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HUMIDITY DETERMINATION IN CONCRETE BY USING THE DIELECTRIC METHOD

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ABSTRACT

The presence of humidity in the building envelope elements decays their structural and technological properties, favours heat losses and, in time, also the deterioration and degradation of the building.
In order to avoid of these aspects it is necessary to know and to mantain under control the level of humidity at the construction materials, in the process of making as well as during their exploitation; it is also necessary to be familiar with the transport phenomena of the humidity in the respective materialş, thirdly it is also obligatory to monitor the space-temporary movement of the humidity front.
This article analyses an electric-dielectric method, which besides the fact that it shows, measures and monitorises the level of humidity in the construction elements, also helps to appreciate the efficiency of some surface protection systems in concordance with the german guide regarding the protection and repairing of the concrete elements.

KEYWORDS: permitivity, dielectric method

1. INTRODUCTION

To determine the effective moisture of the materials and closing elements of a building there were developed some methods like such as:
-Gravimetric method, which makes the difference between the harvesting stage and the dry stage, by weighing;
-Steam determination by balancing pression, based on the connection between the steam pression inside the pores of a material and the partial pression of the air steam, in an indoor location placed near the material, in the moment of the balancing stage;
-Electric methods, based on the electric conductivity of the material or its electric capacity;
-Thermical conduction methods, based on the equilibrium temperature of a metallic wire electrical led;
-Electromagnetic radiations gamma methods, based on radiation diminuation;
-Neutron corpuscular radiation methods, based on diminuation of the thermical neutrons which routes a well known thickness from the material.

Over the years, the researchers tried to provide methods and ways to measure the moisture content in a less destructive way. With all the efforts, the hunanimous opinion is that there is not yet an instrument with a precise accuracy on moisture determination with a reductive way of destructivity, independent of the chemical and structural parameters of the element, with continuos character, repeating on researched area, to provide safety, speed and the posibility in situ appliance.

One of the methods which determines not only the electric permitivity of the complex way of the moist material, but much also solves the problem of the unknown variable composition of the tri-phase mixing solid-water-air, considering also the influence of the salt and the temperature over the dielectric properties of the moist material is the dielectric one.

Compared to the moisture determination by gravimetric classical methods, the dielectric one offers more precision.

2. MEASURING METHOD

The Measuring method is based on the reflection of a high-frequency wave on a coaxial conductor free end, generally, dependent on the dielectric methods of the adiacent material.[1]

For measuring of the reflection coefficient of the liquid and solid substances, we can use an experimental device made from:

◊ a high-frequency generator (width 1 MHz-2080 MHz);

◊ a bidirectional couplor for partial split of the reflected and incidence wave;

◊ a vectorial volt-meter, used to measure the reflection coefficient;

◊ high-frequency conductors between the individual components;

◊ measure probe for which it is necessary to know the electro-technical behaviour.

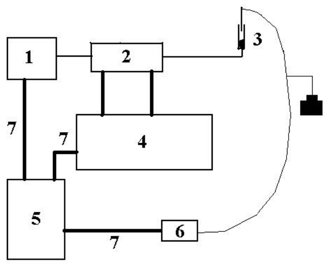

Fig. 1. Block diagram of the humidity measuring device using dielectric method
1 - high frequency generator (frequency width 1 Mhz-2080 Mhz); 2 - bidirectional coupler for partial separation of the incident wave to the reflected wave; 3 - transmitter; 4 - vectorial voltmeter for reflex coefficient measurement; 5-PC; 6 - digital voltmeter; 7 - high frequency conductors

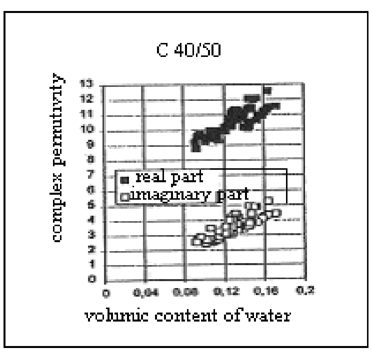

Fig.2 Complex Permitivity of the concrete C40/50, determined at 200 MHz frequency, in function of the gravimetric determined volumic content of humidity

To proceed with the measure, but also for calibration, it was realised a soft with adequate application on PC.

As far as we know the moist materials have some losses on conductivity, that is why we need to insert an additional conductivity, in the equivalent circuit diagram of the probe, in the same way with capacity.

Forschungszentrum Karlsruhe [2] realised a practical experimental ensemble, made for diminuation environments, using a circular probe of guidance of the wave having electro-tehnical known properties.

Because of the fact that most building materials are porous, there was built a special probe using an internal and an external coaxial conductor.

The calibration of this device was realised using different calibration liquids, with different values of the complex electric permeability, over which there been made some accurate measures with the probe.

To analyse the dielectric behavior of the heterogenous mixing there were elaborated some laws, like the Boettcher’s, Maxwell’s Bruggerman-Niesel’s and Looyenga’s.

To apply this method, the Loor model has been used [2]:

$$\varepsilon_m = \varepsilon_b + \sum_{i=1}^{3} \frac{V_i}{3}\left(\varepsilon_i - \varepsilon_b\right) \sum_{j=1}^{3} \frac{1}{1 + A_j\left(\frac{\varepsilon_i}{\varepsilon^*} - 1\right)} \quad (1)$$

where:

ε_m –complex permitivity of the mix

ε_b –complex permitivity of the solid (concrete, stone, etc.)

ε_i - complex permitivity of the inclusions (water, air)

V_i-inclusions volume

ε^*-relative electric permitivity effective near the edges

A_j-elipsoid factors of depolarization.

From the measures applied on different frequences, we obtain an equation system, and by choosing a high frequency width and frequency increment in this interval, we can determine the moist in porous materials. We need to mention the fact that the used frequencies in this method are between 100 and 500 MHz, ranging in speed in steps of 50 to 50 Mhz.

2. EXPERIMENTAL RESULTS

The measures were realised on concrete specimens with different porous structures, of different classes like C20/25, C 30/37,C 40/50 on a number of 15 styles.

At concrete preparation aggregates have been used grains at a maximum length of 16 mm and a granulosity curve constantly growing, water and concrete content being different.

For concrete classes C20/25 and C30/37 preparation we used CEM I 32,5R cement type, and for C40/50 we used CEM I 42,5R.

For salt influence evaluation over the dielectric properties of the moist material, other

series of specimens from concrete of class C30/37 was used.
Concrete's used characteristics are in Table 1:

Table.1

	Water/ Cement	Resistance Class [N/mm^2]	Density [g/cm^3]	Porousi ty
C20/25	0,60	35,25	2,263	0,147
C30/37	0,50	41,10	2,253	0,152
C40/50	0,42	50,51	2,213	0,160

To obtain results as close to reality as we can, we took some measures, such as :

-after mould release, the specimens have been packed in plastic foils to avoid concrete getting dry;

-the specimens have been stored in a climatic chamber for 28 days;

-initial storage has been made at a 20^{0}C temperature;

-after 28 days, the specimens have been stored in climatic compounds, in which were simulated different constant conditions of environment, for 360 days as:

1.Keeping conditions A (samples 1-3), in sorption inside at 66,0% relative humidity.

2.Keeping conditions B (samples 4-6), in sorption inside at 75,5% relative humidity.

3.Keeping conditions C (samples 7-9), in sorption inside at 86,0% relative humidity.

4.Keeping conditions D (samples 10-12), in sorption inside at 97,0% relative humidity.

5.Keeping conditions E (samples 13-15), in water, saturation level.

After 360 days, we reached the balancing humidity level of the concrete.

3. HUMIDITY MEASUREMENT

Because of the fact that there were more keeping conditions of the specimens, the dielectric properties have been measured on each sample lot, using surface probe. To eliminate measuring errors because of the air presence between sample and probe, the measures have been made on the inferior plan of the cylindric specimen made from concrete.

After the measuring using the dielectric method of the specimen humidity,its absolute humidity was determined gravimetrically also (by drying at 105^{0}C). Absolute humidity can be calculated through the next relation:

$$u_m = \frac{m_{ud} - m_{uscat}}{m_{uscat}} \cdot 100 \text{ [\%]} \qquad (2)$$

where:

u_m- mass moist containing [%]

m_{ud}-mass of the moist sample [g]

m_{uscat}-mass of the dry sample [g]

We can determine the mass content of humidity using the sample density as well, by using the equation:

$$u_v = u_m \cdot \frac{\rho_{uscat}}{\rho_a} \text{ [\%]} \qquad (3)$$

where:

u_v-humidity containing volume [%]

ρ_{uscat}-dry material density [g/cm^3]

ρ_a-water density [g/cm^3]

To calculate complex permitivity of the dry concrete we used [1] relation, obtaining the following results:

Table.2

	ε_b
C20/25	5,240-0,038 i
C30/37	5,437-0,051 i
C40/50	5,695-0,073 i

High values of permitivity are influenced because of the water chemical related to hydration products of the cement just like the physically related water which could not be eliminated during the dry out at 105^{0}C.

Because of the fact that the concrete has a porous structure caused by the cement paste, the dielectric behavior is different compared to other building materials. Reaction products generated during the cement hydration process it's not a compact mass, these being made from the hydrated cement gel, which contains a pours system with the diameter between 10^{-5}-10^{-7}mm. Water from the gel pours is losing its characteristic of free water and under the effect of the high superficial forces field whish occurs at the interface with the hydrated cement paste, its move in the alternative electro-magnetic field becomes more difficult.

Volume proportion of the capilar pores and gel pores is calculated in function of the hydrated degree and the rapport water/cement. For the concrete types considered in this experiment, values are given in the following table :

Tabel 3

	Capilar Pores	Gel pores
C20/25	26%	74%
C30/37	17%	83%
C40/50	8%	92%

Because of the high volume of pores from the cement gel, dielectric model of the tri-phase mixture has been extended to include the 4th phase, physically related water, making a necessary the knowledge of the physically related water permeability to ε_{af}=40-10 i. We noticed that there is a good agreement between the gravimetric determinated values of the humidity and the ones obtained by dielectric mode, processing a too low humidity calculated value , the results being given in Fig.3

To elucidate the way in which the ions concentration from the gel pores liquid influences over the dielectric properties, we made measurements with the circular probe over the water from the keeping compound of the specimens, as well as over the normal water from the tap. The results showed that in fresh water salt is $0,4\,^{0}/_{00}$ [g/l], while in the keeping water, using concrete salt, the concentration is $5\,^{0}/_{00}$ [g/l].

We can reach the conclusion that the complex permetivity value modifying the physically related water from ε_{af}=40-10 i. to ε_{af}=35-5 i has satisfying results, however we noticed a growth of the salt ions concentration once the concrete humidity value is getting lower (4 Fig.)

4. SALT INFLUENCE

After 28 days, the second specimens series out of concrete class C30/37 was introduced in a NaCl solution of concentration $57\,^{0}/_{00}$, for 3 weeks. After this treatment, the specimens have been preserved in the ways we have shown before.

The dielectric measurements were the same as the gravimetric ones, despite the salt influence, resulting for the physically related water ε_{af}=40-10 i. This is because the small diffusion transport of the salt ions from the solution inside the porous structure of the concrete during the 3 weeks, but also because of the salt influence concentration which is small compared to the ions quantity dissolved in the liquid from the concrete pores.

By statistical analyisis, this method is used by a Gauss distribution, the evaluation being made by determining the deviation D_u, following the following relation :

$$u_u = \frac{u_{măăsura} - u_{calc}}{u_{măăsura}} \cdot 100\% \qquad (4)$$

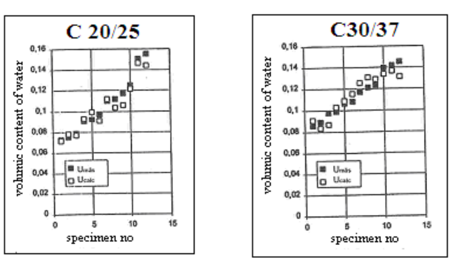

Fig.3 Volumic humidity values determined by dielectric and gravimetric ways

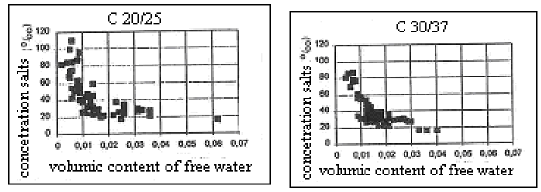

Fig. 4 Salt Concentration function of the volumic content of free water

5.CONCLUSIONS

After the realised researches there was created an experimental ensemble for monitoring the humidity in situ. For this purpose we used a probe built by Neue (3), made of a condenser with spreading field, whose fittings are made from 4 segments.

To obtain the best results, the segments can be pressed pneumatically on the hole surface elimating the air between the fitting and the building material.

Thermical effects can be considered by making temperature measurements with the help of a temperature sensor, attached to one of the fitting's segment.

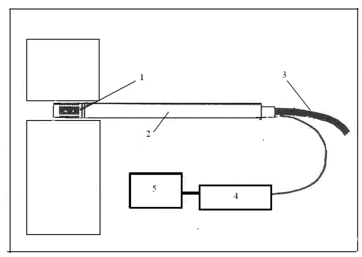

Fig.5 Experimental ensemble designed for monitoring in situ humidity 1 - electrode segment; 2 – probe; 3 - coaxial cable; 4- compressor; 5 – PC.

The probe gets into position, we initiate the series of measurements at different frequencies, but also the probe position must be all the time monitored and controlled by a computer.

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