FIRE RESISTANCE HOLLOW CORE FLOORS

TESTING PRINCIPLES

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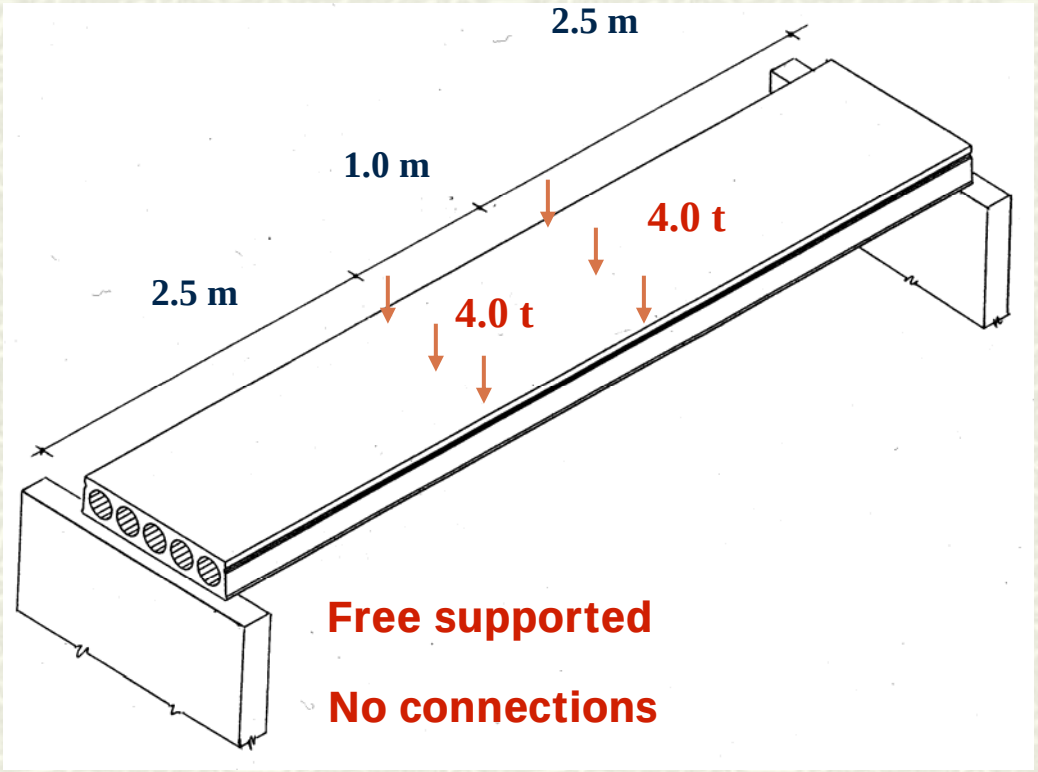
Standard fire test procedure

- First tests in Belgium in 1971 on 265 mm slabs



- one single HC unit
- length 6.00 m

First test

- 6 smooth strands Φ 12.5
- Shear failure at 36 min

Second test

- 6 indented strands Φ 12.5
- Shear failure at 29 min.

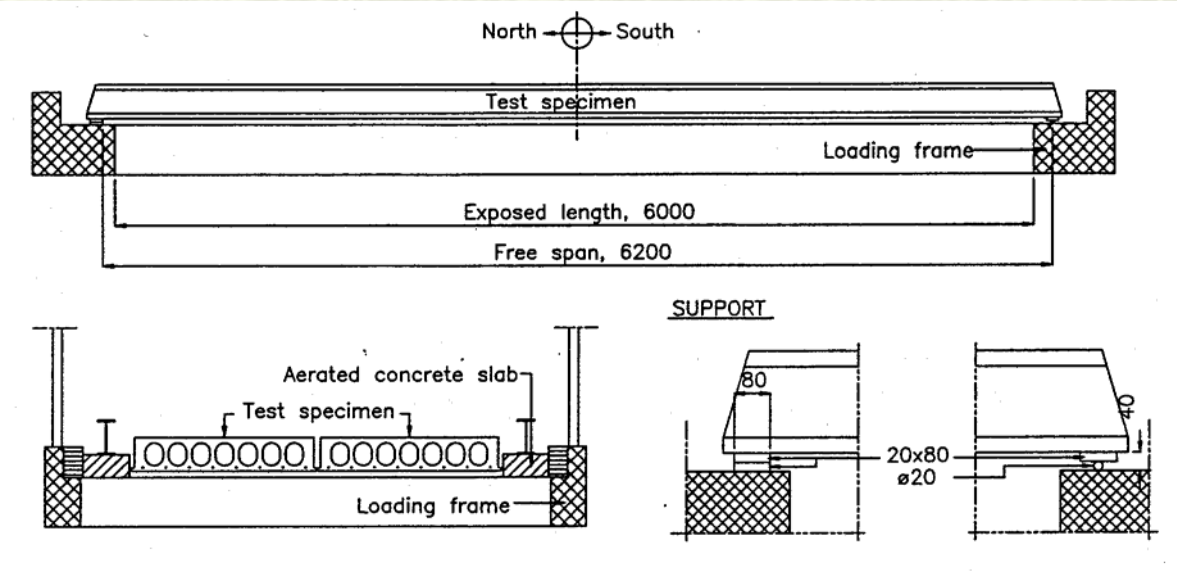
Third test

- 6 strands Φ 12.5 with oval central wire
- Shear failure at 33 min.

Standard fire test procedure

- Tests Danish Institute of Fire Technology 1998

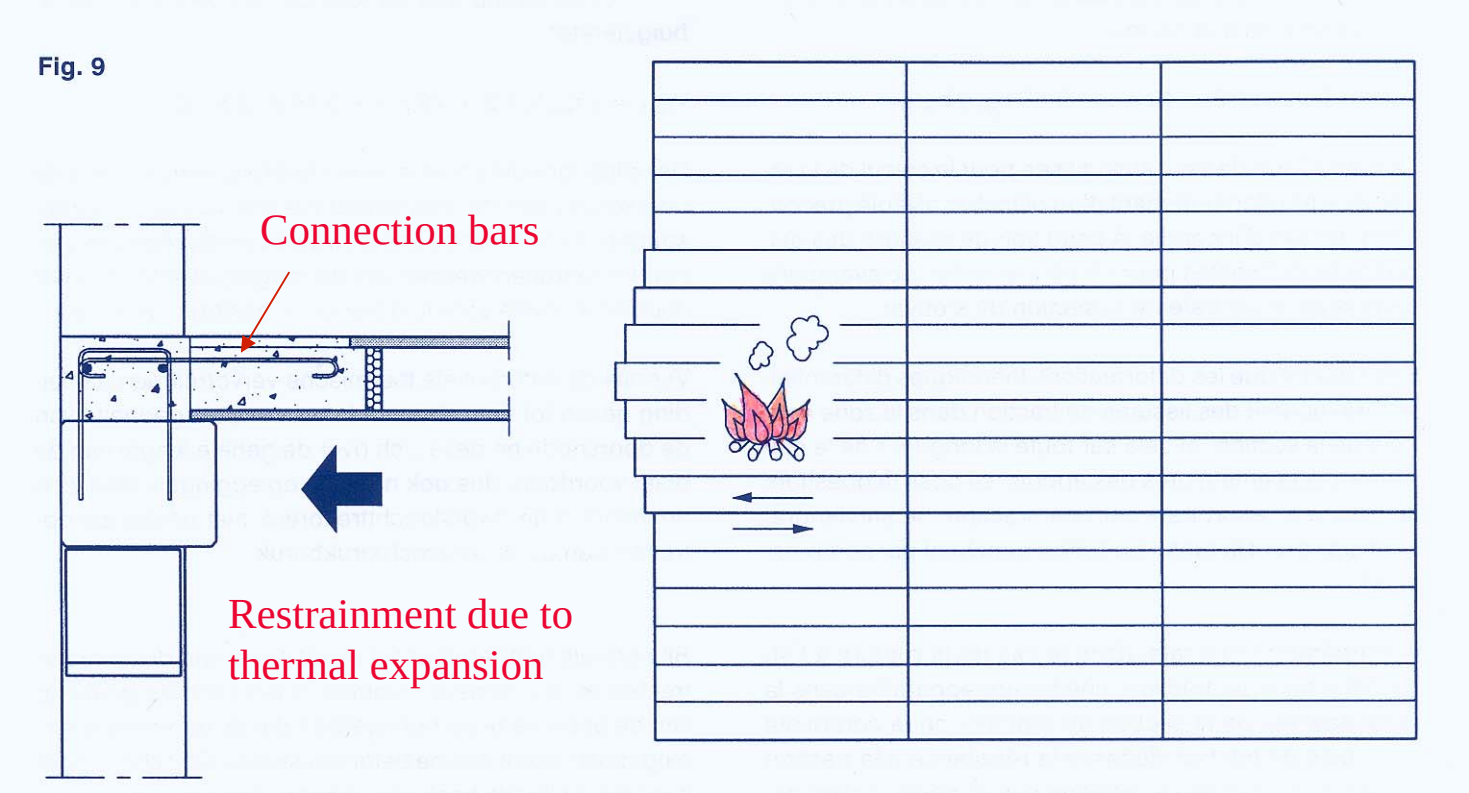
4-point loads 135 kN in total



Test results:	HC 185	22 min. shear failure
	HC 220	26 min. shear failure
	HC 270	21 min. shear failure

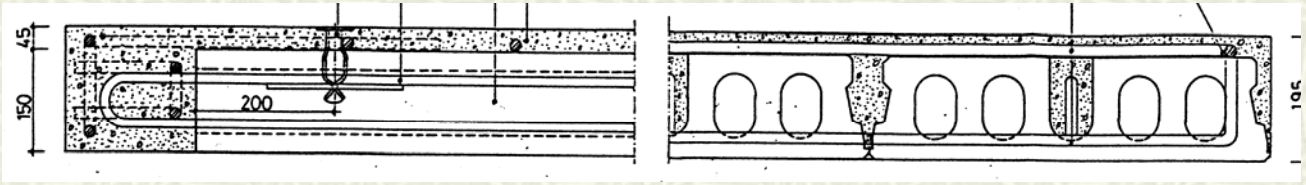
Real floor structure

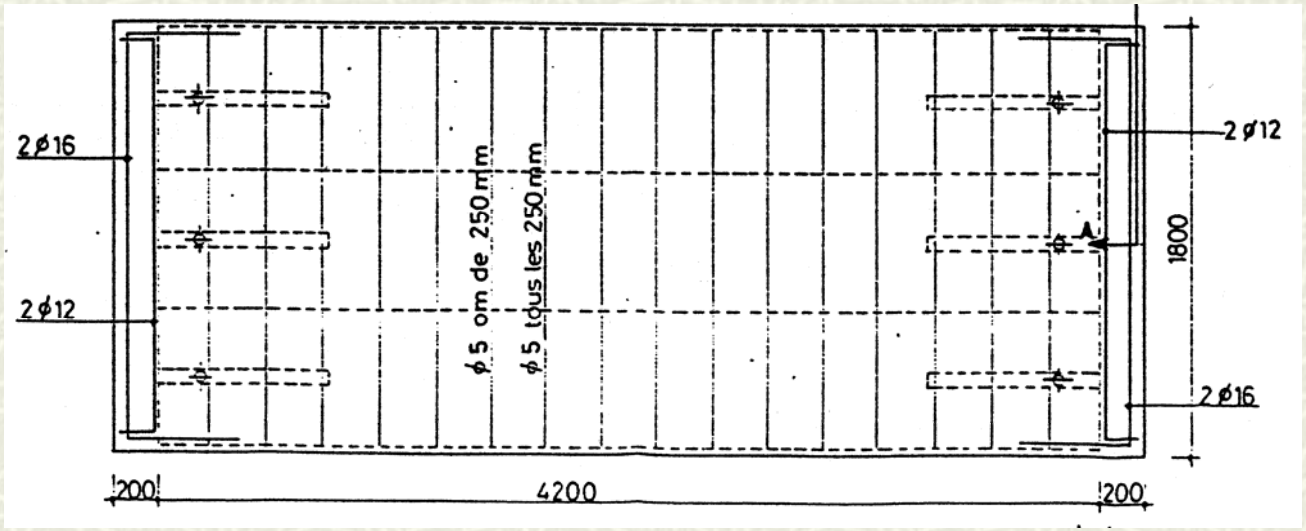
- HC connected to support structure



Importance of connections

- Tests Echo in 1990 on floor composed of 3 units, with topping, end beam and bars in sleeves





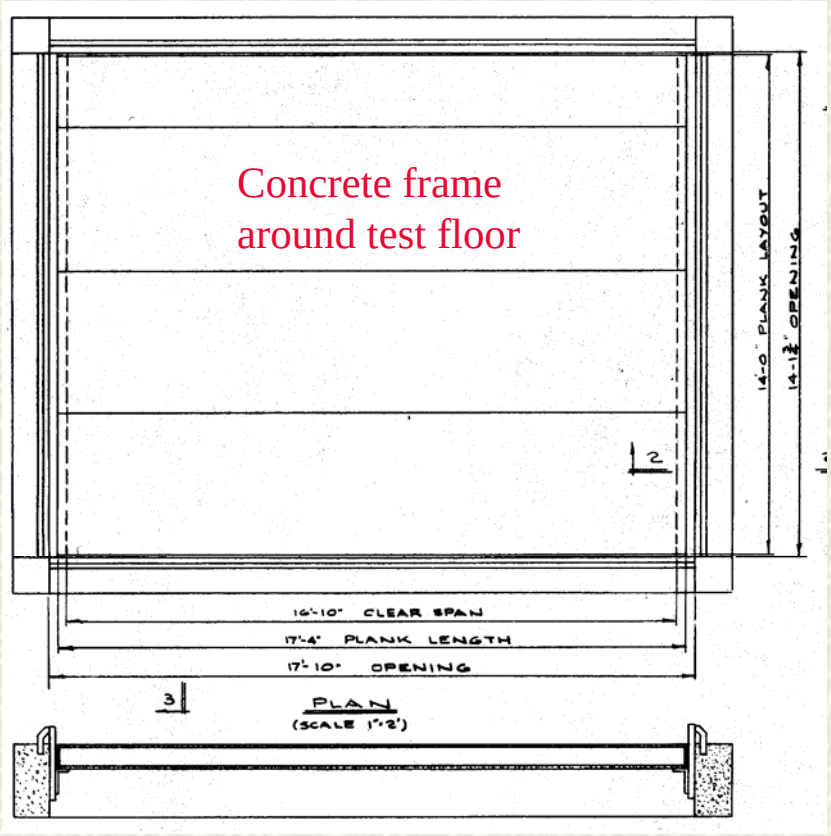
HC 15/600:
bending > 1/30
after 182 min.

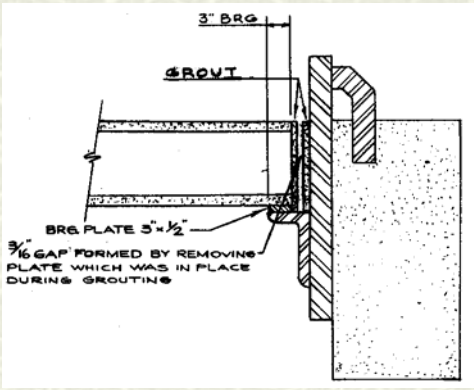
HC 20/600:
bending > 1/30
after 194 min.

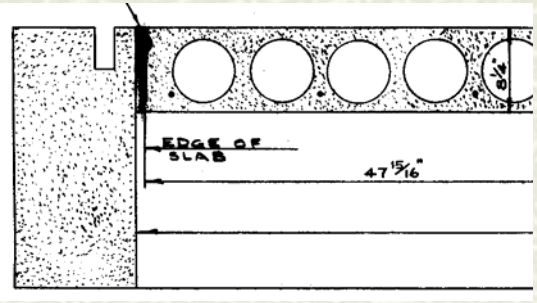
Cover strands
45 mm

Importance of connections

- Tests Underwriters Laboratories USA



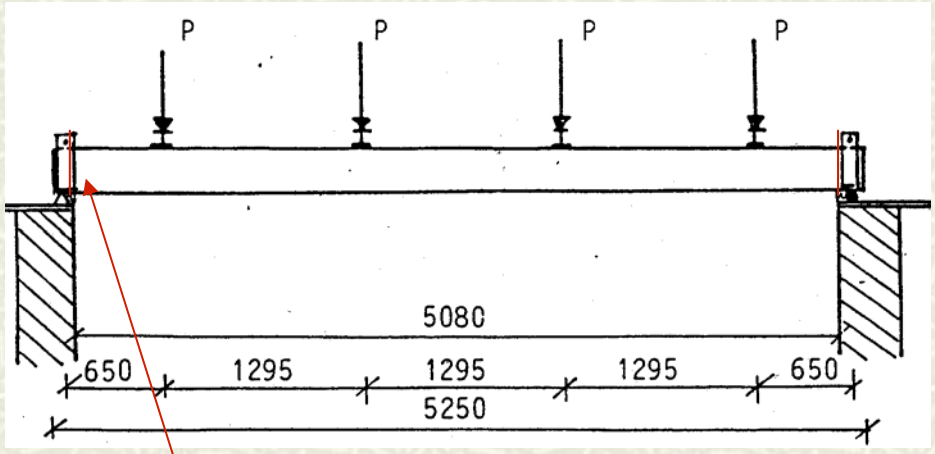


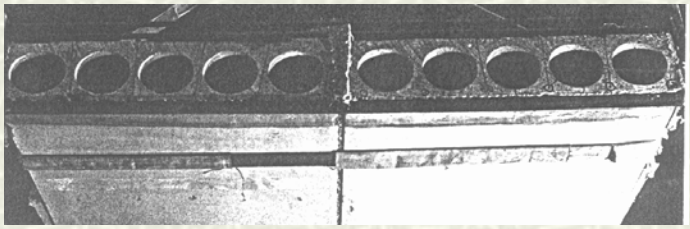


Test results: 2 to 4 hours

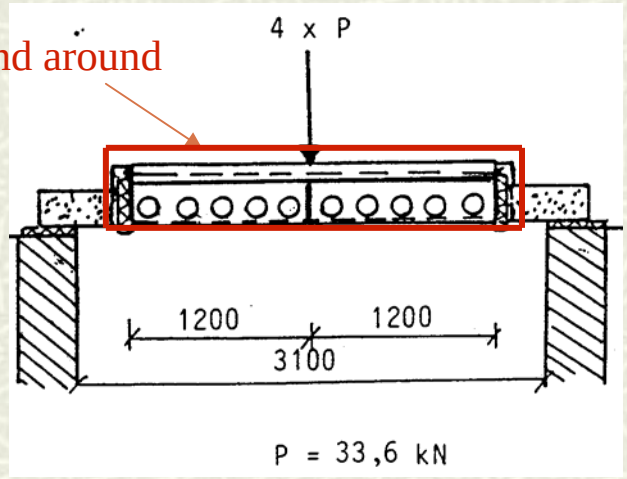
Importance of connections

- Tests in Finland in 1984 on HC 265 mm





Steel band around slab end



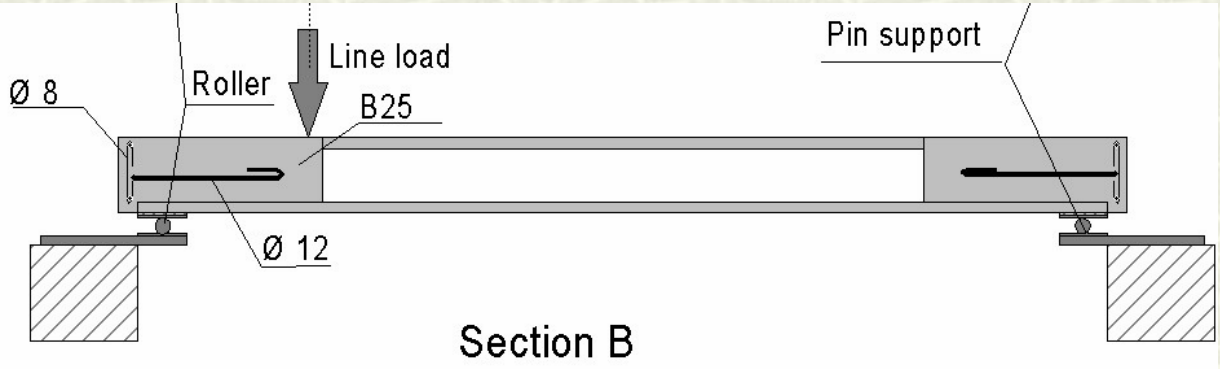
a: loading 10.8 kN/m²
axis distance 35 mm
Rf 60 min.

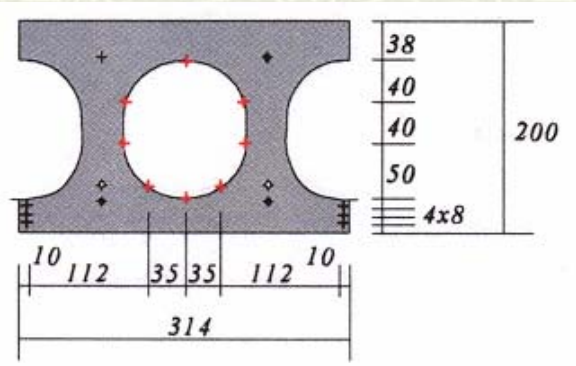
b: loading 1.25 kN/m²
axis distance 65 mm
Rf 130 min.

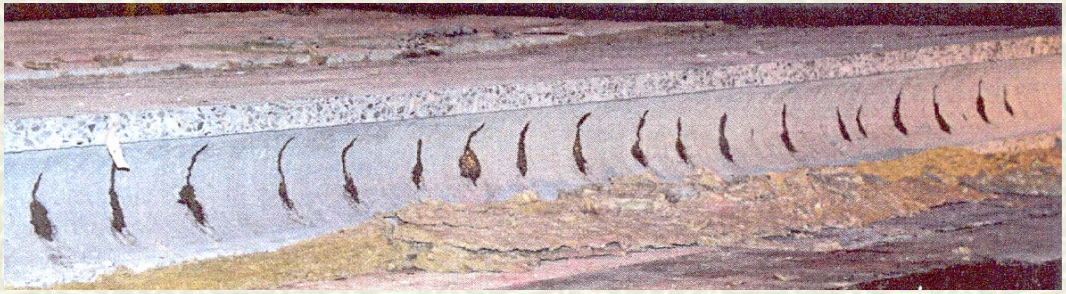
Fire tests at TNO Delft

- Simply supported narrowed units

  Tests on shear capacity and strand anchorage



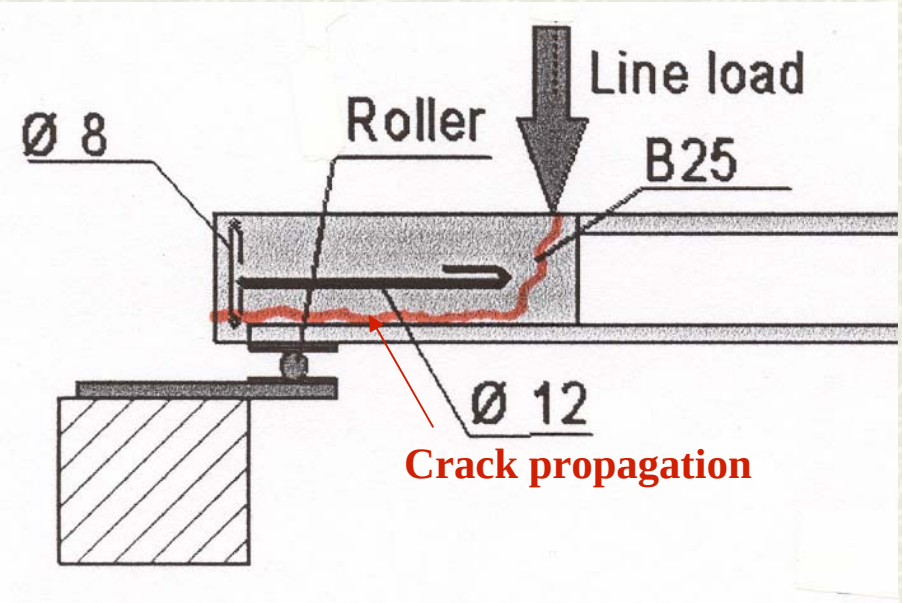




Fire tests at TNO Delft

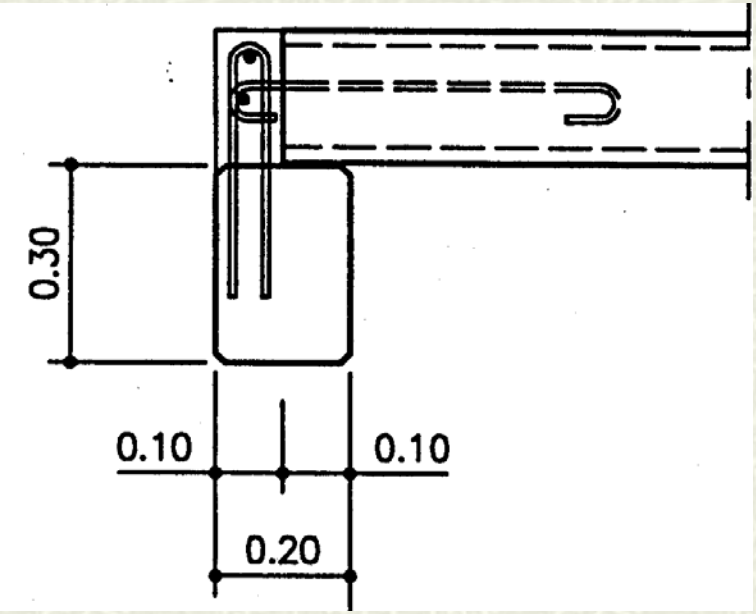
- Test with reinforcement in filled open core

Test set-up TNO



Horizontal crack can propagate till end of slab

Connection in real floor



Horizontal crack cannot propagate; shear friction mechanism can function

Test results TNO

Web	A200	loading:	22%	Rf : 96 min.	Failure:	Anchorage
	X200		16%	125		Flexure
	XB200		18%	125		Anchorage
	XB200 Restrained		18%	159		Flexure
	VX265		23%	35		Shear-tension
	VX265		23%	25		Long. shear
	HVP260		23%	55		Shear-tension
	K400		23%	60		Shear-tension
	K400 Restrained		23%	30		Shear-tension
	K400 Filled Cores		23%	24		Shear-tension
Slab	XB200 filled cores		23%	117		Flexure
	K400		23%	33		Shear-tension
	VX265		23%	33		Shear-tension
	HVP260		23%	40		Anchorage
	HVP260		23%	42		Shear-tension
	HVP 260		23%	39		Shear-tension

Conclusions TNO tests

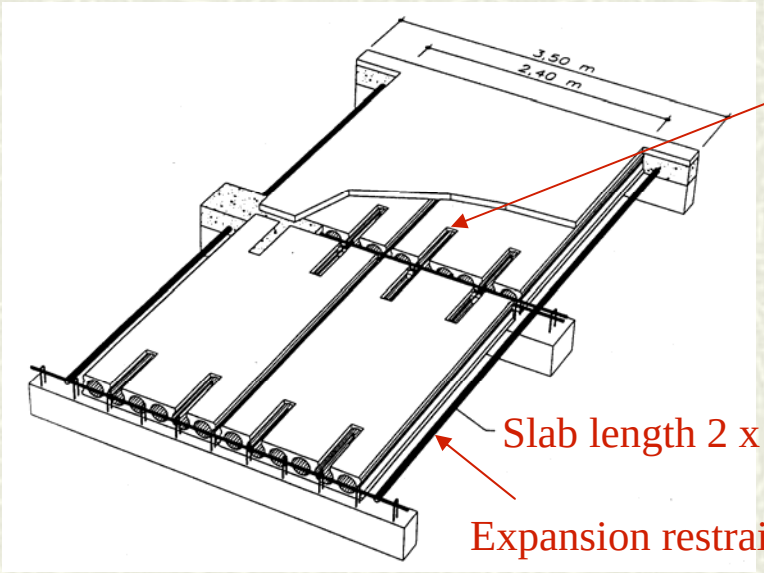
- **BIBM congress 2005: Paper"Fire safe design of HC slabs with respect to shear and anchorage failure - Dr. Fellinger et all.**

"A restraining force has a beneficial effect on the shear and anchorage behaviour. ….. However the available restraint in a practical building is unknown and cannot yet be guarantee, as it is very sensitive to the way in which the HC units are connected to the rest of the construction on site. It has been recommended not to rely on such a beneficial effect, as it can not be assured in the design."

" … a realistic ratio of 17% of the ultimate shear capacity at room temperature is assumed as the design shear capacity under fire conditions. …… At an increase to 22%, it is shown that the fire behaviour limits the design only in rare cases when dealing with short spans and very high loads"

Tests in Belgium

- Shear resistance of hollow core floors



Connecting bars in open sleeves or in longitudinal joints

Concrete topping

Slab length 2 x 3 m

Expansion restraining bar

4 tests with extruded and slip-form slabs

Tests in Belgium

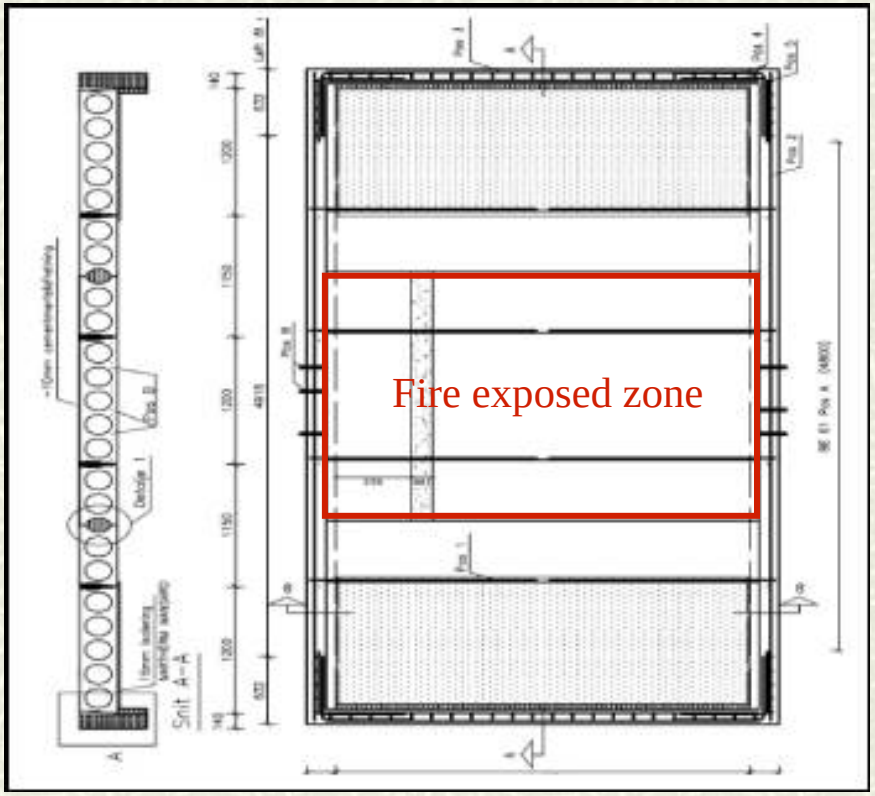
- Preparation of test slabs

Tests in Belgium - results

Test N°	Slab thickness mm	Test load slab centre kN	Fire duration minutes	Failure load after test - kN	V_{Rd} at normal temp.- kN	Shear load/ V_{Rd}
T1 A B	**200** **200 + 50**	**100** **100**	**83** **83**	**178 (B)** **254 (B)**	**79/slab**	**86.8 %**
T2 A B	**200** **200**	**100** **100**	**120** **120**	**292 (B)** **324 (B)**		
T3 A B	**200** **200**	**100** **100**	**120** **120**	**254 (B)** **267 (B)**		
T4 A B	**265** **265 + 30**	**100** **100**	**120** **120**	**305 (B)** **305 (Sh)**	**148/slab**	**56.2 %**

Recent tests in Denmark

- High shear loading



- 60 min fire exposure + 90 min. cooling with the load still applied
- Uniform loading:
  - ⇨ 65 % V_{Rd} : no failure
  - ⇨ 75 % V_{Rd} : no failure
  - ⇨ 80 % V_{Rd} : failure at 45’

Info: www.bef.dk/sw343.asp

Proposal new test procedure

- Better simulation of the real floor structure

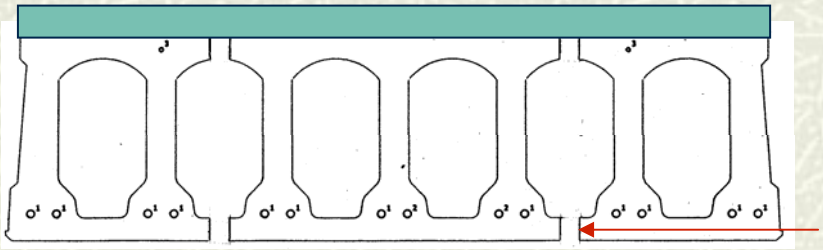
  ⇨ Concrete frame around floor (Underwriters Laboratories)
  The solution enables to restrain the floor in both longitudinal and transversal direction.

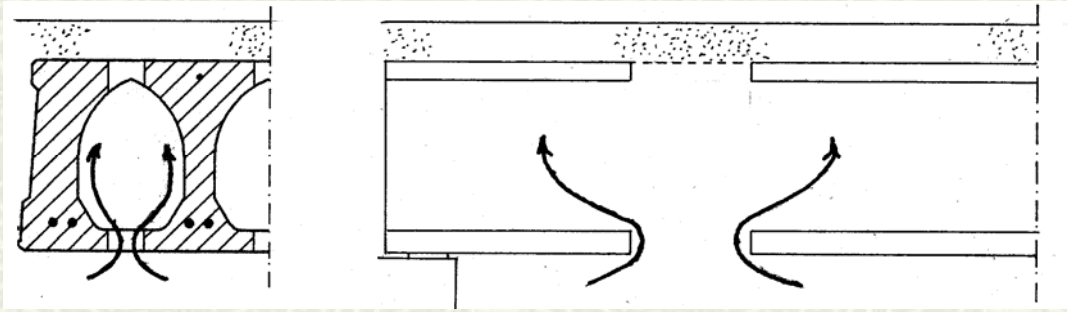
  ⇨ Longitudinal restraining bars. The solution enables only a longitudinal restrainment, but it has proven to be sufficient.

The proposal should be discussed with CEN. Complementary tests could be performed at the new laboratory of CERIB. IPHA should take the initiative together with BIBM.

Rf HC with holes for lifting

- Possible decrease of shear capacity due to higher temperature inside core

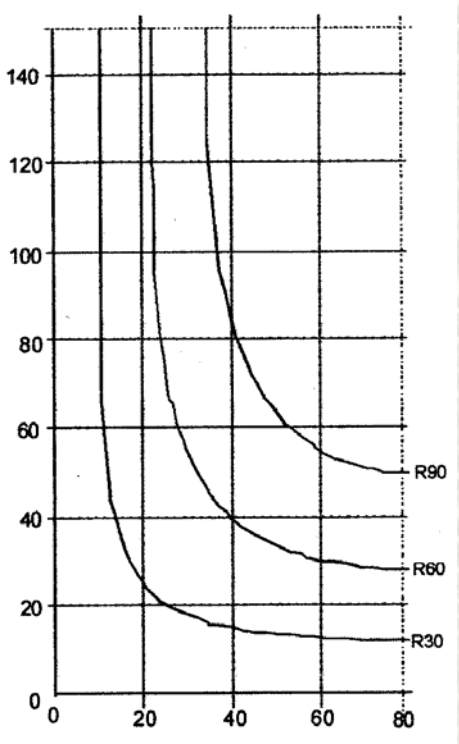




Hot gases entering the cores, may affect concrete strength and steel strength

Rf HC with holes for lifting

- Elevation temperature inside core ?
  - ⇨ No tests data available
  - ⇨ Inside cores not directly exposed to fire
  - ⇨ Penetration of hot gases is limited
  - ⇨ Cores are functioning as buffers
  - ⇨ During fire tests on HC floors, cracks up to 4 mm width appear over the whole slab length, but do not affect the insulation criterion.
  - ⇨ A more uniform temperature inside the cores will probably decrease the thermal stresses inside the webs.
  - ⇨ Isotherm 500 °C inside beam 300 x 160 mm after 90' fire lies at ± 45 mm from the lateral surface.



Isotherm 500°C in a beam of 300 x 160 mm after 30', 60', and 90' exposure

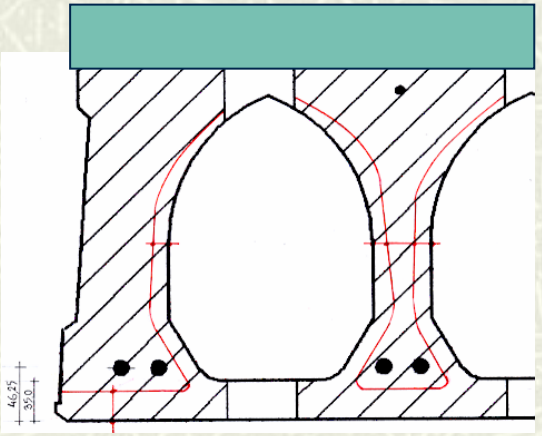
- Conclusions

The outline of the Isotherm at 500°C after 90’ fire exposure is most probably as given on the figure:

⇨ at 30 mm from the soffit (resulting from tests)

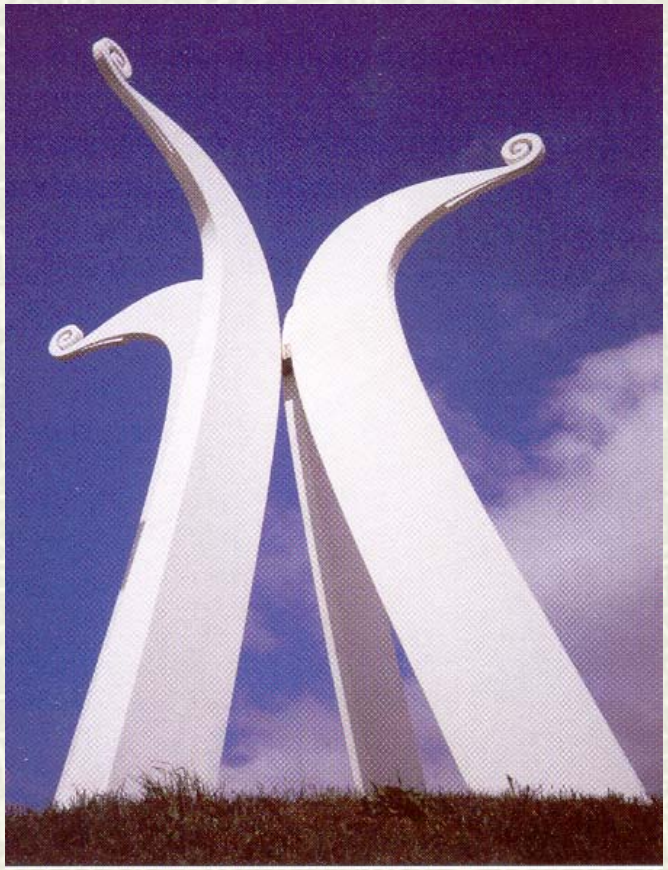
⇨ At 15 mm on an average from the inside of the core

⇨ The strand temperature is about 350°C at 90’



The remaining cross-section inside the isotherm of 500°C is about 77% of the total cross-section. The shear load at the holes is 34.5% of the shear capacity at normal temperature. It can be concluded that the holes do not affect the shear capacity of the slab during a fire.

Precast HC floors: safe in fire



Thank you for

your kind attention