Safety Design in Buildings

Cairo Conference

JW Marriott Hotel Cairo, Thursday, November 5, 2015

Optimization of Intumescent Fireproofing via Structural Analysis

AkzoNobel

Alex D Tsiolas BEng MSc MiFireE
Fire Engineering Manager

Course Description

Fire proofing expert Alex Tsiolas elaborates on structural fire protection by explaining fire resistance ratings, fire testing standards and specification of intumescent fire protection. His talk further showcases structural fire engineering principles and explains benefits and cost optimization opportunities for intumescent coating applications

Presenter

Alex D Tsiolas

Fire Engineering Manager of AkzoNobel

Alex Tsiolas is the Fire Engineering manager at AkzoNobel. He holds a BEng(Hons) in Structural Engineering, MSc in Structural Dynamics and MSc in Fire and Blast Engineering. He is a member of the UK Institution of Fire Engineers (MIFireE).

He has been with AkzoNobel more than 6 years operating in various fields of structural and fire engineering. He started in the company's HQ and centre of excellence in UK as a consultant engineer and member of the global fire protection group. In UK he gained experience in fire resistance testing focused on the performance of intumescent testing. He became proficient in product assessments and certification.

While he was there he was in charge of fire engineering initiatives that covered following areas:

- Translation of fire test data to information that can be used by project engineers
- Author passive fire proofing best practice guides for the wider group
- Support the designs of third-party ad-hoc fire tests to address bespoke scenarios
- Participation in European and UK standards committees and forums
- Support regional business development personnel.

He left the company to complete his national military service and then he joined AkzoNobel again in the Middle East head office in Dubai. He now has the role of the regional fire engineering specialist to facilitate better communication with engineering consultancies and support business development. He actively promotes the use of structural fire engineering in new construction and demonstrates the added value of performance based solutions for the optimization of fire proofing.

Learning Objectives

1. *How to Design Fireproofing for Steel Structures*
2. *How to Optimize Fireproofing for Steel Structures*
3. *What to look out for in Optimized Fireproofing Solutions*
4. *What are the Benefits of Optimized Solutions*

The purpose of this presentation is to convey technical knowledge to the conference participants.

The presentation also contains slides with text that summarises the content of the presentation and the main learning objectives.

These may be used to update CPD records for relevant organisations including the Chartered Institute of Building (CIOB).

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Table of Content / Overview

- **AkzoNobel Middle East – Background & Activities**
- **Structural Fire Protection**
- **What is Structural Fire Engineering**
- **Benefits of Structural Fire Engineering**

The world of AkzoNobel

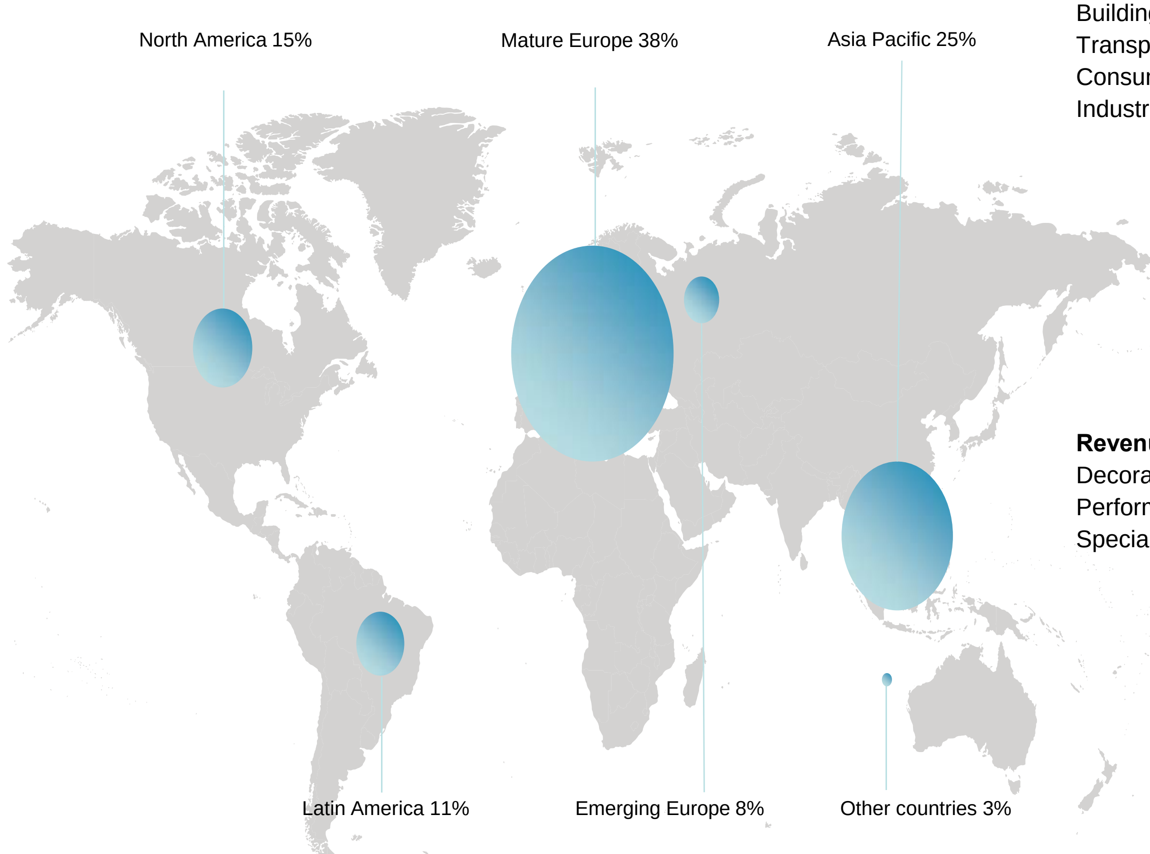
€14.6
billion in revenue

49,600
employees

200+
production sites

80+
countries

Key regions by revenue



Revenue by end-user segment

Buildings and Infrastructure	44%
Transportation	16%
Consumer Goods	16%
Industrial	24%

Revenue by Business Area

Decorative Paints	28%
Performance Coatings	38%
Specialty Chemicals	34%

- All figures relate to 2013

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We have thousands of paint and coatings specifically designed to protect and decorate every type of building component.

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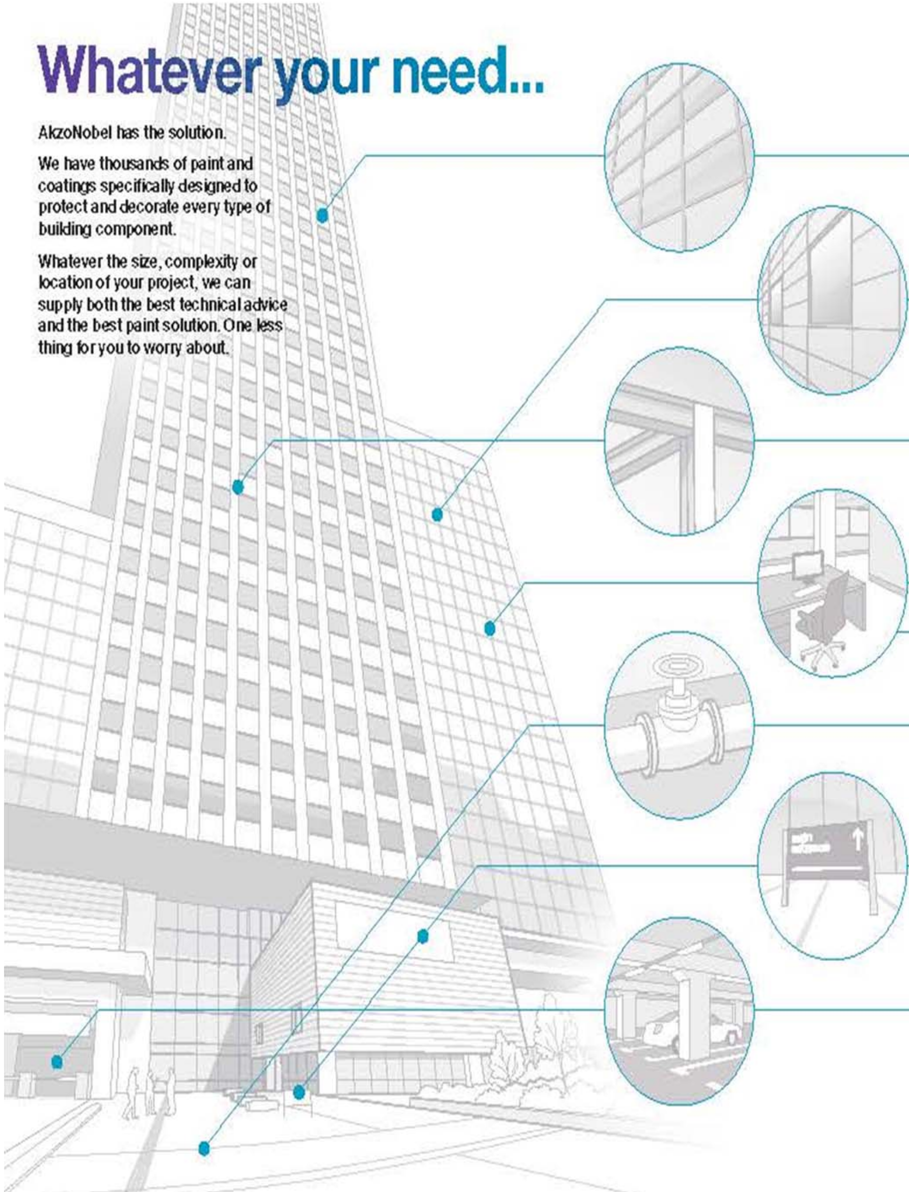

Windows and curtain wall

High performance liquid PVDF and powder coatings for all types of aluminum and steel fenestration & panels.

TRINAR · Interpon powder coatings

Cladding

A complete offer of paints which are factory applied on continuous coil for cladding or powder coatings for pre-formed panels.

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Structural steel

High performance finishes, anti-corrosive and passive fire protection for steel structures in commercial buildings, stadia, airports, stations and high rise.

International · Interchar

Masonry and wood

Architectural paints to brighten, protect and preserve internally and externally.

Dulux · Glidden · sikkens

Building components

A full range of coatings for every type of component from ceiling tiles, switchgear furniture, flooring and HVAC inside the building through to street furniture, pipes & valves underground.

Interpon powder coatings · RESICOAT · International

Signage

Durable and colourful solutions to maintain brand image for internal and external directional and company signage.

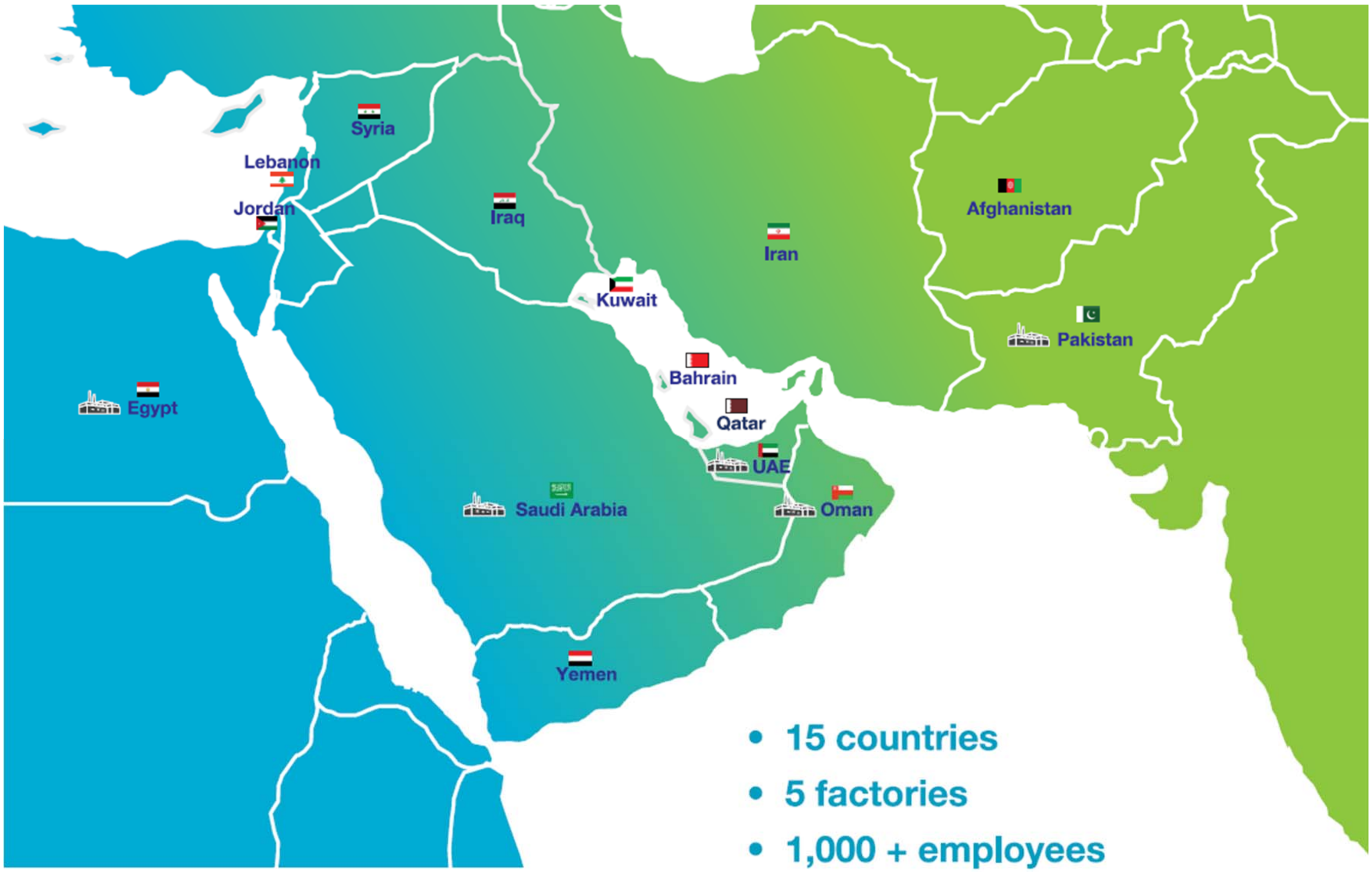
Sign Finishes · Interpon powder coatings

Concrete and floors

Systems to offer protection and to reduce maintenance for floors and industrial environments.

International

AkzoNobel in the Middle East



- 15 countries
- 5 factories
- 1,000 + employees

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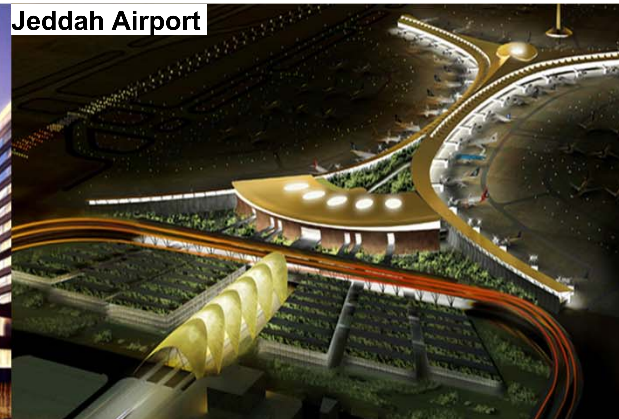
High Value Infrastructure – Track Records


King Abdullah Financial District


Jeddah Airport


Qatar National Museum


King Abdulaziz Sport city


Khalifa Stadium, Qatar


Dubai Blue Waters

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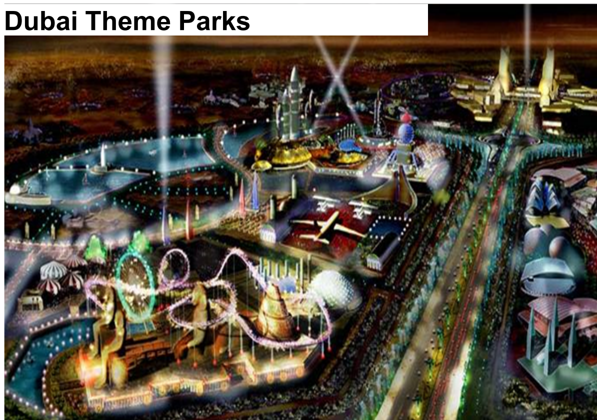
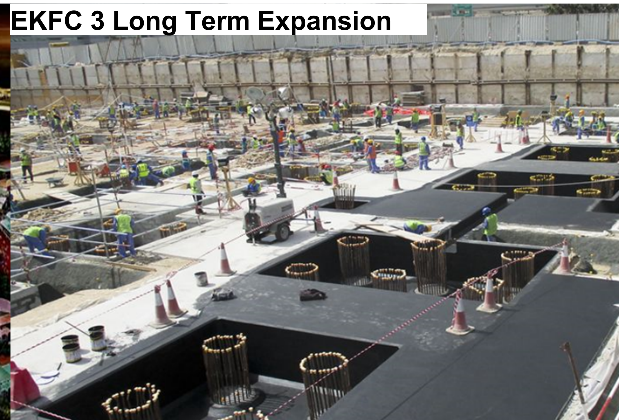
High Value Infrastructure – Ongoing Activities

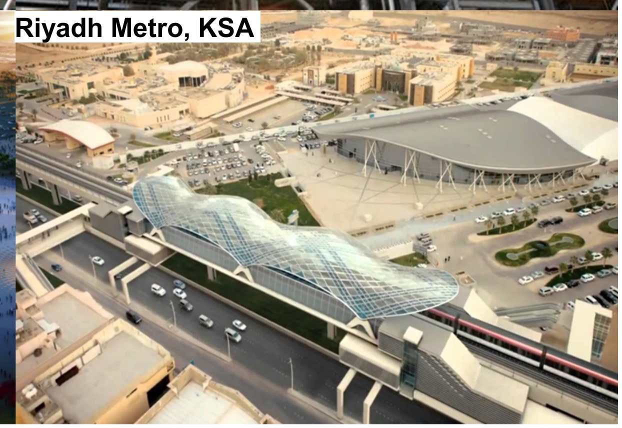

Dubai Theme Parks


EKFC 3 Long Term Expansion


PP13&14, KSA


Expo 2020


Al Wakrah Stadium, Qatar


Riyadh Metro, KSA

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Some Direct and Indirect Customers

Structural Fire Protection for Steel Structures

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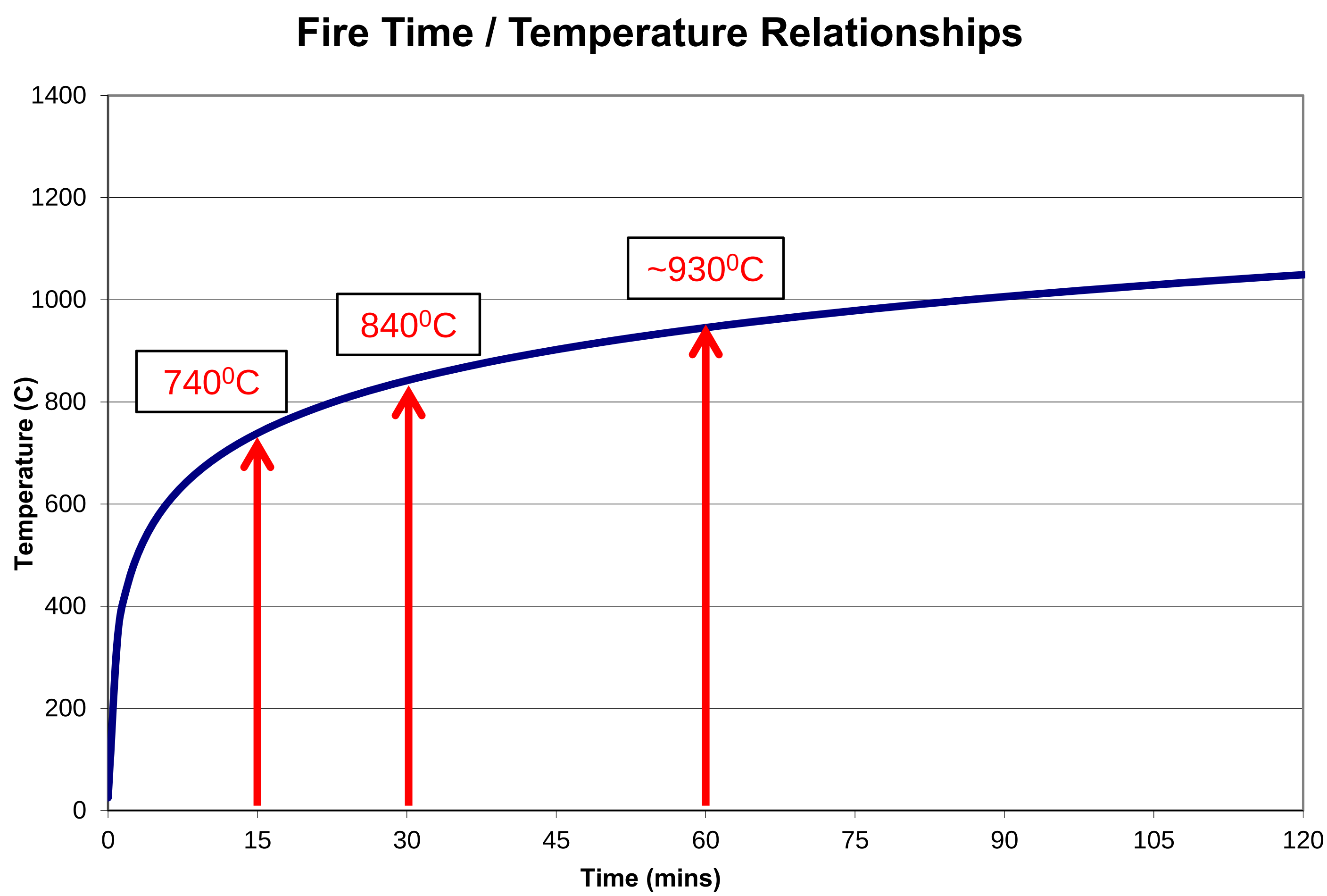
How is a fire defined in a building?



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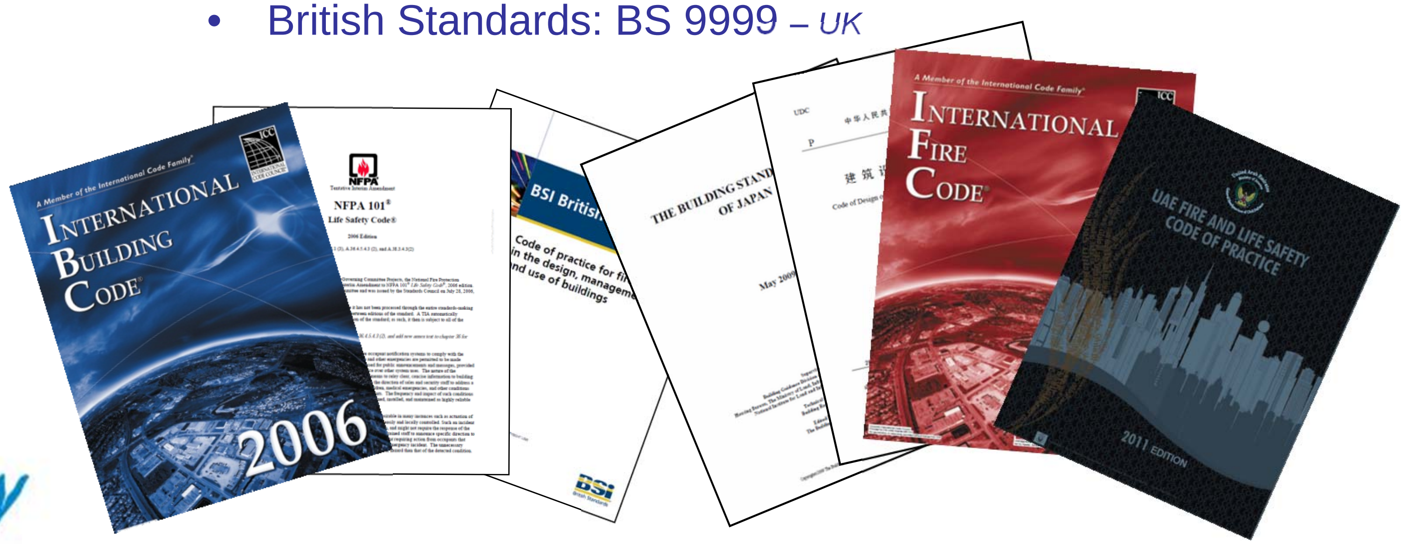
Design Codes and Standards

- 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*



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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°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 4th 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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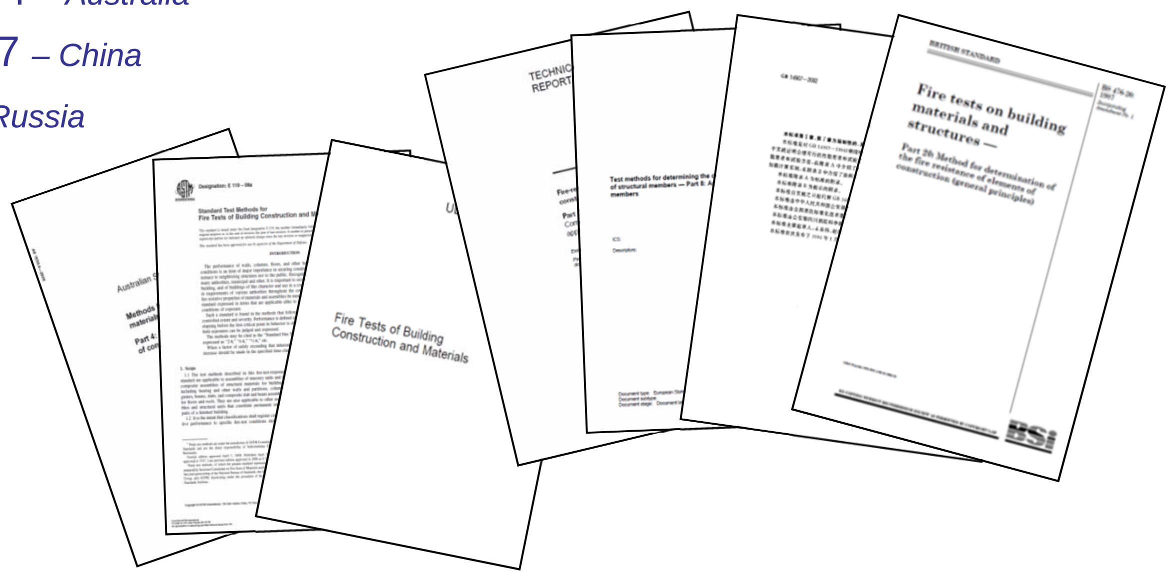
Fire Test Codes and Standards

- 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

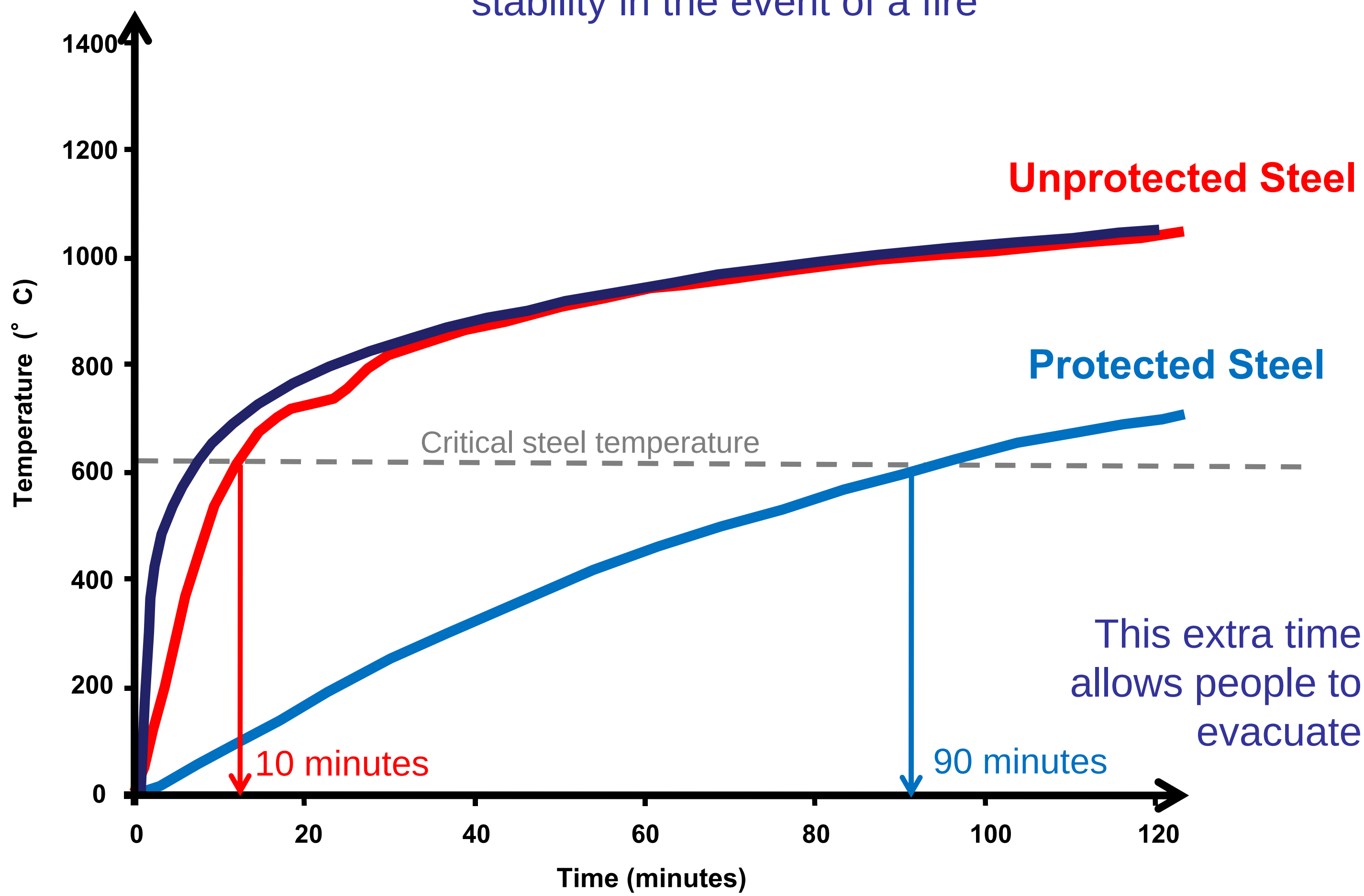
Intumescent coatings

Boards

Cementitious sprays

Insulation blankets

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



Optimization Via Structural Analysis

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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)

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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

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

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Corrosive Environments to ISO 12944

Atmospheric corrosivity categories and examples of typical environments (BS EN ISO 12944-2[1])

Corrosivity category and risk	Low-carbon steel Thickness loss (μm)[a]	Examples of typical environments in a temperate climate (informative only)	
		Exterior	**Interior**
C1 very low	≤ 1.3	-	Heated buildings with clean atmospheres, e.g. offices, shops, schools, hotels
C2 low	> 1.3 to 25	Atmospheres with low level of pollution Mostly rural areas	Unheated buildings where condensation may occur, e.g. depots, sports halls
C3 medium	> 25 to 50	Urban and industrial atmospheres, moderate sulphur dioxide pollution Coastal area with low salinity	Production rooms with high humidity and some air pollution e.g. food-processing plants, laundries, breweries, dairies
C4 high	> 50 to 80	Industrial areas and coastal areas with moderate salinity	Chemical plants, swimming pools, coastal, ship and boatyards
C5-I very high (industrial)	> 80 to 200	Industrial areas with high humidity and aggressive atmosphere	Buildings or areas with almost permanent condensation and high pollution
C5-M very high (marine)	> 80 to 200	Coastal and offshore areas with high salinity	Buildings or areas with almost permanent condensation and high pollution

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AkzoNobel FireProofing vs Environmental Exposure

C1 → C3

- Acrylic
  - Water
  - Solvent
- Epoxy

C4

- Epoxy

C5

- Epoxy

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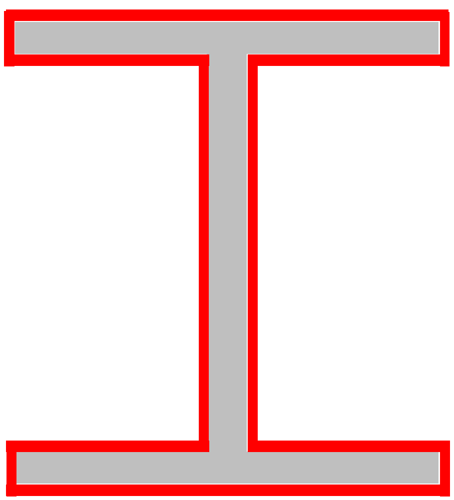
Section Factor

- 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 = 1.51m

Cross-section area, A = 0.00945m^2

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

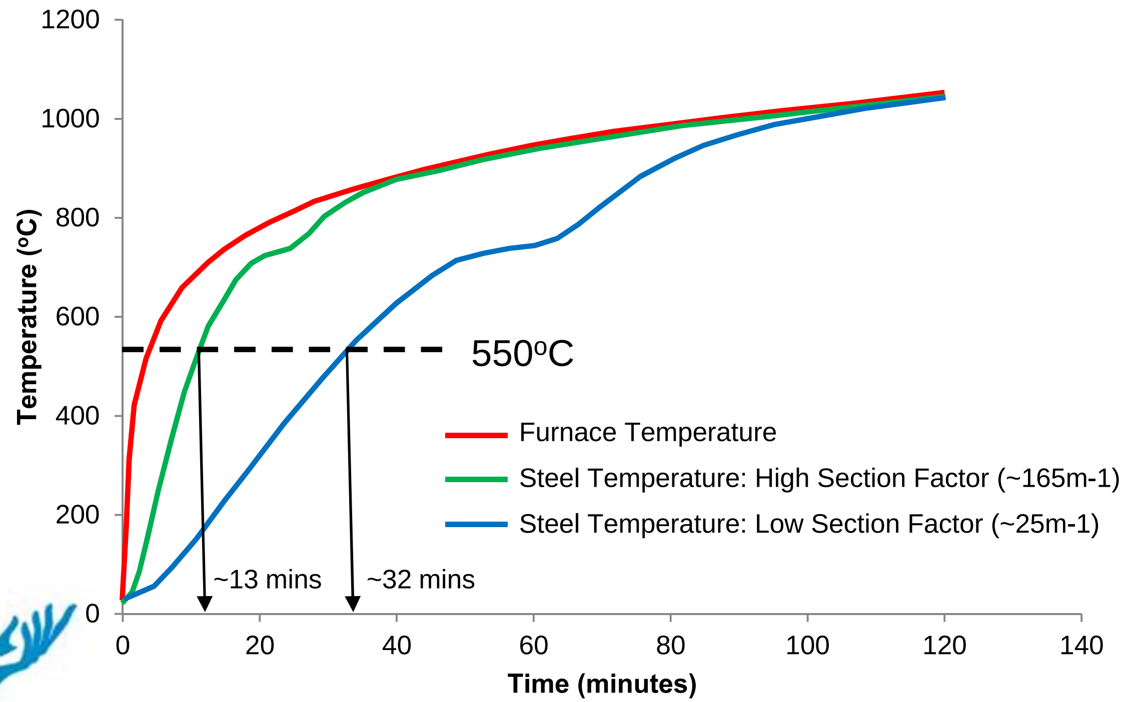
Section Factor – Hp/A = A/V
How steel heats up

- 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
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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

Page 1 of 20

Only valid when authentic CERTIFIRE 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.

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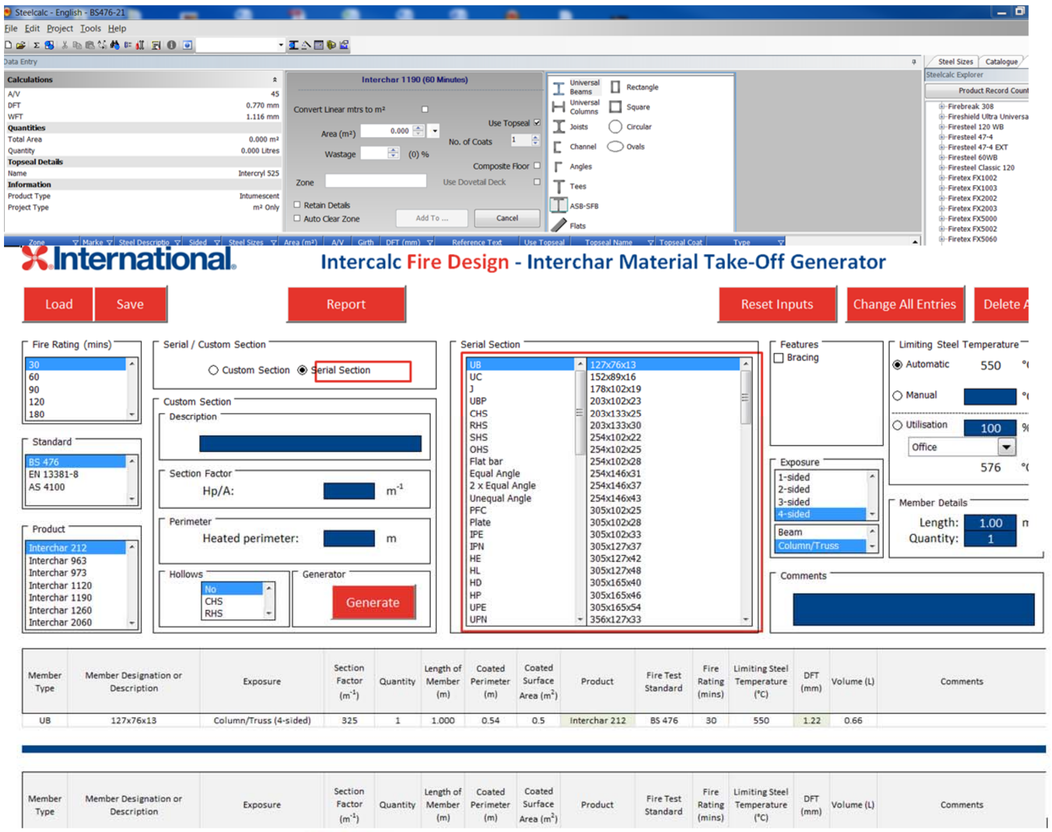
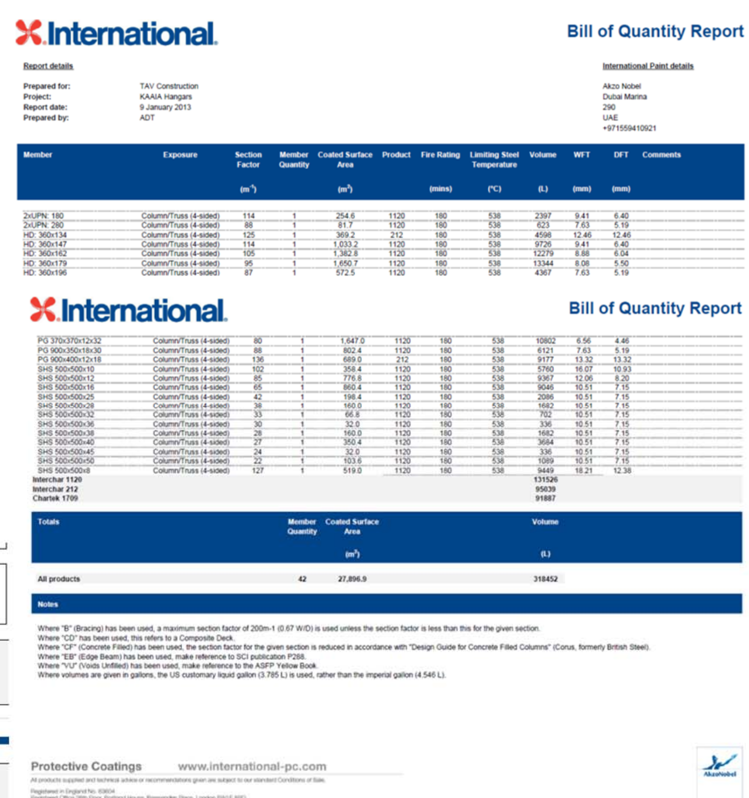
Selecting a Thickness of Paint

Steel BOQ → MTO





How to Optimize Fireproofing for Steel Structures

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- 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

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

Prescriptive Design Approach

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

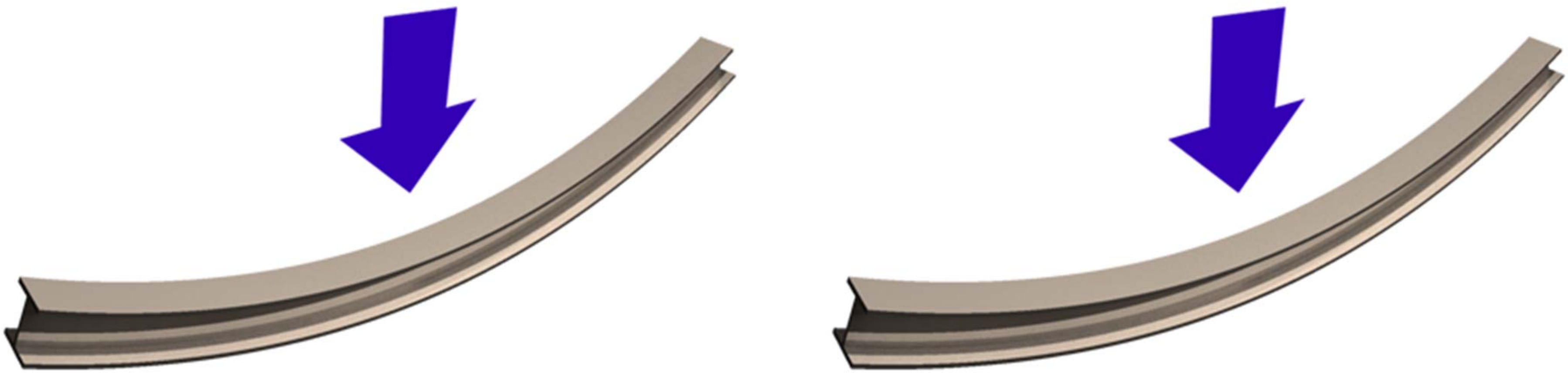
In the UK prescribed design assumes that an unprotected steel column will fail when its temperature reaches 550˚C

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%)

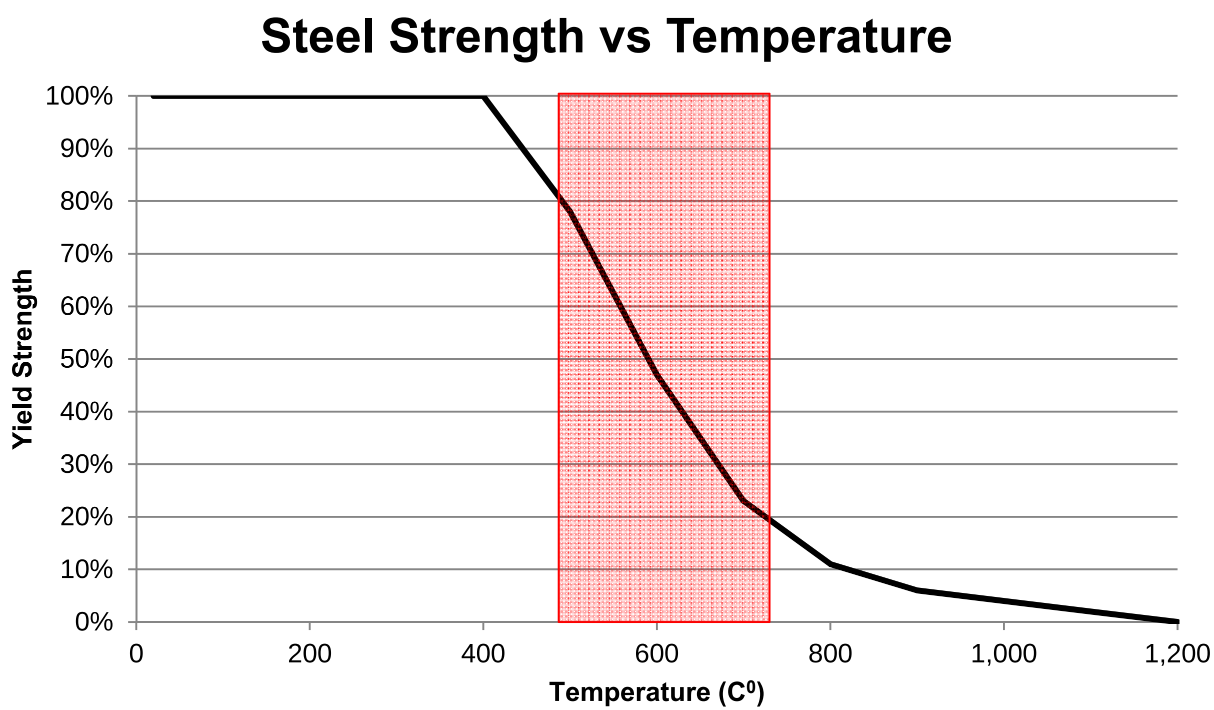


Limiting Steel Temperature == Limiting Steel Temperature

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

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Structural Fire Engineering: Performance Based Design

<u>Critical core temperature:</u>

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

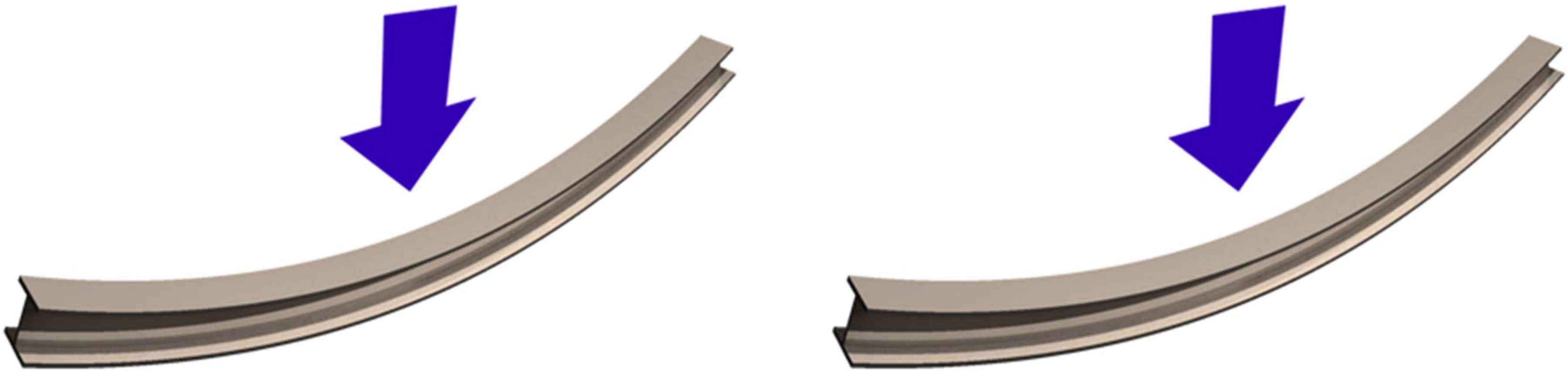
Further simplified as:

Capacity of a steel section **<u>during a fire</u>**

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%)

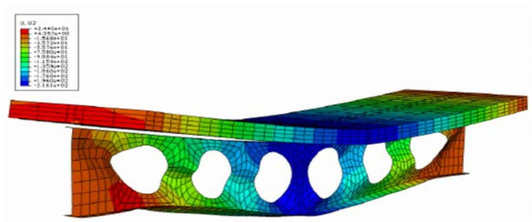


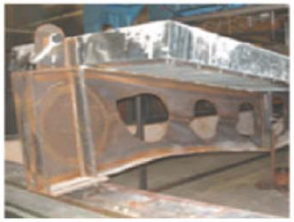
Limiting Steel Temperature >> Limiting Steel Temperature

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...





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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 typically work to a single 538ºC [1000ºF] or 593ºC [1100ºF] limiting temperature but this is currently under review

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

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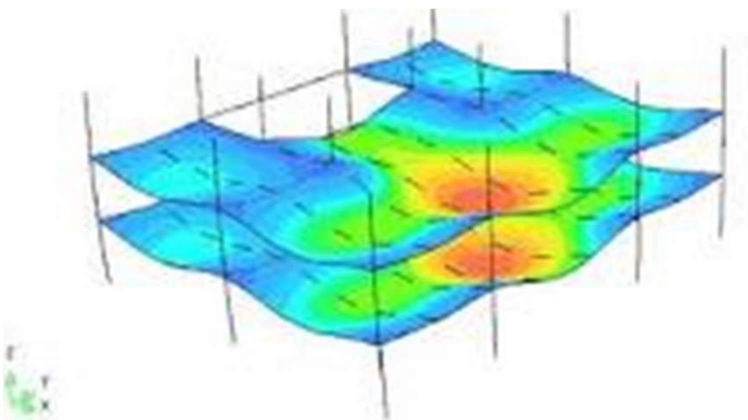
Structural Fire Engineering - Example

	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%**

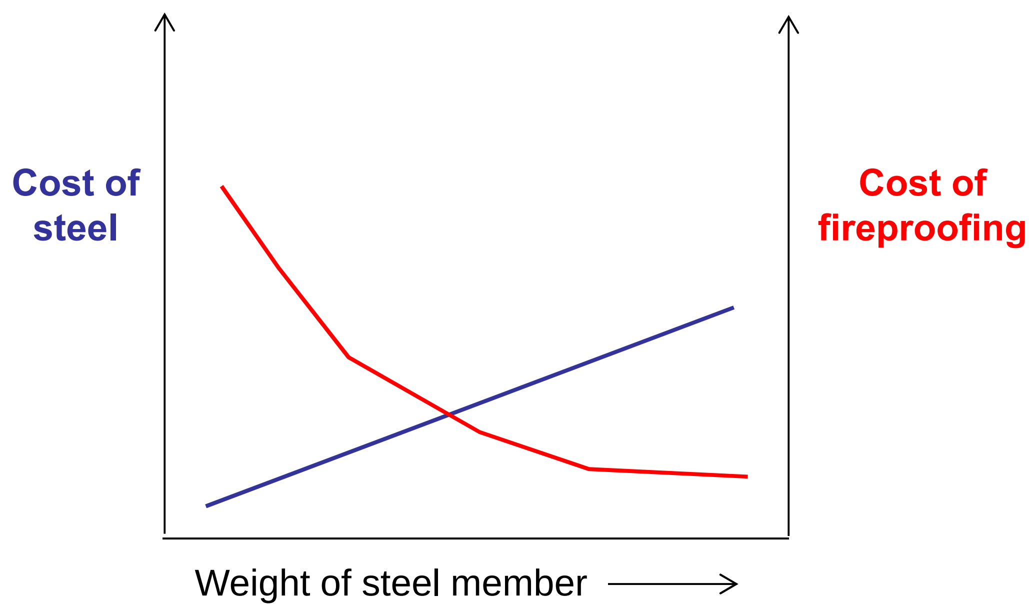
Structural Fire Engineering Optimisation

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



What to Look Out for In Optimized Designs

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

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

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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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

Safety Design in Buildings

Cairo Conference

JW Marriott Hotel Cairo, Thursday, November 5, 2015

Thank you for your attention

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