The Profile Grinder PF-1100, Mark II

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Abstract:

The newly developed Profile Grinder PF-1100, Mark II, is presented. The dimensions chosen of the grinding area and the maximum grinding depth is substantiated and the operation of the grinder outlined. Applications are illustrated on horisontal and vertical surfaces, in-situ, as well as on specimens in the laboratory. Finally, a short summary of the experience with the grinder is given.

Sampling of dust may be obtained accurately at depth increments between 0.25 mm and 2.00 mm chosen by the operator, for chemical analysis of the dust to be performed to establish accurate profiles of relevant concrete properties, e.g. of chlorides or pH.

The PF-1100 Profile Grinder Mark II offers the following advantages over conventional dust collection techniques:

1. The dust is obtained only from a thin slice with a well-defined thickness at the bottom of the 73 mm dia. cavity, not from the side.
2. The dust has a fineness and a homogeneousness equivalent to that of pulverizing concrete of sliced cores in the laboratory using a planetary ball mill.
3. The sampling may be performed entirely on-site eliminating costly and time consuming coring, slicing of the core and pulverizing of the slices in the laboratory.
4. A complete set of samples, e.g. consisting of 20 samples, may be performed within one hour.

Keywords: Profile grinding, Chloride profile, In-situ testing

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1. The need of profile grinding

Profile grinding for establishment of e.g. a chloride profile is traditionally performed by drilling out of dust using percussion drill equipment and dust collection devices with or without vacuum attachments. Such drilling may produce dust with variable particle sizes depending on the force applied to the drill machine, and the dust is not necessasrily drilled out from the bottom of the hole. Also, it is not possible to drill out dust at small depth increments if needed, when the chloride profile is steep in the vicinity of the surface. Dust collection in this manner may, furthermore, require drilling at several locations to make sure the maximum aggregate size is not influencing the representativitines of the sample. However, the sampling is quick and inexpensive to perform.

Otherwise, the most common practice is to drilled out a core with a sufficient diameter, slice it in the laboratory by saw-cutting and pulverize the slices in a ball mill to a required fineness. Alternatively, the core may be attached in a turning lathe and dust produced by means of a diamond bit mounted at the lathe center. Such procedures allow dust at distinct and small depth increments to be produced and collected. The disadvantages are high costs and time consumption, and that rather large holes are left in the structure from the coring often requiring the reinforcement to be cut.

In the following paper the Profile Grinder PF-1100, Mark II, developed by Germann Instruments A/S, is described. The grinder may be used entirely on-site combining quick and inexpensive sampling with laboratory accuracy in terms of how representative the sample is, the fineness of the dust and sampling at small and exact depth increments, if so desired. The standard equipment grinds out dust from an area of 73 mm in diameter. Sampling may, however, also be performed in other patterns with special designed attachment plates, e.g. in between reinforcement in tension without disrupting it.

2. Dimensions of the grinding area and the max. depth of grinding

The grinding area is 73 mm in diameter and the maximum depth is 50 mm.

At each depth increment of 1.0 mm approximately 9.0 gram of dust is available for analysis. For a maximum aggregate size of 15-20 mm this amount of dust is sufficient for the dust sample not to be affected by the presence of aggregates. For a maximum aggregate size between 25-35 mm, 18 gram of dust is needed, corresponding to a depth increment of 2.0 mm.

3. Operation of the grinder

To start out with, the diamond bit tip has to rest against the concrete surface when the grinder is held against the plate felt, see figure 1. This may be done by adjusting the position of the grinding machine in the grinder housing.

The pitch of the thread between the housing and the handle cover is 2.00 mm, consequently e.g. 45 degrees turning of the housing relative to the cover will adjust the diamond bit 0.25 mm downwards downwards if turned clockwise. Each 45 degrees are marked on the housing.

The housing and the handle cover is kept in a locked position prior to grinding by means of a counter nut threaded on the grinder housing. To adjusting the depth for further grinding the counter nut has to be released.

The grinder unit flange is made to rest against the felt and the unit is moved sidewards for the flange to be fully caught between the felt and the plastic cover.

The machine is turned on. The speed of the machine may be selected between 3100 and 7000 r.p.m. In general, the harder the aggregates are, the higher speed is needed. For normal concrete a speed around 4000 r.p.m. is recommended, maximizing the diamond bit life.

The counter nut is released, and the grinding machine with housing is turned clockwise relative to the handle cover, e.g. 90 degrees if 1.00 mm depth increment is needed.

The counter nut is tightened and grinding may commence.

Grinding takes place with both hands on the handles. The grinder is moved in a circle so the flange is following the inner recess of the plate. After one full rotation, the grinder is moved 15-18 mm towards the center of the plate and another rotation is completed for the total 73 mm diameter surface to be worked over with the bit. The grinder is centered in the plate, the machine turned off and the unit removed.

On horisontal surfaces (fig. 1 and 3), the dust is collected with a Dustbuster and poured into a plastic bag. On vertical faces the dust is collected during grinding in a plastic bag attached to the plate (fig.2).

4. Applications

The following figures illustrates the typical applications, grinding in-situ on horisontal and on vertical surfaces and grinding of specimens in the laboratory.

4.1 Grinding in-situ on horisontal surfaces.

The reinforcement is located with a covermeter and the grinding location chosen. Two anchor holes are drilled, supplied with anchors and attached to the clamping pliers. The plate is secured firmly to the surface by means of the pliers at the chosen location.

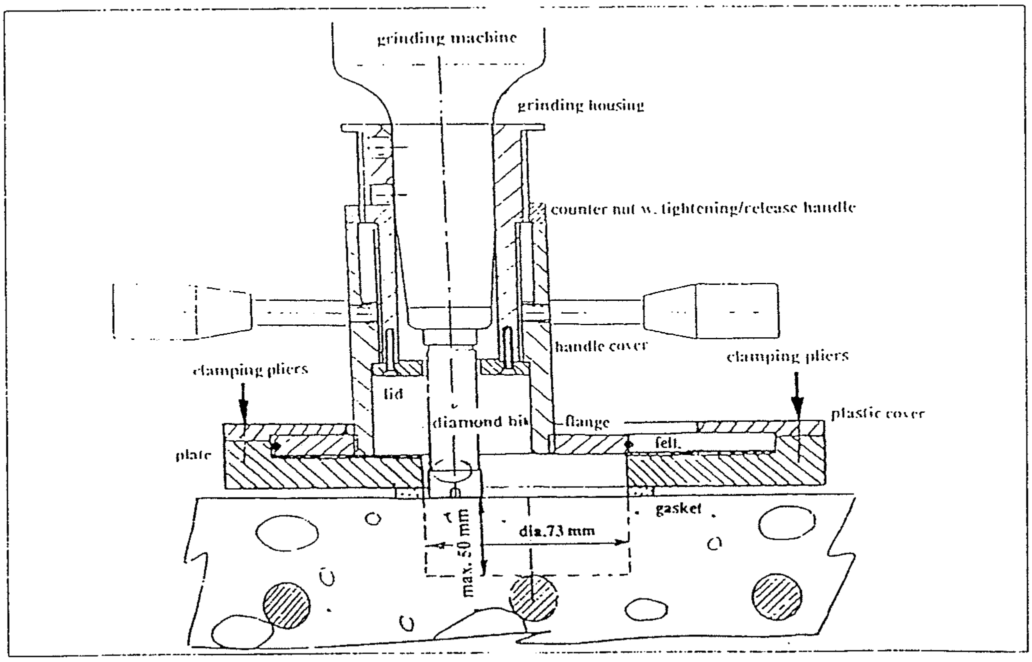

Figure 1. The PF-1100 Profile Grinder, Mark II, used in-situ for grinding out of dust on a horisontal surface.

Grinding takes place as illustrated in section 3. Dust is collected with the Dustbuster and poured into a plastic bag marked with the test location and the depth sampled at, ready for chemical analysis. The Dustbuster has a re-usable filter.

Repeated sampling takes place at the required depth increments until the needed full depth has been reached.

4.2 Grinding in-situ on vertical surfaces

The location of the grinding and the clamping of the plate to the surface is made as previously described. On circular columns the anchors are placed in the direction of the centerline of the column.

Make sure the dust channel of the plate turns downwards. Open the channel by sliding its half-ring sidewards. Attach a plastic bag to the plate as illustrated in figure 2.

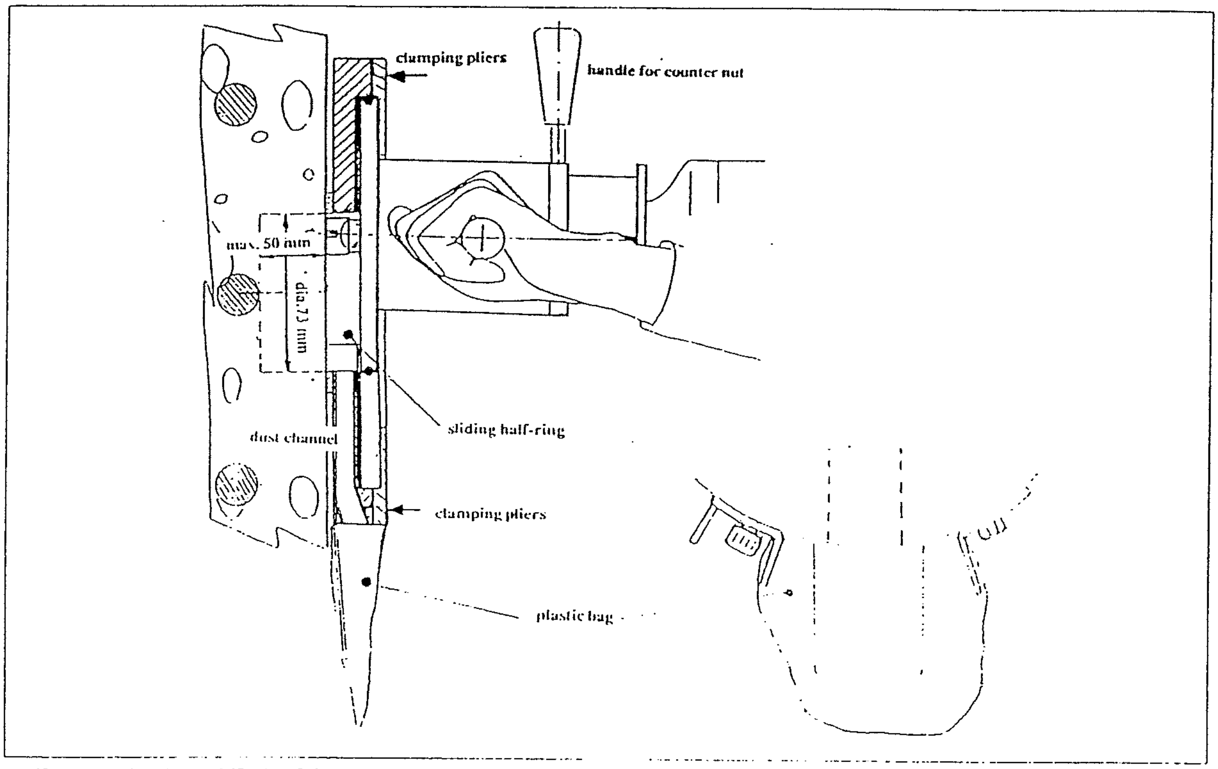

Figure 2. The PF-1100 Profile Grinder, Mark II, used in-situ for grinding out of dust on a vertical surface.

Grinding takes place as outlined in section 3.

After each grinding sequence has been completed the grinding machine is turned off and removed. Remaining dust in the cavity is released with a brush and brushed into the channel of the plate leading to the plastic bag, which is removed and labelled with the test location and the depth sampled at.

Sampling is repeated until the required depth has been reached.

4.3 Grinding in the laboratory on specimens

The PF-1100 Profile Grinder, Mark II, is designed for drilling out of dust of specimens in the laboratory as well, the specimens having a diameter between 95 mm and 105 mm and a height between 60 mm and 70 mm.

Grinding may take place horisontally (shown in figure 3), or vertically by the use of an angle iron attached to the bench plate and secured to the table.

The ring is attached to the plate by means of two bolts, see figure 3, and clamped to the bench plate with the specimen in between. The bench plate is secured to a table with a screw clamp.

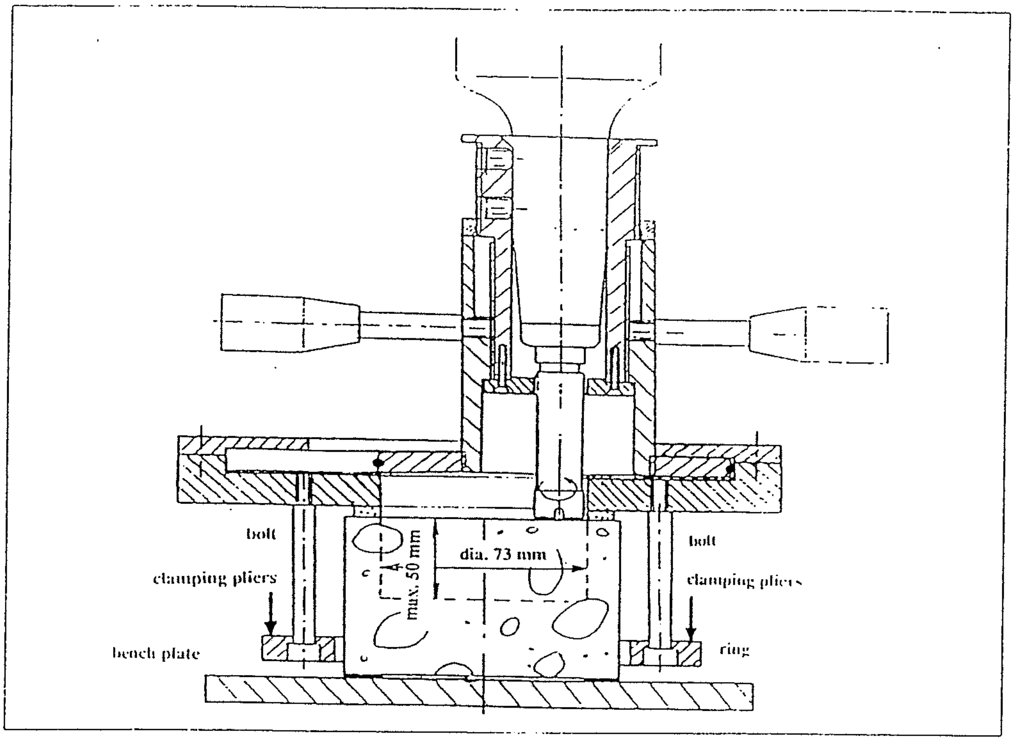

Figure 3. The PF-1100 Profile Grinder, Mark II, used in the laboratory for grinding out of dust of a specimem, the horisontal option being shown.

Grinding takes place as described in section 3.

In case the specimen is placed horisontally as illustrated in figure 3, the dust is collected with the Dustbuster and poured into a plastic bag. For a vertical positioning of the specimen the dust channel of the plate is opened and a plastic bag is secured to the plate at the outlet location so the dust is automatically collected in the bag during grinding.

5. Experience with the PF-1100 Profile Grinder, Mark II

In average, the grinding of each depth increment of e.g. 1 mm, last 30 seconds, and the dust collection about one minut for a trained operator. This is if sampling takes place on a vertical surface. A full profile grinding involving 15-25 samples may be completed within one hour.

On horisontal surfaces where the Dustbuster has to be used for dust collection, the total time elapsed will be 1.5 to 2 hours for a similar number of samples.

The drill bit is worn out after about 200 samples have been taken when grinding on normal concrete. If the concrete contains very hard aggregates or is of a high strength type, the maximum number of samples are about the half before the diamond bit has to be replaced.

The operation of the grinder illustrated and its maintenance has proven to be fairly simple and straight-forwarded for testing technicians.

NOTE: Excessive force applied to the grinding bit may - in combination with "jarring" of the grinder - cause the center axel of the grinder to fail. Should "jarring" occur, first check the diamond bit for sufficient sharpness and presence of the two slots, then adjust the speed and apply only a moderate sidewards pressure during grinding. Check also the quality of the felt on the plate and clean the units sliding parts. Slightly oil the top part of the flange with silicone oil for the flange to slide smoothly against the plastic cover. .

Grinding will, especially on hard materials, generate heat to the bit. Remember to use the wetted sponge to cool off the bit in between each grinding step.

Select the speed of the machine so the most smooth operation is obtained. In general, hard aggregates/paste will need a higher speed than if soft aggregates/paste is present. To start out with use the lowest speed, 3100 r.p.m.

Make sure a new diamond bit always is at hand, should the edge of the bit become rounded and the bit edge blunt, causing "jarring".

The Dustbuster will, fully rechaged over-night, be able to operate 10 minutes before another recharge is needed. Therefore, make the dust collection as quickly as possible with the slowest Dustbuster speed, and clip the Dustbuster on the recharger when not used. The collection of the dust in one sample should not take more than 5-8 seconds.

6. Ordering numbers of spareparts:

Red grinding bit:	PF-1111
Steel ball, 12mm dia.:	PF-1111-1
Green felt for grinding plate:	PF-1110
Plastic bags for dust collection, ea 50:	PF-1106
Seating rubber ring:	PF-1105
Expansion anchors, 8 mm, ea 100:	CC-30-3
Filters, ea 20:	PF-1106-1
Square frame for 150 mm cubes:	PF-1150

7. Examples

In the two first examples profiles were measured by the RCT (acid soluble) after profile grinding and the chloride diffusion coefficient calculated for service life estimation. Another three examples of profile grinding are illustrated in clause 7.3 where RCT was used for analysis as well as the RCTW for water-soluble chlorides.

7.1 Profile Grinding on-site on a concrete sea-wall

Profile grinding was performed on a concrete sea-wall, on year old, in the splashing zone.. The cover was 50 mm.

Testing for chlorides was made in parallel to the grinding. Four powder samples were first taken with depth increments of 0.50 mm followed by additional six with 0.50 mm in between.

The results were plotted in relation to depth, see figure 6.

A rather high chloride content was found with a maximum peak at about 4 mm depth. This peak value corresponded to the depth of carbonation, tested by the Rainbow Indicator. The influence of the carbonation on the chloride profile is explained in detail by e.g. Tuuti, ref. (5), Cady et al, ref. (4) and Fangel et al, ref. (5).

It was decided to keep on sampling at 0.50 mm depth increment intervals with 0.50 mm in between the samples until the chloride profile would level off. Another six samples was taken and measured with the RCT. To obtain the initial chloride content it was decided to drill out with an 18 mm drill bit at depths between 36 and 49 mm, respectively 61-81 mm.

The total profile was plotted as shown in figure 6.

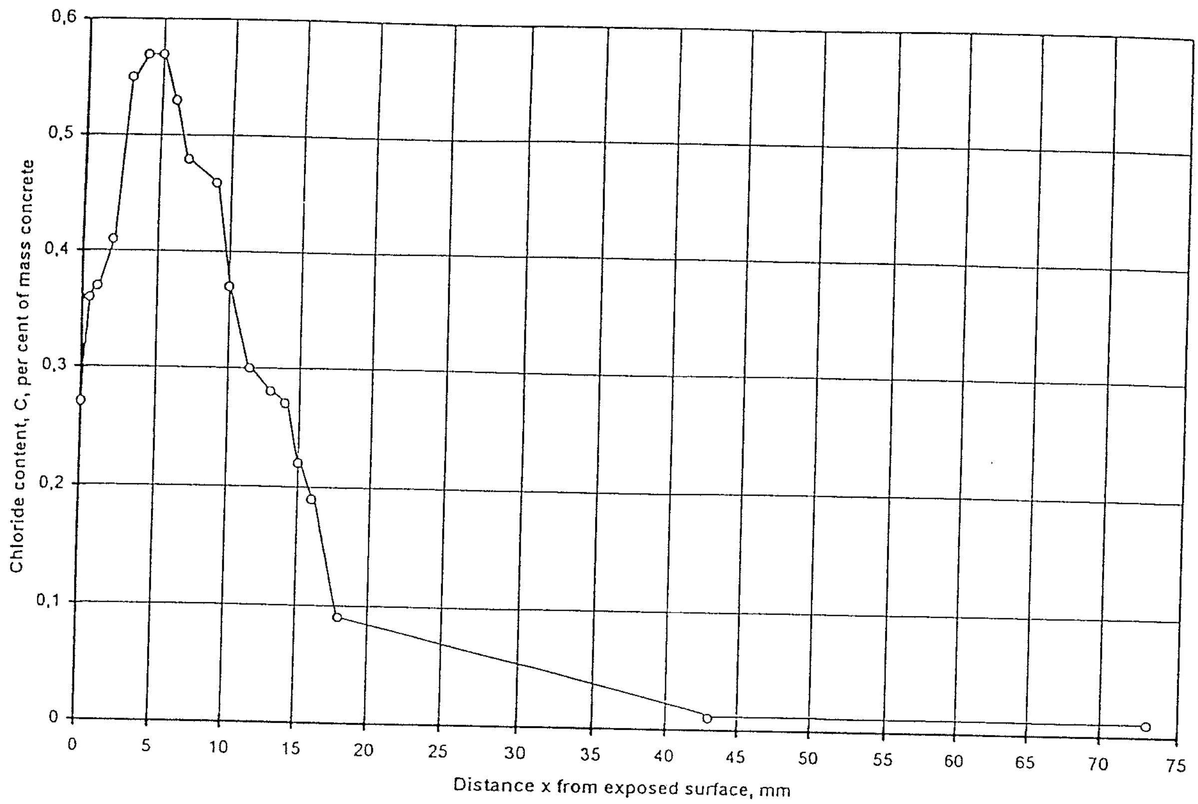

Figure 6. Chloride profile data obtained on the sea-wall by profile grinding and RCT

The purpose of the testing was to estimate the remaining service life of the sea-wall before chloride induced corrosion would occur according to Fick´s Second Law of Diffusion:

$$C(x,t) = C_i + (C_s - C_i) \cdot erfc \frac{x}{2 \cdot \sqrt{t \cdot D_0}}$$

Where:

- C(x,t) is the chloride concentration at a depth "x" in mm from the exposed surface at an age "t" in years since the chloride exposure first took place
- C_i is he initial chloride concentration in % Cl^- by concrete mass.
- C_s is the max. chloride concentration at the surface in % Cl^- by concrete mass.
- erfc is the error function complement (the error function is tabulated in the mathematical handbooks), and
- D_0 is the chloride diffusion coefficient in mm^2/year.

The calculations shown in the following comply with the approximative procedure outlined by Poulsen, refs. (7) and (8).

In figure 7 the test data is given along with calculated parameters for the regression analysis to be performed.

From (mm)	To (mm)	Mean (mm)	Chloride, C(%)	C-C_i	$\sqrt{C-C_i}$	Design
0.00	0.50	0.25	0.2600	0.2506	0.5006	void
0.50	1.00	0.75	0.3600	0.3506	0.5921	void
1.00	1.50	1.25	0.3700	0.3606	0.6005	void
1.50	2.00	1.75	0.4100	0.4006	0.6329	void
2.50	3.00	2.75	0.5500	0.5406	0.7353	void
3.50	4.00	3.75	0.5700	0.5606	0.7487	void
4.50	5.00	4.75	0.5700	0.5606	0.7487	0.7487
5.50	6.00	5.75	0.5300	0.5206	0.7215	0.7215
6.50	7.00	6.75	0.4800	0.4706	0.6860	0.6860
8.50	9.00	8.75	0.4600	0.4506	0.6713	0.6713
10.00	10.50	10.25	0.3700	0.3606	0.6005	0.6005
11.50	12.00	11.75	0.3000	0.2906	0.5395	0.5391
13.00	13.50	13.25	0.2750	0.2656	0.5154	0.5154
14.00	14.50	14.25	0.2600	0.2506	0.5006	0.5006
15.00	15.50	15.25	0.2150	0.2056	0.4534	0.4534
16.50	17.00	16.75	0.1900	0.1806	0.4250	0.4250
18.00	19.00	18.50	0.0940	0.0846	0.2909	0.2909
36.00	49.00	42.50	0.0105	0.0011	0.0332	void
61.00	81.00	71.00	0.0094	0.0000	0.0000	void

Figure 7. The chloride profile data along with parameters for the regression analysis, according to Poulsen, refs. (7) and (8)

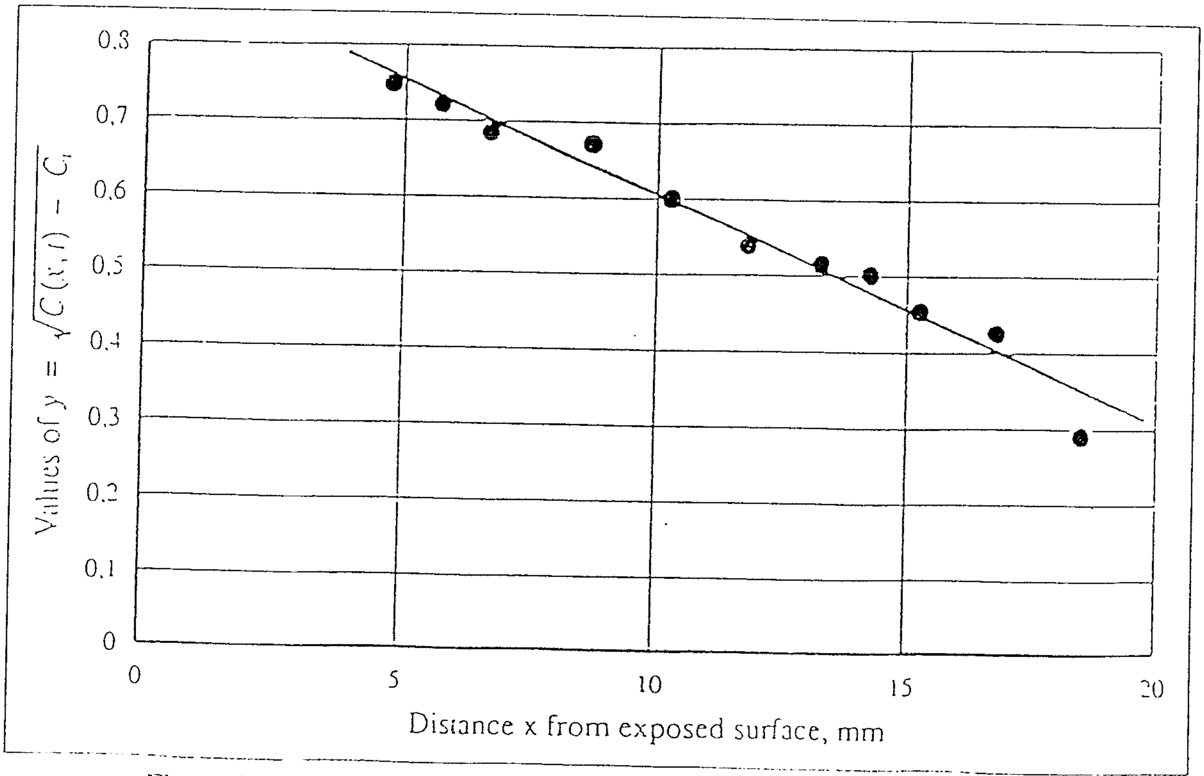

Figure 8. Linear regression analysis for evaluation of the chloride concentration at the surface

The initial concentration (measured at a depth of 61.0 mm - 81.0 mm) is:

$$C_i = 0.0094 \ \% \ Cl^- \text{ by concrete mass}$$

The regression analysis (fig.8) yields:

$$y = 0.9060 - 0.0302 \cdot x$$

by which the chloride concentration at the surface is calculated to be:

$$C_s = 0.9060^2 + 0.0094 = 0.830 \ \% \ Cl^- \text{ by concrete mass}$$

and the chloride diffusion coefficient:

$$D_o = (0.9060/0.0302)^2/12 \cdot 1.0 = 75 \ mm^2/year$$

The first year ingress of the critical chloride concentration (0.050%) is:

$$K_1 = \left(1 - \sqrt{\frac{0.0500 - 0.0094}{0.8300 - 0.0094}}\right) \cdot \sqrt{12 \cdot 75} = 23.3 \ mm \ per \ \sqrt{year}$$

According to Fick´s Second Law of Diffusion, the critical chloride concentration (0.050%, acid soluble) will penatrate to the 50 mm reinforcement depth after another:

$$t = (50/23.3)^2 = 5 \text{ years,}$$

which may be regarded, based on diffusion theory, as the remaining service life of the structure before chloride induced corrosion will take place, unless remedial measures are taken.

A practical and quick approach for calculating the remaining service life approximately is the following, illustrated in five steps:

1. The present depth of the critical chloride level for corrosion occur, 0.05%, is at the moment approximately 25 mm (=d)
2. The structure has been exposed to chlorides for 1 year (=t)
3. A k-factor is calculated as $k = \frac{d}{\sqrt{t}} = \frac{25 \ mm}{\sqrt{1 \ year}} = 25 \ mm / \sqrt{year}$
4. For a cover of D = 50 mm, the D/k relationship is 50 mm/ (25 mm/ $\sqrt{year}$) = 2($\sqrt{year}$)
5. The remaining servicelife is $(D/k)^2 = (2\sqrt{year})^2 = 4$ years

7.2 Profile Grinding on laboratory specimens after ponding

To evaluate the diffusion characteristics of a new mix design, specimens were cast and cured in the laboratory.

The specimens were applied a coating on the cylindrical faces and subjected to a chloride solution following the NT BUILD 443 standard procedure, ref (9).

After an exposure time of 35 days, profile grinding was done in eight steps, each 1 mm in depth increment.

Subsequently, it was decided to grind out additionally four powder samples in 2 x 1 mm steps and to use a drill bit to obtain powder from 16 mm to 30 mm depth.

One chloride profile in total is shown below in fig. 9.

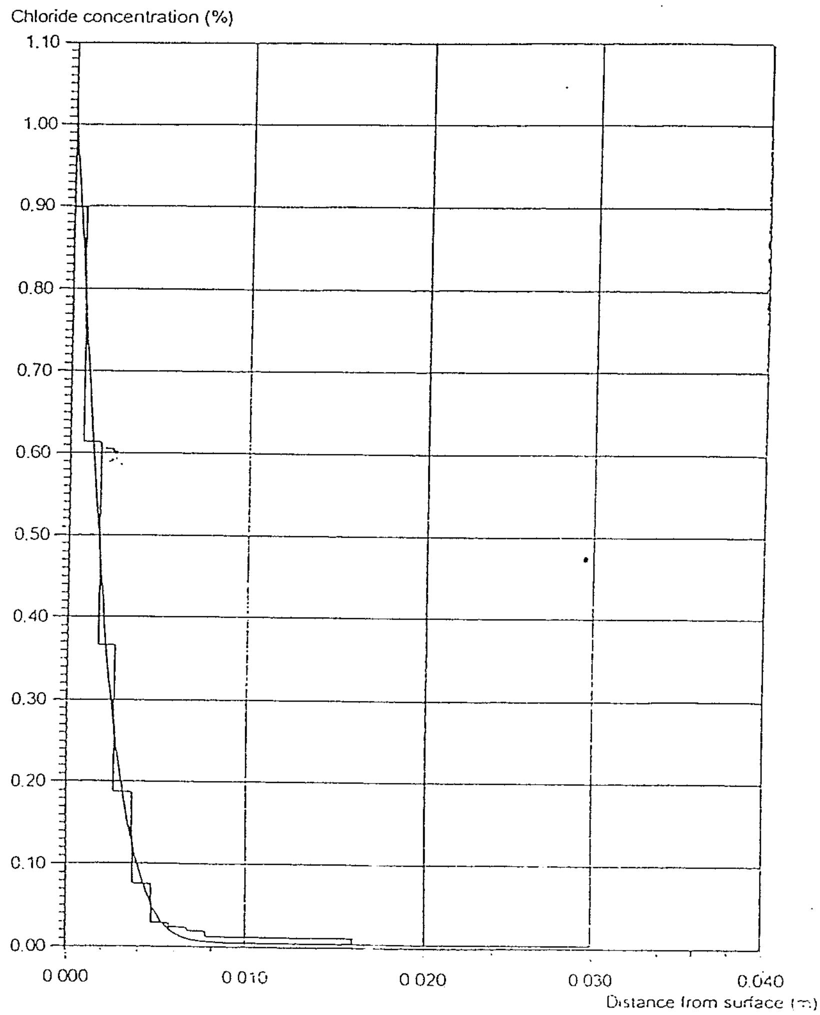

Fig.9. Chloride profile of a specimen determined by profile grinding and testing for chlorides by the RCT

A diffusion coefficient of $D = 0.91 \cdot 10^{-12}$ (m^2/s) or 29 mm^2/year was calculated for service life estimation based on Fick's Second Law of Diffusion, using the calculation procedure in example 7.1 page 7.

7.3 Other examples of chloride profiles

The following three figures illustrate other chloride profiles obtained after profile grinding and measurement with the RCT (for acid soluble chlorides) and the RCTW (for water soluble chlorides).

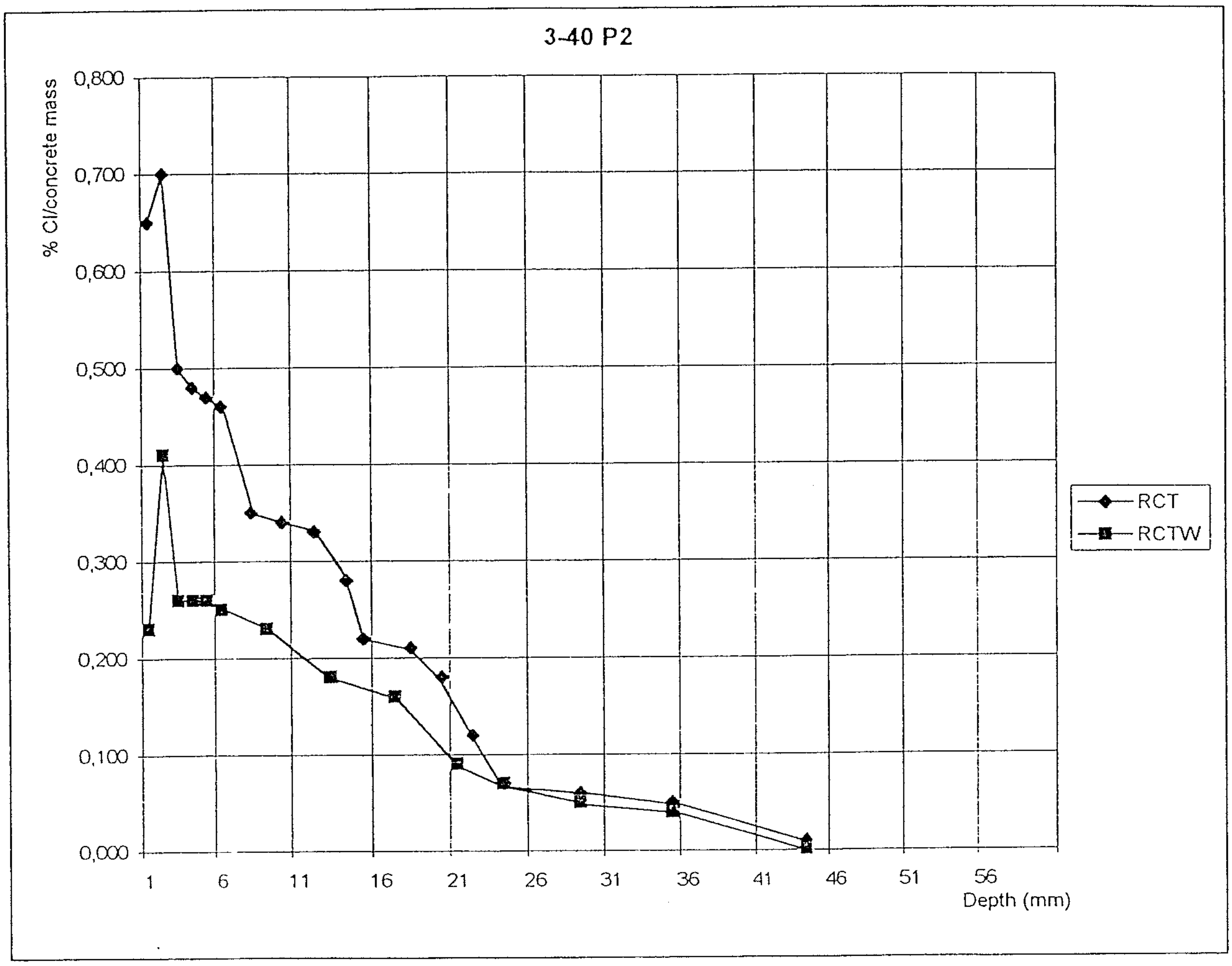

Figure 10. RCT (acid-soluble) and RCTW (water-soluble) chloride measurements on powder after grinding out of a marine structure in the splashing zone, 2 1/2 years old, 5% microsilica and w/(c+SF)=0.40.

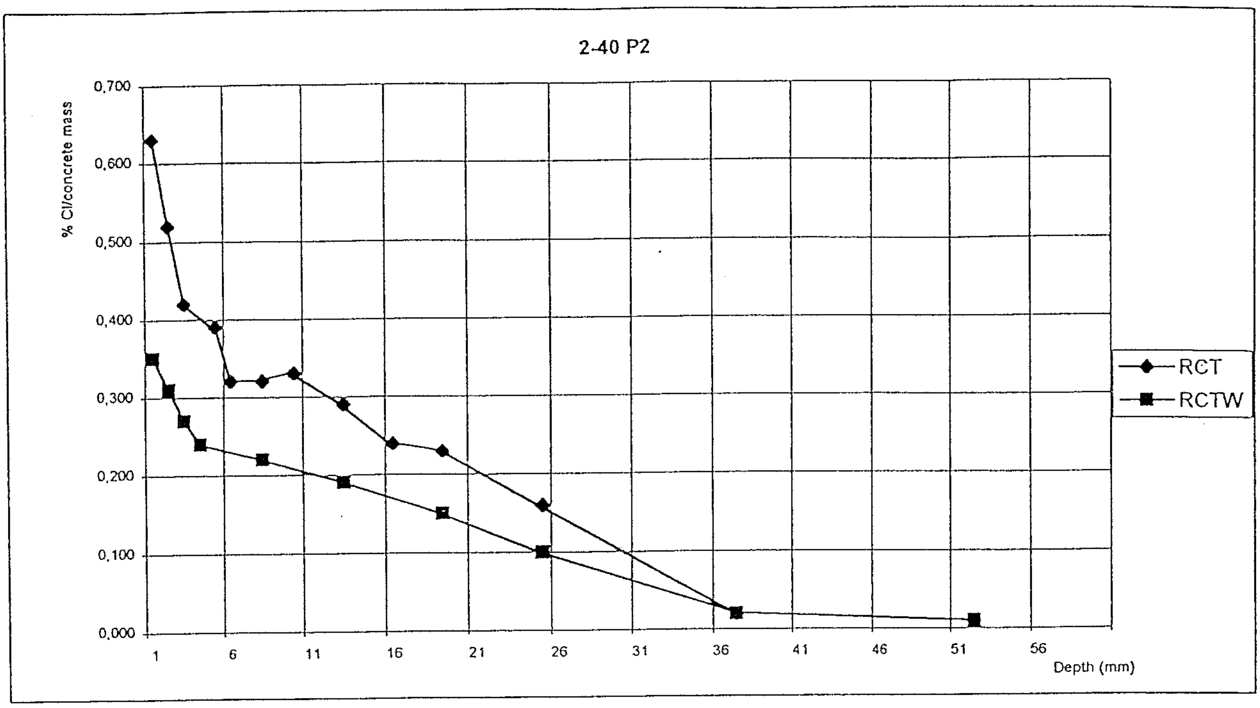

Figure 11. RCT (acid-soluble) and RCTW (water-soluble) chloride measurements on powder after grinding out of a marine structure in the splashing zone, 2 1/2 years old, no puzzolanes and w/c ratio of 0.40

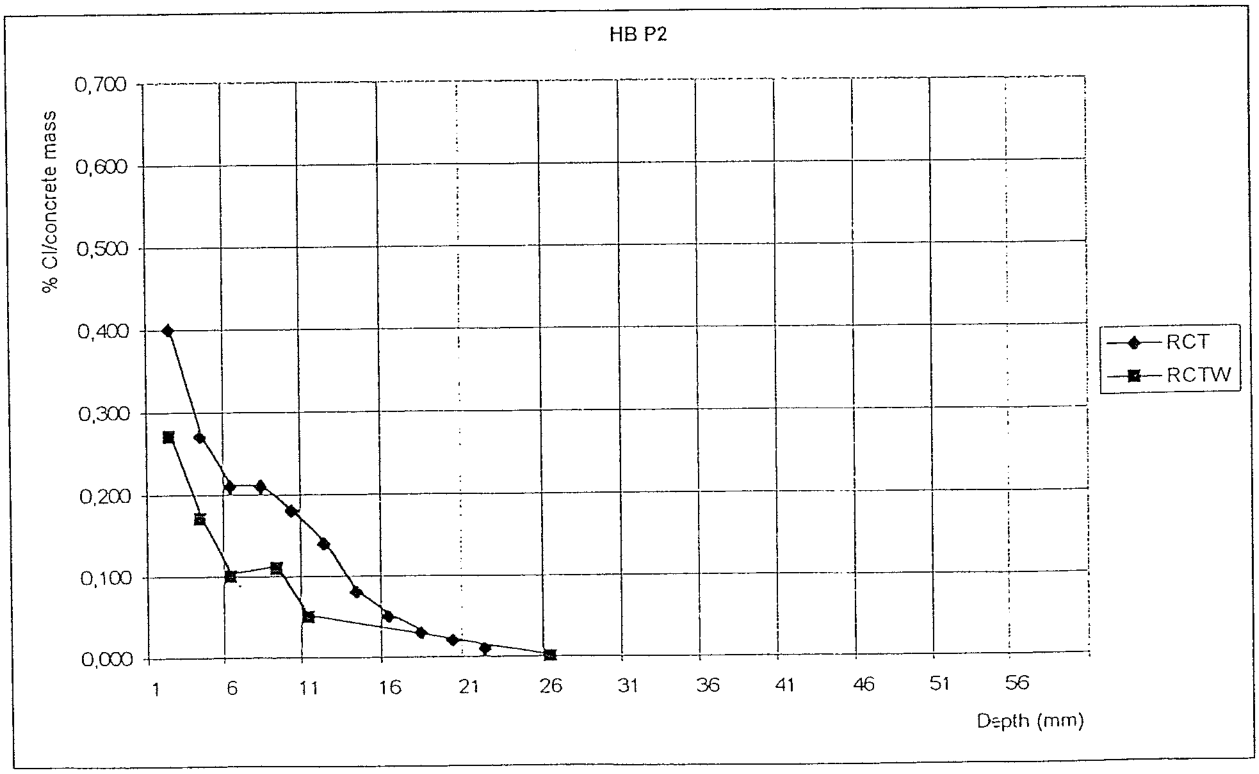

Figure 12. RCT (acid-soluble) and RCTW (water-soluble) chloride measurements on powder after grinding out of a marine structure in the splashing zone, 2 1/2 years old, 20% flyash and w/(c+0.3FA)=0.30

8. References

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