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Evaluation of concrete permeability by critical voltage

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Abstract

A rapid method has been established to evaluate the concrete permeability using critical voltage of concrete (CVC) at limited current. The results are consistent with the water penetration test, ASTM C1202 test, and NEL test results. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: Concrete; Durability; Electrical properties; Permeability

1. Introduction

The durability of concrete is fundamentally based on the permeability of concrete. So rapid evaluation of concrete permeability can be used to indirectly estimate its durability. New approaches to determine the permeability of concrete rapidly, easily, and accurately have been investigated, especially for high performance concrete.

Some methods using the electrical and electrochemical techniques to evaluate the permeability of concrete have been studied in our laboratory in recent years. Several rapid test methods have been established, such as the NEL test method [1,2], and the critical voltage method (shortened as CVC test, meaning critical voltage of concrete). The latter method will be introduced and compared with some test methods in the present paper.

The principle of the CVC test is that the current always gets through the weakest path in the materials and the weakest path determines the permeability of concrete. Similar work has been done on the ceramics before [3], and can be found in the dielectric research area.

2. Experimental procedure

The concrete mixes are listed in Table 1. The maximum size of coarse aggregate is 25 mm. The compressive strength shown in Table 1 is the standard cube's (150 × 150 × 150 mm) strength. Prisms, 100 × 100 × 300 mm, were cast and cured at 20 ± 2°C, RH 90% for 4 weeks. Specimens of about 10 mm thick were cut from the prisms and heated at 75°C until their weight was constant. The heating time is usually 4–7 days. The CVC test is carried out at room temperature using a high voltage generator made by the High Voltage Research Laboratory of our university with a range, 50 kV, 2 mA, DC. The experimental arrangement is illustrated in Fig. 1. The pure copper electrodes were 50 mm in diameter. After installation of the prepared sample between the electrodes, the voltage was applied to the electrodes at a certain speed in the range, 10–1 kV/s. The critical voltage was recorded at the limited current density, usually 5 μA/cm^2. The duration of this test is usually less than 5 min.

The water penetration test follows the Chinese standard JC492-94. The cylinder sample has a top diameter

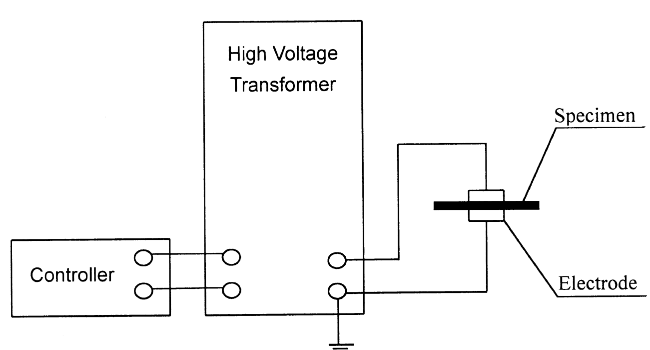

Fig. 1. Schematic of high voltage generator.

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Table 1
Concrete mix

Specimen	W/C	Portland cement (kg/m^3)	Fly ash (kg/m^3)	Sand (kg/m^3)	Coarse aggregate (kg/m^3)	Compressive strength at 28 days (MPa)
S1	0.30	558	–	660	1077	75.4
S2	0.35	525	–	660	1077	72.0
S3	0.40	481	–	660	1077	59.5
S4	0.45	450	–	660	1077	58.0
S5	0.50	422	–	660	1077	48.1
S6	0.60	376	–	660	1077	36.7
F1	0.40	433	48	660	1107	57.0
F2	0.40	385	96	660	1107	49.4
F3	0.40	337	144	660	1107	46.9
F4	0.40	289	192	660	1107	45.0
D1	0.35	450	–	660	1107	71.0
D2	0.35	525	–	660	1107	72.0
D3	0.35	600	–	660	1107	75.7
D4	0.35	675	–	660	1107	76.7

175 mm and bottom 185 mm, and is 150 mm high. After maintaining the pressure at 1.2 MPa for 24 h, the sample is split and the water penetration depths for 30 points are measured and averaged. The ASTM C1202 test follows the ASTM C1202-94 [4], i.e. record the electric quantity passed during 6 h at 60 VDC through the sample in 95 mm diameter and 50 mm thick. The NEL test is the same as the description in Ref. [2], i.e. measure the conductivity of the salt-saturated slice sample, then calculate the chloride diffusivity using Nernst–Einstein equation.

3. Results

3.1. Electrical behavior of concrete

The electrical behavior of concrete is investigated. All the specimens show a nonlinear behavior in the voltage–current relationship. A typical result is shown in Fig. 2. This indicates that the dried concrete specimen is not a pure resistor; it exhibits capacitance as well. This brings some difficulties when establishing the relationship of critical voltages to the physical and chemical parameters of con-

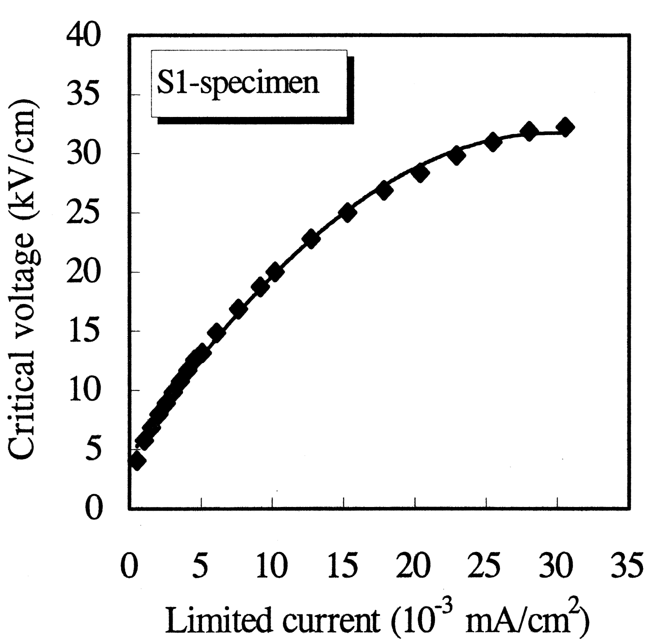

Fig. 2. Relationship between the critical voltage and limited current.

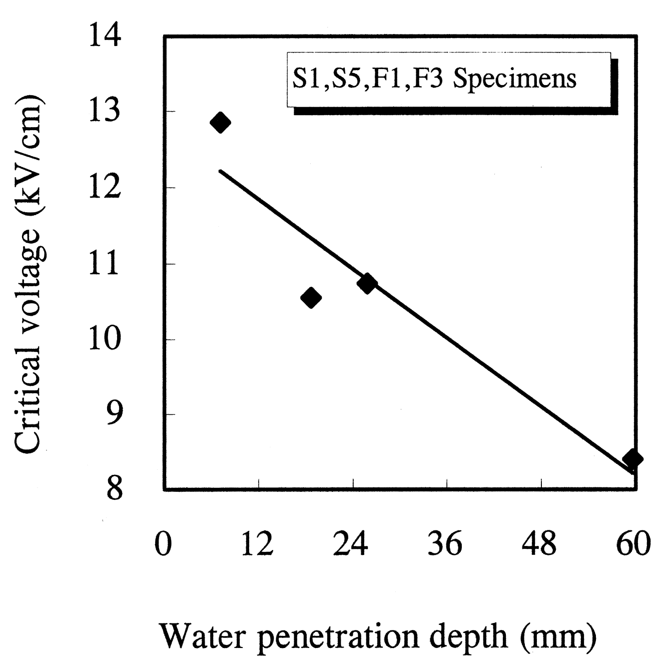

Fig. 3. Comparison of the CVC test with water penetration test.

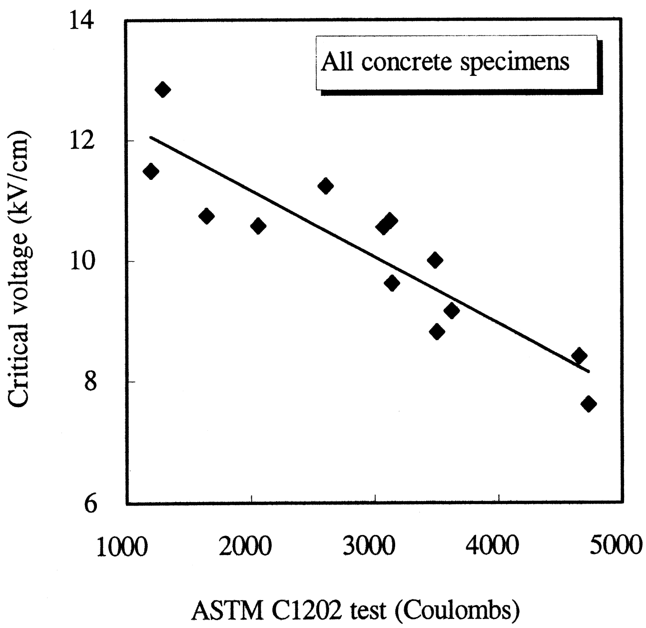

Fig. 4. Comparison of the CVC test with the ASTM C1202 test.

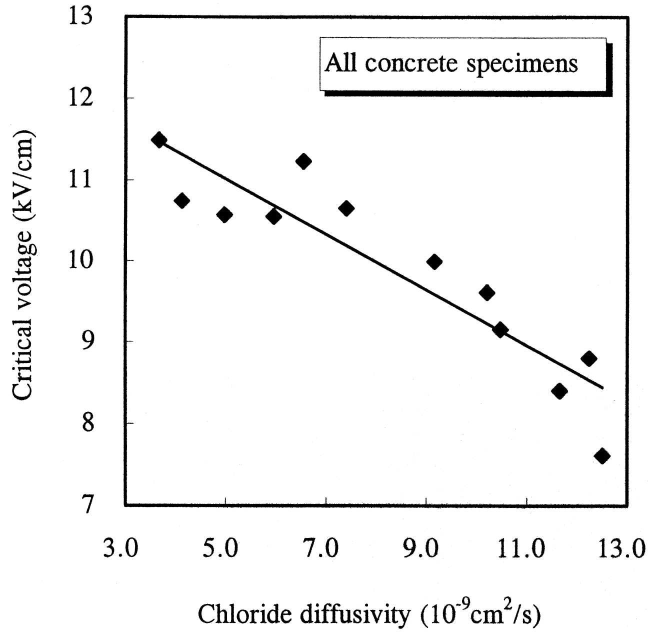

Fig. 5. Comparison of the CVC test with the NEL test.

crete. Fortunately, it was found that at limited currents, the critical voltages are in good linear relation with water/cement ratio, compressive strength, and paste volume. This permits the comparison of the permeability of concrete with different mix proportions and curing time.

3.2. Comparison of the CVC test with some other tests

A comparison of the CVC test with some currently used test methods has been carried out. The results are illustrated in Figs. 3–5. All critical voltages are obtained at the limited current of 5 $\mu A/cm^2$. It can be seen that the critical voltages are consistent with the water penetration depths, the ASTM C1202 coulombs, and the chloride diffusivities. That is to say, the CVC test method can be used to evaluate concrete permeability.

4. Conclusion

Concrete permeability can be evaluated using the critical voltage of dried concrete. The CVC test can be used as a rapid test method to determine the permeability of the concrete.

Acknowledgments

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