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Façade fire performance of low carbon structures

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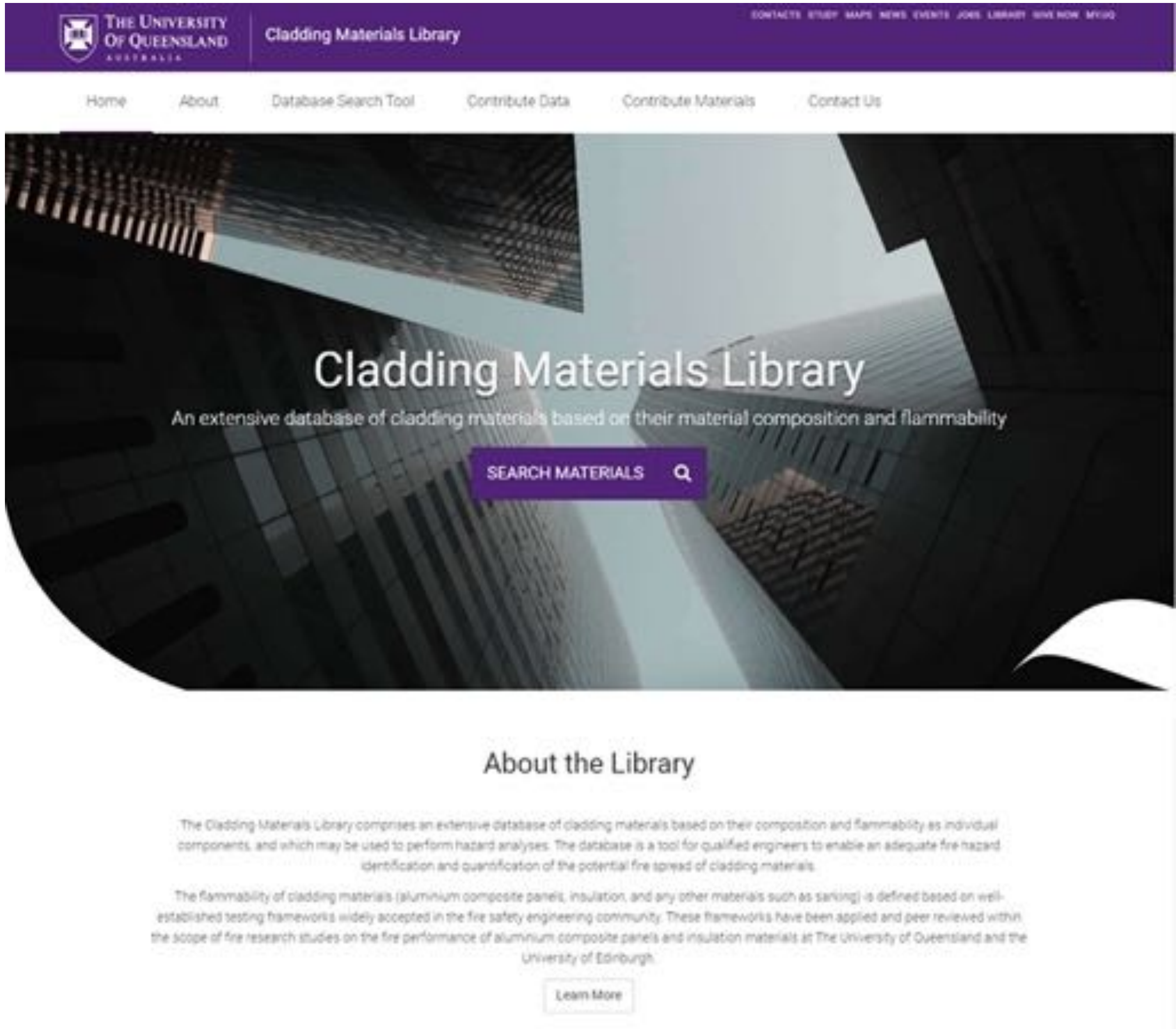
12th May 2023

A WORLD TOP 100 UNIVERSITY

Topic of this presentation

1. Background and context
2. Cladding Materials Library
   - Engineering framework
   - Data published in an open access library
   - Competency framework
3. Implications for structural fire engineering



Some of the team

Background and context

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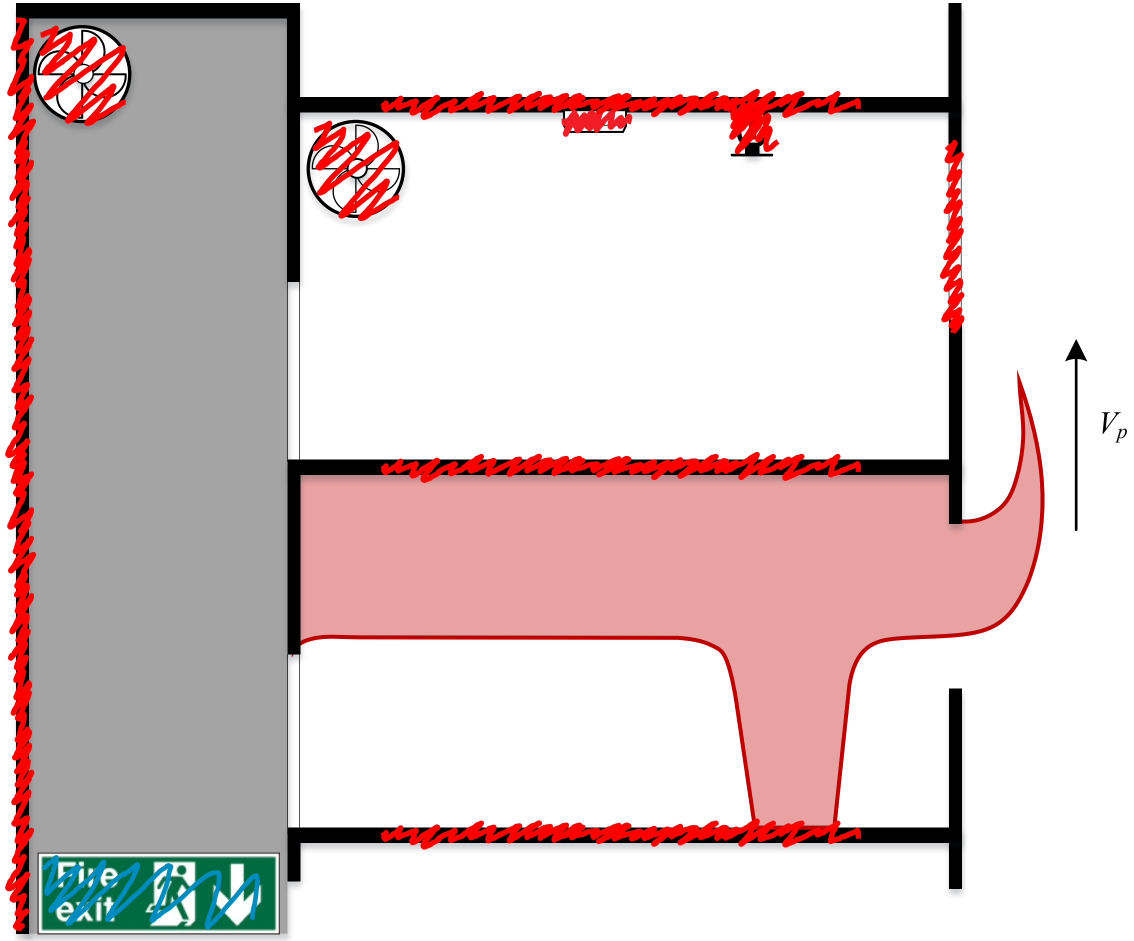
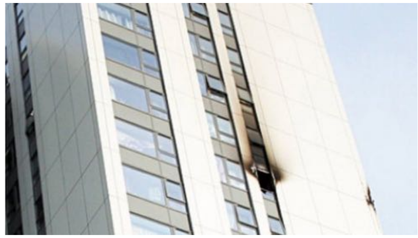
Why vertical flame spread is unacceptable

NIST/Michael Chan





BBC/Camden New Journal

REUTERS/Ahmed Jadallah

Context

- Fire safety strategy and compartmentation reliance
- Robustness, inadequate property protection
- Classic means to ensure vertical compartmentation (spandrels etc.)
- Modern design and construction details
- Encapsulation and material compliance
- Proof of performance
- ‘Unanticipated’ failure mechanisms
- Initial investigations
- Remediation
- Inadequacy of previous methods
- Industry-wide problems and compliance


Contents lists available at ScienceDirect

Construction and Building Materials

Towards a better understanding of fire performance assessment of façade systems: Current situation and a proposed new assessment framework

M.S. McLaggan, J.P. Hidalgo, A.F. Osorio, M.T. Heitzmann, J. Carrascal, D. Lange, C. Maluk, J.L. Torero

ARTICLE INFO

ABSTRACT

1. Introduction

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Queensland Government response

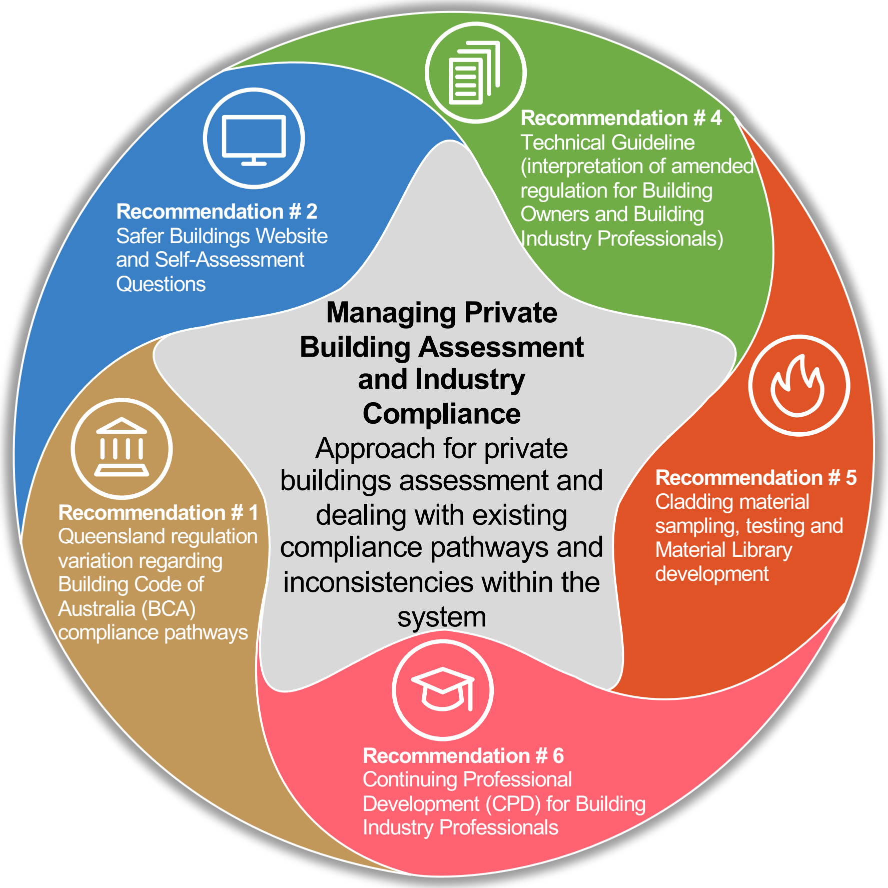
Queensland Non-Conforming Building Products Audit Taskforce

- Establishment of the Non-Conforming Building Products Audit Taskforce, making six recommendations, including:

  Recommendation 4: That the government develop of education and guidance material for building stakeholders

  Recommendation 5: Evaluate possible options for fire testing, and develop a materials library to enable the rapid assessment of claddings

  Recommendation 6: Development of a continuing professional development course to train and educate building professionals



Cladding Materials Library

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1. What are the materials?
2. What are their key properties?
3. How will they behave as part of the *system*?
4. Can the *building* respond to a façade system fire adequately?
5. What skills do building professionals require to assess this?

Testing protocols

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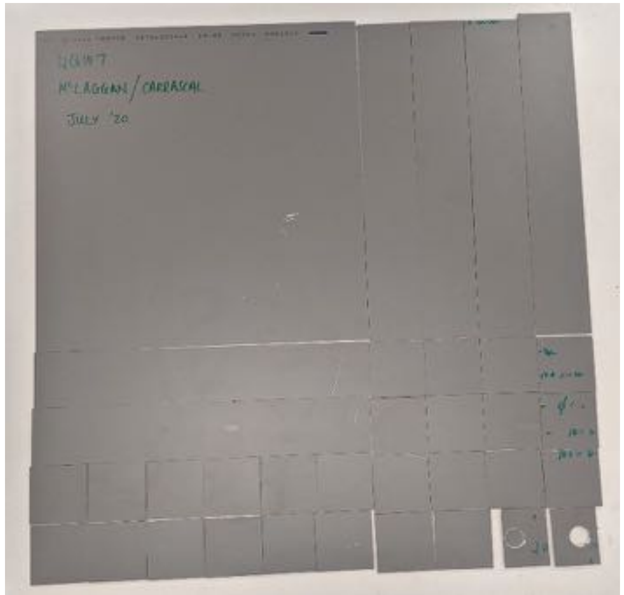
- **Screening protocol** (run on all samples, in the region of 1,100)
  - Deliver a rapid initial assessment of each sample
  - Obtain unique fingerprint associated with each unique material
  - Quick and easy to run

- **Detailed testing protocol** (run on a select number of samples, currently 20+)
  - Determination of material properties
  - Detailed characterisation of flammability performance
  - Key metrics as used in the fire safety engineering community
  - The needed data for engineers to make an assessment



Testing protocols

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- **Screening protocol** (run on all samples, in the region of 1,100)
  - What are the constituent materials in a sample?
  - How much of each component is there?
  - What is the thermal degradation?

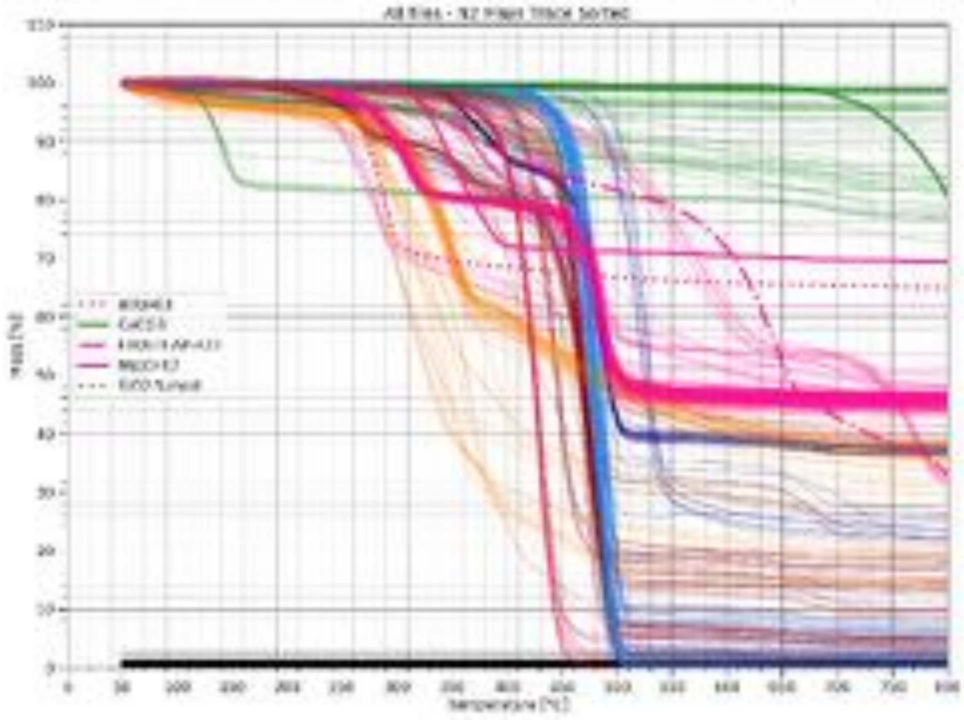
- **Detailed testing protocol** (run on a select number of samples, currently 20+)
  - How much energy does the material release?
  - What are the ignition characteristics?
  - What is the burning behaviour?
  - How much does the flame propagate in both opposed and concurrent conditions?

Cladding Materials Library

www.claddingmaterialslibrary.com

Testing

- 3,856 FTIR tests
- 2,379 EDXRF tests
- 2,485 TGA tests (at about 1.5 hours each)
- 67 bomb calorimeter tests
- 164 cone calorimeter tests
- 156 mass loss calorimeter tests
- 114 lateral flame spread and ignition tests



= 9,221 experiments/tests (thanks Tam *et al.*)

Scaling up

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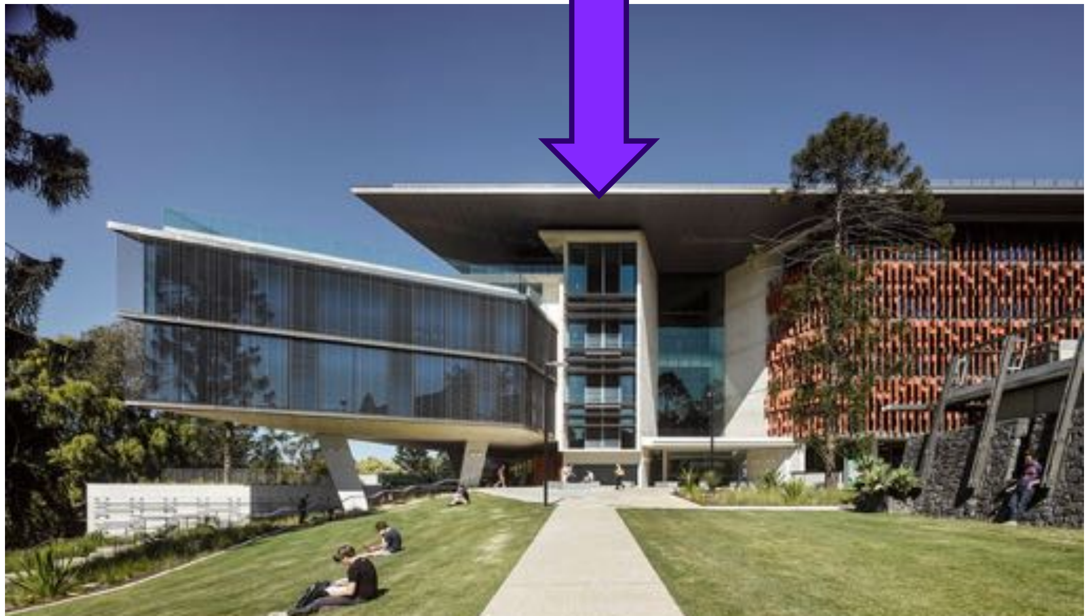
- Hazard classification according to material flammability
- Identify materials which have clearly unacceptable performance
- Identify materials which have the possibility of acceptable performance
- Estimates must be conservative
- Large-scale tests are not a panacea: if they are used, they must represent a *relevant* system and a competent engineer must *interpret* the results



Material-scale

System-scale

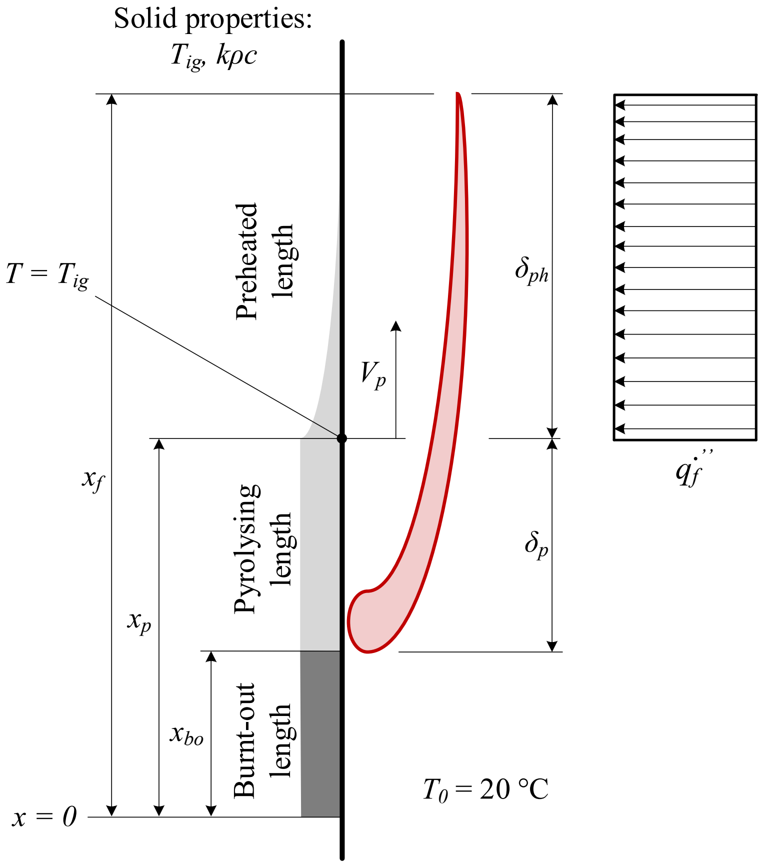
Large-scale



Building

Fundamental concept

Estimate flame spread velocity
vs.
Time to untenable
conditions/structural collapse



Material-scale classification

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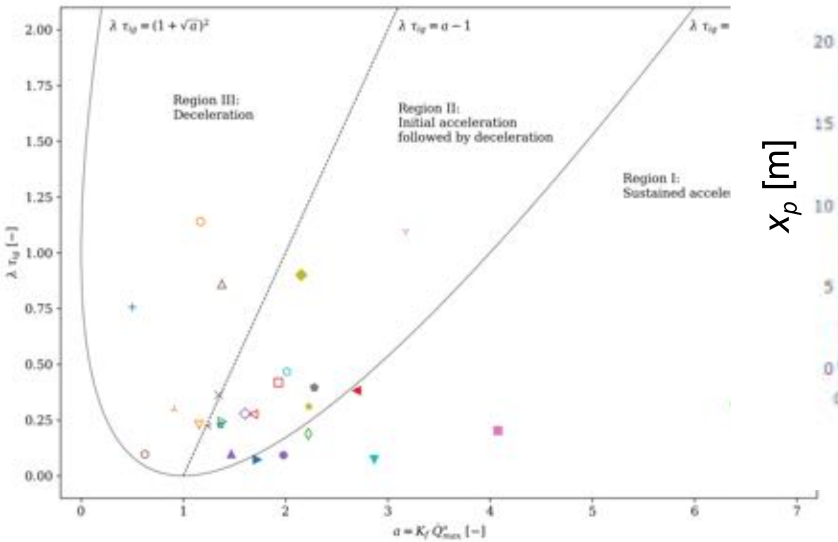
Concurrent (upward) flame spread equation:

$$V_s = \frac{4}{\pi}\frac{\dot{q}_f''^2 \delta_{ph}}{k\rho c}\frac{1}{(T_{ig} - T_0)^2}$$

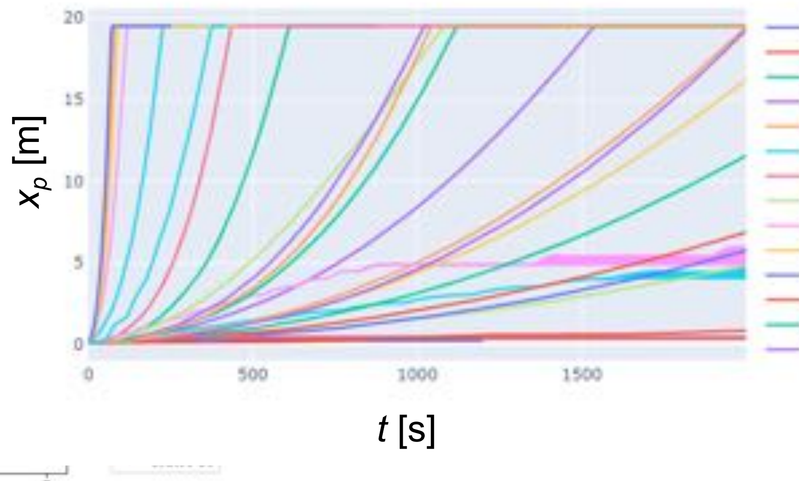
Volterra-type integral:

$$V(t) = \frac{1}{\tau_{ig}}\left[K\left(\dot{Q}_b' + x_{p,0}\dot{Q}''(t) + \int_0^t \dot{Q}''(t - t_p)\, V(t_p)\, dt_p\right)^n - \left(x_{p,0} + \int_0^t V(t_p)\, dt_p\right)\right]$$

Analytical solution



Numerical solution

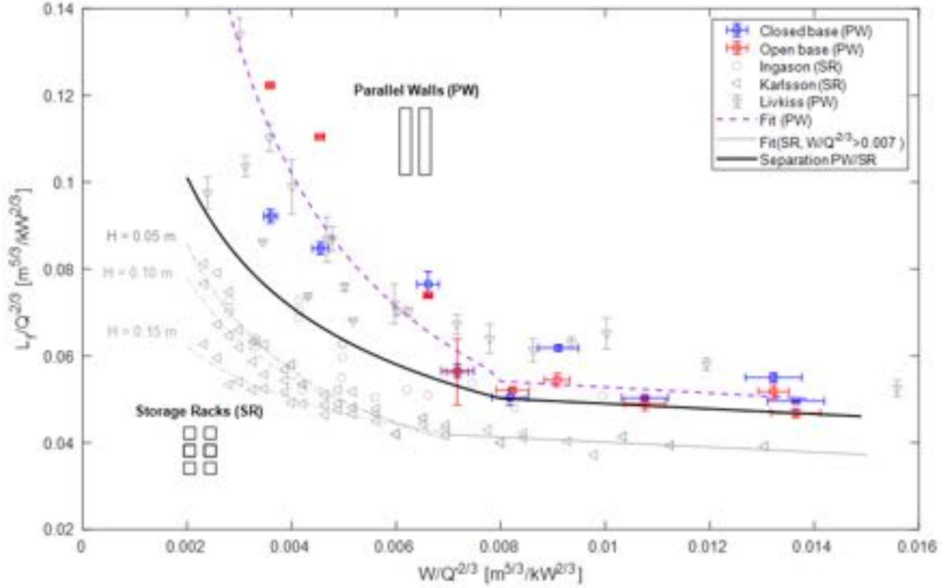


Material ID	Type	$K_f\dot{Q}'' - \frac{t_{ig}}{t_{bo}} - 1$ Eq (10)	$V(t)$ Eq (9)	$\frac{d\delta_{ph}}{dt}$ Exp
INS02	PHF	-0.34	Deceleration	-
ACP22	ACP FR	0.33	Deceleration	-
INS01	PIR	0.49	Finite acceleration	-
ACP15	ACP FR	0.51	Finite acceleration	-
ACP02	ACP FR	0.52	Deceleration	-
ACP34	ACP FR	0.52	Finite acceleration	0
ACP09	ACP FR	0.55	Deceleration	-
OTH01	Phenolic	0.61	Deceleration	-
ACP05	ACP FR	0.73	Finite acceleration	-
INS12	PUR	0.75	Sustained acceleration	-
ACP06-S1	ACP A2/thin film	0.77	Deceleration	-
ACP35	ACP FR	0.81	Finite acceleration	-
ACP04	Cellulose/phenolic	1.02	Finite acceleration	-
OTH24	WPC	1.03	Sustained acceleration	-
ACP11	ACP FR	1.12	Finite acceleration	-
INS05	PIR	1.27	Finite acceleration	> 0
SRK01-S1	Sarking	1.27	Finite acceleration	-
OTH04	Plywood	1.33	Sustained acceleration	< 0
INS04	EPS	1.58	Finite acceleration	-
ACP01	ACP A2	1.66	Deceleration	-
ACP10	ACP A2/thin film	1.74	Finite acceleration	-
INS06	PUR	1.89	Sustained acceleration	-
OTH23	GFRP	1.96	Sustained acceleration	-
ACP07	ACP PE	3.26	Sustained acceleration	> 0
INS03	Polyester wool	3.57	Finite acceleration	-
ACP03	ACP PE	5.67	Sustained acceleration	-

McLaggan, M. S., Gupta, V., Hidalgo, J. P., & Torero, J. L. (2021). Upward Flame Spread for Fire Risk Classification of High-Rise Buildings. International Journal of High-Rise Buildings, 1–20.

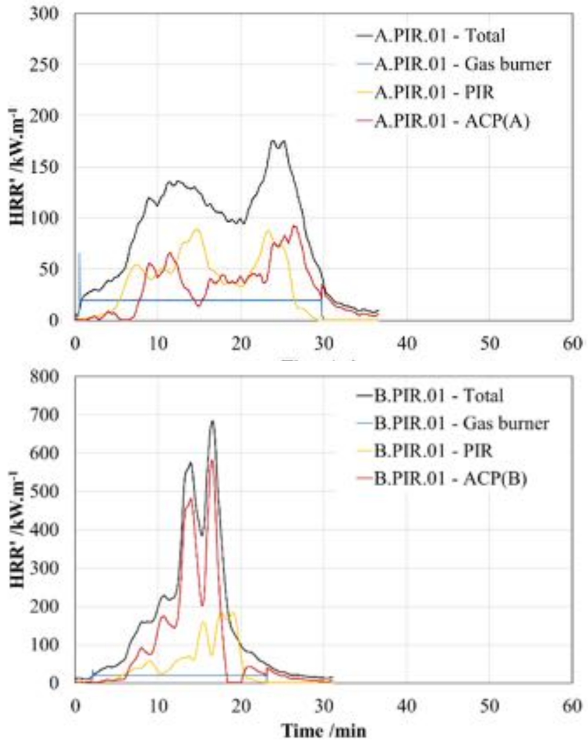
System-scale

Potential flame elongation in inert systems



Mendez, Julian E., et al. "Effect of cavity parameters on the fire dynamics of ventilated façades." *Fire safety journal* 133 (2022): 103671.

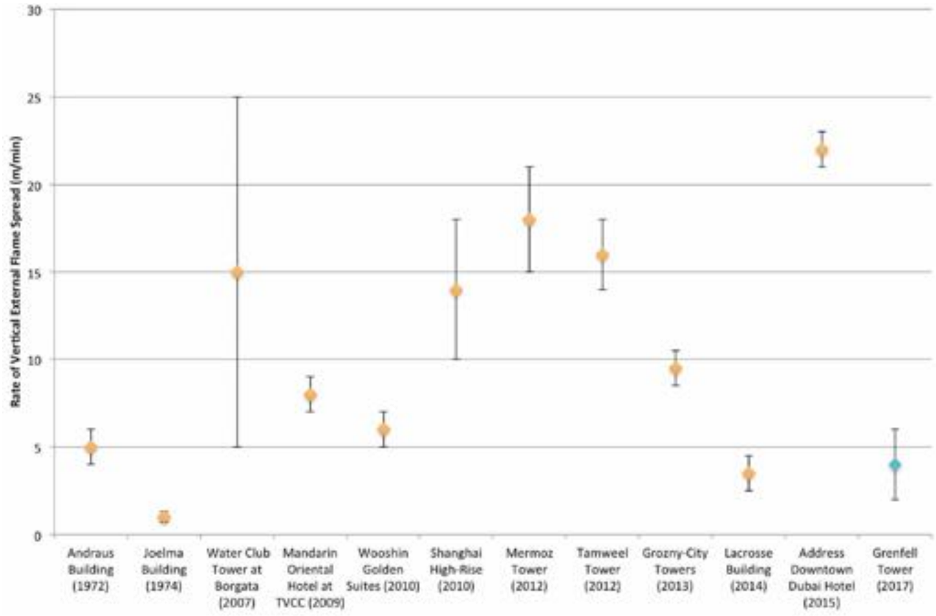
Simplified systems containing combustibles



Garvey, B. *et al.* (2019). Experimental methodology to study the fire contribution of cladding materials. *Proceedings of Interflam* (pp. 2079–2090).

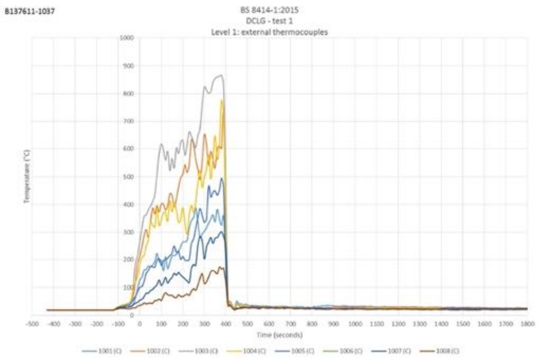
Large-scale data

Real building fires

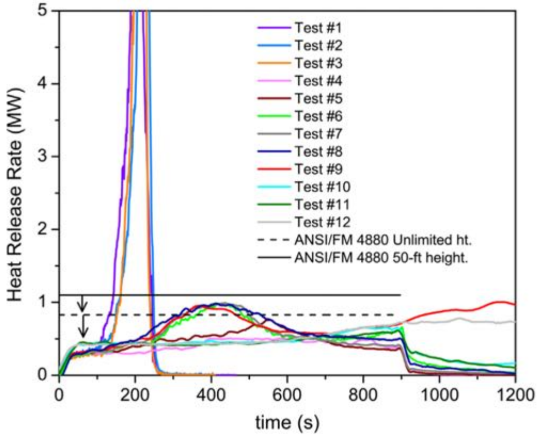


Torero, J. L. (2018). Grenfell Tower Inquiry: Professor Jose Torero expert report (Phase 1 - supplemental), JTOS0000001.

Large-scale test data



BRE Global. (2017). BRE Global Client Report – BS8414-1:2015+A1:2017 test, DCLG test 1.



Agarwal, G., Wang, Y., & Dorofeev, S. (2020). Fire performance evaluation of cladding wall assemblies using the 16-ft high parallel panel test method of ANSI/FM 4880. *Fire and Materials*, April, 1–15.

Competency framework

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CPD for fire safety engineers

A joint CPD programme delivered by…

The University of Queensland Australia

The University of Edinburgh

UCL

https://www.civil.uq.edu.au/fire-externalspreadcpd

Course structure (35 h)

Module 1 – Analysis of the fire strategy of a building (4 h).

Module 2 – Fundamentals of vertical fire spread (7 h).

Module 3 – Review of professionalism and the design process (2 h).

Module 4 – Mechanics of the coupled structure-façade system (1 h).

Module 5 – Cladding Materials Library and Laboratory sessions (7 h).

Module 6 – Reformulation of the fire safety strategy. (11 h).

Module 7 – Examination (3 h).

CPD Day		Day 1	Day 2	Day 3	Day 4	Day 5
8:00	8:15	Registration + Coffee	Morning coffee	Morning coffee	Morning coffee	Morning coffee
8:15	8:30					
8:30	8:45	Explicit fire safety strategy	Introduction	Responding to the 'Shergold & Weir Inquiry'	The Material Library framework	Laboratory session
8:45	9:00		Material composition (polymers)			
9:00	9:15					
9:15	9:30					
9:30	9:45		Thermal decomposition reactions			
9:45	10:00					
10:00	10:15					
10:15	10:30		Coffee break			Coffee break
10:30	10:45	Coffee break	Flaming ignition	Coffee break	Coffee break	Laboratory session
10:45	11:00	Explicit fire safety strategy		Curtain walling systems	The Material Library framework	
11:00	11:15					
11:15	11:30					
11:30	11:45		Heat release rate and burning rate			
11:45	12:00					
12:00	12:15					
12:15	12:30					Lunch
12:30	12:45		Lunch			
12:45	13:00	Lunch		Lunch	Lunch	
13:00	13:15					
13:15	13:30					Exam
13:30	13:45		Flame spread (concurrent and opposed)			
13:45	14:00	Implicit fire safety strategy		Case study 1	Case study 2	
14:00	14:15					
14:15	14:30					
14:30	14:45		Fire retardants			
14:45	15:00					
15:00	15:15					
15:15	15:30	Coffee break	Coffee break	Coffee break	Coffee break	
15:30	15:45	Implicit fire safety strategy and vertical fire spread	External fire plumes	Case study 1	Case study 2	
15:45	16:00					
16:00	16:15					
16:15	16:30		System vs material behaviour			
16:30	16:45					
16:45	17:00					

CPD for building stakeholders

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- 2 day CPD
- For other building professionals, e.g.:
  - Certifiers
  - Manufacturers
  - Building owners
  - Architects
- Professionals need to be able to identify complex problems, know the limit of their abilities, and how to highlight issues
- 75% run by government

Implementation in Queensland

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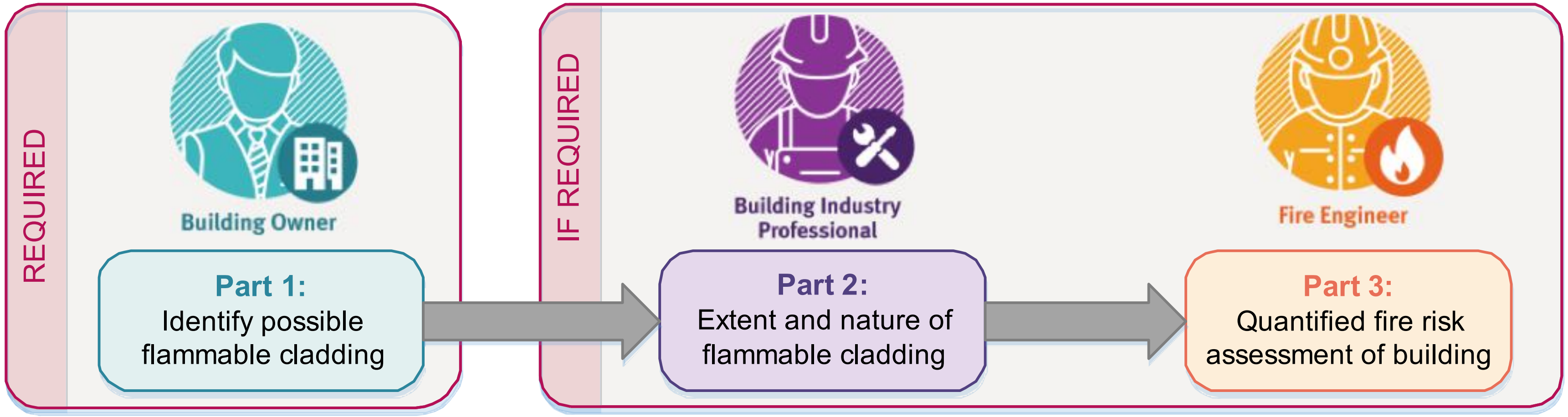
Implementation



19,965+ buildings	~3,750 buildings	938 buildings
Register building Answer basic questions (size, purpose, etc.)	Register details of professional Identify any possible combustible materials	Register details of competent fire engineer Perform testing and conduct fire risk assessment of building Remediation

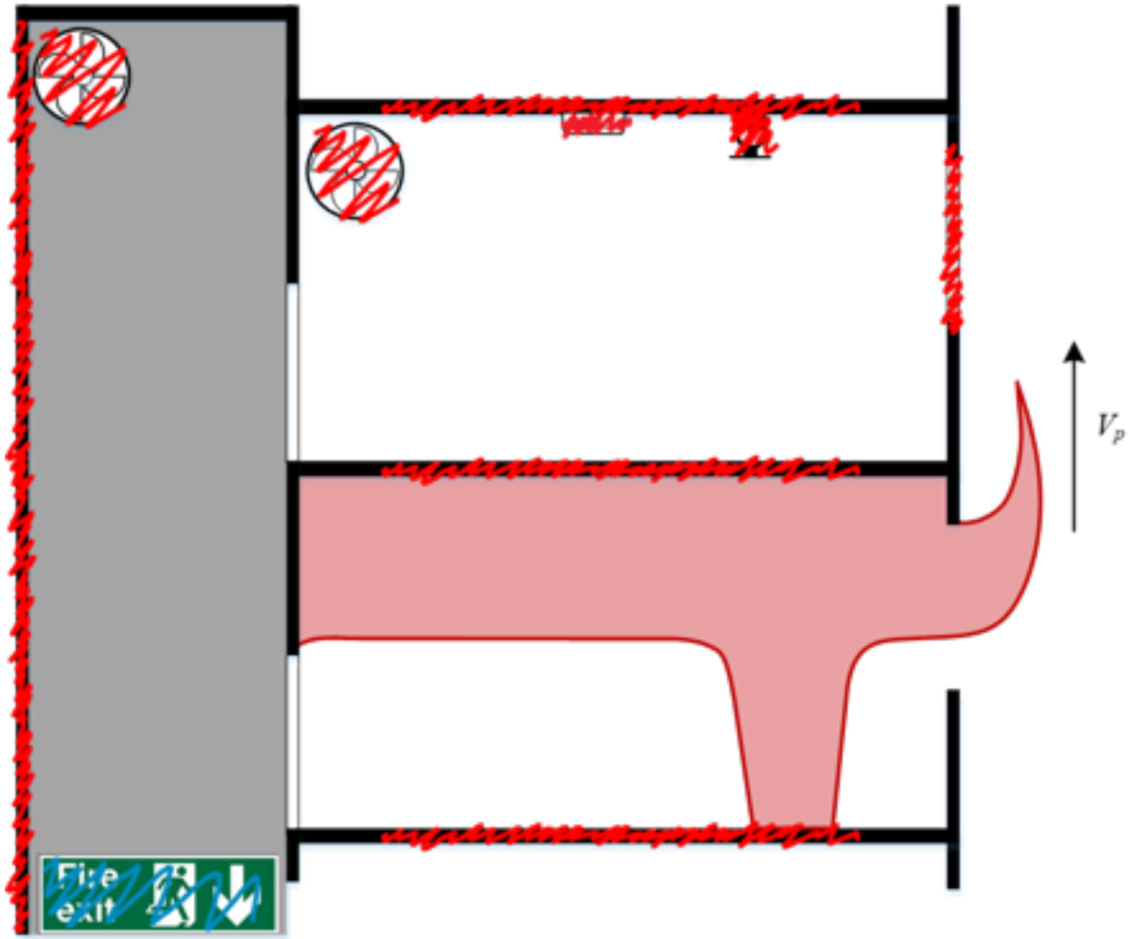
Implications for structural fire engineering

Breach of compartmentation

Façade fires and external fire spread introduce changes to the structural design

Structure must resist:

- Multi-storey or full building fires of a long duration
- Externally spreading fire with a specified velocity, duration and exposure



Mass timber

Impact of mass timber on the façade:

- Increased heat exposure due to greater energy released outside the compartment

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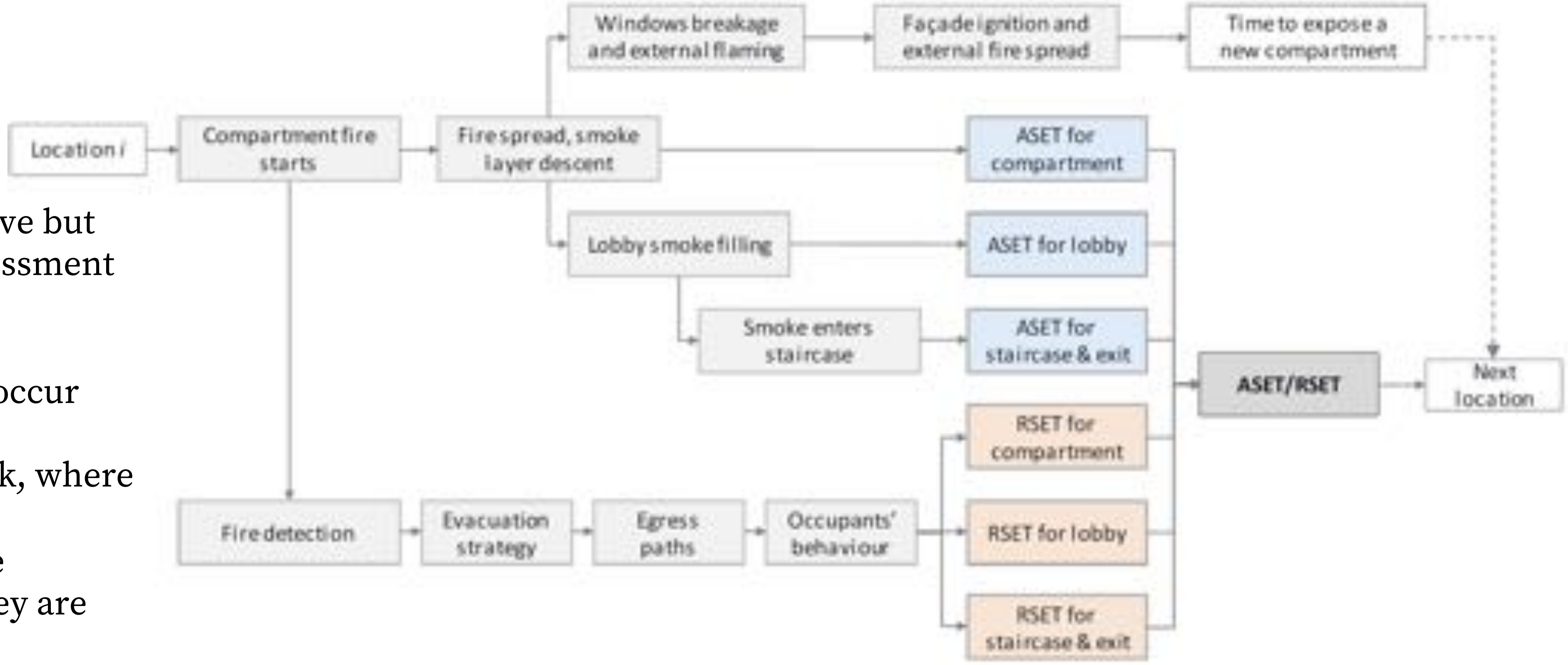
Thanks for listening

Martyn McLaggan
Lecturer in Low Carbon Design

12th May 2023

Possible holistic risk assessment method



- Create a conservative but representative assessment of the building
- Fire is assumed to occur
- Acts as a framework, where more complicated components can be implemented as they are developed
- Identify possible weak areas

J.E. Cadena, M.S. McLaggan, A.F. Osorio, J.L. Torero, D. Lange, Maximum allowable damage approach to fire safety performance quantification, *Fire Safety Journal* (2022), 103537.