CEMENT and CONCRETE RESEARCH. Vol. 1, pp. 461-473, 1971. Pergamon Press, Inc.
Printed in the United States.

DRYING OF CONCRETE AS A NONLINEAR DIFFUSION PROBLEM[a]

Z. P. Bažant* and L. J. Najjar**
Department of Civil Engineering
Northwestern University, Evanston, Illinois 60201

(Communicated by L. E. Copeland)

ABSTRACT

Numerous experimental data on drying of concrete and cement paste are subjected to computer analysis. It is found that for a satisfactory fit of the data the diffusion coefficient must be considered to be a function of pore relative humidity (or specific water content), which makes the diffusion problem of drying nonlinear. The diffusion coefficient is shown to decrease sharply (about 20-times) when passing from 0.9 to 0.6 pore humidity, while below 0.6 it appears to be approximately constant. Improvement over the linear theory used in the past is very substantial and indicates that a realistic prediction of drying is possible.

RÉSUMÉ

Les dates expérimentales nombreuses sur le séchage du béton à l'air sont analysées à l'aide de l'ordinateur électronique. On trouve que pour un accord satisfaisant entre la théorie et résultats de mesure, le coefficient de diffusion doit être considéré comme une fonction de l'humidité relative dans les pores (ou le content spécific de l'eau). Cette dépendence transforme le problème de diffusion à un problème non-linéaire. On montre que le coefficient de diffusion C décroît fortement (à peu près 20-fois) en passant de l'humidité 0.9 à 0.6 dans les pores, tandis qu' au-dessous de 0.6 il apparait comme constant. L'amélioration à l'égard de le théorie linéaire utilisée dans le passé est très substantielle et indique qu' une prédiction réaliste du séchage est possible.

---

[a] The results reported herein have been presented at the ASCE Conference on Frontiers of Research and Practice in Plain Concrete, held in Allerton Park, University of Illinois, Urbana, Sept. 1970.

* Associate Professor of Civil Engineering

** Graduate Student

Prediction of the distribution and time dependence of water content in concrete structures is a problem of considerable practical importance. It is needed for the determination of shrinkage, creep, thermal dilatation, strength, durability, rate of hydration, thermal conductivity, fire resistance and radiation shielding, and is especially important in the design of prestressed concrete pressure vessels for nuclear reactors. However, a satisfactory method of prediction is not available at present. The linear diffusion theory, which has been used in the past, is known to give a very poor correlation with test data. In particular, it is observed that with the progress of drying the remaining mosisture is being lost with ever increasing difficulty and much slower than a linear diffusion theory would predict. This fact has been noted already by Carlson (7) and Pickett (15). The latter proposed to account for it assuming the diffusion coefficient C to decrease with the period of drying. Although with the data and computing devices available at that time no better formulation was possible, it should be pointed out that such an assumption is not generally acceptable since it makes a material property dependent on our choice of the instant of exposure and does not allow a satisfactory fit of the data for various thicknesses analyzed below.

Therefore, the apparent decrease of the diffusion coefficient C with the period of drying must be associated with some other variable. It is postulated here that this variable is the specific water content of concrete, w, or the pore humidity H (relative vapor pressure). The dependence of C upon H has in fact been anticipated since the earliest investigations. But solutions of the drying problems could not have been obtained before electronic computers became available because the above dependence makes the diffusion problem non-linear, and the usual solution by Fourier method inapplicable. Numerical computer analyses of drying of slabs for certain forms of the dependence $C = C(w)$, such as $C = C_0 + C_2 w^n$ where C_0, C_2 and n are constants, have been studied by Pihlajavaara and co-workers (12,13,14) who concluded that the diffusion coefficient C decreases several times when passing from $H = 1.0$ to $H = 0.7$. But no definite conclusions have been made and no attempts of fitting the data on drying and determining the dependence of C upon w or H have been reported. It should be noted, however, that until recently the data available have been insufficient for this purpose. Namely, an unambiguous determination of the dependence of C upon H, which is the primary purpose of this paper, requires the conventional weight measurements during drying to be complemented by direct measurements of the distribution of w or H within the specimen, which could be conveniently carried out only after the development of suitable probe-type humidity gages, especially the Monfore gage (2).

Mathematical Formulation of Drying of Concrete

According to the Fick's law, the specific water content of cement paste or concrete, w (mass per unit volume), should satisfy the following partial differential equation:

$$\frac{\partial w}{\partial t} = \mathrm{div}(C \text{ grad } w) \tag{1}$$

where t = time and C = diffusion coefficient = function of w. This equation applies only when the change of material properties due to hydration is negligible (as in old concrete or low H), the degree of hydration is uniform throughout the body and temperature T is constant. Alternatively, drying of concrete can be also described in terms of pore humidity H since, at constant T and a fixed degree of hydration, $dH = k\, dw$ where k = function of H = cotangent of the slope of the desorption isotherm $w = w(H)$. Thus $\partial w/\partial t = k^{-1}\partial H/\partial t$ and $\text{grad } w = k^{-1}\text{grad } H$, so that Eq. (1) yields

$$\frac{\partial H}{\partial t} = k \, \mathrm{div}(c \text{ grad } H) \tag{2}$$

where $c = C/k$, which can be shown to represent permeability and equal the mass flux due to a unit gradient of H. For dense cement pastes and concretes, k is usually almost constant from H = 0.95 down to about H = 0.2 (16). Then Eq. (2) simplifies as follows

$$\frac{\partial H}{\partial t} = \mathrm{div}(C \text{ grad } H) \tag{3}$$

where the diffusion coefficient C is the same as in Eq. (1), except that it must be regarded as a function of H rather than w.

Equations (1) and (2) or (3) are obviously equivalent. It should be noted, however, that the formulations in terms of w or H would not be equivalent if the change of material properties due to hydration were considered (as is necessary for young concrete) or the temperature were not constant. In this case Eq. (2) must be expanded by additional terms (6) expressing self-desiccation due to hydration and temperature effect upon H. Pore humidity is the more suitable variable since H (unlike w) is directly related to the Gibbs' free energy per unit mass of evaporable water, μ, whose gradient is the actual driving force of diffusion. It should be noted that this gradient is not proportional to the gradient of concentration or grad w, since the degree of hydration, and thus also the pore volume available to evaporable water, are in general nonuniform through the body. In particular, a zero value of grad w does not correspond to a zero value of grad μ (or grad H). But these cases will not be considered in the sequel. To be aware of all of the simplifications implied, it should further be noted that diffusion of water is also caused by gradients of concentration of various ions dissolved in pore water (or osmotic pressures). But in the test data analyzed in the sequel such effects appeared to be unimportant since a satisfactory fit has been obtained without their consideration.

Specimens used for drying tests may usually be regarded as infinite slabs or infinite cylinders. Spheres have also been used. In these cases Eq. (3) takes on the one-dimensional forms:

$$\left.\begin{array}{llllll} \dfrac{\partial H}{\partial t} = \dfrac{\partial}{\partial x}\left(C\,\dfrac{\partial H}{\partial x}\right) & \text{or} & \dfrac{1}{r}\,\dfrac{\partial}{\partial r}\left(Cr\,\dfrac{\partial H}{\partial r}\right) & \text{or} & \dfrac{1}{r^2}\,\dfrac{\partial}{\partial r}\left(Cr^2\,\dfrac{\partial H}{\partial r}\right) & \text{for } r > 0 \\ & & 2C\,\dfrac{\partial^2 H}{\partial r^2} & \text{or} & 3C\,\dfrac{\partial^2 H}{\partial r^2} & \text{for } r = 0 \\ \text{(slab)} & & \text{(cylinder)} & & \text{(sphere)} & \end{array}\right\} \quad (4)$$

where x = thickness coordinate of the slab and r = radius coordinate of the cylinder or sphere. The drying problem is defined by the non-linear differential equation (4) to be satisfied for $0 < x < L$ or $0 < r < R$ and $t > t_0$, with the initial and boundary conditions:

$$\left.\begin{array}{l} H = 1 \quad \text{for } t = t_0 \text{ and } 0 < x < L \text{ or } 0 < r < R \\ H = H_{en} \quad \text{for } t > t_0 \text{ and } x = L \text{ or } x = R \\ \partial H/\partial x = 0 \quad \text{or} \quad \partial H/\partial r = 0 \quad \text{for } t > t_0 \text{ and } x = 0 \text{ or } r = 0 \end{array}\right\} \quad (5)$$

where t_0 = instant of exposure to the drying environment of constant relative humidity H_{en}, L = half-thickness of slab, R = radius of cylinder or sphere; x = 0 at the mid-thickness of slab and r = 0 at the axis of cylinder or center of sphere.

The nonlinear initial boundary value problem given by Eq. (4) and (5) may be solved by the finite difference method. To avoid numerical instability it is necessary to use in each time step either backward or central differences. The former give stronger dampening of the numerical error in the subsequent steps but the latter have a higher order of accuracy and are usually more suitable, although spurious slowly damped oscillations about the correct solution may be encountered, especially when time step Δt becomes large and C strongly varies with H. One of the variants of the central difference method, called Crank-Nicolson method (17), has been used in the computer analyses reported in the sequel. In this method, the analysis of each time step is carried out twice, first with the C-values corresponding to the initial values of H in the time step considered, and subsequently with the improved C-values corresponding to the average value of H within the time step determined from the first analysis.

For the evaluation of weight measurements it is necessary to compute the loss in weight of specimen, $\Delta W(t)$, from time t_0 to time t. Assuming k to be a constant, $1 - \Delta W(t)/\Delta W(\infty) = (\bar{H}(t)-H_{en})/(1-H_{en})$ where $\bar{H}$ = average of H,

$$\bar{H}(t) = \frac{1}{L}\int_0^L H(x,t)dx, \qquad \frac{2}{R^2}\int_0^R H(r,t)rdr, \qquad \frac{3}{R^3}\int_0^R H(r,t)r^2dr \tag{6}$$

(slab) (cylinder) (sphere)

Data Fitting and Variation of the Diffusion Coefficient with Humidity

For fitting of experimental data it is expedient to reduce the number of variables in the problem as much as possible. For a cylinder or sphere, this may be achieved by introducing, instead of t, r, H, new non-dimensional variables t', r', H' defined as follows

$$r' = \frac{r}{R} \quad , \qquad t' = \frac{C_1}{R^2}(t-t_0) \quad , \qquad H' = \frac{H - H_{en}}{1 - H_{en}} \tag{7}$$

where C_1 = value of C at H=1. For a slab, L, x and x' appears in place of R, r and r'. Noting that $\partial/\partial r = R^{-1}\partial/\partial r$, $\partial/\partial t = C_1R^{-2}\partial/\partial t$, Eqs. (4) and (5) for a cylinder, e.g., become:

$$\left.\begin{aligned}
&\frac{\partial H'}{\partial t'} = \frac{1}{r'}\frac{\partial}{\partial r'}\left(\frac{C(H)}{C_1}r'\frac{\partial H'}{\partial r'}\right) \text{ for } 0 < r' \le 1,\\
&\frac{\partial H'}{\partial t'} = 2\,\frac{C(H)}{C_1}\,\frac{\partial^2 H'}{\partial r'^2} \text{ for } r' = 0 \qquad (t' > 0)\\
&H' = 1 \qquad \text{for } t' = 0 \text{ and } 0 \le r' \le 1\\
&H' = 0 \qquad \text{for } t' > 0 \text{ and } r' = 1\\
&\partial H'/\partial r' = 0 \qquad \text{for } t' \ge 0 \text{ and } r' = 0
\end{aligned}\right\} \tag{8}$$

The solution H(t',r'), as well as H(t',x'), is thus seen to become independent of R or L, even if C depends upon H. The dependence upon C is by variables (7) reduced to a dependence upon the ratio $C(H)/C_1$. But owing to the presence of H, which equals $H_{en} + (1-H_{en})H'$, in the first of Eqs. (8), the dependence upon H_{en} cannot be eliminated, except for special forms of the function C(H), such as Eq. (8) introduced in the sequel (or when the problem is linear).

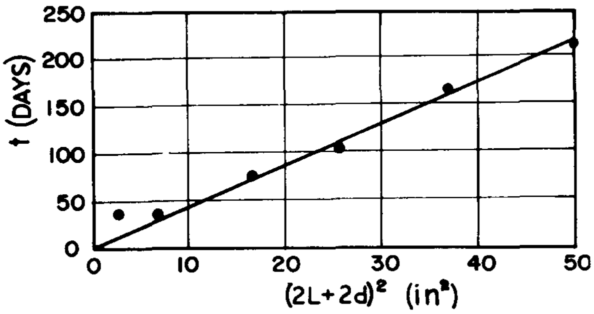

FIG. 1

Time to reach 0.75 humidity at mid-slab for various slab thicknesses (Cf. Table 1), d =0.75 mm.

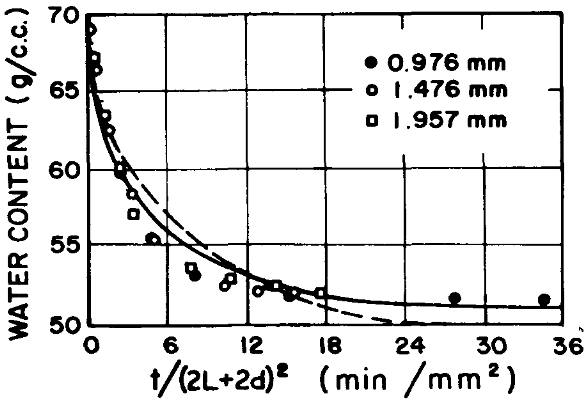

FIG. 2

Water content of specimen versus non-dimensional time, assuming d =0.75 mm (Cf. Table 1). Dashed line indicates linear theory.

According to the non-dimensional variables (7) just discussed, the times needed to reach a certain H in the centers of specimens of different thicknesses ought to be proportional to L^2 or R^2, in spite of the nonlinearity of the problem. Data in Fig. 1 confirm it, with the possible exception of very thin specimens in which grad H is high. But the weight measurements in Fig. 2 are seen to be in approximate coincidence when plotted in the nondimensional time t', Eq. (7), provided that approximately the thickness d = 0.75mm be added to the specimens to account for the finite rate of moisture exchange at the surface which is not much larger than the drying rate of very thin specimens. For the sake of uniformity, the value of d = 0.75mm was assumed even for the data in Fig. 1, although for the large specimen thicknesses in this figure other values of d(e.g. d = 0) would allow an equally good fit. It should be noted that the fits as in Figs. 1 and 2 would be impossible if C depended on grad H.

Variation of the diffusion coefficient C with H has been investigated with the help of a computer program for drying of slabs, cylinders and spheres, based on the method outlined above. A large number of shapes of the surve C(H) have been selected and the results of computations have been output on the CALCOMP Plotter, in terms of the non-dimensional variables (7). Comparing visually these diagrams with the available test data, plotted in the same variables, the curve C(H) giving the relatively best fit over the whole range of data for one and the same concrete has been sought. Linear combinations of linear functions and power functions of various degrees in

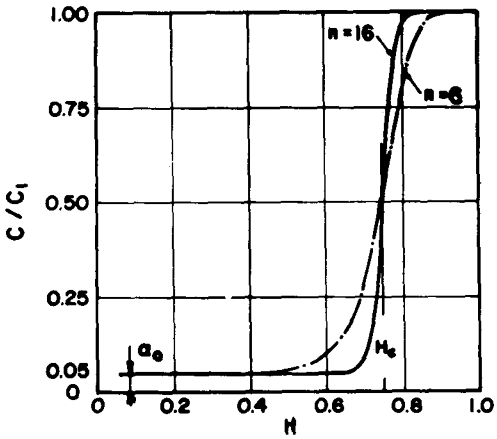

FIG. 3

Diffusion coefficient C versus H according to Eq. 9 for n = 16 and n = 6 (α_0 = 0.05, H_c = 0.75).

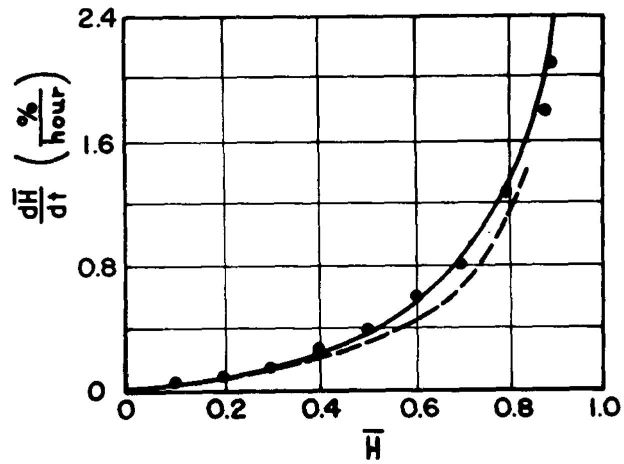

FIG. 4

Rate of change of average humidity versus average humidity (Cf. Table 1). (Dashed line represents linear theory. The initial slopes were assumed as identical.)

H and (1 - H) did not allow an acceptable fit. But an S-shaped curve of the type (shown in Fig. 3):

$$C(H) = C_1\left(\alpha_0 + \frac{1 - \alpha_0}{1 + \left(\frac{1 - H}{1 - H_c}\right)^n}\right) \tag{9}$$

was found to be satisfactory, as is demonstrated by the solid line fits in Figs. 4 to 9. For comparison, the best possible fits based on a linear theory (i.e. with constant C) are shown by the dashed lines. The nonlinear theory is obviously far superior. It should be noted that the time plots in Fig. 5 and the distribution plots in Fig. 6 were all fitted with one and the same expression for C(H), as they had to be. The same can be said about Figs. 7 and 8. Noteworthy is also the fact that the values of parameter H_c, characterizing the location of the drop in the curve C(H), were found to be about the same for different concretes or cement pastes, notably about H_c = 0.75 (see Table 1). Furthermore, the values of parameter α_0, representing the ratio min C/max C, were also quite close and equal about 0.05 (Table 1). The values of the exponent n, characterizing the spread of the drop in C(H) were between n = 6 and n = 16. The absolute values of the diffusion coefficient, characterized by the parameter C_1, were found to scatter more than the other parameters (Table 1), especially in dependence on the w/c (water-cement) ratio, as is documented, e.g., by the data of Aleksandrovskii (4,5) for w/c = 0.82 which yield about 10-times higher value of C_1 than most data in Table 1. (For a study of the dependence of C upon H these data were found to be insufficient.)

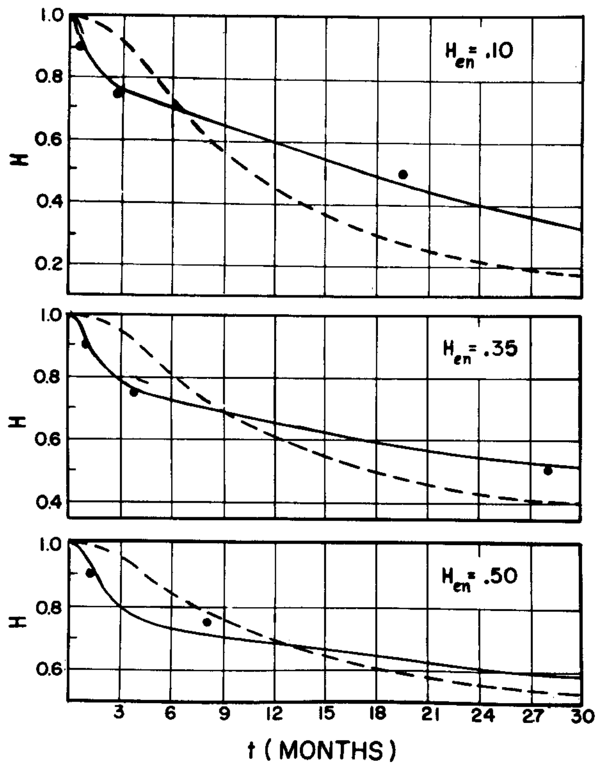

FIG. 5

Mid-slab humidity (Cf. Table 1). Dashed lines represent linear theory.

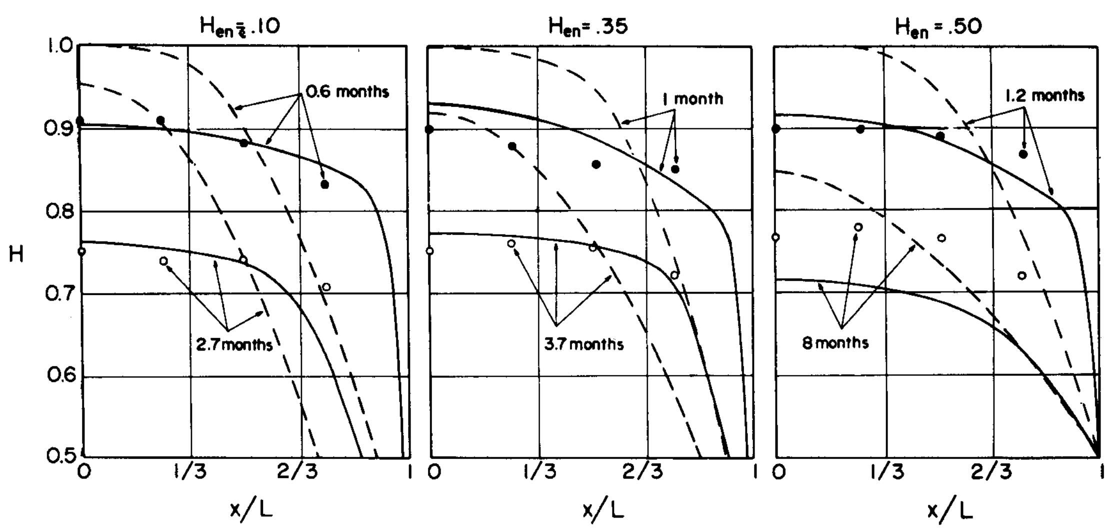

FIG. 6

Distributions of H at various times for the same tests as in Fig.5 (Cf. Table 1). Dashed lines represent linear theory.

TABLE 1

Material Parameters for the Data Analyzed

Figure Reference	1 (1)	2 (10)	5,6 (3)	7 (2)	8,9 (9)	4 (11)	(4)
α_0	-	0.05	0.05	0.05	0.025	0.10	0.05
h_c	-	0.75	0.75	0.75	.792	0.75	0.90 and 0.75
n	-	16	16	16	6	16	16
C_1 (cm^2/day)	.349	.144	0.382	0.187	.239	1.93	.269
Type of specimen	slabs	slabs	slabs	slabs	cylinders	spheres	equivalent to slabs
Thickness or diameter, 2L or 2R	1.5 to 7 in.	1 to 2 mm	6 in.	12 in.	6 in.	4 in.	28 cm
Environmental humidity	0.3 to 0.4 & 0 to 0.05	0.47	0.10;0.35;0.50	0.10	0.50	0.0	0.0
age t_0 (days)	7		7	7	7	30	2 and 5
test temperature	70-75°F	25°C	73 ± 2°F	73°F	73°F ± 2°F	75°F	25°C
water-cement ratio	0.636		0.60	0.45	0.657	0.50	0.82
mix proportions	1:3.67:4.77		1:2.83:5.26	1:2.61:1.75	1:3.26:3.69		
Remarks	Carbonate aggregate concrete	Cement paste in CO_2 free air	Sand & gravel; 4.5 bags of cem. per cu. yard	Sand & gravel; 7 bags of cem. per cu. yard	Elgin sand & gravel	Thames irregular flint; cem:aggr. =1:3	Concrete; cube strength 156 kp /cm^2

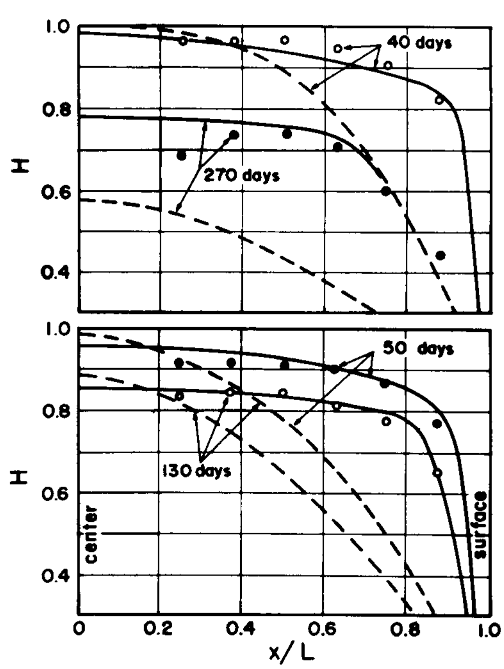

FIG. 7

Distributions of H at various times for data quoted in Table 1. Dashed lines represent linear theory. (All are data from the same specimen.)

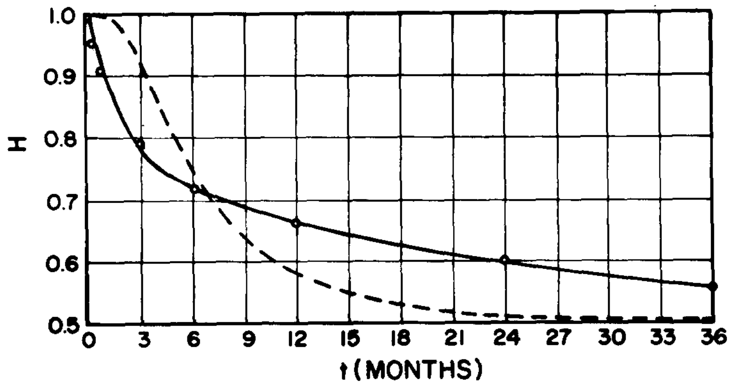

FIG. 8

Mid-cylinder humidity H versus time for data quoted in Table 1. Dashed line represents linear theory.

Expression (9) has the advantage of allowing one further parameter to be eliminated from the problem given by Eqs. (4) and (5). Namely, by expressing H in terms of H' as given by Eq. (7), expression (9) takes the form:

$$C = C_1\left(\alpha_0 + \frac{1 - \alpha_0}{1 + \alpha_1{}^n(1 - H')^n}\right) \qquad \text{where} \qquad \alpha_1 = \frac{1 - H_{en}}{1 - H_c} \tag{10}$$

According to Eqs. (8), the solution is thus found to depend only upon the ratio α_1 rather than on both H_c and H_{en} individually.

The shape of the curve C(H) is of interest for the mechanism of water diffusion through cement paste and concrete. If the flow of vapor were the dominant mechanism in water transport, the diffusion coefficient C would have to be essentially independent of water content or, perhaps, increase with decreasing H because more space becomes available to vapor after drying. The substantial drop in C at drying can be explained only when flow of water

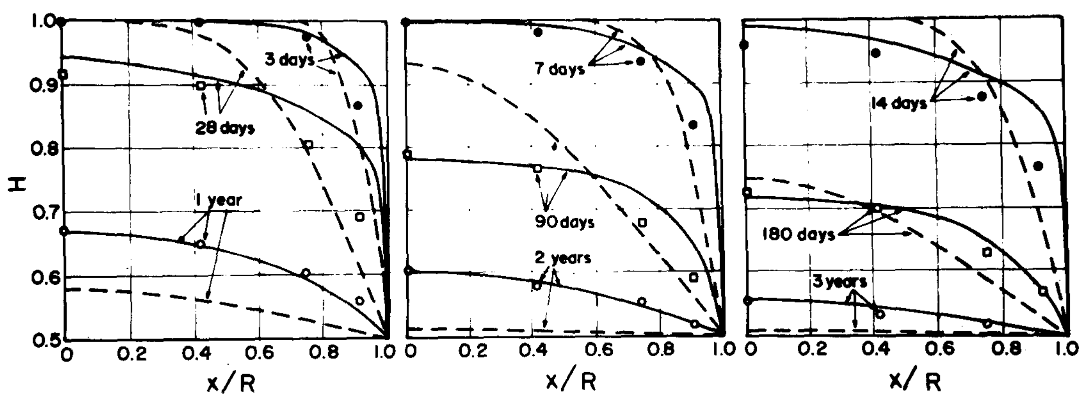

FIG. 9

Distributions of H at various times for data quoted in Table 1. (All are data from the same specimen.)

molecules along thin adsorbed layers within the reach of solid surface forces is considered to be the prevailing mechanism at low humidities, such as $H < 0.6$, while above this limit the flow of capillary water (which comprises water whose distance from the pore surface is more than about five molecules) is of importance. The drop in C is probably due to a transition from a flow of capillary water (with a flow along the upper adsorbed layers) into a flow of firmly held molecules along adsorbed layers of two or three molecules in thickness. Our conclusions thus corroborate the presently prevailing view of the diffusion mechanism, which has been originally introduced for other reasons.

It is curious to note that nonlinear diffusion exhibits some very peculiar and unexpected features. For instance, having two identical specimens drying in environments of different humidities, the time needed to reach a certain humidity in the core may be greater for the specimen which is in the environment of lower humidity. This phenomenon, which could never happen for linear diffusion, may be intuitively explained by the fact that the surface region which dries up quicker attains a lower permeability and thus in effect hinders more strongly further loss of water from the core.

Conclusions

Diffusion coefficient C for drying of concrete strongly decreases when passing from pore humidity 0.9 to 0.6 while below 0.6 it is approximately constant (Fig. 3). The dependence of C upon H may be approximately expressed by the empirical equation (9), in which $H_c \approx 0.75$, $\alpha_0 \approx 0.03$ to 0.10, $n = 6$ to 16, $C_1 = 0.1$ to $0.5\ cm^2/day$ for typical dense concretes of low water-cement ratios. The nonlinear diffusion theory gives a far better prediction of drying of concrete than does the linear theory used in the past.

Acknowledgment

The main part of research reported herein has been supported by the National Science Foundation under Grant No. GK-26030. Additional information on test data provided by Messrs. M. S. Abrams and G. E. Monfore, researchers at Portland Cement Association, Skokie, Illinois, is gratefully appreciated.

References

1. M. S. Abrams and A. H. Gustaferro, "Fire endurance of concrete slabs as influenced by thickness, aggregate type, and moisture," Journal of the Portland Cement Association Research and Development Laboratories 10, No. 2 (PCA Bulletin 223), 9-24 (1968).

2. M. S. Abrams and G. E. Monfore, "Application of a small probe-type relative humidity gage to research on fire resistance of concrete," Journal of the Portland Cement Association Research and Development Laboratories 7, No. 3 (PCA Bulletin 186), 2-12 (1965).

3. M. S. Abrams and D. L. Orals, "Concrete drying methods and their effect on fire resistance," in "Moisture of materials in relation to fire tests," STP No. 385, publ. by American Society for Testing Materials (PCA Bulletin 181), 52-73 (1965).

4. S. V. Aleksandrovskii, "On thermal and hygrometric properties of concrete related to heat and moisture exchange" (in Russian), Akad. Stroit. i Arkhitektury USSR (Moscow), Nauchno-Issled. Inst. Betona i Zhelezobetona (NIIZhB), Issled. Svoistv Betona, Zhelezob. Konstr., Trudy Inst., No. 4, 184-214 (1959).

5. S. V. Aleksandrovskii, "Analysis of plain and reinforced concrete structures for temperature and moisture effects (with account of creep)" (In Russian), Stroyizdat, Moscow (1966).

6. Z. P. Bažant, "Constitutive equation for concrete creep and shrinkage based on thermodynamics of multiphase systems," Materials and Structures (RILEM) 3, No. 13, 3-36 (1970).

7. R. W. Carlson, "Drying shrinkage of large concrete members," American Concrete Institute Journal 33, 327 (1937).

8. H. S. Carslaw and J. C. Jaeger, Conduction of Heat in Solids, 2nd ed., Oxford (1959).

9. J. A. Hanson, "Effects of curing and drying environments on splitting tensile strength," American Concrete Institute Journal 65 (PCA Bulletin D141), 535-543 (1968).

10. R. A. Helmuth and D. H. Turk, "The reversible and irreversible drying shrinkage of hardened portland cement and tricalcium silicate paste," Journal of the Portland Cement Association Research and Development Laboratories 9, No. 2 (PCA Bulletin 215), 8-21 (1967).

11. B. P. Hughes, I. R. G. Lowe and J. Walker, "The diffusion of water in concrete at temperatures between 50 and 95°C," British Journal of Applied Physics 17, 1545-1552 (1966).

12. S. S. H. Kasi and S. E. Pihlajavaara, "An approximate solution of a quasi-linear diffusion problem," Publ. No. 153, The State Institute for Technical Research, Helsinki (1969).

13. S. E. Pihlajavaara and J. Väisänen, "Numerical solution of diffusion equation with diffusivity concentration dependent," Publ. No. 87, State Institute for Technical Research, Helsinki (1965).

14. S. E. Pihlajavaara, "On the main features and methods of investigation of drying and related phenomena in concrete," Ph.D. Thesis, Publ. No. 100, State Institute for Technical Research, Helsinki (1965).

15. G. Pickett, "The effect of change in moisture content on the creep of concrete under a sustained load," American Concrete Institute Journal

36, 333-355 (1942); see also "Shrinkage stresses in concrete," American Concrete Institute Journal 42, (1946).

16. T.C. Powers and T.L. Brownyard, "Studies in the physical properties of hardened portland cement paste", Amer. Concr. Inst. Jour. 42, 101, 249, 469 (1946), 43, 549, 669, 845, 933 (1947) (PCA Bulletin 22).

17. D. U. von Rosenberg, "Methods for the numerical solution of partial differential equations," ed. R. Bellman, American Elsevier (1969).

Appendix - Basic Notations

C, C_1 = diffusion coefficient (Eqs. 1 and 3) and its value at $H = 1$;

H, H_{en}, H_c = pore humidity (relative vapor pressure), environmental humidity and parameter in Eq. (9);

L = half-thickness of slab;

n = exponent in Eq. (9);

r = radius coordinate of a cylinder or sphere;

R = radius of cylinder or sphere;

t, t_0 = time, and instant of exposure to drying environment;

w = mass of water in a unit volume of material;

x = coordinate across the thickness of slab;

α_0 = parameter in Eq. (9);

Prime as in t', x', H' stands for non-dimensional variables, Eq. (7).

Appendix - Note on Dependence of C on Time

As has been noted in the introductory paragraph, the dependence of C upon the drying period of specimen (15), $t-t_0$, is not satisfactory from the fundamental point of view. Namely, this dependence would mean that C depends on some physico-chemical process which changes the material properties and is caused by the drop in water content. Since this drop is non-uniform throughout the specimen, such a process would have to be progressing faster near the surface than in the core. Therefore, the drying period on which C depends would have to be taken different in every point of the specimen and, especially, in the surface and core regions. Nevertheless, the dependence of C upon $t-t_0$ has served as a practically useful empirical formulation allowing considerable improvement in the prediction of drying (within a certain range of thicknesses), as Pickett has clearly demonstrated in his papers. Finally, it should be noted that, as far as the effect of hydration (aging) in young concrete is concerned, dependence on time (or, more correctly, the equivalent hydration period (6)) must be considered. But the effect of aging has not been investigated in this paper.