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Optimization of Intumescent Fireproofing Via Structural Analysis

AkzoNobel

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Tomorrow's Answers Today

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- **Benefits of Structural Fire Engineering**
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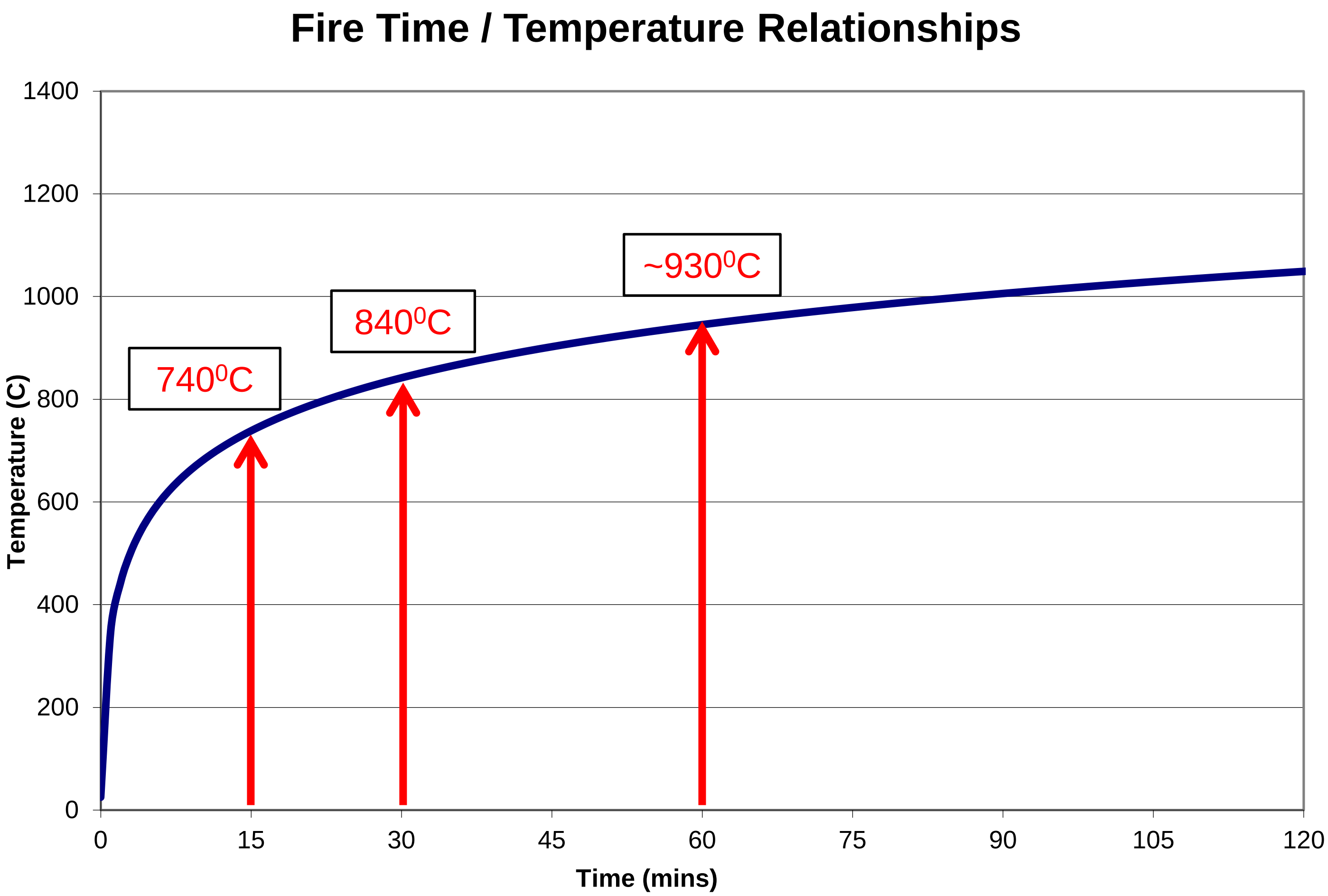
  - Quantified Structural Fire Performance
  - Cost Optimization

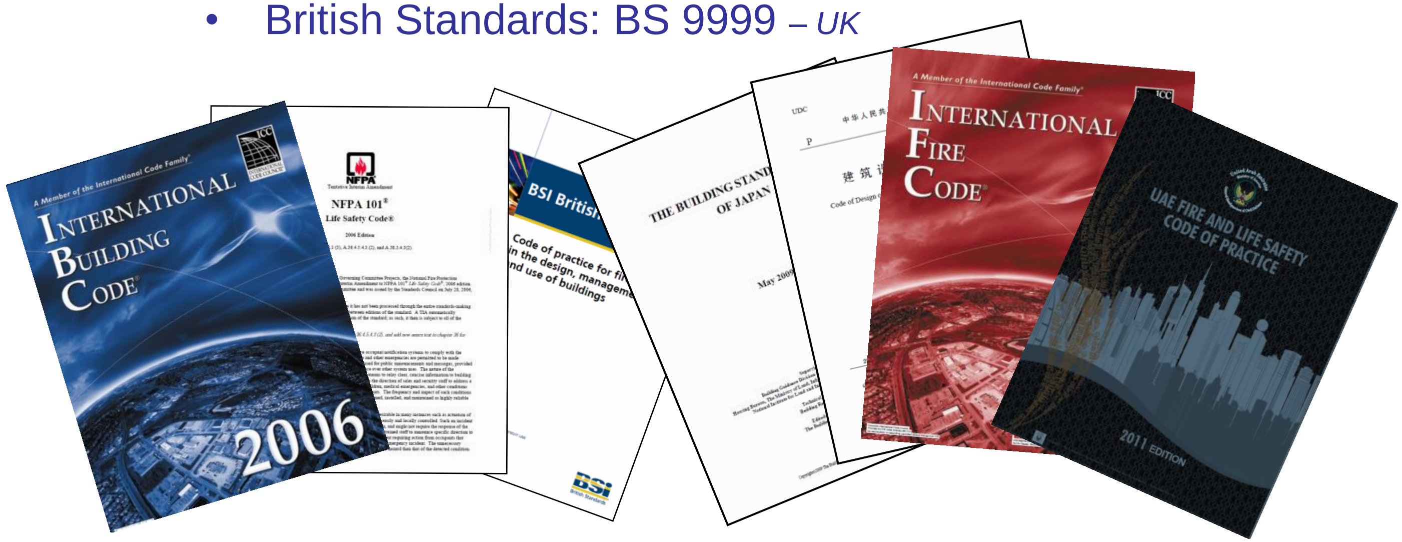
Structural Fire Protection


How is a fire defined in a building?



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
Exterior Bearing Walls[a]							
Supporting more than one floor, columns, or other bearing walls	4	3	2	1	0[b]	2	2
Supporting one floor only	4	3	2	1	0[b]	2	2
Supporting a roof only	4	3	1	1	0[b]	2	2
Interior Bearing Walls							
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
Columns							
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
Beams, Girders, Trusses, and Arches							
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
Floor/Ceiling Assemblies	2	2	2	1	0	1	0
Roof/Ceiling Assemblies	2	1½	1	1	0	1	0
Interior Nonbearing Walls	0	0	0	0	0	0	0
Exterior Nonbearing Walls[c]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]

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

Fire Resistance Ratings

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^{o}C [1000^{o}F] or 593^{o}C [1100^{o}F]
    - BS 476: 520^{o}C, 550^{o}C, 620^{o}C (Guidance)

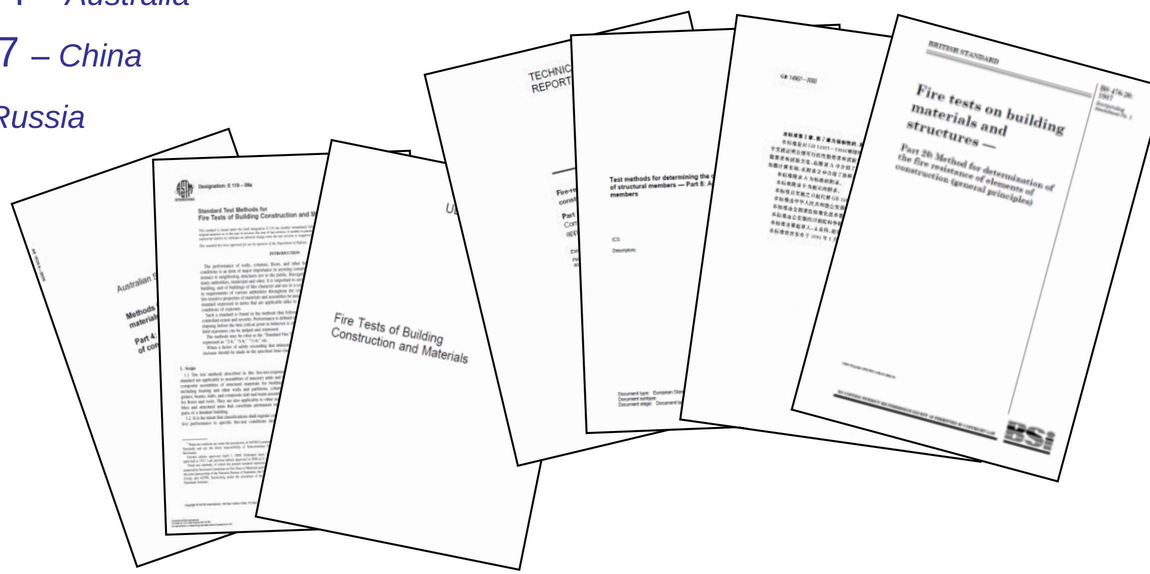
- Typical rating: **620^{o}C at 120 minutes** (for a beam)

SCI 4th November 1997: *"The existing temperatures of 550^{o}C and 620^{o}C are acceptable for most circumstances, but they are not always conservative."*

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

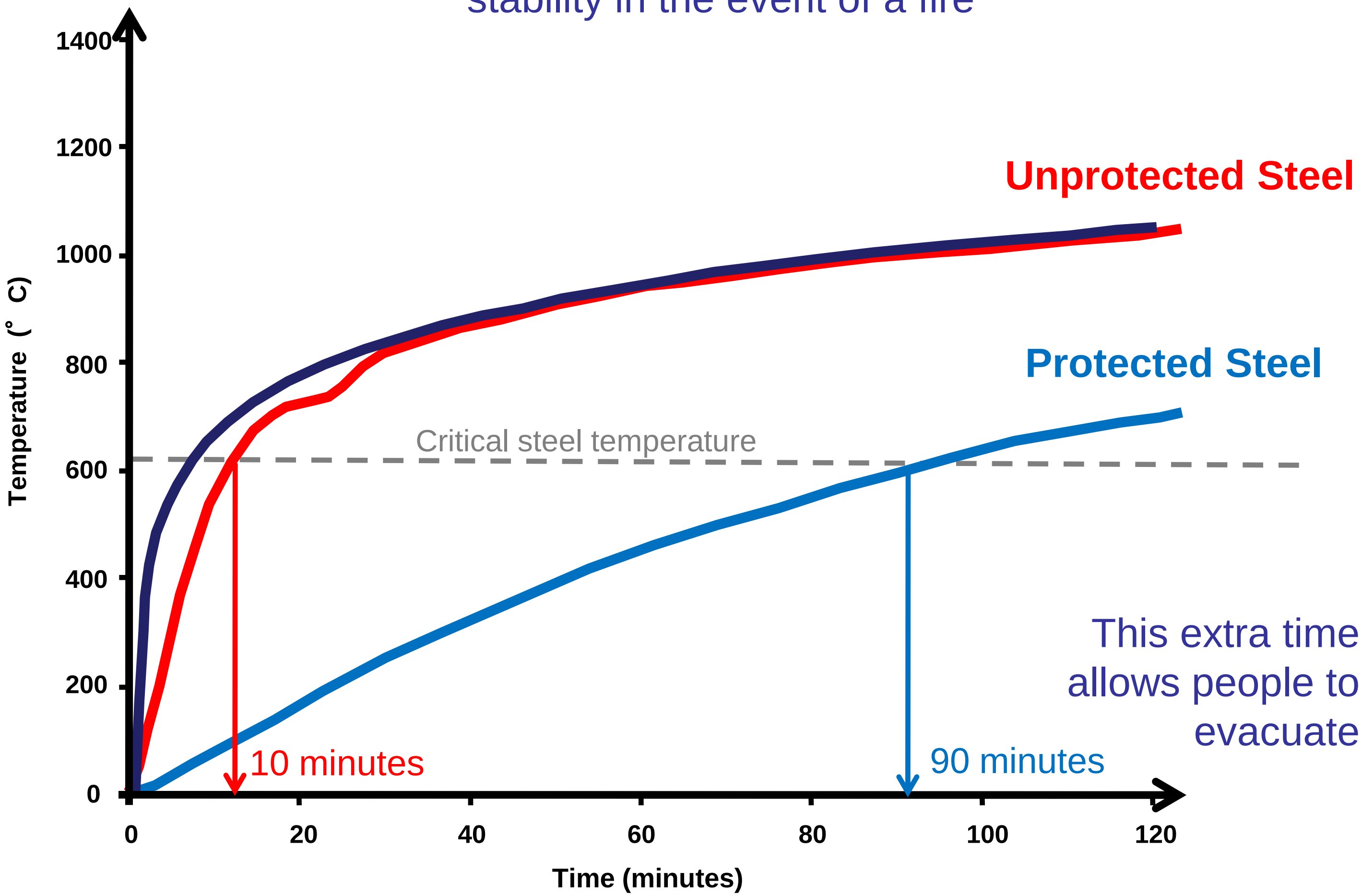
Intumescent coatings

Boards

Cementitious sprays

Insulation blankets

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



This extra time allows people to evacuate

Specification of Intumescent Fire Proofing

Why Intumescent Fire Protection?

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)

Selecting a Thickness of Paint

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^{o}C*
- Steel section: *e.g. UB 406x178x74*

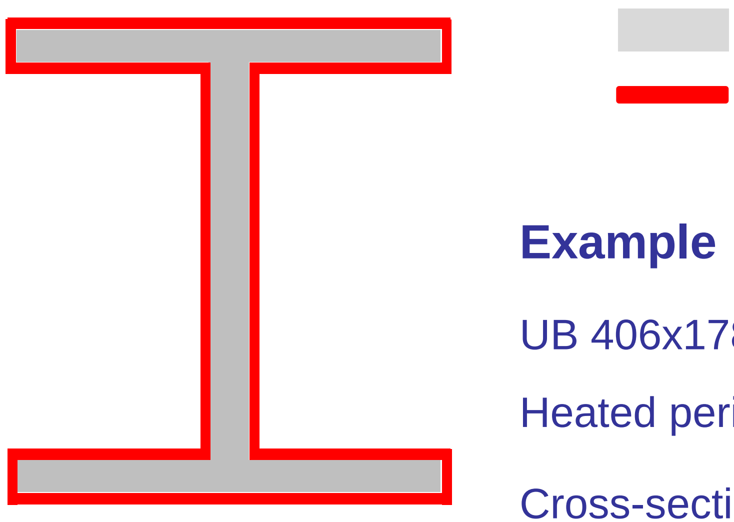
From these a supplier can determine a dry film thickness (DFT) of paint for a range of products that have 3rd party accreditation.

Further information can tailor a specific product for a project

- ○ Environmental exposure – degree of corrosion
- ○ Durability requirements

Section Factor

- 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^2)

H_p: Length of heated steel perimeter (m)

Example

UB 406x178x74: Exposed on 4 sides

Heated perimeter, $H_p = 1.51$m

Cross-section area, $A = 0.00945 m^2$

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

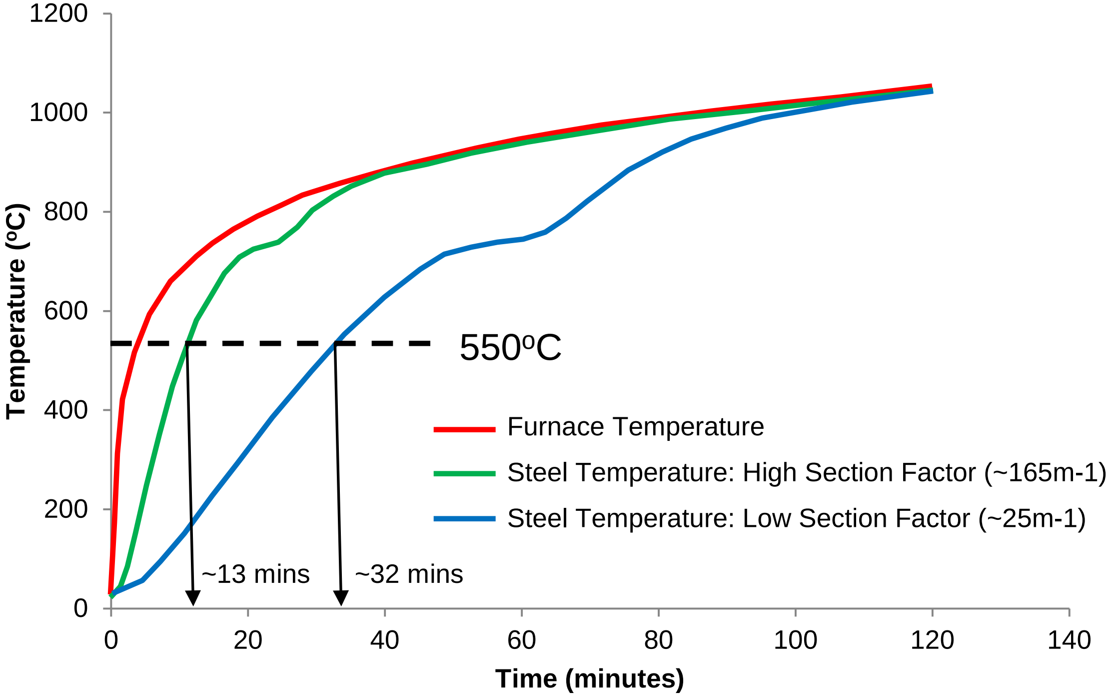
Section Factor – Hp/A = A/V
How steel heats up

- 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?

certifire

1

CERTIFICATE OF APPROVAL
No CF 345

This is to certify that, in accordance with CERTIFIRE's Rules for Certification The undermentioned product of

INTERNATIONAL PAINT LIMITED

Stoneygate Lane, Felling, Gateshead, NE10 0JY
Tel: 0191 469 6111 Fax: 0191 438 3711

Have been assessed against the requirements of the Technical Schedule(s) denoted below and are approved for use subject to the conditions appended hereto:

CERTIFIED PRODUCT	TECHNICAL SCHEDULE
Interchar 963	TS15 Intumescent Coatings for Steelwork

Signed and sealed for and on behalf of CERTIFIRE

Sir Ken Knight
Chairman - Management Council

Issued: 17th February 2004
Reissued: 12th September 2008
Valid to: 14th November 2012

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Only valid when authenticCERTIFIRE Seal is in place

Interchar 963

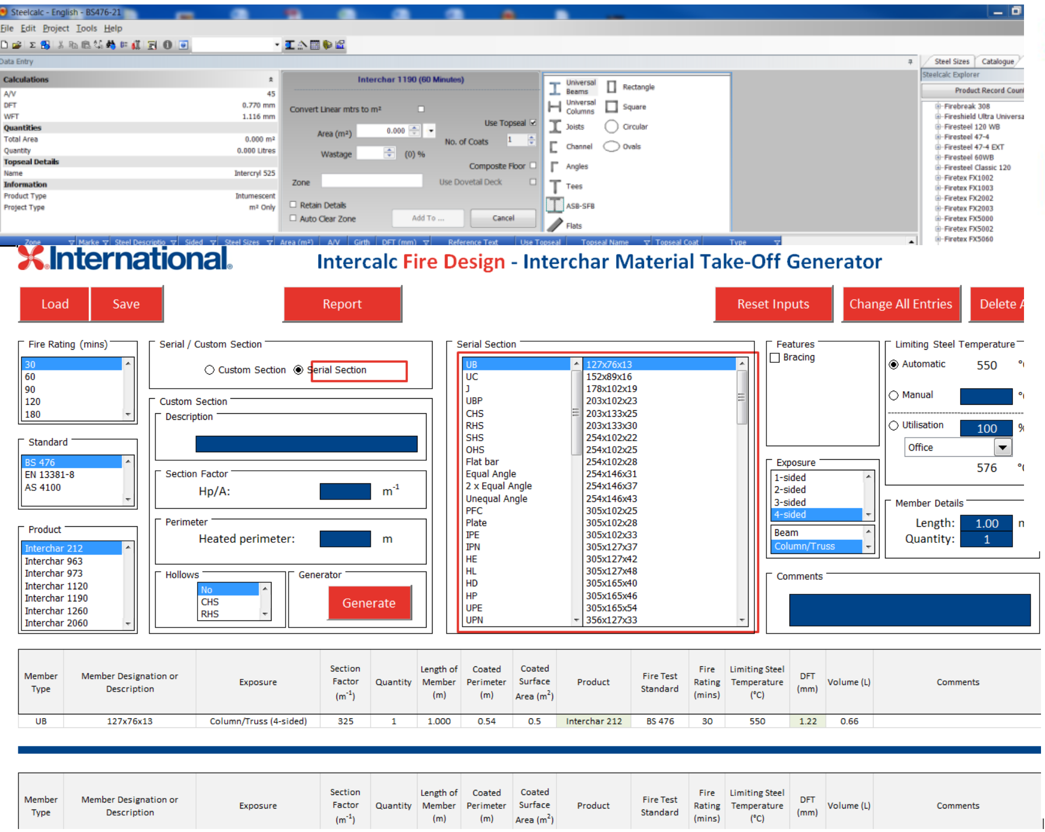
2 Table 6: I-Section Beams 620°C

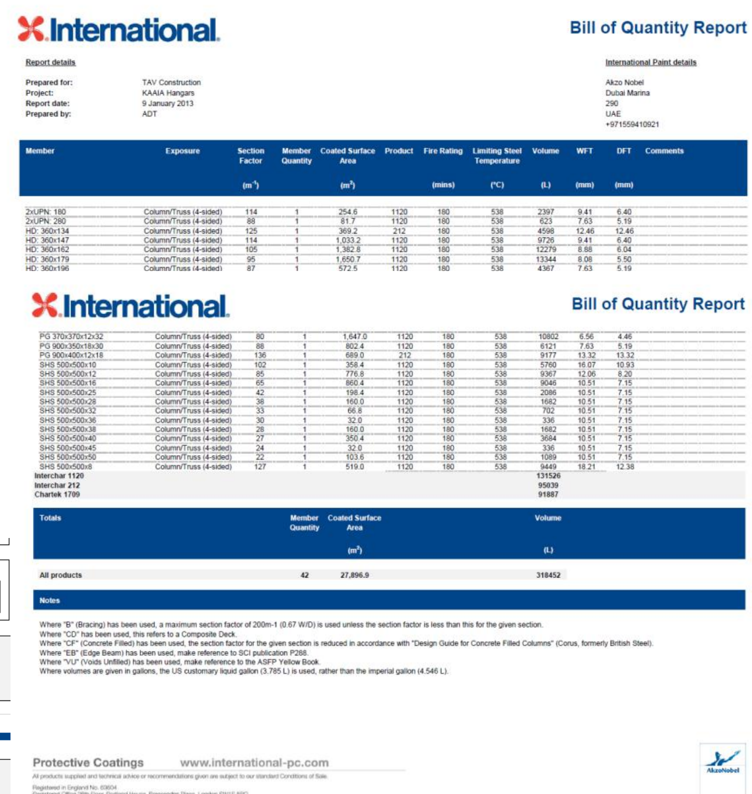
30 minutes		60 minutes		3		90 minutes	
Section factor up to m^{-1}	Thickness mm	Section factor up to m^{-1}	Thickness mm	Section factor up to m^{-1}	Thickness mm	Section factor up to m^{-1}	Thickness mm
290	0.275	30	0.280	170	0.533	60	0.582
295	0.281	35	0.282	175	0.547	65	0.627
300	0.286	40	0.284	180	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		
4		160	0.504	300	1.375		
		165	0.518				

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

Selecting a Thickness of Paint

Steel BOQ → MTO





Structural Fire Design

Selecting a Thickness of Paint

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- Environmental exposure – degree of corrosion
- Durability requirements

Prescriptive Design Approach

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

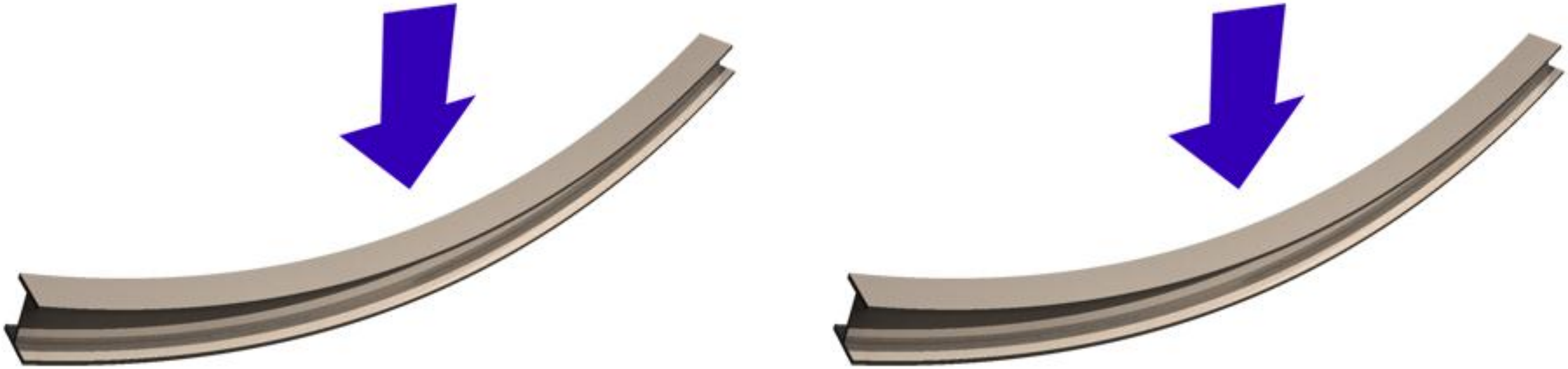
In the UK prescribed design assumes that an unprotected steel column will fail when its temperature reaches 550˚C

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

Prescriptive Fire Protection

Identical Section in both cases

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

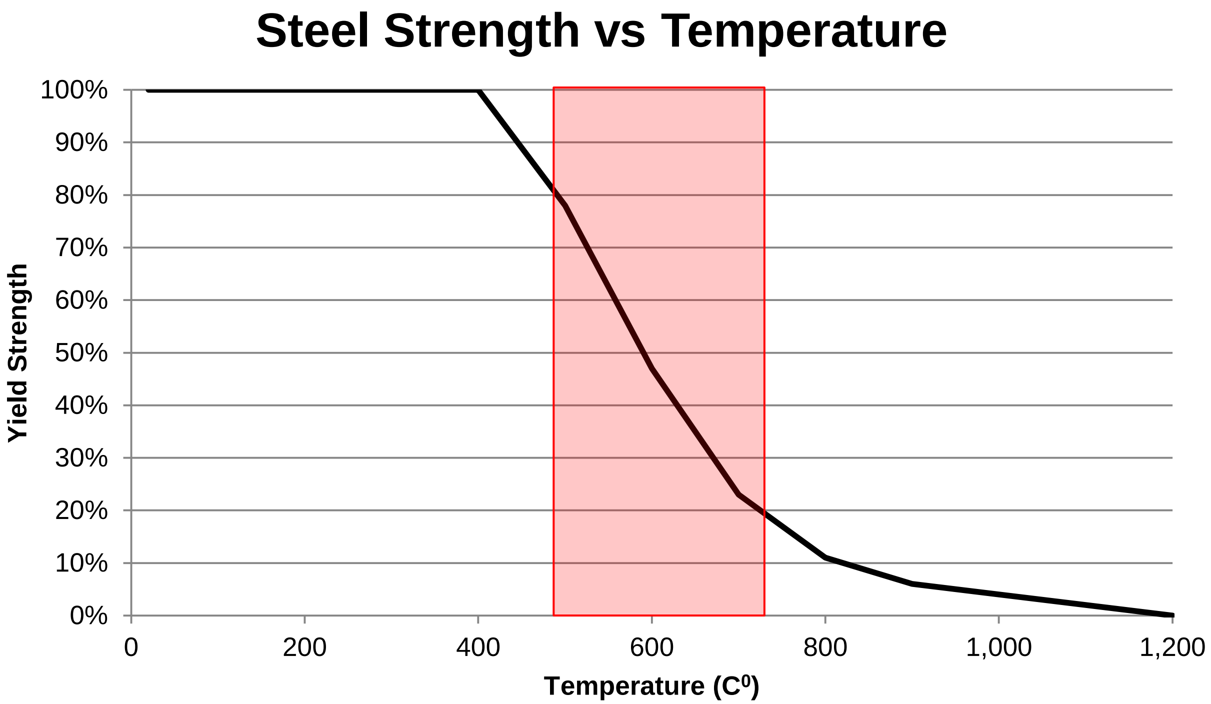


Limiting Steel Temperature == Limiting Steel Temperature

Fire Protection Thickness == Fire Protection Thickness

Structural Fire Engineering

Understanding Structural Engineering & Steel



Assumes that the steel is loaded to a certain stress

Is this always the case?

Analysis at the Fire Limit State

Structural Fire Engineering: Performance Based Design

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...

Performance Based Fire Design

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

Limiting Steel Temperature >> Limiting Steel Temperature

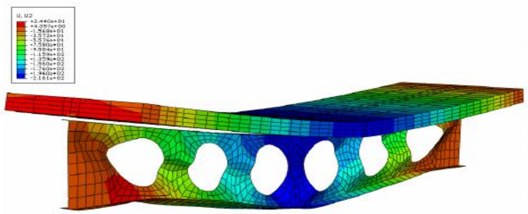
Fire Protection Thickness   <<   Fire Protection Thickness

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...




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 538ºC [1000ºF] or 593ºC [1100ºF] limiting temperature

Table 1: I-Section Beams 400°C

30 minutes				60 minutes	
Section factor up to m^{-1}	Thickness mm	Section factor up to m^{-1}	Thickness mm	Section factor up to m^{-1}	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

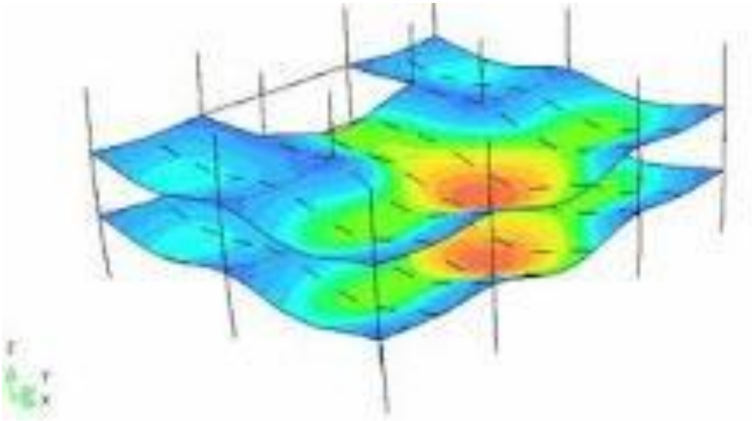
Structural Fire Engineering - Example

Member Analysis		Section Factor Hp/A	Steel Temperature θ	Dry Film Thickness	Number of days required	Fire protection material saving
1	**UKC 202x203x46** Prescriptive Design	200 /m	550^{0}C	3.13 mm	5	**0%**
2	**UKC 202x203x46** Performance based design	200 /m	576^{0}C	2.8 mm	4	**10%**
3	**UKC 202x203x86** Increased steel weight	110 /m	673^{0}C	1.27 mm	2	**59%**
4	**UKC 202x203x46** Increased Steel Strength 235 N/mm^2 to 355 N/mm^2	200 /m	639^{0}C	2.21 mm	3	**29%**

Structural Fire Engineering Optimisation

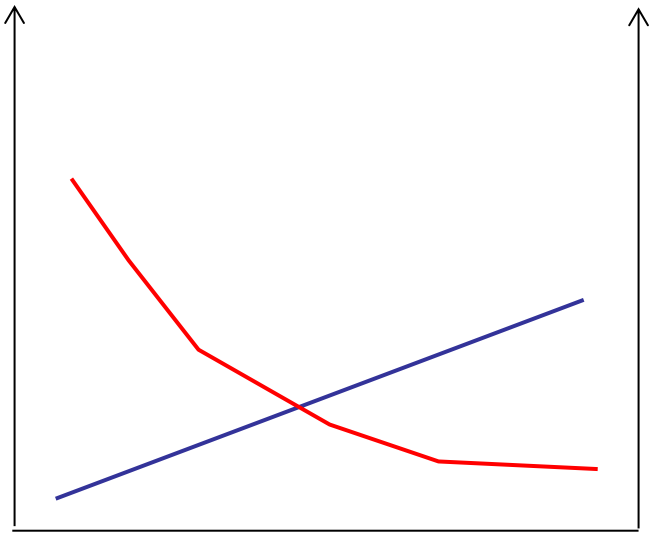
Optimisation

- 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

Cost of steel



Cost of fireproofing

Weight of steel member →

Structural Fire Engineering
DO's & DON'Ts

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!!!

Benefits of Performance Based FP Design

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

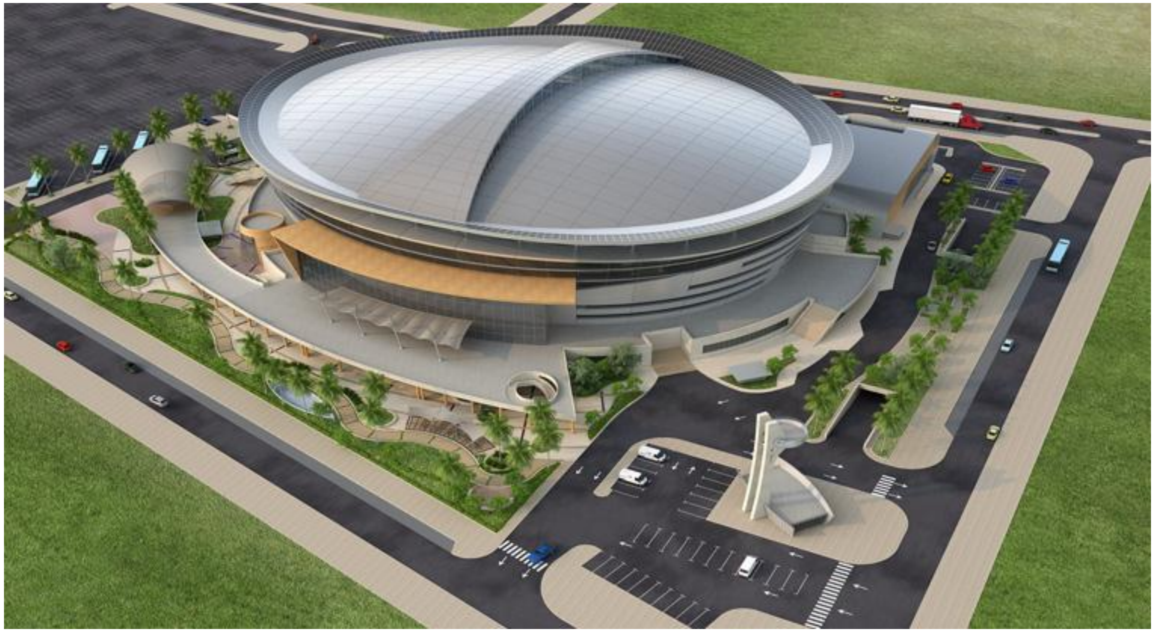
Benefits of Performance Based FP Design

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

Structural Fire Design

Al-Sadd Sports Club - Qatar



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

Structural Fire Design

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

Summary

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

Thank you for your attention

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