Modeling of the behaviour of RC tie-beams reinforced by flat steel rebars: A comparison between 2D and 3D numerical simulation of the steel/concrete interface

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SSCS'2012, 29 Mai - 1 June 2012
Aix-en-Provence - France

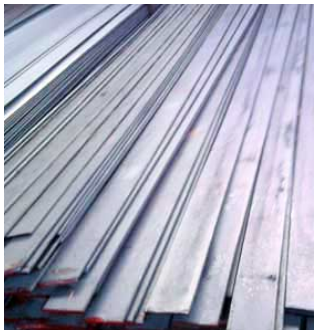
Outline

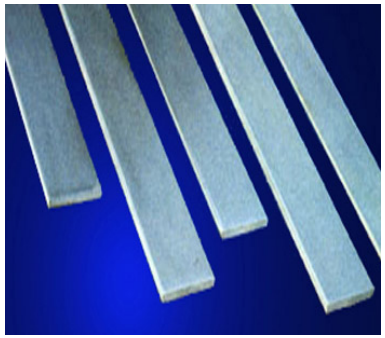
Context

Flat steel

- Appeared the first time in the years 1930-1940
- Used for thin elements
- Advantages : Saving potential of matter on the concrete and the steel, increase the surface of adhesion, easy implementation,...

Smooth flat steel rebars

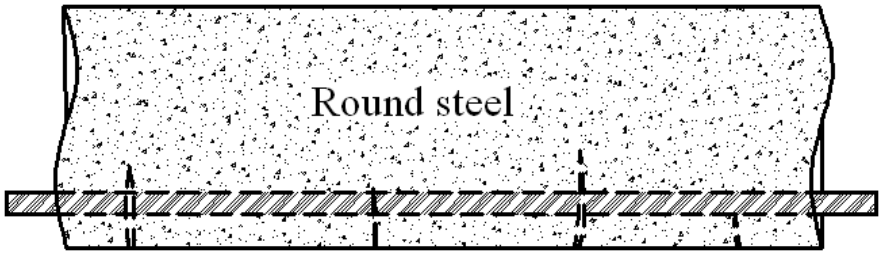


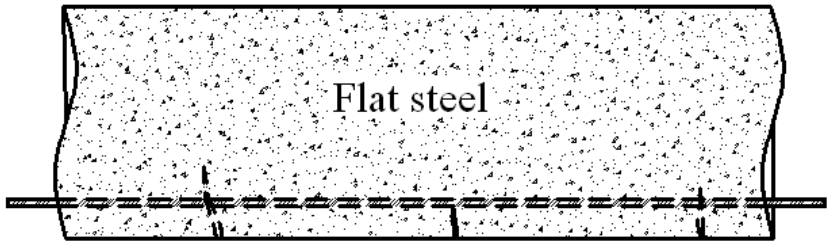


Ribbed flat steel rebars

Matière

Industrial problem





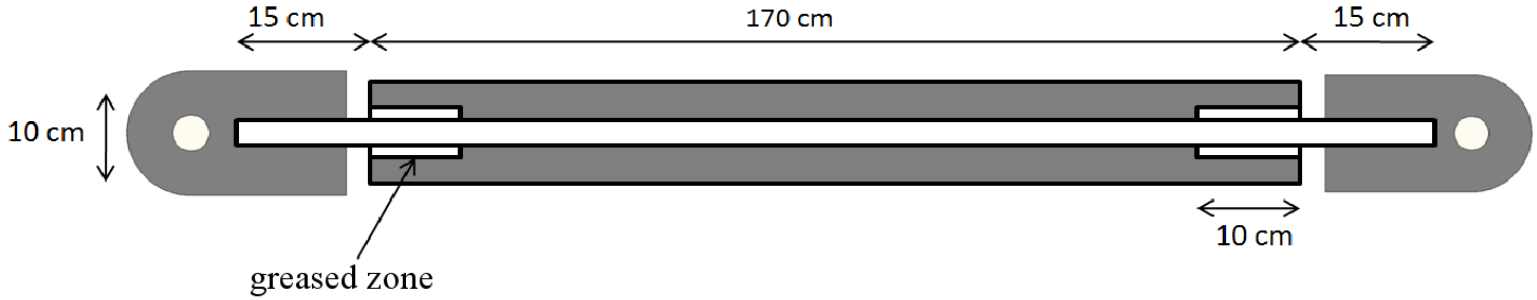
Influence of this flat steel on the :

- Global behavior in service conditions of structures ?
- Repartition of the number and openings of cracks ?

Scientific problem :
the behavior of steel-concrete interface

Numerical modelling of the steel-concrete interface

Study objective - Experimental tests on RC tie-beams



Tie-beam 170 x 10 x 10 cm reinforced by flat steel 22.5 mm x 5 mm

Experimental tests

MATIERE® - Polytech'Clermont Ferrand
measurement (cracking, load/displacement)

Modelling

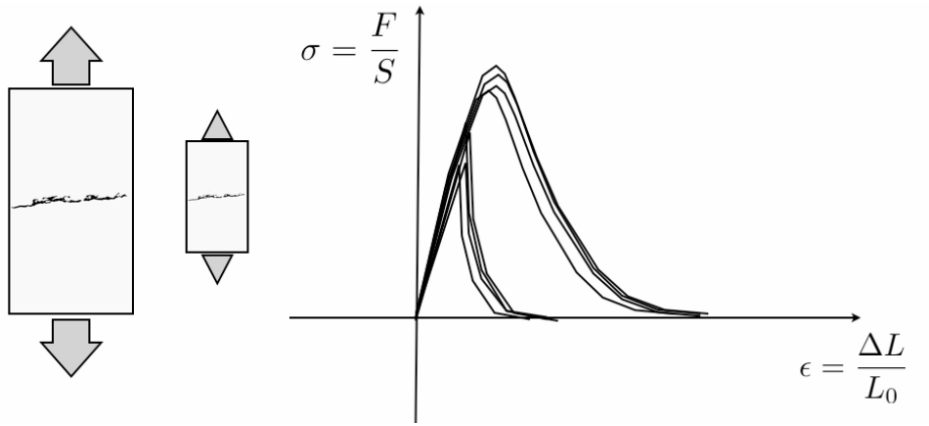
CEM3 - IFSTTAR
Identification of model parameters

Inverse analysis : Identification of parameters of the model interface

Probabilistic model for the mechanical behaviour of the concrete P. Rossi (1991)

Heterogeneity of concrete

- The local mechanical characteristics of concrete (f_t, E_b) are random and dependent on the volume of material solicited

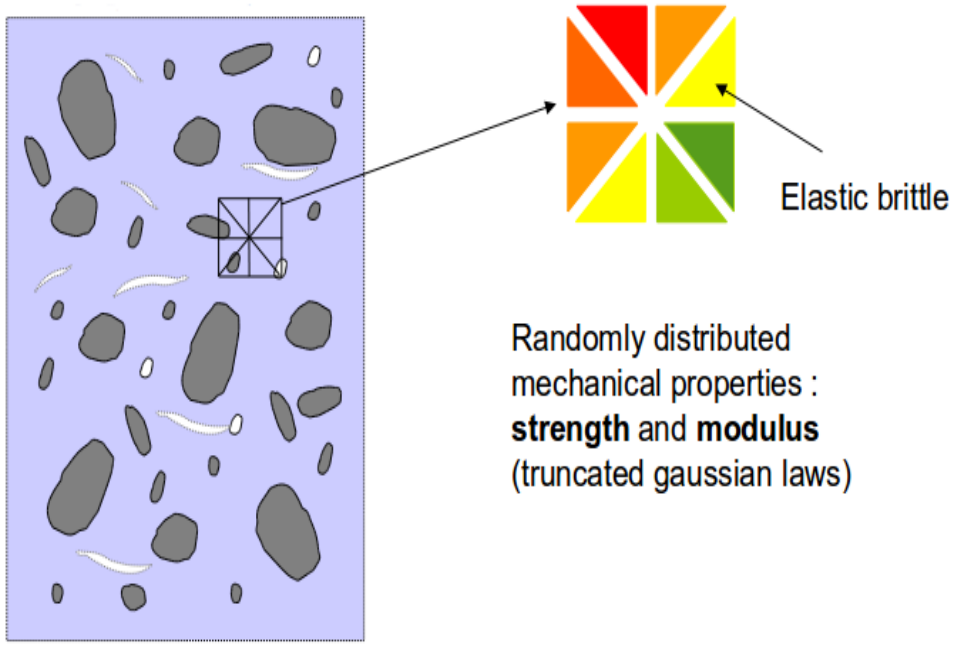


Cracking creation of fracture planes elementary

- The cracking process is driven by the presence of fault in the cement paste, the heterogeneity of the material and the development of gradient stress in the material
- Crack propagation is described via local failure planes that appear randomly

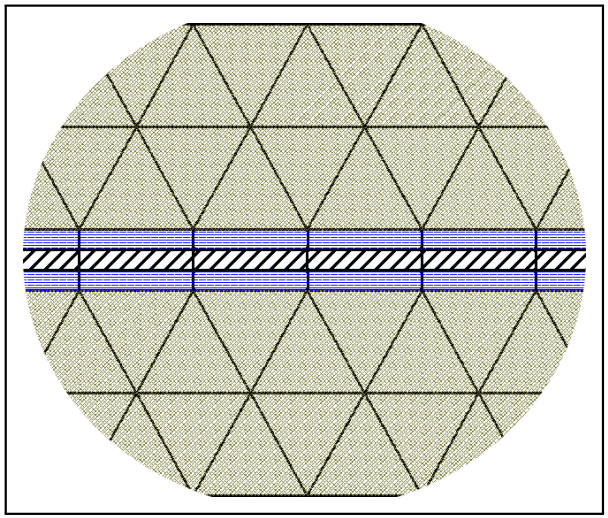
Modelling of steel-concrete interface

A model of steel-concrete interface coherent with the cracking model of concrete



HYP : Physical mechanisms appearing at the specimen scale are supposed to be representative to those appearing at the material scale

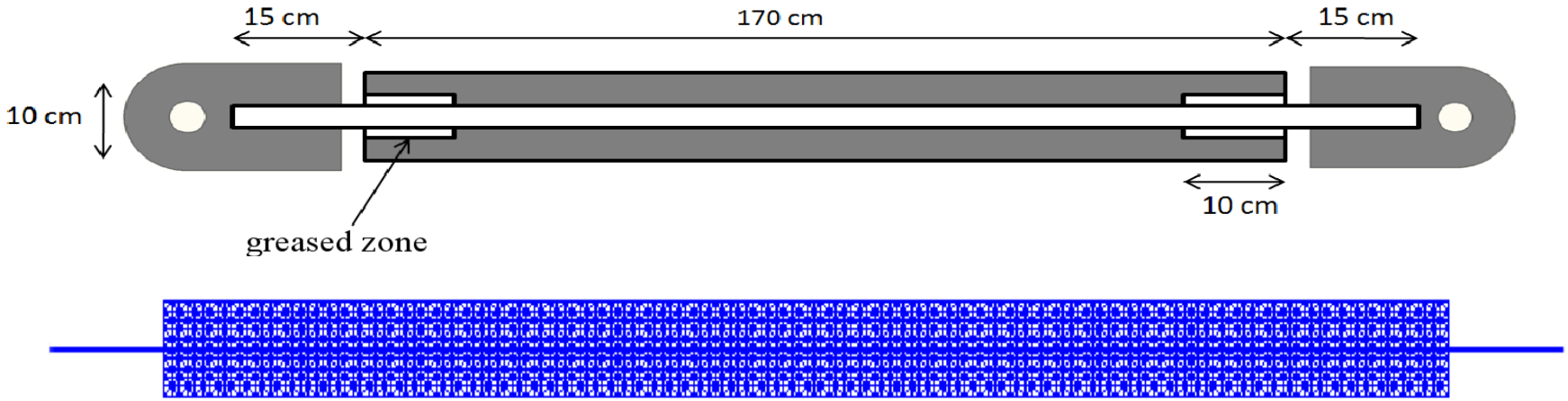
$$m(f_t), \sigma(f_t), \sigma(E) = f\left(V_s/V_g, f_c\right) \rightarrow f\left(V_e/V_g, f_c\right)$$



Model of interface

- Interface element
- Damage law
  - Cohesion C
  - Tangential displacement critical δ_t^{cri}

Modelling of tie-beam reinforced by flat steel



Model	Input parameters	
Cracking of concrete	$f_c = 55$ MPa $E_b = 35000$ MPa $D_g = 16$ mm	$\Rightarrow$ experimentally determined
Interface (steel-concrete)	$C =?$ $\delta_t =?$	$\Rightarrow$ **Objective : to determine with inverse analysis approach**
Flat steel (elastic)	$E_s = 210000$ MPa	

Parametric study on tie-beams reinforced by flat steel

Critical tangential displacement δ_t^{cri}	Cohesion C (MPa) 6	10	15	20	25	30
δ_t^e	9 sim.	9 sim.	9 sim.	9 sim.	9 sim.	9 sim.
$10\mu m$	9 sim.	9 sim.	9 sim.	9 sim.	9 sim.	9 sim.
$15\mu m$	9 sim.	9 sim.	9 sim.	9 sim.	9 sim.	9 sim.
$20\mu m$	9 sim.	9 sim.	9 sim.	9 sim.	9 sim.	9 sim.
$25\mu m$	9 sim.	9 sim.	9 sim.	9 sim.	9 sim.	9 sim.
$30\mu m$	9 sim.	9 sim.	9 sim.	9 sim.	9 sim.	9 sim.

Total : 324 simulations

Comparison :

- **Relative displacement**
- **Number of cracks**
- **Cracks opening**
- **Cracks spacing**

Optimum case :
C = 15 MPa, $\delta_t = 25\ \mu m$

vs

experimental tests

Results on the tie-beams reinforced by flat steel

Figure: Cracking profile of experimental test

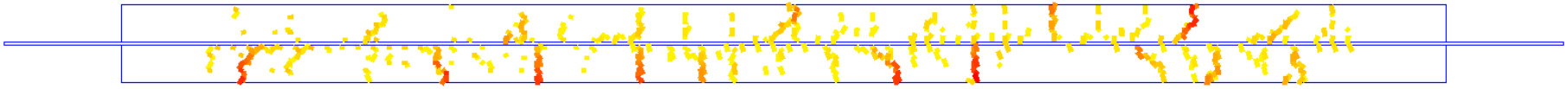


Figure: Cracking profile of tie-beam in 2D simulation

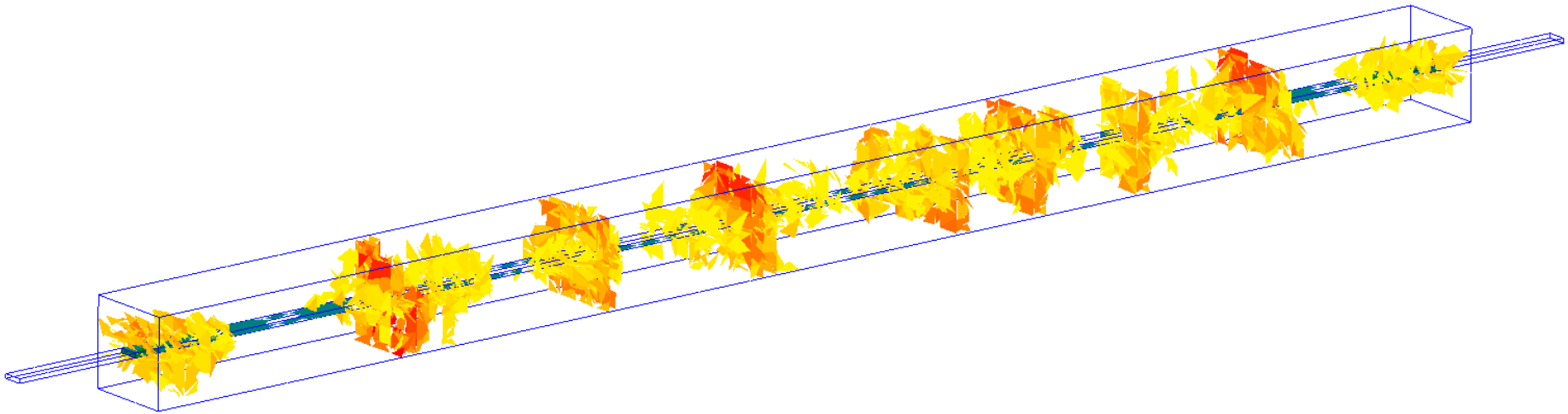


Figure: Cracking profile of tie-beam in 3D simulation

Results on the tie-beams reinforced by flat steel

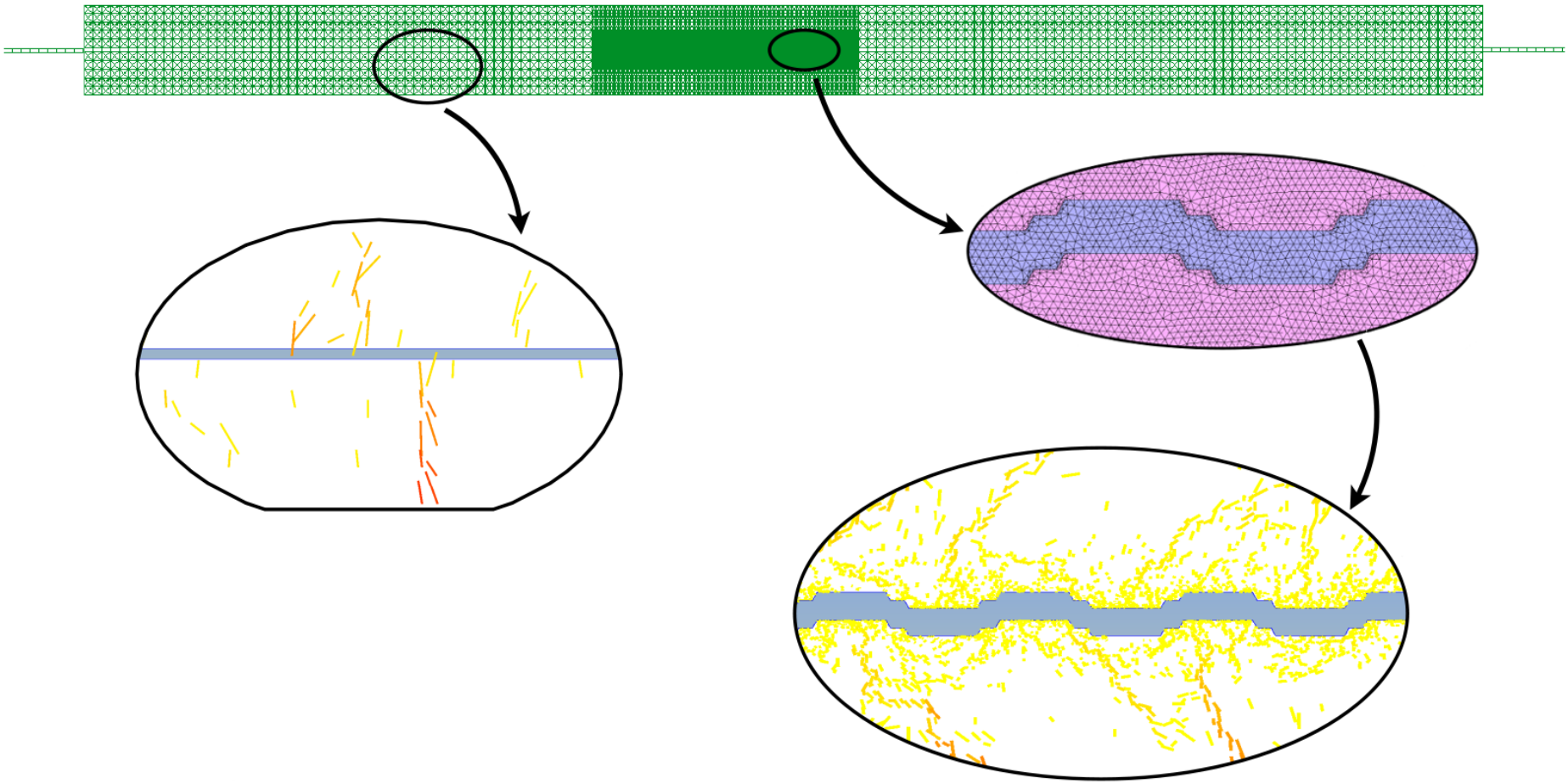


Figure: 2D multi-scale simulation of tie-beam

Results on the tie-beams reinforced by flat steel

Comparison of mean values (C = 15MPa, $\delta_t^{cri} = 25\mu m$) with the experience

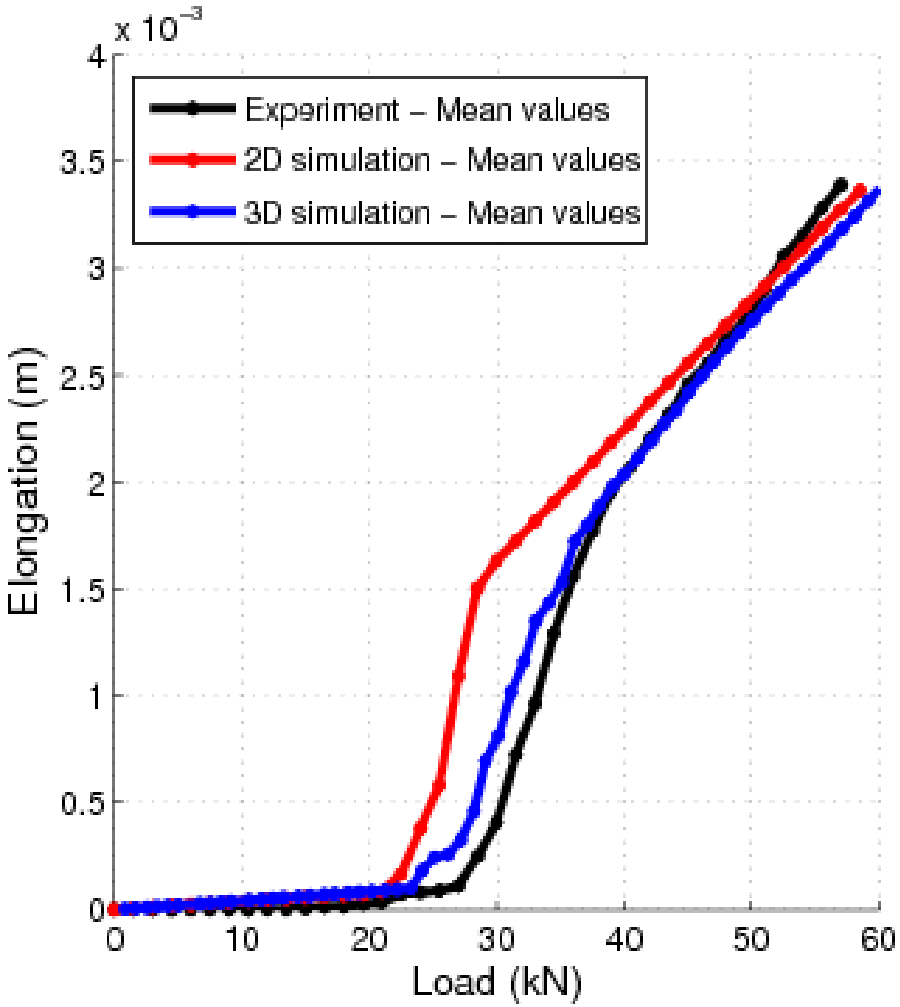


Figure: Elongation (mean curves)

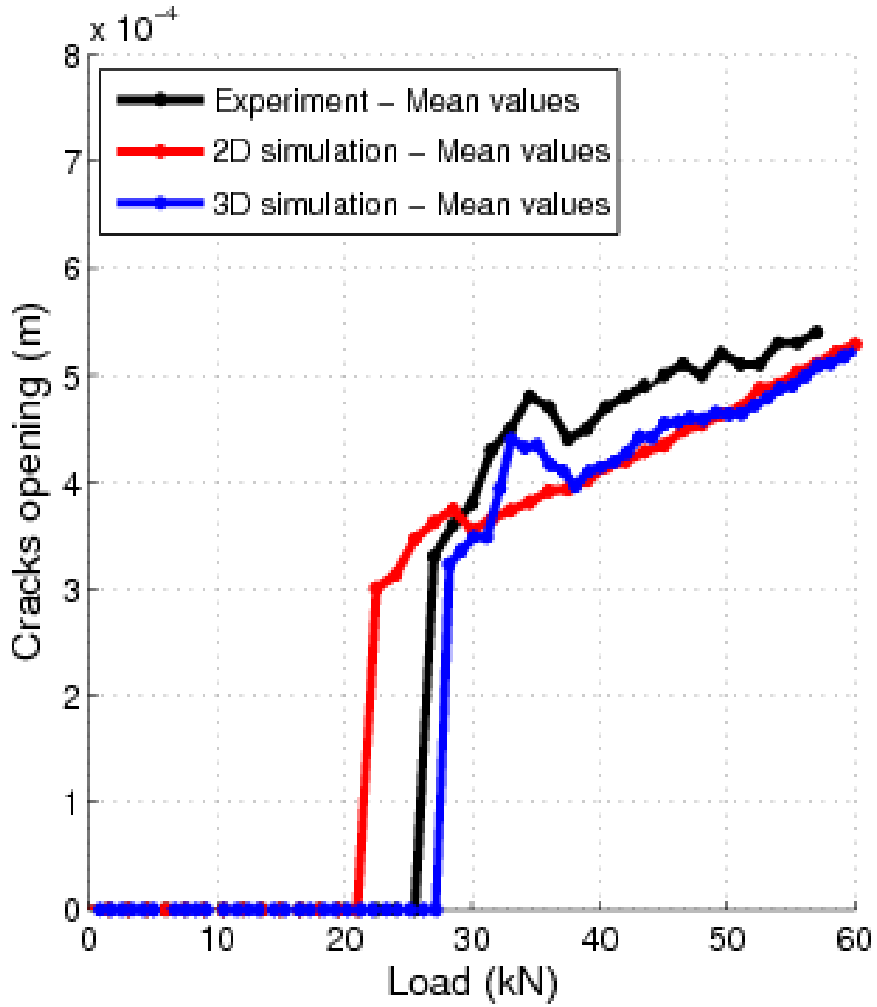


Figure: Cracks opening (mean curves)

Results on the tie-beams reinforced by flat steel

Comparaison of the dispersion (C = 15MPa, $\delta_t^{cri} = 25\mu m$) with the experience

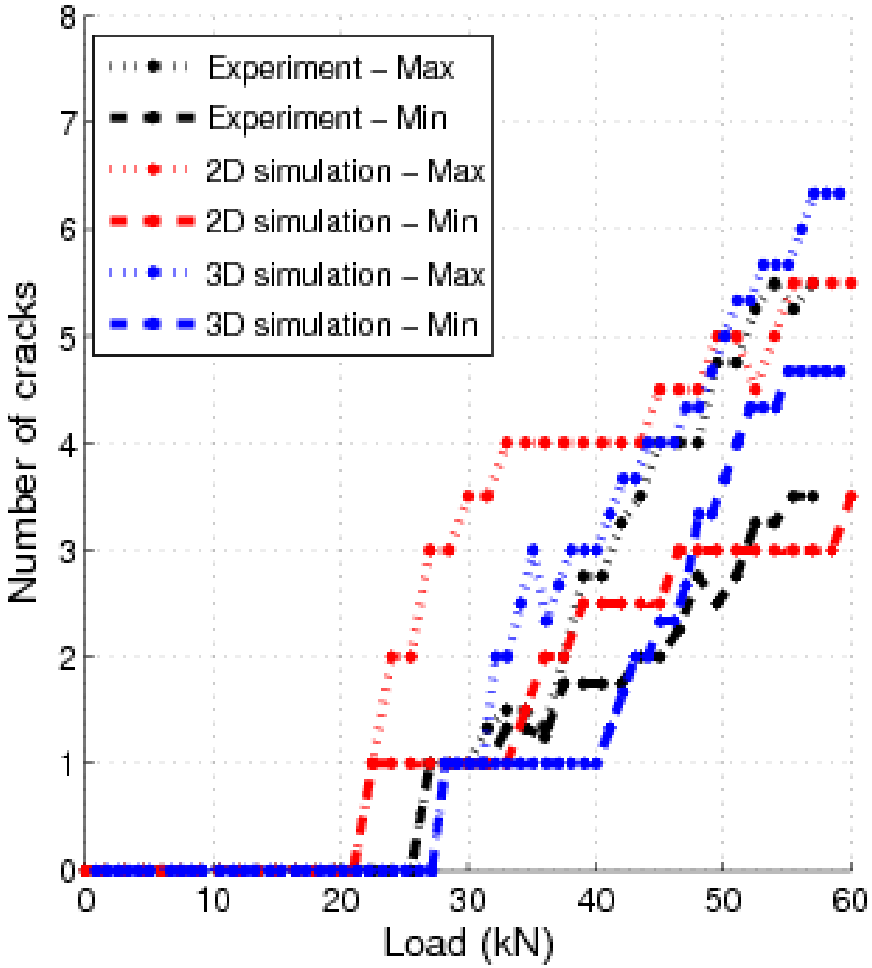


Figure: Number of cracks (min-max curves)

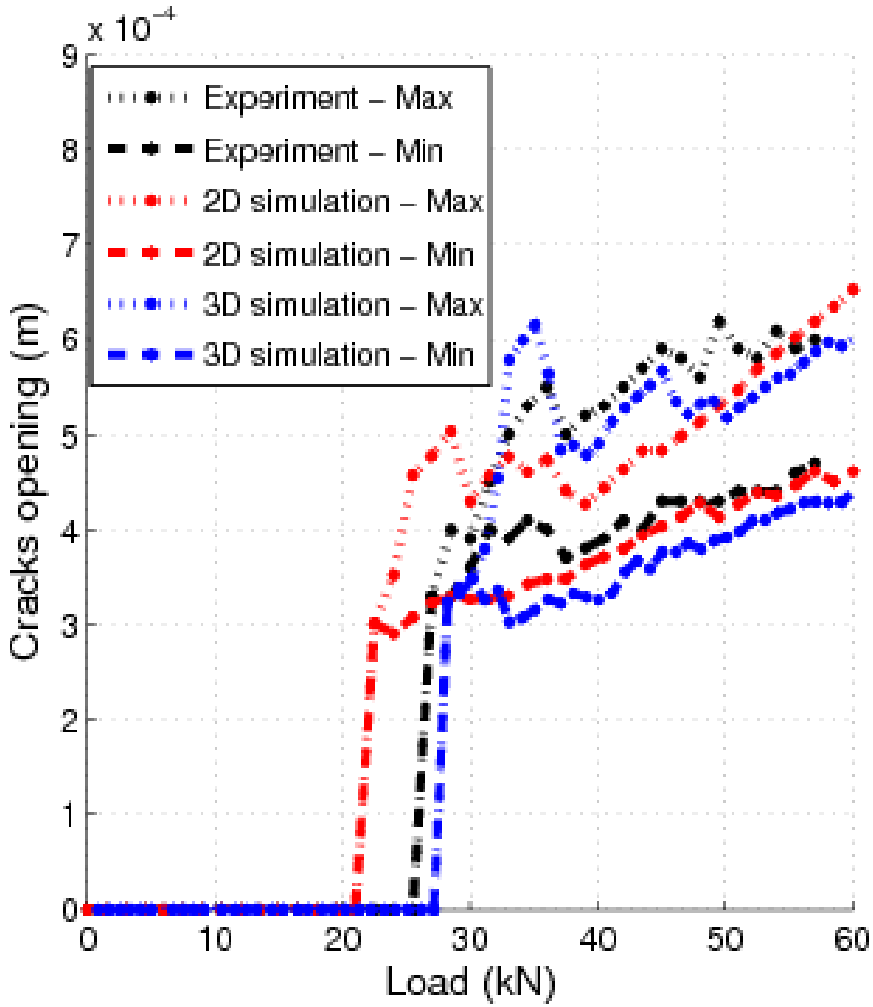


Figure: Cracks opening (min-max curves)

Conclusions

Conclusions

- We have a simple interface model that gives results comparable with the experience
- The model can provide relevant information on the cracking process for a type of reinforcement (giving access to all the micro-macro cracking).
- The inverse analysis approach is relevant to identify the behavior of steel-concrete interface.

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

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SSCS'2012

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Thanks for your attention !

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