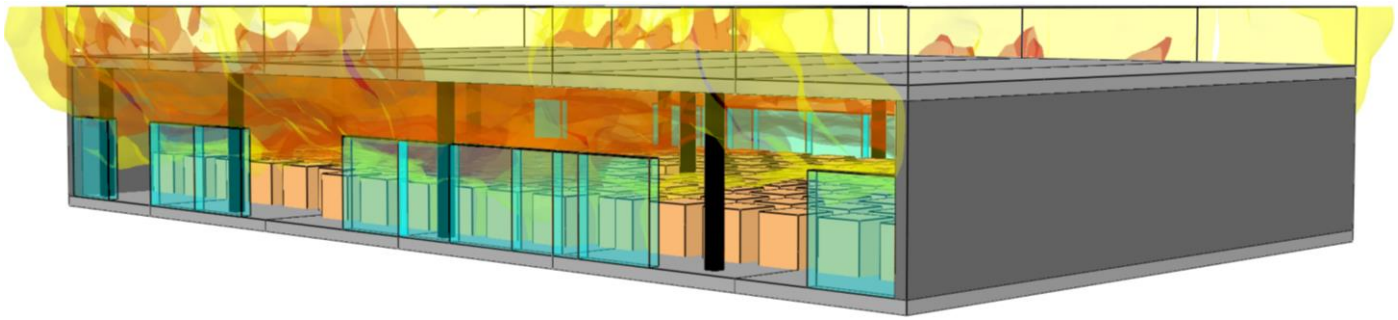

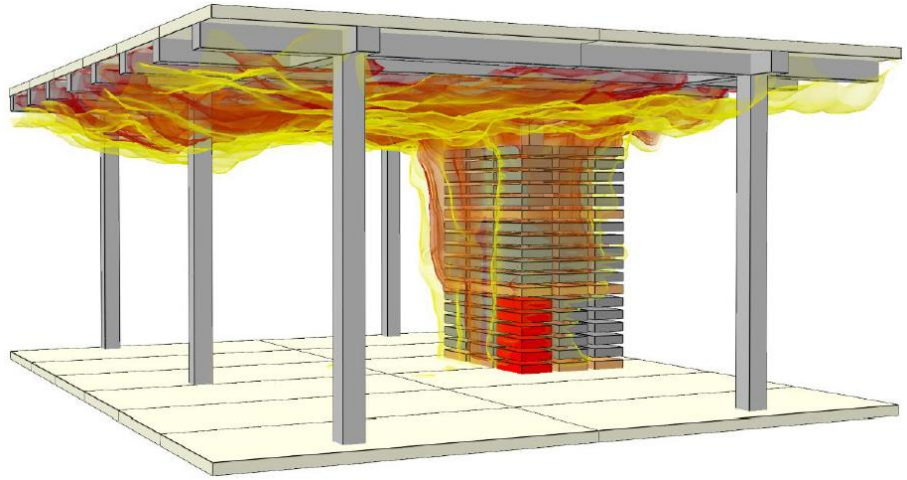

Thermal actions for structural analysis of existing buildings: case study and developments

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&

Julien **DUBOC** – Risk Assessment and Fire Safety Engineer – ISI Sàrl – Lausanne - Switzerland

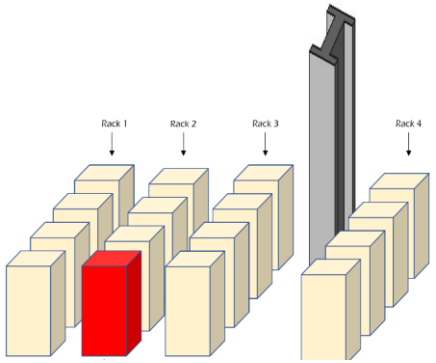
Context of the Study

- ✓ **Two existing buildings with full Sprinkler coverage**
  1. Large open-spaces office building
  2. **Industrial storage warehouse**

- ✓ **Fire safety update : compliance with 2020 standards**
  - Fulfill structural requirements (**R30 ?**)
  - Possible expensive work for the structure to comply fire rating (passive protection)

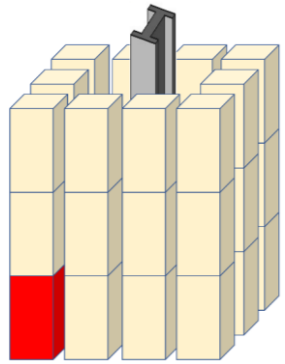
- ✓ **Solution : Performance based approach and design**
  - Advanced CFD analysis with/without sprinkler
  - Advanced FEM structural analysis

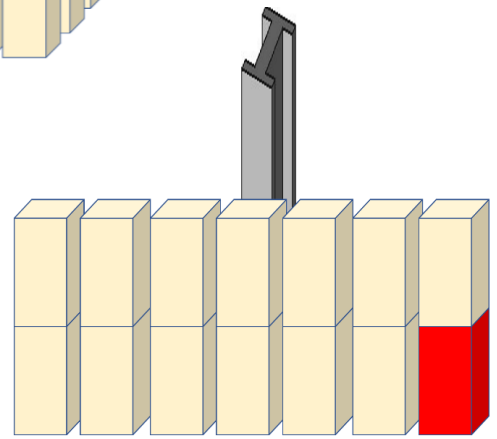
Objectives and Methodology



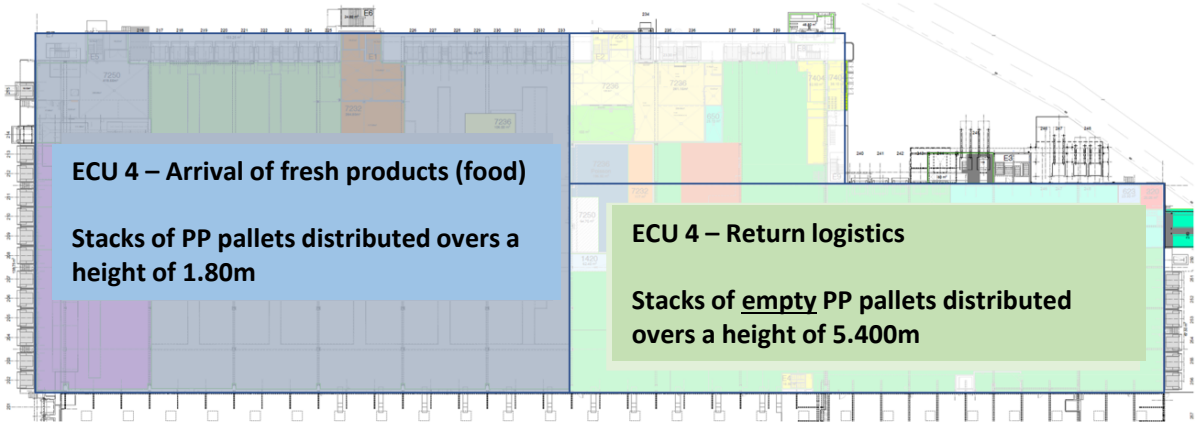
- ✓ **Objectives:**
  - Meet the requirements of current fire safety standards
  - Costs reduction/optimization
  - Appropriate and reasonable measures

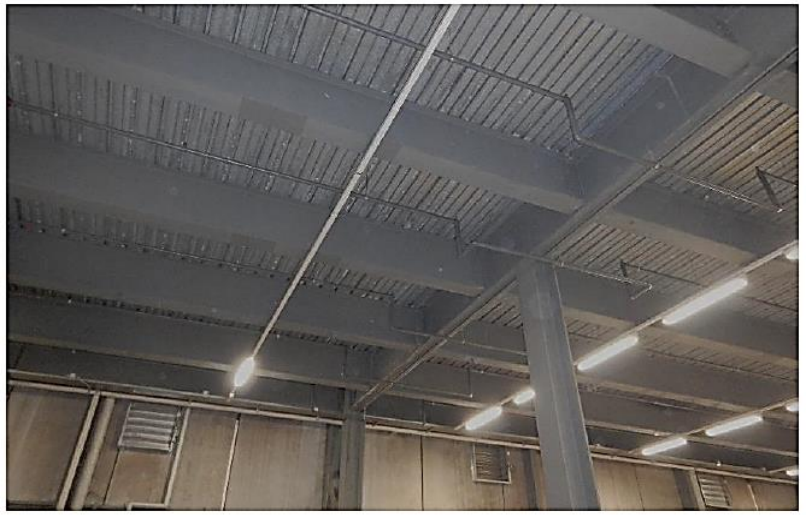
- ✓ **FSE/PBD study in several steps**
  1. ISO fire analysis (check the models, critical temperatures)
  2. Analysis with simplified methods and natural fire approach (compartment fires and localized fires)
  3. Advanced analysis with CFD/FEM models, **with 3 stacks configurations**





Industrial storage warehouse (13'000 m²)





- ✓ **Composite slab**
  - Continuous primary steel beams
  - Secondary composite steel beams
- ✓ **Steel columns**
- ✓ **Sprinkler system**
- ✓ **Structural resistance, fire situation**: **30 min ?**

Fire Safety Engineering study

1. Pre-study with ISO fire

Column Section	Load [KN]	Load in fire situation [KN]	Structural resistance (min)	Critical temperature (°C)	Acceptable results ?
HHD 400x287	4'079	2'419	30	650	LIMIT
HHD 400x237	4'079	2'419	25	620	NO
HEA 400	1'402	832	19	620	NO
HEB 450	1'402	832	24	660	NO
HHD 400x463	5'353	3'175	40	670	YES
HEM 300	4'079	2'419	26	572	NO

Beam Section	Distributed load [KN/m]	Distributed load in fire situation [KN]	Structural resistance (min)	Critical temperature (°C)	Acceptable results ?
HEA 900 1st span	427	254	22	620	NO
HEA 900 other spans	427	254	48	879	YES
Composite beam	60.3	36.4	25	566	NO

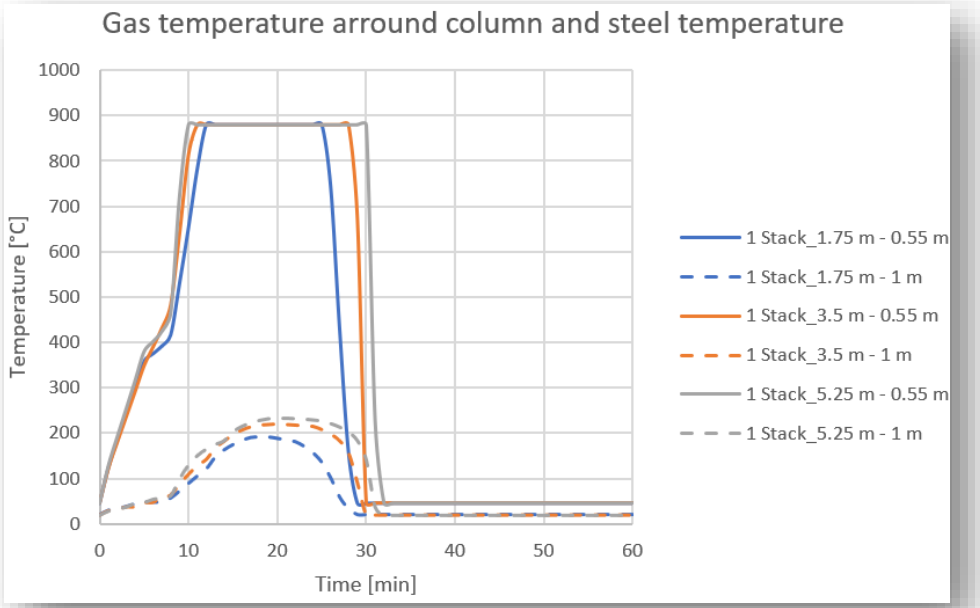
☹ **30 min ISO fire resistance is not achieved**

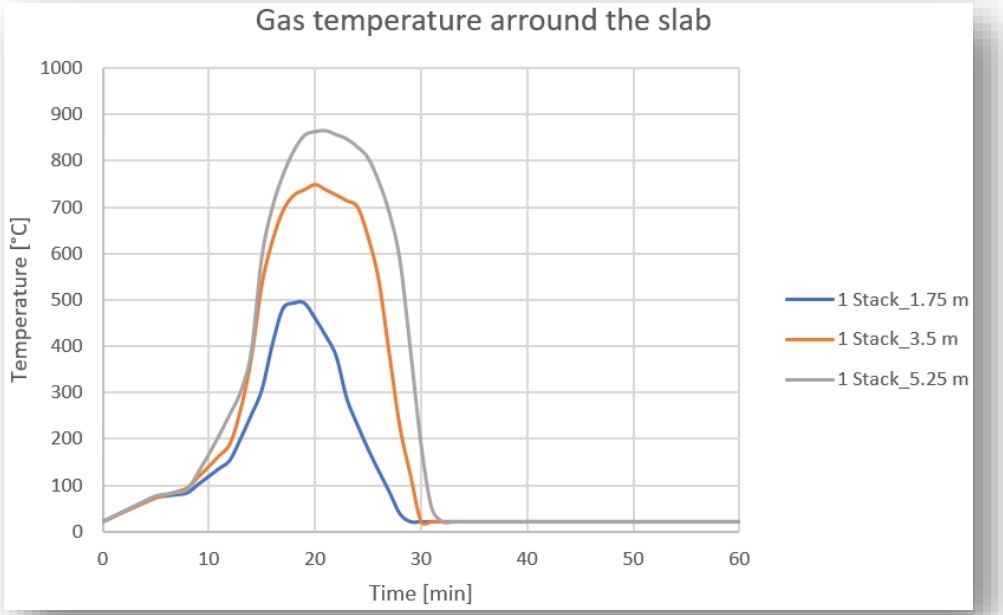
✓ **Critical temperatures are not too low :**
there is a chance with advanced analysis with natural fires

Fire Safety Engineering study

2. Simplified natural fire approach

- Localized fires (as in EN-1991-1-2, Annex C)



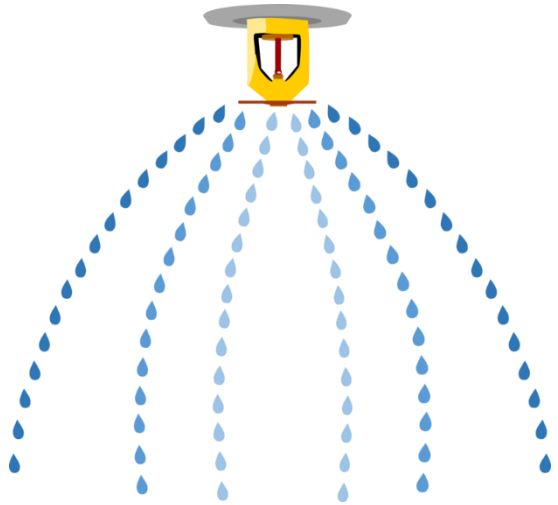


✓High temperatures near to the ceiling

✓Strong columns heating if fire in close contact

Fire Safety Engineering study

- ✓ **Preliminary results**
  - Structural resistance (30 minutes) in fire situation can't be achieved with
    - ☹ ISO fire
    - ☹ Simplified natural fire approach
  - **Limitation of the simplified approach ?**
    - No sprinkler considered in simplified models
  - **Study to be considered with advanced models**
    - Aspersion model included
    - First stack with fixed HRR (no sprinkler action): conservative



Fire Safety Engineering study

✓ Sprinkler considered into CFD models

Scientific publications considered :

- T. Yamada, E. Yanai, H. Naba, M. Sagara, M. Haga, H. Fukumoto et T. Kobayashi, ***Flammability test for fire retardant plastic pallet***, 5th AOSFST, Mewcastle, Australia, 2001.
- J. Vaari, S. Hostikka, T. Sikanen et A. Paajanen, ***Numerical simulations on the performance of waterbased fire suppressions systems***, VTT, 2012
- Babrauskas, V. : Heat release rates. In : National Fire Protection Association (NFPA): **The SFPE handbook of fire protection engineering**. 4e edition, Quincy : edition interne 2008, pp. 3/1-3/59.

Fire Safety Engineering study

- **Sprinkler considered into CFD models**

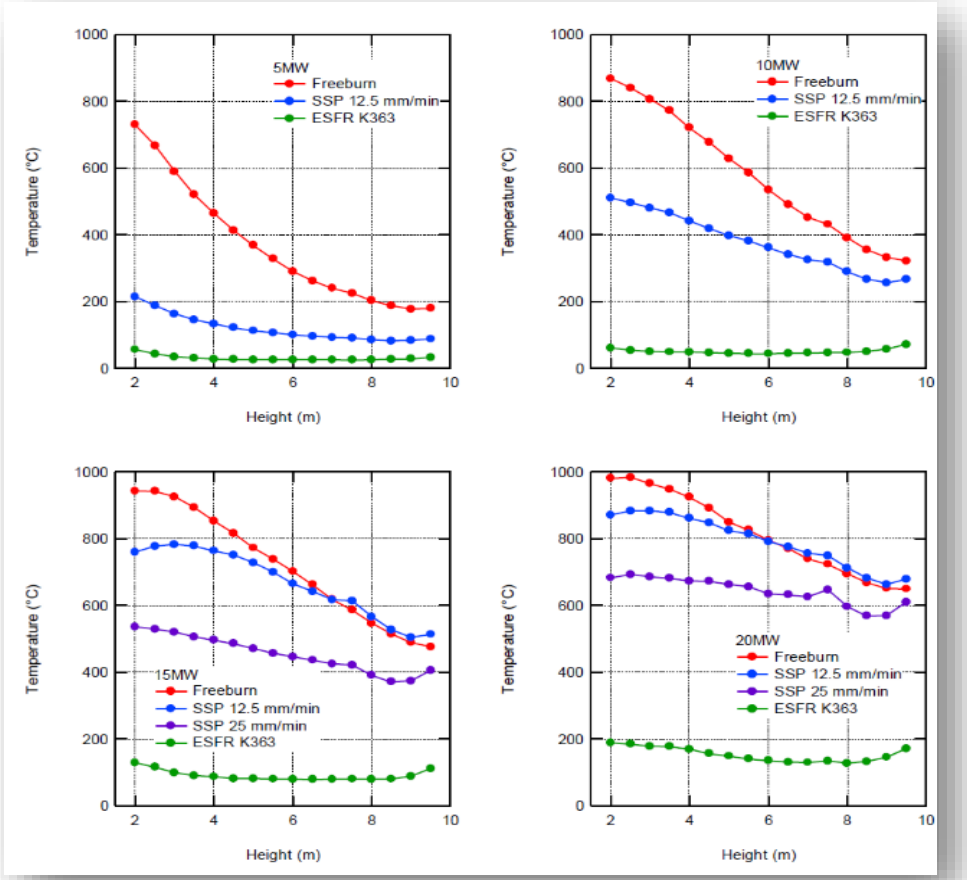
✓ Results available in the literature, about the influence of the sprinkler on the fire and the resulting thermal stress

✓ Tests were carried out on 5, 10, 15 and 20 MW fires with different classes of sprinkler installations.

✓ The influence of the sprinkler on the gas temperature was measured.

✓ **Several CFD were carried out to tune our FDS models :**

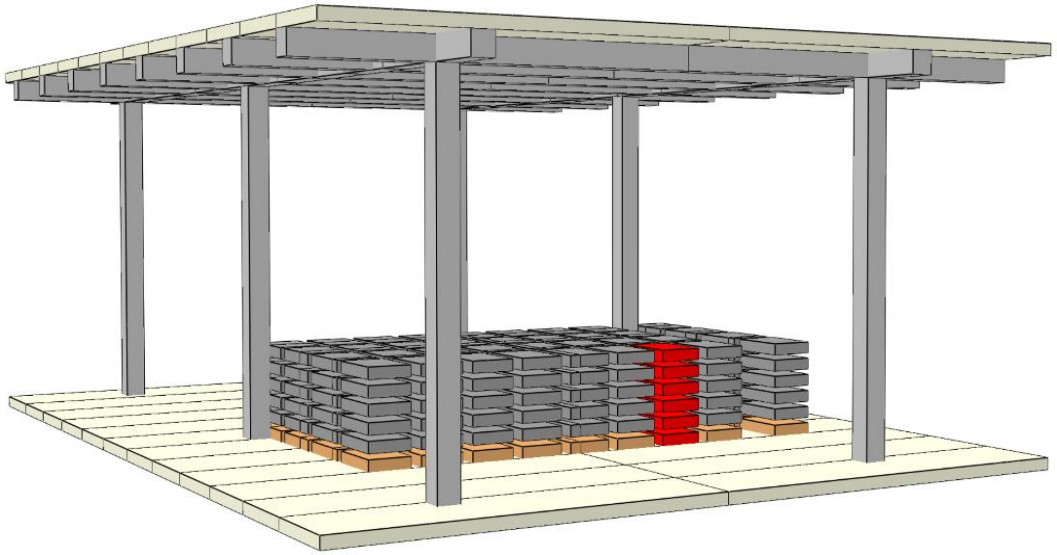
- ✓ **pallets Heat Release Rate (HRR),**
- ✓ **Sprinkler aspersion cone and velocity,**
- ✓ **Fire propagation to other pallets**



J. Vaari, S. Hostikka, T. Sikanen et A. Paajanen, ***Numerical simulations on the performance of waterbased fire suppressions systems****, VTT, 2012*

Fire Safety Engineering study

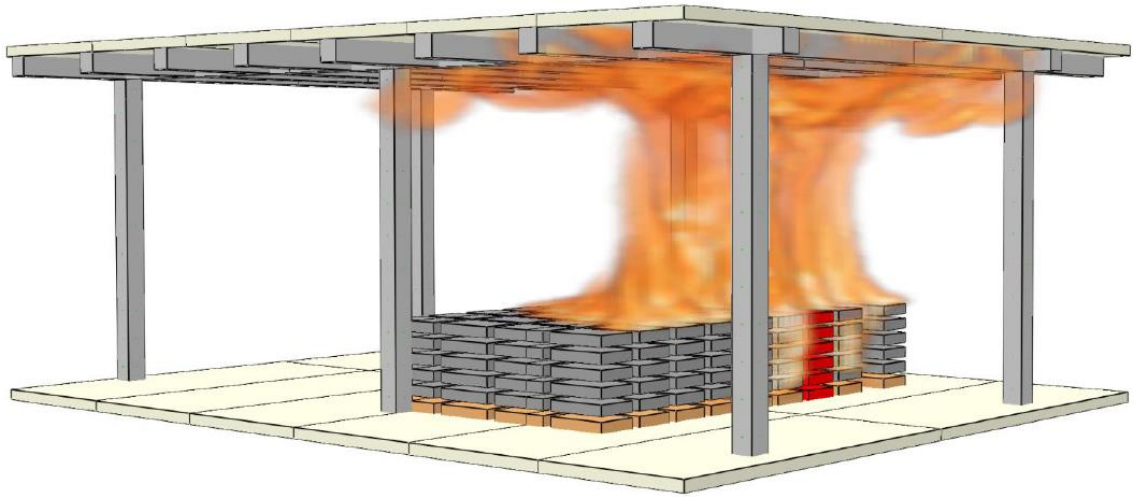
✓Scenario with PP pallets stacks with fresh foods



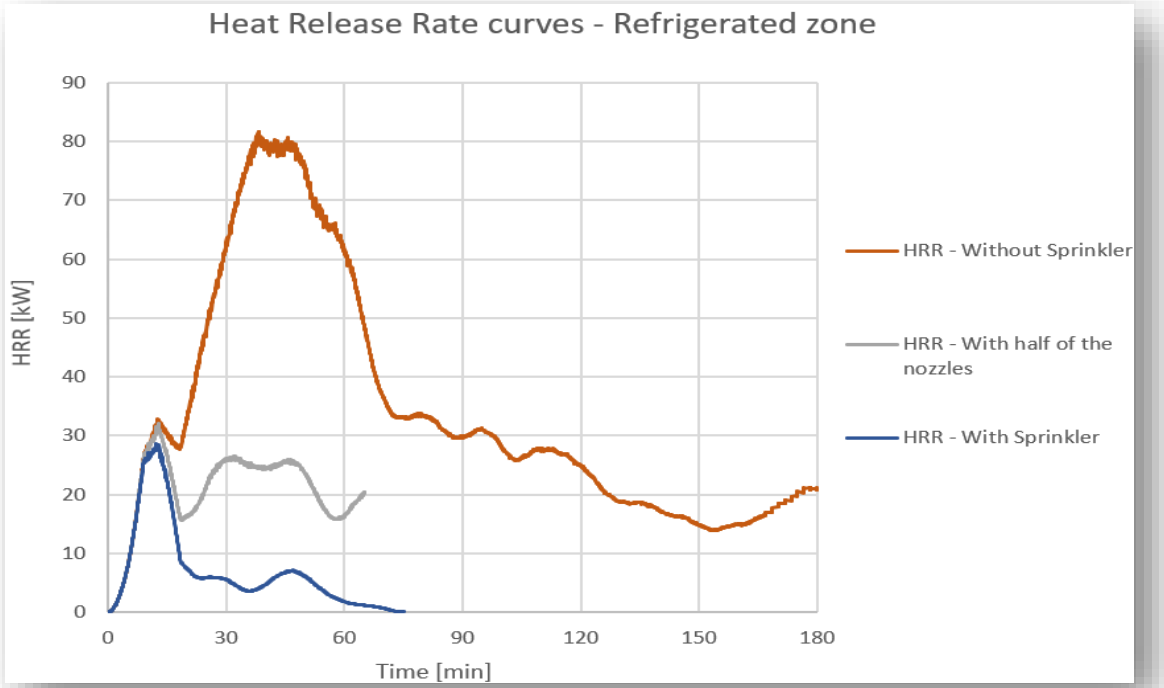
FDS model with the starting fire stack

Fire Safety Engineering study

✓Scenario with PP pallets stacks with fresh foods



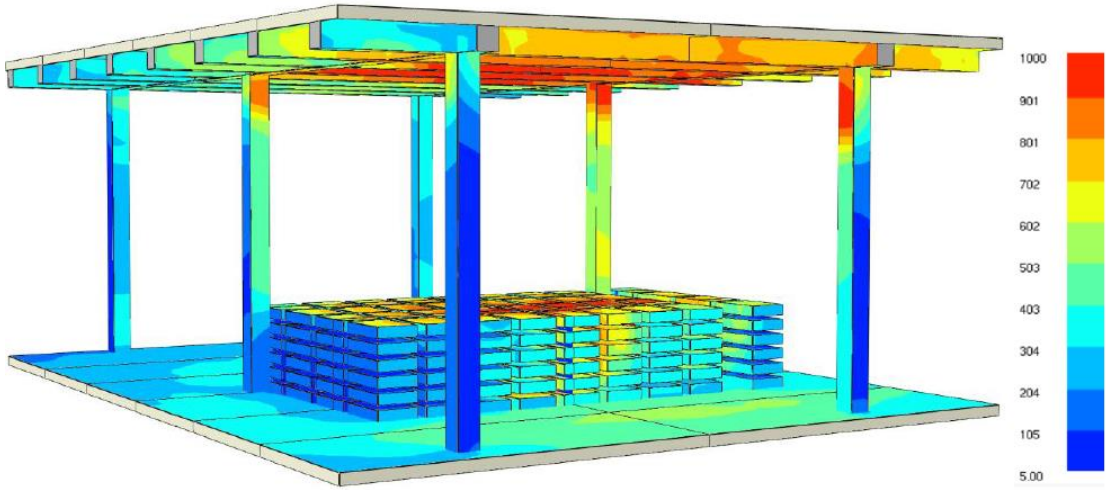
FDS simulation with fire spread



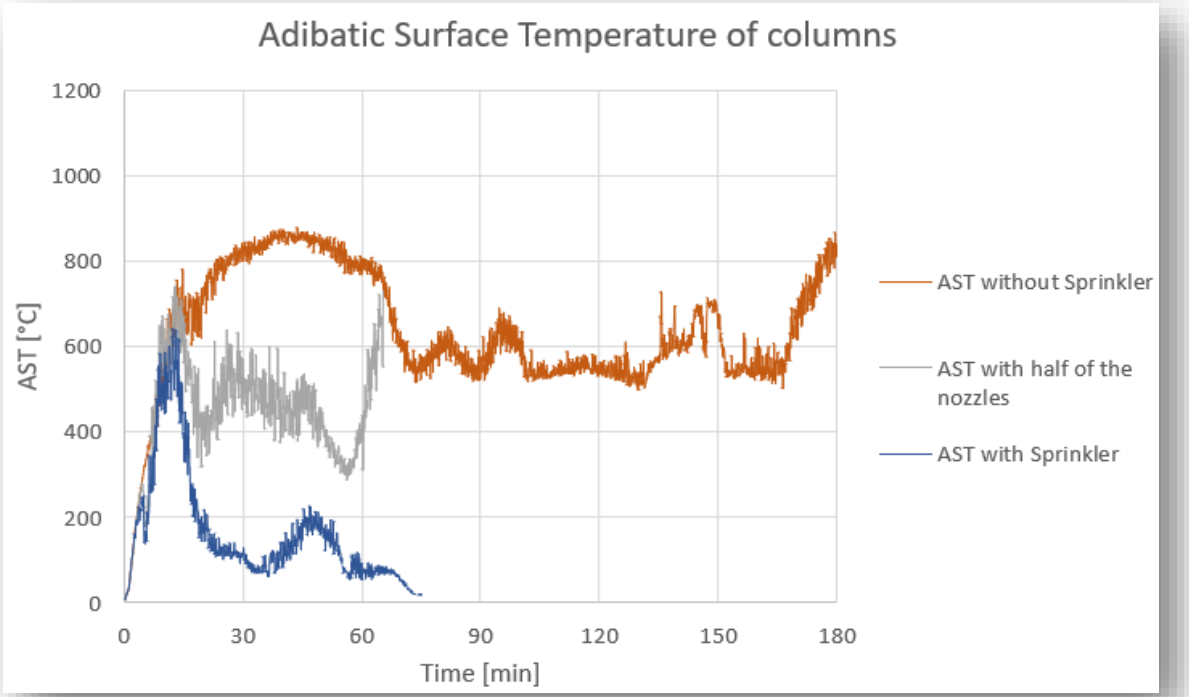
HRR vs time with sprinkler action or not

Fire Safety Engineering study

✓Scenario with PP pallets stacks with fresh foods



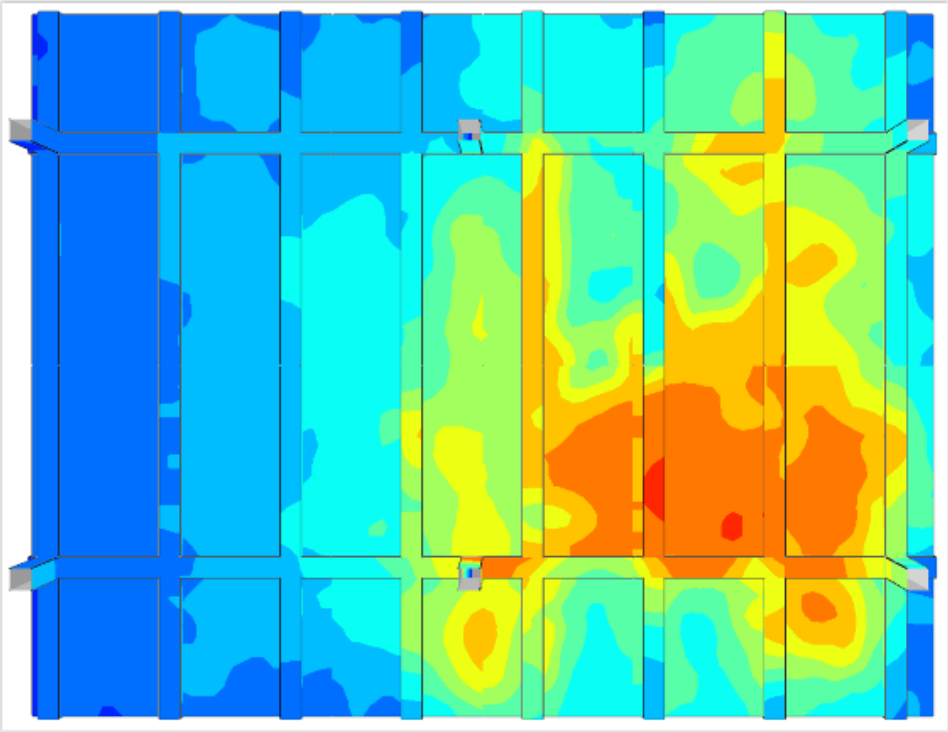
FDS simulation : thermal action on boundaries



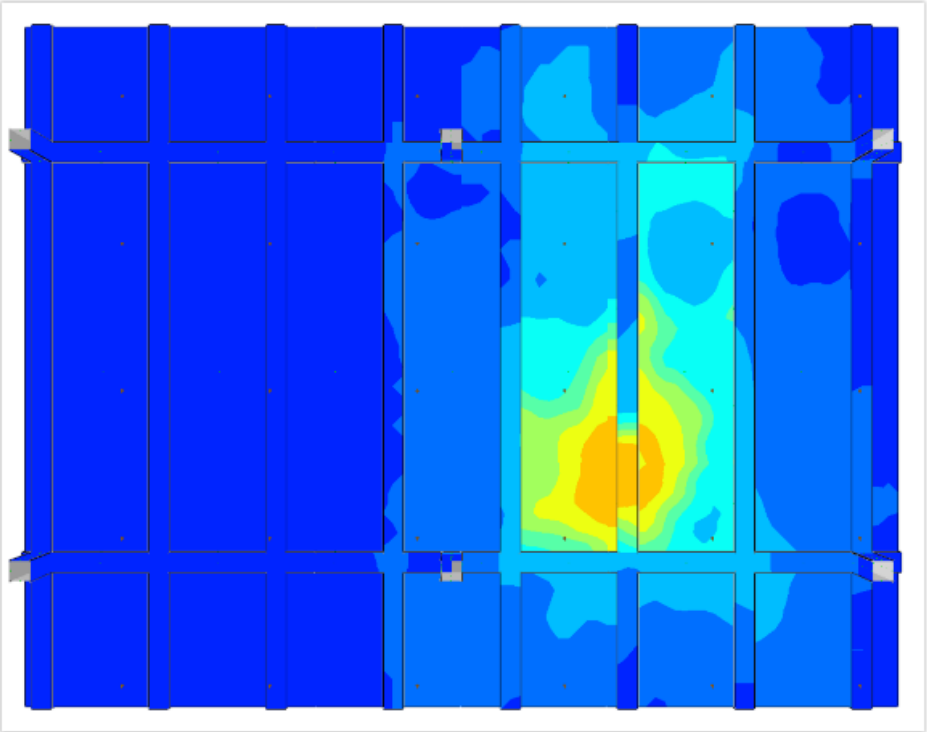
AST temperatures on boundaries : sprinklered or not

Fire Safety Engineering study

✓Scenario with PP pallets stacks with fresh foods

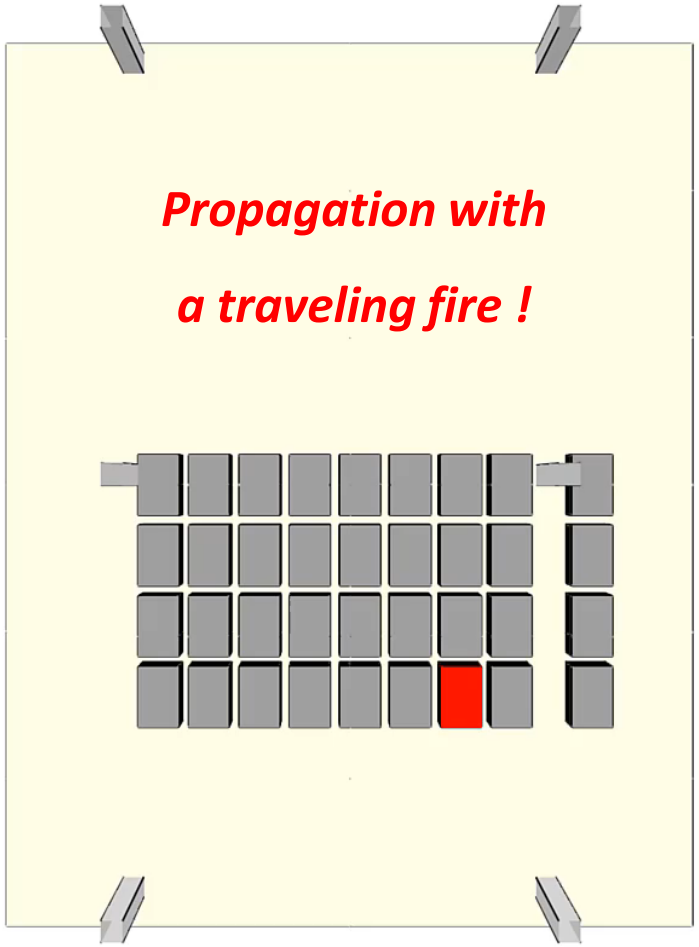


AST temperatures on ceiling :
without sprinkler

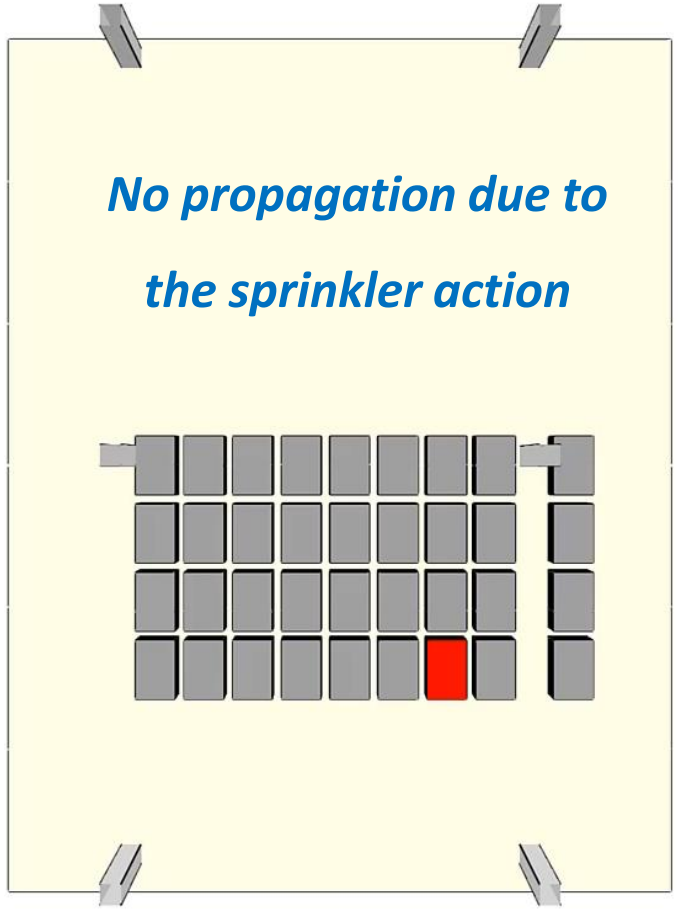


AST temperatures on ceiling :
with sprinkler

Fire Safety Engineering study



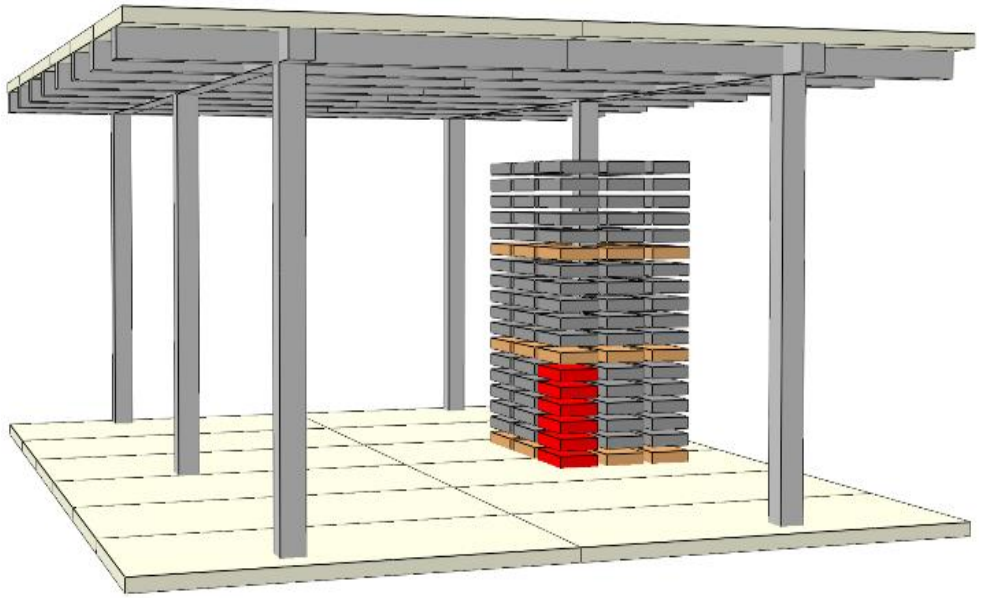
without sprinkler



with sprinkler

Fire Safety Engineering study

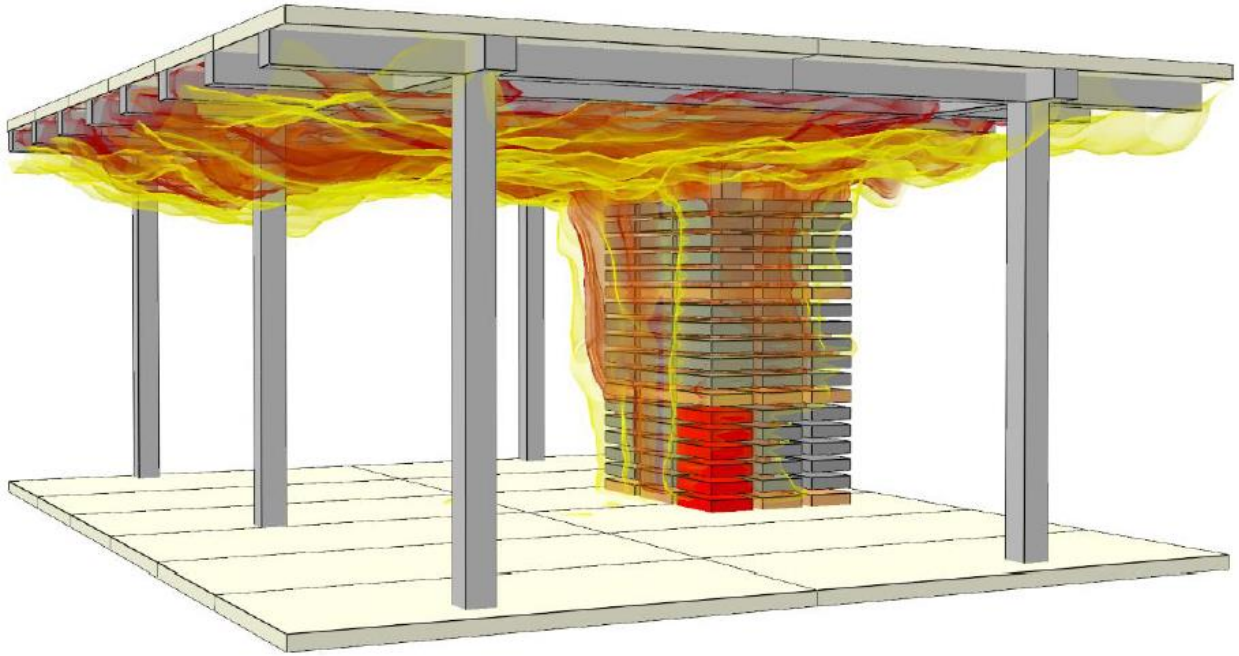
✓Scenario with empty PP pallets stacks



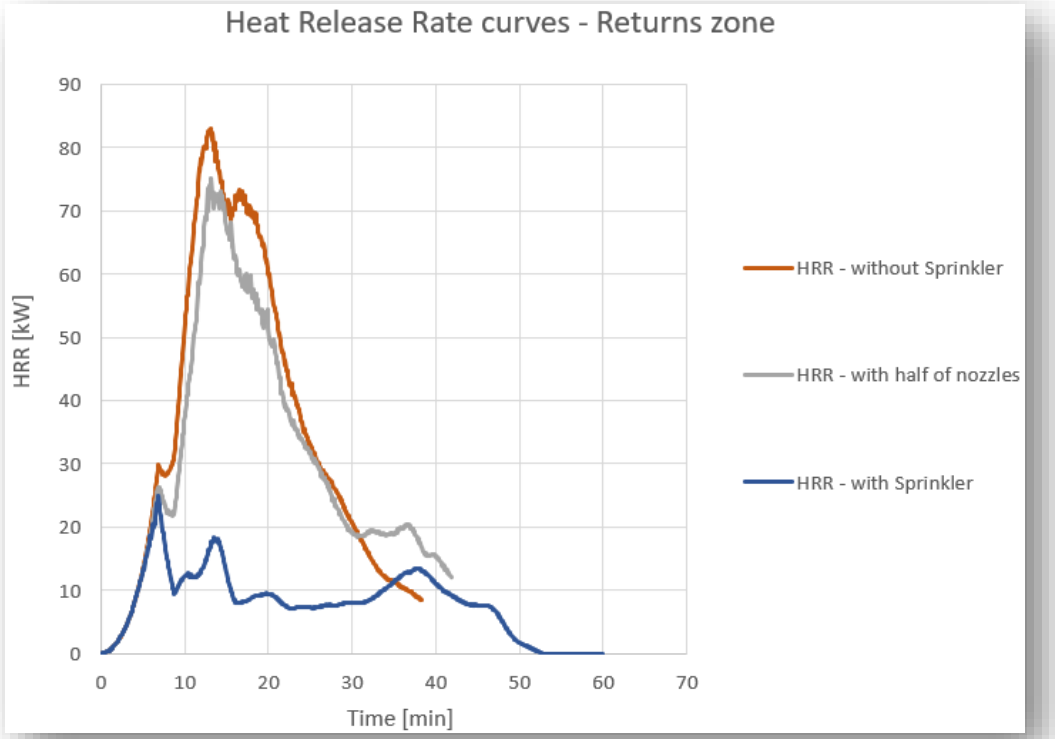
FDS model with the starting fire stack

Fire Safety Engineering study

✓Scenario with empty PP pallets stacks



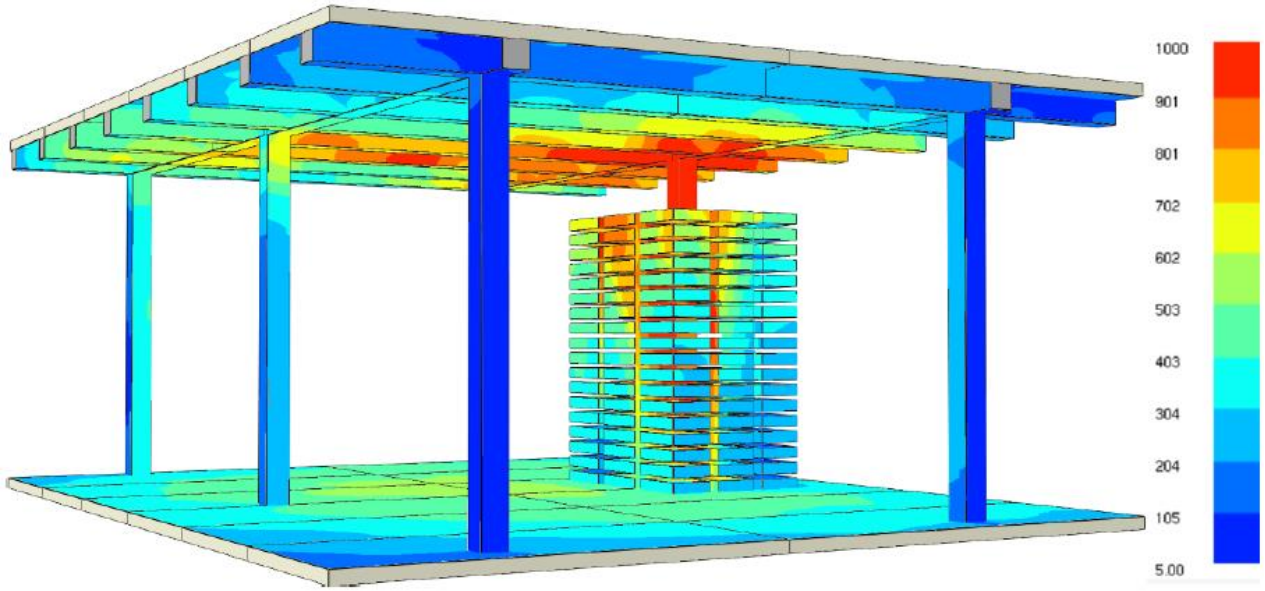
FDS isosurfaces for temperatures visualization



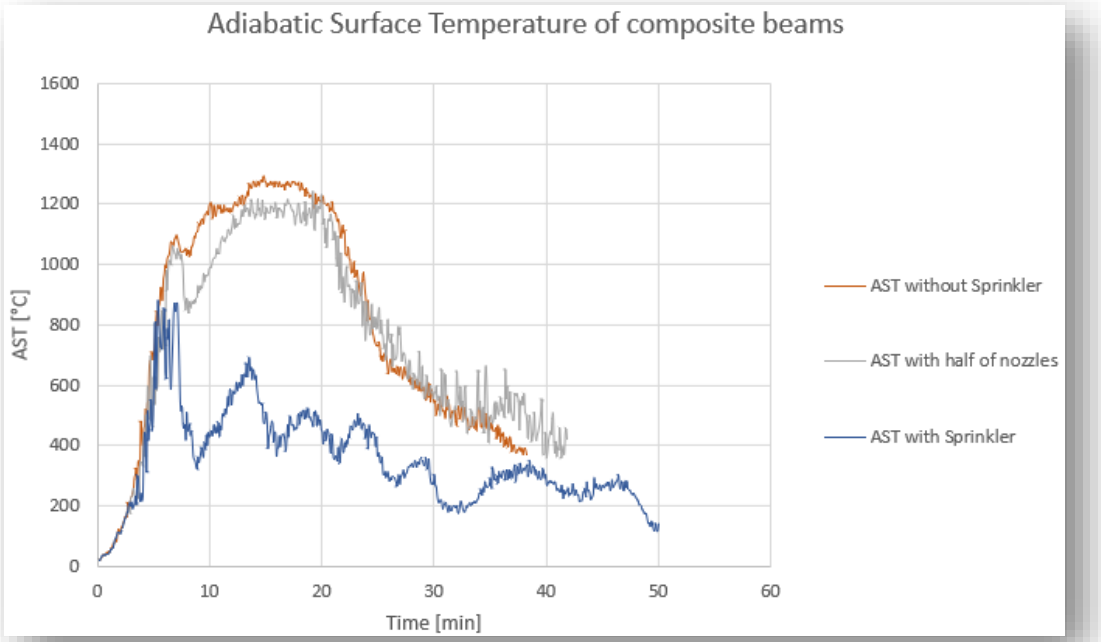
HRR vs time with sprinkler action or not

Fire Safety Engineering study

✓Scenario with empty PP pallets stacks



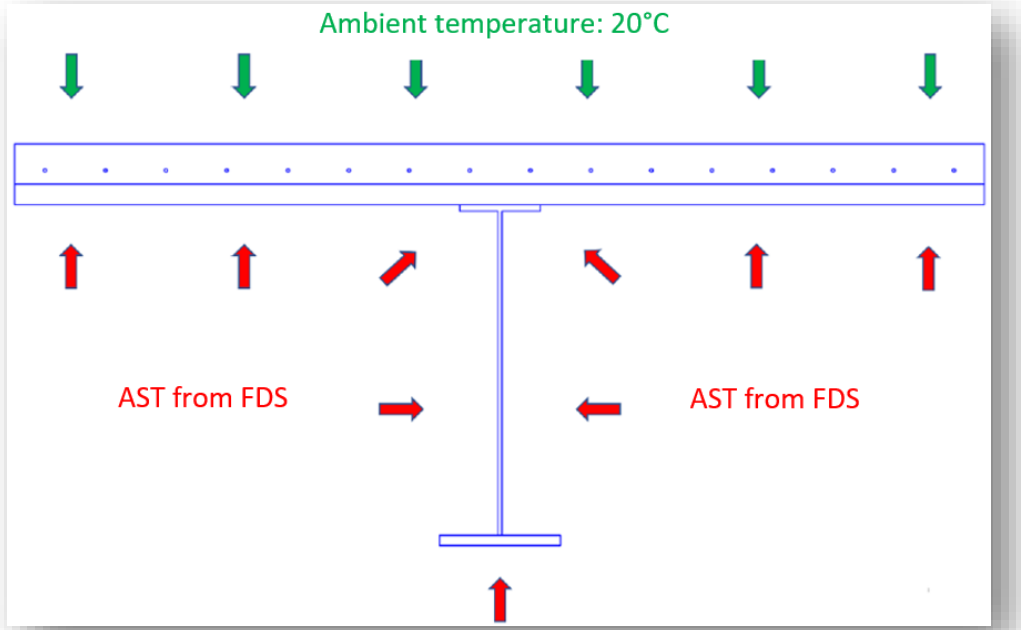
FDS simulation : thermal action on boundaries

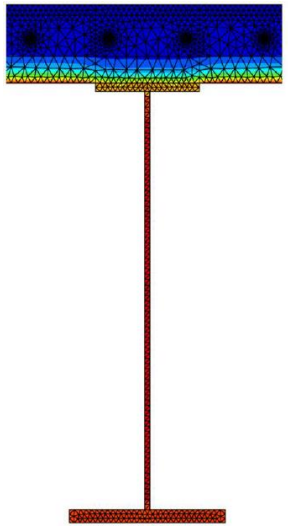


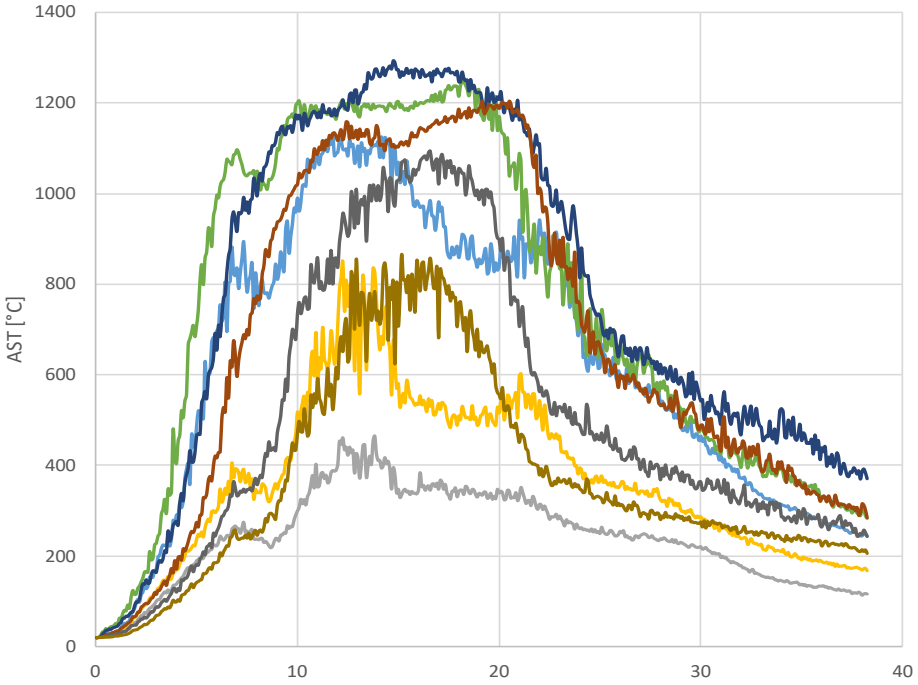
AST temperatures on boundaries : sprinklered and not

Fire Safety Engineering study

✓Heating calculation with SAFIR® (FEM)



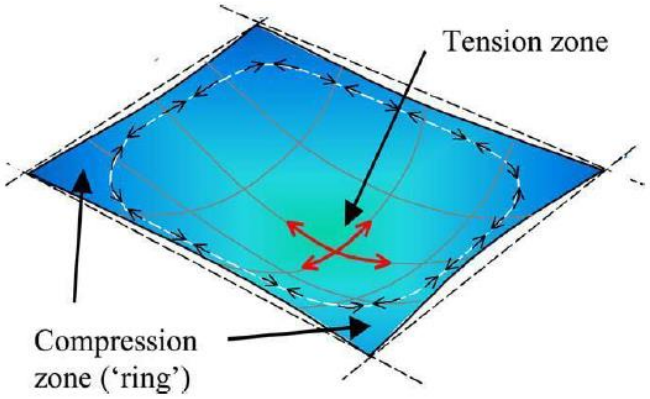


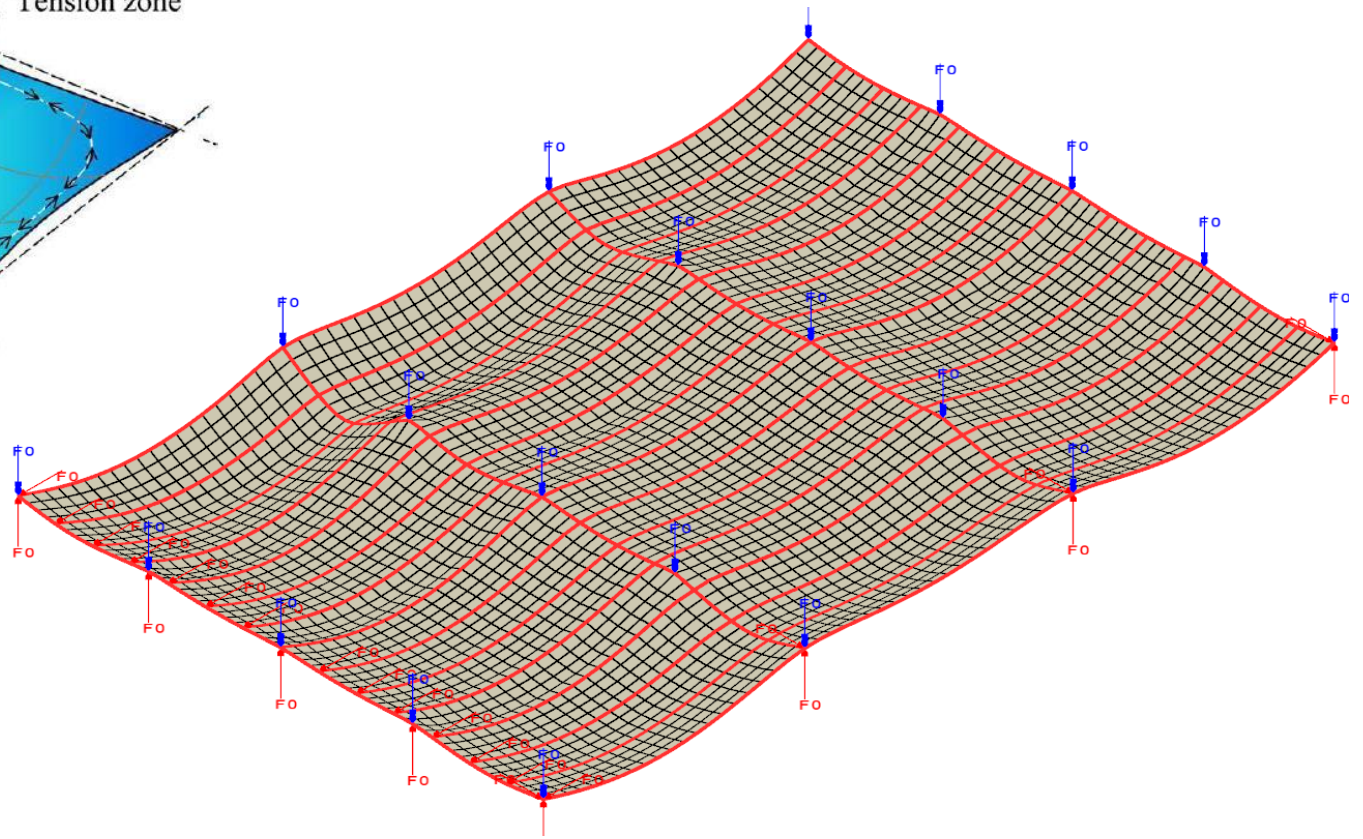


***Thermal transfert* to the structural elements**

Fire Safety Engineering study

✓ Verification of the membrane effect with SAFIR® (FEM)





Fire resistance [s] of structural parts - Natural fire in refrigerated zone	Without Sprinkler	With half of nozzles	With Sprinkler
HEA 900	877	1006	> 4500
Composite beam	934	1018	> 4500
HHD 320x158	1750	N.E.	> 4500
HHD 400x216	2160	N.E.	> 4500
HHD 400x237	2392	N.E.	> 4500
HHD 400x262	2819	N.E.	> 4500
HHD 400x287	3317	N.E.	> 4500
HEA 400	1429	N.E.	> 4500

Fire resistance [s] of structural parts - Natural fire in returns zone	Without Sprinkler	With half of nozzles	With Sprinkler
HEA 900	615	697	> 3000
Composite beam	594	704	> 3000
HHD 320x158	523	N.E.	> 3000
HHD 400x216	614	N.E.	> 3000
HHD 400x237	652	N.E.	> 3000
HHD 400x262	714	N.E.	> 3000
HHD 400x287	775	N.E.	> 3000
HEA 400	427	N.E.	> 3000

Conclusions

- **Fire resistance study of load bearing systems for existing buildings**
  - Complete engineering approach to deal with current fire standards
  - Reduction / Suppression / Optimization of passive fire protection costs

- **FSE methodology**
  - ✓ ISO fire and natural fire approach with simplified models (Eurocodes, Zone models)
    - Good approach in case of low HRR fires
    - Simple geometries
    - No aspersion system
  - ✓ **Advanced study with CFD and FEM models**
    - ✓ **Complex geometry**
    - ✓ **Aspersion sprinkler within the CFD model**
    - ✓ **Accurate structural analysis (membrane effect, robustness, etc.)**
    - ✓ **Very high costs savings as the fire authority validated the study !**

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Thank you for your attention