NATIONAL BUREAU OF STANDARDS REPORT

6116

SOME EXPERIENCE GAINED FROM THE USE OF HUMIDITY SENSING ELEMENTS TO INDICATE THE DRYING OF FIRE TEST SPECIMENS

by

J. V. Ryan

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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ABSTRACT

The presence of water in materials exposed ro fire is known to affect their fire endurance performance. Because of this, use has been made of humidity sensing elements as an aid in determining when test specimens have approached moisture equilibrium with the ambient. The data have indicated that certain procedures may introduce errors. The procedures followed are reviewed and recommendations made.

1. INTRODUCTION

In order that the results of fire endurance tests may be as representative as feasible, the specimens constructed especially for the test must be as closely representative as practicable of similar constructions in buildings after several years of use. For concrete, plaster, masonry and wooden constructions, this makes it necessary that the testing laboratory be concerned, in addition to other factors, with the state-of-dryness of the specimen. Every attempt should be made to allow the specimen to reach moisture equilibrium with the ambient.

For many materials, data on moisture content as related to the relative humidity of the ambient indicate a large change of the former from saturation down to equilibrium with air of relative humidity near 80 percent, and a comparatively small change from there down to equilibrium with air at about 20 percent. Therefore, equilibrium with air at or below 70 percent relative humidity should provide a reasonable indication that the specimen is quite close to its ultimate moisture content.

The National Bureau of Standards' Fire Protection Section has used hygrometer elements in attempts to measure the relative humidities of air believed to be in moisture equilibrium with various parts of specimens. Two types of hygrometer elements have been employed, dye-spot cards and electrical humidity elements. They have been used in arrangements whereby air in contact with the surface or the interior of the specimen has been isolated from the general atmosphere by vapor barriers. It was assumed that the air thus isolated would come to moisture equilibrium with the specimen material, at a relative humidity indicative of the moisture content of the latter. Since the state of dryness was of primary concern, rather than the exact moisture content, it was not necessary to have

accurate calibration charts of moisture content versus relative humidity for the particular concretes, plasters, etc.

Data obtained from some specimens have indicated that the geometries of the vapor barrier systems have been such that moisture equilibrium was not reached rapidly. This report outlines the various physical arrangements employed and the experiences obtained.

2. MEASUREMENT SYSTEMS

The measurement systems consisted of a hygrometer, the test specimen, and an assembly to trap air against some part of the specimen, either the exterior, or an interior surface at the open end of a tube.

2.1 Exterior Measurements

The vapor barrier used was a transparent polyethylene plastic sheet, the lateral dimensions of which were large compared to the thickness of the specimen, or that part of the specimen that might have excess moisture content. The hygrometers were of a commercial type, each consisting of six dye-spots on a piece of blotting paper. By means of color changes they provided an indication of relative humidity in the range from 20 to "over 80 percent." The hygrometer was placed between the specimen surface and the vapor barrier. On smooth surfaces the barrier was secured around its periphery by plastic electrician's tape. This tape was not satisfactory on rough concrete. No attempt was made to find a suitable peripheral seal for such surfaces. This method was used with plastered floors and columns, primarily, in which the plaster and lath were backed by air trapped between the floor joists or between the flanges of the steel column. This trapped air being in moisture equilibrium with the back surface of the lath and plaster, had a similar effect to that of a vapor barrier on this same surface.

2.1 Interior Measurements

In massive or monolithic constructions, the previous method was impracticable and another method was used to determine the dryness at or near the centers of concrete sections. The vapor barriers were pipes or tubes ranging from 1/16 to 1-in. inside diameter and from 8 in. to several feet in length. The tubes of less than 7/8 in. inside diameter were fitted to short pipe nipples of that or greater diameter, into which the hygrometer elements fitted; larger pipes required no extra fitting as an adapter. The end for the insertion of hygrometer element was closed with a pipe cap; the other end was left open (except for a fine screen or gauze to keep concrete out of the tube) and placed in the form before the concrete was poured. The electrical elements were soldered to stiff wire leads, in turn

soldered to Kovar sealed connectors in the pipe caps. These elements, with caps, were used for tubes over the entire diameter range. The dye-spot cards, or strips cut therefrom, were used in tubes of 5/16-in. or greater inside diameter.

3. RESULTS

It should be kept in mind that equilibrium within the closed measuring system is not necessarily indicative of equilibrium between the specimen and the laboratory atmosphere. Usually, the former is reached more rapidly than the latter. The following paragraphs summarize data on the times required for the establishment of equilibrium within the measuring systems. For some systems, the time lag was of the same order of magnitude as that expected for the specimen, thereby limiting the usefulness of the method.

3.1 Exterior Measurements

The results were very good for smooth surfaced materials, such as plaster, having a vapor barrier behind, (or trapped air as mentioned in section 2.1.) However, it was difficult to obtain a satisfactory peripheral seal to any but the best concrete surfaces. The time lag, for thin plaster applications, between placing the element and reaching equilibrium was as little as an hour for fairly wet specimens, and probably not over a day for drier specimens, although it was not always obvious at that time that equilibrium had been established.

3.2 Interior Measurements

The data from electrical elements 1-1/2 in. from the open ends of 1-in. inside diameter pipes, placed in concrete, indicated that moisture equilibrium had been reached in from two to six hours after placing the element within the tube. Data from electrical elements in fittings at the closed ends of long small diameter tubes indicated that equilibrium was not attained for much longer periods. In some instances, three months or more were required to reach equilibrium.

Tests were made in which the electrical elements, bare and in pipe fittings, were brought to equilibrium with air at about 15 percent relative humidity and then exposed to the atmosphere of a laboratory room controlled to about 50 percent relative humidity. The times required for the elements to come to equilibrium with the

latter atmosphere were: 1) bare elements, 2 to 3 min; 2) elements 1-1/2 in. from open ends of 9-1/2 in. long 1-in. inside diameter pipes, about 1-1/4 to 2 hr; 3) elements in 1-in. nipples with fittings to reduce to 5/16-in. tubing, about 6 hr; 4) with nipple and fittings, plus 38-in. of 5/16-in. tubing, about 2 days.

The data from the dye-spot elements did not show as great a spread of times required for the system to come to equilibrium. This was due, presumably, to the fact that they were used in large diameter tubes of comparatively short length, for the most part. One application of these elements was in reinforced concrete T-beams of 11-3/4-in. stem width. The data indicated that the concretes at the centers of the beams were still wet two years after casting.

4. DISCUSSION AND COMMENTS

The exterior measurement procedure is well suited to direct readings but requires a fairly smooth surface. The dimensions of the vapor barrier should be large enough compared to the thickness of the specimen so that edge effects due to lateral migration of moisture are minimized. However, the area covered by the vapor barrier must be small compared to the total surface area in order not to restrict, excessively, the free drying of the specimen.

The pipe or tube method permits measurements at remote locations. However, the use of long tubes of comparatively small diameter seems likely to result in a significant time lag. Comparison of the data from such systems having the open ends in concrete with those from similar systems having the open ends in air shows that much, but not all, of the lag may be attributed to the concrete. This is so because water vapor migrates through concrete more slowly than through air.

In addition to lag, the use of very long, thin tubes may lead to erroneously low readings. When the ratio of the volume of air trapped to the area of the open end (the concrete area from which moisture is taken) is quite large, the concrete near the open end may be dried out significantly in the process of providing the moisture necessary to bring the trapped air to equilibrium. This equilibrium humidity would not be representative of the relatively wet concrete at the center, but of the somewhat drier concrete at or near the normal surface.

Experience has shown that tubes of small diameter may be subject to mechanical damage that reduces the effective diameter or closes the tube completely. This damage may occur during the pouring of the concrete or during later handling of the specimen.

The particular dye-spot elements used were adversely affected by the extremely high humidities experienced shortly after specimens were cast. If the card was subject to very high humidities, the dyes ran and were no longer reliable. No attempt was made to determine the effect of very high humidities on the electrical elements; they were, however, of a type which makes use of an ion exchange resin which is claimed by the manufacturer to be less subject to damage resulting from moisture condensation than other units using hygroscopic salts.

5. RECOMMENDATIONS

The vapor barrier for exterior measurements should be large compared to the specimen's thickness but small compared to its surface area.

Individual dye-spot elements should be discarded if the dye-spots have run, due to very high humidities.

The exterior measurement system is of doubtful value for thick concrete specimens.

The pipe used for interior measurements should be as short as possible and of sufficient diameter to permit insertion of the hygrometer element if this is compatible with the specimen dimensions.

The pipes should be capped whether or not an element is in the pipe, to minimize localized drying of the material adjacent to the open end.

Relative humidity of 70 percent, for air in moisture equilibrium with the specimen, should be low enough to indicate satisfactory dryness. Because of possible lag in the system, however, the data should have established a clear trend of decreasing humidity.

REFERENCE

Some of the general principles of this type of measurement have previously been described in the following reference:

"A Method for Determining the Moisture Condition of Hardened Concrete in Terms of Relative Humidity" by C. A. Menzel, Proc ASTM V 55, 1955.

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

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THE NATIONAL BUREAU OF STANDARDS

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WASHINGTON, D. C.

Electricity and Electronics. Resistance and Reactance. Electron Devices. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Engine Fuels. Free Radicals Research.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Nuclear Physics. Radioactivity. X-rays. Betatron. Nucleonic Instrumentation. Radiological Equipment.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer.

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

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Application Engineering.

- Office of Basic Instrumentation.
- Office of Weights and Measures.

BOULDER, COLORADO

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships. VHF Research.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Systems. Navigation Systems. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Radio Systems Application Engineering. Radio Meteorology.

Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Calibration Center. Microwave Physics. Microwave Circuit Standards.

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