

## R&D in code\_aster

# Numerical modelling of damage/cracking in reinforced concrete structures

### CONTEXT

During an accident, the containment vessel is the third barrier to avoid dissemination of radionuclides. The degradation of the tightness of this reinforced concrete structure has to be anticipated and simulation is one of the tools developed. Several physical phenomena have to be taken into account : one of them is the **damage** (or cracking) of the structure.

### Some scientific challenges

- Behavior of the concrete
- Reinforcements representation
- Prestress
- Decohesion steel - concrete
- Size of the simulations

### Some tools developed in code\_aster

#### □ Different models to describe damage/cracking with a gradation of the accuracy/complexity

- A non-local damage model: **ENDO\_FISS\_EXP**
  - ✓ Complex crack paths
  - ✓ Small and large propagation
  - ✓ Crack opening profiles
- Interface elements + a cohesive law: **CZM\_EXP\_MIX**
  - ✓ Small and large propagation
  - ✓ Crack opening profiles
  - ✓ Closure of the cracks
- A local damage model : **ENDO\_ISOT\_BETON**
  - ✓ Initiation of damage
  - ✓ Localization of cracked areas
  - ✓ Up to the scale of the building

#### □ Description of the decohesion between concrete and steel

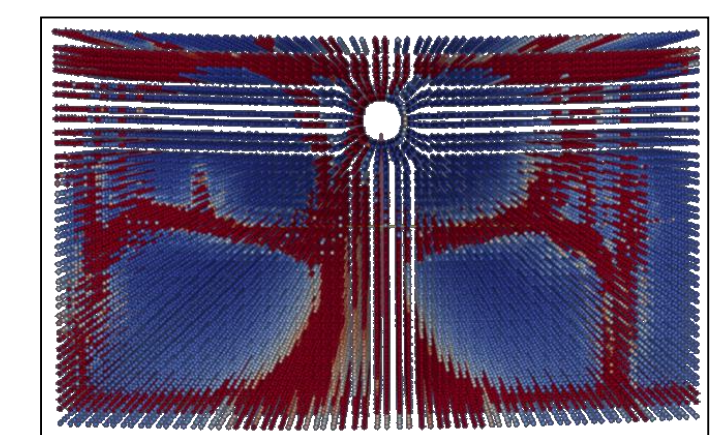
- Interface elements + **CZM\_LAB\_MIX**

### Applications at some parts of a containment vessel :

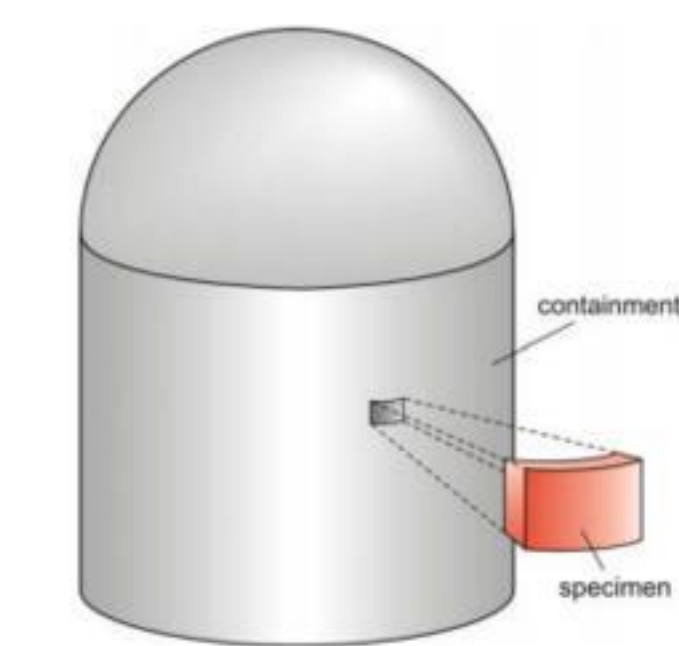
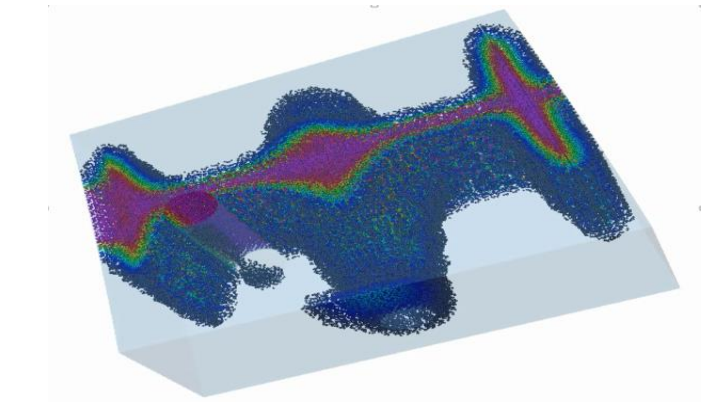
#### Current part: cracking at maximal pressure



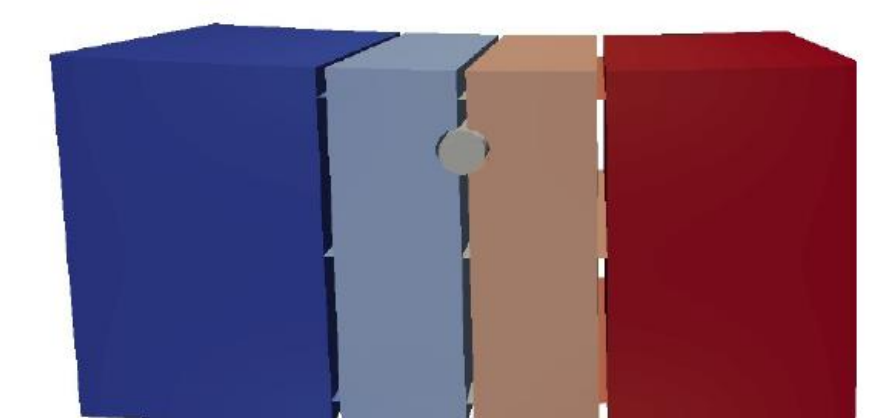
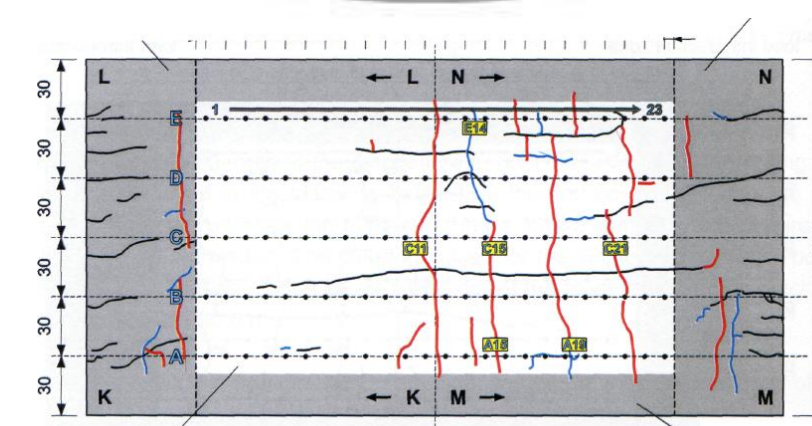
Mock-up before concreting



Crack pattern with damage model : local and non-local (1/4 struct).

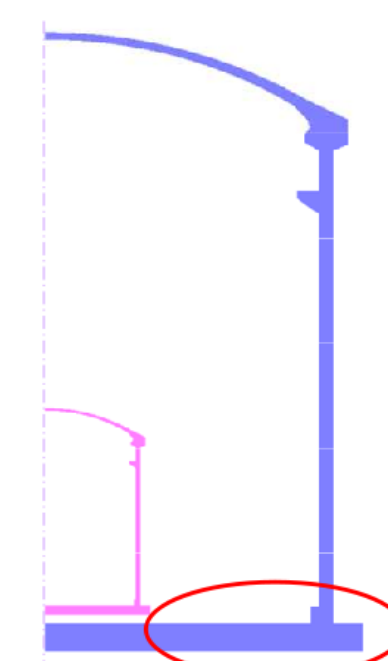


Experimental crack pattern

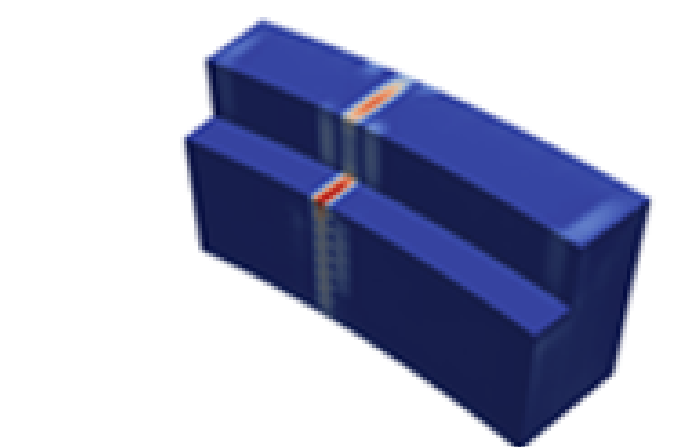
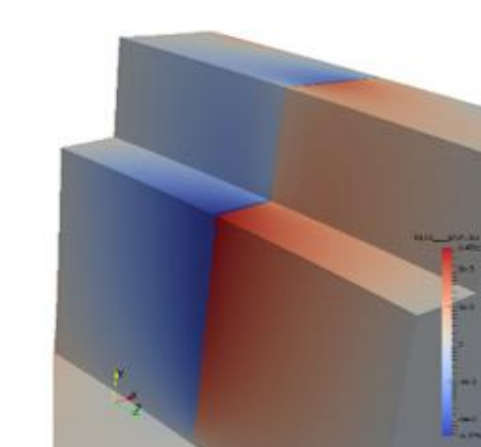


Results with cohesive model

#### Gusset : cracking at early age



Displacement results with cohesive model :



Crack pattern with local damage model

### PhD THESIS

M. David – *Approche multi-échelle du comportement mécanique des structures en béton armé – Application aux enceintes de confinement des centrales nucléaires* – Ecole Polytechnique 2012

A. Carpiuc-Prisacari - *Innovative tests for characterizing mixed-mode fracture of concrete: from pre-defined to interactive and hybrid tests* – Université Paris-Saclay 2015

E. Lefebvre – *Stratégie de modélisation pour suivre des fissures en béton armé précontraint* – Paris Sciences et Lettres 2016

D.E.M. Bouhjiti – *Analyse probabiliste de la fissuration et du confinement des grands ouvrages en béton armé précontraint – Application aux enceintes de confinement des réacteurs nucléaires : Cas VeRCORs -* , Université Grenoble-Alpes 2018

### SOME PUBLICATIONS

E. Lorentz - *A non local damage model for plain concrete consistent with cohesive fracture*, International Journal of Fracture, Volume 207, Issue 2, pp 123–159.

Carpiuc-Prisacari, M. Poncelet, K. Kazymyrenko, F. Hild, H. Leclerc – *Comparison between experimental and numerical results of mixed-mode crack propagation in concrete; Influence of boundary conditions choice*, Cement and Concrete Research, 100 (2017) pp329-340

D. E-M Bouhjiti, MC Blasone, J. Baroth, F. Dufour, B. Masson, S. Michel-Ponnelle - *Statistical modelling of cracking in large concrete structures under Thermo-Hydro-Mechanical loads: Application to Nuclear Containment Buildings. Part 2: Sensitivity analysis* - Nuclear Engineering and Design 334 (2018), pp. 1-23