NATIONAL BUREAU OF STANDARDS REPORT

8152

DETERMINATION OF MOISTURE IN REFRACTORY CONCRETES

by

K. D. Nekrasov, A. E. Fedorov, and V. I. Yastrubinskiy

Research Institute for Reinforced Concrete

of the Academy of Structures and Architecture of USSR

translated from

Ogneupory

v. 28, n. 6, 1963, p. 276-278

by

D. Watstein, NBS

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U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

U. S. DEPARTMENT OF COMMERCE
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The results of the Bureau's research are published either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three periodicals available from the Government Printing Office: The Journal of Research, published in four separate sections, presents complete scientific and technical papers; the Technical News Bulletin presents summary and preliminary reports on work in progress; and Central Radio Propagation Laboratory Ionospheric Predictions provides data for determining the best frequencies to use for radio communications throughout the world. There are also seven series of nonperiodical publications: Monographs, Applied Mathematics Series, Handbooks, Miscellaneous Publications, Technical Notes, Commercial Standards, and Simplified Practice Recommendations.

A complete listing of the Bureau's publications can be found in National Bureau of Standards Circular 460, Publications of the National Bureau of Standards, 1901 to June 1947 ($1.25), and the Supplement to National Bureau of Standards Circular 460, July 1947 to June 1957 ($1.50), and Miscellaneous Publication 240, July 1957 to June 1960 (includes Titles of Papers Published in Outside Journals 1950 to 1959) ($2.25); available from the Superintendent of Documents, Government Printing Office, Washington, D.C., 20402.

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Up to the present time there has been no development of an optimum method of drying and preheating of newly constructed furnaces and other installations constructed of refractory concrete. The control and adjustment of the heating procedure have been delayed because of the absence of apparatus for continuous determination of moisture content at various sections throughout the thickness of the concrete at elevated temperatures.

In the laboratory for refractory concretes of the Scientific Research Institute for Reinforced Concrete of the Academy of Structures and Architecture of USSR, an apparatus was developed for the continuous determination of moisture in refractory concrete during the drying process by measuring the electrical conductivity of sensors embedded in concrete.

The apparatus is intended for studying the kinetics of removal of moisture from concrete, establishing the optimum regime of drying, and also the control and adjustment under industrial conditions of the regime of drying and heating of thermal installations built of refractory concrete.

The method of determination of moisture of materials by the change of electrical conductivity is fairly widely used. However, the existing methods and available devices cannot be used for measuring the moisture at various sections of refractory concretes through their thickness during the drying process.

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* Translated from the Russian <u>Opredelenie vlazhnosti zharostoikikh betonov</u>. K. D. Fedorov and V. I. Iastrubinskii. Ogneupory. v. 28, no. 6, 1963, p. 276-278, by D. Watstein.

The method proposed by the authors permits the measurement of moisture in concrete by means of electrical gages. The small dimensions of the gages permit us to measure the moisture even in thin-wall constructions without affecting their strength. The apparatus can measure the moisture of concrete at a temperature up to 200°C. The precision of measurement of the moisture is ± 0.3%.

The device consists of a gage embedded in concrete, a megohmeter of type M-101 and connecting leads. The sensor consists of a prism of refractory concrete with dimensions of 20 x 20 x 70 mm with steel foil electrodes, with an area of 10 x 50 mm and a thickness of 0.5-0.7 mm attached to two opposing longitudinal edges (Figure 1).

The composition of the mortar for preparation of the sensor is as follows: 8 parts by weight of a water glass with a density of 1.38 grams per cc, 1 part by weight of sodium fluorosilicate, 8 parts by weight of finely ground grog, and 25 parts by weight of an 0-2.5 mm fraction of grog. This composition of the mortar aids rapid development of moisture equilibrium by the sensor and the concrete.

In the preparation of sensor prisms, 70 x 70 x 210 mm blocks are cast. After they harden in air over a period of 3 days at 18 ± 3°C the required prisms are cut from the larger blocks and are fired at 700°C for one hour.

After cooling, electrodes are mounted using a cement of the following composition: 10 parts by weight of water glass with a density of 1.38 grams per cc, 0.8 parts by weight of sodium fluorosilicate and 15 parts by weight of finely ground grog. The materials used in the preparation of the refractory mortar and cement must meet the requirements of the applicable specifications.

The faces of the prism on which the electrodes are mounted must be parallel. Deviations must not exceed 0 ± 0.3 mm. Before mounting, the steel foil is carefully cleaned and is heated. The electrodes must be mounted opposite each other and the thickness of the cement must not exceed 0.2 mm.

After aging for one day, the sensors are heated for 24 hours at 200°C in order to raise the reistance of the cement to moisture. Then the electrodes are soldered to leads with a cross section of 0.5 mm^2 having vinyl chloride insulation.

In order to measure the moisture and the temperature during the drying process as a function of thickness of the concrete, several sensors are embedded along with thermocouples. The sensors are attached to megohmeters and the thermocouples to potentiometers through a switching device.

The electrical resistance of the sensors in the concrete is inversely related to the moisture in the concrete. The device must receive preliminary calibration using a definite type of refractory concrete. The calibration must be carried out at 15° - 20°C and at the drying temperatures.

In order to determine the relationship between the moisture of the concrete and the electrical resistance of the sensors at normal temperature we prepared, from the refractory concrete, 10 specimens with dimensions of 50 x 50 x 100 mm; the sensors were embedded in the specimens. After hardening, the specimens were stored in the laboratory at 15° to 20°C, and were weighed daily and at the same time the electrical resistance of the sensors was measured. The curve 1 shown in Figure 2, is based on these data.

After the weight of the specimens and the electrical resistance of the sensors became stable, they were dried in an oven for 24 hours at 200°C and were weighed after cooling. The moisture content of the specimens, W, %, was determined by the formula

$$W = \frac{P_1 - P_2}{P_2} \cdot 100,$$

where P_1 is the weight of the specimens in grams, and P_2 is the weight of the specimens dried at 200°C grams.

The calibration of the specimens at drying temperatures was carried out in the following manner: the specimens, with embedded sensors, after hardening were dried to various moisture contents with one percent moisture increment and were placed in special metallic containers with hermetic seals (Figure 3).

The hermetic containers are necessary for maintaining constant moisture of the system during the heating. The space between the walls of the container and the specimen was filled with an epoxy resin with a hardener, and the leads were brought outside between 2 rubber inserts.

After 24 hours following placement of the specimens in the containers, the electrical resistance at 15° - 20°C was measured and then the containers were placed in a drying oven where they were maintained at 50°C for a day; after which the electrical resistance was measured in the heated condition. The calibration was carried out by means of two parallel specimens for each percentage of moisture content.

From the data obtained we have constructed the curve showing the relationship between moisture of the concrete and the electrical resistance of the sensors (see Figure 2, curve 2).

The order of construction of the curve for 50°C is as follows: from curve 1 we find the resistance of the specimen at a definite moisture content at 15°C. From this point we draw a horizontal line and upon it mark the resistance of the very same specimen at 50°C.

Similar points are found for all 10 specimens of different moisture content. Through the points thus obtained we derive curve 2. Analogous curves are constructed for 100° and 150°C (see Figure 2, curves 3 and 4).

Conclusions

A portable device for measuring moisture content of concrete at temperatures up to 200°C was developed. The precision of measurements was ± .03 of 1%. The device was verified for basic types of refractory concrete and the results were satisfactory.

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Fig. 1. Schematic drawing of sensor for measurement of moisture in concrete.

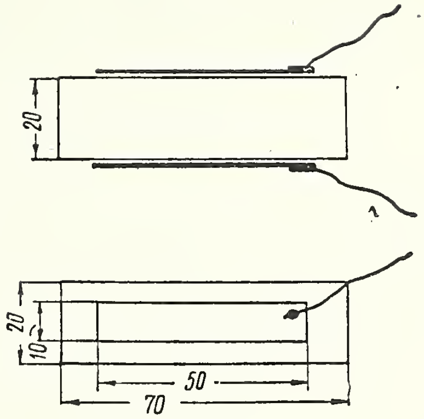


Fig. 2. Relationship between electrical resistance of sensors and moisture in refractory concrete of portland cement and grog at various temperatures: 1-15°C, 2-50°C, 3-100°C, 4-150°C.

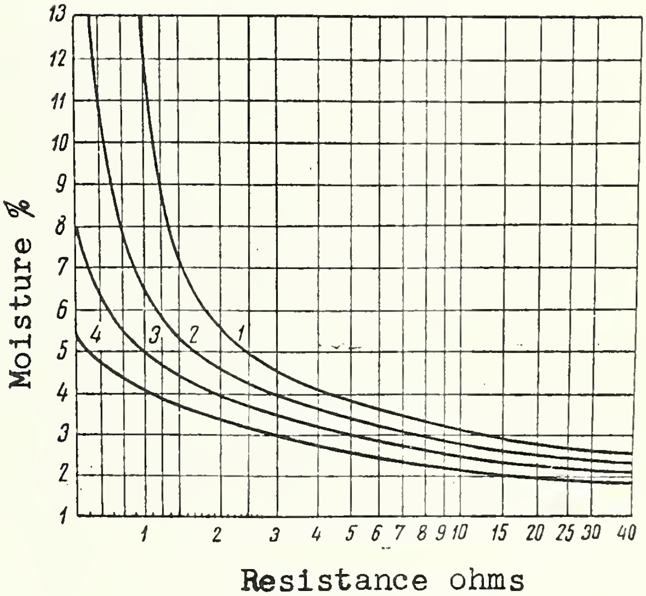
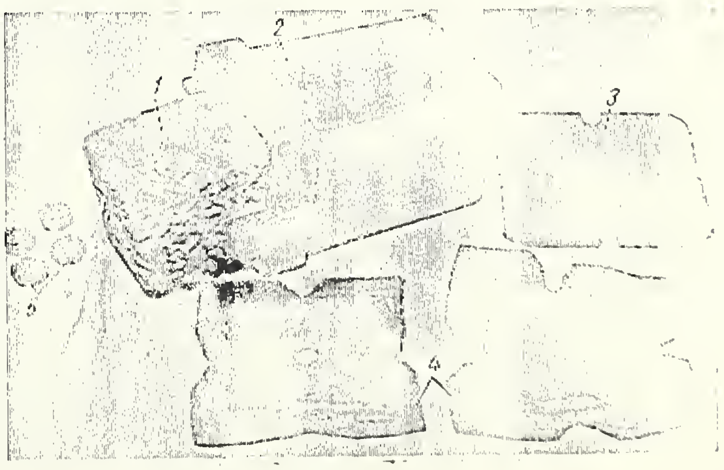


Fig. 3. Hermetically sealed container for calibration of sensors at various temperatures: 1-specimen, 2-container, 3-metal lid, 4-rubber seal, 5-clamping nuts



THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

WASHINGTON, D. C.

Electricity. Resistance and Reactance. Electrochemistry. Electrical Instruments. Magnetic Measurements. Dielectrics. High Voltage. Absolute Electrical Measurements.

Metrology. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Volume.

Heat. Temperature Physics. Heat Measurements. Cryogenic Physics. Equation of State. Statistical Physics.

Radiation Physics. X-ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

Analytical and Inorganic Chemistry. Pure Substances. Spectrochemistry. Solution Chemistry. Standard Reference Materials. Applied Analytical Research. Crystal Chemistry.

Mechanics. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Rheology. Combustion Controls.

Polymers. Macromolecules: Synthesis and Structure. Polymer Chemistry. Polymer Physics. Polymer Characterization. Polymer Evaluation and Testing. Applied Polymer Standards and Research. Dental Research.

Metallurgy. Engineering Metallurgy. Metal Reactions. Metal Physics. Electrolysis and Metal Deposition.

Inorganic Solids. Engineering Ceramics. Glass. Solid State Chemistry. Crystal Growth. Physical Properties. Crystallography.

Building Research. Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials. Metallic Building Materials.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics. Operations Research.

Data Processing Systems. Components and Techniques. Computer Technology. Measurements Automation. Engineering Applications. Systems Analysis.

Atomic Physics. Spectroscopy. Infrared Spectroscopy. Far Ultraviolet Physics. Solid State Physics. Electron Physics. Atomic Physics. Plasma Spectroscopy.

Instrumentation. Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

Physical Chemistry. Thermochemistry. Surface Chemistry. Organic Chemistry. Molecular Spectroscopy. Elementary Processes. Mass Spectrometry. Photochemistry and Radiation Chemistry.

Office of Weights and Measures.

BOULDER, COLO.

CRYOGENIC ENGINEERING LABORATORY

Cryogenic Processes. Cryogenic Properties of Solids. Cryogenic Technical Services. Properties of Cryogenic Fluids.

CENTRAL RADIO PROPAGATION LABORATORY

Ionosphere Research and Propagation. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services. Vertical Soundings Research.

Troposphere and Space Telecommunications. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Spectrum Utilization Research. Radio-Meteorology. Lower Atmosphere Physics.

Radio Systems. Applied Electromagnetic Theory. High Frequency and Very High Frequency Research. Frequency Utilization. Modulation Research. Antenna Research. Radiodetermination.

Upper Atmosphere and Space Physics. Upper Atmosphere and Plasma Physics. High Latitude Ionosphere Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

RADIO STANDARDS LABORATORY

Radio Standards Physics. Frequency and Time Disseminations. Radio and Microwave Materials. Atomic Frequency and Time-Interval Standards. Radio Plasma. Microwave Physics.

Radio Standards Engineering. High Frequency Electrical Standards. High Frequency Calibration Services. High Frequency Impedance Standards. Microwave Calibration Services. Microwave Circuit Standards. Low Frequency Calibration Services.

Joint Institute for Laboratory Astrophysics - NBS Group (Univ. of Colo.).

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