Thermal actions for structural analysis of an office building with large open-space

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Description of the project

New complex of the Swiss audiovisual company

- 4 buildings connected to an hall with exhibitions (1st floor) and an office open-space (2nd floor)

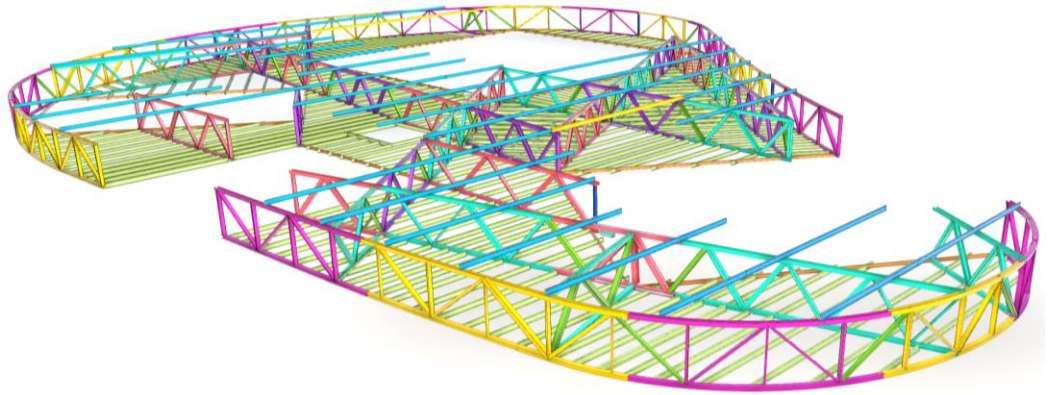
- Radio studios (production, broadcast)
- Exhibitions
- Administration

Fire resistance duration required: R60

- 4 RC buildings, design according to EN 1992-1-2
- Hall and large open-space: steel (composite) structures
  - Ceiling beams
  - Truss members

☒ R60 not achieved

- Passive protection (intumescent coating) ?
  ☒Very expensive
  ☒Application on site very complicated (6m high)



- **<u>Solution:</u> PBD study based on real risks**

PBD study based on risks – Objectives and approach

Reduction / Optimization of the passive protection

PBD approach

- Considering natural fire scenarios based on a risk analysis
  - ➔Hall with exhibitions and open-space with offices and radio studios

- Full sprinklered project
- Large windows on facades

- Risk = moderate → real chance to make savings

Natural fires – Risk analysis

Hall and open-space = covered inner courtyard (Swiss regulation)

- **Maximum** fire load density of 500 MJ/m^2 (Swiss regulation)

Hall : 980 m^2

- Reception / exhibitions / events
  - Localized fire load density

Open-space : 5'440 m^2

- Offices / Meeting rooms / call box
  - Localized fire load density

Natural fires – Scenarios

Hall : 980 m²

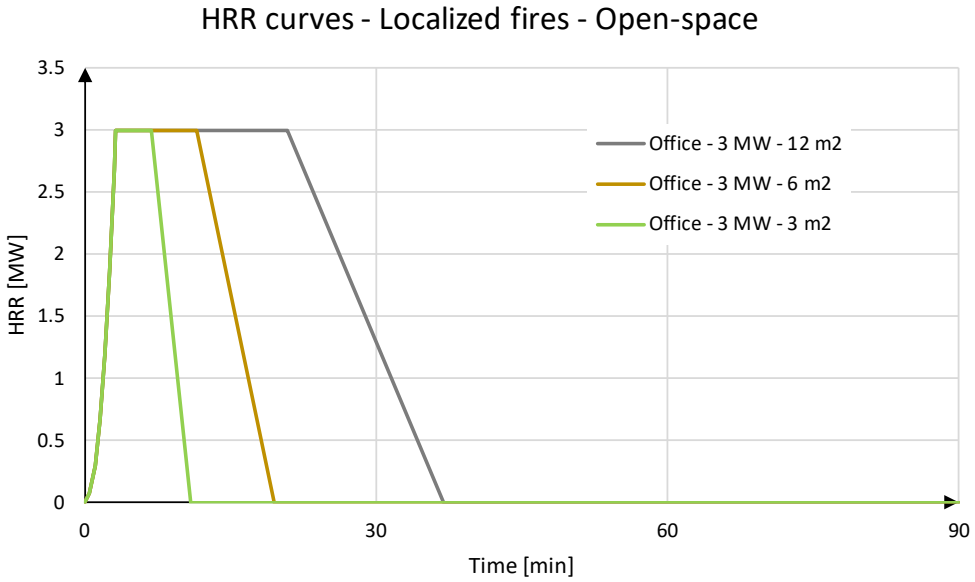
- Localized fire scenarios
  - **6 MW – 31 MJ/kg** (sc. 8, VSICC BT101-01)
  - In exhibitions room fire load density **< 1000 MJ/m²**, up to 3 m high and **> 100 people**
  - Parametric study on fire area: 6 m², 12 m² and 24 m²

- Compartment fire scenario
  - Office standard scenario (EN 1991-1-2, Annex E)
  - **511** MJ/m² – **250** kW/m² – Normal fire growth time **300s**

Natural fires – Scenarios

Open-space : 5440 m²

- Localized fire scenarios
  - **3 MW – 31 MJ/kg** (sc. 5, VSICC BT101-01)
  - Offices with fire load density **> 250 MJ/m²** and **> 100 people**
  - Parametric study on fire area: 3 m², 6 m² and 12 m²



- Compartment fire scenario
  - Office standard scenario (EN 1991-1-2, Annex E)
  - **511** MJ/m² – **250** kW/m² – Normal fire growth time **300s**

Natural fires – Ventilation and active fire fighting measures

Facades with large windows

- Double glazing
- Breakage windows conditions:
  - 20°C: 10% of windows surface open
  - 200°C: 50% of windows surface open
  - 400°C: 90% of windows surface open

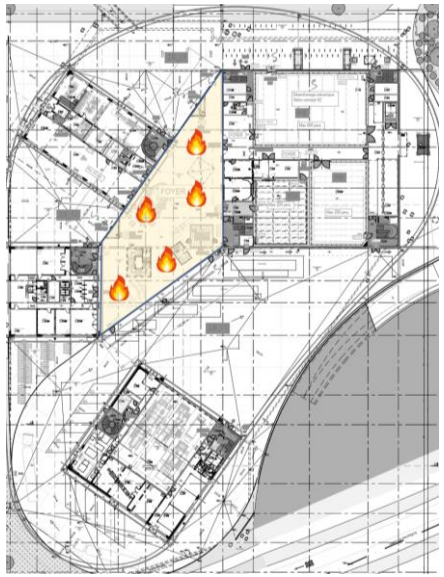
Fire detection + Sprinkler

- Fire load density coefficient adapted (Table E.2, EN 1991-1-2)
  → compartment fire only

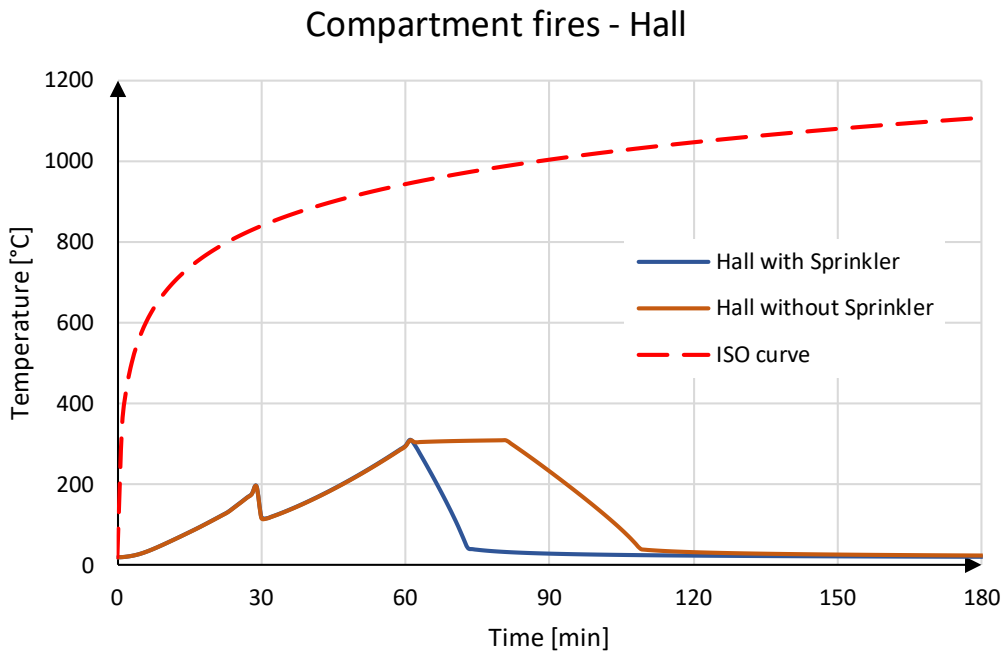
Natural fires – Zones model

Hall : 980 m²

- Temperatures – Time curves



Compartment fire

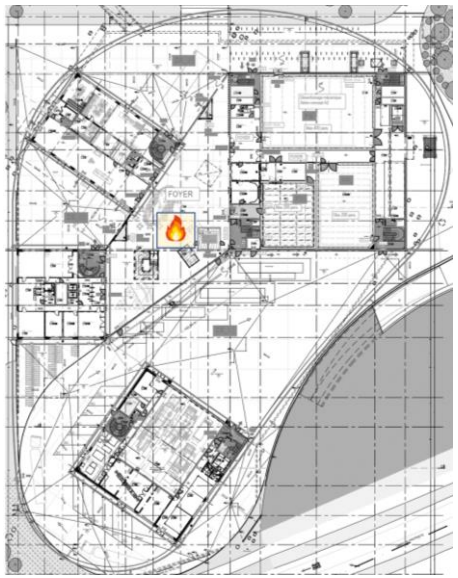


- Gaz temperature < 400°C → steel resistance OK
- Steel structure in hall R60

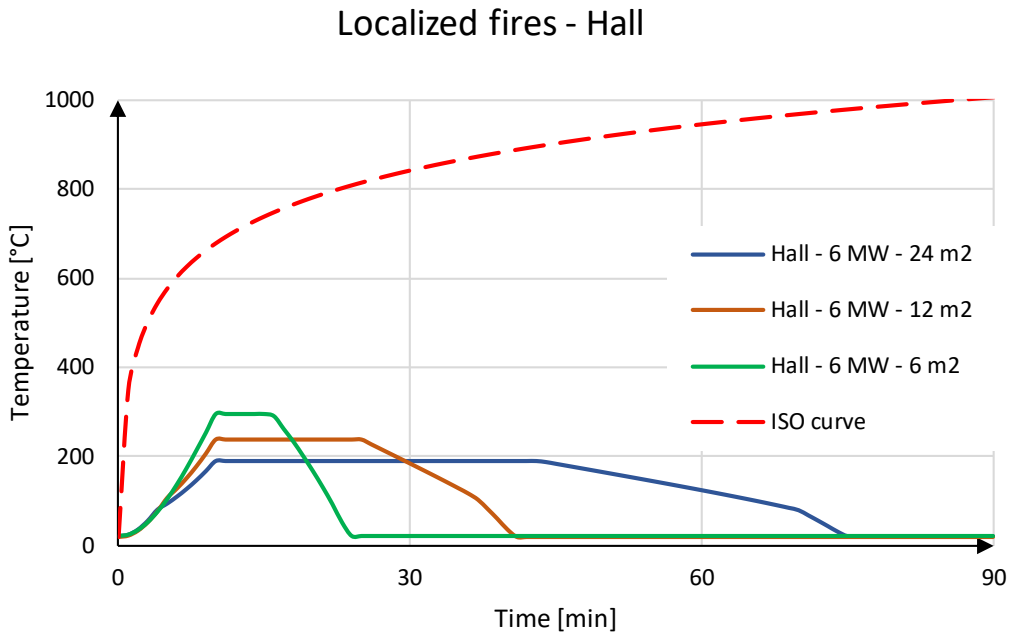
Natural fires – Zones model

Hall : 980 m²

- Temperatures – Time curves



Localized fire



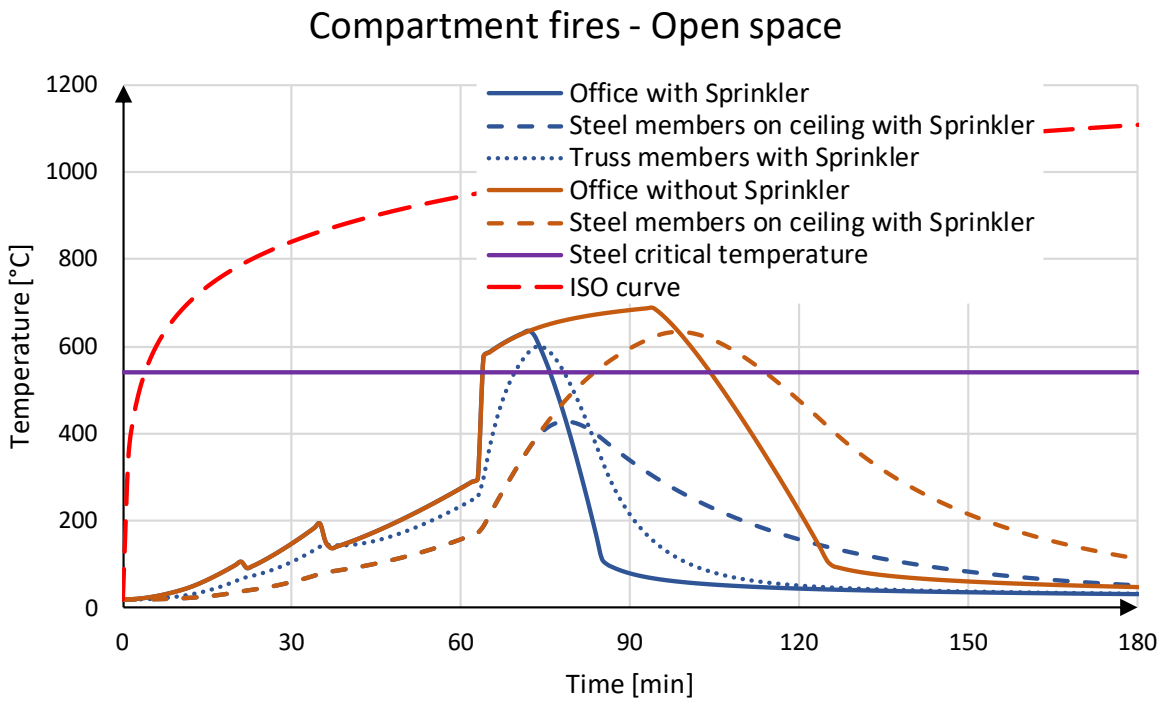
- Gaz temperature < 400°C → steel resistance OK
- Steel structure in hall R60

Natural fires – Zones model

Open-space : 5440 m²

- Temperature – Time curves with Ozone

Compartment fire

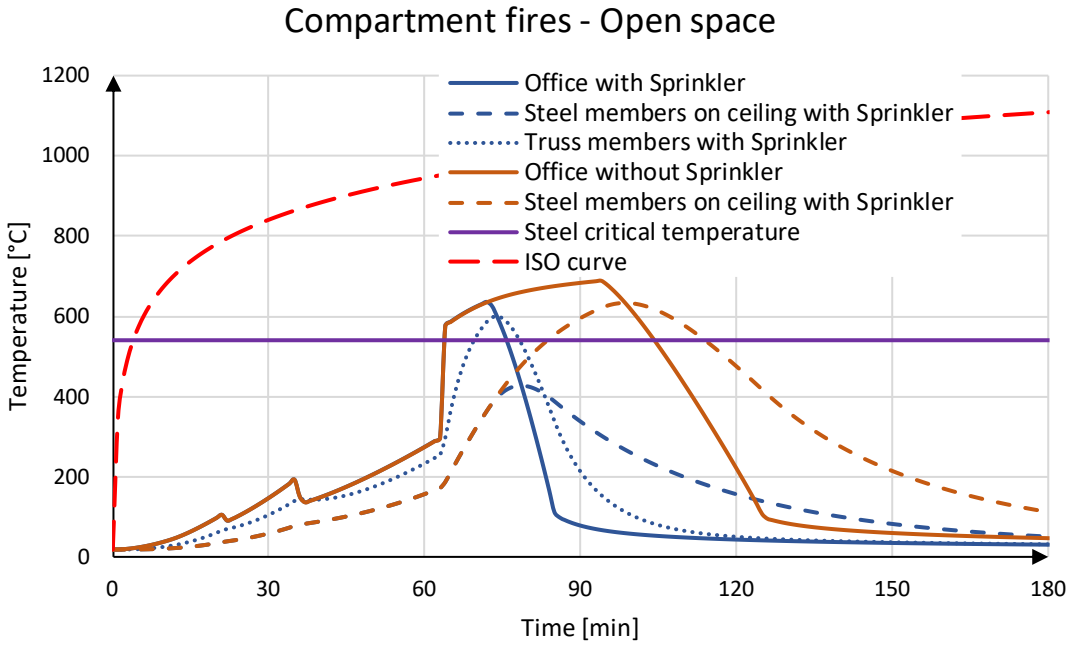


- Gaz temperature **~630°C** → with sprinkler
- Gaz temperature **~690°C** → without sprinkler

Natural fires – Zones model

Open-space : 5440 m²

Compartment fire



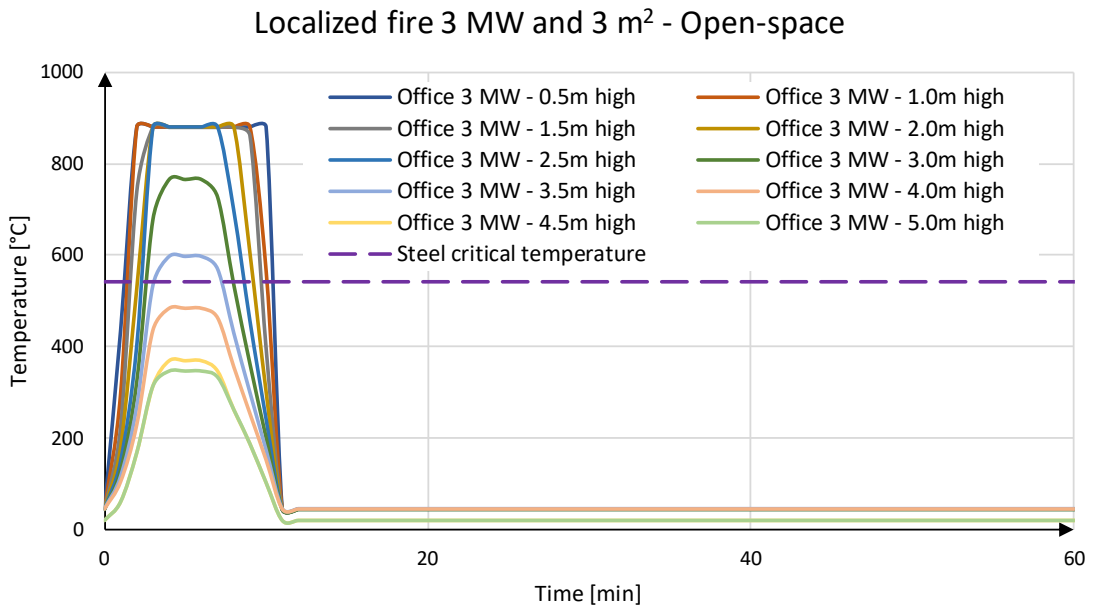
- Without sprinkler: steel members KO
- With sprinkler:
  - Steel members on ceiling OK
  - Truss members KO

Natural fires – Zones model

Open-space 5440 m²

- Temperature – Time curves with Ozone

Localized fire



- Steel members on ceiling → T°C < 400°C → OK
- Truss members → KO

Natural fires – Zones model

Preliminary results

- Natural fires approach with two-zones model
- Compartment fires (with sprinkler) and localized fires (without sprinkler)

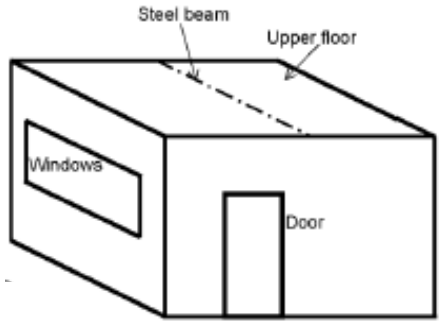
- Steel members in hall → OK **R60**

- Steel members in open-space
  - Beams on ceiling → OK **R60**
  - Truss members → KO **R60**

Natural fires – CFD model

Limitations of zones model

- Simple geometry (rectangular compartment)



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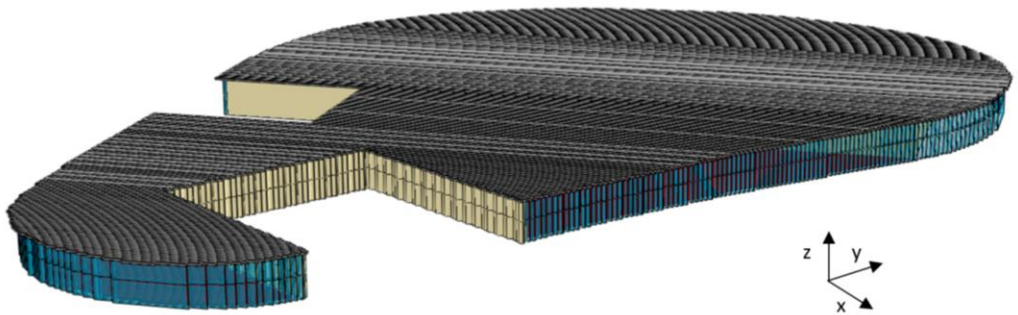


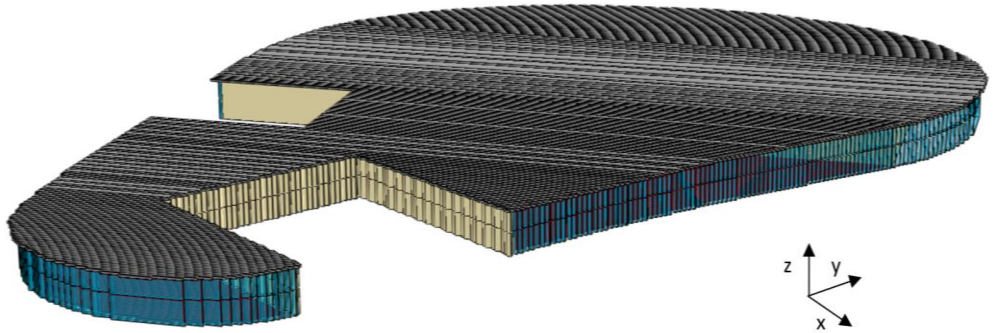
Advanced CFD model

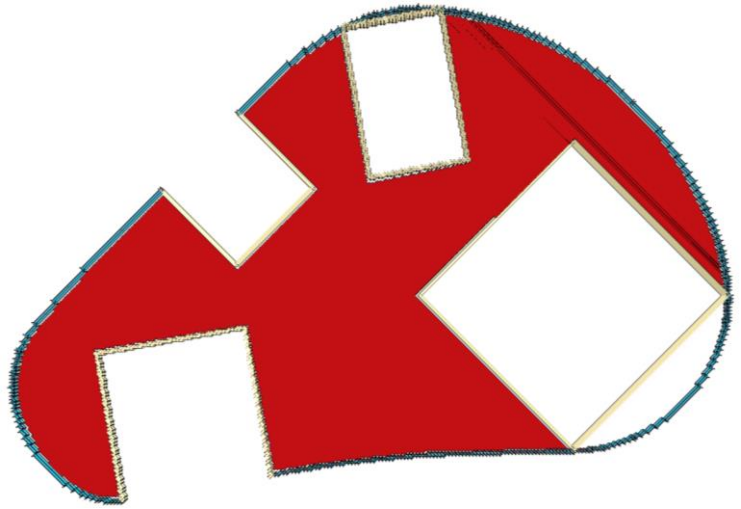
- **Objective:** Validate zones model results

Natural fires – CFD model

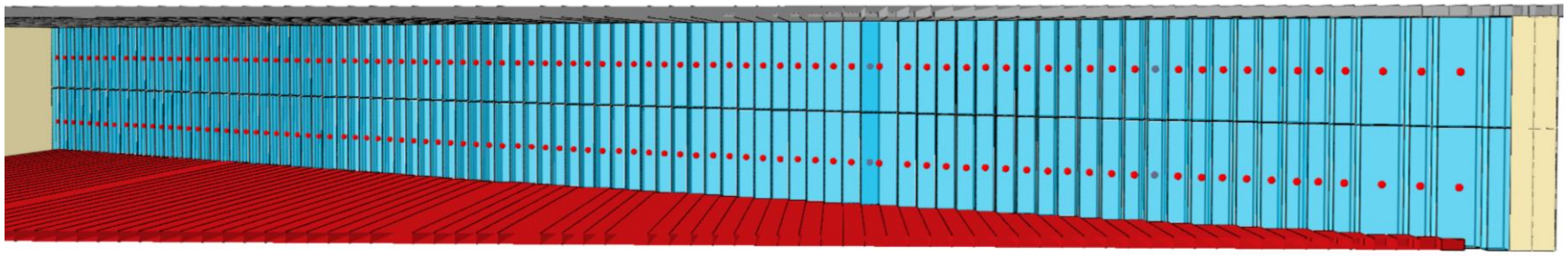
Advanced CFD model

- Complex geometry





- Windows breakage conditions



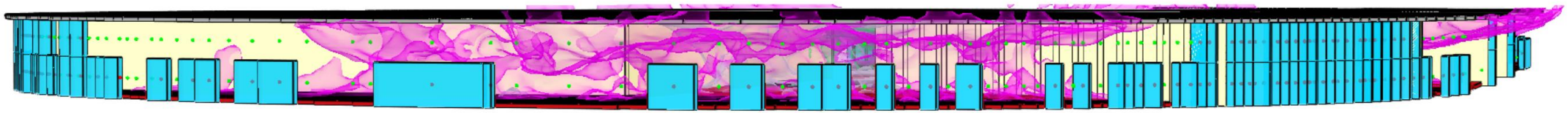
Natural fires – CFD model

Advanced CFD model

- Reaction of combustion: **50% plastic + 50% paper**
  - Representative for office use

- Same fire parameters as zones model
  - HRRPUA – Heat of combustion – Fire load density

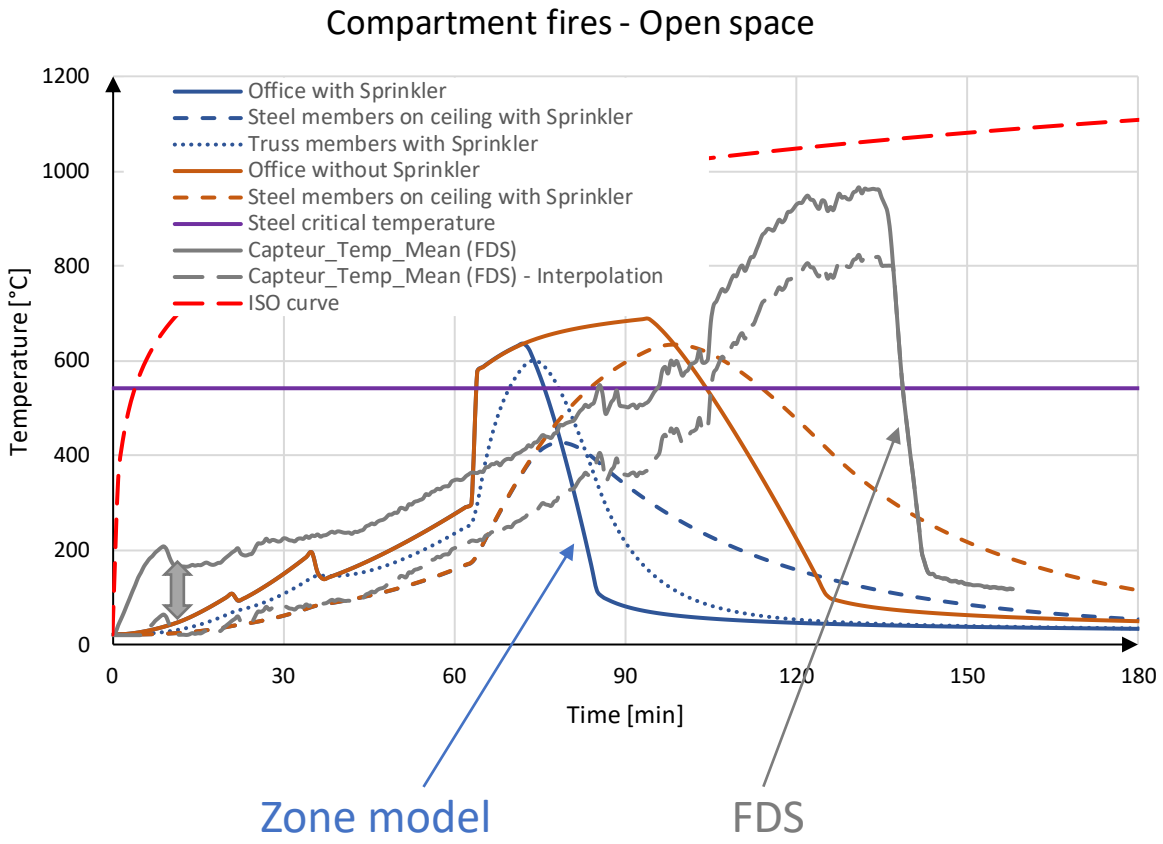
- Uniform mesh size: **25 cm**



Natural fires – CFD model

Advanced CFD model

- Results
  - FDS curve = same trend as zone model
  - Higher temperatures at simulation start
  - All fuel area in fire at the beginning
  - Interpolation of the curve to fit with zones mode curve
  - Gaz temperatures **~800°C**



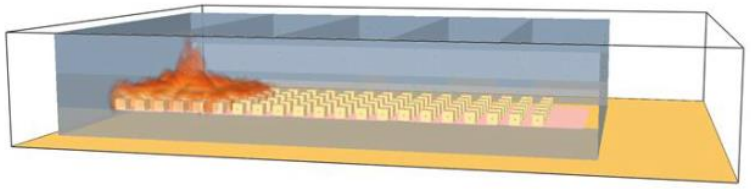
Natural fires – CFD model

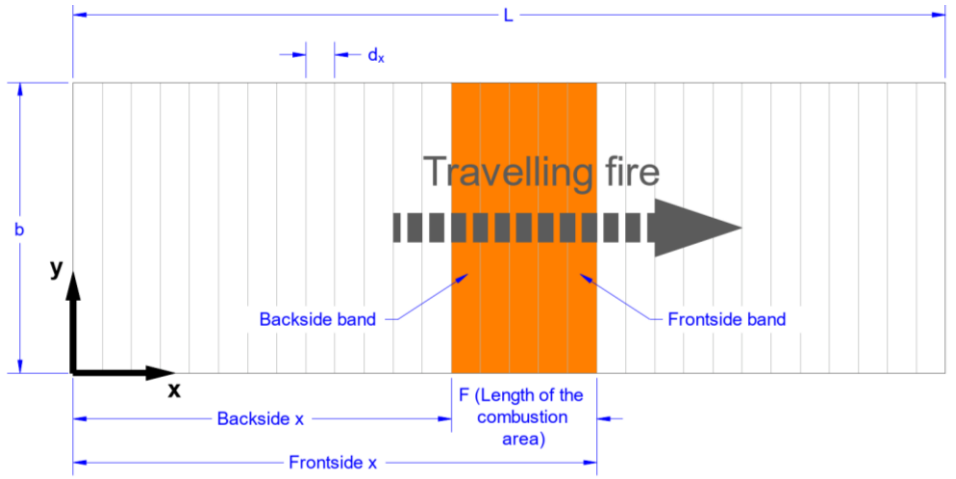
Discussion

- Compartment fire with zones model not totaly validated
  - Good trend but higher temperatures + longer fire duration

- Fully developped compartment fire not likely to append
  - Fuel = several localized combustible area ≠ uniformly distributed fire load density
  - Sprinkler installation: > 90% reliability
  - Large windows on facades

- Travelling fire instead of compartment fire ?





Natural fires – Travelling fire scenario

Travelling fire

- Localized fire which is moving along the compartment
- Recent research and real tests on this topic

Figure 2: (a) Fire load used for the three natural fire tests; (b) Fire test n°1 (travelling fire); (c) Fire test n°2 (travelling fire); (d) Fire test n°3 (travelling fire & flashover)

applied sciences

MDPI

Article

Development of an Analytical Model to Determine the Heat Fluxes to a Structural Element Due to a Travelling Fire

Marion Charlier [1,*], Jean-Marc Franssen [2], Fabien Dumont [2], Ali Nadjai [3] and Olivier Vassart [4]

The current issue and full text archive of this journal is available on Emerald Insight at: https://www.emerald.com/insight/2040-2317.htm

Travelling fire experiments in steel-framed structure: numerical investigations with CFD and FEM

Travelling fire experiments

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Ali Nadjai
FireSERT, Ulster University, Newtownabbey, UK

Natural fires – Travelling fire scenario

Travelling fire

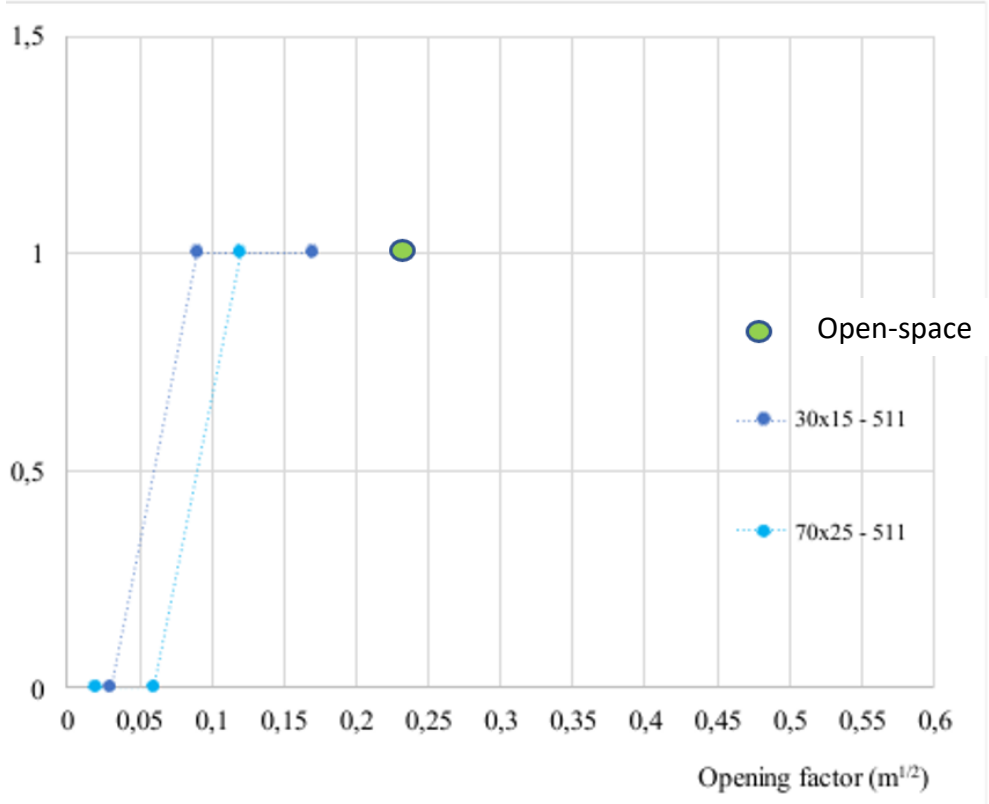
- Localized fire which is moving along the compartment

- Main parameter: **opening factor**

$$O = \frac{\left(A_v \sqrt{h_{eq}}\right)}{A_t}$$

  - **O < 0.1:** Flashover more reliable than travelling fire
  - **O > 0.1:** Travelling fire more reliable than flashover

- **Open-space opening factor: 0.23**



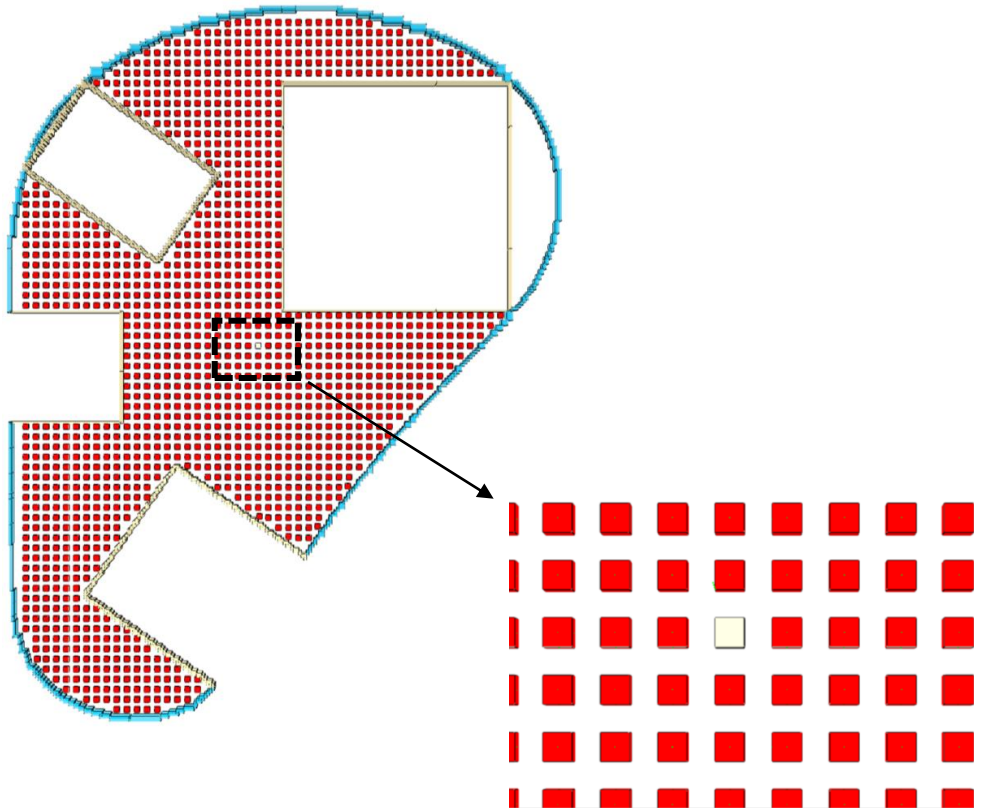
Travelling fire scenario

Localised fire load density ditributed in the open-space

- Combustible bloc of 1 m^3 every 1m → 1’430 blocs
  - Higher spread risk

- Fire spread with surface temperature
  - 250°C (hypothesis for cellulosic materials)
  - Combustion starts if <u>at least</u> one vent reachs 250°C

- Initial fire in the middle of the open-space
  - Ignition far from windows (conservative)



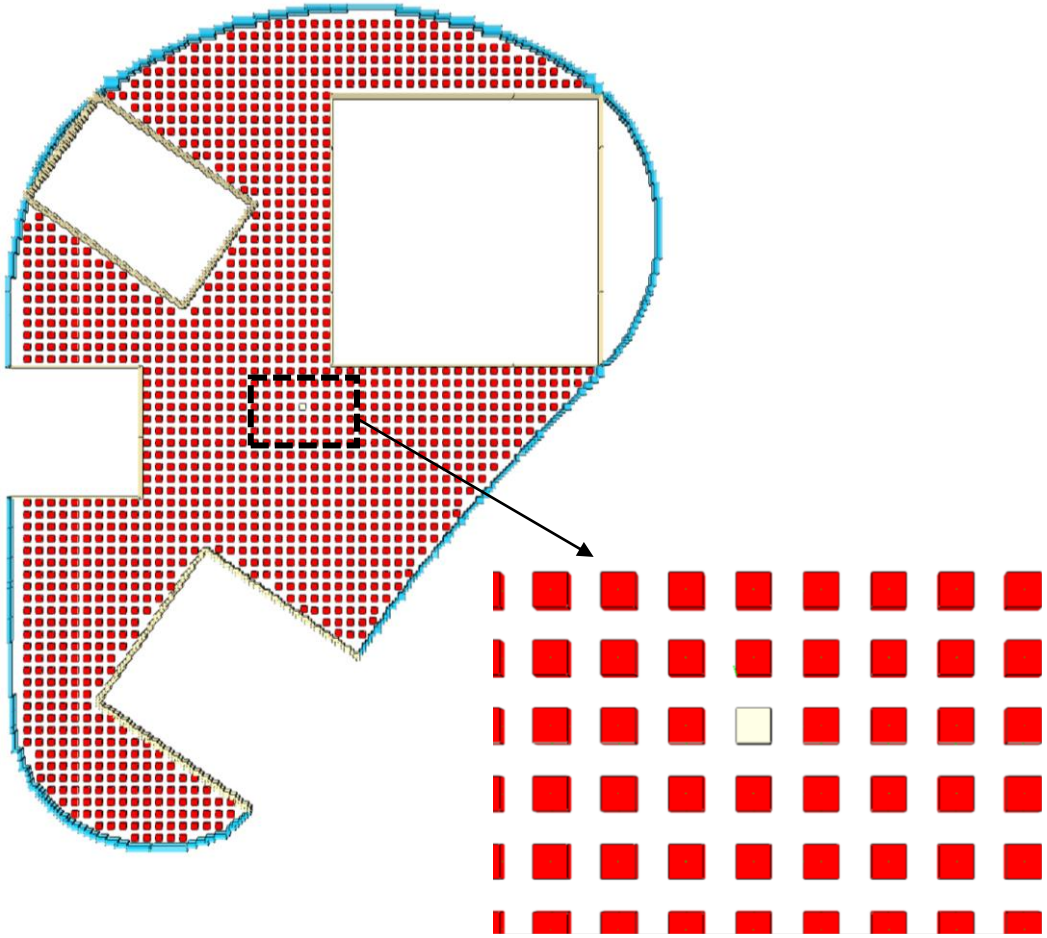
Travelling fire scenario

Compartment fire = 1 fire source

- Fire area: 5’440 m^2
- 250 kW/m^2 → 1360 MW
- 335 MJ/m^2

Travelling fire = 1430 fire sources

- Fire area: 1430 x 1m^2
- 1360 MW / 1430 = <u>951 kW/m^2</u>
- (5440 x 335) / 1430 = <u>1268 MJ/bloc</u>



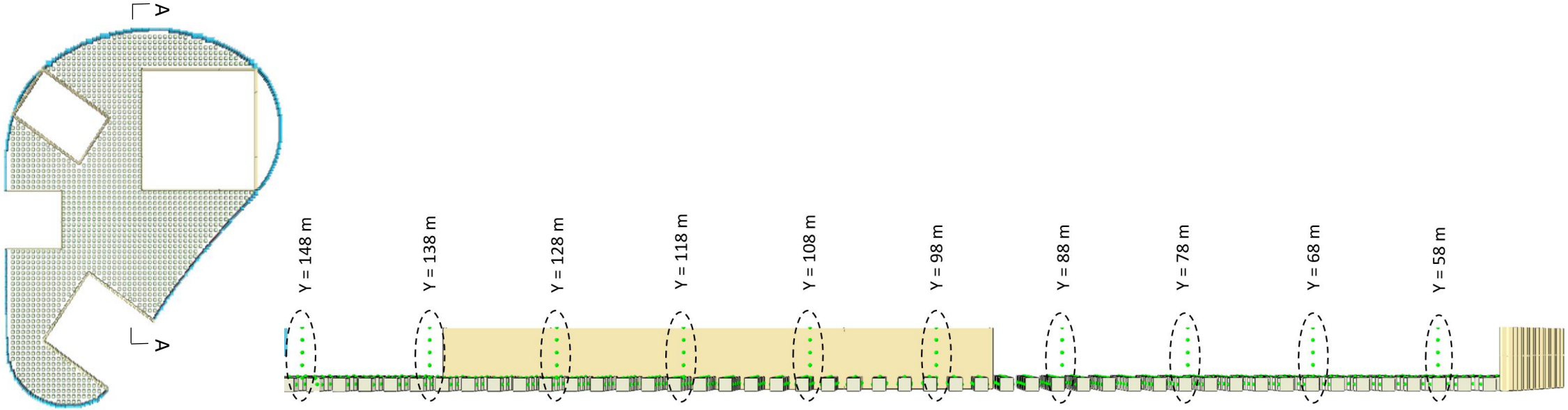
Natural fires – Travelling fire scenario

Results: Fire spread in the open space

Natural fires – Travelling fire scenario

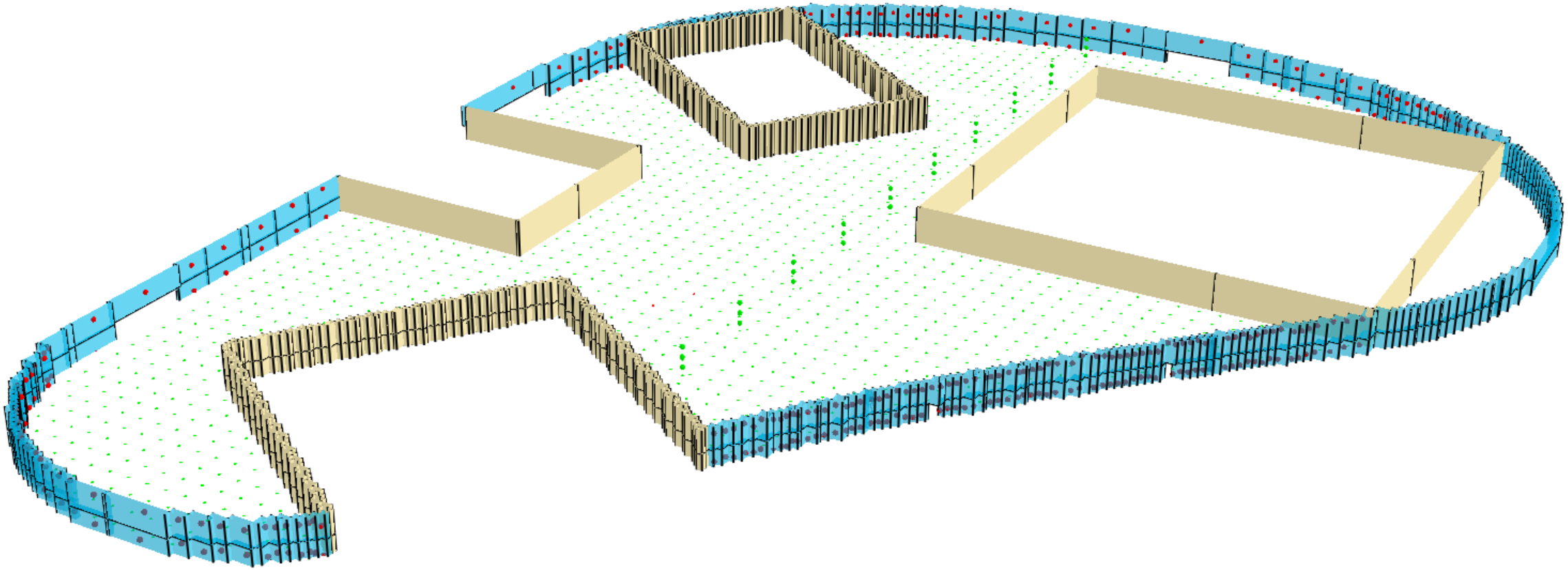
Results: Gas temperature «poles» along the open-space

- Poles with devices located in the middle of the open-space and distributed every 10m
- 5 devices per pole at 1, 2, 3, 4 and 5m high



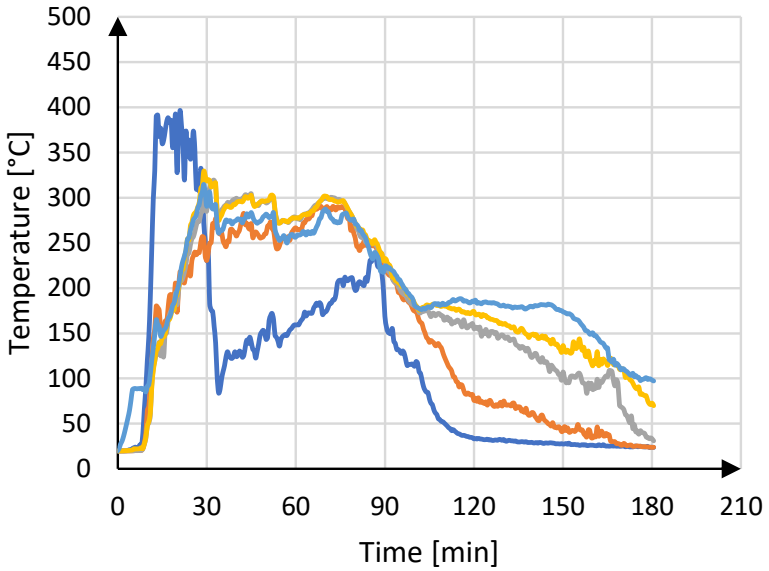
Natural fires – Travelling fire scenario

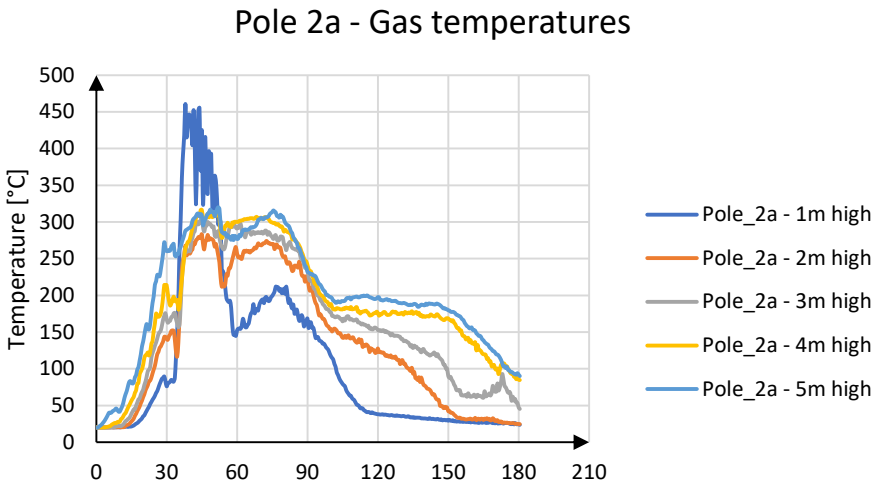
Results: Gas temperature poles along the open-space

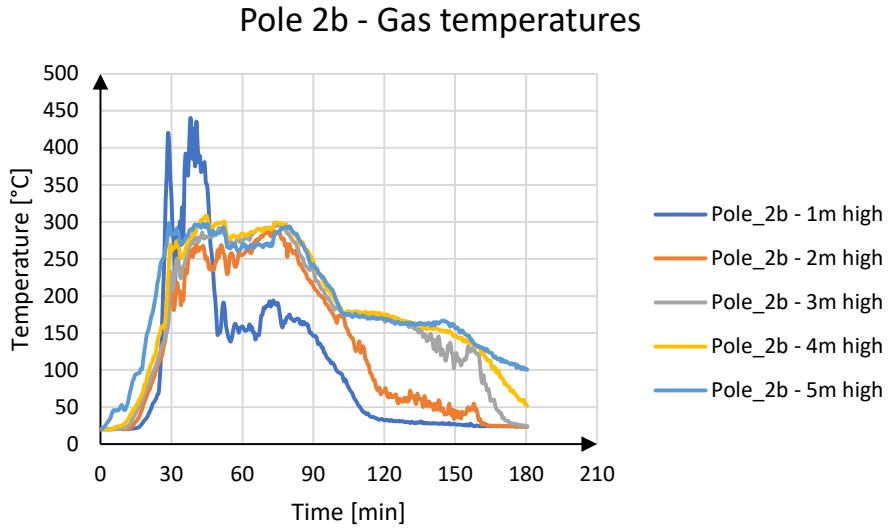


Natural fires – Travelling fire scenario

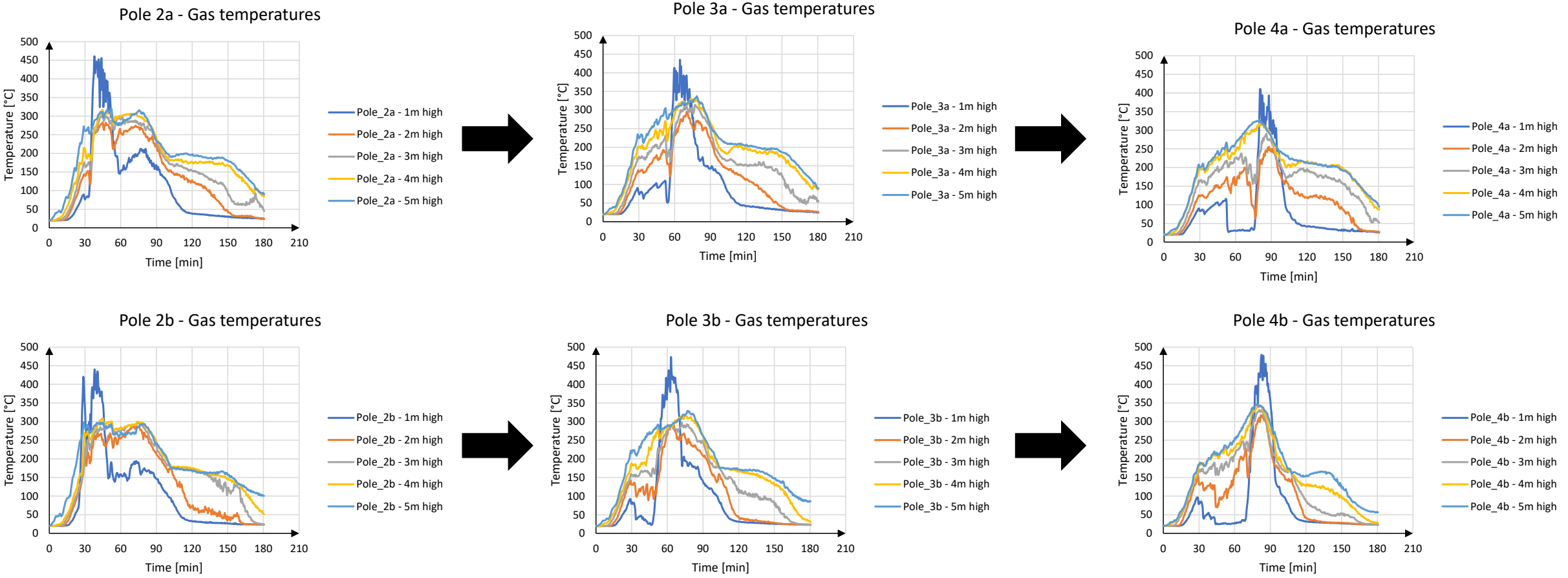
Results: Gas temperature poles





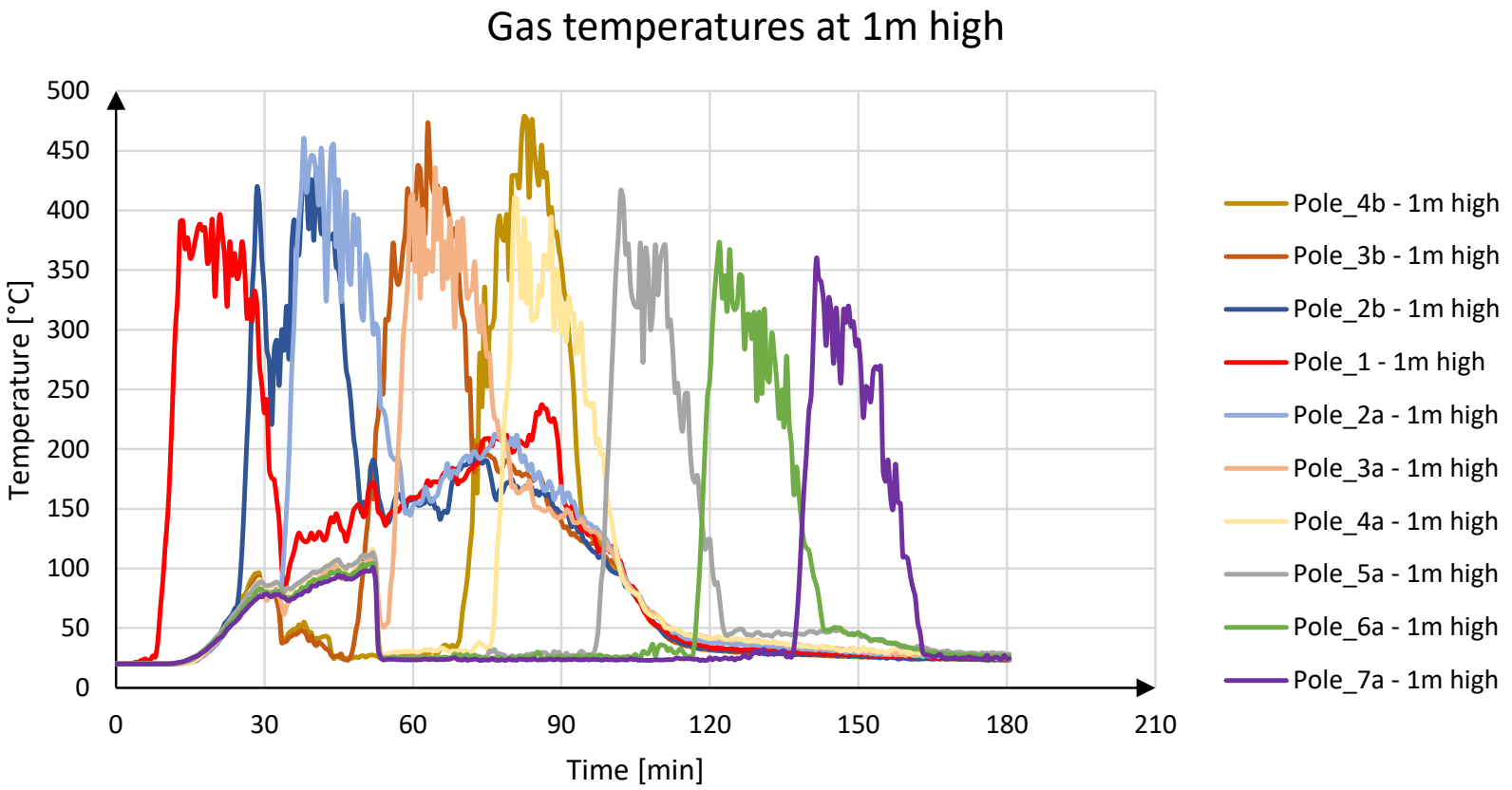


Natural fires – Travelling fire scenario



Natural fires – Travelling fire scenario

Results: Gas temperature poles

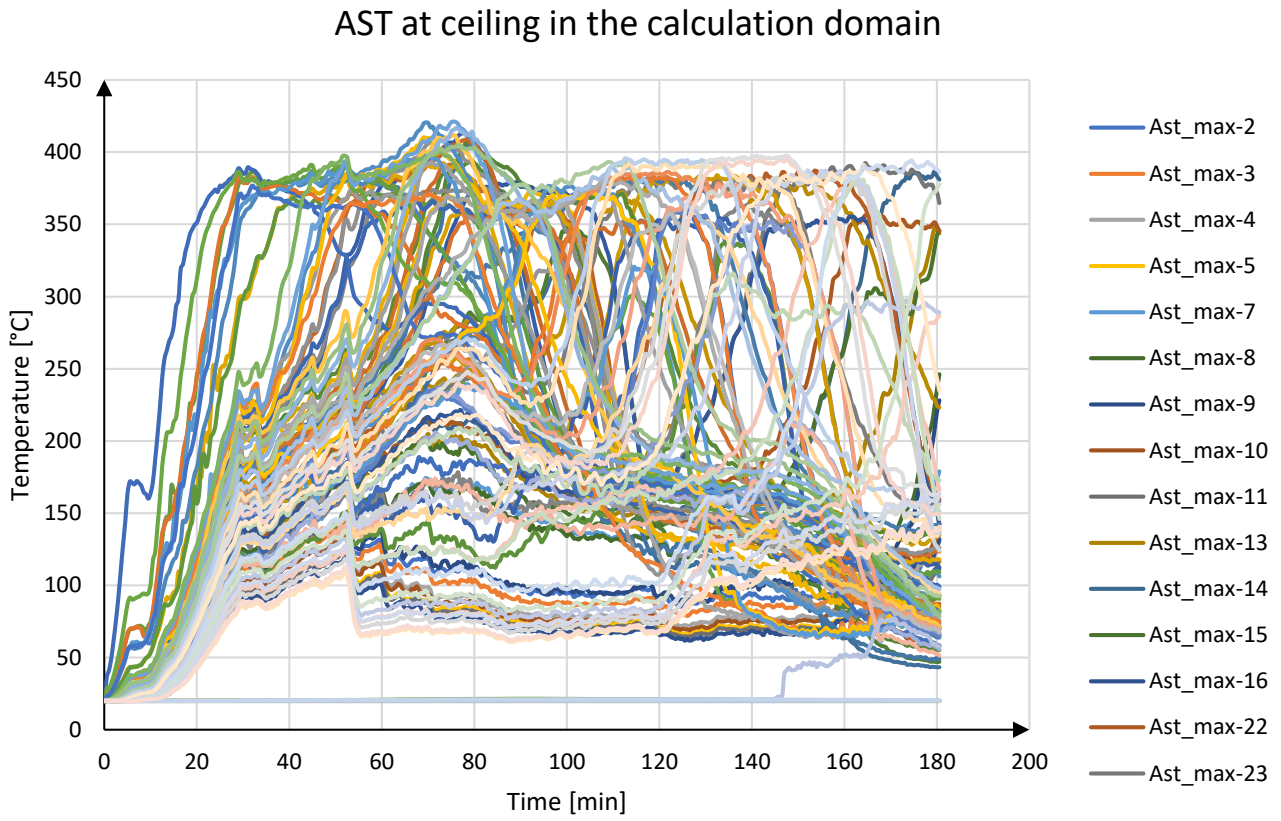


Natural fires – Travelling fire scenario

Results: Adiabatic surface temperatures at ceiling

- Moderate AST
  - ~400°C
  - Steel temp. < steel critical temp

- **Steel structure at ceiling OK**



Conclusion

Different steps in natural fire approach

- Step 1: Compartment and localized fire scenarios with zones model
- Step 2: Compartment fire scenario with CFD model (validation)
- Step 3: Travelling fire scenario with CFD model

✓ Steel structure in hall: OK **R60** (all scenarios)
✓ Steel structure at ceiling in open-space: OK **R60** (all scenarios)
✓ Truss structure in open-space: KO **R60** (localized fires)

✓ **Massive reduction of passive protection = savings !**

Thanks for you attention

Questions are welcome ☺

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