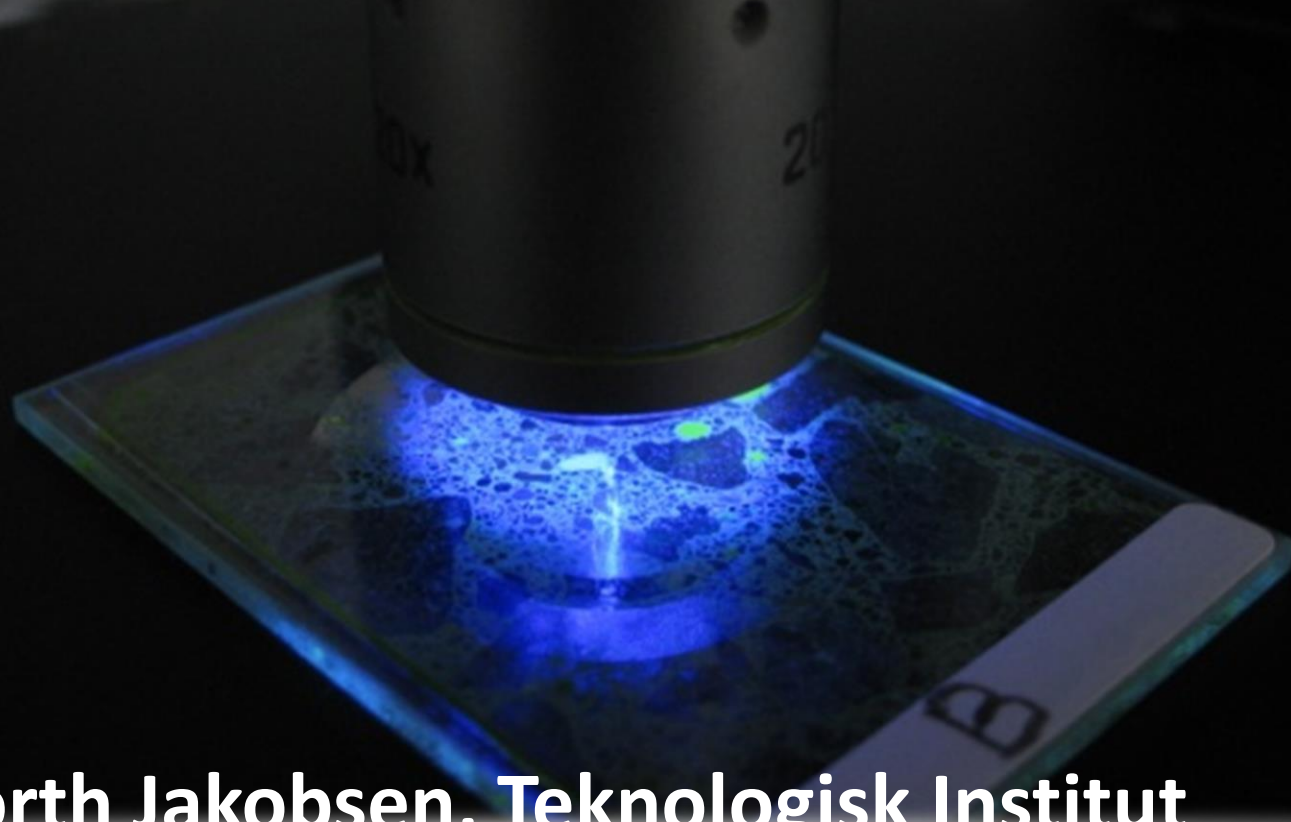


# Petrografi af beton - teori og eksempler fra praksis med forskellige typer af nedbrydning

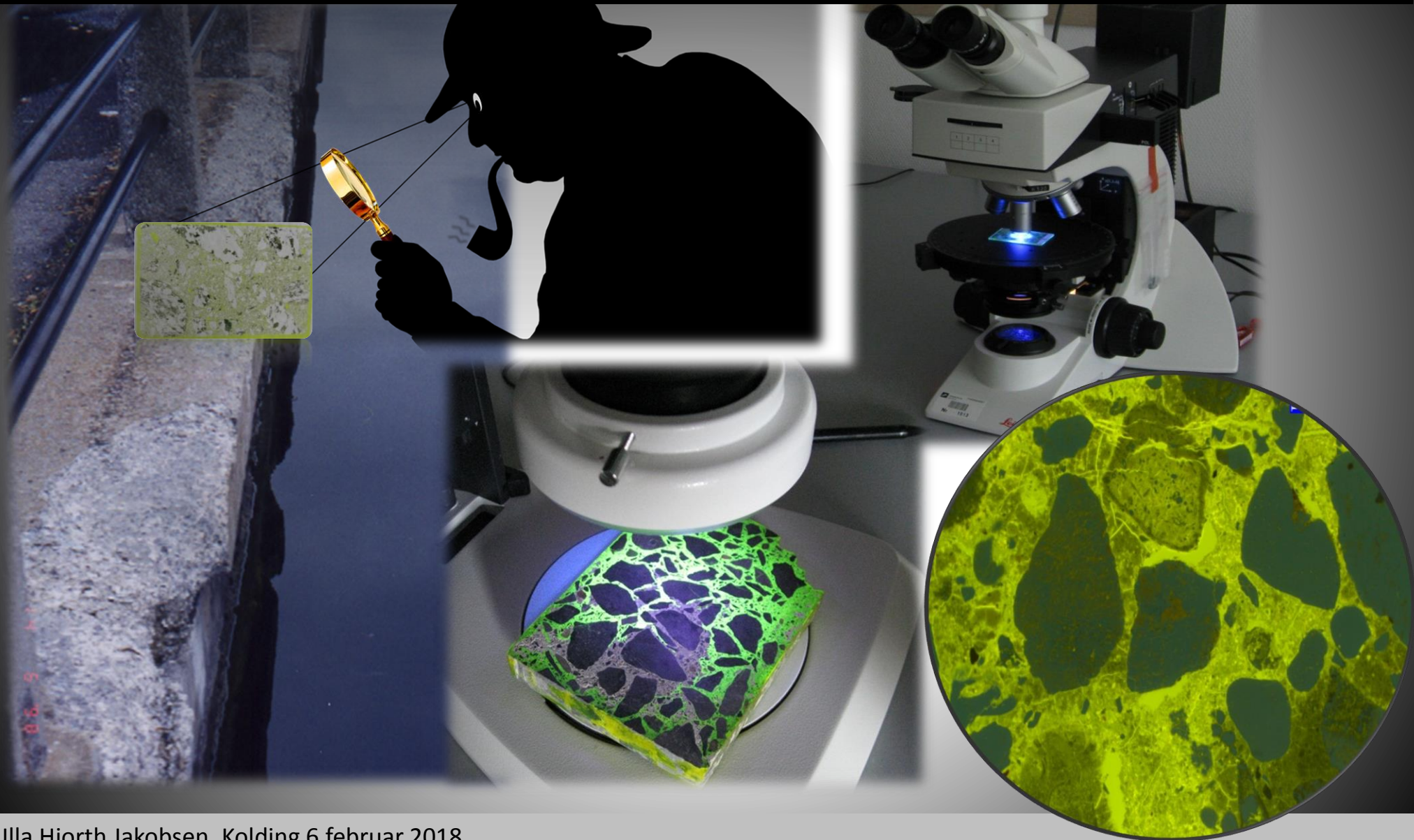


**Ulla Hjorth Jakobsen, Teknologisk Institut**

# Hvad bruges petrografi til?



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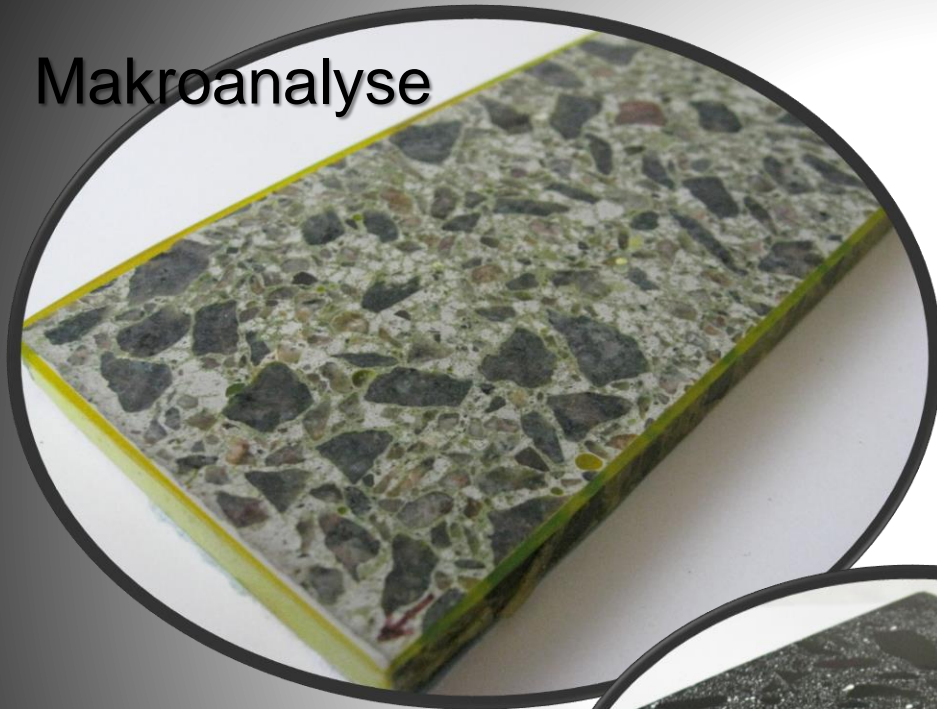


# Hvilke præparater anvendes?

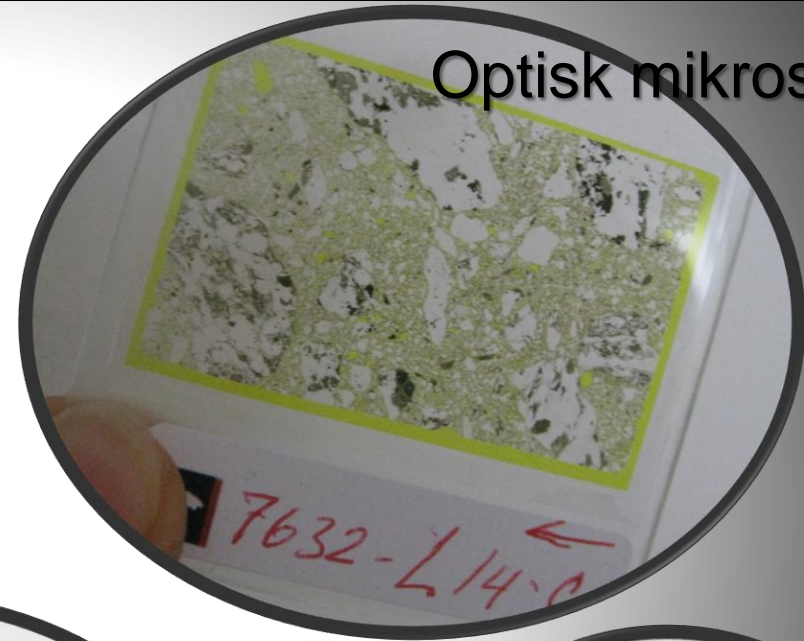


TEKNOLOGISK  
INSTITUT

Makroanalyse



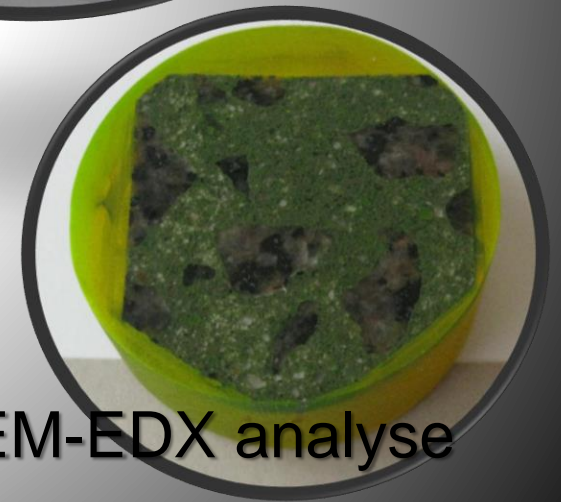
Optisk mikroskopi



Luftporeanalyse



SEM-EDX analyse



# Makroskopisk Undersøgelse



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INSTITUT

Type af stentilslag

Cement pastaens beskaffenhed

Revner  $>10\mu\text{m}$ ; størrelse, form og orientering

Overfladens tilstand, behandling

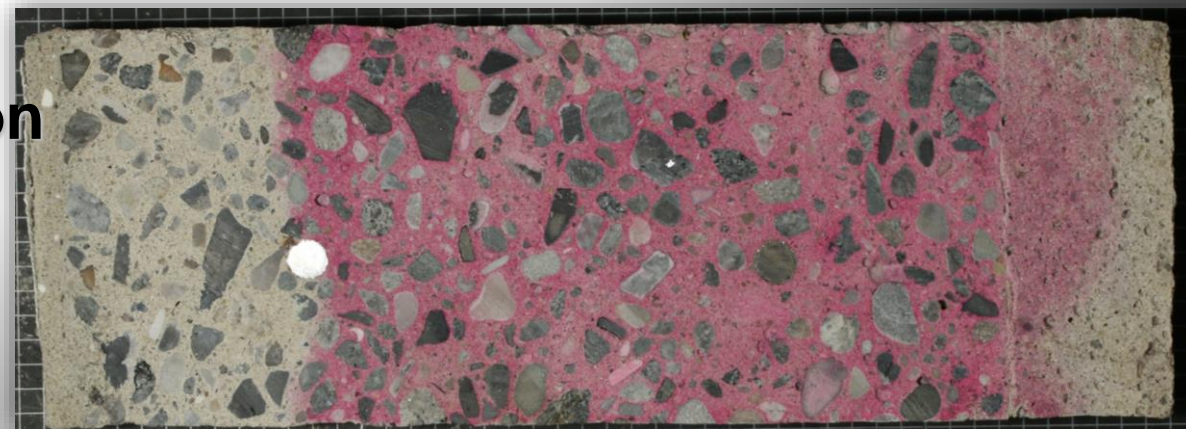
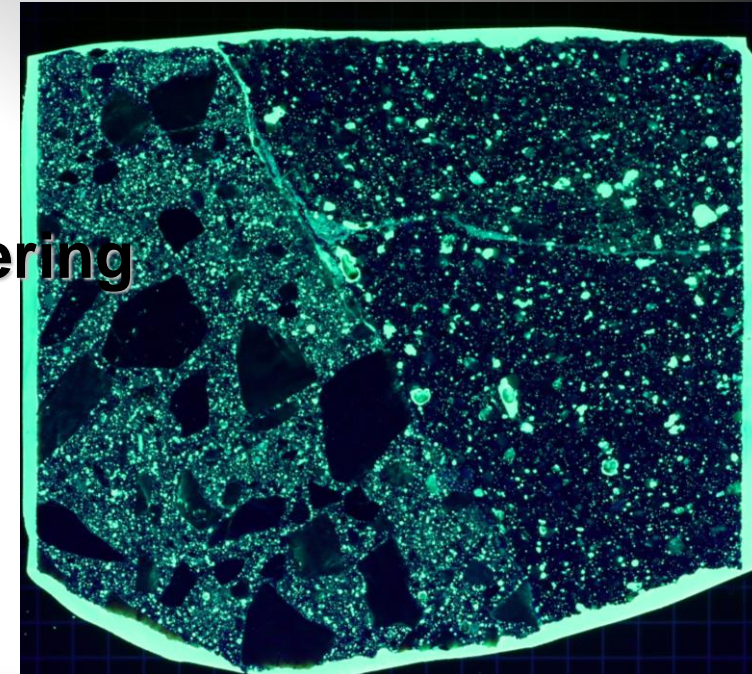
Luftporestrukturen

Verificering af separation, konsolidering

Karbonatisering; position & måling

Identifikation af armering

Dæklagsmåling & korrosion



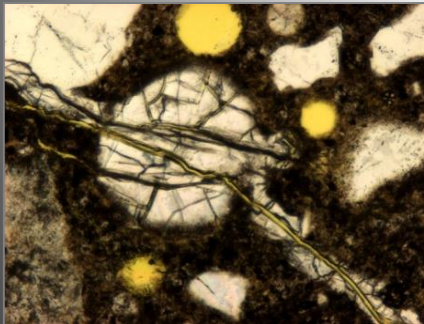
# Hvad ser vi i et fluorescens imprægneret tyndslib?

**Optiske egenskaber (mineralske & amorfe faser)**

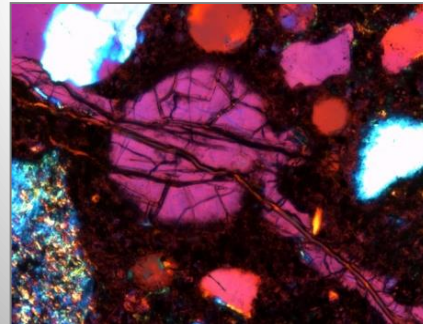
**Morfologi (form og størrelser)**

**Revner og defekter**

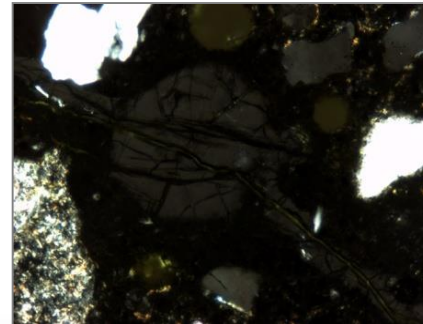
**Porøsiteter**



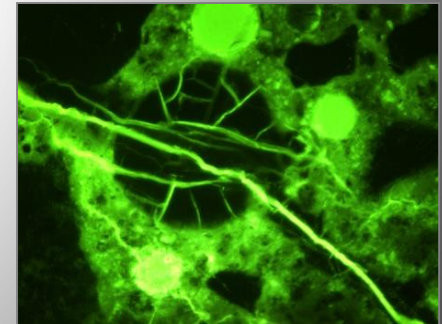
Polariseret lys



m. gipsplade



X-polariseret lys



Fluorescerende lys

# Hvad bruges observationerne til?



**Kvalitetskontrol af beton og delmaterialer**

**Beregne betonsammensætning**

**Evaluerer pastaens sammensætning, homogenitet og hydratiseringsgrad**

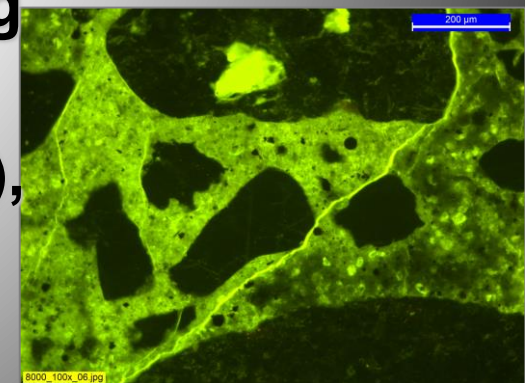
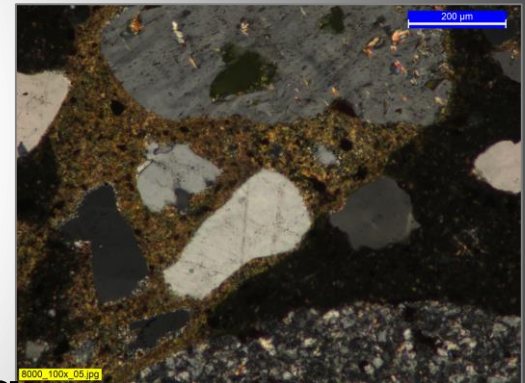
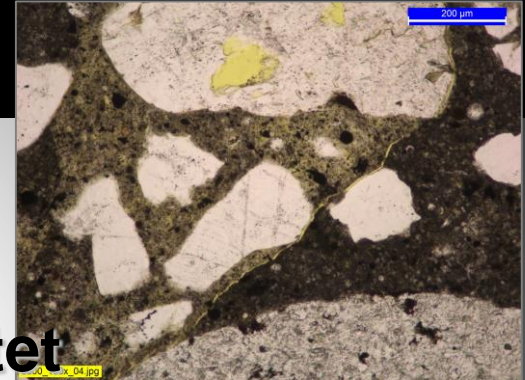
**Bestemme kapillarporøsitet (v/c tal)**

**Vurdere dannelse, type og alder af revner og defekter**

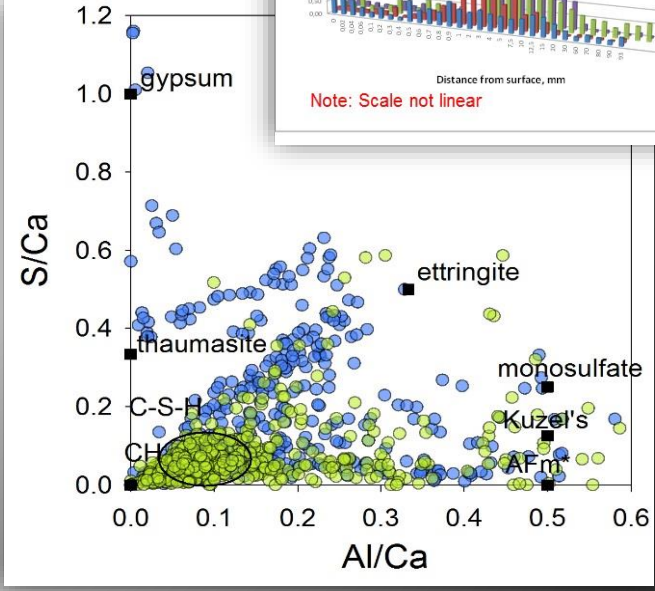
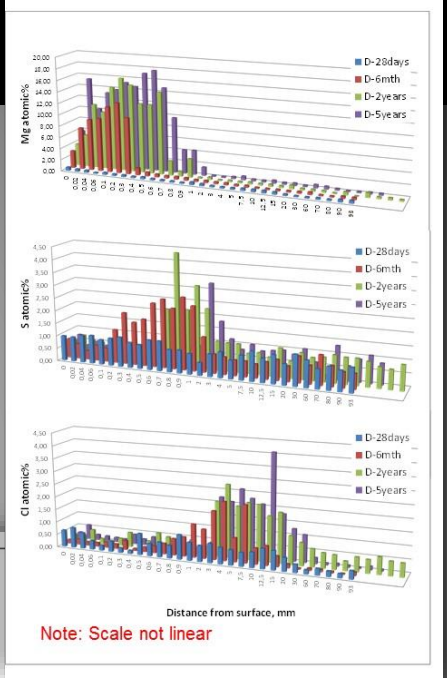
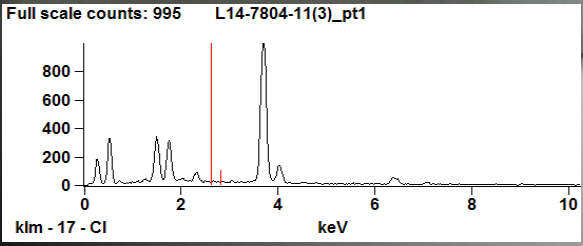
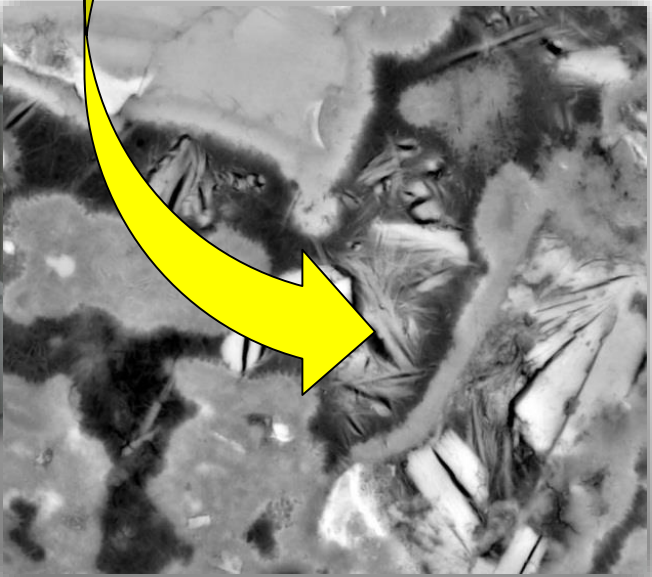
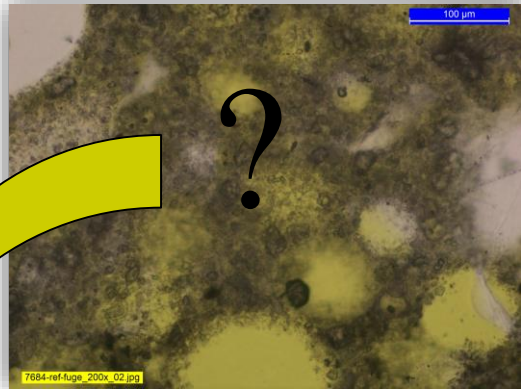
**Verificere og måle karbonatisering og udludning**

**Identificere alkalikiselreaktioner, sulfatangreb, frostangreb, Delayed Ettringite Formation (DEF), brandskade ....**

**Identificere udstøbningsfejl, materialefejl ...**



# Hvornår bruges et Scanning elektron mikroskop?



Studier af morfologi og kemisk sammensætning

# Hvornår gør tyndslib nytte?

Alle steder hvor årsag til problem ønskes belyst!

Hvad fejler min beton?

Hvem har skylden?

Er betonen behandlet korrekt ved blanding og støbning?

Hvornår er revnerne dannet?

Hvorfor er der vedhæftnings defekter?

Hvor dybt kan skaden spores?

Hvordan skal, eller kan jeg reparere skaden?

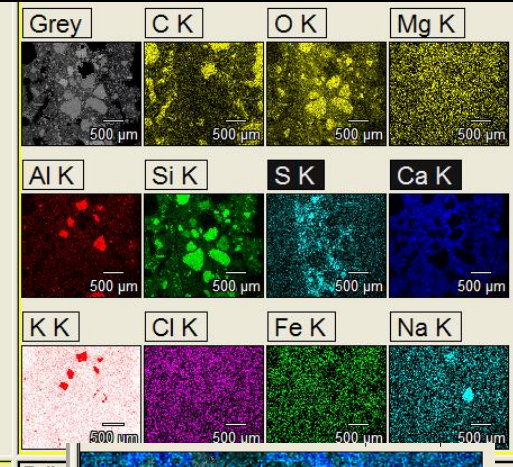
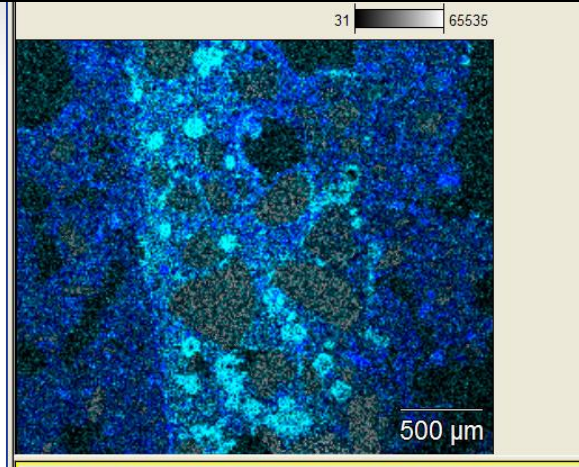
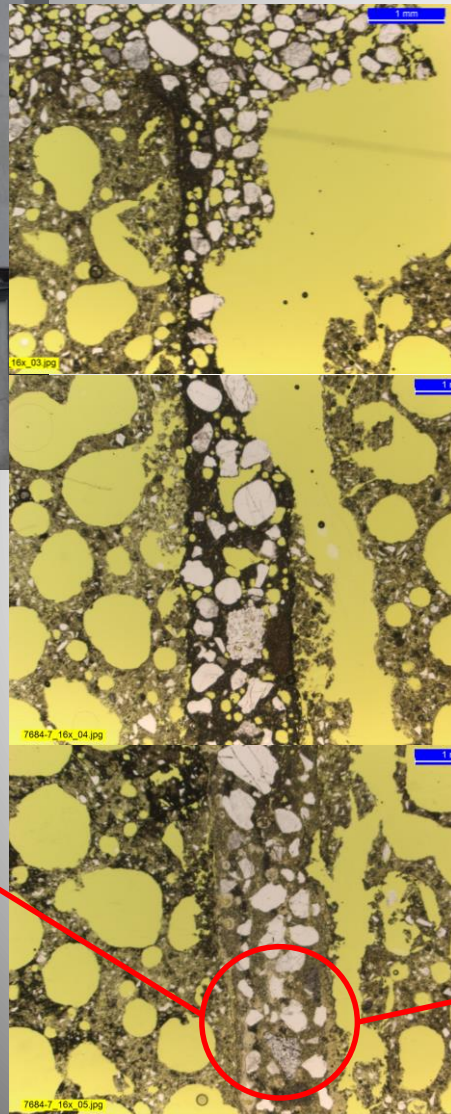
Er materiale valget korrekt?

Hvad er årsag til misfarvninger?

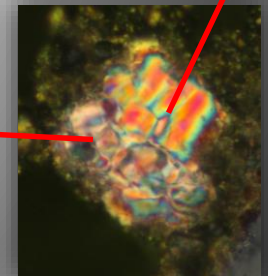
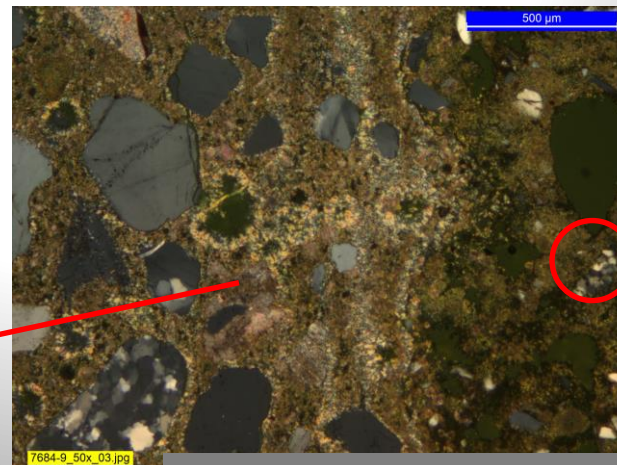
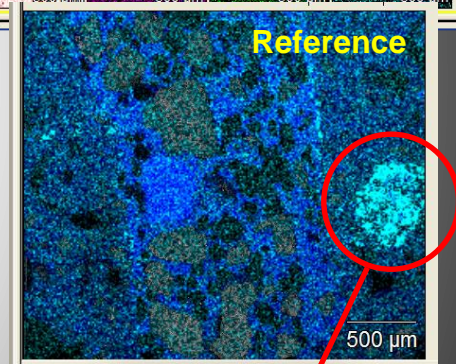
Er der brugt for meget vand i betonen?



# Hvorfor revner facaden?



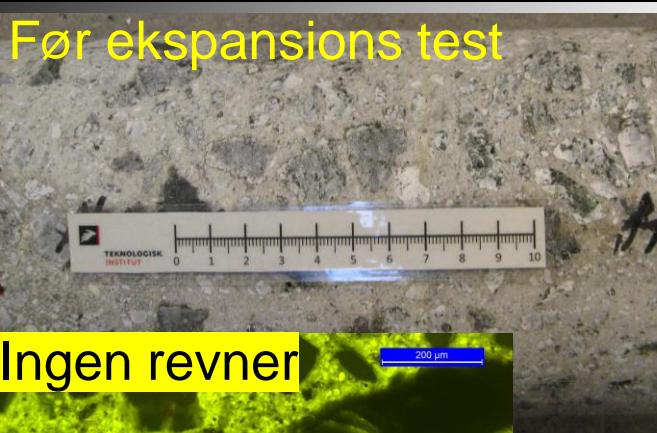
Intern sulfatangreb  
med thaumasit  
dannelse



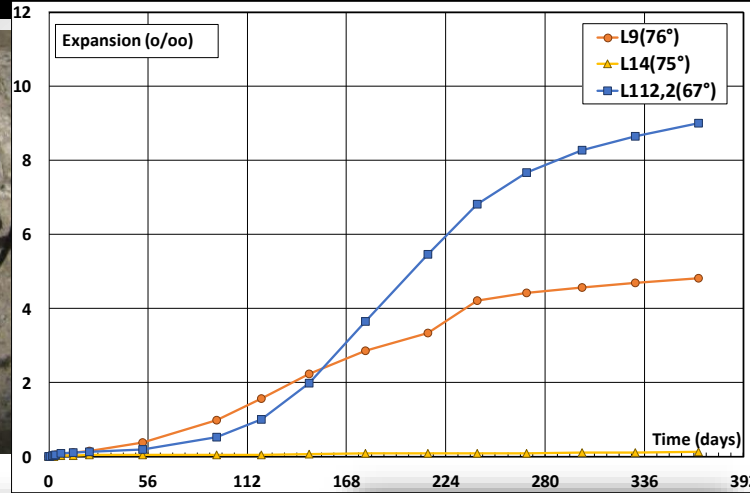
Dannelse af thaumasit kræver overskud af sulfat, karbonat og vand i systemet, og en typisk gennemsnitlig lav temperatur

# Har betonen taget skade af for høj hærde temperatur?

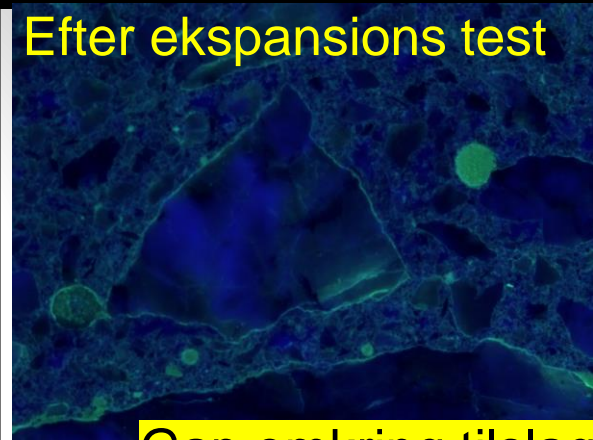
Før ekspansions test



Ingen revner

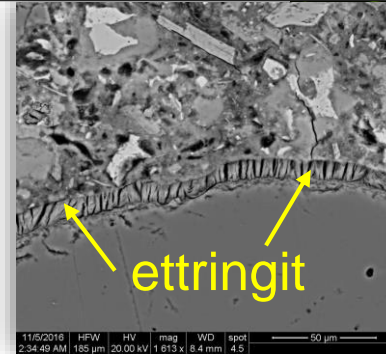
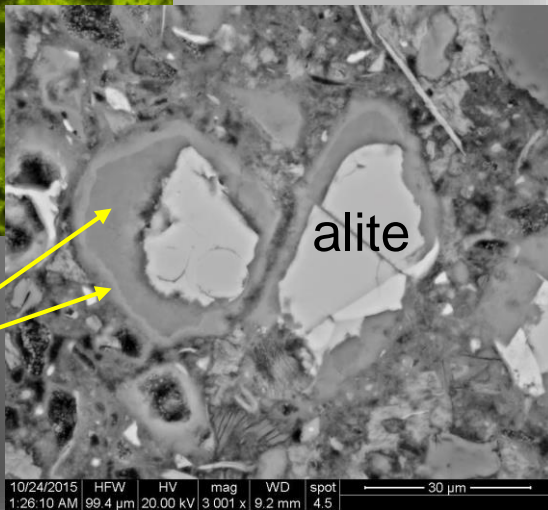


Efter ekspansions test

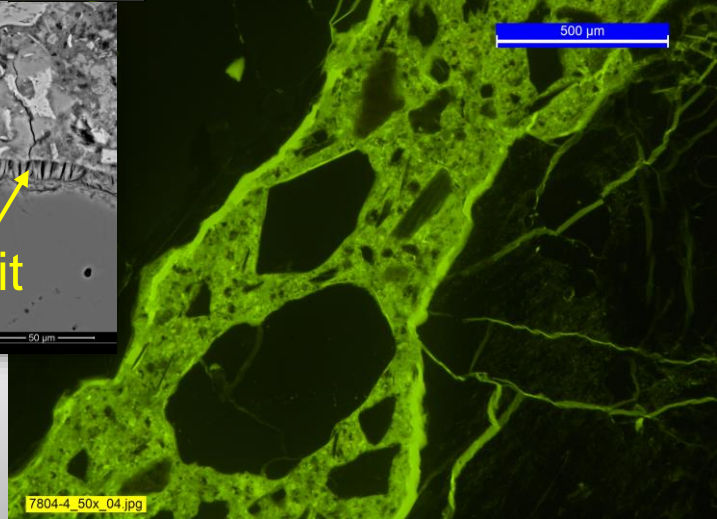


Gap omkring tilslag

Two-toning;  
tegn på høj temp.

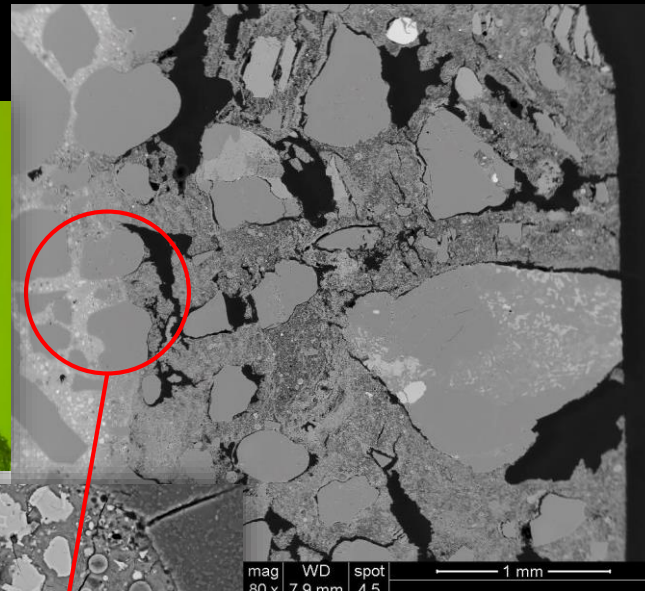
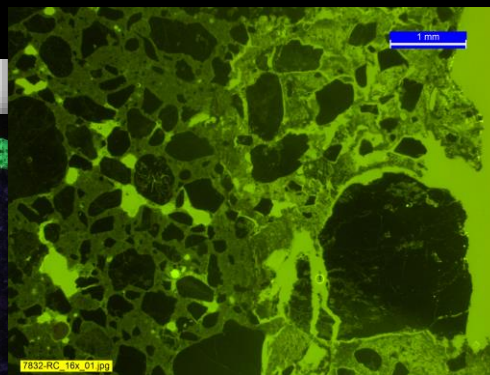
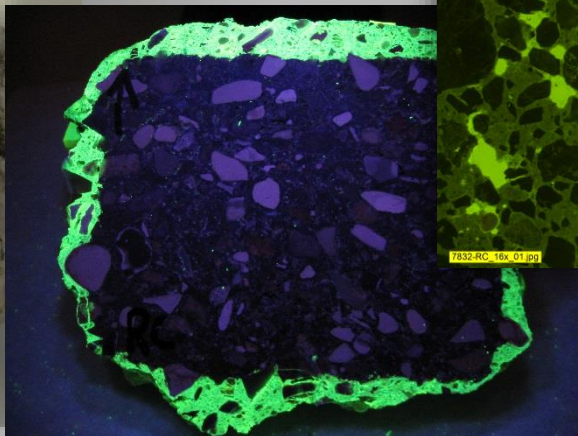


Intern  
sulfatangreb

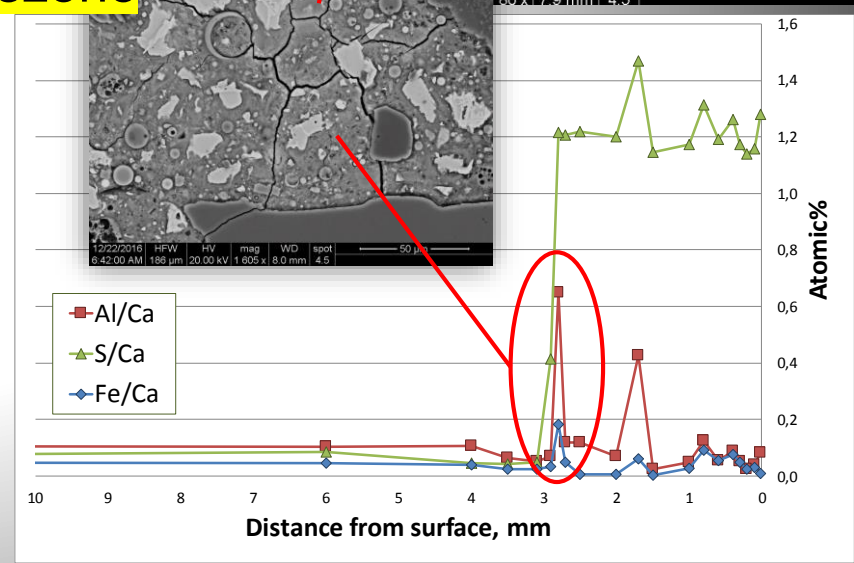
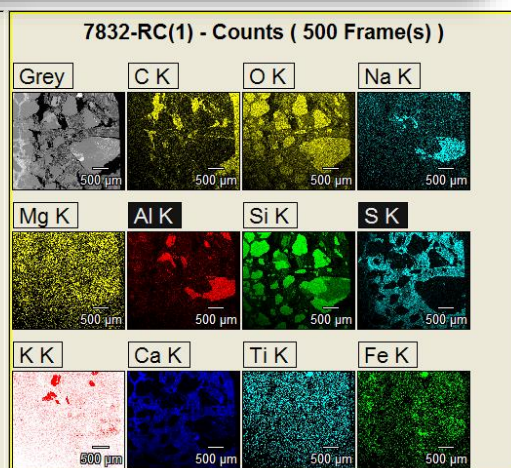
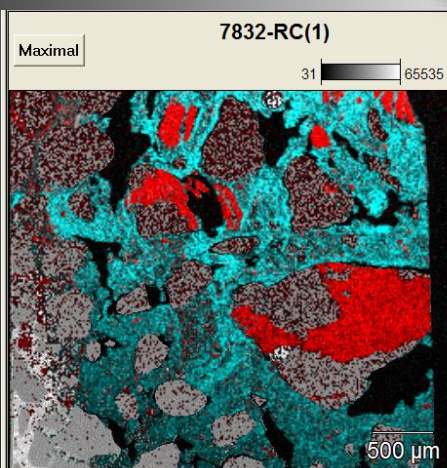


DEF kan forekomme i den hærdede beton hvis hærdetemperaturen har været over 65-70°C, og indholdet af sulfat, C<sub>3</sub>A, og alkali i cementen for høj

# Hvor dybt er betonen påvirket?



Revner foran  
gipszone



Overfladeparallele revner med gips

Eksternt sulfat angreb på beton i kontakt med spildevand.  
Cementpastaen omdannes med tid til gips



# Tak fordi I lyttede



Mikroskop Carl Zeiss 1879