



Laboratory for the Concrete  
Technology and Structural Behaviour



SCSS 2012  
Aix-en-Provence, 31 May 2012

# Use of FEM to Assess Shrinkage Cracking in Restrained Concrete Structures

**L. Leitão**

**M. Azenha**

**C. Sousa**

**Rui Faria**

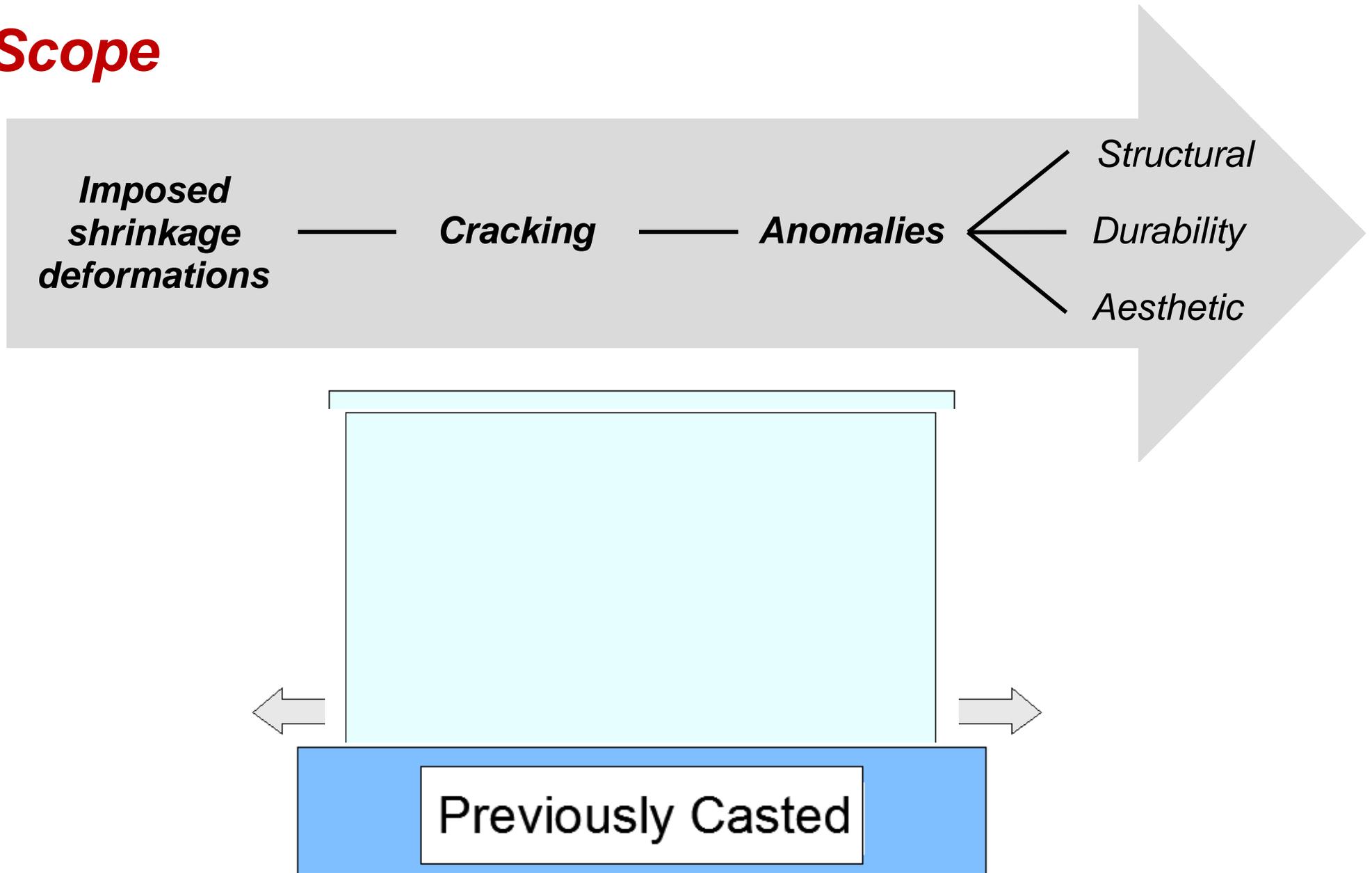


**U. PORTO**

FEUP FACULDADE DE ENGENHARIA  
UNIVERSIDADE DO PORTO



# Scope

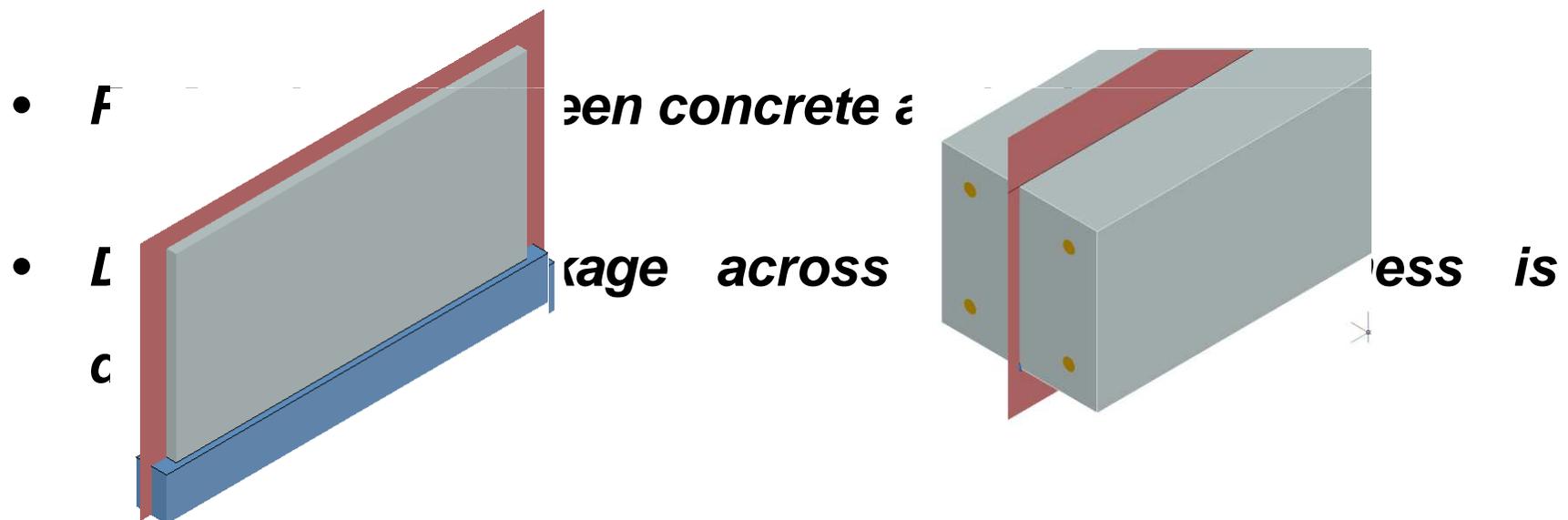


## ***Motivation***

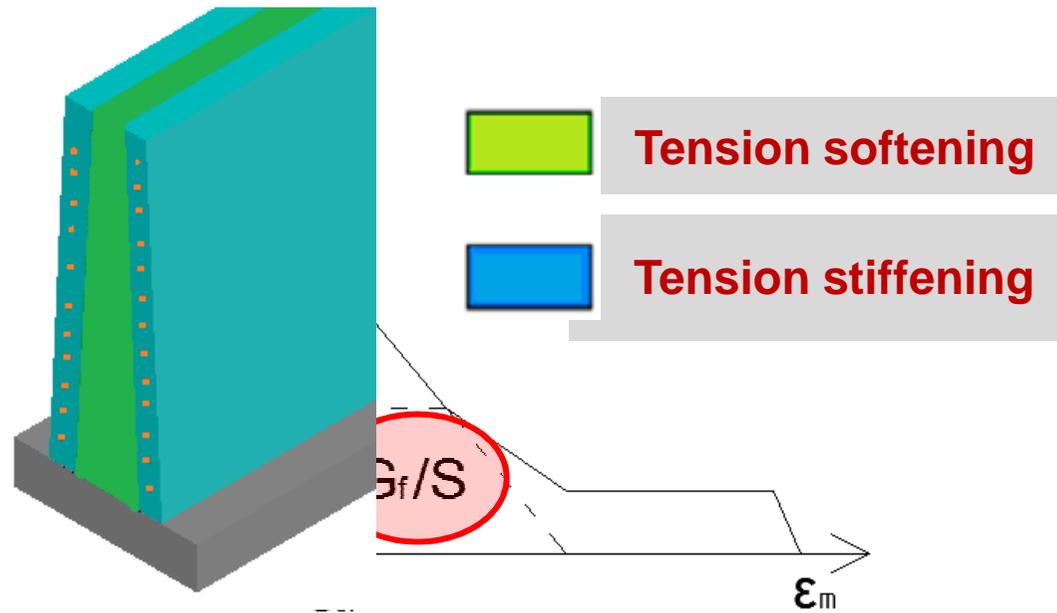
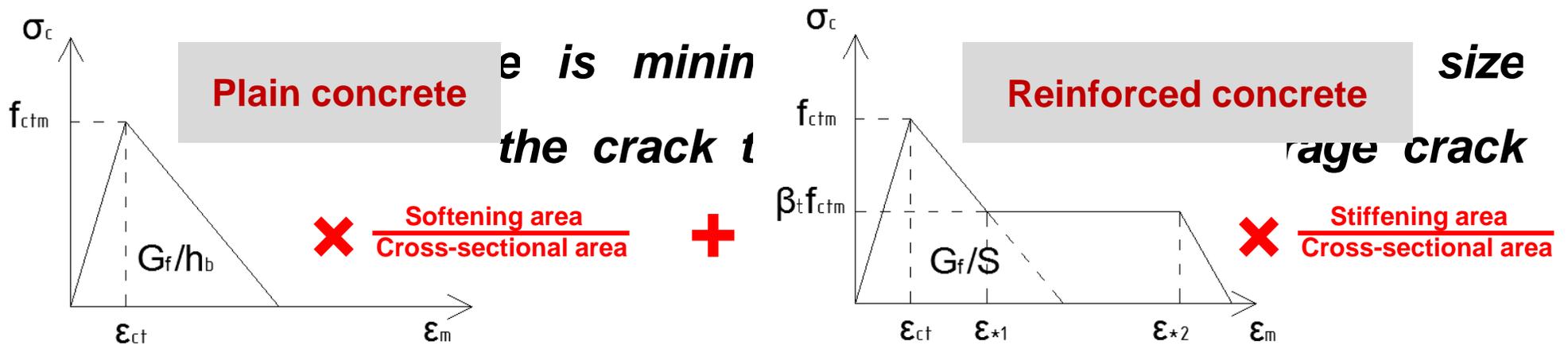
- ***Insufficiency of design code approaches to define reinforcement for controlling shrinkage-induced cracking.***
- ***Use of a NLFE model - as simple as possible - to predict cracking in RC structures.***
- ***Compare the observed cracks in real RC retaining walls to those obtained numerically.***
- ***Understand the importance of correctly estimating the value of the maximum crack spacing ( $l_{s,max}$ ).***

# Modelling strategy

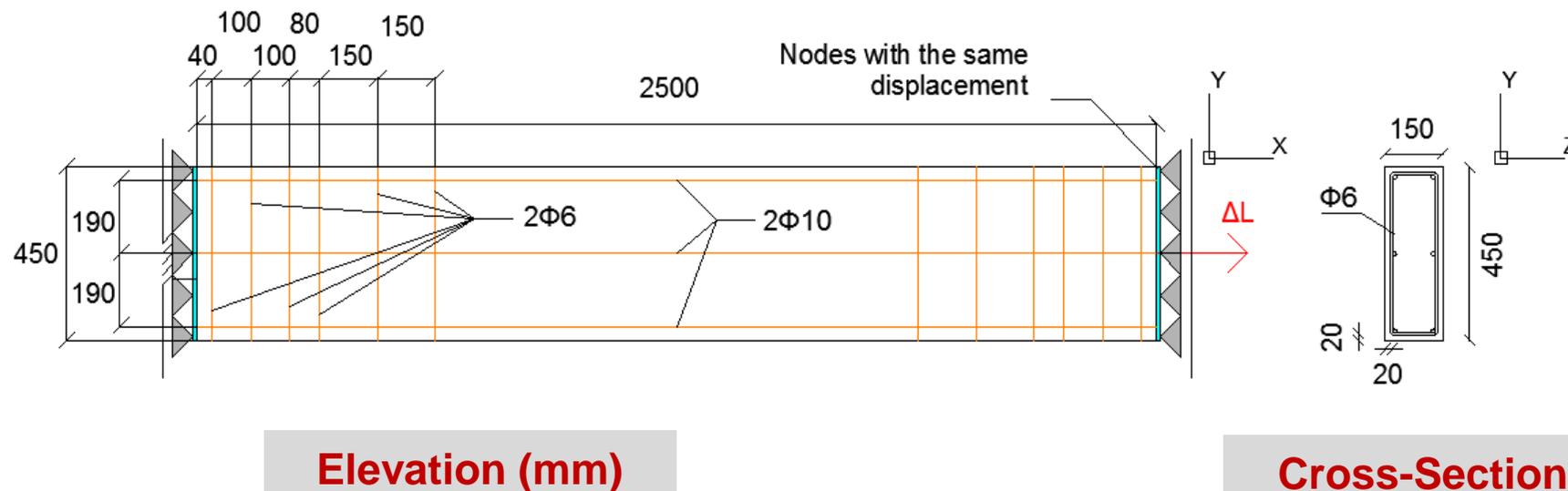
- **Nonlinear software DIANA, using relatively coarse FE meshes.**
- **2D plane stress assumption, with due allowance to creep.**



# Modelling strategy



## Cracking simulation – RC tie Jaccoud 1987



- **Short term tensile test with imposed deformations.**
- **Concrete creep is disregarded.**
- **Strain monitored by a LVDT at the center of the specimen.**

## Cracking simulation – RC tie Jaccoud 1987

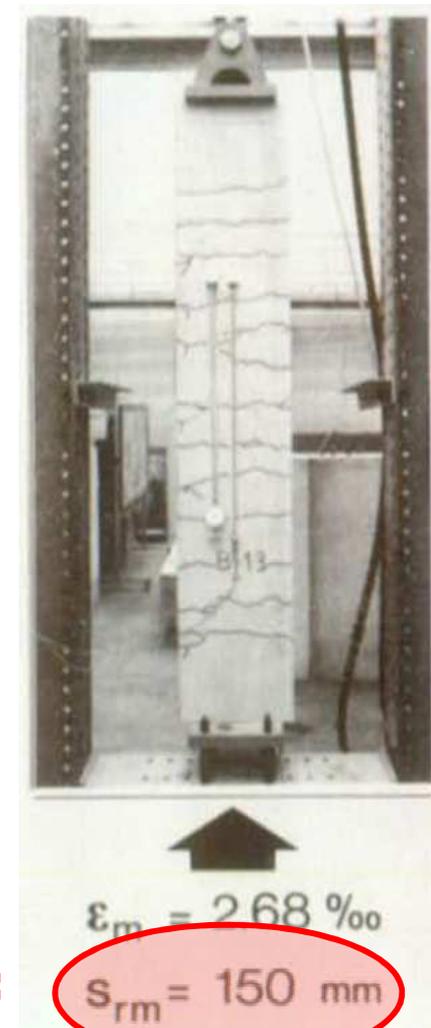
MC90

$$l_{s,max} = \frac{\phi}{3.6 \times \rho_{p,eff}} \approx 0.250m$$

X 2/3

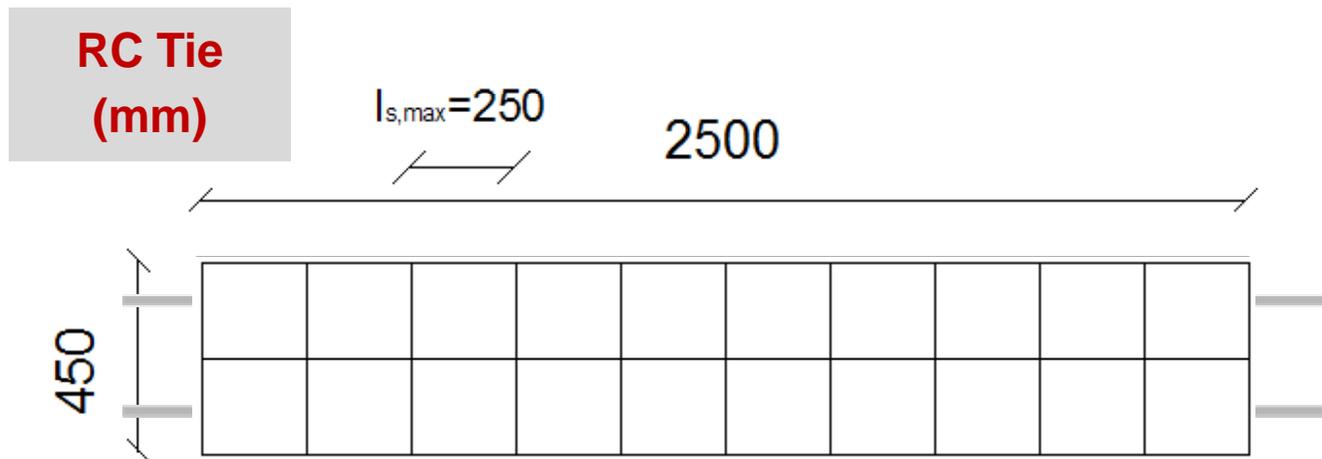
- **FE dimensions specified for the stage of crack formation.**
- **Calculated value for  $l_{s,max}$  is rather coherent with the average crack spacing reported by Jaccoud.**

Jaccoud Tie



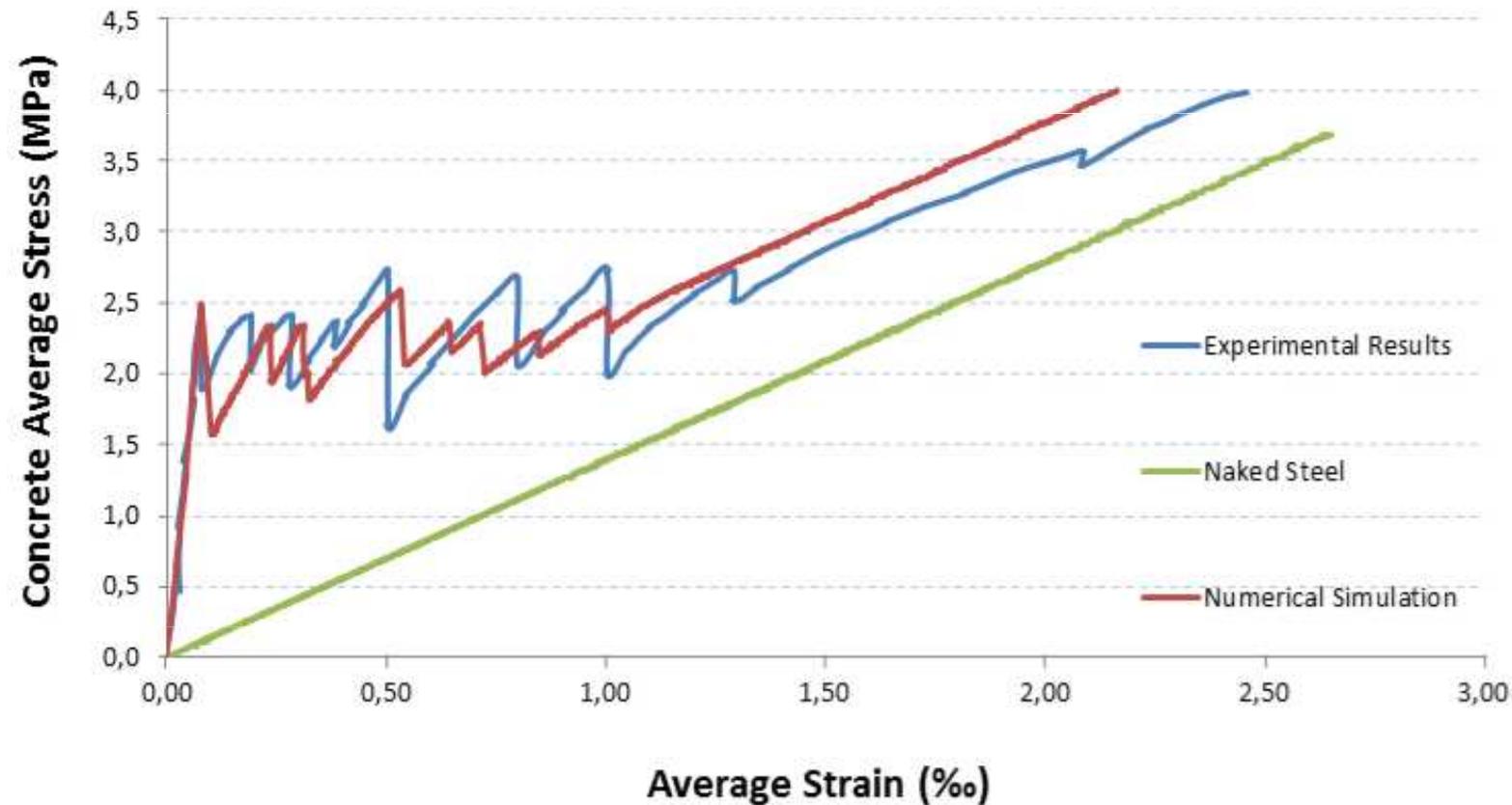
≈

## Cracking Simulation – Jaccoud RC Tie



- ***Tensile strength of concrete estimated based on the experimental data.***
- ***In region MACONC4 no cracks were reported by Jaccoud.***

## Experimental vs Numerical Results



- **None numerical prediction of the early crack formation with phase elements.**
- **Stiffness associated to stabilized cracking phase were simulated.**

# RC retaining wall

- Wall casted in 2004.
- Variable thickness.
- In-situ assessment made in 2011.

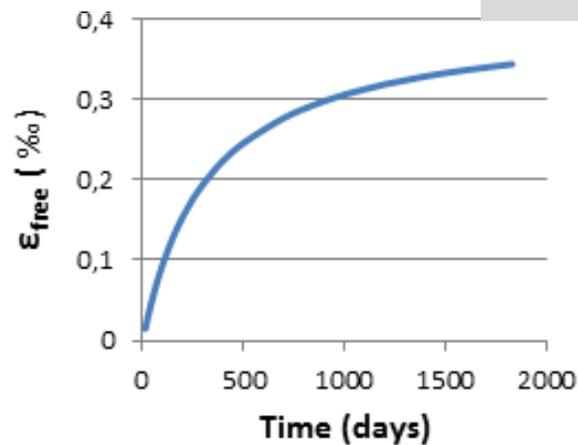
L = 19 m  
H = 4.7m

C25/30  
S500

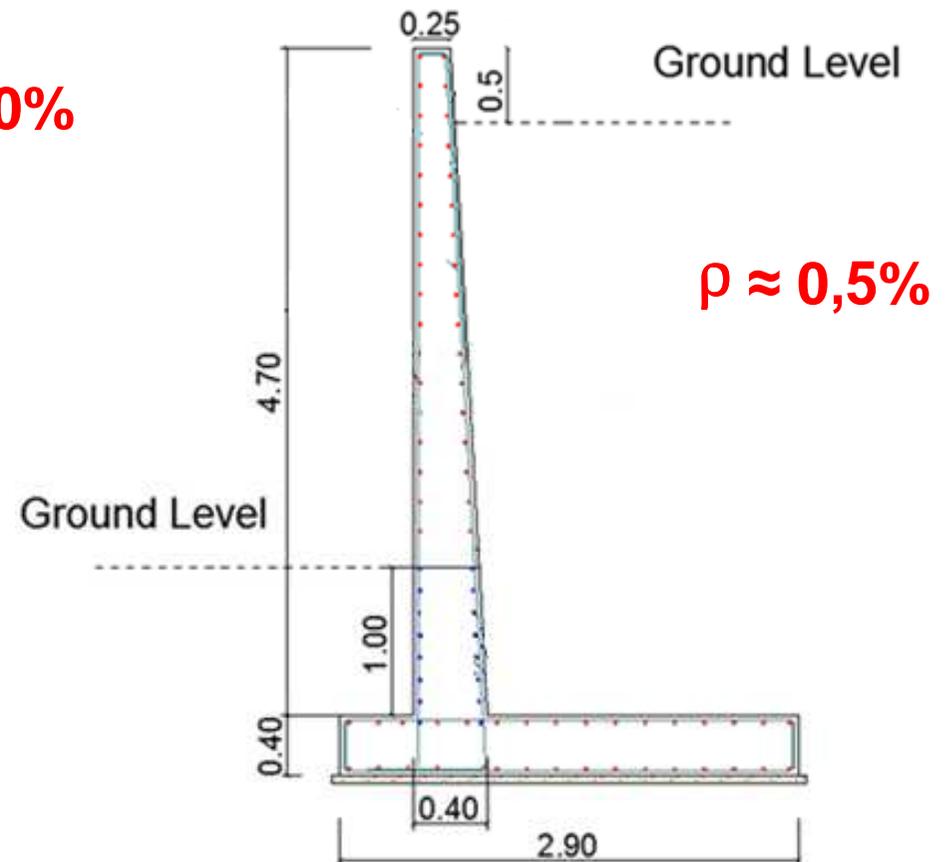
RH = 60%

$\epsilon_{cs,free} = 355 \mu\epsilon$

EC2

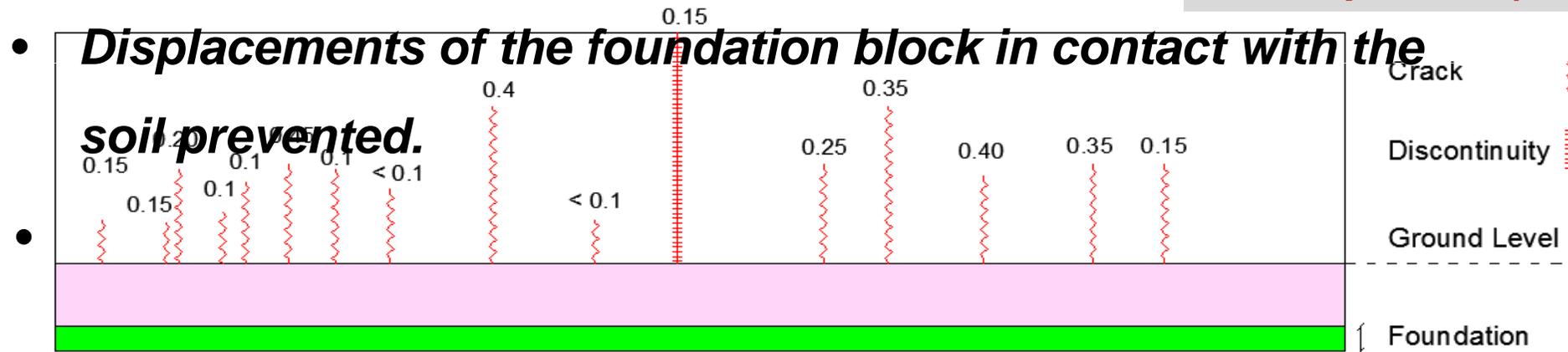


Cross-section



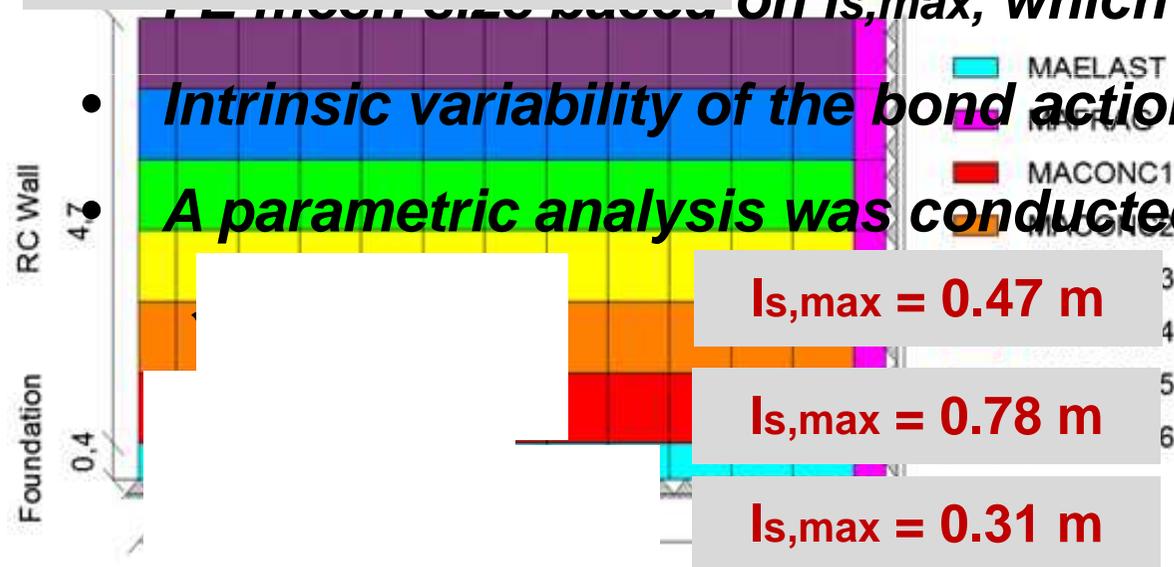
# RC retaining wall

Crack pattern (mm)



FE model ( $l_{s,max} = 0.78$  m)

on  $l_{s,max}$ , which is difficult to obtain.

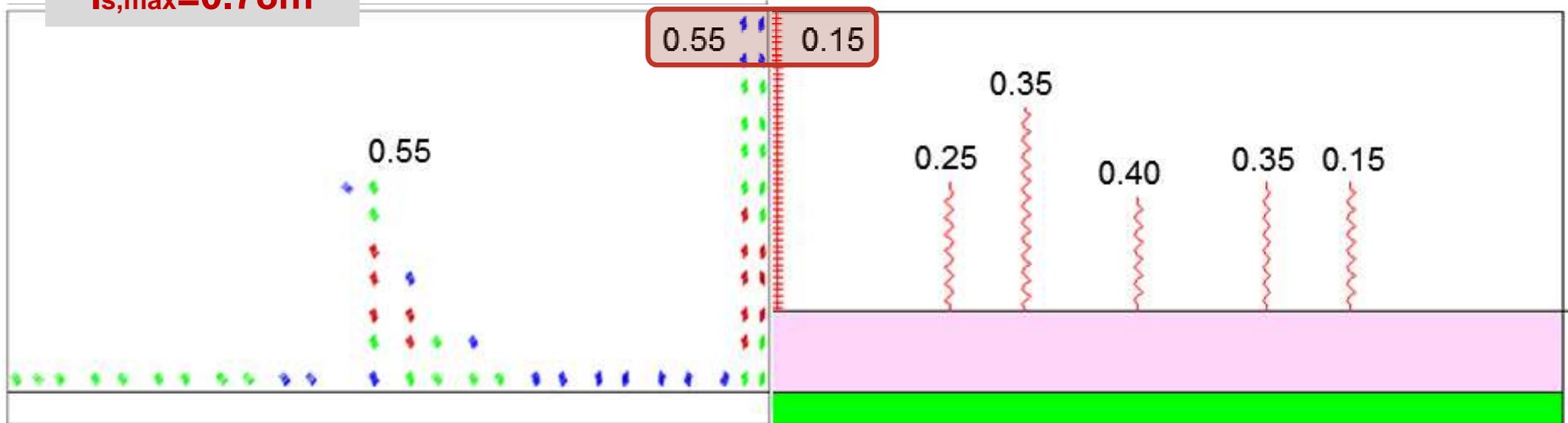


el and concrete.

Model cross-section

# RC retaining wall

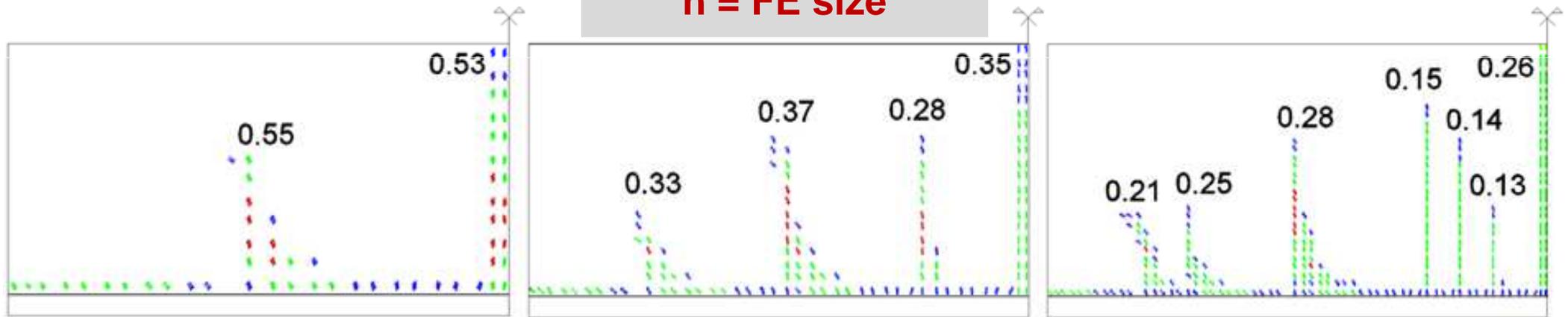
$l_{s,max}=0.78m$



- **MOORE** experimental test for the bond characteristics (good bond values ifors),
- **Good** experimental test for the bond characteristics and **Farid** estimation of crack
- **Crack** propagation and **order** of **crack** limit to **estimated** soft **crack** widths.

# RC retaining wall

**h = FE size**

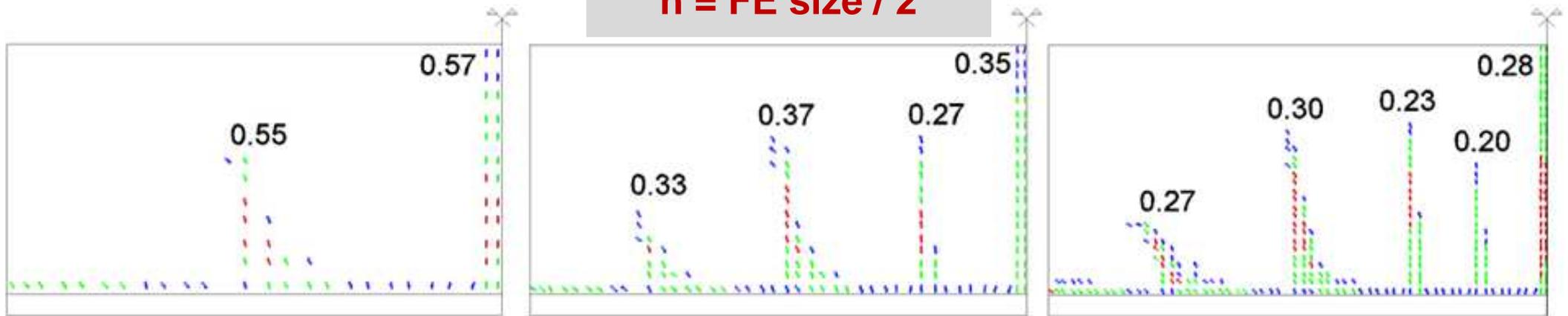


**$I_{s,max}=0.31m$**

**$I_{s,max}=0.47m$**

**$I_{s,max}=0.78m$**

**h = FE size / 2**



## Conclusions

- ✓ ***Good coherence in the RC tie simulation. The proposed methodology captures all the main features expected:***
  - ***the number of formed cracks;***
  - ***the decrease of stiffness during crack formation;***
  - ***the stiffness along the stabilized cracking phase.***
- ✓ ***With the adopted simulation strategy, numerical predictions of the crack width and cracking pattern were coherent with the ones **observed in the retaining wall.*****

(...)

- ✓ **Confirmation of the *importance of the mesh refinement on the obtained results* in structures where the restraint to deformation is not uniform (diminishing FE length increases the number of cracks, while the corresponding crack width decreases).**
- ✓ **The analysed case studies suggest that modified tension stiffening diagrams could be adopted, to ensure objectivity with respect to the FE mesh size, and allow the use of more refined meshes (crack bandwidth has revealed itself much less important).**