The Ninth International Conference on Computational Structures Technology (CST2008)
Athens, Greece, 2-5 September 2008

Numerical Modelling of Shear Connections for Composite Slabs

Noémi Seres, Attila László Joó, László Dunai

Budapest University of Technology and Economics
Department of Structural Engineering
Budapest, Hungary

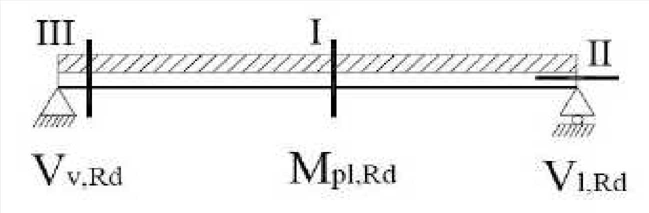
Introduction

- Structural arrangement

Concrete slab
Profile deck
Steel beam

Frictional interlock
Mechanical interlock – rolled embossments

- Failure modes

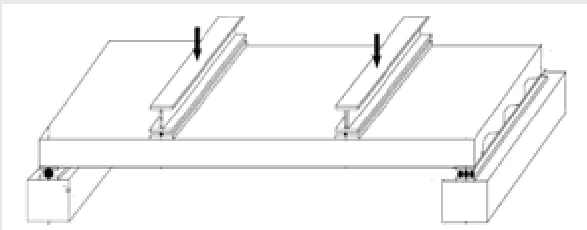


(I) flexural failure (II) longitudinal shear failure (III) vertical shear failure

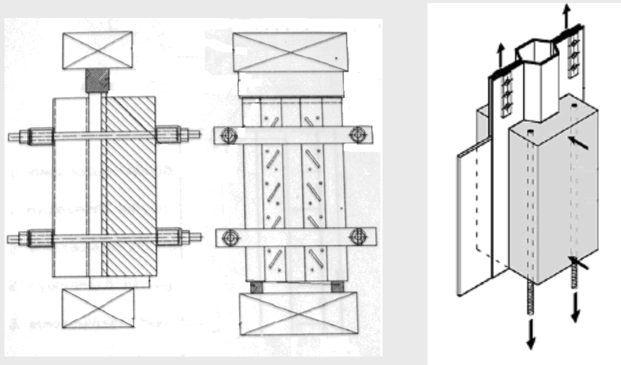
Introduction

- Performance tests

a)



b)



(a) Full – scale test

(b) Small – scale test

- Scope

  (i) simplify the experiments

  (ii) develop an advanced numerical model for the simulation

Experimental program

- Short beam specimens

Geometry: 150x150x700

Type: Concrete beam

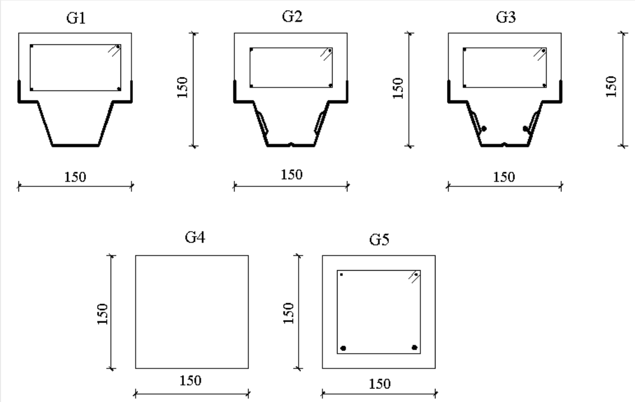
Reinforced concrete beam

Composite beam

– half wave of an open through profile

– with and without rolled embossments

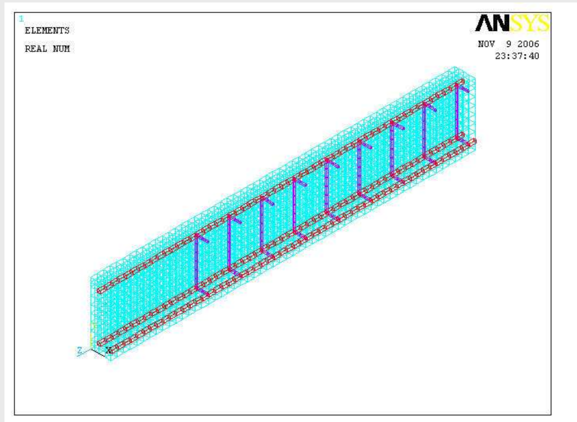
– ~3mm of rim



Verification background for further numerical models

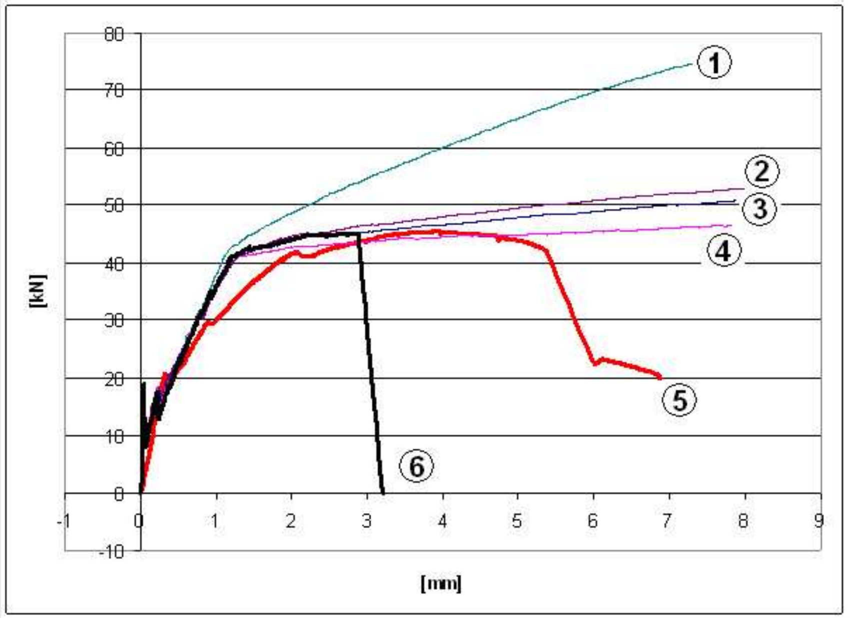
Reinforced concrete modelling

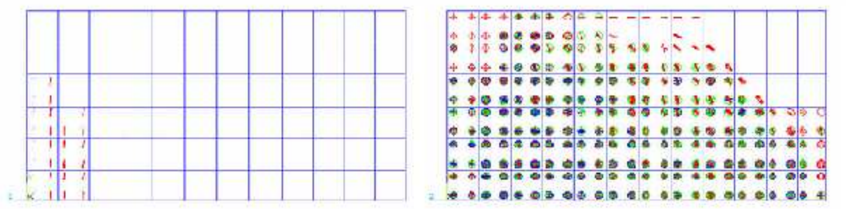
- Reinforced concrete short beam
  - Quarter beam model
  - ANSYS
  - Material properties set by experiments
  - Concrete → Solid65
  - Steel → Link8
  - Small loadsteps
    - Velocity of crack propagation stays low
    - Numerical stability



Reinforced concrete modelling

- Reinforced concrete short beam





1) Full reinforcement, non crushing concrete, shear transfer coefficient=1

2) Without stirrups, non crushing concrete, shear transfer coefficient = 1

3) Only tensioned reinforcement, non crushing concrete, shear transfer coefficient = 1

4) Only tensioned reinforcement, non crushing concrete, shear transfer coefficient = 0.3

5) Experimental results

6) Only tensioned reinforcement, crushing concrete, shear transfer coefficient = 0.3

← Crack patterns for first crack and final state

Local models of rolled embossments

- "Fictive" local model

Composite short beam experimental observations

↓

Major factors in failure

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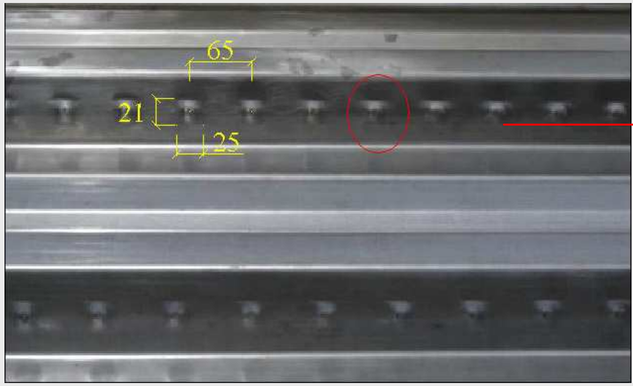
(1) chemical bond,
(2) mechanical bond
  - effect of rolled embossments
} General factors → MODELLING

(3) pull-out of the steel rim. → Short beam's specific factors

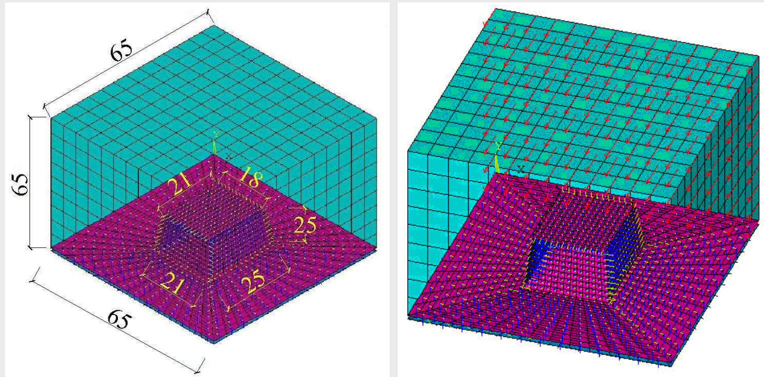
Local models of rolled embossments

- “Fictive” local model

Rectangular dishing type:



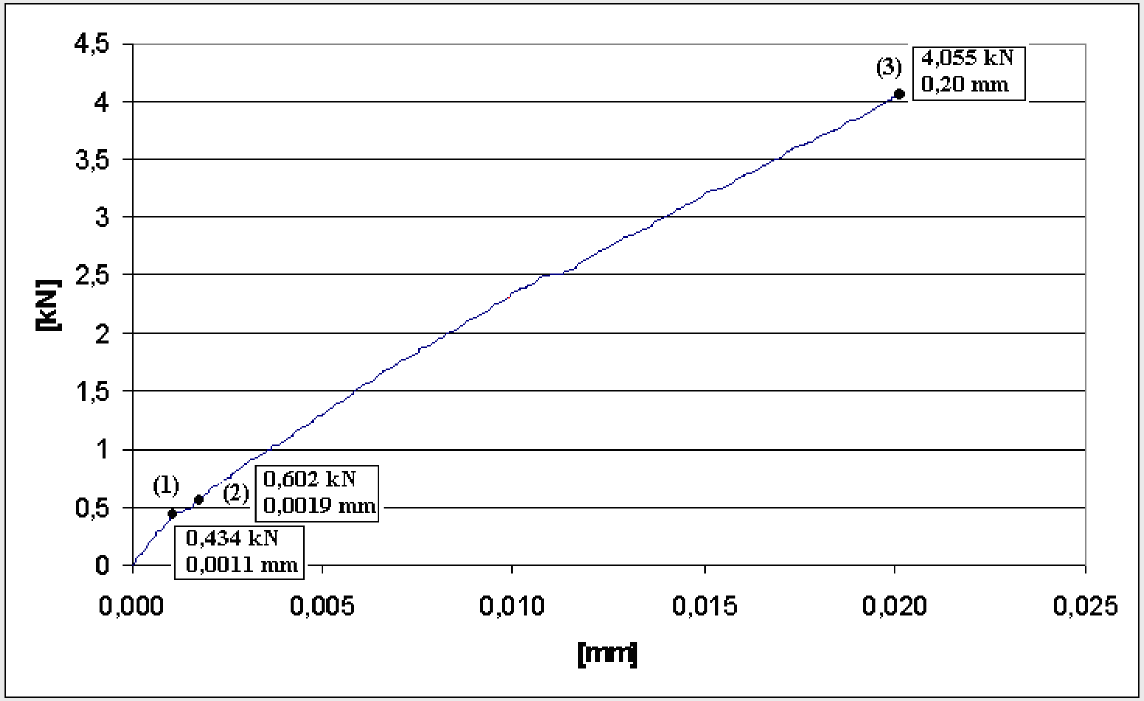
Simplified geometry



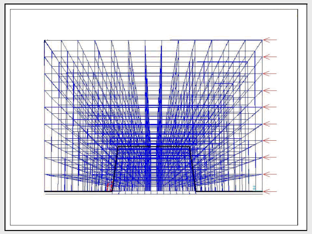
Material	FE in ANSYS
Concrete	Solid65
Steel	Shell181
Chemical interlock	Conta173-Targe170

Local models of rolled embossments

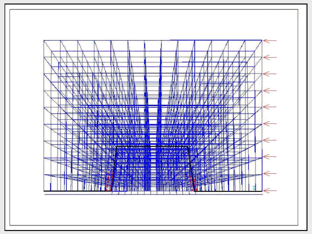
- "Fictive" local model



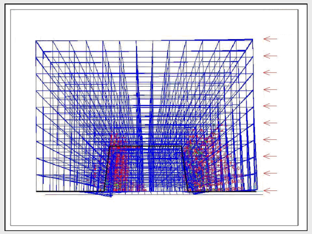
First crack

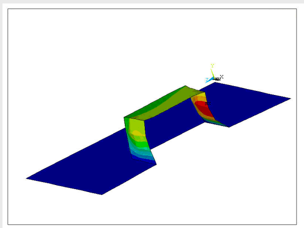


Second crack



Final state: cracks and deformed sheet





Local models of rolled embossments

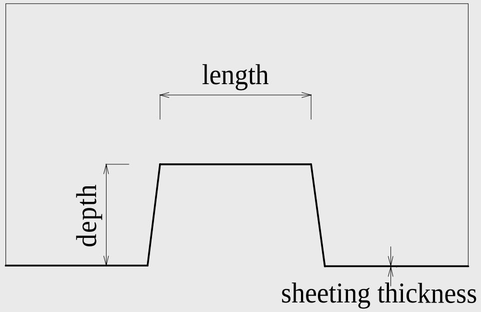
- "Fictive" local model
  - Runtime ~5 hours
  - Significant increase in runtime when increasing the model size
  - Efficient composite beam model
  - Embossments ⟶ spring
  - Spring constant ⟶ local model analysis

Local models of rolled embossments

- Parametric study by fictive models

Parameters:

- Embossment's depth
- Embossment's length
- Sheeting thickness



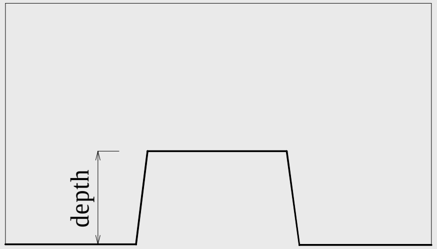
Expected results by experimental observations [1]:

- Deeper embossment → higher shear stress value (most significant)
- Longest length → higher shear resistance (limit!)
- Sheeting thickness → significant effect on stiffness

[1] P. Mäkeläinen, Y. Sun: "The longitudinal shear behaviour of a new steel sheeting profile for composite floor slabs", Journal of Constructional Steel Research, 49, 117-128, 1999

Local models of rolled embossments

- Depth analysis

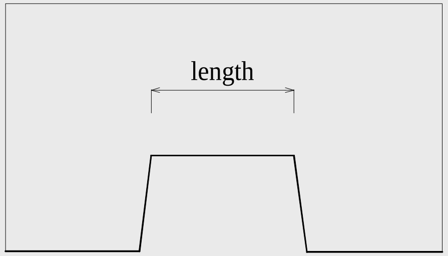


  - Curve’s character remained the same
  - Increase in the load when increasing the depth at the end of linear phase
  - Significant difference in ultimate loads → tendency not obvious

Depth [mm]	Load at the end of the linear phase [kN]	Ultimate load [kN]
10	0.3345	1.304
12.5	0.3588	3.488
15	0.4054	4.055
17.5	0.4095	3.184
22.5	0.4257	3.857
25	0.4340	4.055

Local models of rolled embossments

- Length analysis



  - Increase in load when increasing the length
  - The difference between the ultimate loads in 10% range

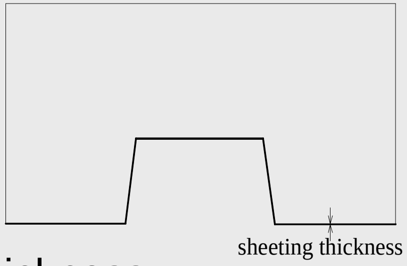
↓

  - The change of length has not significant influence

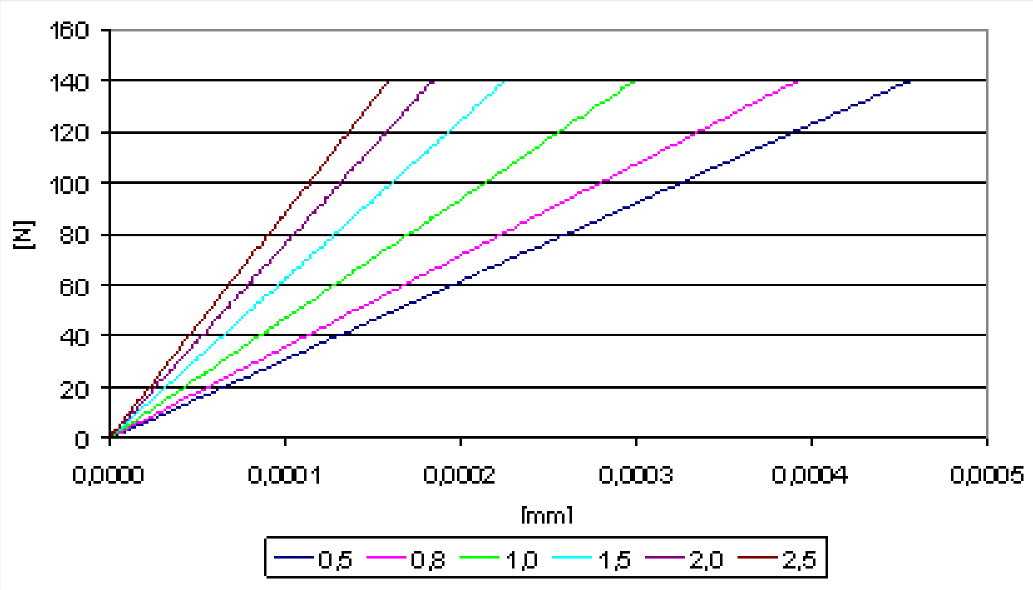
Length [mm]	Load at the end of the linear phase [kN]	Ultimate load [kN]
15	0.3649	3.604
17.5	0.4054	4.054
20	0.4257	3.812
21	0.4340	4.055
22.5	0.4440	3.925
30	0.5292	3.936

Local models of rolled embossments

- Effect of sheeting thickness



  - Increase in stiffness when increasing the sheeting thickness



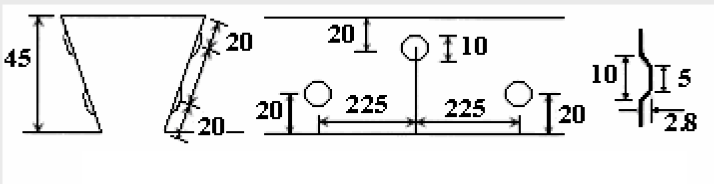
Local models of rolled embossments

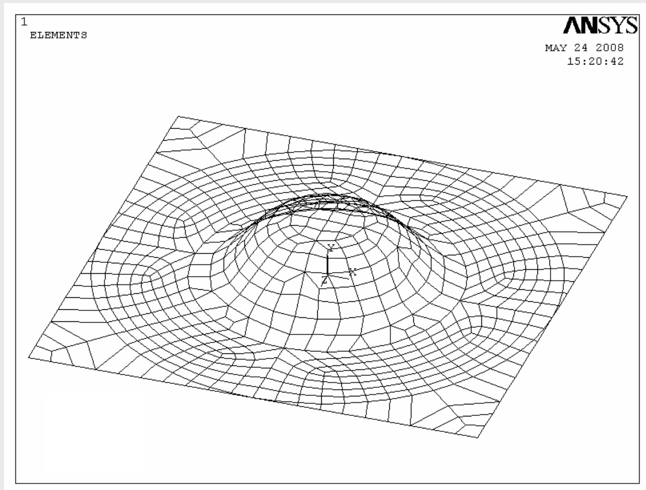
- Modelling of circular embossment

  • Basic behaviours determined for „fictive” local model

  •Refinement → new dishing type

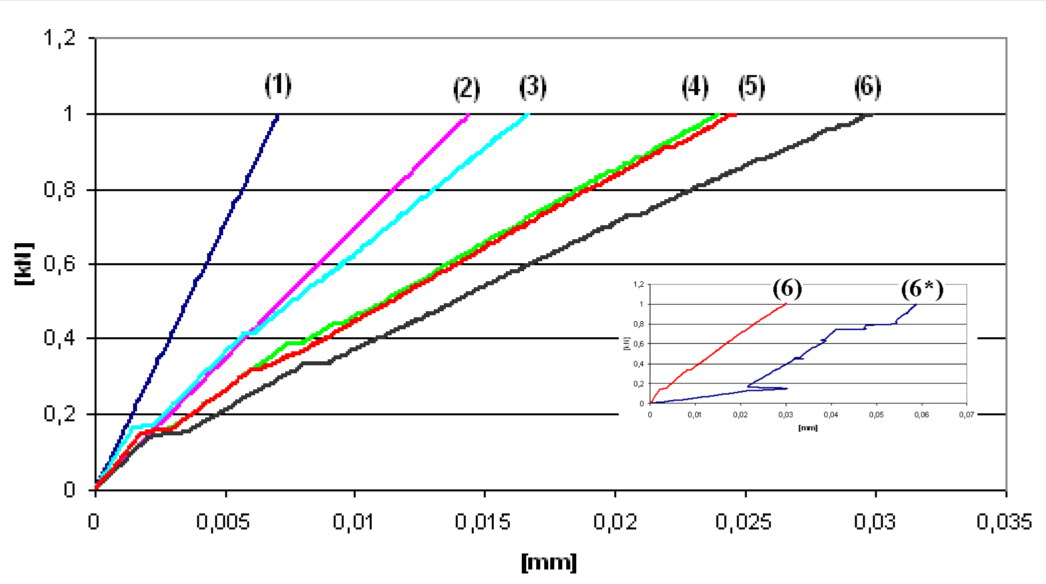
  •Same arrangement as „fictive” model





Local models of rolled embossments

- “Step by step” modelling process, modelling problems



(1) lin. elastic steel properties on the whole model

(2) lin. elastic steel and concrete

(3) non-crushing concrete, shear transfer coefficient=1,0

(4) non-crushing concrete, shear transfer coefficient=0,3

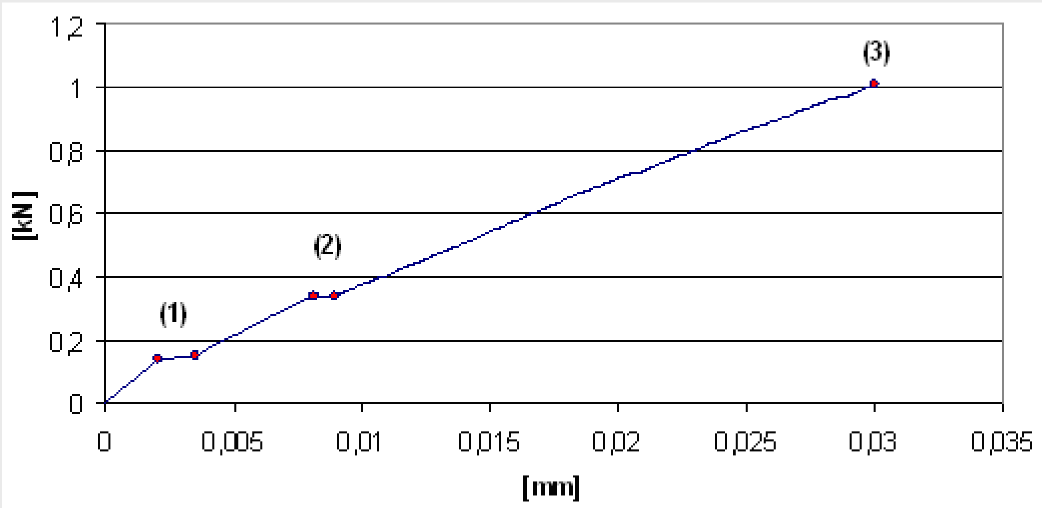
(5) crushing concrete, shear transfer coefficient=0,3

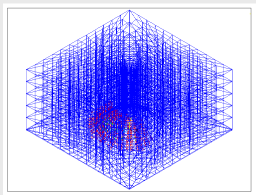
(6) + nonlinearity of steel

→ symmetrical contact surface

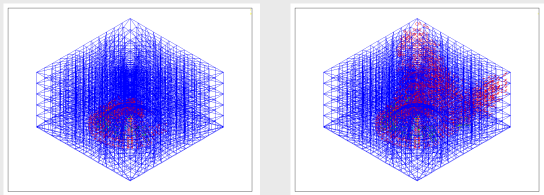
Local models of rolled embossments

- Circular embossment's local model

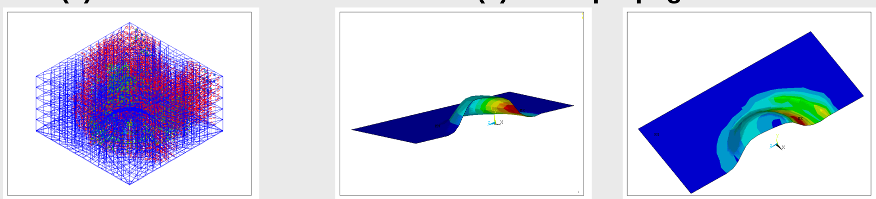




(1) First crack



(2) crack propagation



(3) Final state: crack pattern, steel deformation and stress distribution

Concluding remarks

- Novel alternative of experimental analysis (short beam) for composite connection.
  - Tendency of the failure modes became traceable → numerical analysis
- Adequate concrete and reinforced concrete model
- Numerical local model for fictive rolled embossments
  - Basic behaviour modes
  - Parametric study ↔ published experiments

Contradiction in the results of the depth and length analysis

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Chosen experiment ↔ traditional push-out tests

Necessity of new laboratory experiments to prove the results

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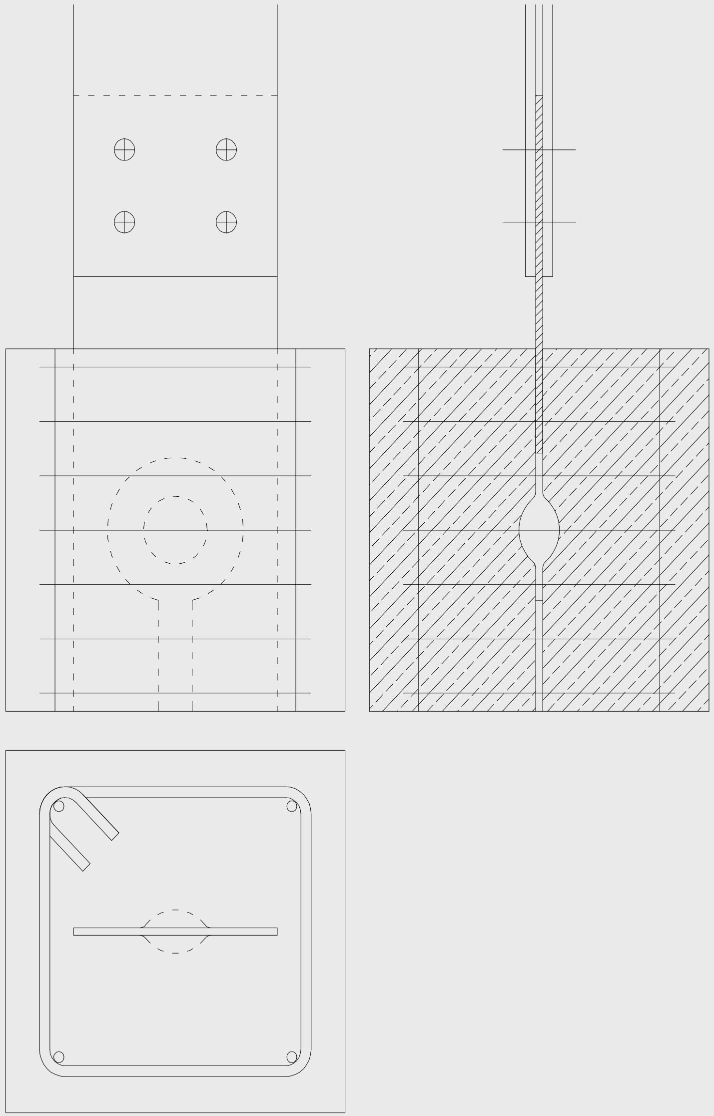
Pilot experimental investigation for local model calibration

Pilot experimental program

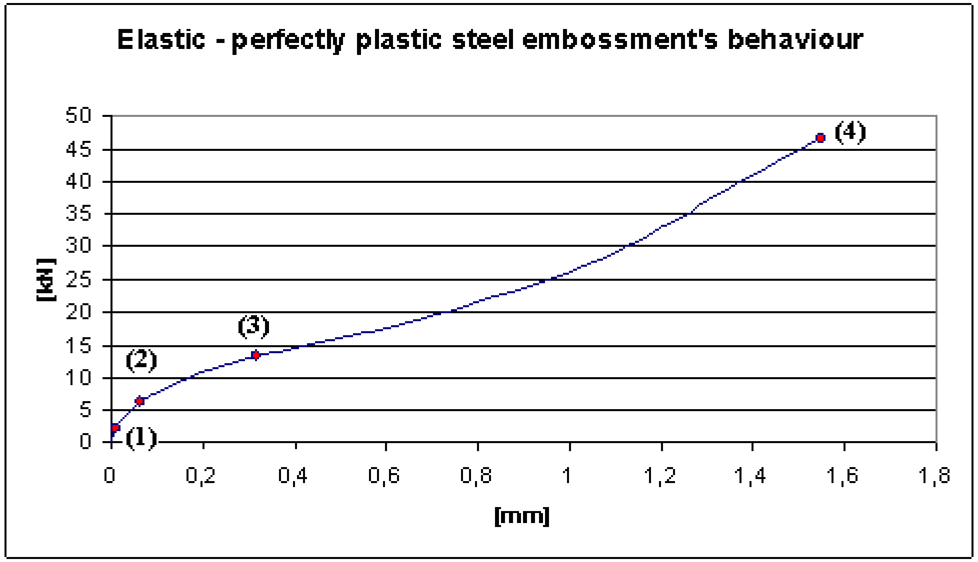
- Special pull-out test
  - 20x20x20 RC cube
  - Embedded steel plate with one enlarged embossment



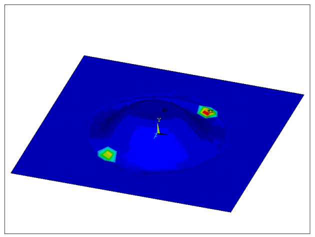
Thank you

Local models of rolled embossments

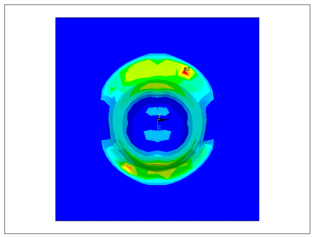
- Modelling of pure steel behaviour



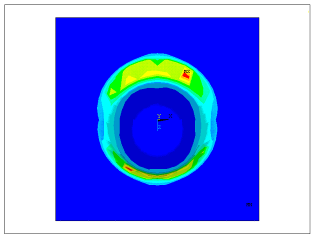
Plastic strain distribution:



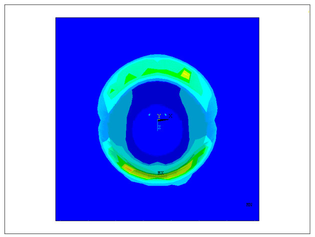
(1) First yielding



(2) Plastic zone on the top



(3) Rearrangement – unloading of the top



(4) Final state

Local models of rolled embossments

- Effect of friction coefficient on the local model

  - Stiffness increase when the friction of coefficient increases