SSCS 2012 Conference
Numerical Modeling Strategies for Sustainable Concrete Structures
29 May – 1 June 2012, Aix-en-Provance, France

DEGRADATION OF THE MECHANICAL PROPERTIES IN ASR-AFFECTED CONCRETE: OVERVIEW & MODELING

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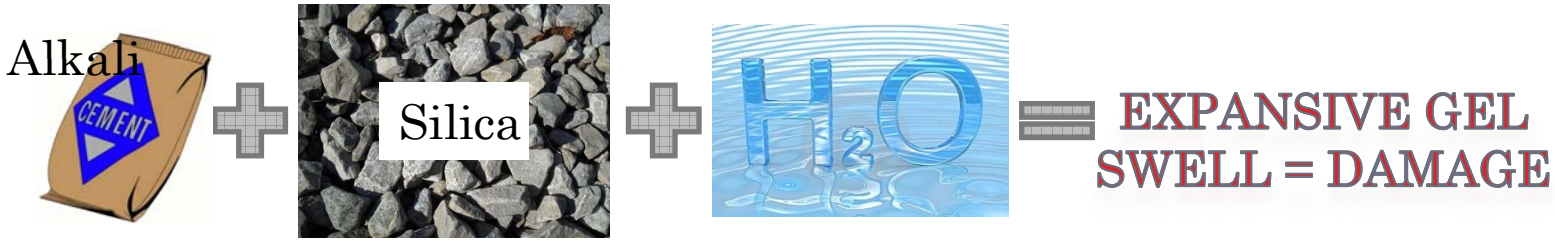
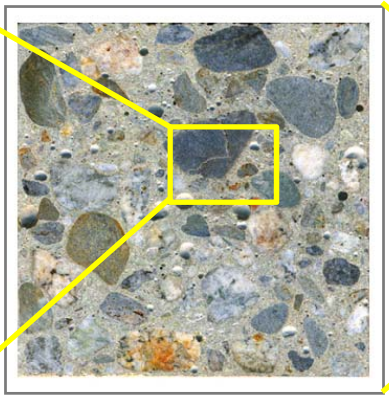
TU Delft Delft University of Technology

ALKALI-SILICA REACTION (ASR)

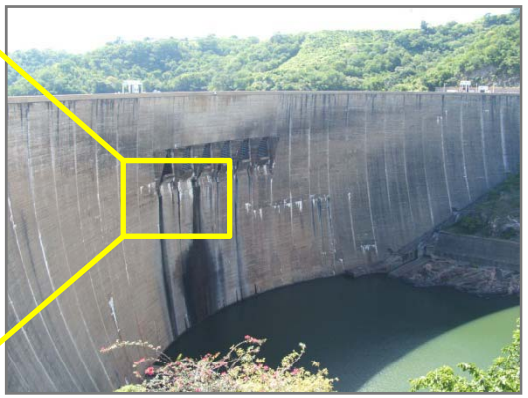


MICRO level

MESO level

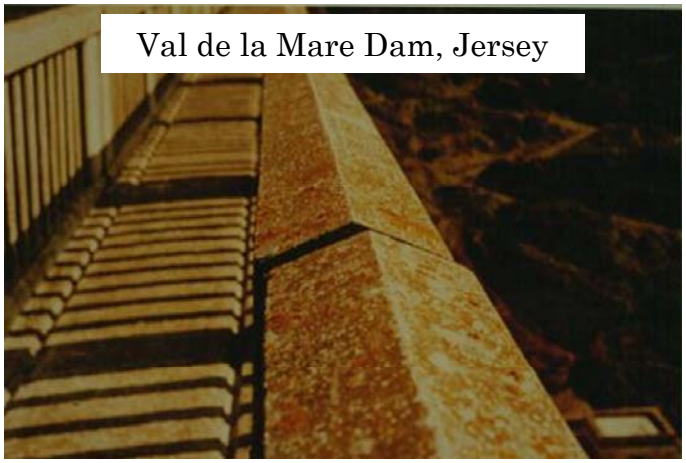


MACRO level



DIFFERENT Points of view

STRUCTURAL ASPECTS



Val de la Mare Dam, Jersey

Montigny Viaduct, Schoonhoven, The Netherlands

Displacements
Deformation
Cracks

→ Loss of Capacity
Loss of Durability

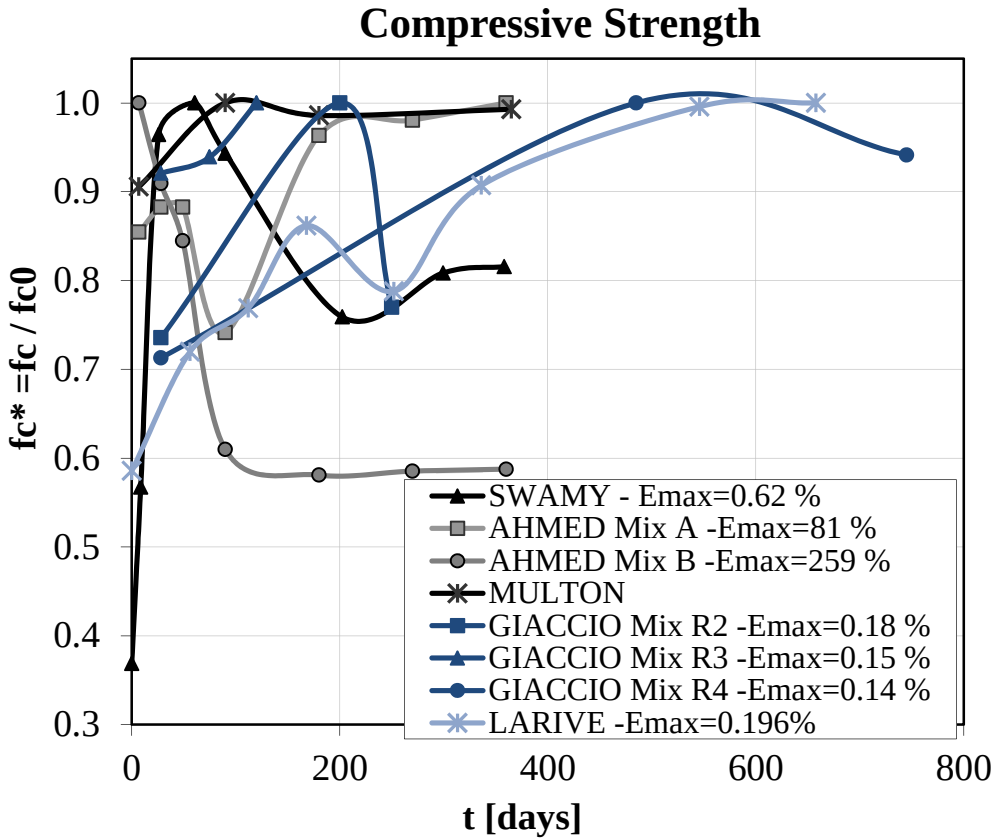
EXPERIMENTS

Test	Conditions	Young's Modulus	Dynamic Modulus Elasticity	Direct Tensile Strength	Indirect Tensile Strength	Modulus of Rupture	Compressive Strength
Swamy	365 days at 23ºC and RH = 96 %		X		X	X	X
Larive	14 days in aluminum foils at 23ºC 386 days in high humidity at 38ºC	X			X		X
Ahmed - Mix A	28 days in water at 20ºC 337 day in water at 38ºC	X		X	X	X	X
Ahmed - Mix B	28 days in water at 20ºC 337 day in water at 38ºC	X		X	X	X	X
Giaccio - Mix R2	1 day in cotton sheet at 21ºC 745 days in water at 38ºC	X					X
Giaccio - Mix R3	1 day in cotton sheet at 21ºC and 745 days in water at 38ºC	X					X
Giaccio - Mix R4	1 day in cotton sheet at 21ºC and 745 days in water at 38ºC	X					X
Multon	14 days in aluminum foils at 38ºC 730 day in water at 38ºC	X			X		X

T = 38 °C
High humidity
Free expansion

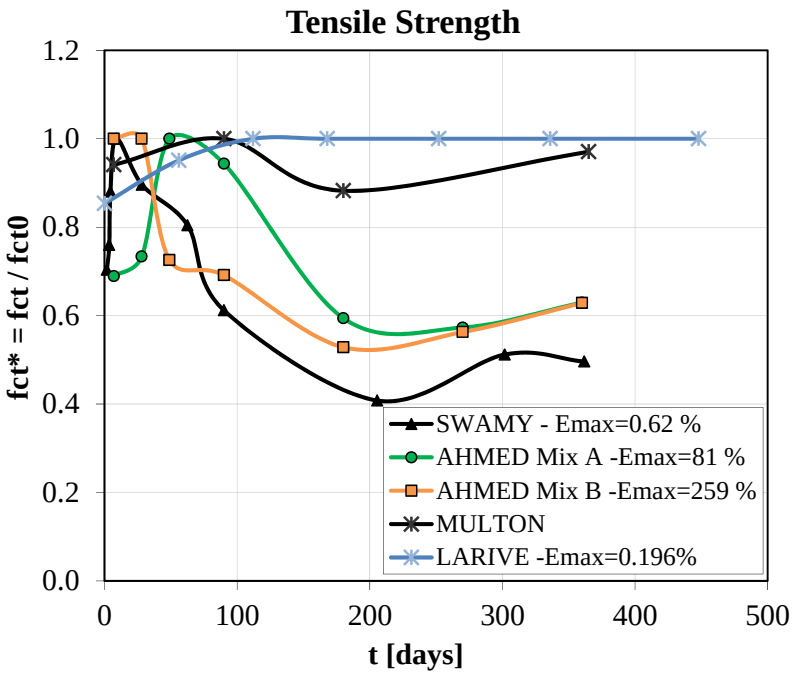
Young's Modulus &
Compressive Strength

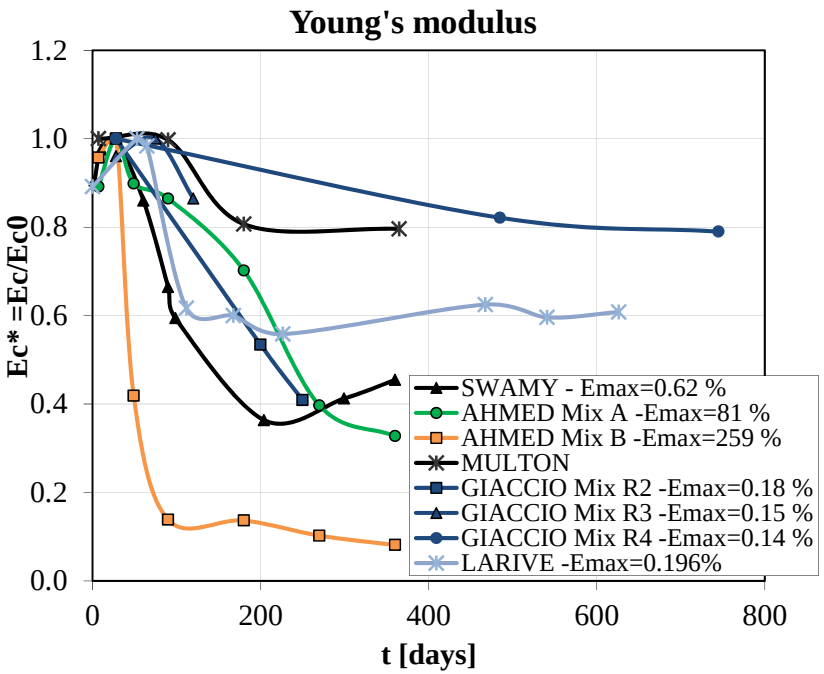
COMPRESSIVE STRENGTH



f_c is not a good indicator to detect the reaction

TENSILE STRENGTH & STIFFNESS

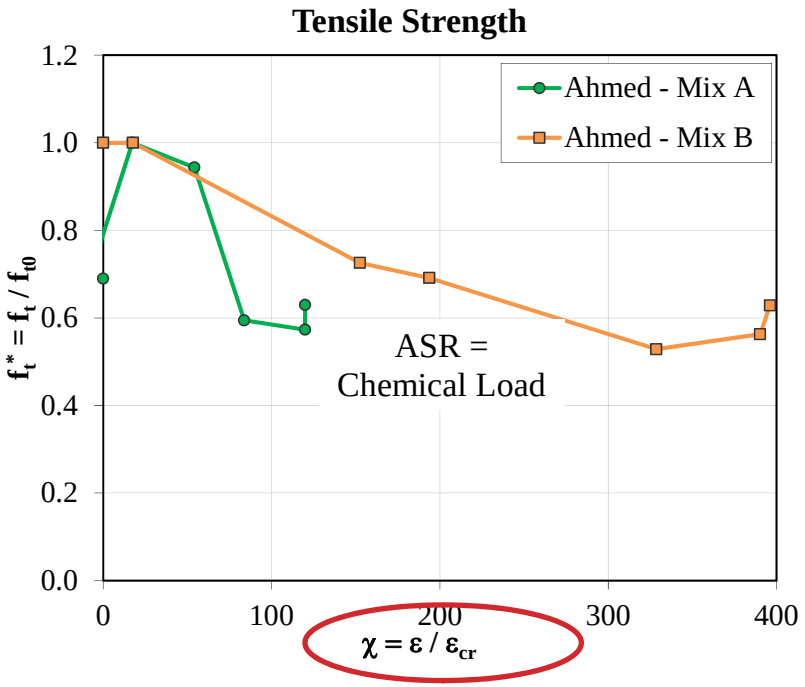


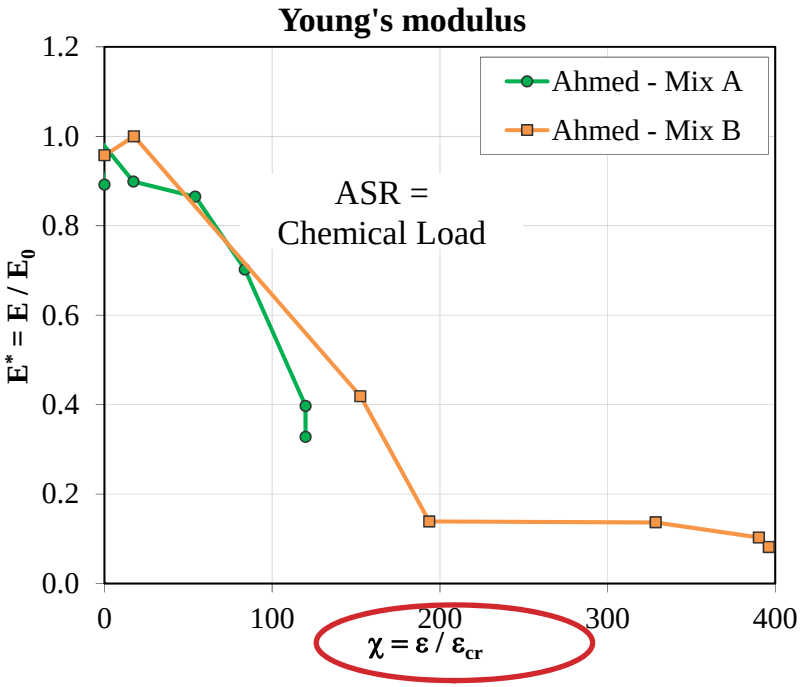


Reduction of Tensile Strength

Reduction of Young's Modulus

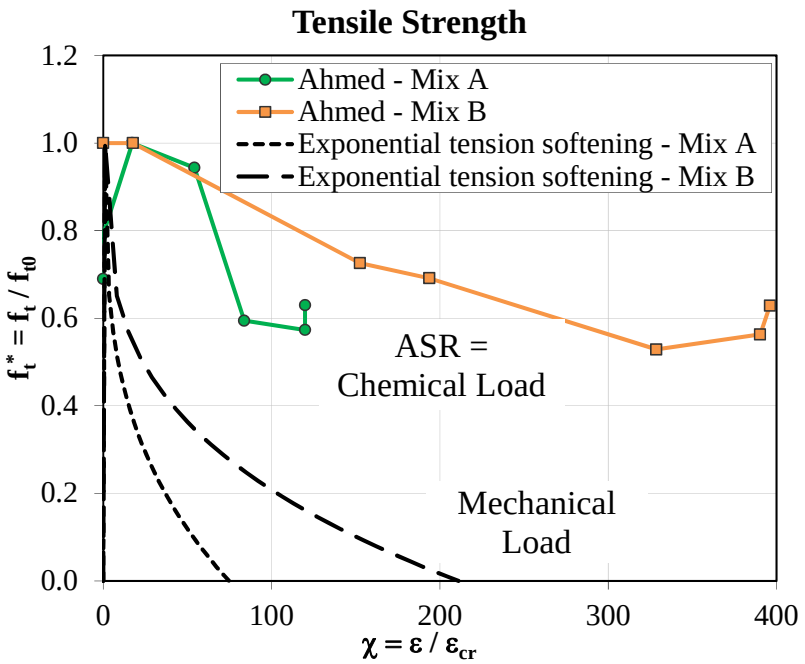
SOUND & ASR-AFFECTED CONCRETE

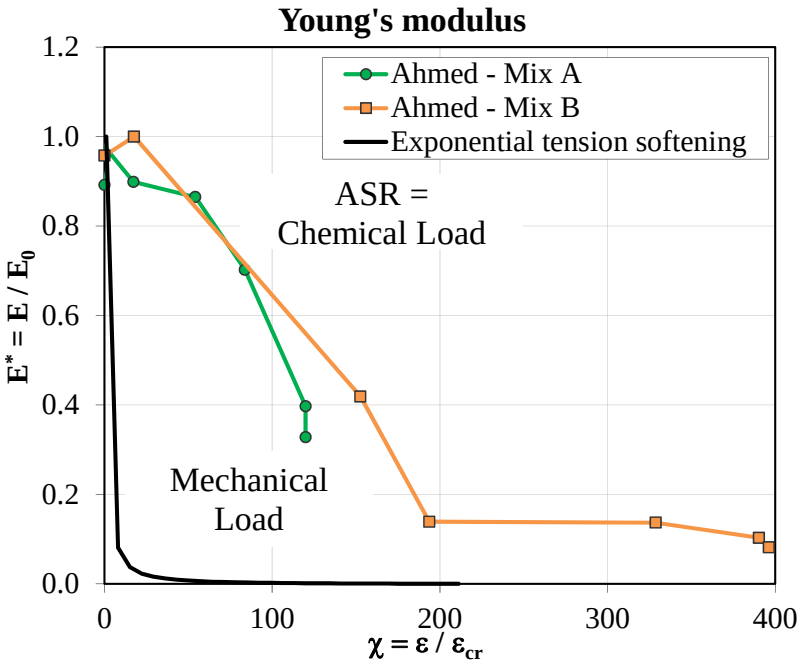




$$\chi = \frac{\varepsilon}{\varepsilon_{cr}} = \frac{current\ \ strain}{strain\ \ at\ \ onset\ \ of\ \ cracking}$$

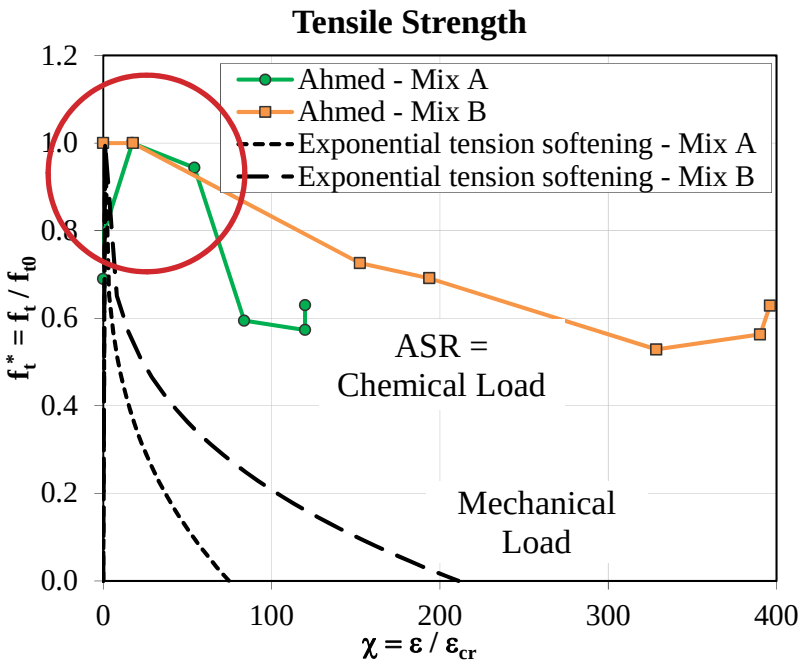
SOUND & ASR-AFFECTED CONCRETE

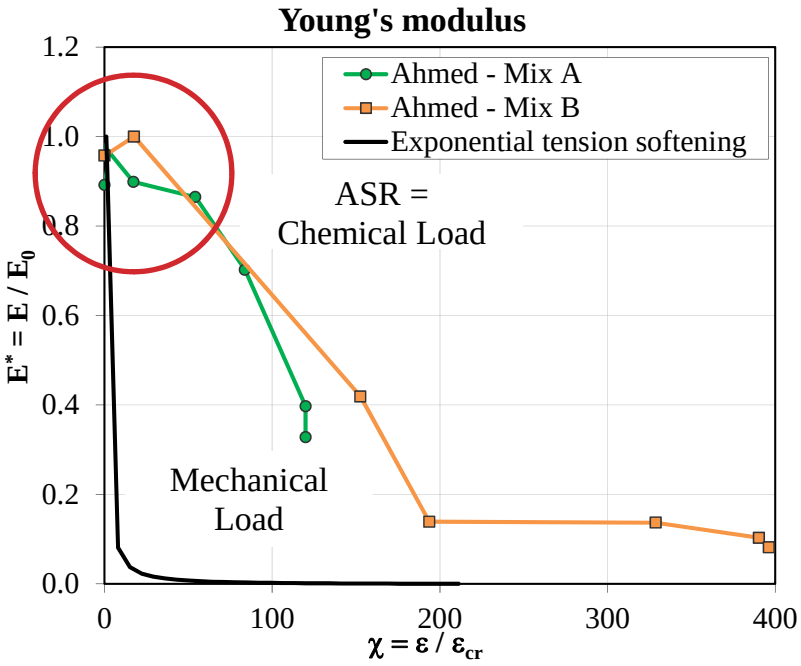




Chemical Load = ASR-affected concrete in free expansion
Mechanical Load = sound concrete under mechanical load

SOUND & ASR-AFFECTED CONCRETE

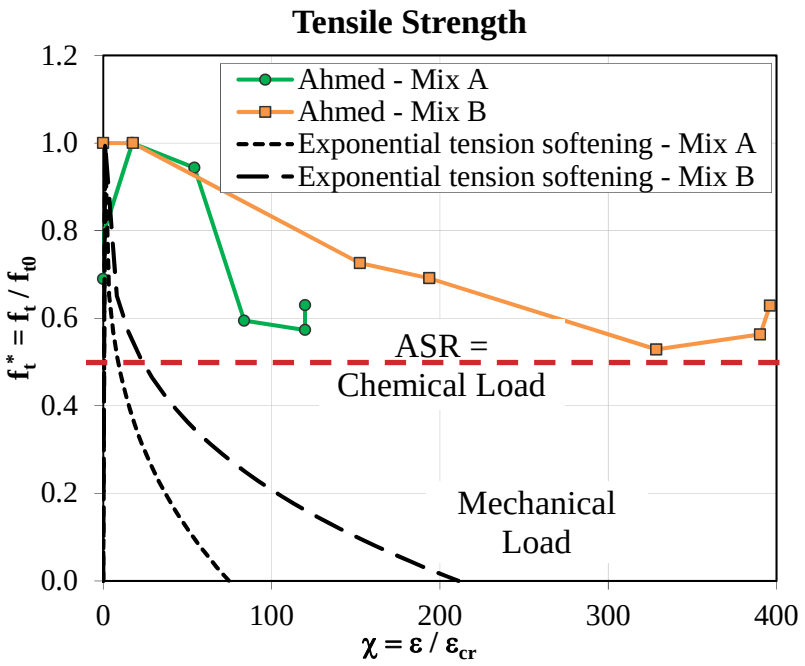


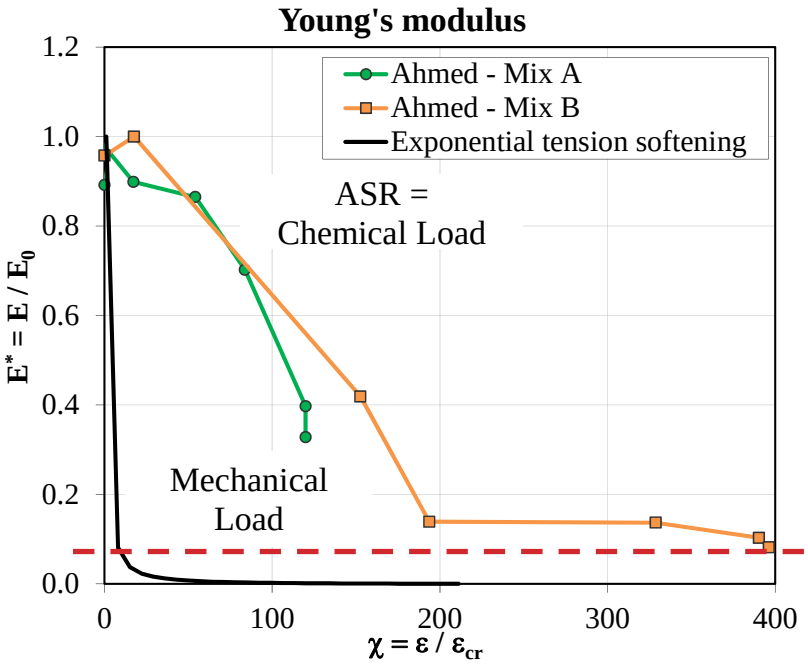


Reduction of Tensile Strength

Reduction of Young's Modulus

SOUND & ASR-AFFECTED CONCRETE





Reduction of Tensile Strength

Reduction of Young's Modulus

STRUCTURAL MODELS

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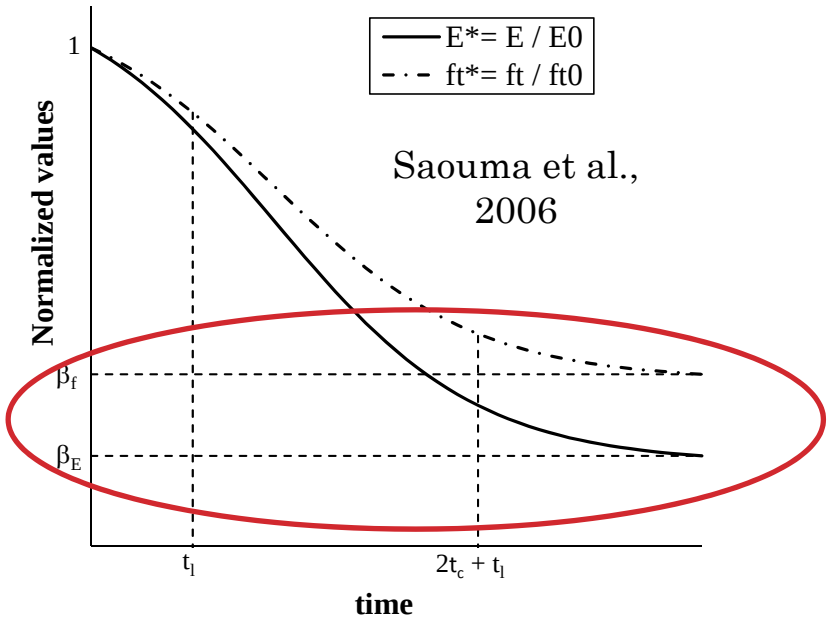
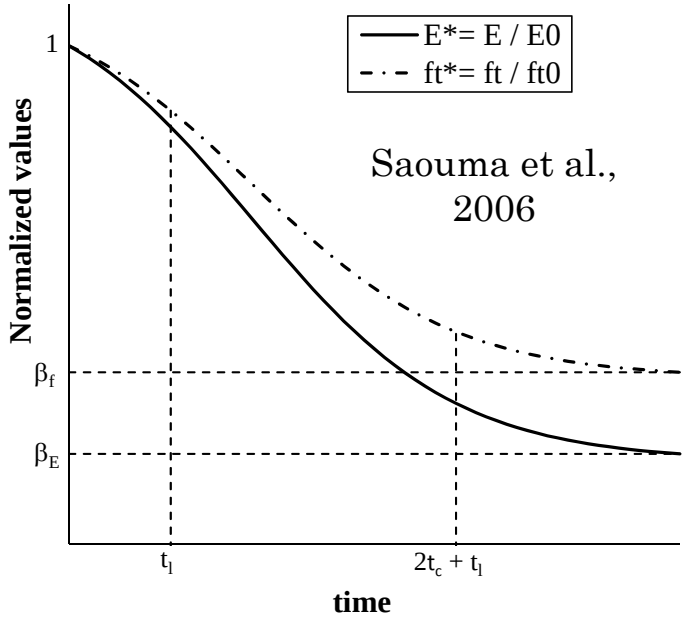
Reduction of Tensile Strength and Young's Modulus

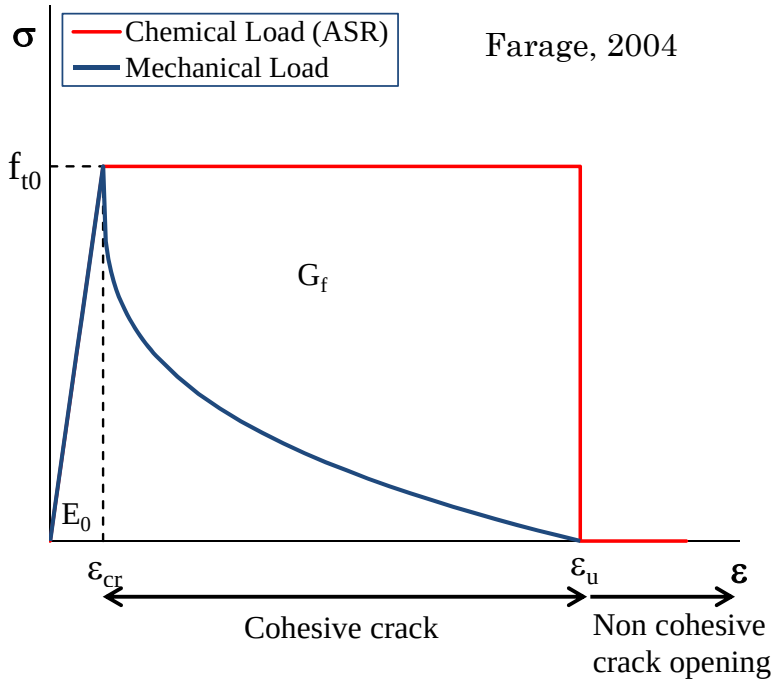
STRUCTURAL MODELS



Reduction of Tensile Strength and Young's Modulus

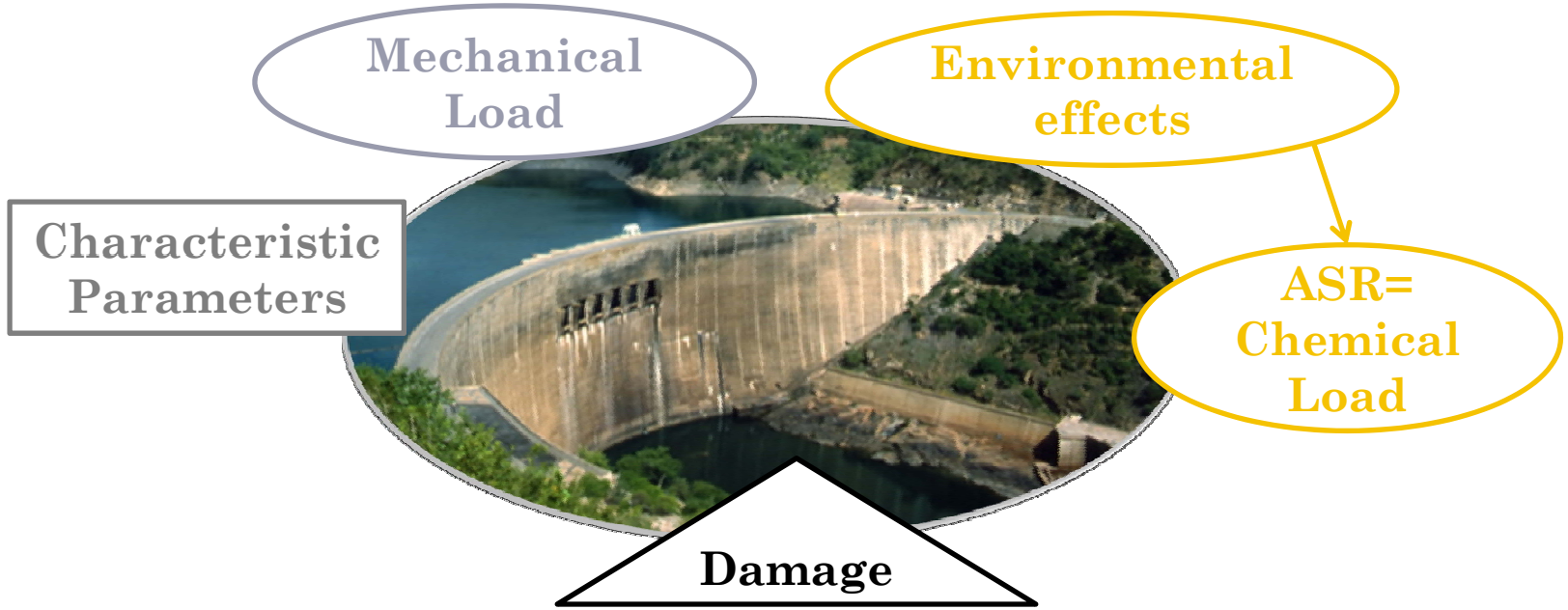
STRUCTURAL MODELS





Reduction of Tensile Strength and Young's Modulus

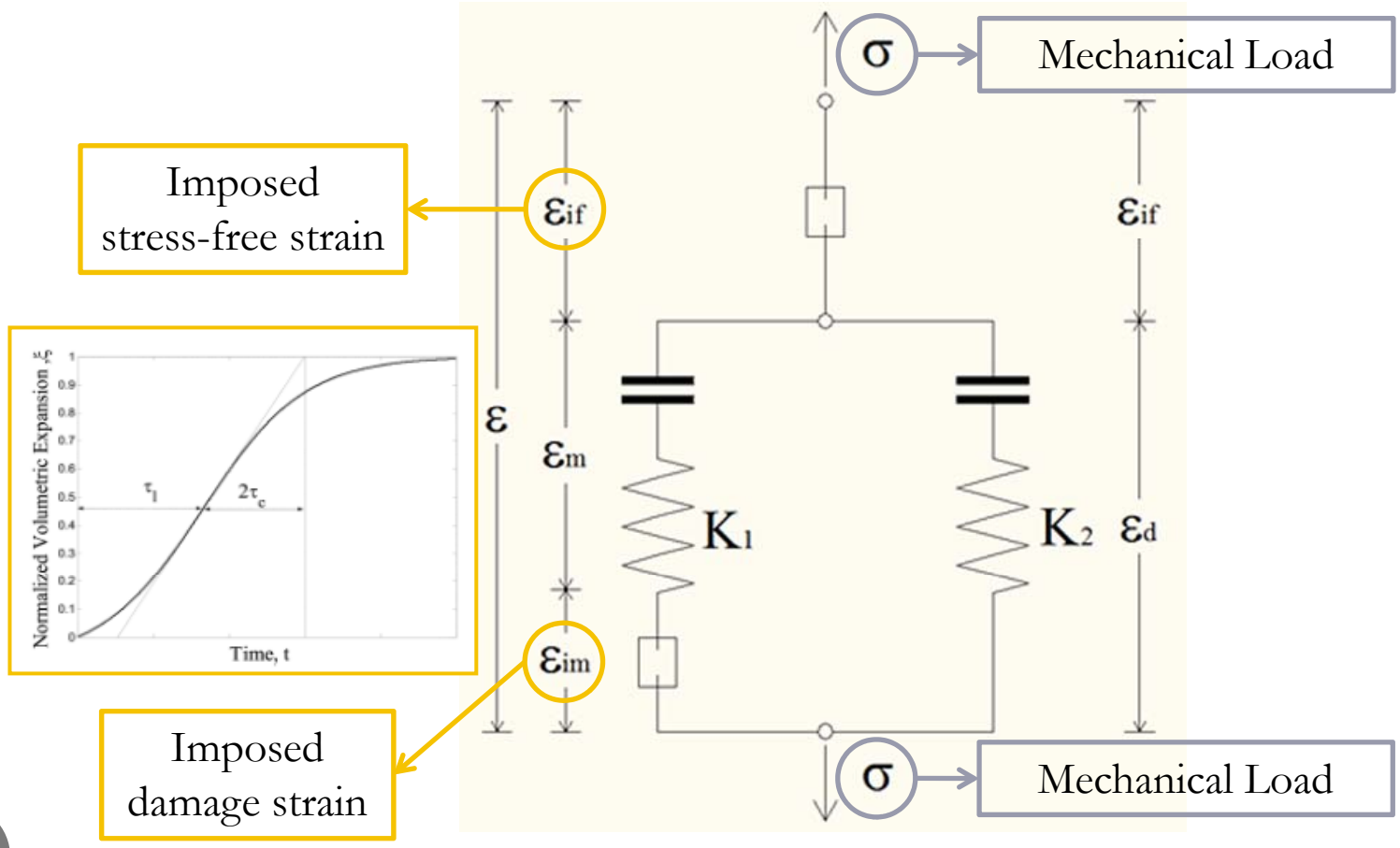
PROPOSED MODEL



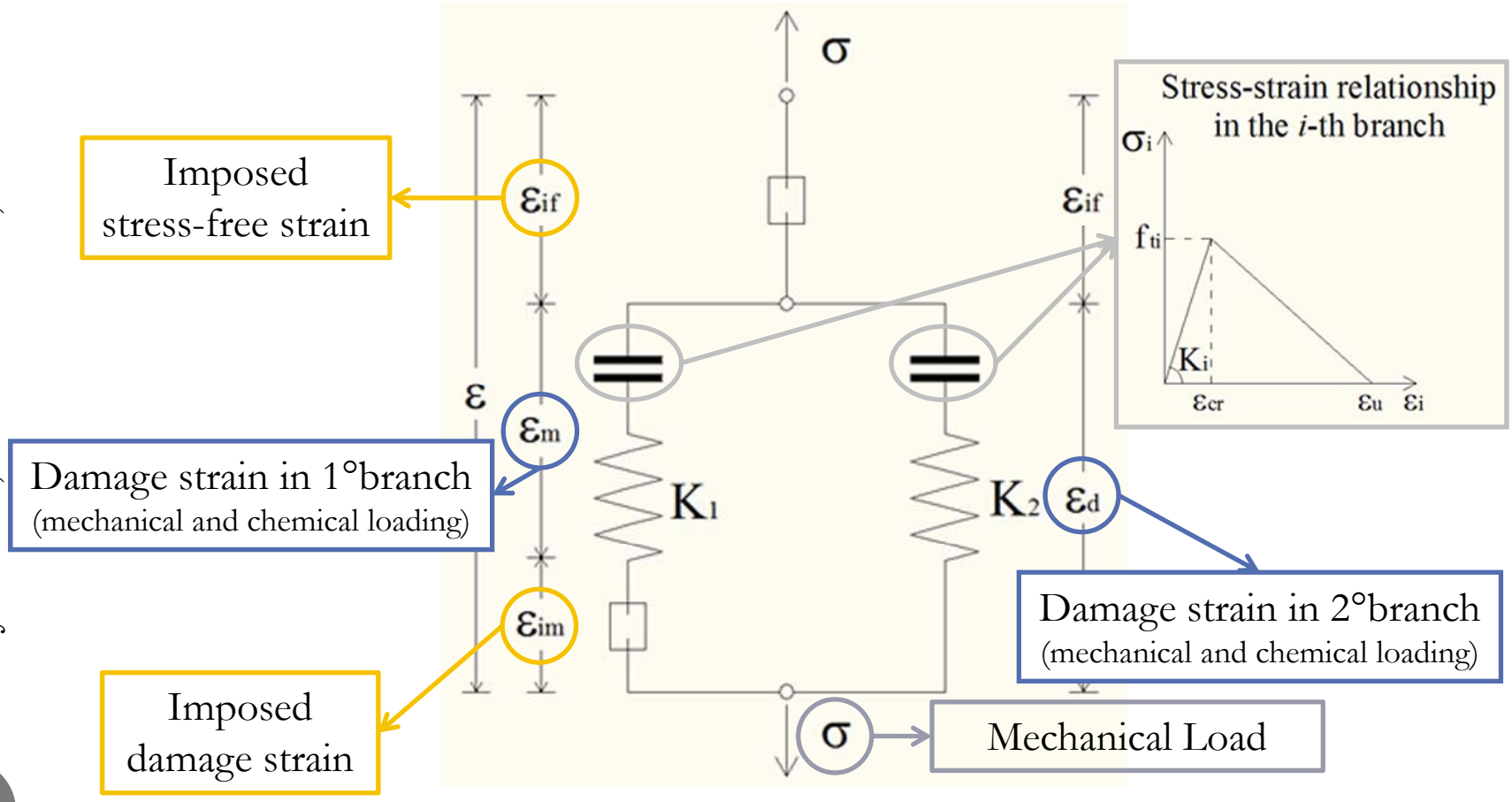
Model suitable for:

- Only Mechanical Load
- Only Chemical Load (ASR swelling)
- **Mechanical Load + Chemical Load**

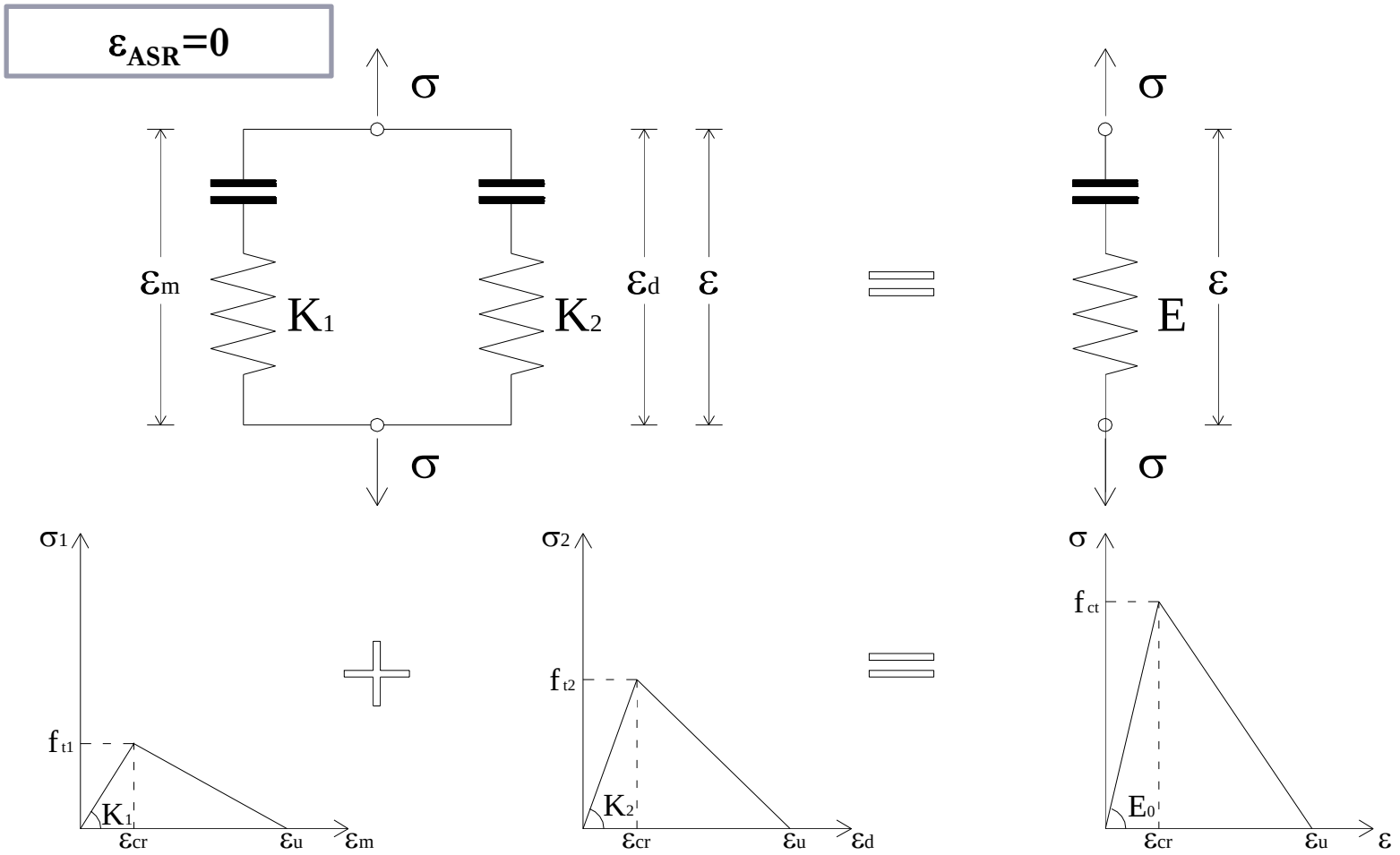
1D Rheological Model



1D Rheological Model

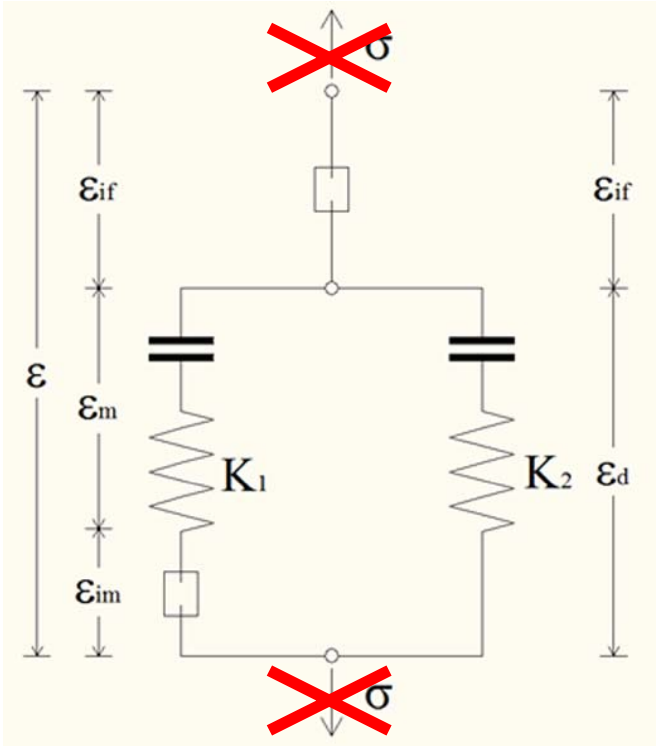


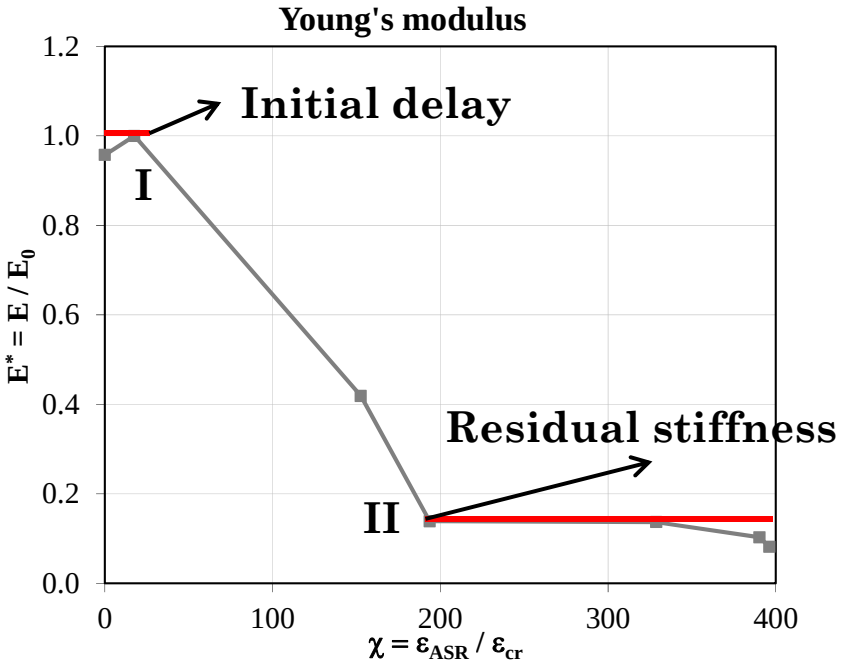
SOUND CONCRETE UNDER MECHANICAL LOAD



ASR-Affected Concrete in Free Expansion

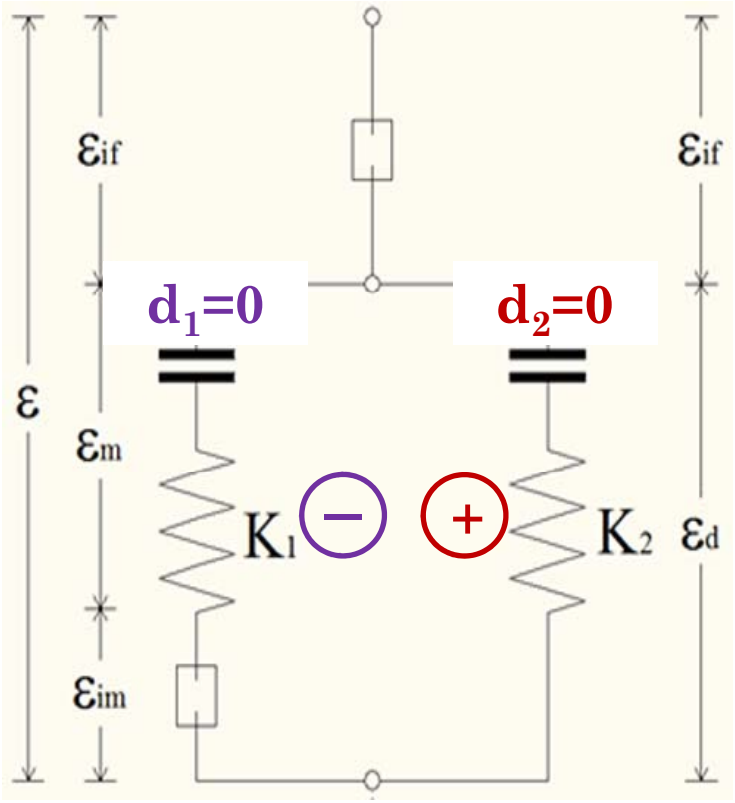
$\sigma=0$ and $\varepsilon=\varepsilon_{ASR}$

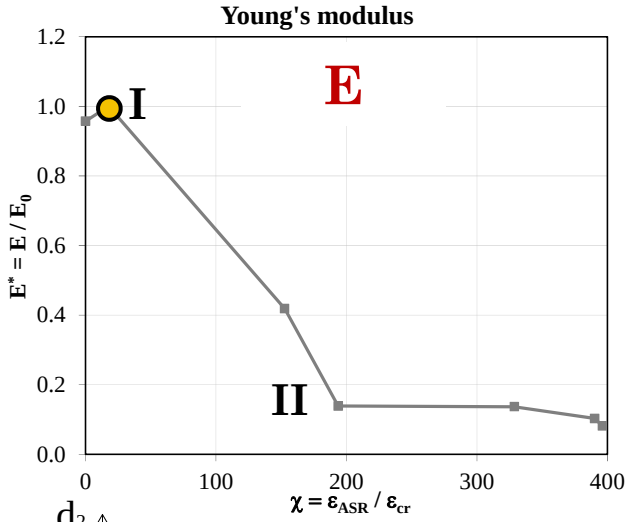


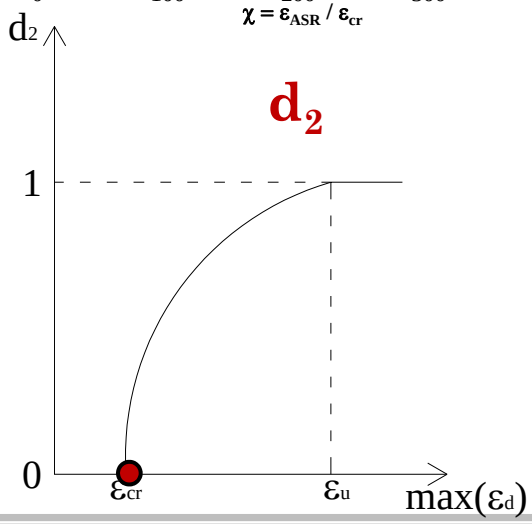


ASR-Affected Concrete in Free Expansion

$\varepsilon=\varepsilon^{I}_{ASR}$

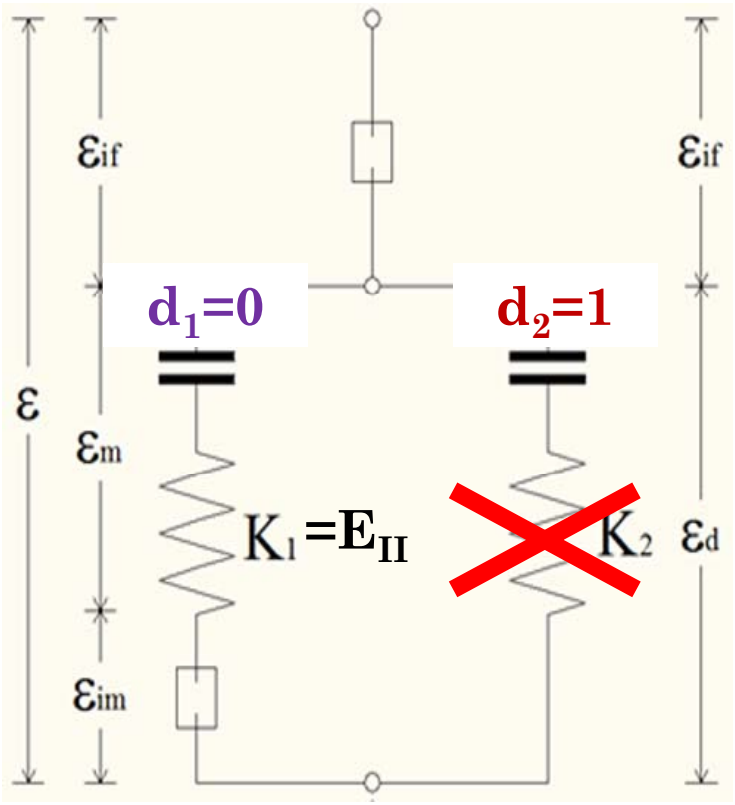


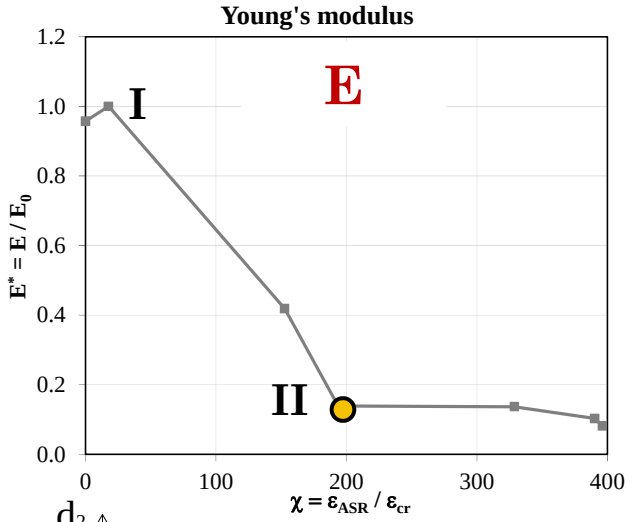


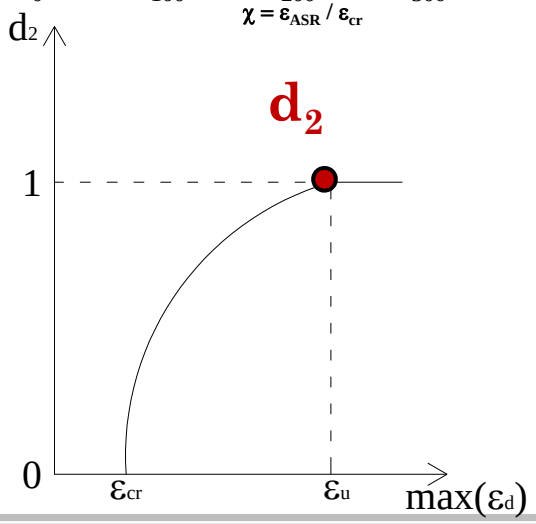


ASR-Affected Concrete in Free Expansion

$\varepsilon = \varepsilon^{II}_{ASR}$

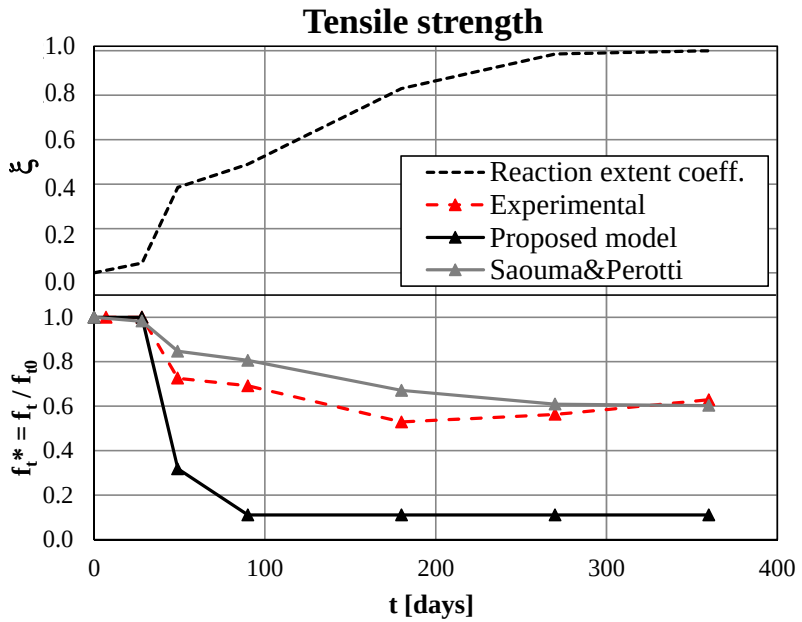


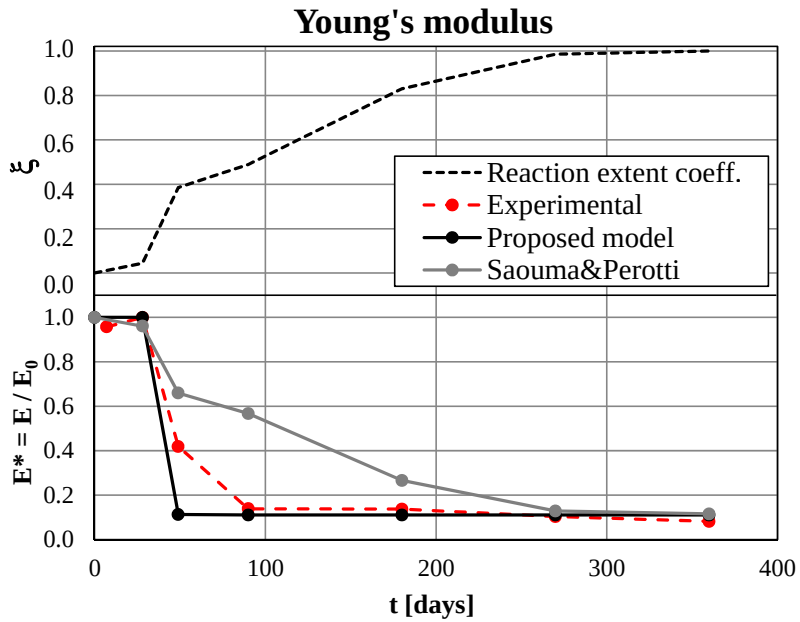




APPLICATION

Ahmed - Mix B





Prediction of Tensile Strength

Prediction of Young's Modulus

ENHANCEMENT OF THE MODEL

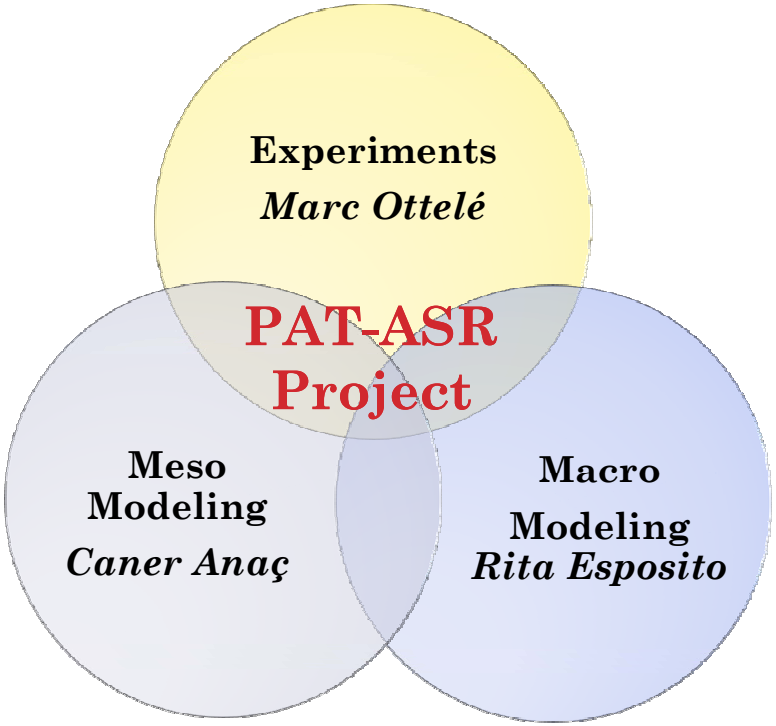
Poromechanics Theory
(Lemarchand & co-workers)

- Understanding the different damage process due to mechanical and chemical loads
- Understanding the different behavior of stiffness and strength
- Modeling the swelling with a more realistic preassure driven approach
- Linking the micro and macro aspects of the problem

CONCLUSIONS

- The degradation of the mechanical properties as well as of the microstructures evolution should be further investigated.

PERFORMANCE ASSESSMENT TOOL FOR ASR



Project Leader: **O. Çopuroğlu**
Supervisors: **M.A.N. Hendriks, E. Schlangen**
PhDs, PD: ***C. Anaç, R. Esposito, M. Ottelé***

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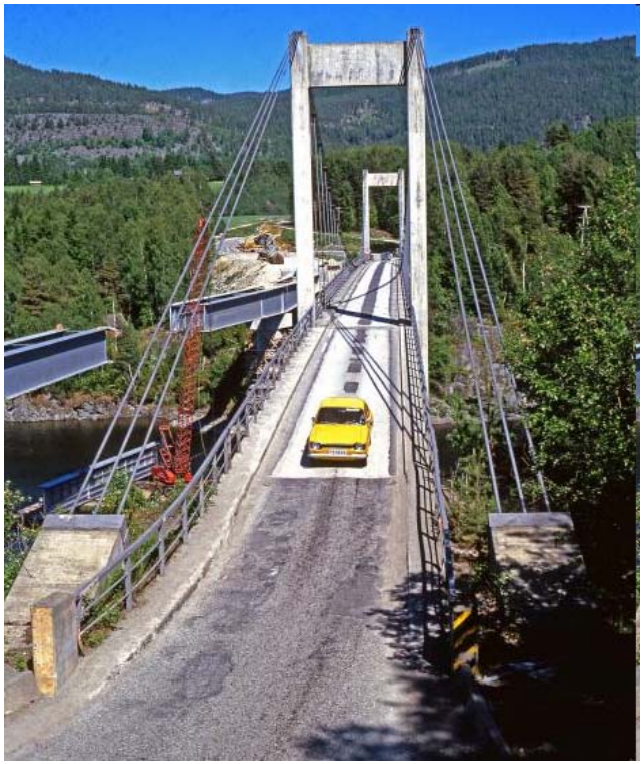
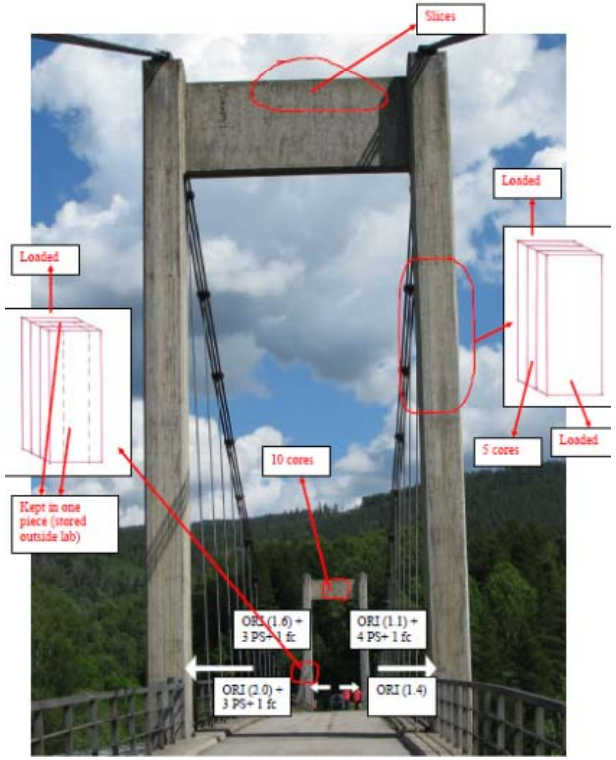
CASE STUDY

Bulit 1958 – Demolished 2009
Available information on mix design



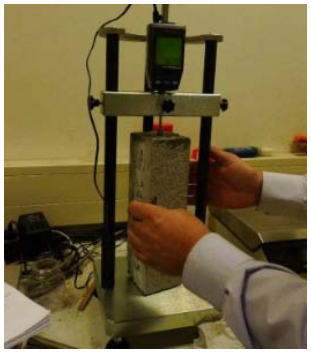
Collaboration with **Public Road Administration Norway**



Nautesund Bridge, Norway

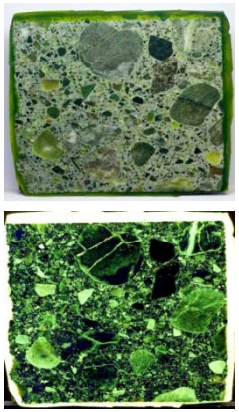
EXPERIMENTS

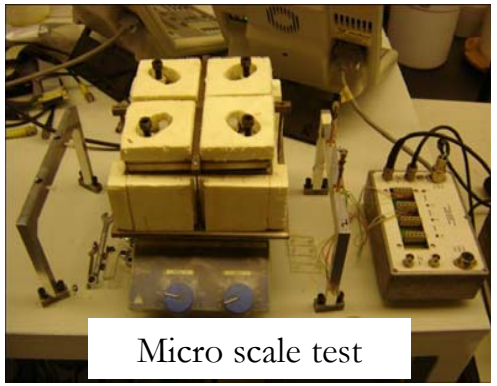
Expansion Measurements



Thin section

Polished section

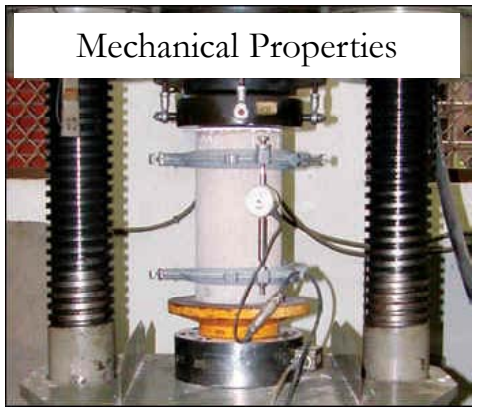




Micro scale test

Expansion **Evolution microstructure** **Evolution pore pressure**

Mechanical Properties

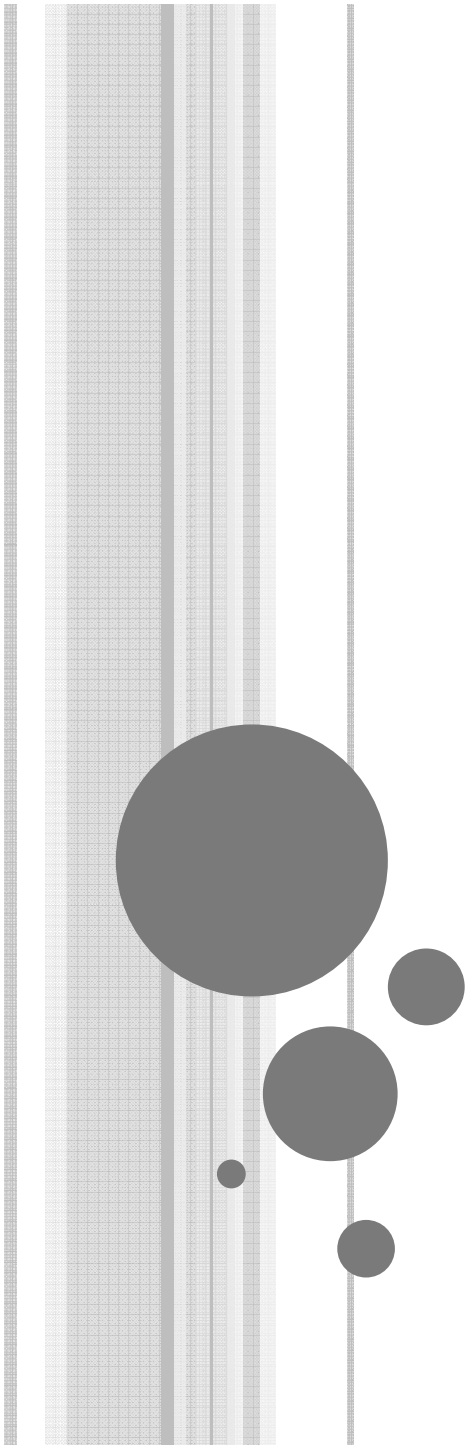


Evolution Mech. Prop.

- Mix Design = **Recovered by Nautesund**
- Temperature = **38 C**
- Humidity **> 90%**
- Time of the test = **52 weeks**

CONCLUSIONS

- The degradation of the mechanical properties as well as of the microstructures evolution should be further investigated.
- Substantial difference in the degradation behavior of sound and ASR-affected concrete.
- f_c is not a good indicator to detect the reaction
- The degradation of E and f_t , due to the swelling, does not occur at the same rate.
- The proposed model can explain the degradation of the stiffness provoked by both mechanical and chemical load.
- In order to enhance the model the poromechanics approach proposed by Lemarchand will be followed.



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THANK YOU FOR YOUR ATTENTION

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