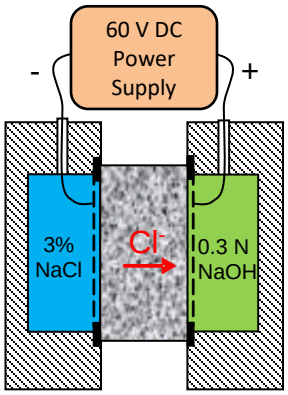
Purpose

The **PROOVE´it** system is used to evaluate the resistance of concrete to the ingress of chloride ions in 3 ways:

- By determining the total electrical charge that passes through a saturated concrete specimen by applying an electrical potential across the specimen in accordance with AASHTO T 277 or ASTM C1202. This is known as the "Rapid Chloride Permeability Test (RCPT)" or as the "Coulomb test".
- By measuring the penetration depth of chloride ions, after an electric potential is applied to the specimen in accordance with Nordtest Build 492 to determine the "Chloride Migration Coefficient," which can be used to estimate the chloride diffusion coefficient for service life calculations.
- By measuring the current passing through a saturated concrete specimen and determining the bulk conductivity in accordance with ASTM C1760.

Principles

ASTM C1202-RCPT Test



ASTM C1202 "Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration" is actually a test of electrical conductance, rather than chloride permeability as it is often stated. In this test, a water-saturated concrete specimen, nominally 100 mm diameter and 50 mm thick, is positioned in a test cell (right) containing fluid reservoirs on both ends of the specimen. One reservoir is filled with a 3 % NaCl solution and the other with a 0.3N NaOH solution. An electrical potential of 60 VDC is applied across the cell. The negative terminal of the potential source is connected to the electrode in the NaCl solution and the positive terminal is connected to the electrode in the NaOH solution. The negatively charged ions will migrate towards the positive terminal resulting in current through the specimen.

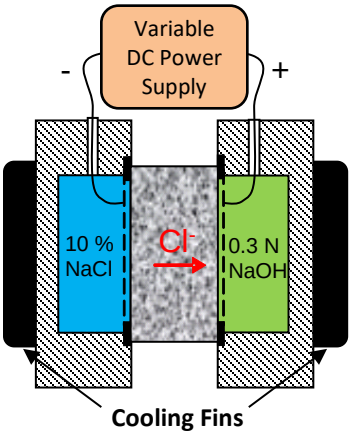
The more permeable is the concrete, the more negative ions will migrate through the specimen, and a higher current will be measured. The current is measured for 6 hours and the area under the curve of current versus time is determined, which represents the total charge or Coulombs passed across the specimen. Test results are corrected for a standard specimen diameter of 95 mm. The Coulomb values are used for classifying the concrete as follows (ASTM C1202):

Table 1

Coulombs	Permeability Class	Typical of
>4000	High	w/c* > 0.5
4000-2000	Moderate	w/c = 0.4 to 0.5
2000-1000	Low	w/c < 0.4
1000-100	Very Low	Latex-modified concrete
<100	Negligible	Polymer concrete

*w/c = water-cement ratio

NT Build 492-Chloride Migration Test



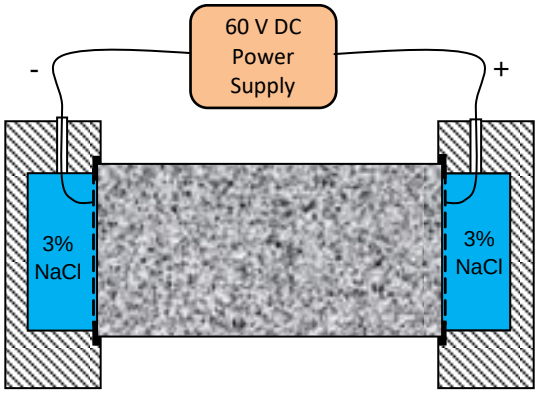
Electrical conductivity is related to the diffusion coefficient. To use **PROOVE´it** for the NT Build 492 "Chloride Migration Coefficient from Non-Steady State Migration Experiments", the reservoir surrounding the negative terminal is filled with a 10 % NaCl solution and the reservoir surrounding the positive terminal is filled with a 0.3N NaOH solution. A 30 VDC potential is applied across the specimen, and the initial current is measured. Based on this measurement, the test voltage and test duration are selected accordingly. For example, if the initial current is between 120 and 180 mA, the test voltage is 15 VDC and the test duration is 24 h, but if the initial current is less than 5 mA, the test is at 60 VDC and 96 h. After the test is completed, the specimen is split, and the chloride ion penetration is measured by spraying the split

surface with a 0.1 M silver nitrate solution, which precipitates as white AgCl where chlorides are present. From the penetration depth and test conditions, the chloride ion migration coefficient is calculated. Because, it is required to maintain a constant temperature in the solutions in the reservoirs, the measuring cells with cooling fins (Part No. PR-1100) are recommended for this test.

There is also an AASHTO test method TP-64, "Standard Method of Test for Predicting Chloride Penetration of Hydraulic Cement Concrete by the Rapid Migration Procedure," that uses the same procedure as NT Build 492. The test result, however, is reported as a rate of penetration, by dividing the depth of penetration, in mm, by the product of applied voltage (V) and the test duration (h).

ASTM C1760-Bulk Electrical Conductivity

ASTM C1760, "Standard Test Method for Bulk Electrical Conductivity of Hardened Concrete," involves the same basic testing procedure as ASTM C1202, with the following exceptions: 1) both reservoirs contain the 3 % NaCl solution; 2) the specimen length (L) can be up to 200 mm; and 3) the current (I) is measured for just 1 minute. With the area of the cross section of the specimen (A), the bulk electrical conductivity (σ) in millisiemens per meter is calculated:



$$\sigma = \frac{I}{V} \cdot \frac{L}{A}$$

Bulk conductivity is related directly to the charge passed through a specimen as measured by ASTM C1202, provided that the current remains constant during the 6 h test duration. If we assume that is valid, the ASTM C1202 coulomb limits can be converted into bulk conductivity limits:

Table 2

Charge passed using ASTM C1202, Coulombs†	Bulk Conductivity mS/m
50	0.27
100*	0.54
1,000*	5.44
2,000*	10.89
4,000*	21.77
10,000	54.43

†It is assumed that current is constant during the 6 h test duration, which is typically not true for high conductivity concrete. Specimen length of 50 mm and a diameter of 95 mm.
*Limiting values in ASTM C1202 used to define different categories of "chloride ion penetrability" (Table 1)

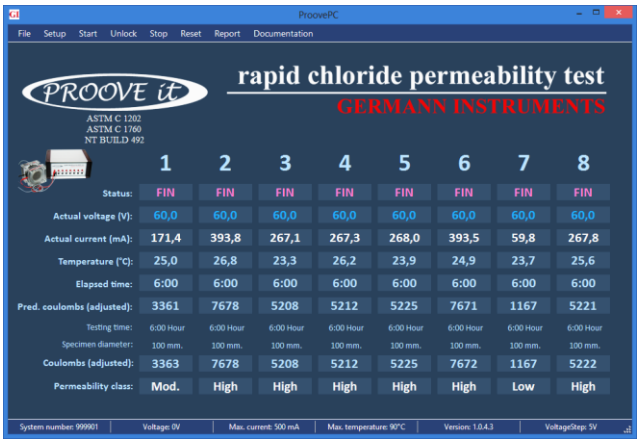
Variability

The repeatability of the RCPT or Coulomb Test is reported to be about 12 % (ASTM C1202), and the repeatability of the migration test is reported to be about 9 % (NT Build 492).

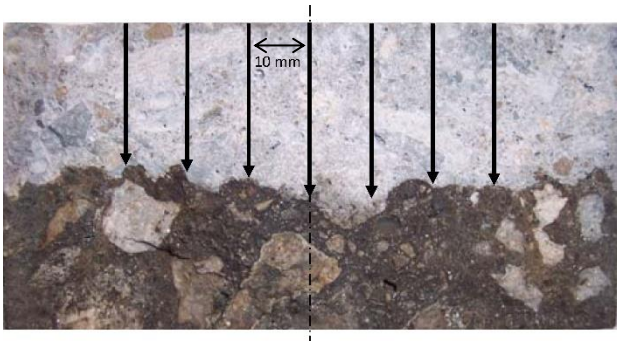
Testing Examples

RCPT: The next image shows the screen display showing the details when **PROOVE´it** is used for the RCPT test (ASTM C1202). The "Status" line for the eight cells indicates OFF, ON, or FIN, depending on whether power to the cell is turned off, if the cell is operating, or if the test has finished. The "Actual voltage" line indicates the test voltage, which has to be the same for all cells. The "Actual current" line indicates the instantaneous current during testing. Readings are updated every 5 seconds. The "Temperature" line indicates the instantaneous temperature in the reservoir solutions

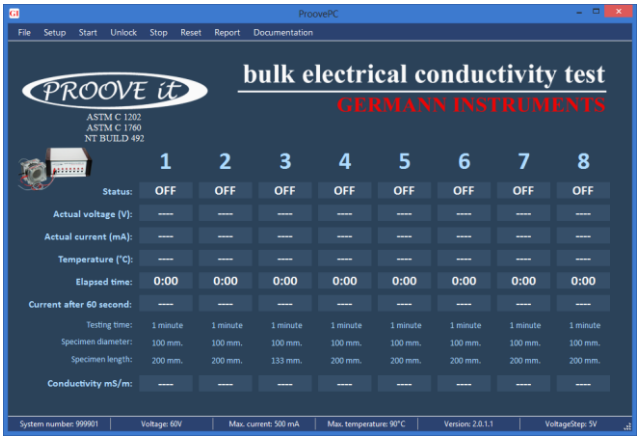
during testing if temperature probes are used. "Elapsed time" indicates the cumulative time since the cell was turned on. The "Pred. coulombs (adjusted)" line indicates the predicted Coulombs at 6 hours, which are estimated continuously every 5 minutes while the test is running. "Testing time" indicates the selected testing time, and the "Specimen diameter" indicates the actual diameter of the specimen. The "Coulombs (adjusted)" line indicates the measured Coulombs at any time during testing, which have been adjusted for a specimen diameter of 95 mm as required by ASTM C1202; so when the test ends, it indicates the test result. The last line shows the "Permeability class" according to ASTM C1202 (Table 1).



Migration: For using **PROOVE´it** to determine the chloride migration coefficient, a two-step process is used. First the cells are set up for a voltage of 30 V and the initial current is recorded. Based on the initial current, the operator selects the test voltage and test duration in accordance with NT Build 492. Test voltage may be from 10 to 60 V, and test duration may be from 6 to 96 h. A higher voltage and longer test duration are required for higher quality concrete mixtures. Cell temperature must be measured during the test. At the end of the test, the specimen is split in half, the surface is sprayed with a 0.1 M silver nitrate solution, and the average depth of chloride penetration is determined by making seven measurements in the central 60 mm of the specimen as shown above. The average chloride penetration, the applied voltage, average temperature of the sodium hydroxide solution, test duration, and specimen thickness are used to calculate the *non-steady-state migration coefficient*.



Conductivity: The image to the right shows the screen display when **PROOVE´it** is used to measure bulk electrical conductivity in accordance with ASTM C1760. A separate module is used for this test. The user sets up the test by entering the length and diameter of the specimens for each cell. The voltage is set to 60 V and the cells are turned on. The test runs for 1 minute, at which time the currents recorded during the last 3 readings are saved, averaged, and used to calculate the bulk conductivity, which is displayed in units of mS/m. For concrete with adjusted Coulomb values in the range of 500 to 4000 C, the bulk conductivity is expected to be in the range of 3 to 20 mS/m (see Table 2).



Test Report

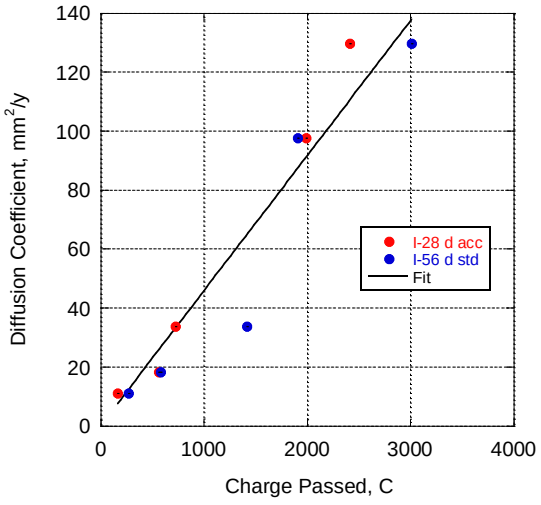
The software includes a **Report Manger** for preparing professional quality test reports, which can be customized with the purchaser's company logo. Data recorded during each test are stored in a database allowing a complete review of data if anomalous results are encountered. Customized labels can be

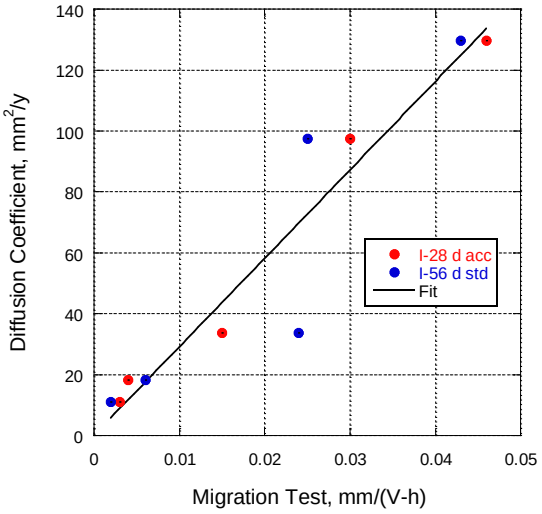
attached to each test for complete project documentation. Test results can be exported to Excel for statistical analysis of the results and preparing user defined control charts.

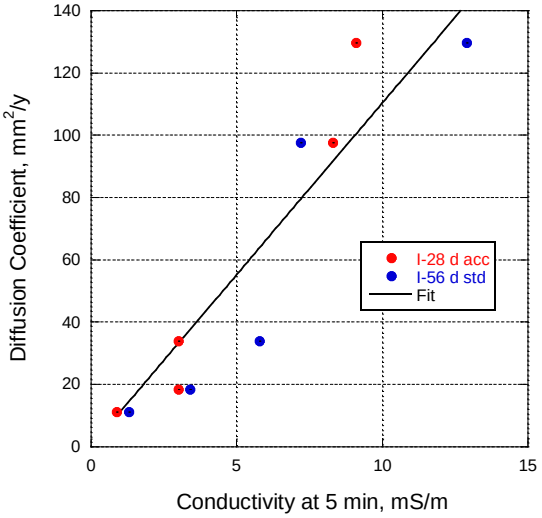
Correlations to Chloride Diffusion Coefficient

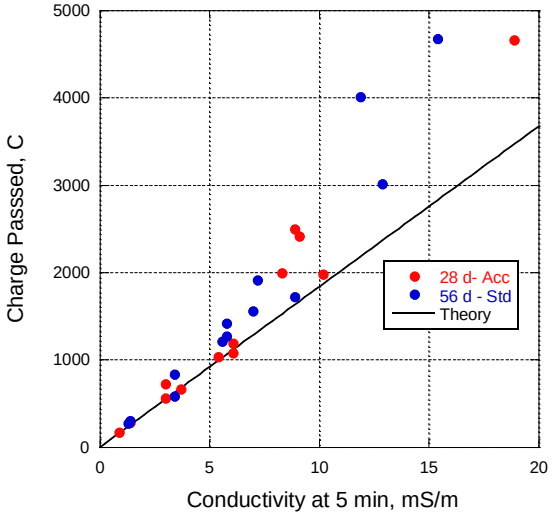
There is a theoretical relationship between the chloride diffusion coefficient and electrical conductivity whose validity has been experimentally investigated. The chloride diffusion coefficient can be determined directly by profile grinding (see **Profile Grinder** data sheet) and testing for chloride content (see **RCT** data sheet) after ponding with NaCl solution as per NT Build 443 "Concrete, Hardened: Accelerated Chloride Penetration" or ASTM C1556 "Test Method for Determining the Apparent Chloride Diffusion Coefficient of Cementitious Mixtures by Bulk Diffusion." The required ponding period is at least 35 days. A correlation can then be developed between the diffusion coefficient and any of the other properties determined with the **PROOVE´it**. The following shows a good example:

In a study by Obla, Kim, and Lobo (2014), the apparent chloride diffusion coefficient was determined as per ASTM C1556. Specimens from 5 concrete mixtures were subjected to 59 days of standard curing and then 16 months of immersion in NaCl solution. Companion specimens were tested as per ASTM C1202 and AASHTO TP 64, after standard curing at 23 °C for 56 days or standard curing for 7 days plus 21 days curing at 38 °C. For the ASTM C1202 tests, the current at 5 minutes was used to calculate the electrical conductivity. The following plots show the correlations between various test results and the relationship between the charge passed and the 5-minute electrical conductivity test.









Reference

Obla, K.H., Kim, H, and Lobo, C.L., 2014, "Selection of Rapid Index Tests and Criteria for Concrete Resistant to Chloride Penetration," presented at Transportation Research Board Meeting, Washington D.C., Jan. 2014.

PROOVE'it Specifications

Power supply unit and software:

- 8-channel unit for testing simultaneously.
- 220 VAC / 60 Hz or 110 VAC / 50 Hz power supply.
- RS-232 serial connection to PC, convertible to USB.
- Short circuit protection Channel locking option.
- Dimensions: ~ 40 x 30 x 15 cm.
- Compatible with Windows 7 / 8 / 10 operating systems.
- Easy and friendly display.
- Auto-correction of measured Coulombs using ASTM C 1202-14 when the diameter of the specimens differs from the standard´s 95 mm.
- Customizable voltage setting: 5 V to 60 V in steps of 5 V (e.g. for NT BUILD 492).
- Max. testing current for protection: 500 mA per Channel.
- Current accuracy ± 0.5 % at 1 to 500 mA.
- Voltage accuracy ± 0.1 V at 5 to 60 V.
- Maximum testing temperature: 90°C (system shuts down to prevent boiling of the solutions).
- Temperature probes with ± 1°C accuracy at 20 – 25°C.
- Report Manager with detailed data.

Measuring cells:

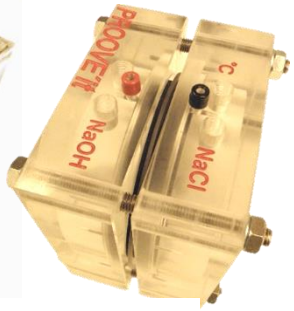
Robust, easy to assemble, auto-seal cells available in different versions:

- ✓ (a) PR-1000 cell: Regular cell as specified by ASTM C 1202-14.
- ✓ (b) PR-1100 cell: Enhanced cell with cooling ribs to keep the temperature of the liquids at room temperature, preventing heating of the specimen. Used for NT BUILD 492 or as a modified cell for ASTM C 1202 with control of temperature.
- ✓ (c) PR-1200 cell: Measuring cell for 200 mm long specimens for ASTM C 1760-12 Bulk Conductivity.
- ✓ (d) PR-1000-113-20: Modified cell for the French standard XP P 18-461 for 113 mm dia. and 20 mm thick specimens (cooling fins can also be mounted here).

(a)

(b)

(c)

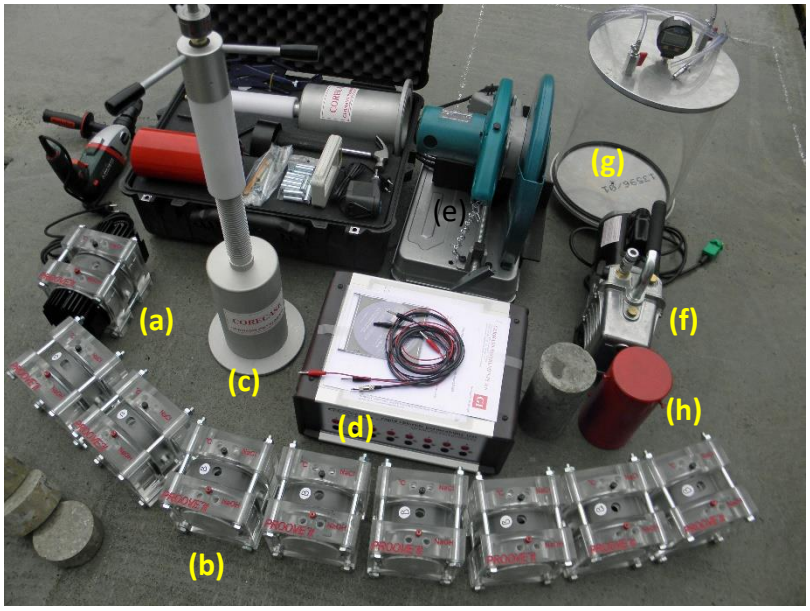


(d)

The following gaskets are available for different specimen diameters. All cells are supplied with the PR-1010B gaskets, unless otherwise specified. The PR-1010B gaskets match the 100-mm core diameter produced by the CEL-100 coring equipment (see **CORECASE** data sheet):

Specimen Diameter	Gasket Ordering #
104 to 102 mm	PR-1010A
101 to 97 mm	PR-1010B
96 to 93 mm	PR-1010C

PROOVE'it System components



(a) Cell with cooling fins (PR-1100)
(b) Eight standard cells (PR-1000)
(c) CORECASE for producing cores of 100 mm in diameter (CEL-100)
(d) PROOVE´it microprocessor power supply (PR-1050) and software (PR-1040)
(e) Diamond saw for cutting 50 mm slices (PR-1090)
(f) Vacuum pump, <10 mmHg or 1.3 kPa (PR-1081)
(g) Vacuum desiccator for max. 16 specimens (PR-1070)
(h) Precision steel mold, reusable for casting 100 mm x 200 mm specimens (MRLN-1009)

NOTE: *A computer is also required with a Windows operating system.*

PROOVE'it Ordering Numbers*

Item	Order #
PROOVE´it power supply for 8 cells	PR-1050
PROOVE´it software for Windows®	PR-1040
Power cable for power supply 230 VAC	PR-1064
Power cable for power supply 110 VAC	PR-1065
RS-232C serial cable for power supply	PR-1066
PROOVE´it cell, standard	PR-1000
PROOVE´it cell, with cooling fins	PR-1100
PROOVE´it cell for bulk conductivity	PR-1200
PROOVE´it cell for bulk conductivity	PR-1000-113-20
Red connecting cord, one per cell	PR-1001
Black connecting cord, one per cell	PR-1002
Temperature probe, one per cell	PR-1005

Item	Order #
User manual	PR-1090
Spare steel mesh for cell	PR-1003
Verification unit	PR-1055
Vacuum desiccator for max. 16 specimens	PR-1070
Vacuum pump, < 50 mm Hg (6.7 kPa)	PR-1080
Vacuum pump, < 10 mm Hg (1.3 kPa)	PR-1081
CORECASE for 100 mm cores	CEL-100
Drilling machine, 1150W	CC-29
Diamond saw for trimming cores	PR-1090
300 mL bottle of 3.0 % NaCl solution	PR-1020
300 mL bottle of 0.3N NaOH solution	PR-1030
Precision steel mold, reusable	MRLN-1009

*These items can be selected as needed to assemble a system to meet the desired requirements

The PR-1055 verification unit is used to verify that the microprocessor power supply is working properly. The unit is connected to line power, 110 VAC or 220 VAC. Each channel of the **PROOVE'it** power supply is set up for testing at a selected voltage and connected to the verification unit. If the **PROOVE'it** system is operating properly, the "Actual current" indicated on the computer screen should be within 30 mA ± 0.1 mA or 300 mA ±0.1 mA for the two switch settings on the verification unit.