

# Cracking analysis of concrete structure elements reinforced by flat steel rebars

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# Background - Industrial problem

## Matière®

New type technological of reinforcement  
by ribbed flat steel rebars



MATIERE patent

Influence on :

- the behavior in the serviceability limite state and ultimate limite state.
- the cracking process of structures (number and openings of cracks).

Numerical modelling of the steel-concrete interface

# Study objective : Beam slab under bending 4 points

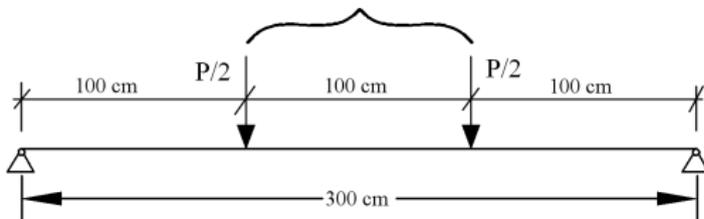
## Experimental tests

**MATIERE®**

**Polytech'Clermont Ferrand**

*measurement (cracking, load/displacement)*

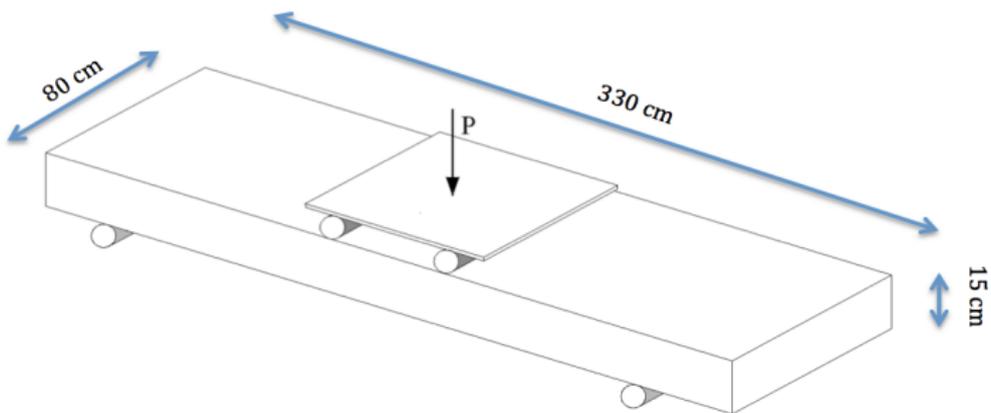
measurement of the cracking  
in the zone of constant moment



Beam slab under bending 4 points



# Study objective : Beam slab under bending 4 points

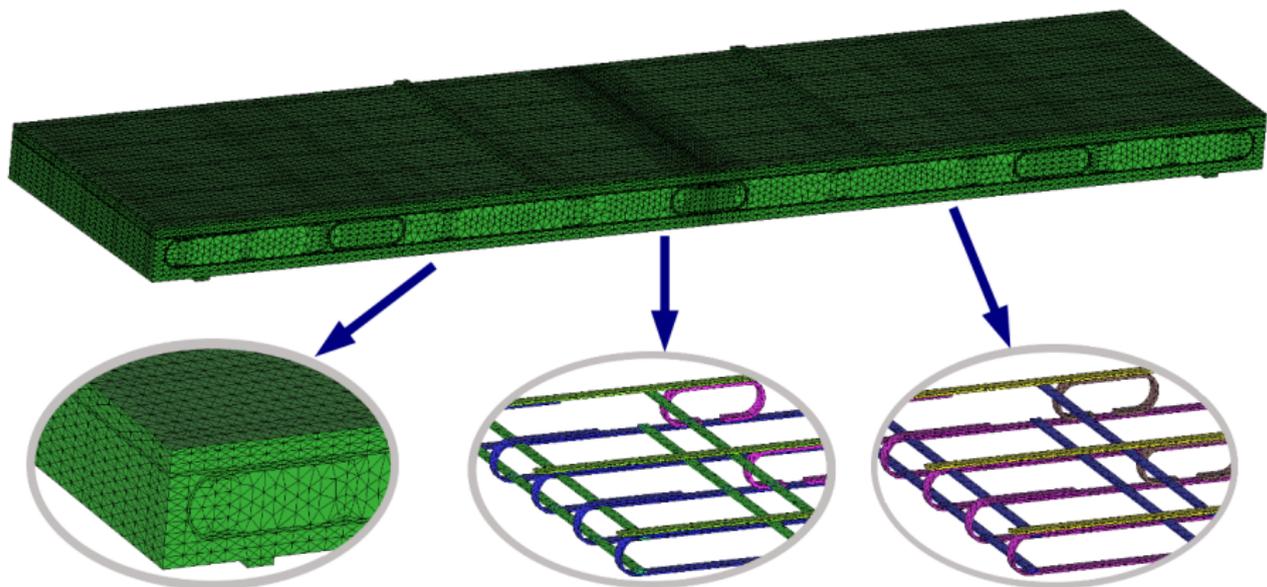


The reinforcement system is adopted from the one of the round steel (equivalent section) - Eurocode

Round steel  $\Phi 12$  mm ( $S_{round} = 113.04 \text{ mm}^2$ )

Flat steel  $22.5 \times 5$  mm ( $S_{plat} = 112.5 \text{ mm}^2$ )

# Modelling of beam-slab reinforced by flat steel



**Concrete**

**Probabilistic cracking  
model**

**Flat steel rebars**

**Von-Mises plasticity  
criterium**

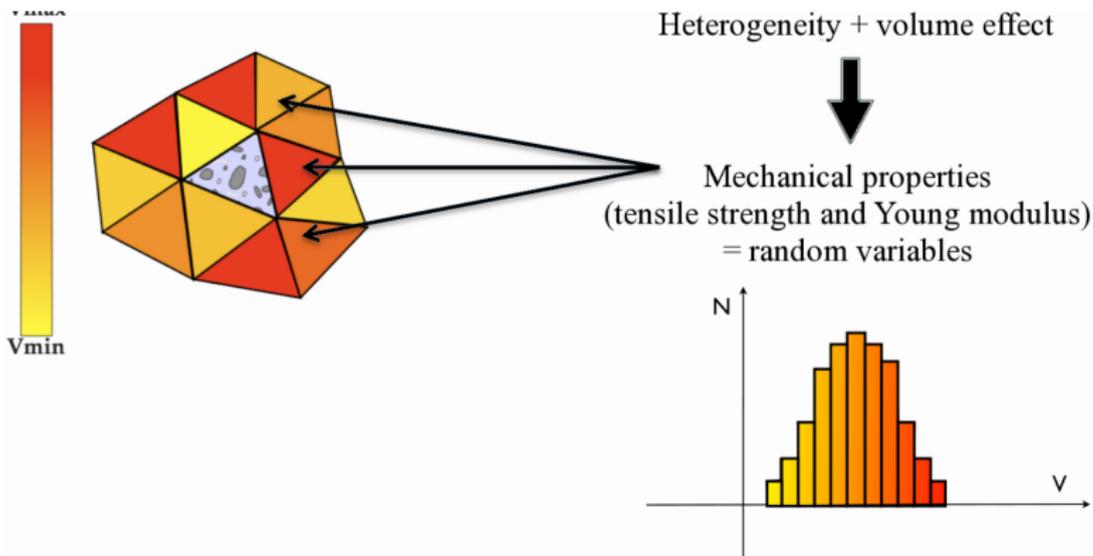
**Steel/concrete interface**

**Damage behaviour**  
 $C?$ ,  $\delta_{\epsilon}^{cri}?$

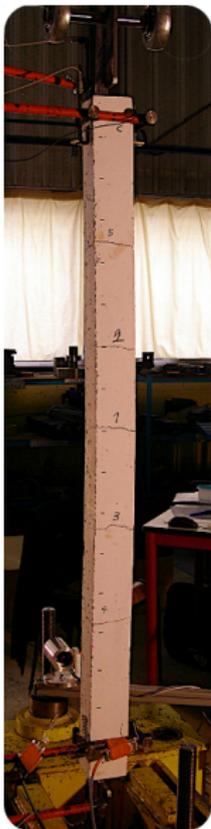
# Probabilistic model for the mechanical behaviour of the concrete

Rossi et al. 89 and 94, Tailhan et al. 2010

$$\begin{cases} m(X) = F_{mX}(V_S/V_A, f_c) \\ \sigma(X) = F_{\sigma X}(V_S/V_A, f_c) \end{cases} \quad \text{with} \quad \begin{matrix} X = f_t, E_c \\ f_c, E_c, D_g \text{ experimentally determined} \end{matrix}$$



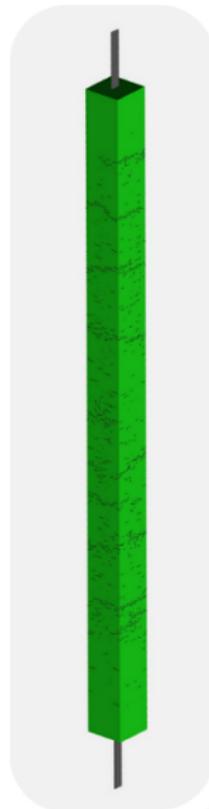
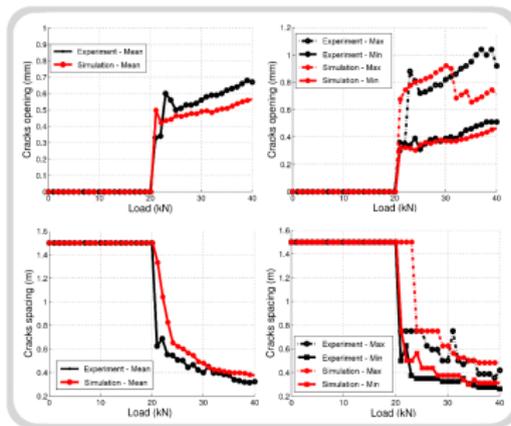
# Identification of mechanical parameters



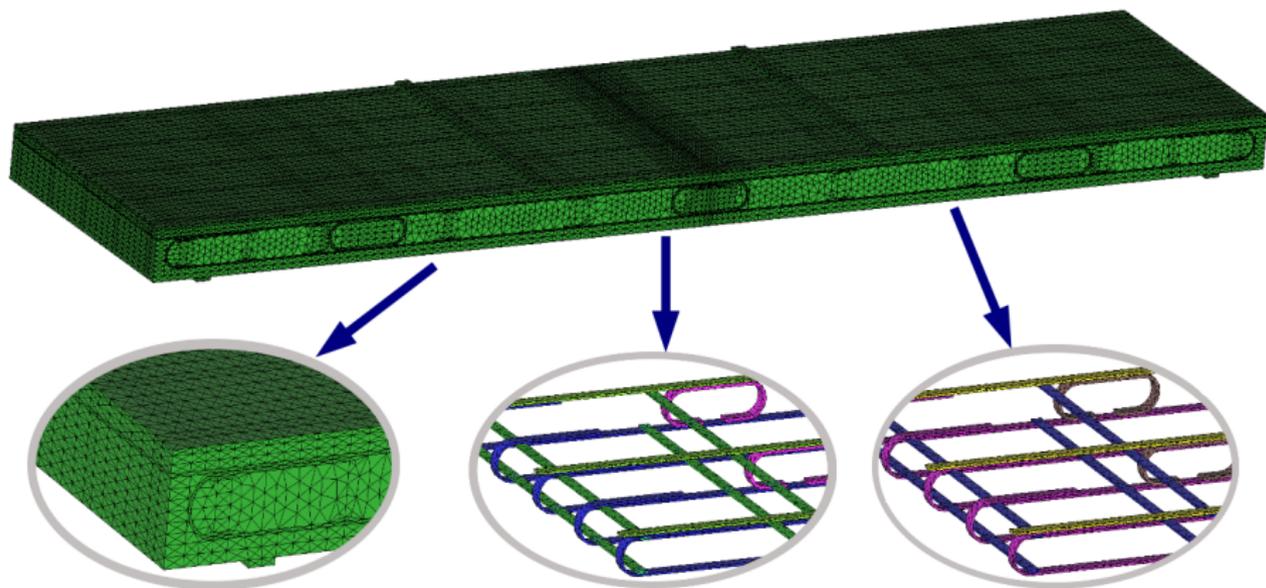
The behaviour of steel/concrete interface influence the cracking process of the concrete structures

Inverse analysis approach  
(based on Monte-Carlo simulations)

⇒ Optimum value of  $C$  and  $\delta_{\tau}^{cri}$



# Modelling of beam-slab reinforced by flat steel



## Concrete

$$f_c = 55 \text{ MPa}$$

$$E = 35000 \text{ MPa}$$

$$D_g = 16 \text{ mm}$$

## Flat steel rebars

$$E_s = 210000 \text{ MPa}$$

$$R_e = 640 \text{ MPa}$$

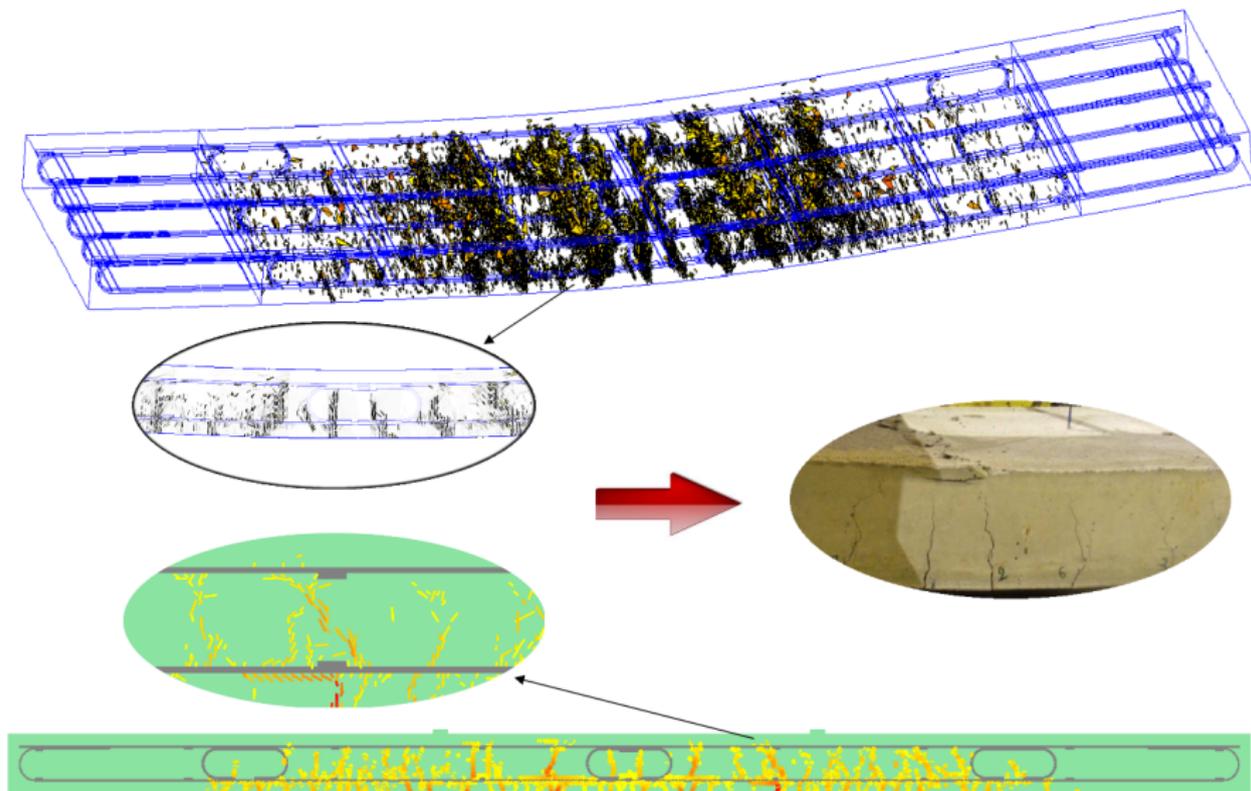
$$R_u = 720 \text{ MPa}$$

## Steel/concrete interface

$$C = 15 \text{ MPa}$$

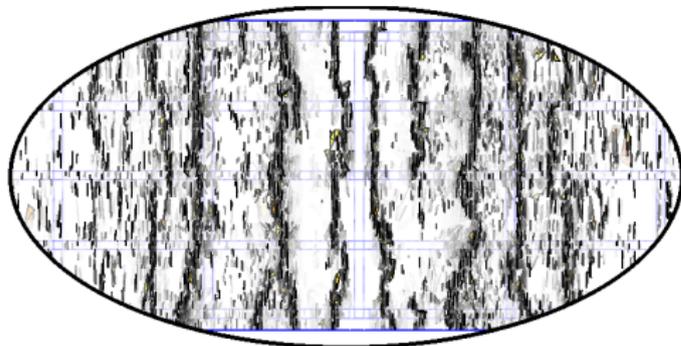
$$\delta_t^{cri} = 25 \text{ } \mu\text{m}$$

# Results of the beam slab reinforced by flat steel (bending 4 points)



**Figure:** Cracking profile of beam slab

# Results of the beam slab reinforced by flat steel (bending 4 points)



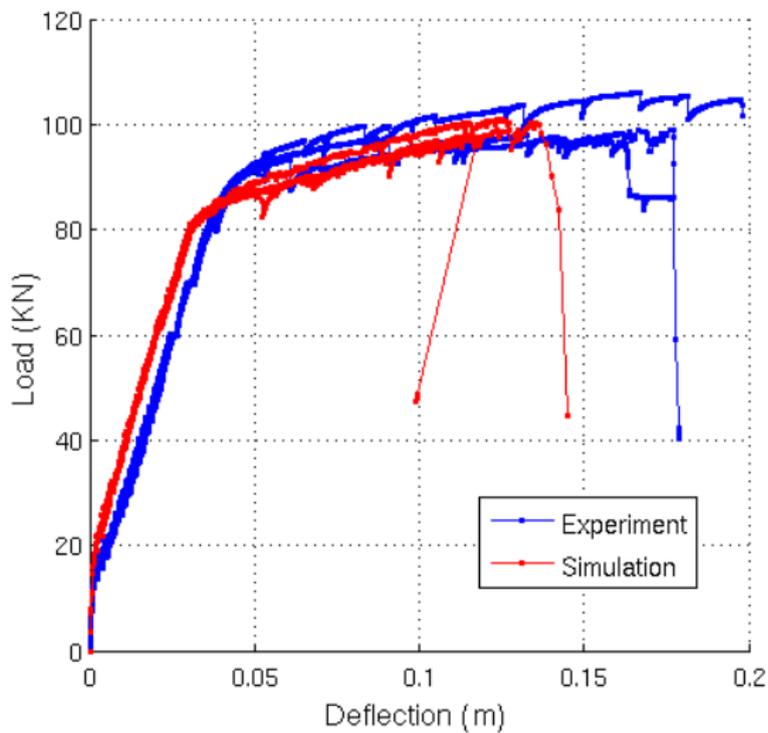
3D simulation

Experiment



**Figure:** Cracking profile at the bottom of beam slab

# Results of the beam slab reinforced by flat steel (bending 4 points)

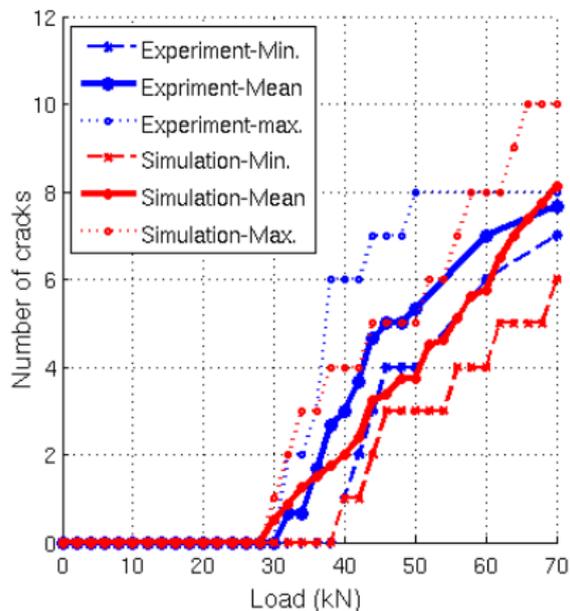


good agreement

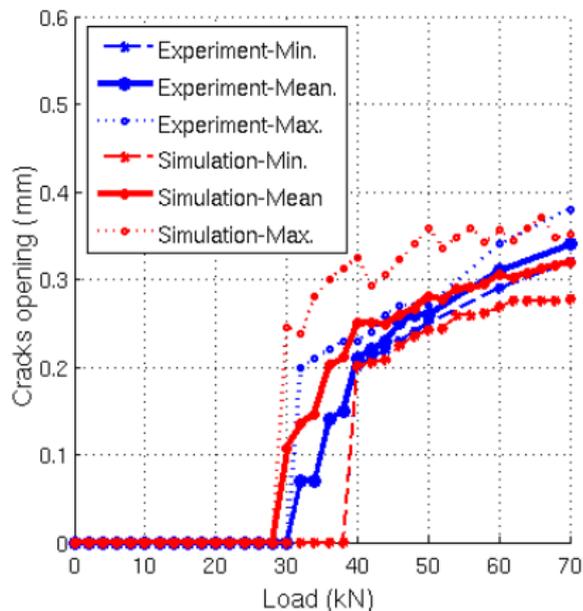
**Figure:** Deflection in the midspan of the beam

# Results of the beam slab reinforced by flat steel (bending 4 points)

## Mean and dispersion (min-max) values



(a) Number of cracks

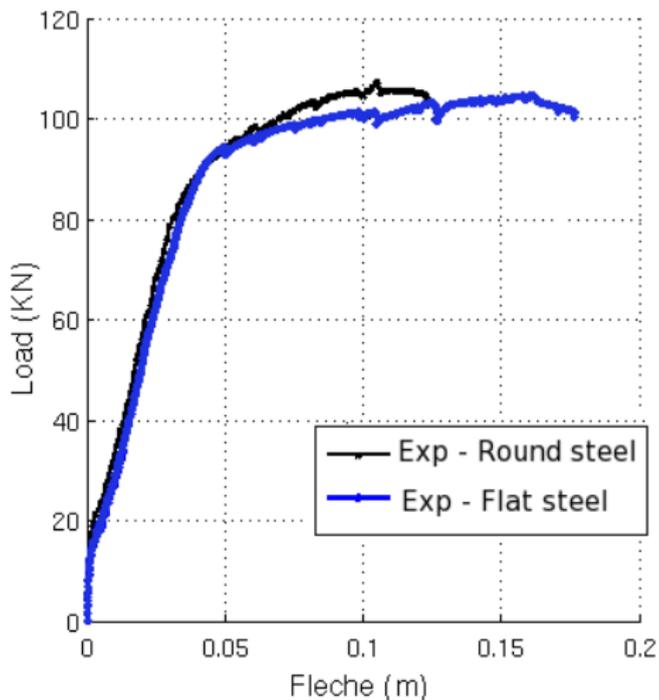


(b) Cracks opening

# Beam slab reinforced by flat steel (bending 4 points) vs. round steel

Beam reinforced by round steel ( $h=16$  cm) .vs. Beam reinforced by flat steel ( $h=15$  cm)

⇒ saving 1cm of thickness of concrete.



# Conclusions

- The numerical tool can predict the failure of RC structures.
- The model can provide relevant information on the global behaviour (load-displacement) and also local behaviour (cracking process).
- The flat steel can be used in RC structures instead of the traditional round steel.
- By using the flat steel, we can save in the matter of concrete (reduce  $CO_2$  emissions).

# Numerical probabilistic simulation of cracking processes in RC tie-beams subjected to tension and reinforced by flat steel rebars

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Thanks for your attention !

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