Engineering Mechanics Institute Conference 2022
Baltimore, Maryland | May 31–June 3, 2022

Post-fire Stability and Performance of Tall Steel Buildings

Serdar SELAMET, Associate Professor
Department of Civil Engineering
Boğaziçi University

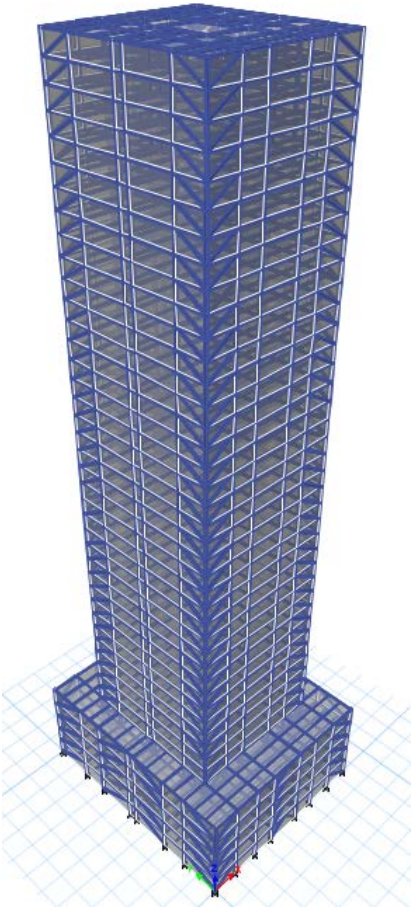
BOUNFIRE Research Group

1 June 2022

Boğaziçi Üniversitesi 1863 — 150TH YIL | YEAR

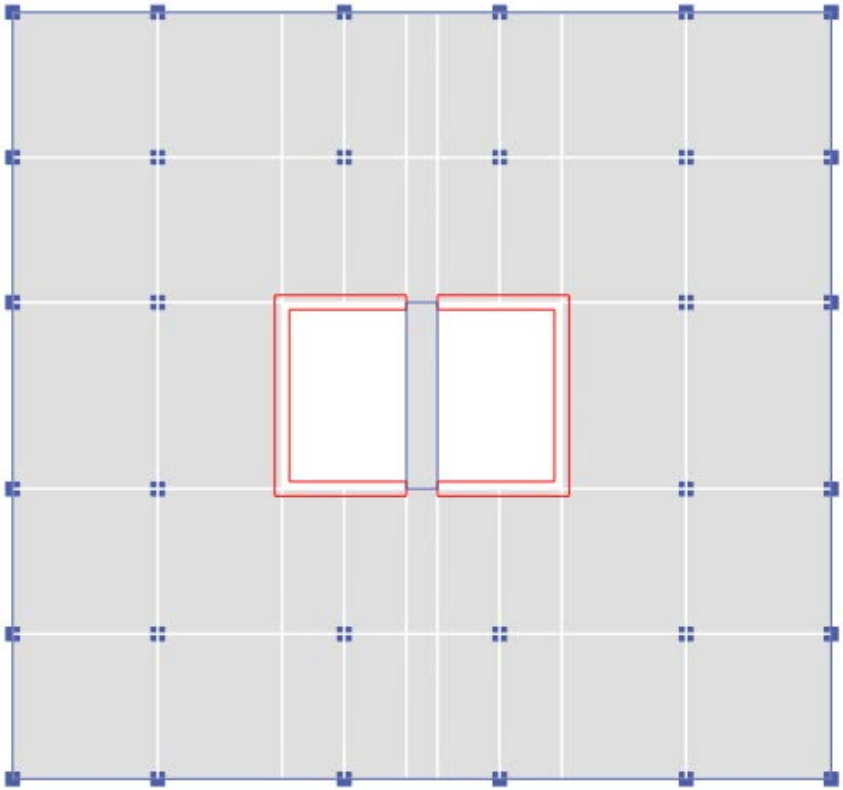
Background and Motivation

- Fire poses a high risk for the structural integrity of tall steel buildings.
- The case study is 42-story steel building with a concrete core designed as a residential building. The structure has 960m^2 floor area with 154m total height.
- The building is subjected to 2 fire scenarios spreading to 3 of the lower floors.
- Subsequently, the building is subjected to Design Level Earthquake.
- Permanent deflections and loss of stifness after fire may cause a change in the dynamic characteristics of tall steel buildings and affect the seismic performance.



Floor Layout

Structural



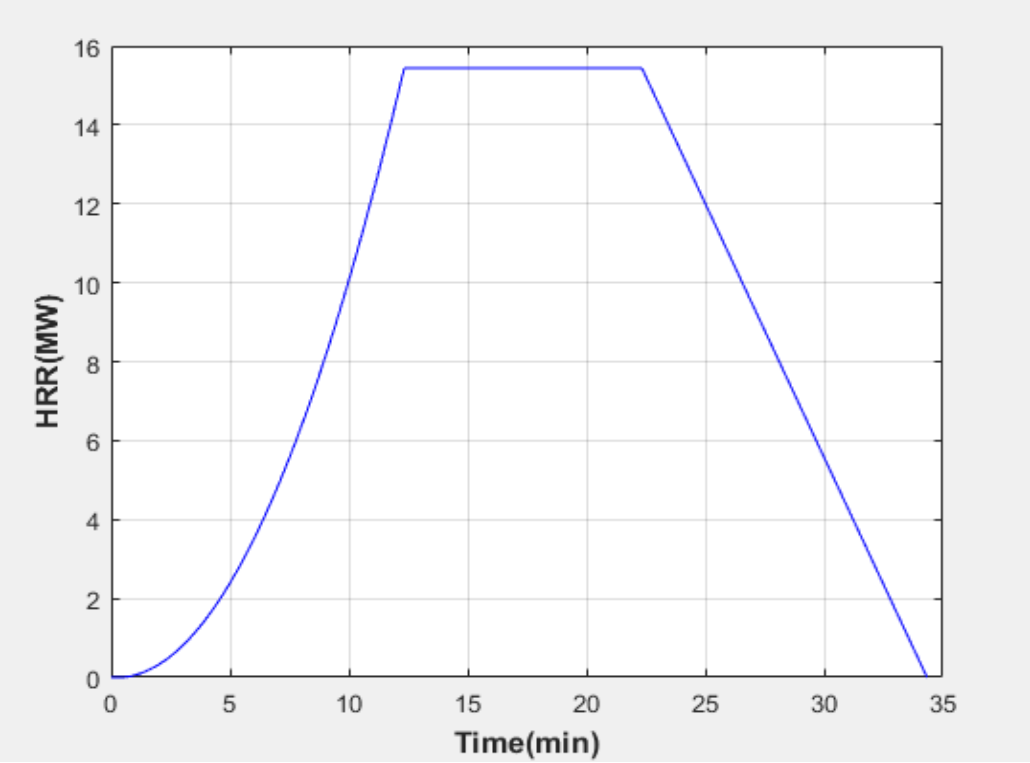
Architectural

Fire Scenarios

Two fire scenarios are investigated using Fire Dynamics Simulator (FDS). The fire starts in the living room and allowed to spread to the other regions in the apartment.

- SCENARIO A - Eurocode 1-1-2 [EN 1991] fire load estimation in dwellings (780 MJ/m^2) with medium fire growth rate.

HEAT RELEASE CURVE

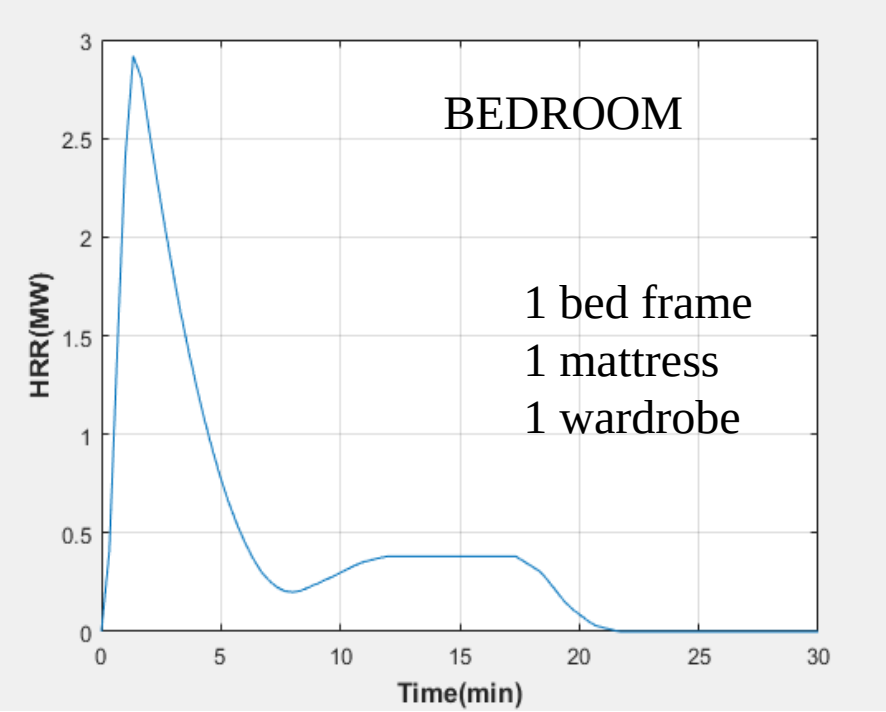


Fire Scenarios

Two fire scenarios are investigated using Fire Dynamics Simulator (FDS). The fire starts in the living room and allowed to spread to the other regions in the apartment.

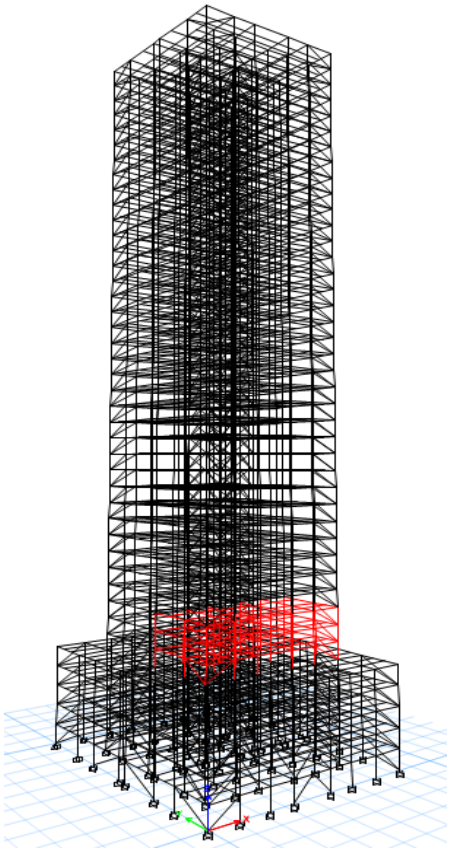
- SCENARIO B - Fire load is estimated from surveys of commonly used combustible items in modern residential apartments. **166 MJ/m^2** for living room, **81 MJ/m^2** for bedroom.

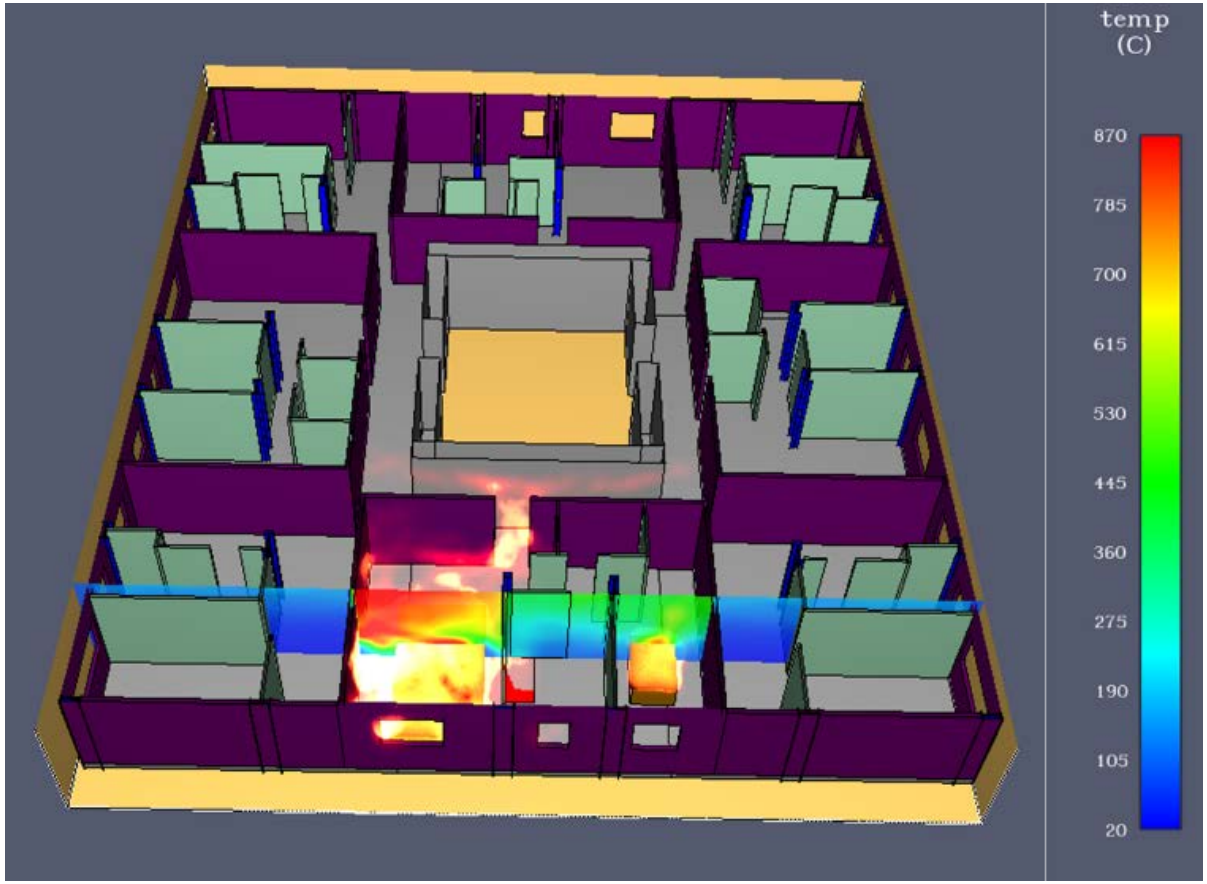
HEAT RELEASE RATE CURVES



FDS Results

Half of the floor areas of 6th, 7th and 8th consecutive floors are subjected to gas temperatures in 600-900ºC range. The vertical fire spread from floor-to-floor is assumed as 5 minutes.

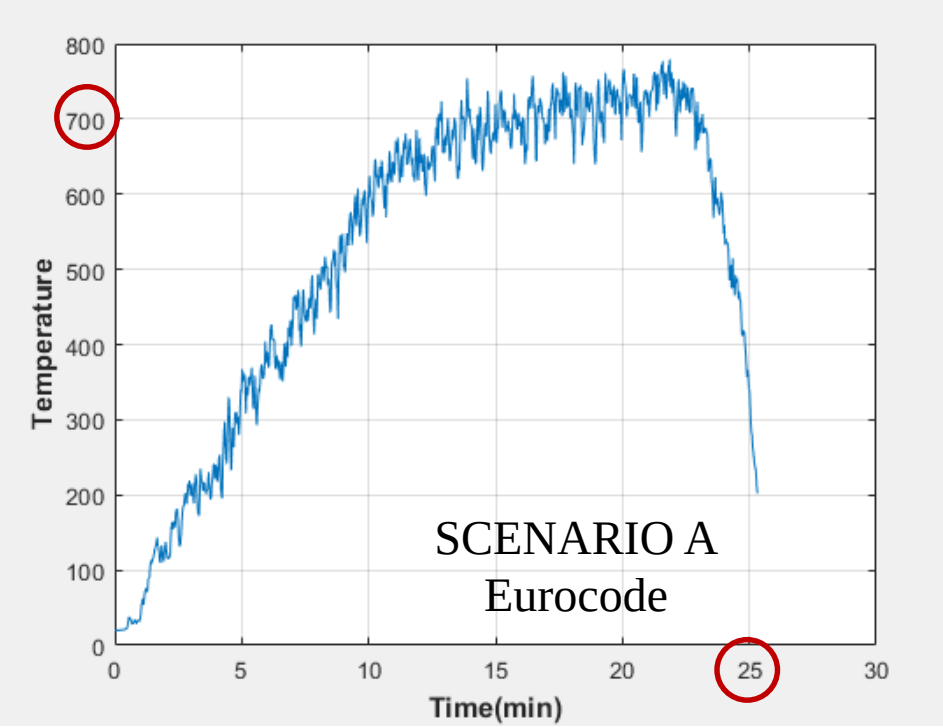


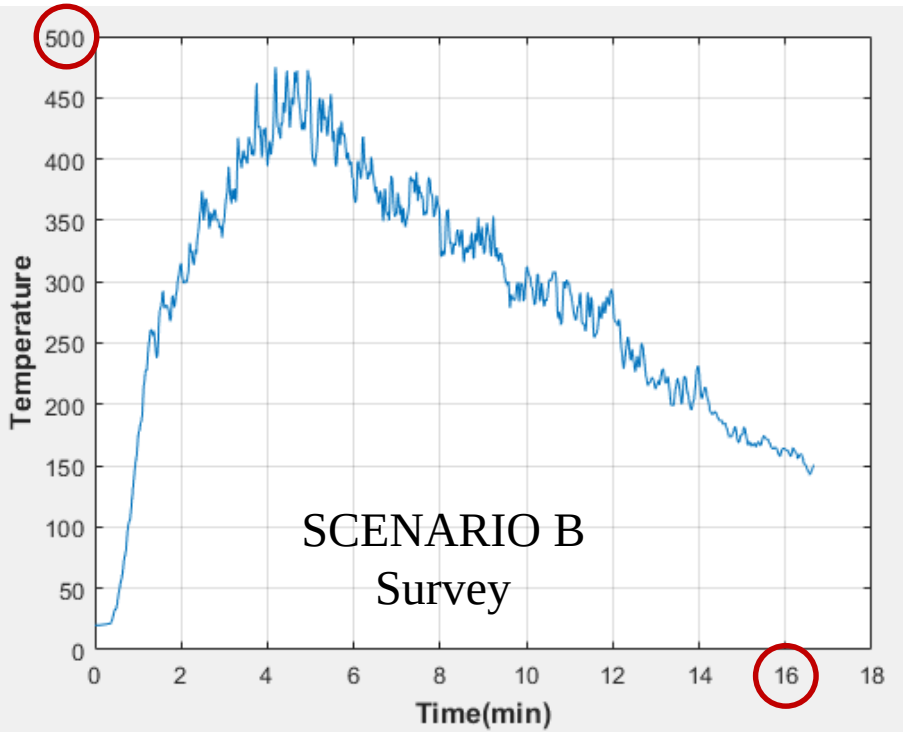


Typical fire development in the apartments

FDS Results

The maximum temperatures in internal columns ranged from 500 to 700ºC.





Internal column temperatures

Earthquake Scenario

11 ground motions are selected for **Design Level Earthquake** with 475 years of return period.

Search parameters: magnitude range 6.3~7.3; fault rupture distance 15~55 km

Earthquake Name	Record Station	Scale Factor	Magnitude Mw	Rrup (km)
Darfield - New Zealand (2010)	LPCC	1.07	7.00	25.67
Tottori – Japan (2000)	SMNH10	1.18	6.61	15.59
Darfield - New Zealand (2010)	CSHS	1.64	7.00	43.60
Chi Chi – Taiwan (1999)	CHY086	2.03	6.20	33.66
Chi Chi – Taiwan (1999)	TCU138	2.28	6.2	33.57
Chi Chi – Taiwan (1999)	CHY042	2.33	6.2	34.13
Tottori – Japan (2000)	OKYH07	2.38	6.61	15.23
Hector Mine (1999)	Hector	2.86	7.13	50.42
Duzce – Turkey (1999)	Lamont 1060	3.33	7.14	25.88
Landers (1992)	Twentynine	4.44	7.28	41.33
Kobe Japan (1995)	Chihaya	4.87	6.9	49.91

Post-fire Earthquake Response

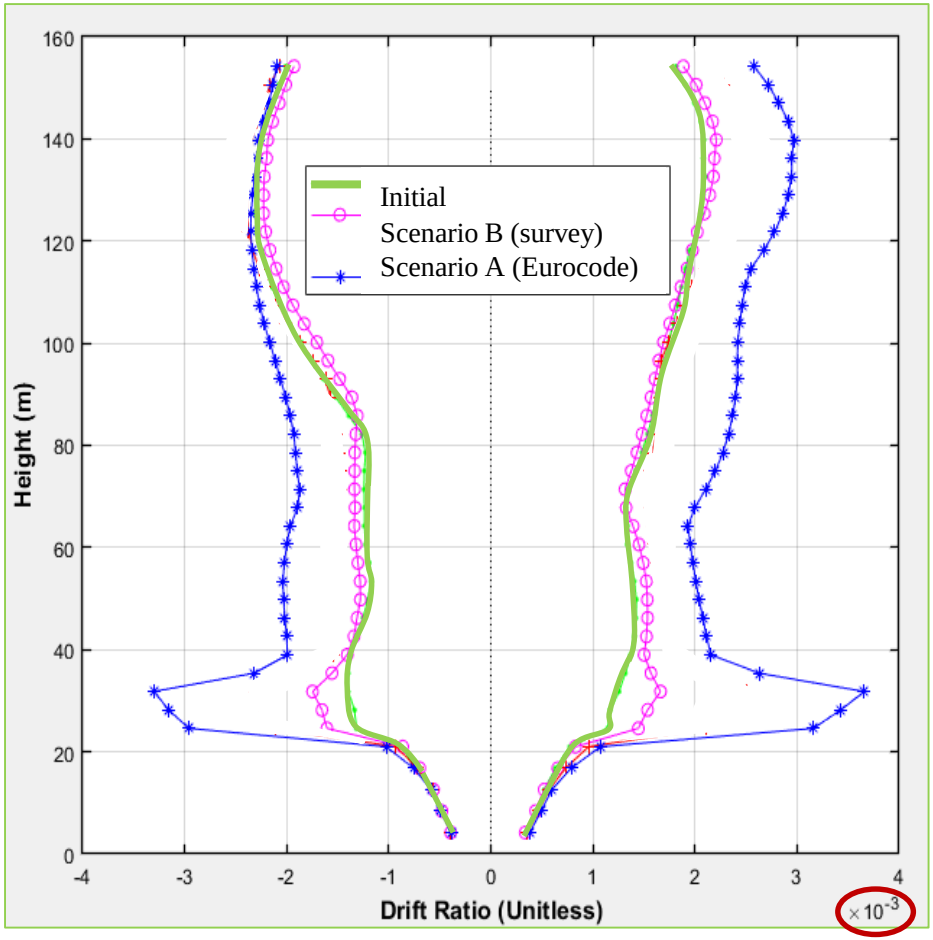
The inter-story drift ratio is considered as as the key response parameter and significant cause leading to damage of buildings during earthquake ground motion.

Post-fire modal response of tall building

Case	Period (sec)		
Mode	Before fire	Floors 6-8 Scenario B (max 500°C)	Floors 6-8 Scenario A (max 700°C)
1	4.65	4.74 (+2%)	5.13 (+10%)
2	4.64	4.73 (+2%)	5.08 (+9%)
3	3.32	3.38 (+2%)	3.57 (+8%)

Acceptance criteria for inter-story drift ratios according to FEMA 356.

	Limit State		
Structural system	Collapse Prevention	Life Safety	Immediate Occupancy
Moment frames	5%	1%	0.7%
Braced frames	2%	0.5%	0.5%



Max. inter-story drift ratio along the bldg. height (Hector Mine)

Conclusion

- The temperature dependent change in the modal properties and earthquake response of the case study tall building are investigated.
- Two fire scenarios are developed for Eurocode (780 MJ/m^2) and Survey method (166 MJ/m^2 living room, 81 MJ/m^2 bedrooms).
- Dynamic characteristics of the tall building changes under given fire scenarios in the earthquake response due to permanent deflections, loss of stiffness and strength of internal columns.
- When the fire spreads to 3 consecutive floors (6th, 7th and 8th) with a peak temperature range of 500-700°C, the period of the tall building in the first 3 modes increases up to 10%.
- The inter-story drift ratio of the tall building is in the maximum range between 0.3% to 0.4%. The structure remains below the immediate occupancy threshold of 0.5% by FEMA 356 and thereby, it has satisfactory post-fire performance for Fire Scenario A (Eurocode) and Scenario B (Survey).

THANK YOU.

- QUESTIONS?

Serdar SELAMET, Ph.D.
Associate Professor
Department of Civil Engineering
Director of BOUNFIRE Research Group
(http://www.structuralfire.com)
Istanbul, Turkey
serdar.selamet@boun.edu.tr
GSM: +90 533 239 1254