International Conference

APPLICATIONS OF STRUCTURAL FIRE ENGINEERING

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SAPIENZA UNIVERSITÀ DI ROMA

Structural analysis of steel structures under fire loading – initial considerations

Introduction

This paper builds on assumptions and findings from a second paper of the same authors presented at the conference (*Definition and Selection of Design Fire Scenarios*), and focuses on the structural analysis of steel structures under fire loading, within the performance based design framework. The use of FEM analysis with thermo-plastic materials and with geometric nonlinearities and the modeling of the fire action using parametric curves allows the faithful evaluation of the effective behaviour of steel structures subject to fire.

The structures under inquiry, although both in steel, are characterized by distinctive features due to their different construction and complexity, the first one being a simple frame structure, while the second a somewhat more complex structure in truss. For the sake of brevity, the main focus is given to the 2nd structure.

Objective of the analyses* is to highlight some of the peculiar effects arising from the fire loading, and to provide a starting point for the characterization of the collapse resistance of the structures.

*The performed analyses 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

Performance based design

Level 1 — Define goal/objective and functional requirements — **Qualitative**

Level 2 — Define performance requirements

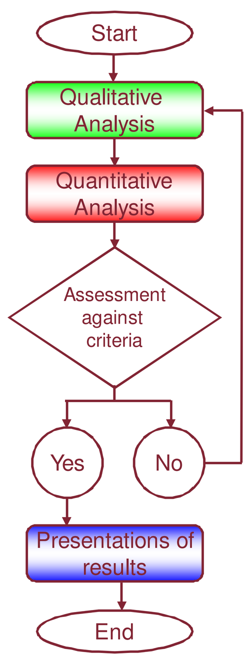
Level 3 — Perform preliminary design — **Quantitative**

Level 4 — Perform performance check

- by **calculation**
- by **testing**
- by combined **testing** and **calculation**
- by Prescriptive Provision check

Performance approach — **Prescriptive approach**

The adopted design procedure



Qualitative Analysis

Safety Objective: To avoid the collapse of the structure

Performance Level: No attainment of the collapse

Fire Scenarios: Fire localized in various zones

Quantitative Analysis

Fire Action Modeling: Nominal curve, ISO834

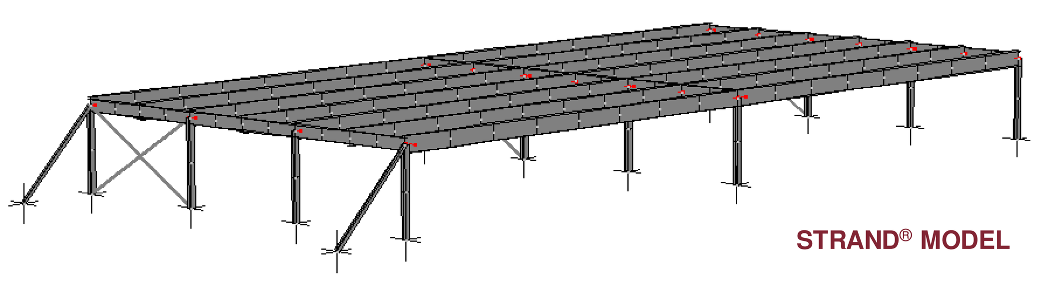
Heat Transfer Modeling: No transfer, temperature applied only to the elements involved in the localized fire

Structural Modeling: Geometry and material non linear Analysis (STRAND® and ADINA®)

Structural analysis of a single storey steel framed open deck car park under fire

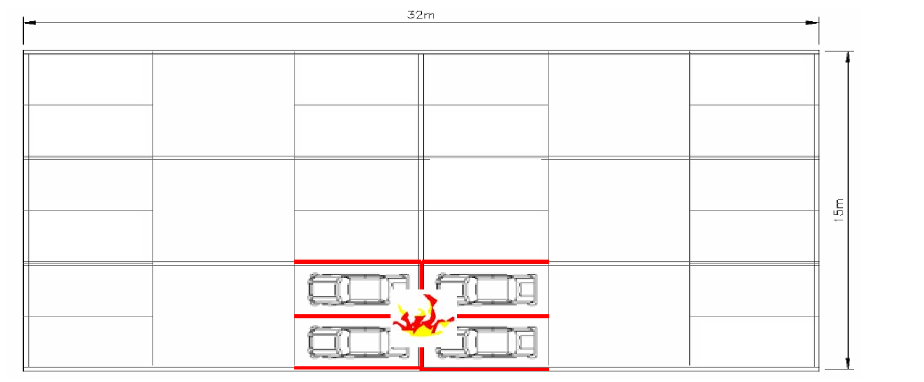
The structure under inquiry

REAL STRUCTURE

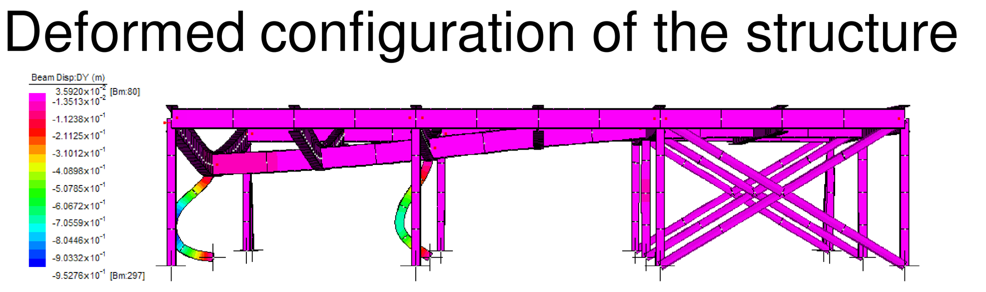


STRAND® MODEL

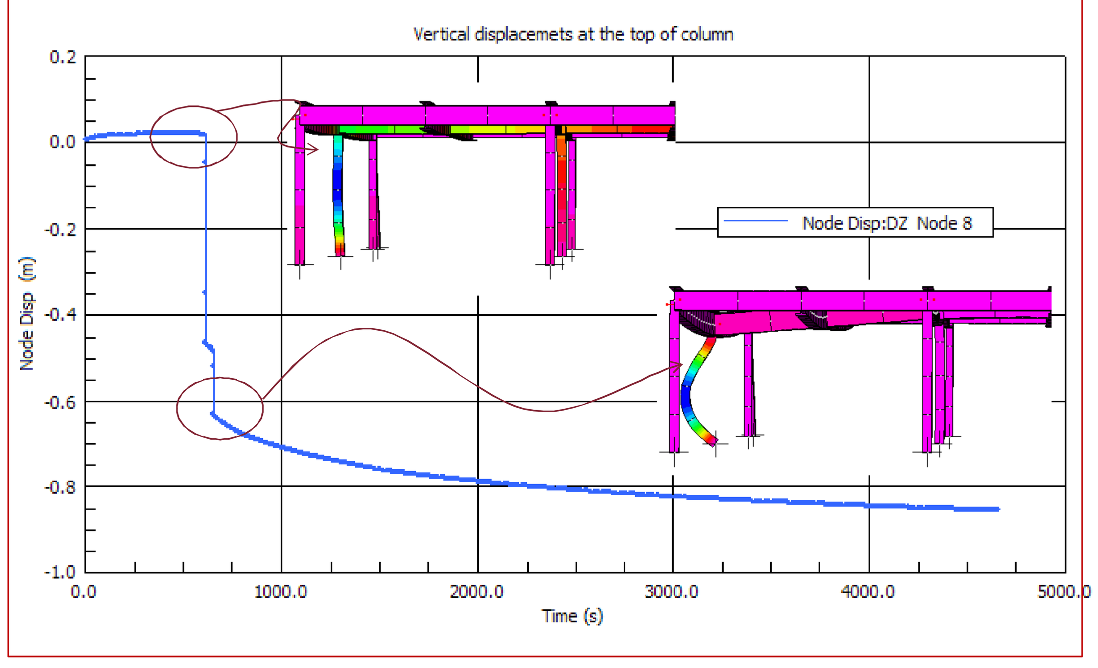
One of the considered fire scenarios



Deformed configuration of the structure

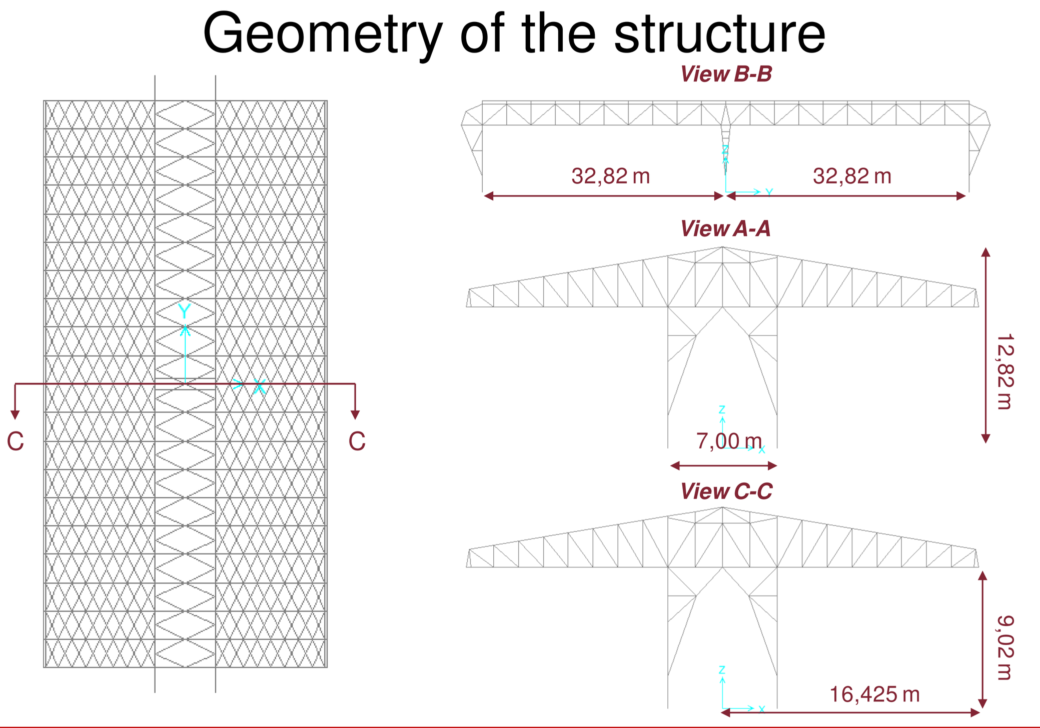


Vertical displacement of the column in time



Structural analysis of an industrial facility under fire

Geometry of the structure



Materials and FEM modeling

Material

- Steel S235
- Concrete Rck 35

Finite Element:

Non linear isobeam

N° node: 1205

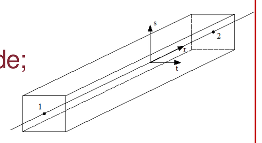
N° elements: 4422

N° sections: 27

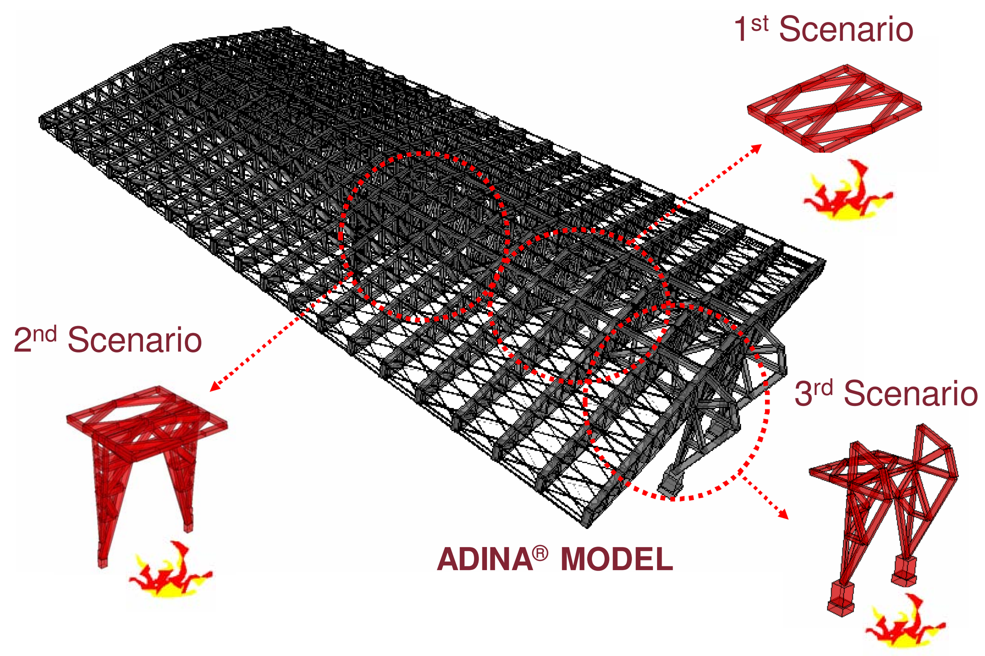
Element mesh density: 2

T (°C)	E (Pa)	s_Y (Pa)	E_{Pl} (Pa)	α_T (°C^{-1})
0	2.10E+11	2.35E+08	1.05E+10	1.17E-05
20	2.10E+11	2.35E+08	1.05E+10	1.17E-05
100	2.10E+11	2.35E+08	1.05E+10	1.20E-05
200	1.89E+11	2.35E+08	9.45E+09	1.23E-05
300	1.68E+11	2.35E+08	8.40E+09	1.26E-05
400	1.47E+11	2.35E+08	7.35E+09	1.30E-05
500	1.26E+11	1.83E+08	6.30E+09	1.31E-05
600	6.51E+10	1.10E+08	3.26E+09	1.34E-05
700	2.73E+10	5.41E+07	1.37E+09	1.36E-05
800	1.89E+10	2.59E+07	9.45E+08	1.38E-05
900	1.42E+10	1.41E+07	7.08E+08	1.40E-05

- 2 node isobeam;
- General 3D beam with six degrees of freedom per node;
- Elements have constant rectangular cross-section;

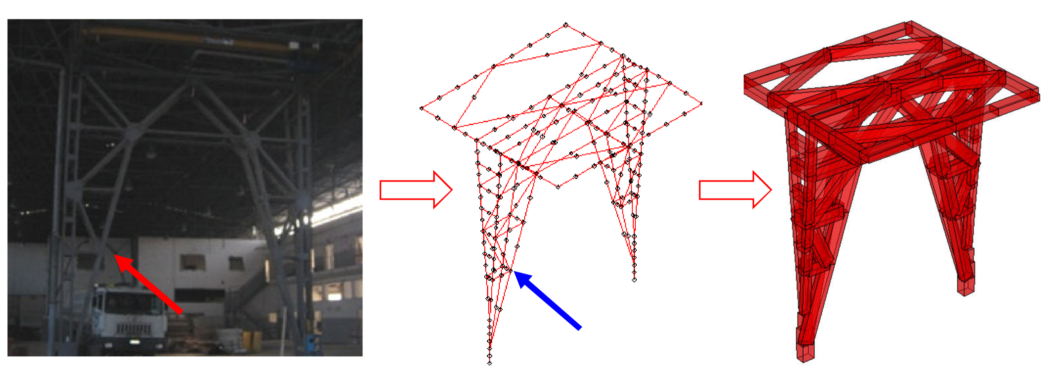


Fire scenario overview

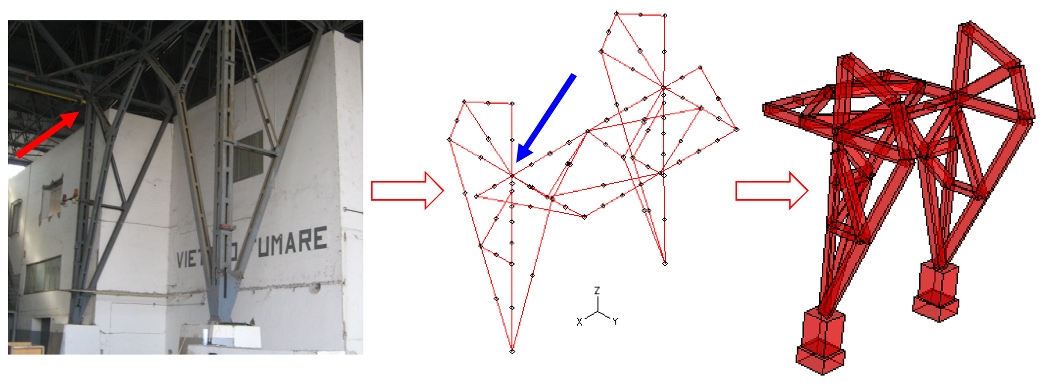


Structural analysis of an industrial facility under fire - results for the 2nd and 3rd scenario

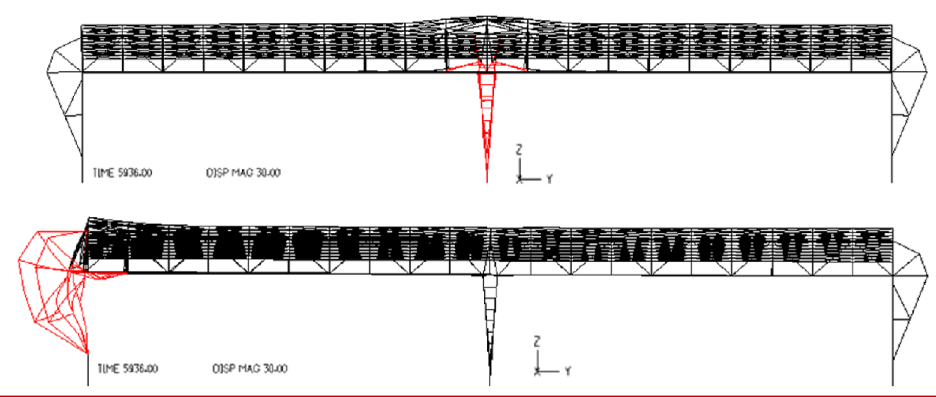
2nd scenario - central column



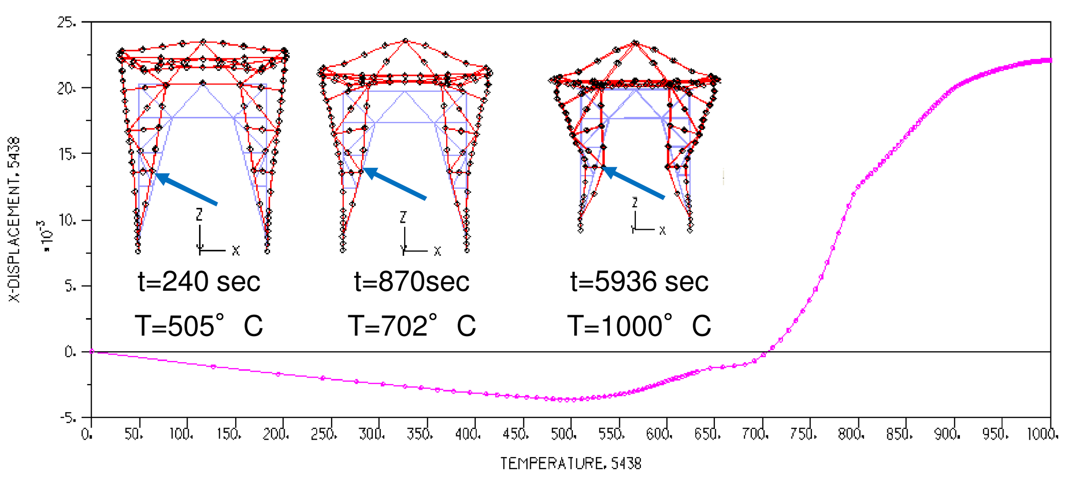
3rd scenario – lateral column



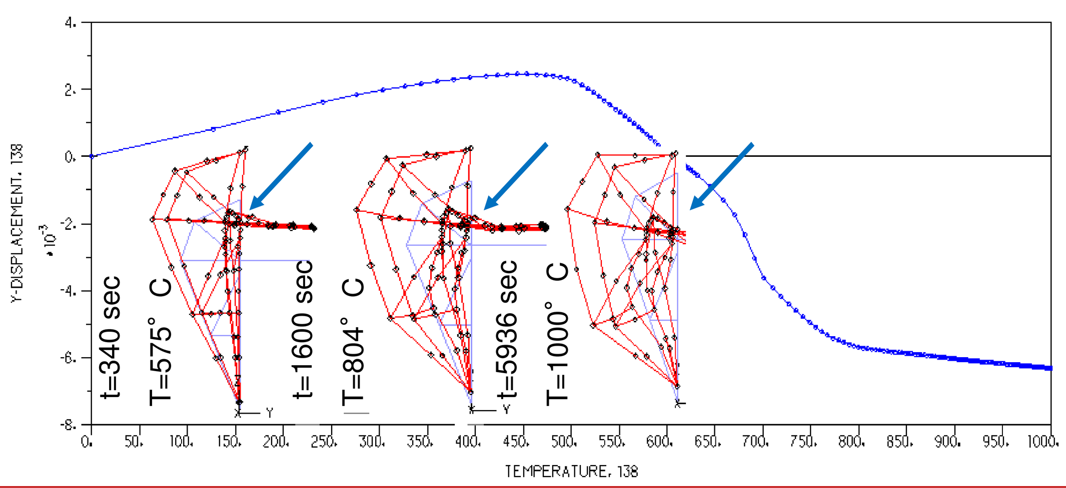
Deformed configurations



Node displacement (x-axis)



Node displacement (y-axis)



Conclusions and considerations

It is possible to conclude that for the scenarios involving the columns of the industrial facility, after about **800 s**, corresponding to a temperature of **700° C**, the structure shows brusque changes of stiffness. Hence, this temperature represents a **critical state** corresponding to a less safe state regarding the stability of the structure.

These findings can be of help in order to:

- demonstrate and certify the performance of the structure in terms of resistance to fire (in the design phase);
- identify in a correct way the operations to obtain the pre-established performance requirements (in a retrofitting phase).

STRUCTURAL ANALYSIS OF STEEL STRUCTURES UNDER FIRE LOADING

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