Project HOLCOFIRE - update

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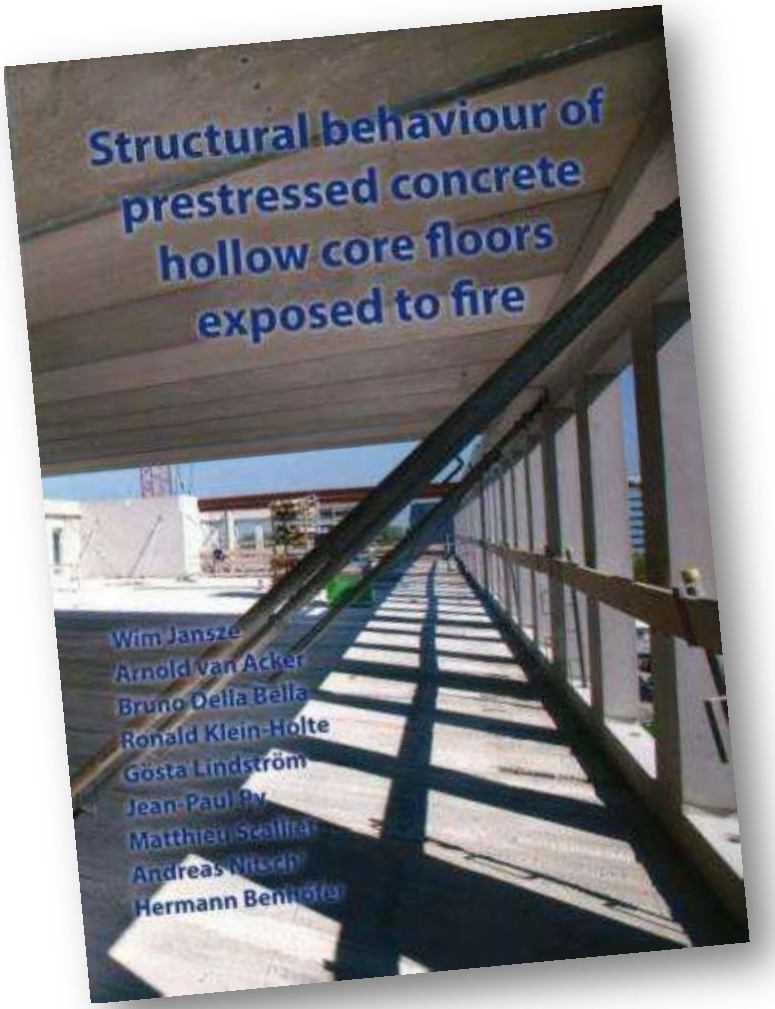
On behalf of BIBM/IPHA

IPHA
INTERNATIONAL PRESTRESSED HOLLOWCORE ASSOCIATION

in cooperation with StruSoft

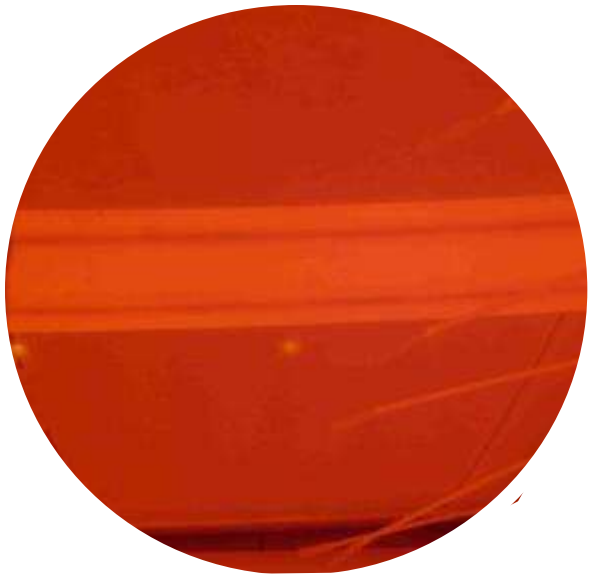
PROJECT HOLCOFIRE



- **Kick-off May 2010 Brussels**
- **Executed 2010 –2013 under BIBM PG HC**
- **For and by the industry**
- **Results published February 2014, book is freely available at IPHA, ISBN978-90-8891-812-4**
- **22 May 2015 project closure letter to all 12 partners including IPHA**

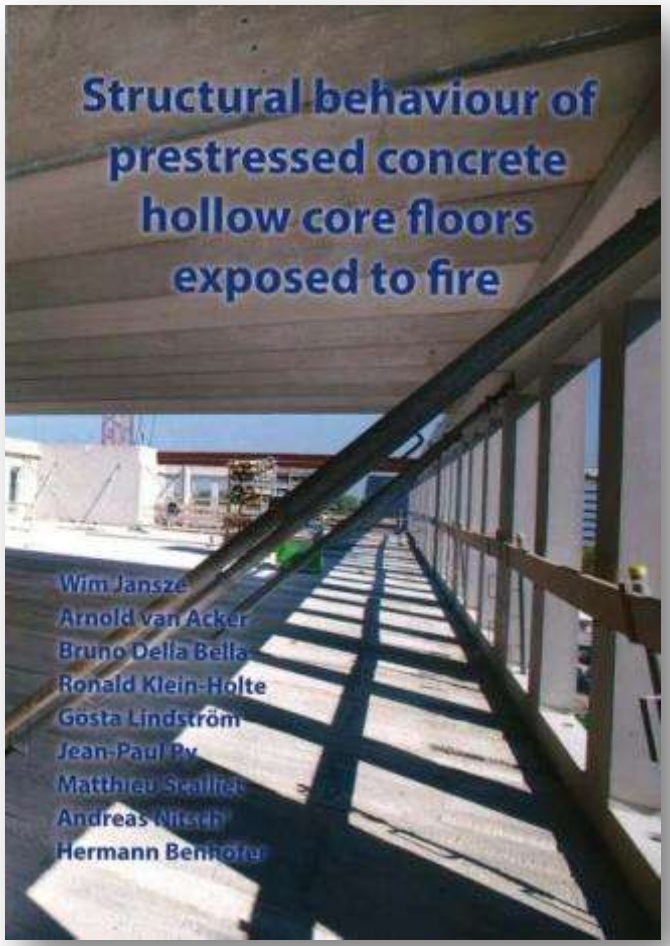
What was the main objective

- **Get <u>full understanding</u> of the behaviour of pre-stressed hollow cores under fire conditions which will lead to the <u>full acceptance</u> in Europe**



Holcofire Lessons learned

- The product meets regulations and requirements
- The product performs well when exposed to fire
- In specific cases fires in car parks are more severe than standard fires



Annex G Shear and anchorage

Empirical shear equation inspired from EN 1992-1-1 6.2a formula:

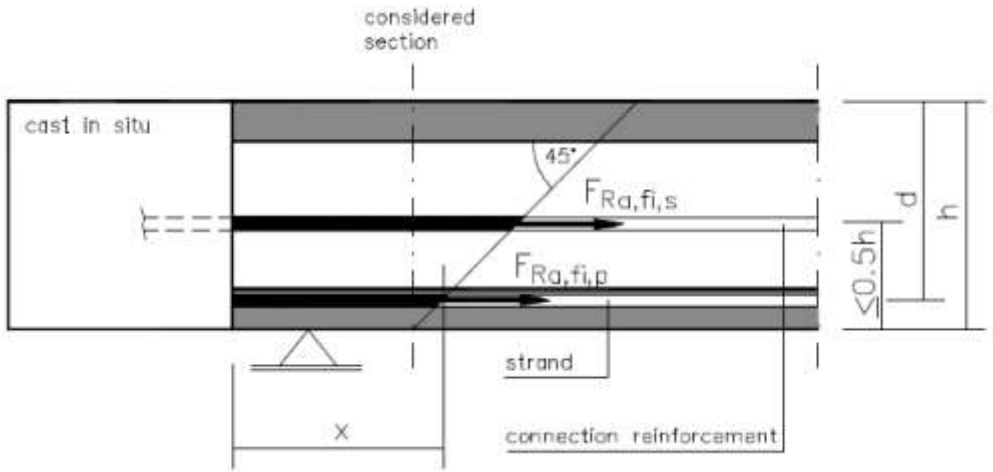
$$V_{Rd,c} = [C_{Rd,c} k (100\,\rho_l\, f_{ck})^{1/3} + k_1\,\sigma_{cp}]\, b_w d$$

$$V_{Rd,c,fi} = [C_{\theta.1} + \alpha_k \cdot C_{\theta.2}] \cdot b_w \cdot d$$

$$C_{\theta.1} = 0.15 \cdot \min(k_p(\theta_p)\sigma_{cp,20°C}; \frac{F_{R,a,fi,p}}{A_c})$$

$$\alpha_k = 1 + \sqrt{\frac{200}{d}} \leq 2{,}0$$

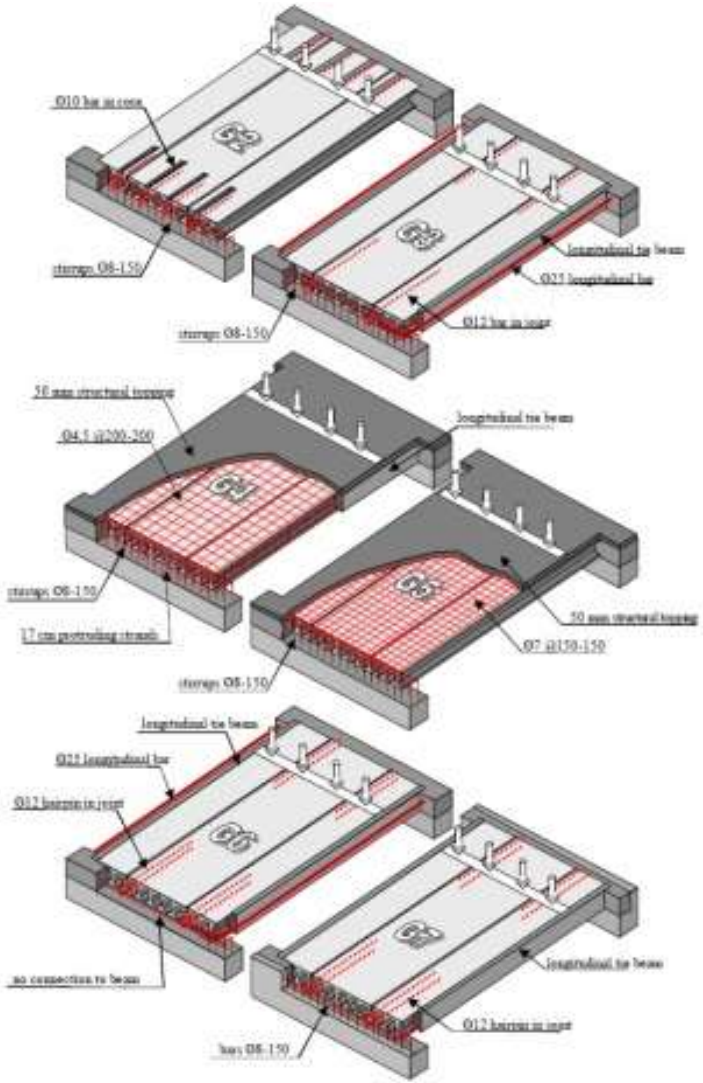
$$C_{\theta.2} = \sqrt[3]{0.58 \cdot \frac{F_{R,a,fi}}{f_{yk} \cdot b_w \cdot d} \cdot f_{c.fi.m}}$$



$C_{\theta.1}$	Coefficient accounting for concrete stress under fire conditions
$k_{p(\theta p)}$	Strength reduction factor for the prestressing steel (EN 1992-1-2 clause 4.2.4.3.)
$\sigma_{cp,20℃}$	Average concrete stress due to prestressing at normal temperature
A_c	Concrete section area
$F_{R,a,fi,p}$	Force capacity of prestressing steel anchored in considered cross section
$C_{\theta.2}$	Coefficient accounting for anchored longitudinal reinforcement:
$F_{R,a,fi}$	Force capacity of prestress and reinforcement anchored in considered cross section
f_{yk}	Characteristic yield strength of the reinforcement
$f_{c.fi.m}$	Average strength of concrete at elevated temperature, fc,fi,m
b_w	Total web thickness of the hollow core slab
d	Effective depth at ambient temperature

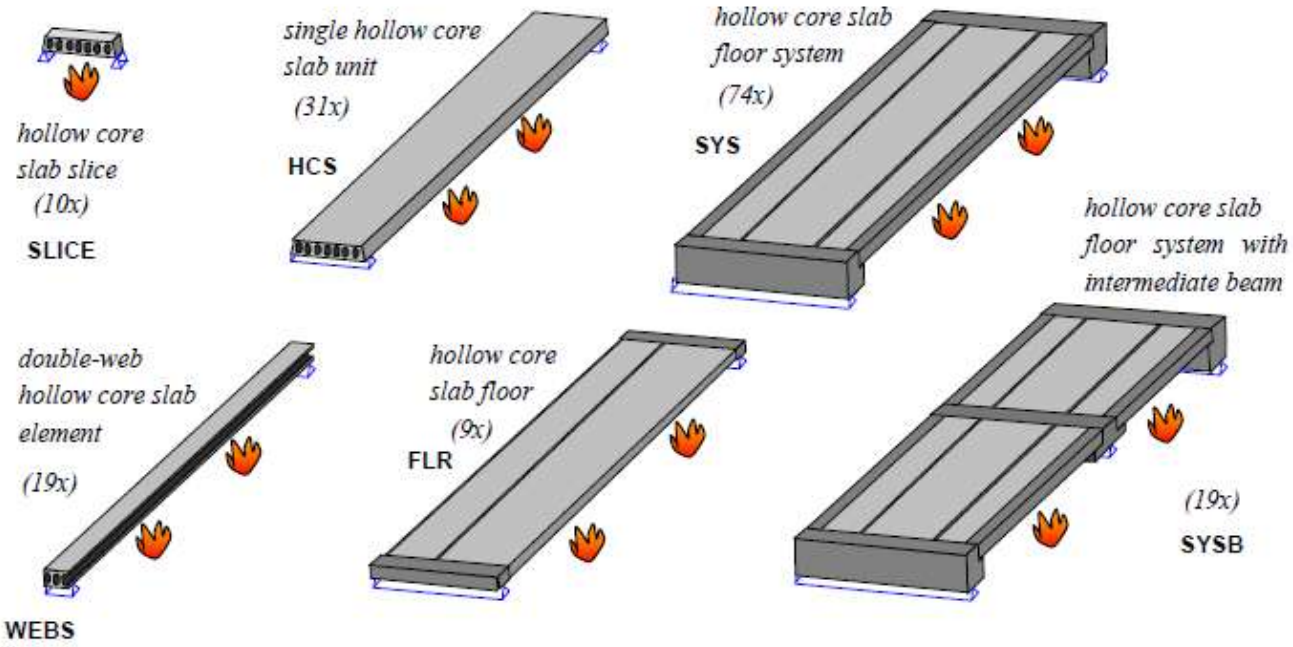
Tests on shear and anchorage

- **6 shear fire tests conducted; configuration in accordance with application in specific country**
- **EN 1168 Annex G shear and anchorage capacity confirmed**
- **Review by prof. Hosser (TU Braunzweig)**



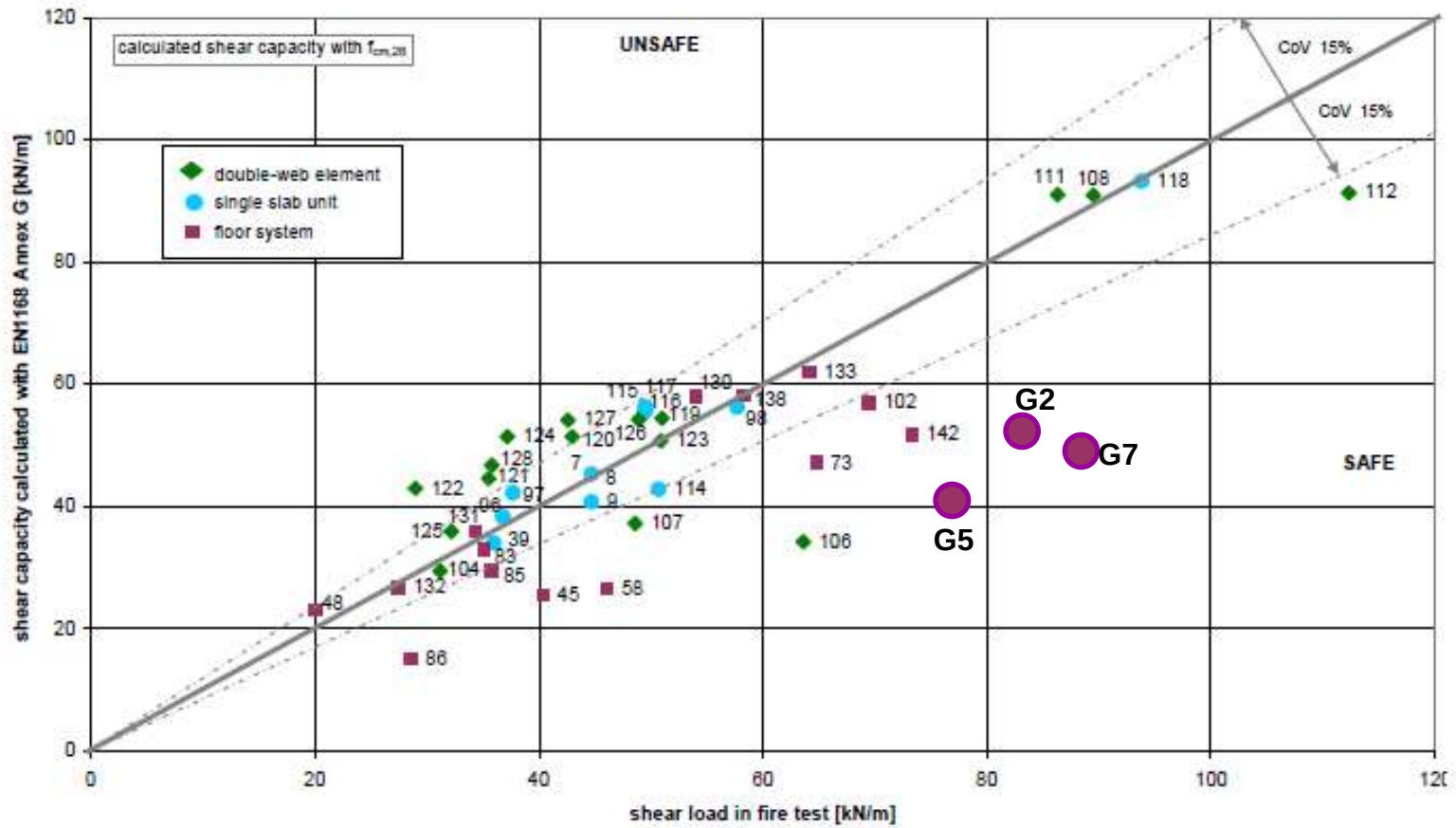
Holcofire Database

- 162 fire results analysed
- 94.5% of these results can be fully explained
- EN 1168 Annex G shear and anchorage re-confirmed
- Reviewed by prof. T. Vrouwenvelder and prof. J. Walraven



Holcofire Database and G-series

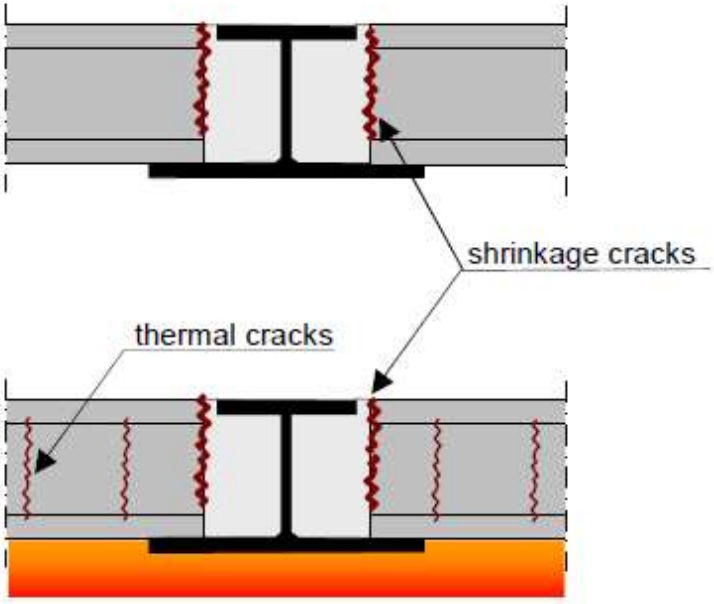
- **Shear capacity: test versus EN 1168 Annex G calculation**

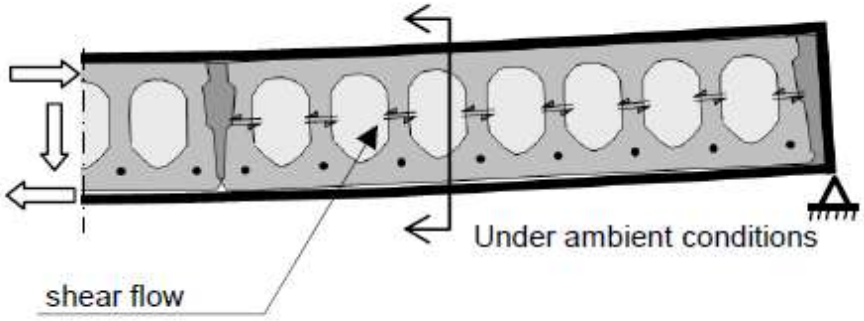


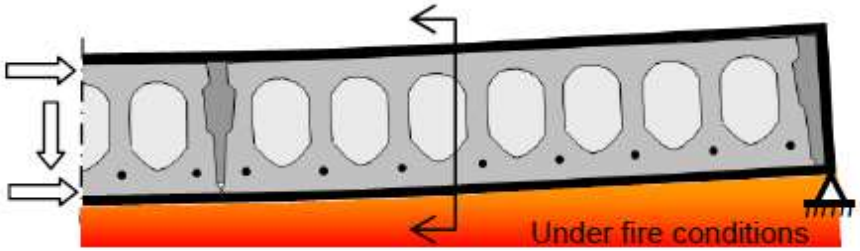
Flexible supports: Annex G is applicable

EN 1168 Annex G can be used to determine the shear and anchorage capacity for flexible supports

- Due to expansion of soffit another compression force is introduced that compensates additional shear stresses
- Due to vertical web cracking by definition no shear tension







Rotterdam fire October 2007

Fire loading in fire case Rotterdam

- **Rotterdam fire was exceptional in temperature and growth**
  - At 20 minutes, 33% higher temperature compared to ISO fire
  - At 20 minutes, 3x faster temperature increase compared to ISO fire
- **The car park fire was a travelling fire**
- **Large forces and fast cooling down due to extinguish boat**
- **No premature collapse**

Rotterdam case was an incident

Horizontal web cracking

- Thick toppings can restrain a floor.

  This can lead to horizontal cracking.

- The thickness of the topping where horizontal cracking can occur is found to be 25%-30% of the depth of the slab

- However, in practice, shrinkage in floors in buildings can prevent the occurrence of horizontal web cracks
- Horizontal blocking can also restrain a floor. In theory it is a decisive parameter, but the magnitude of actual restraints in real applications is unknown

Considerations with regard to spalling

- **When “wet” all concrete structures show spalling.**

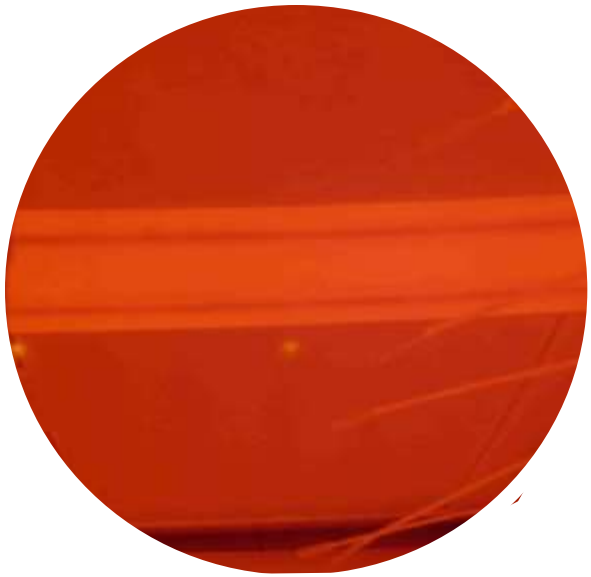





- **But concrete structures are very resilient, andf failure due to fires is very, very rare.**

Status on main objective in 2015

- **Get <u>full understanding</u> of the behaviour of pre-stressed hollow cores under fire conditions which will lead to the <u>full acceptance</u> in Europe**



Update The Netherlands

- **The commission concluded that** *"... in viewpoint of Dutch regulations ..... the total of all test results, real fires, model calculations, and track record show that on the basis of the recommendations with a sufficient degree of reliability, the probability of disproportional damage is sufficiently small.* **"**

- **The (to be published) recommendations contain an additional rule regarding the limitation of structural topping for new construction (for CC2b and CC3)** ***(not for CC1 and CC2a!)***

  t ≤ 0.25 x depth hollowcore

- **In case the thickness of structural topping is larger, then:**
  - Risk analysis
  - Alternative load path
  - Sprinkler installation
  - Fire protection

Update Germany

- **No critical situation anymore, as the “Zulassung” (approval) has been extended by DIBt for 5 years.**
- **The German system with “Zulassung” is under discussion on a European level**
- **But DIBt had requested a fire test in Berlin at BAM research institut, and the way how to execute the test is under discussion. Hollow core industry is involved.**
- **A technical day “colloqium” will be organized in Germany with universitiy professors to bring formally the state-of-the-art in the industry on a higher level**

Deutsches Institut für Bautechnik DIBt

Update France and UK

- **No issues, but regulatory institutions in France and UK are looking very much to The Netherlands what will be decided and published by the Dutch commission for recommendations (t ≤ 0.25 x depth hollowcore)**

Denmark

- **Fire issue is “smouldering”**
- **Abeo A/S (and Prof. Hertz) raised “questions” on the fire resistance of hollow core slabs**
  - 2 letters written to Ministry of Climate, Energy and Building
    - EN1168 can’t be used to document R120 for slabs without transversal reinforcement.
    - EN1168 is not used correctly by the Danish producers as due to spalling 500 °C rule should be used
  - Danish Standard asked members of S-EN1992 to comment
  - Jesper Frobert Jensen is appointed to draft the answer

Abeo A/S is a company delivering SL-deck; a SuperLight Deck “capable of withstanding 4 hours of standard fire”