20 September 2012: International Workshop
Protecting historic centres during emergencies

The Fire Risk Control effectiveness assessment using correlations, fast running tools and a CFD code in an historic hotel building

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Summary

- **The presentation summarizes the approach followed to assess the fire risk at a multi-storey building of high historical value located in Italy. It includes the adopted fire protection system as well as the results of an analysis finalized to the assessment of the effectiveness of smoke control strategies having the main goal of controlling temperature and visibility to increase the occupants egress safety.**
- **The building is a cultural heritage construction, more than 20 m high, with unique main hall and admittance area, and it is characterized by a central atrium covered by a large ornamental glazed skylight.**

The Fire Risk in City centers and the challenges

- **There is no specific aspect in the fire hazard that may be identified because of the location of a building in the center of an historical city.**
- **The limited possibility to control it, by the intervention of the fire rescue organizations is the key factor when evaluating the risk.**
- **The consequence is that we need buildings that are "INTRINSICALLY SAFE", which means that:**
  - **They protect themselves by a built-in fire protection system**
  - **They allow the safe evacuation of the occupants by granting a given time of control of the smoke spread.**

How to assess it versus the Fire Authorities

- **In the majority of cases the level of safety of a building, especially if used to host people, like an hotel or a meeting centre, must be assessed versus a Fire Authority that shall approve it.**
- **The fire protection system can only be assessed by the conformity to the applicable standards and the approval by recognized organizations.**
- **The Smoke control system can also be assessed by means of an engineering approach that allows to model the smoke movement in a building appropriately.**

The Building Fire Protection System 1/3

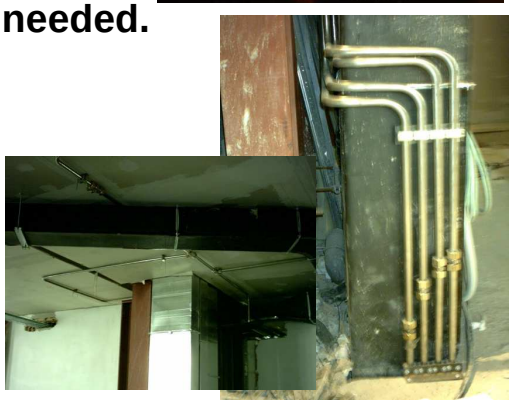
- **The building under examination is protected by a complete fire protection system that will grant the fire to be controlled and possibly suppressed with a minimum intervention from the personnel available in the building.**

- **Should it be a sprinkler system designed and installed in accordance with a recognized standard, using approved components, and properly maintained, there is no problem in providing the required protection.**

The Building Fire Protection System 2/3

- **In some instances a water mist system may be selected as an alternate protection because of space problems and of the possibility of the water mist system piping, especially for the high pressure type, to be bended and shaped as needed.**

- **The water supply is often another reason for selecting a water mist system, being also the few tenths cubic meters of water required for a light hazard application too much for the location of the building.**



The Building Fire Protection System 3/3

- **The water mist system shall follow a different process versus the traditional sprinkler systems.**
- **It shall be designed and installed in accordance with a recognized standard (e.g. NFPA 750).**
- **It shall be fire tested according to a consolidated fire test protocol, and shall be approved.**
- **The ANSI/FM 5560 standard includes a “Light Hazard” fire test protocol that can be suitable for these applications.**

The smoke control system

- **A smoke control system was identified as a mean to control temperature and visibility to increase the occupants egress safety**
  - **In the main entrance atrium**
  - **In the adjoining spaces**
- **Goals: temperature, concentration of smoke and visibility in all the areas included in the scope of the analysis not to affect significantly the safety of the occupants.**
- **Performance criteria:**
  - **Visibility: > 10 m (approx 25 m for light emitting signs)**
  - **Temperature: < 50°C (20°C ΔT from ordinary ambient conditions)**
  - **CO_2 concentration: < 0.5%**
  - **Soot concentration: < 1,3 ● 10-5 kg/m3 (used in calculations with ECART)**
- **Engineering approach including modeling of the smoke movement in a complex building.**

The smoke control system / activities

Working phases	Activities	Means employed
Preliminary	Data acquisition: diagrams and drawings, inspections,... Identification of fire scenarios. Identification of the analysis tools to be used to simulate the fire behavior and the combustion products propagation	
I	Phenomena's physics – mathematical analysis	Correlations (SFPE handbook - BFRL/NIST)
II	Analysis of main safety variables (time effective – several scenarios)	3D well mixed & fast running numerical code (ECART 4w0f vs.)
III	Analysis of main safety variables (slower computation – selected scenarios)	3D CFD numerical code (FDS 4.07)

- **The analysis by correlations was aimed at quantifying the values of the main variables.**
- **The second step, by fast-running & well-mixed type FVM numerical code, was focused on the quick assessment of many fire scenarios, characterized by different inputs and boundary conditions.**
- **The third step was dedicated to the analysis of the design fire scenarios, considered most relevant according to the results of the previous analysis.**

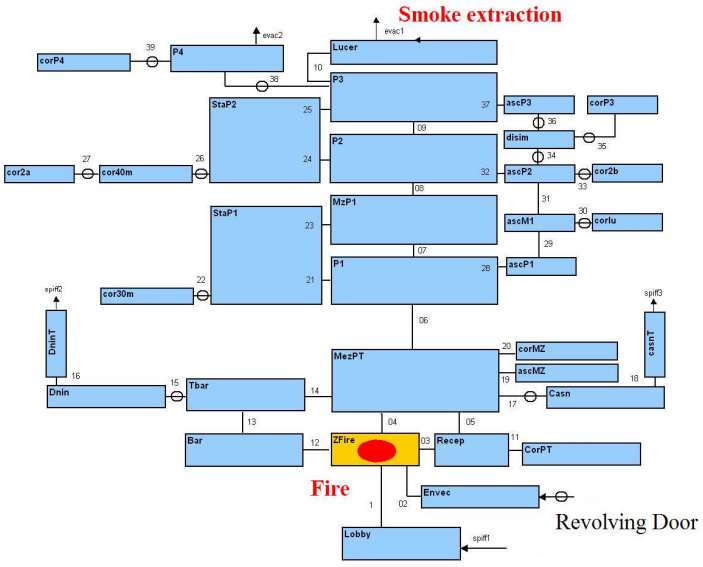
The smoke control system / Numerical tools

Physics-mathematical correlations (SFPE Handbook, NIST, FPEtool): quantification of *max smoke temperature under ornamental skylight, natural convection smoke flow trough ornamental skylight openings, corridor ventilation critical velocity, external window – door – wall forces*.

Fast-running & well-mixed type FVM numerical code (ECART 4w0f): quantification of *temperature, CO_2 and soot concentrations of control volumes*.

CFD FVM numerical code (FDS 4.07): quantification of *temperature, CO_2 and soot concentrations of control volumes*.

The smoke control system / ECART

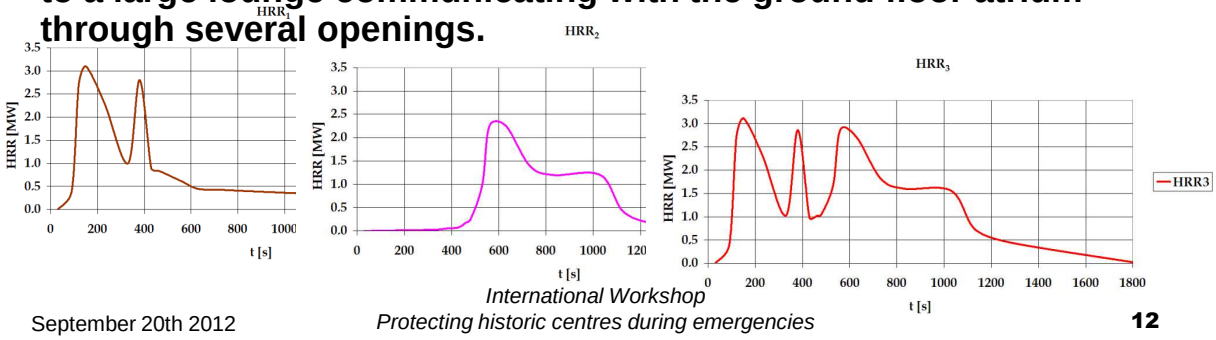


- Development started in 1989
- Originally designed for nuclear safety analysis
- Funded, along the years, by ENEL and Italian Government, with additional scientific and financial supports by UE, EdF, ENEA, University of Pisa, Polytechnics of Milan and Turin
- Presently managed and developed by CESI RICERCA

- Not plant-dependent
- Thermal-hydraulic behavior of the system and its structures
- Simulation of fires, vent systems and sprinklers/water mist systems
- Chemical reactions of airborne species and transport/removal of toxic or radioactive smokes

Fire Scenarios / Design fire

- **The fire scenarios that were analyzed were based on the three types of design fires, that were considered singularly or in combination:**
  - **dresser and travel bags combustion,**
  - **suitcases combustion,**
  - **furniture and furnishings of a guest suite.**
- **The HRR curves were imposed and the combustible material was modeled as equivalent to a set of plastic, wood and textile substances representative of an usual real situation.**
- **The design fires were placed in various areas, including the reception area (ground floor atrium) and in a suite at the first floor, connected to a large lounge communicating with the ground floor atrium through several openings.**



Fire Scenarios / List of runs

Fire cases and protection strategies

Cases	*Descriptions*
1	HRR_1 – C.A. + N.V. - t= 75 s from fire starting
2	HRR_2 – C.A. + N.V. - t= 430 s from fire starting
3	HRR_3 – C.A. + N.V. - t= 75 s from fire starting
1v	HRR_1 – C.A. + N.V. + Orv - t= 75 s from fire starting
2v	HRR_2 – C.A. + N.V. + Orv – t= 430 s from fire starting
3v	HRR_3 – C.A. + N.V. + Orv - t= 75 s from fire starting
3vF	HRR_3 – C.A. + F.V. + Orv – t= 75 s from fire starting
3vFF	HRR_3 – C.A. + F.V.'+ Orv – t= 75 s from fire starting
3vFFF	HRR_3 – C.A. + F.V.($^+$) + Orv – t= 75 s from fire starting
vFFF	HRR=0 – C.A. + F.V.($^+$) + Orv – t= 75 s from fire starting
vFFF'	HRR=0 – C.A. + F.V.($^+$) + Orv – t= 75 s from fire starting (+ Opening of supplementar surfaces to outside)
3v-o	HRR_3 – C.A.+ N.V.($^+$) + Orv – t= 75 s from fire starting
3vFFF-s	HRR_4 (suite 31-32, first floor) – C.A.+ F.V.($^+$) + Orv - t= 75 s from fire starting

C.A.: Closing Activation (floor doors closing to isolate the hotel egress path)

N.V.: Natural Ventilation (smoke and heat exhaust devices 4x1.5 m^2 – external skylight; 1x1.5 m^2 - floor n. 4)

Orv: doors opening (to outside)

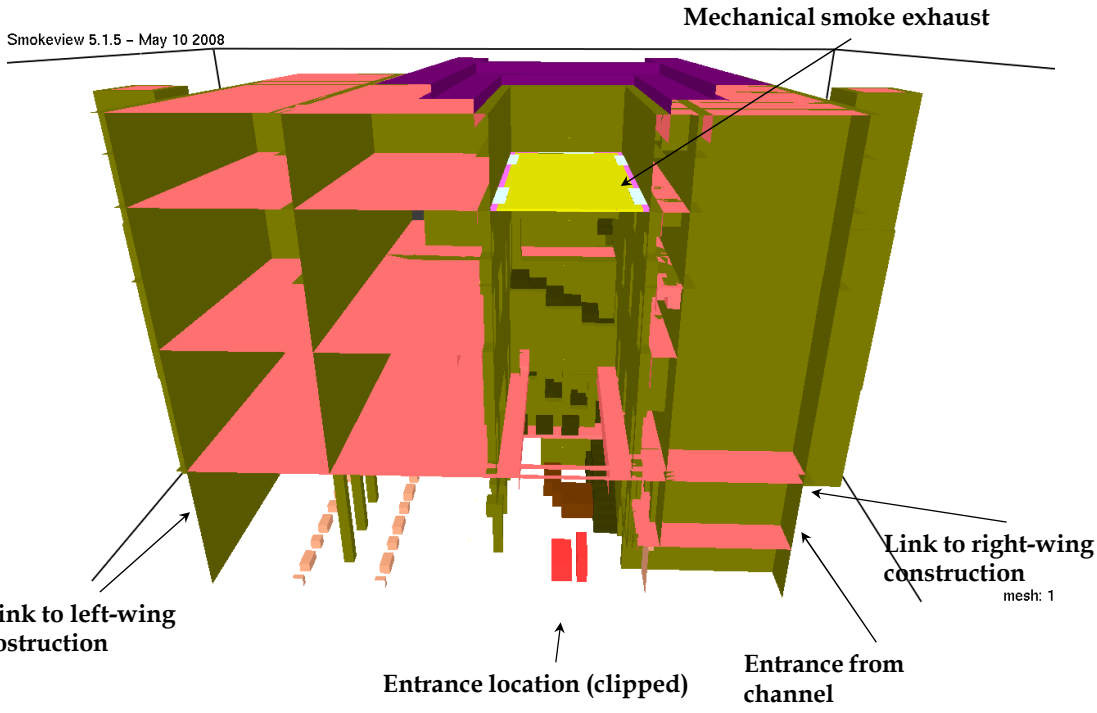
F.V.: Forced ventilation (4 smoke extractors - external skylight)

F.V.': Forced ventilation (1 large smoke extractor - ornamental skylight)

F.V.($^+$): Forced ventilation (6 distributed smoke extractors - ornamental skylight)

N.V.($^+$): Natural Ventilation (smoke and heat exhaust devices 6x4 m^2 - external skylight, 24 m^2 - ornamental skylight)

Fire Scenarios / Geometry



Results 1/3

Fire effects: t [s] from fire starting (FDS)

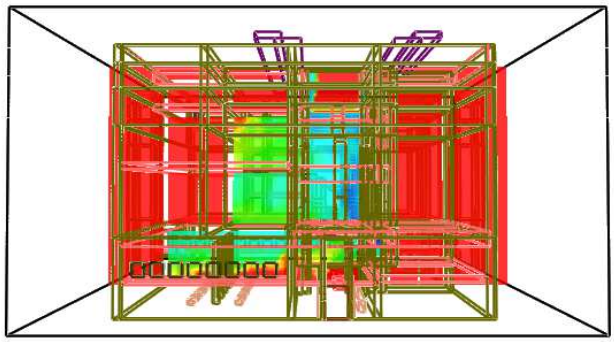
Cases	Reception and Stair PT-PMT [s]	Bar [s]	Entrance-exit [s]	Ground floor corridor [s]
3	320	370	500	460
3v	110	210	250	> 288
3vF	150	~200	~200	~200
3vFF	190	220	250	465
3vFFF	190	230	250	465
3v-o	190	220	130	> 645
3vFFF-s	> 661	> 661	> 661	> 661

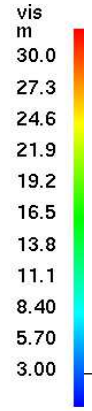
Ground floor

Cases	Corridor [s]	Stair P3-P4 [s]	Lifting hall [s]
3	80	80	80
3v	80	90	90
3vF	80	90	85
3vFF	80	100	100
3vFFF	80	100	100
3v-o	80	80	80
3vFFF-s	220	220	220

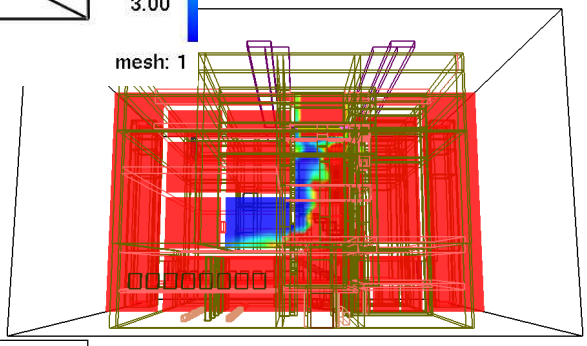
Third floor

Results 2/3





t> 300 s



3vFFF-s

Results 3/3

- The analysis proved the effectiveness of a ventilation strategy based on mechanical smoke exhaust from the central atrium.
- The simulations demonstrated the effectiveness of the ventilation strategy in cases 3vFFF e 3vFFF-s
- In these cases, under the fire scenarios being considered, conditions are such that the occupants can safely egress, provided that a few additional measures are put in place.
- To effectively exhaust the required flow, openings at ground floor are required.
- In the calculations this arrangement has been achieved simulating automatic openings towards the right side of the building, where the building features allowed for modification of existing openings without impact on the heritage building

Conclusions

- **The current fire protection technology allows to provide an adequate level of safety to heritage buildings, especially to those located in historic centres where the immediate intervention of the fire and rescue service is not possible**
- **It is crucial that the performance of the fire protection systems is proven and reliable.**
  - **In general for fire protection systems (such as water based protection systems) this can be achieved if the systems are designed, installed and maintained in conformity to the applicable standards and the approval by recognized organizations**
  - **Additionally, for smoke control systems the fire safety engineering methods provide an invaluable tool, especially when the prescriptive design methods can not be applied to a specific building due to complex geometries or cultural heritage safeguard provisions.**

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Thanks for your attention

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