Fire ‘Resistance’ Testing

Where are we, how did we get here & where are we going?

Prof Luke Bisby
Arup Chair of Fire & Structures
University of Edinburgh

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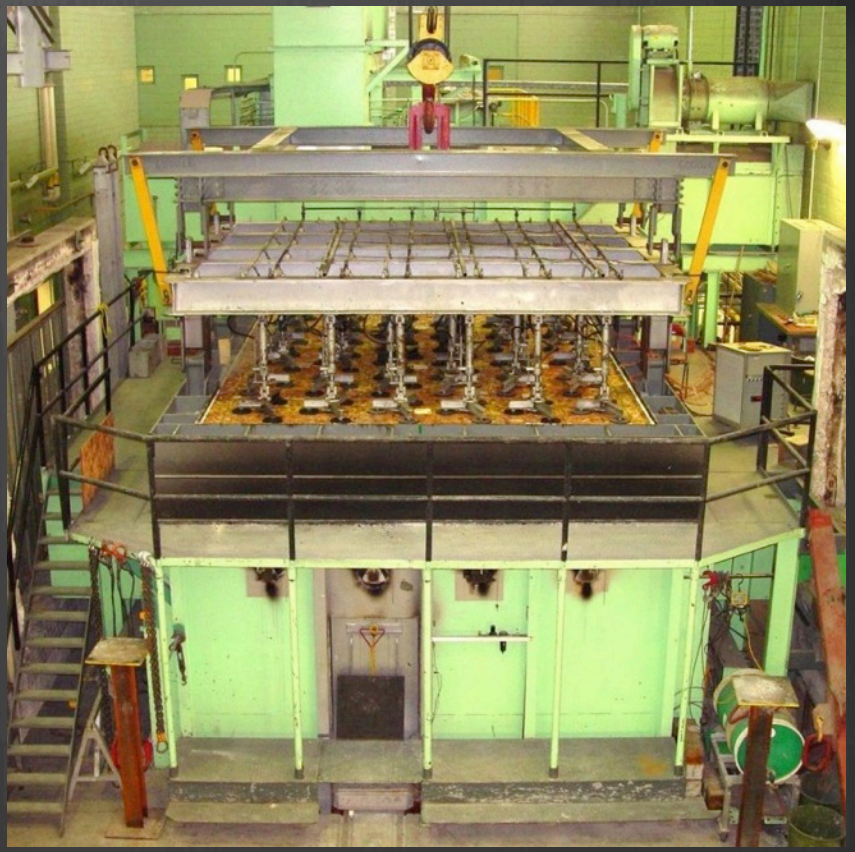
Maintain stability & prevent the spread of fire for a reasonable period…
Do we have the data we need?
What ARE the data we need?

Fire ‘Resistance’ Testing

Stewart & Woolson (1902)



Bisby (2003)

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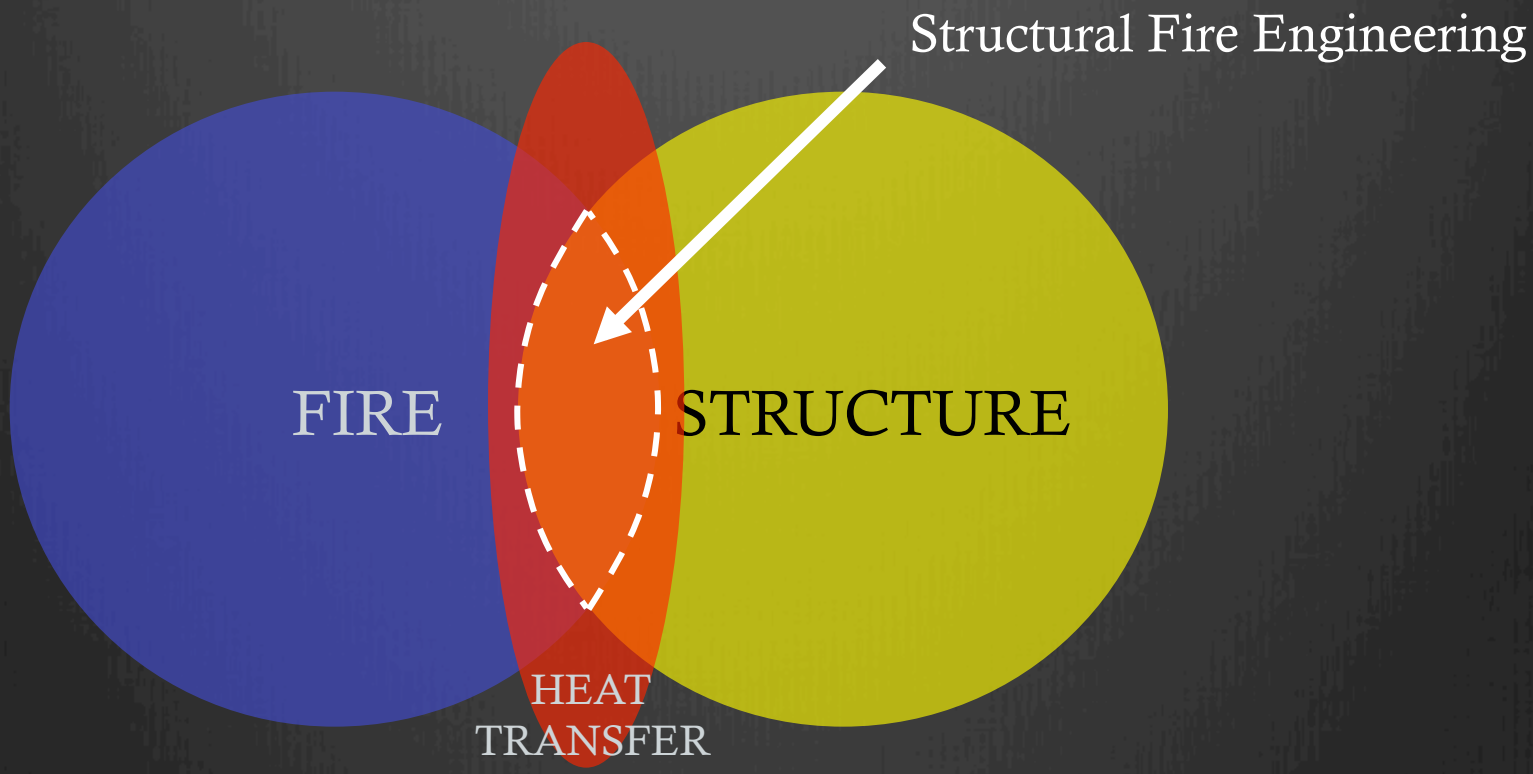
1974 – Lame Substitutions*



*a term coined by Dr Guillermo Rein, Imperial College

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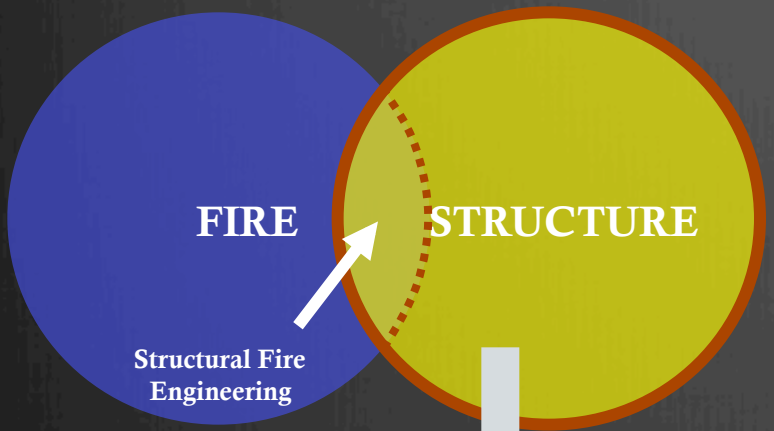
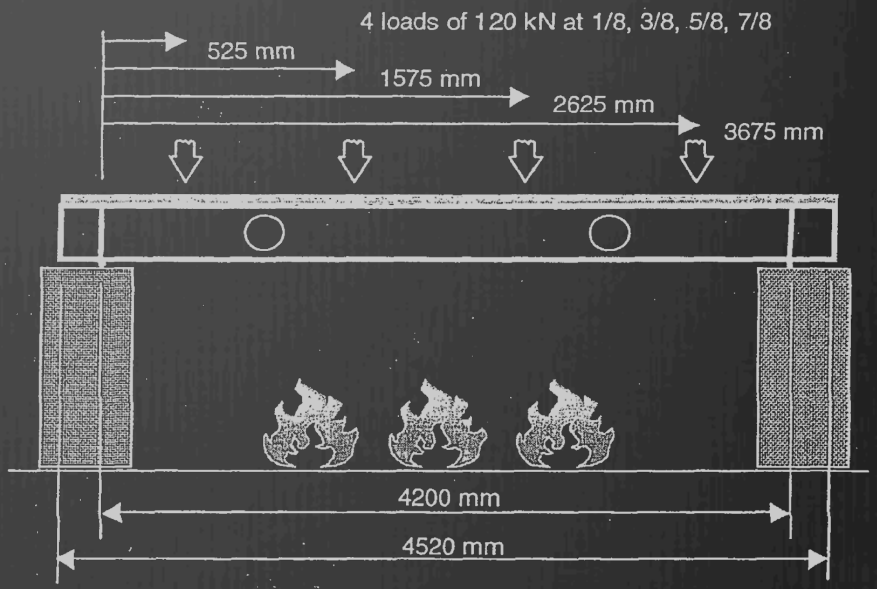
Lame Substitution 1 – By Fire Engineers





$T_{failure} = 550^{o}C$

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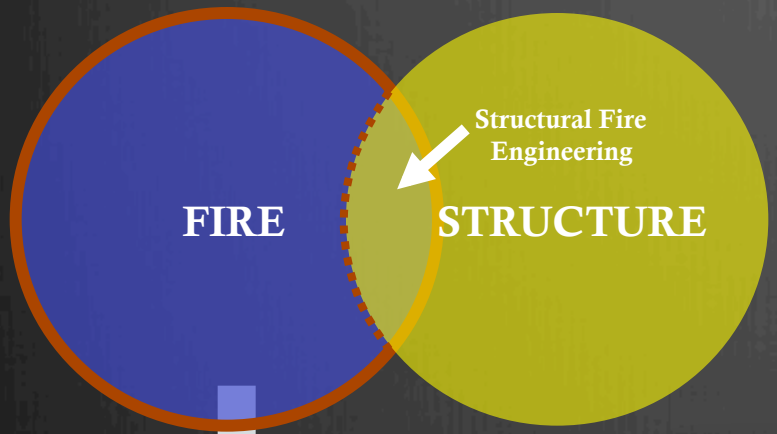
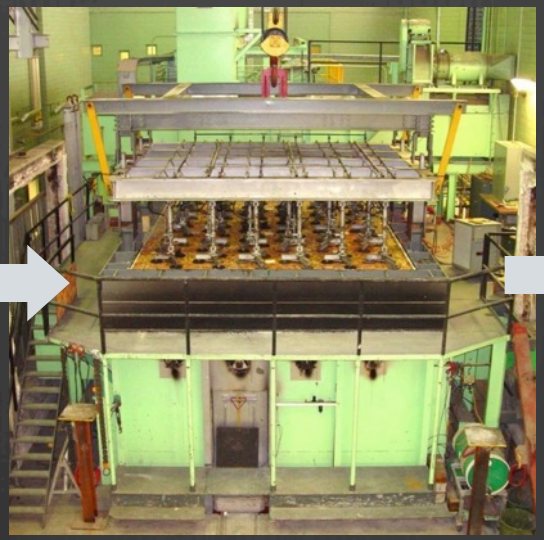
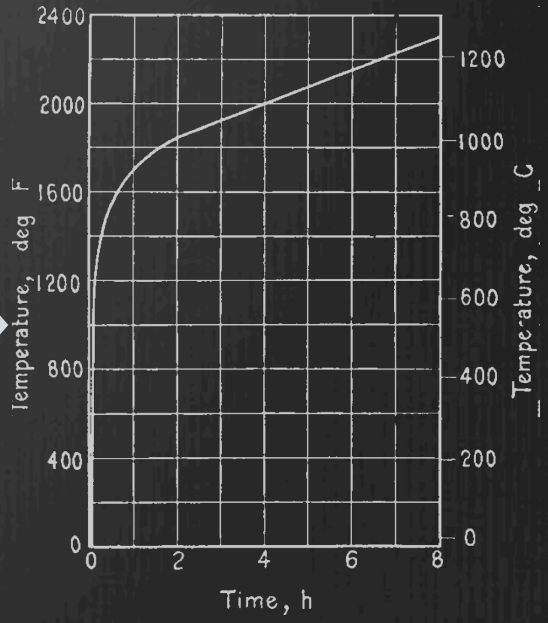
Lame Substitution 2 – By "Structural" Engineers







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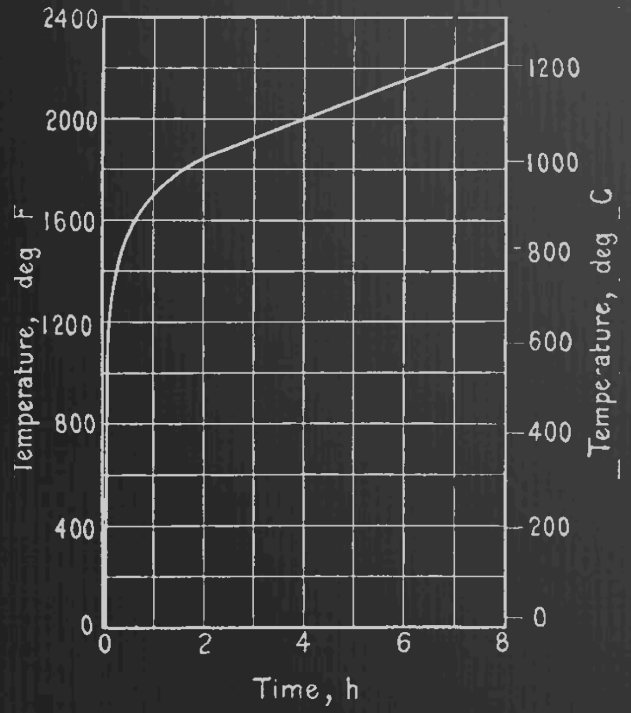
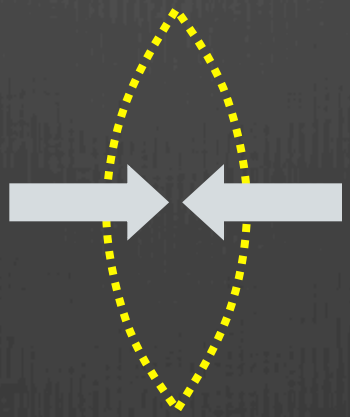
Lame Substitution 3 – **Status Quo 1974**

Structural Fire Engineering?!





$T_{failure} = 550°C$

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May 2014

Structural Journal of the American Concrete Institute
Cover Photo!

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1974-2014

Mapping change in structural fire resistance testing (& analysis) through key events & the work of (some of) Edinburgh's graduates

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Centre Georges Pompidou (Law 1977)

Explicit recognition that **the 'standard' fire may not be applicable**

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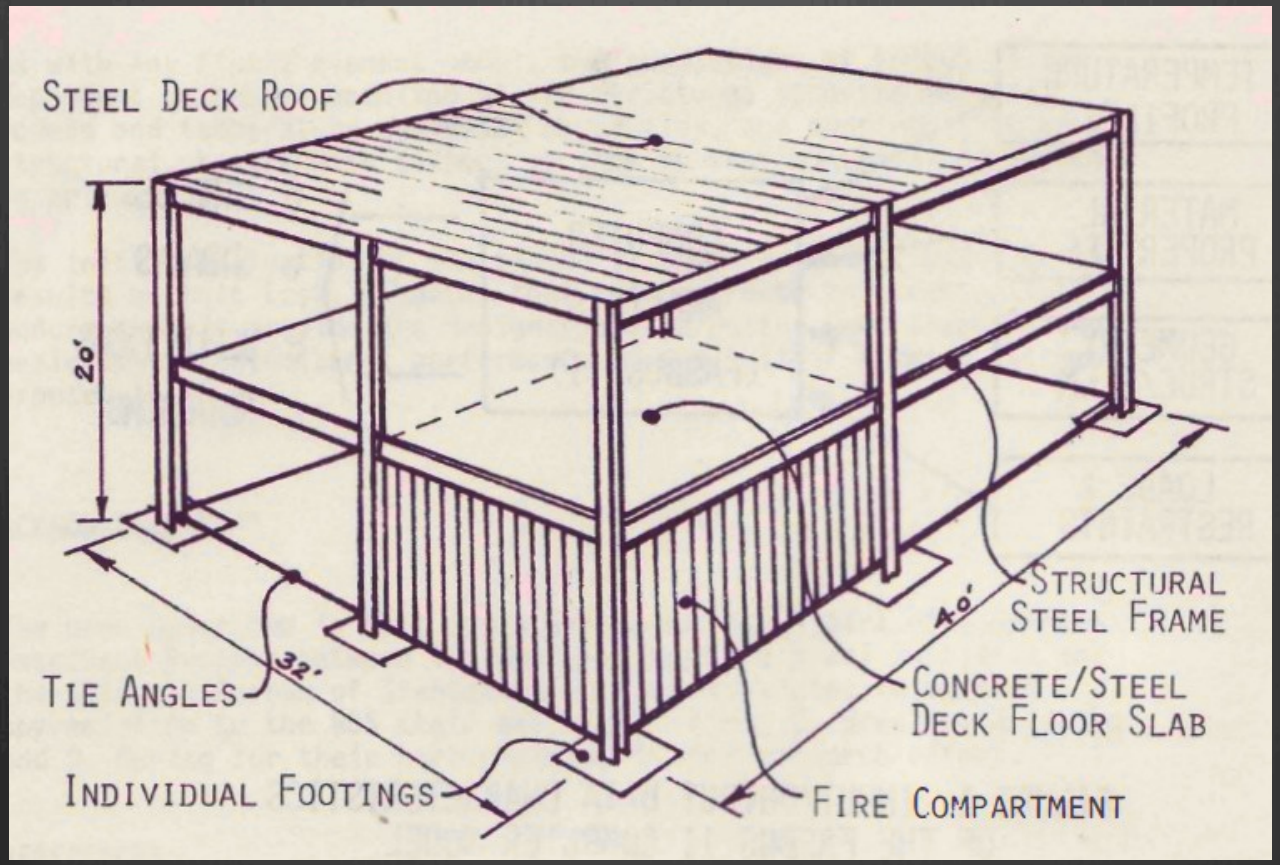
The Renaissance – NIST (1982)



Explicit recognition of the **significance of full-structure response** to fire – Need for **experimental data for finite element model validation**

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Broadgate Phase 8 (1990)

Demonstrated ability of **unprotected steelwork** to resist a severe fire in a real building

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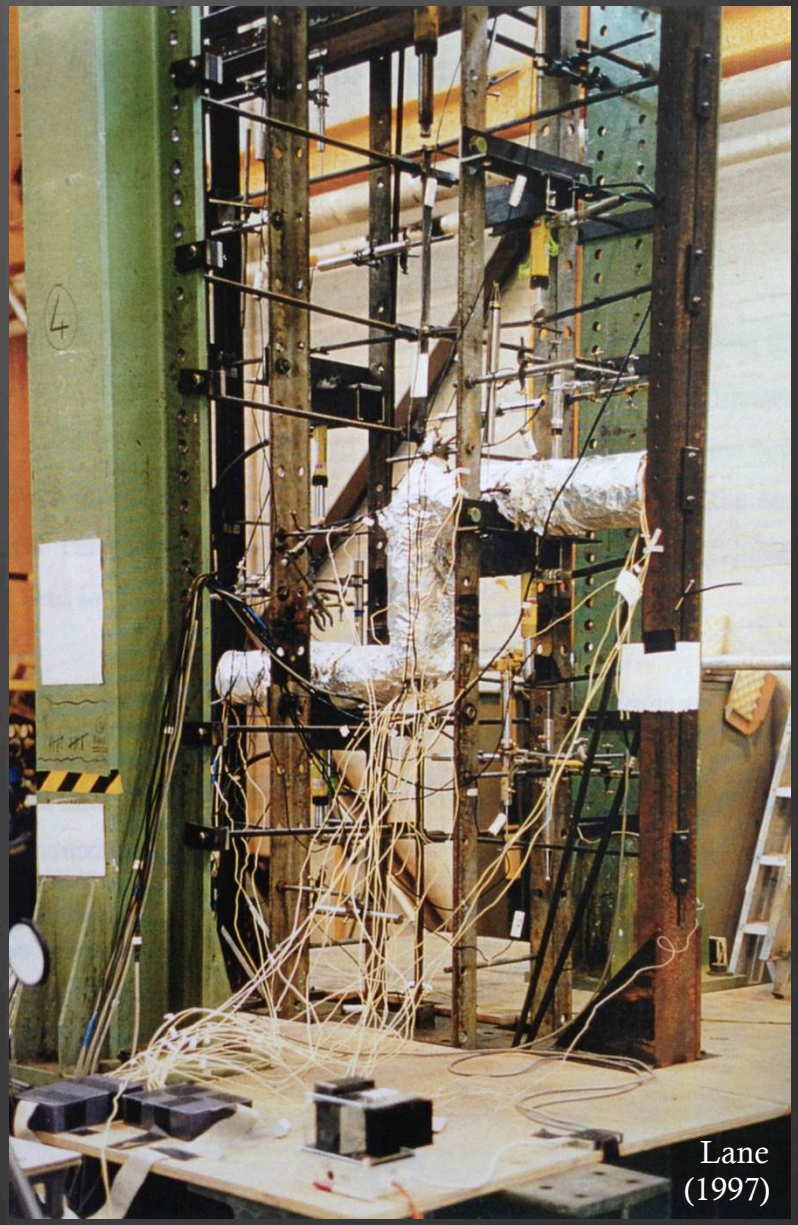
Lane (1997)

The Response of **Steel Frame Structures** under Fire Conditions


Lane (1997)

The 1st structural fire engineering experiments at Edinburgh

NOTE: Pre-Cardington!

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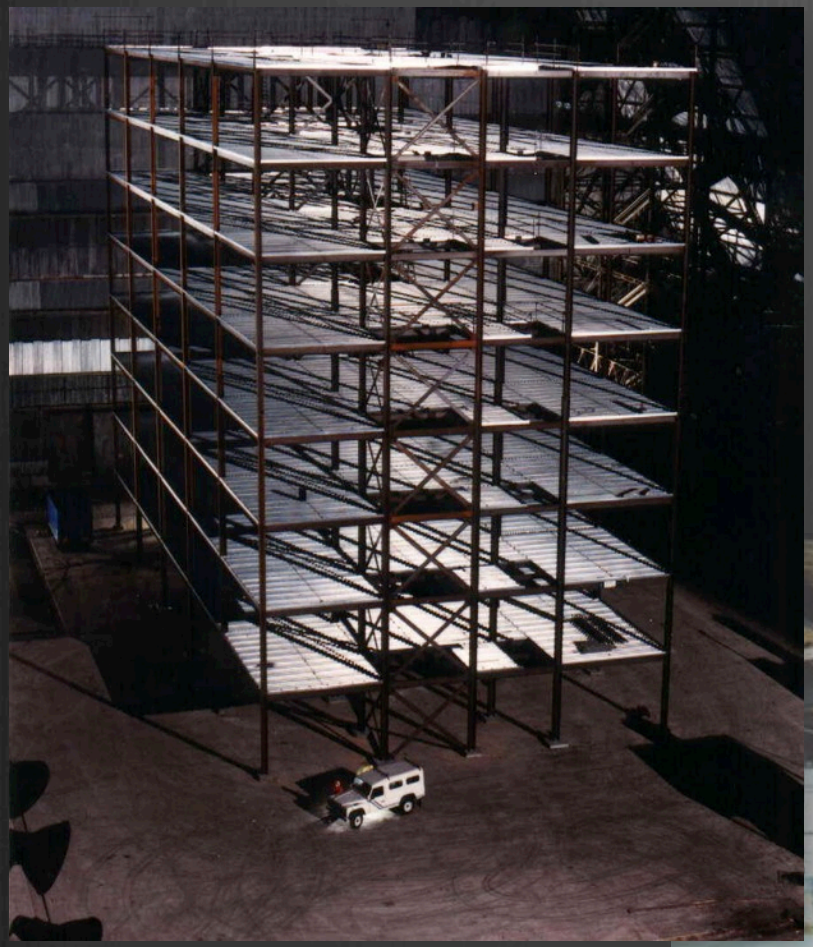
Cardington Fire Tests (1995/96)



http://www.mace.manchester.ac.uk/project/research/structures/strucfire/default.htm

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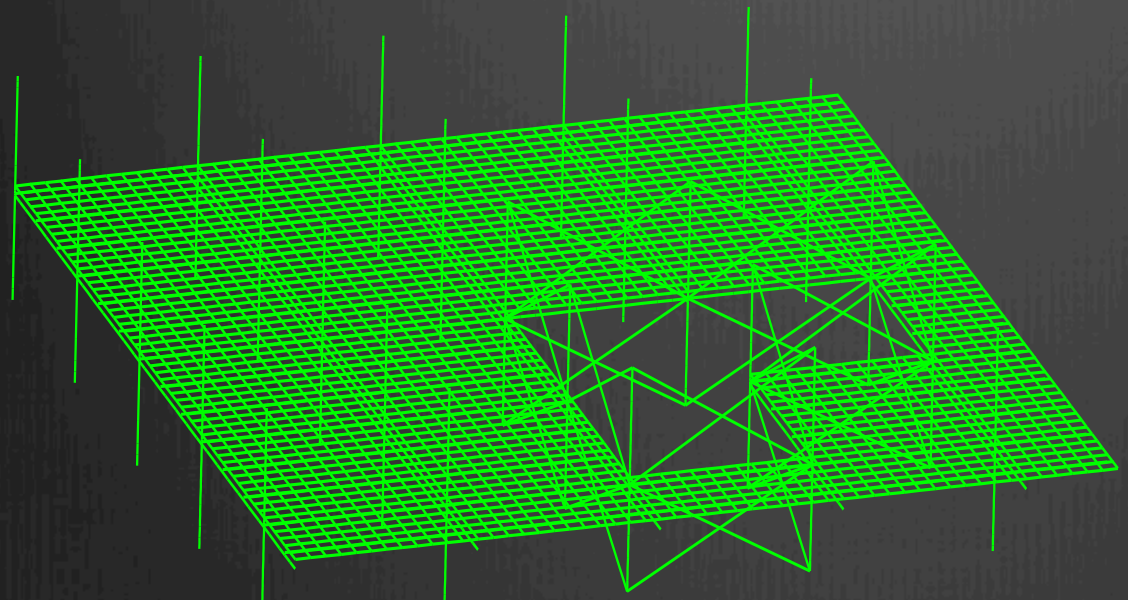
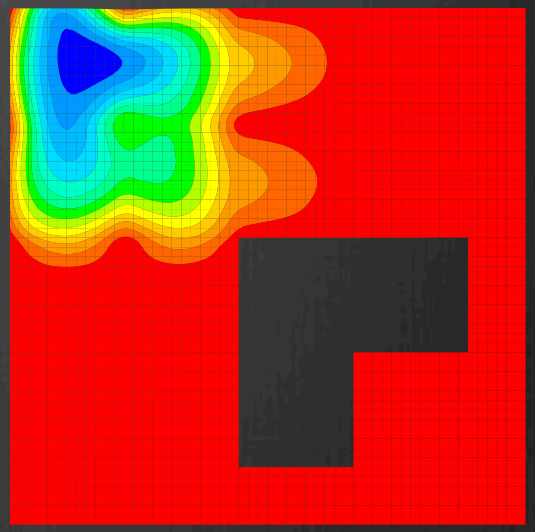
Gillie ('00), Lamont ('01), Cameron ('03)

'To understand and **exploit the results of the fire tests at Cardington** so that **rational design guidance** can be developed for the fire limit state'





Lamont (2001)

'Behaviour is radically different from the present design philosophy, a new philosophy is required based on **new definitions of the fire limit state**'

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WTC 1, 2 & 7 (2001)

'The Terrorists did it'

Total collapse of **three** steel buildings **due to fire**

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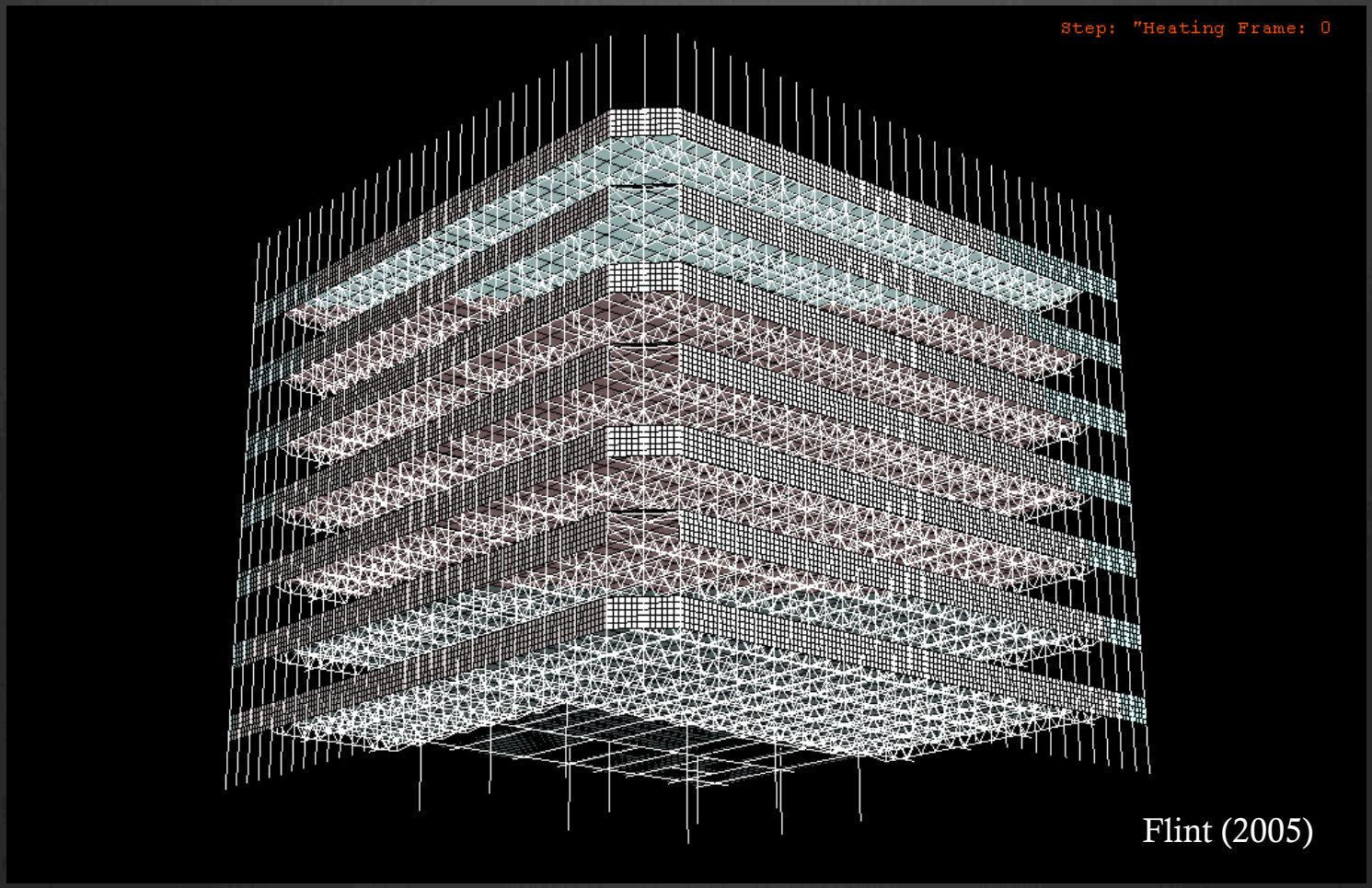
Flint (’05), Jowsey* (’06), Roben (’10)



Flint (2005)

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The Result

Where are we?

Plantation Place
(2004)

Heron Tower
(2011)

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So it's all good news?

Where now?

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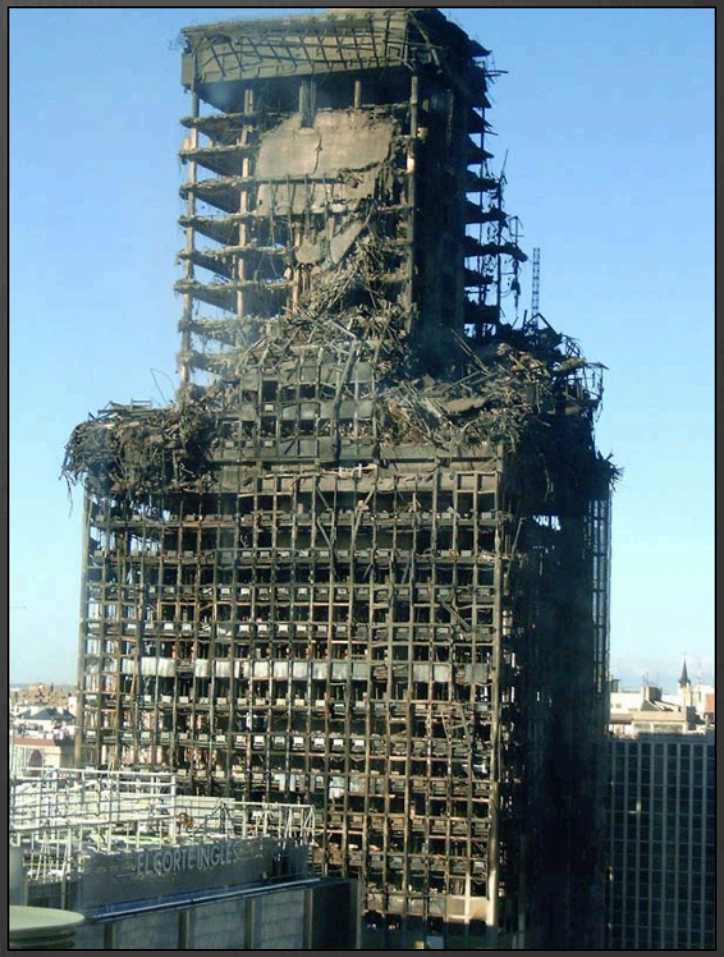
Torre Windsor (2006)



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Cardington Concrete Frame (2001)

The slab remained stable and supported the load ‘by compressive membrane action at small slab vertical displacement’

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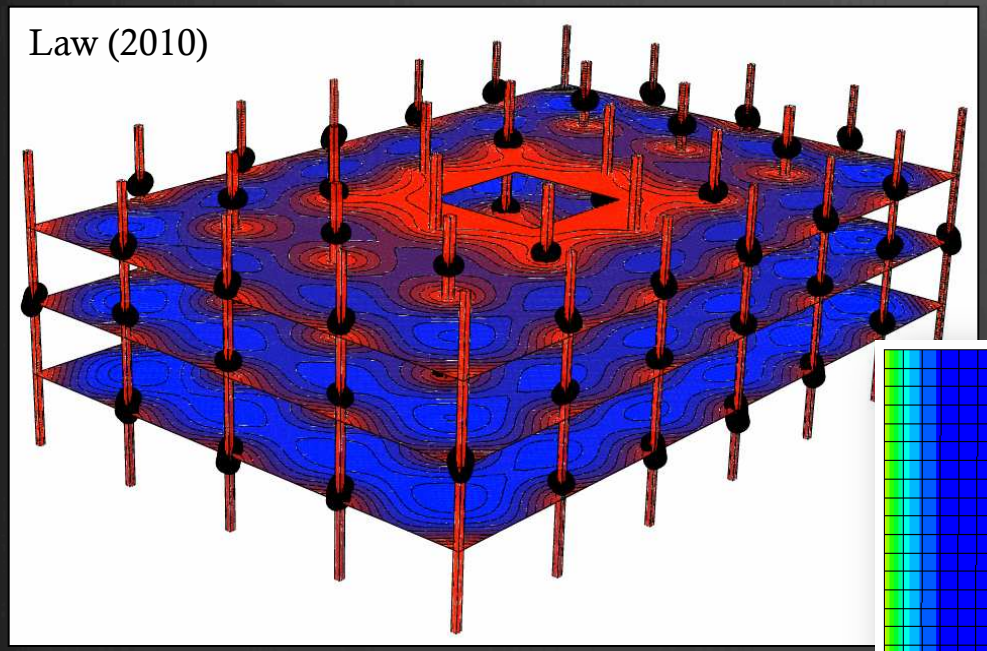
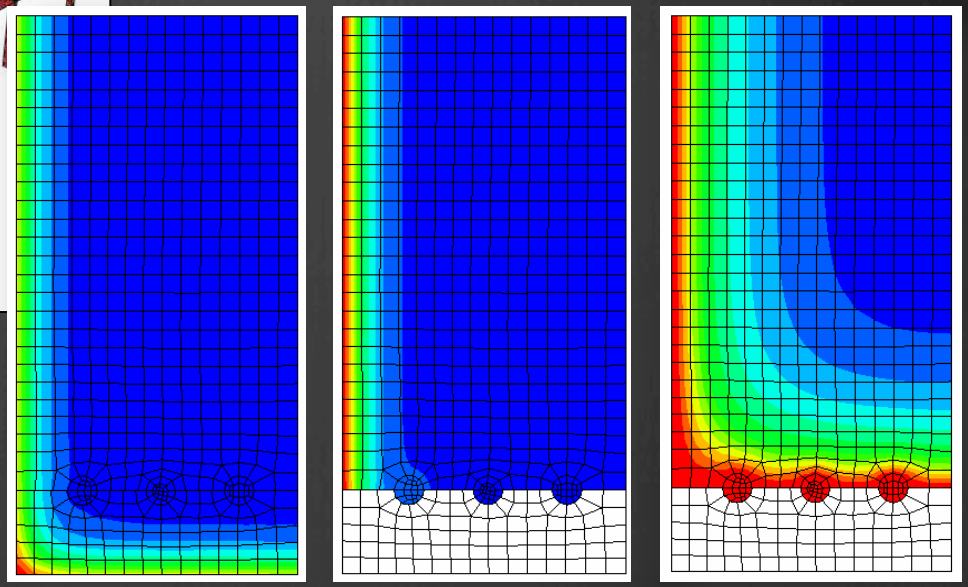
Fletcher (’09), Law (’10), Deeny (’11)



Full-frame response and behaviour under travelling fires

Deeny (2011)



Impacts of cover spalling on response of concrete buildings in fire

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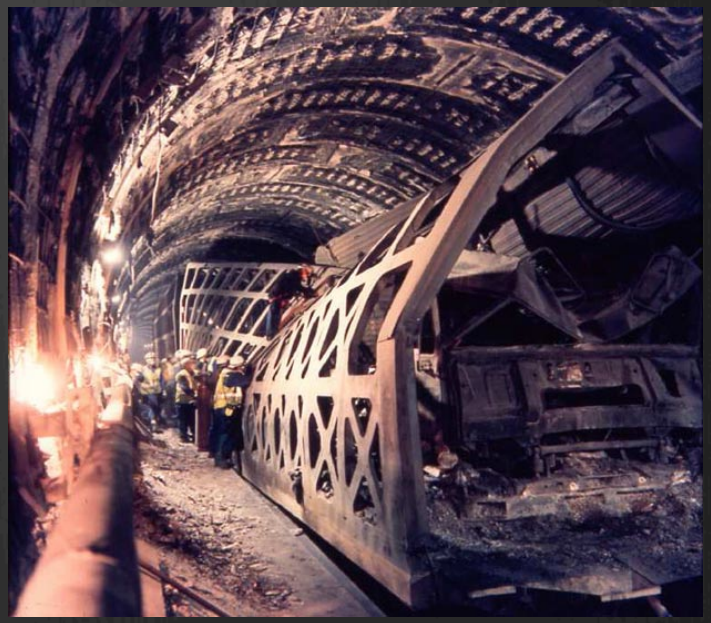
Gretzenbach (2004)

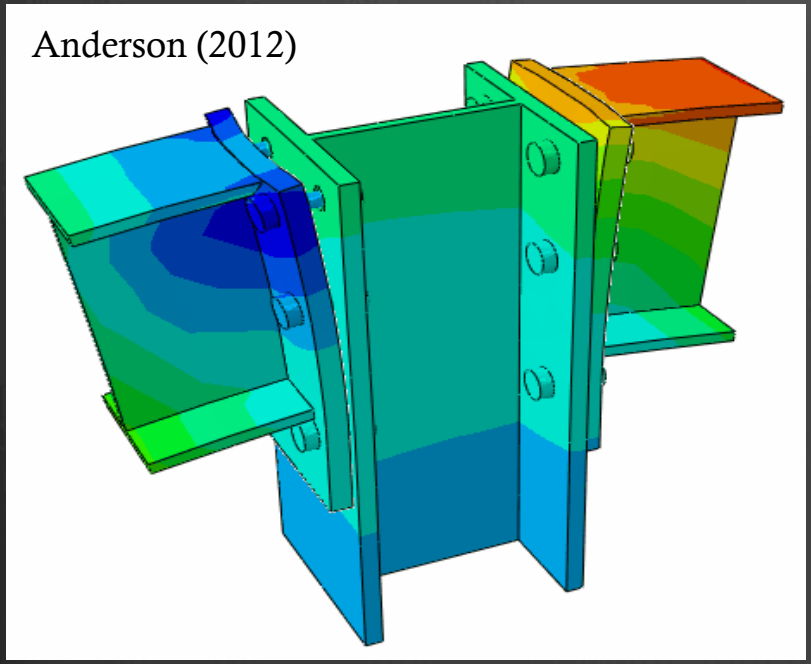
Rotterdam (2007)

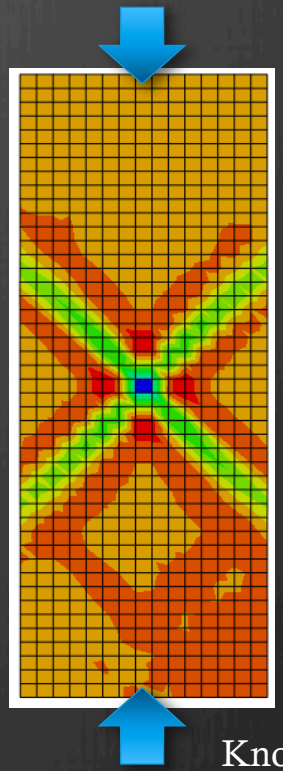
Tunnel Fires (’94-’08)



Anderson (2012)

Knox (2012)





Knox (2012)

A **notable absence of high quality test data** for the purposes of careful and detailed model validation

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The Future?

Structural Fire Testing – Drivers?

1. **Economic** – Client saves money (e.g. on fire protection)
2. **Architecture** – Enable interesting/unusual buildings (e.g. Pompidou, Heron Tower)
3. **Innovation** – Ensure/demonstrate that new or evolving methods, materials, or designs are safe (e.g. CLT)
4. **Sustainability?** – Structural optimization removes inherent redundancies (e.g. post-tensioned flat slabs)
5. **Property Protection?** – Reducing the direct/indirect costs of fire (who cares about the true cost of fire?)
6. **Safety?** – Interrogate the building

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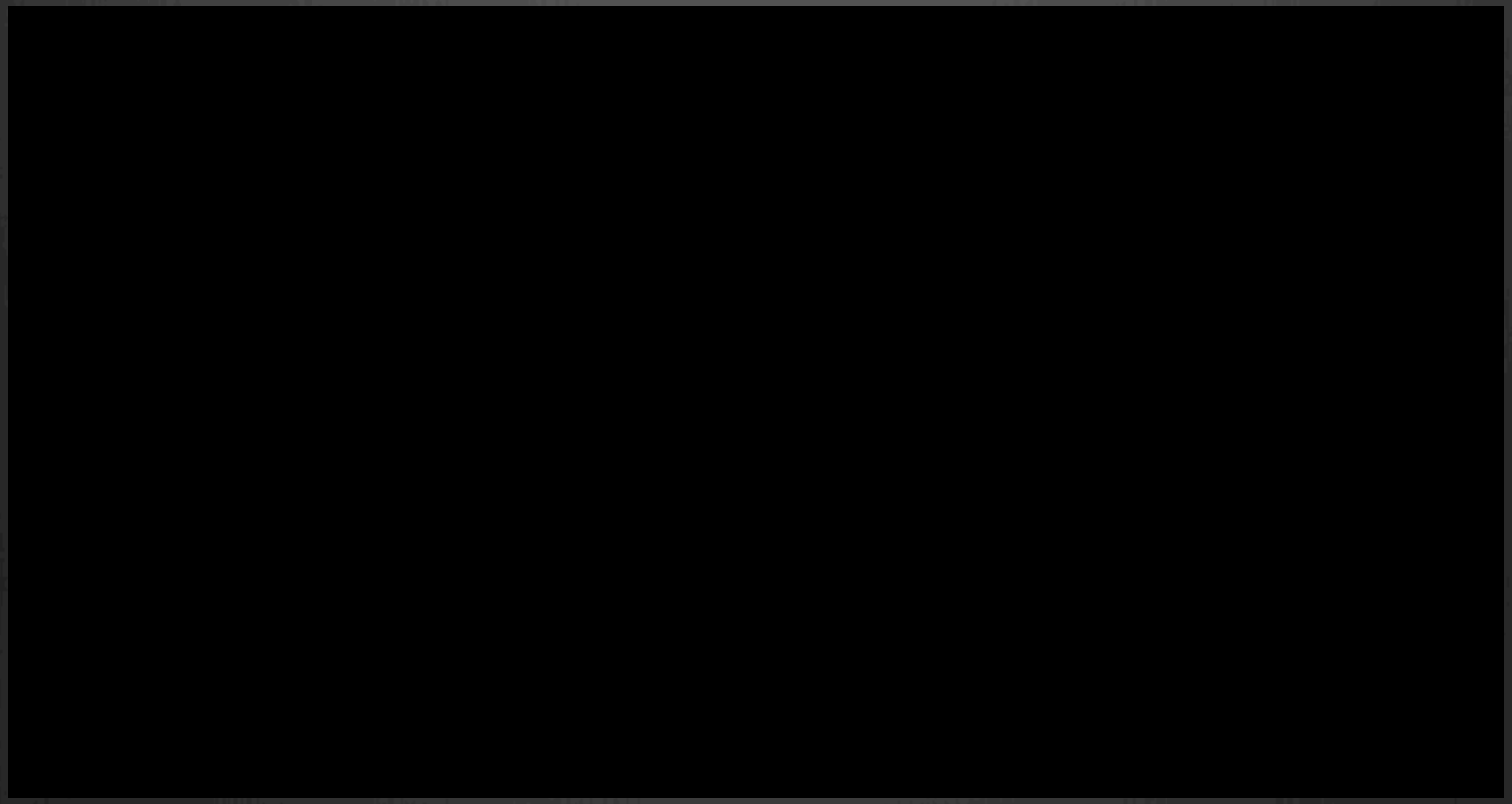
Opportunity 1 – **Real Fires**

Buildings – Tunnels – Offshore & Petrochemical



Preventing the tail from wagging the dog

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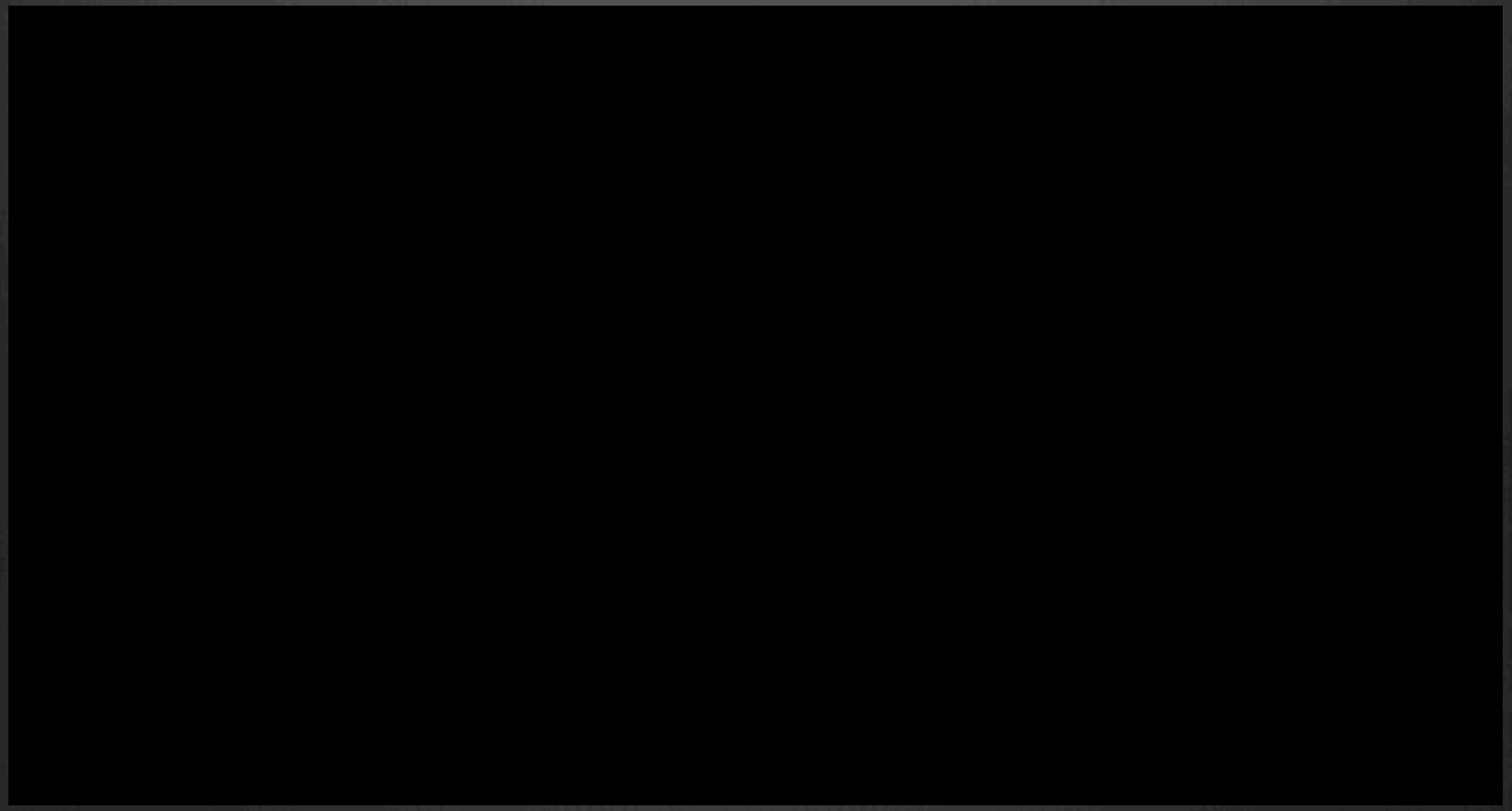
Opportunity 2 – **Real Material Response**

Maluk (2014) – **H-TRIS**



A thermal/mechanical test method applicable to ‘any’ fire scenario

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Fire-Induced Concrete Spalling

Maluk (2014)

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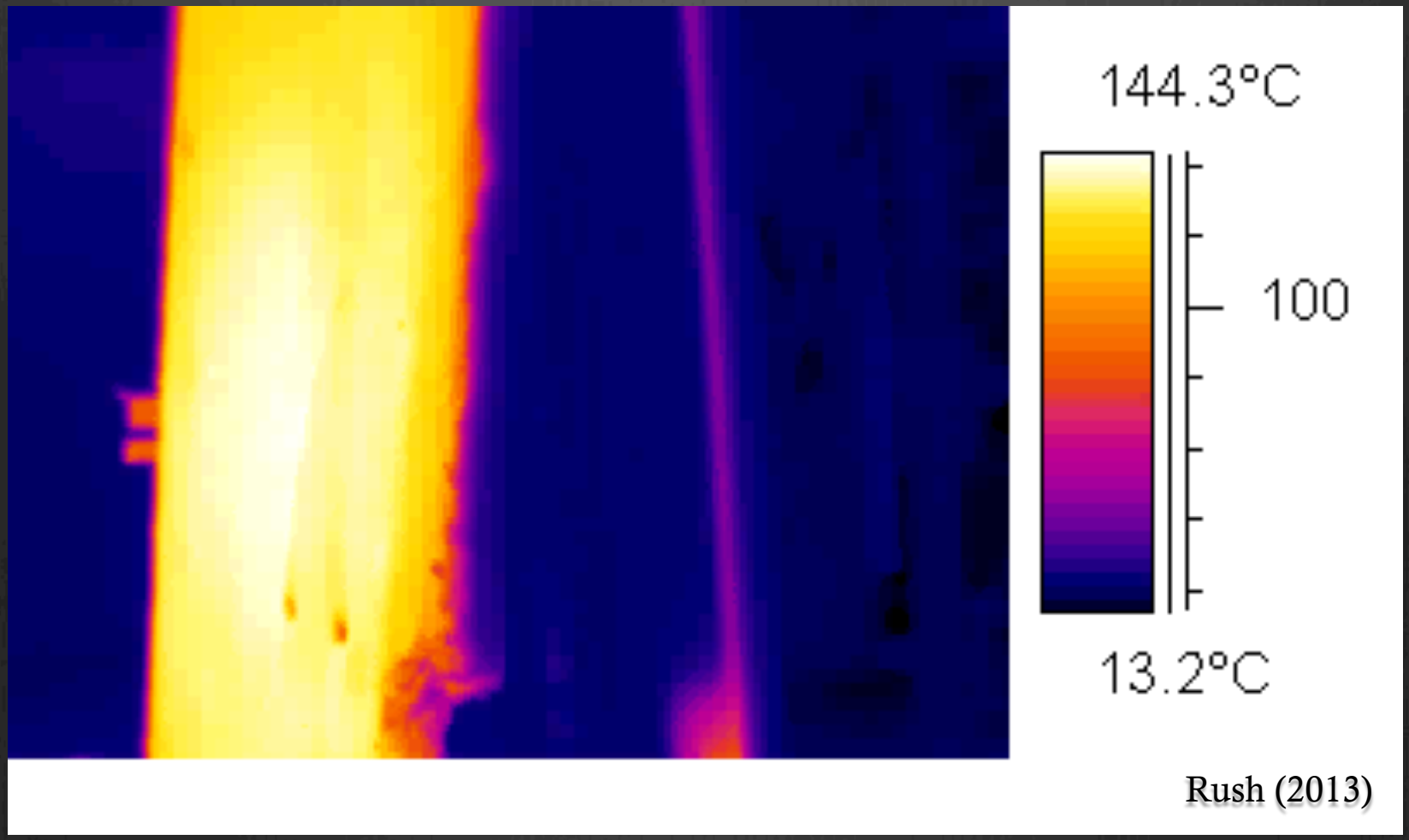
Performance of Fire Protection Coatings



Rush (2013)

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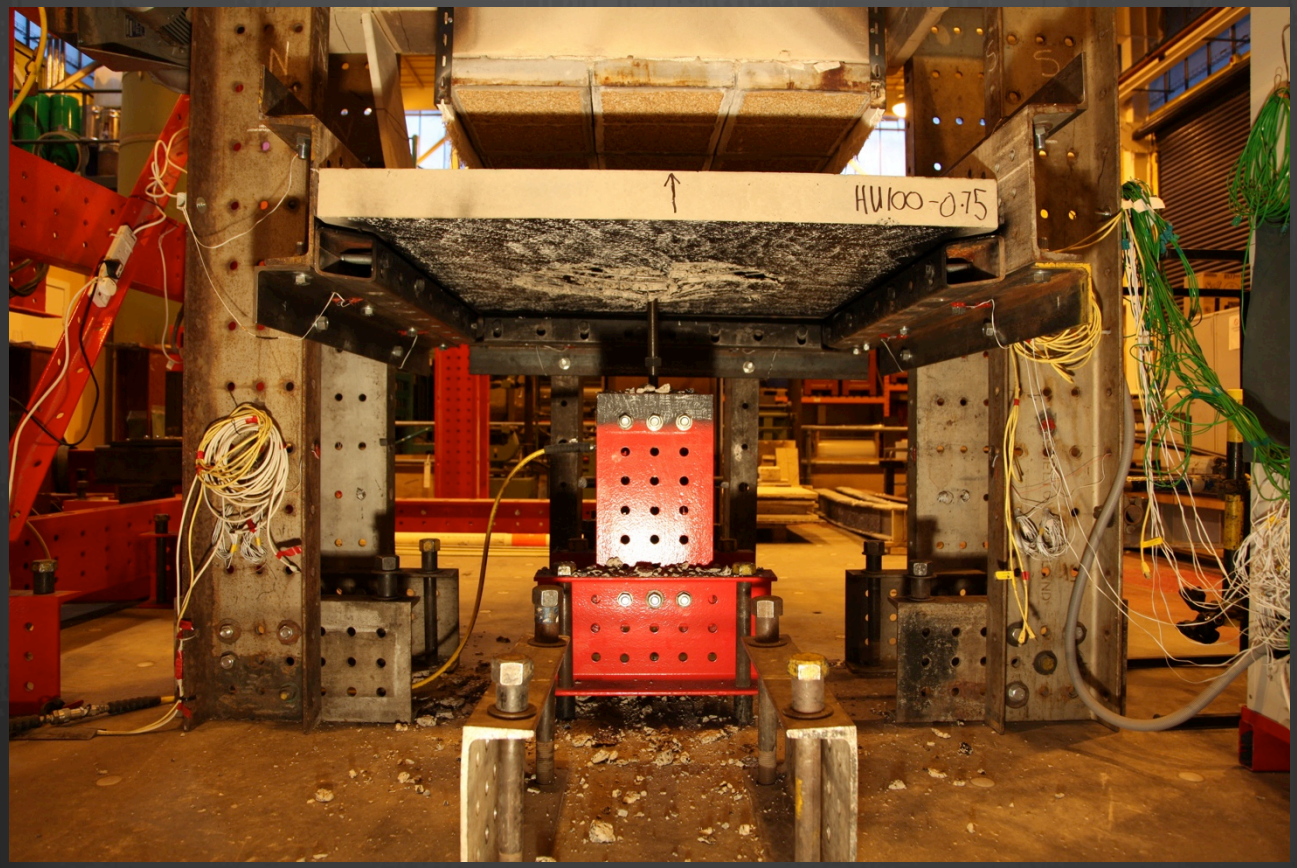
Opportunity 3 – **Structure-Fire Model Validation**

Fox (2013), Gales (2013)



Extremely careful control and measurement of **thermal and structural boundary conditions** in single element tests (validation data)

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Gritzo (2014)

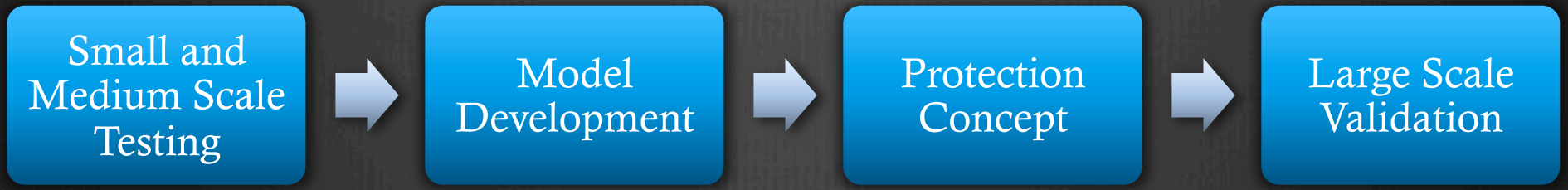

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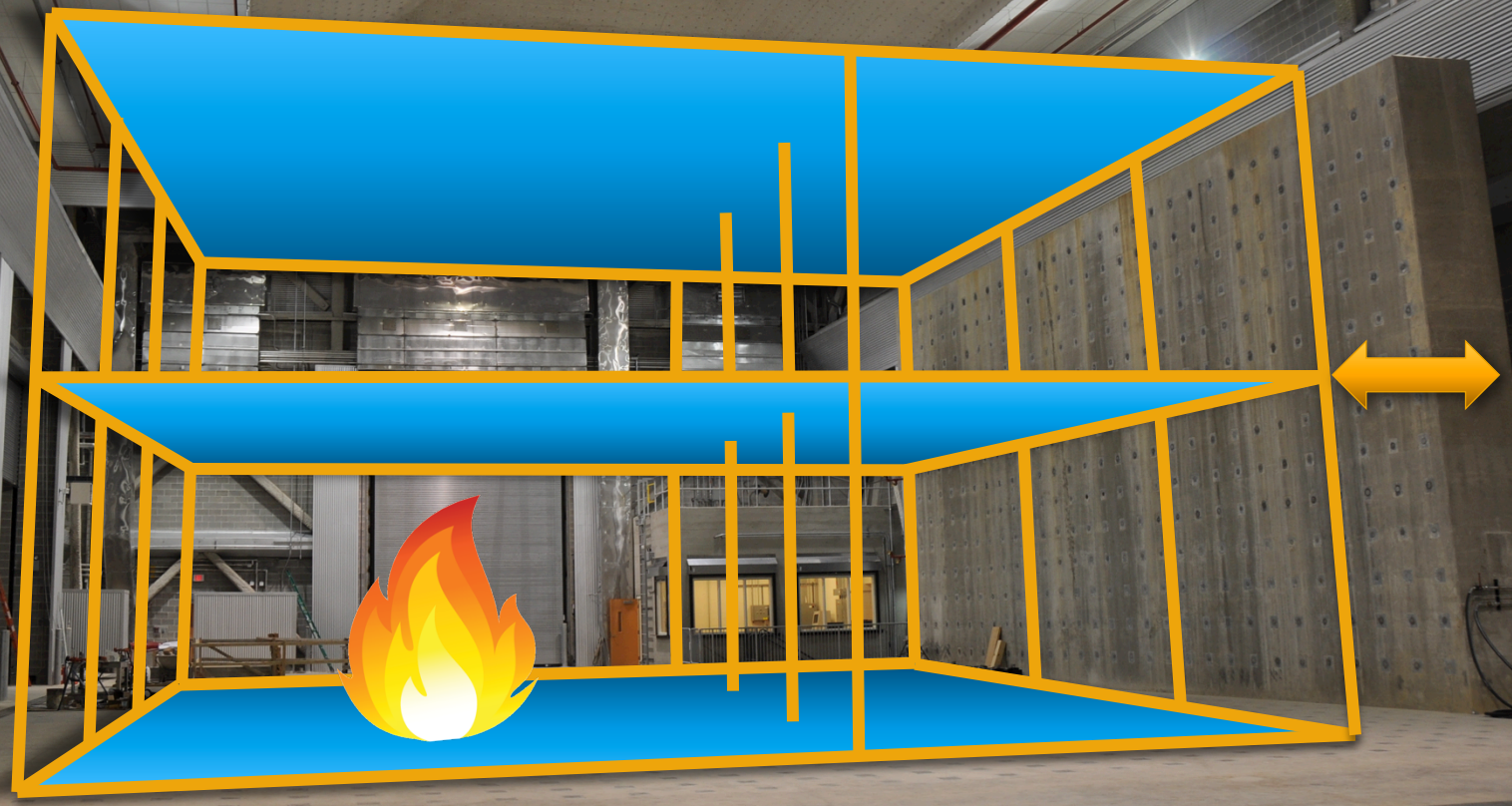
Photo courtesy Jiann Yang @ NIST



NIST's National Fire Research Laboratory

Structure-Fire Model Validation

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Opportunity 4 – **Probabilistic Analysis**

Cost £$€ ?

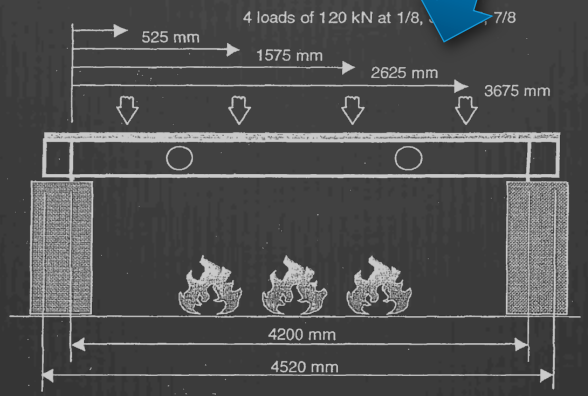
$$gDV = \iiint P\,[DV|DM]\,dP\,[DM|RM]\,dP\,[RM|IM]\,dg_{IM}$$

Loss analysis — *Structural analysis*

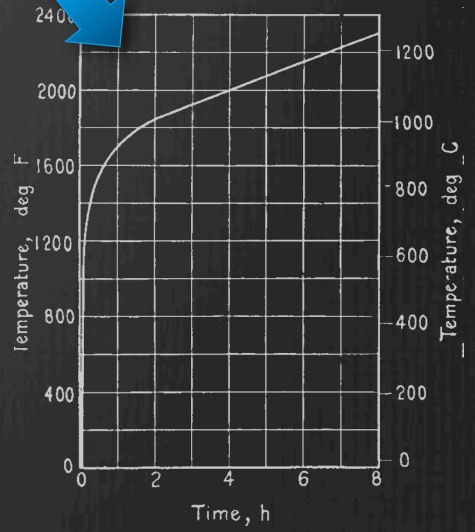
Damage analysis — *Hazard analysis*

R E I

Damage



Response



Intensity Measure

Lange (2009), Rush (2013)

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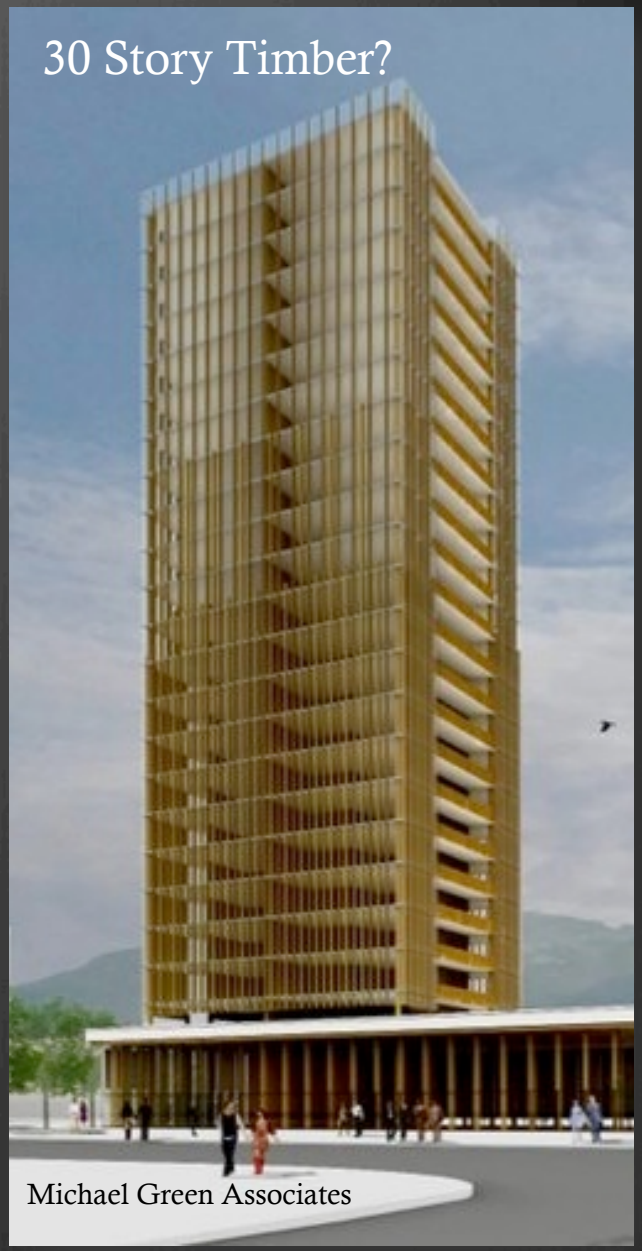
The Challenge

Develop the **knowledge, tools, skills,** and **attitudes** to design and deliver a more beautiful, functional, economical, resilient, and sustainable built environment…

… whilst meeting society's **expected level of safety** and without squandering **scarce resources**



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What data do we need?
And why?