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Concrete durability field testing in Finland

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ABSTRACT

There are three Finnish concrete field testing stations containing approximately 90 different concrete mixture designs that have been placed over a 10 year period. There is no other method as reliable as field testing to get reference data for service life models. In field testing all interacted deterioration is included - e.g. chloride penetration is interacting with carbonation and frost deterioration. Field testing includes e.g. moisture, salt exposure, temperature and solar radiation variations and effects of carbon dioxide and hydration with time. This presentation is mainly concentrated on relatively new highway field testing and sheltered carbonation testing in Finland. Some field results and comparison with laboratory testing results are presented [1].

Key words: Field testing, durability, frost-salt, frost, chloride, carbonation, interacted deterioration, ageing

1 INTRODUCTION

Of the Finnish field stations, two are without salt and one highway testing field has salt exposure. The fields without salt exposure are in southern and northern Finland. Several test series with different binding materials have been prepared during three different projects at the EU, Nordic and Finnish levels. Some parallel highway field concretes are located in field stations in both Borås, Sweden, and in Kotka, Finland, to find out possible differences.

All field testing results for the mixes prepared after 2007 in the national DuraInt project as well as all the updated field testing data for the former field testing projects in Finland - CONLIFE (2001-04) and a parallel national project YmpBetoni (2002 - 04) with Finnish ecological binding materials are today summarized in an Excel-format database. This data will be updated for the service life modelling work together with other available field testing data, such as the longer-term BTB-project data (Borås, 1996). All of the above projects have included extensive laboratory testing programs. Here only the most recent DuraInt field testing results and comparison with laboratory testing is presented. Field testing has included also e.g. collection of weather data and data on highway salting. At the highway field there has also been specimen for concrete temperature and humidity follow up and a novel study on the use of optical fibres for the measurement of concrete moisture content (Englund/Fortum R&D).

This presentation is in connection with separate presentations on interacted laboratory (Holt & Leivo, VTT) and service life prediction studies (Vesikari, VTT).

2 CHLORIDE PENETRATION STUDIES

The aim was to get long term field testing data and understand the effect of binding material, w/b ratio, air content and specific concrete surface treatments (impregnation, form lining) on chloride penetration. Field specimen (300 x 300 x 500 mm^3, 2/concrete) were placed mainly at a distance of 4.5 m from the road lane on wooden stands. For some parallel specimen this exposure distance is also 6 m, 8 m and 10 m. Four parallel concretes are at Borås testing field in Sweden. For field chloride analysis, cylinders (ø100 mm) were cored from the field specimen. Powder samples were taken from these cylinders for chloride content analyses by a profile grinding method and by dry-slicing. Chloride profiles have so far been created after the 1st and mostly also after the 3rd winter. These profiles represent the vertical surfaces facing towards the highway. I the laboratory chloride migration coefficients (D_{nssm}) were measured at 3 months age by the CTH-method (NT Build 492). In Figures 1 and 2 there are some examples on the results to date.

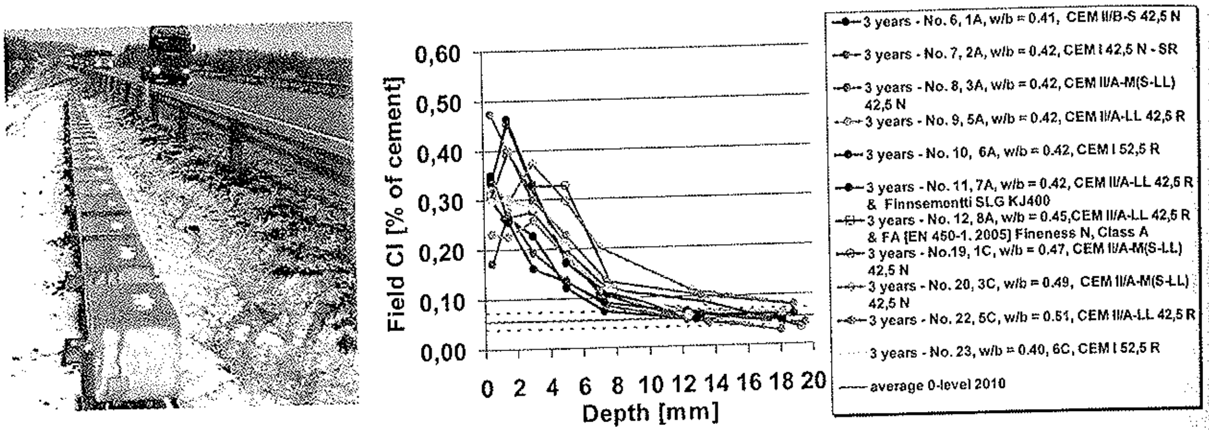

Figure 1. Field specimen for chloride penetration studies at highway testing field and chloride ingress profiles after three winters (2007-2010) for specimen with different binding materials and w/b ratios. All these specimens are at 4.5 m from the highway lane.

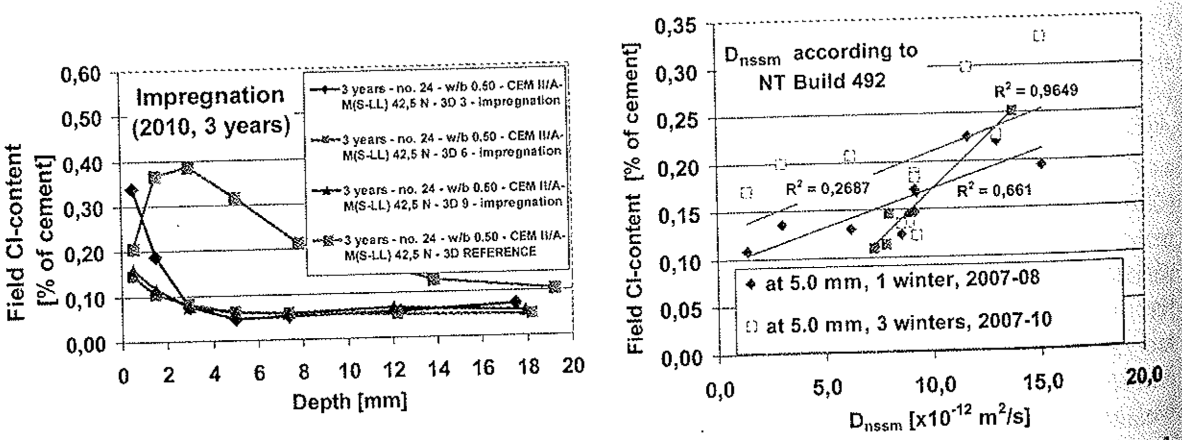

Figure 2. Left chloride ingress profiles after the 3rd winter season for the specimen with impregnation and for the reference, and right chloride content at field at 5.0 mm from the specimens surface after the 1st and 3rd winter season as a function of D_{nssm} (NT Build 492). Good correlation only after the 1st winter season.

3 CARBONATION STUDIES

After de-moulding at 1 d, carbonation specimen (beams 100x100x500 mm^3) were cured in water. At 7 d they were moved to a climatic room with RH 65 % (+ 20 °C). Measurement of carbonation depth was done essentially as described in [EN 13295]. Testing in the field and laboratory after 7 d age was otherwise as below:

- Carbonation continued in laboratory climatic room with RH 65 % (+20 °C).
- Field carbonation sheltered was started at about concrete age 28 d.
- Accelerated carbonation in a sealed cabinet with 1 % CO_2, RH 60 % and 21°C was started at concrete age 28 d.

The average field carbonation times are 268 days and 772 days (January 2011). The coefficients for carbonation (k-values) were calculated by the common equation: Carbonation [mm] = $k\sqrt{t}$, where t is the carbonation time [d] and k is the coefficient for carbonation [mm/d$^{0.5}$]. Some examples from the field and laboratory results are presented in Figures 3A - D. There is quite good general correlation between field, laboratory RH 65 % and 1 % CO_2 accelerated carbonation (Fig. 3A). The effect of e.g. w/b, compressive strength (Fig. 3C) or CO_2-diffusion coefficient, binding materials and air content (Fig. 3D) should be included in the modelling of field carbonation, as well as all the exposure factors.

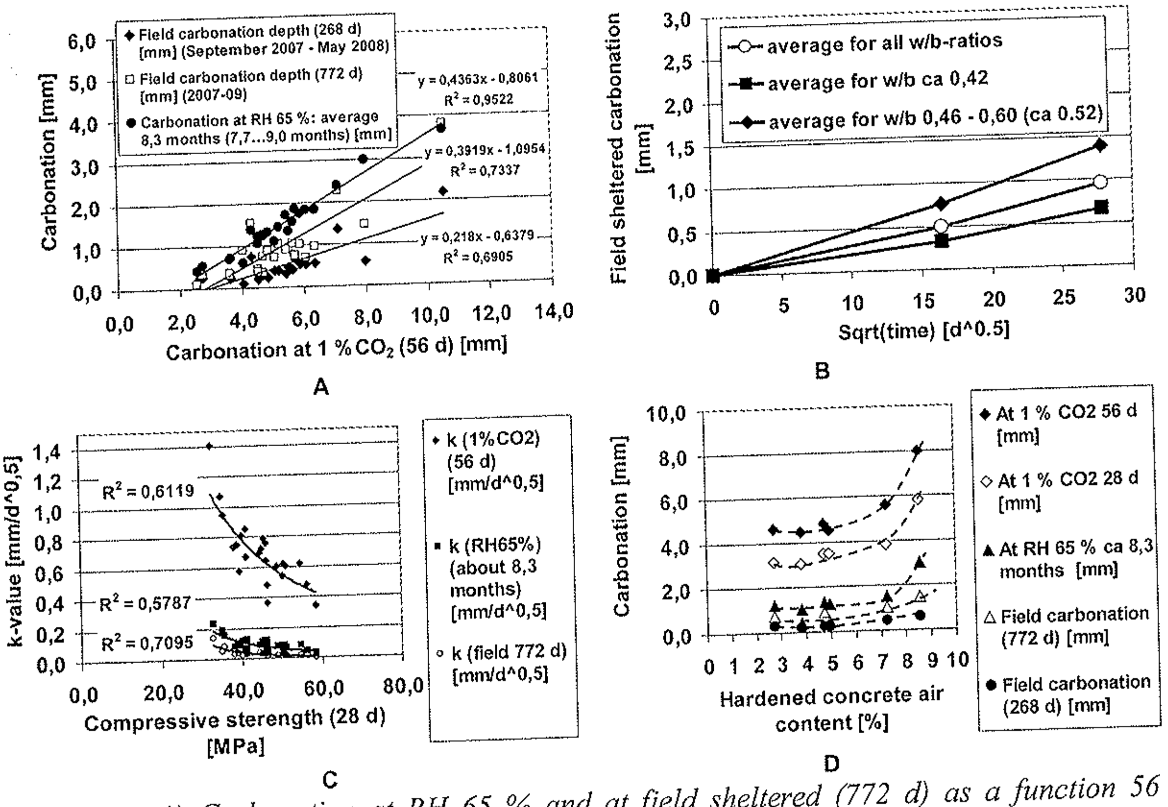

Figure 3 A) Carbonation at RH 65 % and at field sheltered (772 d) as a function 56 d carbonation at 1 % CO_2 (at RH 60 %). B) Field carbonation sheltered as a function of square root of time for concretes with w/b ca 0.42 (14 mixes), with w/b 0.46 – 0.60 (9 mixes, average w/b ca 0.52) and the average carbonation for all the concretes (14 + 9 = 23 mixes). C) Carbonation k-value as a function of compressive strength. D) Carbonation as a function of air content, when the binding material (CEM II/A-M(S-LL) 42,5 N) and w/c ratio (0.42) is the same for all the mixes.

4 FROST-SALT AND FROST STUDIES

The aim was to get field testing data as well as versatile laboratory testing results on the effect of binding material, w/b ratio, air content and air pore structure on freeze-thaw durability with and without salt exposure. Field specimen (75x150x150 mm^3), (3+1)/concrete) were situated in wooden stands in the field with no salt exposure and in addition in metal racks at the highway field with salt exposure (Fig. 4A). Frost- or frost-salt scaling (volume change) and internal deterioration (RDM by ultrasound and fundamental frequency) have been monitored. There was an extra field specimen for future thin section studies on e.g. cracking, scaling and carbonation. After three winters (2007-10) there has been no major deterioration yet. Even the concretes with no air entrainment have managed well so far (3 winters) beside the highway.

In all 21 mixes the frost-salt/frost testing was done in laboratory after three curing conditions:

a) By the standard Slab test method at 28 d [CEN/TR 15177, CEN/TS 12390-9].
b) As 'aged and carbonated' after ca 1 year at RH 65%, i.e. including also surface drying at RH 65 % (+20 °C).
c) As 'aged but not carbonated' (>1 year at RH 65 %). In this case at RH 65 % partly carbonated surface layer (10 mm) was sawed off. Sawing off the surface layer also meant that the final testing surface drying degree was smaller than in the case b) above.

Testing was always started in the normal way, by re-saturation of the specimens. Frost-salt scaling after 56 cycles is presented in Fig. 4B. It can be seen that carbonation and ca 1 year drying at RH 65 % clearly affected the frost-salt scaling. Hydration, carbonation and drying will have an effect on frost-salt scaling. Thus all ageing should be included in the models for frost-salt scaling. Concrete composition will have an effect on the significance of ageing.

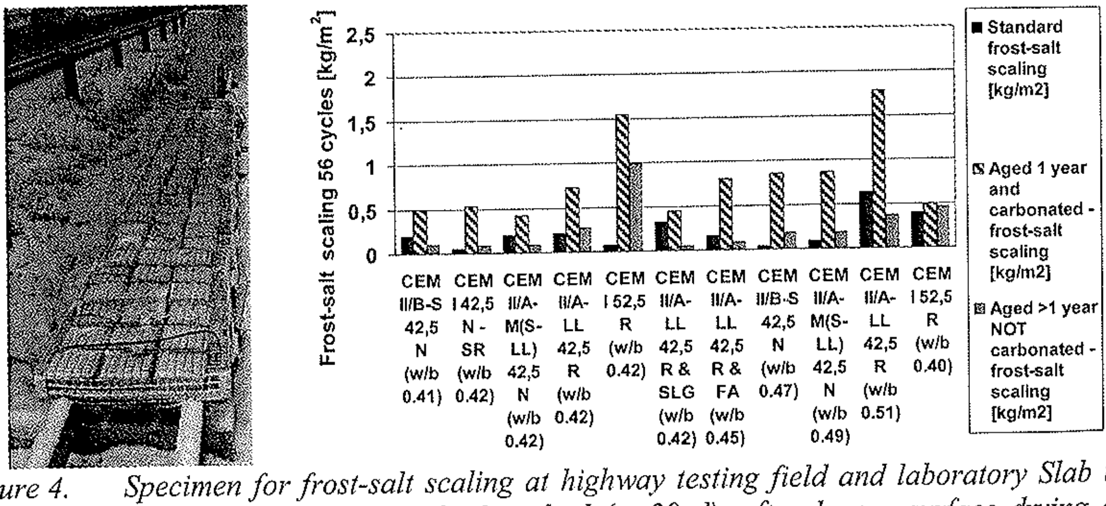

Figure 4. Specimen for frost-salt scaling at highway testing field and laboratory Slab test frost-salt scaling (56 cycles) by standard method (at 28 d), after 1 year surface drying and carbonation at RH 65 % and after no carbonation and lower surface drying degree at RH 65 % (age over 1 year, 10 mm surface layer was sawed off before testing).

REFERENCES

1. Kuosa, H. 2011. Concrete durability field testing. Field and laboratory results 2007 - -2010. Research Report VTT-R-00482-11.