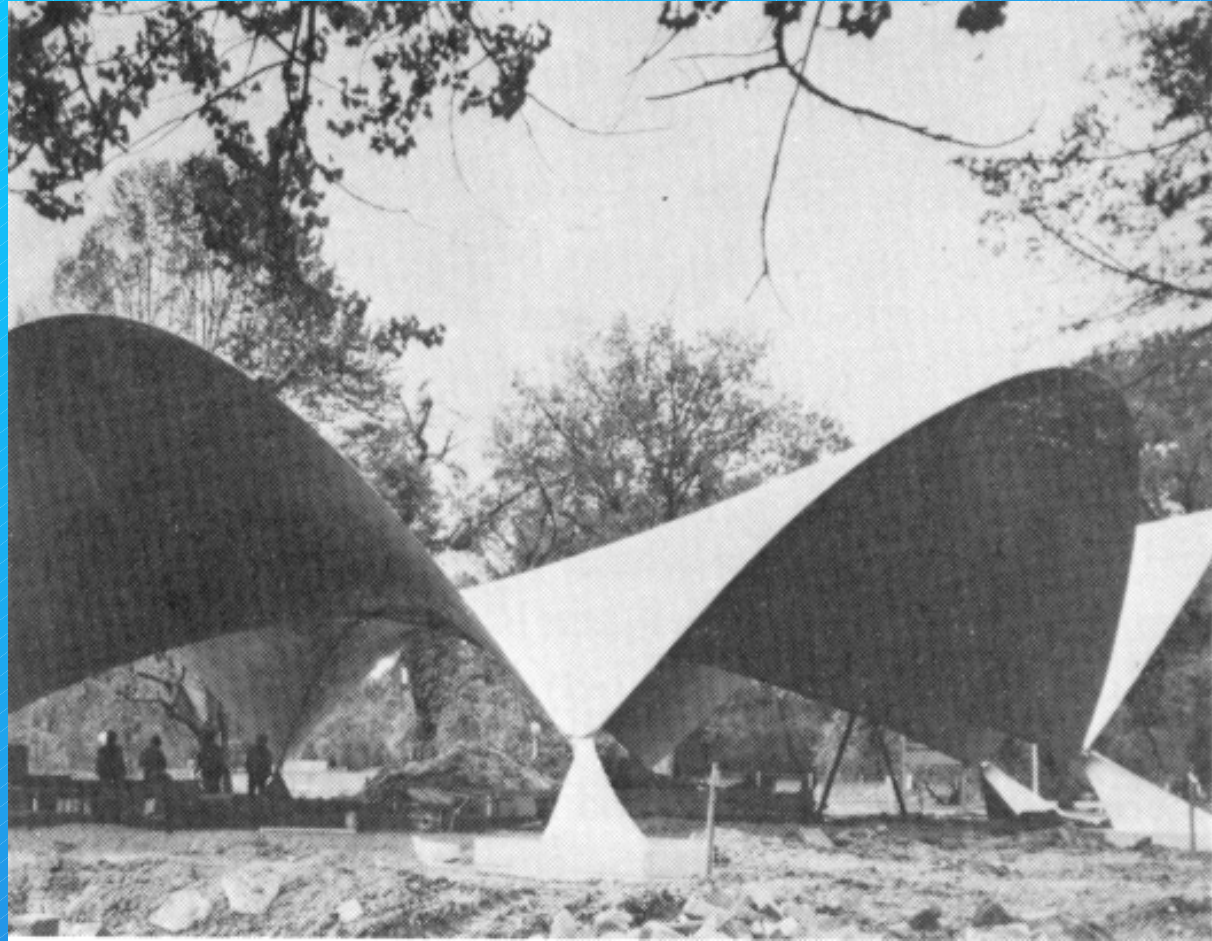


# Ponte Fabrizio, Rome 64 BC



# Stuttgart Pavilion



Fiber reinforced concrete

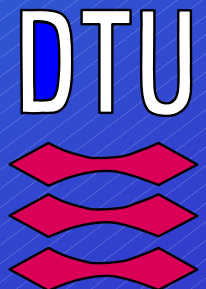
Span: 31 m

Shell Thickness: 15 mm

# Autogenous phenomena in cement-based materials

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Building Materials Group  
Technical University of Denmark



# Autogenous conditions - Definition

- Sealed
- Constant temperature
- Unrestrained

# Terminology - confusion

## Autogenous deformation

- Autogenous shrinkage
- Autogenous volume change
- Autogenous length change
  
- Endogenous shrinkage
- Indigenous shrinkage
- Hydration shrinkage
- Self-desiccation shrinkage
- Chemical shrinkage
- Bulk chemical shrinkage
- External chemical shrinkage

# Terminology

## Autogenous phenomena

### Autogenous deformation

Self-desiccation shrinkage

Expansion due to salts

### Autogenous RH-change

Self-desiccation

RH-change due to dissolved salts

## Non-autogenous phenomena

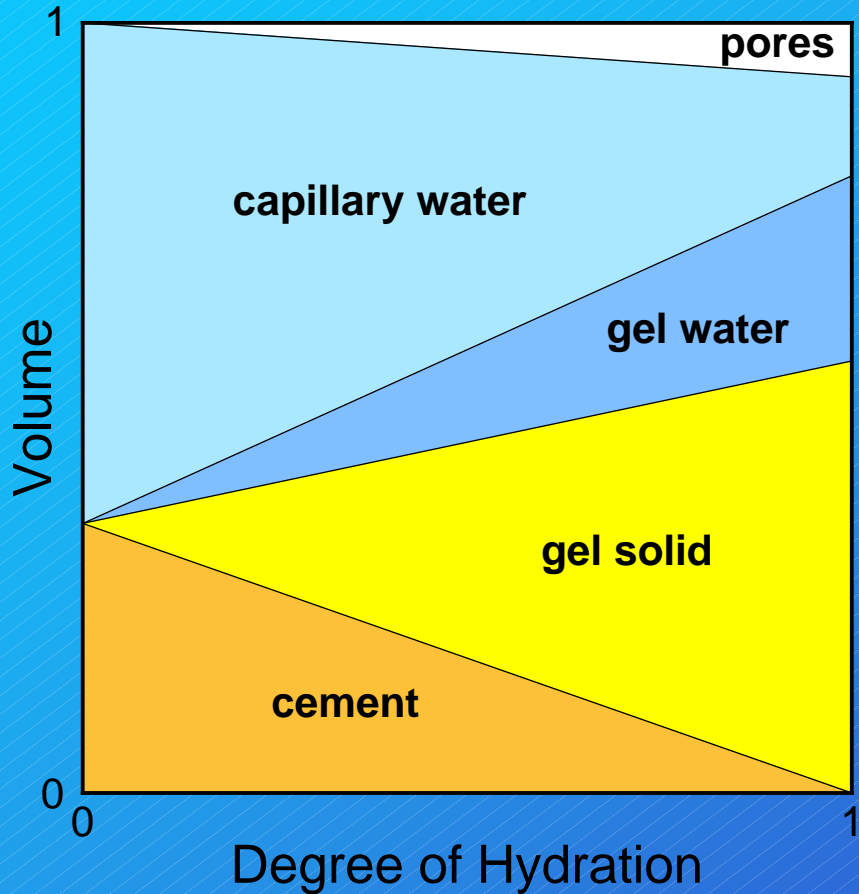
Carbonation shrinkage

Thermal deformation

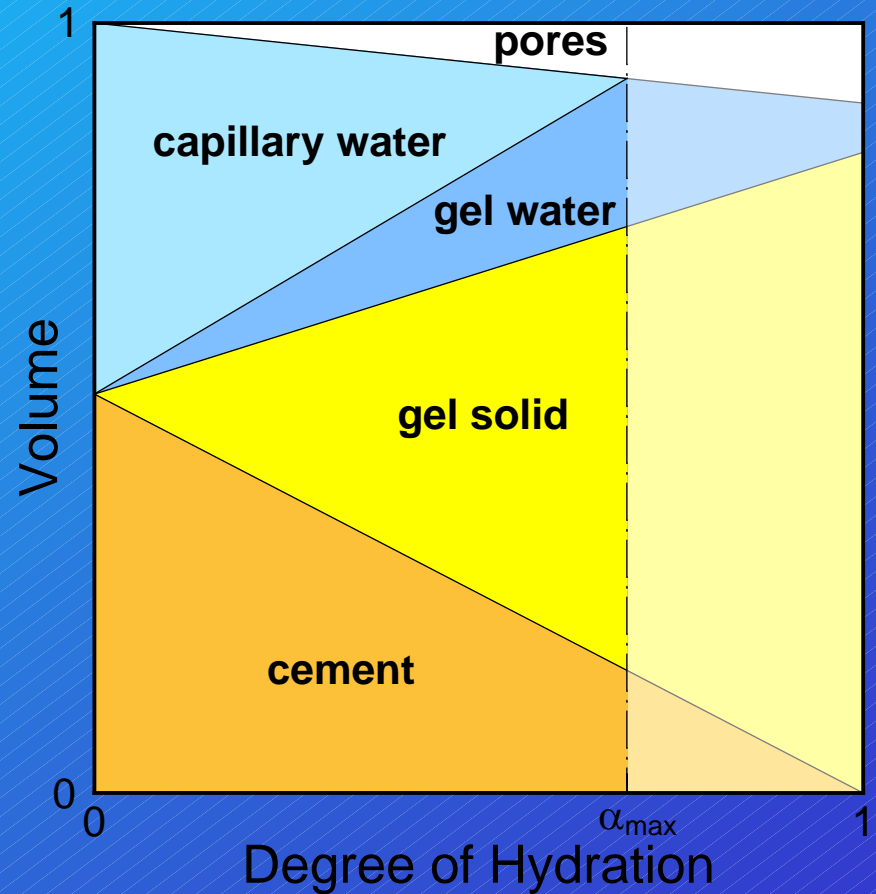
Deformation due to external loads

# Powers' Model

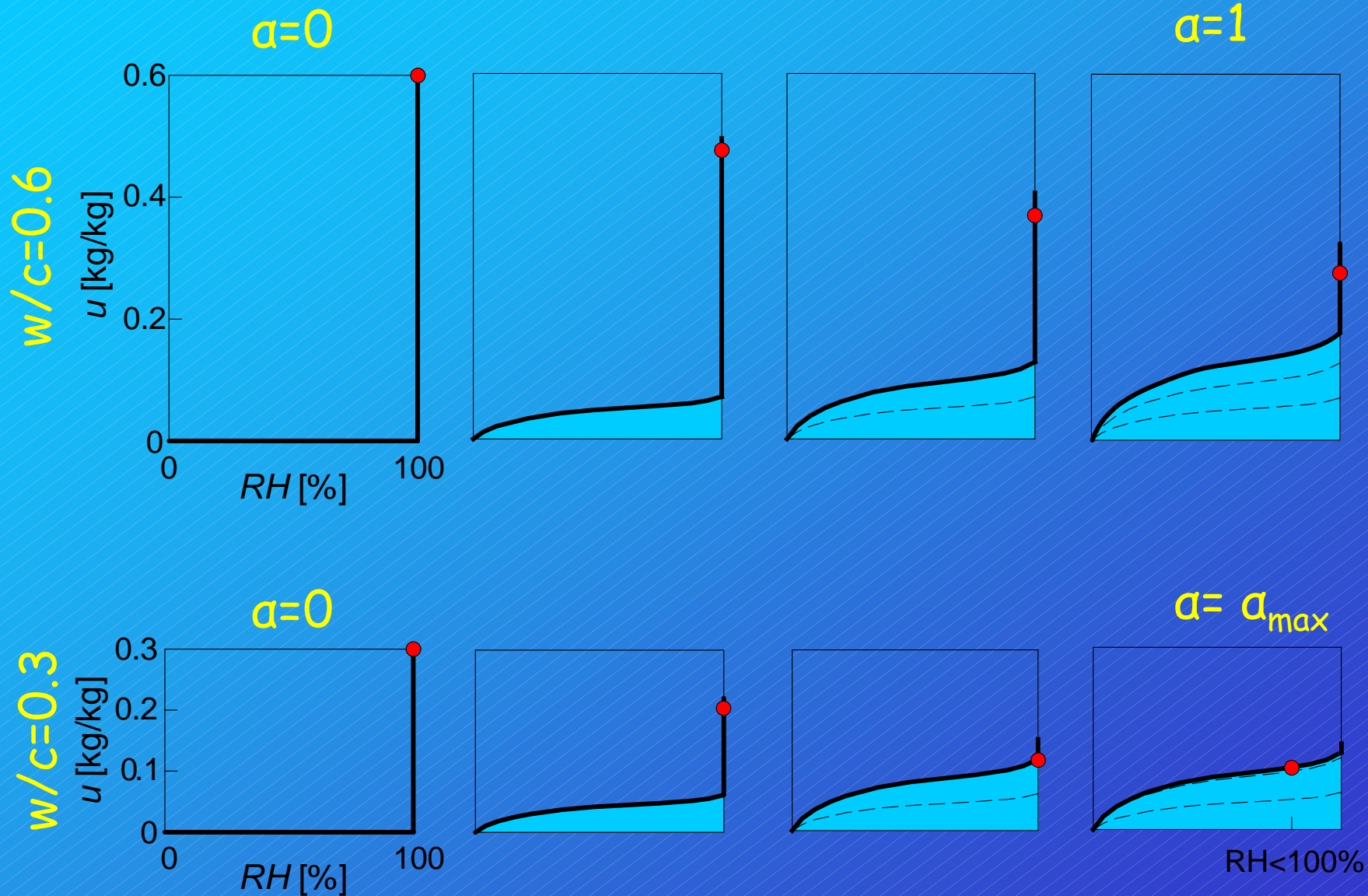
$w/c > 0.42$   
Sealed system



$w/c < 0.42$   
Sealed system



# Sorption isotherms - schematic

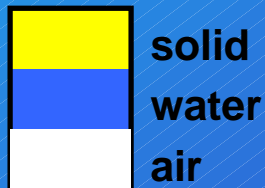
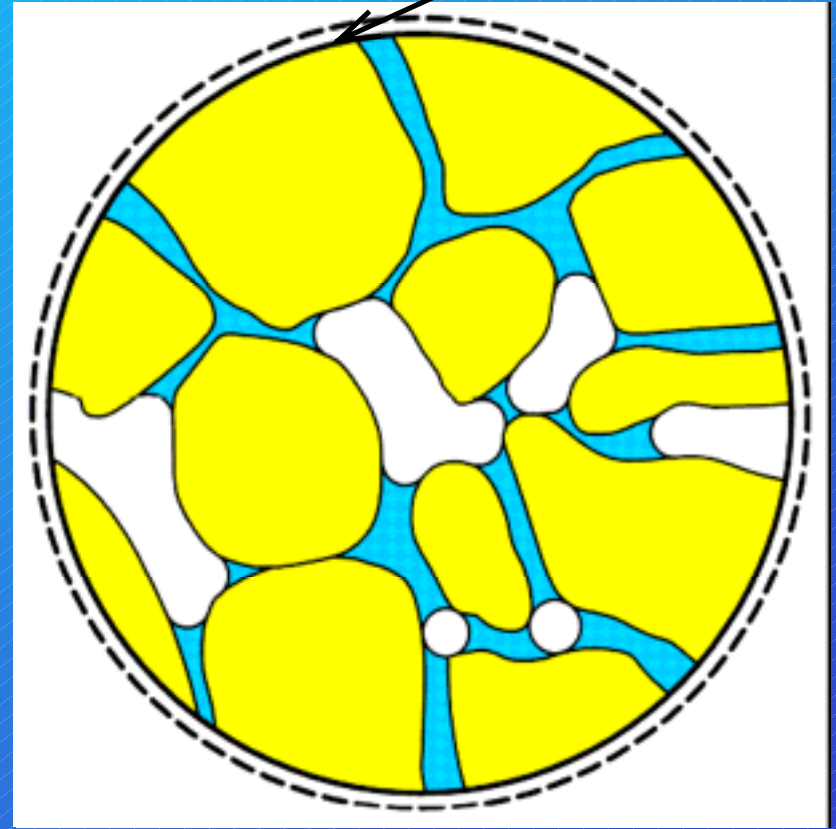
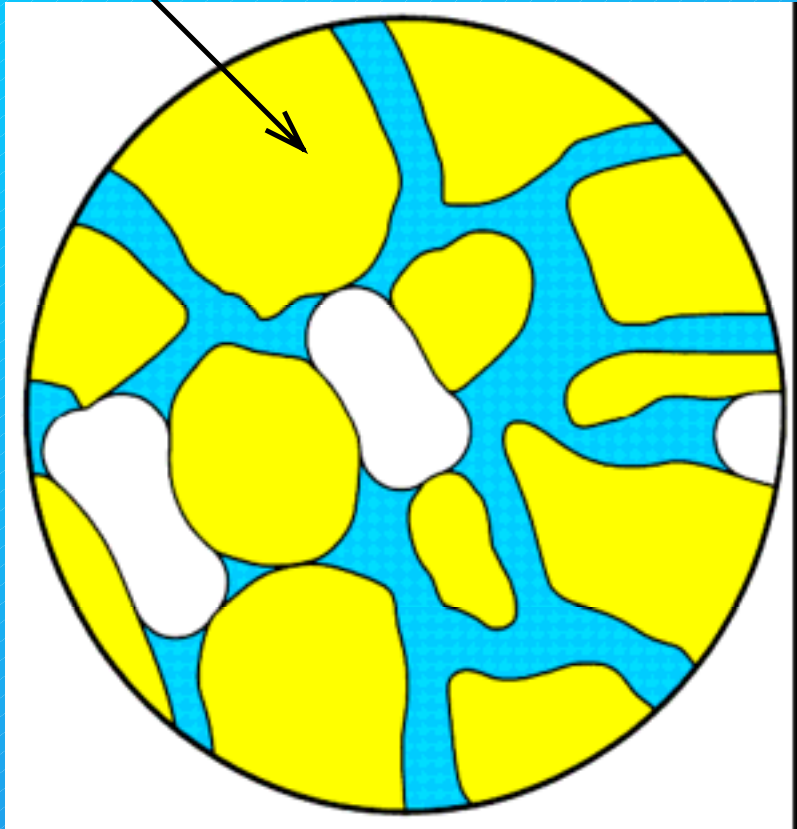




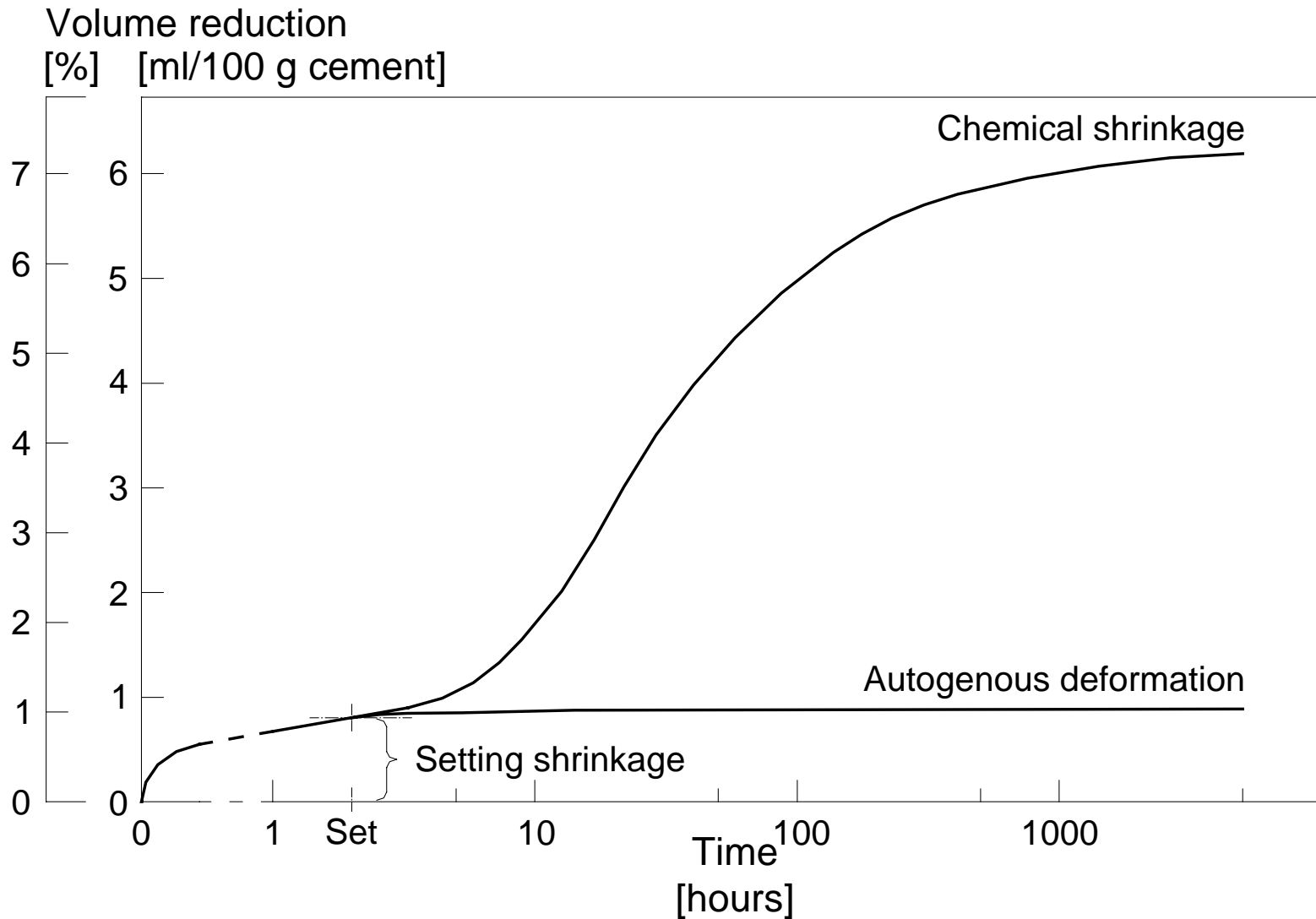
# Schematic cross-section

Chemical  
Shrinkage

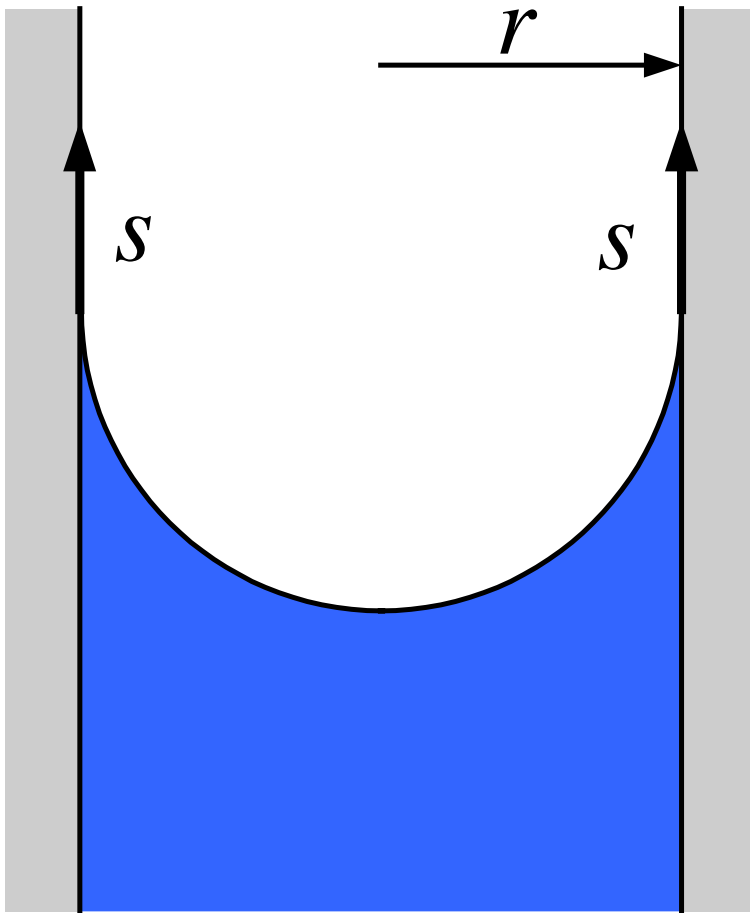
Self-deiscation  
Shrinkage



# Volume reduction during hydration



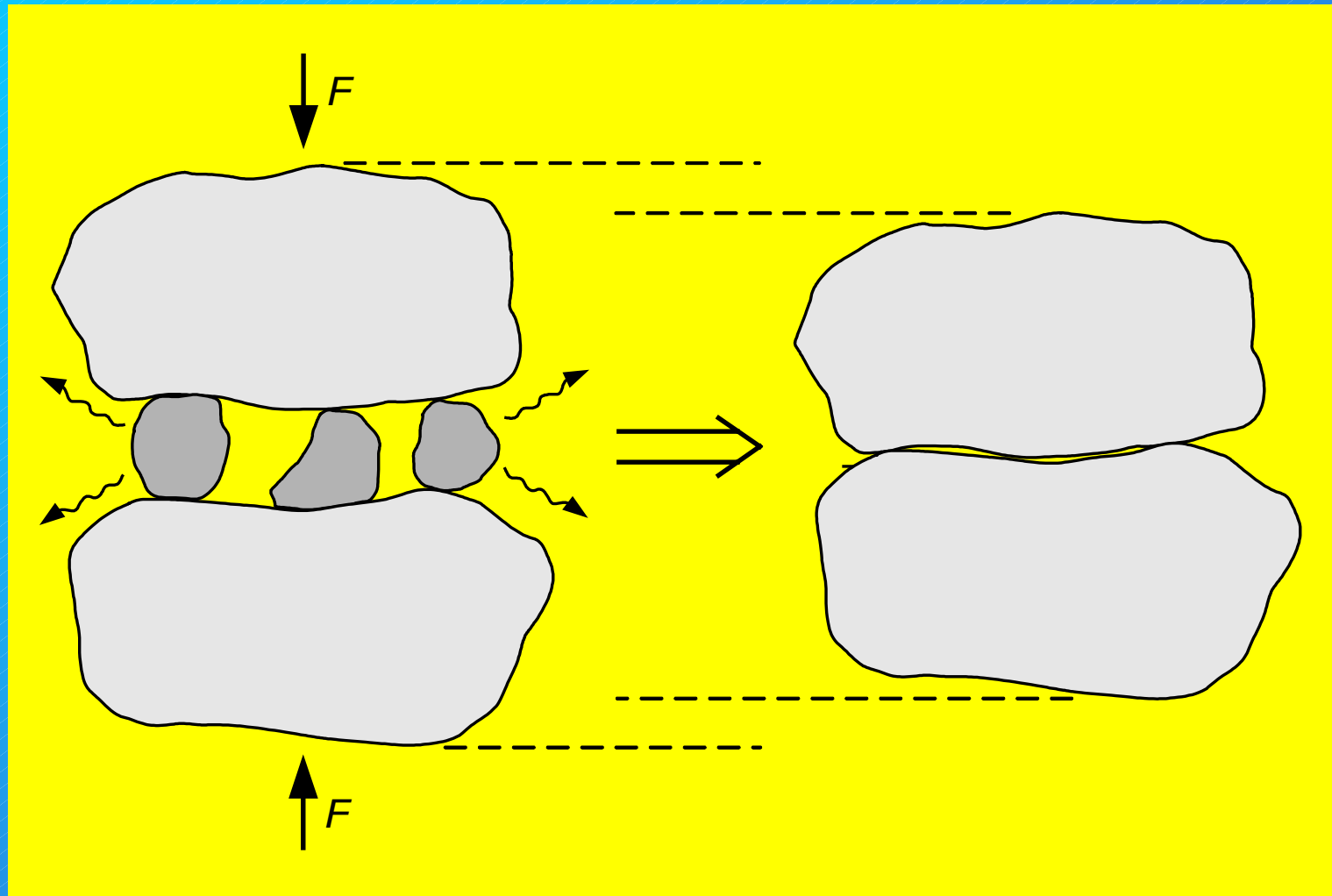
# The Kelvin equation



$$p = -\frac{2\sigma}{r}$$

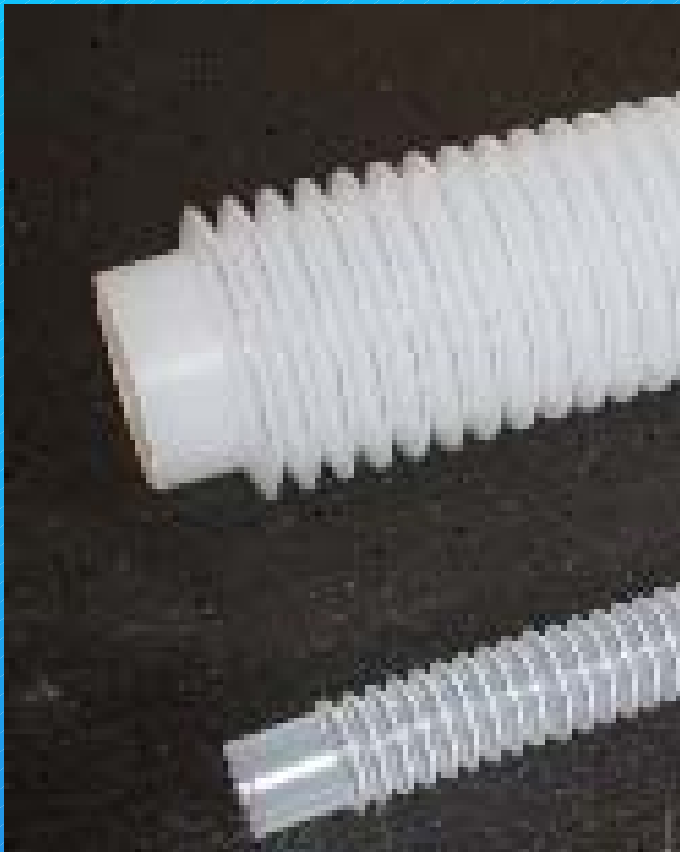
$$\ln(RH) = -\frac{2M\sigma}{\rho rRT}$$

# A shrinkage mechanism

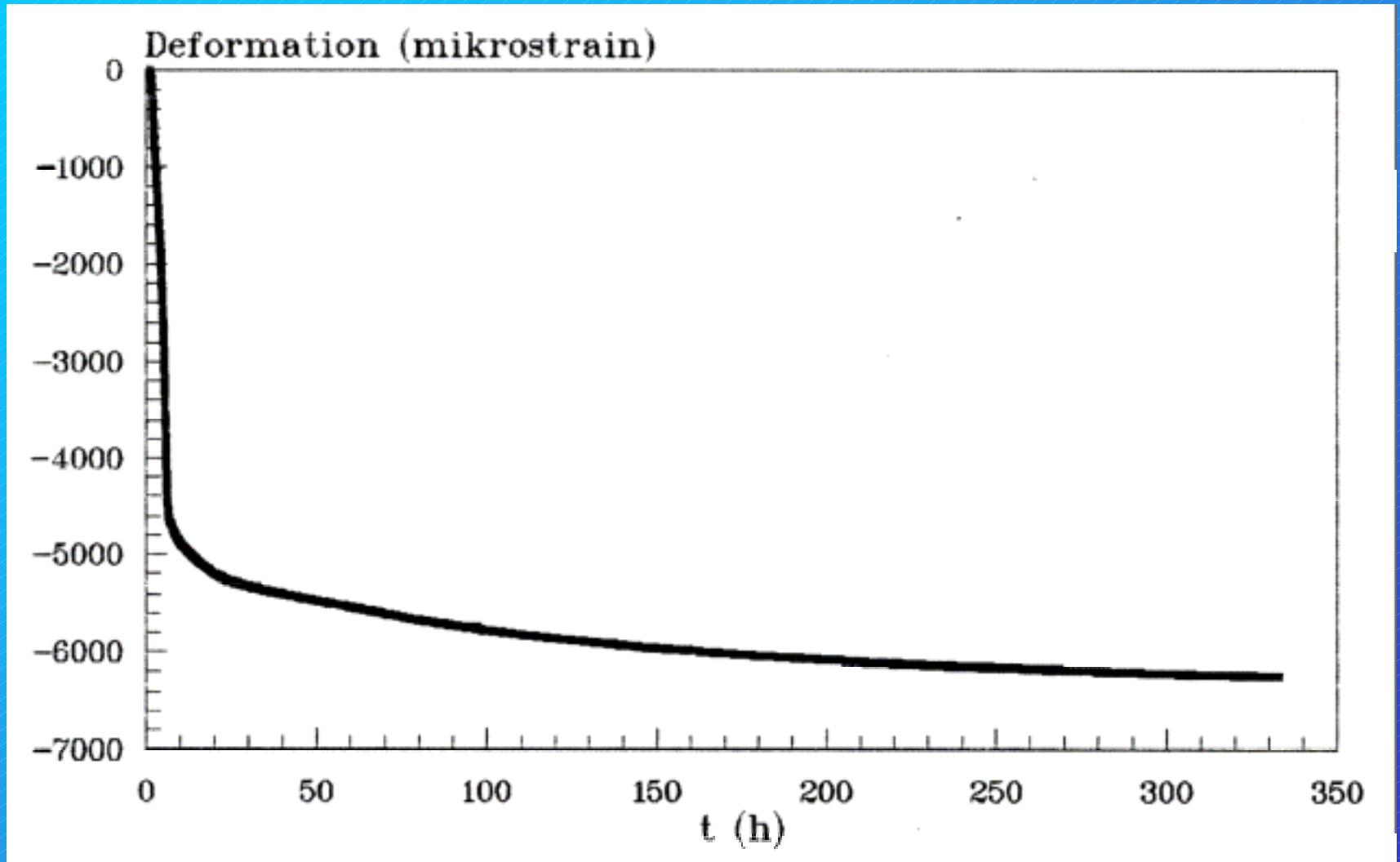


# Autogenous strain - linear technique

## Corrugated moulds

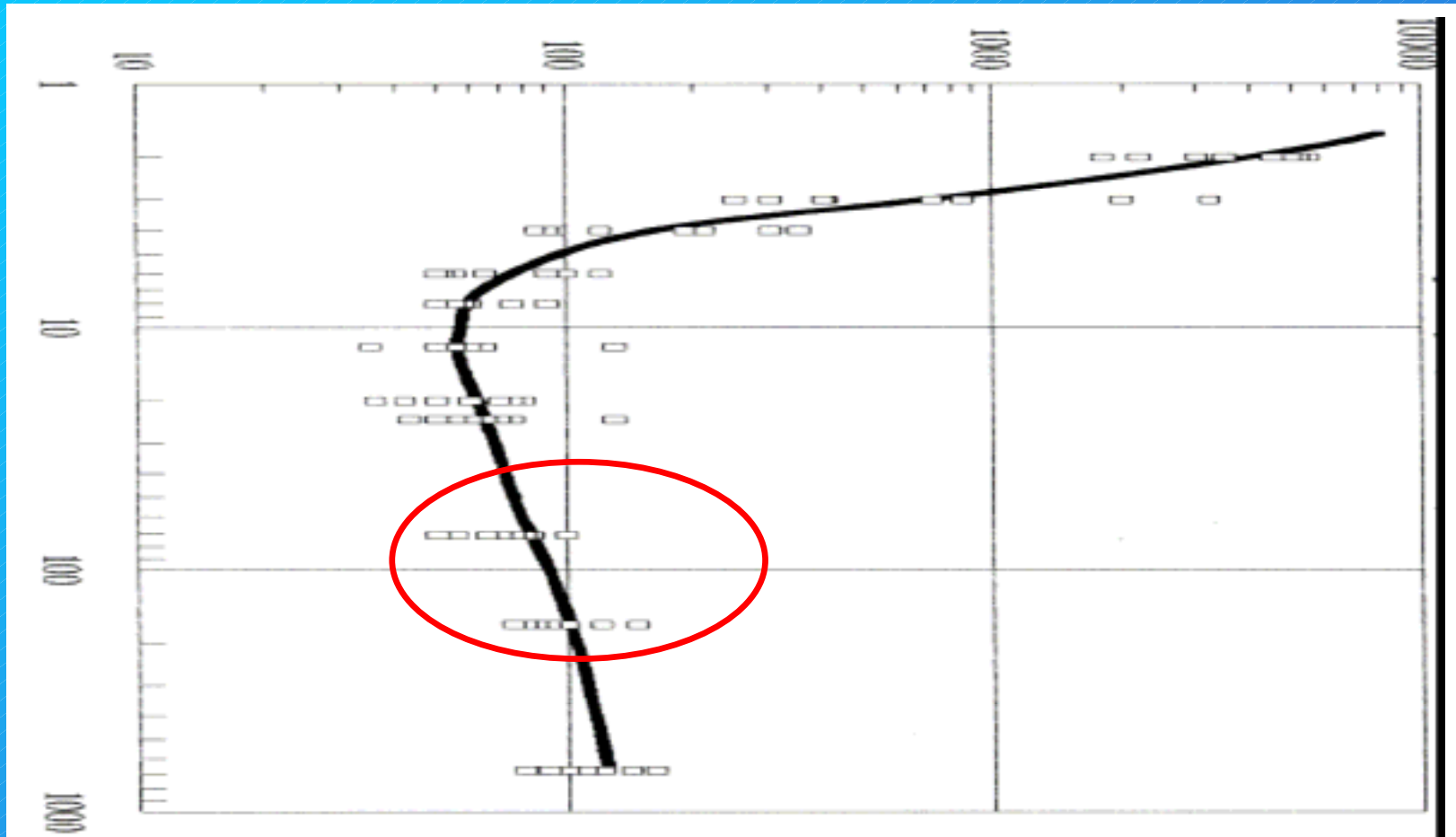


# Autogenous strain



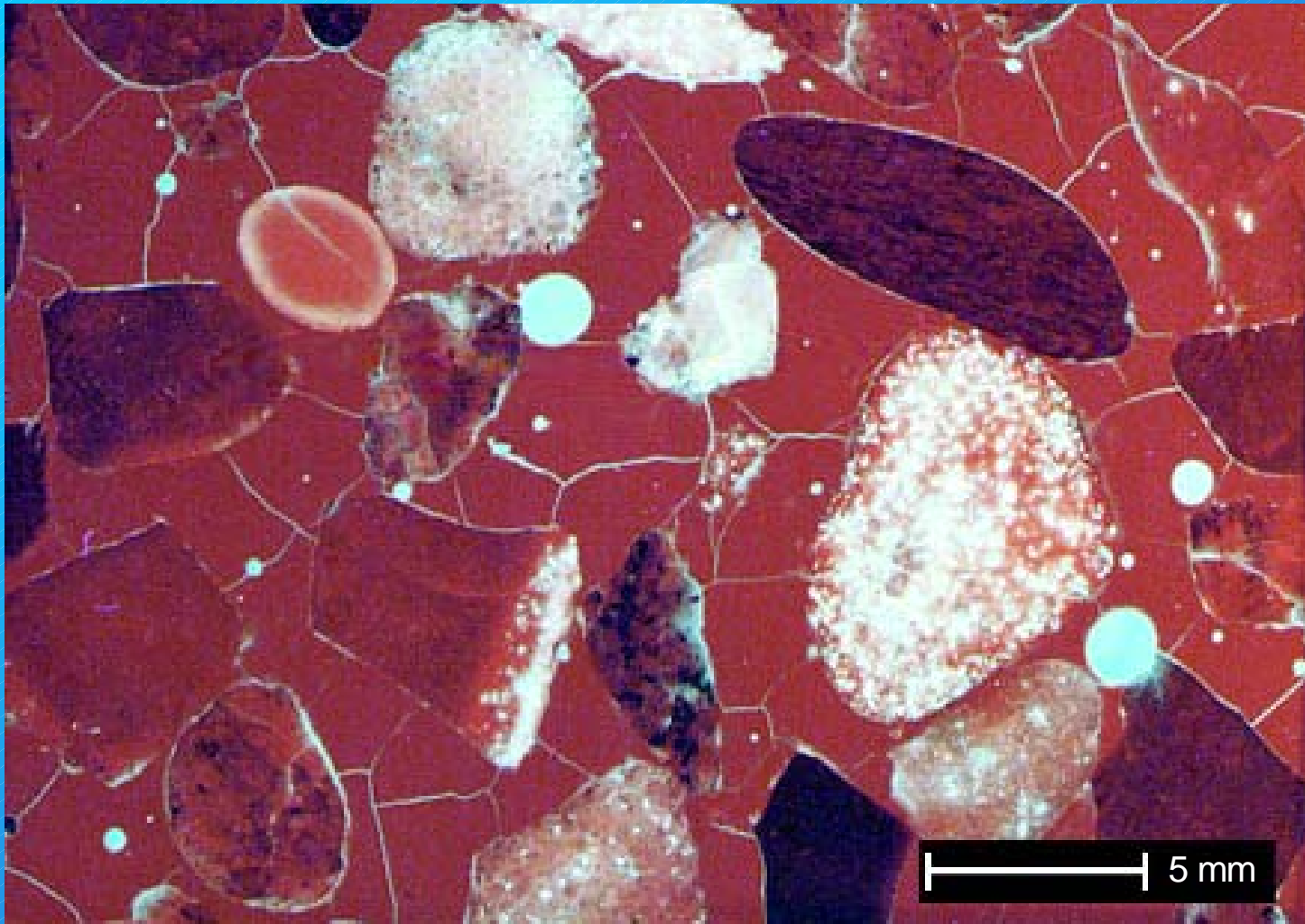
# Tensile strain capacity

Ultimate tensile strain ( $\mu\text{m}/\text{m}$ )



Time (h)

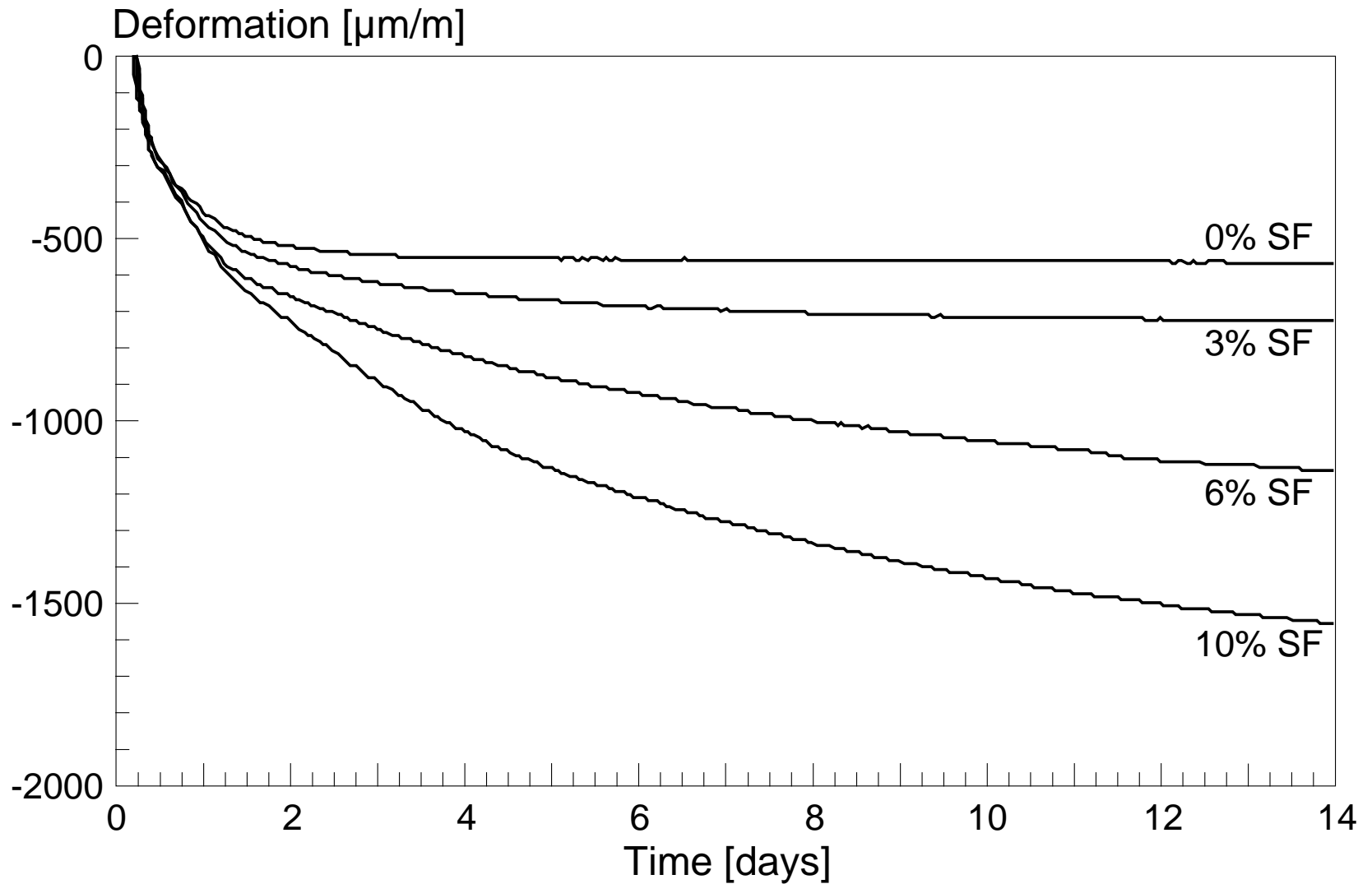
# Internal microcracking



*(Dela & Stang 2001)*



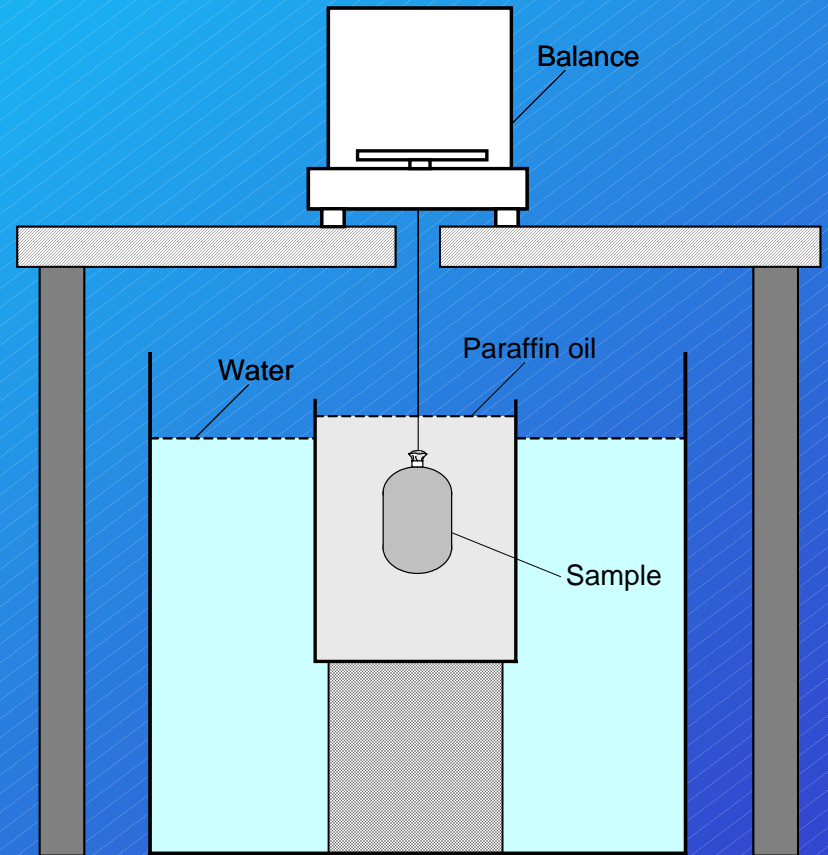
# Autogenous deformation



# Measurement techniques of AS

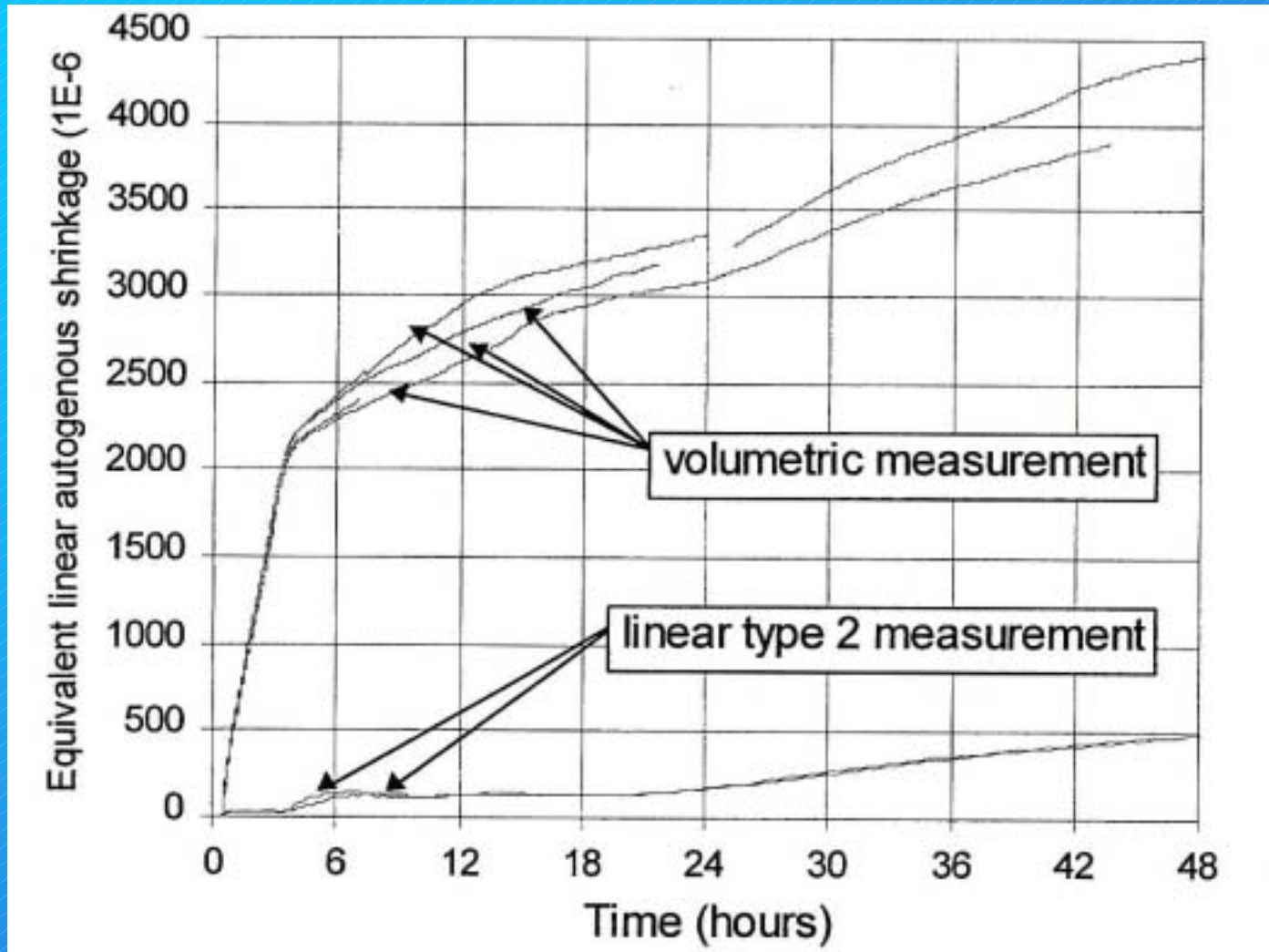
- Volumetric measurements
- Linear measurements

# Volumetric measurements



*(Justnes et al. 1996)*

# Volumetric vs. Linear - results

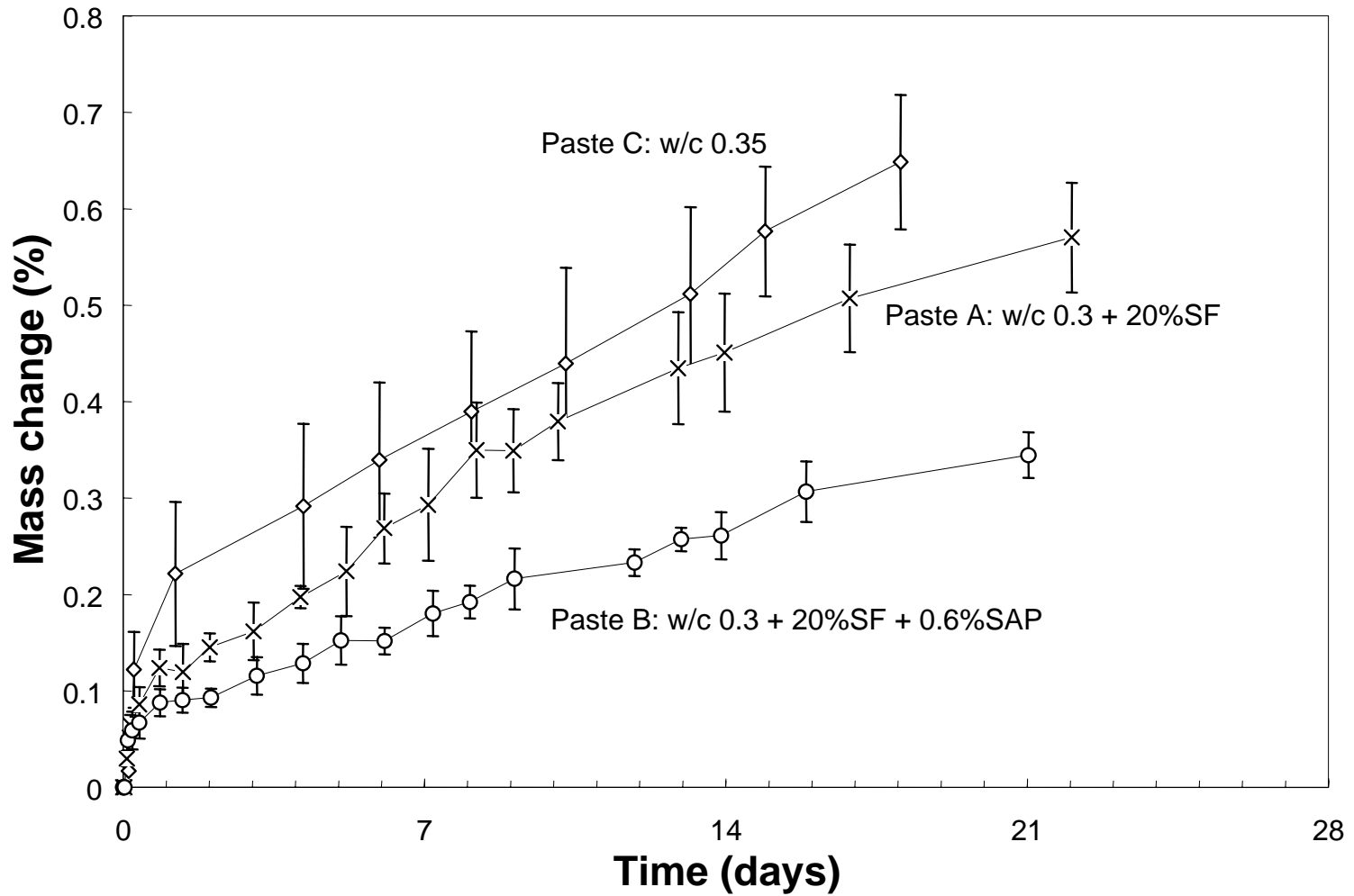


*(Barcelo et al. 1999)*

# Volumetric vs. Linear measurement

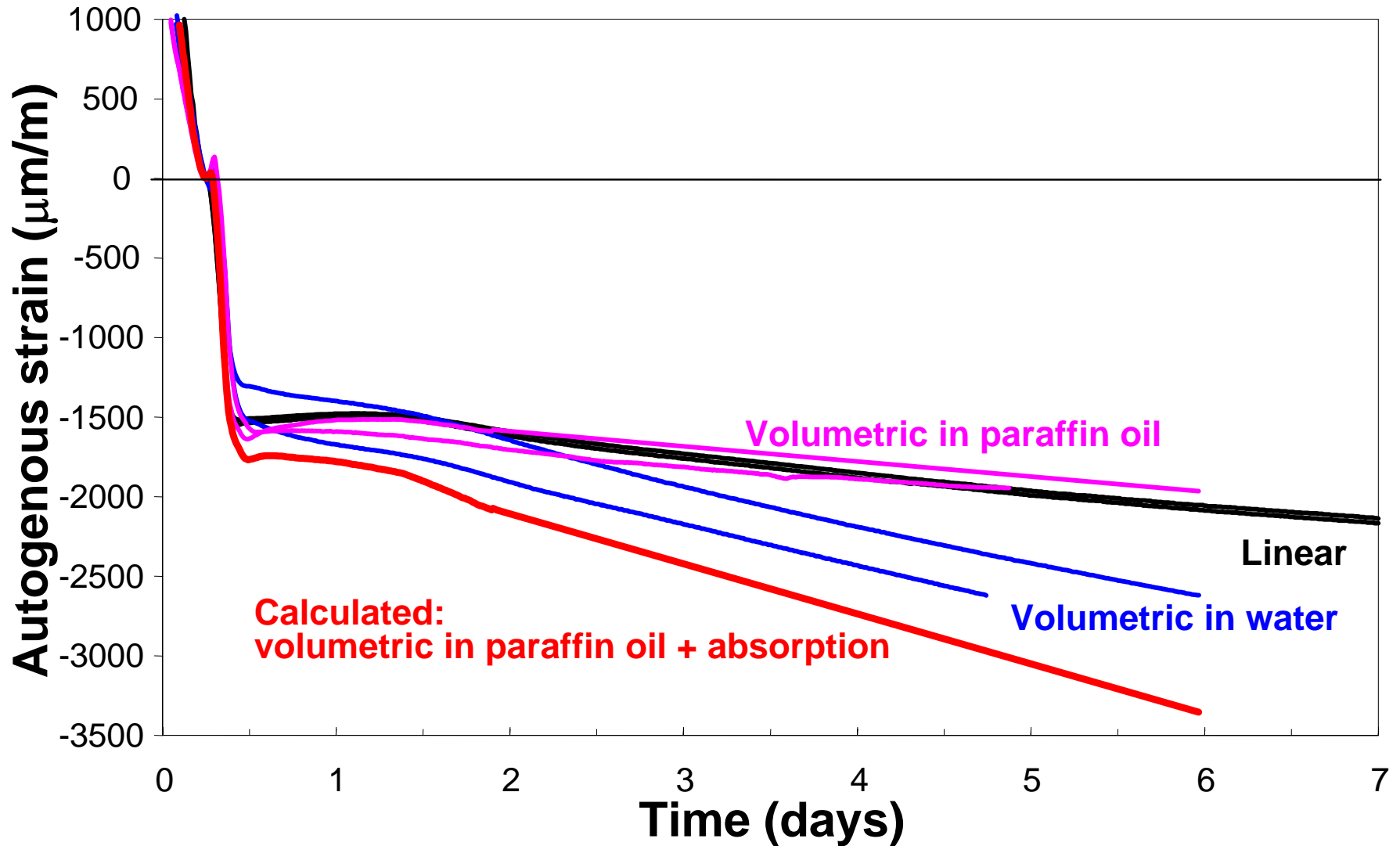
- Measured volumetric strain much greater
  - 70 years of disagreement!
- Few comparisons on same materials
- Many artifacts

# Absorption from water bath (1)



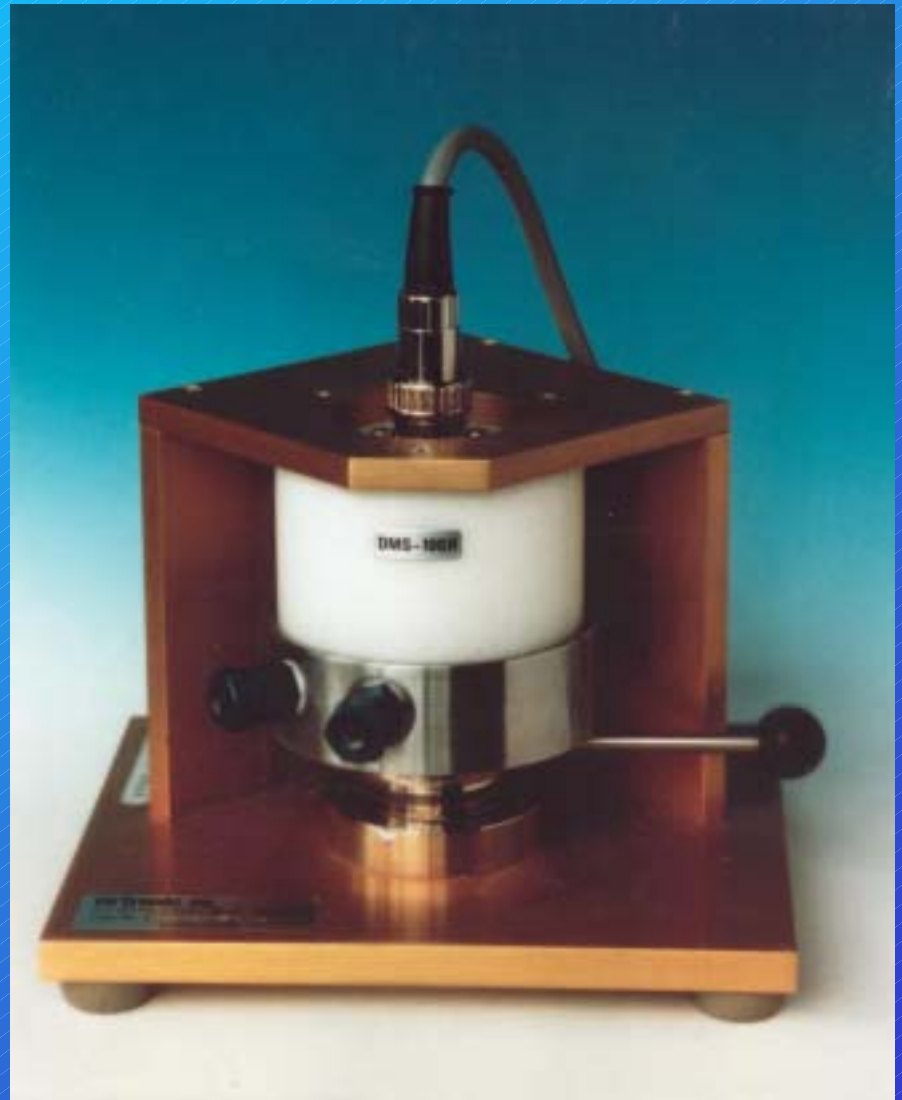
*Permeable membranes!*

# Absorption from water bath (2)



# Autogenous relative humidity

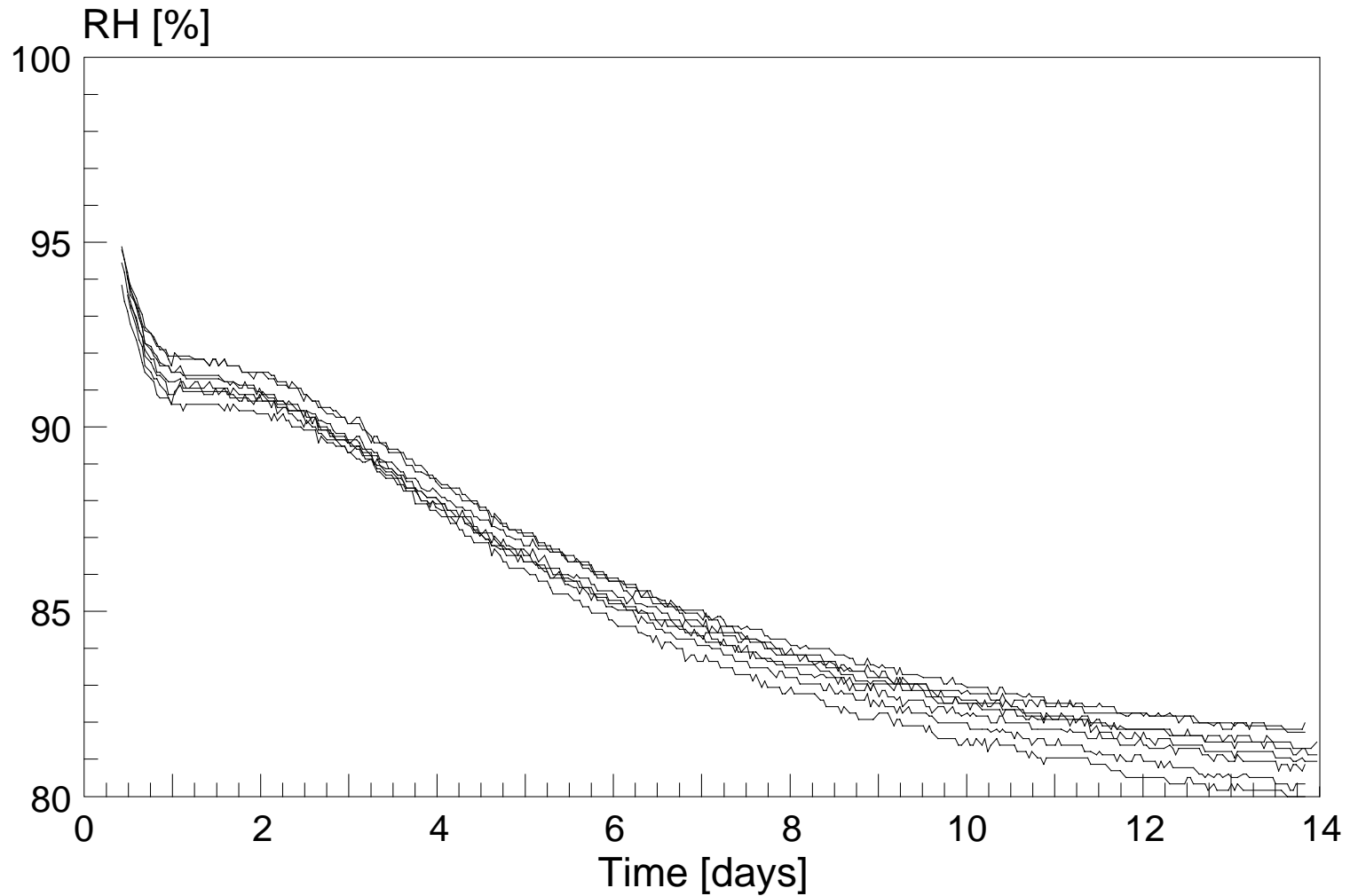
Rotronic  
Hygroscopt DT



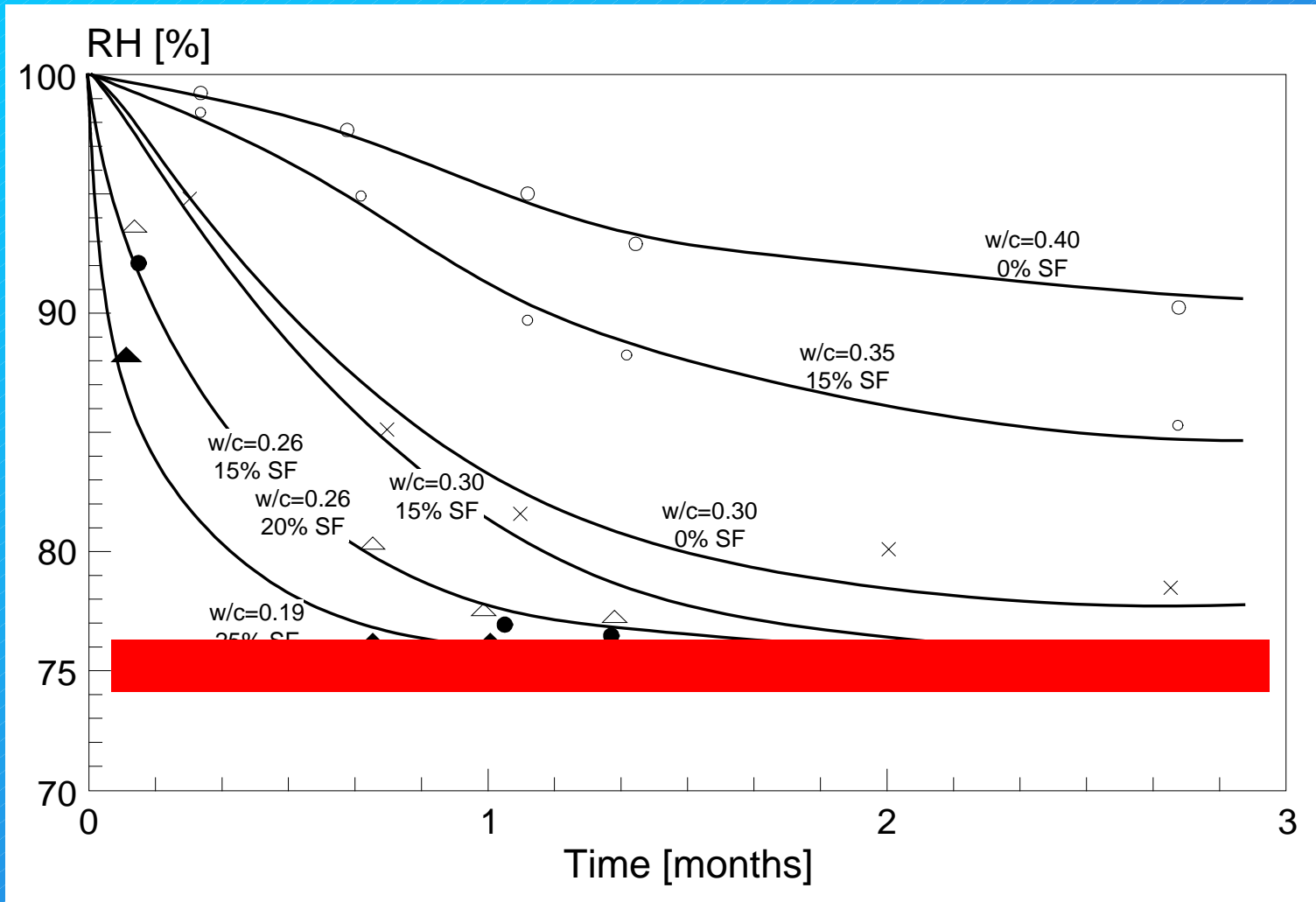
*(Jensen & Hansen 1988)*



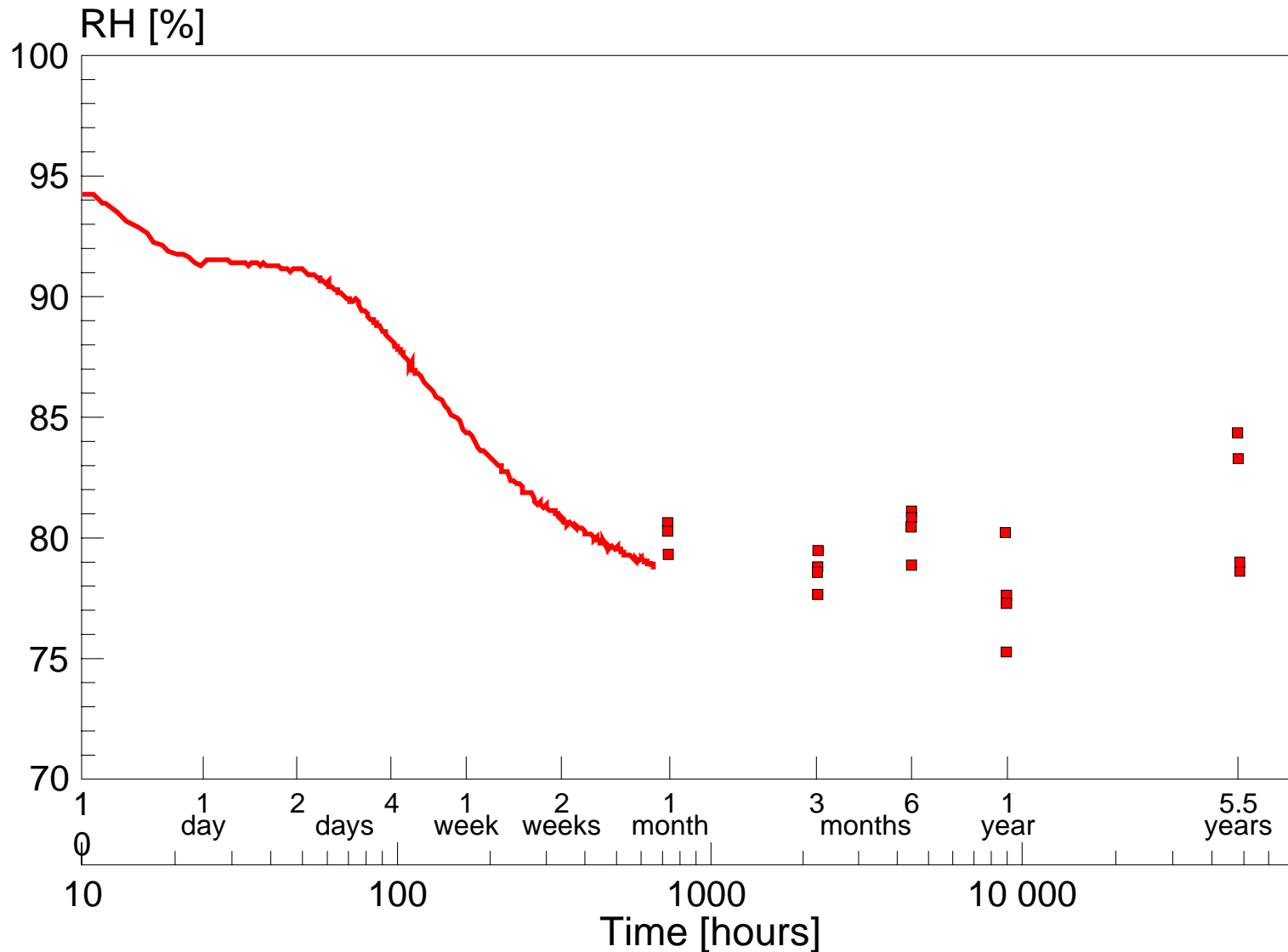
# Autogenous relative humidity



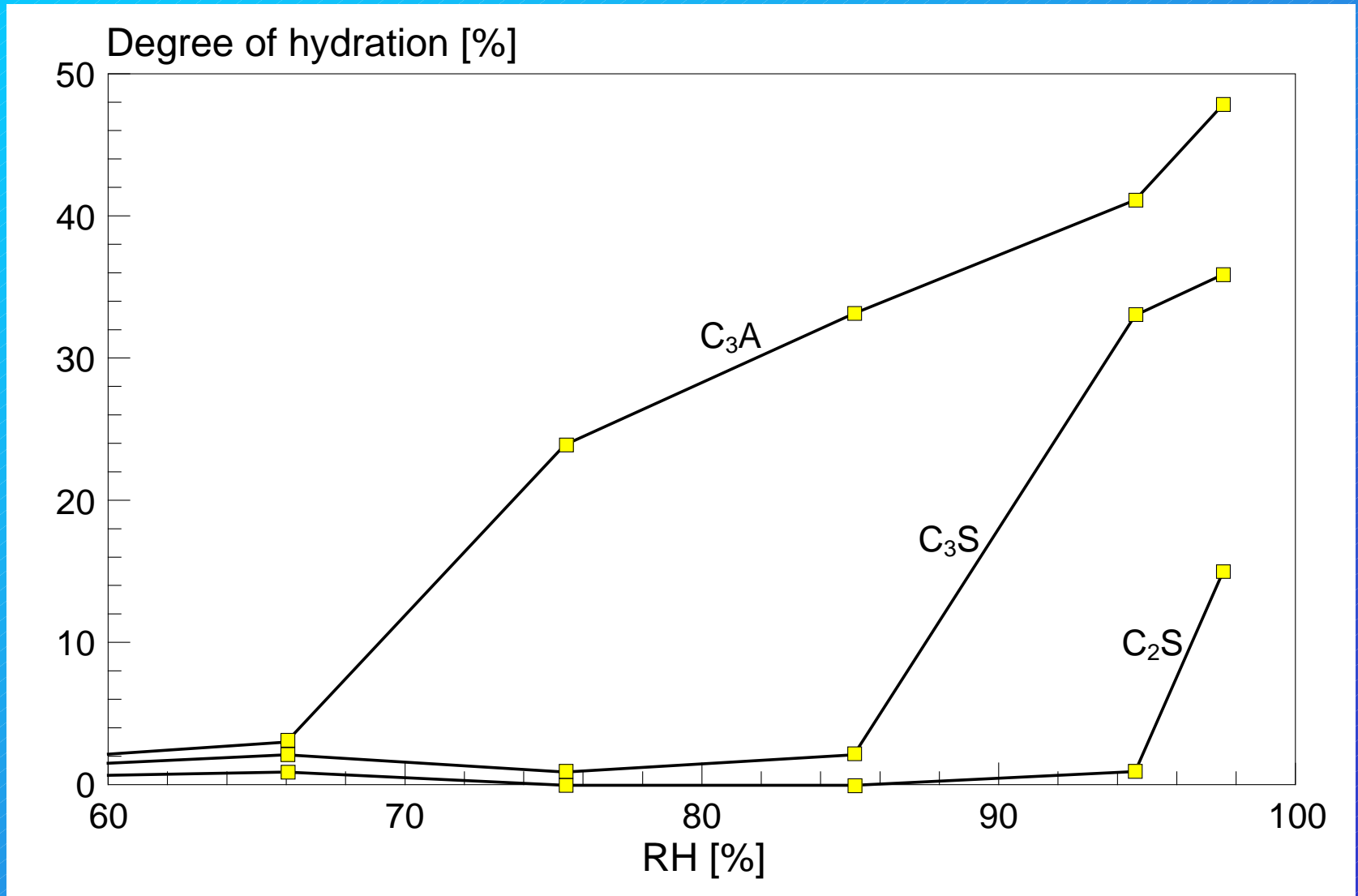
# Nature of autogenous RH



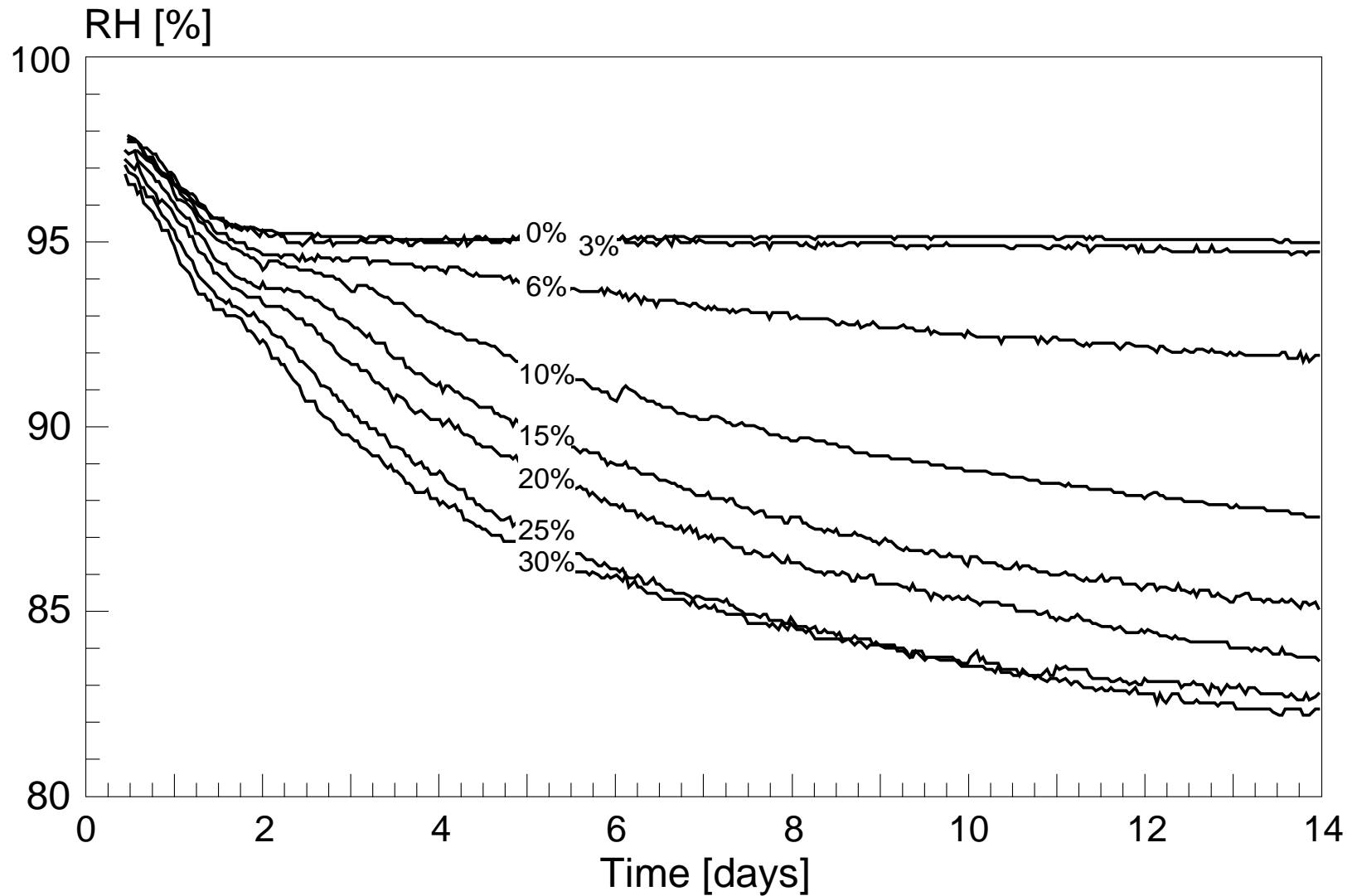
# Long term autogenous RH



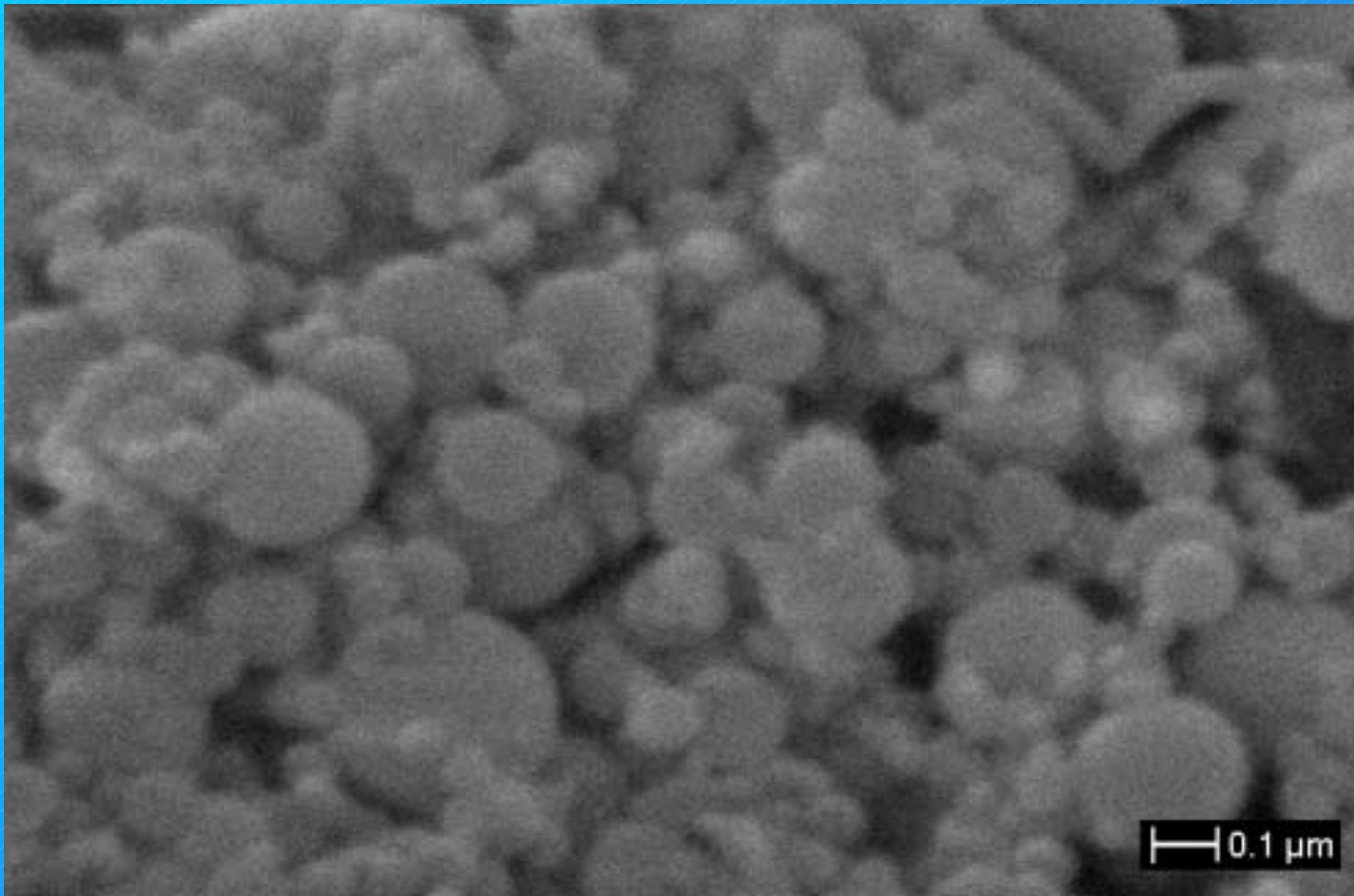
# Clinker mineral hydration at reduced RHs



# Autogenous relative humidity

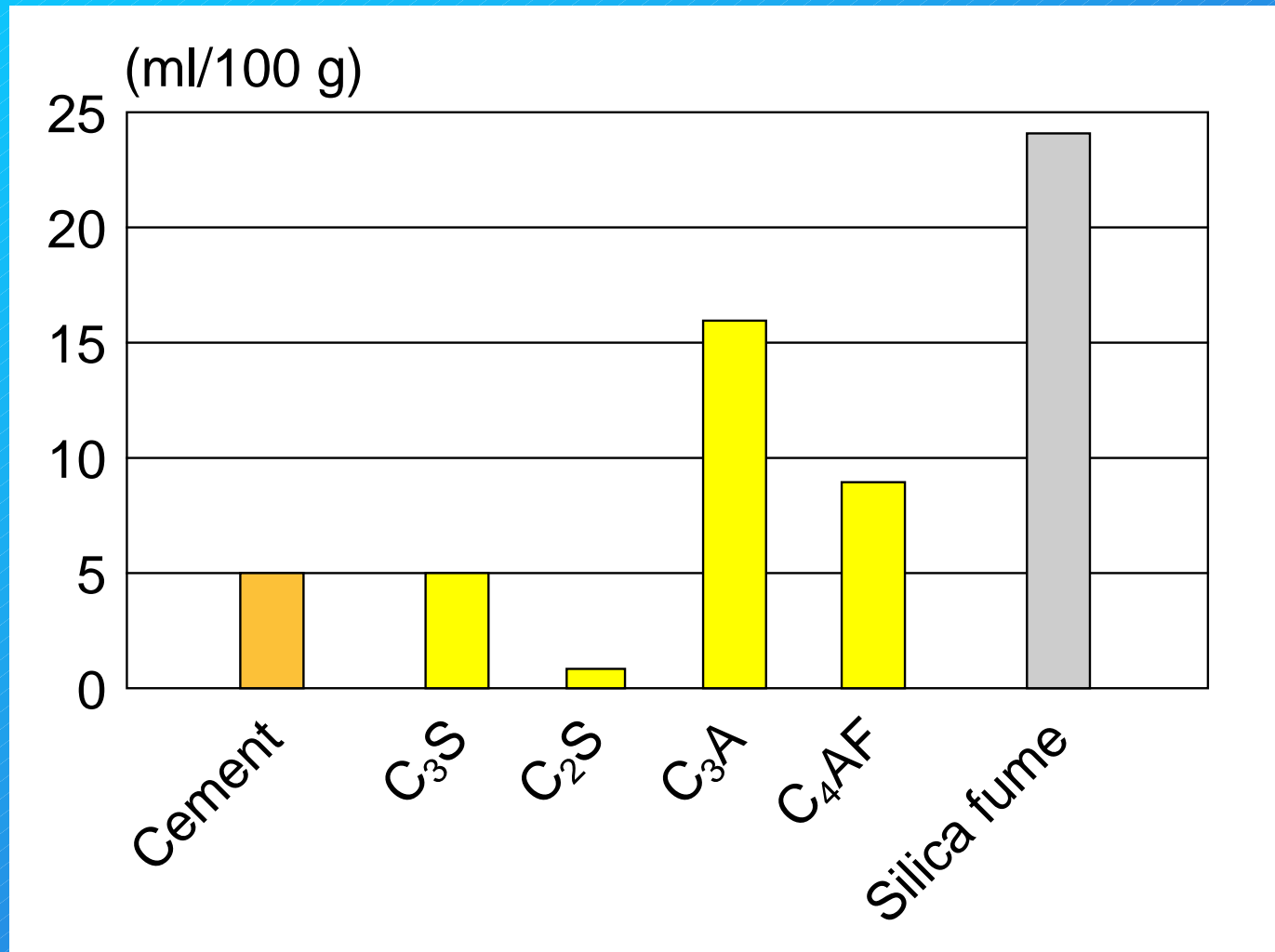


# Silica fume

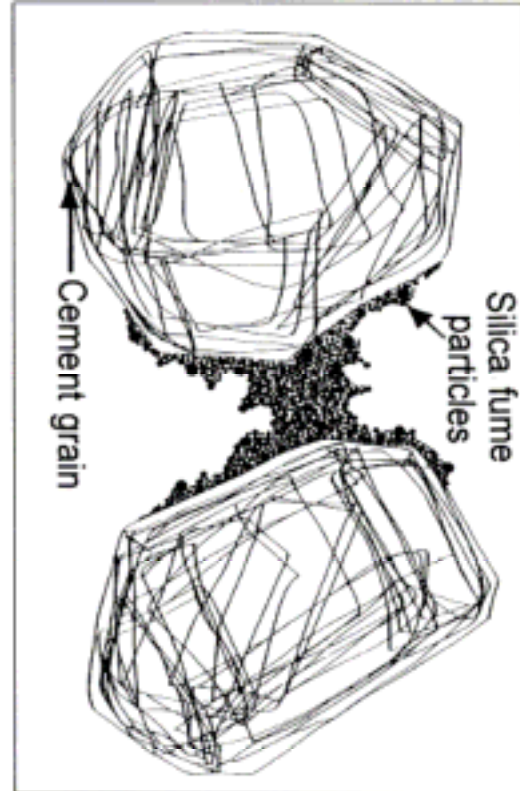
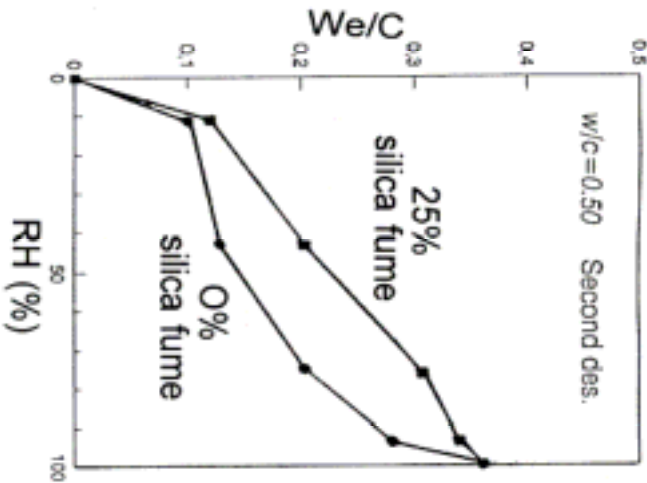
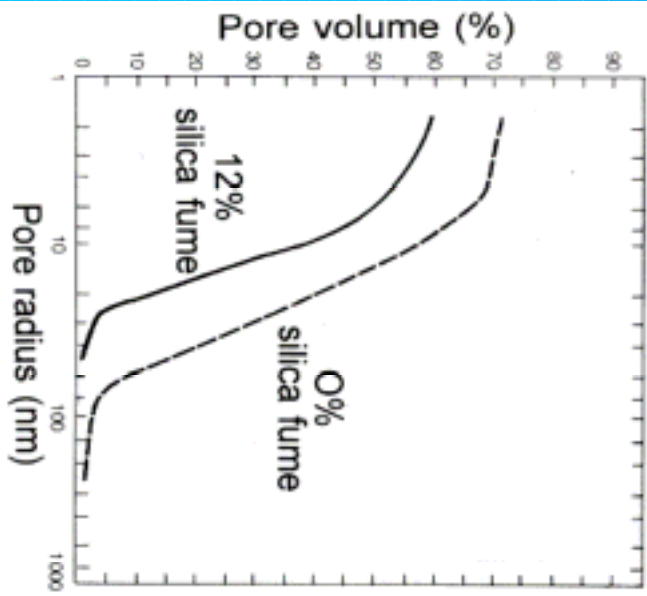


Almost pure, amorphous  $\text{SiO}_2$   
Typical particle size:  $0.1 \mu\text{m}$

# Chemical shrinkage of components



# Effect of silica fume





# Approximate reaction equations

- Alite:



- Belite:



- Aluminate phase:



- Ferrite phase:



- Silica fume:



# Long term component reaction

