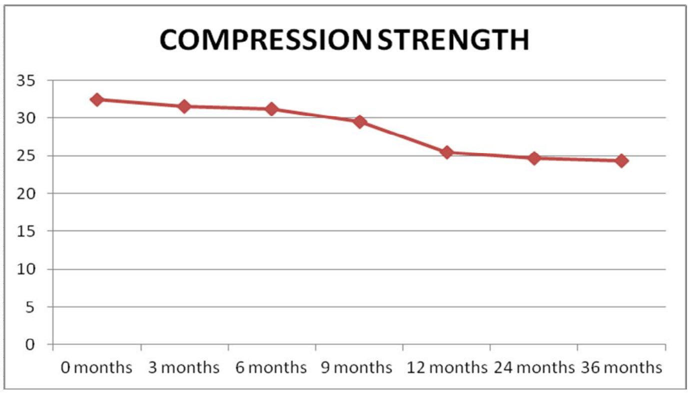

Fig. 1 – Compression strength

In the case of permeability's determination can be observed a small modification during the 36 months, respectively the 10.3 value for the witnesses samples and than 9, 24 and 36 months the 10.1 cm value (Fig. 2). These results are leading to the idea that the levigation is less than was anticipated and the dissolved calcium hydroxideis not entirely removed from the exterior of the samples.

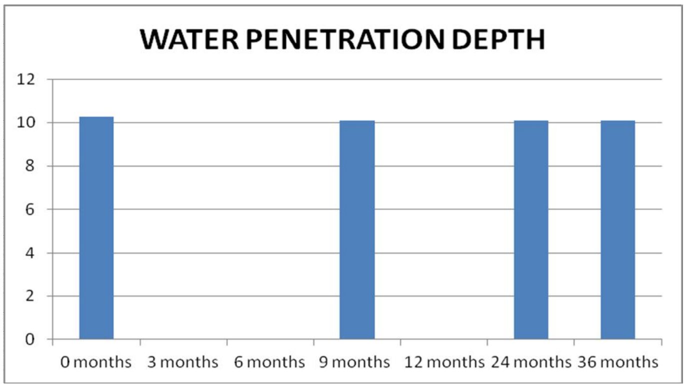

Fig. 2 – Water penetration depth.

From the modification of the volumic mass point of view, can be noticed that in the first three month no mass loss is registered as a consequence of the subjecting of the samples to corrosion, at 9 month can be observed a significantly reduced value (Fig. 3). The slowly decrease tendency of the volumic mass is kept to the end of the testing, respectively 36 months.

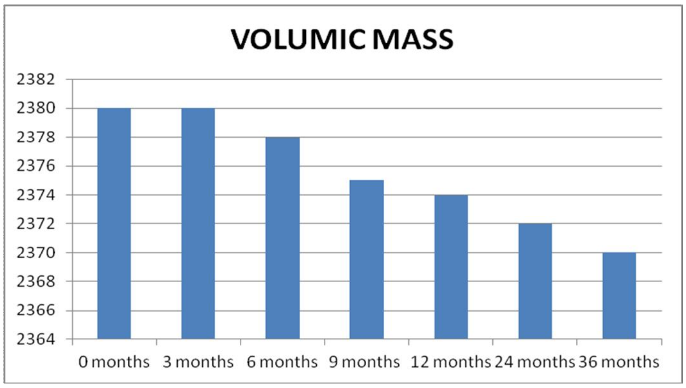

Fig. 3 – Volumic mass.

5. Conclusions

The methodology presented in this paper represents an util instrument for the appreciation og the concretes that are subjected to disolving – levigation corrosion in time behavior. Becase the modiffiations that are appearing in the concretes structure are occuring *in situ*, this method of accelerated corrosion realisation cancontribute to the evaluation of strenghth and permeability modiffications in a more reduced time, so to realize more resistant to this atack type concretes mixtures.

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METODOLOGIE PRIVIND EVALUAREA ÎN TIMP A UNOR CARACTERISTICI ALE BETOANELOR SUPUSE LA COROZIUNE PRIN DIZOLVARE-LEVIGARE

(Rezumat)

Se prezintă o metodologie privind evaluarea în timp a unor caracteristici ale betoanelor supuse la coroziune prin dizolvare-levigare. Sunt descrise metoda de realizare a coroziunii accelerate, programul experimental utilizat şi sunt prezentate rezultatele unor încercări mecanice efectuate pe probele supuse acestui tip de atac coroziv.