

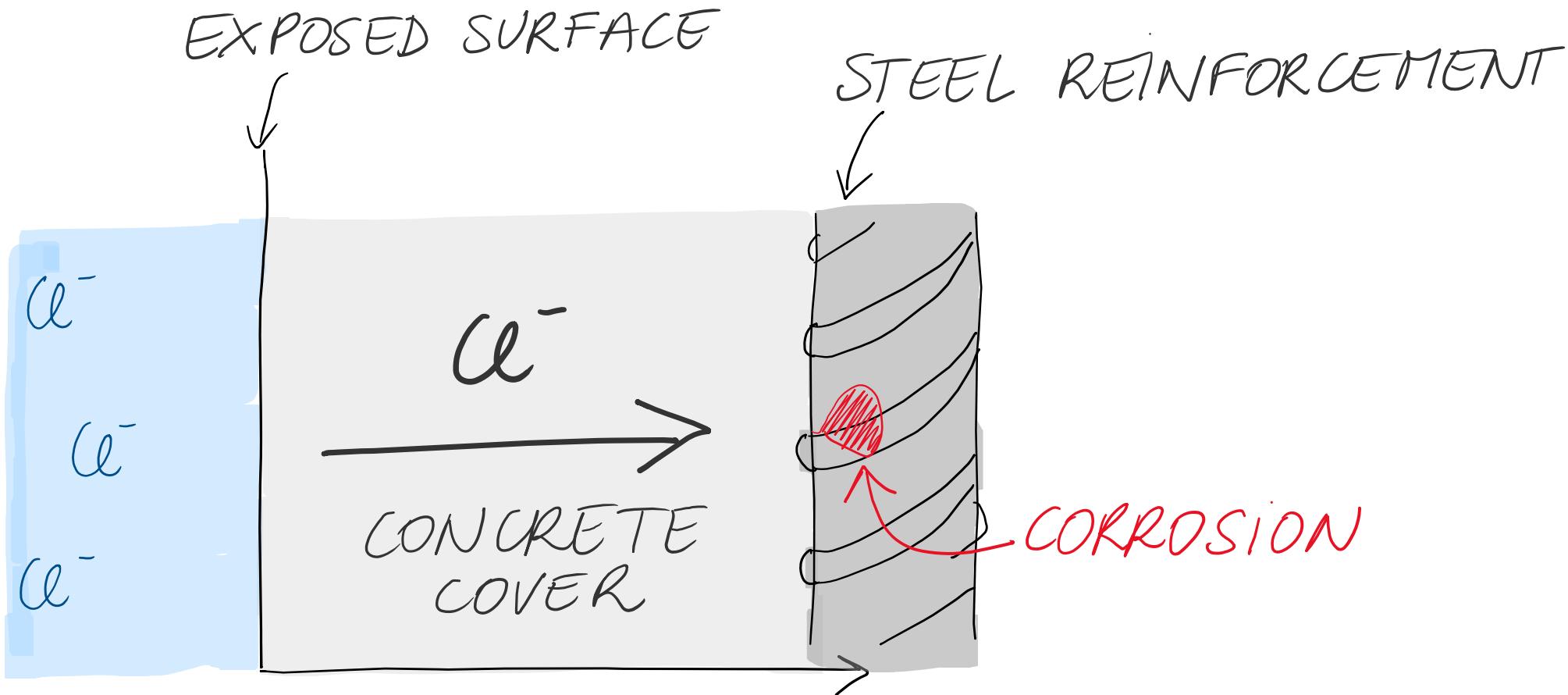
Long-term behavior of concrete in marine environment

Klaartje De Weerdt, NTNU

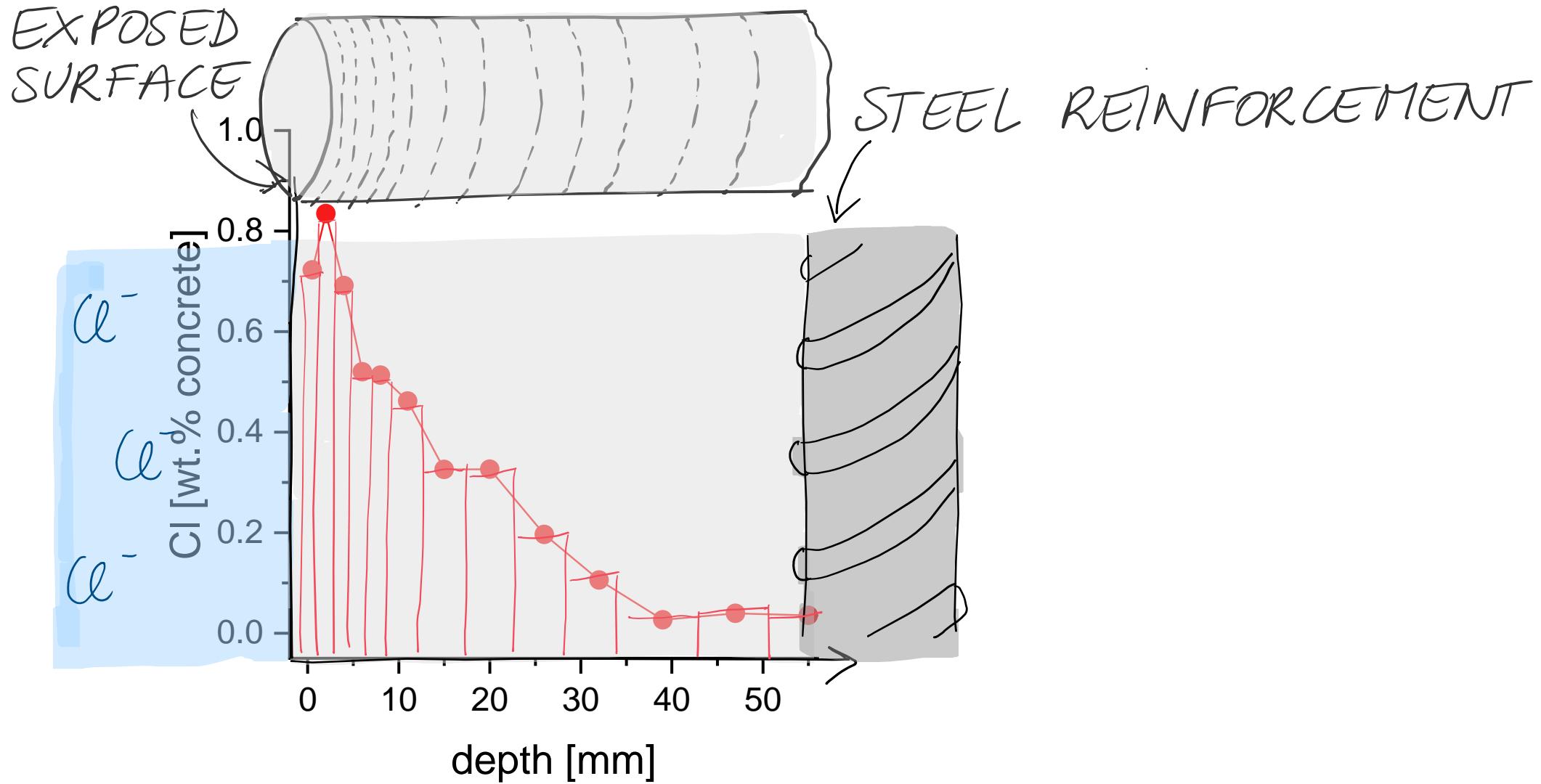
Wolfgang Kunther, DTU



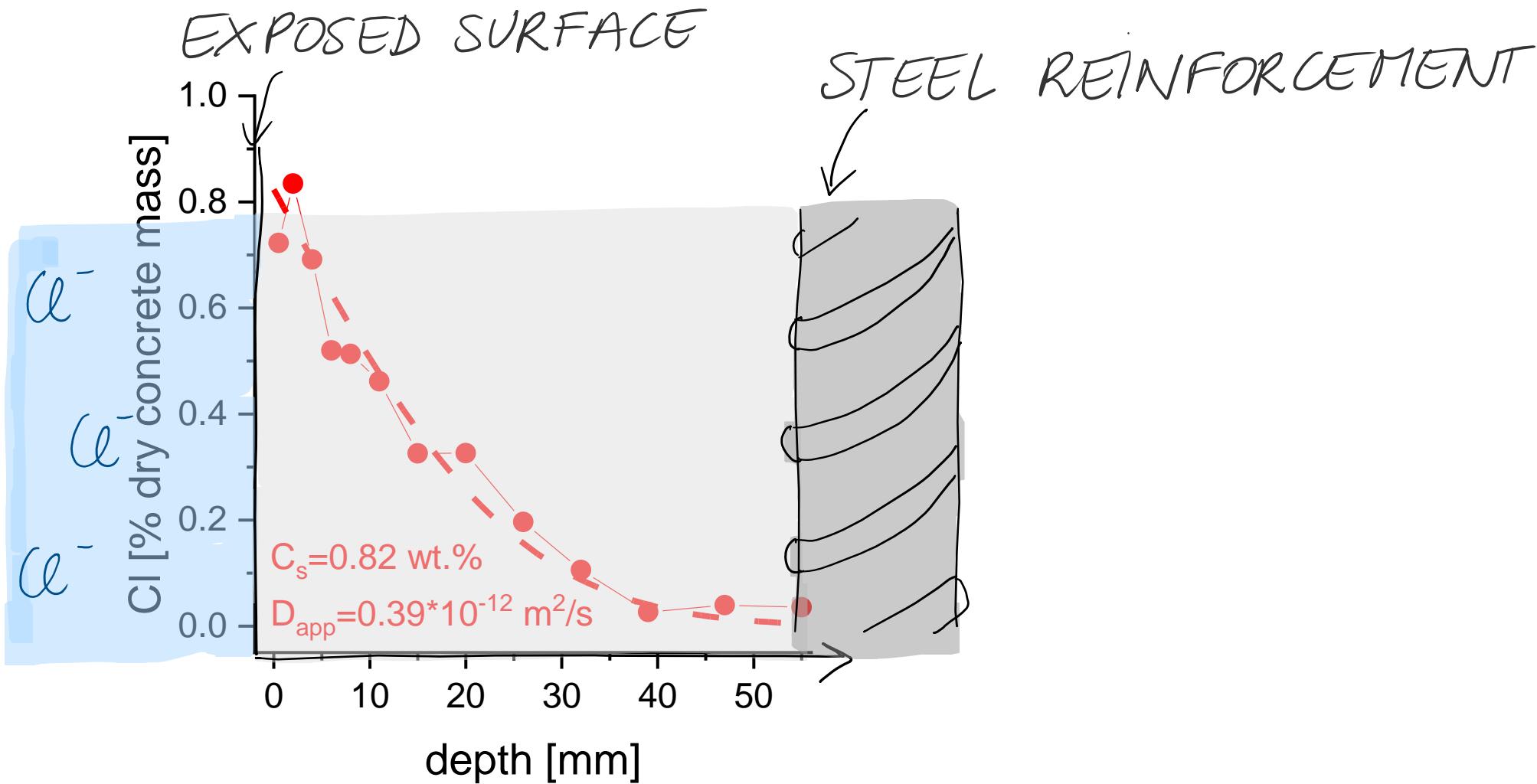
Chloride-induced reinforcement corrosion



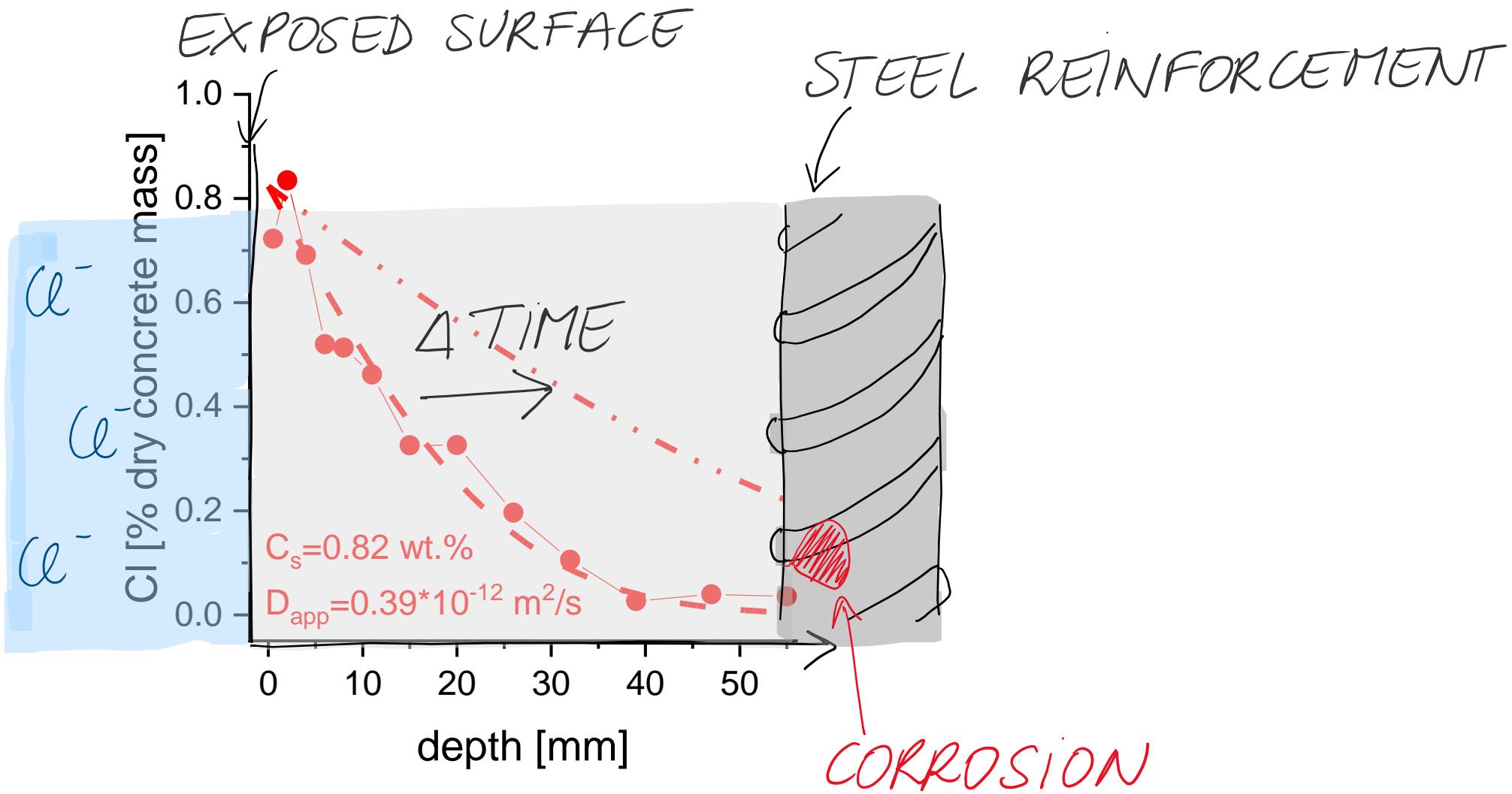
Chloride-induced reinforcement corrosion



Chloride-induced reinforcement corrosion



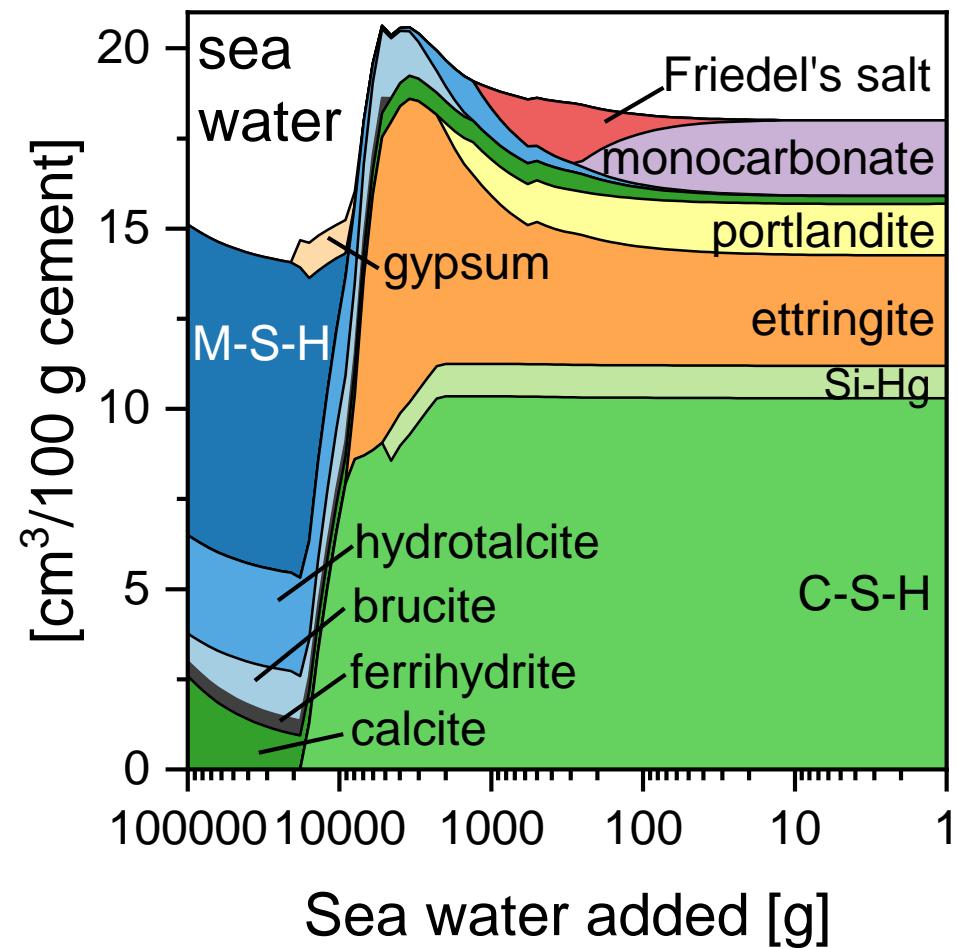
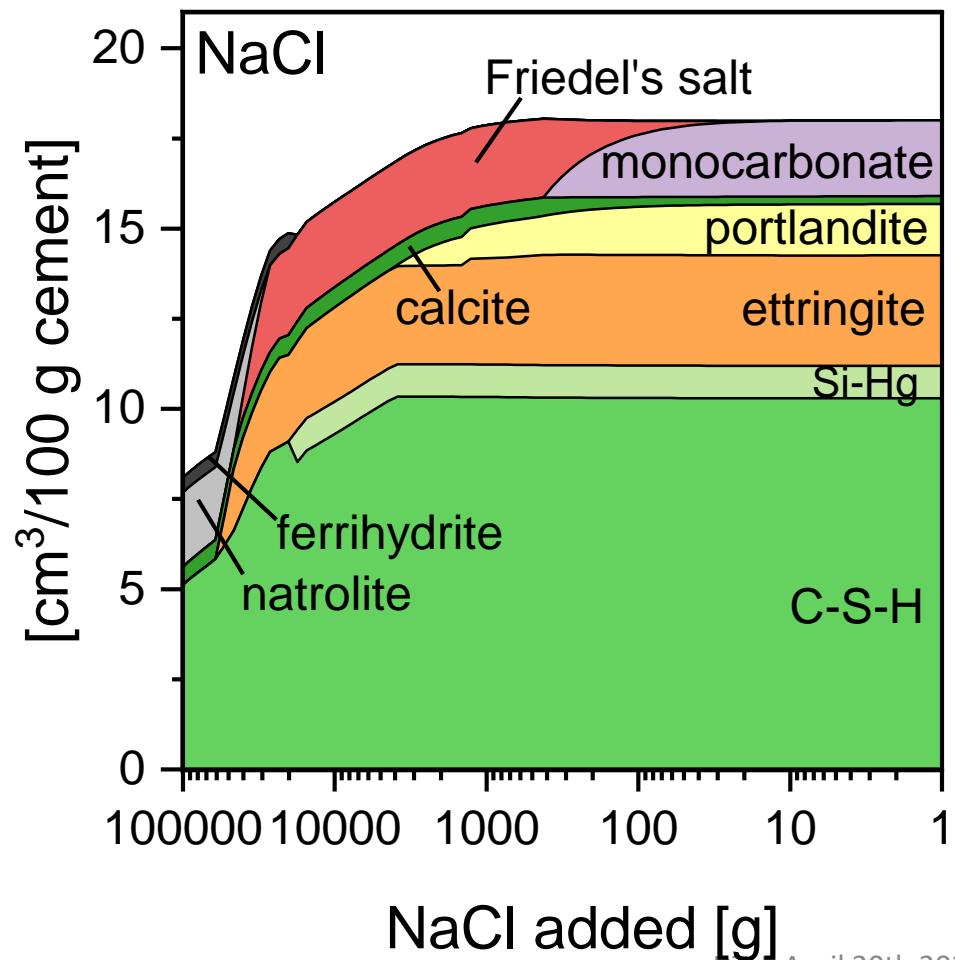
Chloride-induced reinforcement corrosion



Comparing seawater composition with pore solution in concrete

Concentration [mmol/L]	K	Na	Ca	Mg	Al	Si	SO ₄	Cl	HCO ₃	pH
NaCl solution (3%)	-	545	-	-	-	-	-	545	-	7.1
Seawater (Trondheim Fjord)	8.9	411	8.8	47	-	-	26.9	548	n.d.	n.d.
Seawater (Atlantic ocean)	9.7	457	10	56	-	-	27.8	536	2.3	7.7
Seawater (Baltic)	1.8	93	1.2	11	-	-	17.8	110	n.d.	n.d.
Pore solution cement paste	532	279	1.2	-	0.31	0.29	27.6	-	-	13.7

NaCl vs. seawater



Laboratory exposure



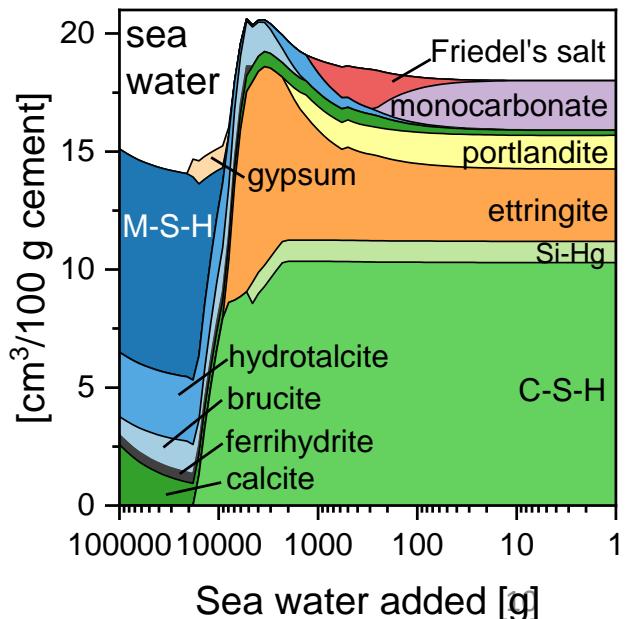
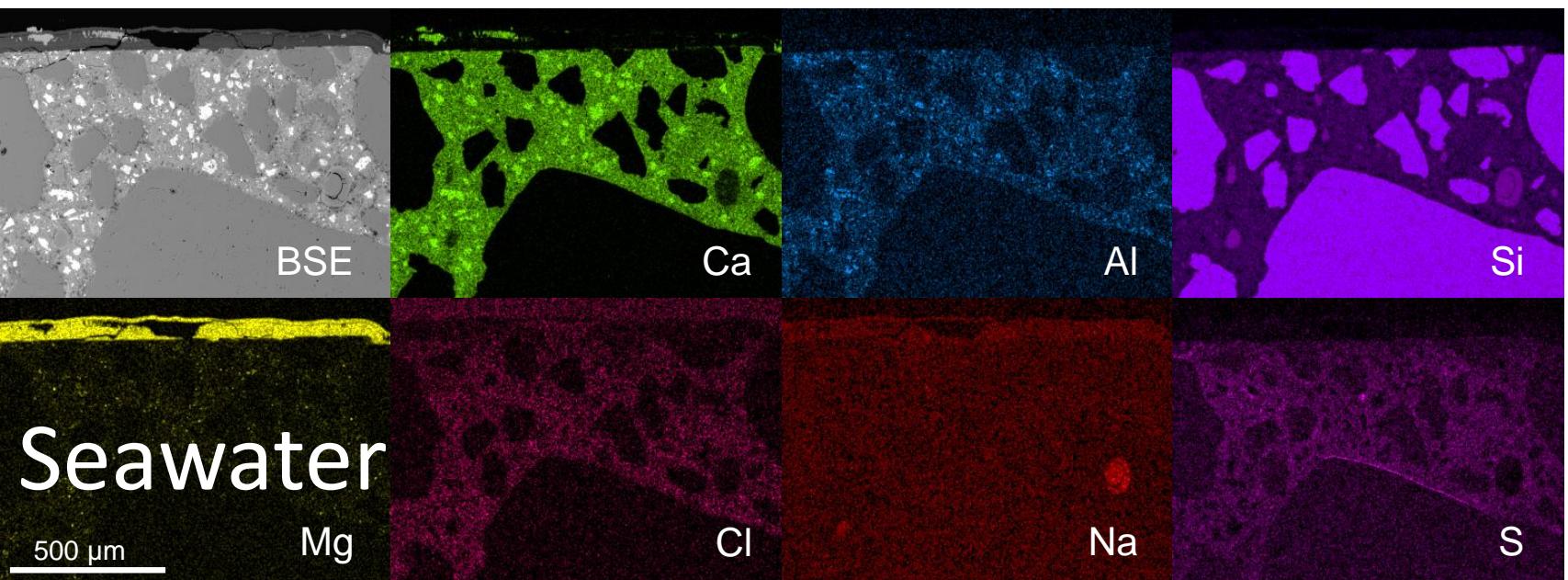
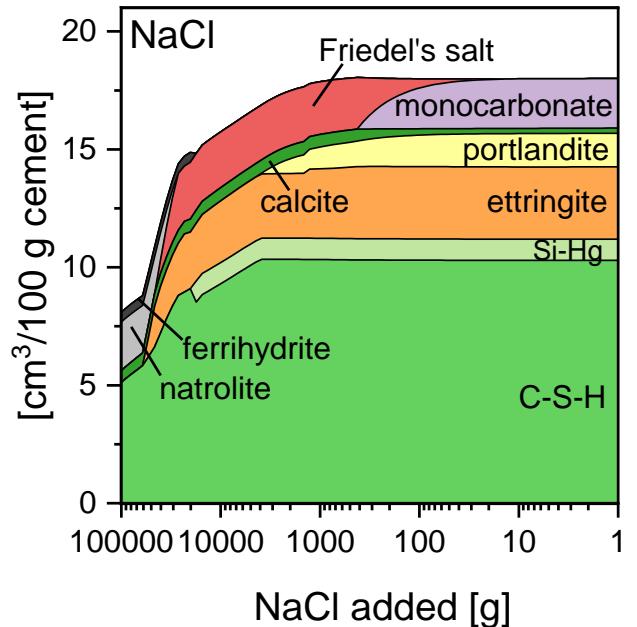
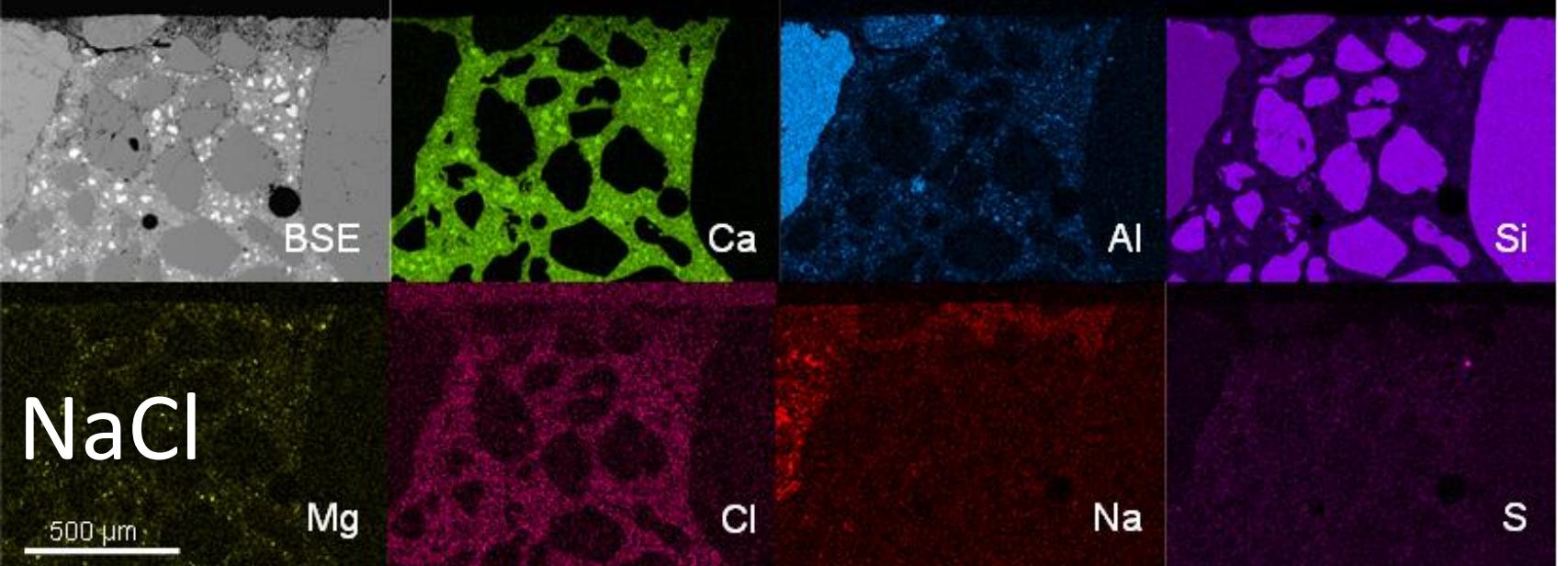
Comparing chloride ingress from seawater and NaCl solution in Portland cement mortar

K. De Weerdt^{a,*}, B. Lothenbach^{a,b}, M.R. Geiker^a

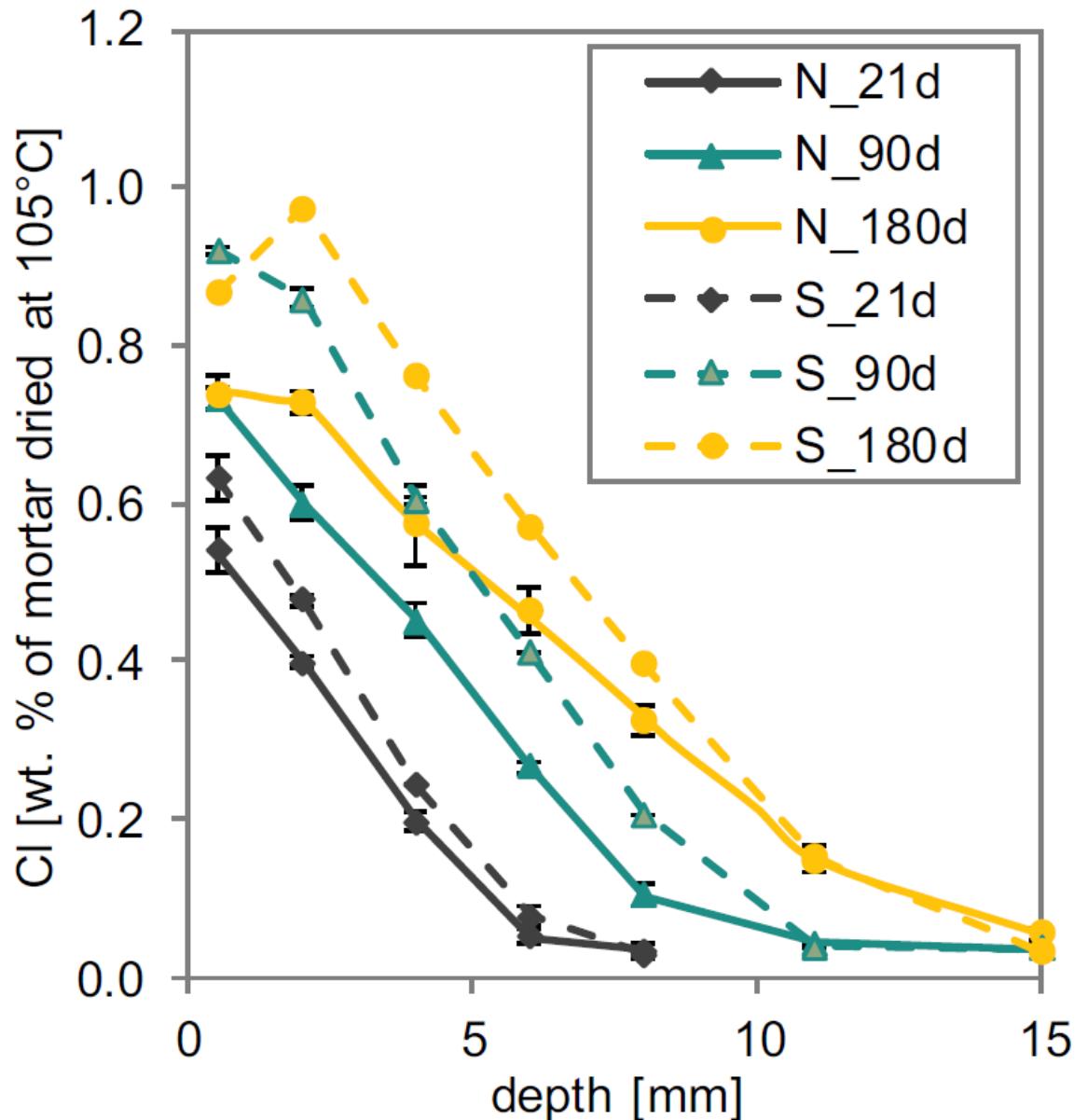
^a Department of Structural Engineering, NTNU, Norway

^b EMPA, Dübendorf, Switzerland





Impact of the other ions on Cl ingress



Marine exposure

Cement & Concrete Composites 47 (2014) 53–63

Contents lists available at [ScienceDirect](#)

Cement & Concrete Composites

journal homepage: www.elsevier.com/locate/cemconcomp



ELSEVIER



Changes in the phase assemblage of concrete exposed to sea water

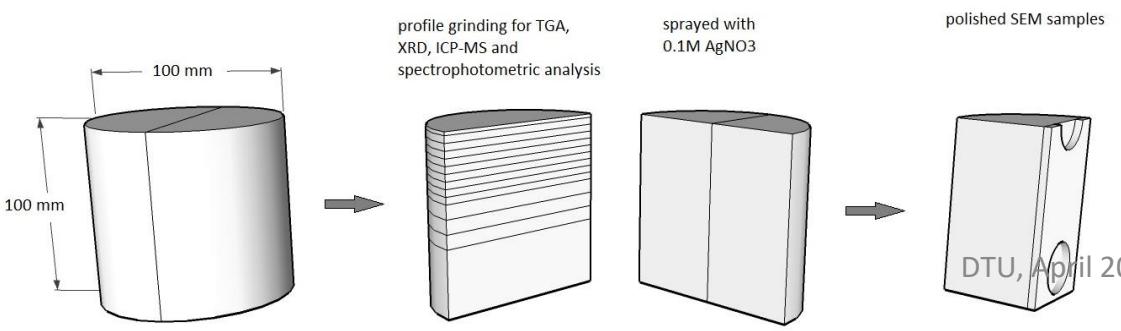
Klaartje De Weerdt ^{a,b,*}, Harald Justnes ^b, Mette R. Geiker ^a



10 year old concrete wall in tidal zone



Spring 2013



DTU, April 20th 2022, Klaartje De Weerd (NTNU)

Spring 2013

Marine exposure: Focus concrete



ELSEVIER

Elemental zonation in marine concrete

Ulla Hjorth Jakobsen ^a, Klaartje De Weerdt ^{b,*}, Mette R. Geiker ^b

^a Danish Technological Institute, Taastrup, Denmark

^b NTNU, Department for Structural Engineering, Trondheim, Norway

Light microscopy appearance

dense
dense
dense, drying cracks
porous
opaline paste
porous
unaltered paste

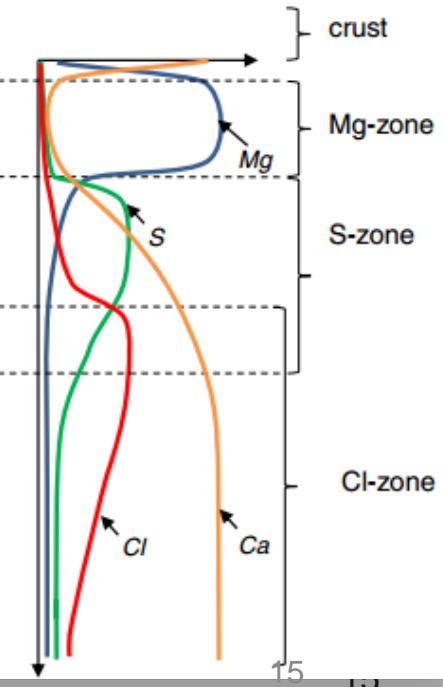
phases

Calcite, Brucite
carbonation
gel-like phase
popcorn-carbonation
precipitates airvoids

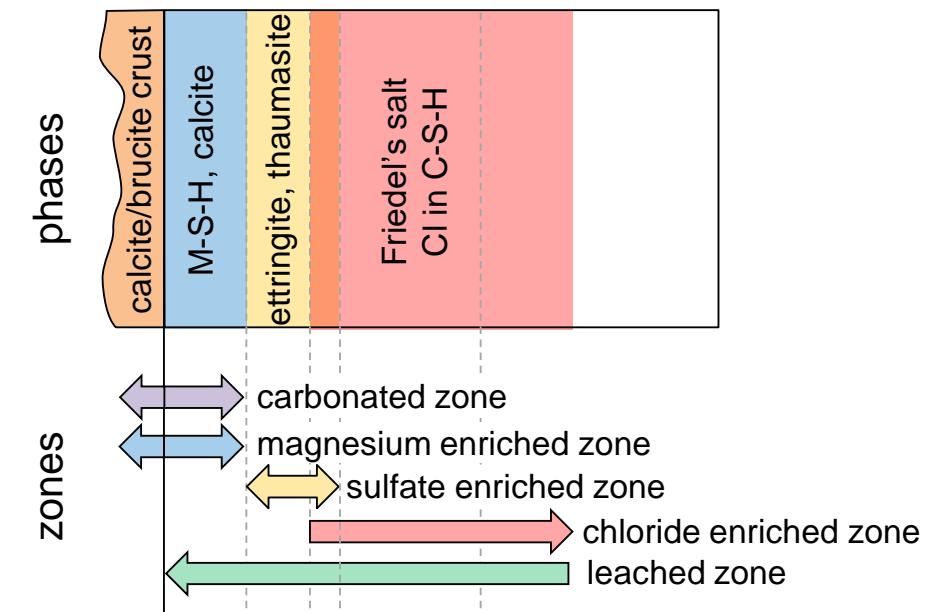
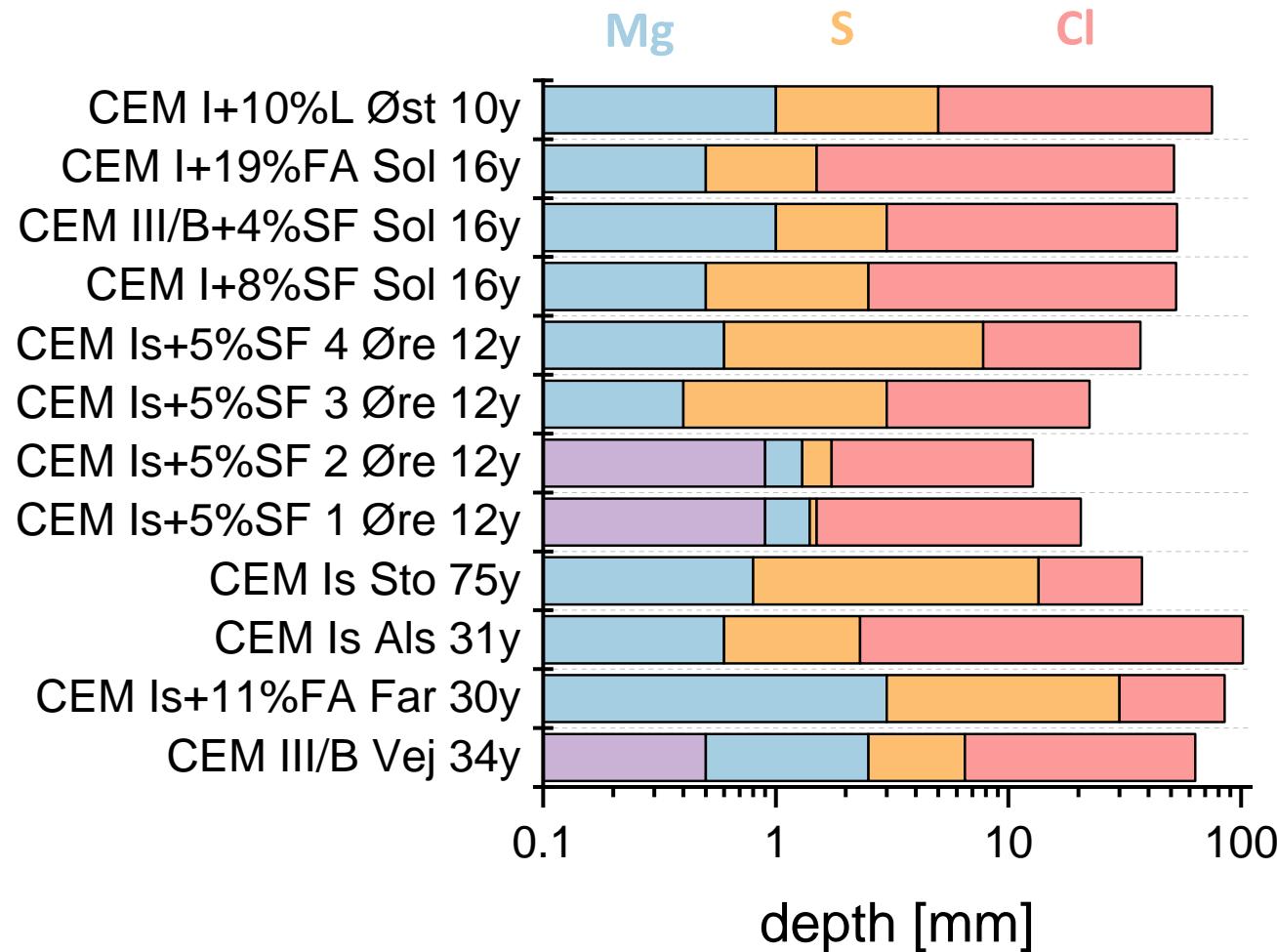
SEM-EDS phases

CC, MH
M-S-H
Ettringite
Thaumasite
Gypsum

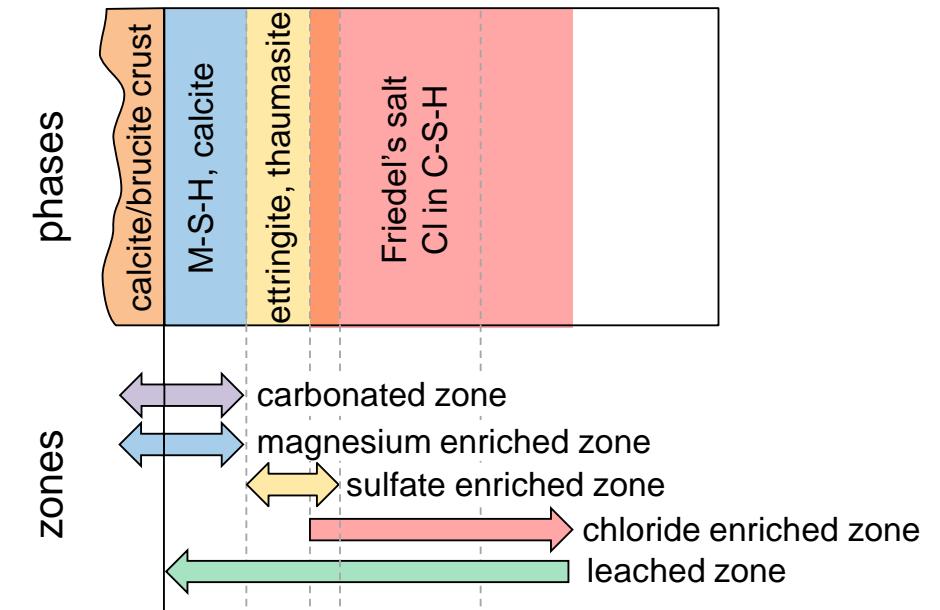
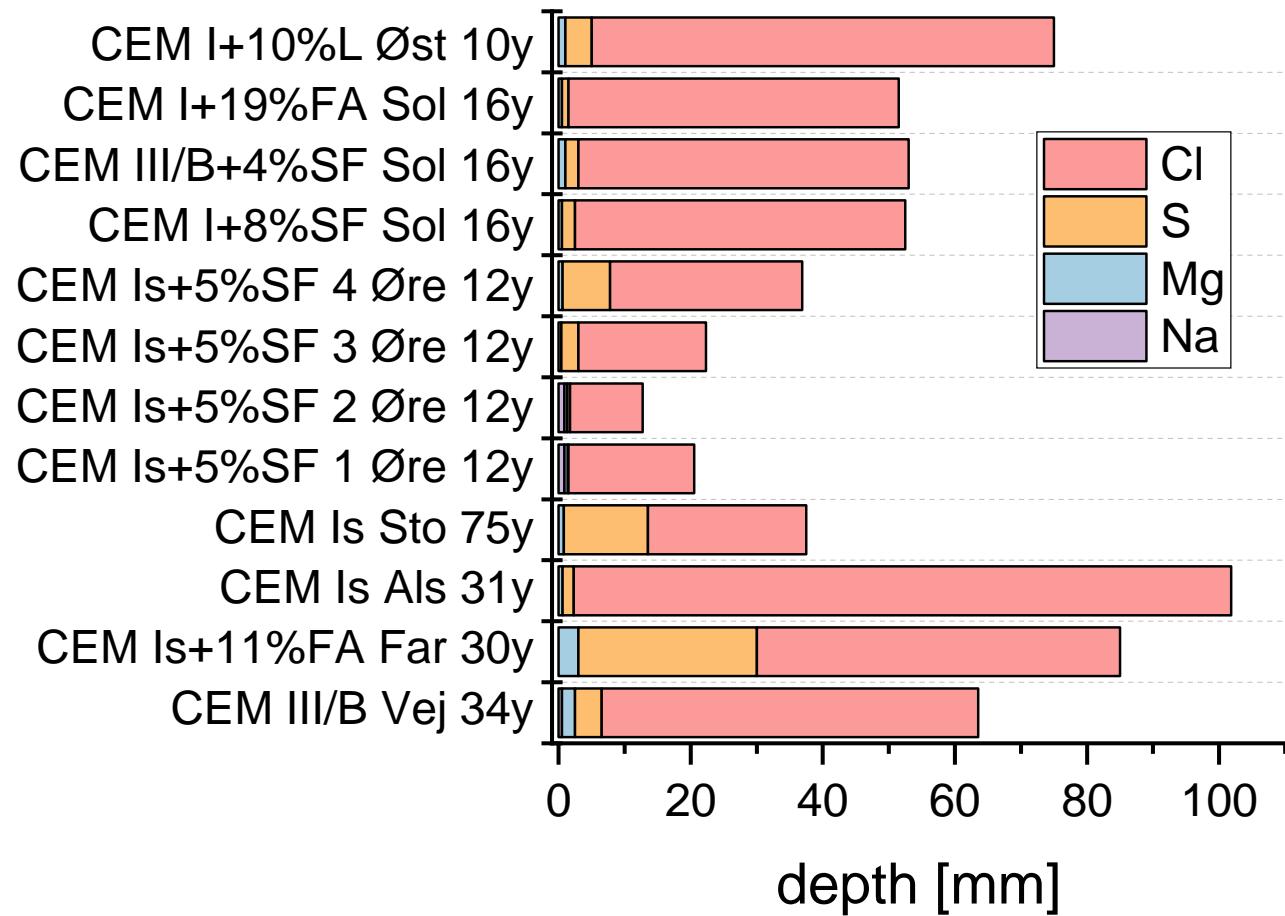
elemental profiles



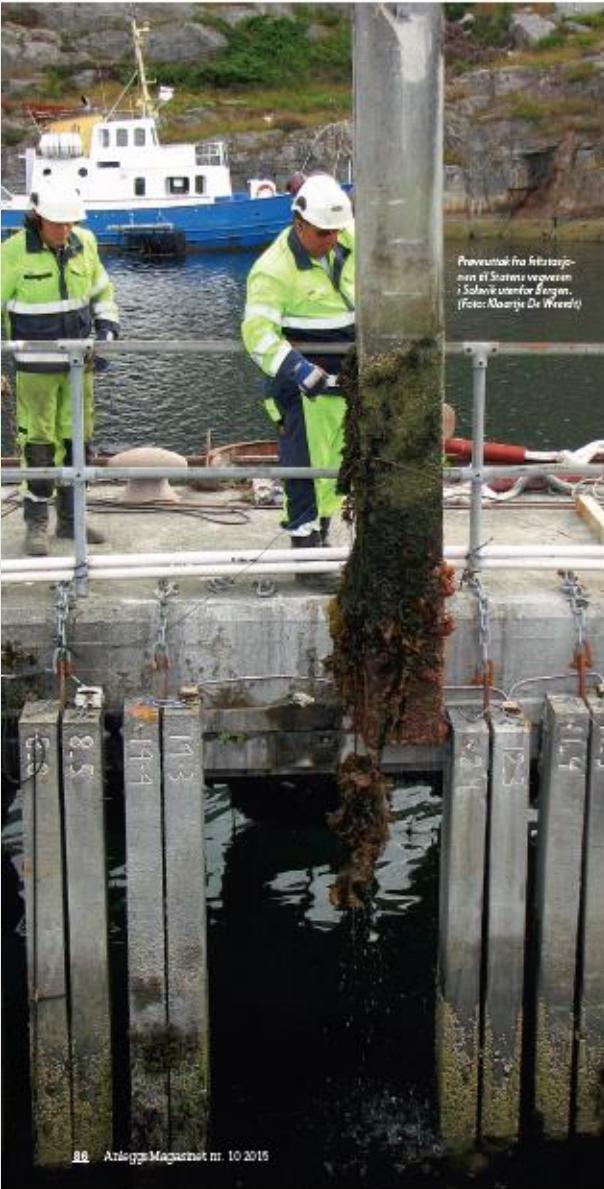
Zonation independent of exposure site/concrete



Mainly the outer 10 mm is affected



Marine exposure: 16 years – biological side effects



Hvor er kloridene i betong?

Det er avgjørende viktig å forstå de underliggende mekanismene når klorid trenger inn i betong. Bare da kan vi sørge for miljøvennlige og bærekraftige konstruksjoner, med forutsigbar levetid.

Construction and Building Materials 120 (2016) 418–431

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat



Towards the understanding of chloride profiles in marine exposed concrete, impact of leaching and moisture content

Klaartje De Weerdt ^{a,*}, Denisa Orsáková ^b, Arnaud C.A. Müller ^c, Claus K. Larsen ^{d,a}, Bård Pedersen ^d, Mette R. Geiker ^a



Innlepet, og ny analysemetode utviklet. Den tidligere metoden mistet fasas ut siden den krevede kloridsalv, som nå er forbudt. I tillegg er det sett om å anskaffe en XRF-skanner som kan lage 2D-kart av leidstann på sagte betongoverflater, og prøvekort legges hvor kloridene finnes seg i betongen.

Hvorfor trenger dette? Norge og resten av verden har hattest mye erfaring med ammert betongkonstruksjoner som er utsatt for kloridholdig miljø. Enhver mye kloridutsatt konstruksjon må følge regler for vann-

minter på markedet. Hovedgrunnen er at Portlandcementproduksjonen gir store CO₂-utslipp, som oppstår av to grunner. Cementen produseres i en ovn ved 1450 grader, og krever mye brannol.

Dessuten er kalkstein hovedingrediensen i cement. Under cementproduksjonen omfattes kalsitsteinen (CaCO₃) til CaO- og CO₂ slippes ut.

Klorider kan utenfra Ingenting bryter ned ammerte betongkonstruksjoner mer effektivt en kloridholdig ammertekonsesjon. Tinsaker og sjøvann begrens konstruksjonenes levetid. Bare se på kaler, bruker og parkeringshus.

Før

Ittiden kunne kloridene bli blandet inn i betongen

når stål, sand eller vann fra sjøen ble brukt eller ved å tilsette kloridholdige additiver.

Nå er dette forbudt, og det er strenge begrensninger

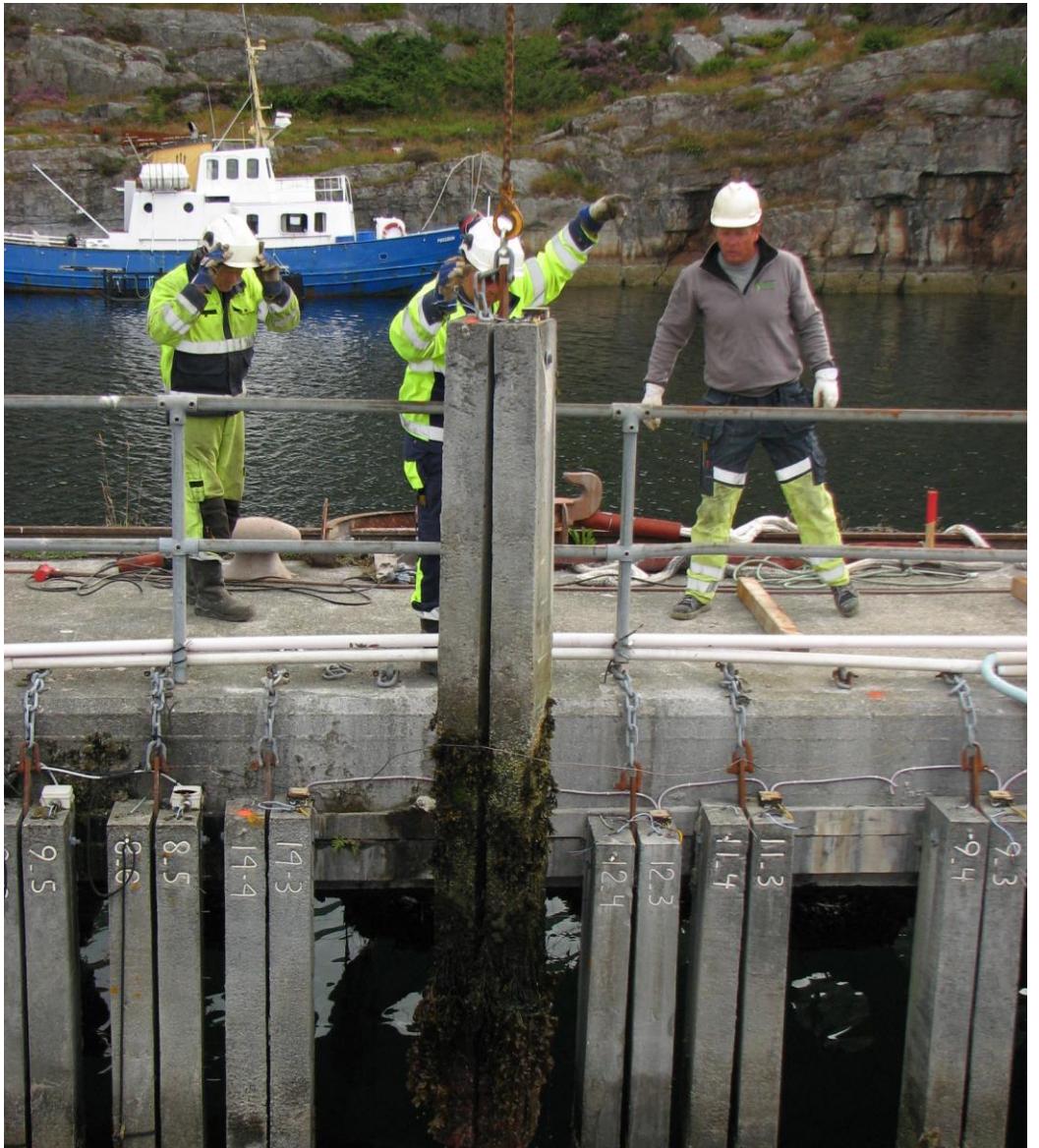


Analyse med nøytralgrønn for å identifisere kloridholdige materialer. Foto: Giedrus Ziegut



DTU, April 20th 2022, Klaartje De Weerdt (NTNU)

August 2013
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DTU, April 20th 2022, Klaartje De Weerdt (NTNU)



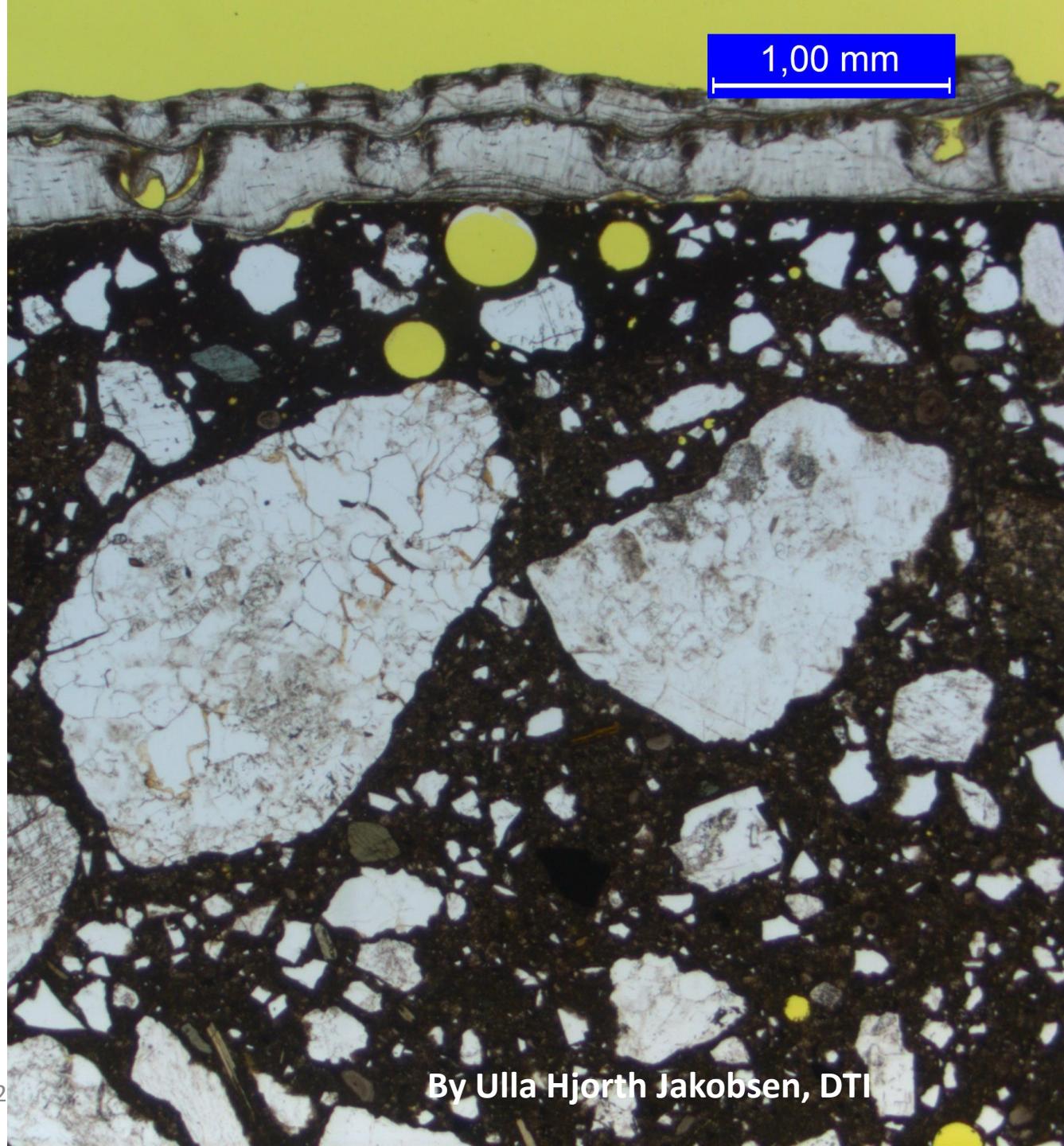
Marine exposure: 16 years – biological side effects



1,00 mm

Take home message

- Concrete in seawater is prone to phase changes at the surface
- Though the depth affected is limited to about 10 mm even after 75 years
- The formed calcite and brucite/M-S-H crust seems to form a favorable basis for biological growth.





1,00 mm

Thank you for your attention.
Any questions?

By Ulla Hjorth Jakobsen, DTI