Fire Codes: Application & Reliability

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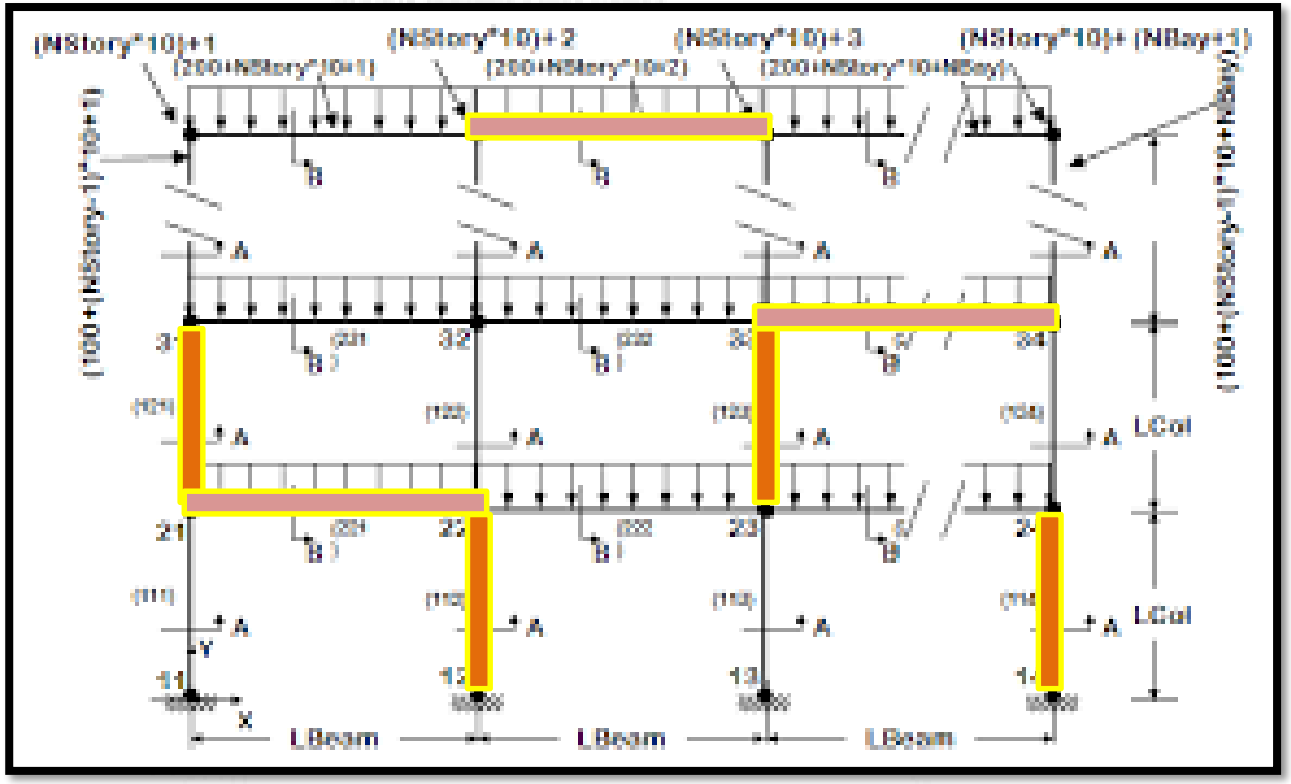
Prescriptive-based versus performance-based codes

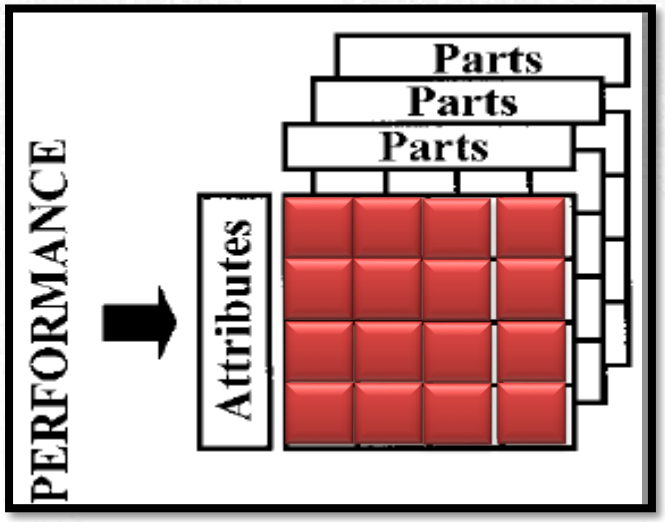
- Over the history of building codes, two different paradigms have emerged, signifying profoundly different approaches to form and function.
- Building codes are often classified as either prescriptive- or performance-based in the nature.
- The history of performance-based codes is rather short as they have become accessible in more than two decades whereas the prescriptive-based codes have a long history in contrast.
- The performance-based codes have not yet fully be promoted due to significant number of limitations.
- Employing prescriptive-based fire codes, it is easy to use what is explicitly mentioned by regulations.

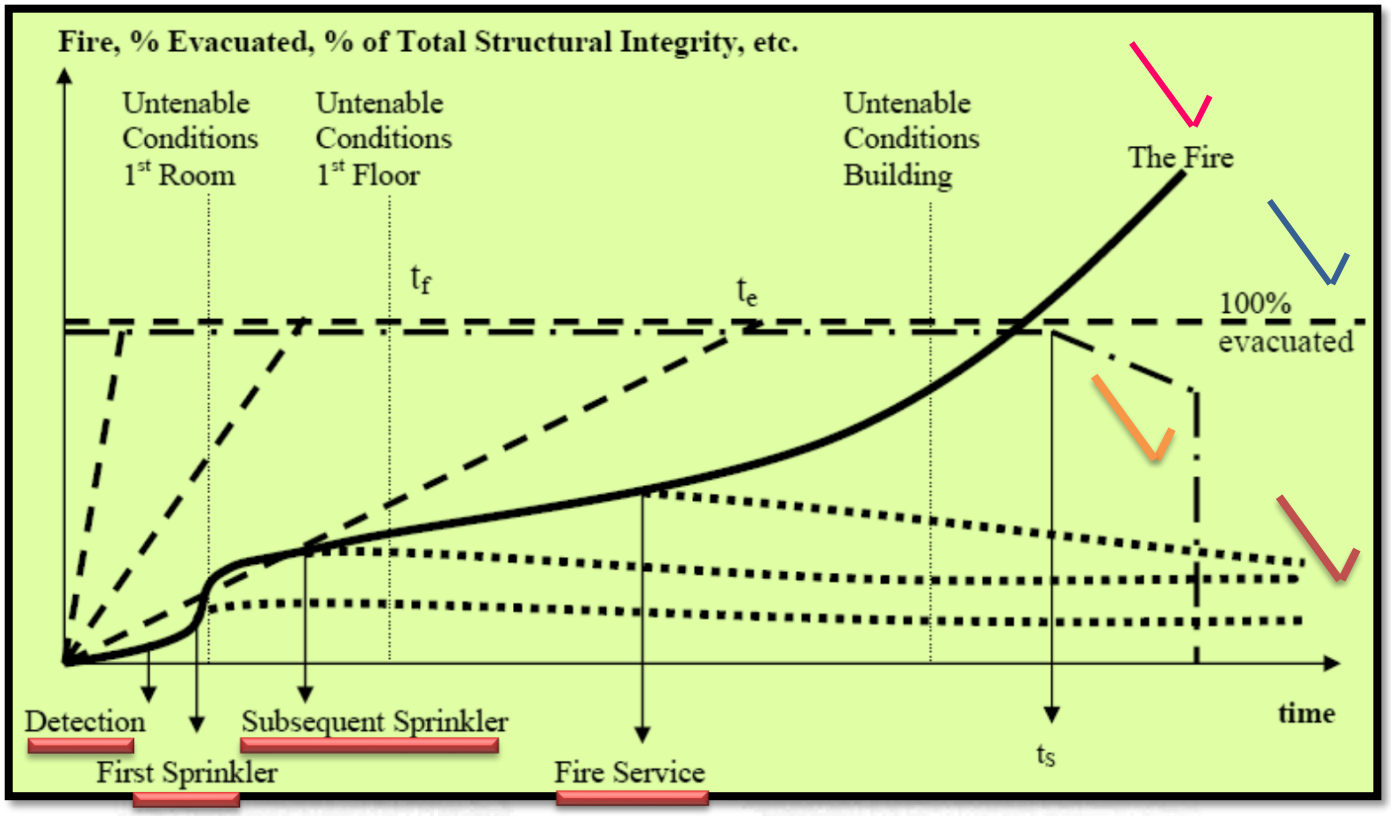
- Assume that a three-story structure has to be fireproofed- regardless of the required fire resistance rating (FRR).
- Using a prescriptive-based fire code, every single element has to have the required FRR, meaning that the structural elements are working independently



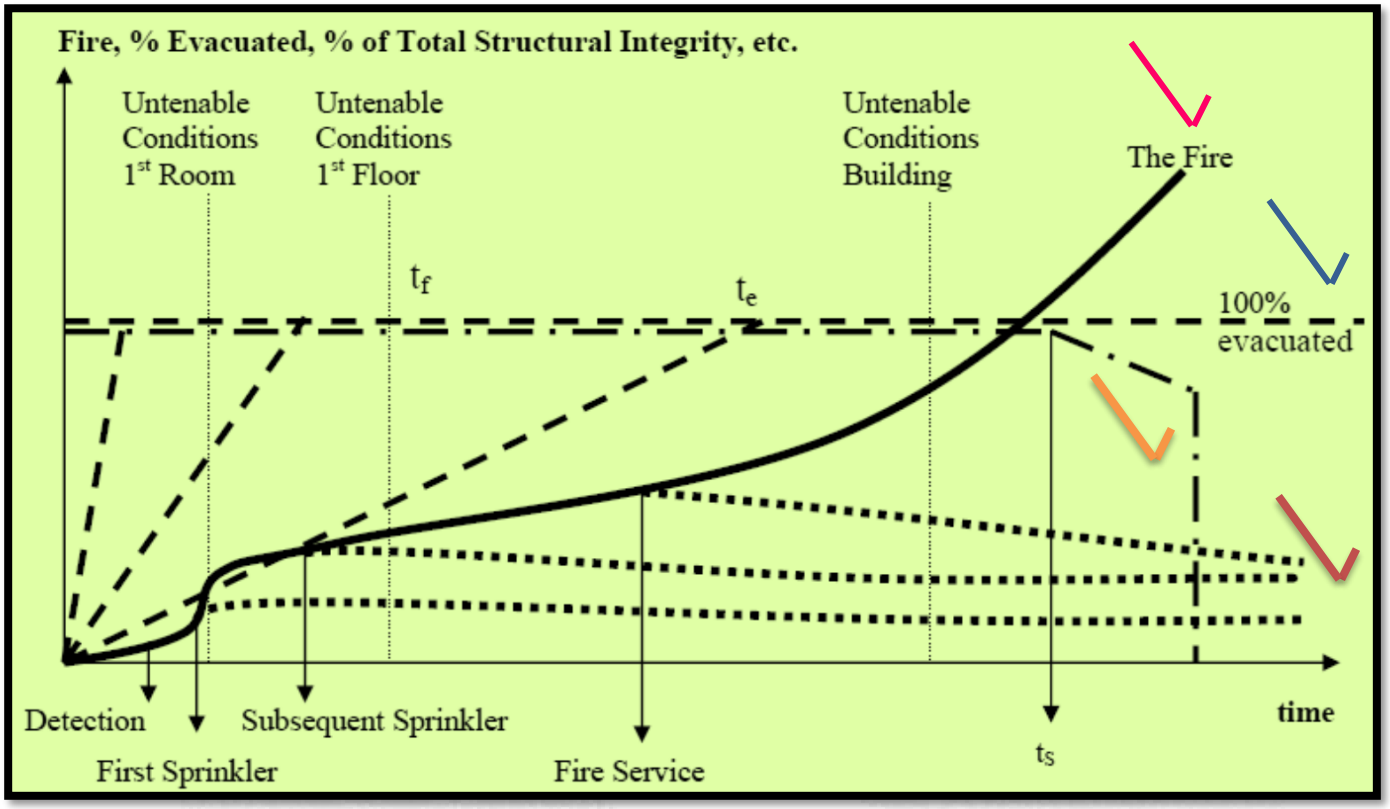
Performance-based codes, advantages

- Construction requirements are specified according to defined performance criteria in an explicit manner.
- In other word, in performance-based codes, the performance is targeted rather than the attributes and the methods.
- Using performance-based codes, there will be more flexibility in design and most likely reduction in unnecessary construction costs.





- The thick line corresponds to the “fire size,”
- The dotted lines to the possible outcome of the different forms of intervention (sprinkler activation, fire service).
- The dashed lines are the percentage of people evacuated, with the ultimate goal of 100% represented by a horizontal dashed line.
- The dashed & dotted line corresponds to the percentage of the full structural integrity of the building.



Time to evacuation (te);

Untenable conditions in the particular compartment (tf); $t_e << t_f$

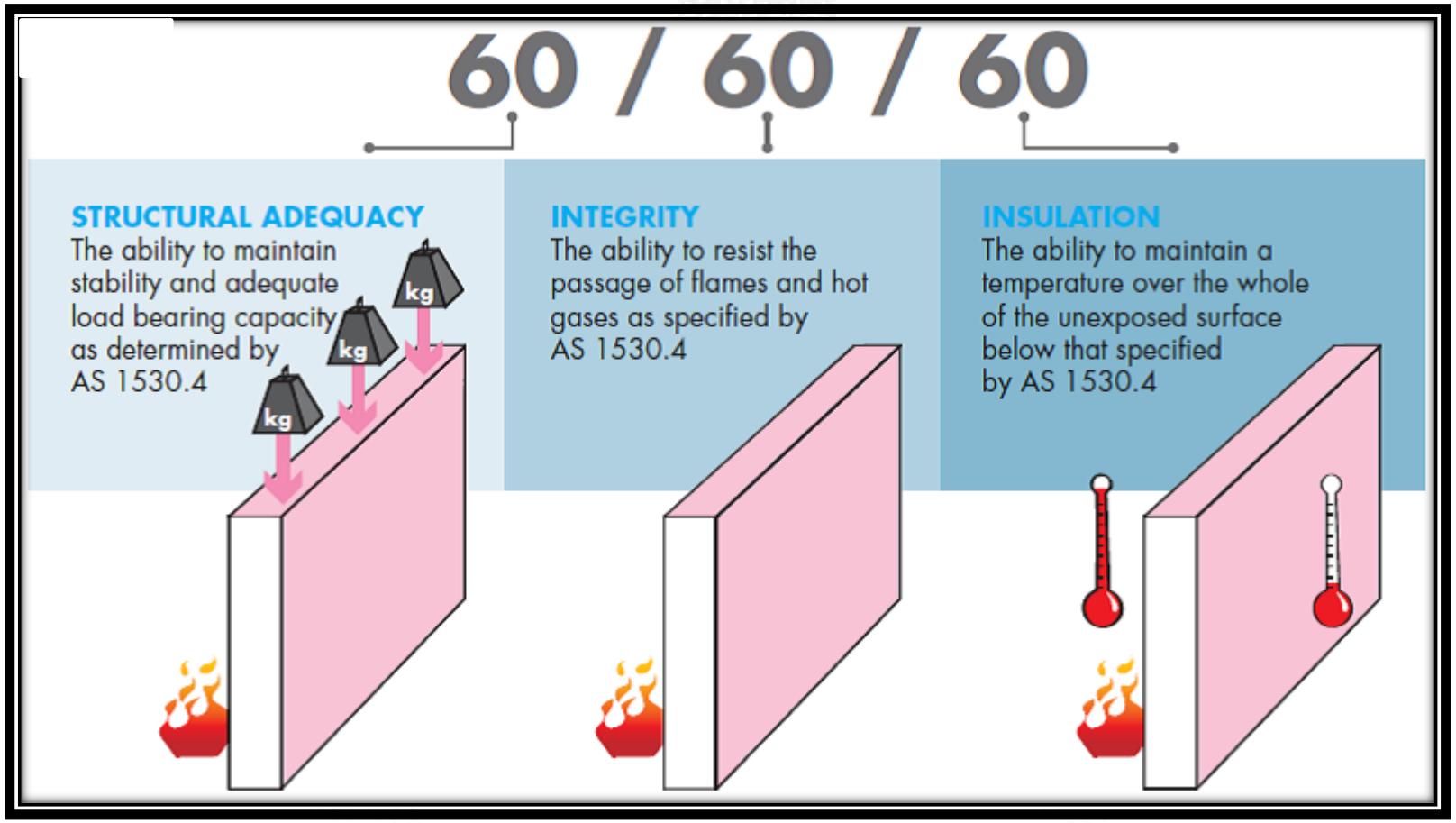
The time when structural integrity starts to be compromised (ts). $t_e << t_s$

Application of prescriptive-based fire codes in building industry

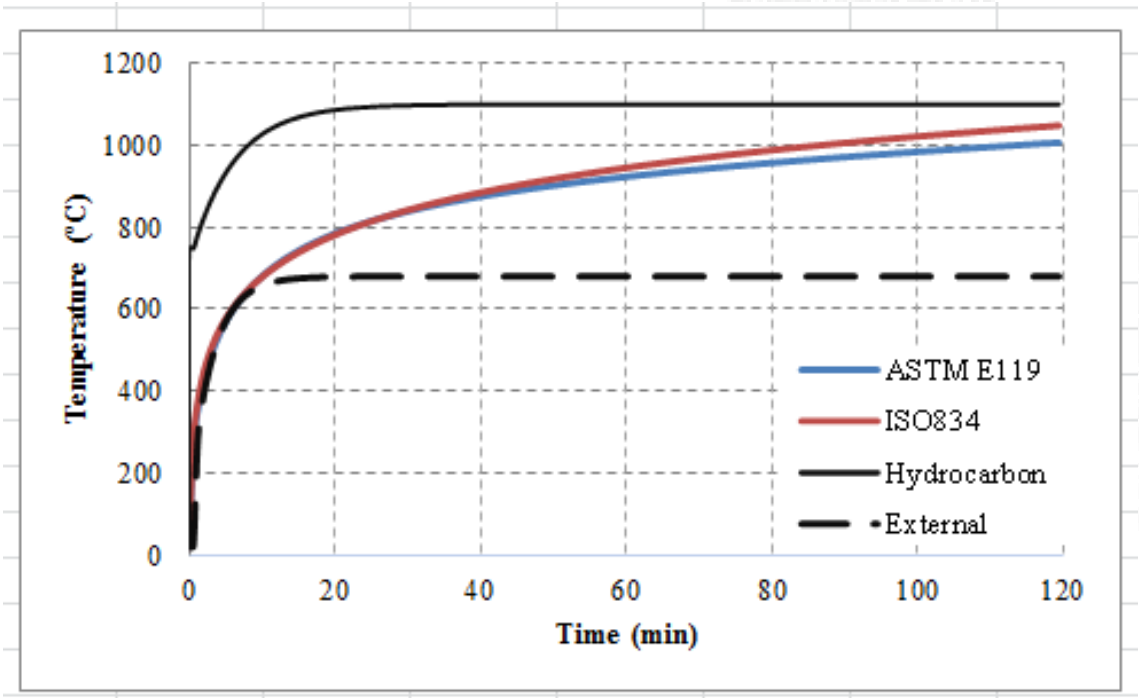
Fire resistance rating (FRR) is the ability of a building element to withstand a fire under test conditions for a certain period of time and consists of three criteria as follows:

- Structural adequacy
- Integrity
- Insulation

For example:


60 / 60 / 60
STRUCTURAL ADEQUACY
The ability to maintain stability and adequate load bearing capacity as determined by AS 1530.4
kg
kg
kg
INTEGRITY
The ability to resist the passage of flames and hot gases as specified by AS 1530.4
INSULATION
The ability to maintain a temperature over the whole of the unexposed surface below that specified by AS 1530.4

Various standard fires (time-temperature curves)

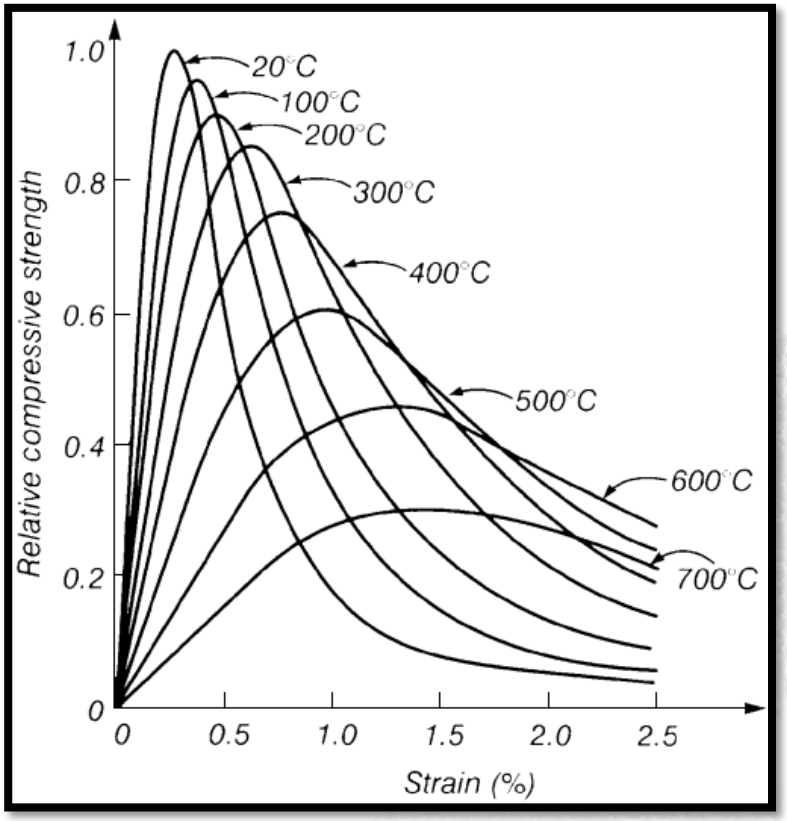


$$T = 750[1 - e^{-3.79533(t_h)0.5}] + 170.41(t_h)^{0.5} + T_0$$

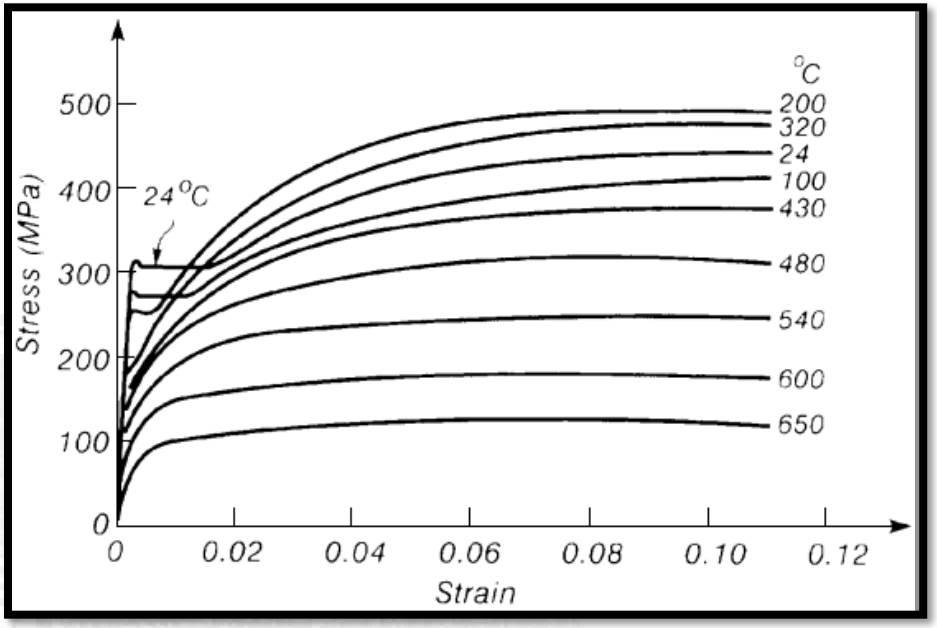
$$T = 345\log_{10}(8t + 1) + T_0$$

$$T = 1080(1 - 0.325e^{-0.167t} - 0.675e^{-2.5t}) + T_0$$

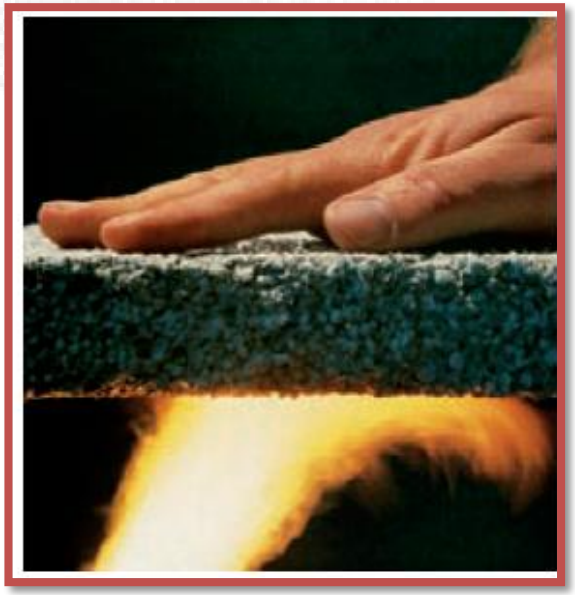
$$T = 660(1 - 0.687e^{-0.32t} - 0.313e^{-3.8t}) + T_0$$



Hot-rolled steel



Concrete



Tabulated data

Fire resistance rating of columns

Standard fire resistance (min)	Column exposed on more than one side		Column exposed on one side	
	Minimum dimensions (mm)	Minimum cover (mm)	Minimum dimensions (mm)	Minimum cover (mm)
30	200	32	155	25
60	250	46	155	25
90	350	53	155	25
120	350*	57	175	35
180	450*	70	230	55
240	450*	75	295	70

Fire resistance rating of non-load bearing walls (partitions)

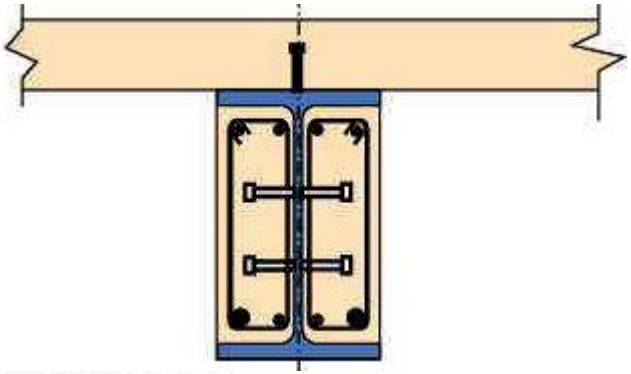
Standard fire resistance (min)	Minimum wall thickness (mm)
30	60
60	80
90	100
120	120
180	150
240	175

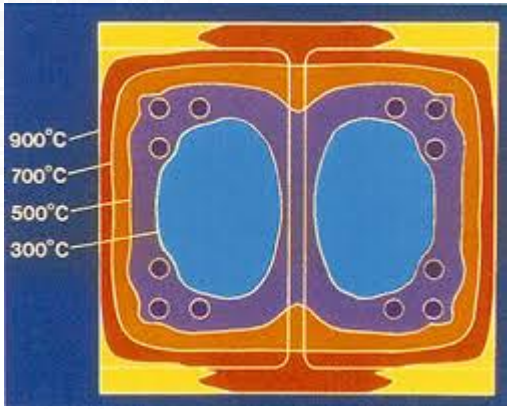
Fire resistance rating of load bearing walls

Standard fire resistance (min)	Column exposed on more than one side		Column exposed on one side	
	Minimum dimensions (mm)	Minimum cover (mm)	Minimum dimensions (mm)	Minimum cover (mm)
30	120	10	120	10
60	130	10	140	10
90	140	25	170	25
120	160	35	220	35
180	210	50	270	55
240	270	60	350	60

Providing adequate FRR for steel structures

Concrete encasement





Insulation materials

- Cementitious based
- Gypsum based
- Mineral based
- Color based

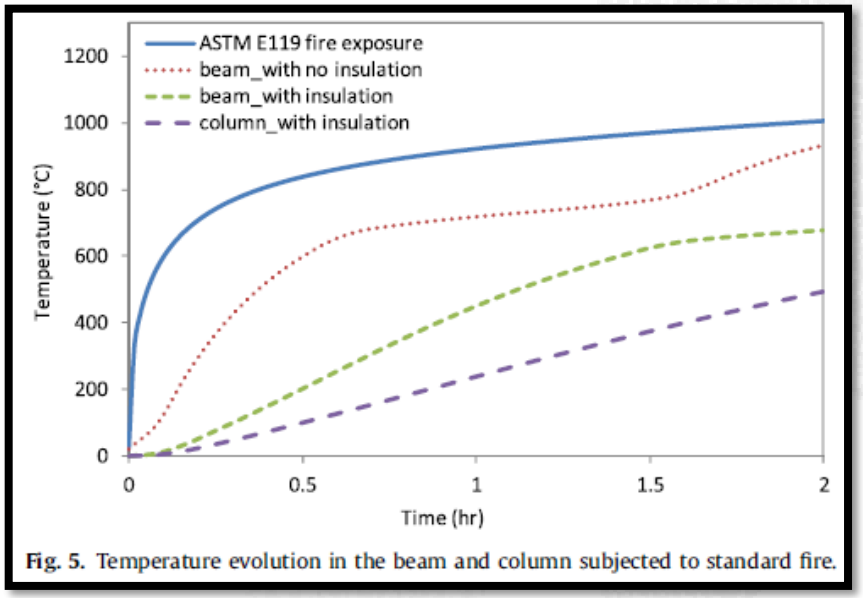


Fig. 5. Temperature evolution in the beam and column subjected to standard fire.

Are we sure that using prescriptive fire codes can always guarantee our safety?

(a) Buckled column and deformed beams (b) Floor deformation

Figure: Damages from the Broadgate fire. (From Steel Construction Industry Forum (SCIF), *Investigation of Broadgate Phase 8 Fire*, Steel Construction Institute, Ascot, UK, 1991. With permission.)

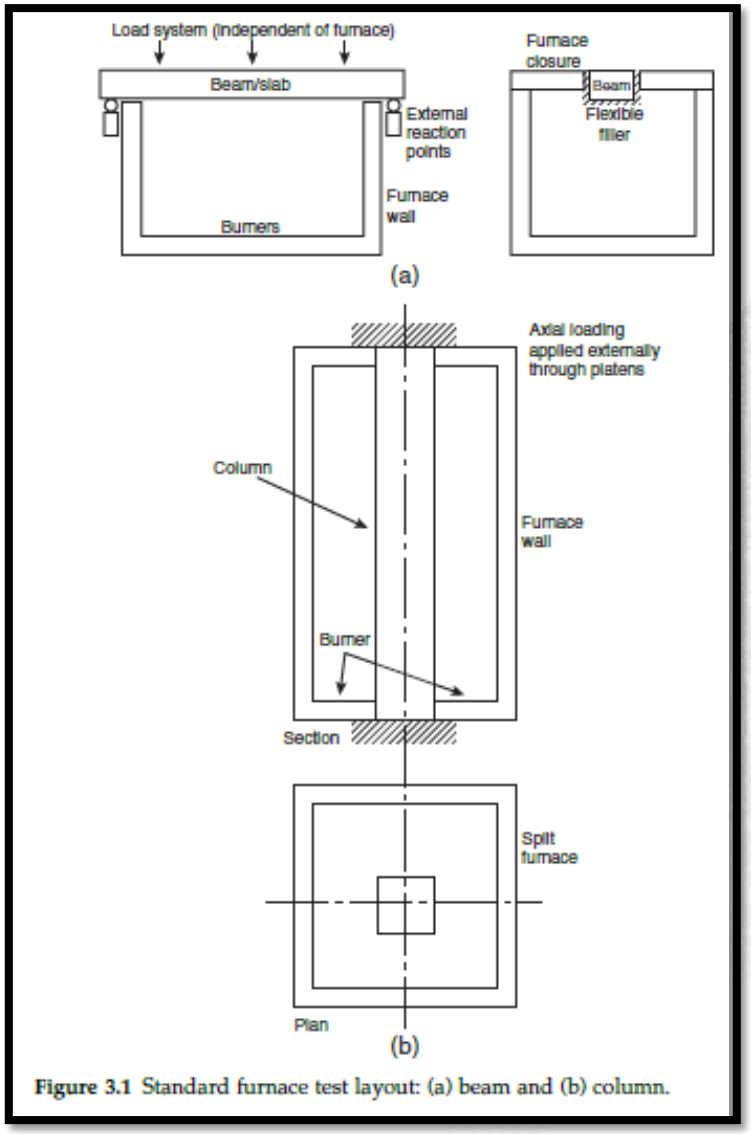
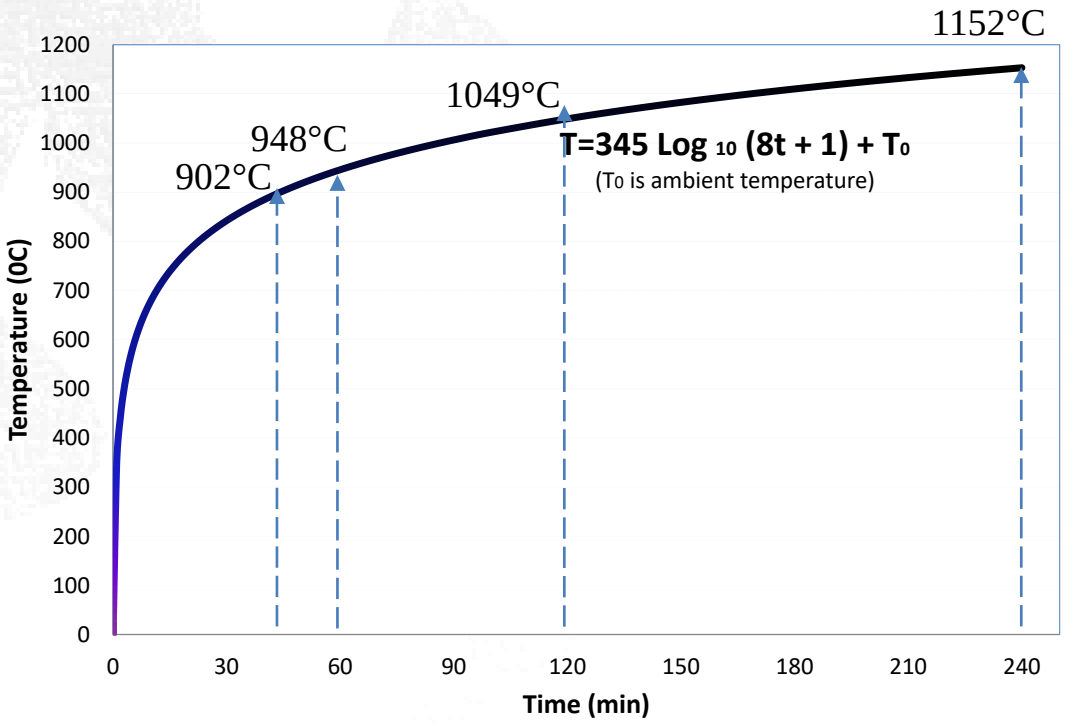


Figure 3.1 Standard furnace test layout: (a) beam and (b) column.

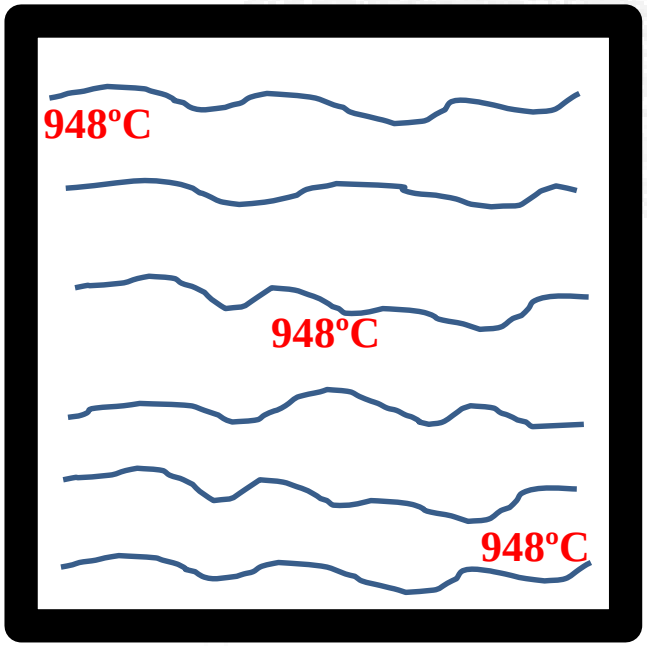
NFPA 251: 16 Chapters; 8 Appendices

A compartment with dimensions of 4.3 m length, 3.4 m width, and 3.0 m height.

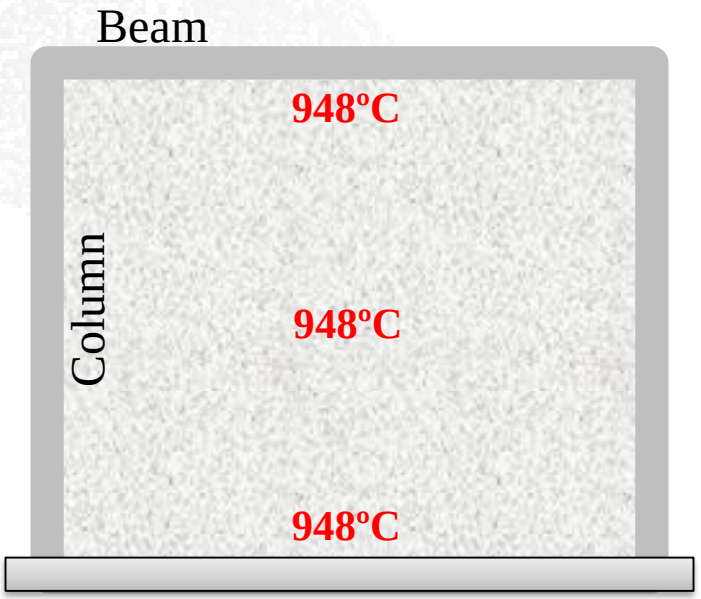


There are two reasons to support the assumption that the standard fires can be used for small compartments:

1. In small compartments the distribution of temperature in all directions is almost uniform.
2. If the fire curve is plotted based on performance-based codes, the variation in temperature over time is often less than that of standard fires; thus, the assumptions based on prescriptive codes are often conservative.



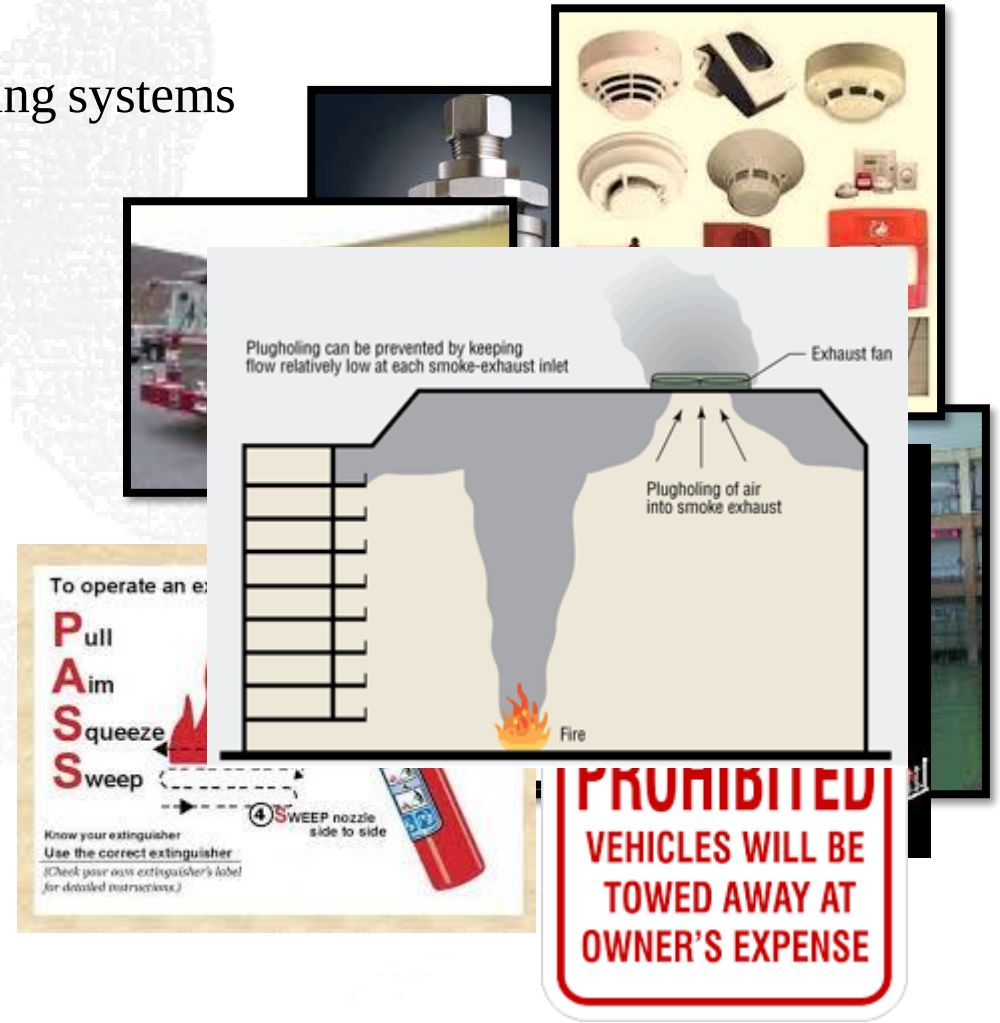
Plan

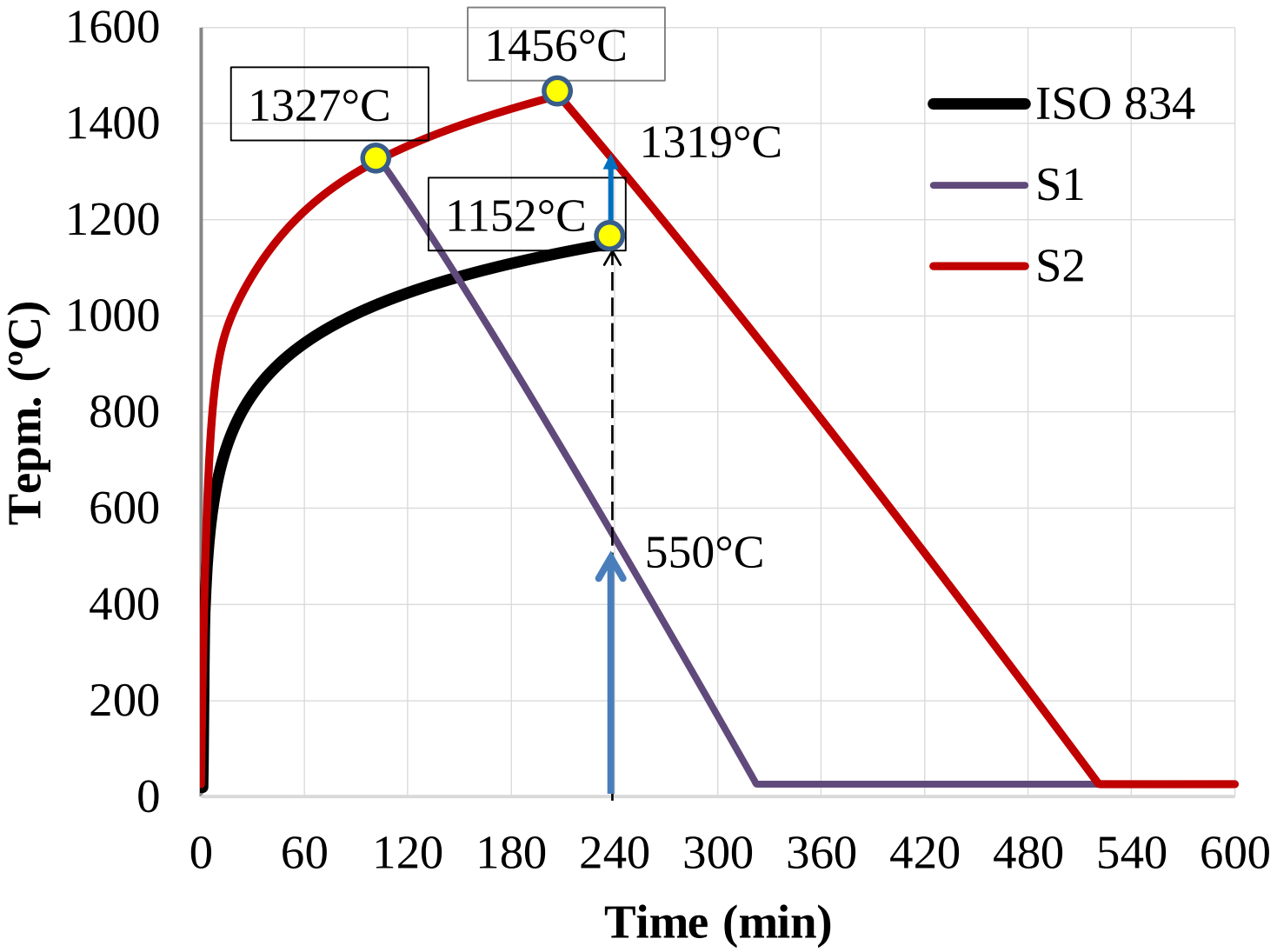


Elevation

And also: internal and external fire suppression facilities

- Automatic water extinguishing systems
- Water supply
- Automatic fire detection
- Automatic fire alarm
- Automatic transmission
- An on-site fire brigade
- An off-site fire brigade
- Safe access routes
- Normal firefighting devices
- Smoke exhaust systems




1600
1400
1200
1000
800
600
400
200
0
Tepm. (°C)
1456°C
1327°C
1319°C
1152°C
550°C
ISO 834
S1
S2
0
60
120
180
240
300
360
420
480
540
600
Time (min)

- If the shown fire curves (based on the ISO834 or S1 and S2) are applied to a small compartment, while there would be some differences in the results, the required FRR is often met.
- However, in large compartments and tall structures, the results are not similar one to another, as follows:

A) If a compartment is partitioned, the fire spreads successively from one point to the next.

B) If the compartment is open flat, the distribution of temperature is highly non-uniform, called as horizontally traveling fire.

C) If the structure is tall, the possibility of vertically travelling fire is often the case.

D) The possibility of progressive collapse in tall structures cannot be ignored.

E) The effect of irregularity on the performance of tall structures is much more than that of low rise structures.

F) The number of fire scenarios in tall structures is much higher than that in low-rise structures; hence, more complexity.

G) While the effect of the load ratio on the FRR of elements is not explicitly mentioned when using standard fires, it does play an important role in changing the FRR.

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