Durability Index Testing
Procedure Manual

January 2007 (Rev.)
CONCRETE DURABILITY INDEX TESTING

PART 1: STANDARD PROCEDURE FOR PREPARATION OF TEST SPECIMENS

SCOPE
This test method describes how to cut and prepare test specimens to perform the concrete durability index tests as originally described by Alexander, Ballim and Mackechnie (1).

Where durability index results are required for concrete mix acceptance and mix design purposes, representative samples can be prepared from concrete cubes, cast in the laboratory. Where durability index results are required for quality control purposes on site, representative samples shall be taken from the structure itself.

This test method shall not be used for concrete with a maximum nominal aggregate size exceeding 26.5 mm.

1. TEST SPECIMENS
a) The test specimens considered in this method statement are circular discs prepared by coring and cutting concrete cubes in the laboratory, or by taking cores from concrete elements on site.
b) Each test specimen shall consist of a 70 ± 2 mm diameter, 25 ± 2 mm thick concrete disc.

2. APPARATUS
a) A water-cooled diamond tipped core barrel with a nominal inner diameter of 70 mm, attached to a suitable coring drill.
b) A holding device in which cubes can be clamped firmly and securely to ensure they remain in position while coring takes place.
c) A water-cooled moveable bed diamond saw.
d) A facing machine (optional)

3. PREPARATION OF SPECIMENS FROM CUBES
a) Concrete cubes shall be cast according to the relevant specification, and with minimum dimensions of 100 mm.
b) The cubes shall be cured according to standard or project specifications. The duration and method of curing, and concrete age at time of test must be reported.
c) Coring of the cubes must take place at 28 ± 3 days after casting, unless otherwise required by project specifications.
d) Direction of coring must be perpendicular to the casting direction.
e) Clamp the cube firmly into the holding device and place the core barrel perpendicular to and in the centre of the concrete face to be cored (with a tolerance of 2 mm in any direction).
f) Core the entire way through the cube, ensuring that when the far side is reached and the core breaks off, the extent of the rough zone created is not greater than 5 mm from the end of the core. This may require slowing the speed of travel of the core drill as it approaches the far side. The sides of the core shall be parallel and within 5° of perpendicular to the face.

g) Cut the first 5 mm from the cored face of the core and discard. Cut the required thickness (25 ± 2 mm) of the test specimen from the core.  

Note: The outer 5 mm can be removed by grinding with a facing machine as an alternative to cutting.

h) Mark the test specimens with the correct reference number on the original interior face.

i) Where a specimen is damaged during the coring and cutting process, e.g. where aggregate spalls from the surfaces to be tested, this specimen shall not be used for testing.

j) The durability index test procedure shall be started immediately after cutting.

5. PREPARATION OF SPECIMENS FROM SITE ELEMENTS

Note: This section only describes the procedure of preparation of test specimens from site concrete elements. The project specifications should indicate frequency and number of cores per exposed surface area of concrete elements.

a) Coring must take place between 28 and 35 days after casting, unless otherwise required by project specifications.

b) Place the core barrel perpendicular to the surface of the concrete, and secure it so that it cannot move.

c) Core to a depth of 60-80 mm. The sides of the core must be parallel and within 5° of perpendicular to the face.

d) Break off the core from the concrete face with a hammer and chisel, ensuring the surface 35 mm is undamaged.

e) Mark each core and remove to the laboratory in sealed plastic bags.

f) Cut the first 5 mm from the exposed face of the core and discard. Cut the required thickness (25 ± 2 mm) of the test specimen from the core.  

Note: The outer 5 mm can be removed by grinding with a facing machine as an alternative to cutting.

g) Mark the test specimens with the correct reference number on the originally interior face.

h) Where a specimen is damaged during this process, e.g. where aggregate spalls from the surfaces to be tested, such a specimen shall not be used for testing.
i) Between coring and cutting, the specimens shall be kept at ambient conditions in the laboratory for a maximum of 3 days. The durability index test procedure shall be started immediately after cutting.

6. REFERENCES

(1) Alexander MG, Ballim Y, Mackechnie JM, ‘Concrete durability index testing manual’ Research Monograph No. 4, Departments of Civil Engineering University of Cape Town and University of the Witwatersrand, March 1999


(3) Gouws SM, ‘Durability Index Approach – Progress Report 1: Method Statements Summary document of major amendments to Durability Index Test Methods as agreed upon by Durability Index Test Method working group (Under the auspices of the C&CI Technical Committee, University of the Witwatersrand, 19 August 2003.)


7. REVISIONS

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CONCRETE DURABILITY INDEX TESTING

PART 2: STANDARD PROCEDURE FOR OXYGEN PERMEABILITY TEST

SCOPE

This test method sets out the procedure for determining the oxygen permeability index as originally described by Alexander, Ballim and Mackechnie\(^1\). The method described herein supersedes the 1999 version in ref. 1.

The test is suitable for the evaluation of materials and mix proportions for design purposes, and for research and development. The test can also be used for quality control of concrete on site. It is not recommended that this test be performed before 28 days after casting. Specimen age may have a significant effect on the test results, depending on the type of concrete and the curing procedure.

The oven drying procedure has been selected to result in the minimum degree of micro-structural alteration of the concrete specimens, while still giving minimal uniform moisture content. Research has shown, however, that significant amounts of micro-structural damage may occur for some high quality concrete\(^2\) notably high strength concrete incorporating silica fume. Thus care should be taken in interpreting the test results from these concretes.

This test method shall not be used for concrete with a maximum nominal aggregate size exceeding 26.5 mm.

1. APPARATUS

a) An oven capable of maintaining a temperature of 50 ± 2\(^\circ\)C.

\textit{Note: Most lab ovens are of the forced draft, ventilated type. If, however, the oven being used is of the closed (unventilated) type, then the relative humidity inside the oven must be maintained by the inclusion of trays of saturated calcium chloride solution. The trays should provide a total exposed area of at least 1 \text{m}^2 \text{per} 1 \text{m}^3 \text{of volume of the oven and should contain sufficient solid calcium chloride to show above the surface of the solution throughout the test.}}

b) Permeability test arrangement as shown in Figure 1. The permeability cell should have a volume of 5 \text{L}, with a tolerance of ± 5\%, and should be housed in a room where the temperature is controlled at 23 ± 2 \text{\degree C}. The air-tightness of the equipment needs to be tested on a regular basis using impermeable test specimens. A 0 \text{kPa} drop in pressure from an initial chamber pressure of 100 \text{kPa} over a 24 hour period is required.

c) Compressible rubber collars with Shore Hardness 39A, as shown in Figure 2 for each cell, that allow a tight fit around the specimen to eliminate any leakage of oxygen, except through the pores of the specimen. The collars must be replaced when cracks and tears occur.
d) Gauges or pressure transducers, with an accuracy of at least 0.5 kPa.

e) Standard grade 99.8% oxygen supply and regulator capable of regulating pressure to 120 kPa.

f) Vernier calliper, capable of reading to 0.02 mm.

g) Desiccator, large enough to hold as many specimens as will be tested simultaneously, containing anhydrous silica gel as the desiccant, with
the relative humidity controlled at a maximum of 60 %. Note: Not required if relative humidity in the laboratory is below 60 %.

2. TEST SPECIMENS

a) Four test specimens are required per test. Each specimen shall consist of a 70 ± 2 mm diameter concrete disc with a thickness of 25 ± 2 mm cored and cut in accordance with Concrete Durability Index Testing, Part 1.

b) Mark the specimens of the same reference 1, 2, 3 and 4 on the inner face.

3. CONDITIONING OF SPECIMENS

a) Directly after cutting the specimens shall placed in the oven at 50 ± 2°C for 7 days ± 4 hours.

4. TESTING OF SPECIMENS

a) Cool the specimens to 23 ± 2 °C in the desiccator. This cooling period should last for no less than 2 hours and no longer than 4 hours. Alternatively, the specimens may be cooled for no less than 2 hours and no longer than 4 hours, on a steel tray in a room where the ambient conditions are controlled at 23 ± 2 °C and <60 % relative humidity for the duration of the cooling period.

b) Measure to the nearest 0.02 mm the thickness and diameter of each specimen with the vernier calliper at 4 points equally spaced around the perimeter of the specimen, and record. Determine the average of the four readings and record to the nearest 0.02 mm.

c) Place the specimen in the compressible collar within the rigid sleeve with the test face (outer face) at the bottom. No gaps should be visible between the sides of the test specimen and the collar. The specimens shall be placed so that the outer face rests against the lip of the collar, see Figure 3.

Figure 3. Proper Positioning of Specimen in Collar.

d) Place the sample, collar and rigid sleeve on top of the test chamber so that it covers the hole. Place the solid ring (the solid ring is optional depending on the equipment arrangement) on top of the collar, once again ensuring that no gaps are visible between the collar and the sheath. Place the coverplate on top of the solid ring, see Figure 4.

e) Partially tighten the top screw into the coverplate to ensure that it is centred. On the underside of the coverplate is a groove. The edges to solid ring (or the collar if a ring is not present) should be within the groove. If this is not the case, adjust the location of the bottom portion.
Once the specimen has been centred, tighten the apparatus – first finger tight and then one and a half revolutions with a spanner.

f) Start each test within 30 min after removing the specimen from the desiccator.

g) Open the oxygen inlet and outlet valves of the permeability cells and allow oxygen to flow through the permeameter for 5 seconds. This will purge the test chamber of gases other than oxygen.

h) Close the oxygen outlet valve of the permeability cells.

i) When the pressure is above 100 kPa on the gauge of the permeability cell, close the inlet valve.

j) Tap the gauge to ensure a correct reading. Adjust the pressure in the cell to $100 \pm 5$ kPa by opening the outlet valve slightly. Record the initial time, $t_0$, to the nearest minute and initial exact pressure, $P_0$, to the nearest 0.5 kPa. This initial pressure shall be within 5 kPa of 100 kPa. Use $t_0$ and $P_0$ as such in the calculations.

k) After 5 minutes tap the gauge and record the time and pressure reading. If the pressure drops too quickly ($> 5$ kPa per minute), there may be a leak present. In such a case, release the pressure in the chamber, check that the sample fits tightly in the collar, and restart the test immediately, starting at paragraph (g).

l) Subsequent readings should be taken with sufficient frequency that the pressure has dropped $5 \pm 1$ kPa between readings. For each reading, note the time to the nearest minute and pressure in the test cell to the nearest 0.5 kPa.

m) The test may be terminated when the pressure has dropped to $50 \pm 2.5$ kPa or after 6 hours $\pm 15$ min, whichever occurs first. A minimum of 8 readings is required.

Note: It is possible to automate the readings. In this case, pressure readings shall be recorded on the computer at 15 minute intervals until the pressure drops to $50 \pm 5$ kPa or up to 6 hours $\pm 15$ min, whichever occurs first. All the data points so generated shall be used in the calculation.

n) The same specimens that were used in the oxygen permeability test can also be used in the water sorptivity test. For details of the procedure, please refer to Part 3: ‘Standard Procedure for Water Sorptivity Test’.
5. CALCULATIONS

NOTE: A standard spreadsheet has been developed to perform the calculations described below, and it is strongly recommended that this spreadsheet be utilized. A copy of this spreadsheet is a free download from www.civil.uct.ac.za in the ‘Concrete and Cement-based Materials’ Research Group Section.

a) Determine the best fit line using linear regression of \( \ln(P_o/P_t) \) against \( t \), forcing the regression line through the \((0,0)\) point where:

\[ P_o = \text{initial pressure at start of test (at time } t_o \text{) to the nearest } 0.5 \text{ kPa} \]
\[ P_t = \text{subsequent readings in pressure to the nearest } 0.5 \text{ kPa at times } t, \text{ measured from } t_o \]
\[ t = \text{time in seconds, recorded to the nearest minute.} \]

b) The coefficient of correlation should be greater than 0.99. Where the correlation is less than 0.99 a retest should be done on the same specimen. If the subsequent test of the specimen also has a correlation coefficient of less than 0.99, this specimen should be discarded and another test specimen prepared.

Note: Every reading recorded as described in section 4 shall be used in the regression analysis. No data points shall be excluded in the determination of the correlation coefficient. No additional manipulation or exclusion of data points is allowed in order to improve the correlation coefficient. If the correlation coefficient is less than 0.99, the sample shall be retested.

Note: The slope of the linear regression line forced through the \((0,0)\) point can be calculated from the equation:

\[
z = \frac{\sum \left[ \ln(P_o / P_t) \right]^2}{\sum \ln(P_o / P_t) t} \]

and the \( r^2 \) value can be calculated from the equation:

\[
r^2 = 1 - \frac{\sum (t_i - t_{p,i})^2}{\sum t_i^2 - (\sum t_{p,i})^2 / n} \]

where

- \( t_i \) is the time at any given pressure reading
- \( t_{p,i} \) is the predicted time at the same pressure reading (based on the linear regression)
- \( n \) is the number of data points being considered

The ‘slope’ and ‘rsq’ functions available in Excel CANNOT be used, as they do not force the line through the zero point.

c) The D’arcy coefficient of permeability is given by:

\[
k = \frac{\omega V g d}{R A \phi} \]
k = coefficient of permeability of test specimen (m/s)
ω = molecular mass of oxygen = 32 g/mol
V = volume of oxygen under pressure in permeameter (m$^3$) recorded to the nearest 0.01 litre or 0.00001 m$^3$. The volume of the pressure cell includes the volume of the opening in the top plate and the rubber collar annulus below the sample. The volume shall be determined by dimensional measurement, accurate to the nearest mm, or by the volume of water contained.
g = acceleration due to gravity (9.81 m/s$^2$)
R = universal gas constant = (8.313 Nm/K mol)
d = average specimen thickness (m)
ϕ = temperature (K)
z = slope of the line determined in the regression analysis
c) The coefficient of permeability is calculated for each of the test specimens. The oxygen permeability index (OPI) is given as the negative log of the average of the coefficients of permeability of the specimens, which for four specimens is:
   \[ OPI = - \log_{10} \left[ \frac{1}{4} (k_1+k_2+k_3+k_4) \right] \]

6. REPORTING
Report the following:

a) Each individual test determination of a specimen (i.e. k value) to three significant figures
b) The oxygen permeability index to two decimal places.
c) Identification number of specimens.
d) Description of specimen. This is particularly important in this test since the test is stated to be indicative of macro-structural problems. Specifically mention whether there are visible cracks, honeycombing defects or visible bleed paths present.

The following shall be reported if known

e) Source of the specimen.
f) Location of specimen within core or cylinder.
g) Type of concrete, including binder type, water/cement ratio and other relevant data supplied with the specimen.
h) Curing history.
i) Unusual specimen preparation e.g. removal of surface treatment.
j) Test operator.
k) Age of concrete at time of testing.

7. REFERENCES
(1) Alexander MG, Ballim Y, Mackechnie JM, 'Concrete durability index testing manual' Research Monograph No. 4, Departments of Civil
Engineering, University of Cape Town and University of the Witwatersrand, March 1999


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CONCRETE DURABILITY INDEX TESTING

PART 3: STANDARD PROCEDURE FOR WATER SORPTIVITY TEST

SCOPE

This test method sets out the procedure for determining the water sorptivity index as originally described by Alexander, Ballim and Mackechnie \(^{(1)}\). The method described herein supersedes the 1999 version in ref. 1.

The test is suitable for the evaluation of materials and mix proportions for design purposes, and for research and development. The test can also be used for quality control of concrete on site. It is not recommended that this test be performed before 28 days after casting. Specimen age may have a significant effect on the test results, depending on the type of concrete and the curing procedure. Care should be taken in interpreting the results of this test when it is used on surface treated concretes, or on concrete that has been exposed to environmental influences such as carbonation or marine salts.

The oven drying procedure has been selected to result in the minimum degree of micro-structural alteration of the concrete specimens, while still giving minimal uniform moisture content. Research has shown, however, that significant amounts of micro-structural damage may occur for high quality concrete.\(^{(2)}\) Thus care should be taken in interpreting the test results from these concretes.

This test method shall not be used for concrete with a maximum nominal aggregate size exceeding 26.5 mm.

Specific commercial products are mentioned for illustration purposes only. This is not intended to be an endorsement of any particular product or company.

1. APPARATUS

a) An oven capable of maintaining a temperature of 50 ± 2°C.

Note: Most lab ovens are of the forced draft, ventilated type. If, however, the oven being used is of the closed (unventilated) type, then the relative humidity inside the oven must be maintained by the inclusion of trays of saturated calcium chloride solution. The trays should provide a total exposed area of at least 1 m\(^2\) per 1 m\(^3\) of volume of the oven and should contain sufficient solid calcium chloride to show above the surface of the solution throughout the test.

b) Vacuum saturation facility as shown in Figure 1.

c) Plastic or stainless steel tray 20 mm deep and large enough to hold as many specimens as will be tested simultaneously.

d) Ten layers of absorbent paper towel. Alternatively 2 rollers or 4 pins can be used to support the specimens tested.
e) Vernier calliper.
f) Measuring scale with accuracy to 0.01 g.
g) A solution of tap water saturated with calcium hydroxide. (5 grams of Ca(OH)_2 per 1 litre of water), maintained at 23 ± 2°C.
h) One or more stopwatches as required.
i) Sealant to provide a watertight seal around the vertical curved edges of the specimens without blocking any part of the test face whatsoever. Any of the following can be used:
   - Epoxy paint (e.g. ABE Epidermix 365 or Sikaguard Wetseal A+B)
   - Packaging tape

k) Desiccator, large enough to hold as many specimens as will be tested simultaneously, containing anhydrous silica gel as the desiccant, with the relative humidity controlled at a maximum of 60 %. (Not required if relative humidity in the laboratory is below 60 %.)

2. TEST SPECIMENS

a) Four test specimens are required per test. Each specimen shall consist of a 70 ± 2 mm diameter concrete disc with a thickness of 25 ± 2 mm, cored and cut in accordance with Concrete Durability Index Testing, Part 1. It is permitted to use specimens that have previously been used in the oxygen permeability test, provided they have not been exposed to moisture. Refer to Part 2: ‘Standard Procedure for Oxygen Permeability Test’.

b) Mark the specimens of the same reference 1, 2, 3 and 4 on the inner face.
3. CONDITIONING OF SPECIMENS

a) Directly after cutting, the specimens shall be placed in the oven at 50 ± 2°C for 7 days ± 4 hrs. If the specimens have been previously tested in the oxygen permeability cells, they shall be tested immediately upon removal. No additional drying is necessary provided the specimens have not got wet or have had an opportunity to absorb moisture from the atmosphere.

d) Seal the vertical curved sides of the specimens using any of the recommended products as per the product specifications. If epoxy paint is used, care shall be taken not to get the epoxy on the flat test surfaces and there shall be no pinholes. After coating with epoxy paint, return the specimens to the desiccator or room where the ambient conditions are controlled to 23 ± 2°C and < 60% relative humidity and allow the epoxy to dry for 18 to 24 hours. If packaging tape is used, apply to the curved vertical edges at this time. No additional drying period is needed in this case. In either case, the extent of the protection must extend to the extreme edge of the sides towards the test face.

4. TESTING OF SPECIMENS

a) The water sorptivity test shall be conducted in a room in which the temperature is controlled at 23 ± 2°C.

b) If the specimens are taped and have not been previously tested in the oxygen permeability test, cool the specimens to 23 ± 2°C in the desiccator. This cooling period should last for no less than 2 hours and no longer than 4 hours. Alternatively, the specimens may be cooled, for no less than 2 hours and no longer than 4 hours, on a steel tray in a room where the ambient conditions are controlled at 23 ± 2°C and <60% relative humidity for the duration of the cooling period.

b) Measure to the nearest 0.02 mm the thickness and diameter of each specimen with the vernier calliper at 4 points equally spaced around the perimeter of the specimen, and record. Determine the average of the four readings and record to the nearest 0.02 mm.

c) Place the 10 layers of paper towel on the tray. Alternatively, place the rollers/pins in position to support the specimen in the solution.
d) Pour calcium hydroxide solution into the tray. If used, the paper towel should be saturated and water is visible on the top surface. All air bubbles shall be removed by smoothing the paper pad towards the edges, see Figure 2a. If rollers or pins are used, they should be arranged as to support the specimens and the calcium hydroxide solution should be above the top of the support, Figure 2b. The final water level should be such that it will be slightly above the bottom edge of the specimen and a maximum 2 mm up the side of the specimen as shown in Figure 3. Dampen an additional piece of paper towel for use in removing the excess water from the specimens (in paragraph (g)) and keep next to the tray to be used during the test.

e) Within 30 min after removing the specimen from the desiccator, or oxygen permeability cell for taped specimens, determine the mass of the specimen to an accuracy of 0.01 g and record as the dry mass at time 0. This mass must be determined after the method used to seal the sides of the specimens (either epoxy or tape) has been applied.

f) Immediately place the specimen with the test face (outer face or originally exposed face) on the wet paper pad/pins/rollers and start the stopwatch.

g) Weigh the specimen at 3, 5, 7, 9, 12, 16, 20 and 25 minutes, after patting it once on the damp piece of absorbent paper. The specimen should appear saturated surface dry (SSD) on the exposed face at the time the mass is determined, i.e. it should look damp, but not have free water on the test face. During removal of a specimen from the tray for weighing, care must be taken to prevent dripping from one specimen onto the top of another.

h) Record the mass of the specimen to the nearest 0.01 g and replace the specimens each time with the test face on the wet paper or rollers/pins if used. The patting and mass determination procedure must not take longer than 15 seconds per specimen on each occasion that the mass is determined. The stopwatch shall not be stopped during the weighing procedure.

i) Within a maximum of 1 day after weighing of the specimen is completed, place the specimen in the vacuum saturation tank. The epoxy or the tape must be left in place. The specimens shall be arranged so as to maximize their exposed surface area. This is typically done by standing the individual specimens upon their curved edges, rather than the flat side, as in Figure 4. Seal the lid with petroleum jelly and close it.
j) Evacuate the tank to between -75 and -80 kPa and maintain the specimens under vacuum of between -75 and -80 kPa for 3 hours ± 15 min. The pressure must not be allowed to rise above -75 kPa during this period.

k) After 3 hours ± 15 min isolate the tank and allow calcium hydroxide saturated water to flow into the chamber until the water level is approximately 40 mm above the top of the specimens. Air shall not be allowed to enter the vacuum chamber during this procedure.

l) Re-establish the vacuum between -75 and -80 kPa. This shall be maintained for 1 hour ± 15 minutes. At no point during this time period shall the vacuum be permitted to rise above -75 kPa.

m) After 1 hour ± 15 min, release the vacuum and allow air to enter. Allow the specimens to soak for a further 18 ± 1 hours.

n) After 18 ± 1 hr soaking, remove the specimens from the solution, dry the surface to a SSD condition with a paper towel, and immediately weigh to an accuracy of 0.01 g. Record this as the vacuum saturated mass $M_{sv}$ of the specimen.

5. CALCULATIONS

NOTE: A standard spreadsheet has been developed to perform the calculations described below, and it is strongly recommended that this spreadsheet be utilized. A copy of this spreadsheet is a free download from [www.civil.uct.ac.za](http://www.civil.uct.ac.za) in the ‘Concrete and Cement-based Materials’ Research Group Section.

a) Determine the effective porosity (n) of each specimen as follows:

$$n = \frac{M_{sv} - M_{s0}}{Ad\rho_w}$$

where:

- $M_{sv}$ = the vacuum saturated mass of the specimen determined in section 4(n) to the nearest 0.01 g.
- $M_{s0}$ = mass of the specimen at $t=0$ to the nearest 0.01 g.
- $A$ = cross-sectional area of the specimen to the nearest 0.02 mm$^2$.
- $d$ = average specimen thickness to the nearest 0.02 mm.
- $\rho_w$ = density of water = 10$^{-3}$ g/mm$^3$.

b) Plot the mass gain ($M_{wt}$) versus the square root of time (in hours)

$$M_{wt} = F \sqrt{t}$$

where:

- $F$ = the slope of the best fit line from plotting $M_{wt}$ against $\sqrt{t}$ (g/$\sqrt{hr}$)
- $t$ = time in hours after a specimen is first exposed to water on its lower face, to the nearest 0.001 hr
\[ M_{wt} = M_{st} - M_{so} \]
\[ M_{st} = \text{mass to the nearest 0.01 g of the specimen at time } t \]

Note: No allowance shall be made for the time taken to wipe and weigh each sample in the calculation.

Note: Do not include the zero time reading in the data

c) Determine the correlation coefficient of the data. A minimum value of 0.98 must be achieved. If the coefficient of correlation is found to be less than 0.98 upon initial analysis, this may be due to approaching saturation condition of the sample during the latter part of the test. If this is the case, discard the last (25 min) value from your analysis, and re-determine the correlation coefficient. If the correlation coefficient is above 0.98, this is satisfactory. If not, discard the next value, and re-analyse until a correlation coefficient of above 0.98 is achieved or there are less than 5 data points remaining. If this is not possible with a data set of five or more values, then a sorptivity value is not able to be determined with this test specimen. This data set must still be reported, with a note that a sorptivity value with a correlation coefficient greater than 0.98 could not be determined. Record the greatest range of data able to give a correlation coefficient above 0.98.

d) Determine the slope of the line of best fit (F) by linear regression analysis using the range of data from 5c).

Note: A simple way to calculate the slope of the regression line is by entering the data in a Microsoft Excel range and use the function SLOPE {data range of \( M_{wt} \); data range \( \sqrt{t} \)}. The correlation coefficient can be obtained by using the RSQ {data range \( M_{wt} \); data range of \( \sqrt{t} \)} function.

e) The water sorptivity of the specimen (S) is given by:

\[ S = \frac{F_d}{M_{sv} - M_{so}} \]

f) The procedure 5b) through 5f) is carried out separately for each specimen. The sorptivity index is given as the average of the water sorptivity of at least three valid individual test determinations.\(^{(3)}\)

6. REPORTING

Report the following:

a) Identification number of specimen.

b) Description of specimen.

c) The effective porosity of each specimen to the nearest 1 decimal place.

d) The water sorptivity of each individual specimen.

e) The water sorptivity index to the nearest 1 decimal place.

f) The range of data used in the calculations.

The following shall also be reported if known:

g) Source of the specimen.
h) Location of specimen within core or cylinder.

i) Type of concrete, including binder type, water/cement ratio and other relevant data supplied with the specimen.

j) Curing history.

k) Unusual specimen preparation e.g. removal of surface treatment.

l) Test operator.

m) Age of concrete at the time of testing.

7. REFERENCES

(1) Alexander M.G., Ballim Y., Mackechnie J.M., ‘Concrete durability index testing manual’ Research Monograph no. 4, Departments of Civil Engineering, University of Cape Town and University of the Witwatersrand, March 1999


8. REVISIONS

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CONCRETE DURABILITY INDEX TESTING

PART 4: STANDARD PROCEDURE FOR
CHLORIDE CONDUCTIVITY TEST

SCOPE

This test method sets out the procedure for determining the chloride conductivity index as originally described by Alexander, Ballim and Mackechnie (1). The method described herein supersedes the 1999 version in ref. 1.

The test is suitable for the evaluation of materials and mix proportions for design purposes and for research and development. The test can also be used for quality control of concrete on site. Specimen age may have a significant effect on the test results, depending on the type of concrete and the curing procedure. Care should be taken in interpreting the results of this test when it is used on surface treated concretes. In general, the test should not be performed on concrete that has been exposed to environmental influences such as carbonation or marine salts.

The oven drying procedure has been selected to result in the minimum degree of micro-structural alteration of the concrete specimens, while still resulting in minimal uniform moisture content. Research has shown, however, that significant amounts of micro-structural damage may occur for some high quality concrete. (2) Thus care should be taken in interpreting the test results from these concretes.

Since the test results are a function of the electrical resistance of the specimen, the presence of reinforcing steel or other embedded electrically conductive material may have a significant effect.

This test method shall not be used for concrete with a maximum nominal aggregate size exceeding 26.5 mm.

Care should be taken when performing this test, since the chloride solution used is hazardous to the skin. It is recommended that gloves be used.

1. APPARATUS

   a) An oven capable of maintaining a temperature of 50 ± 2°C.

   Note: Most lab ovens are of the forced draft, ventilated type. If, however, the oven being used is of the closed (unventilated) type, then the relative humidity inside the oven must be maintained by the inclusion of trays of saturated calcium chloride solution. The trays should provide a total exposed area of at least 1 m² per 1 m³ of volume of the oven and should contain sufficient solid calcium chloride to show above the surface of the solution throughout the test.

   b) Vacuum saturation facility as shown in Figure 1.

   c) Conduction cell as shown in Figure 2 with anode and cathode parts permanently marked on the outside of the cell. The flexible collars need to be replaced when cracks or tears occur.
d) DC power supply 0-12 Volt, 0-1 Ampere stabilised.

e) Digital voltmeter and ammeter (two multi-meters), 4 digits, 0-20 V range, 0-300 mA, rated accuracy 0.1 %.

f) Electrical cables and plugs.

g) Weighing scale capable of determining mass to 0.01 g.

h) 10 litre container with a lid.

i) CP grade NaCl (99% purity).

j) Desiccator, large enough to hold as many specimens as will be tested simultaneously, containing anhydrous silica gel as the desiccant, with the relative humidity controlled at a maximum of 60 %. (Not required if the relative humidity in the laboratory is below 60 %.)
Note: Due to the highly corrosive solutions used during the test, all equipment must be cleaned thoroughly with warm soapy water after each use. The copper electrodes and banana plugs need to be cleaned with sandpaper or an acidic solution. Replacement electrical connections are necessary from time to time. To protect electrical test equipment, it is advisable to place such equipment on a shelf above the bench on which the conductivity cell is placed.

2. CHEMICAL SOLUTIONS

a) 5.0 M sodium chloride solution: Add 2.93 kg of NaCl (salt) to the 10-litre container. Add tap water to the 10-litre mark. Stir occasionally for 1 day or until all the salt has dissolved. Seal the lid of the container. The solution must be maintained at 23 ±2°C.

3. TEST SPECIMENS

a) Four test specimens are required per test. The test specimen shall consist of a 70 ± 2 mm diameter concrete disc with a thickness of 25 ± 2 mm cored and cut in accordance with Concrete Durability Index Testing, Part 1.

b) Mark the specimens of the same reference 1, 2, 3 and 4 on the inner face.

4. CONDITIONING OF SPECIMENS

a) Directly after cutting, the specimens shall be placed in the oven at 50 ± 2°C for seven days ± 4 hours.

b) Measure to the nearest 0.02 mm the thickness and diameter of each specimen with the vernier calliper at 4 points equally spaced around the perimeter of the specimen, and record. Determine the average of the four readings, and record to the nearest 0.02 mm. Determine the dry mass of the specimens to the nearest 0.01 g.

c) Place the specimens in the vacuum saturation tank. The specimens shall be arranged so as to maximize their exposed surface area. This is typically done by standing the individual specimens upon their curved edges, rather than the flat side, as in Figure 3. Seal the lid with petroleum jelly and close it.

d) Evacuate the tank to between -75 and -80 kPa and maintain the specimens under vacuum of between -75 and -80 kPa for 3 hours ± 15 min. The pressure must not be allowed to rise above -75 kPa during this period.

e) After 3 hours ± 15 min isolate the tank and allow the salt solution to enter the vacuum tank without releasing the vacuum to cover all the specimens to a depth of approximately 40 mm. Air shall not be allowed to enter the vacuum chamber above the top of the specimens during this procedure.
f) Re-establish the vacuum between -75 and -80 kPa. This shall be maintained for 1 hour ± 15 minutes. At no point during this time period shall the vacuum be permitted to rise above -75 kPa.

g) After 1 hour ± 15 min, release the vacuum and allow air to enter. Allow the specimens to soak for a further 18 ± 1 hours.

h) After 18 ± 1 hours soaking, remove the specimens from the solution, dry the surface with a paper towel to a SSD condition and immediately weigh to an accuracy of 0.01 g. Record this as the vacuum saturated mass $M_S$ of the specimen. The test procedure as described in Section 5 shall commence immediately after this weighing.

5. TESTING OF SPECIMENS

a) The chloride conductivity test must be conducted in a room in which the temperature is controlled at 23 ± 2 °C.

b) Unscrew the connecting points and fill the luggin capillaries (small plastic tubes shown in Figure 4) of the chloride cell and both chambers of the cell with the 5.0 M NaCl solution.

c) With the flexible collar in the rigid ring central portion of the cells, place a concrete sample within the flexible collar. The concrete sample must be placed so that one face is against the plastic lip of the rigid ring, as in Figure 5.

d) Screw the central portion of the cell into the cathode section of the cell. The cathode section has a solid plastic lip that must press against and compress the
flexible collar. The correct alignment is shown in Figure 6. Screw the combined sections into the anode part of the cell. Tighten both parts sufficiently to ensure sealing of the sample and that no leaks occur.

e) Place the conduction cell horizontally.
g) Connect the ammeter and voltmeter as shown in Figure 2.
h) Adjust the DC power supply until the voltage applied across the specimen is approximately 10 Volts.

*Note: The preferred specimen test voltage is 10 V, but 5 V may be used for very permeable specimens.*

i) Simultaneously record the current and voltage readings.
j) Testing should be completed within 15 minutes of removing a specimen from the NaCl solution.
k) Specimens can be re-tested within 30 minutes of the first test, but should be discarded after that and cannot be re-tested. Specimens should be kept in the NaCl solution during this time.

6. CALCULATIONS

a) For each test specimen, individually calculate the chloride conductivity using the equation:

\[
\sigma = \frac{it}{VA}
\]

where:
- \( \sigma \) = conductivity of the specimen (mS/cm)
- \( i \) = electric current (mA)
- \( V \) = voltage difference (V)
- \( t \) = average thickness of specimen (cm)
- \( A \) = cross-sectional area of the specimen (cm\(^2\))

b) The chloride conductivity index is given as the average of the chloride conductivity of at least three valid individual test determinations.

c) The porosity is determined by:

\[
n = \frac{M_S - M_D}{At\rho_s}
\]

where:
- \( M_S \) = the vacuum saturated mass of the specimen determined in section 4(h) to the nearest 0.01 g.
- \( M_D \) = mass of the dry specimen determined in section 4(b) to the nearest 0.01 g.
- \( A \) = cross-sectional area of the specimen to the nearest 0.02 mm\(^2\).
- \( t \) = average specimen thickness to the nearest 0.02 mm.
- \( \rho_s \) = density of salt solution = 1.19 x 10\(^{-3}\) g/mm\(^3\).

*Note: It has been found that the porosity determined from the chloride conductivity test is normally lower than that determined in the sorptivity test.*
7. REPORTING

Report the following:

a) Identification number of specimen.
b) Description of specimen.
c) The chloride conductivity of each individual specimen.
d) The chloride conductivity index to the nearest 2 decimal places.
e) The porosity of the individual test specimens.

The following shall also be reported if known:

f) Source of the specimen.
g) Location of specimen within core or cylinder.
h) Type of concrete, including binder type, water/cement ratio and other relevant data supplied with the sample.
i) Curing history.
j) Unusual specimen preparation e.g. removal of surface treatment.
k) Test operator.
l) Age of concrete at time of testing.

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