Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte
Band: 57/1/57/2 (1989)

Artikel: Test methods for on-site assessment of durability
Autor: Bunte, Dieter / Rostásy, Ferdinand S.
DOI: https://doi.org/10.5169/seals-44234

Test Methods for On-site Assessment of Durability

Essais pour l'estimation in situ de la durabilité

In situ Prüfung der Dauerhaftigkeit

Dieter BUNTE
Dipl. -Ing.
TU Braunschweig
Braunschweig, FR Germany

D. Bunte, born 1959. Research assistant for structural materials, at the Institut für Baustoffe, Massivbau und Brandschutz

Ferdinand S. ROSTÁSY
Prof. Dr. -Ing
TU Braunschweig
Braunschweig, FR Germany

F. S. Rostásy, born 1932. Professor for structural materials, at the Institut für Baustoffe, Massivbau und Brandschutz

ZUSAMMENFASSUNG

Zur Dauerhaftigkeitsprognose sind Methoden zur Prüfung der Betondichtigkeit erforderlich. Die Möglichkeiten und Grenzen einiger Methoden werden erläutert.

SUMMARY

Prediction of durability requires on-site test methods for the assessment of tightness of concrete cover. Potentials and limits of several methods are discussed.

RÉSUMÉ

Pour la prévision de la durabilité des méthodes d'essai pour mesurer la perméabilité du béton sont nécessaires. Les possibilités et limites de quelques méthodes sont discutées.

1. INTRODUCTION

Tools for the assessment of durability of reinforced concrete members become increasingly important. The necessity for such tools arises already for the just completed structure and for the older one as well: quality control for the just completed structure; assessment of durability and decision for repair for the older structure.

In a climatic region such as the FRG, the most common damage is the corrosion of the reinforcement adjacent to the exposed surface. Corrosion commences once the surface of steel has been depassivated and if certain electrochemical prerequites coexist. Depassivation of steel and initiation of corrosion depend on the transport of gases and fluids through the pore structure of concrete and on the ensueing chemical reactions [1]. Thus, durability depends on depth, tightness and chemical composition of concrete cover.

This fact led to the development of test methods to assess the perviousness of the cover. The description and appraisal of these methods, their potentials and limits, will be dealt with.

2. SURVEY OF TEST METHODS

2.1 Necessity for on-site test methods

For the assessment of the condition several test methods are available. These are usually laboratory methods for the determination of: carbonation depth, chemical composition and pore structure of concrete, coefficients of gas and water transport, etc. These methods usually are destructive ones because they require core extraction. If a statistically sound appraisal of condition is needed, high costs arise.

Of advantage are on-site, non-destructive tests for the determination of the cover. Also available are on-site test methods of the perviousness of cover. These tests may substitute laboratory tests. They can be performed repeatedly, economically, and expediently.

2.2 Existing methods

Most methods for the on-site testing of the tightness have been developed for quality control of the just fabricated precast element and less for the assessment of durability of the aged structure. The principal aim of all methods is a qualified information on the influence of curing or the combined influence of curing and water/cement ratio on the diffusivity of pore structure for CO_2 and water vapour.

A suitable method must meet certain standards with respect to: evidential strength, selectivity, repeatability, simplicity and cost. The methods dealt with here represent a selection, they meet these standards. The following methods are discussed: the air permeability test methods by Schönlin and Hilsdorf [2] and by Figg [3], and the initial surface water absorption test ISAT [4].

All methods presuppose that a low initial perviousness will render a high durability. This assumption is necessary, but not sufficient; furthermore it is essentially not verified. In course of the specific test, only the first millimeters of cover are permeated. This fact raises the question of representativity of test results for the total cover's protective quality [7].

2.3 Transport mechanisms and test methods

For carbonation and steel corrosion the diffusion of oxygen, carbon dioxyde and water vapour as well as the sorption of aqueous solution are the relevant transport mechanisms. Diffusion at natural conditions is extremely slow. This fact and unsurmountable experimental difficulties discard diffusion's measurement on-site. As substitute for gas diffusion other transport mechanisms are chosen for on-site testing, such as the permeation of gas or fluid and the absorption of water.

Permeability testing: These tests are used for the assessment of concrete quality and curing [2], [5]. The driving potential is a pressure difference either below or above the atmospheric pressure (medium: air or nitrogen). The permeability K for the stationary flow of nonsorbent gas is described by the Hagen-Poiseuille law (Fig. 1). The principal set-up of the permeability test of Schönlin-Hilsdorf (a, [2]) and Figg (b, [3]) are shown in Fig. 2. Both methods work in the unsteady pressure range. The lapse of time Δt is measured during which a defined initial pressure p_{io} is relaxed by a definend difference Δp of the known gas volume V. The time difference Δt is used to express the permeability index [2].

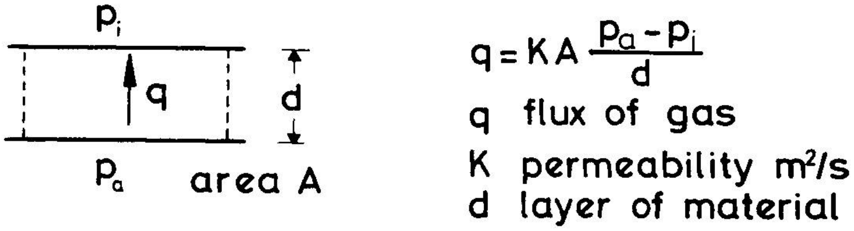

Fig. 1: Hagen-Poiseuille's Law

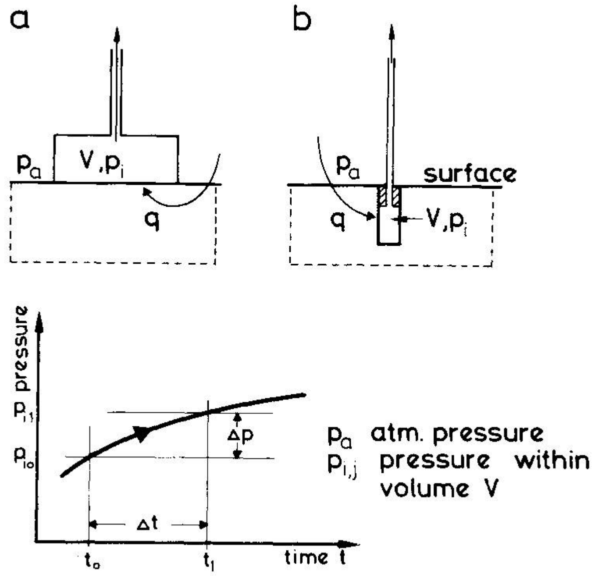

Fig. 2: Permeability test of Schönlin-Hilsdorf (a) and Figg (b)

$$I_{perm} = \frac{V}{\Delta t} \frac{\Delta p}{p_a - \Delta p/2} \quad (1)$$

with p_a, atmospheric pressure. The permeability index also depends on experimental parameters such as: total pressurized volume V, pressure range, magnitude and distribution of moisture and temperature within cover, geometry of permeated concrete surface. If the experimental parameters are strictly defined, the test methods are suitable to differentiate clearly with respect to the quality of curing. The coefficient of variation of Figg's method was determined in laboratory tests in the following range for different batches of identical concrete: V ≈ 11 % for oven-dried concrete, V ≈ 30 % for concrete dried at 50 °C and lower.

Absorption tests: These tests serve the same purpose as permeability tests. Their results may also be used for durability prediction [6]. The ingress of water occurs by capillary suction. Transport of water by capillary tension is described by Bernoulli's law. Assuming a one-dimensional flow at the on-set of suction, the volume of water v_w per unit contact area can be expressed by (s. Fig. 3):

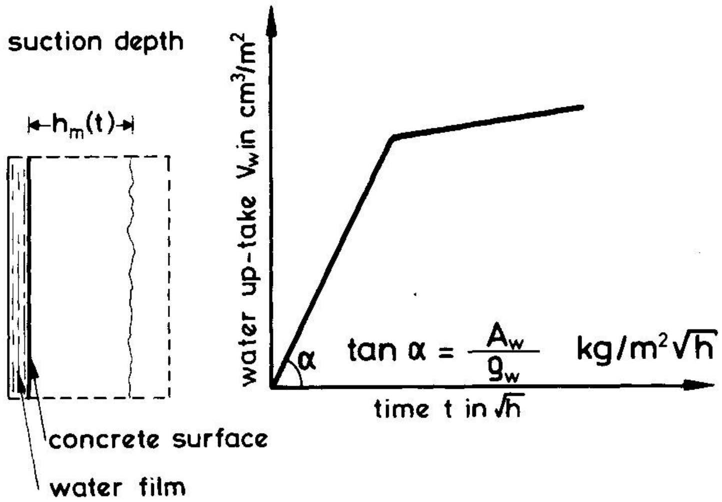

Fig. 3: Capillary water absorption

$$v_w = \frac{A_w}{\rho_w}\sqrt{t_s} \qquad (2)$$

with A_w, coefficient of water absorption; ρ_w, density of water and t_s, suction time. The coefficient A_w can be expressed by pore structural parameters [6]:

$$A_w = K_2\sqrt{2r_h}\,\frac{\epsilon_{abs}}{a_{Tabs}} \qquad (3)$$

ϵ_{abs} ....effective capillary porosity, part of the total porosity within the range 100 nm ≤ r ≤ 10 μm

$r_h = \epsilon_{abs}/S_{abs}$ ..... hydraulic radius; S_{abs} = specific surface

$a_T = h_{id}/h_m > 1$ .... tortuosity factor which relates the suction depth of the ideal porous body h_{id} to that of the real porous body h_m

K_2 .... physical coefficient related to surface tension, contact angle, viscosity and temperature of water

Although the effective capillary porosity and the hydraulic radius may be determined in the laboratory, for example by mercury intrusion, the tortuosity remains unknown. Thus, the coefficient A_w must be determined experimentally.

2.4 ISA-test

One method to measure the absorption of water on-site is the ISA-test (initial surface absorption), which is standardized in BS 1881, pt 5. Fig. 4 shows the test set-up. A cap is sealed onto the concrete surface and then filled with water with a small pressure head. The rate of water intake can be derived from the rate of the retracting meniscus of the scaled glass capillary, after closing the tap. The ISA-value is taken at certain time values t_S.

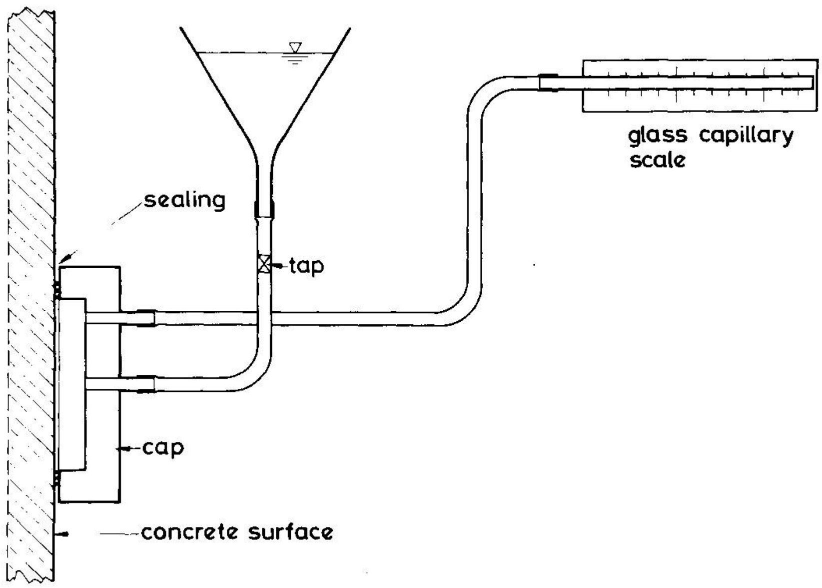

Fig. 4: Set-up of ISAT

The ISA-value is the non-steady, threedimensional flux of water. It can be approximatly expressed with Equ.(2) (see Fig. 5):

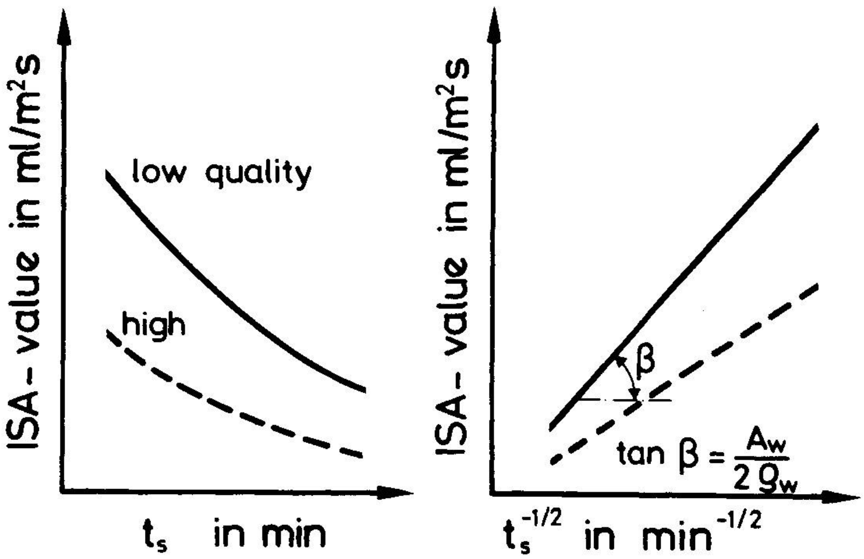

Fig. 5: Development of ISA-value vs. suction time

$$\dot{v}_W(t_S) = \frac{dv_W}{dt_S} = \frac{A_W}{2\rho_W} t_S^{-\frac{1}{2}} = ISA(t_S) \qquad (4)$$

The volume v_w corresponds to the effective capillary porosity (r > 100 nm) which can be filled by water, dependent on the momentaneous moisture content and

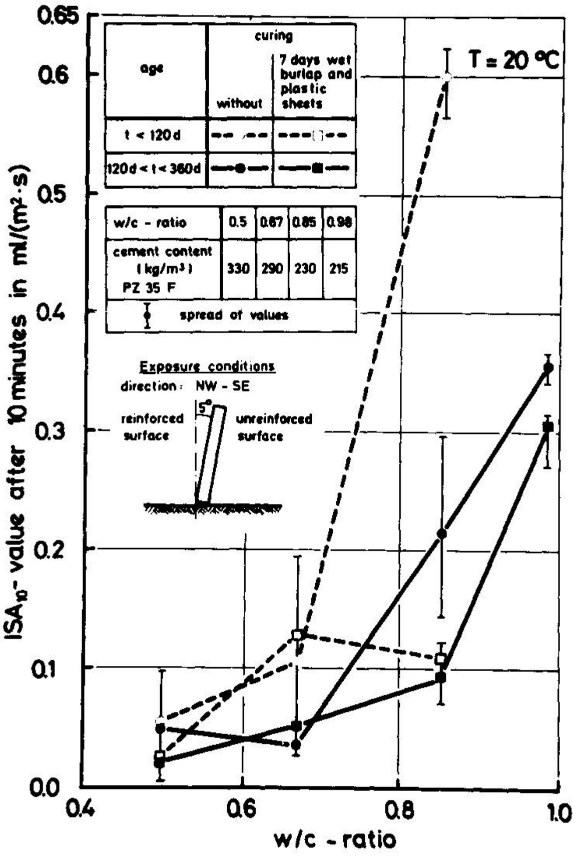

Fig. 6: Results of ISA_{10}-tests on the unreinforced surface of walls vs. w/c-ratio

temperature. Tests [6] proved that the ISA-reading is well correlated with pore structural properties as expressed by Equ.(3) and (4). The parameters water/cement ratio, curing and age can be satisfactorily identified and roughly quantified (see Fig. 6). Fig. 6 shows results for walls exposed unsheltered to weather (up to five readings per point in different locations). The coefficient of variation is about 33 %.

The moisture content of cover is of great influence [4]. Thus, ISA-tests should not be performed immediately after rainfall. A drying period of at least 2 days is necessary.

3. APPLICATION

The application of ISA-tests for the assessment of the quality of concrete and curing is shown in [4]. The application for prediction of durability is attempted in [7]. This requires the estimation of that portion of total porosity which is accessible for CO_2-diffusion. By insertion of the diffundable porosity into a carbonation law a model for the prediction of durability can be developed. The procedure is shown in [7].

REFERENCES:

[1] Rehm, G.: Korrosion von Stahl und Beton - Ein gelöstes Problem? Vorträge auf dem Deutschen Betontag, Berlin 23. - 25.04.1987

[2] Schönlin, K.; Hilsdorf, H.: Evaluation of the effectiveness of curing of concrete structures. Concrete durability, K. and B. Mather International Conference, Vol. 1, 1987

[3] Figg, Y.W.: Methods of measuring the air and water permeability of concrete, Mag. of Con. Res., Vol. 25, 1973

[4] Dhir, R.K.; Hewlett, P.C.; Chon, Y.N.: Near surface characteristics of concrete assessment and development of in-situ tests methods, Mag. of Con. Res., Vol. 39, 1987

[5] Concrete Society technical report: Permeability of concrete and its control, Papers of a one-day conference, London, 1985

[6] Rostásy, F.S.; Bunte, D.: Assessment of durability of concrete surfaces, Durability of non-metallic inorganic building materials - DFG Abschluß-kolloqium, Karlsruhe 04./05.10.1988

[7] Rostásy, F.S.; Bunte, D.: On the evaluation of conditions and durability of concrete panels exposed to weather, IABSE-Symposium, Durability of structures, Lisbon 06. - 08.09.1989