

RAPID CHLORIDE TEST, THE RCT-METHOD

Measurements of the chloride content of concrete, in-situ

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BACKGROUND

Concrete's ability to resist freeze-thaw cycles is reduced by the presence of chlorides. Even air entrained concrete is susceptible.

In reinforced concrete structures, chlorides may attack the reinforcement by breaking down the rebars' passive film, leading to corrosion. In addition to weakening the reinforcement, the resultant corrosion products may exercise expansion forces on the surrounding concrete, thereby causing delamination and spalling of the cover layer.

Thus, chlorides in structural reinforced concrete may reduce the safety margin before structural collapse. Disintegration of the concrete surface will only accelerate any present damage.

Chlorides may be present from the beginning in fresh concrete or may invade the structure be means of the environment.

Some years ago, accelerators containing substantial amounts of chlorides were permitted in the mixing of concrete. Recently, this practice has been changed. Now only minimal amounts are allowed, if any, and non-chloride accelerators used.

Chlorides may be carried to a structure from the environment in various ways. Inland, chlorides in the air may appreciably contribute to the chloride charge of the concrete surface. Concrete in a marine environment receives chlorides from sea sand and sea water. Outdoor concrete structures near coastlines constantly receive airborne chloride ions.

Freshwater swimming pools may contain chloride from the chlorination of the water. Any structure that contains or carries saltwater is exposed to chloride attack and ingress. The greatest concern comes from deicing salts which cause major damage to bridges, parking structures and concrete balconies.

For frost damage to occur in concrete, the critical content of chlorides (Ref. 1) would be at least 0.02% of the concrete's mass (approximately 0.14 % by cement mass).

Depending on the actual conditions, the critical content for corrosion of the reinforcement (Ref. 2) can be in the range of 0.02% to 0.05% of the concrete's mass (0.14% to 0.35% by cement mass).

The standards of various countries state that the chloride content must be measured

in relation to the concrete's mass. Measurement of the chloride content is usually performed on drilled out cores.

According to the standards, the cores have to be sliced by sawcutting. Each slice is then crushed, pulverized, measured by weight, and dissolved in acid. After which, the chloride content is determined by titration.

All this has to be performed in a laboratory, requiring additional people in the process. This makes for a long and tedious procedure.

To the consulting engineer or client, this chain of time consuming steps disrupts the logical flow of the survey. Precious time is lost that could be used for immediate supplementary testing in critical areas. Other in-situ testing techniques may not give the total picture of the structure's condition.

THE RAPID CHLORIDE TEST (RCT) - METHOD

The RCT was developed and patented by Germann Instruments in 1987. Since then, numerous countries, specifically Western Europe and North America, have evaluated, tested and approved the use of the RCT.

One measurement takes approximately ten minutes. Only minimal training is required after basic instruction.

With the RCT, the number of tests are determined on site. Due to the speed and ease of the RCT, additional in-situ tests for suspected problems can be done immediately.

THE RCT-PROCEDURE

STEP 1. A hammer drill is used to drill into the concrete at the test location. For quick preliminary testing, an 8mm (0.3 in.) masonry drill bit is used with a dust collection bowl adapted for use with the drill bit.

For accurate testing and measurement of chloride profiles, an 18mm (0.7 in.) drill bit is used with a specially made dust collecting pan (Fig.1). Dust is drilled out at three locations, 100mm (4 in.) apart and about 6mm (1/4 in.) deep so that ten grams of dust are obtained. By clamping the dust pan to the surface as illustrated, the hardened steel center ring will guide the drill bit, allowing only dust that the drill bit tip cuts be collect-

ed. This procedure makes it possible to collect dust at different depths to obtain the chloride profile, regardless of the depth of drilling.

STEP 2. Dust from the same depth location is poured into a plastic bag and mixed together. An ampoule is filled with the dust and compressed with a rod until there is enough compacted dust to reach the red marking line. This indicates 1.5 grams by mass of concrete (Fig. 2).

STEP 3. This 1.5 grams of dust is poured into a plastic bottle that contains 10ml of instant chloride extraction liquid (Fig. 3). The lid is tightened securely and the bottle shaken for five minutes.

STEP 4. The tip of a calibrated, chloride sensitive membrane electrode is submerged into the liquid. The electrode is attached to a digital handheld meter. When the millivolt reading is stable, the value is recorded (Fig. 4) and plotted on the calibration curve (Fig. 5). The chloride content of the concrete, as a percentage of concrete mass, can be read directly off the curve.

Before and after each test series, the electrode is calibrated on four calibration liquids, one each of 0.005%, 0.020%, 0.050%, and 0.500% chloride ions. This is to ensure a stable calibration curve (as used in Fig. 5).

By having the calibration liquid at the same temperature as the extraction liquid, no correction for different temperatures has to be made, although the calibration curve will change position (slightly) with temperature.

The instant extraction liquid automatically removes any ions that may disturb the chloride measurement, specifically sulfides. The composition of the liquid is such that even the use of 85% blast furnace slag in the cement will not compromise the accuracy of the chloride measurement.

COMPARATIVE ANALYSES

Ever since its inception, the RCT has been calibrated, in Scandinavia and Canada, to standard titration tests, ion-chromatography and chemical autoanalyses (Fig. 6 to 9). The graphs have only been drawn to make comparison easier.

The analyses in Figure 6 and 7 are comparisons between the RCT and standard titrations done on dust from cores drilled in

the same location. The measurements in Figure 6 are from three Danish consulting engineering companies: 1) Cowiconsult(o), 2) Birch & Krogboe(●), and 3) The Danish Institute of Technology(○), and one Canadian consulting, engineering and testing company in Toronto, Trow Ltd(x).

The analyses in Figure 7 were supplied by the Helsinki University of Technology in Finland. Again, the comparative method is standard titrations.

Figure 8 shows the results of the RCT compared to ion-chromatography performed on the same dust. The analyses were supplied by the Swedish Testing Institute in Stockholm.

Figure 9 compares the RCT results against chemical autoanalyses made on bricks. The analyses were done by the Technical University of Denmark.

PRACTICAL EXPERIENCE WITH THE RCT-METHOD

The following is a summary of the first three years experience with the RCT-method.

1. The quantity of aggregates in the test sample must be representative of normal concrete. The RCT-method accomplishes this as describes in STEP 1 of the RCT procedure.

If the concrete is carbonated, the highest chloride concentration will usually be in the carbonation front. If this concentration will have to be measured, the sample must be taken from the front to a depth of 6mm (0.25 in.).

2. Logically, the finer the dust particles, the faster the extraction liquid removes the chlorides from the dust sample. Only moderate pressure should be exerted on the drill when drilling out the sample dust. This ensures an appropriate particle size, approximately 0.05mm (0.002 in.).

3. The dust must not be wet. If it is, it has to be dried, e.g. on a piece of blotting paper. Naturally, the drilling process removes any normal excess moisture.

4. The 1.5 gram sample size is measured by a volumetric method (STEP 2 of the RCT procedure) simply because it is impossible to handle a precision scale on site. In the beginning, the accuracy of this method can be checked by actually weight within $\pm 2.5\%$. Until then, it would be prudent to run two samples from the same dust to check for variations in the weight.

5. Shaking time for the dust, after being added to the extraction liquid, was set at five minutes, though three is usually sufficient. However, if the dust particle size is as large as 0.15mm (0.006 in.) diameter, the liquid will need the full five minutes of shaking to extract the chloride.

6. The temperature of the liquids will determine the position of the calibration curve on the chart (Fig. 5). For an increase or decrease of 10°C (18°F), the curve will shift position (slope changes slightly) about 10mv. The accuracy of the measurements will not be affected as long as the temperature of the calibration liquids is the same as of the extraction liquid.

7. If the membrane of the electrode is scratched or etched, the calibration curve will change its position and slope significantly. A new electrode must then be used.

To prevent scratching of the membrane, a rubber stop ring is supplied with the electrode. The distance is set to keep the electrode tip from touching the dust that is at the bottom of the extraction liquid bottle after shaking.

Etching of the membrane will take place if the electrode is stored over a long period of time without removing the extraction liquid from the membrane. To avoid this, clean the electrode membrane carefully with distilled water or place it in distilled water when not in use.

Contamination of the electrode membrane may occur after a long period of use. If this happens, the slope of the calibration curve will change from that shown in Figure 5. The membrane tip will have to be ground with a special polishing paper. By conscientiously following the instructions and exercising care, electrode life can range from 3000 to 5000 tests.

8. The calibration liquids may become contaminated, especially the weaker ones. This will also change the slope of the calibration curve. To check the degree of contamination, compare them with a new set of calibration liquids.

APPLICATIONS

The RCT-method is used to measure, in-situ, the chloride content of suspect, reinforced concrete structures. This can be done at the surface only or at various depths to establish a chloride profile. Other in-situ testing can be used in conjunction with the RCT, e.g. test for potentials and electrical resistance for corrosion activity, carbonation, tensile and compressive strength.

Chloride testing is frequently used to determine the depth of bad concrete for removal during repairs.

The effectiveness of electro-chemical extraction of chlorides from contaminated reinforced structures can be ascertained by RCT.

RCT can also measure the chloride content of fresh concrete or concrete constituents, allowing on-site checking of concrete before it is cast.

The RCT is portable and contained entirely in a small suitcase (Fig. 10).

CONCLUSIONS

The RCT-method makes it possible to quickly conduct a large number of in-situ tests to determine a structure's chloride content.

For all practical purposes, the accuracy of the RCT is equivalent to standard laboratory titration tests as given is ASTM C 114, NT BUILD 208 and DS 423.28 and has been accepted as such.

Because RCT is less expensive and time consuming, it has started to supplant laboratory testing.

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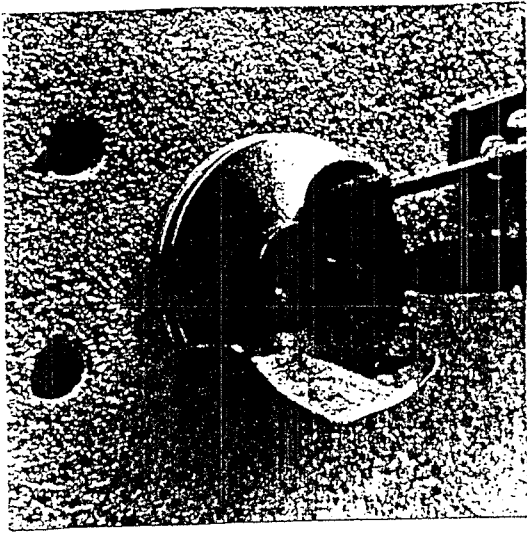


Figure 1. Drilling of dust with 18mm (0.7 in.) drill bit and hammer drill machine.

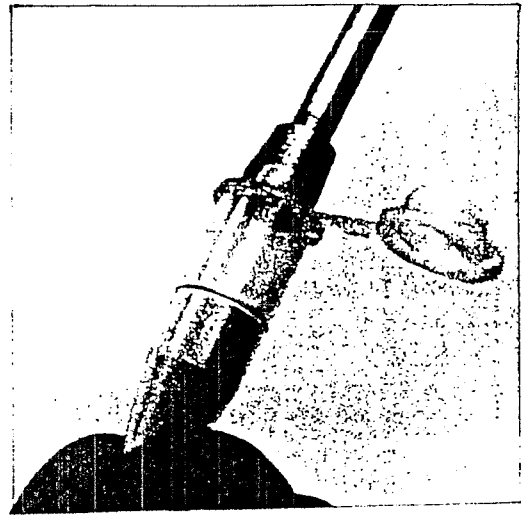


Figure 2. Compression of dust in ampoule to red 1.5 gram indication line.



Figure 3. The 1.5 gram dust is poured into the instant extraction liquid container (shown here) and shaken for 5 minutes.

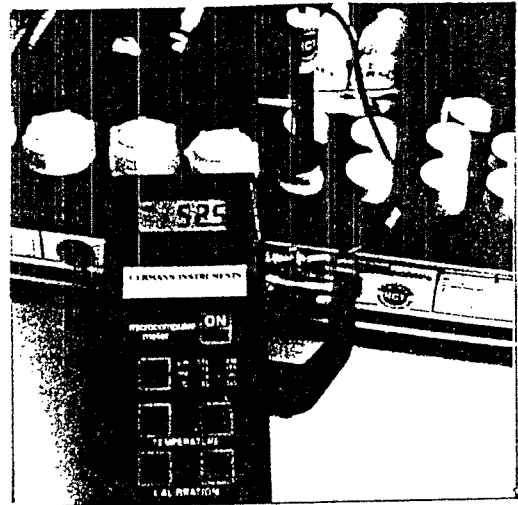


Figure 4. Measurement of millivolt value with chloride sensitive electrode.

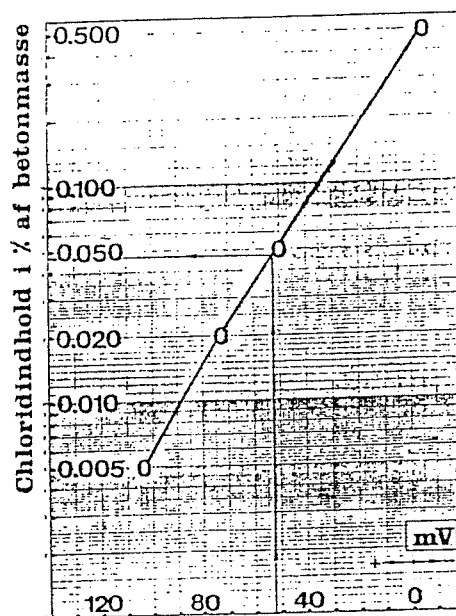


Figure 5. Determination of the chloride content by % of concrete mass.

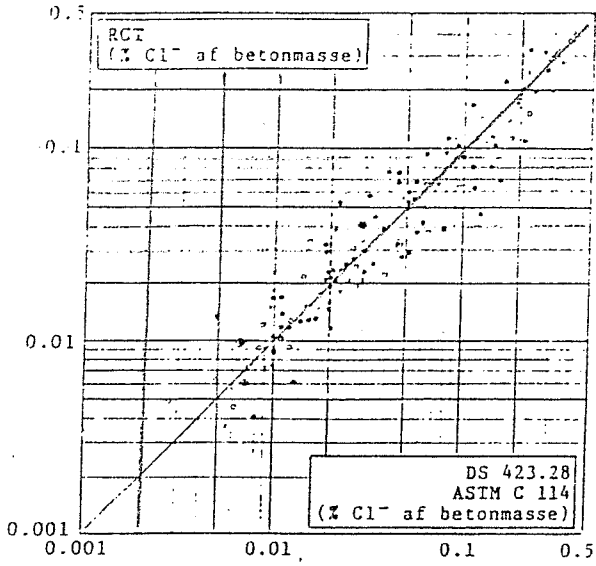


Figure 6. RCT results compared to standard titrations (ASTM C 114 and DS 423.28), ref. 2.

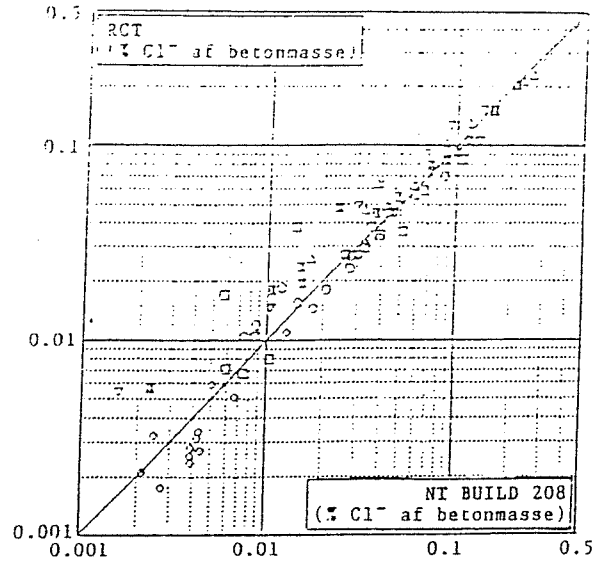


Figure 7. RCT results compared to standard titration tests (NT BUILD 208), ref. 3.

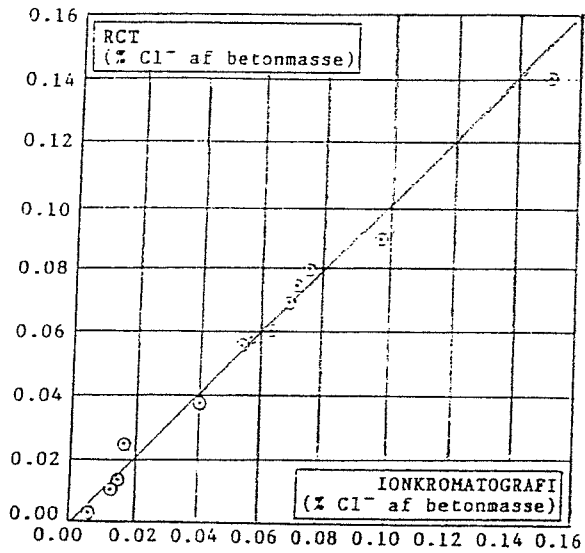


Figure 8. RCT results compared to ion-chromatography, ref. 4.

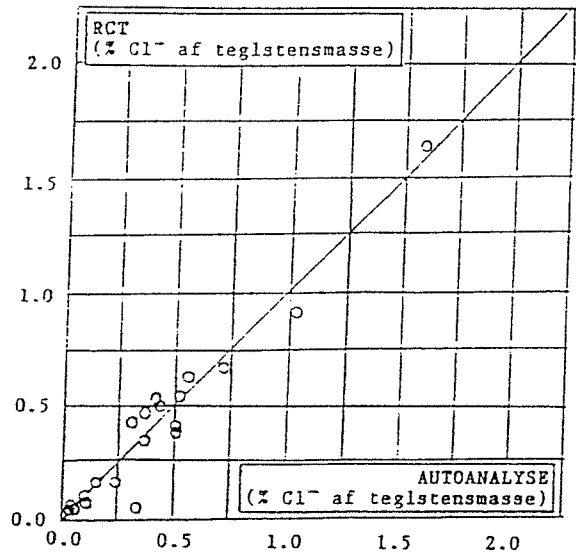


Figure 9. RCT results compared to chemical autoanalyses, ref. 5.