

**cost** Integrated Fire Engineering and Response  
COST action network number TU0904 in domain Transport and Urban Development

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## Fire Following Earthquake

The behavior of Moment Resisting Steel Frames subjected to standard fire after earthquake, using SAFIR code.

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## Organization of the Presentation

- Input data definition.
- Discussion about calculation procedure.
- How to apply the results obtained from the analysis.
- Discussion about the effects of horizontal load speed on the results.
- Discussion about the effects of mesh density on the results.

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## Input Data

- Mechanical property of steel at elevated temperature as indicated by Eurocode 3-1 (implemented in SAFIR).
- No hardening is taken into account.
- Steel grade S235.

Geometrical Model

Cross Sections and Fire Scenario

Distributed Loads, Masses

Storey	Load [kN/m]	Mass [t/m]
Storey		
Current Storey	27.3	2.73
Top Storey	23.7	2.37

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## Input data

### Fire Input Data

- Thermal load represented by Standard ISO 834 Fire Curve.
- Fire applied on four sides of column cross section.
- Fire applied on three sides of beam cross section (slab effect).
- Fire scenario located at first floor.

### Analysis Options

- Type of analysis: dynamic non linear (Newton - Raphson, first order).
- Number of integration points (Gauss Points): 2.
- Beam Finite Elements' Size: various sizes (nodes number 1449).

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## Methodology of Analysis

- Evaluation of asymptotic convergence range to choose meshes' sizes.

Meshes density study.

Nodes Number [-]	Pre-Earthquake Collapse Time [m]	Post-Earthquake Collapse Time [m]
500	32	30
750	25	23
1000	18	16
1250	15	14
1449	14	13
1750	14	13
2000	13	12

Nodes distribution for the study case.

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## Methodology of Analysis

- Thermal analysis to evaluate temperature along the cross sections before earthquake.

Beam temperature's distribution at different time

Column temperature's distribution at different time

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## Methodology of Analysis

- Thermo-Mechanical analysis to evaluate collapse time under fire in pre earthquake condition. (Collapse time: 14 minutes; Collapse mechanism: local)

Deformed shape after 5 minutes of standard fire      Deformed shape after 10 minutes of standard fire      Deformed shape at collapse (14 minutes)

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## Methodology of Analysis

- Non linear incremental analysis to evaluate the structure's behavior subjected to horizontal forces (collapse mechanism: global; total top horizontal displacement 41 cm; maximum base shear 952 KN).

Deformed Shape      Push Over Curve

Displacement [cm]	Base Shear [KN]
0	0
10.00	400
20.00	800
30.00	900
40.00	952
50.00	952

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## Methodology of Analysis

- Definition of lateral load functions to simulate Earthquake action (total displacement: 39 cm).

Push Over Curve

Earthquake Simulation

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## Methodology of Analysis

- Definition of temperature function to simulate FFE scenario and to perform thermal analysis in FFE scenario.

Standard Fire ISO 834 to simulate FFE.

Beam's top and bottom flange temperature; slab effect.

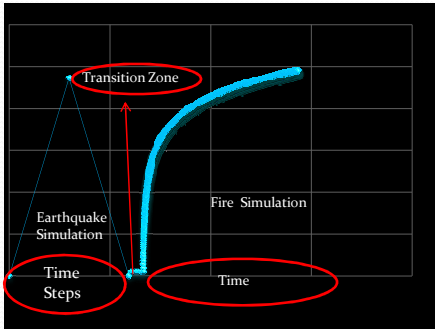
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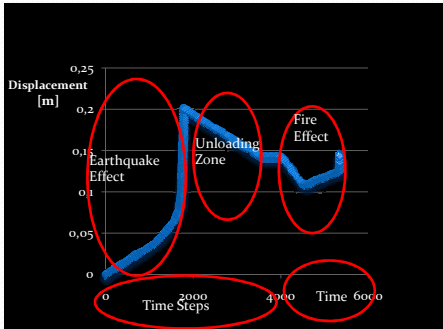
## Methodology of Analysis

- Thermo-Mechanical analysis to evaluate collapse time in FFE scenario.

Schematic Representation of FFE Simulation.



Simulation's effect on a mechanical parameter.



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## Stress Evolution

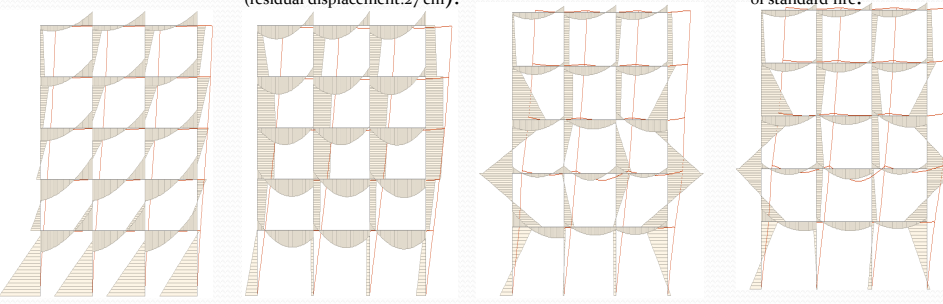
- Bending Moment distribution and associated deformed shapes in a FFE problem.

At generic step of seismic analysis.

At the end of seismic analysis (residual displacement: 27 cm).

After 5 minutes of standard fire.

At collapse after 12 minutes of standard fire.



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## Stress Evolution

-Axial Force distribution and associated deformed shapes in a FFE problem.

At generic step of seismic analysis.      At the end of seismic analysis (residual displacement: 27 cm).      After 5 minutes of standard fire.      At collapse after 12 minutes of standard fire.

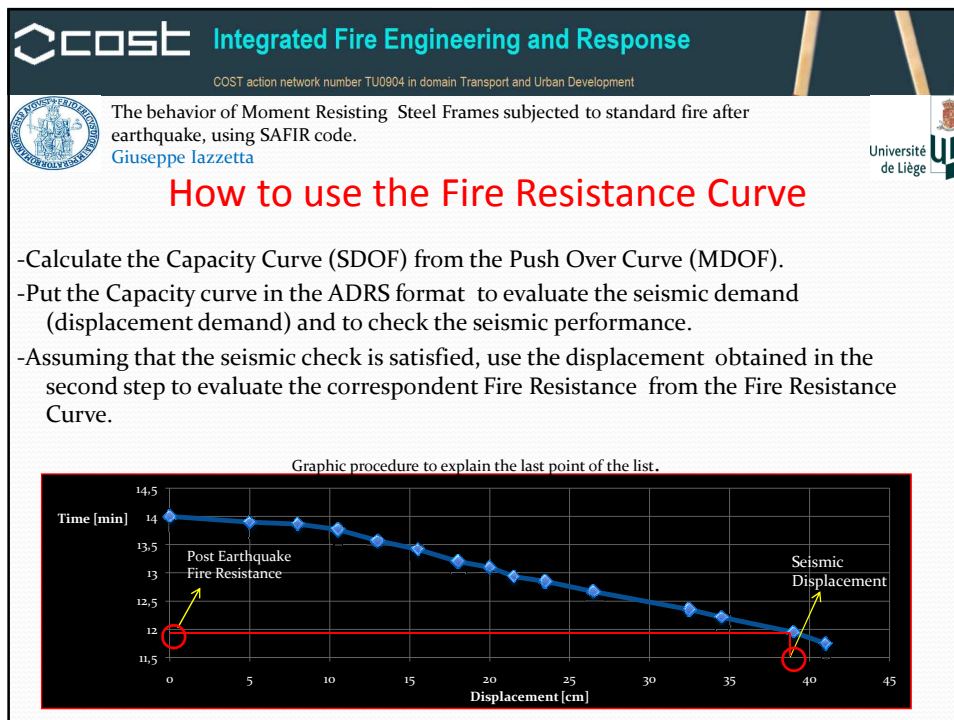
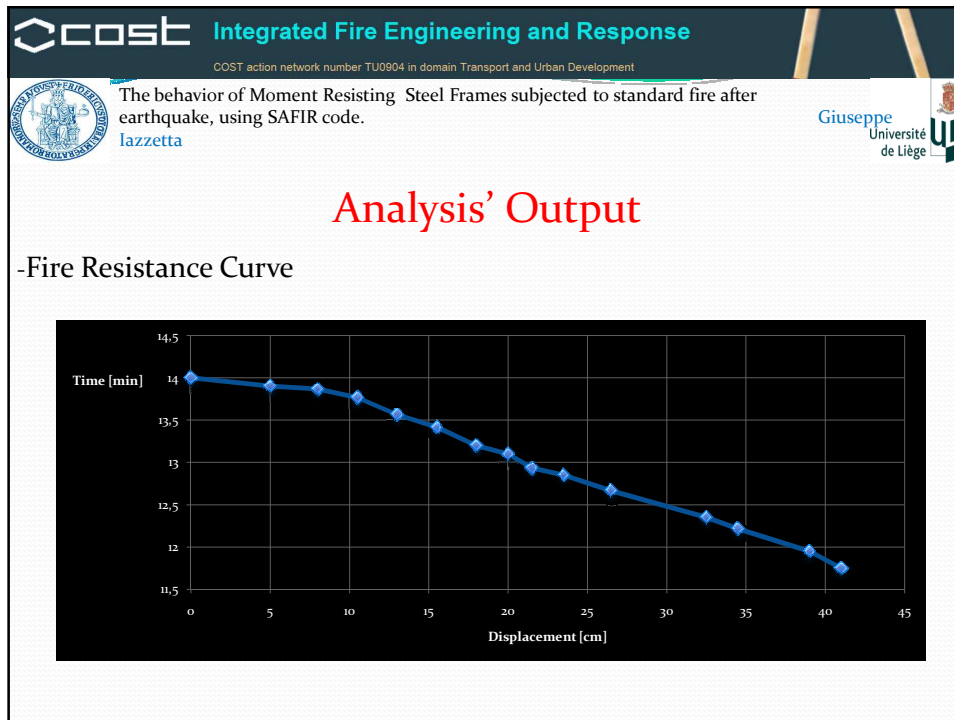
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## Collapse Mechanism

-Collapse deformed shapes and associated failure modes.

Seismic failure mode: GLOBAL      Fire failure mode: LOCAL      FFE failure mode: GLOBAL





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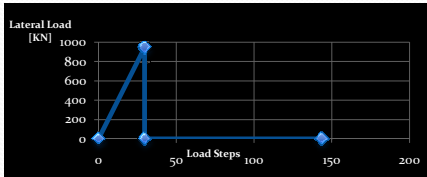
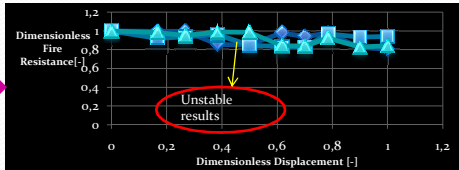
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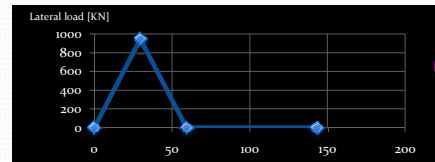
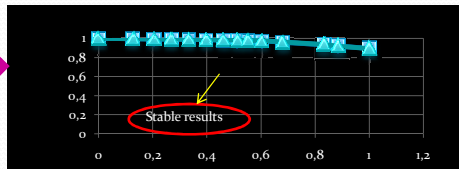
### About SAFIR

-Horizontal load's speed influence on the results' stability.

Lateral load function with instantaneous unload.

Lateral load function with slow unload.

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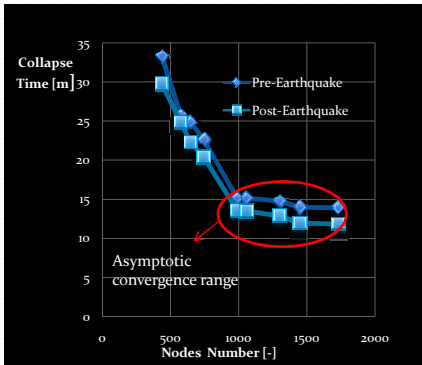
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### About SAFIR

-Mesh Density Influence on the result.

Collapse time as function of nodes' number.



Dimensionless fire resistance curve for three different number of nodes. (ultimate displacement 41 cm)

