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Course Description

Structural Fire Engineering

June 4, 2015

This webinar will provide a solid background on structural fire engineering, starting with the fundamentals of fire resistance including fire resistance ratings and then will introduce the structural fire engineering approaches being used today. These methodologies range from simplified structural checks to advanced numerical models. The lecture will demonstrate how structural fire engineering can benefit projects including how it can help owners, contractors, designers and fabricators in meeting today's industry challenges. In the examples provided, the corresponding savings is quantified to assist in understanding the benefit. The opportunities for application will be given in the context of current codes and standards.

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Learning Objectives

- Gain an understanding of the current accepted codes and standards in North America for structural fire engineering.
- Become familiar with common approaches adopted within the industry and consideration of fire as a load case, design fires, structural analysis, steelwork specifications and passive fire protection solutions.
- Learn and understand simplified approaches combined with a fundamental understanding of structural assessments to produce a robust and quantified design at elevated temperature.
- Gain an understanding of fire resistance ratings together with simplified analyses of structural members to define a value-engineered solution to bring substantial material and cost savings to a project through illustrations and design examples of beams and columns.

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STRUCTURAL FIRE ENGINEERING

Allan Jowsey PhD MEng CEng MIFireE MSFPE MASCE

Fire Engineering Manager

AkzoNobel

International

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Agenda

- Overview on Fire Engineering
  - Markets
  - Drivers
  - Key considerations
- Fire resistance fundamentals
  - Fire resistance ratings
  - Passive fire protection
- Structural Fire Engineering
  - Structural concepts
  - Methodologies
  - Optimisation
  - Benefits
- Worked examples
  - Fire engineering
  - Structural fire engineering
- Summary

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Overview on Fire Engineering

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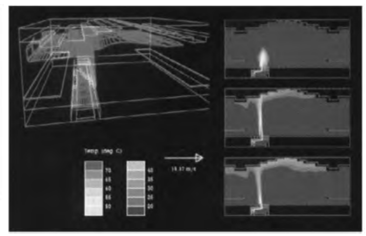
Fire Engineering

"The use of science, engineering, analysis and common sense to provide fire safety precautions tailored to a building"

- **Fire Safety Management**
- **Evacuation**
- **Fire Modelling**
- **Smoke Control**
- **Heat Transfer**
- **Structural Fire Engineering**



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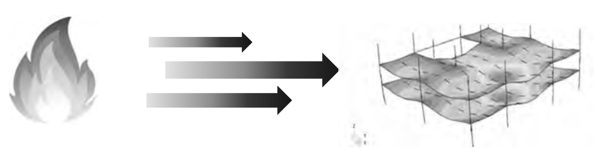
Structural Fire Engineering

The design of structures to withstand the effects of fire at elevated temperature



Specialist **Advanced** ***Complex*** **Expensive** **Value-Engineering** ***Cost saving*** ***Optimisation*** **Approvals**

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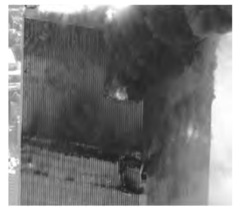
Typical Markets

- **The markets for structural fire engineering**

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Benefits

•Typically more economical designs, while still maintaining acceptable levels of safety

•Permits more innovative and complex buildings which were not possible due to prescriptive nature of some codes

•A better understanding of actual structural behavior in fire

•More robust buildings, i.e. strengthening ‘weak’ links in a structure

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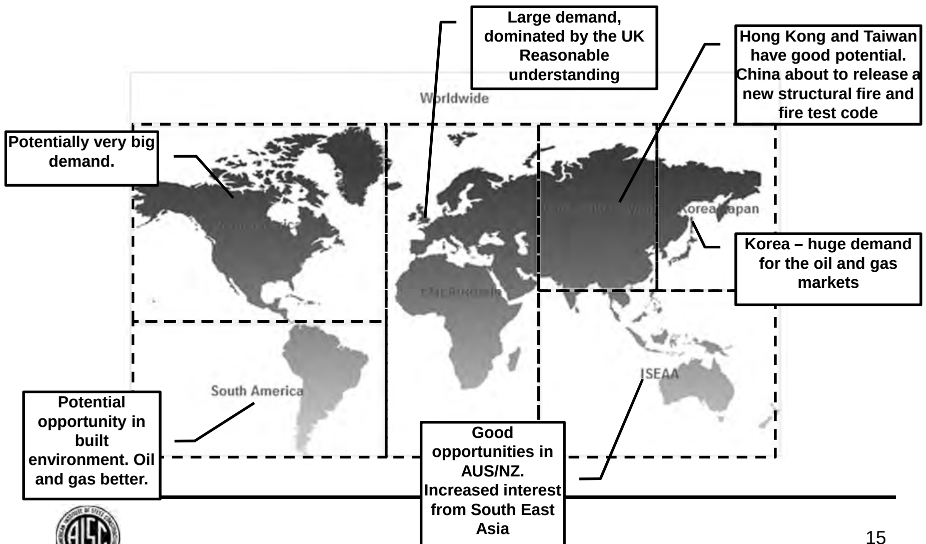
Global Acceptance



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Drivers for Fire Resistance

There are two key reasons for ensuring appropriate fire protection

1.Life-Safety

Life-safety measures are considered to be mandatory by fire, building or safety codes. Typically, the codes mandate specific methods of fire protection with very little flexibility in their selection.

2.Asset Protection

Investment-related fire protection is not commonly mandated by legislation but instead is driven by economic reasons such as: -

- asset losses
- revenue losses
- the possible loss of customers

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Fire Protection Measures

ACTIVE

Require a certain amount of motion or response in order to work, e.g.: -

•Automatic detection (smoke and/or flame)
•Suppression systems

PASSIVE

Effectively remains 'silent' within a building until a fire occurs, e.g.: -

•Compartmentation and fire barriers
•Fire stopping
•Steelwork protection

Both active **AND** passive fire protection measures are integral to the fire safety design of a building. Use of one, does not negate the use of the other.

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Methods and Drivers

Approaches: -
'Traditional' structural fire engineering approaches: -

•Design fire assessment and modelling
•Elimination of fire protection from members
•Modification to fire resistance periods
•Structural resistance checks (hot design)

Undertaken/requested by: -

•Structural engineers
•Fire engineers
•Contractors
•Steelwork fabricators
•Applicators

Robust design
Cost savings
Quantified performance
Value engineering
Construction sequencing
Practical considerations
Sustainability benefits

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Considerations and Basis

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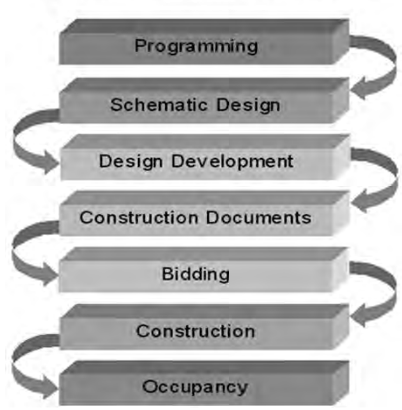
Within the Contract Chain

Stages of Design

- Fire resistance is typically defined early in a project
- Fire protection is typically an 'after-thought' of design
- If considered together at an early stage :-
  - Economic savings
  - Robust and safe designs
  - Quantified performance in fire

Construction Project Phases



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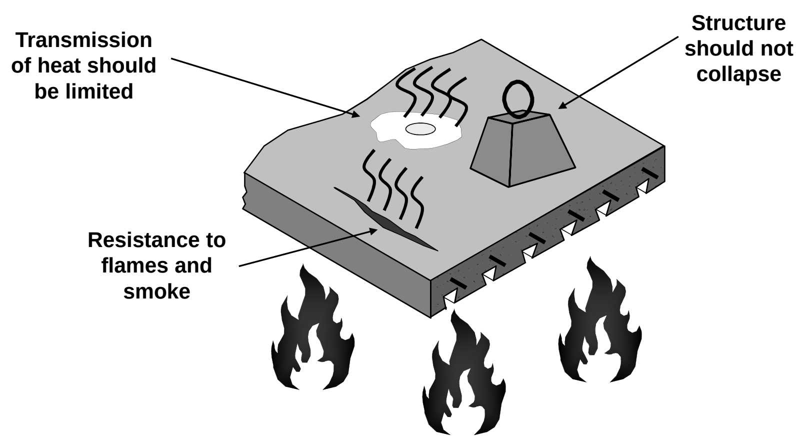
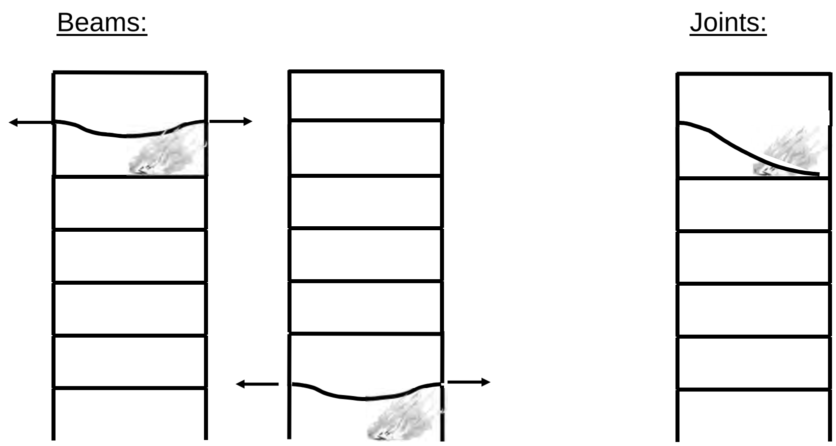
Fire Resistance Concepts



Consequence of Failure



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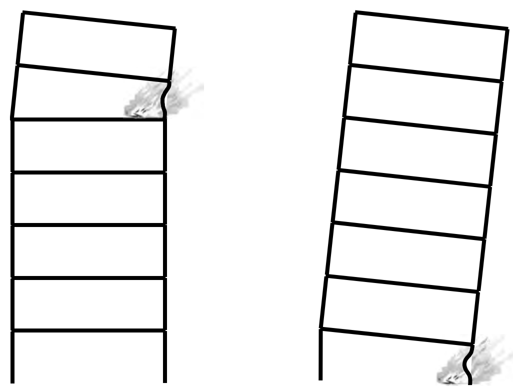
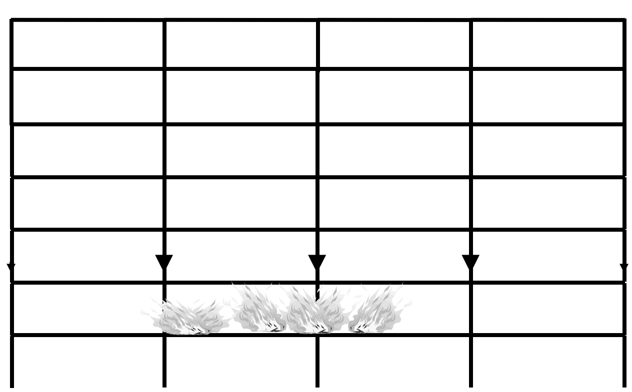
Consequence of Failure

Columns:



Consequence of Failure

Disproportionate collapse:



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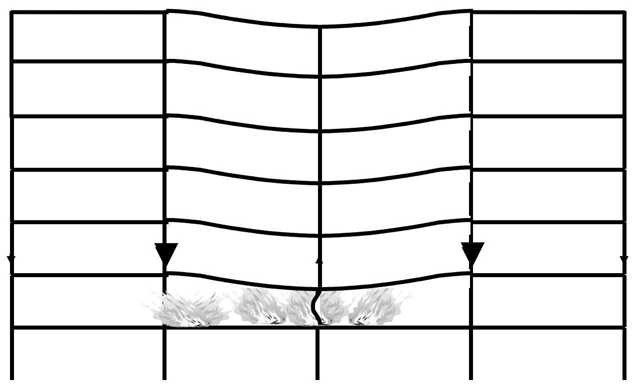
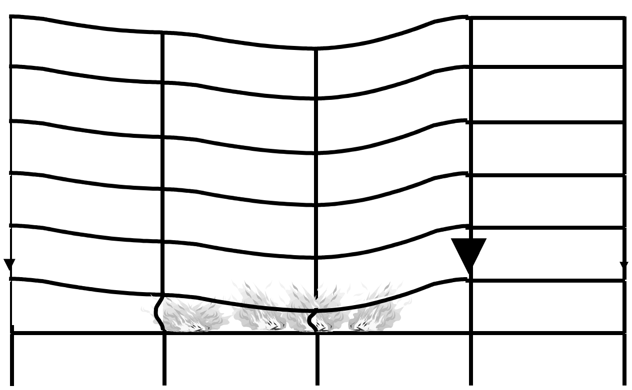
Consequence of Failure

Disproportionate collapse:



Consequence of Failure

Disproportionate collapse:



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Connection Design Comparison

<u>‘Ambient’ design</u>

- Structural design loads assessed
- Forces and moments defined
  - Idealised e.g. pinned
- Detailed design by specialist
- Checked by the structural engineer

- Bolt spacing
- Direct shear
- Moment connection

- Bolt capacity checks
  - Shear
  - Tension

<u>Fire design</u>

- **?**
- **Assumed to be okay based on ambient design…**
- **Applied protection**

- **What about**
  - **Loss of bolt strength?**
  - **Bolt ductility?**
  - **Connection ductility?**
  - **Heating forces?**
    - Thermal expansion
  - **Cooling forces?**
    - Contraction

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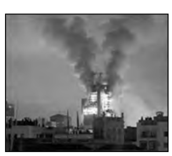
Fire Protection



- Passive fire protection keeps steel relatively cool
  - Maintains structural stability
  - Allows people to evacuate
  - Provides safety to attending fire-fighters

- Fire protection is governed by <u>strict</u> legislative requirements

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Fire Protection Options

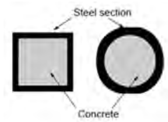
Intumescent coatings

Boards

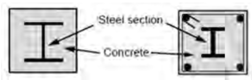
Cementitious sprays (SFRM)

Insulation blankets

Concrete filling



Concrete encasement



Bolt caps

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Codes and Standards

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Design Codes and Standards

There are a wide range of International fire safety codes that define all aspects of fire design in a building, including the structural fire resistance rating: -

- NFPA 101 / NBCC *– Americas, Canada, Middle East and South Asia*
- International Building Code *– Americas, Canada, Middle East and South Asia*
- Approved Document B *– England and Wales*
- British Standards: BS 9999 *– UK*

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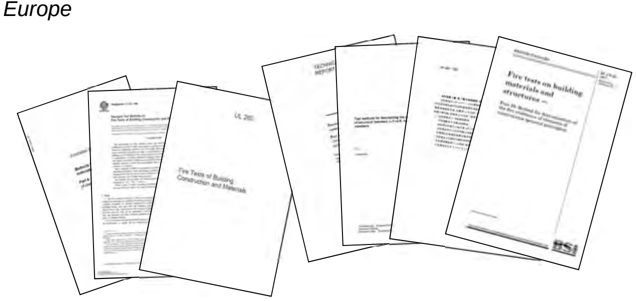
Fire Test Codes and Standards

The design codes call for protection to elements of structures to be tested in accordance with one of a number of fire test standards, including: -

oUL 263 / ASTM E-119 / CAN/ULC-S101 – *US, Canada & Middle East*
oBS 476: Part 21 – *UK, Brazil, South East Asia, Belgium, New Zealand, Middle East*
oEN 13381 – *Mainland Europe*
oAS 1530.4 – *Australia*
oGB 14907 – *China*
oGOST – *Russia*



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Setting Fire Resistance Ratings

Fire resistance periods for elements of structure (independent of ventilation conditions)

Use	Sprinklered or unsprinklered [B]	Minimum periods of fire resistance, in minutes					
		Depth below access level of lowest basement		Height [C] of top occupied storey above access level			
		More than 10 m	Not more than 10 m	Not more than 5 m	Not more than 18 m	Not more than 30 m	More than 30 m
Office	Unsprinklered	90	60	30	60	90	Not allowed
	Sprinklered	60	60	30	30	60	120
Industrial: high hazard	Unsprinklered	N/A [D]	120	90	120	150	Not allowed
	Sprinklered	150	90	60	90	90	120
Industrial: ordinary hazard	Unsprinklered	N/A [D]	120	60	90	120	Not allowed
	Sprinklered	90	60	30	60	60	90
Industrial: low hazard	Unsprinklered	90	60	30	60	90	Not allowed
	Sprinklered	60	30	30	30	60	60
Storage: low hazard	Unsprinklered	90	60	30	60	90	Not allowed
	Sprinklered	60	30	30	30	60	60
Car parks:							
– open-sided car park	Unsprinklered	—	—	15 [E]	15	30	30
– any other car park	Unsprinklered	90	60	30	60	90	120
Shops and commercial	Unsprinklered	90	60	60	60	90	Not allowed
	Sprinklered	90	60	30	60	60	120

Fire resistance ratings are typically set by an architect or engineer using a simple look-up table.

Ratings are based on: -

- **Occupancy use** (risk of fire)
- **Height of the structure** (for evacuation and access for fire-fighters)
- **Provision of a suppression system** (may act to control a fire)

Example: Office building, 100m high with a sprinkler system

Rating: **120 minutes** for load-bearing elements of structure

Above example based on BS 9999. Other standards or guidance documents may prescribe a different rating.

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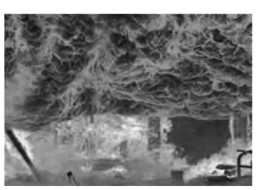
Setting Fire Resistance Ratings

- IBC / NFPA

- Intended use and occupancy
- Building area and height
- Fire department accessibility
- Distance from other buildings
- Sprinklers and smoke alarm systems
- Construction materials

The greater the risk of fire, the higher the fire resistance rating



"The structural frame shall be considered to be the columns and girders, beams, trusses and spandrels having direct connections to the columns and bracing members designed to carry gravity loads."

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IBC Example

Consider same example: 100m (328ft) high – 25 storeys – Office Building

Table II.1 IBC Use and Occupancy Classifications	
Group	**Use**
A	Assembly
B	Business
E	Educational
F	Factory
H	High-Hazard
I	Institutional
M	Mercantile
R	Residential
S	Storage
U	Utility and Misc.

Table II.2 IBC Construction Types	
Type	**Description of Materials**
I	Noncombustible
II	Noncombustible
III	Exterior walls-Noncombustible Interior building elements- Combustible or Noncombustible
IV	Heavy Timber, HT Exterior walls - Noncombustible
V	Combustible or Noncombustible

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IBC Example

ALLOWABLE HEIGHT AND BUILDING AREAS[a]
Height limitations shown as stories and feet above grade plane.
Area limitations as determined by the definition of "Area, building," per story

		TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
GROUP	HGT(feet) HGT(S)	UL	160	65	55	65	55	65	50	40
A-1	S	UL	5	3	2	3	2	3	2	1
	A	UL	UL	15,500	8,500	14,000	8,500	15,000	11,500	5,500
A-2	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-3	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-4	S	UL	11	3	2	3	2	3	2	1
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,500	6,000
A-5	S	UL	UL	UL	UL	UL	UL	UL	UL	UL
	A	UL	UL	UL	UL	UL	UL	UL	UL	UL
B	S	UL	11	5	4	5	4	5	3	2
	A	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
E	S	UL	5	3	2	3	2	3	1	1
	A	UL	UL	26,500	14,500	23,500	14,500	25,500	18,500	9,500
F-1	S	UL	11	4	2	3	2	4	2	1
	A	UL	UL	25,000	15,500	19,000	12,000	33,500	14,000	8,500
F-2	S	UL	11	5	3	4	3	5	3	2
	A	UL	UL	37,500	23,000	28,500	18,000	50,500	21,000	13,000
H-1	S	1	1	1	1	1	1	1	1	NP
	A	21,000	16,500	11,000	7,000	9,500	7,000	10,500	7,500	NP

The presence of a fire suppression system and amount of perimeter access to a public way improve the fire safety of a building. This may allow for increasing allowable floor areas.

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IBC Example

FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (hours)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A[e]	B	A[e]	B	HT	A[e]	B
Structural frame[a]	3[b]	2[b]	1	0	1	0	HT	1	0
Bearing walls Exterior[g] Interior	 3 3[b]	 2 2[b]	 1 1	 0 0	 2 1	 2 0	 2 1/HT	 1 1	 0 0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[f]	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction Including supporting beams and joists	2	2	1	0	1	0	HT	1	0
Roof construction Including supporting beams and joists	1½[c]	1[c, d]	1[c, d]	0[c, d]	1[c, d]	0[c, d]	HT	1[c, d]	0

Note: for buildings with sprinkler control valves at each floor, reductions in fire resistance ratings may be possible for high-rise buildings.

For example for buildings not greater than 420 feet (128 m) in height Type IA can be reduced to Type IB. See IBC section 403 for further details.

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Building Code Requirements

- **Prescriptive vs Performance**

IBC allows both prescriptive and performance based fire-resistant designs, although emphasis is mainly on the former

Alternative methods must meet the fire exposure and criteria specified in the ASTM E-119 fire test standard

Can provide greater flexibility for architects

703.3 Alternative methods for determining fire resistance.

1. *Fire resistance designs documented in approved sources.*
2. *Prescriptive designs of fire resistance rated building elements as prescribed in Section 719.*
3. *Calculations in accordance with Section 720.*
4. *Engineering analysis based on a comparison of building element designs having fire resistance ratings as determined by the test procedures set forth in ASTM E119.*
5. *Alternative protection methods as allowed by Section 104.11.*

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Fire Resistance Ratings

Defining a Fire Resistance Rating

- At 120 minutes for example, what is the acceptance criteria..?
    - o *"Structural stability shall be maintained for a reasonable period of time…"*
    - o *"The element can no longer sustain its superimposed load"*

- Limiting steel temperatures
    - o Historically associated closely to the Approval or Fire Test Standard
        - ASTM E-119 / ANSI/UL 263: **538ºC**, **593ºC**
        - BS 476: **520ºC**, **550ºC**, **620ºC**
        - Mainland Europe: **500ºC**
        - Offshore industry: **400ºC**

SCI 4th November 1997: *"The existing temperatures are acceptable for most circumstances, but they are not always conservative."*

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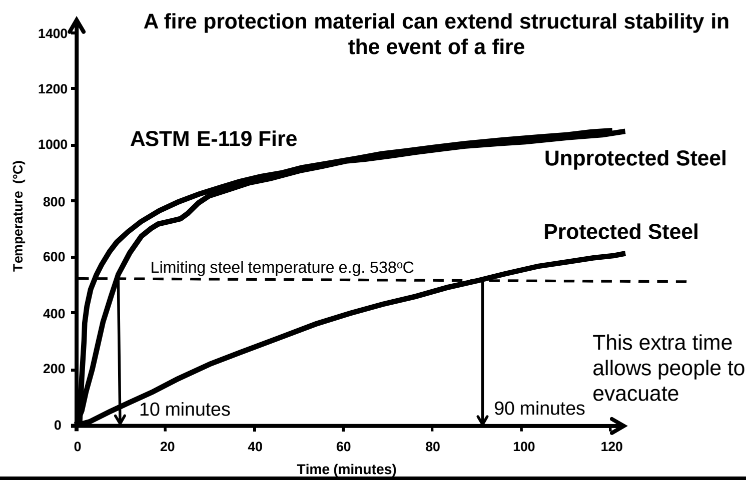
Fire Protection Concept



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Fire Behavior

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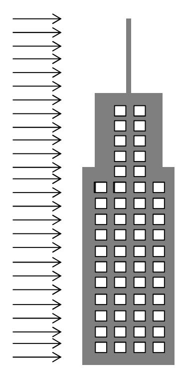
Fire Load

- Structural engineers assess numerous load cases: -
  - Ultimate limit state
  - Serviceability limit state
  - Wind
  - Snow
  - Seismic
  - Vibration analysis

» But what about fire..??



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Fire Engineering

- Fire engineers may work on a project and look to *reduce* the fire resistance period down to a lower value

- This based on a study of the anticipated fire severity risk in a building based on
  - fuel load
  - room geometry
  - ventilation conditions
  - the presence of a sprinkler system

  » But is this ***structural*** fire engineering….?

- A Fire Engineer's assessment to modify the fire resistance period is subject to approval by the Authority Having Jurisdiction. In many cases this may involve scrutiny by a third party.

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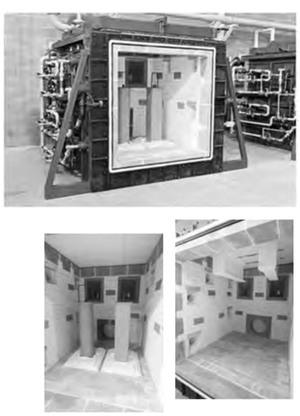
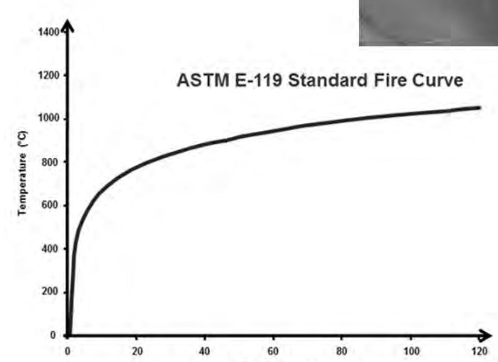
Design Fires

- Furnace fire (Standard Fire)





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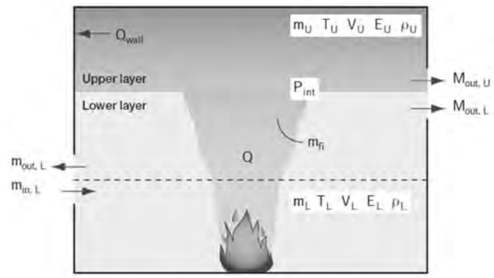
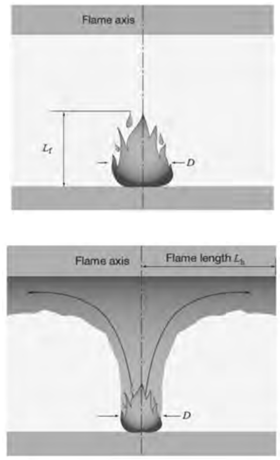
Design Fires

- Localized fire
- Fully developed fire





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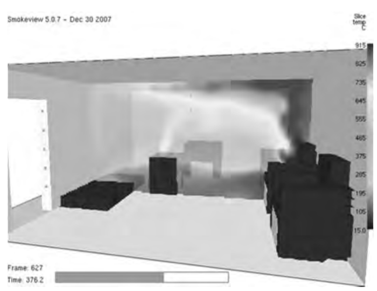
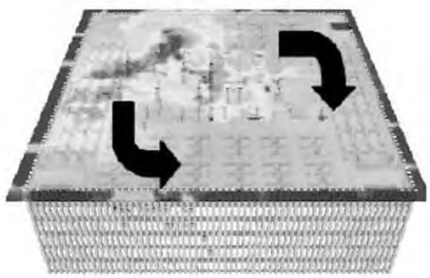
Design Fires

- Computational Fluid Dynamics (CFD)
- Full spatial and temporal resolution
- Be mindful of validation and verification





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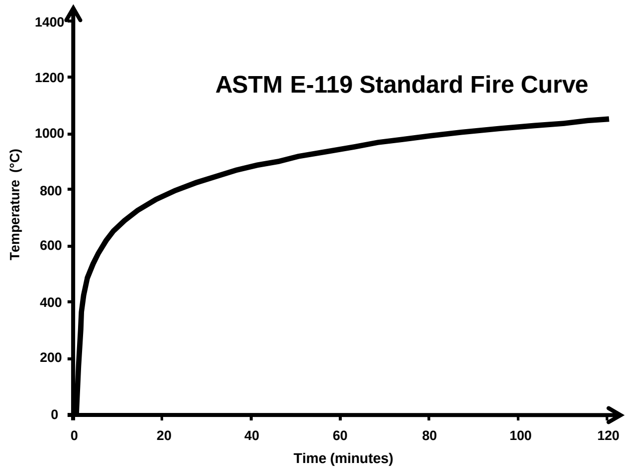
Fire Engineering



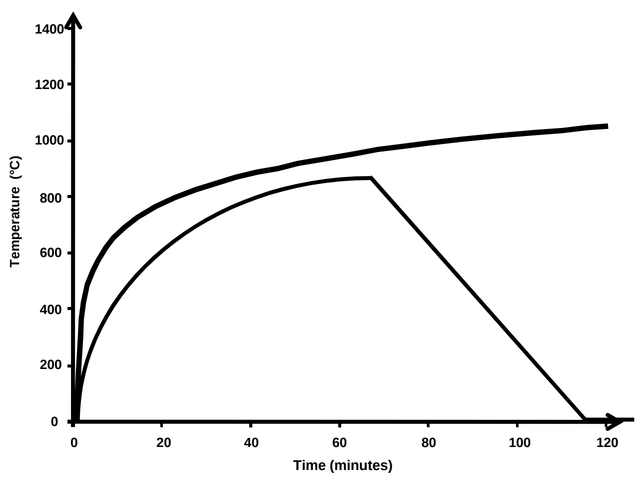
Fire Engineering

Ventilation

Fuel load

Suppression

Geometry



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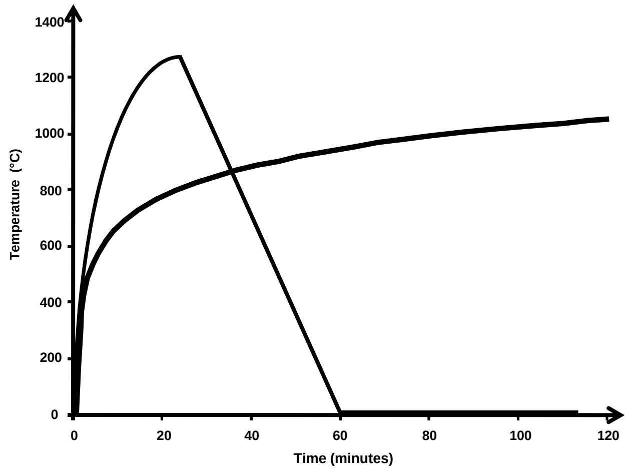
Fire Engineering

Ventilation

Fuel load

Suppression

Geometry



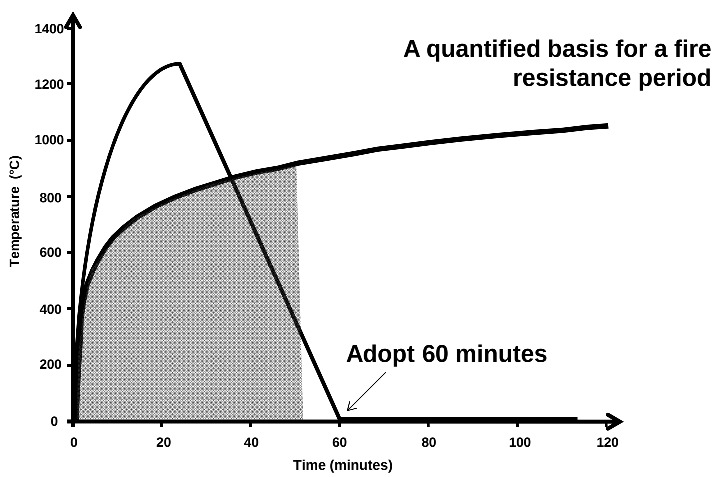
Fire Engineering

Ventilation

Fuel load

Suppression

Geometry



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Illustrated Benefits

- Benefits of modifying a fire resistance period using fire engineering

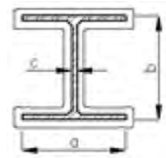
Fire Resistance Period	Example Protection Thickness
3 hrs	0.42”
2 hrs	0.26”
1.5 hrs	0.22”
1 hr	0.09”

Example based on an epoxy intumescent coating for a steel column with a W/D of 1.34 for illustrative purposes only

39%

14%

58%



- A proposed reduction in fire resistance period should ideally be quantified with a structural capacity check to ensure robustness
- Must always be discussed with the Authority Having Jurisdiction

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There's always a solution in steel.

Heat Transfer

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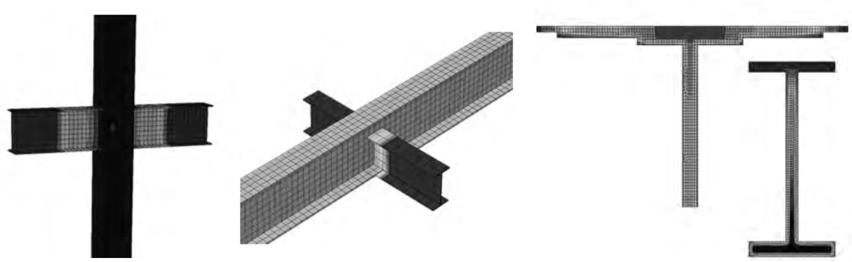
Structural Temperatures

- Once the fire load is assessed it is important to understand how structural elements heat up.
- Their maximum temperature is typically most important, however restrained thermal expansion and contraction effects may also be important.



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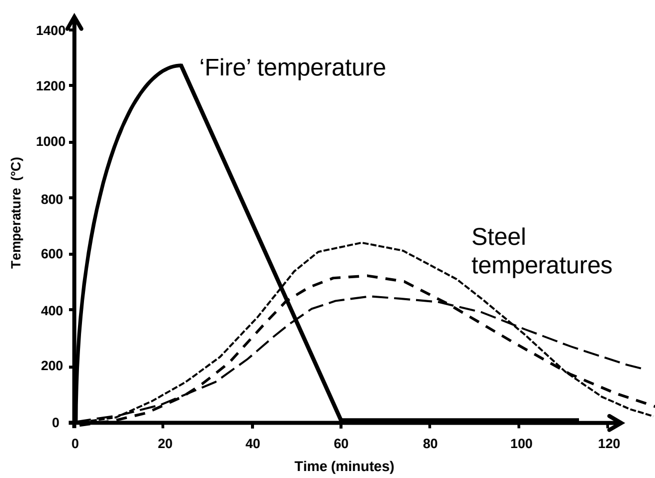
Steel Temperatures

Simple heat transfer equations exist to assess temperature development of steel – either unprotected or protected.

These can be used in conjunction with an advanced finite element analysis to check full thermal load bearing capacity capability.



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There's always a solution in steel.

Structural Assessment

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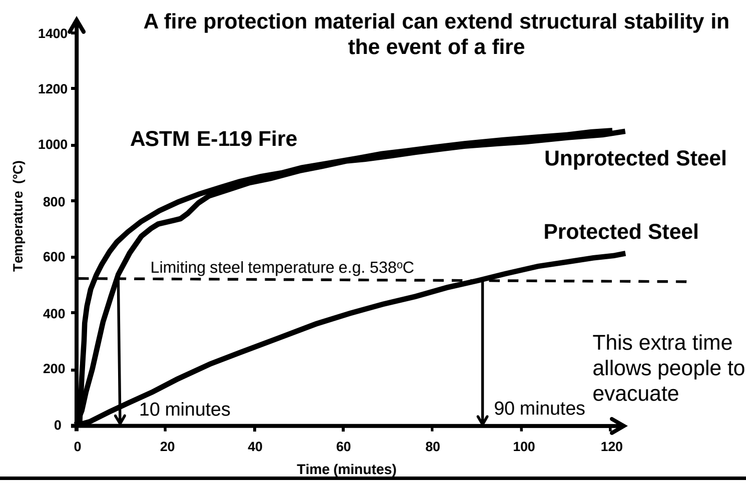
Fire Protection Concept



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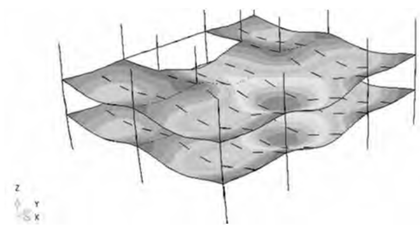
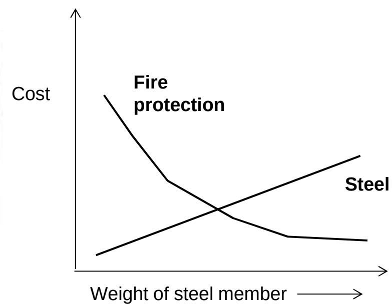
Optimisation

- Optimisation of steelwork and fire protection combined
- Opportunities for designers to show up-front savings to their client – provided costs are accurately quantified





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Codes and Standards

Structural Fire Design is recognised by a variety of structural analysis codes, standards and guidance documents to complement every project: -

- **British Standards**
- **Eurocodes**
- **AISC Standards (ASD & LRFD)**
- ISO Standards
- ABS Standards
- API Standards
- DNV Standards
- Lloyds Register
- NORSOK Standards
- FABIG Guidance Documents

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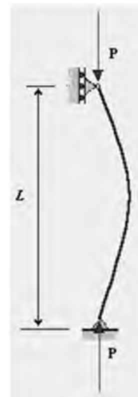
Structural Fire Engineering

- The limiting steel temperature can be defined as the temperature that the steel will reach whilst still maintaining enough strength to carry an amount of load and thus prevent collapse
- This is not the temperature at which the structure will actually collapse
- The limiting steel temperature is then used to determine
  - (a) the amount of passive fire protection that is required
  - (b) whether passive fire protection is needed at all based on design fire analysis
- It is a function of the applied load



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Structural Fire Engineering

- A limiting steel temperature for each member can be determined by a number of different calculations
  - **Tensile or buckling resistance for tension or compression members**
  - **Moment and shear resistance for beams**
  - **Lateral torsional buckling resistance moment for beams**
- Beams with web openings have even more modes of failure to consider...

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Structural Fire Design

- AISC 360-10 Appendix 4: Structural Design for Fire Conditions
- CSA-S16 Annex K: Structural Design for Fire Conditions
  - Permits structural fire design approaches using LRFD Methods for a given load combination (also e.g. ASCE 7 Chapter E)

$$1.2D + A_k + (0.5\,L \text{ or } 0.2S)$$

$$(0.9 \text{ or } 1.2)D + A_k + 0.2W$$

where
A_k = load effect from the extraordinary event
D = dead load
L = live load
S = snow load
W = wind load

  - Load factors reflect small probability of a joint occurrence and correspond to the mean of the yearly maximum load
  - Strength retention factors provided – very similar to Eurocode and high steel strain limits of BS 5950-8

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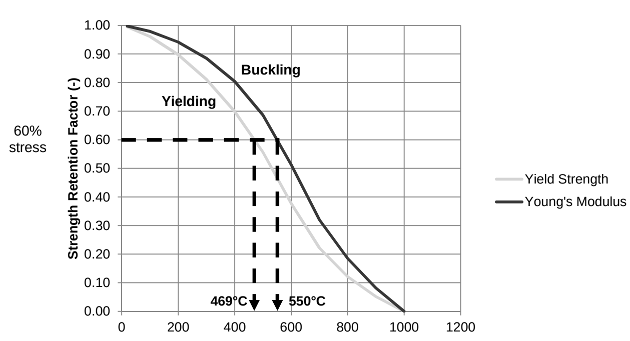
The Basis for 538°C

- A36 Steel Strength Retention Factors (from the SFPE Handbook)
- 36 ksi = 248 N/mm²



Young's Modulus retention factor at 60% stress: -

550° (1022°F) which may have been rounded down to be 538°C (1000°F)

Note: SFPE Handbook clearly states that 538°C was based on 60% reduction of yield strength…

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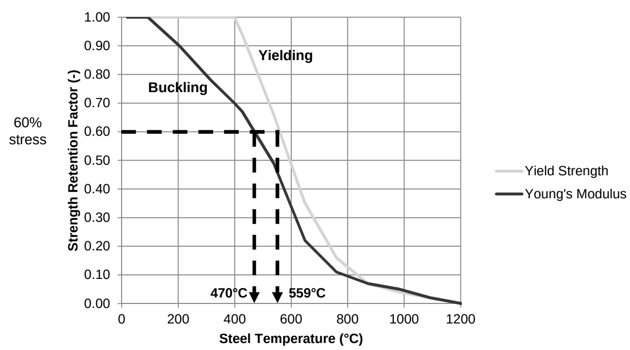
The Basis for 538°C

- AISC & CSA S16 Strength Retention Factors
- (Considered to be based on a 2% strain limit of steel – limit state design)



Young's Modulus retention factor at 60% stress: -

470° (875°F)

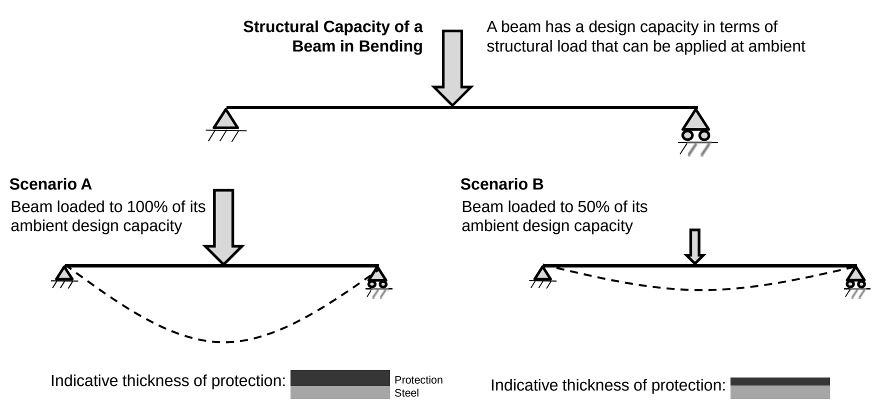
Yield Strength retention factor at 60% stress: -

559° (1038°F)

Note that the curves appear to have been swapped from A36 steel…

Stress in Structural Members

Linking Fire Protection Thicknesses to Structural Load



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Rated Designs

- Fire-resistant construction assemblies are documented in building codes, standards, test reports, and directories of testing laboratories
- Fire-resistant designs relate to proprietary materials and tested assemblies are constructed to closely match the intended construction
- Important that any fire-resistant design: -
  - Aligns with need for fire resistance in the given project
  - Is appropriate for any structural fire engineering proposal
  - Is understood in terms of its limitation in terms of capability and application
  - Has supporting certification

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Fire Resistance Listings

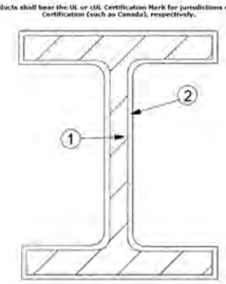
- Example listing

Design No. X664

[illegible]

Ratings — 1, 1-1/2, 2 and 3 Hr. (See Item 2)

* Indicates such products shall bear the UL or cUL Certification Mark for jurisdictions employing the UL or cUL Certification (such as Canada), respectively.



2. **Mastic and Intumescent Coatings*** — Two component spray materials applied in one or more coats as described in the application instructions to the thicknesses shown below. Thicknesses below include the 50 microns of primer.

Steel		1 Hour Rating	1-1/2 Hour Rating	2 Hour Rating	3 Hour Rating
Size	W/D	Min Thkns (in.)	Min Thkns (in.)	Min Thkns (in.)	Min Thkns (in.)
W6x16	0.58	0.132	0.288	0.422	NR
W8x24	0.59	0.132	0.286	0.418	NR
W10x26	0.61	0.132	0.281	0.412	NR
W14x34	0.63	0.132	0.277	0.405	NR
W10x33	0.66	0.132	0.270	0.396	NR
W8x31	0.66	0.132	0.270	0.396	NR
W21x44	0.67	0.132	0.268	0.393	NR
W16x40	0.68	0.132	0.266	0.390	NR
W18x40	0.68	0.132	0.266	0.390	NR
W8x28	0.68	0.132	0.266	0.390	NR
W6x25	0.69	0.132	0.264	0.387	NR
W10x30	0.70	0.132	0.262	0.384	NR
W12x35	0.70	0.132	0.262	0.384	NR
W14x38	0.70	0.132	0.262	0.384	NR
W12x40	0.74	0.132	0.254	0.372	NR
W8x35	0.74	0.132	0.254	0.372	NR
W14x43	0.75	0.132	0.253	0.370	NR
W24x55	0.75	0.132	0.253	0.370	NR

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Optimizing Fire Protection

Many fire test standards adopt thicknesses for variable limiting steel temperatures
Their use is subject to acceptance by the Authority Having Jurisdiction (AHJ) on the project

ASTM E-119 currently only prescribes a single point failure temperature
Beams: 593°C (1100°F)
Columns: 538°C (1000°F)

- It can be shown that these temperatures may not always be conservative
- A robust assessment should evaluate each member temperature
- Invariably, this approach can be used to optimize fire protection and produce cost-effective designs

BS 476	4-Sided Columns							
	120 minutes							
W/D	687 °F	777 °F	867 °F	957 °F	1047 °F	1137 °F	1227 °F	1317 °F
5.36	0.156	0.119	0.109	0.097	0.086	0.084	0.078	0.078
4.47	0.179	0.137	0.125	0.112	0.100	0.097	0.095	0.091
3.83	0.199	0.153	0.139	0.125	0.111	0.108	0.106	0.101
3.35	0.218	0.168	0.153	0.137	0.123	0.120	0.117	0.111
2.98	0.234	0.181	0.165	0.148	0.133	0.129	0.127	0.121
2.68	0.250	0.193	0.176	0.158	0.143	0.139	0.136	0.130
2.44	0.264	0.205	0.186	0.168	0.151	0.147	0.144	0.138
2.23	0.278	0.216	0.196	0.177	0.159	0.156	0.153	0.145
2.06	0.289	0.225	0.205	0.185	0.167	0.163	0.160	0.152
1.91	0.301	0.235	0.213	0.193	0.174	0.171	0.167	0.159
1.79	0.311	0.243	0.221	0.199	0.181	0.177	0.174	0.165
1.68	0.322	0.251	0.228	0.206	0.187	0.183	0.180	0.171
1.58	0.331	0.258	0.235	0.213	0.193	0.189	0.186	0.176
1.49	0.339	0.266	0.241	0.219	0.199	0.195	0.192	0.182
1.41	0.347	0.272	0.247	0.224	0.204	0.201	0.197	0.187
1.34	0.356	0.279	0.253	0.230	0.209	0.206	0.202	0.191
1.28	0.362	0.285	0.258	0.234	0.214	0.210	0.207	0.196
1.22	0.369	0.291	0.263	0.239	0.219	0.215	0.211	0.200
1.17	0.376	0.296	0.266	0.244	0.223	0.219	0.216	0.204
0.50	0.483	0.385	0.349	0.320	0.296	0.294	0.291	0.273
0.49	0.485	0.387	0.350	0.321	0.298	0.296	0.292	0.274
0.48	0.487	0.389	0.351	0.322	0.299	0.297	0.294	0.276
0.47	0.489	0.390	0.353	0.324	0.300	0.298	0.295	0.277
0.46	0.491	0.391	0.354	0.325	0.301	0.299	0.296	0.278
0.45	0.492	0.393	0.355	0.326	0.303	0.300	0.297	0.279
0.45	0.494	0.394	0.357	0.328	0.304	0.302	0.298	0.280
0.44	0.495	0.396	0.358	0.329	0.305	0.303	0.299	0.281
0.43	0.497	0.397	0.359	0.330	0.306	0.304	0.301	0.282
0.43	0.498	0.398	0.360	0.331	0.307	0.305	0.302	0.283
0.42	0.500	0.399	0.361	0.332	0.308	0.306	0.302	0.284
0.41	0.501	0.401	0.362	0.333	0.309	0.307	0.303	0.285
0.41	0.503	0.402	0.363	0.334	0.310	0.308	0.304	0.286

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Examples

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Example

1. Fire Engineering

•**2hr** rated column (500°C)
- Protection thickness: 3.402mm

•**1hr** rated columns (500°C)
- Protection thickness 1.861mm

•Saving **45%** on material

2. Structural Engineering

•2hr rated column (**500°C**)
- Protection thickness: 3.402mm

•2hr rated columns (**653°C**)
- Protection thickness 1.783mm

•Saving **47%** on material

3. Structural Fire Engineering

•**2hr** rated column (**500°C)**
- Protection thickness: 3.402mm

•**1hr** rated columns (**653°C)**
- Protection thickness 1.156mm

•Saving **66%** on material

•Additionally, now only a single coat application

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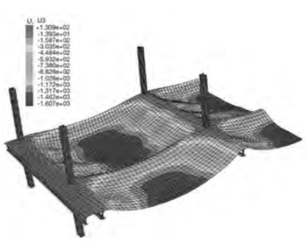
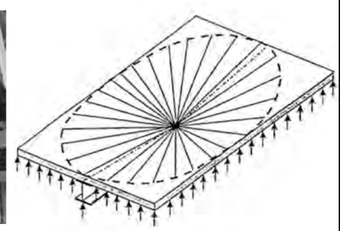
Example

- Removal of protection from secondary members
- Relies on tensile membrane action with the composite slab to redistribute and carry loads





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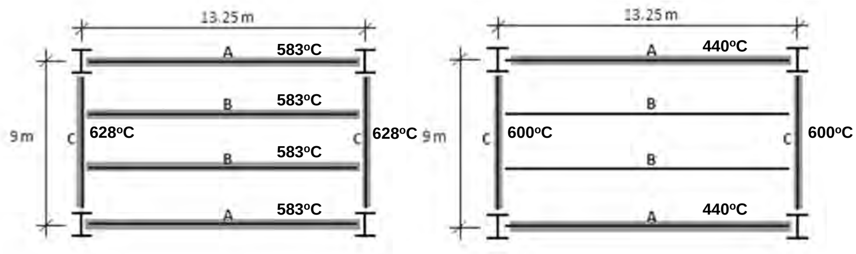
Example



- Left: ‘prescriptive’ protection
- Right: fire engineered to remove secondary member protection

- Note lower steel failure temperatures resulting from load redistribution in fire for the engineered solution

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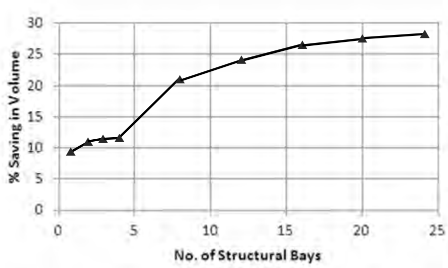
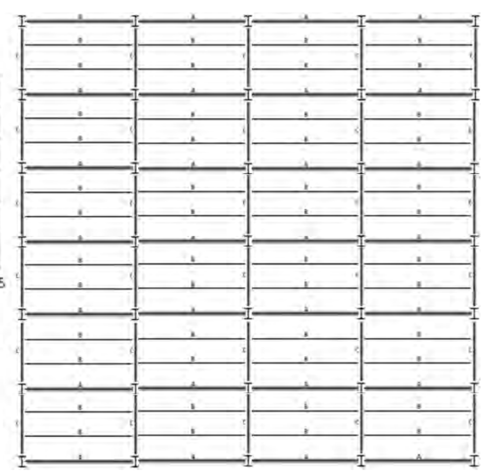
Example





- Material savings of up to 30% possible for this example

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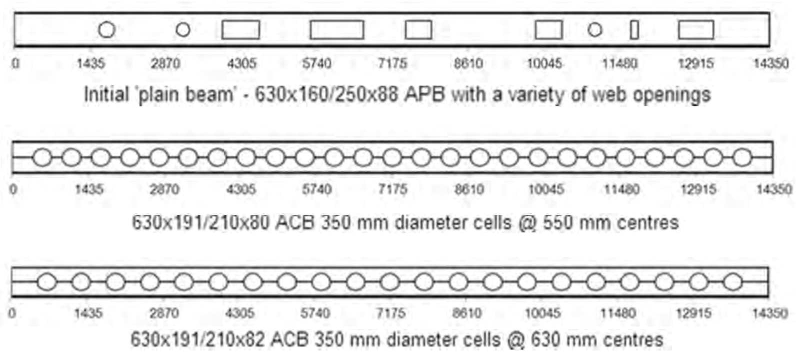
Optimisation Example

Consider different designs with fire protection impacts…



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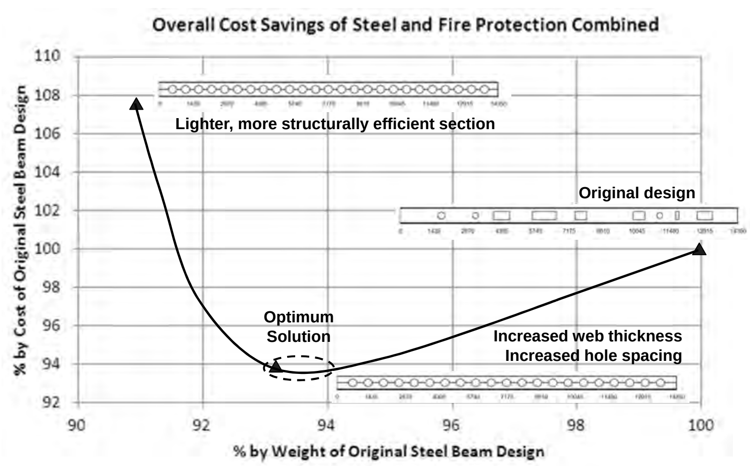
Optimisation Example



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Sources of Further Information

structural
STEEL

Sources of Further Information

- AISC 360-10 Appendix 4: Structural Design for Fire
- AISC Steel Design Guide 19: Fire Resistance of Structural Steel Framing
- AISC: Fire – Facts for Steel Framed Buildings
- ASCE/SFPE 29: Standard Calculation Methods for Structural Fire Protection
- ASCE 7 Appendix: Performance Based Design Procedures for Fire Effects on Structures
- SFPE Handbook
- UL 263 Fire Resistance Listings
- IStructE: Guide to the Advanced Fire Safety Engineering of Structures

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Summary

structural STEEL

Summary

Recap: -

- Structural Fire Engineering
- Many markets and many possibilities
- Performance-based design permitted by code

Design fire → Heat transfer → Structural response

- Extensively used globally
- Multitude of standardized references
- Case studies exist
- Not new to North America

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Summary

- Huge potential demand globally for Structural Fire Engineering
- Different drivers from different parts of the contract chain

- An increasing engagement with structural engineers
- Relatively simple resistance checks can bring added value and robustness
- Advanced methods can bring further benefits

- Methods exist in AISC standards and guidance documents
- Be aware that fire testing (ASTM E-119) at present generally doesn't use variable temperatures

- Engage with Authorities Having Jurisdiction
- Increased awareness and education continuing at present

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Summary

- Structural fire engineering: -
  - o allows designers to exploit the properties of structural steel to its maximum capacity in the fire limit state

- If used effectively it can bring significant benefits to a project, including **robust** and **safe designs**, **quantified structural performance** and potential **cost savings**

- Structural engineers have the ability to assess performance in fire

Fire should be treated as an important load case
Fire protection should not be an after-thought of design

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STRUCTURAL FIRE ENGINEERING

Allan Jowsey PhD MEng CEng
MIFireE MSFPE MASCE

Fire Engineering Manager

AkzoNobel
International

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CEU/PDH Certificates

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- Completely fill out online form. Don't forget to check the boxes next to each attendee's name!

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- New reporting site (URL will be provided in the forthcoming email).
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Thank You

Please give us your feedback!
Survey at conclusion of webinar.