FEMTC 2022

Fire and Evacuation Modelling Technical Conference

THUNDERHEAD ENGINEERING

CFD FEA SERVICE

& FSE PROGETTI

Paper Factory Fire Safety Engineering

R Poletto – CFD FEA SERVICE

J. Di Pierno – FSE Progetti

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STUDY INTRODUCTION

FSE Analysis of a paper factory

FSE [Fire Safety Engineering] approach as prescribed by Italian DM 03.08.2015

BIM/CFD/FSE approach using:

- Revit
- Pyrosim
- PathFinder
- FDS

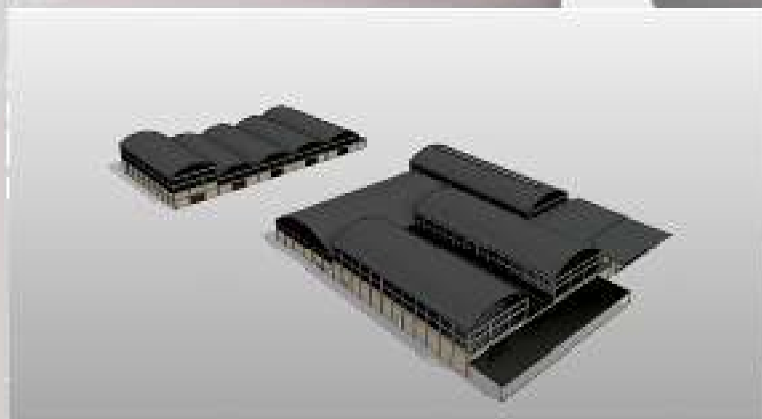
Study of FDS scalability in two scenarios

- FDS version 6.7.9
- Use of multiCore/Thread approach
- CloudHPC hardware resources

OBJECTIVES OF THE PROJECT

S.2 – Fire Resistance

Ensure that fire resistance requirements are maintained for a period sufficient to evacuate occupants to a safe place outside the building;



Sito

- Cartiera
- Toscana
- Lucca

S.3 - Compartmentalization

Calculation of the separation distance (S.3 Compartmentalization);

S.4 - Exodus

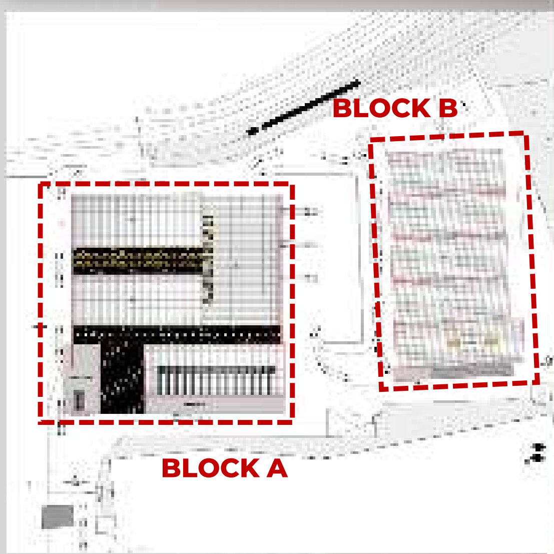
The occupants reach a safe place before the fire causes incapacitating conditions in the areas of activity crossed during the exodus.

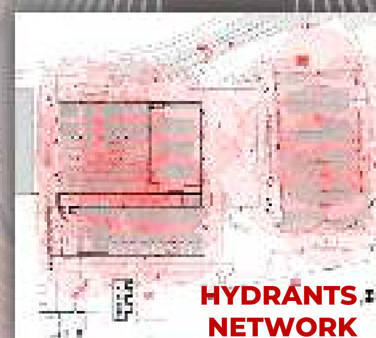
PROJECT DESCRIPTION

2 Manufactured
BLOCK A – 4 Buildings + 2 Canopies
BLOCK B – 5 Buildings

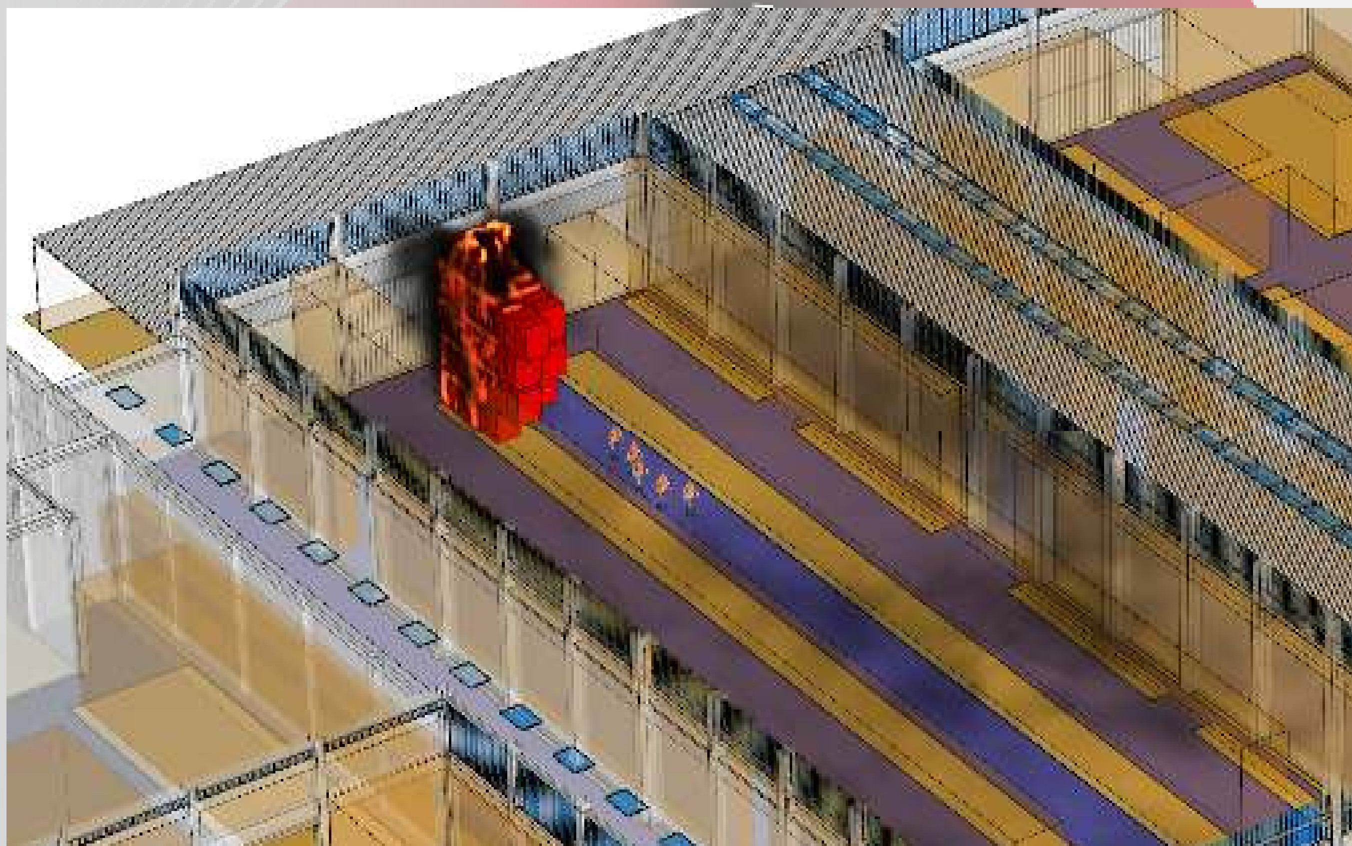
Surface
BLOCK A – 10.000 m2
BLOCK B – 6.000 m2

Storage
Paper/Cardboard in Reels
Max stacking height = 7,25m





Characteristics of occupants



Prevailing characteristics of the occupants:
The occupants are considered to be in a **waking** state and are **familiar** with the building, as it is a work activity.

Crowding:
Inside building A is considered at the same time the presence of **5 people.**

Formation:
Firefighting personnel with **medium risk** level training.

CRITICAL POINTS

Reasons for non-applicability of the **COMPLIANT SOLUTIONS**

Fire resistance (S.2):

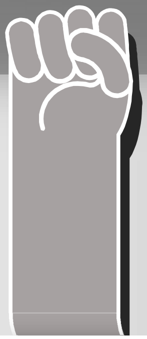
- **class 240** (Level compliant solution III)
- **economically not actionable** the protection of structures and/or the installation of an automatic active protection system.

Compartmentalization (S.3):

- **The separation distance is not respected** on free sky space from other buildings and borders.

Exodus (S.4):

- **Longer exodus lengths** compared to limit values from compliant solution.



Application of **ALTERNATIVE SOLUTIONS**

Fire Resistance Strategy (S.2):

- Definition of **Natural Fire Curves**
- Analysis of the **thermal transient** for the effects of the second order.

Partitioning Strategy (S.3):

- threshold values are fixed for the quantities of **radiation** and **temperature** of fumes.

Exodus Strategy (S.4):

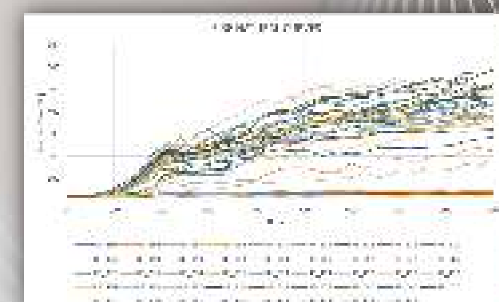
- life benefit thresholds are established.

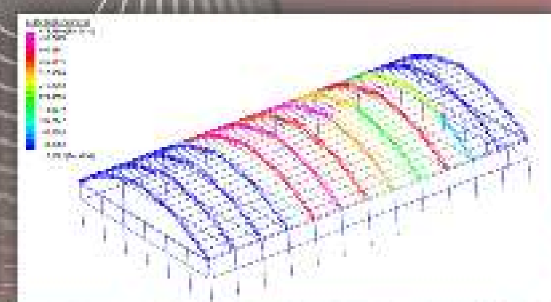
FIRE SAFETY ENGINEERING

Fire Resistance Strategy (S.2)

Steel structures are affected by the maximum temperature reached as they have a very low thermal inertia and a negligible sectional gradient.
In any case, since these are natural fires, it is still advisable to examine the thermal transient to analyse the stresses induced by the effects of the second order as a result of the prevented deformations.

The reinforced concrete structures are affected not only by the maximum temperature reached, but also by the time of application. In fact, they have a high thermal inertia, and not negligible gradient within the section.





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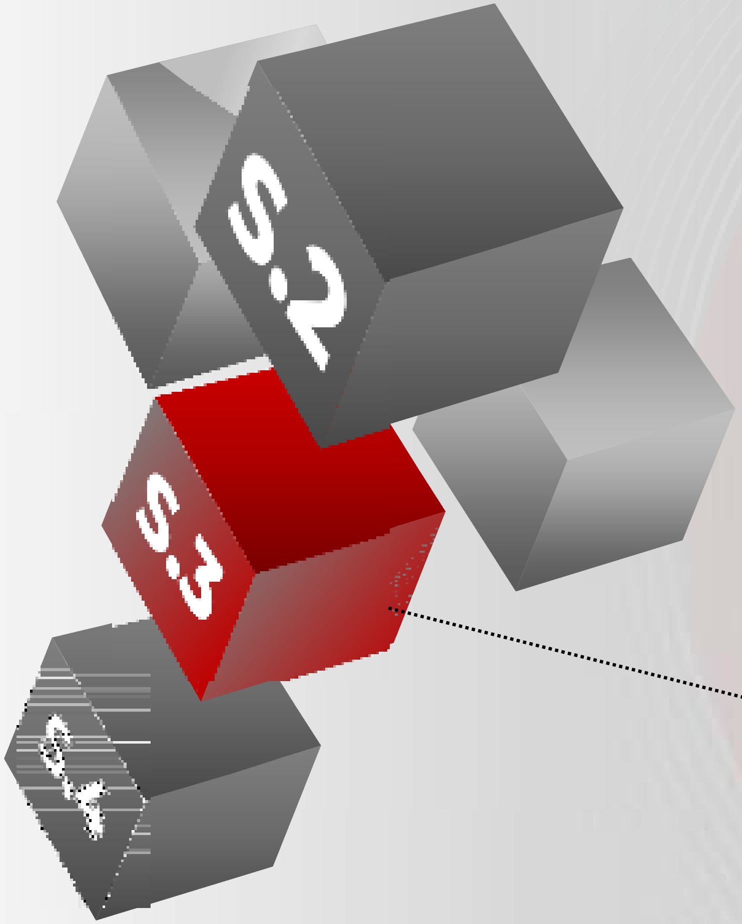

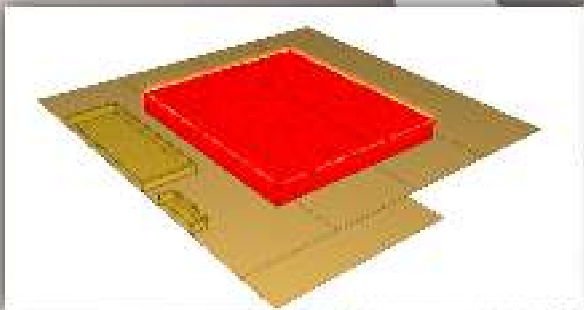

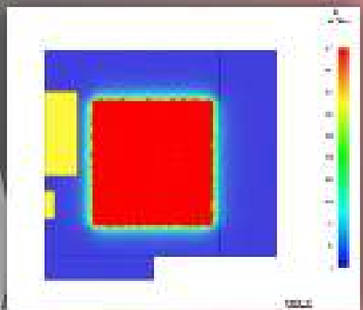

Partitioning Strategy (S.3)

In order to limit the spread of fire, threshold values are set for the radiation quantities and temperature of the fumes. As a precautionary measure, it is considered as the maximum value of Radiative Energy E = 12.6 kW / m2 in accordance with paragraph S.3.8 point 2 of Ministerial Decree 03.08.2015.

The irradiation threshold is considered adequately conservative to limit the ignition of any type of material, as it represents the conventional limit value within which the wood is not triggered in stationary air.

Eng. J. Di Pierno - jordy@fseprogetti.it

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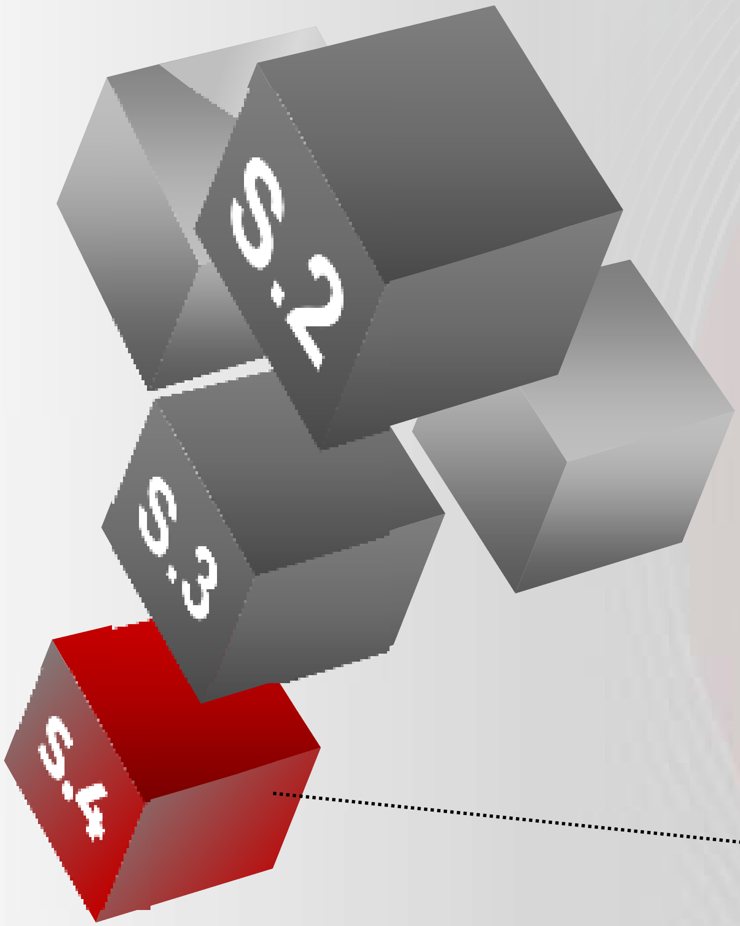
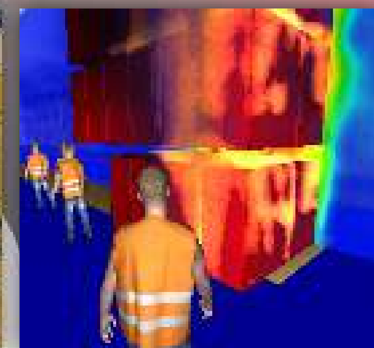




Exodus Strategy (S.4)

For the purposes of life-saving design, life performance thresholds shall be established. These are the thresholds used to define the incapacitation of occupants exposed to fire and its products. Chapter M.3 provides examples of numerical values that can be used for such designs.
By definition, occupants achieve incapacitation when they become unable to secure themselves. This condition is achieved when the following parameters are exceeded:

Visibility = 10 m (z=1,8 m)
Temperature = 60 °C (z=1,8 m)
Radiation = 2,5 kW/m² (z=1,8 m)
FED/FEC = 0,1

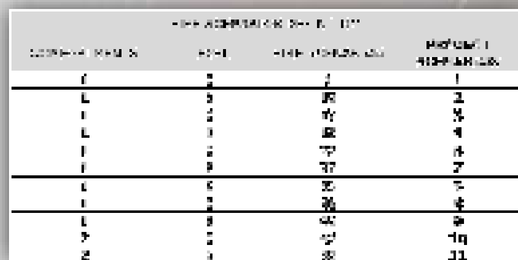
PROJECT FIRE SCENARIOS

Among the most burdensome project scenarios identified, 2 of the most representative scenarios are analyzed.

Project Scenario 3:

This fire scenario was chosen as the most burdensome with regard to the fire resistance of the structures; it is located in a central position, in the center of the covering beam and as regards the exodus it is near the US4 emergency exit. There is material at room temperature stored on shelving up to 7.25m.

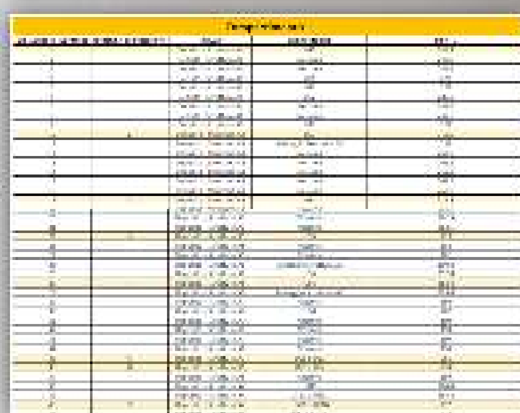
Performance level:
Fire Resistance of Structures – Level II
Exodus – Level I

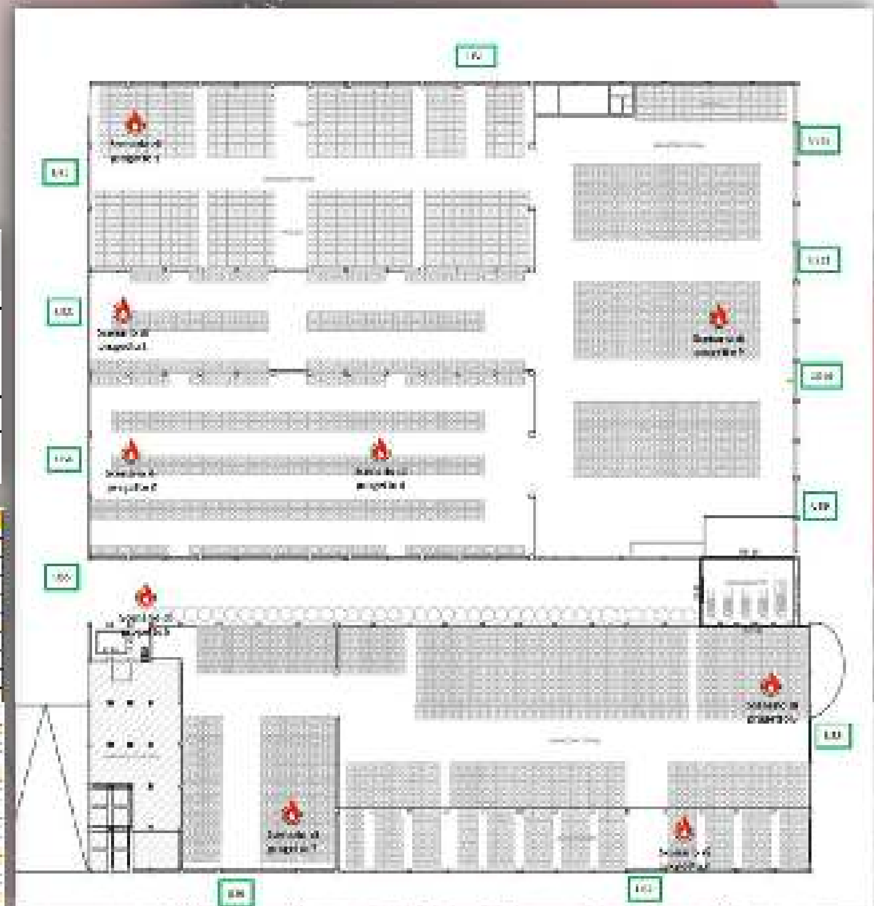


Project scenario 4:

This fire scenario was chosen as the most burdensome with regard to compartmentalization, i.e. for the calculation of the separation distance. The fire is located in the center of the warehouse and spreads throughout the room developing high radiation values.

Performance level:
Compartmentalization – Level II

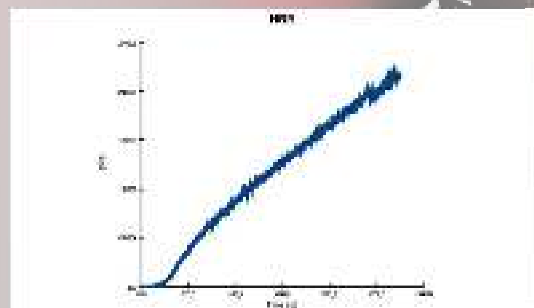


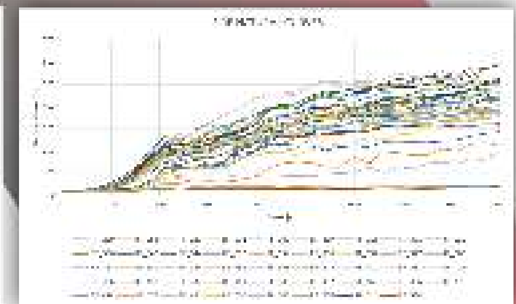


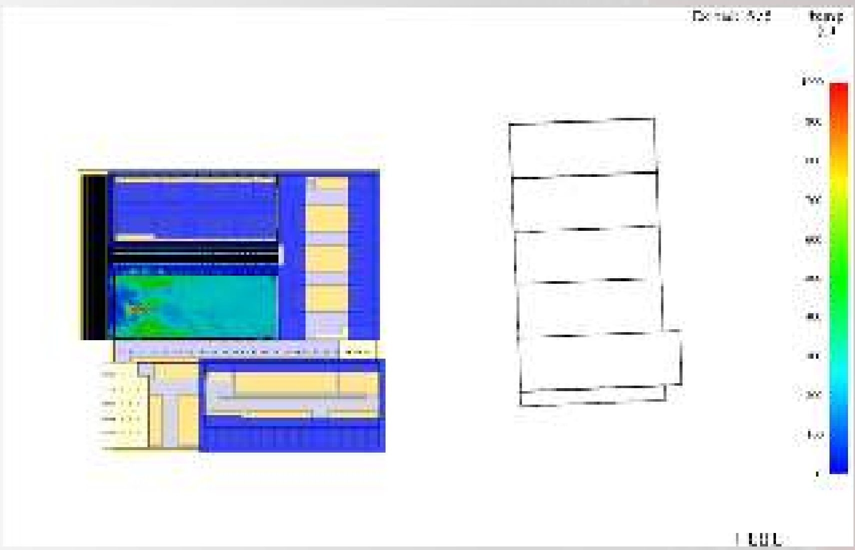
BIM Model

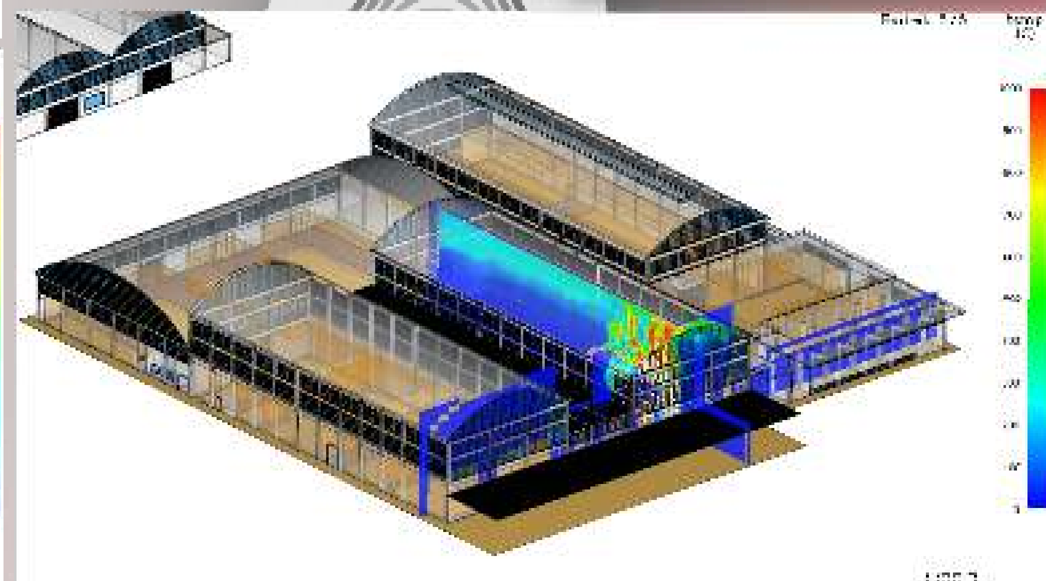
Project Scenario 3

Strategy S.2 – FIRE RESISTANCE









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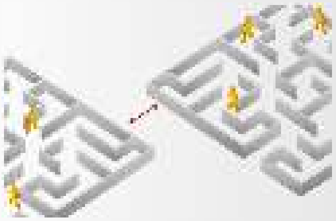
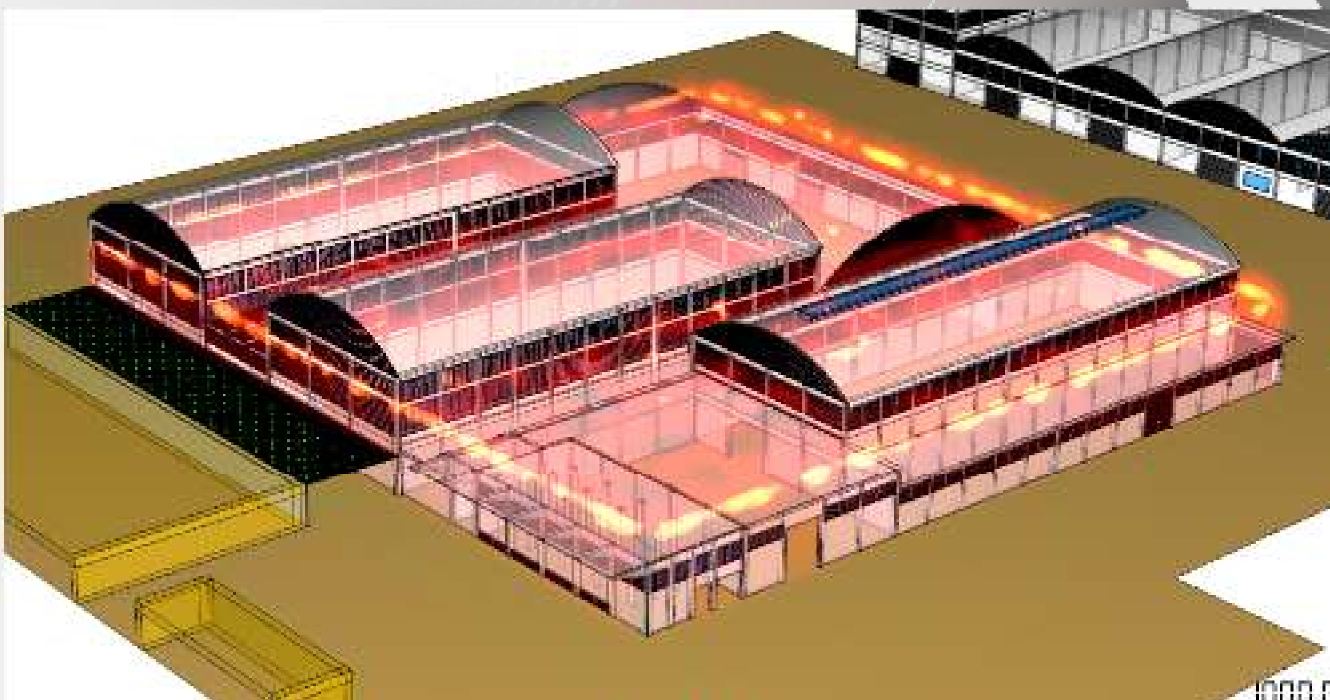
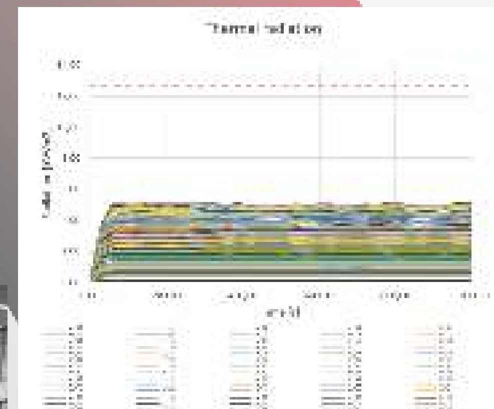
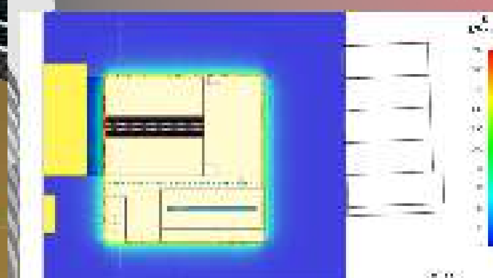
Project Scenario 4

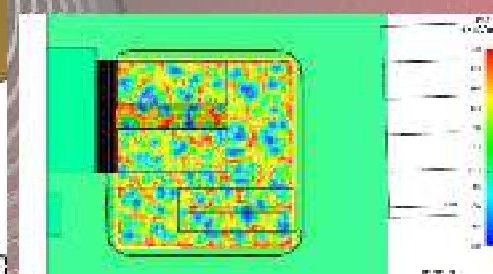
Strategy S.3 - COMPARTMENTALIZATION





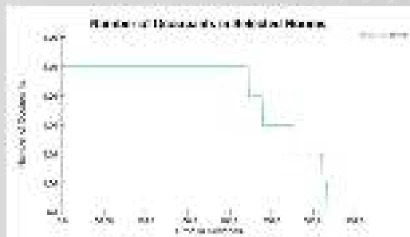


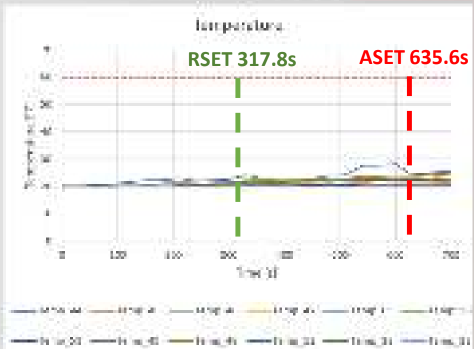




Project Scenario 3

Strategy S.4 - EXODUS





Eng. J. Di Pierno - jordy@fseprogetti.it

CONCLUSIONS FSE ANALYSIS

With the use of alternative solutions it was possible to guarantee the related levels of performance to the fire prevention strategies adopted.

The fire resistance of the structures for the first 15min of natural fire and the implosive collapse is verified to avoid damage outside the area on which the building stands.

With regard to the safety of the occupants, ASET-RSET checks were carried out, demonstrating that for the hypothesized project fire scenario (selected among all fire scenarios) the occupants can leave the building without compromising their safety, guaranteeing the conditions even on uncovered space in the areas identified as a temporary safe place.

In addition, through a simulation of the fire at an advanced stage, it was also possible to verify the compartmentalization to other activities and deposits of combustible material to prevent the fire from spreading due to thermal radiation.

Finally, in the field of BIM modeling it can be concluded by saying that interoperability is fluid and free of instability if you use a simplified model for export within the calculation software.
As for the information relating to the materials constituting the surfaces, applicable in the BIM field, there are still some shortcomings that do not allow relative communication between software.

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SCALABILITY DEFINITION

WHAT ACTUALLY SCALABILITY MEANS?

Scalability means that when we increase the number of hardware resource used to solve a problem we ALSO reduce the time required to get a solution.
I.E. if you run an FDS simulation on 4 CPUs we expect to get the results in ¼ of the time required by running the simulation on 1 CPU.

DICTIONARY

CPU - unit that identifies the part of the hardware resources used for computation

RAM - unit that identifies the part of the hardware resources used as memory

$$S = T_1 / T_N$$

SpeedUp - how much the solution speed increases as we increase the number of CPUs involved in the problem

$$E = S / N = T_1 / (N\ T_N)$$

Efficiency - how much the solution speed increases compared to the increase of CPUs

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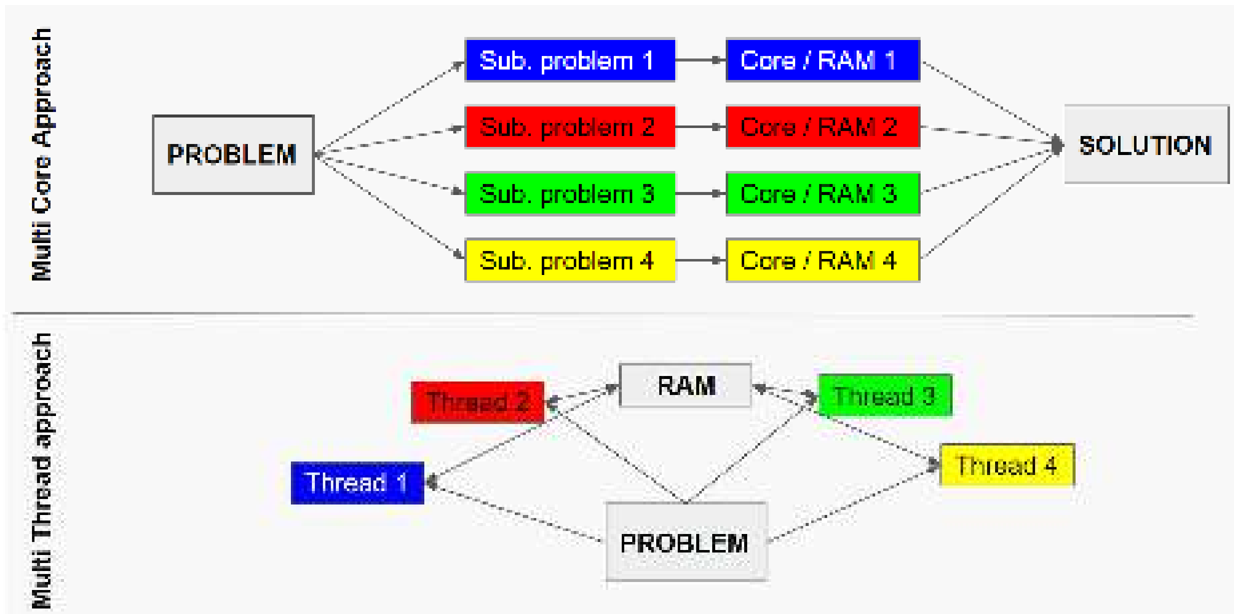
FDS SCALABILITY

Scalability test has been conducted in order to evaluate the platform for cloudHPC provided on the cloud (https://cloudhpc.cloud).

FDS version: 6.7.9
Hardware: 2nd Gen AMD EPYC™ ROME Processors 3.1GHz



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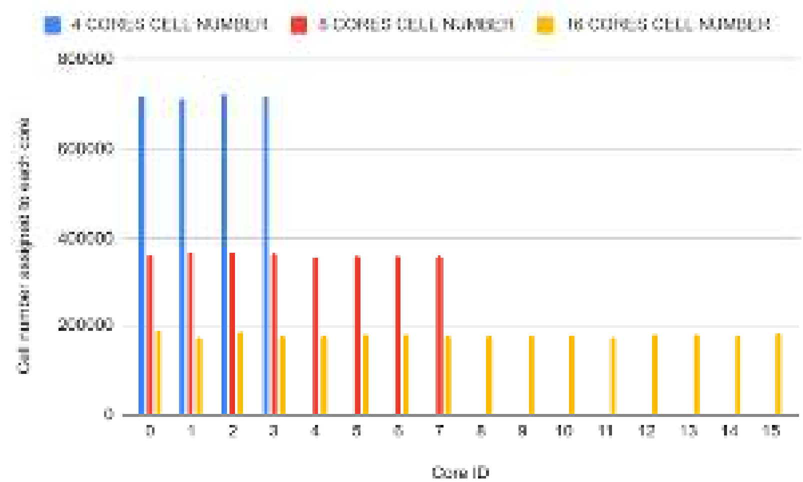
WORKLOAD BALANCE

Case performed: Block A and B

Workload: 2,866,928 and 2,249,448 cells respectively

MultiCore approach using manual mesh decomposition (multiple &MESH with MPI_PROCESS definition for each mesh)



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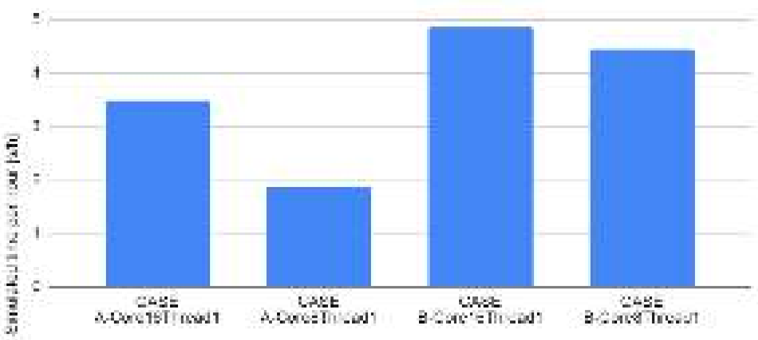
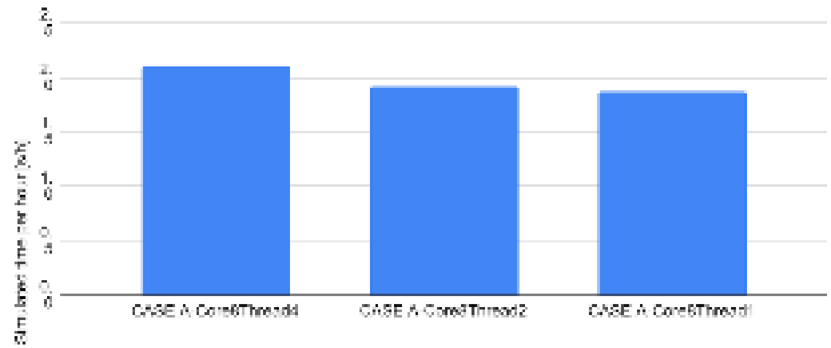
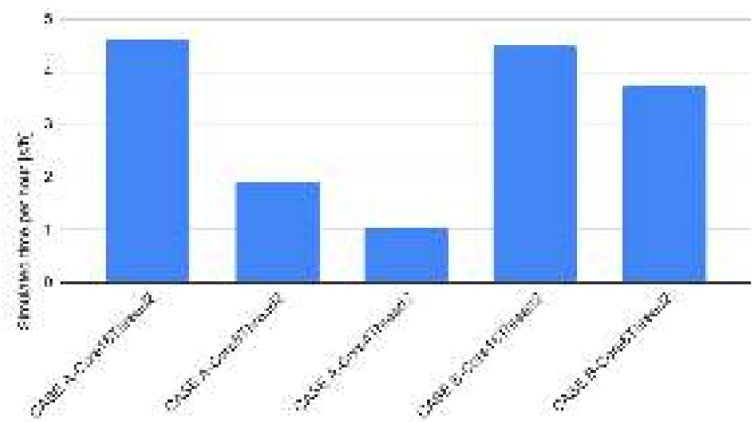
SCALABILITY RESULTS







- Good scalability for CASE-A with Thread = 1
    - CASE-B scalability affected be fire concentrated in just one mesh
- Good scalability for CASE-A when comparing Thread = 2
- FDS 6.7.9 uses two separate solver for multiCore only and multiCore/multiThread approach. The multiCore only is now the most efficient method in terms of speed-up

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SCALABILITY CONCLUSIONS

- Scalability tested on FDS 6.7.9 with cloudHPC solution (https://cloudhpc.cloud)
- MultiCore only approach in the tested case proved to be the most efficient way to reach scalability
- Scalability guaranted for workload in range 150,000 / 750,000 cells per each core/thread

SIDE CONCLUSIONS

- Cloud hardware resources allowed to perform multiple scenarios and scalability tests simultaneously
- 2nd Gen AMD EPYC™ ROME Processors 3.1GHz by cloudHPC used for the simulation with a number of core ranging from 1 to 224

REFERENCES

- DM 03.08.2015 e s.m.i. – "Testo coordinato dell'allegato I del DM 3 agosto 2015 Codice di prevenzione incendi "
- ISO 23932 "FSE - General principles"
- BS PD 7974-0 "Application of FSE principles to the design of buildings - Part 0: Guide to design framework and FSE procedures"
- SOCIETY OF FIRE PROTECNTION ENGINEERING, 2008. SFPE Handbook of fire Protection Engineering. 5th edition. USA: National Dire Protection Association
- ISO 16732-1 "Fire safety engineering - Fire risk assessment", descrive l'applicazione alla valutazione del rischio di incendio delle metodologie proprie dell'analisi di rischio, come l'albero dei guasti e l'albero degli eventi
- ISO/TR 16738 "Fire-safety engineering - Technical information on methods for evaluating behaviour and movement of people"

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THANK YOU FOR YOUR ATTENTION

QUESTION TIME

R Poletto – CFD FEA SERVICE

Via Borgo Grande 19 37044 Cologna V.ta VR

ruggero.poletto@cfdfeaservice.it

FSE PROGETTI.

Via Ferruccio Parri, 931, 47522 Cesena FC

+39 333 2468160 info@fseprogetti.it

Eng. Jordy Di Pierno

jordy@fseprogetti.it

https://www.linkedin.com/in/jordydipierno

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