INTERNATIONAL PRESTRESSED HOLLOWCORE ASSOCIATION

HOLCOFIRE

Behaviour of prestressed hollowcore floors exposed to fire

Fire case parking garage Lloydstraat, Rotterdam

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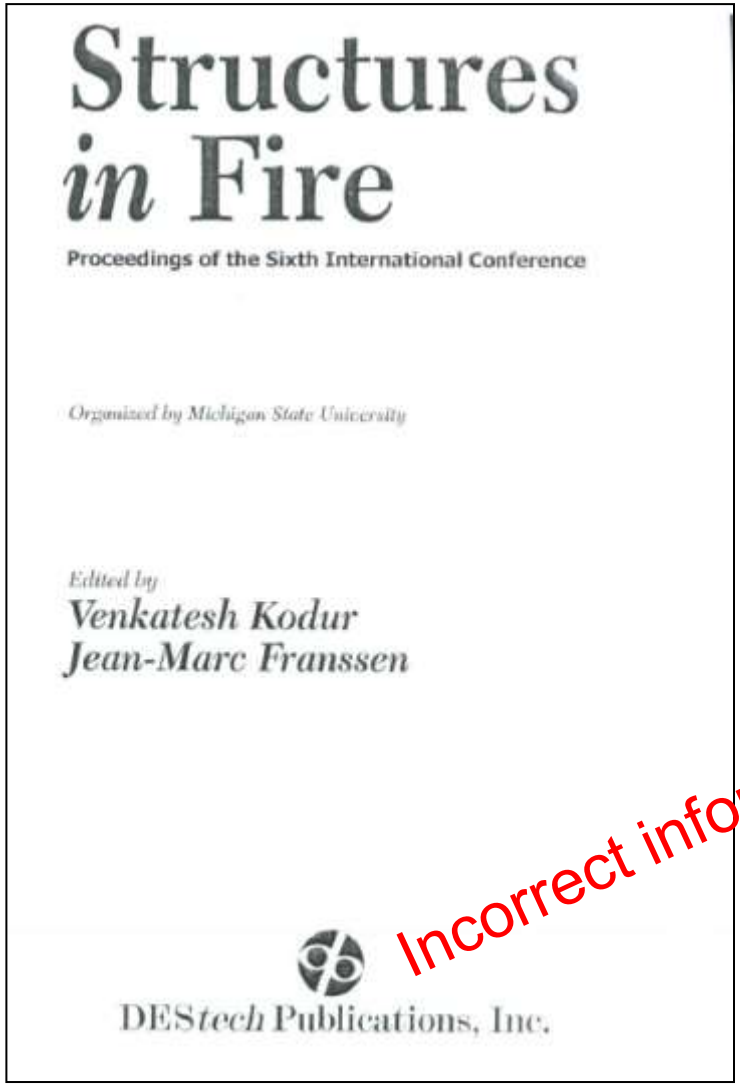
Content

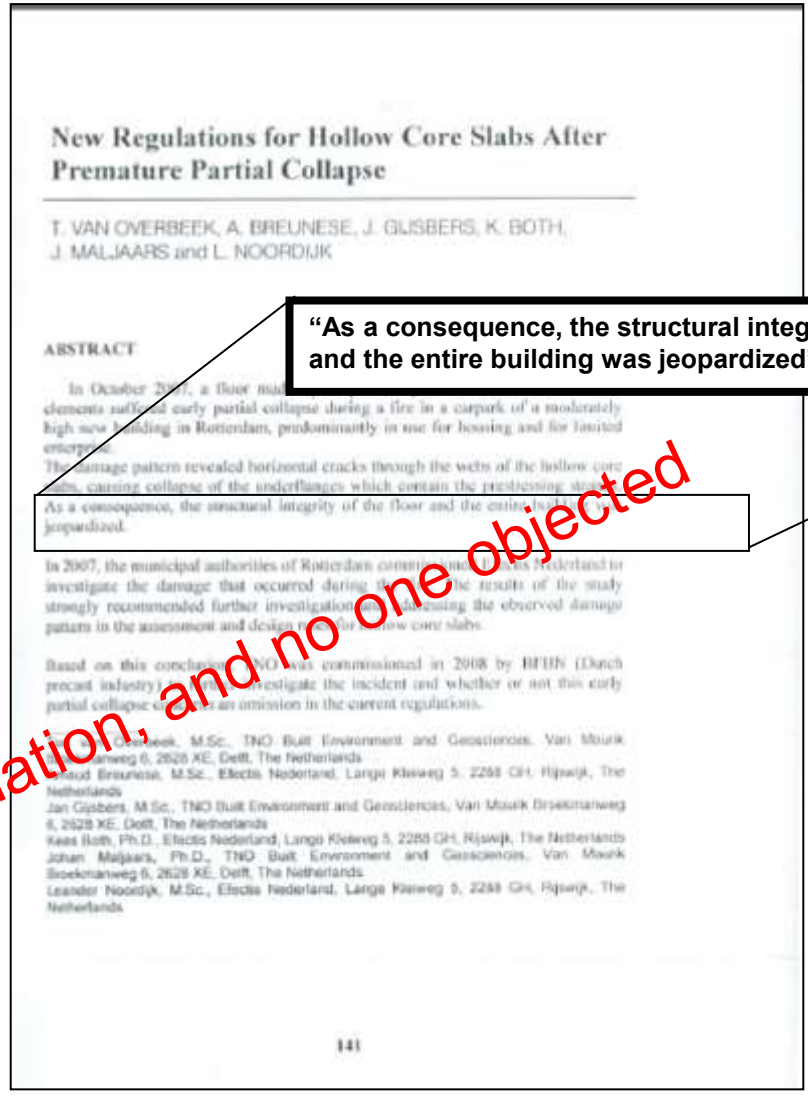
- A look back on Rotterdam fire
- Rumours floating around
- Administrative playing field prior to the fire
- Facts and observations
- Analysis
- Fire simulation using CFD model
- Delamination of bottom flange (step by step)
- Other concrete structures at fire
- Conclusions

“Rotterdam fire”

- This is a well known photo seen in many conferences and used against hollow core

“Rotterdam fire” dogma internationally spread





Incorrect information, and no one objected

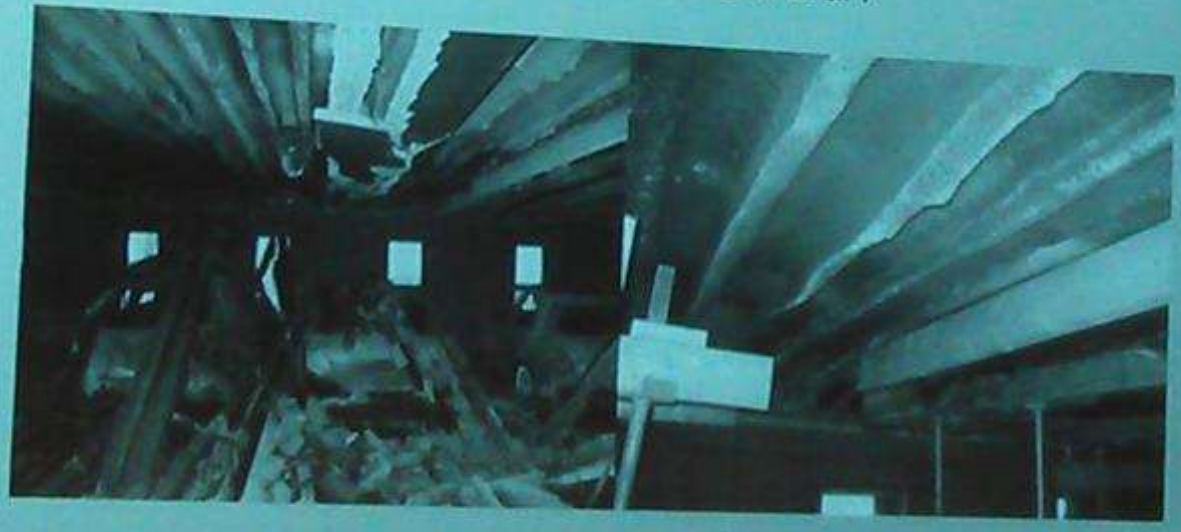
And ....

ICITECH

INTRODUCTION

HOLLOW CORE SLABS

Premature failure is detected in the literature under fire events.
Car Park Rotterdam, Overbeek et al .



“Rotterdam fire”

What happened?
We can explain what we see?
Can we explain the phenomena?

Fire; a political discussion in NL

- 2001 Volendam-New-Years Fire
  - 14 people died
  - New administrative regulations
- 2004 Catshuis fire
  - 1 died
  - No permit, concluded that administration failed
- 2005 Schiphol fire
  - 11 died
  - Judicial Authority + Building Authority responsible
  - Both Ministers resigned

→ After 2005 govermental authorities were looking for security in building permits and building regulations

→ Note: no hollow cores involved

1 October 2007 “Rotterdam fire”

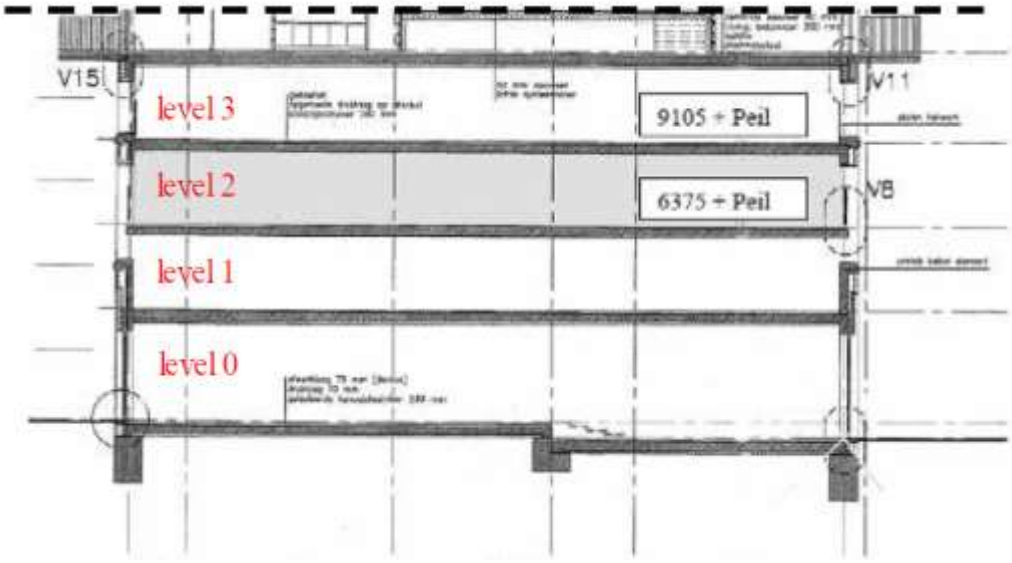
- Now we understand better at what sentiment the discussions were held in The Netherlands on this fire

Llyodstraat building, Rotterdam

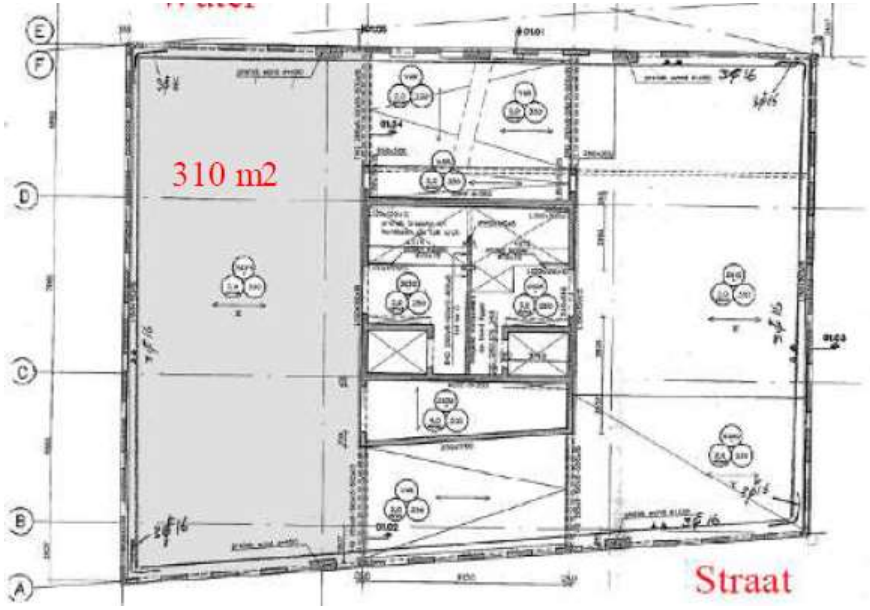
- 12 storey building
  - Level 4 to 11 apartments
    - Filligran floors
  - Level 0 to 3 garage
    - Fire compartment 2100 m^2
    - Total of 60 cars
    - Hollow core floors

Llyodstraat building, Rotterdam

cross section
levels 0-3

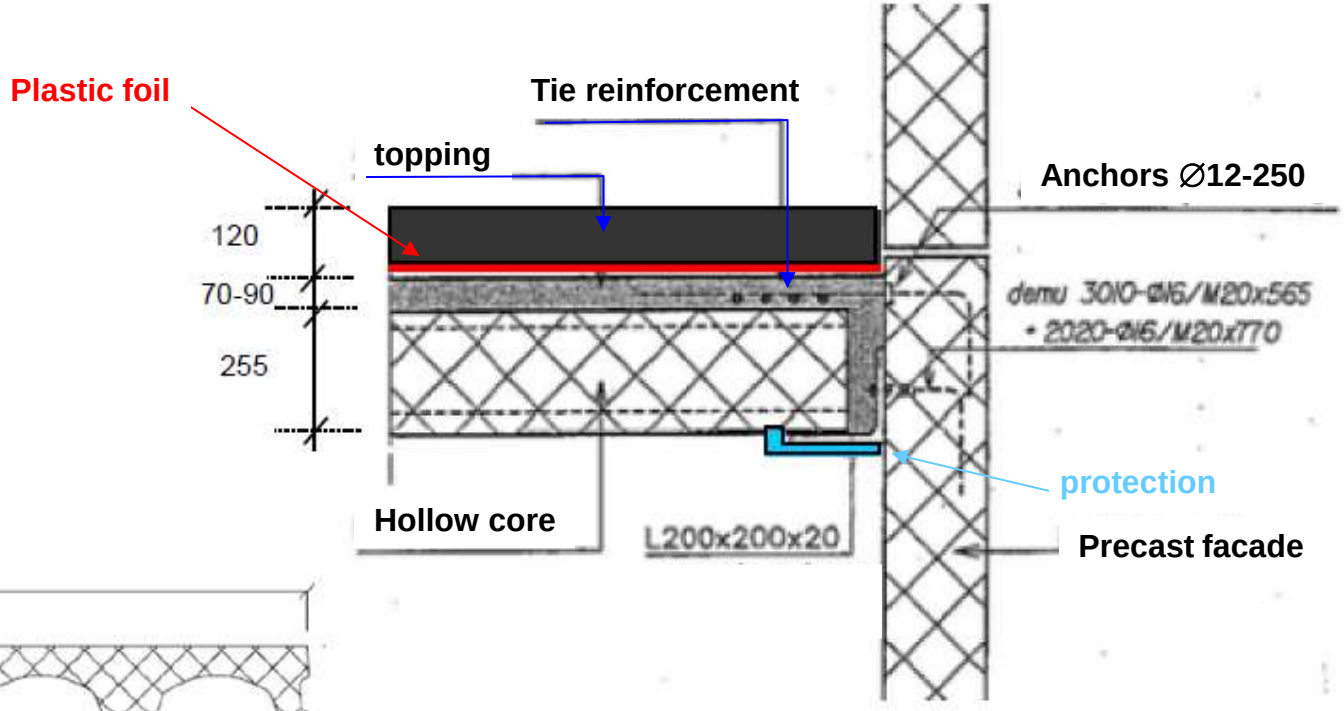


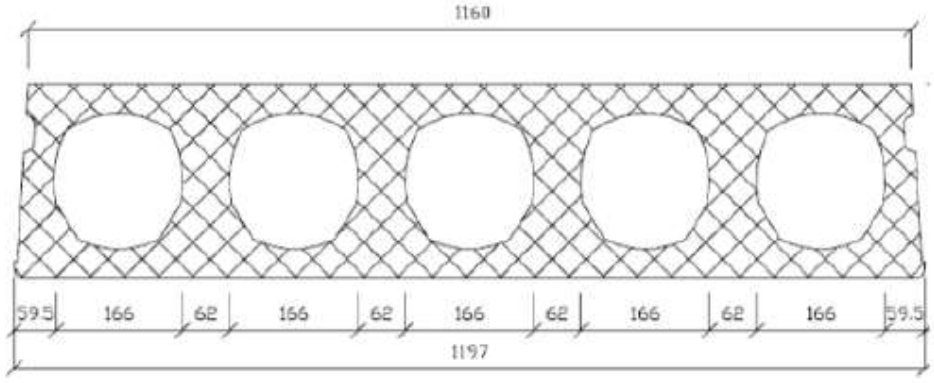
top view
level 2



Cross section over support

HCS 255 mm
Strands 10 x ∅12.5 mm

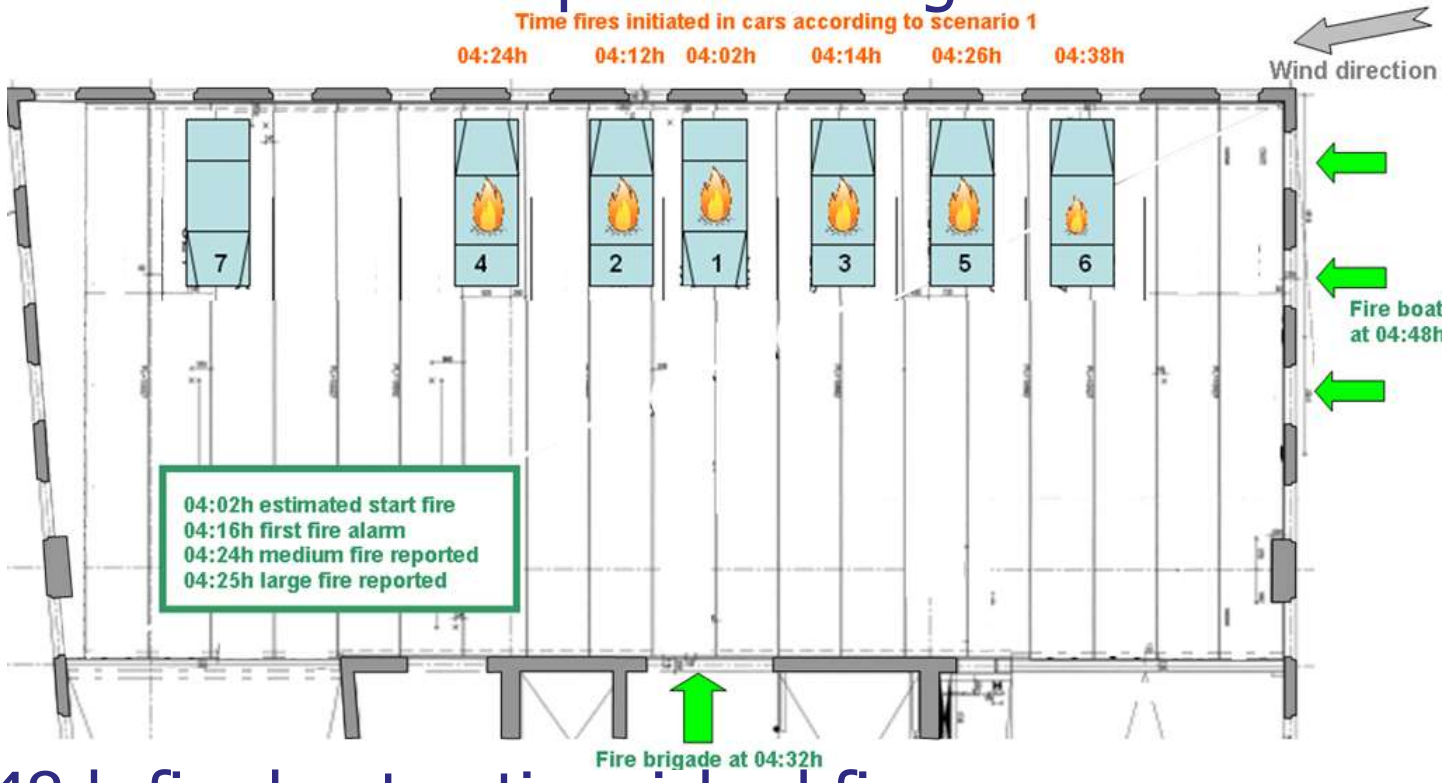




•	structural topping:	1.80 kN/m^2
•	Hollow core slabs 260-5:	3.70 kN/m^2
•	Finishing:	1.20 kN/m^2
•	Total dead load:	6.70 kN/m^2
•	Extreme live load:	2.00 kN/m^2
•	frequent/quasi-permanent value:	0.7

1st October 2007 (scenario 1)

- Fire reported at 4.16 h by occupants
- At 4.25 h fire was reported as big fire



- 4.48 h fire boat extinguished fire
- 5.01 h fire under control

Photos taken 2nd October 2007

- Floor of level 3 did not collapse !!
- Four cars that were parked on level 3 were removed the next day

One day after the fire
No damage !!

Criteria REI fullfilled !

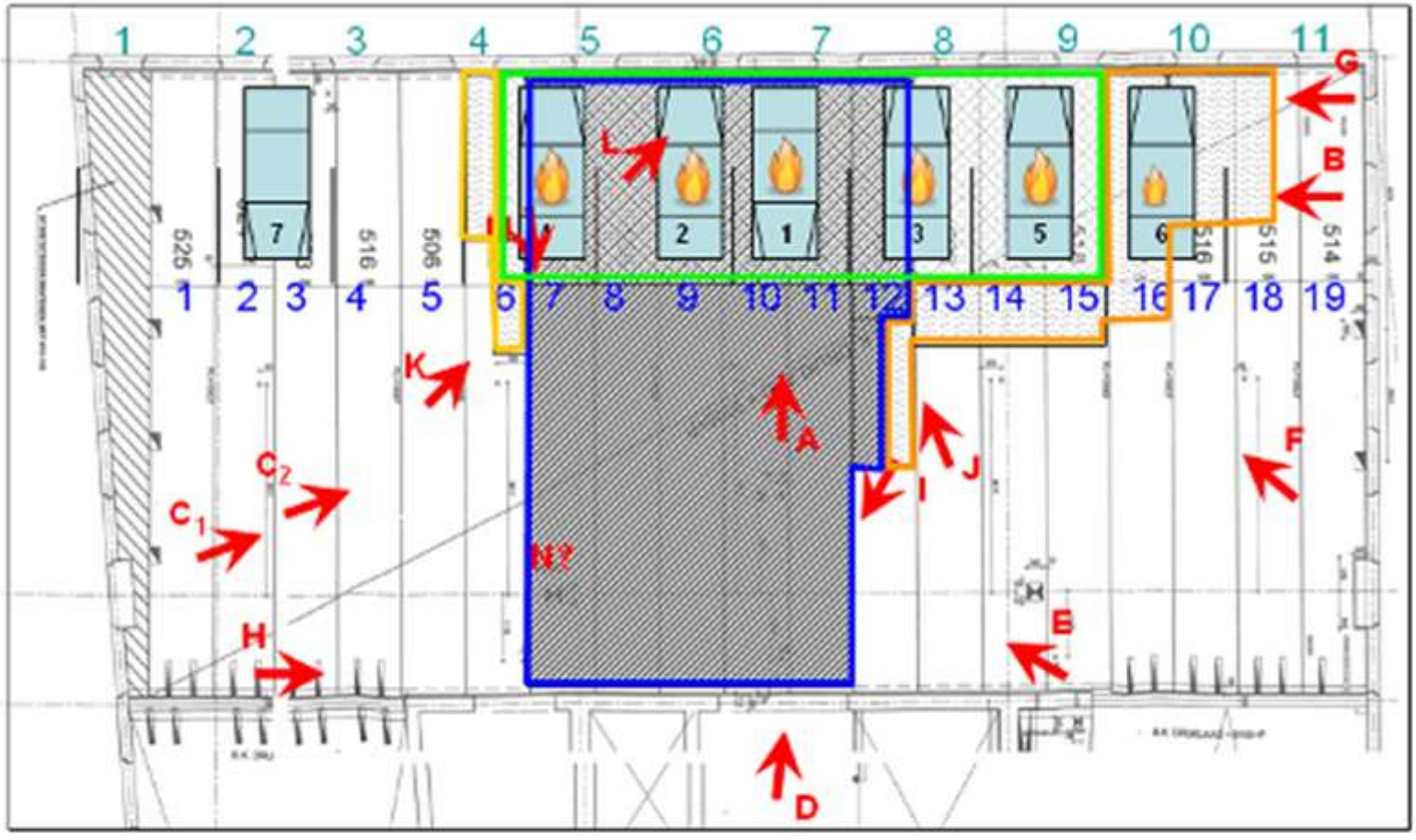
Photos taken 2nd October 2007

- Extensive spalling on external facade surface (left)
- Hollow core floor ceiling with open cores (right)

Photos taken 2nd October 2007

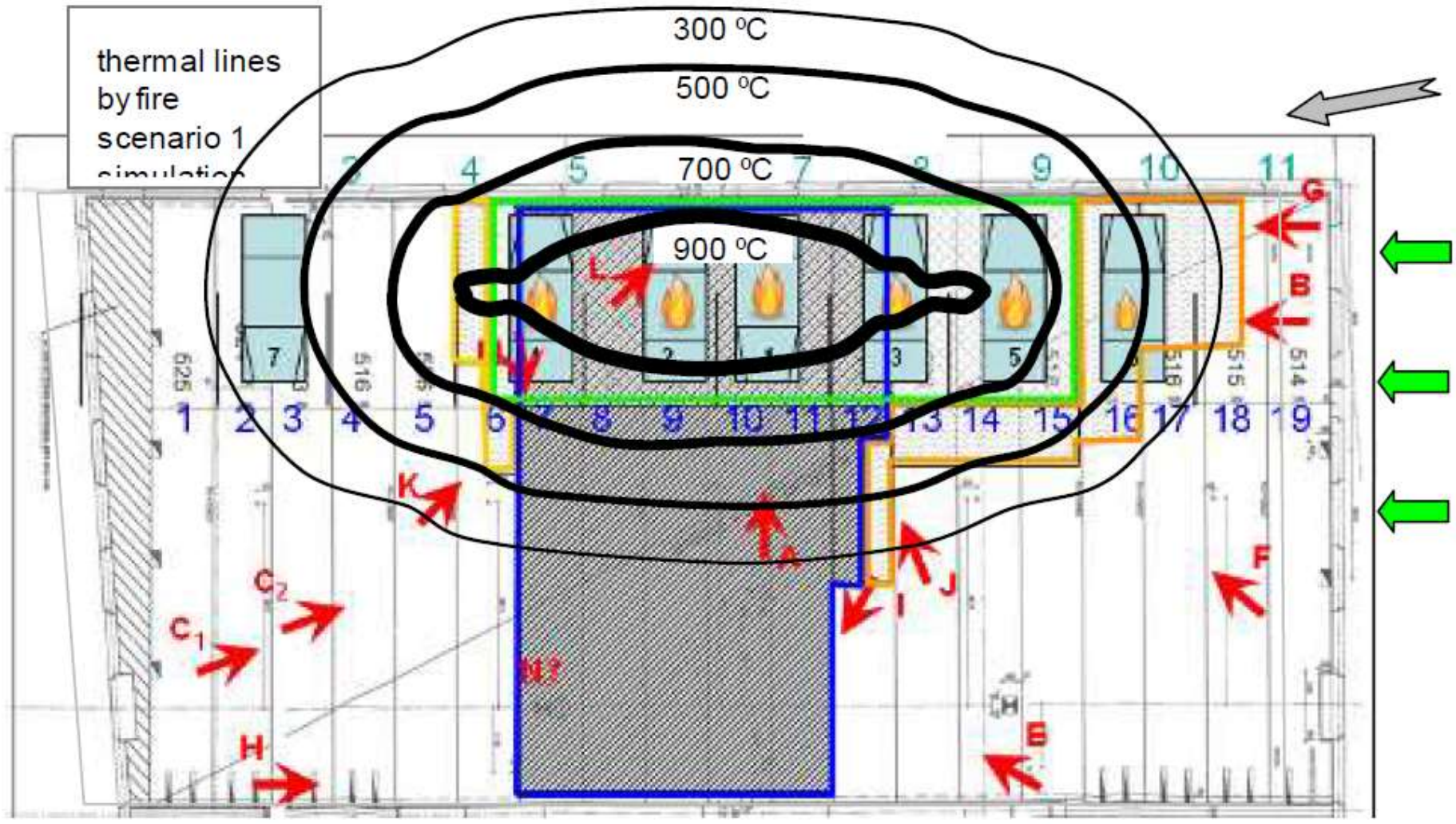
- Underflanges of hollow cores felt down
- Support of the hollow core slab was intact
- Strands were exposed

Damage to slabs: overview



(scenario 1)

Heat development (scenario 1)



Video

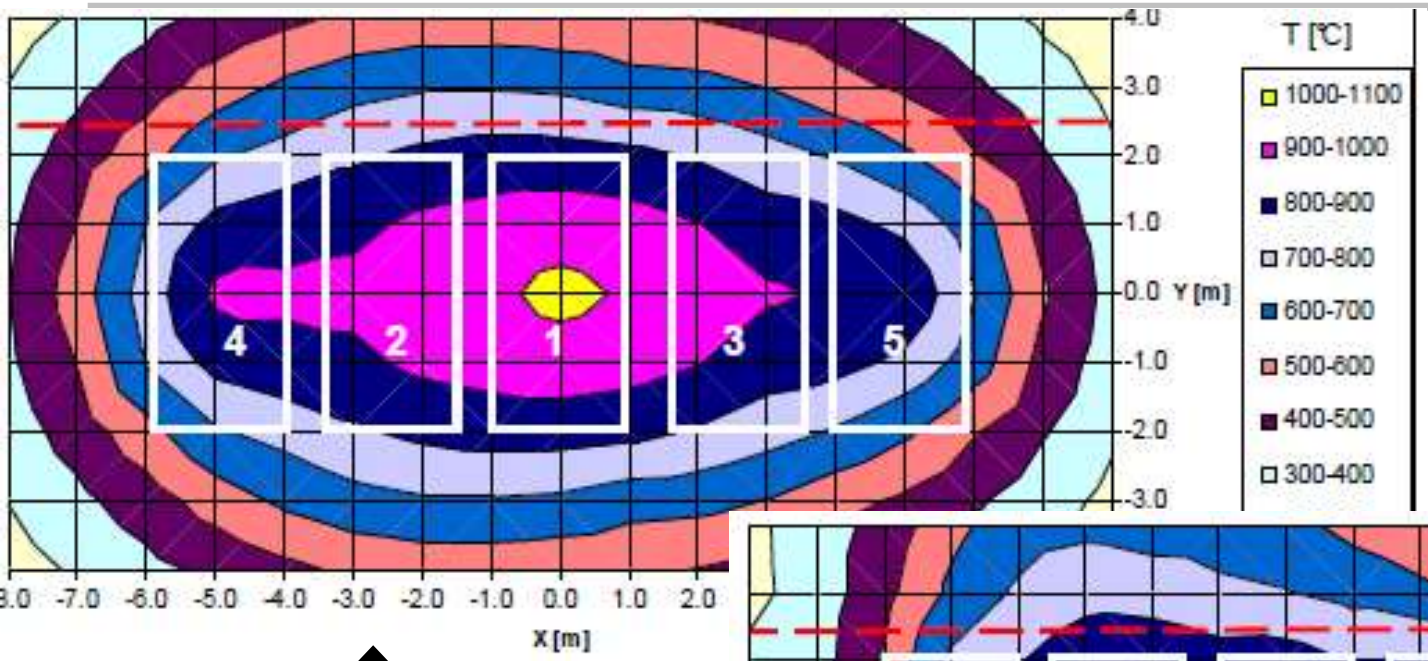
Background and new approach

- Efectis and TNO
  - research in 2009 and 2011
  - CaPaFi 2.0
- Questions:
  1. Influence of a nearly closed wall on CaPaFi results
  2. Influence of wind and real parking geometry
  3. Influence of exact number of cars involved in the fire

➡ ***New approach with Fire Dynamics Simulator (FDS5)***

CaPaFi vs FDS5

Temperature distribution under the ceiling

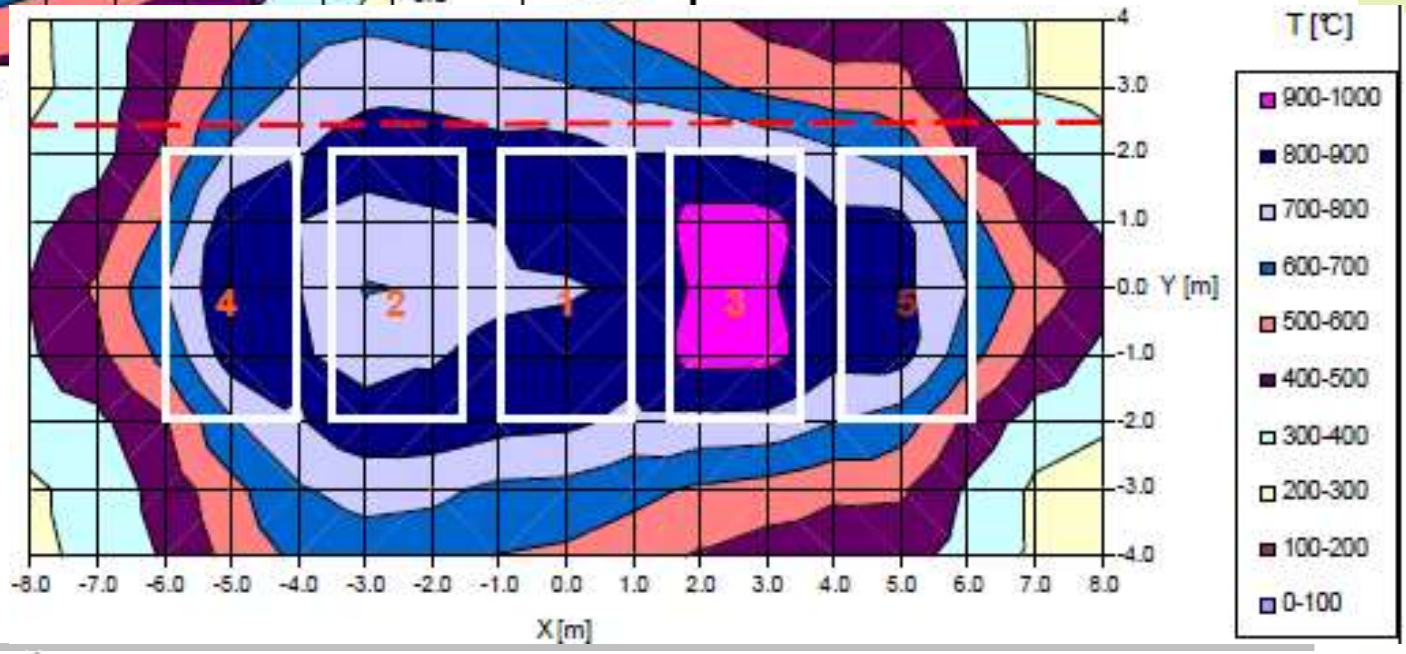


CaPaFi

The same input

- After 30 minutes

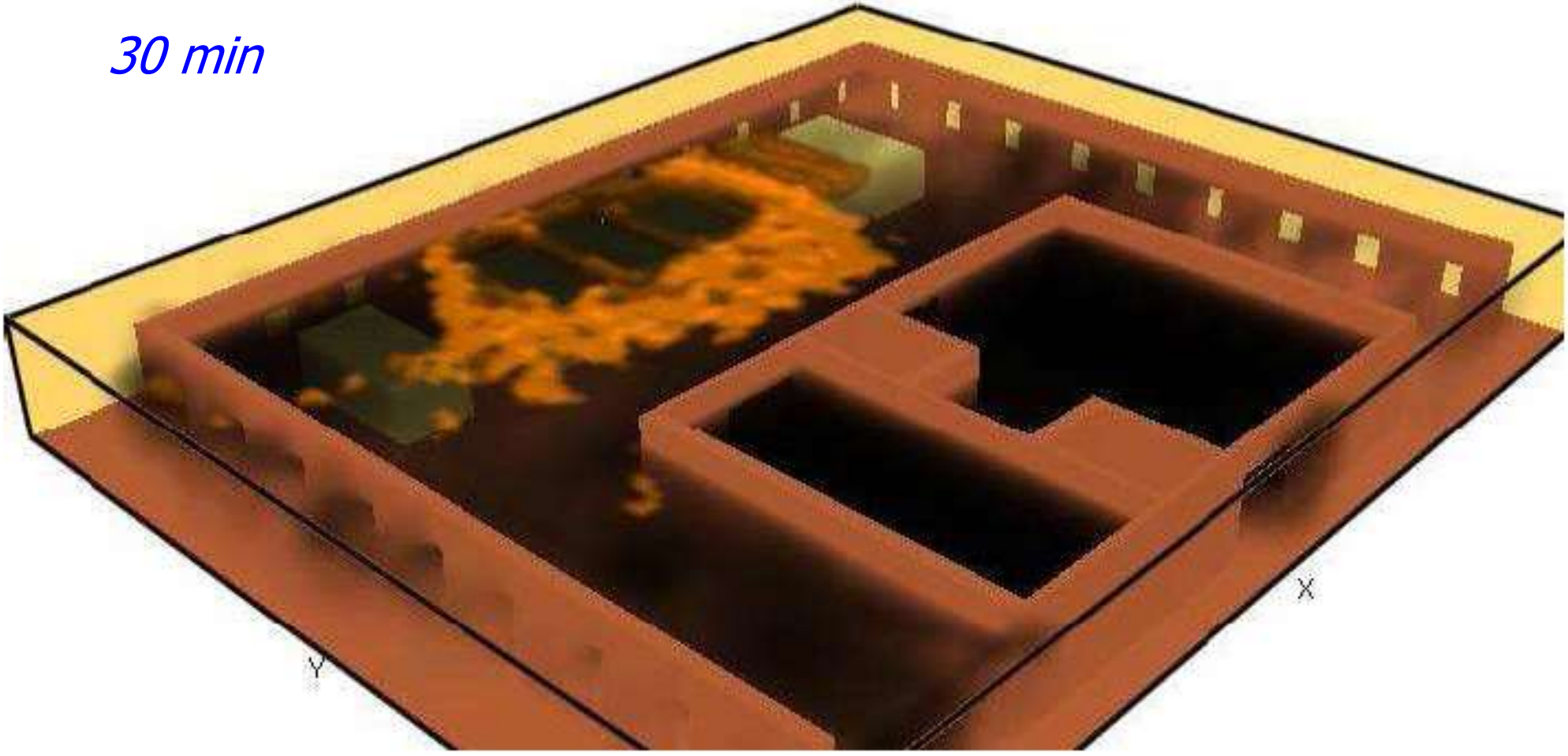
FDS5 simulation ➔



Fire scenario 1 in Fire Dynamics Simulator (FDS5)

- Smoke development

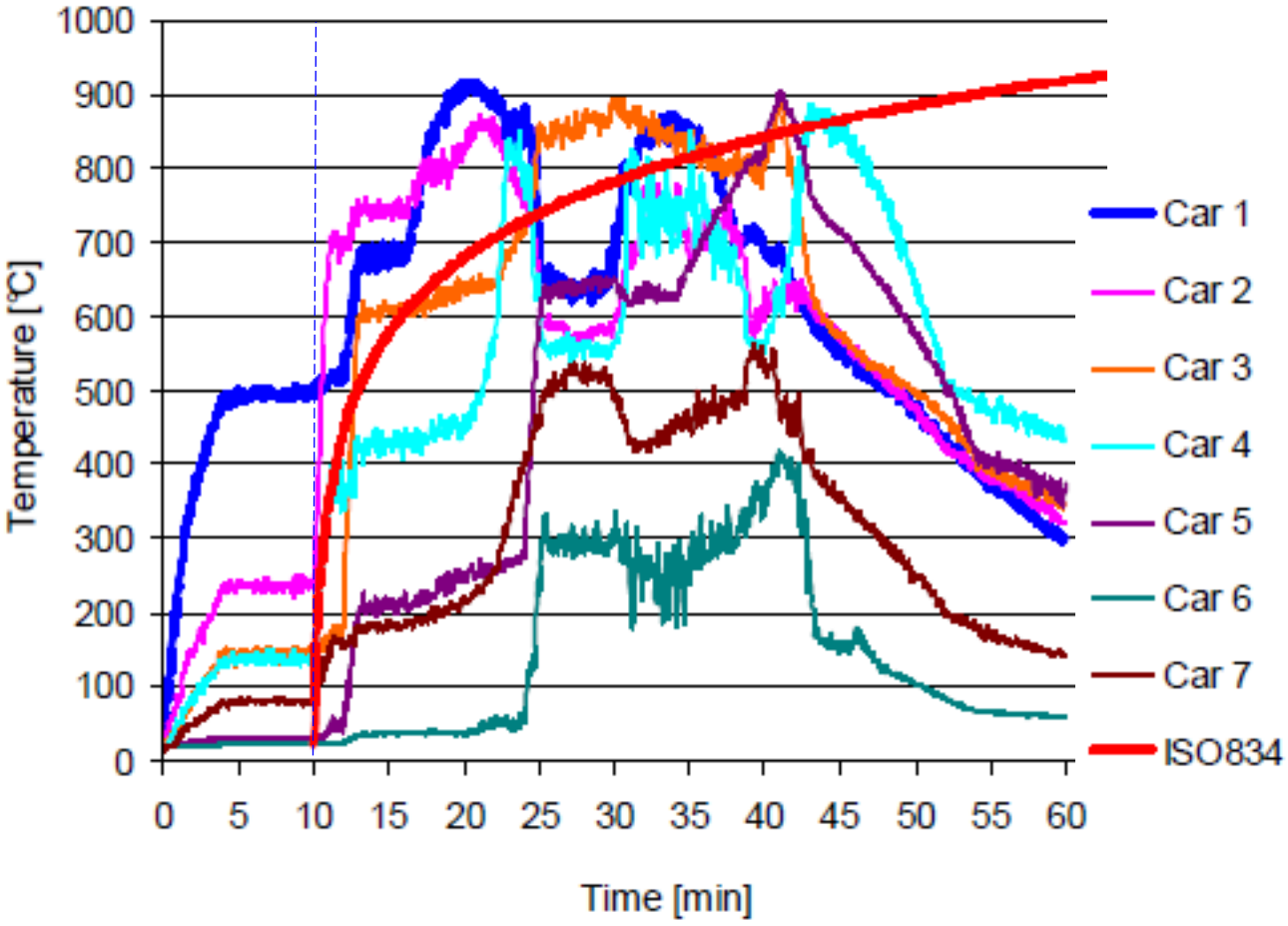
30 min

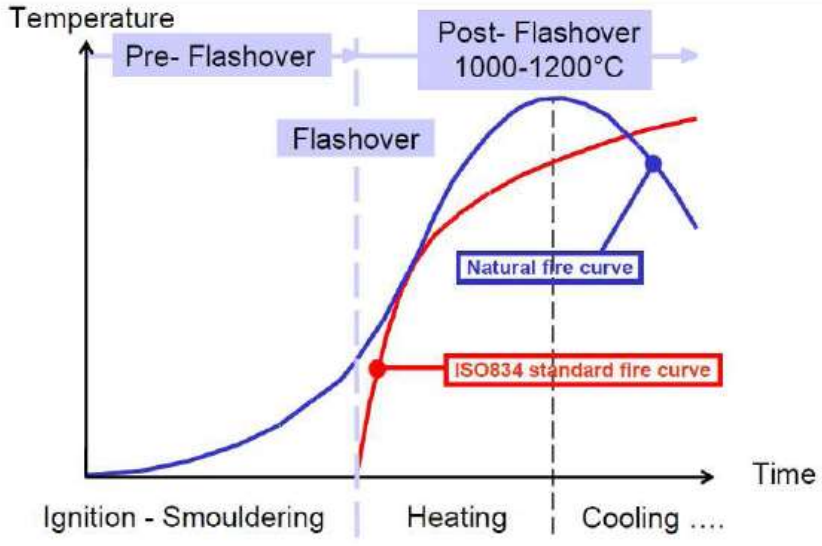


Fire scenario 1 in Fire Dynamics Simulator (FDS5)

Gas temperature evolution in time

- Comparison with ISO 834 curve



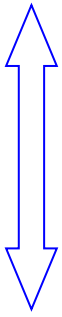


- Natural fire concept

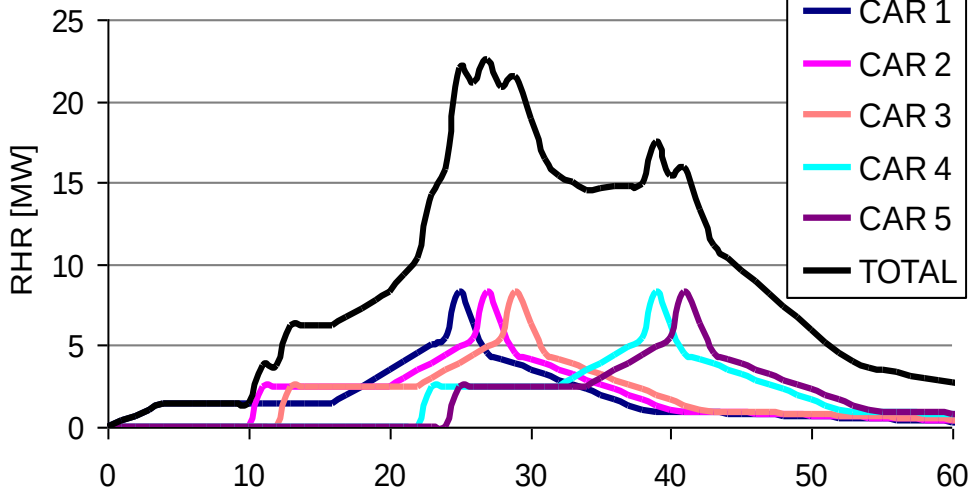
Fire scenario 1 in Fire Dynamics Simulator

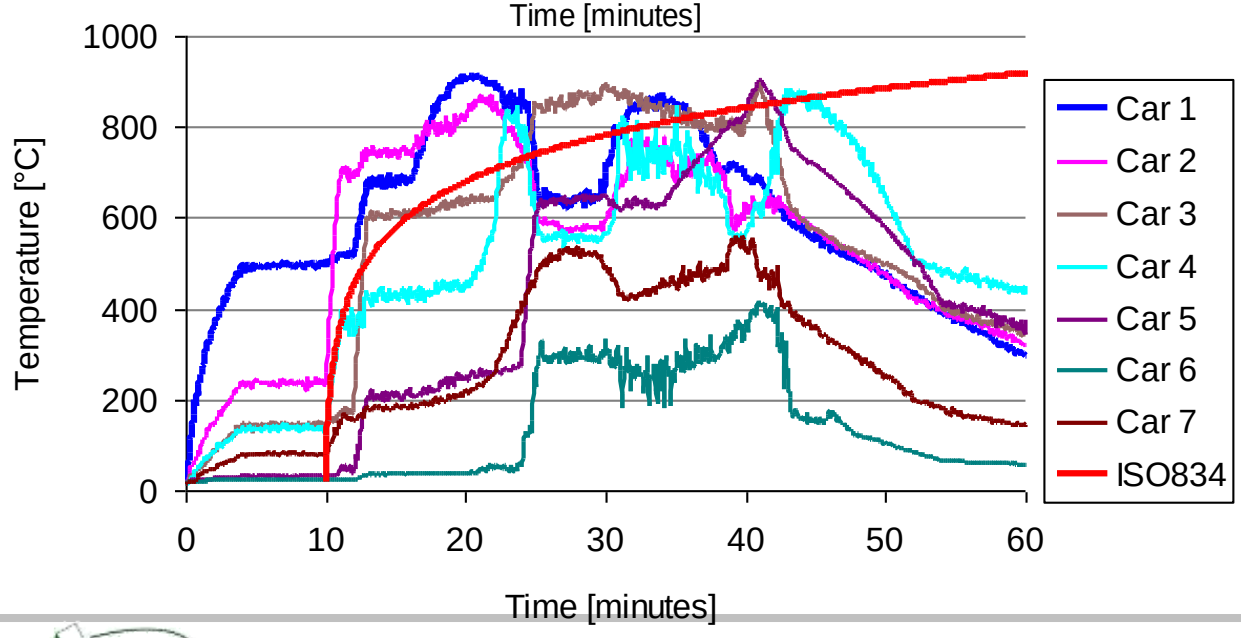
Gas temperature evolution in time

- Heat release rate



- Gas temperature

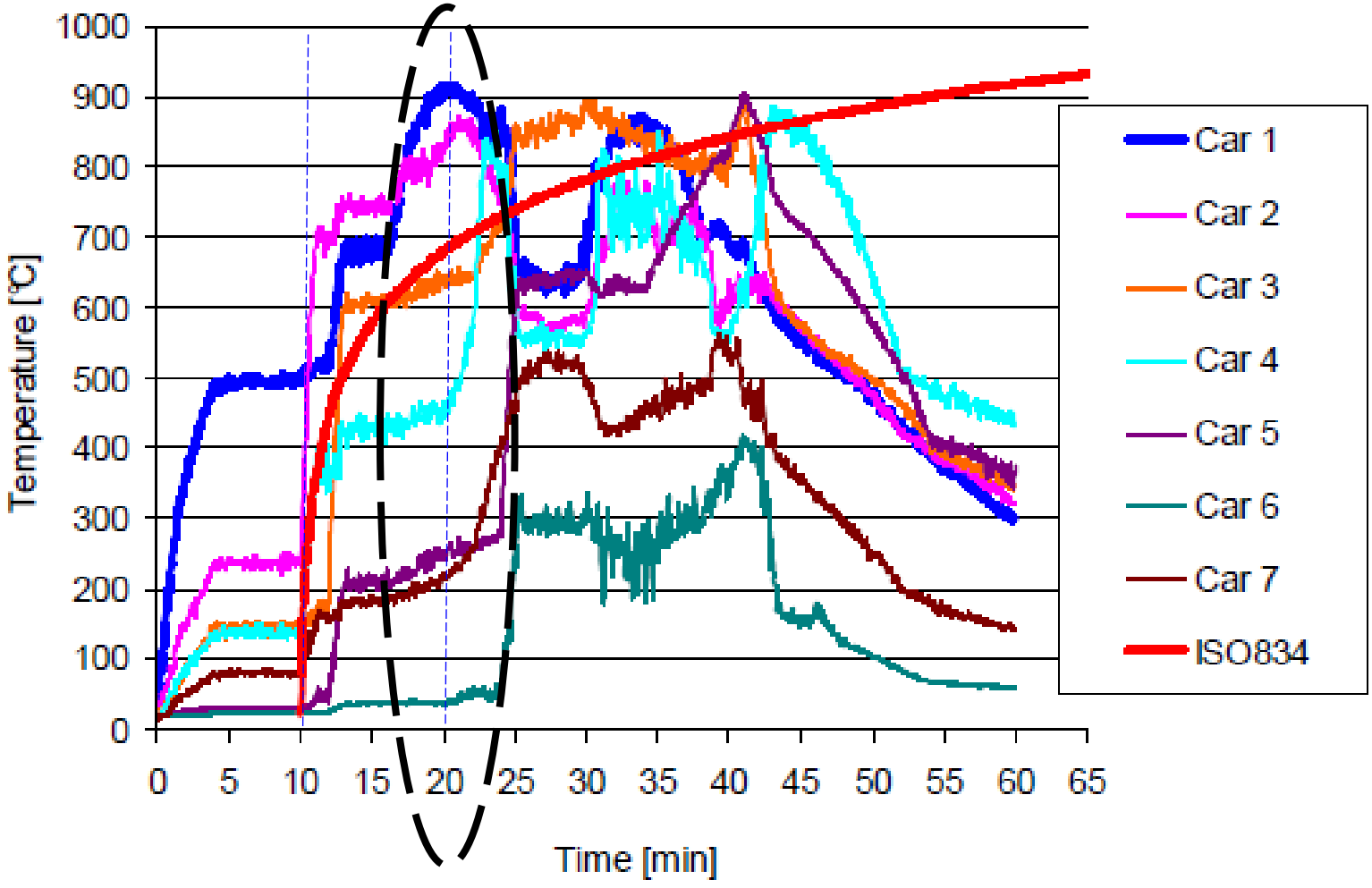




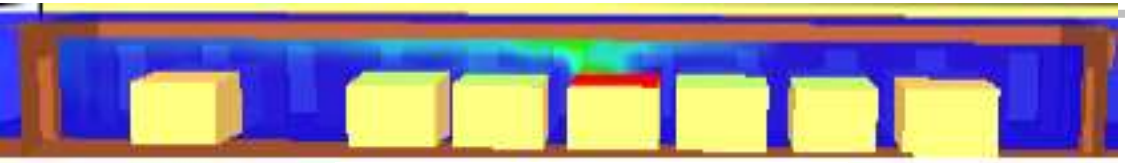
Fire scenario 1 in Fire Dynamics Simulator

Gas temperature evolution in time

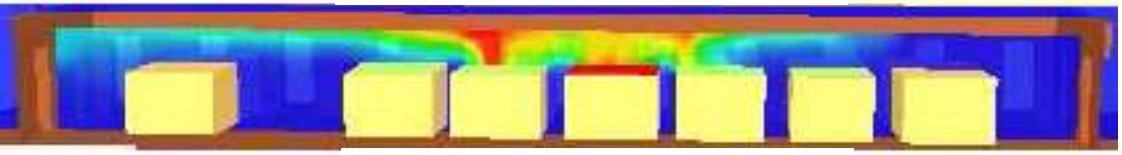
- Comparison with ISO 834 curve



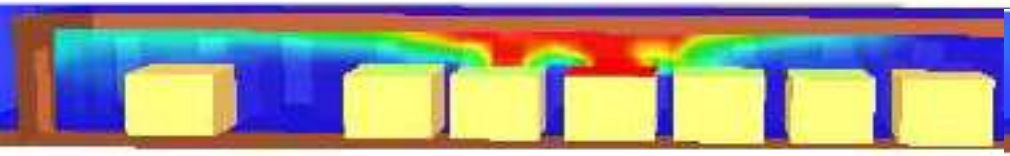
Fire scenario 1 in Fire Dynamics Simulator



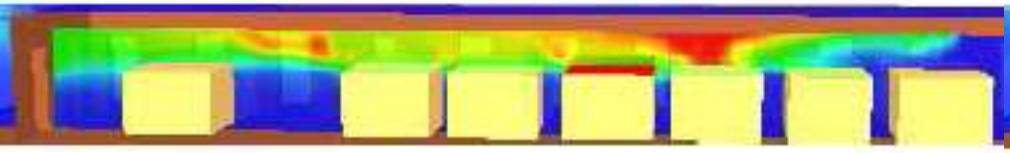
After 10 minutes



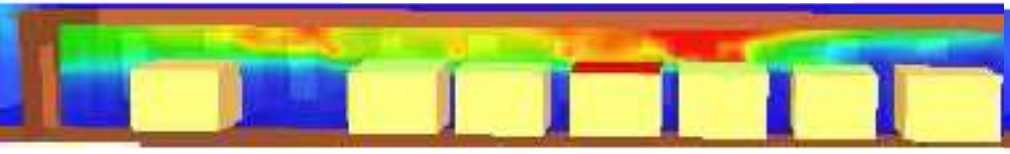
After 15 minutes



After 20 minutes



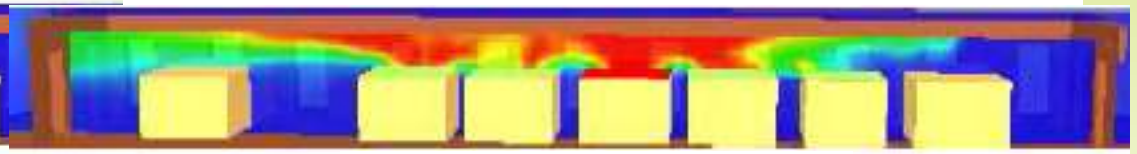
After 25 minutes



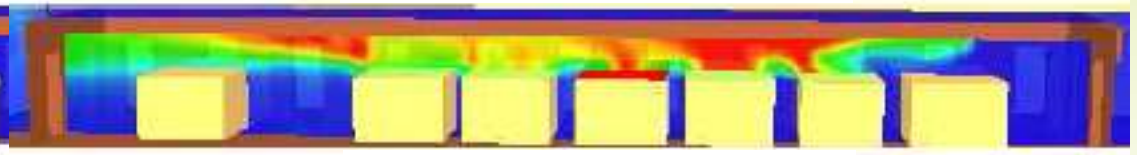
After 30 minutes

Slide through
the centre of cars

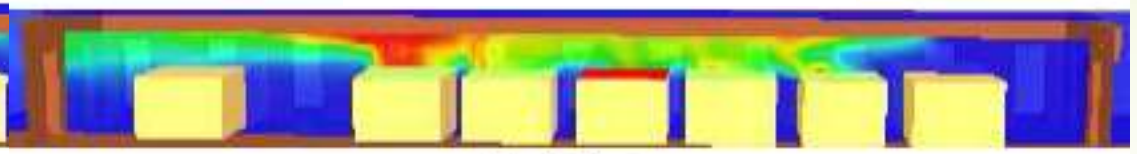
"Travelling fires"



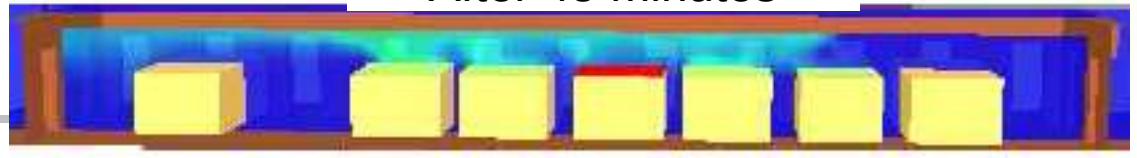
After 35 minutes



After 40 minutes



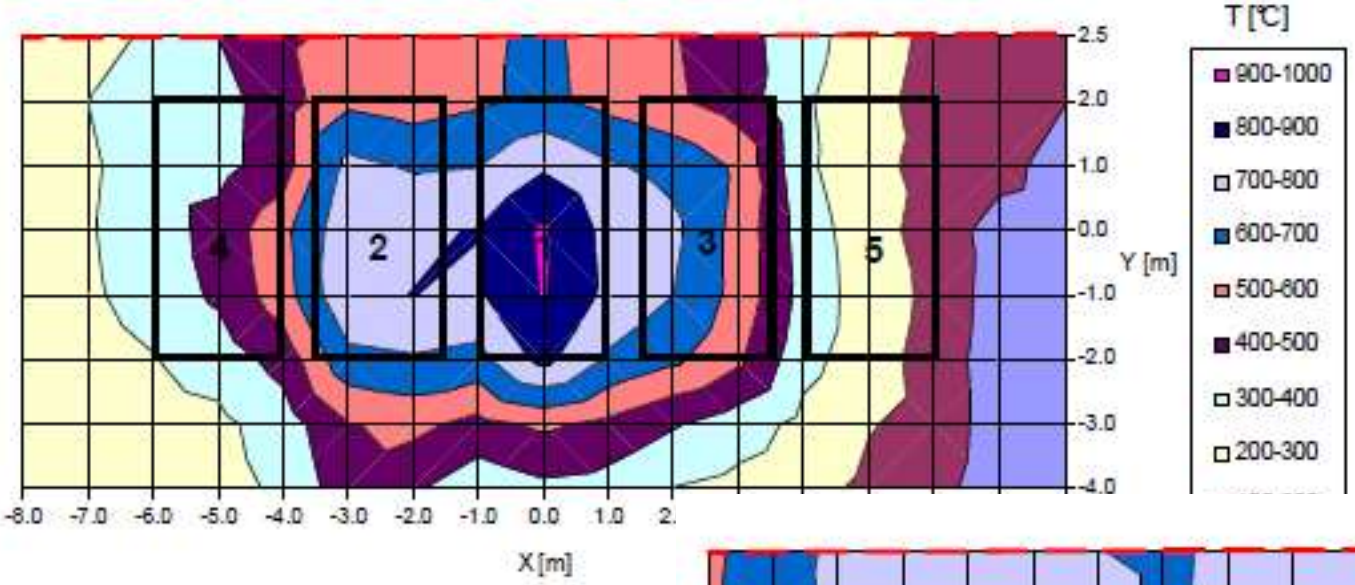
After 45 minutes



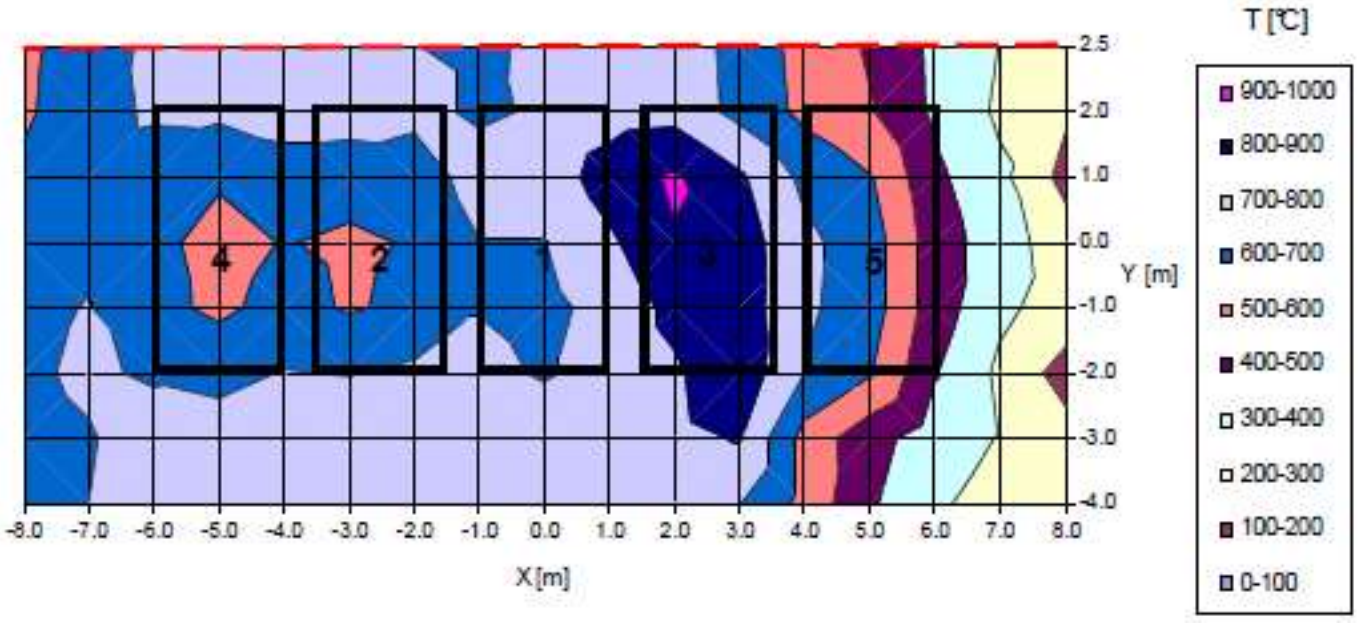
After 60 minutes

Fire scenario 1 in Fire Dynamics Simulator

Temperature distribution under the ceiling



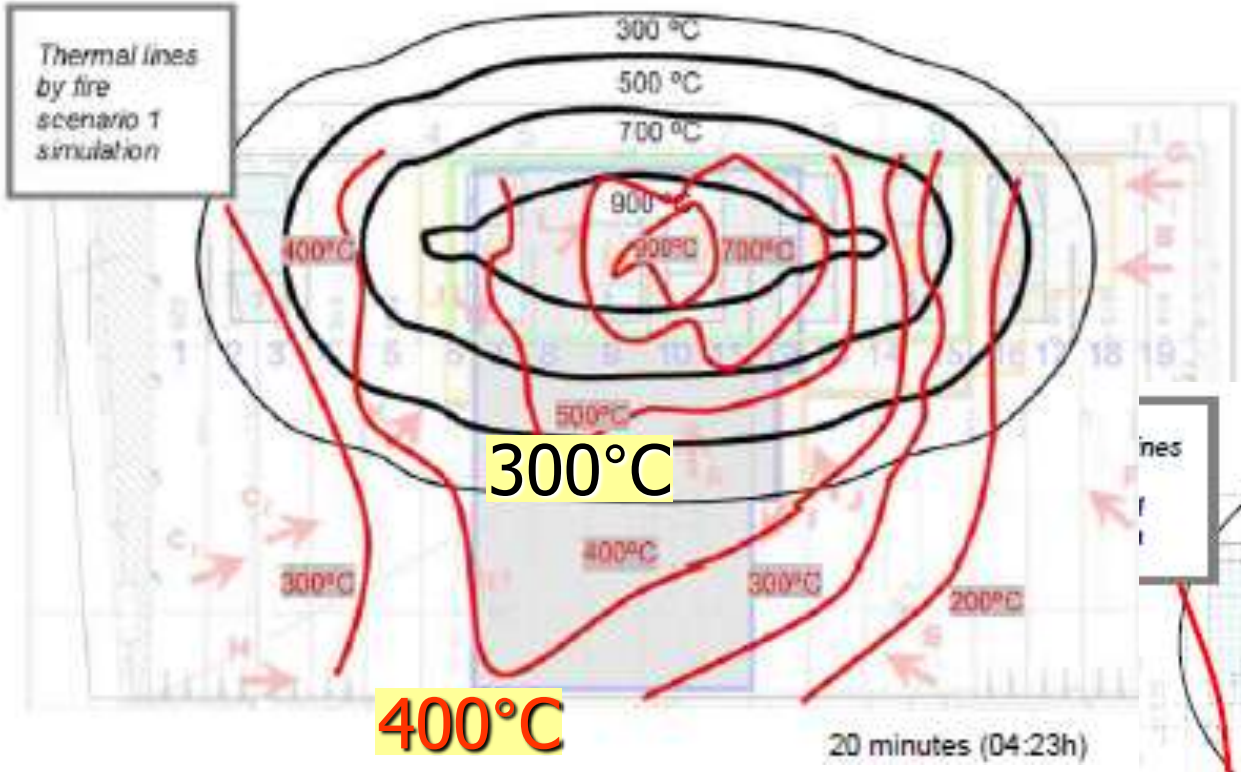
- At 20 minutes



- At 30 minutes

Temperature isolines with CaPaFi and FDS5

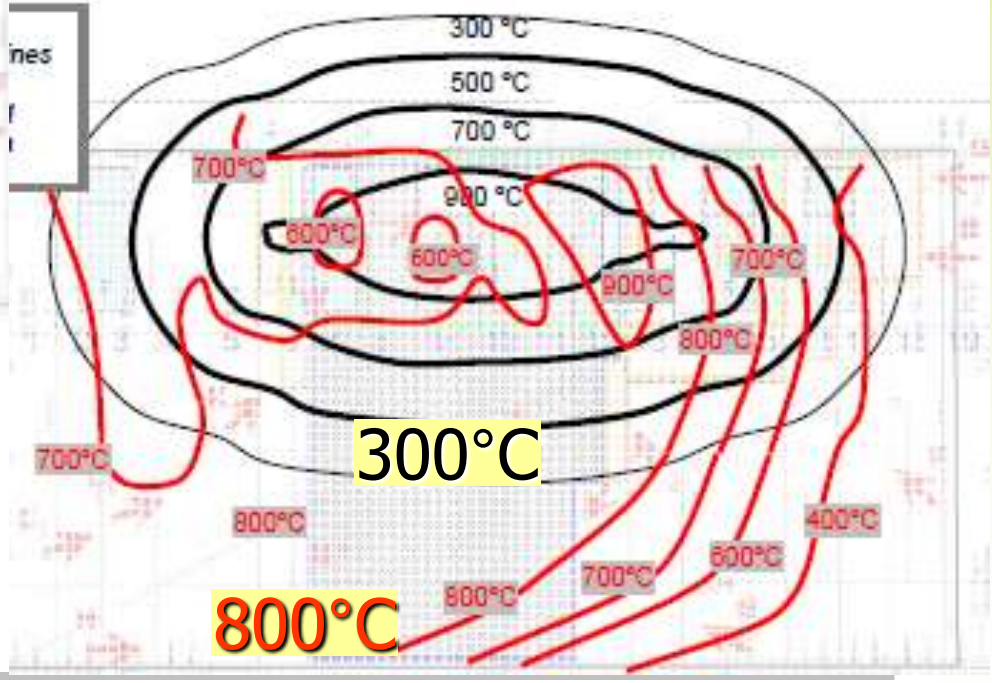
- At 20 minutes



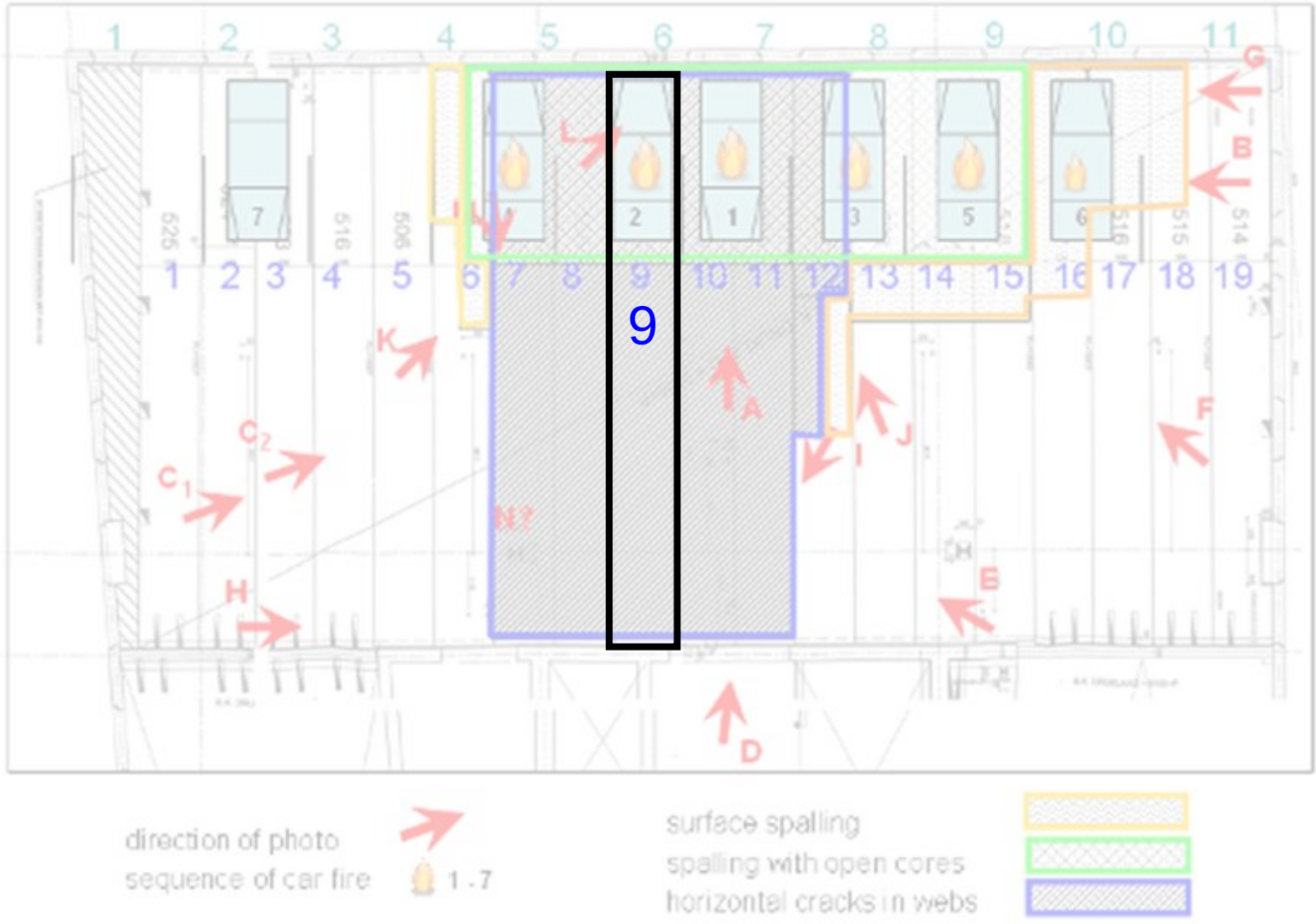
Black isolines - **CaPaFi**

Red isolines - **FDS5**

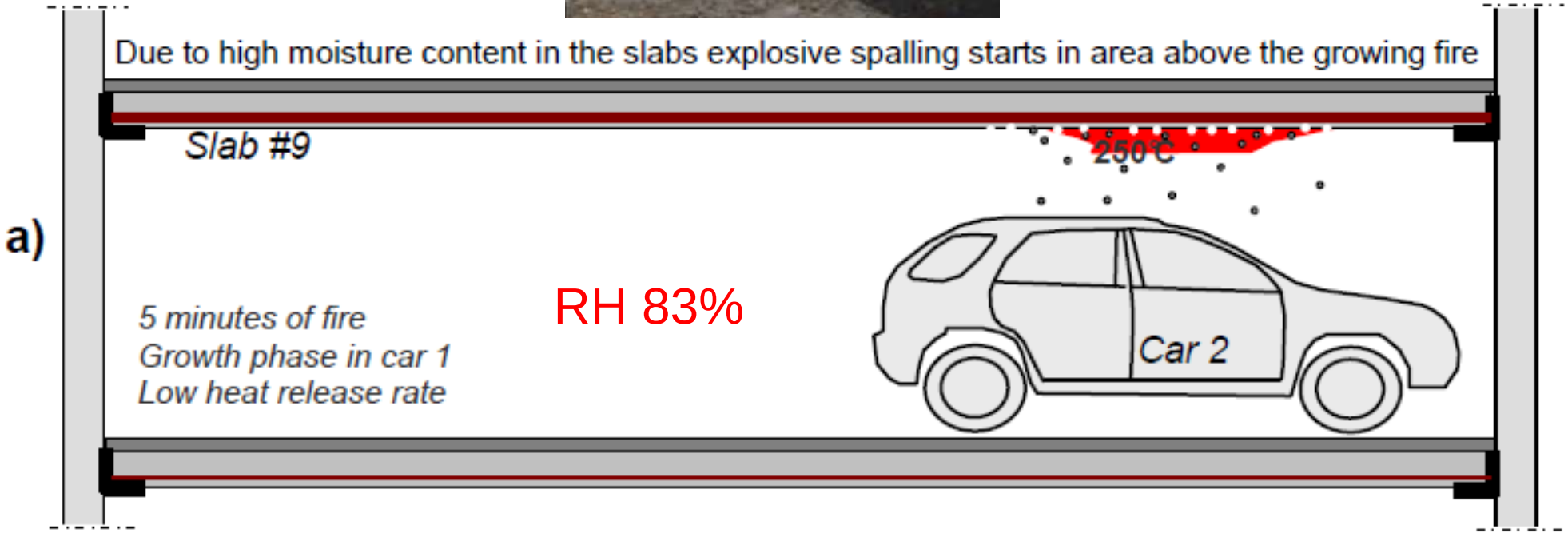
- At 30 minutes



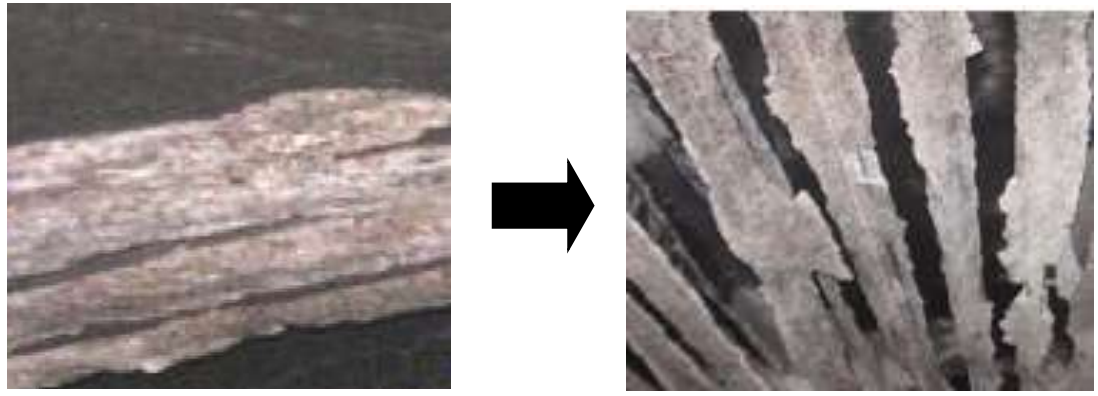
Focus on slab #9 above car 2

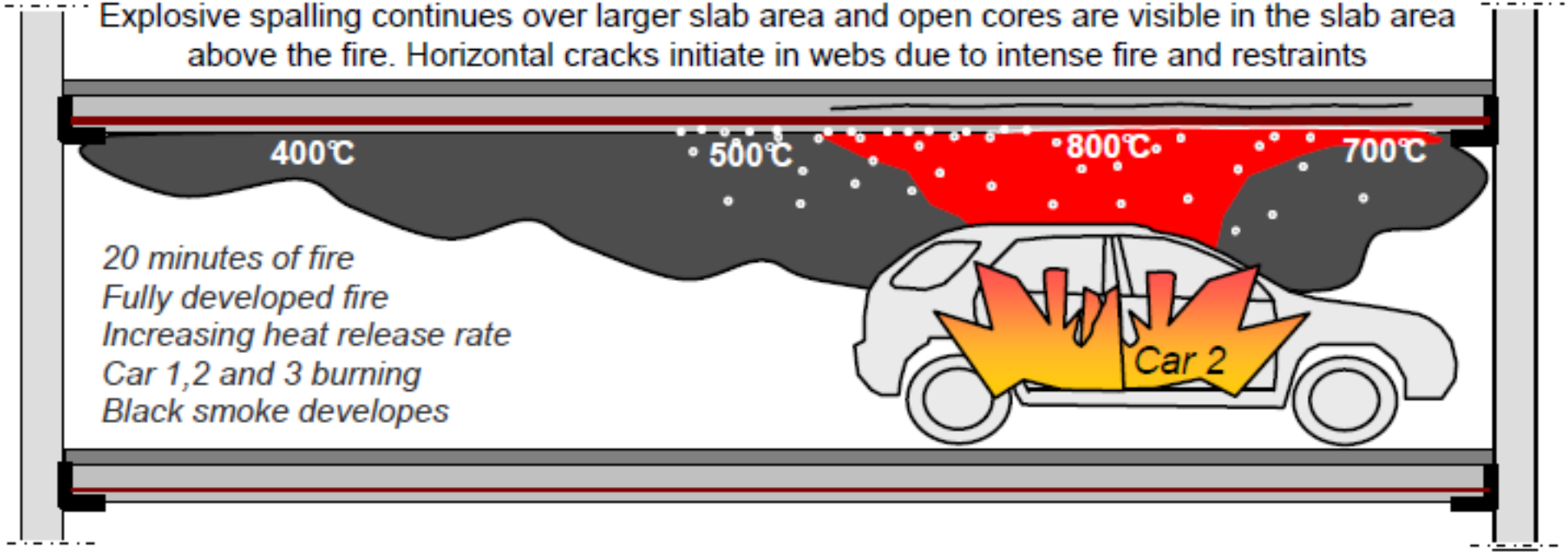


Phase a) Rotterdam slab #9

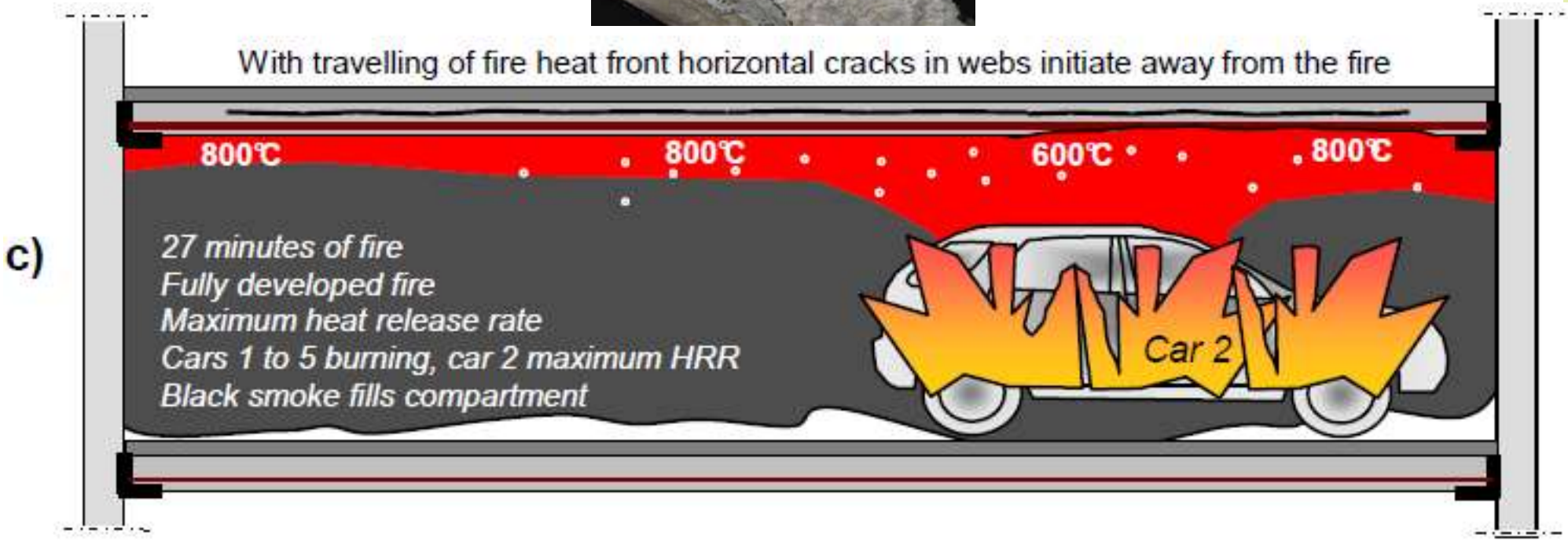


Phase b) Rotterdam slab #9

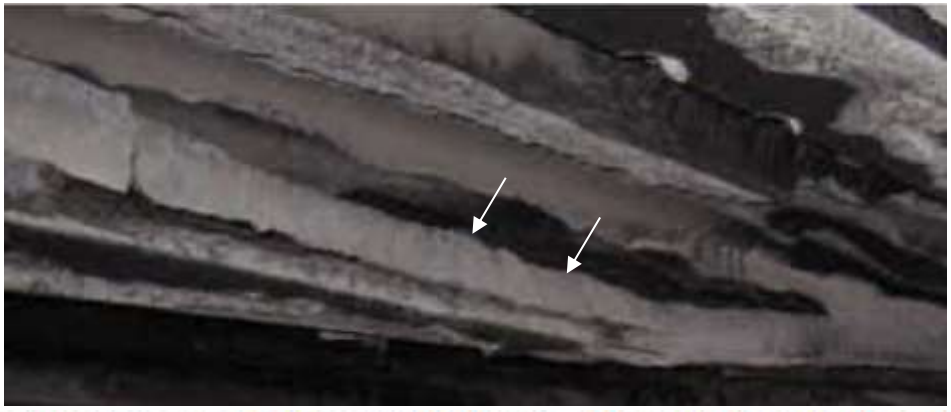


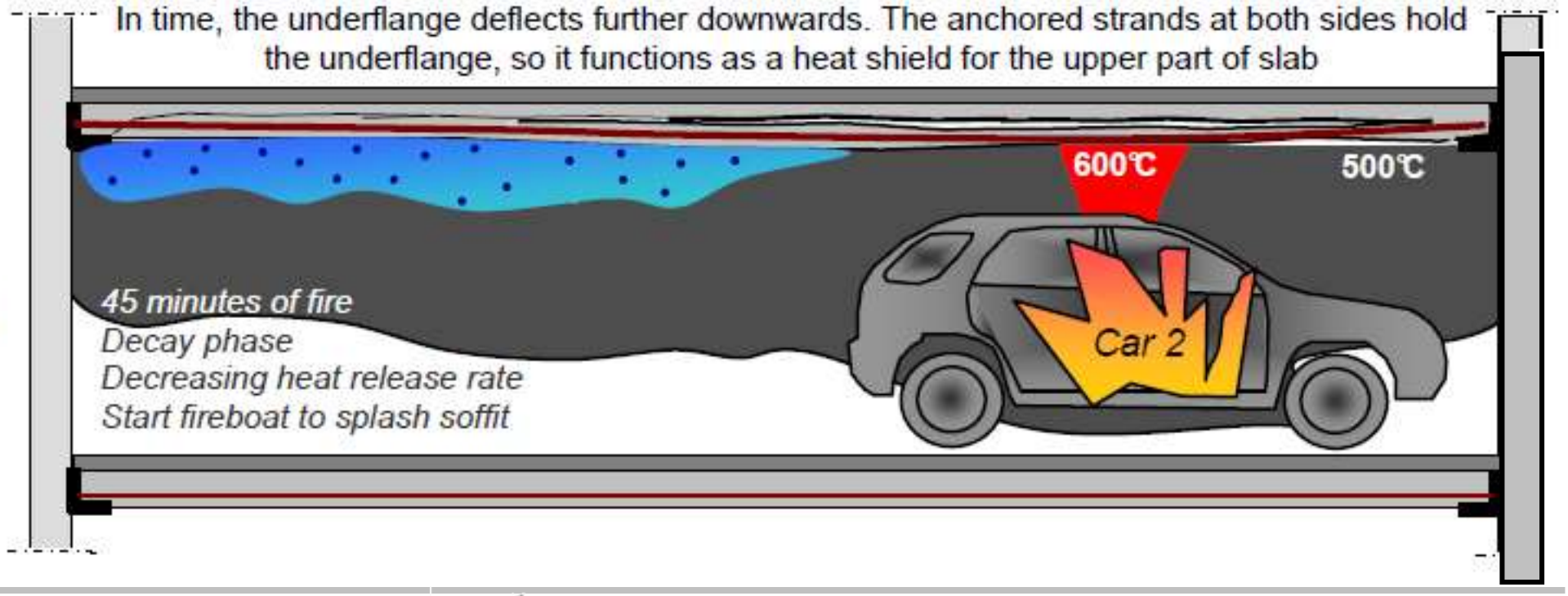


Phase c) Rotterdam slab #9

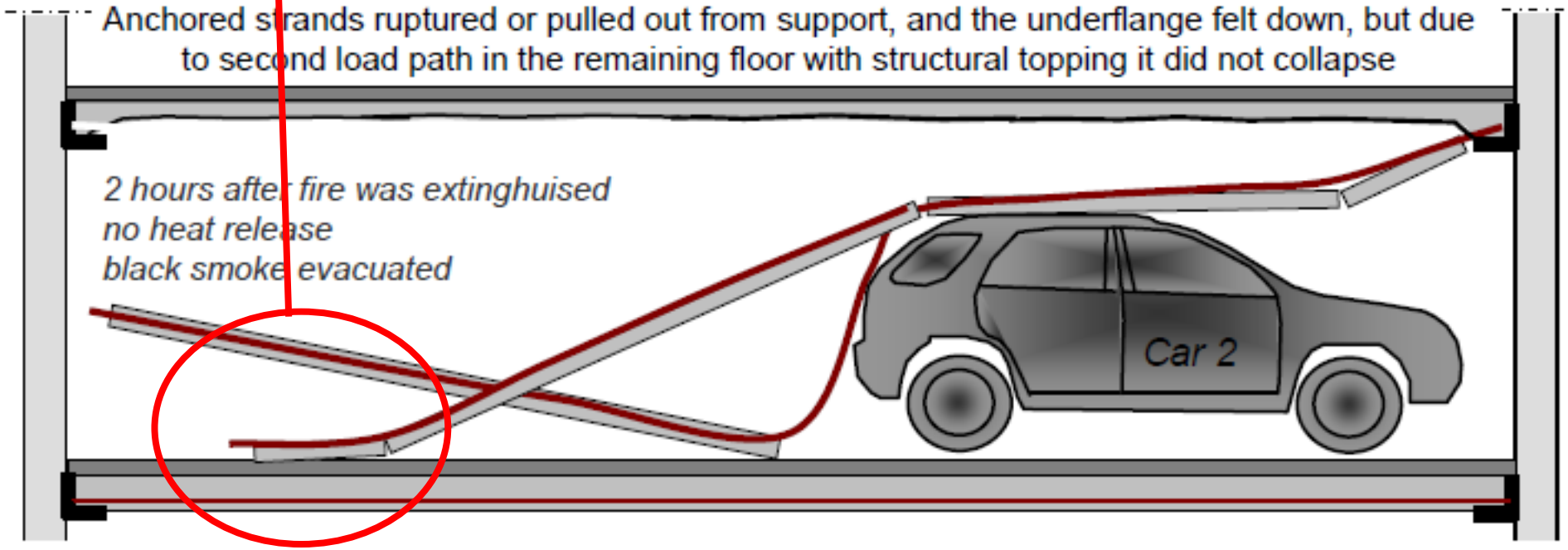


Phase d) Rotterdam slab #9





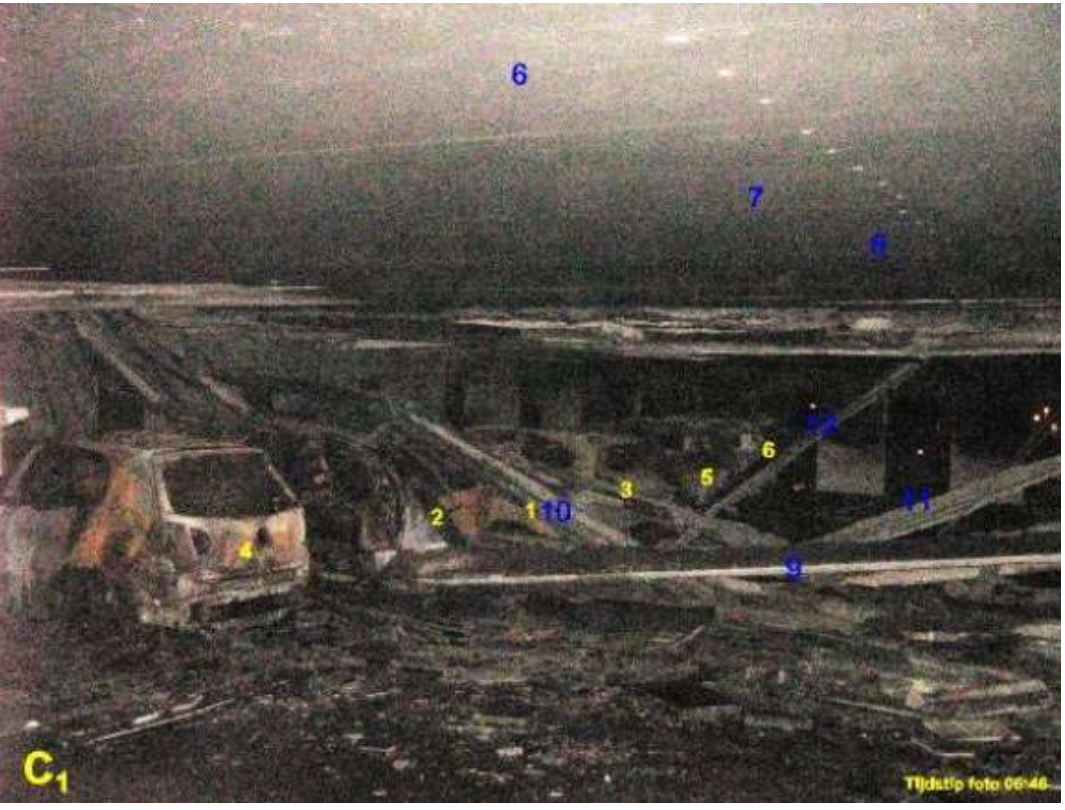
Phase e) Rotterdam slab #9



Falling down of underflanges

- Soffits of slabs #9, #10, #11, and part #12 felt down during or just after the fire (first photos are taken at 06.46 h)
- But ....
- Soffits of slabs #7 and #8 felt down several hours later

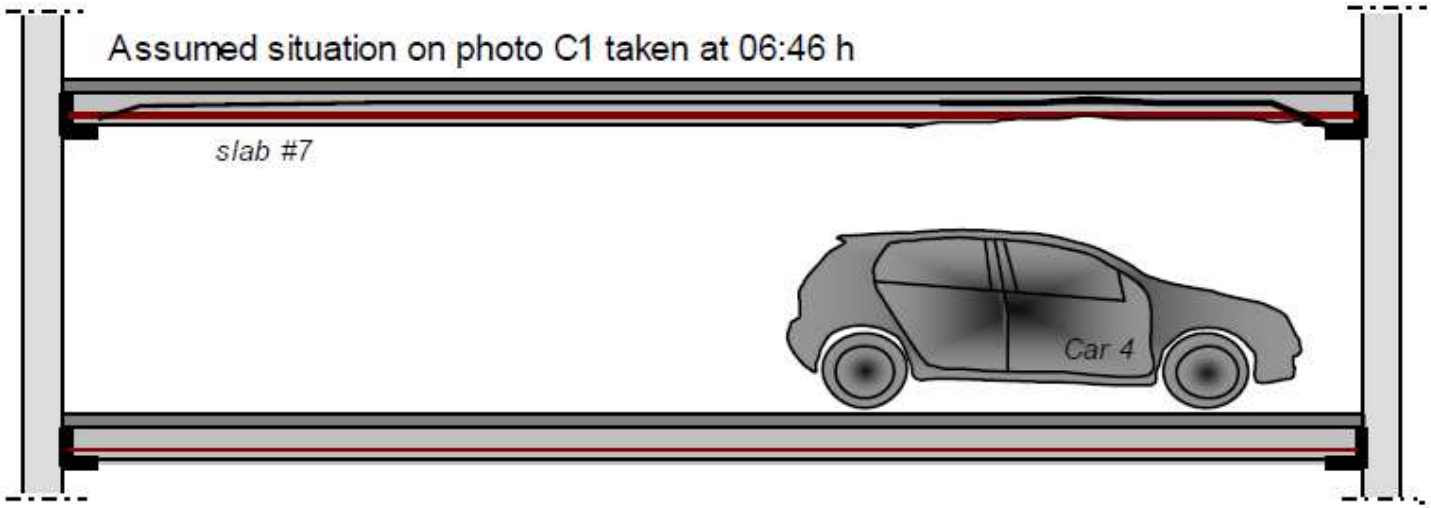
Slab #7

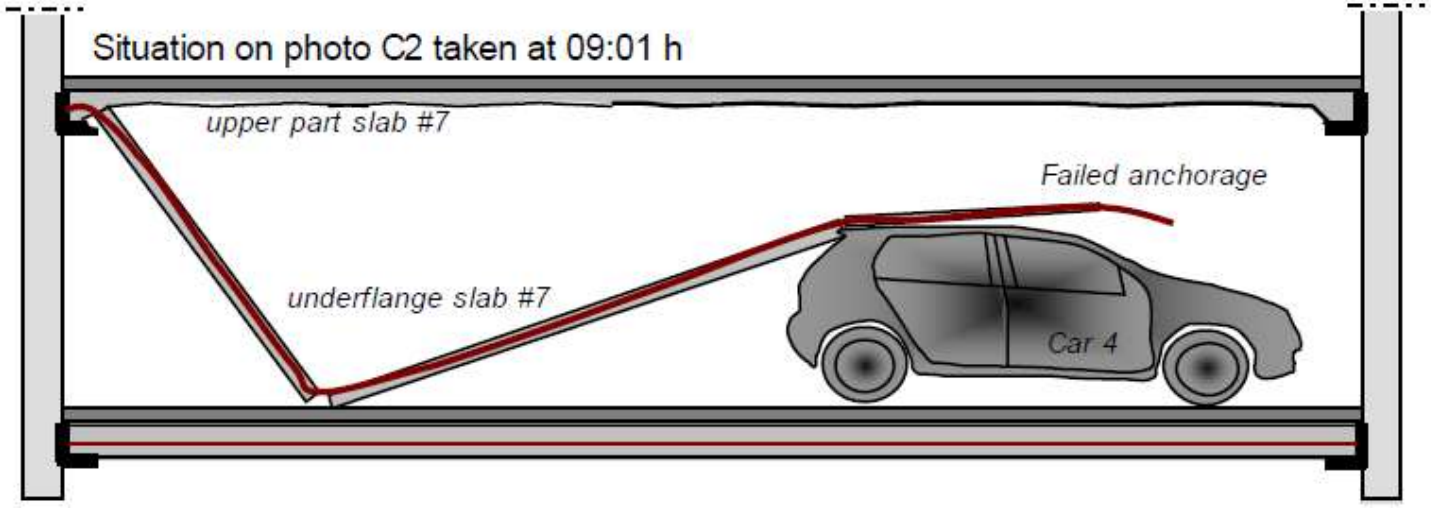


06:46 h

and 09:01 h

Slab #7


Assumed situation on photo C1 taken at 06:46 h
slab #7
Car 4


Situation on photo C2 taken at 09:01 h
upper part slab #7
Failed anchorage
underflange slab #7
Car 4

Falling down of underflanges

- Failure of anchorage led to falling down of underflanges

- allthough the horizontal cracks are there ..
- as long as the strands are well anchored into the support ....
- the underflanges will not fall down ...
- And the slabs will keep their load bearing function

Falling down of underflanges

- Influence of impulse load from fire boat ?
- In action at 04:48
  - Spouted through the building ➔ v = 19 m/s
  - 3 guns together
    - 35 000 litre/minute
    - spraying on the same position
    - Res. force 11 kN

The “Rotterdam” phenomena are also seen in other structures, i.e. cast-in situ floors

Or filligran floors .....

Or even in tunneling

Two examples of fire spalling of concrete: (left) the Mont Blanc tunnel and (right) the Channel Tunnel after the fire. The damage to the concrete is clearly visible.

Conclusion Rotterdam fire

- Scale of the real fire
  - More than 30% higher maximum temperatures at 20 minutes
  - 4 times higher temperature increase rate before 20 minutes
  - Travelling fire concept: temperature peaks vary in time and position
- Product fulfilled the regulation
  - REI were met after the fire
  - But safety for fire fighters was the main issue
- Strong influences on slabs from
  - Explosive spalling (moisture level >>3%)
  - Restraints (to be addressed in next presentation)