



# Optimization of Intumescent Fireproofing Via Structural Analysis



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Fire Engineering Manager



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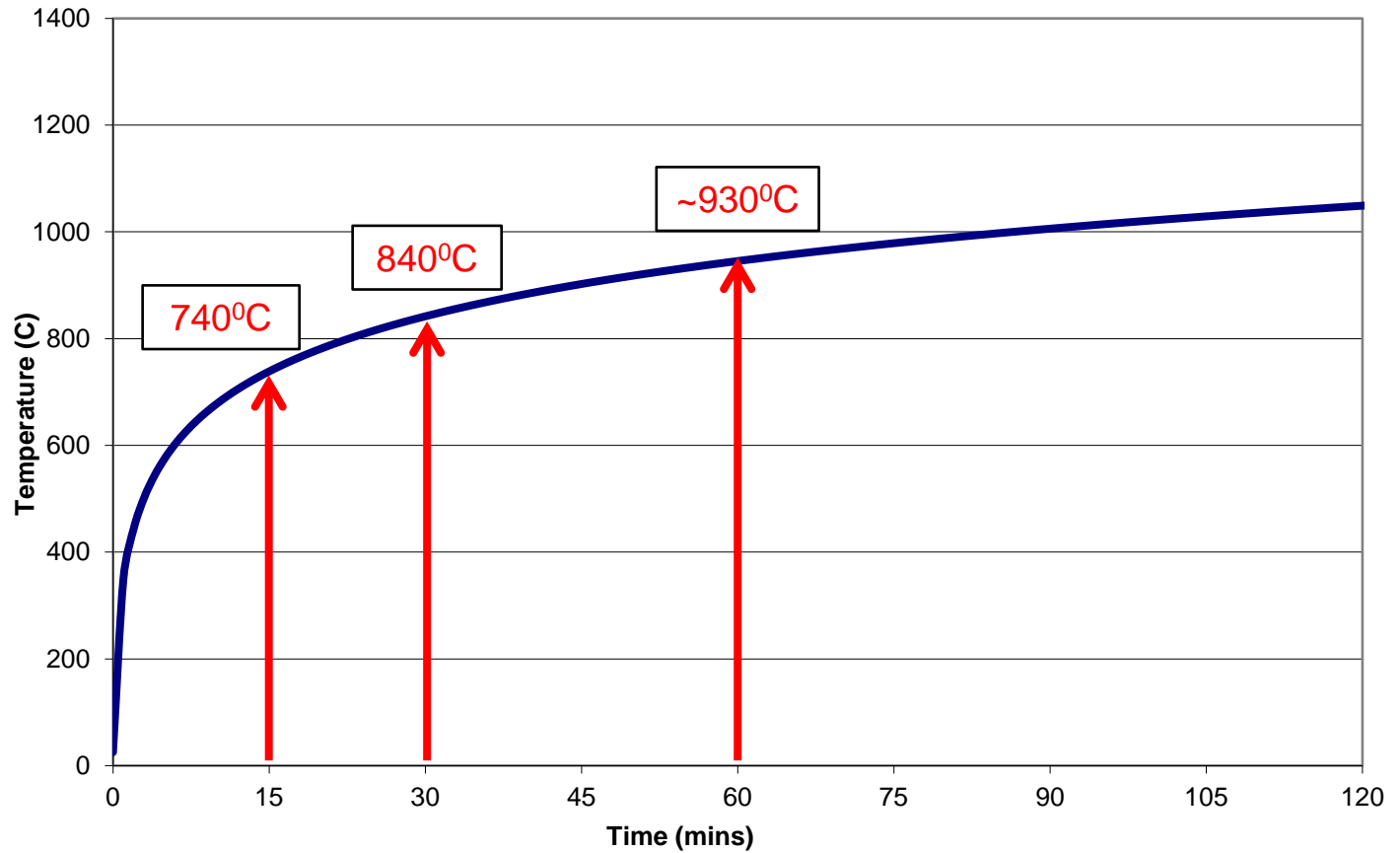


# Structural Fire Protection



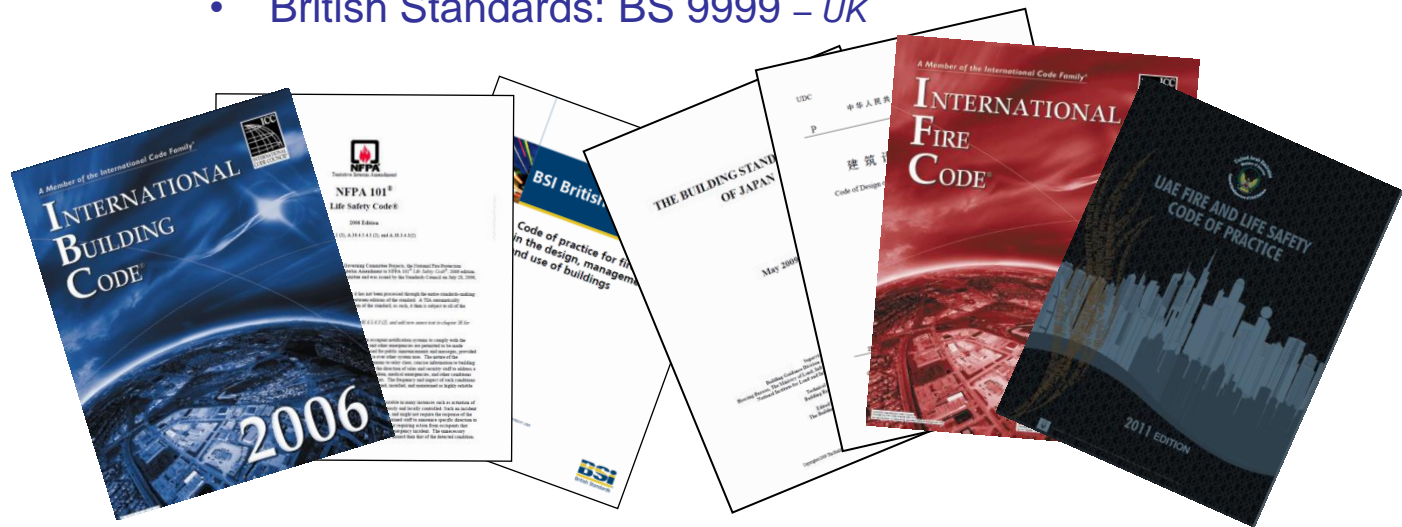
# How is a fire defined in a building?

## Fire Time / Temperature Relationships



# Design Codes and Standards

- There is a wide range of International and national fire safety codes that define all aspects of fire design in a building, including the structural fire resistance rating: -
  - NFPA 101 – *Americas, Canada and Middle East*
  - International Building Code – *Americas, Canada and Middle East*
  - UAE Fire and Life Safety Code of Practice - UAE
  - Approved Document B – *England and Wales*
  - British Standards: BS 9999 – *UK*



# How are Fire Resistance Ratings Set?

Table 7.2.1.1 Fire Resistance Ratings for Type I Through Type V Construction (hr)

Construction Element	Type I		Type II			Type III	
	442	332	222	111	000	211	200
<b>Exterior Bearing Walls<sup>a</sup></b>							
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0 <sup>b</sup>	2	2
Supporting one floor only	4	3	2	1	0 <sup>b</sup>	2	2
Supporting a roof only	4	3		1	0 <sup>b</sup>	2	2
<b>Interior Bearing Walls</b>							
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0
Supporting one floor only	3	2	2	1	0	1	0
Supporting roofs only	3	2		1	0	1	0
<b>Columns</b>							
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0
Supporting one floor only	3	2	2	1	0	1	0
Supporting roofs only	3	2	1	1	0	1	0
<b>Beams, Girders, Trusses, and Arches</b>							
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0
Supporting one floor only	2	2	2	1	0	1	0
Supporting roofs only	2	2	1	1	0	1	0
<b>Floor/Ceiling Assemblies</b>	2	2	2	1	0	1	0
<b>Roof/Ceiling Assemblies</b>	2	1½	1	1	0	1	0
<b>Interior Nonbearing Walls</b>	0	0	0	0	0	0	0
<b>Exterior Nonbearing Walls<sup>c</sup></b>	0 <sup>b</sup>	0 <sup>b</sup>	0 <sup>b</sup>	0 <sup>b</sup>	0 <sup>b</sup>	0 <sup>b</sup>	0 <sup>b</sup>

Above example based on NFPA 5000. Other standards or guidance documents may prescribe a different rating.

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

Ratings are based on: -

- **Type of Construction**
  - Safety classification
  - Construction materials
- **Fire Resistant Construction Code**
  - Floor area and stories
  - Building occupancy type
  - Provision of a suppression system
- **Specific Construction Element**
  - Structural purpose of the element

Example: Office building, 50m high with a sprinkler system

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



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# Fire Resistance Ratings

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## Defining a Fire Resistance Rating

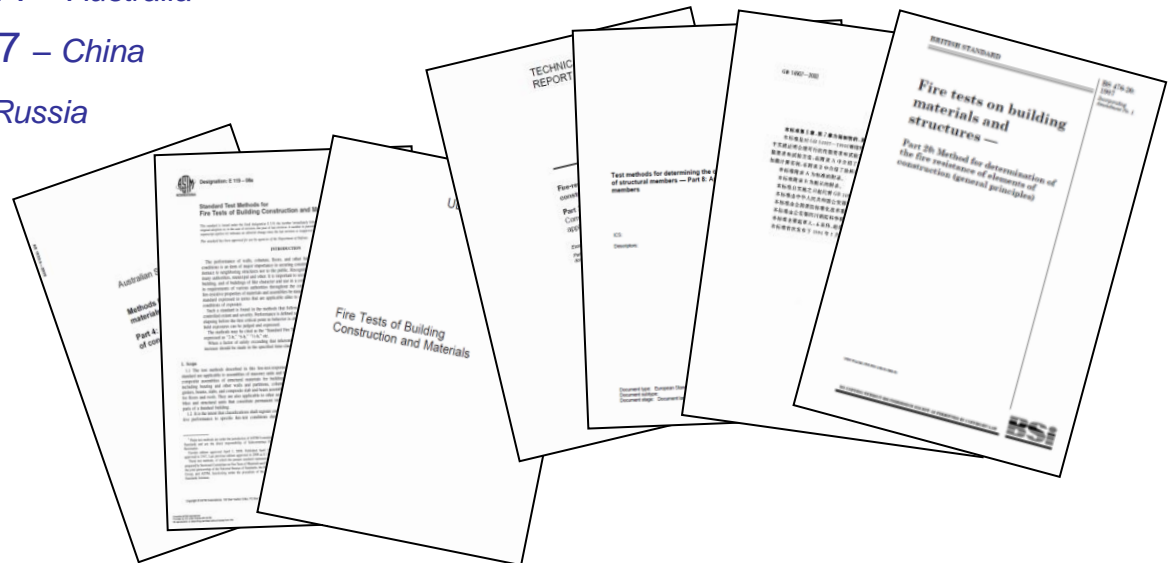
- At 120 minutes for example, what is the acceptance criteria..?
  - “*Structural stability shall be maintained for a reasonable period of time...*”
- Limiting steel temperatures
  - Associated closely to the Approval Standard
    - UL 263 / ASTM E-119: 538°C [1000°F] or 593°C [1100°F]
    - BS 476: 520°C, 550°C, 620°C (Guidance)
- Typical rating: **620°C at 120 minutes** (for a beam)

SCI 4<sup>th</sup> November 1997: “*The existing temperatures of 550°C and 620°C are acceptable for most circumstances, but they are not always conservative.*”

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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: -
  - UL 263 / ASTM E-119 – *Americas, Canada & Middle East*
  - BS 476: Part 21 – *UK, Brazil, South East Asia, Belgium, New Zealand, Middle East*
  - EN 13381 – *Mainland Europe*
  - AS 1530.4 – *Australia*
  - GB 14907 – *China*
  - GOST – *Russia*



# Fire Protection Concept

Intumescent coatings



Boards



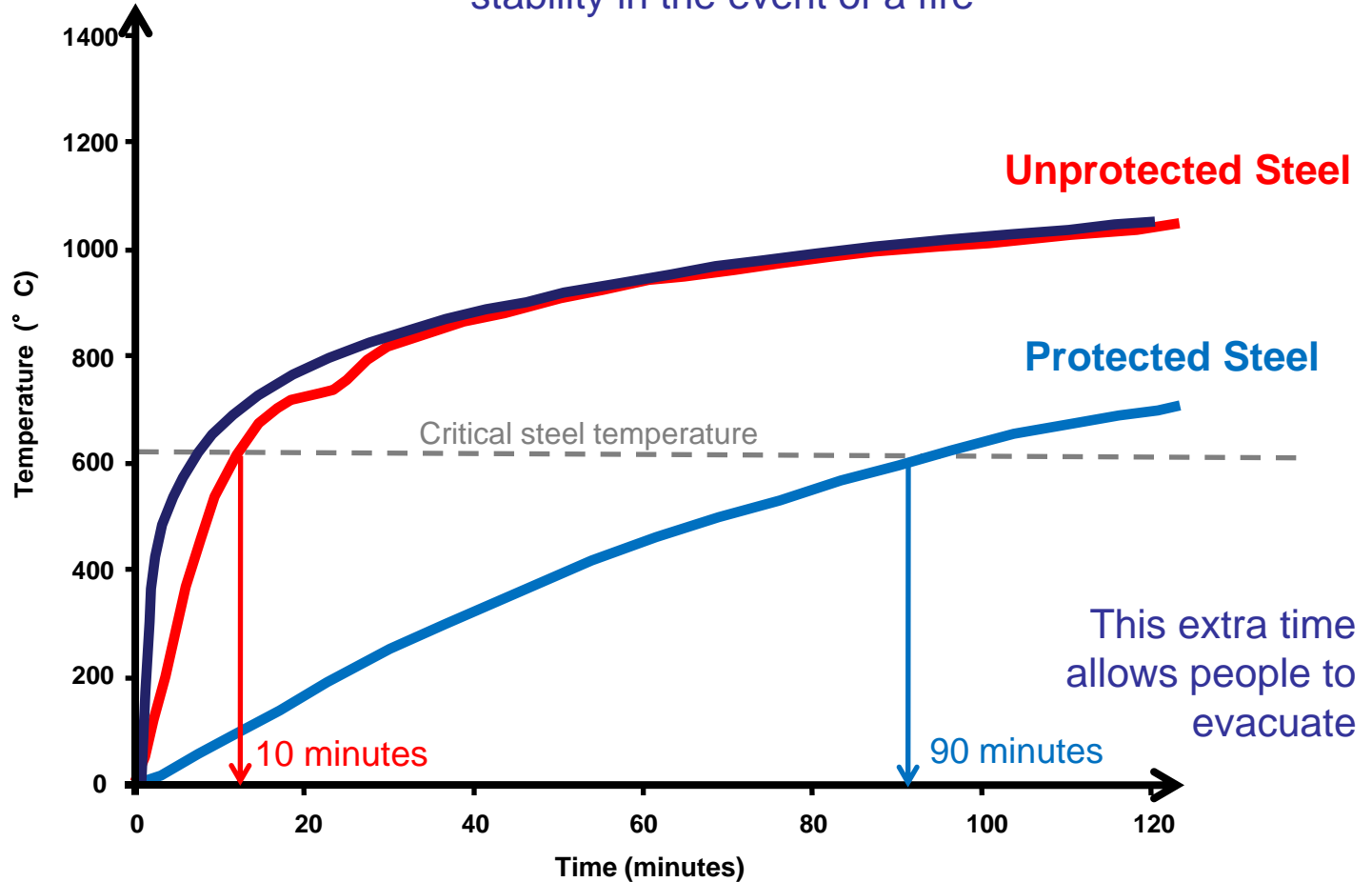
Cementitious sprays



Insulation blankets



A fireproofing material can extend structural stability in the event of a fire



# Specification of Intumescent Fire Proofing



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# Why Intumescent Fire Protection?

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## Typical Benefits of Intumescent Coatings

- Aesthetically pleasing with full colour options
- High quality finish can be achieved
- Very low thickness requirements (few millimetres)
- Part of a corrosion protection system
  - Steel needs to be painted anyway
- High productivity in steel preparation
- Durability for transportation
- Easy & Clean application
- Maintenance Free
- Can cater for all environments (indoors/outdoors/marine etc)





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# Selecting a Thickness of Paint

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## How do Suppliers Establish a Thickness of Intumescent?

Typically the following information is required: -

- Standard for approval: *e.g. BS 476: 20-22*
- Fire resistance period: *e.g. 60 minutes*
- Structural section: *e.g. I-beam*
- Degree of exposure: *e.g. 3-sided with a concrete slab on top*
- Limiting steel temperature: *e.g. 620°C*
- Steel section: *e.g. UB 406x178x74*

From these a supplier can determine a dry film thickness (DFT) of paint for a range of products that have 3<sup>rd</sup> party accreditation.

Further information can tailor a specific product for a project

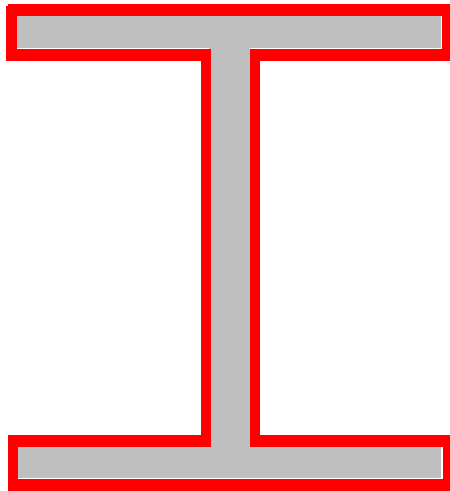
- Environmental exposure – degree of corrosion
  - Durability requirements
-

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# Section Factor

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- The rate of temperature increase of a steel cross-section can be determined by the ratio of the **heated surface perimeter** to the **area** of the cross section



■ A: Area of steel cross-section (m<sup>2</sup>)

— H<sub>p</sub>: Length of heated steel perimeter (m)

## Example

UB 406x178x74: Exposed on 4 sides

Heated perimeter,  $H_p = 1.51\text{m}$

Cross-section area,  $A = 0.00945\text{m}^2$

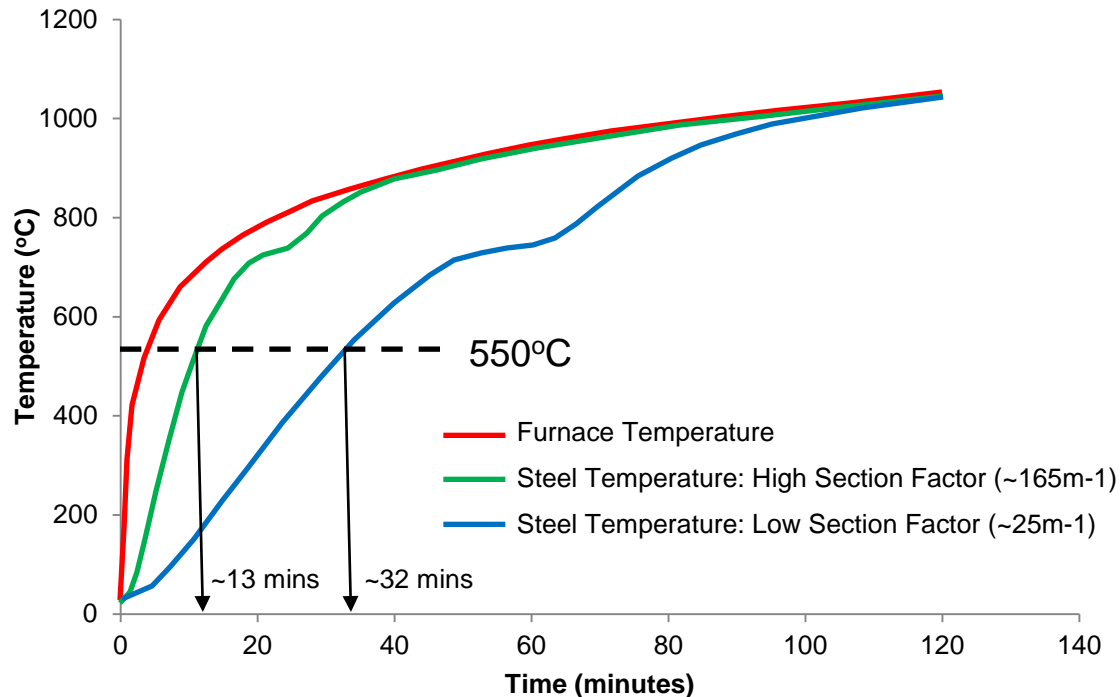
$$\text{Section Factor, } H_p/A = \frac{1.51}{0.00945} = 160\text{m}^{-1}$$

# Section Factor – $H_p/A = A/V$

## How steel heats up

- Slender Sections: **High** Section Factor  
Heat relatively **quickly** when unprotected

- Stocky Sections: **Low** Section Factor  
Heat relatively **slowly** when unprotected



# Selecting a Thickness of Paint

## How do Suppliers Establish a Thickness of Intumescent?



Interchar 963

**2** Table 6: I-Section Beams 620°C

30 minutes		60 minutes				90 minutes	
Section factor up to m <sup>2</sup>	Thickness mm	Section factor up to m <sup>2</sup>	Thickness mm	Section factor up to m <sup>2</sup>	Thickness mm	Section factor up to m <sup>2</sup>	Thickness mm
290	0.275	30	0.280	170	0.533	60	0.582
295	0.281	35	0.282	175	0.547	65	0.627
300	0.286	40	0.284	180	0.561	70	0.671
305	0.291	45	0.285	185	0.575	75	0.716
310	0.297	50	0.287	190	0.589	80	0.760
315	0.302	55	0.289	195	0.603	85	0.805
320	0.308	60	0.290	200	0.618	90	0.849
		65	0.292	205	0.632	95	0.894
		70	0.294	210	0.646	100	0.938
		75	0.296	215	0.660	105	0.983
		80	0.297	220	0.674	110	1.027
		85	0.299	225	0.707	115	1.072
		90	0.306	230	0.751	120	1.116
		95	0.320	235	0.796	125	1.161
		100	0.334	240	0.840	130	1.205
		105	0.348	245	0.885	135	1.250
		110	0.362	250	0.929	140	1.295
		115	0.377	255	0.974	145	1.339
		120	0.391	260	1.018	150	1.384
		125	0.405	265	1.063		
		130	0.419	270	1.108		
		135	0.433	275	1.152		
		140	0.447	280	1.197		
		145	0.462	285	1.241		
		150	0.476	290	1.286		
		155	0.490	295	1.330		
		160	0.504	300	1.375		
		165	0.518				

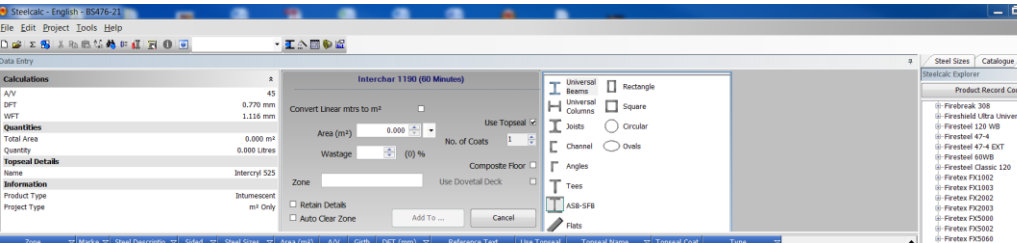
**3**

**4**

Thickness is intumescent only. Three sided beams with a concrete slab.

# Selecting a Thickness of Paint

## Steel BOQ → MTO



### Bill of Quantity Report

**Report details**

Prepared for: TAV Construction  
 Project: KAAIA Hangars  
 Report date: 9 January 2013  
 Prepared by: ADT

**International Paint details**

Alco Nobel  
 Dubai Marina  
 UAE  
 +97155410921

Member	Exposure	Section Factor (m <sup>2</sup> )	Member Quantity	Coated Surface Area (m <sup>2</sup> )	Product	Fire Rating (mins)	Limiting Steel Temperature (°C)	Volume (L)	Wt (mm)	DFT (mm)	Comments
ZULPH 180	Column/Truss (4-sided)	114	1	254.6	1120 180	538	2207	8.41	4.40		
ZULPH 280	Column/Truss (4-sided)	88	1	81.7	1120 180	538	623	7.63	5.19		
HD 360x134	Column/Truss (4-sided)	125	1	369.2	212 180	538	4598	12.46	12.46		
HD 360x147	Column/Truss (4-sided)	114	1	1,033.2	1120 180	538	9729	9.41	6.49		
HD 360x162	Column/Truss (4-sided)	105	1	1,382.8	1120 180	538	12279	8.88	6.04		
HD 360x179	Column/Truss (4-sided)	95	1	1,850.7	1120 180	538	13344	8.08	5.50		
HD 360x196	Column/Truss (4-sided)	87	1	572.5	1120 180	538	4307	7.63	5.19		



### Intercal Fire Design - Interchar Material Take-Off Generator

Buttons: Load, Save, Report, Reset Inputs, Change All Entries, Delete

**Fire Rating (mins)**: 30, 60, 90, 120, 180

**Standard**: BS 476, EN 13381-8, AS 4100

**Product**: Interchar 212, Interchar 963, Interchar 973, Interchar 1120, Interchar 1190, Interchar 1260, Interchar 2060

**Serial / Custom Section**: Custom Section, Serial Section

**Custom Section**: Section Factor, Hp/A: m<sup>2</sup>

**Perimeter**: Heated perimeter: m

**Hollows**: No, CHS, RHS

**Generator**: Generate

**Serial Section**

UB	Description	Quantity
127x76x13	127x76x13	325
UC	152x89x16	
J	178x102x19	
LBP	203x102x23	
CHS	203x133x25	
RHS	203x133x30	
SHS	254x102x22	
DHS	254x102x25	
Flat bar	254x102x28	
Equal Angle	254x146x31	
2 x Equal Angle	254x146x37	
Unequal Angle	254x146x43	
PFC	305x102x25	
Plate	305x102x28	
IPN	305x102x33	
IPN	305x127x37	
HE	305x127x42	
HL	305x127x48	
HD	305x165x40	
HP	305x165x46	
LPE	305x165x54	
LUFN	356x127x33	

**Features**: Bracing

**Limiting Steel Temperature**: Automatic 550, Manual, Utilisation 100

**Office**: 576

**Exposure**: 1-sided, 2-sided, 3-sided, 4-sided

**Member Details**: Length: 1.00, Quantity: 1

**Comments**



### Bill of Quantity Report

SHS 300x300x13x32	Column/Truss (4-sided)	80	1	1,847.0	1120 180	538	10962	6.66	4.46		
PG 960x360x18x30	Column/Truss (4-sided)	86	1	802.4	1120 180	538	6121	7.63	5.19		
PG 960x480x21x18	Column/Truss (4-sided)	136	1	699.0	212 180	538	5177	13.32	13.32		
SHS 500x500x10	Column/Truss (4-sided)	102	1	559.4	1120 180	538	5760	16.07	10.93		
SHS 500x500x12	Column/Truss (4-sided)	85	1	776.9	1120 180	538	6367	12.09	8.20		
SHS 500x500x16	Column/Truss (4-sided)	65	1	862.4	1120 180	538	9046	16.51	7.15		
SHS 500x500x25	Column/Truss (4-sided)	42	1	198.4	1120 180	538	2086	16.51	7.15		
SHS 500x500x38	Column/Truss (4-sided)	36	1	160.0	1120 180	538	1682	16.51	7.15		
SHS 500x500x52	Column/Truss (4-sided)	33	1	66.8	1120 180	538	702	16.51	7.15		
SHS 500x500x68	Column/Truss (4-sided)	30	1	32.0	1120 180	538	336	16.51	7.15		
SHS 500x500x86	Column/Truss (4-sided)	25	1	160.0	1120 180	538	1682	16.51	7.15		
SHS 500x500x90	Column/Truss (4-sided)	27	1	350.4	1120 180	538	3684	16.51	7.15		
SHS 500x500x95	Column/Truss (4-sided)	24	1	32.0	1120 180	538	336	16.51	7.15		
SHS 500x500x50	Column/Truss (4-sided)	22	1	103.6	1120 180	538	1039	16.51	7.15		
SHS 500x500x58	Column/Truss (4-sided)	22	1	519.0	1120 180	538	4449	18.21	12.38		
Interchar 1126							131536				
Interchar 212							99039				
Charles 1109							91887				

Totals	Member Quantity	Coated Surface Area (m <sup>2</sup> )	Volume (L)
All products	42	27,896.9	318452

**Notes**

Where "B" (Bracing) has been used, a maximum section factor of 200m-1 (0.67 W/D) is used unless the section factor is less than this for the given section.  
 Where "CD" (Concrete Filled) has been used, this refers to a Composite Deck.  
 Where "CF" (Concrete Filled) has been used, the section factor for the given section is reduced in accordance with "Design Guide for Concrete Filled Columns" (Conur, formerly British Steel).  
 Where "EB" (Edge Beam) has been used, make reference to the ASEP Yellow Book.  
 Where "UL" (Unfilled) has been used, make reference to the ASEP Yellow Book.  
 Where volumes are given in gallons, the US customary liquid gallon (3.785 L) is used, rather than the imperial gallon (4.546 L).

Member Type	Member Designation or Description	Exposure	Section Factor (m <sup>2</sup> )	Quantity	Length of Member (m)	Coated Perimeter (m)	Coated Surface Area (m <sup>2</sup> )	Product	Fire Test Standard	Fire Rating (mins)	Limiting Steel Temperature (°C)	DFT (mm)	Volume (L)	Comments
UB	127x76x13	Column/Truss (4-sided)	325	1	1,000	0.54	0.5	Interchar 212	BS 476	30	550	1.22	0.66	

Member Type	Member Designation or Description	Exposure	Section Factor (m <sup>2</sup> )	Quantity	Length of Member (m)	Coated Perimeter (m)	Coated Surface Area (m <sup>2</sup> )	Product	Fire Test Standard	Fire Rating (mins)	Limiting Steel Temperature (°C)	DFT (mm)	Volume (L)	Comments
UB	127x76x13	Column/Truss (4-sided)	325	1	1,000	0.54	0.5	Interchar 212	BS 476	30	550	1.22	0.66	

### Protective Coatings [www.international-pc.com](http://www.international-pc.com)

All products supplied and technical advice or recommendations given are subject to our standard Conditions of Sale.  
 Registered in England No. 08504  
 Registered Office: 20th Floor, Portland House, Broadwater Place, London EC1R 6BS





# Structural Fire Design



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# Selecting a Thickness of Paint

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## How do Suppliers Establish a Thickness of Intumescent?

Typically the following information is required: -

- Standard for approval: *e.g. BS 476: 20-22*
- Fire resistance period: *e.g. 60 minutes*
- Structural section: *e.g. I-beam*
- Degree of exposure: *e.g. 3-sided with a concrete slab on top*
- Limiting steel temperature: *e.g. 620°C*
- Steel section: *e.g. UB 406x178x74*

From these a supplier can determine a dry film thickness (DFT) of paint for a range of products that have 3<sup>rd</sup> party accreditation.

Further information can tailor a specific product for a project

- Environmental exposure – degree of corrosion
  - Durability requirements
-

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# Prescriptive Design Approach

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Prescriptive design does not consider the amount of actual load on a structural element, but assumes a fixed temperature

In the UK prescribed design assumes that an unprotected steel column will fail when its temperature reaches 550°C

Similarly a temperature of 620°C will cause the failure of an unprotected steel beam supporting a concrete floor.

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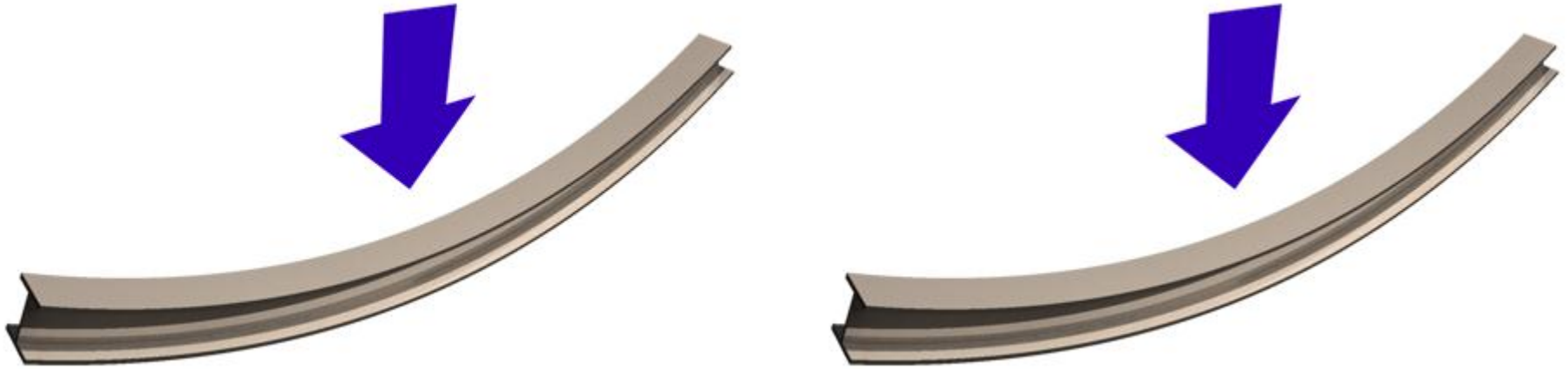
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# Prescriptive Fire Protection

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Identical Section in both cases

Steel Utilization (e.g. 60%) vs Steel Utilization (e.g. 80%)



Limiting Steel Temperature == Limiting Steel Temperature

Fire Protection Thickness == Fire Protection Thickness

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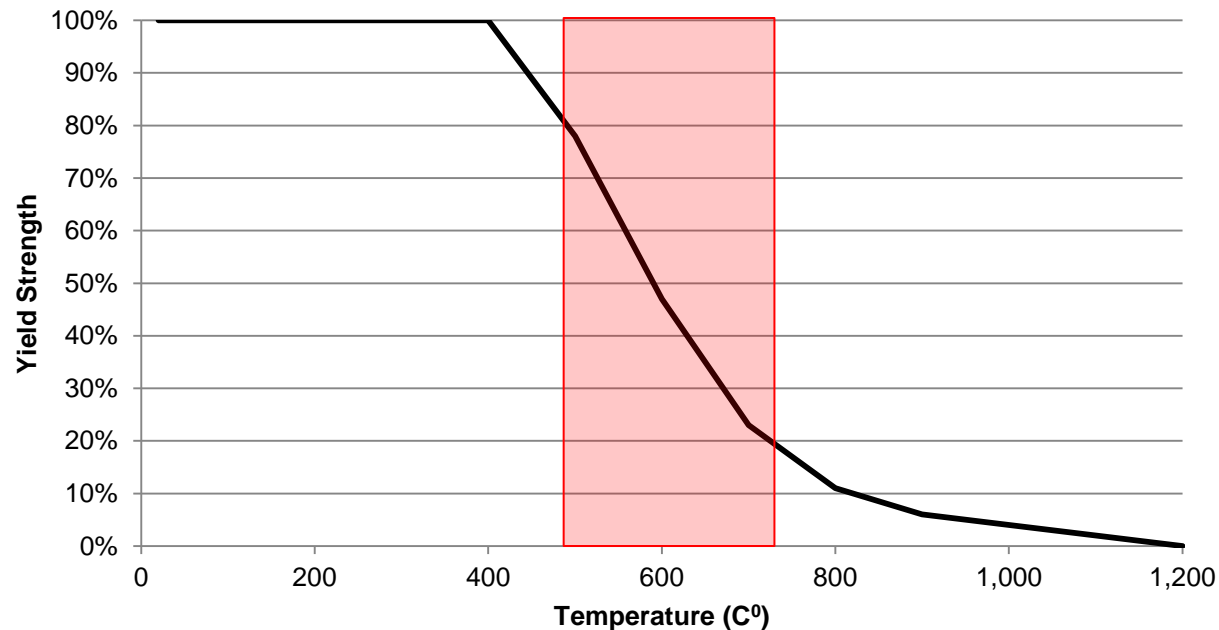
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# Structural Fire Engineering

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## Understanding Structural Engineering & Steel

### Steel Strength vs Temperature



Assumes that the steel is loaded to a certain stress

Is this always the case?

Analysis at the Fire Limit State

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# Structural Fire Engineering: Performance Based Design

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## Critical core temperature:

Defined as the maximum temperature a steel section can reach while still maintaining its load

Further simplified as:

Capacity of a steel section during a fire

Fireproofing manufacturers expect this to be provided in tenders, but it never is...

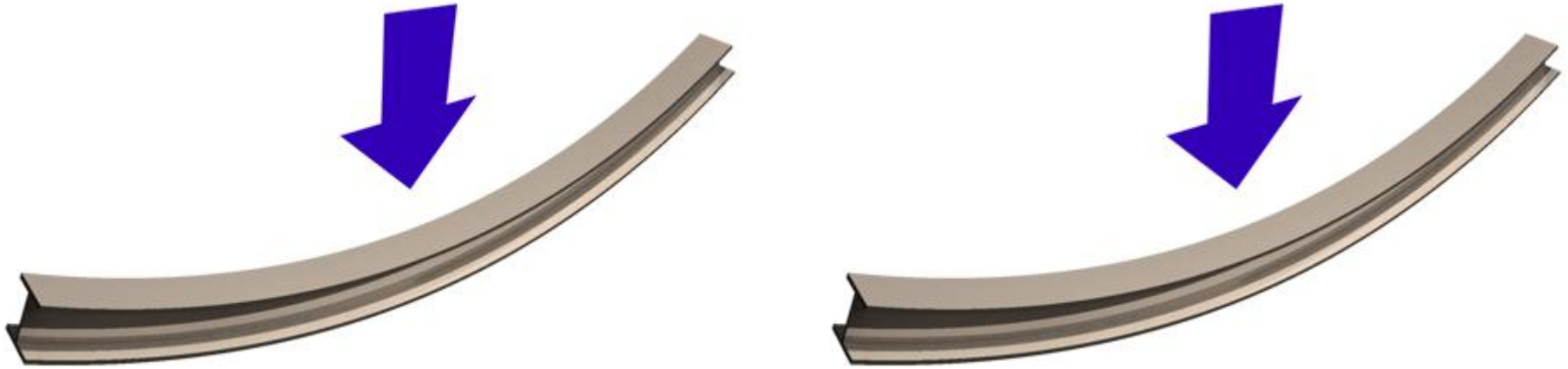
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# Performance Based Fire Design

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Steel Utilization (e.g. 60%) vs Steel Utilization (e.g. 80%)



Limiting Steel Temperature >> Limiting Steel Temperature

Fire Protection Thickness << Fire Protection Thickness

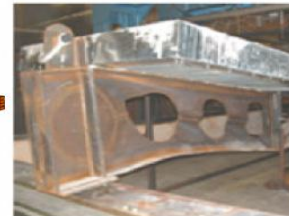
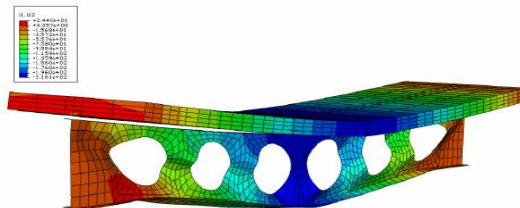
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# Structural Fire Engineering

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- 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...



# Structural Fire Engineering and Fireproofing Solutions

## Multi-Temperature Assessment Data (MTA)

- UK and European fire testing methods (BS 476: 20-22 and EN 13381) make allowance for varying limiting steel temperatures
- US test methods work to a single 538°C [1000°F] or 593°C [1100°F] limiting temperature

30 minutes				60 minutes	
Section factor up to m <sup>-1</sup>	Thickness mm	Section factor up to m <sup>-1</sup>	Thickness mm	Section factor up to m <sup>-1</sup>	Thickness mm
120	0.275	225	0.475	30	0.478
125	0.285	230	0.484	35	0.513
130	0.294	235	0.494	40	0.548
135	0.304	240	0.503	45	0.583
140	0.313	245	0.513	50	0.617
145	0.323	250	0.522	55	0.652
150	0.332	255	0.532	60	0.687
155	0.342	260	0.541	65	0.722

Table 2: I-Section Beams 450°C
Table 3: I-Section Beams 500°C
Table 4: I-Section Beams 550°C
Table 5: I-Section Beams 600°C
Table 6: I-Section Beams 620°C
Table 7: I-Section Beams 650°C
Table 8: I-Section Beams 700°C

# Structural Fire Engineering - Example

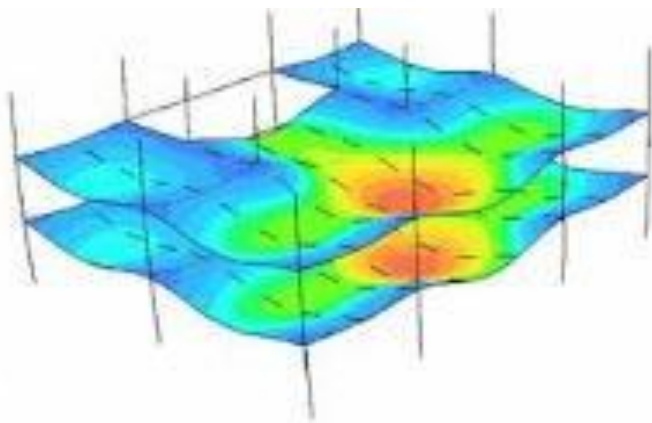
Member Analysis		Section Factor $H_p/A$	Steel Temperature $\theta$	Dry Film Thickness	Number of days required	Fire protection material saving
1	<b>UKC 202x203x46</b> Prescriptive Design	200 /m	550°C	3.13 mm	5	<b>0%</b>
2	<b>UKC 202x203x46</b> Performance based design	200 /m	576°C	2.8 mm	4	<b>10%</b>
3	<b>UKC 202x203x86</b> Increased steel weight	110 /m	673°C	1.27 mm	2	<b>59%</b>
4	<b>UKC 202x203x46</b> Increased Steel Strength 235 N/mm <sup>2</sup> to 355 N/mm <sup>2</sup>	200 /m	639°C	2.21 mm	3	<b>29%</b>



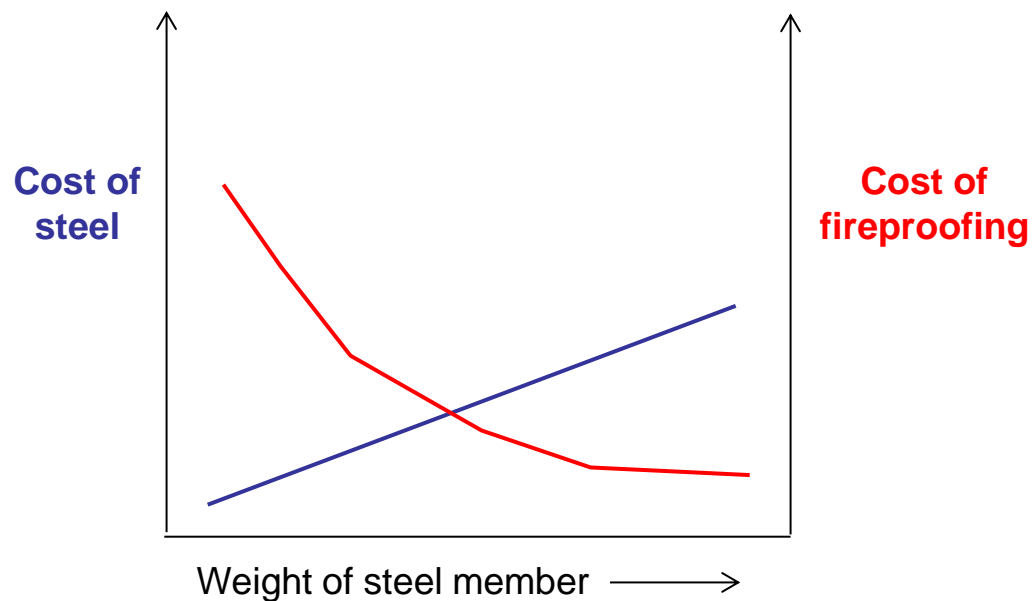
# Structural Fire Engineering Optimisation

## Optimisation

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



In some instances, steel can be cheaper than fireproofing materials



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# Structural Fire Engineering

## DO's & DON'Ts

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### DO

- Optimize fire proofing based on project requirements
- Question basis of temperature selections
- Question product limitations – Hp/A & Temperatures

### DON'T

- Don't accept material thicknesses without certifications
  - Don't accept increased limiting temperatures without a report
  - Don't accept anything that is not understood!!!
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# Benefits of Performance Based FP Design

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## Safe and Robust Designs in Buildings

- Demonstrate building integrity in a fire
- Identify potentially weak areas

## Quantified Structural Performance

- Understand the limitations of steel at elevated temperatures
  - Enable performance based design
  - Add value in design
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# Benefits of Performance Based FP Design

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## Cost Optimization

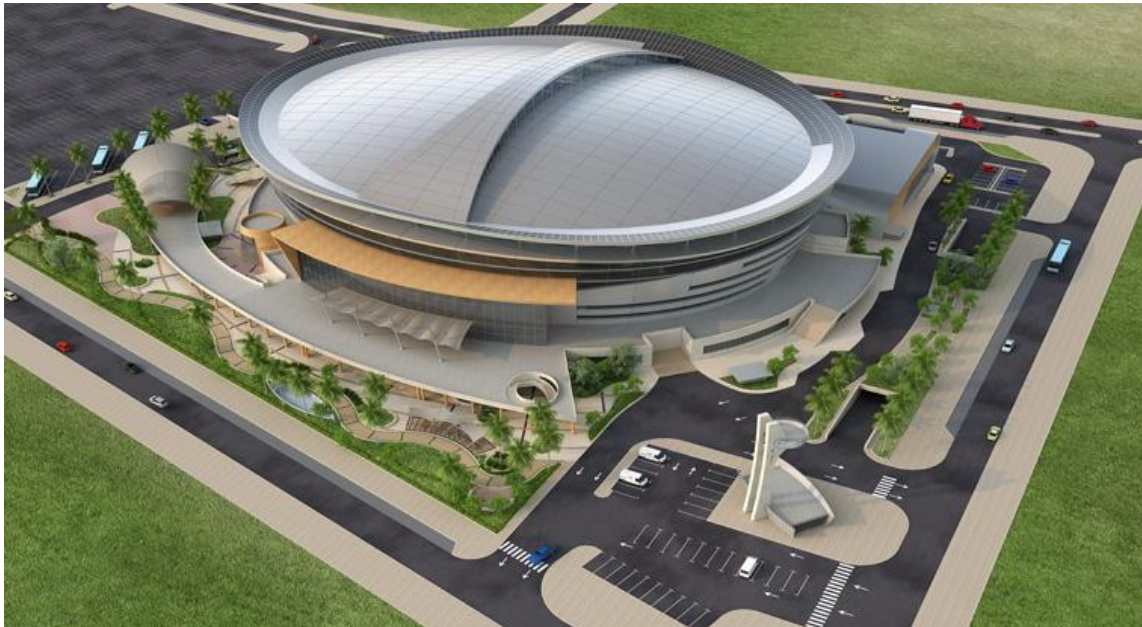
- Enable performance based design of fire protection materials
    - Optimized construction material usage
    - Steel optimized on par with PFP to ensure max value
  - Reduced number of coats resulting in faster preparation times
  - Reduced scaffolding times
  - Reduced erection times
  - Reduced manhours on site
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# Structural Fire Design

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## Al-Sadd Sports Club - Qatar



Value	\$5 Billion
Client	Fosters
Contractor	Nurol
Product	Interchar 1190
Scenario	R120
Volume	90,000 L
Status	Won

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# Structural Fire Design

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## Emirates Sky Cargo - Dubai World Central



Value	\$100+m
Client	Emirates
Contractor	Amana Steel Buildings
Product	Interchar 1190
Scenario	R90 – FM Approval
Volume	300,000 L
Status	Specified and won

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# Summary

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## **Intumescent Coatings**

- Structural Fire Proofing
- Data Required for system design
- Process to establish material thicknesses/volumes

## **Structural Fire Design**

- Critical core temperatures
- Steel behaviour at elevated temperatures
- Calculation of optimum steel temperatures

## **Benefits of Fire Design**

- Promoting safe design in buildings
  - Fire limit state should be treated as an important load case
  - By addressing fire protection in early stages of design significant costs savings can be demonstrated
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**Thank you for your attention**

