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Test Smart – Build Right

RCT, Rapid Chloride Test Certificate

February 1st, 2018

RCT measurement performed on-site

With the RCT-500 Kit, the Rapid Chloride Test, *the acid soluble amount of chlorides* in percentage of concrete mass is measured on concrete powder drilled out of the structure, on-site.

The test is performed in a matter of minutes.

With *the **acid soluble amount of chlorides*** is understood the amount of free chlorides in the pore solution and the physical bound chlorides, attached to e.g. the faces of the capillary pores.

Note that the chemical bound chlorides in the concrete matrix are not measured, as they do not participate in corrosion of reinforcement. Only the free chlorides and the physical bound chlorides participate in the corrosion process of the reinforcement.

Note that only the free chlorides can also be measured by the RCTW, ref. 15, using other extraction liquids. The acid soluble chlorides with the RCT is, however, usually the preferred method.

The testing can be made on-site, simple and quickly, offering great economic savings compared to traditional testing for chlorides - coring, transportation of the core to the laboratory, slicing of the core, pulverizing of the slices, testing by standard laboratory titration and reporting.

For accurate profiling on-site, or of ponded specimens, the Profile Grinder is available. This is used for service life calculations, ref. 14.

In ref. (3) fourteen correlations between RCT and standard laboratory testing (e.g. potentiometric titrations and ion chromatography), performed from 1991 to 1997, are summarized. The conclusion is the RCT correlate well to such laboratory testing.

In a major field survey made by the Norwegian Road Laboratory - Fluge et al, ref. (11) - the conclusion is:

"The results from 40 control measurements performed by titration using exactly the same concrete powder drilled out in 1992 were consistent with the results from RCT. The results show an average deviation between RCT and Norwegian Standard NS 3671 titration of +/-15%. The results from analysis in 1993 and 1994 also show a very good correspondence with the test results from the extended condition survey using RCT. Based on the test results, the accuracy of RCT is considered good enough for chloride analysis in condition surveys".

From 1998 and onwards concrete powders produced by the Swedish National Testing and Research Institute (SP) with known amount of chlorides have been offered separately for comparison as described in section 9 of this manual, page 17. The powders contain different chloride contents as well as different binders - Ordinary Portland Cement, Flyash Cement and Slag Cement.

From testing on these powders, it is concluded, that the variation of the RCT is +/-4% compared to the known amount of chlorides when measured accurately. This is provided the RCT-1023 vial with the dissolved 1.5 gram of concrete dust is left standing overnight before testing, or corrected for with a factor of 1.05 to 1.20, depending on the chloride content after 5 minutes of shaking followed by testing.

Based on testing of these powders it is also concluded that the RCT has the same precision as the AASHTO T 260 standard potentiometric titration.

Round Robin investigations in Scandinavia are reported page 6 and 7 in this certificate.

Correlations between RCT and laboratory testing

The RCT has been correlated to laboratory testing in many investigations during the past twenty years, ref. (3). The comparisons have been made to laboratory standard titrations, e.g. as stated in the standards ASTM C 114-81 and DS 423.28, NS 3671, to ion chromatography or to auto analysis.

Figure 1 and 2 illustrate some of the performed correlations.

Compared to one of the most accurate laboratory tests, the ion chromatography measurement marked "O" in figure 1, the deviation of the RCT is 5%, in average, from the obtained correlation.

The "within-test" variation of the RCT performed on the same powder is normally about 5%.

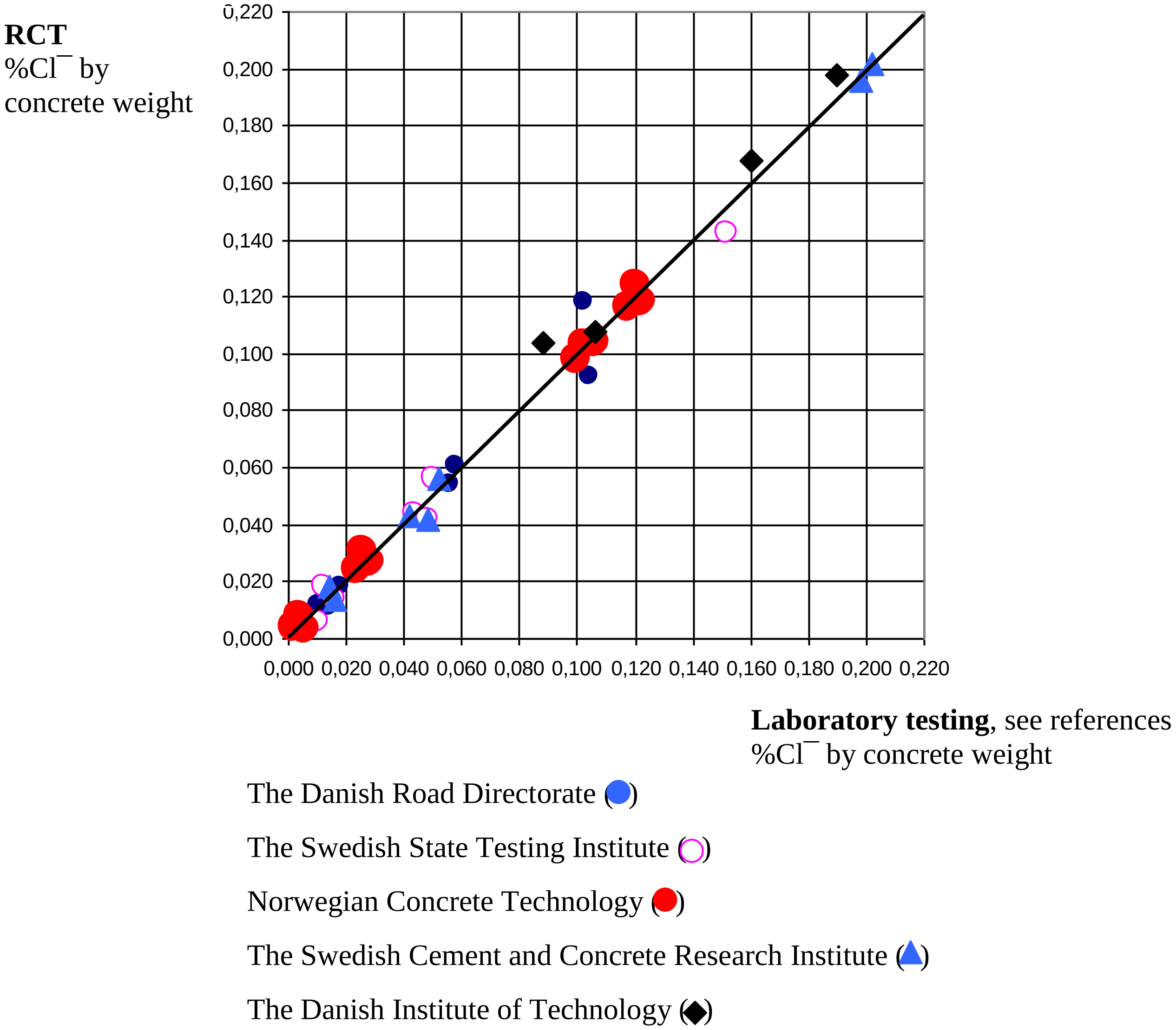


Fig.1. Correlations between RCT and standard titrations or ion chromatography made in the laboratory, ref. (3).

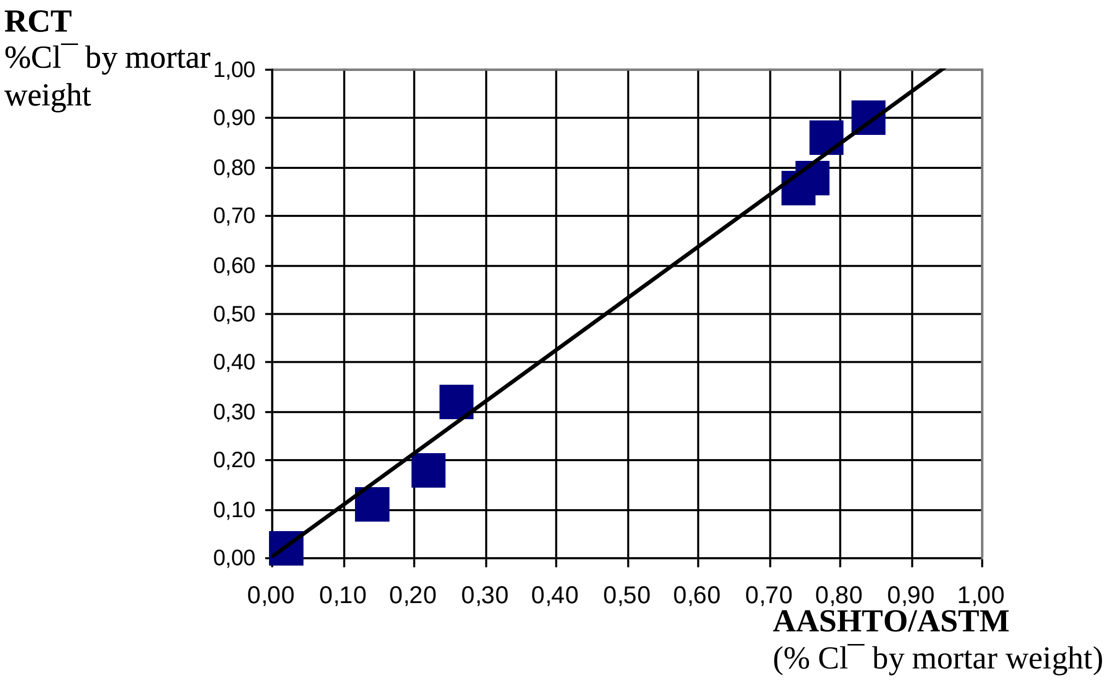


Fig. 2. RCT compared to AASHTO/ASTM measurements on mortar specimens after ponding.

SOURCE: Report FHWA-RD-96-207: "Improved concretes for corrosion resistance", May 1997, Federal Highway Administration, Washington, USA.

RCT Reference Concrete Powders with known chloride content.

Chloride content in concrete is an important index indicating the status of reinforced concrete structures in respect to chloride-induced corrosion.

In order to secure the test results of the RCT, Germann Instruments offer concrete powders with known chloride content.

The powders can be used for practicing with the RCT or for checking the performance of the RCT-kit.

In the following, the powders are described. The known amount of chlorides is stated as well as the chloride content measured by AASHTO T 260 potentiometric titration and the RCT.

Based on testing with the powders, it is shown that for accurate estimation, the instant results with the RCT need to be multiplied by a factor to obtain the RCT result after 12 hours of extraction. Alternatively, accurate measurements can be made after 12 hours of extraction.

Also, it is shown that the $RCT_{12\ hours}$ test result has a precision, compared to the actual content of chlorides in the powder samples, that is at least as good as the AASHTO T 260 potentiometric titration result.

The concrete powders and the actual chloride content of the powders.

The concrete powders have been prepared at the Swedish national Testing and Research Institute by adding a known amount of sodium chloride to a known amount of well-hydrated concrete powder produced from hardened concrete. After the adding of the chlorides further hydration has taken place, followed by drying and pulverizing of the samples. In this manner, the added chlorides react with the cement as they would in reality by diffusion, when chlorides penetrate into concrete.

The powders have the following fineness:

Particle size	< 0.125 mm	0.125-0.25 mm	0.25-0.5 mm	>0.5 mm
Percent	~ 70%	~ 20%	~ 10%	0%

The powders are produced from concrete with three different types of binders.

1. 100% ordinary Portland Cement (European designation “CEM1”) called *Portland Cement.*
2. 30% flyash (ranging from 21% to 35%) + ordinary Portland Cement (European designation “CEM II/B-V”), called *Flyash Cement*
3. 70% slag (ranging from 66% to 80%) + ordinary Portland Cement (European designation “CEM III/B”), called *Slag Cement.*

The background chloride content in the powder and the weight increment due to a further hydration after adding the chlorides have been taken into account in the calculation of the total chloride content in the powder:

Cement type *	Calculated total chloride content in weight percent of concrete		
Portland Cement	0.023%	0.071%	0.328%
Flyash Cement	0.020%	0.057%	0.244%
Slag Cement	0.020%	0.056%	0.244%

* according to ENV 197-1

AASHTO T 260 potentiometric titration investigation of the powders.

The powders have been tested in accordance with AASHTO T 260 potentiometric titration in a Scandinavian round-robin test through a Nordtest project.

Five certified laboratories participated. The average results are in parenthesis shown in the table below.

The average coefficient of variation on the repeatability was 2.3% and on the reproductivity between the laboratories 5.7%.

Cement type	Calculated total chloride content in weight percent of concrete (Potentiometric titration values* in parenthesis)		
Portland Cement	0.023% (0.024%)	0.071% (0.070%)	0.328% (0.314%)
Flyash Cement	0.020% (0.019%)	0.057% (0.052%)	0.244% (0.229%)
Slag Cement	0.020% (0.019%)	0.056% (0.052%)	0.244% (0.231%)

* according to AASHTO T 260, Potentiometric Titration

RCT investigation of the powders

In the table below RCT results are reported in comparison to the calculated known amounts of chlorides and to AASHTO T 260 potentiometric titrations.

The RCT results are shown after 5 minutes of shaking of the RCT vial and after 12 hours of extraction. After 12 hours the RCT values are stable.

	Calculated % Cl¯/weight	AASHTO T 260 % Cl¯/weight	RCT $_{5\ minutes}$ % Cl¯/weight	RCT $_{12\ hours}$ % Cl¯/weight	% increase RCT$_{5\ min}$ to RCT$_{12\ hours}$
Portland Cement (CEM I)	0.023	0.024	0.018	0.022	22
	0.071	0.070	0.064	0.072	13
	0.328	0.314	0.305	0.321	5
Flyash Cement (CEM II/B-V)	0.020	0.019	0.016	0.019	19
	0.057	0.052	0.054	0.061	13
	0.244	0.229	0.218	0.238	9
Slag Cement (CEM III/B)	0.020	0.019	0.016	0.019	19
	0.056	0.052	0.052	0.059	14
	0.244	0.231	0.218	0.238	9

The deviation between the calculated, known amount of the chlorides and the AASHTO T 260 potentiometric titration range from 4.4% to – 8.8%, with an average of –5.3%.

The deviation between the calculated, known amount of chlorides and the RCT$_{12\ hour's}$ results range between +7.0% and –5.0%, with an average of –3.6%.

The increase of the RCT$_{5\ minutes}$ results compared to the RCT$_{12\ hours}$ results is illustrated in fig. 3 dependent on the chloride content measured by RCT$_{5\ minutes}$.

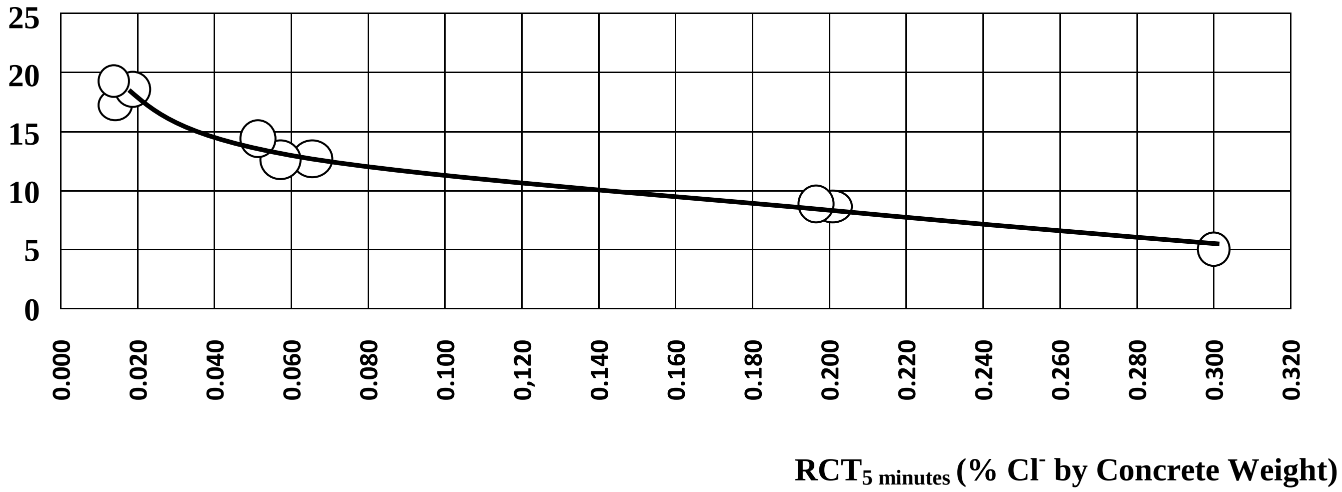


Fig. 3. The increase in instant RCT results after 12 hours of extraction. The increase is shown in relation to the chloride content measured after 5 minutes of vial shaking.

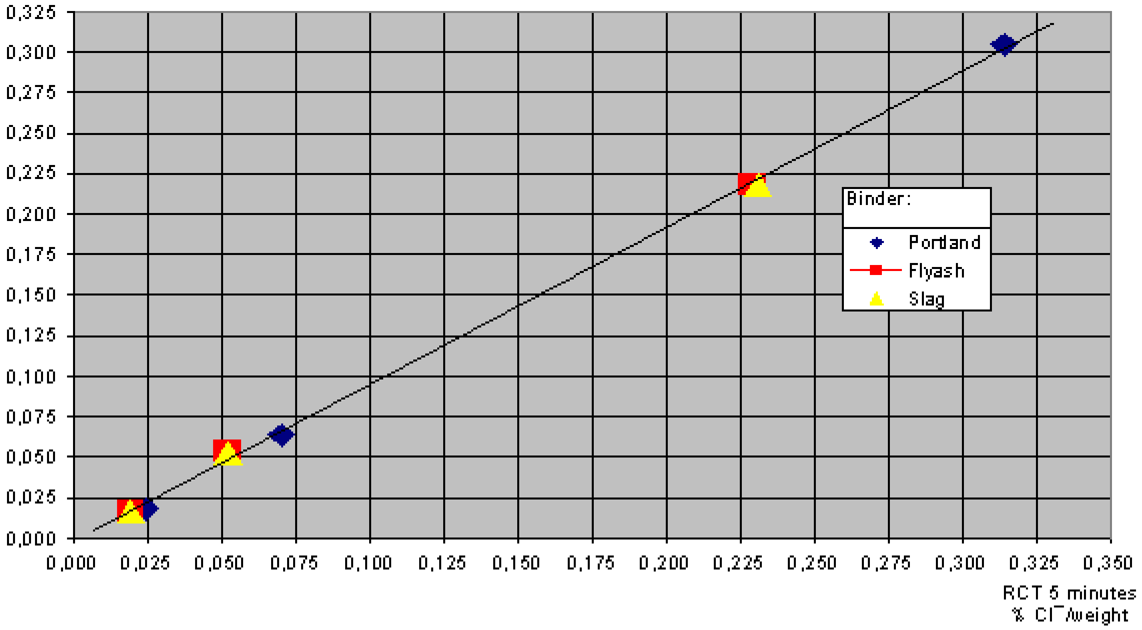
Example:

sample	After 5 min shaking	***Predicted 12 hours***	**Actual values after 12 hours**	**Titration results AASHTO T260**
	%Cl/weight	%Cl/weight	%Cl/weight	%Cl/weight
1	0.061%	***0.070%***	**0.070%**	**0.071% to 0.074**
2	0.061%	***0.070%***	**0.071%**	
3	0.063%	***0.072%***	**0.072%**	

The predicted values at 12 hours are calculated as results after 5 minutes of shaking added 14%

Fig. 4 illustrate the correlation obtained between $RCT_{5\ minutes}$ and the AASHTO T 260

$RCT_{5\ minutes}$
% Cl^- by concrete weight



AASHTO T 260
% Cl- by concrete weight

Fig.4. Relationship between $RCT_{5\ minutes}$ and AASHTO T 260 potentiometric titration.

Variation of the RCT

RCT testing on 10 samples of each of the reference concrete powders produced a test variation of +/- 1.7% in average, the "within test variation", V_w.

The test variation between the $RCT_{12\ hours}$ and the calculated, known amount of chlorides is +/- 3.6%, the V_c.

The total variation of measurement with the RCT is calculated as:

$$V_T = \sqrt{V_w^2 + V_c^2} = \sqrt{1.7^2 + 3.6^2} = 4\%$$

Round Robin investigation in Scandinavia

In a study conducted by CBI Betonginstitut in Borås, Sweden, six Scandinavian laboratories (two Danish and four Swedish labs) measured with their individual RCT equipment in a blind test the acid soluble content of chlorides of six concrete powders drilled out on a structure at different depth towards the reinforcement. The values stated in the table below are in % Cl^- by concrete weight.

Sample #	Lab 1	Lab 2	Lab 3	Lab 4	Lab 5	Lab 6	***Average***	***V***
1	0.072	0.086	0.079	0.072	0.071	0.073	***0.076***	***0.005***
2	0.080	0.082	0.087	0.085	0.086	0.085	***0.084***	***0.003***
3	0.048	0.055	0.041	0.045	0.046	0.054	***0.048***	***0.006***
4	0.018	0.013	0.021	0.021	0.020	0.021	***0.019***	***0.003***
5	0.007	0.009	0.013	0.009	0.008	0.013	***0.010***	***0.003***
6	0.003	0.004	0.004	0.002	0.003	0.006	***0.004***	***0.001***

The overall variation is 0.003 % Cl- by concrete weight

Round Robin investigation in Denmark

Three consulting engineering companies and one contractor conducted for the Danish Railways parallel RCT testing on concrete powders drilled out at different locations on Danish railroad bridges.

The RCT results are stated below in % Cl- by concrete weight

Location		F1-P1	F1-P1	F2-P1	F2-P1	F2-P3	F3-P1	F3-P1	F3-P3
Depth (mm)		60-100	100-150	60-100	100-150	100-150	60-100	100-150	60-100
Eng.1	RCT	0.181	0.172	0.091	0.025	0.103	0.023	0.009	0.113
Eng.2	RCT	0.170	0.170	0.090	0.020	0.110	0.020	0.010	0.120
Eng.3	RCT	0.181	0.179	0.091	0.026	0.118	0.026	0.010	0.113
Contr.1	RCT	0.170	0.170	0.074	0.023	0.098	0.021	0.010	0.130

Average	***0.176***	***0.173***	***0.087***	***0.024***	***0.107***	***0.023***	***0.010***	***0.119***
Variation	***0.006***	***0.004***	***0.007***	***0.002***	***0.007***	***0.002***	***0.000***	***0.007***

The overall variation is 0.004 % Cl- by concrete weight

Conclusions

For accurate results, the RCT vial should be left standing overnight before measurement is made.

Alternatively, if the test result is needed after 5 minutes of shaking of the vials, the $RCT_{5\ minutes}$ result should be multiplied by a factor as indicated in fig. 3 The factor is between 1.05 and 1.20 depending on the $RCT_{5\ minutes}$ result obtained.

For correlating the $RCT_{5\ minutes}$ result to AASHTO T 260 potentiometric titration, fig. 4 can be used.

The $RCT_{12\ hours}$ result has a precision compared to the calculated, known amounts of chlorides at least as good as the AASHTO T 260 potentiometric titration.

The type of binder of the concrete does not influence the RCT results, whether it is Portland Cement, Flyash or Slag.

The reference concrete powders with known amount of chlorides are useful for checking the RCT system in total as well as for performing Round Robin comparative testing.

Should the amount of chlorides be needed in relation to the cement weight. the amount of cement in relation to the mass of concrete has to be estimated. As an example, for 330 kg/m^3 of cement and a mass of concrete of 2400 kg/m^3 a factor of 2400/330 = 7.3 has to be multiplied on the RCT results. For e.g. 0.050% Cl^-/concrete mass measured by the RCT, the amount of chlorides by cement weight will be ~0.050% x 7.3 = 0.365% Cl^-/cement weight.

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