Experimental investigation of individual embossed mechanical bond in composite floor

Noémi Seres, László DUNAI
Table of contents

- Subject– experimental analysis of the mechanical bond in composite floors

- Layout:
  - Introduction
  - Experimental investigation
  - Concluding remarks
  - Next step of the research
Introduction

- Structural layout
  - 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) Full-scale specimens
  b) Small scale specimens of push-out test

• Scope
  • Simplify the experiments
  • Develop an advanced numerical model for the simulation
Numerical pre-study

- Model levels
  1. Concrete material model
  2. Composite connection model
  3. Composite beam model

ANSYS
Numerical pre-study

- Concrete material model
  - Simply supported RC beam
  - ANSYS code
  - Appropriate concrete material model
Numerical pre-study

- Local model of embossed mechanical bond
  - Basic behaviour
  - Parametric study

  Simplified geometry

  Complex behaviour
  Experimental verification
  Benchmark experiments for local model verification
Experimental program

- **Layout**
  - Two plate thicknesses
  - Six specimens
  - One enlarged embossment
  - Strain gauge measurement
  - Two plates back-to-back in the concrete cube
  - Separation with spacer plate
  - Free deformation of the embossment is insured
  - Avoid global failure in concrete→ stirrups
Experimental program

• Strain gauges

Strain gauges (a) basic and (b) supplementary
Experimental program

• Strain gauges
Experimental program

• Specimens
## Experimental program

<table>
<thead>
<tr>
<th>Sign</th>
<th>Sheeting thickness [mm]</th>
<th>Strain gauges [pc]</th>
<th>Concrete cube size [cm]</th>
<th>Steel plate size [mm]</th>
<th>Embossment diameter/height [mm]</th>
<th>$f_y/f_u$ of steel [N/mm$^2$]</th>
<th>$f_{ck}$ of concrete [N/mm$^2$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>1.5 mm</td>
<td>5</td>
<td>20x20x20</td>
<td>340x120</td>
<td>37.4/10</td>
<td>444/510</td>
<td>43.35</td>
</tr>
<tr>
<td>1.2</td>
<td>1.5 mm</td>
<td>5</td>
<td>20x20x20</td>
<td>340x120</td>
<td>37.4/10</td>
<td>444/510</td>
<td>43.35</td>
</tr>
<tr>
<td>1.3</td>
<td>1.5 mm</td>
<td>15</td>
<td>20x20x20</td>
<td>340x120</td>
<td>37.4/10</td>
<td>444/510</td>
<td>43.35</td>
</tr>
<tr>
<td>2.1</td>
<td>2 mm</td>
<td>5</td>
<td>20x20x20</td>
<td>340x120</td>
<td>37.4/10</td>
<td>459/534</td>
<td>43.35</td>
</tr>
<tr>
<td>2.2</td>
<td>2 mm</td>
<td>5</td>
<td>20x20x20</td>
<td>340x120</td>
<td>37.4/10</td>
<td>459/534</td>
<td>43.35</td>
</tr>
<tr>
<td>2.3</td>
<td>2 mm</td>
<td>15</td>
<td>20x20x20</td>
<td>340x120</td>
<td>37.4/10</td>
<td>459/534</td>
<td>43.35</td>
</tr>
</tbody>
</table>

* yield stress/ultimate stress  
** compressive strength
Experimental program

• Execution
  - Loading frame
  - Support from above
  - Centralized and uniform load transfer
  ↓
  - Hard rubber pad on the supported concrete surface
  - Strain measurement
  - Relative displacement measurement
Test results

• Failure
  - First crack on the exterior side of concrete
  - Crack propagation
  - Slip of the plate
  - Two kinds of cracks

Concrete failure: (a) crack type #1 (b) crack type #2

Embossment’s failure
Test results

- Force – displacement

![Graph showing force-displacement relationship with markers indicating various forces and displacements.]

- 1st yielding on the steel plate
- 2.2 specimen
- 1.3 specimen

<table>
<thead>
<tr>
<th>Force [kN]</th>
<th>Displacement [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.9</td>
<td></td>
</tr>
<tr>
<td>28.8</td>
<td></td>
</tr>
<tr>
<td>31.6</td>
<td></td>
</tr>
<tr>
<td>40.6</td>
<td></td>
</tr>
<tr>
<td>42.2</td>
<td></td>
</tr>
<tr>
<td>20.6</td>
<td></td>
</tr>
<tr>
<td>21.9</td>
<td></td>
</tr>
<tr>
<td>16.4</td>
<td></td>
</tr>
</tbody>
</table>
Test results

• Results

<table>
<thead>
<tr>
<th>Sign</th>
<th>End of linear phase [kN]</th>
<th>1st crack [kN]</th>
<th>Slip of plate [kN]</th>
<th>Ultimate load [kN]</th>
<th>1st yielding on steel plate [kN]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.3</td>
<td>16,4</td>
<td>21,9</td>
<td>28,8</td>
<td>31,6</td>
<td>4,39</td>
</tr>
<tr>
<td>2.2</td>
<td>20,6</td>
<td>29,3</td>
<td>40,6</td>
<td>42,2</td>
<td>5,62</td>
</tr>
</tbody>
</table>

• Design characteristics

<table>
<thead>
<tr>
<th>Plate thickness [mm]</th>
<th>Initial stiffness [N/mm]</th>
<th>Load carrying capacity [kN]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,5</td>
<td>5 722</td>
<td>34,33</td>
</tr>
<tr>
<td>2,0</td>
<td>11 637</td>
<td>42,2</td>
</tr>
</tbody>
</table>
Test results

• Strain measurement
  - same behaviour by position and by specimen type
  - yielding at very low load level (5–10 kN)
  - yielding at #2 gauge position

Strains on specimen 2.2 at gauge position #3

Yielding strain 2300 µm/m
Concluding remarks

- Experimental investigation of an individual embossment
- New test specimen is introduced → local analysis
- Basic behaviour modes are observed
- Quantitative evaluation of the results
- Validation of the developed advanced numerical model for the embossment’s behaviour
- Embossments interaction
Next step of the research

- Numerical modelling

Force – displacement

Numerical model

Experiment
Acknowledgement

• Special thanks for the financial support:

  – OTKA T049305 project, Hungary
  – Hungarian Academy of Engineering Foundation–Rubik International Foundation
Thank you for your attention