Improving fire resistance of existing concrete slabs by concrete topping

Is EN 1992-1-2 annex E telling the truth, and can it be used?

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Content

• What’s up?
• Introduction; building and problem setting
• Bearing and failure mechanism; some reflections
• Annex E of Eurocode EN 1992-1-1; briefly for continuous slabs
• Case study for the Linné-Plantes building
• Interface between topping and existing slab
• Numerical approach by SAFIR®
• Conclusions; answers and an open question
What’s up

• Main purpose of existing codes = design of new buildings
• What with existing buildings and in particular their shortcomings?
• Do we need to think on another way or can we just apply the codes?

The most easy way to fix problems in an existing building can be reversed to the solution that we would apply in a new building.

• In this case study; a leak of concrete cover on the bottom can be solved by an extra in situ reinforced topping
Introduction

• Some images (before the bombs)
Introduction

• Typical floor layout & section
# Introduction

- Preliminary data

<table>
<thead>
<tr>
<th>Level</th>
<th>Location</th>
<th>( h_s ) (mm)</th>
<th>( h_1 ) (mm)</th>
<th>Principal reinforcement</th>
<th>Transverse reinforcement</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>bar</td>
<td>distance (mm)</td>
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<tr>
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<td>?</td>
<td>102</td>
<td>12</td>
<td>180</td>
<td>8</td>
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<td></td>
<td></td>
<td>345</td>
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</table>

**mean over all**: 166, 100, 12, 21
Introduction

• Discoveries during demolishing works
Failure mechanisms; some reflections

• Bending for a continuous slab, deformation < h/2 till max h
  
  ![Rotational spring or hinge](image)

• Compressive membrane action; compression arch
  
  ![Compressive arch](image)

No need for reinforcement at the bottom
Failure mechanisms; some reflections

• Tensile membrane action, catenary action

• Tensile membrane action with compressive ring
  • Same issues as for tensile membrane action

=> Some complexities with position reinforcement, analytical design rules, ...

Need for reinforcement at the bottom + large deflections

• Shifting the moment line for continuous slabs

\[
M_{Ed,fi} = \frac{w_{Ed,fi} l_{eff}^2}{8} = \frac{w_{Ed,fi} (l_{eff})^2}{2}
\]

\[
M_{Rd,fi} = A_s b_{fy,\theta} (h_1 - c - \frac{\Theta}{2} - \frac{A_s b_{fy,\theta}}{2b_{ck}} - i_\theta)
\]

• Issue of interface not covered
Case study for the Linné-Plantes building

Slab; $M_{Ed,fi} = (2.5+1.5+1.2+0.3\cdot2.0)\cdot4.7^2/8 = 16.02 \text{ kNm}$

- $M_{Rd,fi,\text{span}} = 0.87 \text{ kNm}$ with $k_s(\theta) = 0.07$, $x = 2+8/2 = 6 \text{ mm} \Rightarrow 900^\circ\text{C}$
- $M_{Rd1,fi} = M_{Rd2,fi} = 16.02-0.87 > 15.15 \text{ kNm}$ with #150/6+Ø10/150mm?
- EN 1992-1-2 graphs:

$\Rightarrow$ Equilibrium guaranteed

\[
M_{Rd1,fi} = M_{Rd2,fi} = (262 + 188) \cdot 1 \cdot 500 \left(100 + 6 + \frac{10}{2} - \frac{450 \cdot 1 \cdot 500}{2 \cdot 1000 \cdot 30} - 36\right) = 16.03 \text{ kNm}
\]
Case study for the Linné-Plantes building

Beam of TT-frame; $M_{Ed,fi} = (23.78 + 3.13) \cdot 6.75^2 / 8 = 153 \text{ kNm}$

- With $(3.5 + 4.7) / 2 \cdot (2.50 + 1.50 + 1.2 + 0.3 \cdot 2) = 23.78 \text{ kN/m}$

- New façade + inner wall + beam =
  $(3.5 + 4.7) / 2 \cdot [3.93 + (0.12 \cdot 0.43 + 0.2 \cdot 0.7) \cdot 25] = 35.75 \text{ kN @1.20 m}$

- Principal beam = $0.25 \cdot 0.50 \cdot 25 = 3.13 \text{ kN/m @1.60 m}$

- $M_{Rd1,fi,max} = M_{Rd2,fi,max} = 35.75 \cdot 1.2 + 3.13 \cdot 1.6^2 / 2 = 47 \text{ kNm}$

- $M_{Rd,fi,span} > M_{Ed,fi} - M_{Rd1,fi,max} = 153 - 47 = 106 \text{ kNm}$?

$=>$ Equilibrium not guaranteed with one level; need for push down

$M_{Rd,fi,span} = (5 \cdot 380 \cdot 0.25) \cdot 300 \left(560 - 18 \frac{22}{2} - \frac{5 \cdot 380 \cdot 0.25 \cdot 300}{2 \cdot 250 \cdot 30}\right) = 74 \text{ kNm}$
Interface between topping and existing slab


• Reciprocal theorem of shear stresses; we consider that the shear stress perpendicular to the surface is equal to the tensile stress
• So the reduction of the shear stress at this interface has the same behavior as the reduction of the tensile stress.

\[ V_{Edi,fi} = (2.5 + 1.5 + 1.2 + 0.3 \cdot 2) \cdot \frac{4.7}{2} = 13.63 \frac{kN}{m} \]

\[ V_{Rdi,fi} = k_{ct} (\theta) \cdot c \cdot \frac{f_{ctk,0.05}}{\gamma_c} \cdot z \cdot b_i \]

\[ = 0.9 \cdot 0.2 \cdot \frac{2.0}{1} \cdot 0.9 \cdot (100 + 6 + \frac{10}{2}) \cdot 1000 = 35.96kN/m \]
Interface between topping and existing slab

• Is an ISO fire representative enough to deal with this problem?
• What happens in a real fire (with gas peak temperature @ 60 min.)?
Numerical approach by SAFIR®

- Model = half part
Numerical approach by SAFIR®

• Cantilever reinforcement: 0.124 m @ 7200s
Numerical approach by SAFIR®

• Compressive membrane action reinforcement: 0.164 m @ 7200s
Numerical approach by SAFIR®

• Full option, shutting with a gun is not even better: 0.129 m @ 7200s
Conclusions

• Missing bearing capacity in case of fire can be solved by adding an extra upper reinforcement in a new in situ concrete topping.

• The question that an ISO fire would be representative enough to judge the bearing capacity of the interface, couldn’t be answered.

• Location or concentration of the extra upper reinforcement seems to be of lesser importance. Due to the still limited deformations handling as a cantilever moments seems to be the best fit. But also other distributions react well.

• Model uncertainties still to investigate => without vertical support,...
Questions, answers, suggestions?

Anyway thanks for the opportunity to deal this information.

Just for information; StuBeCo operations will be very soon integrated in Sweco Belgium