IIBCC 2024

FIRE RESISTIVE FACADES

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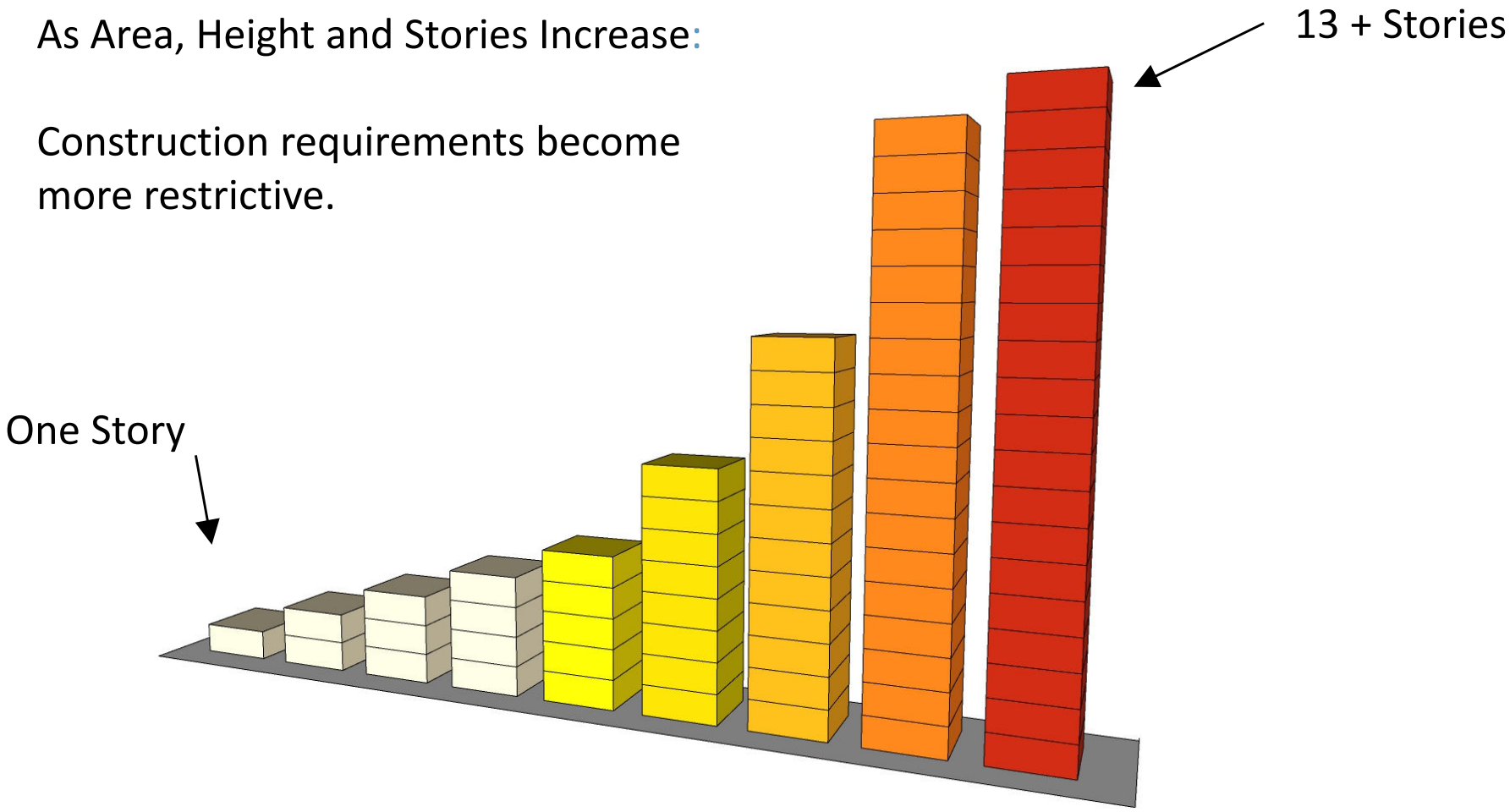
Licensed Architect since 1990, 33 Years

This presentation is conceptual and summary in nature. This presentation is for educational purposes only.

FIRE RESISTIVE FACADES

As Area, Height and Stories Increase:

Construction requirements become more restrictive.



Wood (Combustible) ---------- Concrete and Steel (Non-Combustible)*

*In the US, special requirements for Heavy Timber, Mass Timber, etc.

Fire Events:

14 Stories, Apartment Building, Campanar, Valencia Spain –February 22, 2024

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14 Stories, Apartment Building, Campanar, Valencia Spain – February 22, 2024

Fire Events:

24 stories, Residential Tower, Grenfell Tower, London, England, June 14, 2017

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Fire Events:

79 Stores Dubai Torch Tower, August 3, 2017

Facade Material:

- Campanar Apartment Building, Valencia, Spain: Aluminum Composite Material. Polyethylene core. Mineral wool insulation *(El Pais, February 23, 2024)*

- Grenfell Tower, West London, UK: PE core, Aluminum Composite Material cladding. Polyisocyanurate foam insulation with aluminum foil facing. Waterproof membrane. 50 mm air cavity. Concrete wall. *(Journal of Hazardous Materials)* Some areas of Phenolic foam. *(Global Technical Services Group)*

- Torch Tower, Dubai: Aluminum composite panels. Plastic cores. (*Façade Tectonics, Terri Meyer Boake, University of Waterloo)*

Facade Material: Apartment Building, Valencia, Spain

Source: Global Technical Services Group, External fire spread is a killer, June 12, 2024

Important Features of High-Rise Facade:

- Facade combustibility:
  - Cladding combustibility
  - Insulation combustibility
  - Waterproofing membrane (WRB)
- Structure combustibility

Grenfell Tower: Structure did not collapse

Source: Dan Kitwood, Getty Images

Important Features of High-Rise Facade:

- Combustibility
- Air gap behind cladding
- Horizontal/ Vertical fire stopping
- Construction details of cladding, insulation, and waterproofing
- Smoke generation

Building Codes in the United States:

International Building Code (IBC)

National Fire Protection Association 101 (NFPA 101)

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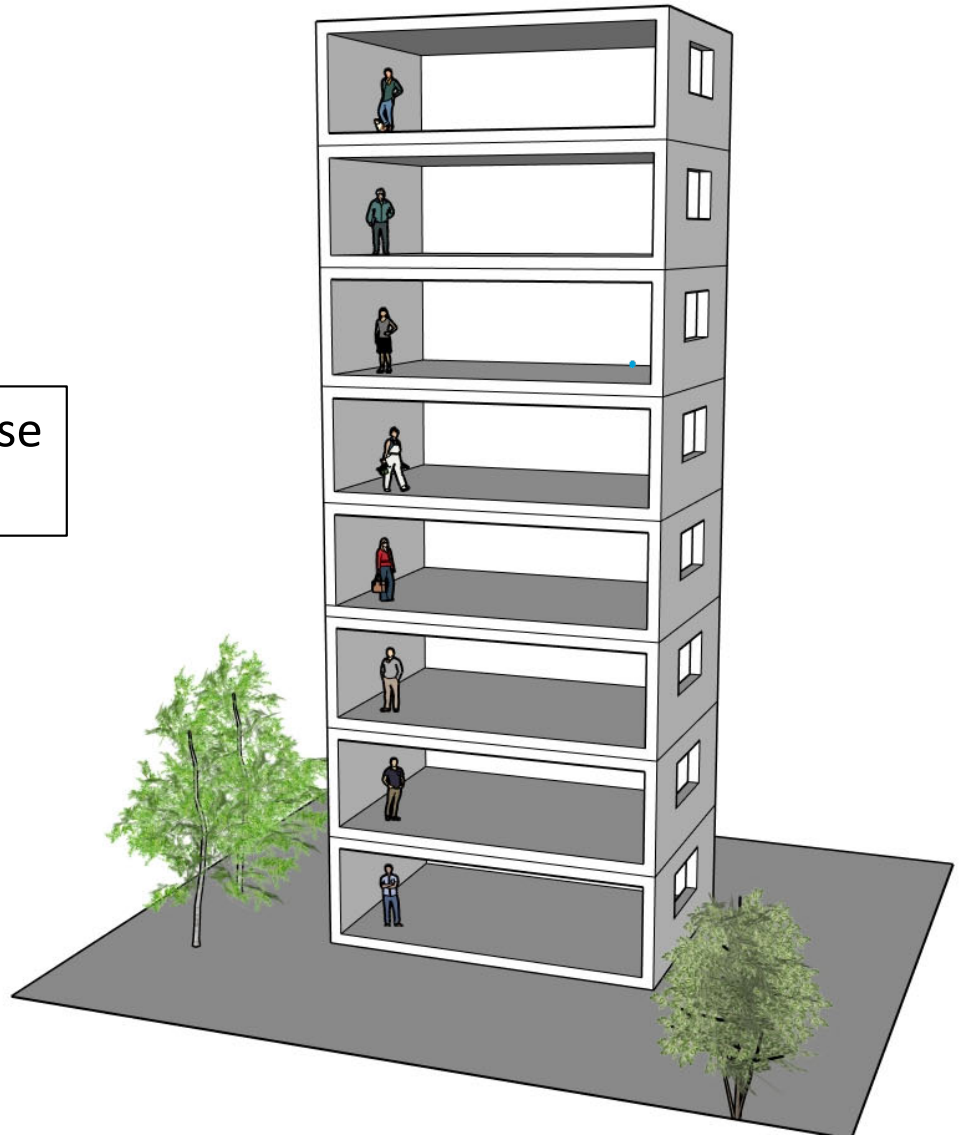
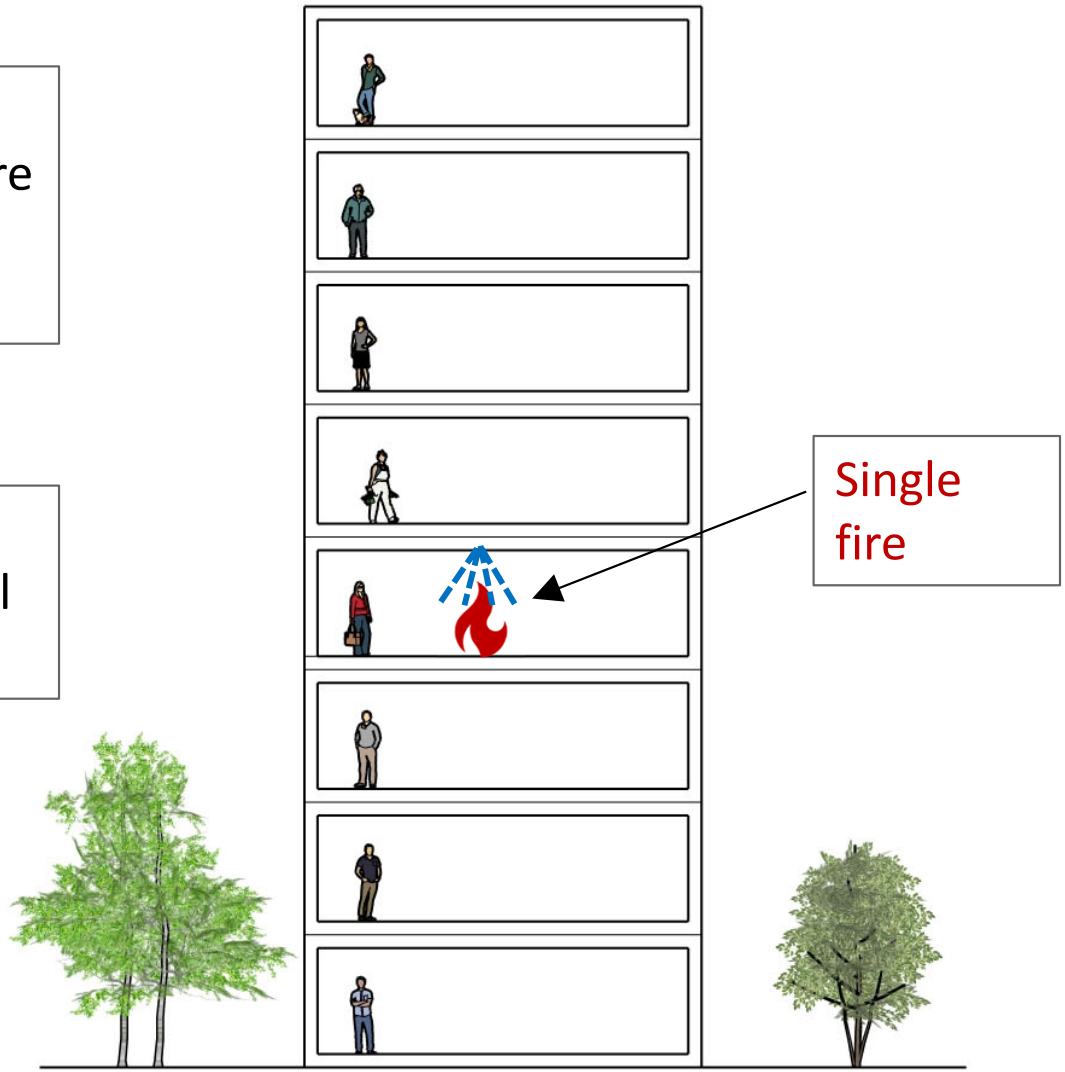
Example High-Rise building



Fire Resistive Facades

Fire Sprinkler designed for one fire at a time inside the building (NFPA 13)

Note: No Fire sprinkler at Grenfell Tower*



*Firefighting History The Grenfell Tower inferno. June 14, 2023

Fire Sprinklers: NFPA 13-22 (In the USA)

NFPA 13: 1.1 Scope:

> *"1.1.3 This standard is written with the assumption that the sprinkler system shall be design to protect against a single fire originating within the building."* [Emphasis Added]

- **Single Fire**
- **Within the Building**
- **Not outside the Building**

NFPA 13 Standard for the Installation of Sprinkler Systems, 2022

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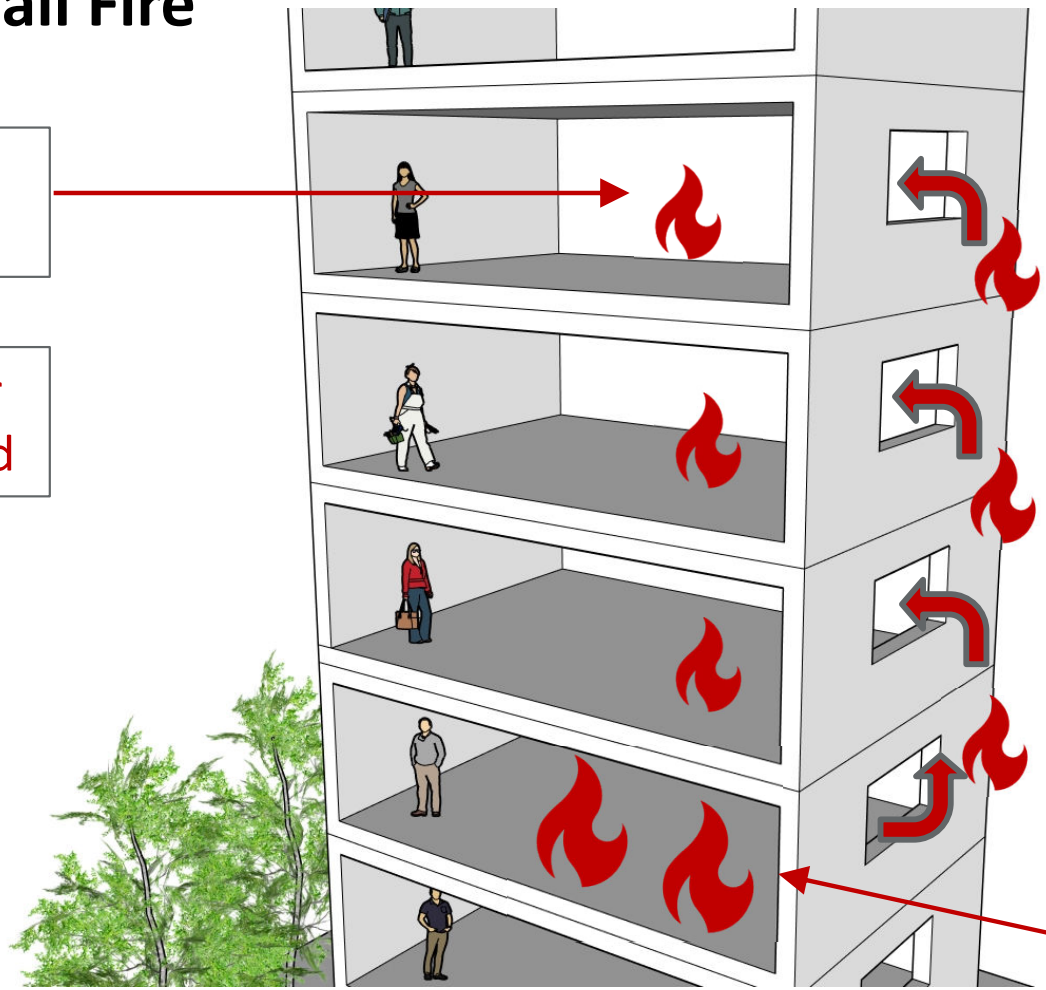
External Wall Fire

Secondary fires

Fire Sprinkler overwhelmed



NFPA 13: No fire sprinkler typical at exterior facade

Initial fire

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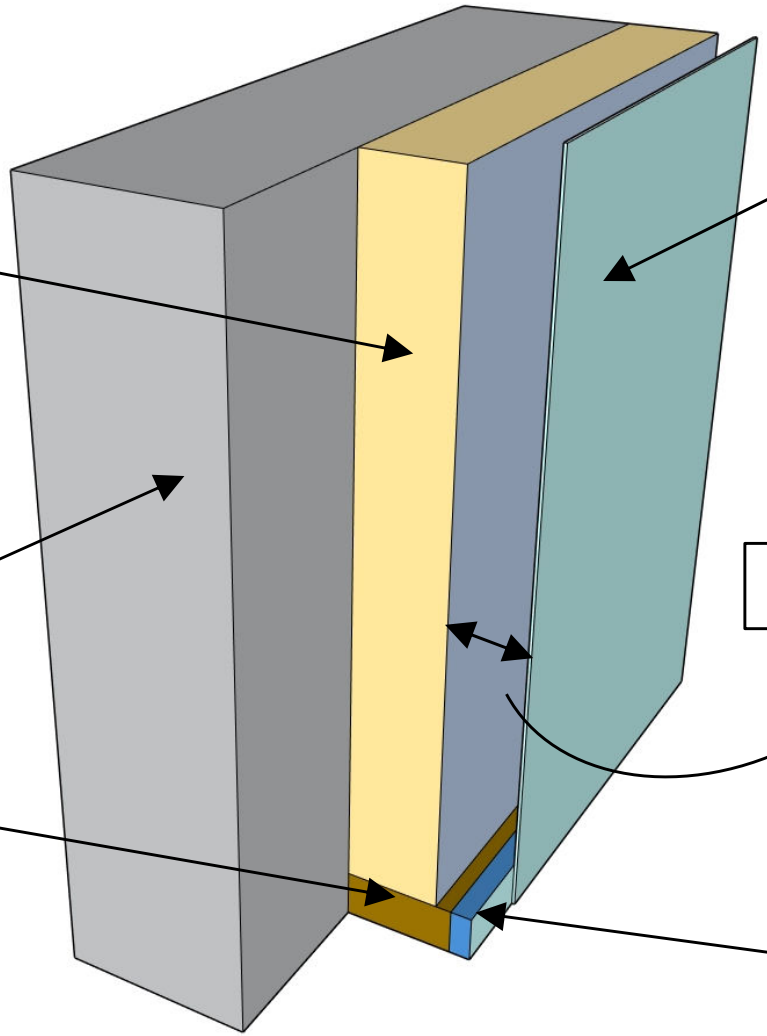
Grenfell Tower:



Assembly description from Journal of Hazardous Materials, Fire behaviour of modern façade materials – Understanding the Grenfell Tower fire, Sean T. Mckenna et al. 2019

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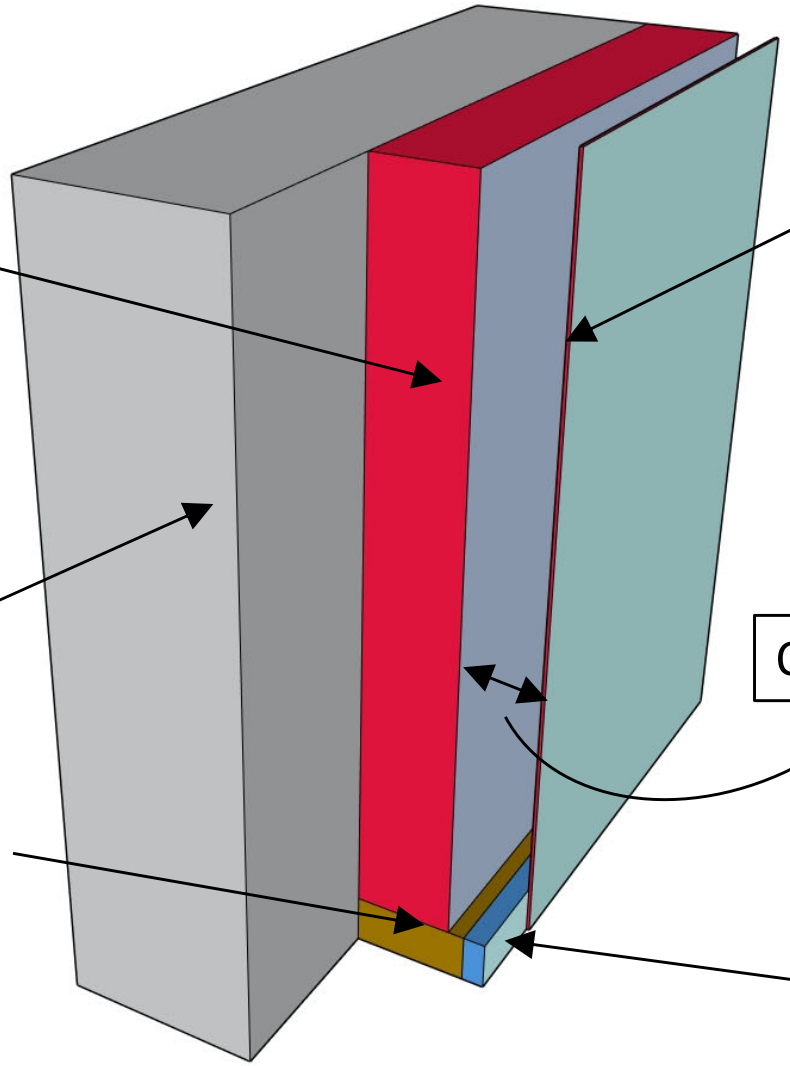
Grenfell Tower:



Combustible:
Polyisocyanurate insulation foam (PIR), with aluminum foil

Inside

Concrete wall

Stone wool fire stopping

Combustible:
Cladding polyethene core, aluminum each side of core

Outside

Air cavity

Intumescent seal when activated

Assembly description from Journal of Hazardous Materials, Fire behaviour of modern façade materials – Understanding the Grenfell Tower fire, Sean T. Mckenna et al. 2019

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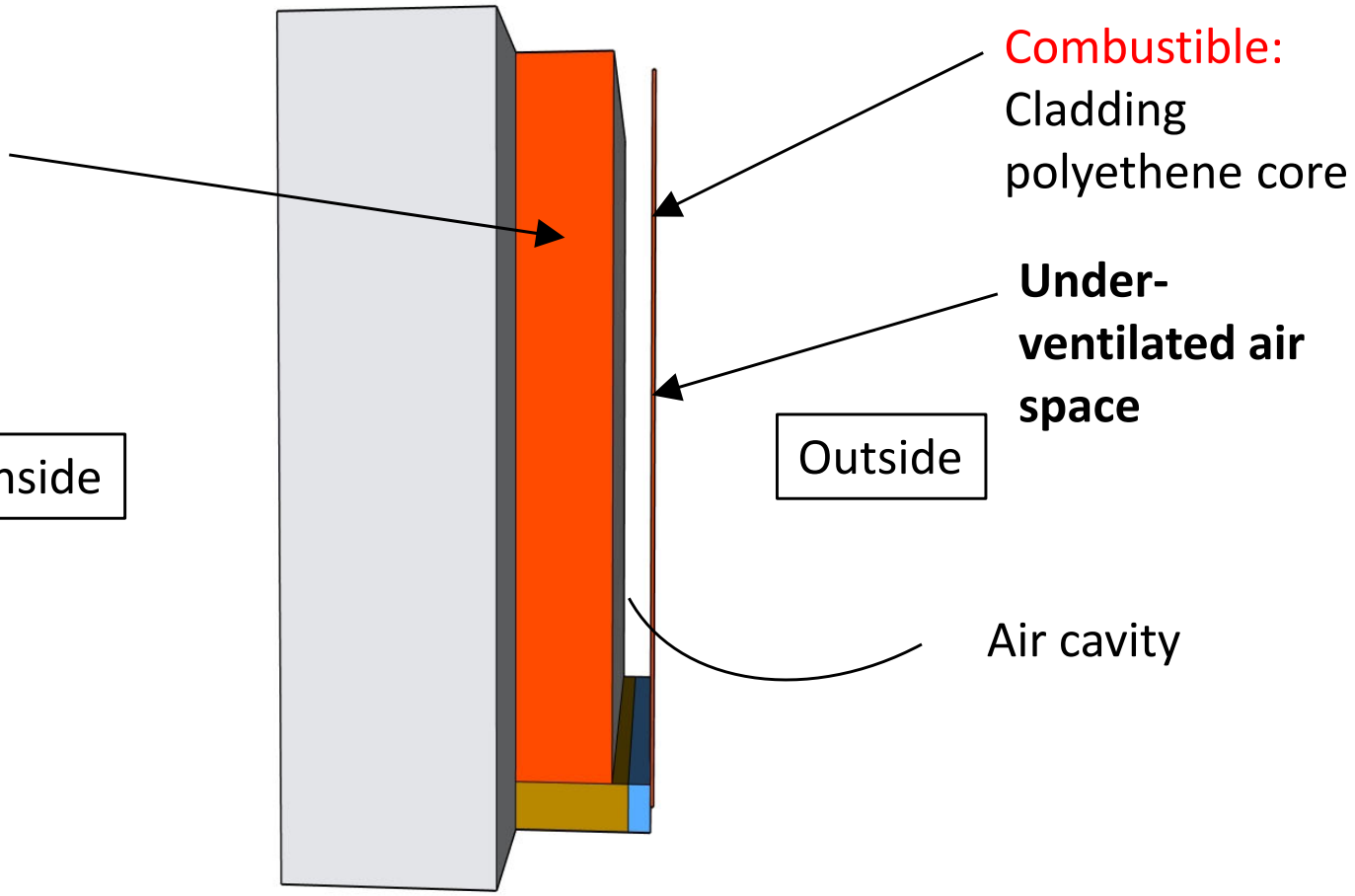
Grenfell Tower:



Assembly description from Journal of Hazardous Materials, Fire behaviour of modern façade materials – Understanding the Grenfell Tower fire, Sean T. Mckenna et al. 2019

Smoke Danger:

"Most fire deaths, and most fire injuries result from inhalation of toxic fire effluents."

Energy and Buildings. Assessment of fire toxicity of building insulation materials. Anna A. Stec, T. Richard Hull, August 2011.

Smoke and Toxic Gas Danger:

Grenfell fire

Wall Street Journal, June 14 2017

Smoke and Toxic Gas Danger:

Grenfell fire

*NBC News June 13, 2017. * Fire behavior of modern façade materials, Sean T. McKenna et. al Journal of Hazardous Materials 368 (2019)*

Smoke and Toxic Gas Danger:

Grenfell fire

"In most cases the smoke from the burning façade appears to have entered the building before the contents of each apartment ignited, so the smoke toxicity of the façade is an important factor in the tragedy."

Fire behavior of modern façade materials, Sean T. McKenna et. al Journal of Hazardous Materials 368 (2019)

Smoke Control in Buildings (in the USA)

Chapter 9 of the IBC

Maintenance of a 'Tenable Environment'

Not to protect contents or for fire suppression.

Other Chapters of the IBC

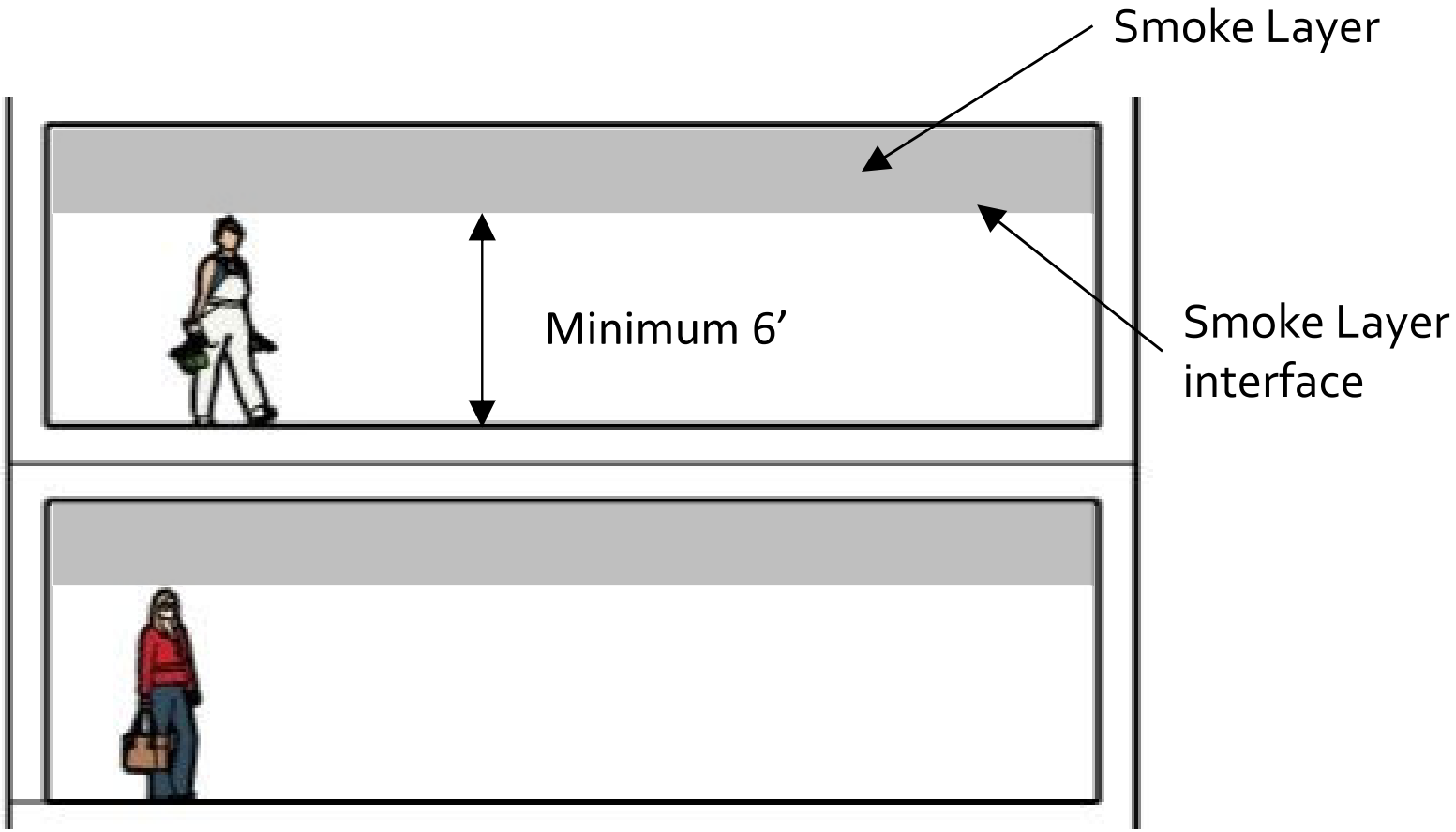
High-Rise (Smoke proof enclosure stairs)

Hospitals (Smoke compartments, smoke barriers, etc.)

Prisons (Smoke compartments, smoke barriers, etc.)

Smoke control in Buildings: (in the USA)

IBC 909.8.1 Smoke Layer (in smoke zone). Exhaust Method



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Toxic fire effluents:

"Toxic product yields depend on the material composition and the fire conditions."

Toxic product yields change with stages of a fire:

"In large scale tests the greatest toxic product yields usually occur under oxygen-depleted conditions, when the fire is ventilation controlled"

Energy and Buildings. Assessment of fire toxicity of building insulation materials. Anna A. Stec, T. Richard Hull, August 2011.

Measurement of Toxic Product Yields[3]

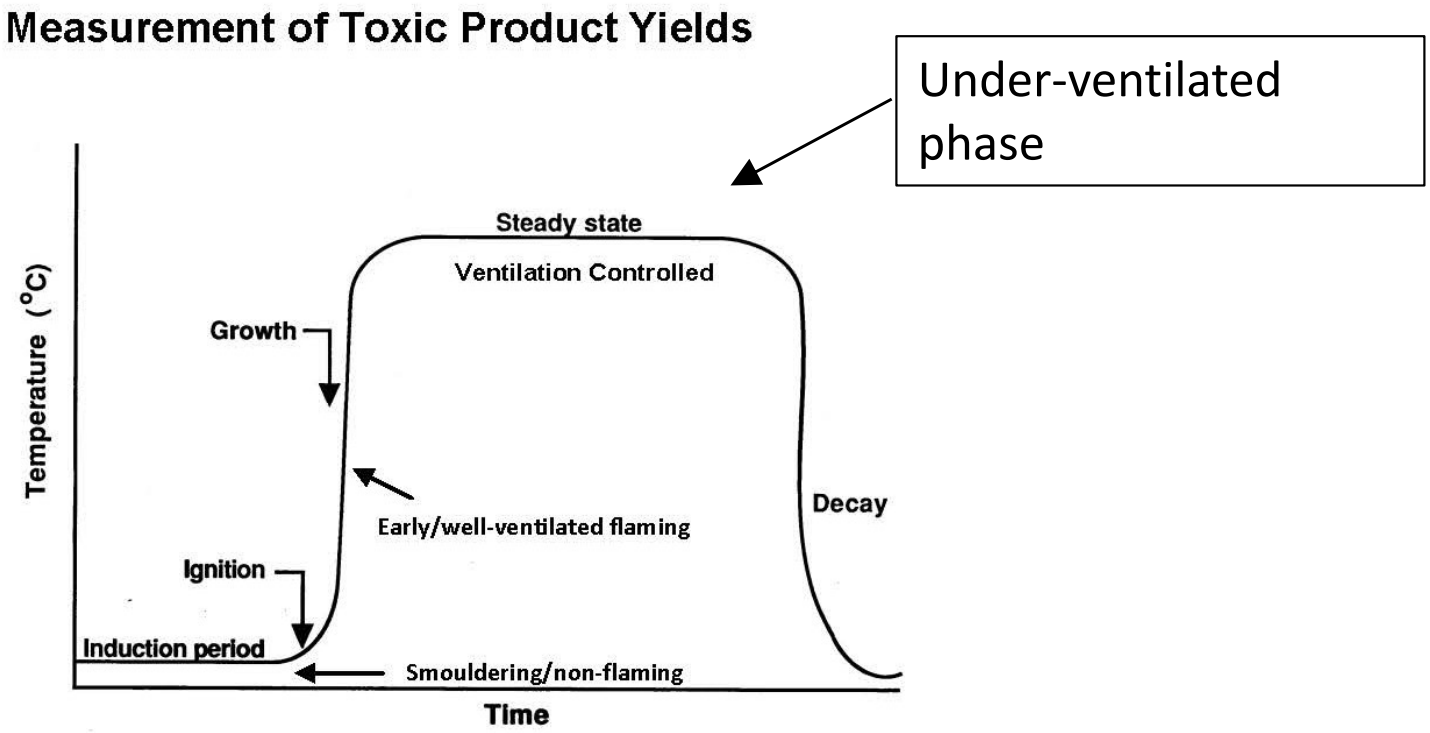

Figure 2 Idealised fire growth curve

Assessment of fire toxicity of building insulation materials. Anna A. Stec, T. Richard Hull, August 2011.

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Table 8 LC_{50} for different products

Material	Fire Conditions	Equivalence ratio ϕ	LC_{50} g/m^3
GW	Smouldering	—	163.6
	T=825°C No flaming	—	129.5
SW	Smouldering	—	388.1
	T=850°C No flaming	—	172.1
PHF	Smouldering	—	186.3
	Well-Ventilated	0.64	43.3
	Under-ventilated	1.29	22.3
	Under-ventilated	1.84	21.0
EPS	Smouldering	—	5648.5
	Well-Ventilated	0.80	28.4
	Under-ventilated	1.16	27.9
	Under-ventilated	1.75	27.6
PUR	Smouldering	—	337.2
	Well-Ventilated	0.69	15.7
	Under-ventilated	1.24	10.3
	Under-ventilated	2.00	11.4
PIR	Smouldering	—	498.4
	Well-Ventilated	0.75	16.5
	Under-ventilated	1.34	10.7
	Under-ventilated	1.97	8.3

Fire Conditions:
a. Smouldering
b. Well-ventilated
c. Under-ventilated

Smaller numbers = higher fire toxicity

Assessment of fire toxicity of building insulation materials. Anna A. Stec, T. Richard Hull, August 2011

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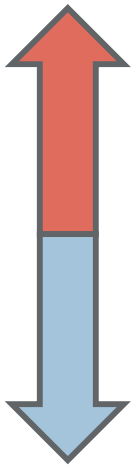
Toxicity of insulations in certain fire stages and ventilation: (For ventilation controlled or under-ventilated condition)

Most Toxic



Less Toxic

- Polyisocyanurate (PIR): Most toxic
- Polyurethane (PUR)
- Phenolic (PhF)
- Expanded Polystyrene (EPS)
- Glass wool (GW)
- Stone wool (SW): Least toxic

For well ventilated: order is PIR>PUR>EPS>PHF.

Energy and Buildings. Assessment of fire toxicity of building insulation materials. Anna A. Stec, T. Richard Hull, August 2011

Toxicity of insulations in certain fire stages and ventilation:

"Incapacitation and lethality may be estimated for 50% of an exposed population in terms of a fractional effective dose (FED), …When the FED equals 1, the equations predict that half of the exposed population would be incapacitated or killed."

Journal of Hazardous Materials, Fire behaviour of modern façade materials – Understanding the Grenfell Tower fire, Sean T. Mckenna et al. 2019.

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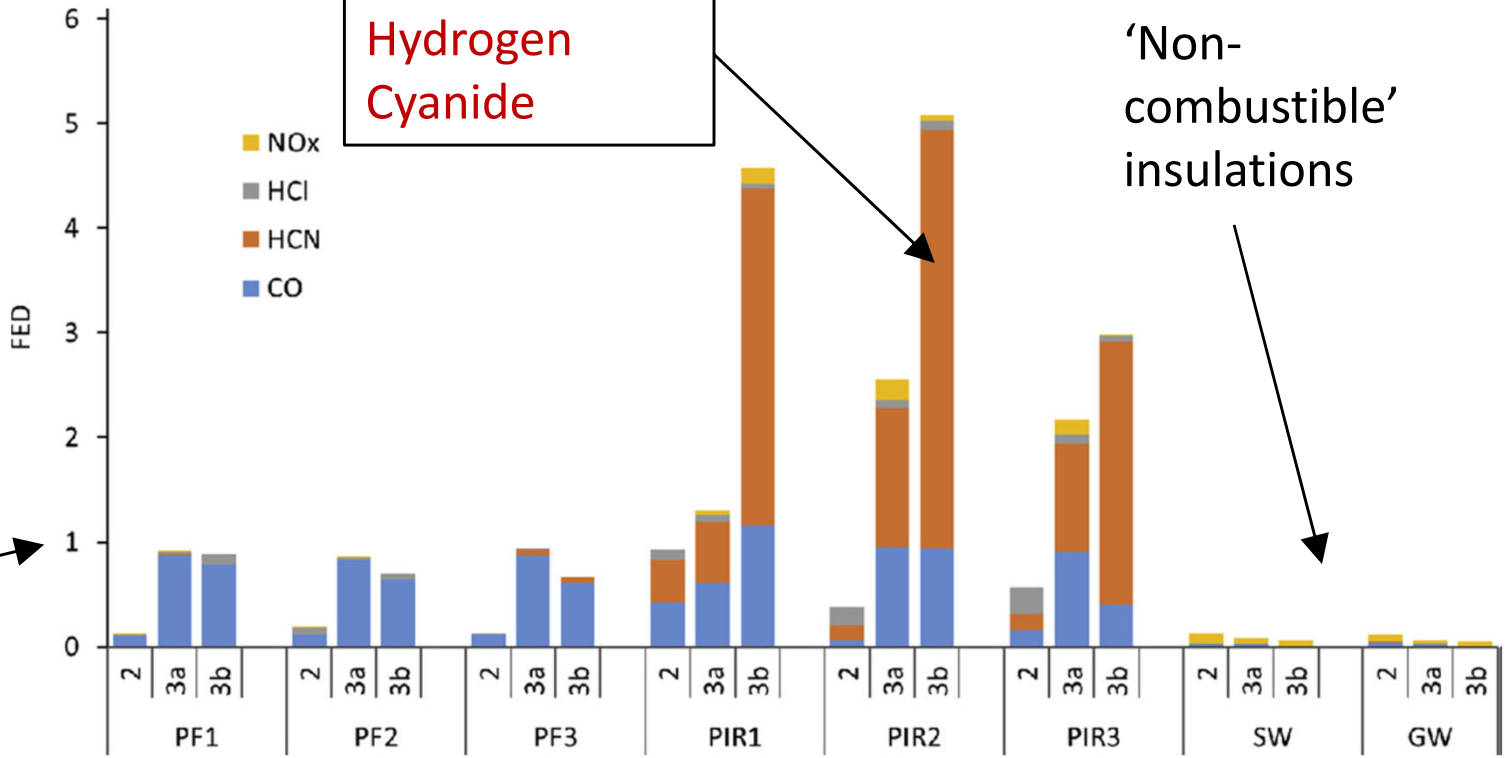
"FED for incapacitation following 5 min exposure from burning 1 kg with the effluent dispersed in a volume of 50 m^3."

PF: Phenolic Foam
PIR: Polyiso Foam
SW: Stone wool
GW: Glass wool

HCN: Hydrogen Cyanide

'Non-combustible' insulations

FED of 1



Journal of Hazardous Materials, Fire behaviour of modern façade materials – Understanding the Grenfell Tower fire, Sean T. Mckenna et al. 2019. Page 121

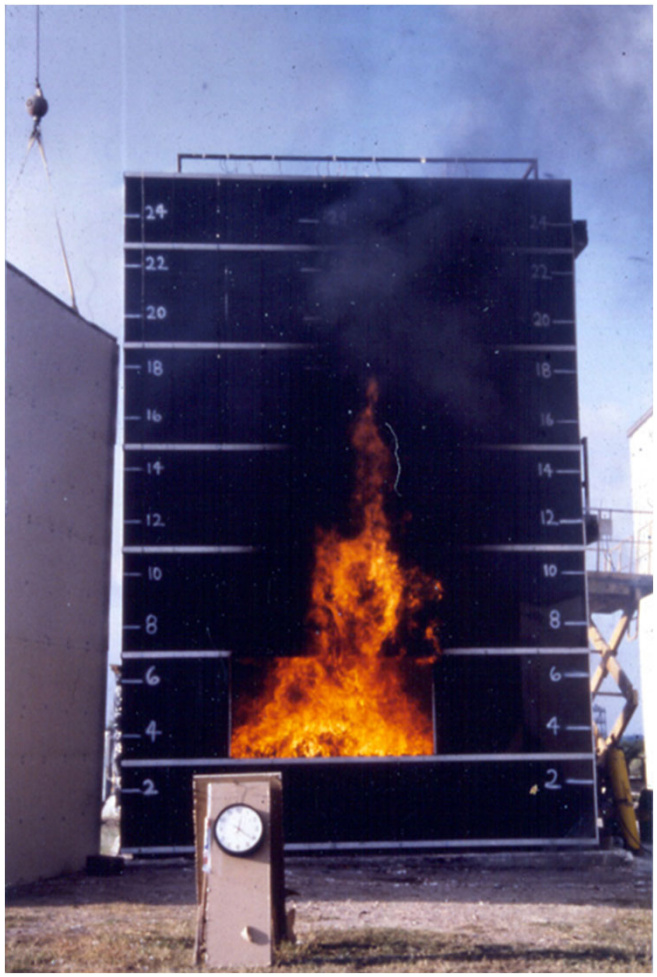
Fire Testing Standards: NFPA 285 (In USA)

Assembly test Based in old UBC 17-6/ UBC 26-4 Standards

Full scale test (In IBC)

Required for cladding assembly with combustible foam, ACM cladding, HPL cladding, over certain heights and on certain Types of Construction.

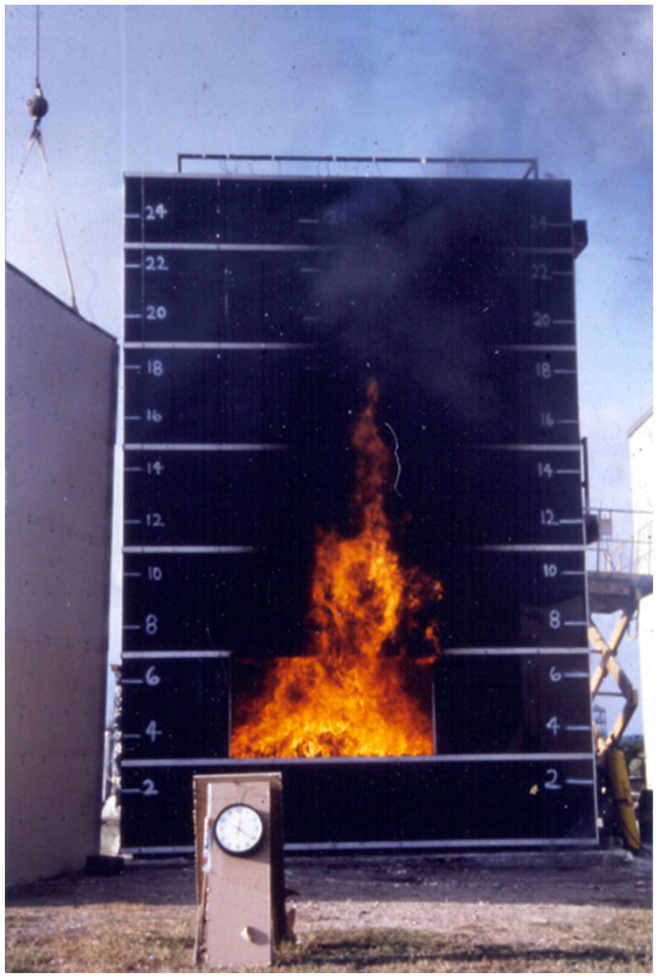
Not required for non-combustible facade.



Fire Testing Standards: NFPA 285 (In USA)

Tests fire spread (Propagation)

Tests ‘Chimney’ effect of air spaces behind cladding



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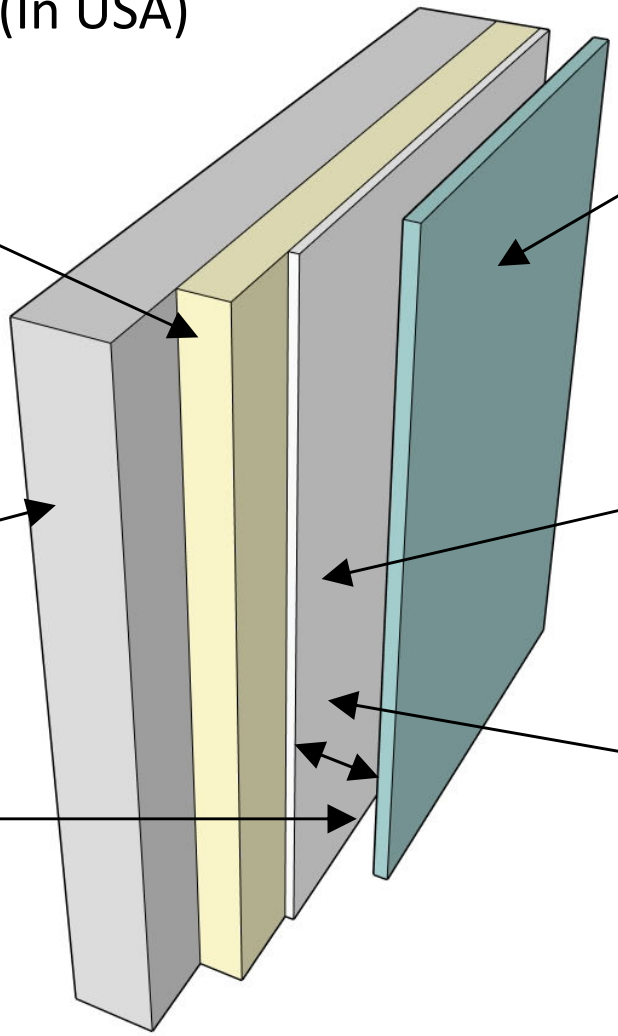
Cladding Design Options: (In USA)



NFPA 285 compliant assembly with foam insulation, or non-combustible insulation

NFPA 285 compliant assembly, or Non-combustible cladding

Outside

Inside

Layer of Non-combustible sheathing may assist with NFPA 285

Wall framing

Fire stopping of air cavity may not be required if assembly is NFPA 285 compliant.

NFPA 285 compliant assembly with waterproofing (WRB) or WRB as allowed by code

Note: Additional plastic insulation and other Building Code requirements apply

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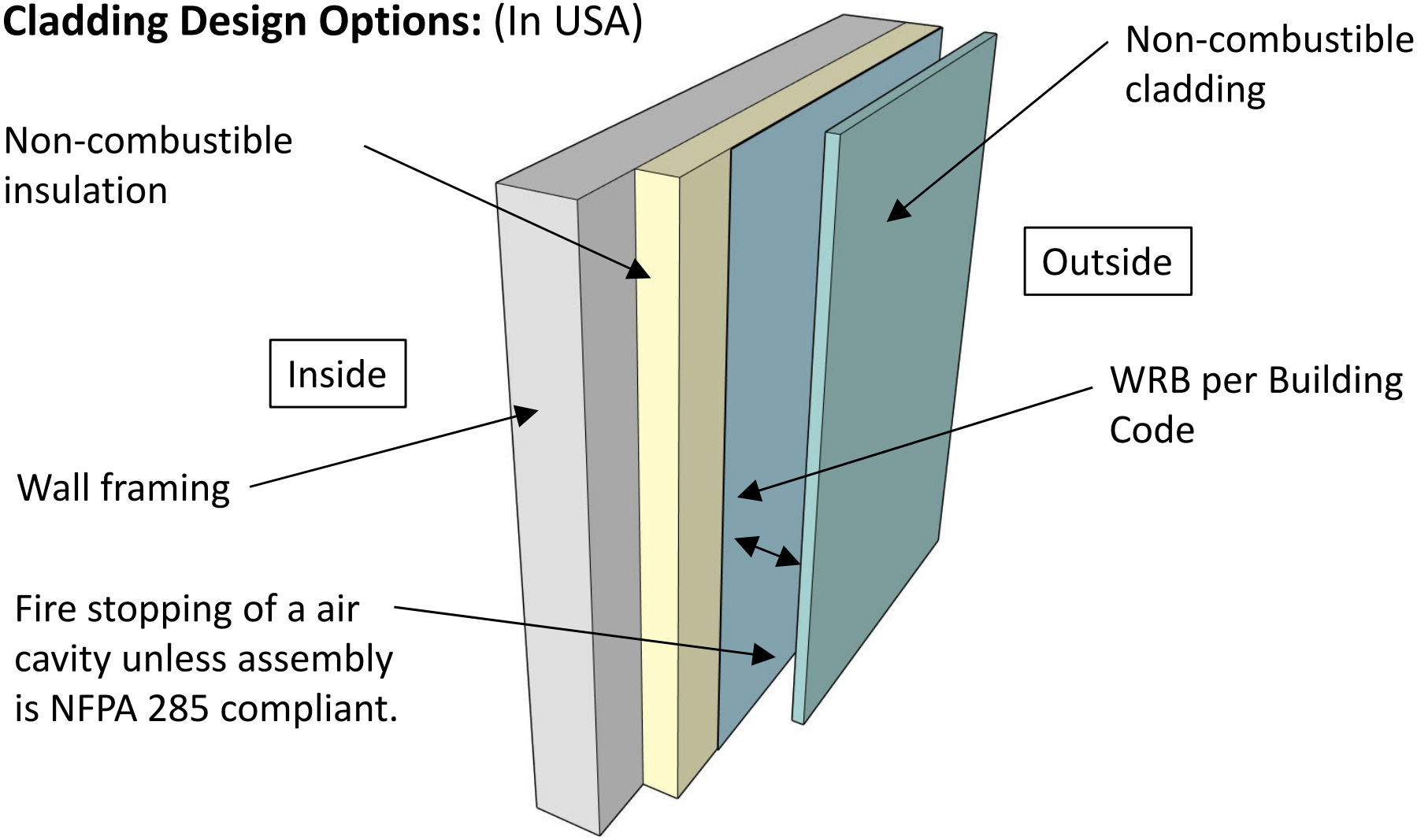
Cladding Design Options: (In USA)



Note: Additional Building Code requirements apply

Material Standards in the Building Code: Four main fire related standards

Non-combustible:

ASTM E136: Combustibility (Exception for **composite materials**, see IBC 703.5.2)

Flame Spread and Smoke Index:

ASTM E84: Flame spread and smoke index

NFPA 285: Flame spread and temperature requirements for combustible cladding assemblies

Fire rated assemblies:

ASTM E119: Time temperature curve and additional criteria

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Material Standards in the Building Code:

Examples of Non-combustible Cladding, ASTM E136:

- Stone
- Fiber Cement
- Precast concrete
- Certain composites
- Magnesium oxide panels? There is a dispute.*

*See USG: The Truth Behind Noncombustibility Claims of Magnesium Oxide Structural Panels, November 2, 2022

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Material Standards in the Building Code:

Examples of Combustible Cladding:

- EIFS (With foam plastic insulation)
- High Pressure laminates
- Fiber reinforced plastics

These materials tested to ASTM E 84 for flame spread and smoke generation. Requirements depend on the material and the height of the building.

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Material Standards in the Building Code:

Examples of Non-combustible Insulation:

- Mineral wool (Stone wool)
- Glass fiber (Glass wool)

Examples of Combustible Insulation:

- Foam plastics
- Cellulose

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Material Standards in the Building Code: Four main fire related standards

Building-Integrated Photovoltaic (BIPV) in High-Rises

Typical glass and aluminum systems (Non-combustible)

Glazing or Curtainwall code requirements

May include plastic elements or films (Combustible)

Include electrical elements (Electrical Code, NFPA 70)

(Some UL standards apply as well)

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Conclusion:

- Non-combustible cladding materials create lower fire spread and toxic smoke risk then combustible claddings and assemblies.
- Careful design of the air space behind cladding panels impacts the fire performance due to chimney effects.
- Combustible elements often include plastic foam insulation, combustible waterproofing, and in cases, combustible cladding.
- Non-Combustible materials can be used, or Combustible materials conforming to NFPA 285 and ASTM E 84.