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APPLICATIONS OF STRUCTURAL FIRE ENGINEERING
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SAPIENZA UNIVERSITÀ DI ROMA

Definition and selection of design fire scenarios – Initial considerations

Introduction

This paper covers many of the Fire Safety Engineering (FSE) aspects, aiming at the definition and selection of design fire scenarios. Within this perspective, two single concepts are further considered (the second one, also as a complement to the other):

•The Performance Based Fire Safety Design (PBFSD) of the structure;

•The Fire Risk Assessment (FRA) of the structure.

The addressed issues* show that only with a faithful representation of the system, a truthful definition of fire scenarios and, as will be shown, detailed advanced analysis, it is possible to have a clear view on the consequences of a fire.

The design fire scenarios identified and selected in this paper, led to the implementation of design fires in FEM, shown in a second paper of the same authors presented at the conference (*Structural analysis of steel structures under fire loading*), aiming at the assessment of specific structural performances, in particular the collapse resistance of the structure.

*Aspects covered in this study are related to the association, in quality of member, of one of the authors (Professor Ing. Franco Bontempi), with the Italian commission for the fire safety of metal structures (*Commissione per la Sicurezza delle Costruzioni in Acciaio in caso d'Incendio*).

Fondazione Promozione Acciaio

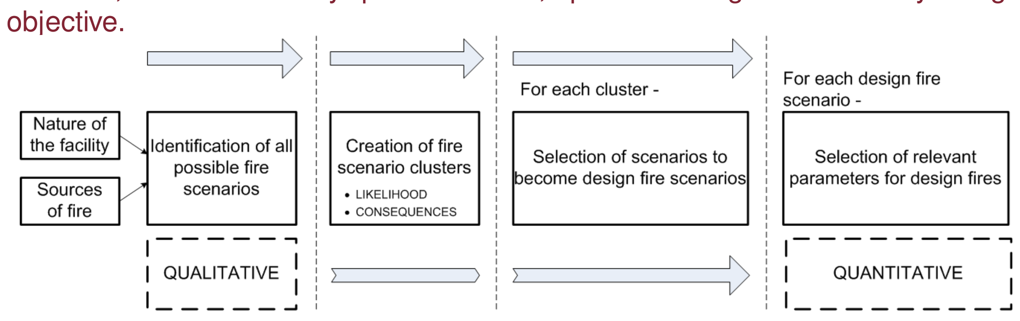
Commissione per la Sicurezza delle Costruzioni in Acciaio in caso d'Incendio

Design fire scenarios and design fires

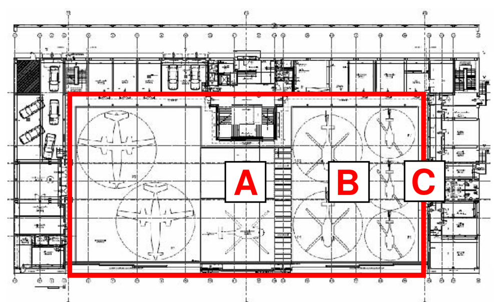
For the appropriate fire performance assessment of the structure, fire scenarios have to be identified, with the consequent selection of design fire scenarios, and finally, of the design fires. In the process of selecting a design fire, several phases have to be considered. These are documented in many International codes and standards.

The considered schematic flowchart is, closely based on indication provided in the ISO/PDTS 16733 committee draft, in which the various phases leading to the selection of design fires are described.

From the considered design fire scenarios, one or more design fires are obtained, characterized by quantified data, specific for a given fire safety design objective.

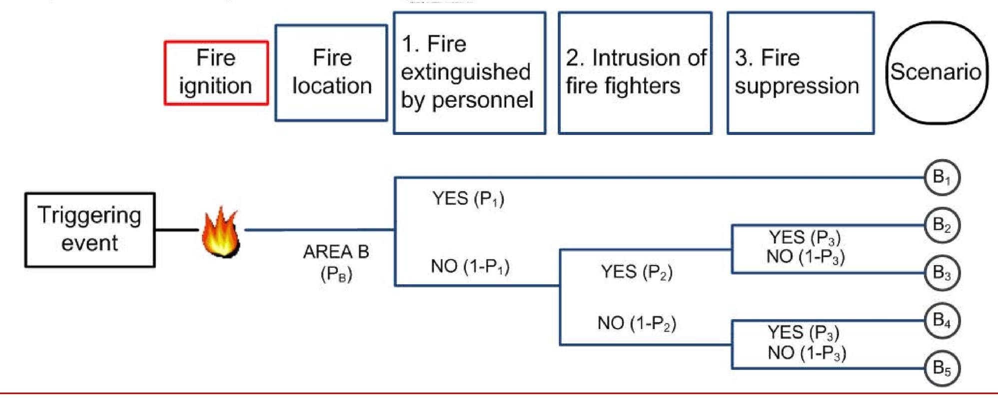


Event tree after the fire ignition in a facility



Identification of fire risk prone areas in an industrial facility

• The central zone of the building (Area A).
• The central zone of the span (Area B).
• The outer zone (Area C).



Fire curves and CFD modeling

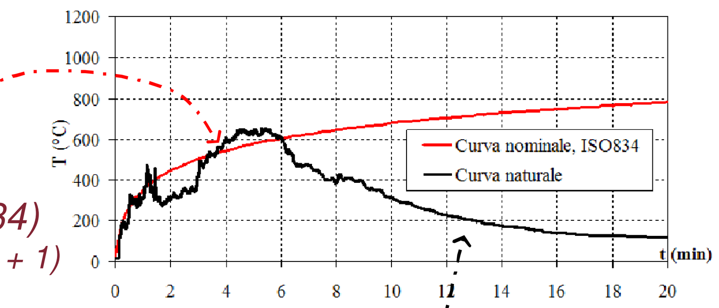
Fire curves

Nominal

a. *Standard (ISO834)*
T = 20 + 345 log (8t + 1)

b. *Hydrocarbon*
T = 1080 (1 - 0.325 e^-0.167t - 0.675 e^-2.5t)+20

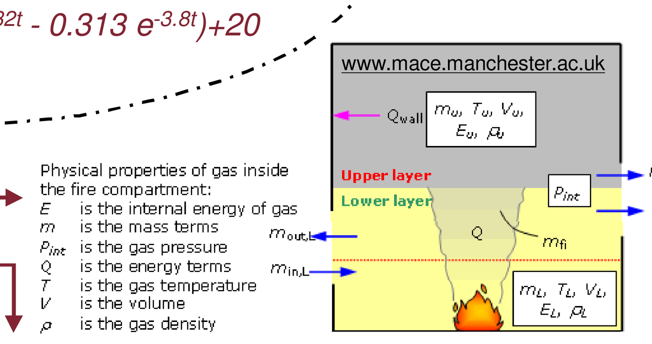
c. *Outside*
T = 660(1-0.687 e^-0.32t - 0.313 e^-3.8t)+20



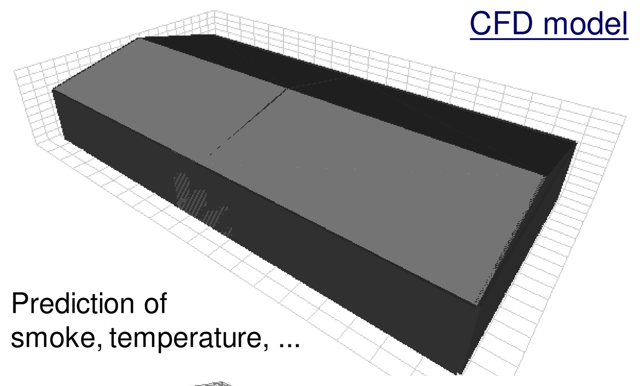
Natural

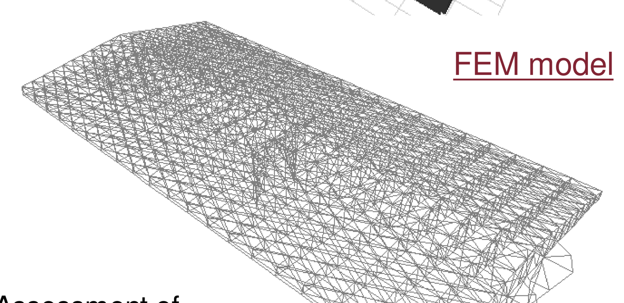
a. *Zone models*

b. *Field models*

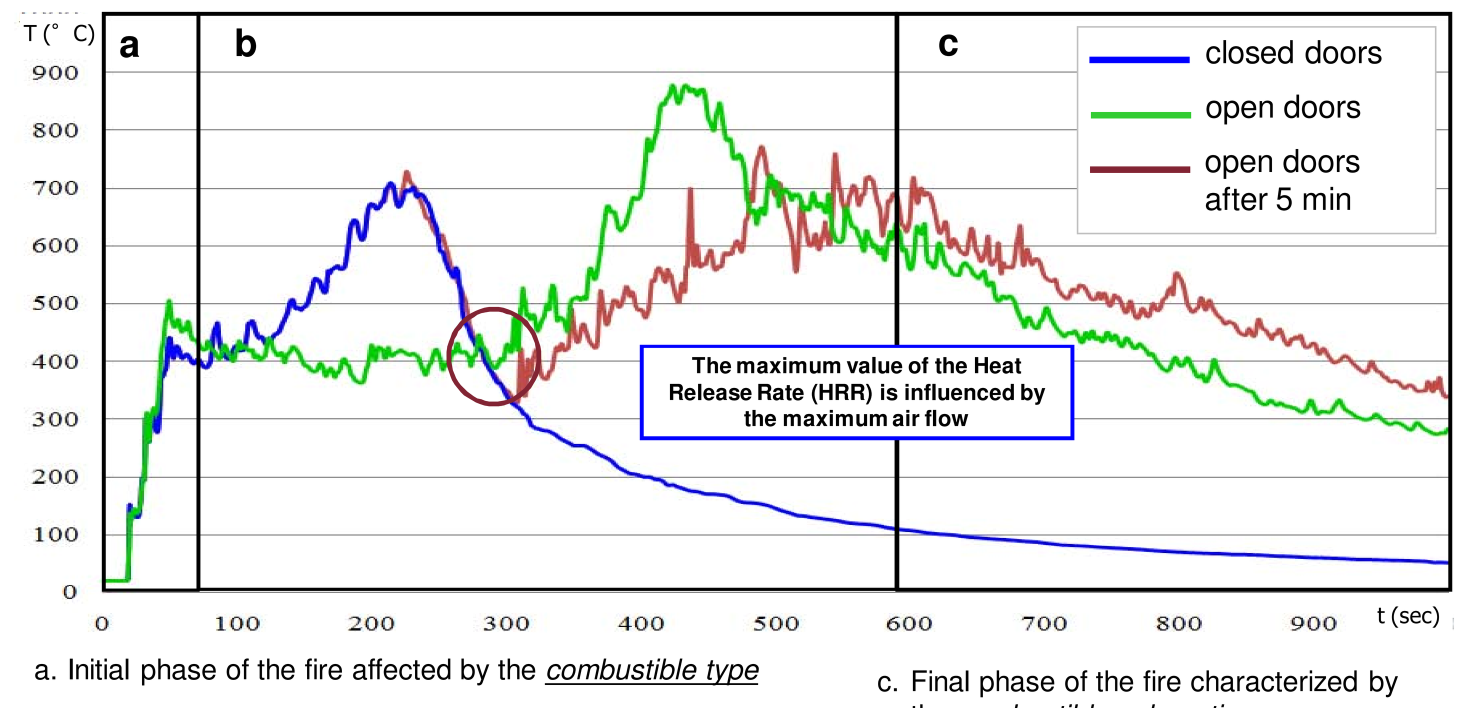


CFD and FEM models





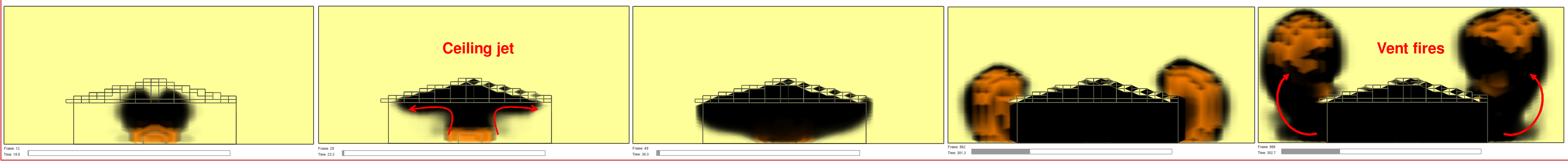
Temperature evolution for different scenarios



a. Initial phase of the fire affected by the *combustible type*

b. Phase of the fire controlled by the *ventilation surface*

c. Final phase of the fire characterized by the *combustible exhaustion*



FEM and thermo-plastic transient analysis

Thermo-plastic transient analysis

Temperature evolution

a. *Due to the fire curve*
b. *Due to element conductivity*

Material degradation

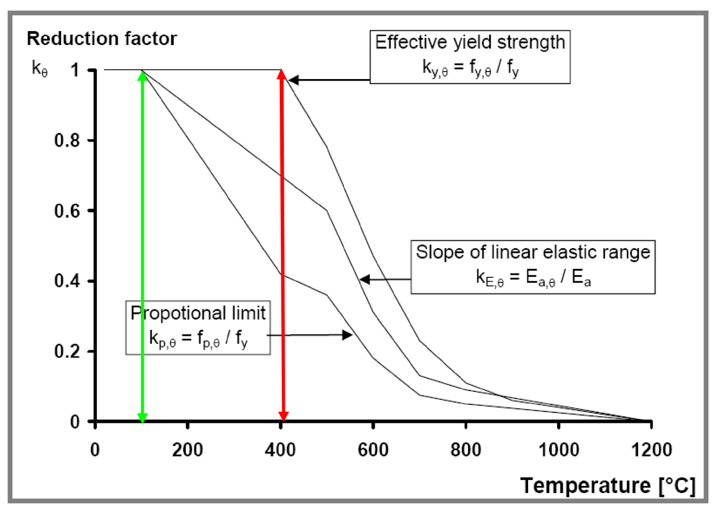
a. *Proportionality value*
b. *Yield value*
c. *Young's modulus*
d. *Thermal expansion*

Geometric NL

a. *II ord. theory (buckling)*
b. *Large displacement (bowing effect)*

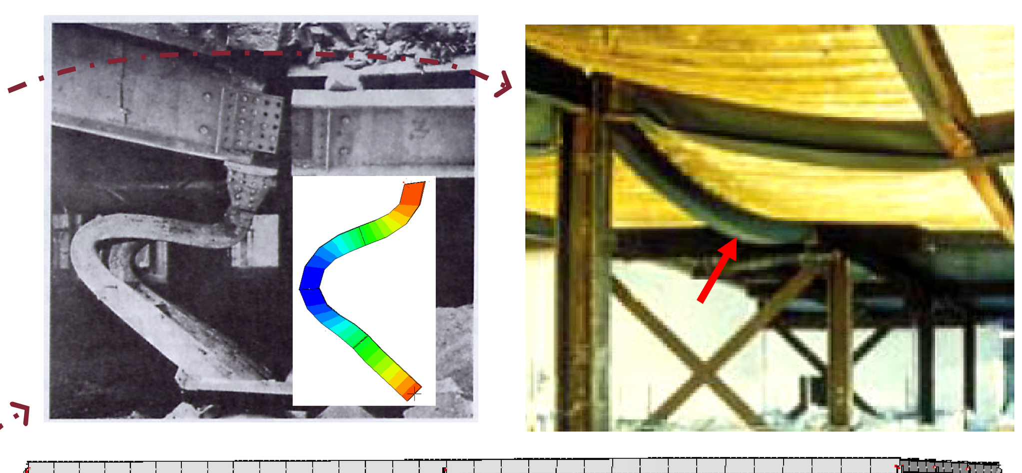
Material plasticity

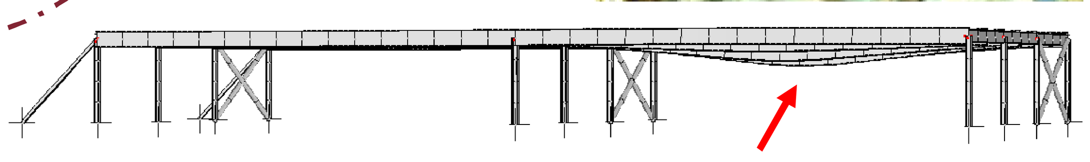
a. *Lumped or spread modeling*
b. *Coupling with geometric NL (thermal buckling)*

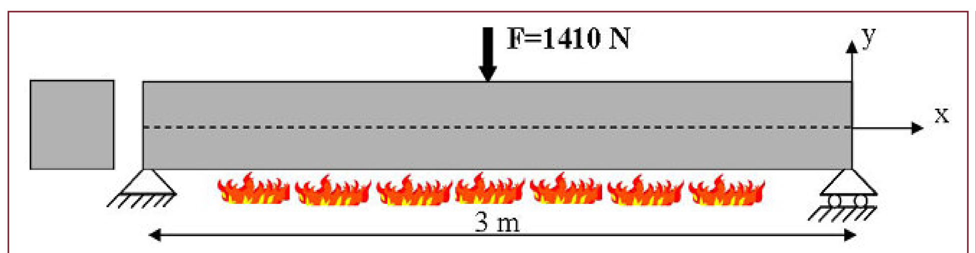


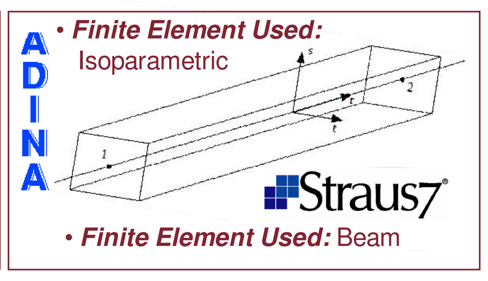
Steel Temperature θ_a	Reduction factors at temperature θ_a relative to the value of f_y or E_a at 20°C: Reduction factor (relative to f_y) for effective yield strength $k_{y,\theta} = f_{y,\theta}/f_y$	Reduction factor (relative to f_y) for proportional limit $k_{p,\theta} = f_{p,\theta}/f_y$	Reduction factor (relative to E_a) for the slope of the linear elastic range $k_{E,\theta} = E_{a,\theta}/E_a$
20°C	1,000	1,000	1,000
100°C	1,000	1,000	1,000
200°C	1,000	0,807	0,900
300°C	1,000	0,613	0,800
400°C	1,000	0,420	0,700
500°C	0,780	0,360	0,600
600°C	0,470	0,180	0,310
700°C	0,230	0,075	0,130
800°C	0,110	0,050	0,090
900°C	0,060	0,0375	0,0675
1000°C	0,040	0,0250	0,0450
1100°C	0,020	0,0125	0,0225
1200°C	0,000	0,0000	0,0000

NOTE: For intermediate values of the steel temperature, linear interpolation may be used.



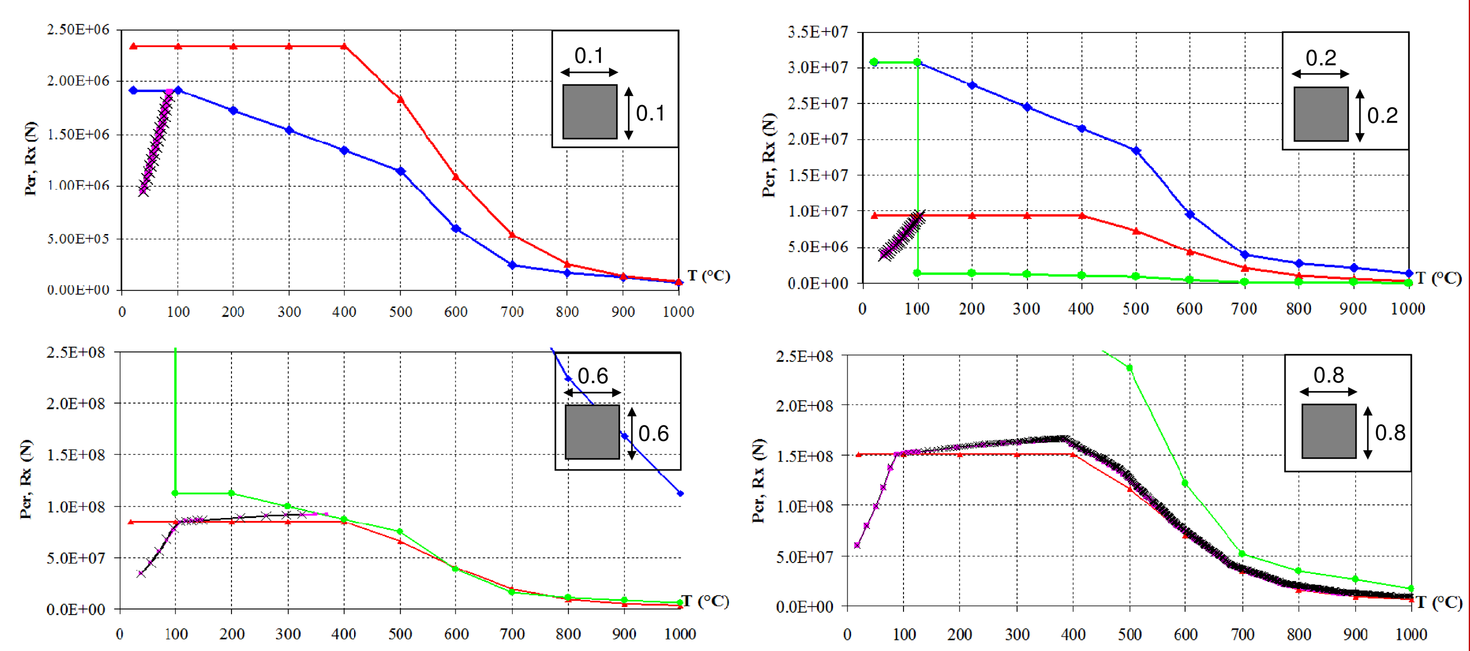






- P_{cr} elastic
- P_{cr} elastic-plastic
- P_{cr} yield
- R_x STRAND
- R_x ADINA

Point	Section	T (°C)	Collapse for achievement of
A	0.1x0.1	77	Elastic Buckling Load (Euler)
B	0.2x0.2	89,5	Elastic-Plastic Buckling Load (Shanley)
C	0.6x0.6	331	Elastic-Plastic Buckling Load (Shanley)
D	0.8x0.8	1000	No collapse



Safety check

The structural performance in presence of fire includes requirements for fire resistance for the structural elements (e.g. beams, slabs, columns) or for the structural system as a whole (avoidance of excessive vibrations, etc.).

A very important step to guarantee a pre-set level of safety is to verify that the resistance of the structure under fire is higher than the fire severity (*fire resistance* > *fire severity*). Three techniques are broadly accepted for checking the fire resistance, respectively in the time, temperature and resistance domain.

Domain	Units	Fire resistance	Fire severity
Time	Hours	Time over the structure is weakened	Duration of fire
Temperature	°C	Temperature over the structure is weakened	Maximum temperature reached during fire
Resistance	KN or KNm	Load bearing capacity at high temperature	Applied load during fire

DEFINITION AND SELECTION OF DESIGN FIRE SCENARIOS

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