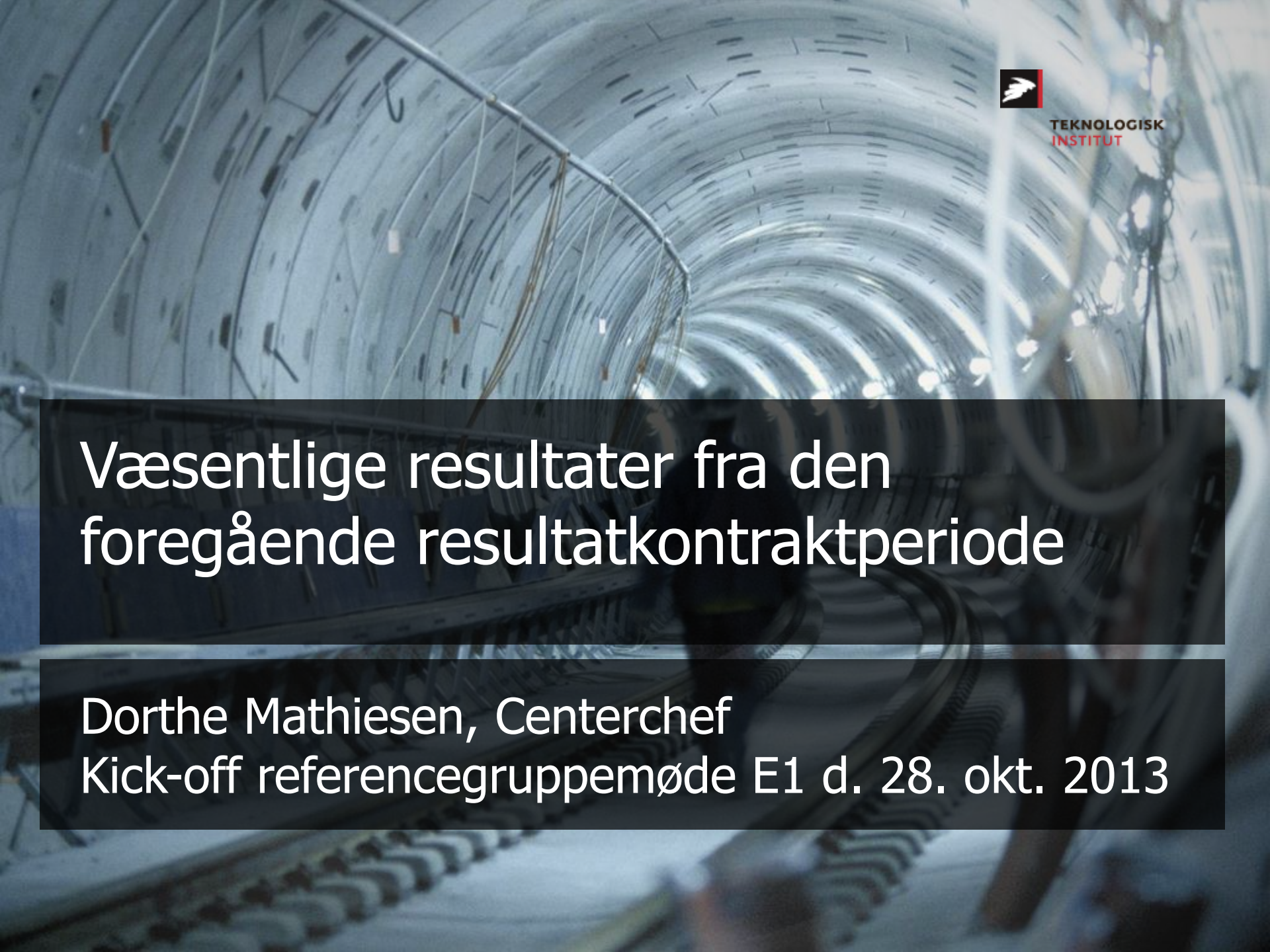
TEKNOLOGISK
INSTITUT

it's all about innovation



Væsentlige resultater fra den foregående resultatkontraktperiode

Dorthe Mathiesen, Centerchef

Kick-off referencegruppemøde E1 d. 28. okt. 2013

Indhold

TEKNOLOGISK INSTITUT

- Målet
- Samarbejdet
- Projektstart
- Væsentligste resultater

Målet

TEKNOLOGISK INSTITUT

1. Tæt og forpligtende samarbejde mellem Teknologisk Institut og DTU Byg
2. At styrke dansk forskning og udvikling indenfor betonkonstruktioner og skabe ny viden og nye resultater
3. At samle og formidle viden om betonkonstruktioners holdbarhed og levetid til den brede betonindustri

Samarbejdet

TEKNOLOGISK INSTITUT

Formidlingspartnere/kunder

Små og mellem-store rådgivere, entrepre-nører og producen-ter

Udenland-ske virk-somheder

Samarbejdspartnere

EPFL, Delft, NTNU, Imperial College, Stanford

COWI, Rambøll, Carl Bro, MT Højgaard

Banedanmark, Vejdirektoratet, Femern Bælt, Metroselskabet

Kernepartnere

Teknologisk Institut, Beton

DTU Byg

Projektstart

TEKNOLOGISK INSTITUT

- Kontrakt TI/FI October 2010
- Rekruttering af DTU og TI ansatte
- Møder med interessenter
- Nedsatte referencegruppe
- Bruttoliste med idéer
- Projektplaner udarbejdet
- Kick off 2011

Projektstart

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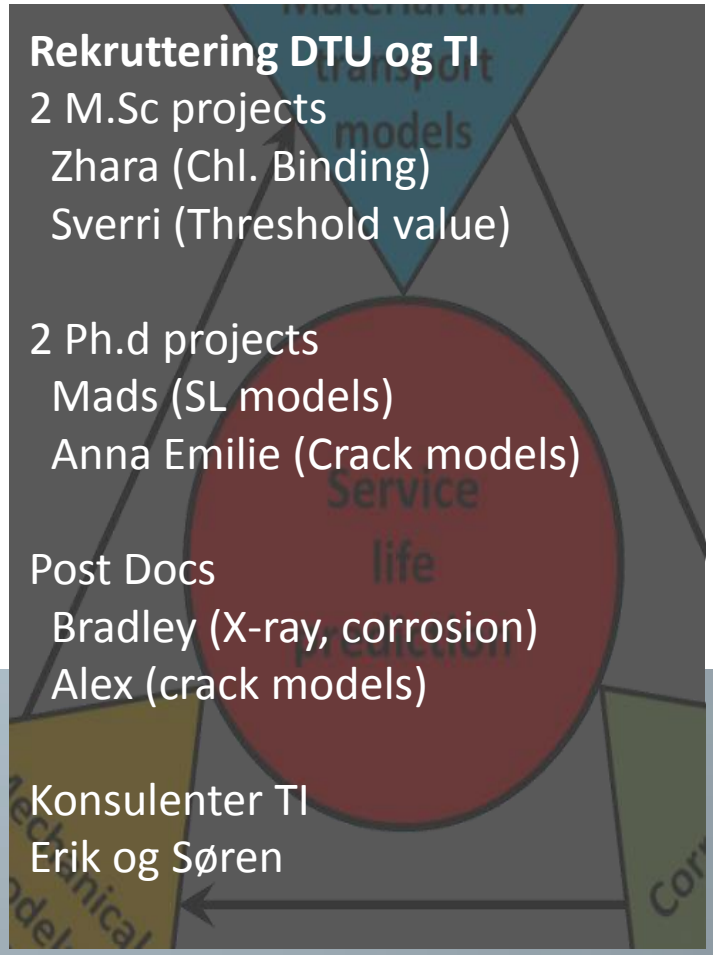

Projektstart

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Titles of proposed project ideas

Materials

Id	Title
M1	Long term durability of sea water exposed concrete constructions
M2	Chloride binding and models for transportation
M3	Chloride threshold value
M4	Frost resistance
M5	Alkali – Silica Reactions / Alkali – Carbonate reactions
M6	Self healing of cracks

Execution

Id	Title
E1	The influence of faults in the execution phase on long term durability
E2	The influence of rheology and casting procedure (SCC) on long term durability
E3	Influence of hardening temperature on the development of properties of concrete containing substantial amounts of fly ash or slag
E4	The influence of temperature, cement and binder composition on the risk of delayed ettringite formation
E5	Developing a re-usable experimental setup for obtaining more accurate input parameters for hardening simulations of temperature and stress
E6	The effect of surface treatment on the long term durability
E7	The effect of form cloth on long term durability of concrete structures

Construction

Id	Title
C1	The effect of micro defects/cracks on carbonation, chloride and sulfate ingress
C2	The consequences of cracks and the understanding of the damages in the interface between the concrete and the reinforcement
C3	Durability of steel fibre reinforced concrete structures exposed to sea water
C4	Combined effect of mechanical fatigue and deterioration
C5	The effect of mechanical stress levels on rebar corrosion
C6	New repair methods, strategies and materials
C7	Methods for determination of remaining service life

Service life models

Id	Title
S1	Verification and updating existing models for prediction of service life
S2	New design tools for durability

Projektstart

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Materials

M1 Long term durability of sea water exposed concrete constructions	Project type
Purpose The project aims is to evaluate the long term durability of Danish sea water exposed concrete constructions made with different types of concrete by characterizing the microstructure of young as well as old concrete exposed to sea water under the optical microscope and in the scanning electron microscope. Particularly the effect of different binder combinations on the apparent resistance to sulfate attack and chloride ingress will be investigated, e.g. two questions that this project seek to answers is: - do we see more evidence of sulfate attack in old concrete made with cement that where sulfate resistant than in more modern concrete with sulfate resistant cement, fly ash and silica fume? - Is it possible to see how the chloride is bound in the concrete and hence potentially explain differences in threshold values? *Content* Baring in mind the importance of investigating different binder combinations a selection of existing Danish sea water exposed concrete structures for further investigation is made. The selection will also take into account the content of the DTI thin section archive, however, it is expected that some additional coring of samples from structures of interest will be needed. As much information about the selected concrete structures as possible will be collected, i.e. age, mix design, position where existing samples are taken, etc. The microstructure of the concrete of the selected structures is characterized by optical and scanning electron microscopy. Hopefully, for some structures it will be possible to have samples of relatively young concrete as well as older concrete, so that the development of the microstructure can be described. It is not expected that it will be possible to find existing structures covering all binder systems of interest, and certainly not young concrete. For this reason the project hopes to be able to used samples from the many different concrete types at the Femern exposure site in Rødby Havn. The part of the micro analysis involving chloride is expected to contribute valuable information regarding chloride binding, i.e. there is a strong synergetic connection to project M2 described below. Another element of the micro analysis will be SEM-EDX analysis aimed at investigating the presence of different sulfate phases and changes in which phases are dominant over time. The inward progression of micro-structural changes with time is essential. Can it be quantified how chloride binding evolves over time? Can and how can sulfate attack develop over time with the formation of distinct micro-	Project has been initiated at DTI. Cooperation with the Danish Road Directorate and other external partners, who have access to relevant data is foreseen.

Projektstart

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Overblik over aktiviteter

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Chloride binding in concrete

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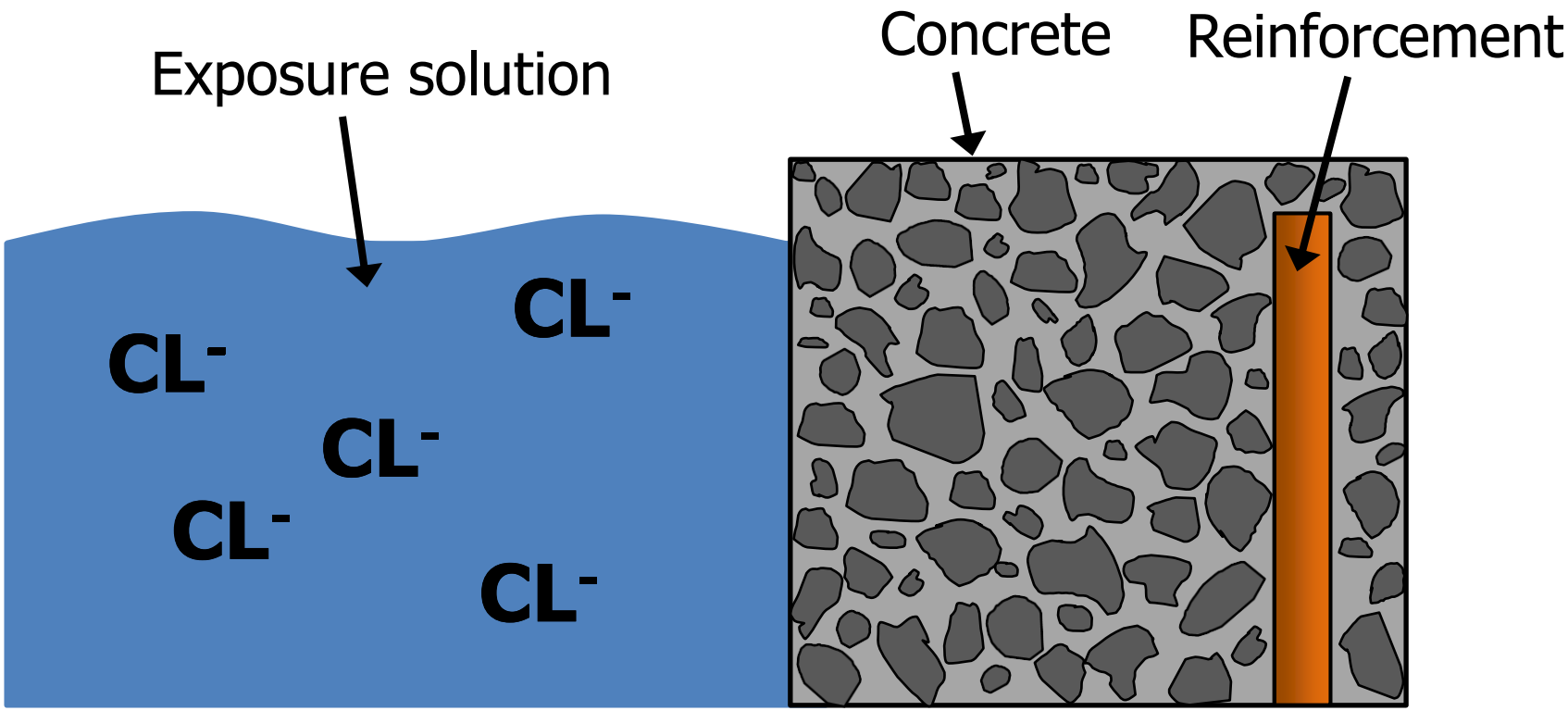

Model for chloride binding

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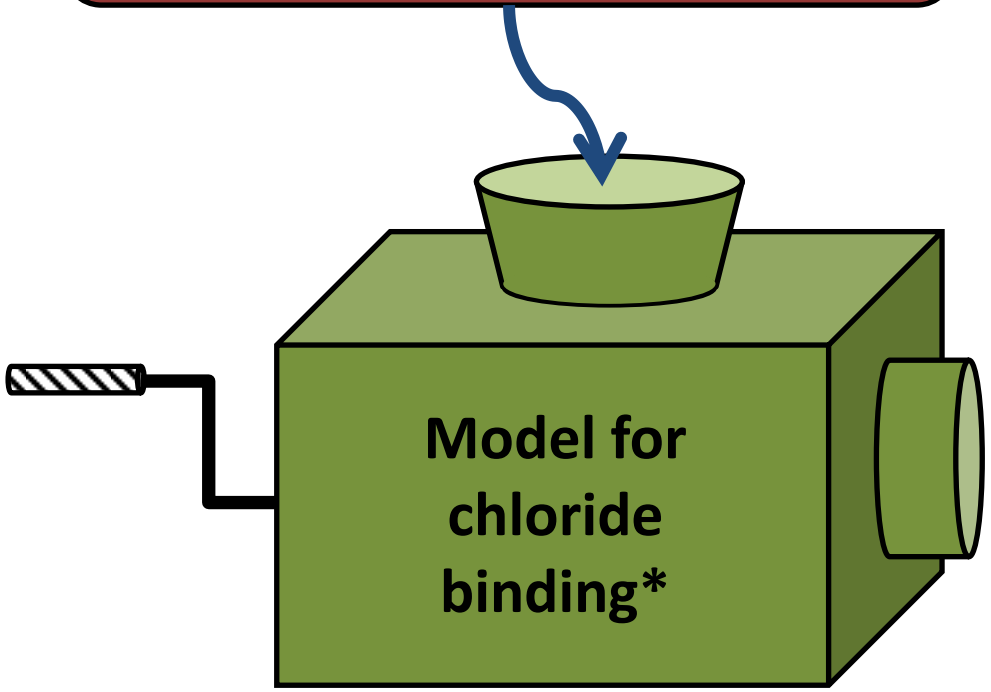
Input

- Chemical composition of system



Output

- Quantification of chloride binding.
- Chemical composition of pore solution: $[Cl^-]$, $[Na^+]$, $[OH^-]$, $[Ca^{2+}]$.
- Phase assemblage of hydrated system.

* *Nielsen, E.P. The durability of white Portland cement to chemical attack. PhD thesis R-084, DTU·BYG, 2004.*

Model predictions

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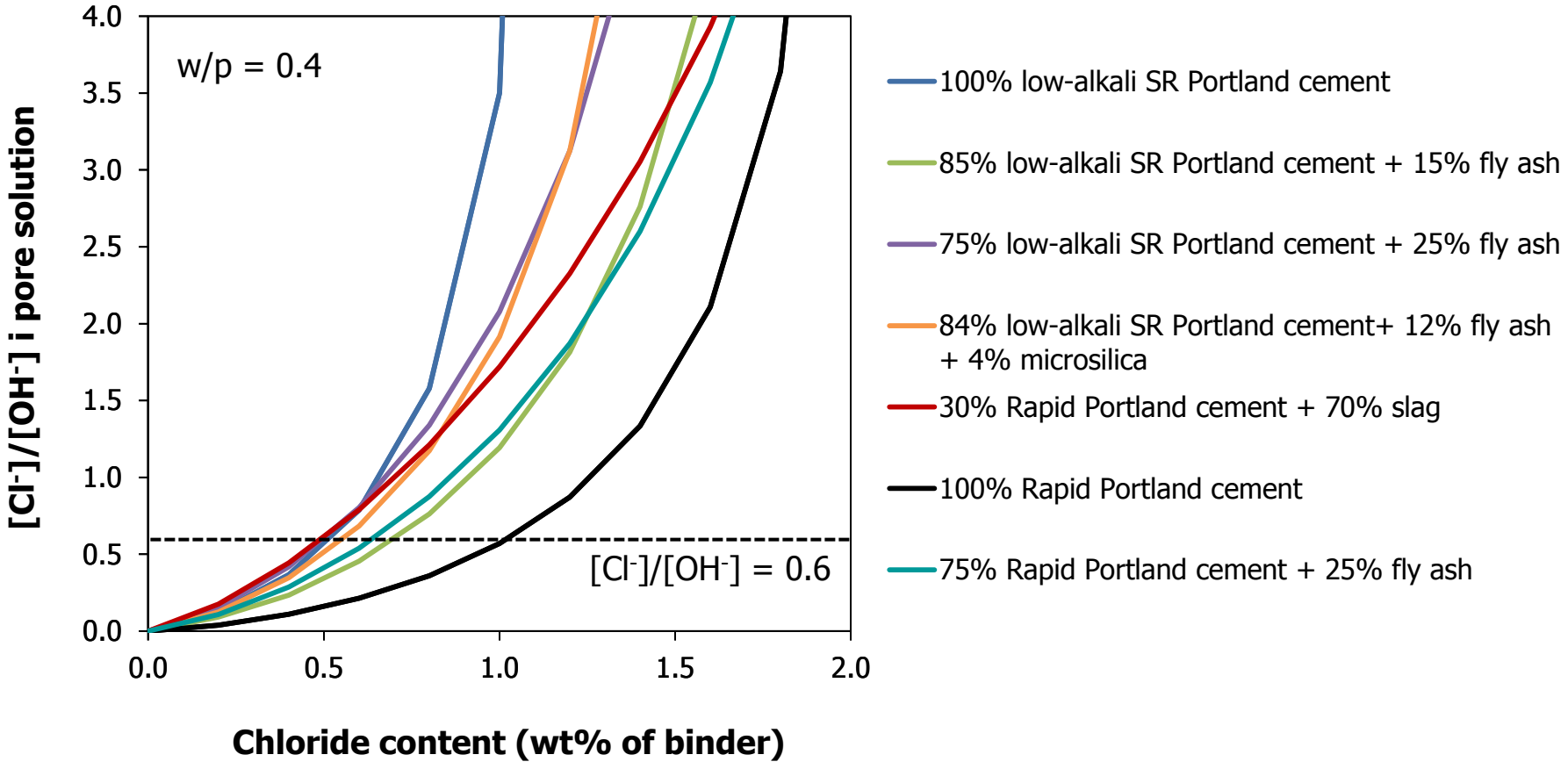


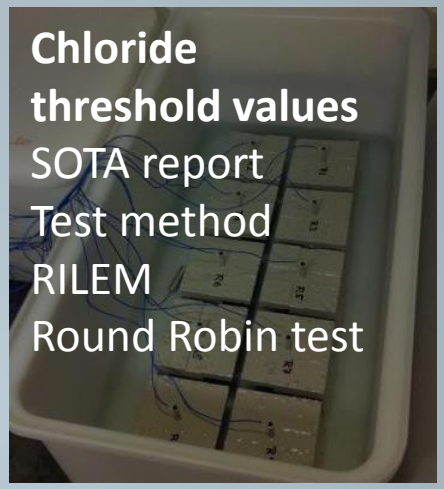
Overblik over aktiviteter

TEKNOLOGISK INSTITUT

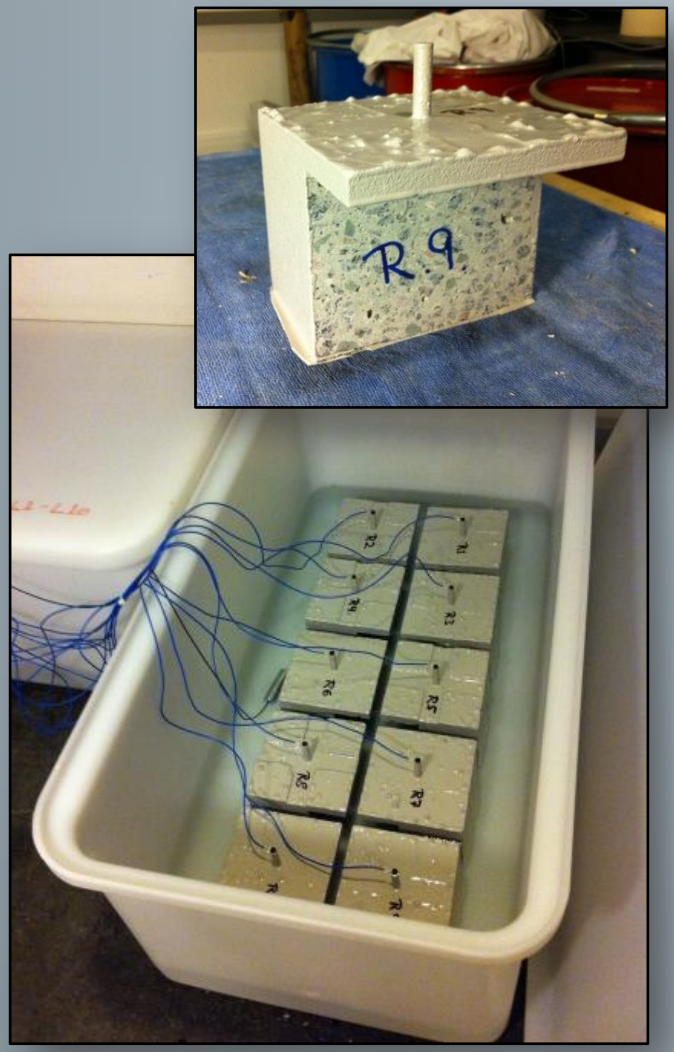
Long term durability
- 4 bridges
- Chloride profiles
- Microstructure
- SEM/EDS
- Comparison
- Reporting

Chloride binding
- Modelling
- 2 test verifications
- Tool developed

Chloride threshold values
- SOTA report
- Test method
- RILEM
- Round Robin test



Lab metode
- endnu ikke fundet egnet hurtig metode



Felt metode
- tager tid men giver værdier

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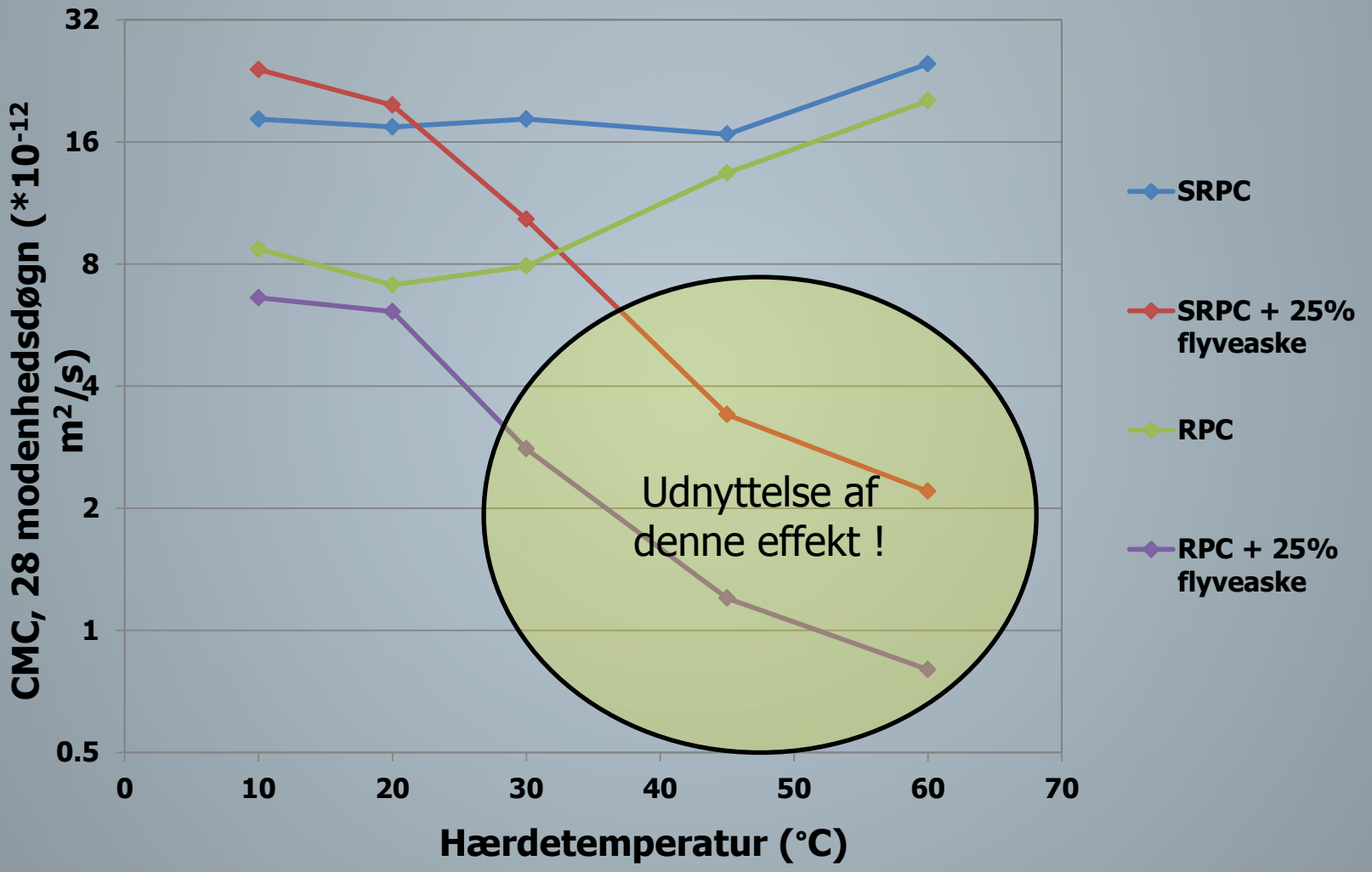
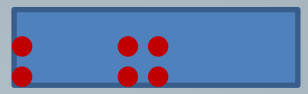
Properties as a function of temp.
- Strength
- Chloride migration
- Frost
- Isolated forms test

Hærdetemperaturens indflydelse på tætheden overfor chlorid



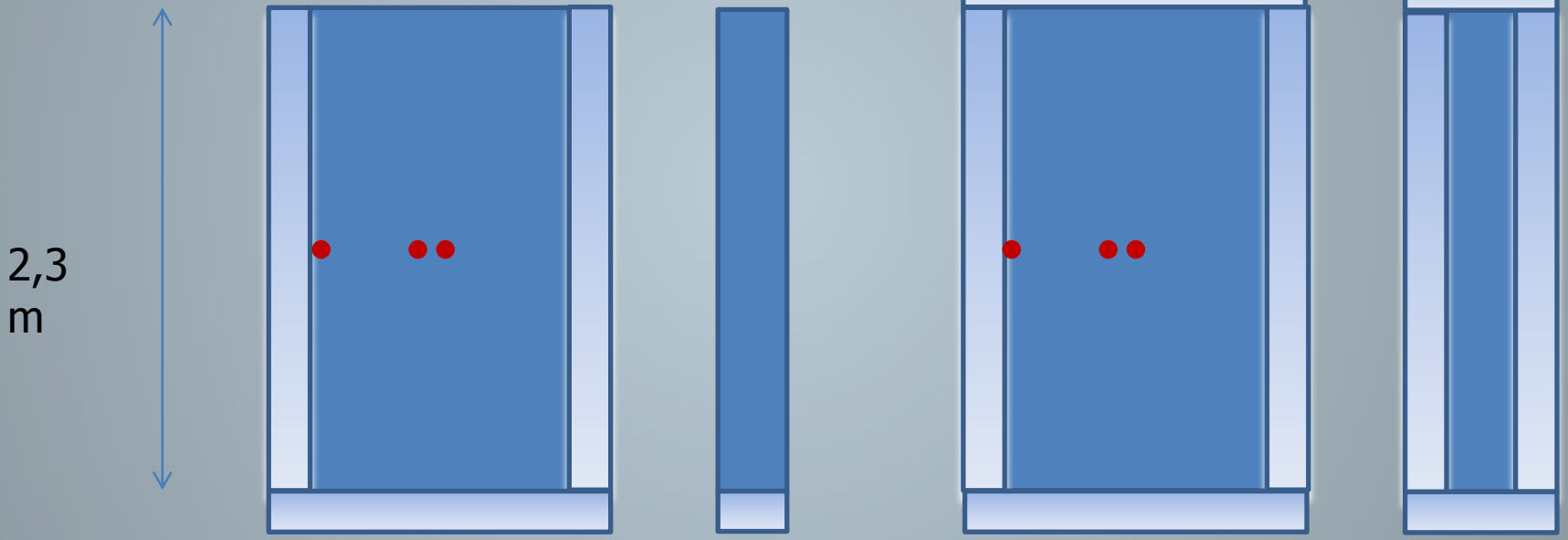
Isoleret vs. uisoleret form



Termoføler

Forsøgsopstilling 1: uisoleret

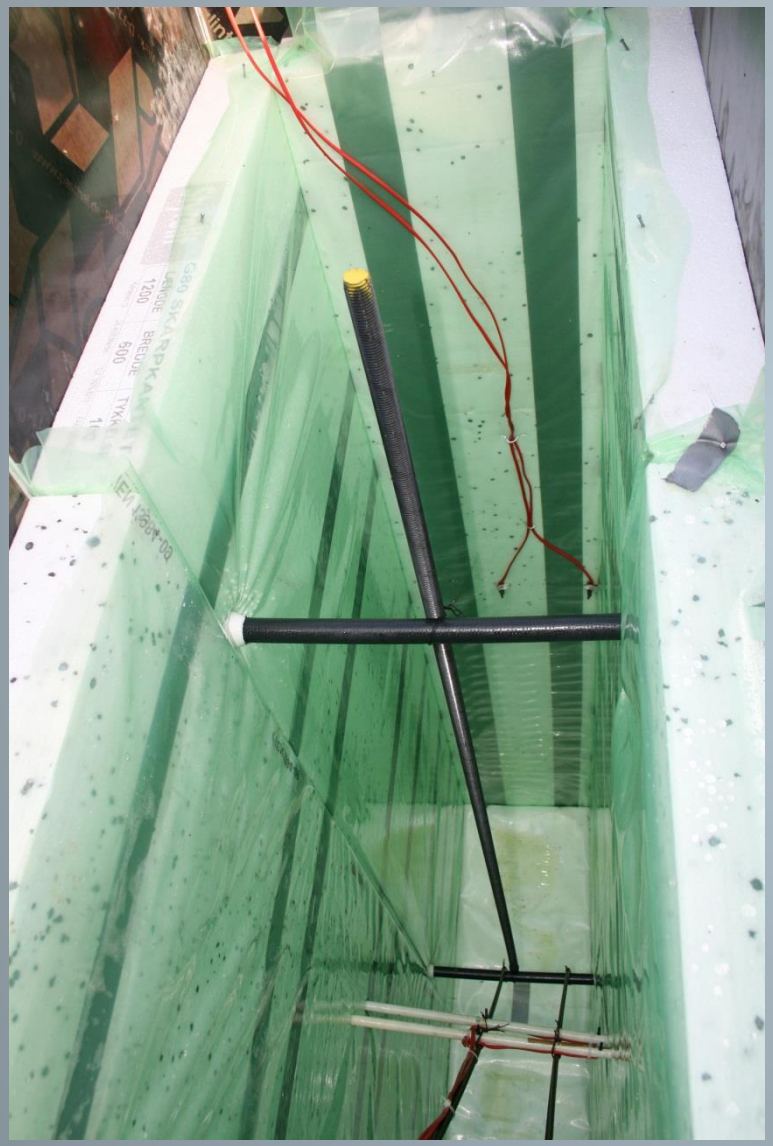
Forsøgsopstilling 2: isoleret

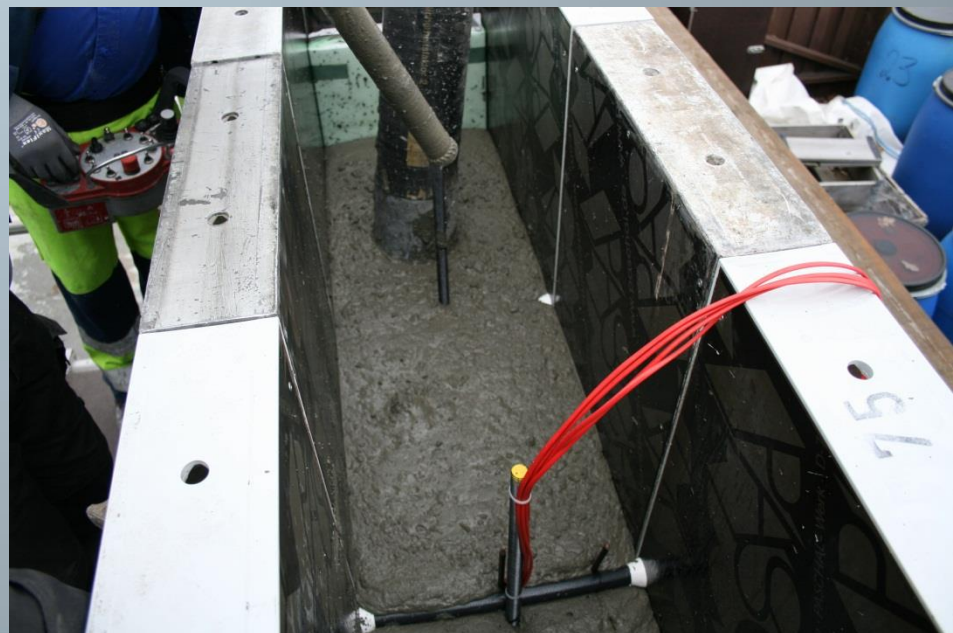


Bund og ender isoleret med 10 cm polystyren

Fuldstændig isoleret med 10 cm polystyren

Billeder – forme, støbning





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Critical structure details
- Poker vibrator
- Spacers
- Brochure

Rheology and casting methods
- Variations rheology
- Brochure

Overblik over aktiviteter

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Fehmarnbelt exposure site
- Results on www
- Brochure
- Microstructure
- SEM – EDX
- Data sheets

Fehmarnbelt Exposure Site

Femern A/S, the Owner of the coming Fehmarnbelt Fixed Link, through an open tender process selected the Concrete Centre at Dani Technological Institute as its external concrete laboratory.

The contract involved the design, production and testing of a range of concrete types of interest to Femern including some concrete with instrumentation for monitoring of the initaiation and progress of corrosion, establishing an exposure site in Rødbyhavn harbour term testing of concrete, monitoring of the concrete at the exposure site.

An extensive testing program of the selected fifteen concrete types including three SCCs was initiated comprising documentation of:

- Workability, density, and air content
- Initial setting time and bleeding
- Strength development (compressive and split tensile)
- Frost resistance and air void structure
- Chloride ingress resistance
- Microstructure (petrographic analysis).

The concrete was produced under strict control at the Concrete Centre's HighTech Concrete Laboratory. Altogether thirtyseven concr blocks and a large number of small test specimens were produced. Fifteen large concrete blocks (400 litres – 2 x 1 x 0.2 m) each ha different concrete composition and seven instrumented blocks have been placed partly submerged in Rødbyhavn harbour. The concr blocks will be monitored closely at least until the end of the construction period, which is expected to be in 2020.

Overblik over aktiviteter

TEKNOLOGISK INSTITUT

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Fehmarnbelt exposure site
- Results on www
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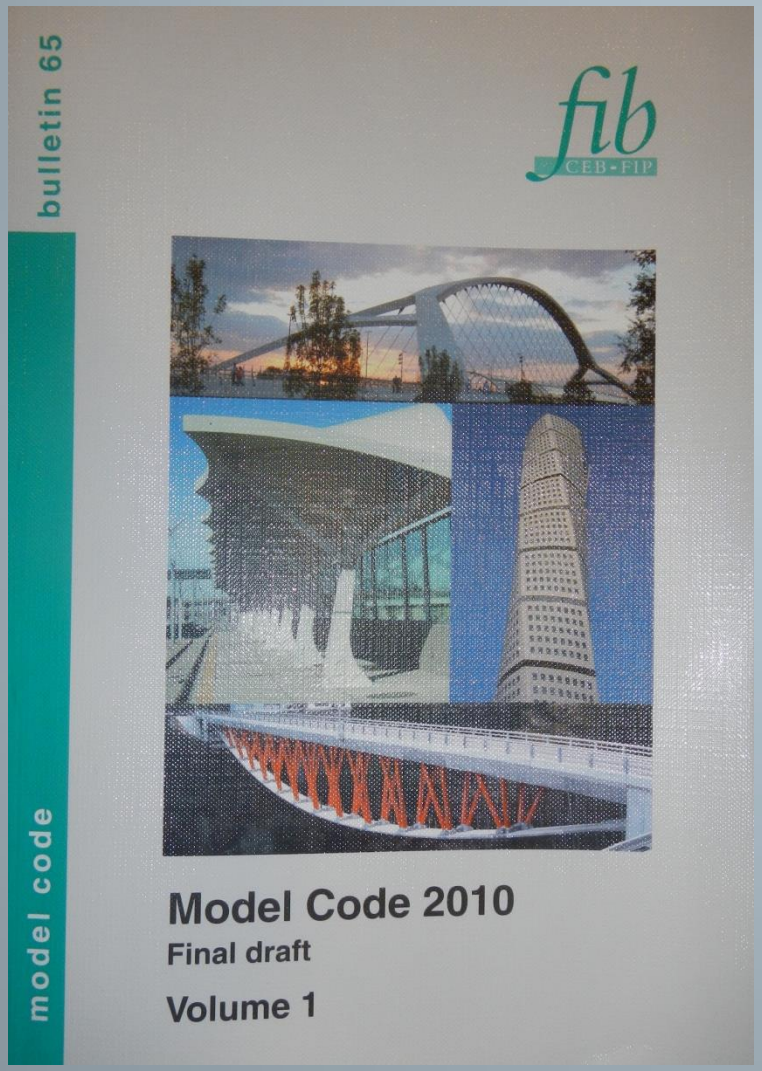
Data and dissemination
- Birth certificate
- www
- Papers
- Presentations
- Newsletters

Fødselsattest – FIB Model Code 2010

Fødselsattesten er beskrevet i FIB Model Code 2010



3.5.4 Quality Management in Construction

3.5.4.1 Objectives

To meet the minimum requirements for QM in construction, as specified in the execution standard and as assumed in the design.

3.5.4.2 "As-Built Documentation": Birth Certificate Document

The "As-Built-Documentation" shall be a reliable representation of the project as actually constructed. It shall include the results of the initial inspection of the completed work/project. The extent of the inspection of the completed work and the content of the "As-built-documentation" will depend on the nature and size of the project, on the design assumptions and on the verification methods, as well as on the QM and the control measures for the project.

Information included in "As-Built-Documentation" shall allow a conformity evaluation to be performed upon the completed work/elements of the project.

An extract of the "As-built-Documentation", named Birth Certificate Document (BCD), will include the results of an initial inspection of a new structure. The content of the BCD is usually limited to the documentation of the direct input parameters for the future condition control of the structure, such as cover thickness to the reinforcement, diffusion coefficient for the concrete cover, etc.

BCD might serve as a basis for monitoring of the condition of the structure and for planning conservation activities during its service life. Recommendations upon conservation procedures, which depend on the specifics of the project, are given in chapter 9.

Fødselsattest

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Eksempel på en fødselsattest for en betonkonstruktion

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Fødselsattest

Generel information	
Konstruktionens navn	Femern beton A (Large Block)
Bygherre	Femern A/S
Entreprenør	Teknologisk Institut, Beton
Byggeår	2009
Geografisk placering	Marin feltekspponeringsplads ved Rødbyhavn, Danmark
Eksponerings-/miljøklasse	Aggressiv og ekstra aggressiv
Specificeret levetid	120 år
Kortfattet beskrivelse af konstruktionen	Prøveelement af beton til eksponering i marint miljø ved felteksponeringsplads i Rødbyhavn. Elementet er fremstillet i dimensionerne 2000 x 1000 x 200 mm og er placeret delvist neddykket i havnebassinet ved eksponeringspladsen. Elementet har således både en del, som er anbragt i et *splash zone*-miljø, og en del, som er konstant neddykket i havvand.

Mix design og betonegenskaber				
Dato for støbning	16. december 2009			
Materiale			**SSD [kg/m³]**	
Lavalkali sulfatbestandig Portland cement (CEM I 42.5 N) (HS/EA/≤2)			360,2	
Fint tilslag (Storebæltssand) 0/2 mm			686,4	
Groft tilslag (Rønnegranit) 4/8 mm			371,4	
Groft tilslag (Rønnegranit) 8/16 mm			262,0	
Groft tilslag (Rønnegranit) 16/22 mm			521,3	
Amex® SB 22 (luftindblandingsmiddel)			1,7	
Glenium® SKY 532-SU (superplastificeringsmiddel)			2,7	
Vand			140,2	
Vand/pulver-forhold	**Luftindhold [%]**	**Densitet [kg/m³]**	**Sætmål [mm]**	**Flydemål [mm]**
0,399	5,8	2310,0	200	-
Øvrige detaljer	Betonen blev fremstillet på Teknologisk Instituts fuldautomatiske blandeanlæg i Taastrup og selve blandingen blev foretaget i en 375/250 Haarup mixer. Det støbte element blev afformet fra støbeform af krydsfinér efter en opnået modenhed på mindst 24 timer. Herefter blev elementet tildækket med plastik. Eksponering for havvand skete den 8. april 2010, dvs. efter 113 døgns hærdning (svarende til en modenhed på ca. 45 døgn).			

Materialer og konstruktionsdetaljer	
Armeringstype	Der er ikke anvendt armeringsjern i prøveelementet
Afstandsholdere	-
Dæklagets tykkelse	-

1

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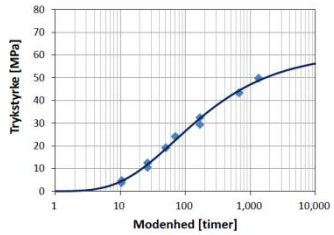
Resultater fra laboratorietests	
	Resultater
ng af hærdnet	Nedenstående graf viser den målte udvikling af trykstyrken som funktion af modenhed for den anvendte beton. Trykstyrken ved hver modenhedstermin er et gennemsnit af to målinger. Den sammenhængende kurve viser *best fit* til de målte data.



id penetration, eret	Chloriddiffusionskoefficient (ved 28 døgns modenhed): $D_* = 8{,}7\ 10^{-12}$ m²/s.
efficient	Chloridmigrationskoefficient (ved 28 døgns modenhed): $D_{nssm} = 16{,}3 \cdot 10^{-12}$ m²/s.
ng	Afbindingstid: 5 timer og 0 min.
stresistens	Betonens frostresistens klassificeres som værende "meget god".

Udførelsesfejl og kritiske konstruktionsdetaljer

påfyldning af den friske beton i støbeformen blev udført i henhold til anvisningerne i HETEK Report no. 74, g – Højkvalitetsbeton – Entreprenørens teknologi"), dog ved anvendelse af en Ø40 mm nedstiksvibrator, større en den anbefalede maksimale diameter på 33,3 mm. Denne fremgangsmåde blev godkendt af

2

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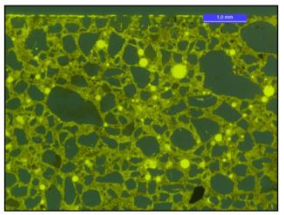
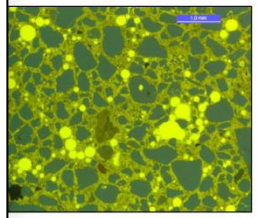
Mikroskopiske undersøgelser	
ID	[Her angives informationer vedr. prøvenavne, tyndslibsnumre, etc.]
	28 døgn
ationer	Optisk mirkoskopi: • Tyndt calcitlag på betonoverflade. • Karbonatiseret pasta ikke observeret. • Ensartet porøsitet i pasta gennem hele kernen. • Vand/cement-forhold estimeret til ca. 0,45. • Ingen revner i overfladen. • Generelt ingen revner i pasta med undtagelse af få vedhæftningsrevner. • Relativt dårlig luftpore-struktur, som synes lavere end 4,5%, få af de mindste luftporer. • Enkelte agglomerater af luftporer observeret.

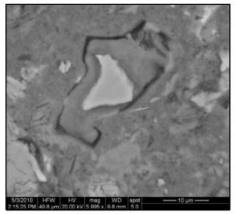
nslib af hele den undersøgte kerne (200 mm) efter oxy-imprægnering og slibning til -2 mm niveau.



Mikrofoto af betonens overflade. Foto optaget vha. fluorescerende lys.



Mikrofoto af betonens indre. Foto optaget vha. fluorescerende lys.



Delvis hydratiseret alitkorn med gab mellem det indre og det ydre hydratiseringsprodukt. Backscatter foto fra scannings-elektronmikroskop.

3

Sammenfatning

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- Unik samling af data
- Nye modeller og værktøjer
- Ny viden tilgængelig for alle
- Styrket samarbejde mellem forskningsmiljøer i Danmark
- Dansk Ekspertcenter for konstruktioner til infrastrukturen fortsætter