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The significance of Structural Thermal Breaks in high rise fire design and building energy performance

Webinar in partnership with the Institute of Structural Engineers

Chris Lister, Commercial Manager Structural Thermal Breaks, Farrat

21st June 2022

Webinar agenda

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- Who are Farrat
- What is a Structural Thermal Break
- Performance – Structural
- Performance – Thermal
- Performance - Fire
- BEEAM & LEED & Passive House performance
- Safe Specification - International Sustainable Standards Board
- Case studies
- Q & A

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Who are Farrat

- Third generation family business
- Headquarters in Manchester, United Kingdom
- Sales office in Baden, Switzerland

We are 'Engineers on a mission' to delight our customers, wherever they are in the world, with the best technical solutions to their engineering challenges

Engineers on a mission

We take great pride in the engineering problems we solve, the projects we deliver, the research and development we create and in helping to inspire the next generation of engineers and scientists.

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What we do

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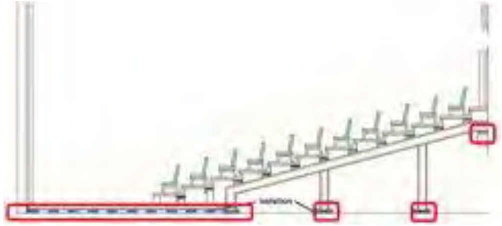
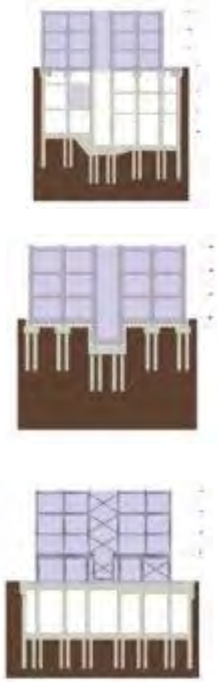
Building Acoustics

Helping developers and design teams maximize the potential (space, function, value etc.) of a building by overcoming challenging acoustic, structural and construction constraints



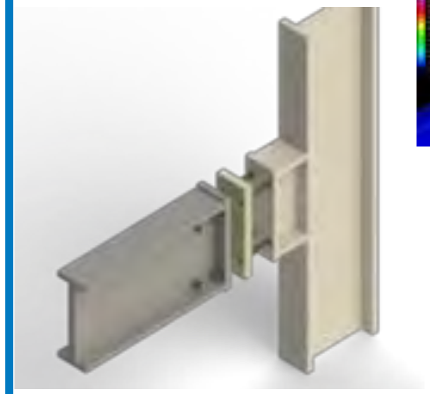


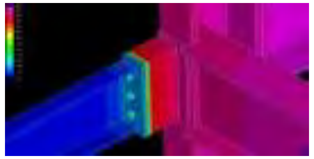
Key Sectors

- Building Vibration Isolation
- Theatres, Concert / events halls
- Cinemas / Bowling Alleys

Structural Thermal Breaks

Enabling architects, structural engineers and contractors to create the details they want by overcoming thermal bridging in challenging, load bearing point and linear connections



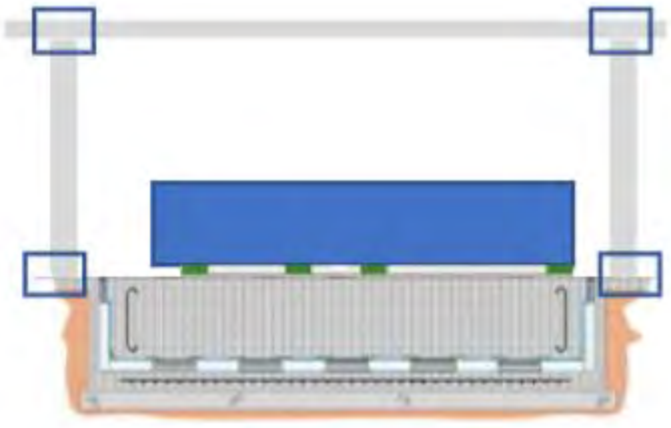


Key Sectors

- Steel frame structures
- Balconies
- Façades
- Architectural metalwork

Industrial Vibration Control

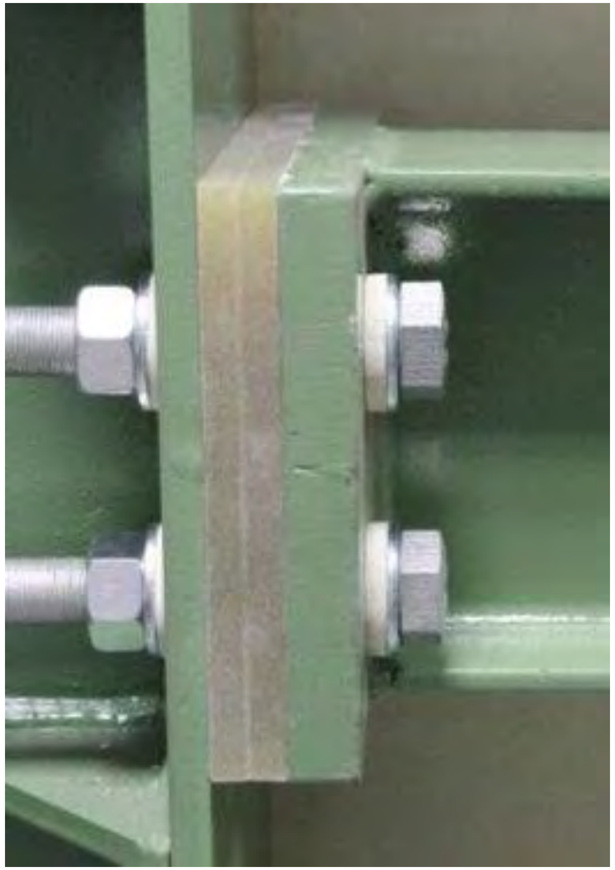
Support manufacturing plants to maximise OEE (quality, performance and availability) by overcoming the effects of vibration in machinery and building structures

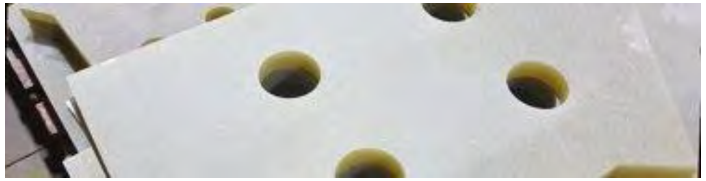


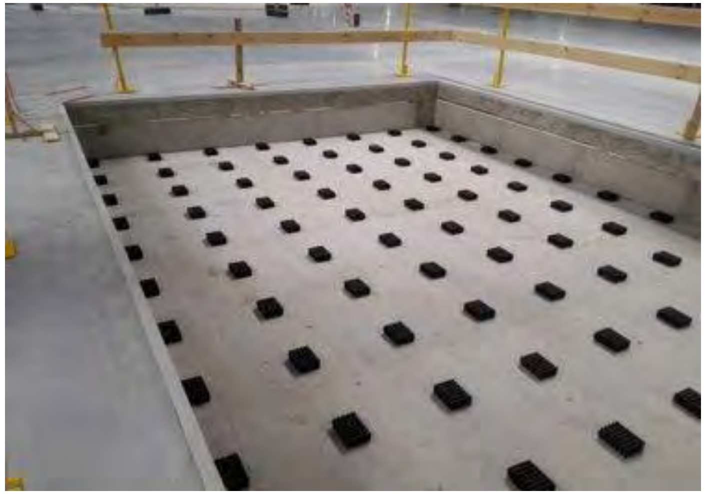
Key Sectors

- Metal production
  - Rolled coil
- Metal forming
  - Can making
  - Automotive

Solutions we manufacture







Structural Thermal Breaks

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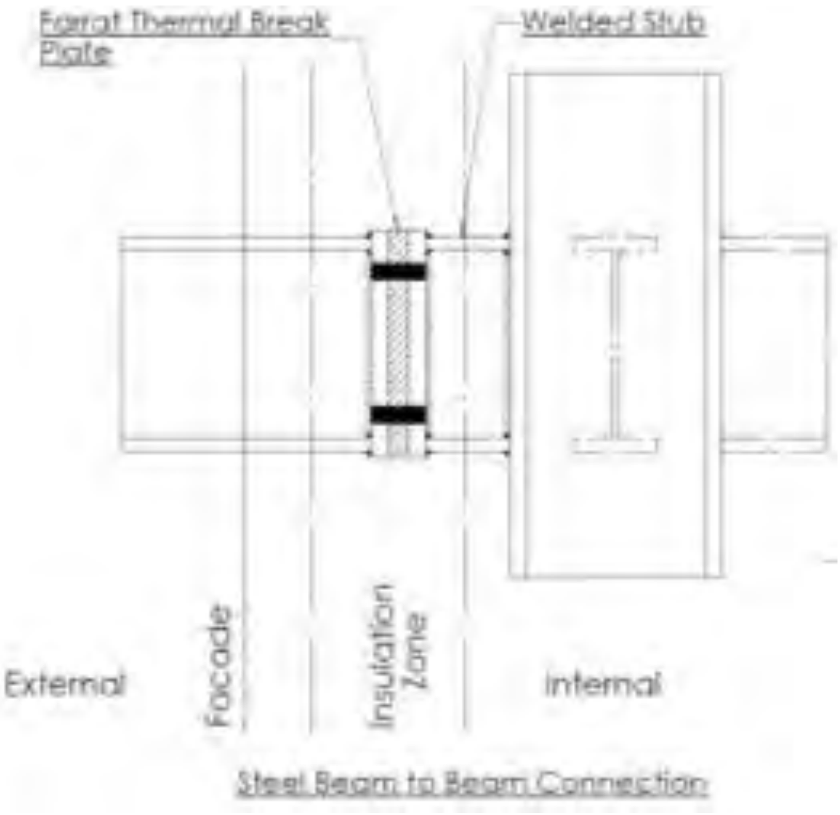
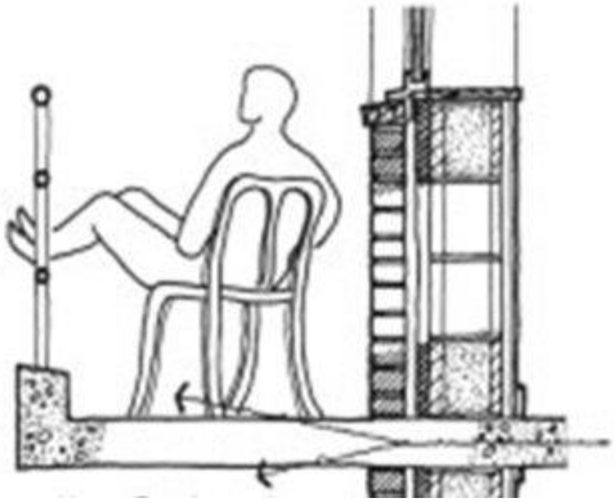
Why use Structural Thermal Breaks?

Two Primary issues

- Energy Loss
- Condensation Risk





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Structural Thermal Breaks

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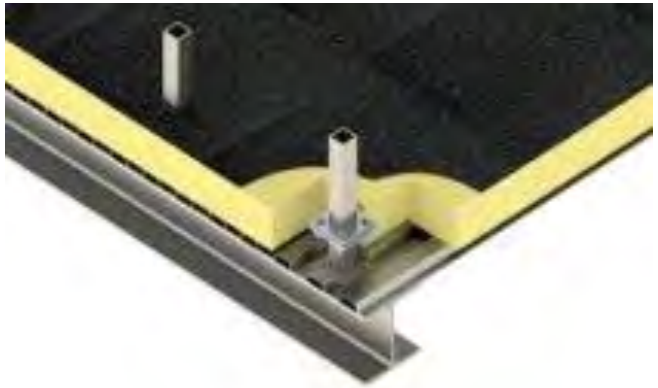
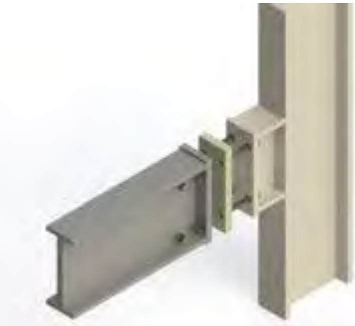
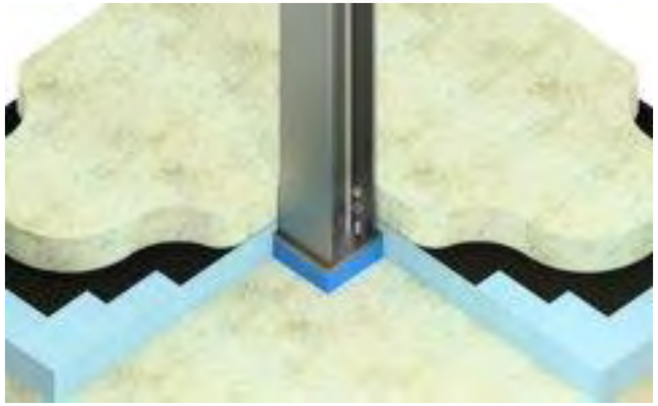
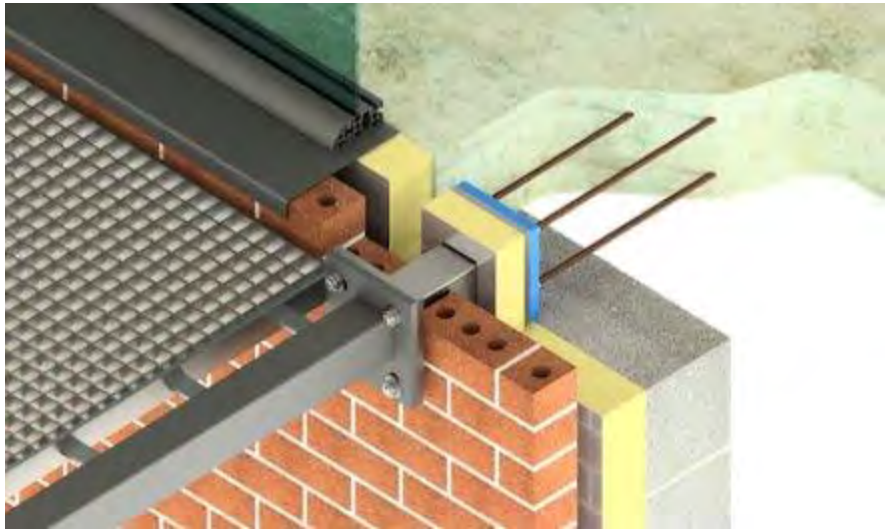
Application examples

- Column Base Plates / Structural Connections
- Façade Systems
- Balconies
- Steel & Masonry (Linear)
- Balustrades (Point)









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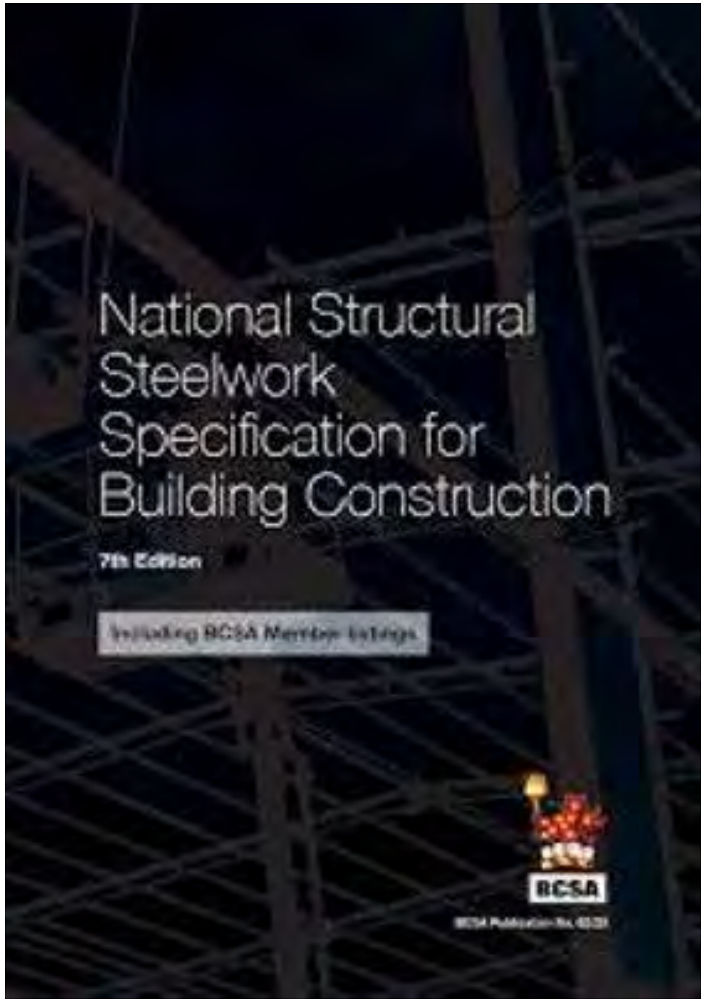
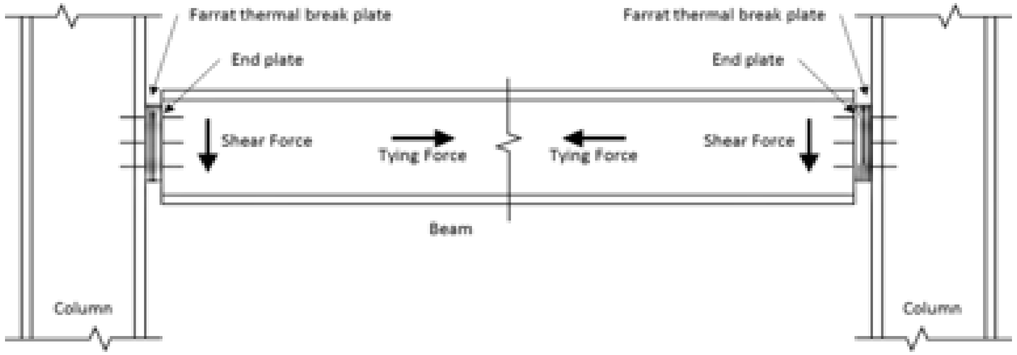
Design – Structural Performance



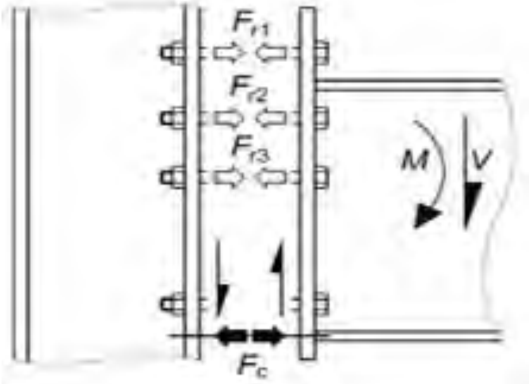
Structural Thermal Breaks

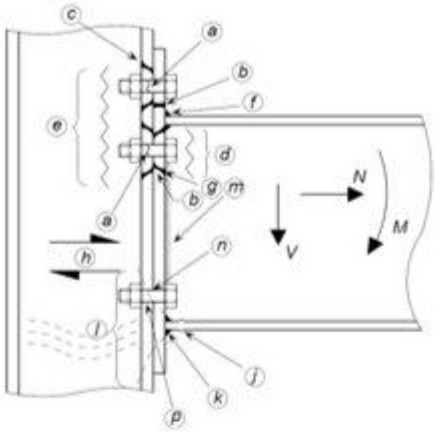
Design – Structural Performance

- Simple connections



- Moment connections





ZONE	REF	COMPONENT	Procedure
TENSION	a	Bolt tension	STEP IA
	b	End plate bending	STEP IA
	c	Column flange bending	STEP IA
	d	Beam web tension	STEP IB
	e	Column web tension	STEP IB
	f	Flange to end plate weld	STEP 7
	g	Web to end plate weld	STEP 7
HORIZONTAL SHEAR	h	Column web panel shear	STEP 3
COMPRESSION	j	Beam flange compression	STEP 2
	k	Beam flange weld	STEP 7
	l	Column web	STEP 2
VERTICAL SHEAR	m	Web to end plate weld	STEP 7
	n	Bolt shear	STEP 5
	p	Bolt bearing (plate or flange)	STEP 5

Structural Thermal Breaks

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Design – Structural Performance

- Compression Stress

$Fc \leq B \times L \times fcd$

Fc	is the applied compression force (ULS)
fcd	is the design value for compressive strength (thermal break)
B	is the depth of the compression zone on the thermal break
L	is the width of the compression zone on the thermal break

$B = t_{f,b} + 2(s + t_p)$

Where:

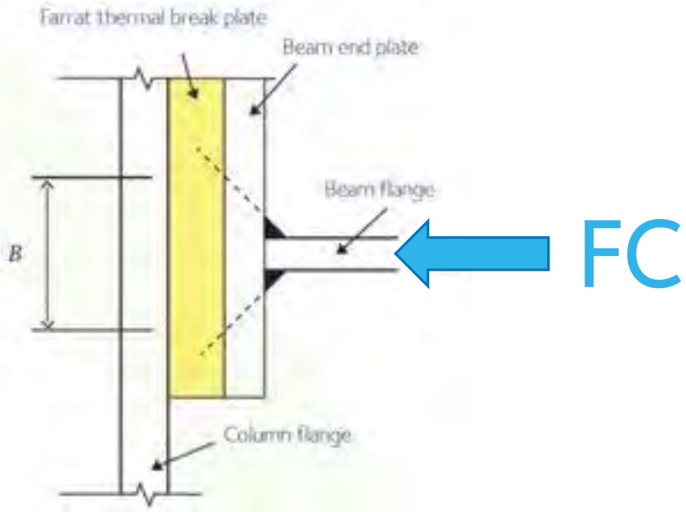
$t_{f,b}$	is the beam flange thickness
s	is the weld leg length
t_p	is the end plate thickness

$L = b_b + 2 \times t_p$

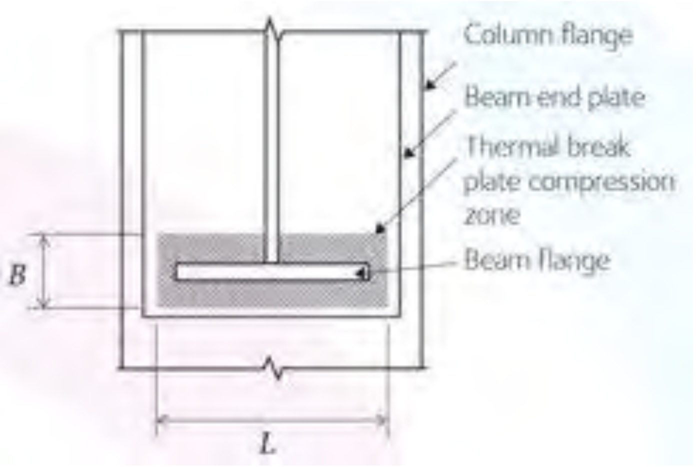
Where:

b_b	is the beam flange width
t_p	is the end plate thickness

Dispersion of force – Dimension *B*



Dispersion of force – Dimension *L*



Structural Thermal Breaks

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Design – Structural Performance

- Additional rotation due to compression of thermal break

$$\Delta T = \frac{t_{tb} \times \sigma_{tb}}{E_{tb}}$$

where:

t_{tb} is the thickness of the thermal break plate

σ_{tb} is the stress in the compression zone of the thermal break plate (SLS)

E_{tb} is the elastic modulus of the thermal break plate

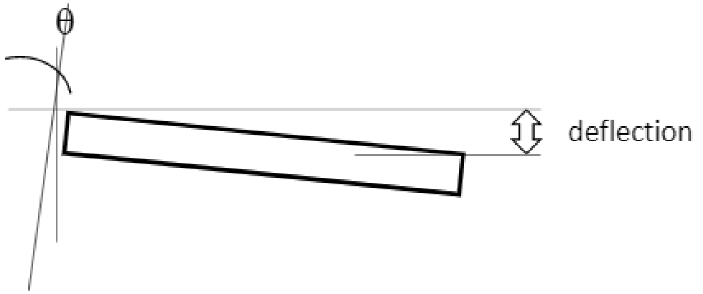
$$\theta = \text{Arcsin}\left(\frac{\Delta T}{h_b}\right)$$

where:

h_b is the depth of the beam

Strain due to compressive stress at SLS + allowance for long term creep [TBK +20% and TBL + 30% of initial creep;

i.e. 0.41mm +20% = 0.492mm]



Example:

CONNECTION PROPERTY	FARRAT TBK	FARRAT TBL
Depth of beam (mm)	150	150
Thickness of thermal break plate (mm)	25	25
Stress in compression zone of thermal break plate at serviceability limit state (SLS), (N/mm², MPa)	85	35
Elastic modulus of thermal break plate (N/mm², MPa)	5178	2586
Compression of thermal break plate (mm)	0.410	0.338
Additional compression of thermal break plate due to creep [TBK +20% : TBL +30%]	0.492	0.439
Additional rotation of connection (Degrees)	0.188	0.168

Structural Thermal Breaks

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Design Structural Performance

Bolt shear resistance

- The number of packs should be kept to a minimum (less than 4)
- The total thickness of packs tpa should not exceed 4d/3, where d is the nominal diameter of the bolt
- If tpa exceeds d/3, the shear resistance of the bolts should be reduced by the factor βp given in the expression

15mm TB - M12 minimum

25mm TB - M20 minimum

48mm TB – M36 minimum

$$\beta_p = \frac{9d}{8d + 3t_{pa}}$$

Where:

d is nominal bolt diameter

t_{pa} is the total thickness of packs

Large grip lengths

- A thermal break in a connection will increase the total grip Length (Tg) of the bolts
- If Tg exceeds 5d then the shear resistance of the bolts with large grip lengths should be reduced by the factor βg given in the expression

$$\beta_g = \frac{8d}{3d + T_g}$$

where:

d is nominal bolt diameter

T_g is the total grip length of the bolt

Structural Thermal Breaks

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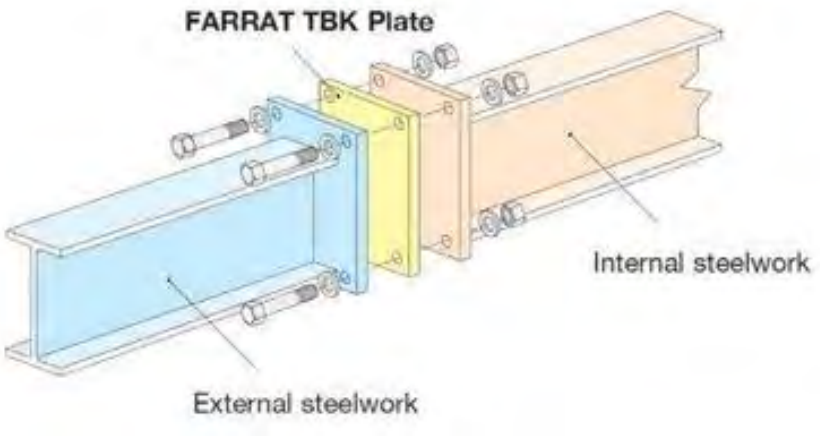
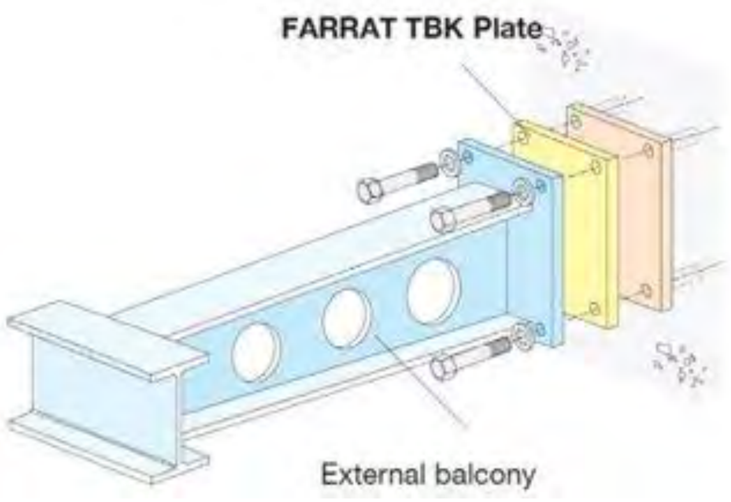
Design – Steel Construction Institute SCI Summary

- Check that the thermal break plate can resist the applied compression forces.
- Check that any additional rotation due to the compression of the thermal break plate (including allowance for long term creep) is acceptable.
- Check that the shear resistance of the bolts is acceptable given that there may be a reduction in resistance due to:
  - Packs
  - Large grip lengths
- For connections using preloaded bolts:
  - Check the slip resistance of the connection taking into account the coefficient of friction and number of friction surfaces
  - Check that the thermal break plate can resist the local compression forces around bolts





Structural Thermal Breaks

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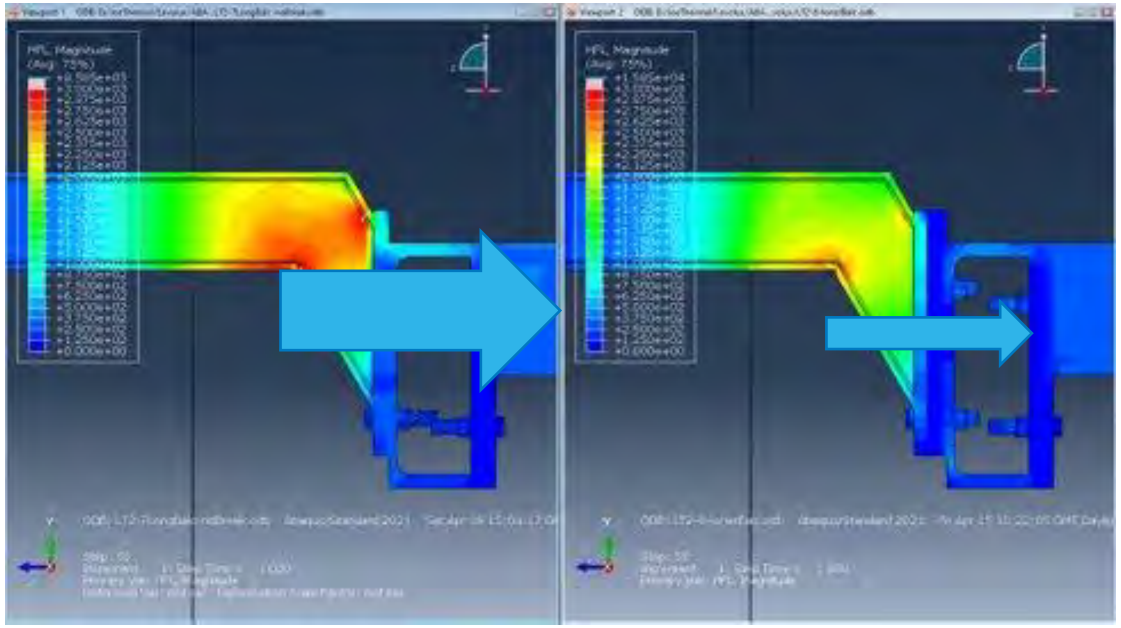
Energy Loss

Thermal Conductivity values:

Steel 50.0 W/m-k
Stainless Steel 43.0 W/m-k
Concrete 2.1 W/m-k
Farrat TBL 0.292 W/m-k
Wood 0.22 W/m-k
Farrat TBF 0.20 W/m-k
Farrat TBK 0.187 W/m-k
Soft wall insulation 0.02 W/m-k or so



Heat Loss is quantified using three parameters:

- Plane elements U value (W/m²K) [eg. floors, walls, windows]
- Linear elements ψ value (W/mK) [eg. Interface window/wall opening]
- Localised elements χ value (W/K) [eg. structural element penetrating through wall]

Structural Thermal Breaks

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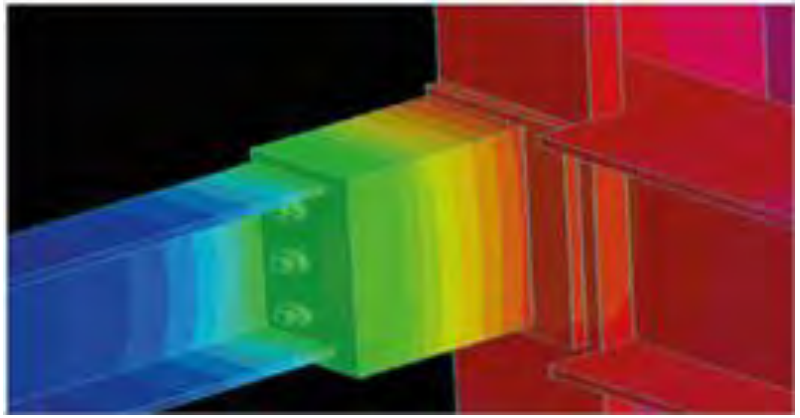
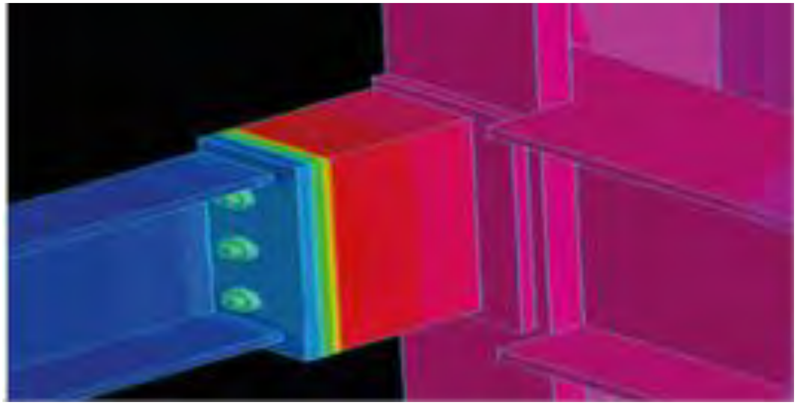
Condensation

Type of Building	Critical Temperature Factor
Storage Buildings	0.30
Offices, retail premises	0.50
Dwellings, residential buildings, schools	0.75
Sports halls, kitchens, canteens	0.80
Swimming pools, laundries, breweries	0.90



Thermal bridge in a connection without a Farrat Structural Thermal Break. The temperature of the steel is on the hot side of the outer-wall system (9.8 °C) and heat loss (χ value) is 1,31W / K.



Distribution of temperature with Farrat Structural Thermal Break plate (TBK). The temperature on the hot side of the facade system has been improved to 16.5 °C and the heat loss is limited to 0.35 W/K = 73% less heat loss.

Structural Thermal Breaks

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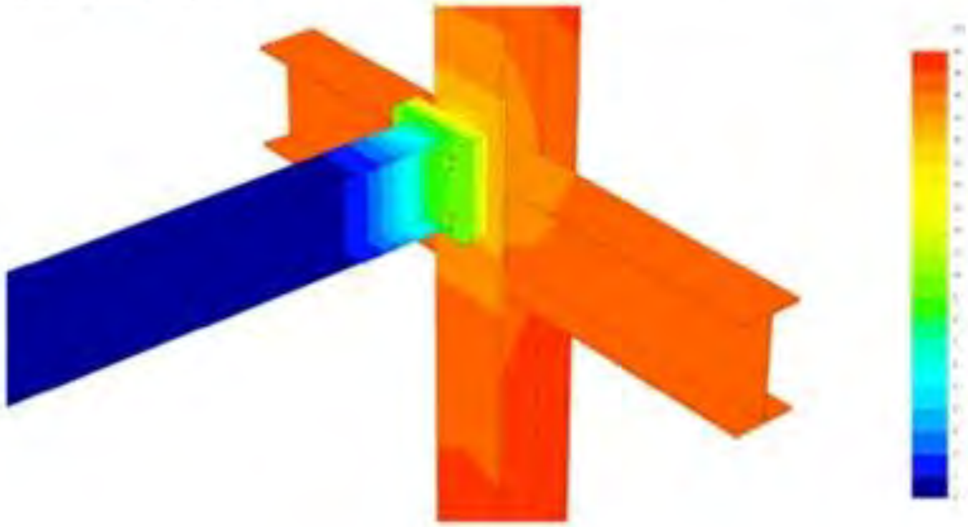
Building Research Establishment (BRE)

The below isometric image illustrates the temperature profile across the steel to steel connection (small beam) for an example detail, with all surrounding materials excluded



Steel to steel connection – 'small' beam

The results were as follows:

	Variation description	Thermal break material	Wall U-value (W/m²K)	Ψ-value (W/mK)	Temperature factor (f)	χ-value (W/K)
Steel to steel - small beam	Detail 0.0 - Base case (no cantilever)	N/A	0.18	0.077	0.97	-
	Detail 0.1 - with cantilever (no thermal break)	N/A	0.18	0.393	0.90	0.474
	Detail 1.0 - 5mm TBK	TBK	0.18	0.356	0.91	0.419
	Detail 2.0 - 15mm TBK	TBK	0.18	0.345	0.91	0.401
	Detail 3.0 - 25mm TBK	TBK	0.18	0.336	0.91	0.388
	Detail 4.0 - 5mm TBL	TBL	0.18	0.361	0.91	0.427
	Detail 5.0 - 15mm TBL	TBL	0.18	0.349	0.91	0.409
	Detail 6.0 - 25mm TBL	TBL	0.18	0.341	0.91	0.396
	Detail 7.0 - 25mm TBK, wall U-value = 0.21	TBK	0.21	0.345	0.91	0.383
	Detail 8.0 - 25mm TBK, wall U-value = 0.18	TBK	0.18	0.336	0.91	0.388
	Detail 9.0 - 25mm TBK, wall U-value = 0.15	TBK	0.15	0.328	0.91	0.393

Table 4 - Steel to steel connection – 'small' beam results

Type of Building	Critical Temperature Factor (f_{CRsi})
Storage Buildings	0.30
Offices, retail premises	0.50
Dwellings, residential buildings, schools	0.75
Sports halls, kitchens, canteens	0.80
Swimming pools, laundries, breweries	0.90

Structural Thermal Breaks

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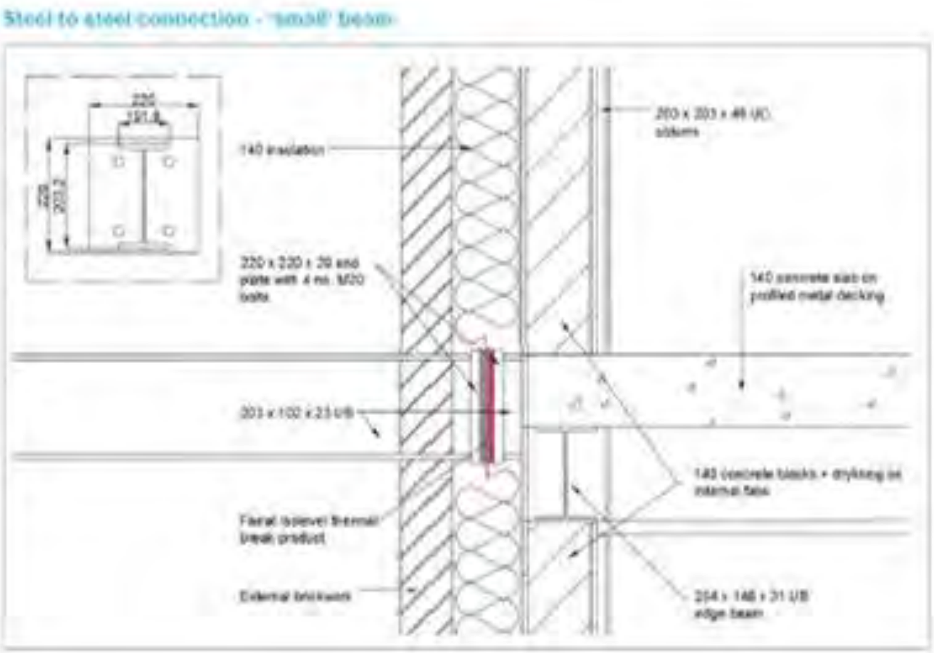
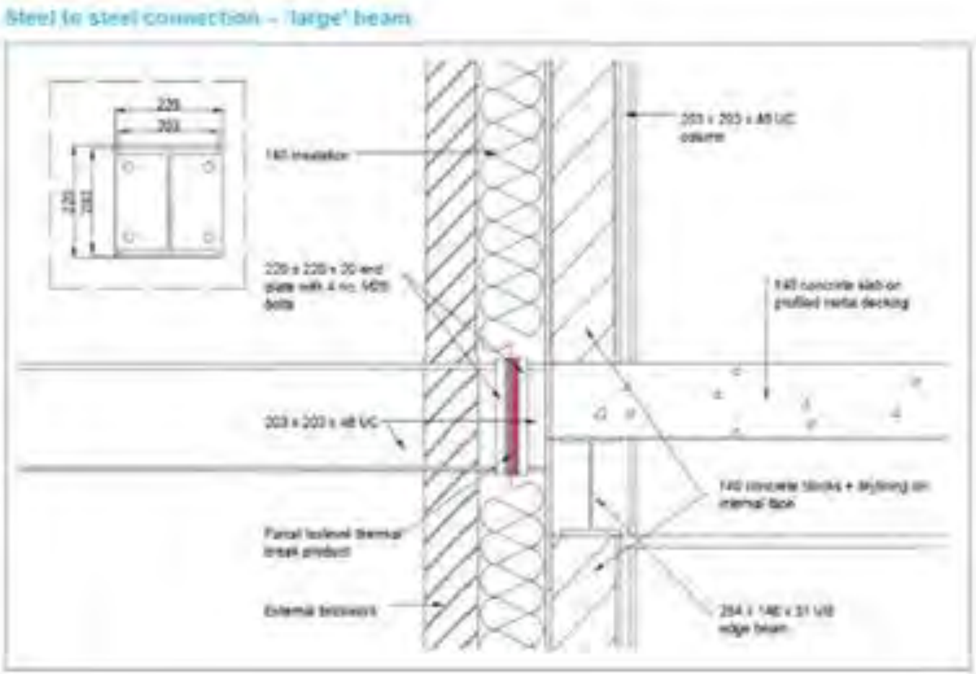
BRE Report on the impact of thermal breaks

bre





Structural Thermal Breaks

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Report on the impact of thermal breaks

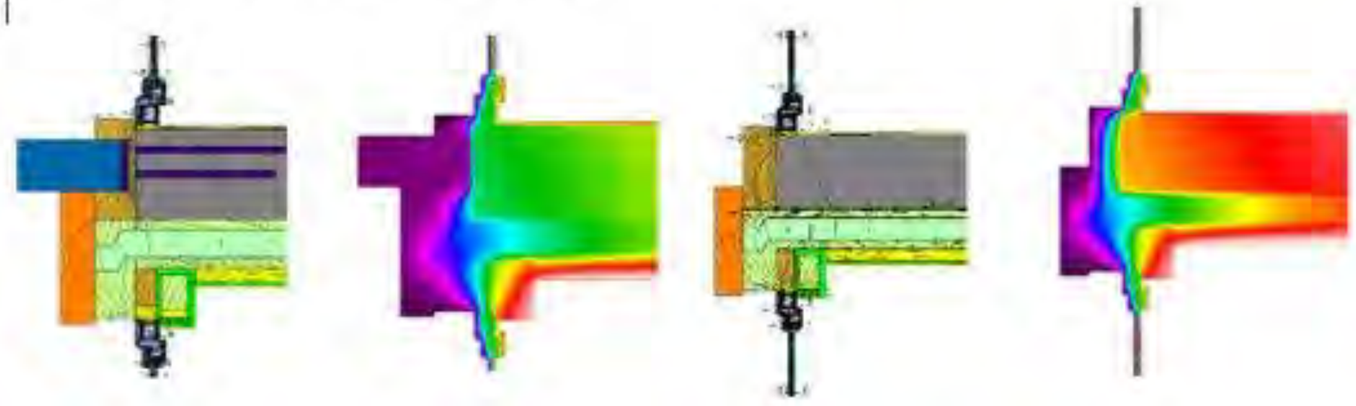
Inspection report abstract

Definition	Simulation of the thermal bridge loss coefficient ψ and the temperature factor $f_{(R_{si})}$ according to DIN EN ISO 10211 -2 [1]
Product description	**Farrat Structural Thermal Break TBF 20 mm**
Method / Software	Using Finite-Element Method/Therm 7.3

Boundary conditions

Air temperature inside	20 °C
Air temperature outside	-5 °C
Internal heat transfer resistance	0,13 m²K/W
Internal heat transfer coefficient (reduced radiation/convection)	0,20 m²K/W
External heat transfer resistance	0,04 m²K/W

Results	Calculated Values	Reference Values
Ψ Value [W/(mK)]	**0,45**	**1.0**
$f_{R_{si}}$ [-]	**0,76**	**0.7**



Structural Thermal Breaks

Design – Thermal summary

- Keep the number and size of structural penetrations to a minimum
- Choose a material with the combination of the highest compressive strength and lowest thermal conductivity (λ) lambda Value
- Locate your structural connection on the thermal envelope line
- Ensure your connection detail can adequately accommodate a sufficiently thick Structural thermal break (15mm to 25mm)

Structural Thermal Breaks

Design – Fire performance

Fire

Generally thermal breaks as used in locations that do not require fire protection. When the connections requires a fire rating then the following options are available:

- A board fire protection system can be applied
- Sprayed fire protection can be applied. The compatibility of the applied fire protection material should be checked with the thermal break material.
- The connection may be designed on the assumption of complete loss of the thermal break material in the accidental condition. For accidental conditions excessive deformations are acceptable provided that the stability of the structure is maintained.

Durability

Thermal break are manufactured from appropriate materials for the application and are normally installed in protected environments, the façade/ roof enclosures.

Structural Thermal Breaks

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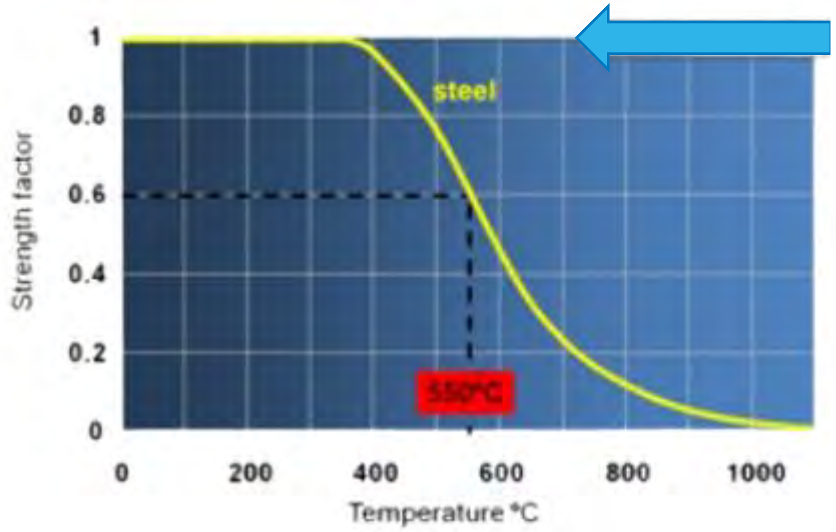
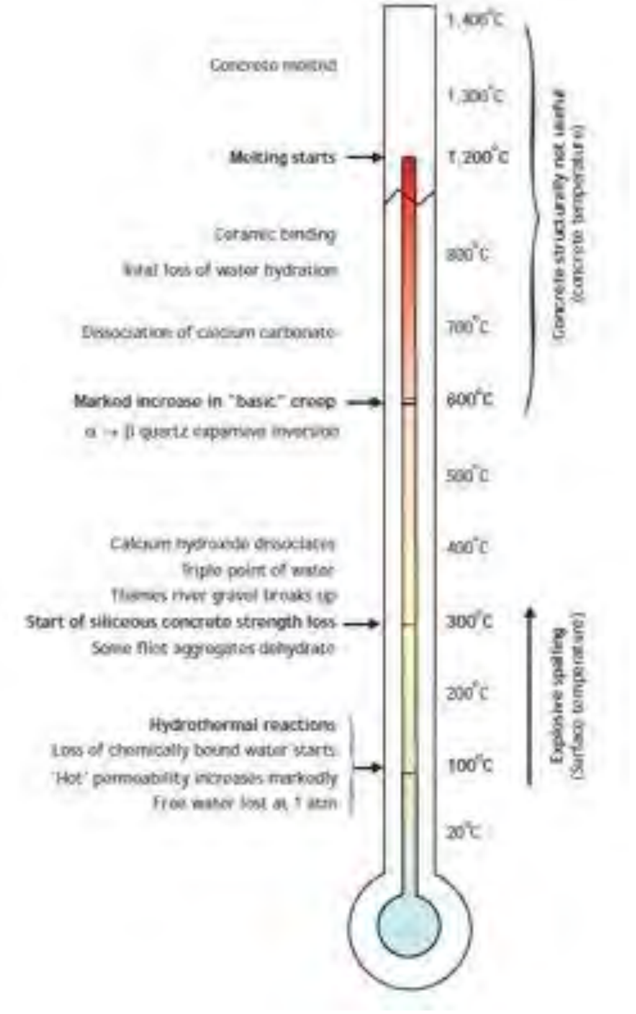
Design – Fire performance

Performance of structures

Strength loss for steel is generally accepted to begin at about 300 °C and increases rapidly after 400 °C.

By 550 °C steel retains approximately 60% of its room temperature yield strength, and 45% of its stiffness.





Structural Thermal Breaks

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Design – Fire performance

(a) The Torch Building (Dubai) during the fire

(b) The Torch Building (Dubai) after the fire

(c) The Lacrosse Building (Melbourne) during the fire

(d) The Lacrosse Building (Melbourne) after the fire

(e) The Address Building (Dubai) during the fire

(f) The Address building (Dubai) after the fire

Structural Thermal Breaks

Design – Fire performance

Fire regulation

Requirements under Approved Document B, Section B4, Regulation 7, paragraph (3)(i), exempt thermal break materials designed to address the requirements of approved document L to minimise cold bridging

Fire reality

Building owners, Investors and Insurers are stipulating and in some cases insisting on the use of Non- combustible materials to future proof buildings from up coming regulatory change.

Thermal breaks in a steel to steel connection are a structural element, contributing to the structures ability to avoid catastrophic collapse for the given period of protection.

Structural Thermal breaks can typically be situated in façade zones.

The new Fire Safety Act – Greater burden on specifiers to substantiate their material choices as 'responsible persons'

Structural Thermal Breaks

Design – Fire performance

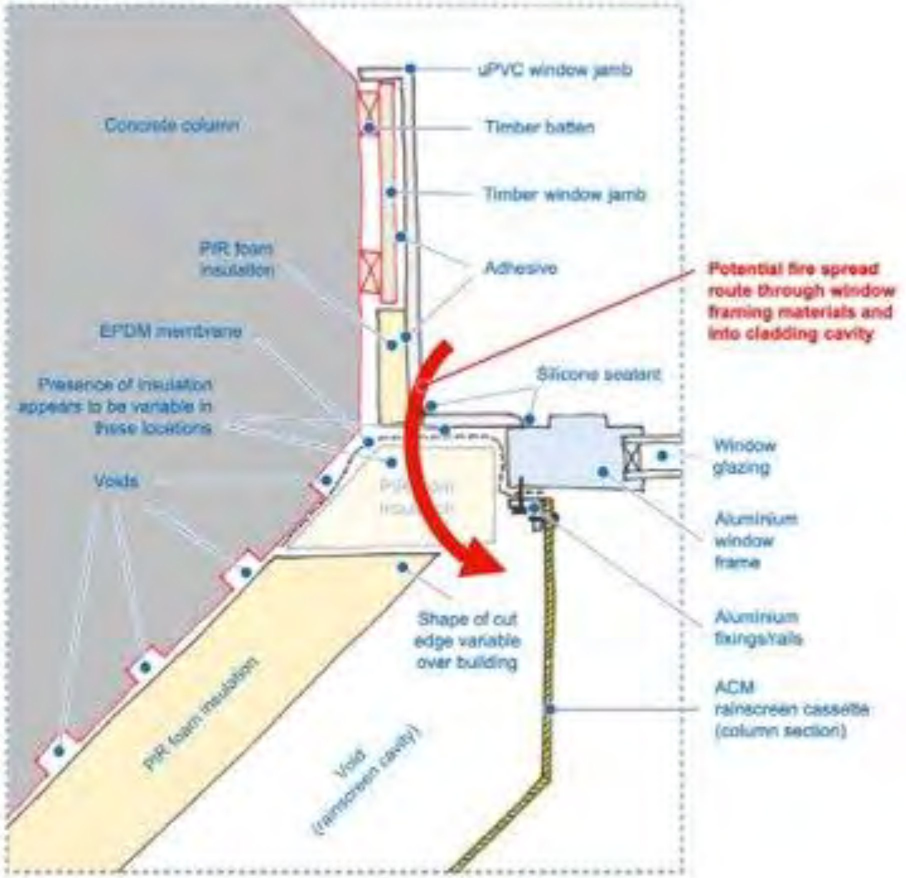

Figure 22.16

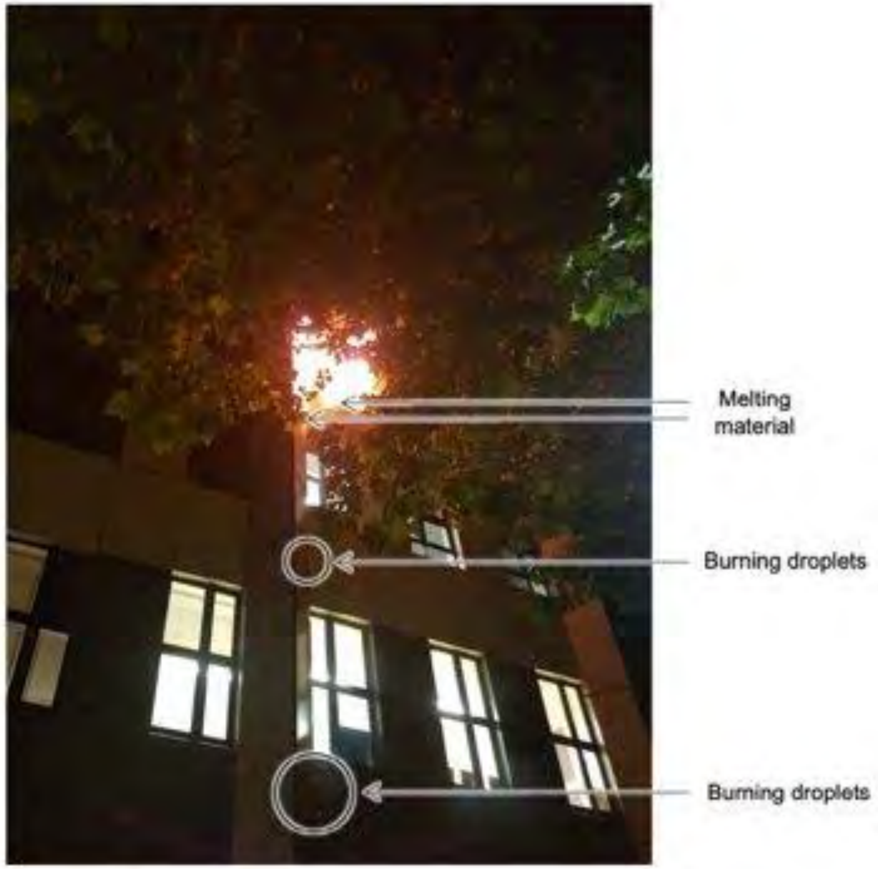

Figure 22.13

Structural Thermal Breaks

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Design – Fire testing

Figure 4: TBF Thermal Break connected between sections

TBF Thermal Break

Figure 5: TBF Sections Pre-Firetest

Structural Thermal Breaks

Design – Fire testing


Figure 8: TBF Sections Post-Firetest


Figure 17: TBF Coated Post-Firetest


Figure 18: TBF Uncoated Post-Firetest

Structural Thermal Breaks

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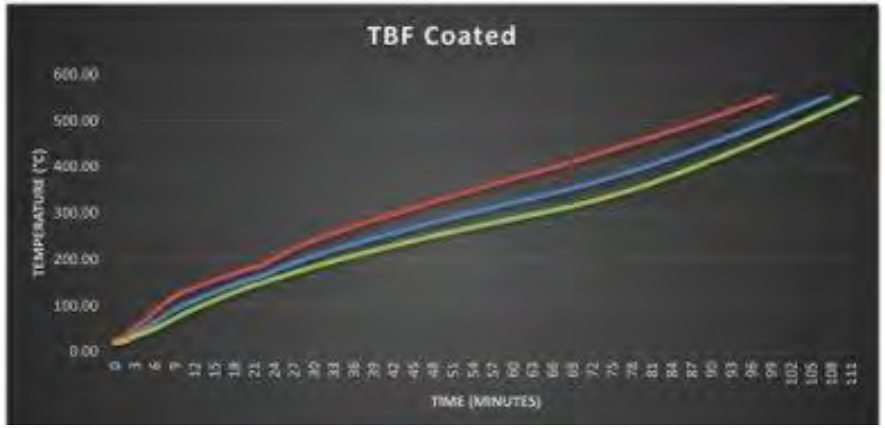
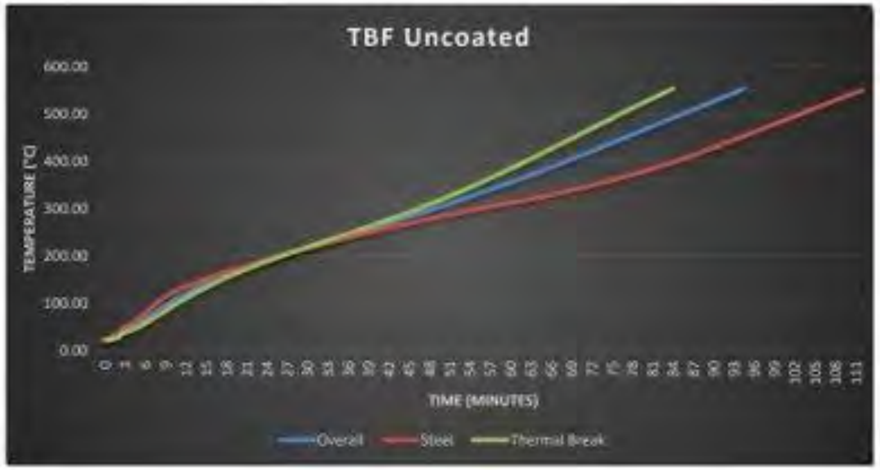
Design – Fire testing





Furnace Temperature – FT13628 TBF Sections

Time	Furnace	Cellulosic Curve	Time	Furnace	Cellulosic Curve	Time	Furnace	Cellulosic Curve
0	101.3117	20	31	836.1426	847	75	965.819	979
1	418.54	349	32	833.9996	851	80	973.5253	988
2	409.5019	445	34	854.002	860	85	985.8177	997
3	470.269	502	35	857.1621	865	90	994.7766	1006
4	507.7204	544	36	866.2819	869	95	1001.564	1014
5	587.867	576	37	872.1399	873	100	1012.483	1022
6	602.9327	603	38	865.9735	877	105	1020.115	1029
7	622.2813	626	39	874.5243	881	110	1030.097	1038
8	633.9004	645	40	876.8497	885	115	1036.69	1043
9	636.6883	663	41	879.4498	888	120	1042.116	1049
10	670.8587	678	42	885.2354	892			
11	679.639	693	43	883.5658	896			
12	692.3696	705	44	893.6629	899			
13	714.1206	717	45	895.5193	902			
14	726.8754	728	46	893.4571	906			
15	726.618	739	47	902.0557	909			
16	734.1214	748	48	903.2408	912			
17	752.153	757	49	905.1655	915			
18	756.886	766	50	904.049	918			
19	764.9236	774	51	907.999	921			
20	768.3808	781	52	916.3053	924			
21	774.1671	789	53	914.7195	927			
22	781.6987	796	54	919.3228	930			
23	786.0635	802	55	922.4417	932			
24	795.0427	809	56	921.7554	935			
25	795.4709	815	57	928.7029	938			
26	801.8616	820	58	928.4729	940			
27	819.0182	826	59	935.562	943			
28	829.0841	832	60	933.675	945			
29	828.2194	837	65	941.985	957			
30	836.6233	842	70	954.9224	968			

Structural Thermal Breaks

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Design – Fire testing

Figure 2.1 – Compression test setup

EN604 compressive strength testing @700°C

Table 3.1 – Compression test results

ID	Cross Section Area [mm²]	Max. Load [N]	Max. Stress [MPa]
M26070#1	77.82	22656	291.1
M26070#2	75.25	17812	195.8
M26070#3	75.58	18856	249.5
M26070#4	78.68	23300	296.1
M26070#5	77.39	24148	312.0
Average	76.94	21354	268.9

Structural Thermal Breaks

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Design – Fire testing

bre

BRE Global Test Report

EN ISO 1716 Gross heat of combustion (calorific value) test on Farrat Structural Thermal Break, Farrat TBF

Prepared for: Farrat Isolevel Limited
Date: [illegible] March [illegible]
Report Number: [illegible] Issue 1

Fire Behaviour		Smoke Production			Flaming Droplets	
A2	-	s	1	,	d	0

i.e. A2 – s1 , d0

Reaction to fire classification: A2-s1, d0

SIGNED

Matthew Dale
Principal Certification Engineer
Technical Department

APPROVED

S Deeming
Principal Engineer
Technical Department
on behalf of warringtonfire

warringtonfire

Warringtonfire
Holmesfield Road
Warrington
WA1 2DS

T: +44 (0)1925 655 116
info.warrington@warringtonfire.com
warringtonfire.com

Title:

CLASSIFICATION OF REACTION TO FIRE PERFORMANCE IN ACCORDANCE WITH EN 13501-1:2018.

Notified Body No:

0833

Product Name:

"Farrat TBF"

Report No:

WF 424837

Issue No:

1

Prepared for:

Farrat Isolevel Ltd
Balmoral Road
Altrincham
WA15 8HJ

Structural Thermal Breaks

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Design – Fire design summary

- Ensure materials are independently certified EN13501-1 - A2,s1,d0 as a minimum
- Choose a material with independent verification of performance at high temperatures, up to 700°C to EN604
- Choose a material that is compatible and performs with any fire protection system likely to be used (intumescent coatings or boards)
- Ensure materials he been subject to prolonged fire testing (120 minutes) with temperatures exceeding 1000 °C

Structural Thermal Breaks

Specification

Material needs to be

- Part of Building Structure – Calculated structural performance
- Part of Thermal envelope and energy usage calculations
- Part of the fire protection envelope – certified performance

Structural Thermal Breaks

Specification

How does a specifier understand which material to choose?

Structural Thermal Breaks

Farrat
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Specification

CCPI verification

CCPI CODE FOR CONSTRUCTION PRODUCT INFORMATION

- Independent and robust verification, working to build more confidence with the public and external stakeholders and setting the market for UK construction products ahead of others.
- A change to organising systems and processes in relation to product information – supporting compliance with anticipated new regulatory requirements and giving specifiers, clients and more assurance regarding the information provided on the performance and use of the construction products they select.
- A focus on culture, leadership and ethics, CCPI will build more confidence, and support an environment for healthy challenge within organisations regarding product performance and safety helping to generate product information that is reliable and correctly stated.

BREEAM,LEED & Passive House

Farrat
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Exemplar environmental performance buildings

- Manufacturing under an ISO14001 accredited system
- Responsibly sourced raw materials
- Reliability and traceability
- Calculated performance in use
- Post installation performance gap analysis
- Transparent publication of energy saving performance figures

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Engineers on a mission

20 Ropemaker Street

London

Material: Farrat TBF (steel connections)

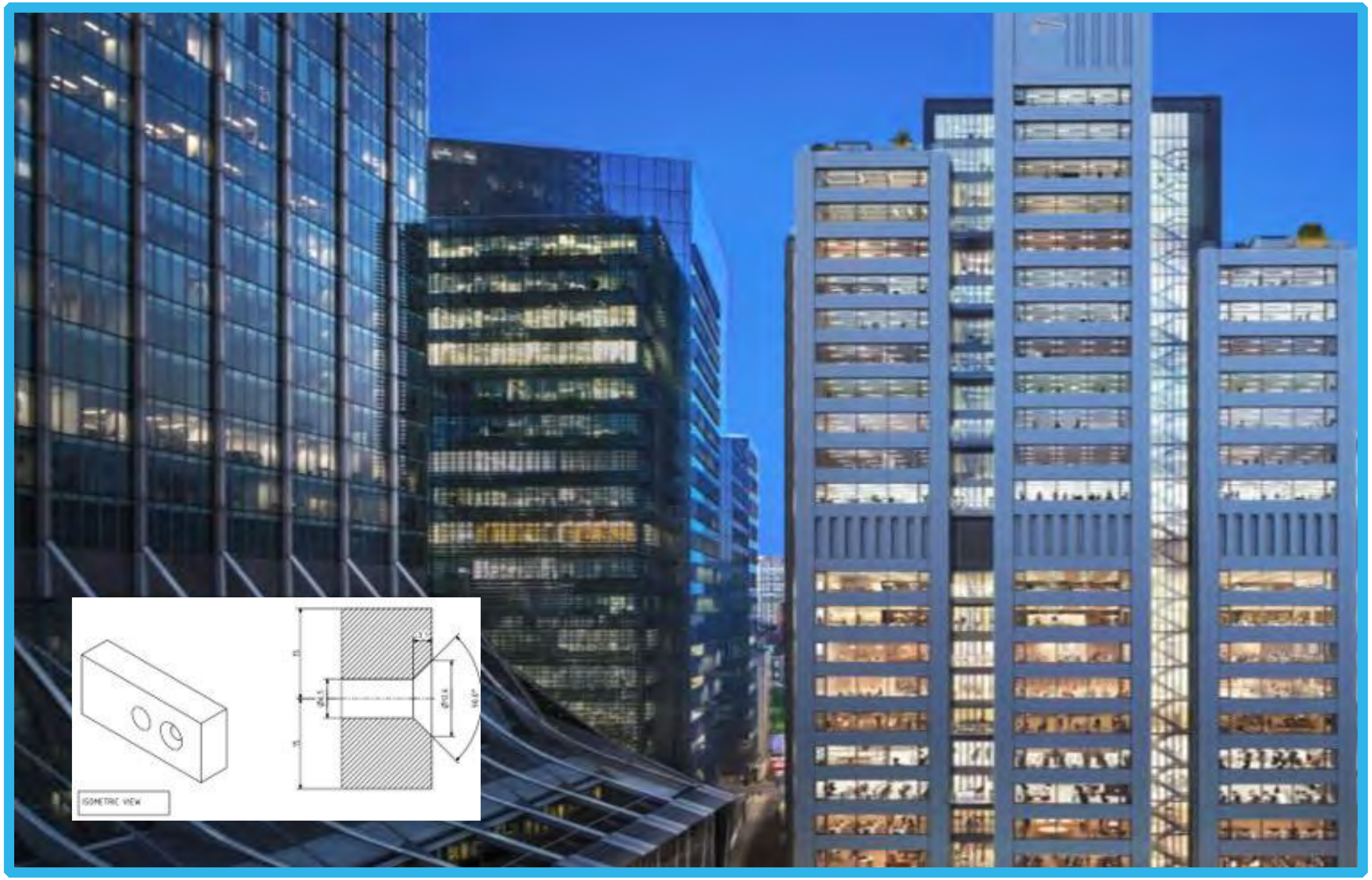
Client: Old Park Lane Management (Josef Gartner)

Type: Offices and retail

This office and retail building will deliver approx. 40.000 sqm offices and 10.000 sqm retail. In November 2020 the project was awarded BREEAM

Outstanding at design stage, thought to be the largest-ever commercial project to secure the accreditation at this stage. The building is due for completion in 2023.

- BREEAM Certification
- 40.000 sqm offices
- 10.000 sqm retail



Paddington Square

Farrat

Engineers on a mission

London

Material: Farrat TBF (steel connections)

Client: William Hare

Contractor: Mace

Type: Mixed Use Development, New Build

A new £825M transformation of the Paddington Square area, located between Paddington Station and St Mary's Hospital in the centre of London.

- 5,500 tonnes of steel utilised with the steel frame
- 80,000 qs.ft retail space
- 350,000 sq.ft workspace
- 21,000 sq.ft bar and restaurant
- 14-floors with exposed steel beams and columns

The Hinge

Aarhus, Denmark

Material: Farrat TBF
(column connections)

Client: Haucon

Type: Mixed Use, New Build

Located in the new city gate, 'The Hinge' will act as a landmark development between the historic town and new district, as part of a highly ambitious plan to create an innovative and sustainable urban focal point.

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CERN

Switzerland

Material: Farrat TBK (façade connections)

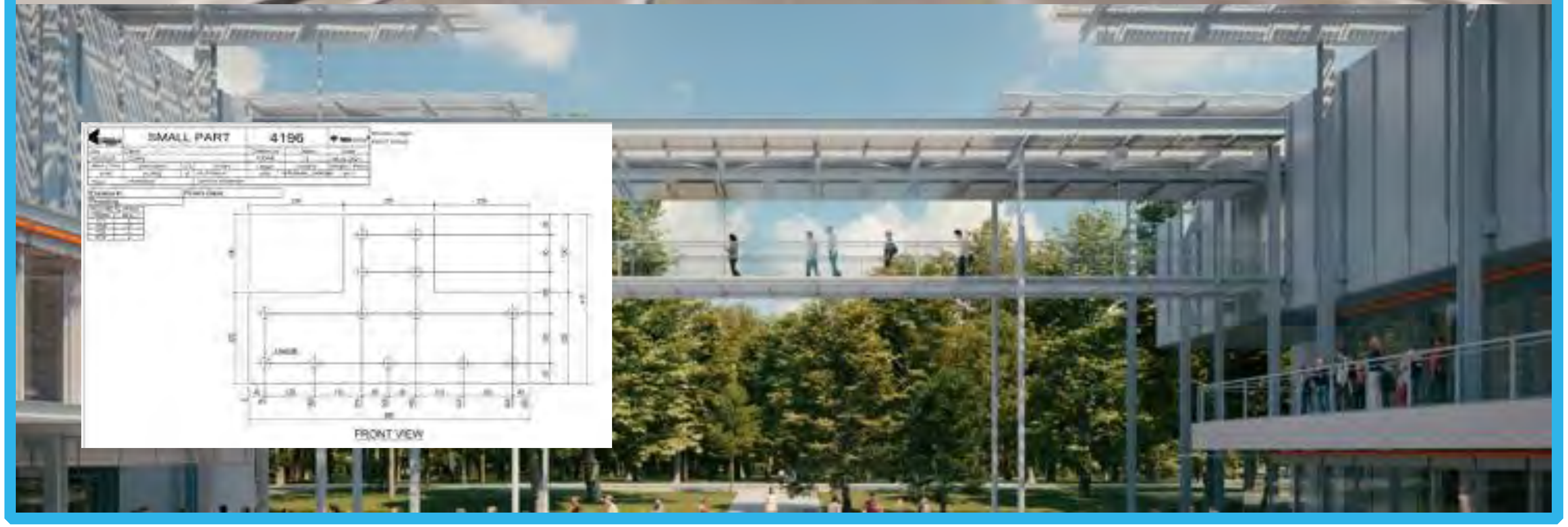
Client: Cimolai

Type: Pavilion, New Build

CERN is building a new scientific education and outreach centre, designed by world-renowned architects, Renzo Piano Building Workshop and funded through external donations, with the leading contribution coming from FCA Foundation.

The project, located within the area of the European Center for Nuclear Research, is composed of three pavilions and two tubular structures in metal and glass carpentry, arranged along a main axis. The project is completed by a steel-glass overhead walkway along the transversal axis that will allow you to cross the tramway line and connect all the various units.

- 1,600 t metal carpentry
- 4,320 sqm steel facades + insulation
- 2,060 sqm glass facades
- 315 sqm of glass floor



Riyadh City Metro

Riyadh

Material: Farrat TBK ((steel connections)

Client: Al Ghurair Construction

Type: Pavilion, New Build

Riyadh Metro is one of the giant projects in the world. It includes 85 railway stations, apart from six major metro lines that have been established to cover the capital city of Riyadh from all directions. There is a network of buses, and all these cover an area of 1800 km.

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Mohammed VI Tower

Rabat, Morocco

Material: Farrat TBF (façade connections)

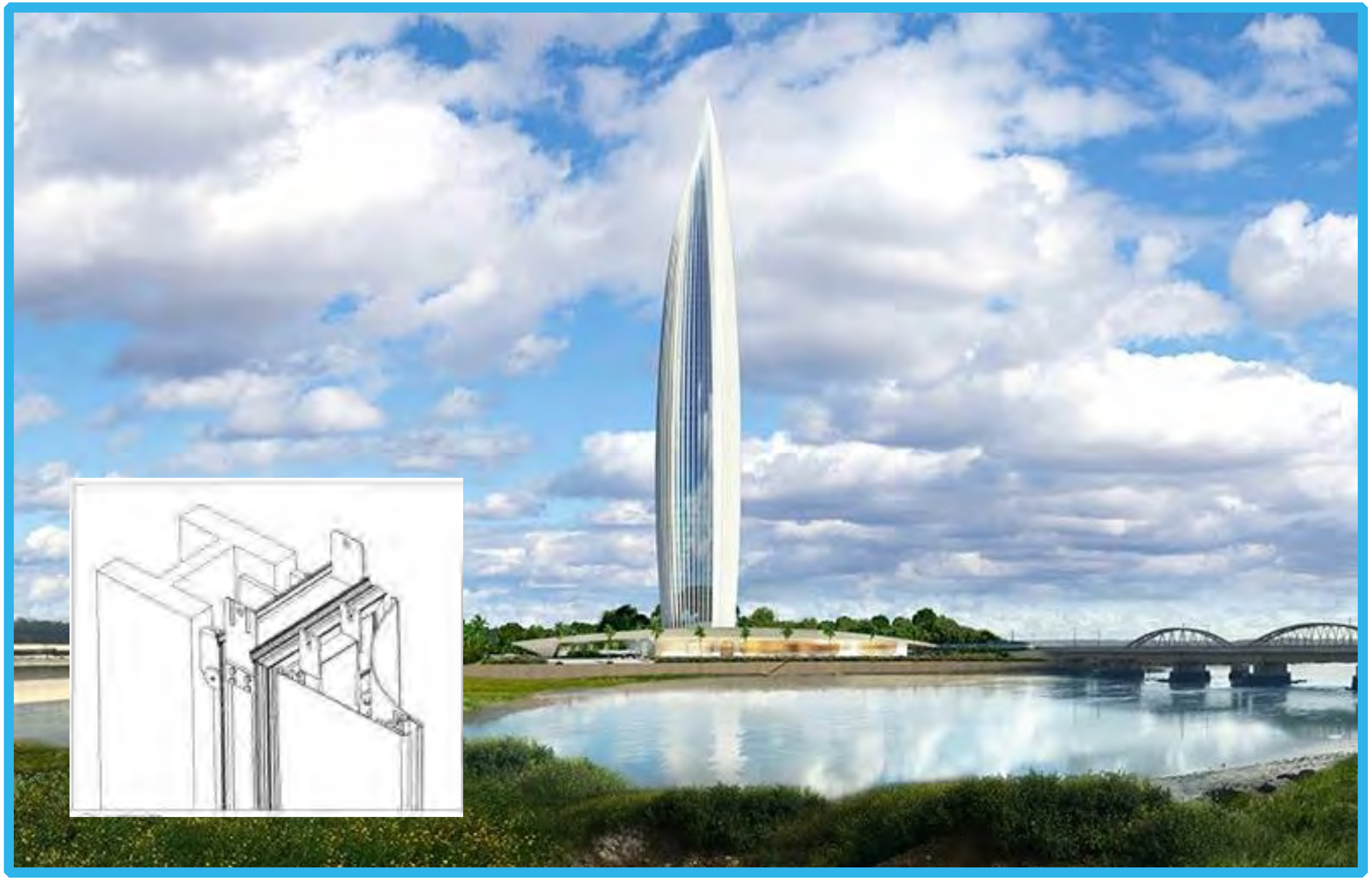
Client: Besix

Type: Mixed Use, New Build

BESIX and Six Construct are building the Mohammed VI Tower, the tallest tower in Africa. The tower will meet the highest environmental standards with LEED Gold and HQE certifications and be built to high environmental standards, with a stunning appearance, and packed with innovations developed by BESIX's Engineering Department.

- 250-meters high Mohammed VI Tower is designed to be visible from 50 kilometers all around.
- Total area of 102,800 m²
- Over 55 stories.
- Facilities include a luxury hotel, offices, high-end apartments, and a viewing terrace.

Farrat
Engineers on a mission




Thank you
21st June 2022