WG1 meeting – Praha – Czech Republic – 30-31 March 2007

Urban Habitat Constructions under Catastrophic Events:

Fire after earthquake

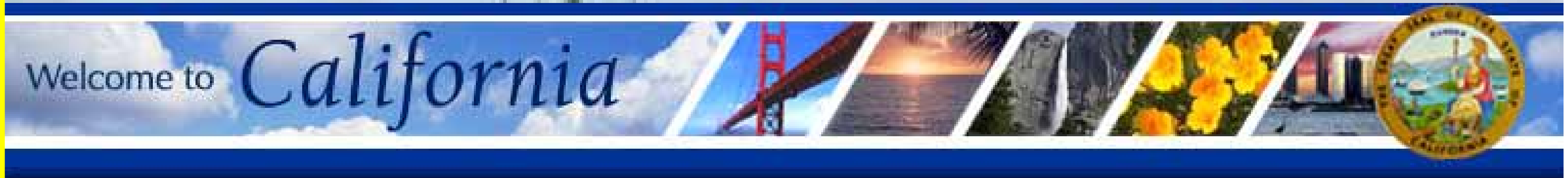
B. Faggiano

University “Federico II” of Naples

Contents:

HIGH RISK of a fire developing after an earthquake:

Guidelines for prevention against earthquakes and safety rules



Department of Conservation

Earthquakes

BE PREPARED:
BEFORE, DURING AND AFTER AN EARTHQUAKE

After an Earthquake

Check for fire or fire hazards.

If you smell gas, shut off the main gas valve. If there's evidence of damage to electrical wiring, shut off the power at the control box.

Contents:

HIGH RISK of a fire developing after an earthquake:

Guidelines for prevention against earthquakes and safety rules

City of Berkeley
Earthquake Home Safety Guide

FAMILY EMERGENCY LIST

PREVENT FIRES

Fires caused by earthquakes are great threats to life and property. During an earthquake, unsecured water heaters can topple or move, causing their gas lines to leak and resulting in an explosion or fire.

ACT NOW:

______ 1. Strap your water heater securely to the wall.
______ 2. Install smoke detectors in several locations. The Berkeley Fire Code recommends a smoke detector in each bedroom and in hallways serving sleeping areas on each floor.
______ 3. Install fire extinguishers in high-risk areas, like the kitchen and garage. Make sure they are easily accessible.
______ 4. Learn the location of utility shutoff points.

- Locate your main gas shutoff valve and obtain a wrench that fits the valve. After a major disaster, shut off the gas immediately **only** if you smell gas, or if you notice the dials on the gas meter turning quickly.
- Locate your water service shutoff.
- Locate your main electricity panel. Shut it off after a quake if you see sparks or broken wires, or smell burning insulation.

______ 5. Move gasoline, other flammable liquids, pesticides, household chemicals, and other hazardous materials to a shed or other ventilated location.
______ 6. Store hazardous materials in unbreakable containers away from sources of ignition.

....

Contents:

HIGH RISK of a fire developing after an earthquake:

Guidelines for prevention against earthquakes and safety rules

Pasadena Fire Department

What to Do After an Earthquake

Look for and extinguish small fires. Eliminate fire hazards. Putting out small fires quickly, using available resources, will prevent them from spreading…

Fire is the most common hazard following earthquakes….

Fires followed the San Francisco earthquake of 1906 for three days, creating more damage than the earthquake.

Contents:

HIGH RISK of a fire developing after an earthquake:

Guidelines for prevention against earthquakes and safety rules

When The Earthquake Is Over

1) *What should I do if I have property damage?*
2) *How will I know if my house is safe to live in after an earthquake?*
3) **What should I do if I have a fire after the earthquake?**
4) *Where can I go to get food and shelter if my house is destroyed?*
5) *Why can't I expect to get any help from emergency services personnel for 72 hours?*
6) *Why shouldn't I use my telephone immediately after an earthquake?*
7) *How can I check on my family after an earthquake?*

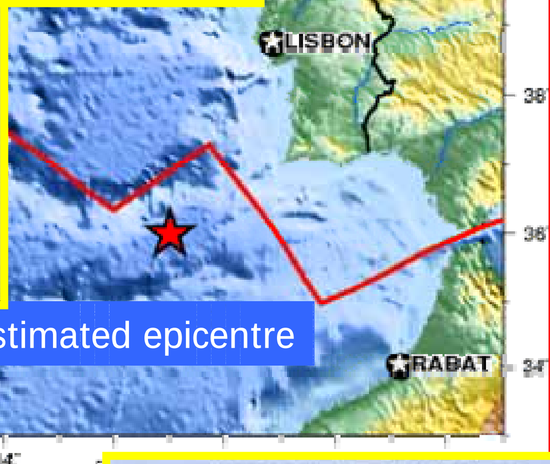
3) What should I do if I have a fire after the earthquake?

Make sure that everyone is out of the house, and then call the fire department (911) from a neighbor's house or by cell phone. If it is a small fire, you may be able to put it out yourself. If you have a gas line going into the home, and a fire in the home, turn off the gas at the gas main if at all possible. ***Keep in mind that there will be many fires and the fire departments may not have enough equipment and personnel to respond immediately.***

Contents:

HIGH RISK of a fire developing after an earthquake:

Lisbon, Portugal, 1755

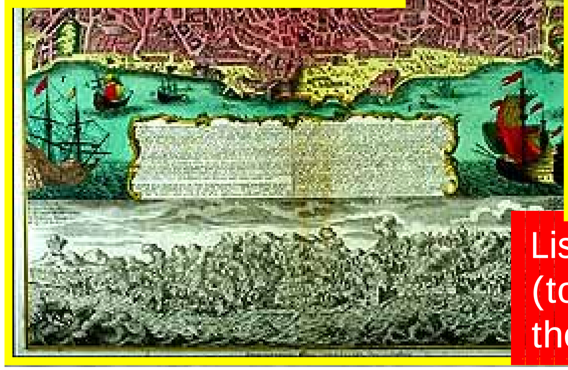


Estimated epicentre

Czech broadsheet

*The **Great Lisbon Earthquake**, was one of the most destructive and deadly earthquake in history, killing between 60,000 and 100,000 people. The quake was followed by a tsunami and **fire**, resulting in the near-total destruction of Lisbon.*

*Contemporary reports state that the earthquake lasted between three-and-a-half and six minutes, causing gigantic fissures five metres (16 ft) wide to appear in the city centre. The survivors rushed to the open space of the docks for safety and watched as the water receded, revealing a sea floor littered by lost cargo and old shipwrecks. Approximately forty minutes after the earthquake, an enormous tsunami engulfed the harbour and downtown, rushing up the Tagus river. It was followed by two more waves. In the areas unaffected by the tsunami **fire quickly broke out, and flames raged for five days.***



Lisbon is shown before (top) and after (bottom) the earthquake

"The Great Earthquake of Lisbon" in the *Illustrated London News* on 1850

Frontispiece from the book by Hartwig (1887)

Contents:

HIGH RISK of a fire developing after an earthquake:

Lisbon, Portugal, 1755

Of a Lisbon population of 275,000, up to 90,000 were killed. Another 10,000 were killed in Morocco. 85% of Lisbon's buildings were destroyed.

THE FIRE

Soon after the earthquake, several fires broke out, mostly started by cooking fires and candles…many inhabitants fled from their homes and left fires burning. Narrow streets full of fallen debris prevented access to the fire sites…..the fire reached catastrophic proportions….The flames raged for five days.

All of the downtown area, from St. Paul's quarter to St. Roch, and from Carmo and Trindade to the Rossio square area to the Castle and Alfama quarters were burned, along with the Ribeira, Rua Nova, and Rossio quarters. Remolares, Barrio Alto, Limoeiro, and Alfama, were partially burned.

Several buildings which had suffered little damage due to the earthquake were destroyed by the fire.

The Royal Palace and the Opera House were totally gutted by the flames. The Patriarchal suffered relatively little damage in the earthquake, and religious services continued there during the afternoon, but the church was evacuated as the fire approached. Later the building was completely burned out….

Contents:

HIGH RISK of a fire developing after an earthquake:

San Francisco, California, USA, 1906

The Bancroft library

The Day Our City Trembled

1906 the rocks snapped six to nine miles below the surface of the earth.....The epicenter was located on the San Andreas Fault at the boundary of San Francisco and San Mateo counties. The magnitude 7.8 earthquake, lasting forty to sixty-five seconds, was not the strongest ever experienced in California, or for that matter, in the United States. But it was the closest to a major population center...

Fire Fighting

Fire in the Western Addition, taken from Lafayette Square. Sacramento and Gough Sts

Jackson Street near Mason Street looking toward the Bay

Contents:

HIGH RISK of a fire developing after an earthquake:

San Francisco, California, USA, 1906

The "Great Fire"…scorched 508 city blocks, or 4.7 square miles, of San Francisco……….April 21, the city still smoked, but the fire was finished…..

Map of San Francisco Showing Burned District

Courtesy of The San Francisco Museum of Modern Art

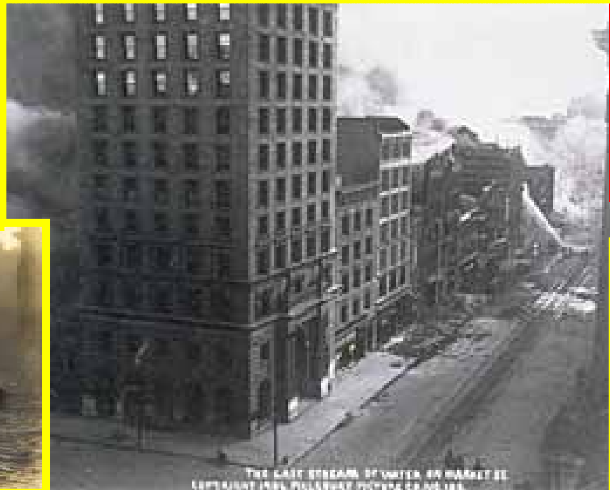
Market Street and the Ferry Building on fire after the earthquake of 1906 in San Francisco

Contents:

HIGH RISK of a fire developing after an earthquake:

San Francisco, California, USA, 1906

The Bancroft library



The last stream of water on Market Street. Lasted five minutes

Dynamiting near the Emporium

A Firestorm From Hell

The unexpected earthquake caused most of the deaths — somewhere between 3,000 and 5,000 people.

Firestorms fed by fierce winds raged for three days in San Francisco and caused the majority of the damage….

The water system's distribution pipes in the city broke, leaving little water with which to fight the many fires that flared up within the first hour. Horse-drawn fire engines sped from one hydrant to another, but frustrated firemen found very little water to pour on the fast-spreading flames. Underground cisterns were tapped for what little water they contained, and a few hoses were coupled together and sucked water from the bay. The hot, dry desert winds blowing from the northeast fanned the flames, whose great heat — exceeding 2,000 degrees — was enough to ***combust the interiors of steel-framed buildings.*** *There was nothing to do but use the only tool that was available, and that was explosives. The extensive dynamiting only spread the flames…The intent was to demolish buildings to create firebreaks that would contain the flames…But perhaps the worst damage was the creation of even more fires as flaming debris ignited ruptured gas lines….*

*…..****the earthquake and fires combined to cause the nations' greatest urban tragedy****.*

Contents:

HIGH RISK of a fire developing after an earthquake:

Northridge, California, USA, 1994

Flowing water from a broken water distribution main mixes with fire caused by a broken gas line. Balboa Blvd. north of Rinaldi Street January

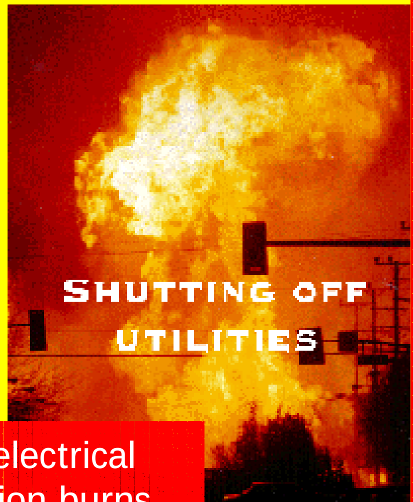


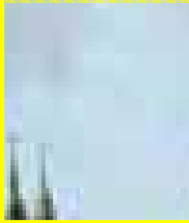
Photo courtesy of Gene Blevins Action Photography (818) 787-7572
Natural gas leaking from a distribution main on Balboa Blvd. ignites following the 1994 Northridge Earthquake

An electrical station burns following the Northridge Earthquake

Contents:

HIGH RISK of a fire developing after an earthquake:

Hyougoken-Nambu, Kobe, Japan, 1995



FIRE

When the earthquake hit, fire broke out throughout the city……… Over 300 fires quickly started, especially among the remains of wooden buildings; these fires were caused by cookers, live electric wires and hot embers from fireplaces.

By the next day, teams of firefighters had arrived from all over Japan, but despite this there were..

at least a dozen major fires that burned for up to two whole days…

before they were brought under control.

Research conducted at the Kobe University suggests that ..

500 deaths were due to fires, and that almost 7000 buildings were destroyed by fire alone.

Fortunately, it rained soon after, otherwise the damage would have been even greater.

Contents:

HIGH RISK of a fire developing after an earthquake:

Hyougoken-Nambu, Kobe, Japan, 1995

URBAN FIRES AFTER THE EARTHQUAKE

1. Fires Following the Great Hanshin Earthquake in K... 2nd Asia Symposium on Fire Science and Technolo...
2. The Performance of Fire Protection of Buildings ag... Awaji Earthquake, HOKUGO Akihiko, Proceedings... and Safety, March 1996 (in English)
3. Spread of Fires Following the Great Hanshin Earthq... Symposium on Fires and Earthquake, May 1995 (in...
4. An investigation on urban fires after The Hyogoken... fires and their burnt areas -, HAYASHI Yoshihiko,I... HASEMI Yuji and TANAKA Takeyoshi, Proceedings of annual meeting, August 1995 (in Japanese)
5. An Investigation on urban fires after The Hyogoken Nambu Earthquake (part 2) -Large Scale Fire and characteristics of the cities-, ITOIGAWA Eiichi, HOKUGO Akihiko, HASEMI Yuji, TANAKA Takeyoshi, HAYASHI Yoshihiko, Architectural Institute of Japan, Summaries of Technical Papers of Annual Meeting 1995, pp.175-176, August 1995.(in Japanese)
6. An investigation on urban fires after The Hyogoken Nambu Earthquake (Part 3) - Fire Spread and fire stopping elements -, HOKUGO Akihiko, ITOIGAWA Eiichi, HASEMI Yuji, TANAKA Takeyoshi and HAYASHI Yoshihiko, Proceedings of annual meeting, August 1995 (in Japanese)
7. An investigation on urban fires after The Hyogoken Nambu Earthquake (Part 4) - Method and Example of On-site Investigation -, HASEMI Yuji, ITOIGAWA Eiichi, HOKUGO Akihiko, TANAKA Takeyoshi and HAYASHI Yoshihiko, Proceedings of annual meeting, August 1995 (in Japanese)
8. Fire Stop Factors of the Urban Fires following the Great Hanshin Earthquake, HOKUGO Akihiko, Manual for Wooden Housing, Kenchiku Chishiki, January 1996 (in Japanese)
9. Investigation into Fires and General Public Behaviors following the Great Hanshin Earthquake (Part 3) - Damages inside the dwellings and human response to stoves in use - , HOKUGO Akihiko, SUZUKI Keiko, NAKADAIRA Kazutaka, IKEHATA Yuka, HAYASHI Hiroaki, KAKEGAWA Syuji, Proceedings of annual meeting, May 1996 (in Japanese)

PAPERS RELATED TO 1995 HYOUGOKEN-NANBU EARTHQUAKE BY BRI STAFF

10. Damage by Fires in Urban Area struck by 1995 Hyogoken Nambu Earthquake, ITOIGAWA Eiichi, The City Planning Institute of Japan, Regeneration of Cities after 1995 Hyogoken Nambu Earthquake -Reports, Proposal, Materials-, pp.81-88, May 1995 (in Japanese)
11. Promotion and Resistant Factors of Urban Fires in an Urban Area after 1995 Hyogoken Nambu Earthquake, ITOIGAWA Eiichi, Architectural Institute of Japan, Architectural Institute of Japan, Materials of the Conference "What are the problems? -From the Experience of Damage of Urban Fire after 1995 Hyogoken Nambu Earthquake- pp.7-12, August 1996 (in Japanese)
12. Urban Disaster Mitigation Problems and Measures for Densely Built-up Area, ITOIGAWA Eiichi, Japan Housing Association, The JUTAKU A Monthly of the Housing, Vol.44, pp.77-11, December 1995 (in Japanese)
13. Measures against Urban Fires, ITOIGAWA Eiichi, Japan Association for Fire Science and Engineering, Post Earthquake Fire in an Urban Area and Measures, pp.35-43, January 1996 (in Japanese)
14. Measures against Urban Fires -Damage by Urban Fires after 1995 Hyogoken Nambu Earthquake and its problems-, ITOIGAWA Eiichi, Shizuoka Prefecture, Building/Urban Disaster Mitigation Problems and Measures against Large Scale Earthquake, pp.35-43, February 1996 (in Japanese)
15. Fires involving single building, HOKUGO Akihiko, An Investigation Report on the fires following the 1995 Southern Hyogo Prefecture Earthquake, Japan Association for Fire Science and Engineering, November 1996 (in Japanese)
16. Damages to the Buildings and the People around Burt Area, HOKUGO Akihiko, An Investigation Report on the fires following the 1995 Southern Hyogo Prefecture Earthquake, Japan Association for Fire Science and Engineering, November 1996 (in Japanese)
17. Graphic database for the fires, HOKUGO Akihiko, An Investigation Report on the fires following the 1995 Southern Hyogo Prefecture Earthquake, Japan Association for Fire Science and Engineering, November 1996 (in Japanese)
18. Damages to the Buildings around Burt Area, HOKUGO Akihiko, Kasai, Vol.47, 2, Japan Association for Fire Science and Engineering, April 1996 (in Japanese)
19. The Performance of Fire Protection of Buildings against the Fires Following the Great Hanshin-Awaji Earthquake, HOKUGO Akihiko, Proceedings of the 5th International Symposium on Fire Safety Science, March 1997 (in English)

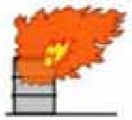
BUILDING RESEARCH INSTITUTE

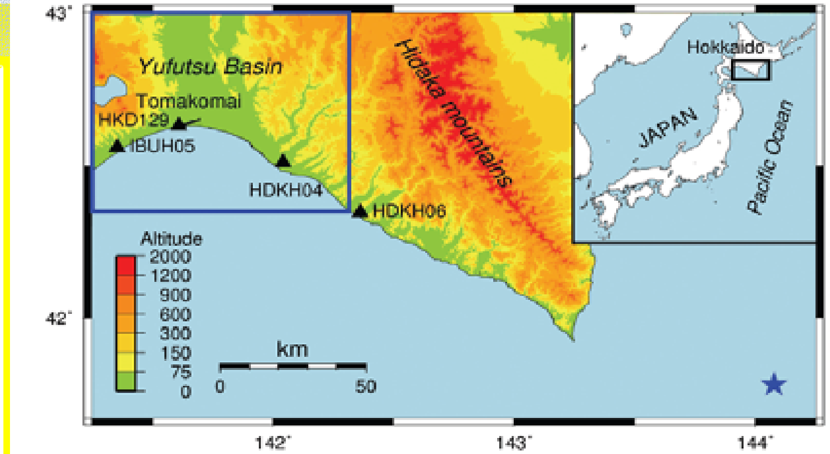
Contents:

HIGH RISK of a fire developing after an earthquake:

Tomakomai, Hokkaido, Japan, 2003

naphtha





▲ **Figure 2.** Index map of the Tomakomai and Hidaka regions in Hokkaido, Japan. The black triangles denote seismometer stations in and around the Yufutsu basin, where strong ground motions from the 2003 Tokachi-oki earthquake were observed. The blue star indicates the epicenter of the earthquake.

Fire of a floating roof tank of crude oil caused due to a large earthquake and full face fire of another floating roof tank two days later

▲ **Figure 1.** Aerial view of the fire in the oil tank damaged by long-period ground motions from the 2003 Tokachi-oki, Japan, earthqua (courtesy of Dr. Hiroshi Koseki, National Research Institute of Fire and Disaster, Japan).

A fire occurred at a 33,000 kL crude oil floating roof tank and attached piping in a refinery at which there was an earthquake with a seismic intensity of lower 6 and a magnitude of 8.
The fire was extinguished after about 7 hours.
Two days after the earthquake, a fire occurred in a 33,000 kl floating roof storage tank containing naphtha, which was damaged by the earthquake. During the earthquake, the floating roof was aunken and naphtha floated above the roof, and ignited…
This was the first fire of its type at a floating roof tank in Japan.
It took 44 hours to extinguish the fire.
There was insufficient foam available, and it had to be collected from whole country……

Contents:

HIGH RISK of a fire developing after an earthquake:

RISKS SOURCES:

Fire in central Kobe

DAMAGE TO:

- **pipelines,**
- **electric wiring,**
- **active and passive fire protection systems,**
- **the building structures**

OPERATING DIFFICULTIES for firemen :

- **obstruction of roads,**
- **multiple fires,**
- **difficulties in water supply**

HOWEVER

Design of structures for fire exposure is outside the scope of the structural engineer's work in the majority of building projects.

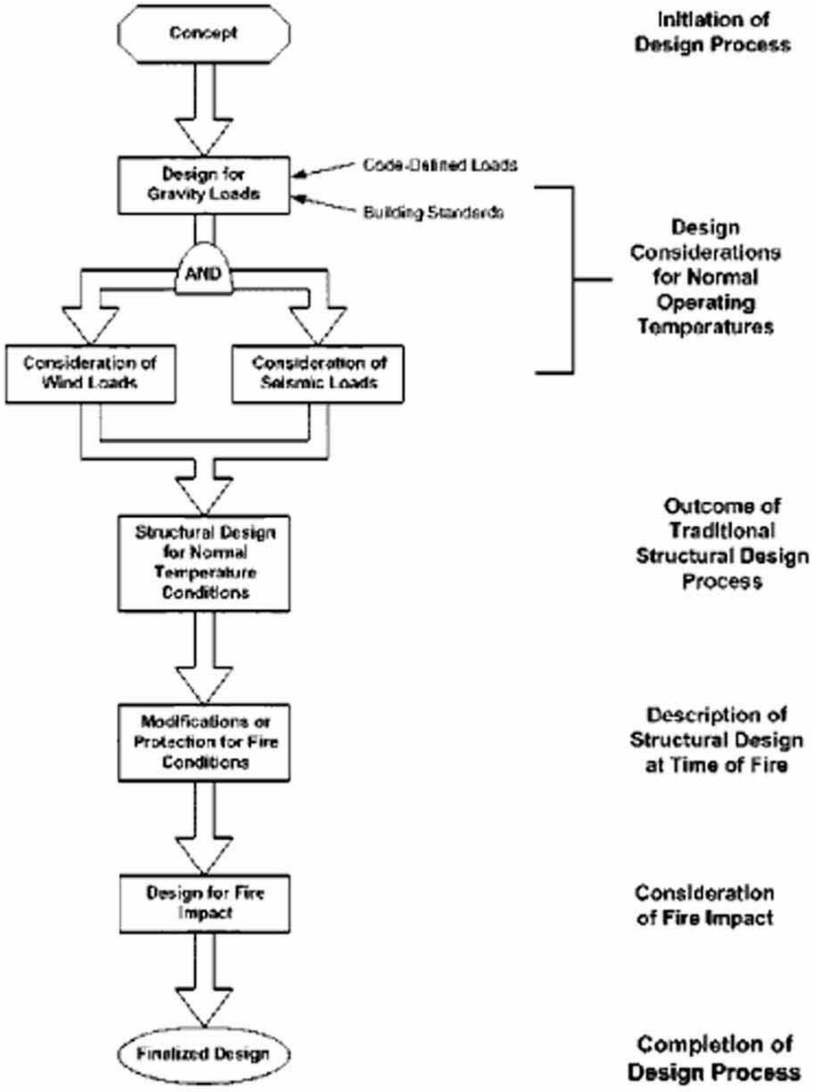
Fire protection engineers are seldom members of building design teams; their participation is limited to exceptional circumstances or unique structures.

Contents:

PERFORMANCE BASED DESIGN APPROACH for Structural Fire Safety

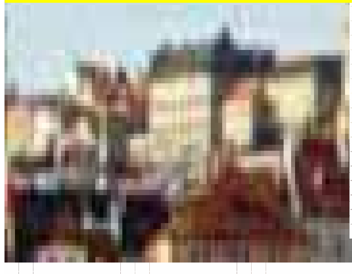
PERFORMANCE BASED DESIGN gives the opportunity to integrating fire safety engineering into the design process for structural framing systems.

International Code (USA, Australia, UK, New Zealand, Sweden and Eurocode) have already adopted performance-based approaches to structural fire safety.



Performance-based structural fire safety Johann et al. 2006

Contents:



PERFORMANCE BASED DESIGN APPROACH for Structural Fire Safety

Structural systems may serve two main functions during a fire event:

1. ***To continue to support loads***
   so that building occupants can exit safely and firefighters have sufficient time to respond and control the fire.

2. ***To serve as a barrier and/or support other barriers to fire propagation***
   - the collapse of a floor could allow a fire on one story to spread into another story.
   - excessive deflection of a floor may contribute to the instability and failure of a partition wall, which could allow the fire to spread into adjacent compartments.

FIRE PERFORMANCE CRITERIA for a structural system may include:

- ***Limitations on member deformation or requirements for serviceability***;
- ***Requirements for load-carrying capacity*** - prevention of collapse;
- ***Time to failure requirements*** - to allow occupant egress and suppression activities;
- ***Fire containment requirements*** - limitations on the impact of a fire on structural members distant from the fire and prevention of room-to-room fire spread.

ASSESSMENT OF A STRUCTURE'S RESPONSE TO FIRE requires the ability to analyze the effects of fires on:

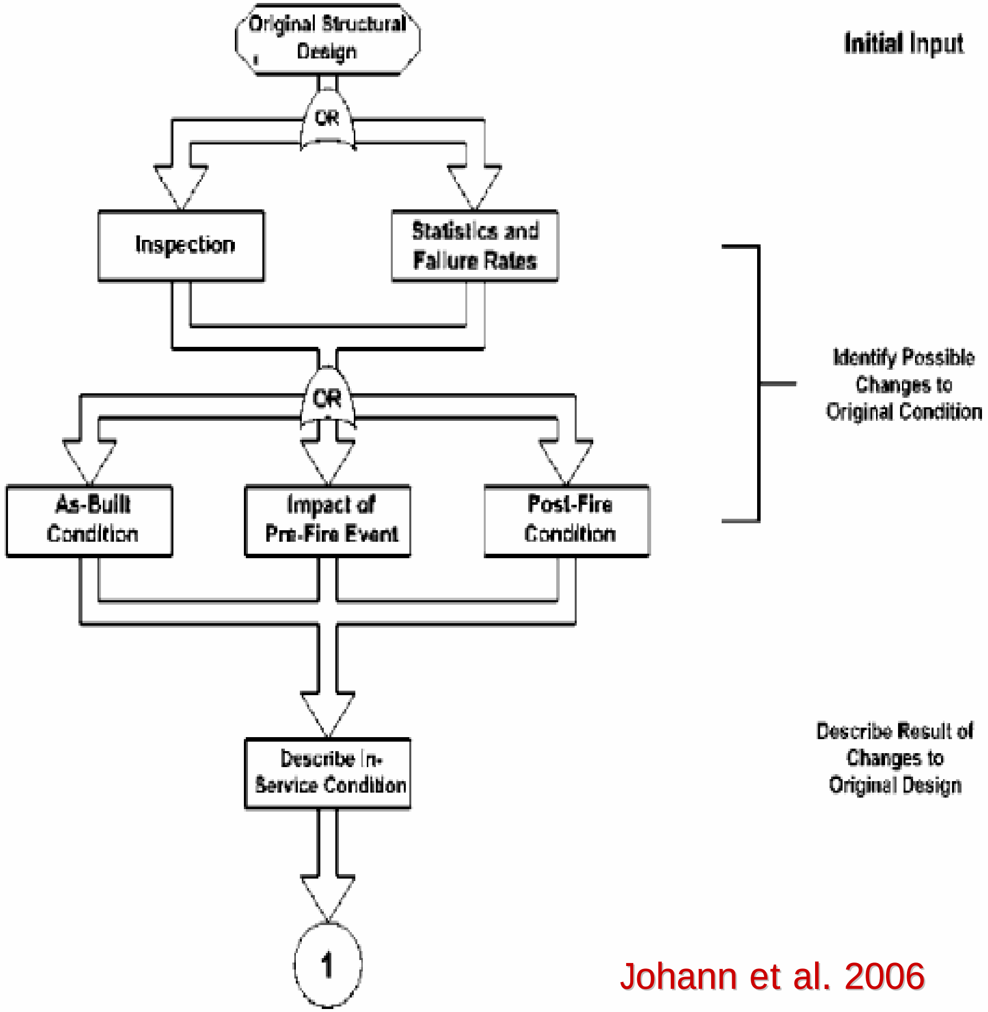
- individual structural members and connections,
- assemblies of members,
- entire structural frames,
- as well as interactions between components.

Contents:

PERFORMANCE BASED DESIGN APPROACH for Structural Fire Safety

CATEGORIES OF STRUCTURAL MODIFICATIONS occurring during the service life of a building to be considered in the design process:

- Passive protection of structural members by adding insulation,coatings, barriers, etc.;
- Differences between the originally specified structural configuration and/or protection and the as-built condition;
- Normal operation and deterioration: rust, corrosion and other environment-related deterioration mechanisms, as well as aspects of building operation that may cause inadvertent damage or long-term wear to structural members or their fireprotective insulation or coatings.
- ***Changes to the structural configuration and/or protection caused by prefire events such as earthquakes, blasts, accidental loss of protective material, etc.;***
- Changes to the structural configuration and/or protection subsequent to a fire.



Johann et al. 2006

Contents:

PERFORMANCE BASED DESIGN APPROACH for Structural Fire Safety

Fire in central Kobe

An important field of study is the development of a systematic approach to address the probability and extent of damage to structural and fire protection elements conditional on different life cycle events.

ASSESSMENT OF POST-EARTHQUAKE FIRE BEHAVIOUR OF STRUCTURES

Evaluation of the effects of earthquake-induced damage on fire resistance and collapse modes:

the more the structural behaviour is degraded after an earthquake the more time up to collapse due to fire is short, and the collapse mode under fire can change as respect to the pre-earthquake one

The theoretical knowledge, empirical information and analytical capability and technology that have been developed in the community of fire protection engineers must be integrated into the structural design process.

SCOPE

Sound design for guaranteeing fire safety of buildings exposed to post-earthquake fire risk

by fitting fire resistance according to prefixed performance levels

Development of a quantitative proposal for both fire-safety and seismic design codes

Contents:

ASSESSMENT OF POST-EARTHQUAKE FIRE BEHAVIOUR OF STRUCTURES

ANALYSIS METHODOLOGY

- **Reproduction of the actual phases of the phenomena, from the application of vertical service loads and earthquake induced damage up to the exposure of the structure to fire**
- **Identification of the seismic damage state, according to pre-fixed performance levels, by means of nonlinear pushover analyses or by non linear time-history incremental dynamic analyses**
- **Analysis under fire of structures already damaged by earthquake, starting from each previously defined performance level**
- **Correlation between the seismic performance levels and the behaviour of corresponding damaged structures under fire in terms of fire resistance and collapse mode.**
- **DEFINITION OF INTEGRATED SEISMIC AND FIRE DESIGN CRITERIA**

Contents:

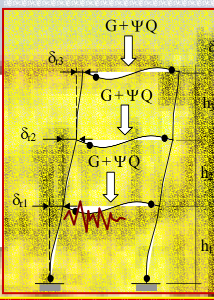
ASSESSMENT OF POST-EARTHQUAKE FIRE BEHAVIOUR OF STRUCTURES

APPLICATION TO STEEL MR FRAMES

Della Corte et al.,2003

Analysis Procedure

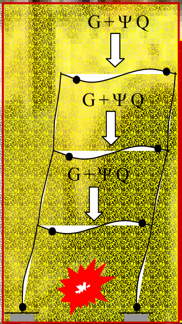
1. Structural analysis under seismic action: damage distribution and extent
   Different acceleration record and multiple levels of earthquake intensities, hence earthquake-induced damage

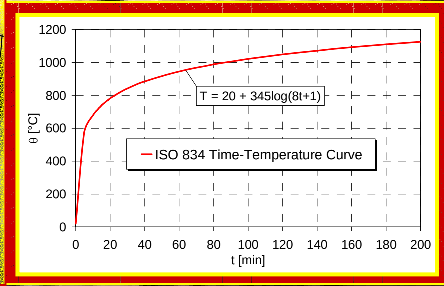


Residual deformed shape of the frame after the earthquake

2. Structural analysis under fire: fire resistance ratings
   According to the chosen thermal program corresponding to a fire event and to the earthquake intensity

   Simplified structural models: *Fire analysis performed on the frame presenting a residual deformed geometry due to damage after the earthquake*





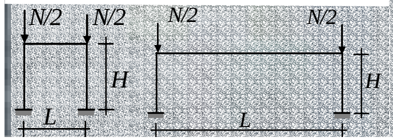
'Standard' ISO Time-Temperature Curve

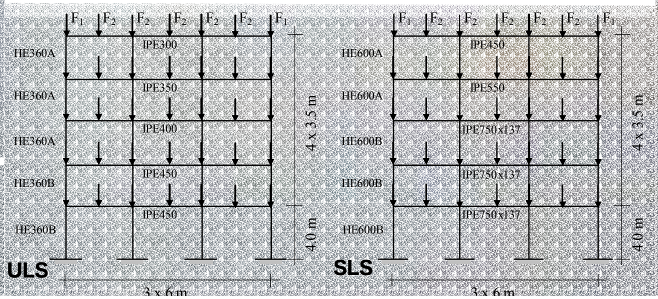
Study cases

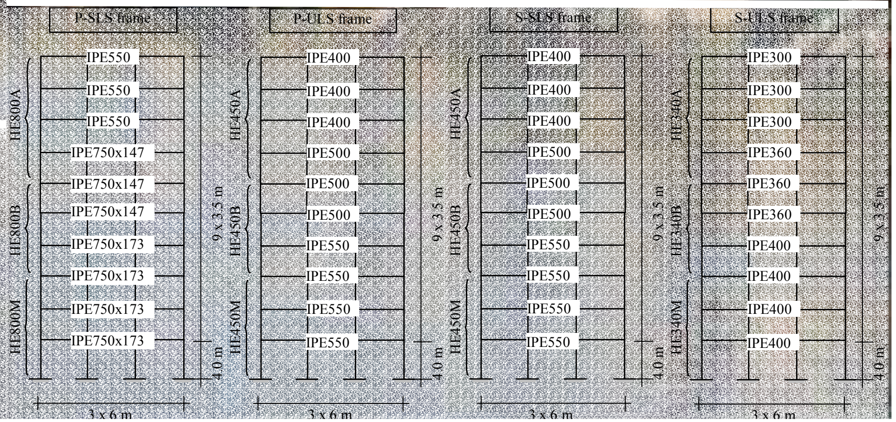
10 Story Frames

5 Story Frames

Portal frames







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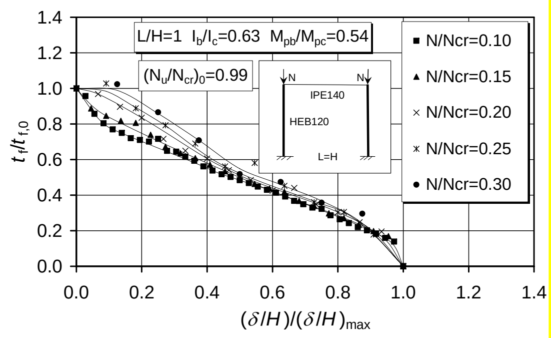
ASSESSMENT OF POST-EARTHQUAKE FIRE BEHAVIOUR OF STRUCTURES

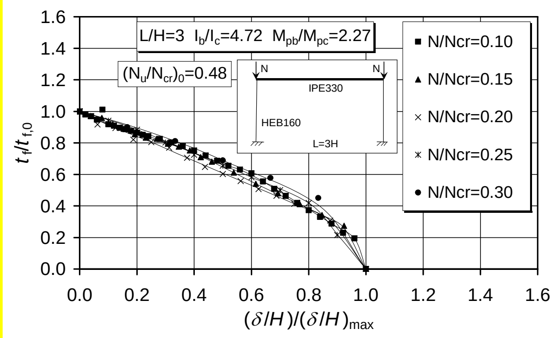
APPLICATION TO STEEL MR FRAMES

Della Corte et al.,2003

SIMPLE PORTAL FRAMES

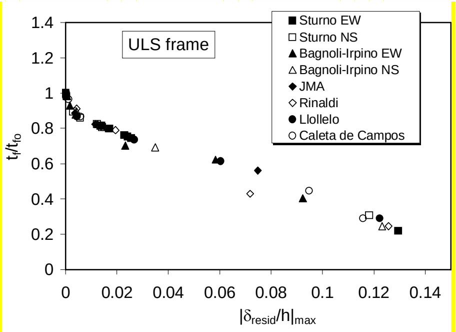
Fire resistance ratings reduction for steel portal frames subject to geometrical damage

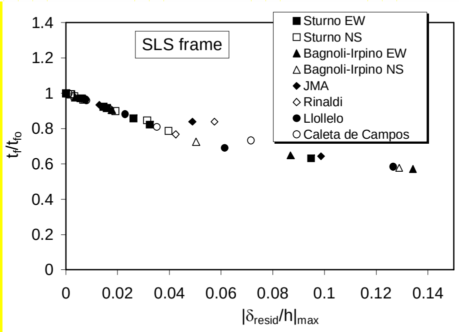




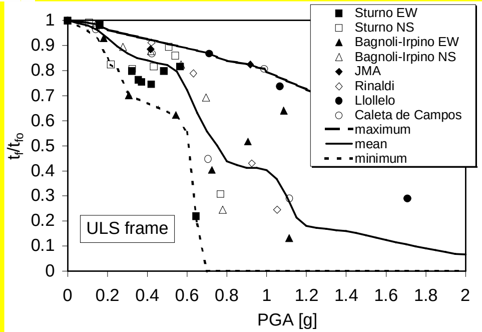
5 STORY FRAMES

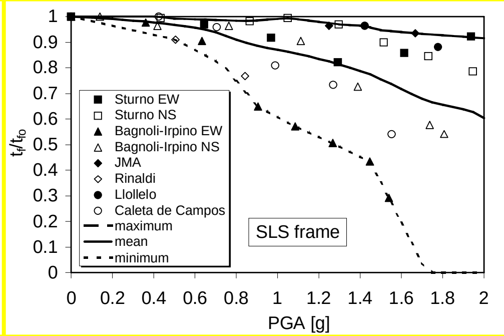
Normalised fire resistance rating vs. the maximum residual inter-story drift angle for ULS and SLS frame





Normalised fire resistance rating vs. site seismic intensity for ULS and SLS frame





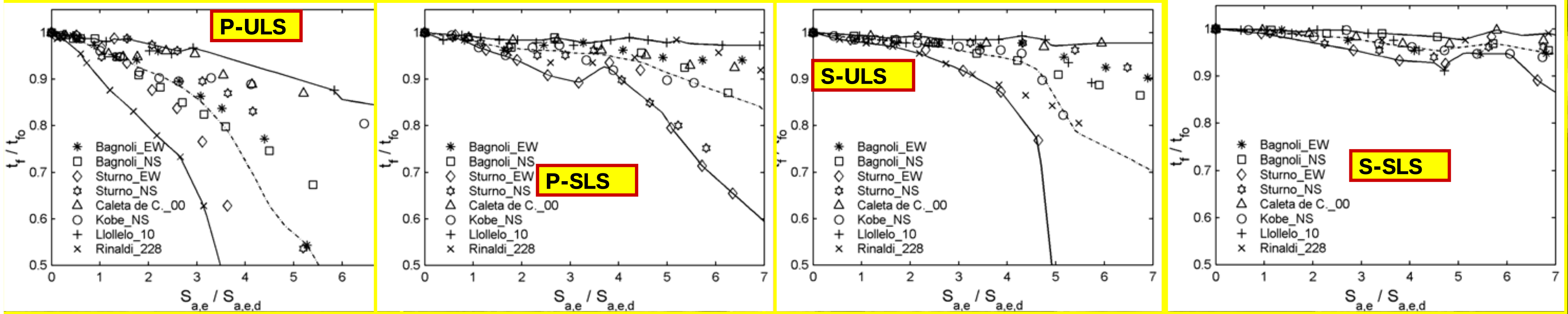
ASSESSMENT OF POST-EARTHQUAKE FIRE BEHAVIOUR OF STRUCTURES

APPLICATION TO STEEL MR FRAMES

Della Corte et al.,2003

10 STORY FRAMES

Normalised fire resistance rating vs. normalized seismic intensity for P/S-ULS and P/S-SLS frame



The type of collapse mechanism

- During the pre-earthquake fires, the undamaged frames collapsed on themselves, without appreciable lateral displacement
- The earthquake-induced damage produces a lateral stability type of collapse mechanism

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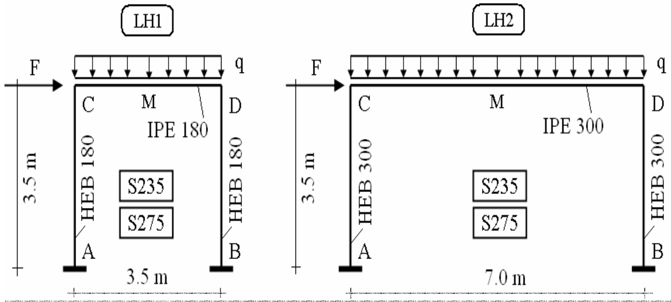
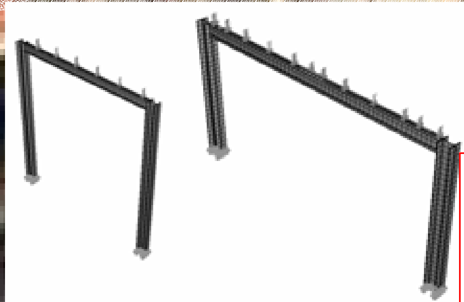
STUDY CASES

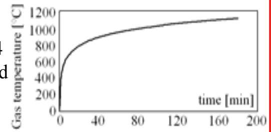


FEM MODELS



FIRE

ISO834 standard curve.

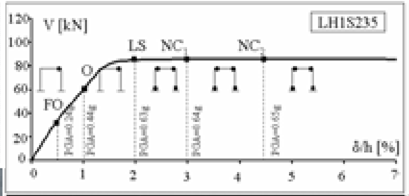


SEISMIC PERFORMANCE LEVELS -PL (SEAOC Vision 2000)

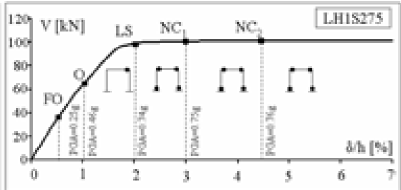
PL	Interstorey drift (δ/h)	Plastic rotations (Θ)
FO	0.002-0.005	0 (elastic range)
O	0.002-0.01	≈ 0 (negligible damage)
LS	0.01-0.02	0.01-0.03
NC	0.02-0.04	0.02-0.05

SEISMIC PUSHOVER ANALYSES Identification of the performance levels (PL).

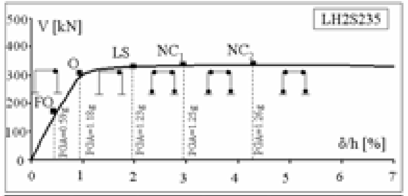
V-d/h (base shear-lateral drift) curves



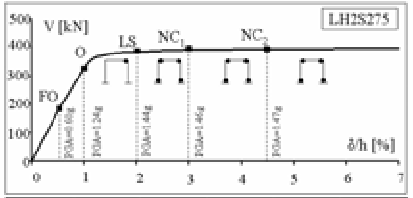
δ/h	0.5%	1 %	2 %	3 %	4.4 %
PL	FO	O	LS	NC_1	NC_2
Θ_{plA}	0	0	0.004	0.018	0.031
Θ_{plC}	0	0	0.007	0.020	0.032
Θ_{plD}	0.002	0.014	0.024	0.039	0.050
Θ_{plB}	0	0	0.005	0.019	0.031



δ/h	0.5%	1 %	2 %	3 %	4.4 %
PL	FO	O	LS	NC_1	NC_2
Θ_{plA}	0	0	0.001	0.013	0.026
Θ_{plC}	0	0	0.008	0.021	0.033
Θ_{plD}	0	0.008	0.023	0.037	0.050
Θ_{plB}	0	0	0.002	0.015	0.028



δ/h	0.5%	1 %	2 %	3 %	4.3 %
PL	FO	O	LS	NC_1	NC_2
Θ_{plA}	0	0	0.010	0.021	0.034
Θ_{plC}	0	0	0.007	0.015	0.027
Θ_{plD}	0.002	0.010	0.026	0.037	0.050
Θ_{plB}	0	0	0.010	0.020	0.033



δ/h	0.5%	1 %	2 %	3 %	4.5 %
PL	FO	O	LS	NC_1	NC_2
Θ_{plA}	0	0	0.010	0.020	0.036
Θ_{plC}	0	0	0.008	0.016	0.030
Θ_{plD}	0	0.007	0.023	0.034	0.050
Θ_{plB}	0	0	0.010	0.020	0.035

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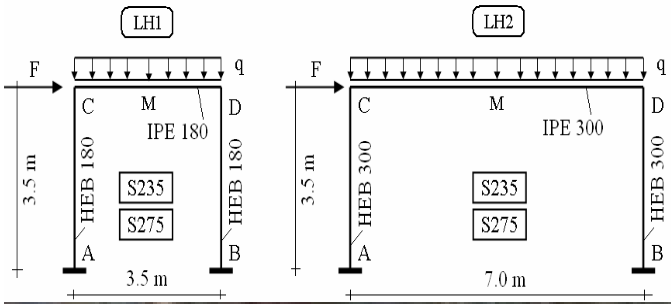
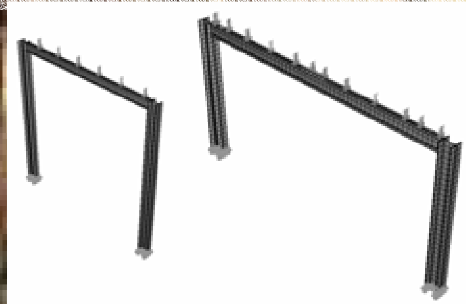


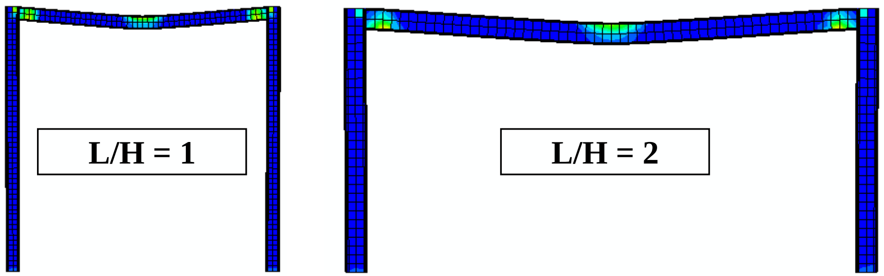
FEM MODELS



L / H=1 Steel grade	PL	R [min]	0.05 beam plastic hinge
S235	FO	14' 24"	M
	O	14' 22"	M
	LS	14' 20"	D
	NC_1	14' 18"	D
S275	FO	15' 20"	M
	O	15' 18"	M
	LS	15' 15"	D
	NC_1	15' 13"	D

L / H=2 Steel grade	PL	R [min]	0.05 beam plastic hinge
S235	FO	15' 23"	M
	O	15' 23"	M
	LS	15' 20"	D
	NC_1	15' 16"	D
S275	FO	16' 10"	M
	O	16' 10"	M
	LS	16' 07"	D
	NC_1	16' 05"	D

FIRE AFTER EARTHQUAKE ANALYSES

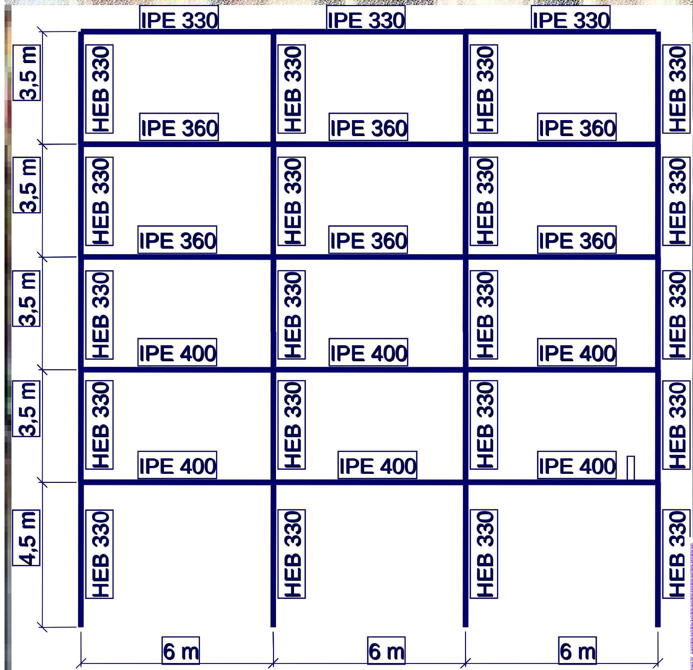


Contents:

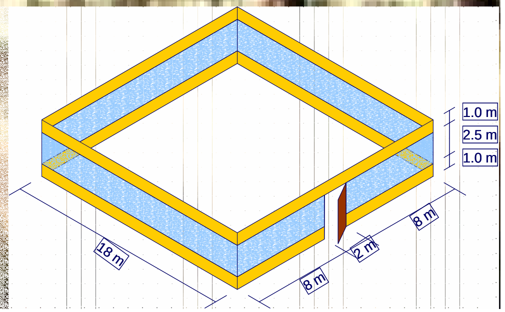
FIRE AFTER EARTHQUAKE NATURAL FIRE CONCEPT

Dan Pintea & Raul Zaharia
“Politehnica” University Timisoara

The Office Building



The fire compartment



The Data

Fire compartment / Fire Area =324 m²
Occupancy: Office
Characteristic fire load density $q_{f,k}$= 511 MJ/m²
Design fire load dens $q_{f,d} = q_{f,k} \cdot m \cdot \delta_{q1} \cdot \delta_{q2} \cdot \delta_n$

	Auto Water Exting.	Indep Water Supply	Auto Fire Detection	Alarm Fire Brigade	Fire Brigade	Access Routes	Fire Fight Devices	Smoke Exhaust	Total
	δ_{n1}	δ_{n2}	$\delta_{n3/n4}$	δ_{n5}	$\delta_{n6/n7}$	δ_{n8}	δ_{n9}	δ_{n10}	δ_n
Before	0.61	0.87	0.73	0.87	0.78	1.0	1.0	1.0	0.26
After	1.0	1.0	1.0	1.0	1.0	1.5	1.5	1.0	2.25

Contents:

- Della Corte, G., Landolfo, R.. Post-Earthquake Fire Resistance of Steel Structures. In E. Zio, Demichela M., Piccinini N. (eds), Safety and Reliability, Towards a Safer World (Proceedings of the European Conference on Safety and Reliability – ESREL 2001), Torino: Politecnico di Torino, 3: 1739-1746, 2001.
- *Della Corte, G., Landolfo, R., Mazzolani, F.M.. Post-earthquake fire resistance of moment-resisting steel frames. Fire Safety Journal, 38 (2003), 593-612, Elsevier Ltd.*
- Della Corte G., Faggiano B., Mazzolani F.M. 2005. On the structural effects of fire following earthquake. In Proceedings of the Final Conference COST C12 “Improving buildings' structural quality by new technologies”, Innsbruck, Austria, 20-22 January 2005.
- *Faggiano B., Della Corte G., Mazzolani F.M., Landolfo R. 2005. Post-earthquake fire resistance of moment resisting steel frames. In Proceedings of the Eurosteel Conference on Steel and Composite Structures, 8-10 Giugno, Maastricht, The Neetherlands.*
- Johann M.A., Albano L.D., Fitzgerald R.W., Meacham B.J. Performance-based structural fire safety ASCE Journal of Performance of Constructed Facilities 20(1):45-53, 2006
- *Faggiano B., Esposto M., Mazzolani F.M., Landolfo R., 2007. Fire analysis on steel portal frames damaged after earthquake according to performance based design. In Proceedings of the Workshop COST C26 action, Prague, RC, March 2007.*