ERNEST 2017 report

Concrete modelling for impact simulations

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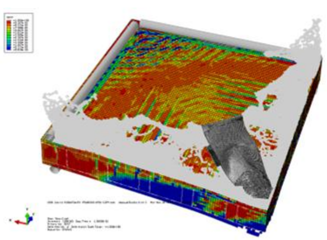
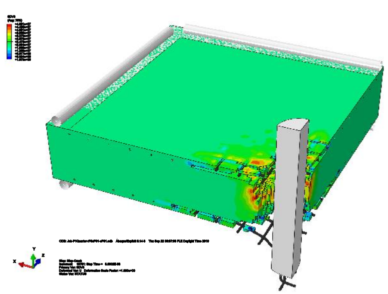
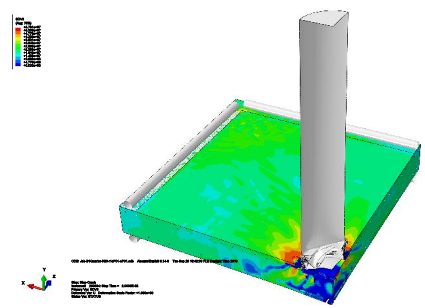
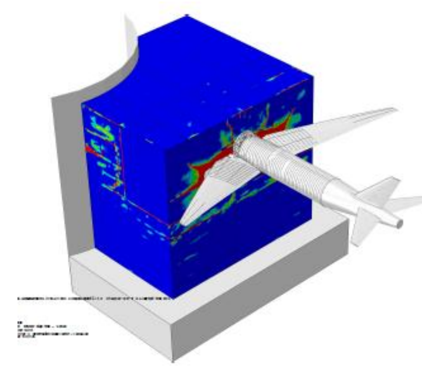
Introduction

Why accurate material modelling in impact simulations?

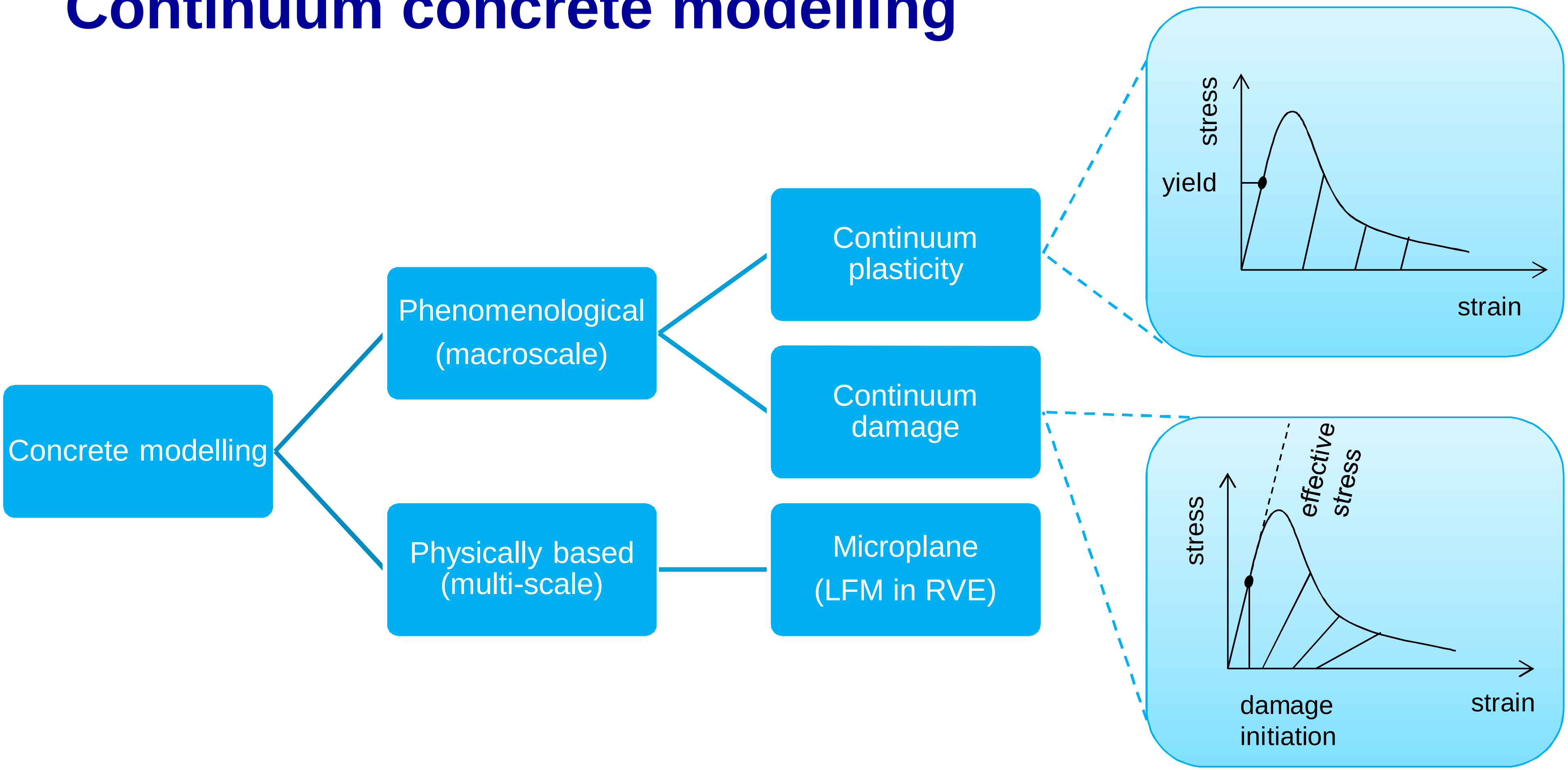
- Concrete is a difficult material to model (heterogeneous, anisotropic, porous, multi-phase, multi-scale, brittle, …)

- Behavior under impact is poorly known (strain rate effect, inertia effect, capillary effect, high speed crack propagation, …)

- Effect of concrete material model parameters predominant in large scale structural impact simulations.

Continuum concrete modelling



Impact simulation

Phenomenological | Physical (micro-scale)

rate dependence (compression)

Quasi-static confinement dependence

Void compaction

Inertia effects

Free water covection

rate dependence (tension)

Crack propagation inertia

Literature survey of continuum concrete models

	Plasticity	Damage	NL-elasticity	Fracture	Impact effects
Ottosen (1977) -> Winfrith	x				
Mazars (1986) -> PRM (2010)		x			strain rate
Krieg (1978) -> KST (1983)	x		x		confinement
Bazant (1996) ”Microplane”				x	
Lubliner & al. (1989) ”Barcelona”	x	x			
Lee & Fenves (1998)	x	x			
User defined Abaqus CDP	x	x			strain rate + confinement
X.D. Vu (2013) (PRM + KST)	x	x	x		strain rate + confinement

Goals

use state-of-the-art material models in impact simulations

customize Abaqus materials (CDP)

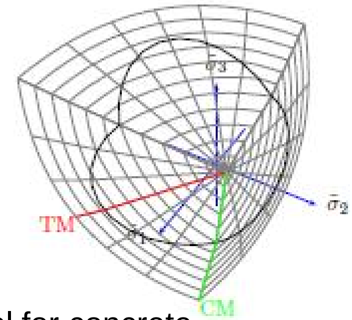
write Abaqus user materials

get deeper knowledge in continuum mechanics

investigate alternative methods (DEM, meshless Lagrangian, peridynamics, …)

What has been done so far...

What has been done so far… in a nutshell



- Literature survey of concrete modelling
  - ✓Thermodynamic damage-plasticity continuum approach
  - ✓The ”Barcelona” concrete model (J Lubliner, et Al. A plastic-damage model for concrete. Int.J. of Solids and Structure, 1989.)
  - ✓The ”Lee-Fenves” concrete model (J.H. Lee and G. Fenves. Plastic-damage model for cyclic loading of concrete structures. Journal of Engineering mechanics, 1998.)
- Enhancement of the Abaqus CDP model
  - ✓A confinement stress dependent concrete model (T. Gabet. Thèse: Comportement triaxial du béton sous fortes contraintes: influence du trajet de chargement. Université Joseph Fourier, Grenoble, 2006.)
  - ✓Study of element deletion as a way of materializing cracks in impact simulations

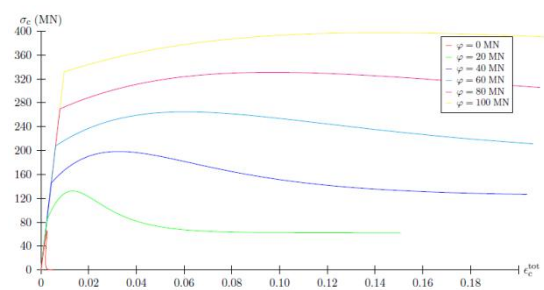
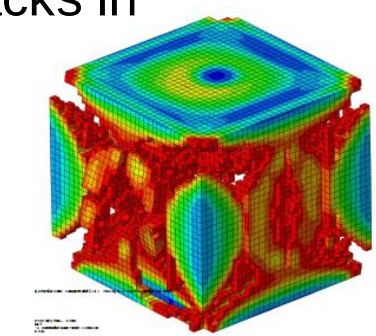
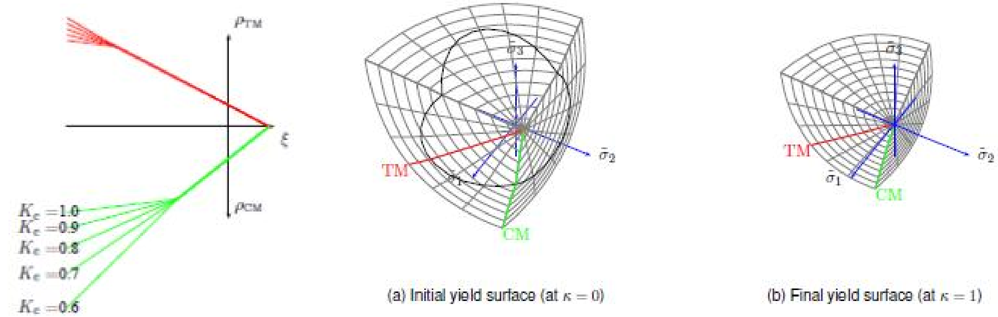
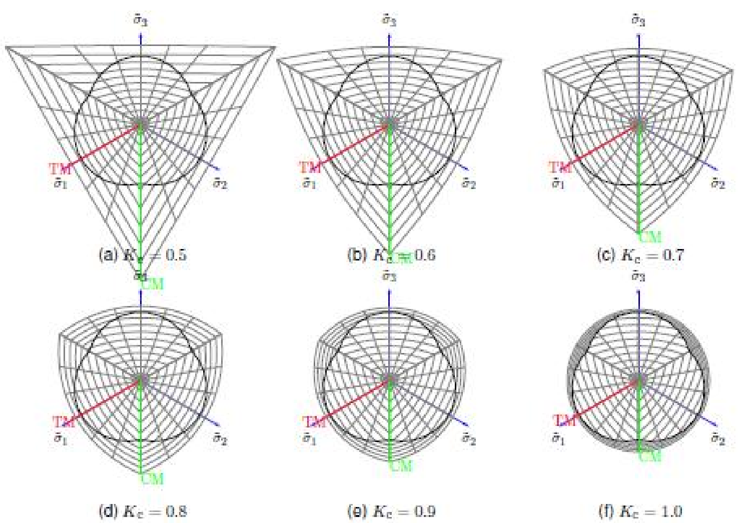


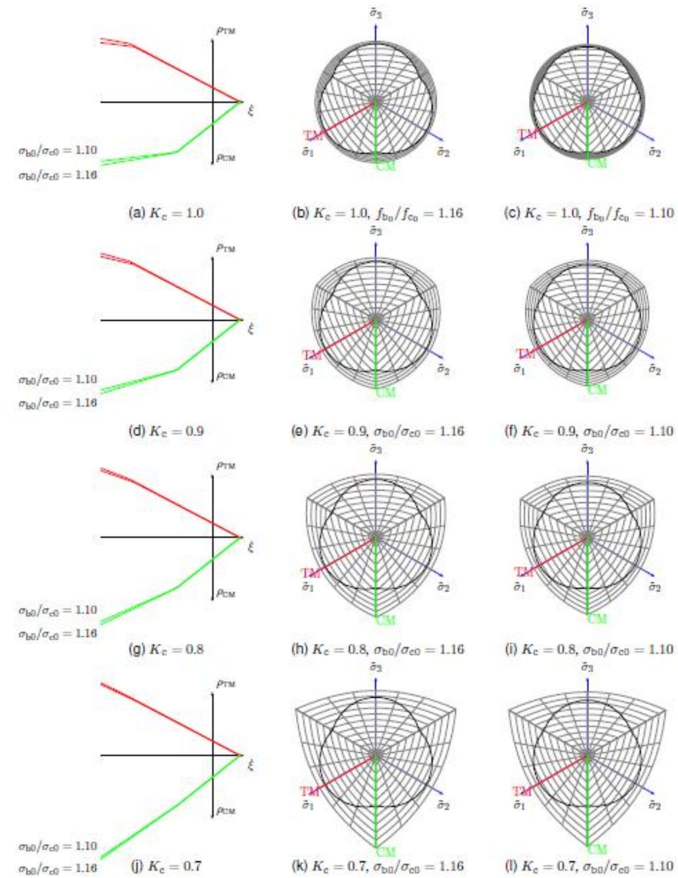
Figure 15: Confined uniaxial stress versus total strain C60/75



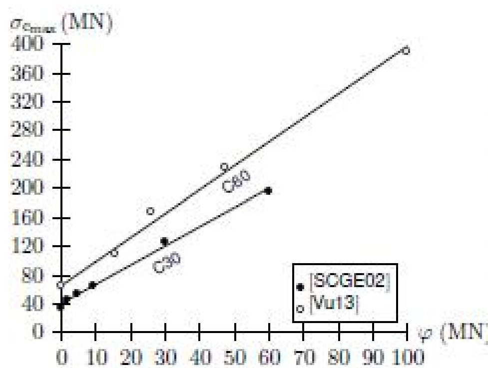
Material parameter sensitivity study: shape of the yield surface



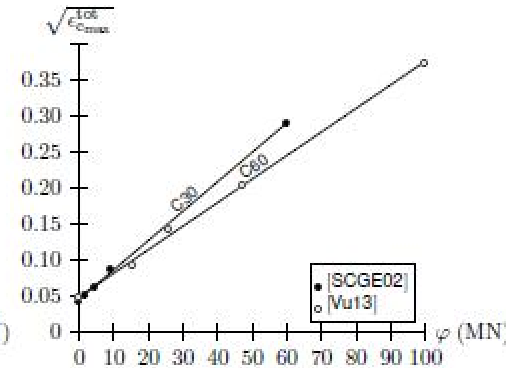




Study of triaxiality of concrete: dependence on confinement stress



(a) Confinement stress dependent axial peak stress



(b) Confinement stress dependent axial strain at peak

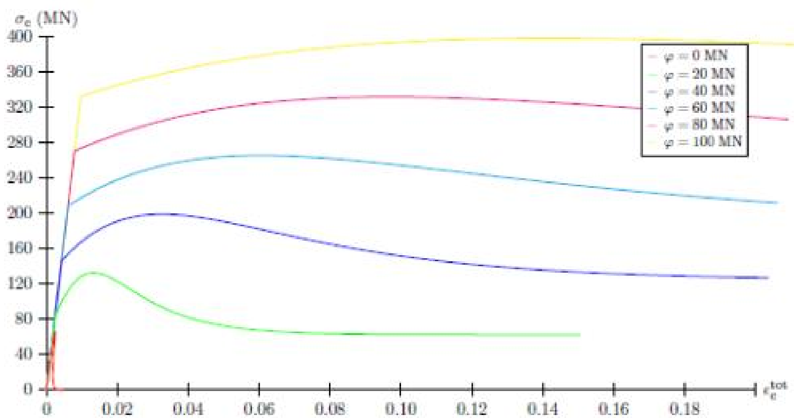


Figure 15: Confined uniaxial stress versus total strain C60/75

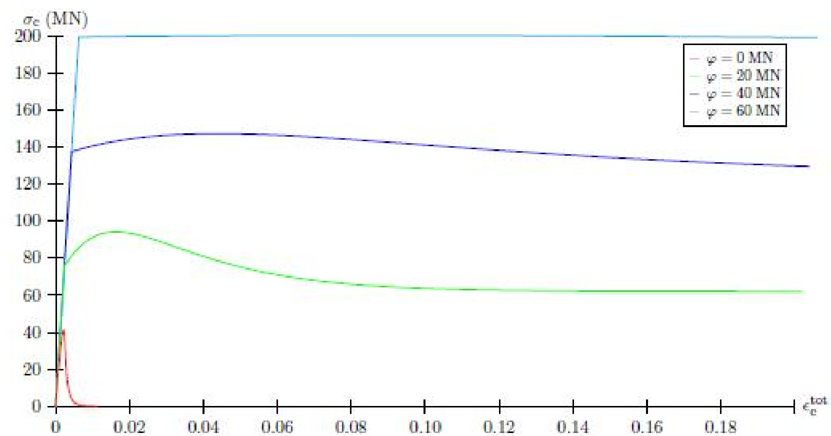
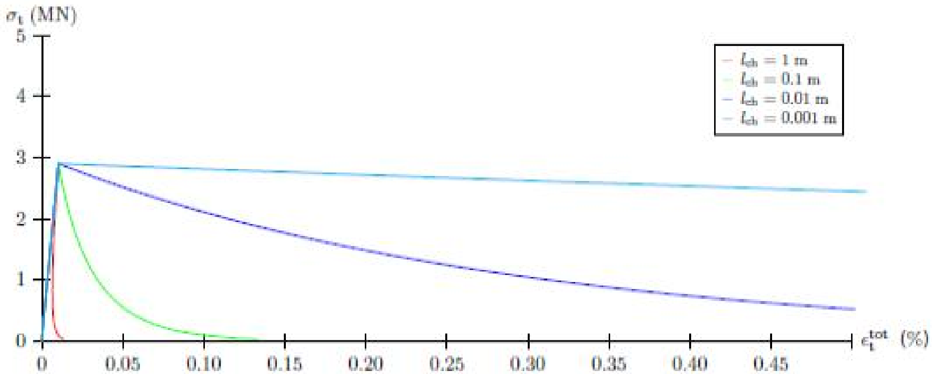


Figure 14: Confined uniaxial stress versus total strain C30/37

Investigation of mesh size regularization according to Hillerborg's method

grade	C25/30	C32/40	C40/50	C50/60	C65/80
f_{t_0} (MPa)	2.6	3.0	3.5	4.1	4.5
G_F (N/m)	70	90	120	150	210



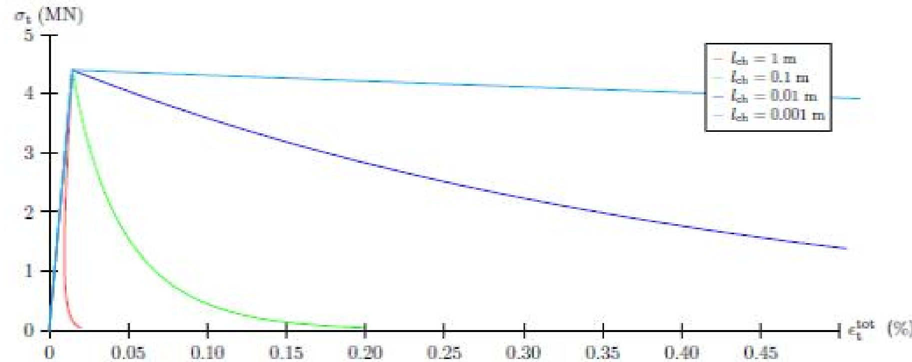


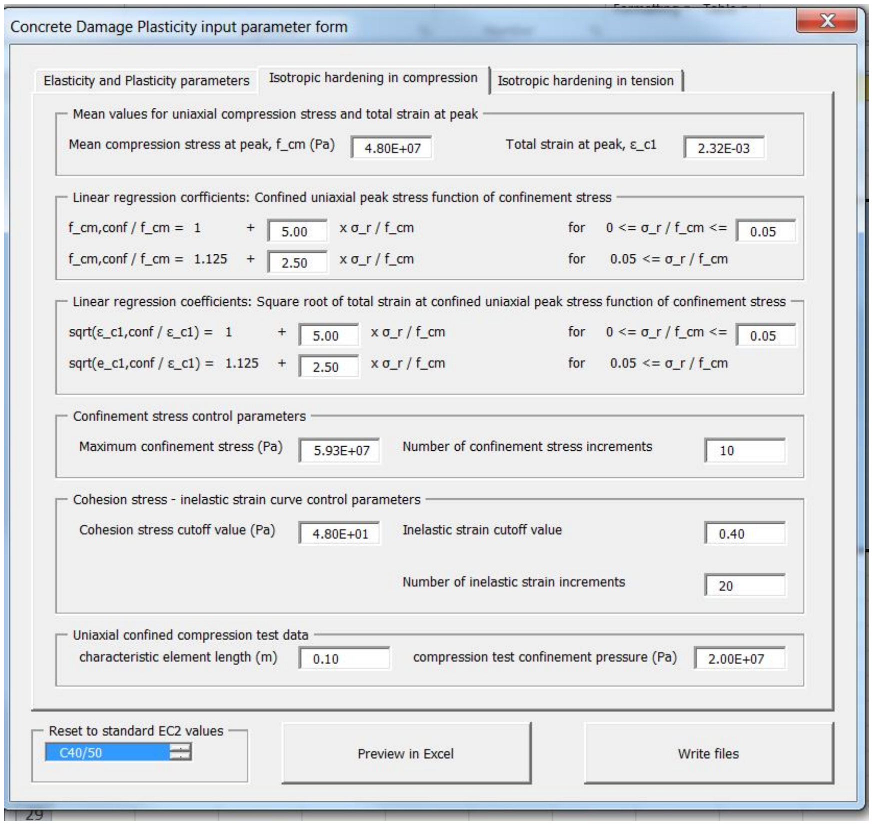
Figure 19: Uniaxial tension stress versus total strain C60/75

Future plans

Plans for 2017

- SMiRT-24: ”A physically motivated element deletion criteria for the concrete damage plasticity model”
- Enhance CDP with strain rate sensitivity in tension
- Write a VBA-Excel routine for material input data generation

Plans for 2017: material data generator


Concrete Damage Plasticity input parameter form

Elasticity and Plasticity parameters | Isotropic hardening in compression | Isotropic hardening in tension

Mean values for uniaxial compression stress and total strain at peak
Mean compression stress at peak, f_cm (Pa) 4.80E+07 Total strain at peak, ε_c1 2.32E-03

Linear regression corfficients: Confined uniaxial peak stress function of confinement stress
f_cm,conf / f_cm = 1 + 5.00 x σ_r / f_cm for 0 <= σ_r / f_cm <= 0.05
f_cm,conf / f_cm = 1.125 + 2.50 x σ_r / f_cm for 0.05 <= σ_r / f_cm

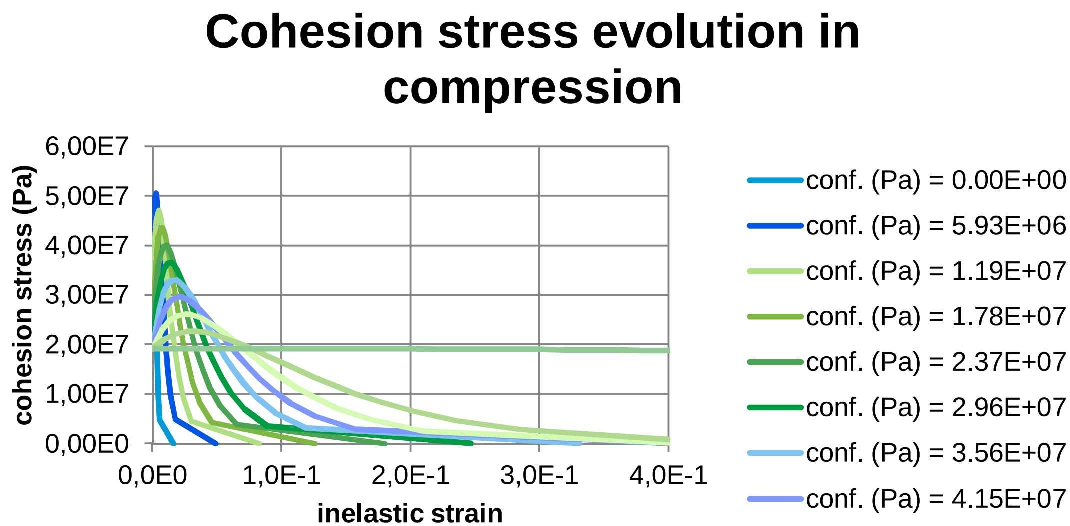
Linear regression coefficients: Square root of total strain at confined uniaxial peak stress function of confinement stress
sqrt(ε_c1,conf / ε_c1) = 1 + 5.00 x σ_r / f_cm for 0 <= σ_r / f_cm <= 0.05
sqrt(e_c1,conf / ε_c1) = 1.125 + 2.50 x σ_r / f_cm for 0.05 <= σ_r / f_cm

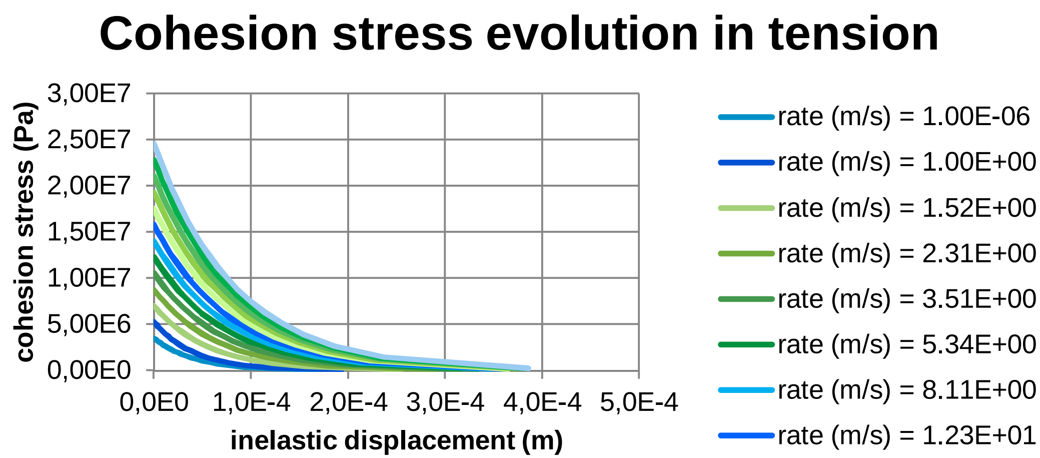
Confinement stress control parameters
Maximum confinement stress (Pa) 5.93E+07 Number of confinement stress increments 10

Cohesion stress - inelastic strain curve control parameters
Cohesion stress cutoff value (Pa) 4.80E+01 Inelastic strain cutoff value 0.40
Number of inelastic strain increments 20

Uniaxial confined compression test data
characteristic element length (m) 0.10 compression test confinement pressure (Pa) 2.00E+07

Reset to standard EC2 values
C40/50
Preview in Excel
Write files

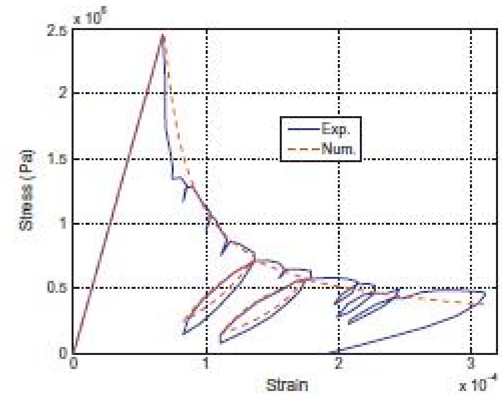




Plans for 2018 and later

- Aquire the know-how to write Abaqus user materials

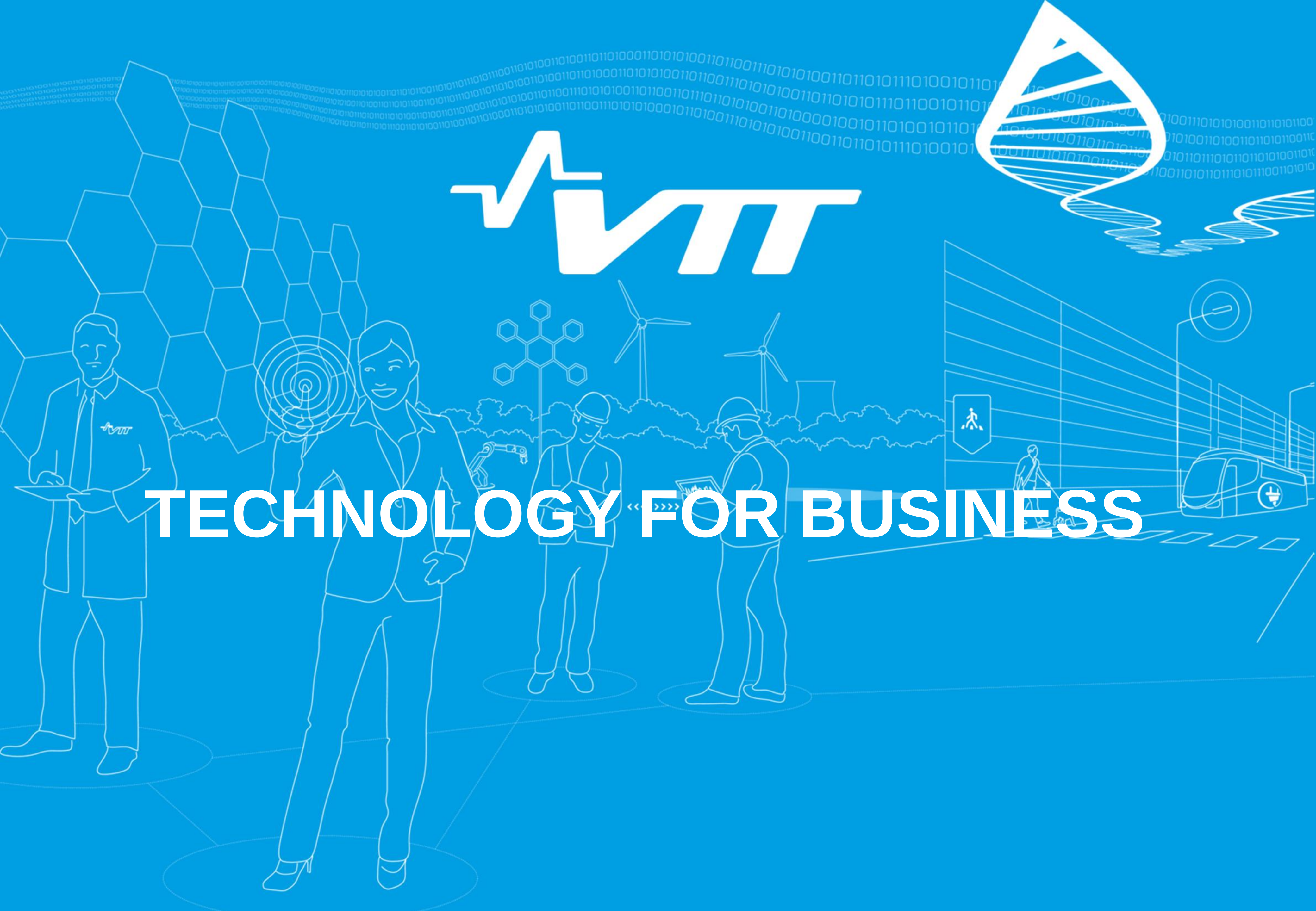
- Apply to the Ragueneau-Gatuingt-Cremona crack frictional dissipation model to include hysteresis



- Build a comprehensive material library to be used in concrete structure simulations.

to conclude ...


base camp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