World Wide Inspiration in Steel Construction

ArcelorMittal

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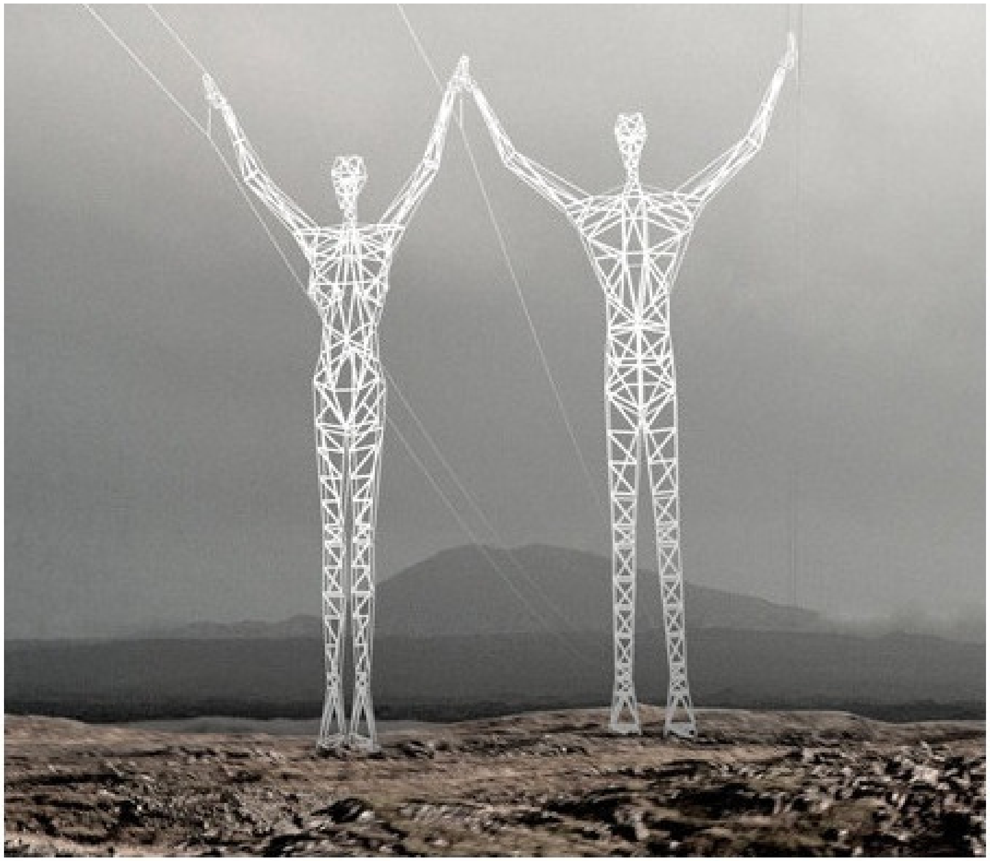
Inspiration

Inspiration (from the Latin *inspirare*, meaning "to breathe into") refers to an unconscious burst of creativity.

Jin Choi & Thomas Shine, Choi+Shine Architects [www.choishine.com]

Inspiration – "Land of Giants" (2008)

Proposal for power transmission pylons in Iceland



Jin Choi & Thomas Shine, Choi+Shine Architects [www.choishine.com]

Inspiration – Denver Art Museum

Use & Structure

Architect: Libeskind
Engineer: Arup
Fabricator: Zimmerman

146,000 sq ft

Steel from (LU):
Jumbos in A913 Gr.65

structurearchives.org

buildipedia.com

Inspiration – Panorama platform in Tyrol (A)

Use & Structure

A panorama platform made of weather resistant steel

Realise Inspiration …

Innovation:

Material

- High performance: strength and toughness
- Quality (product and fabrication)

Design

- Economic (investment + operational = LCC)
- Durability

Concept

- Functionality
- Aesthetics
- Flexibility
- Realisation: Short construction times, ease in maintenance, ...

> 30 workers on SWFC(101 floors) window-cleaning team

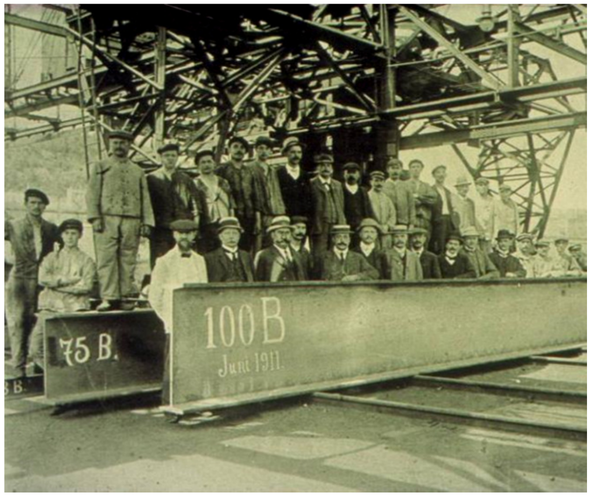
⇒ Sustainability: ecological, economical, socio-cultural, technical oriented, process oriented

Material: ArcelorMittal Europe – Long Products

Rolled beams

Blast furnace

Ingot casting



June 1911 – Differdange (LU)
First hot-rolled section of
1000 mm deep (314 kg/m)

Before 1950, steel grades characterised:

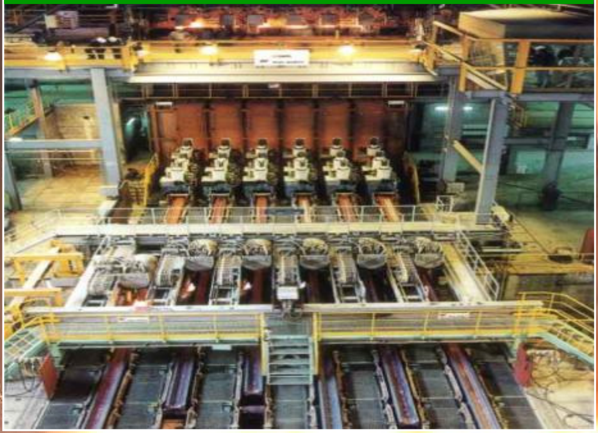
- low mech. properties (Re=210-320 MPa)
- low toughness and ductility
- poor weldability due to
  high CE values

Material: ArcelorMittal Europe – Long Products

Modern production of rolled beams (LU)

Electric Arc Furnace

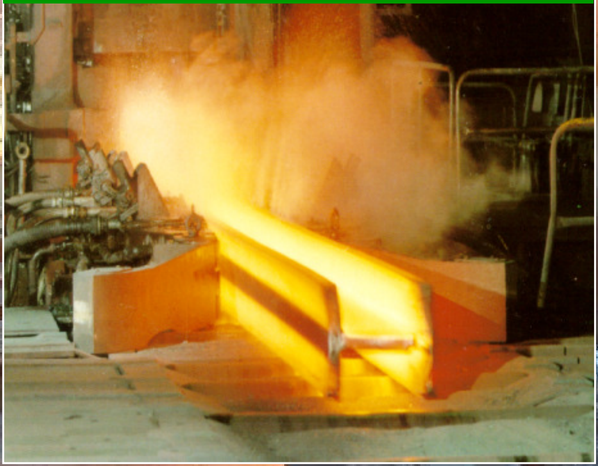
Continuous Casting



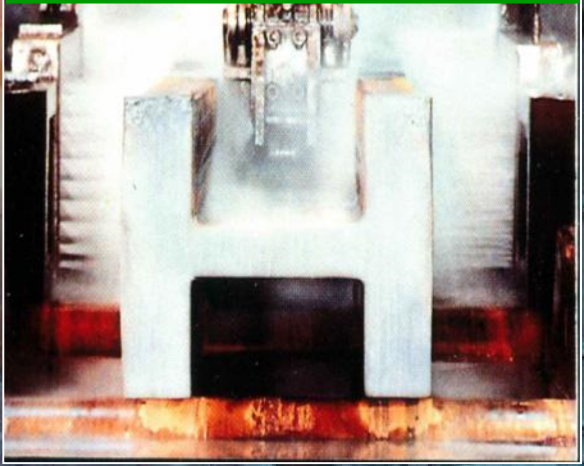
Semi-prod. (beam-blank)

Rolling mill

Selective cooling

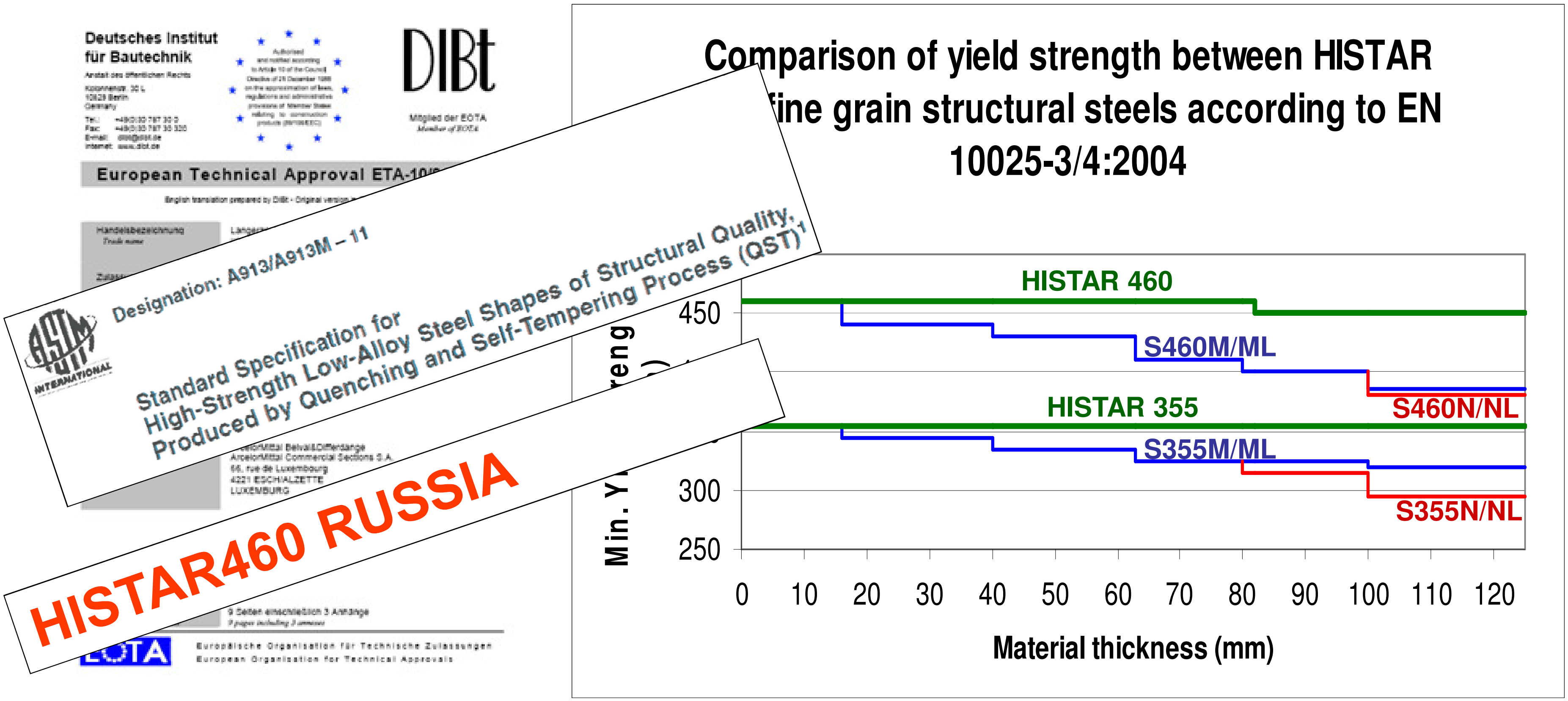


QST-process



Material: HISTAR

European Technical Approval / A913

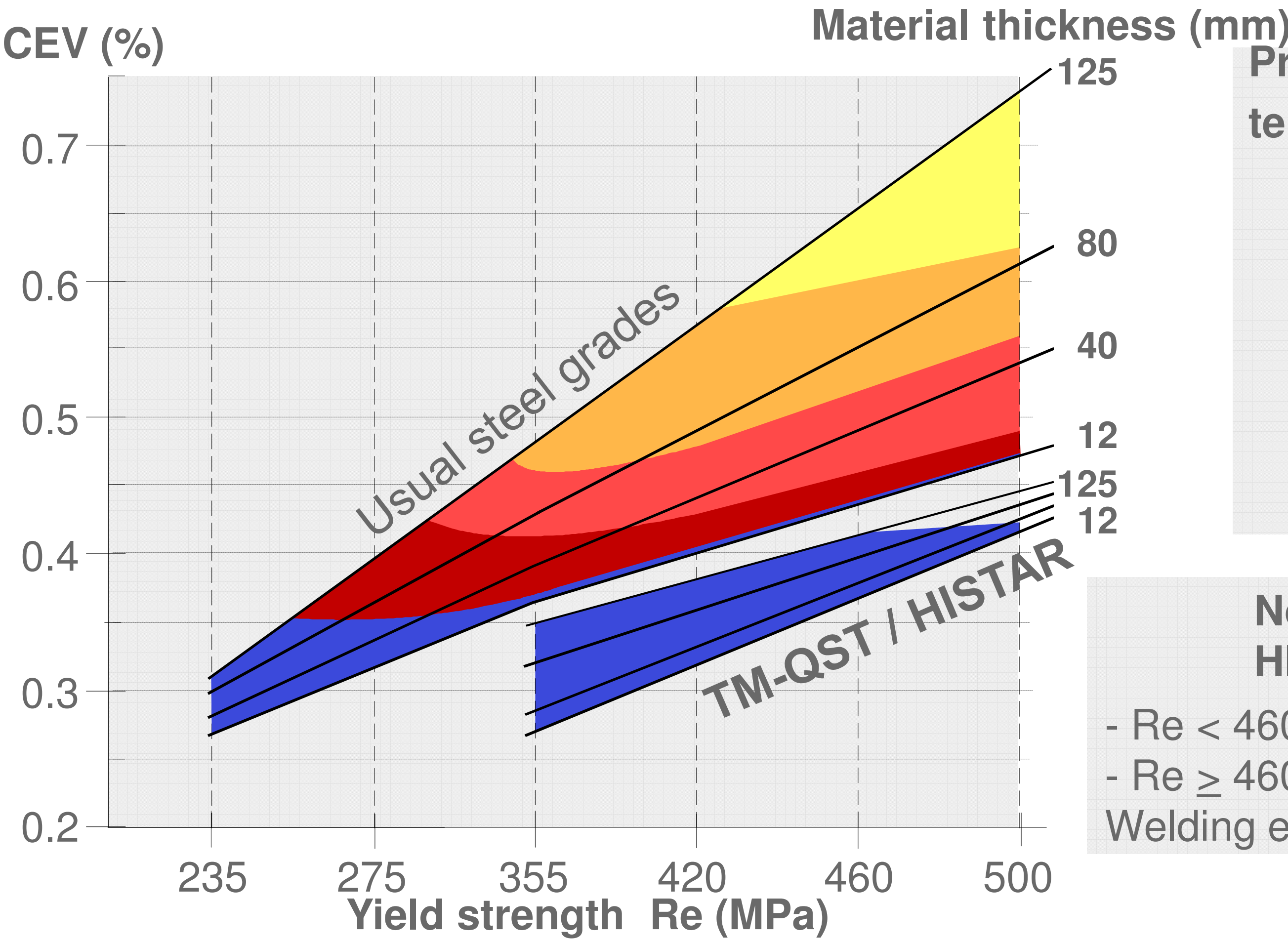


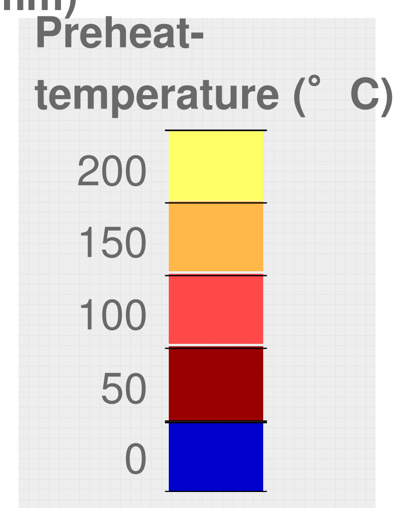
Advanced TM+SC/QST rolling processes are the key to a new generation of fine-grained steel grades with:

- **High strength**
- **Good toughness and ductility**
- **Excellent weldability / No preheating**

Material: HISTAR weldability

Weldability and preheat temperatures (EN 1011-2)





No preheating for HISTAR steels if:

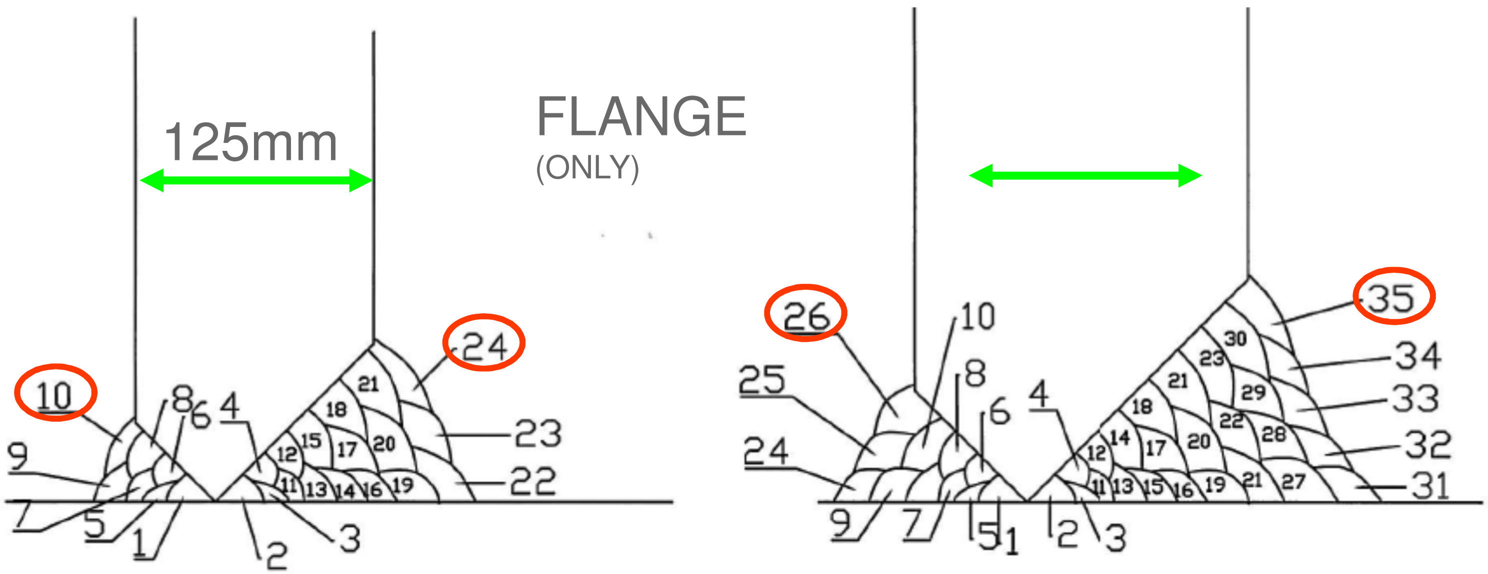
- Re < 460 MPa: $H_2 \leq$ 10 ml/100g
- Re $\geq$ 460 MPa: $H_2 \leq$ 5 ml/100g

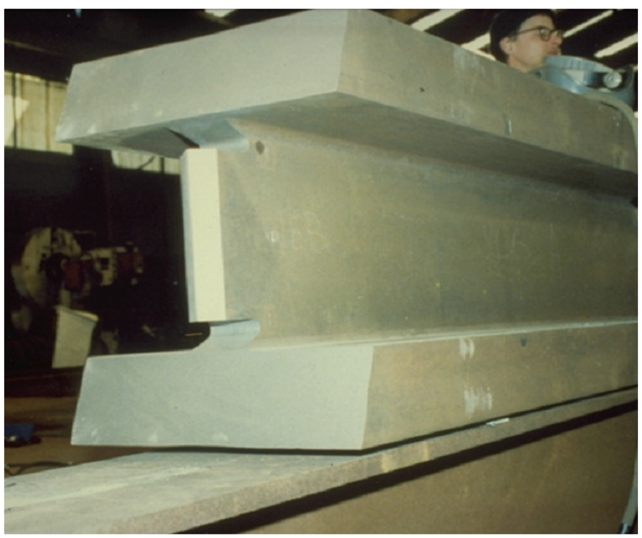
Welding energy: E ≥ 10 kJ/cm

$$CE\,(\%) = C + \frac{Mn}{6} + \frac{(Cr + Mo + V)}{5} + \frac{(Cu + Ni)}{15}$$

Material: HISTAR weldability

HD 400 x 1086 kg/m in HISTAR 460





ArcelorMittal Europe-LP (LU)

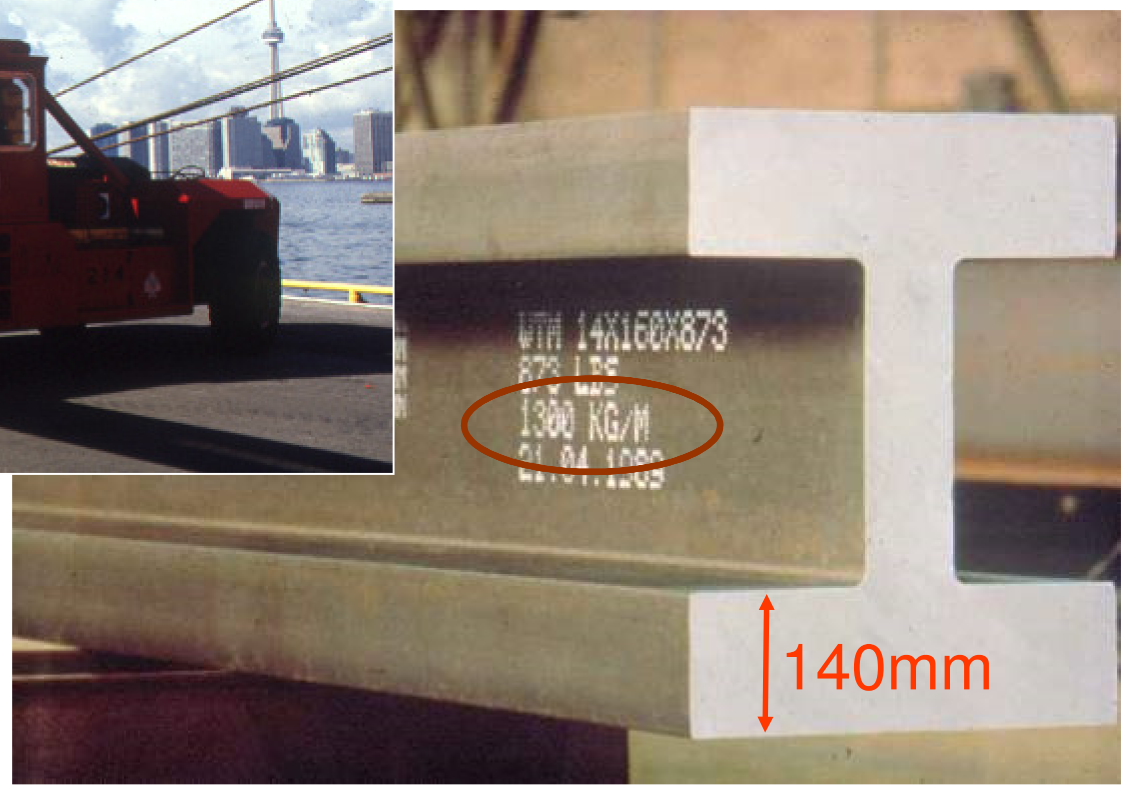
Highest sections:

~ 1100 mm (44”)

⇒ e.g. for bridges

ArcelorMittal Europe – Long Products

Jumbo sections for High-rise buildings



- > 900 high-rise buildings in the U.S.A.
- > 1500 high-rise buildings worldwide

Buildings in New York with Jumbo Shapes from ArcelorMittal Europe – Long Products

Freedom Tower - Manhattan

1776 ft (541m)
69 Office Floors
105 Floors total

Concrete Core with a perimeter of steel columns (total of 80,000 tons of steel)

Approx. 8,100 MT Jumbos in A913 Gr.65 (LU)

Architect:
David Childs SOM

Structural Engineer:
WSP Cantor Seinuk

Bay Adelaide Center


Bay Adelaide West with facades of the 1926 National Building © upstateknitter

Office building in Toronto (CA)

- Height: 218 m (715 ft)
- Floor area 108,000 m2 (1,160,000 sq ft)
- Construction: 2007 - 2009
- Owner / Developer / Manager: Brookfield Properties
- Architect: WZMH Architects
- Structural engineer: Halcrow Yolles

History:

1980s: first tower development: 57-storey office tower for almost a billion dollars investment
1990: Start of construction
1993: Construction halted: recession and office vacancies
U-Parking garage and six-storey stand as stump

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The six-storey "stump" till 2005, as a symbol of 1990s recession until (demolition in 2006)

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⇒ ArcelorMittal sold A913 Grade 65 for this project (ca. 5000to) (first time Grade 65 sold to Canada)

⇒ Steel used for NY Sloan Kettering Hospital (first project in Grade 65 in NY)

Sloan Kettering Hospital (MSK)

Memorial Sloan Kettering Cancer Center (MSK or MSKCC)

Built in 1997

First project in NY with A913 Grade 65

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History:

2005: Re-design ⇒ towers West and East
Mixed-use high-rise towers of 43/50 storeys
North and west facades of “National Building” preserved

2007 – 2009: Bay Adelaide West with 51 storeys

⇒ ArcelorMittal resold A913 Grade 65 for this project (ca. 5000to)

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⇒ ArcelorMittal resold A913 Grade 65 for this project (ca. 5000to)

2013 - 2015: Bay Adelaide East at 44 storeys

⇒ ArcelorMittal sold A913 Grade 65/**70** for this project

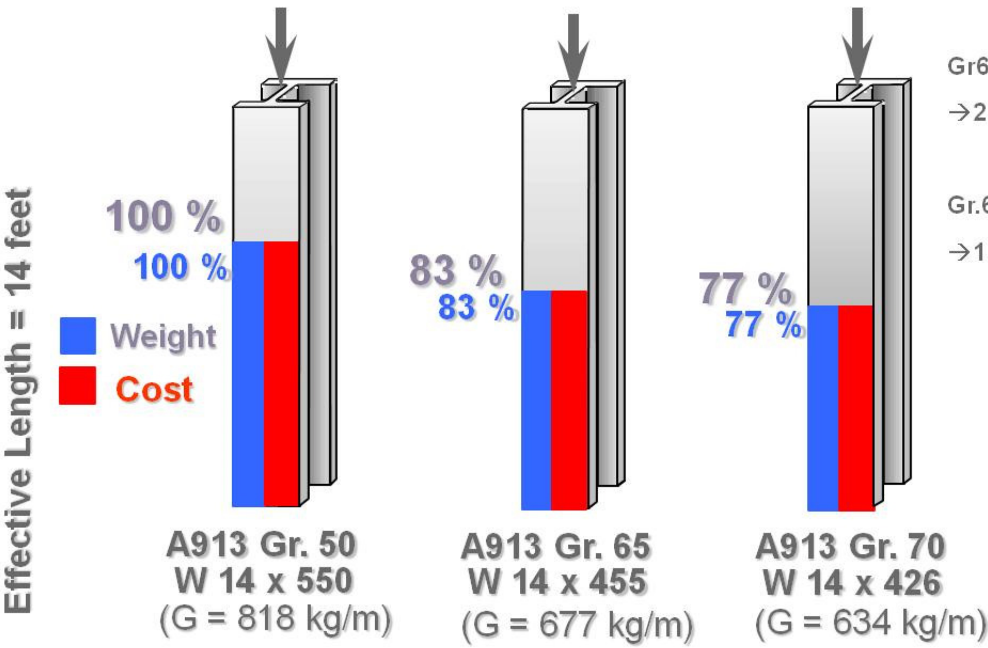
Bay Adelhaide East

First project of Gr.70 in CA (2014)

Mechnical properties

Grade	Yield Strength Min. ksi	[MPa]	Tensile Strength Min. ksi	[MPa]	Elongation (%), Min. 200 mm 8 in.	50 mm 2 in.
50	50	[345]	65	[450]	18	21
65	65	[450]	80	[550]	15	17
70	70	[485]	90	[620]	14	16

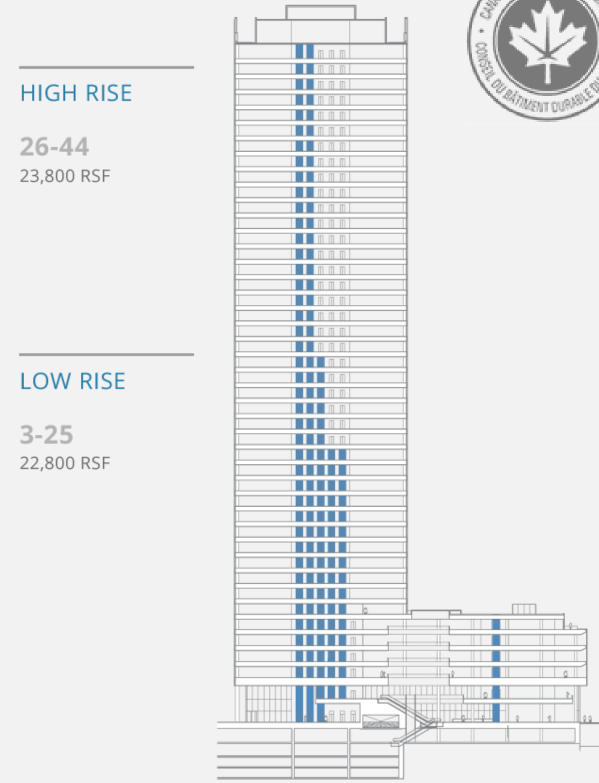
HISTAR 355
HISTAR 460
since 2011



Gr65 i/o Gr50
→2 Foot-Weight Drop

Gr.65 i/o Gr70
→1 Foot-Weight Drop

Bay Adelaide East, Toronto



150 North Riverside, Chicago (US)

Building …
53-story Class A office building
~ 1.2 million rentable square feet

Sustainability …
LEED-CS Gold Precertified
Maximization of open space
Use of low-VOC, non-emitting materials
Significant natural daylight use

ArcelorMittal …
Customer: Zalk- Josephs

Total tonnage: **484 t**
W36x16.5 in grade 65

Additional tonnage (estimation): **1220 t**
W14x16 partly grade 65 / grade 70

Remark:
First project of Gr.70 in USA (2014)

Material: Introduction of S500 (Grade 70) to EN

Tranfer of knowledge to EN10025 (2015/2016):
EN10025-2: **S500J0**
EN10025-4: **S500M** and **S500ML**

Table 4 — Mechanical properties – Tensile test properties at room temperature for steel grades S275 to S500

Designation		Minimum yield strength R_{eH} [a] MPa[b] Nominal thickness mm						Tensile strength R_m [a] MPa[b] Nominal thickness mm					Minimum percentage elongation after fracture[c] % $L_0 = 5,65 \sqrt{S_0}$
According EN 10027-1	According EN 10027-2	≤ 16	> 16 ≤ 40	> 40 ≤ 63	> 63 ≤ 80	> 80 ≤ 100	> 100 ≤ 120 [d]	≤ 40	> 40 ≤ 63	> 63 ≤ 80	> 80 ≤ 100	> 100 ≤ 120 [d]	
S275M S275ML	1.8818 1.8819	275	265	255	245	245	240	370 to 530	360 to 520	350 to 510	350 to 510	350 to 510	24
S355M S355ML	1.8823 1.8834	355	345	335	325	325	320	470 to 630	450 to 610	440 to 600	440 to 600	430 to 590	22
S420M S420ML	1.8825 1.8836	420	400	390	380	370	365	520 to 680	500 to 660	480 to 640	470 to 630	460 to 620	19
S460M S460ML	1.8827 1.8838	460	440	430	410	400	385	540 to 720	530 to 710	510 to 690	500 to 680	490 to 660	17
S500M S500ML	1.8829 1.8839	500	480	460	450	450	450	580 to 760	580 to 760	580 to 760	560 to 750	560 to 750	15

[a] For plate, strip and wide flats with widths ≥ 600 mm the direction transverse (t) to the rolling direction applies. For all other products the values apply for the direction parallel (l) to the rolling direction.

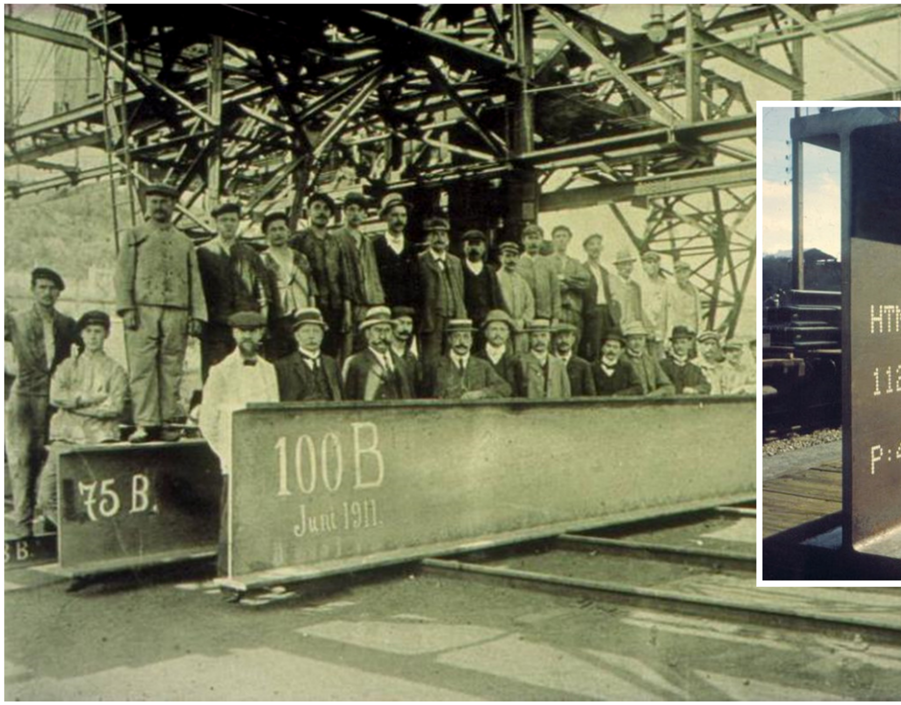
[b] 1 MPa = 1 N/mm^2.

[c] For product thickness < 3 mm for which test pieces with a gauge length of L_0 = 80 mm shall be tested, the values shall be agreed at the time of the order.

[d] For long products a thickness ≤ 150 mm applies.

ArcelorMittal Europe – Long Products

New structural shapes

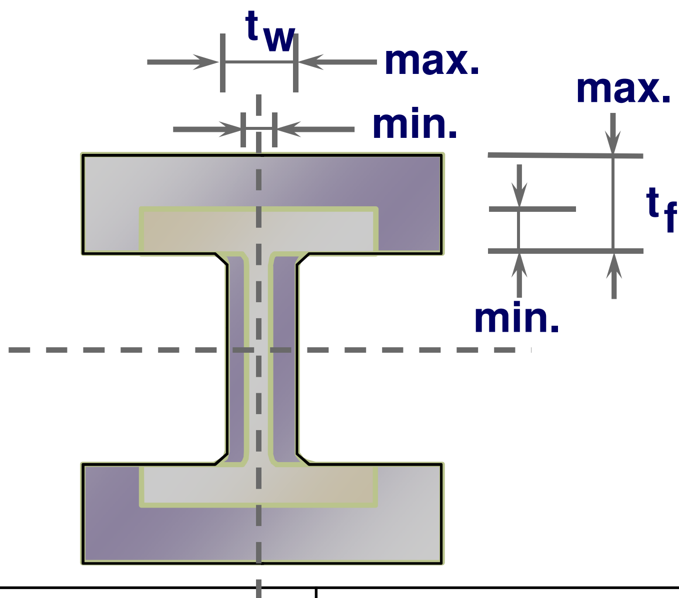


June 1911 – Differdange
First hot-rolled section 1000 mm deep
(1000mm deep, 314 kg/m)

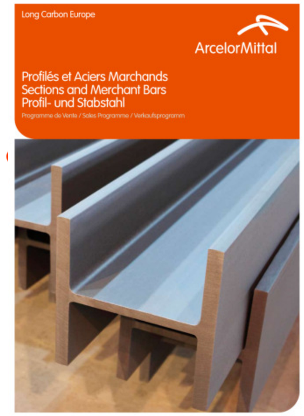
June 2011 – Differdange
First rolling HL920x1377 and HD400x1202
(1377 / 1202 kg/m)

ArcelorMittal Europe – Long Products

New structural shapes



World record in Jumbo Sections



ASTM A6/A6M – 13

		G	h	b	t_w	t_f
		kg/m	mm	mm	mm	mm
W 14 x 16 x 808	HD400 x 1202	1202	580	471	95	130
W 14 x 16 x 873	**HD400 x 1299**					
W 36 x 16.5 x 723	HL920 x 1077					
W 36 x 16.5 x 802	HL920 x 1194					
W 36 x 16.5 x 853	HL920 x 1269	1269	1093	461	64,0	115,1
W 36 x 16.5 x 925	**HL920 x 1377**	**1377**	1093	473	76,7	115,1
W 40 x 16 x 655	HL1000 x 976	976	1108	428	50	89,9

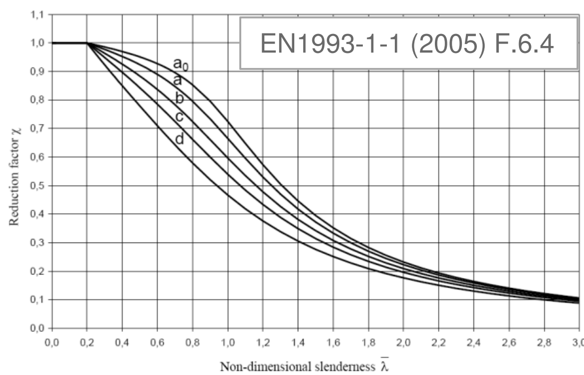
$h/b > 1{,}2$ and $t_f > 100$mm

Design - New structural shapes

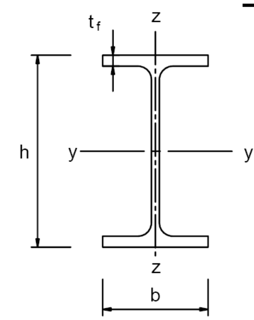
- For column design buckling may be decisive
- From 1960 onwards, more than 1000 buckling tests on colums with varying section (I, H, T, U, circular and square hollow sections) and slenderness ratio $(55 \leq \bar{\lambda} < 160)$

  $\Rightarrow$ buckling curves by Rondal/Maquoi
  (probabilistic approach relating column strength to slenderness)

EN1993-1-1 (2005) F.6.4



EN1993-1-1 (2005) T.6.2



Cross section		Limits	Buckling about axis	Buckling curve: S 235, S 275, S 355, S 420	Buckling curve: S 460
Rolled sections	$h/b > 1,2$	$t_f \leq 40$ mm	y – y z – z	a b	a_0 a_0
		$40 \text{ mm} < t_f \leq 100$	y – y z – z	b c	a a
	$h/b \leq 1,2$	$t_f \leq 100$ mm	y – y z – z	b c	a a
		$t_f > 100$ mm	y – y z – z	d d	c c

- New column sizes exceed limits of EN ($h/b > 1,2$ and $t_f > 100$mm)

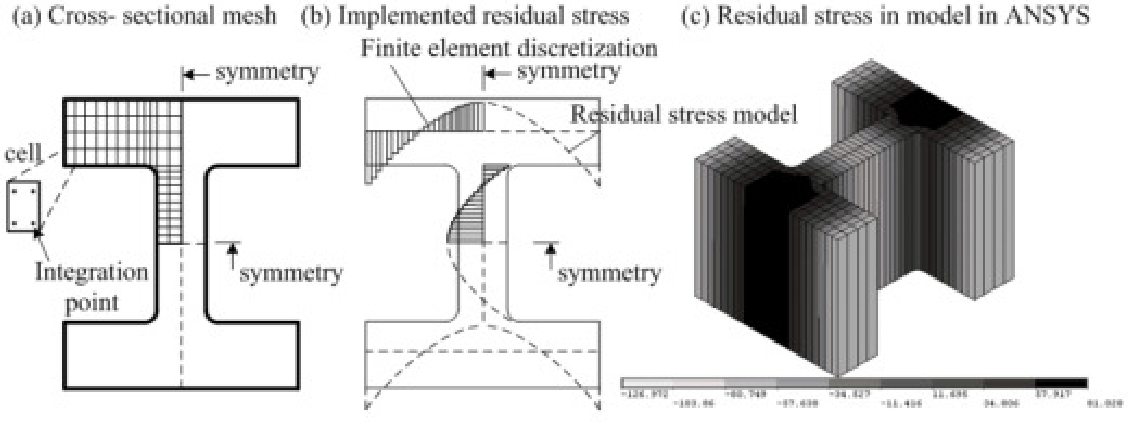
? Are imperfections of existing tests transferable

- Metallurgical imperfections
- Geometrical imperfections
- Deviations in load introduction

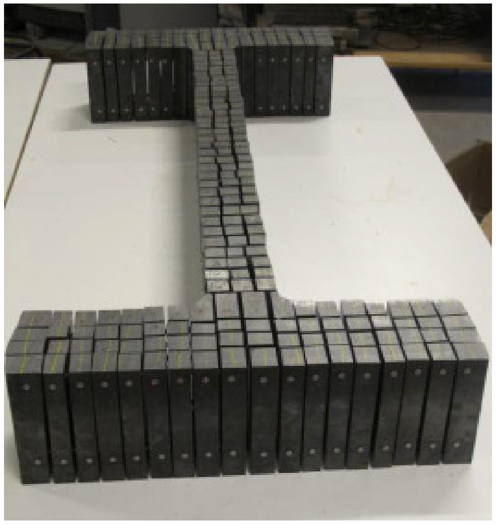
Design - New structural shapes

Analyses to obtain buckling curves

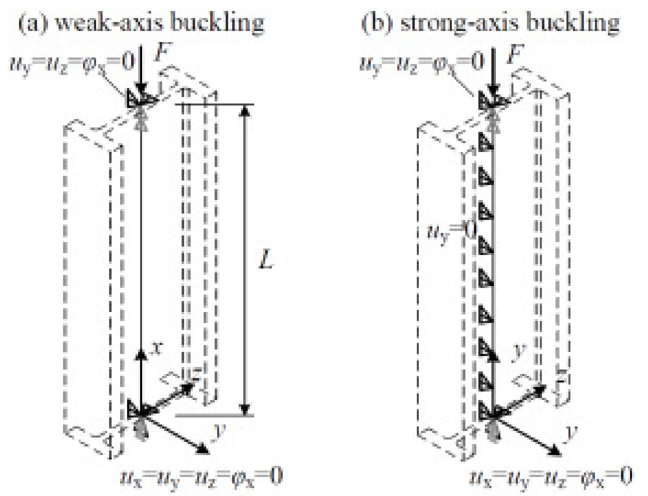
Complete sectioned specimen
(HD400x1202)



Finite element discretization of cross-section and implemented residual stresses
(for HD 400x1202)



Complete sectioned specimen
(HL920x1377)



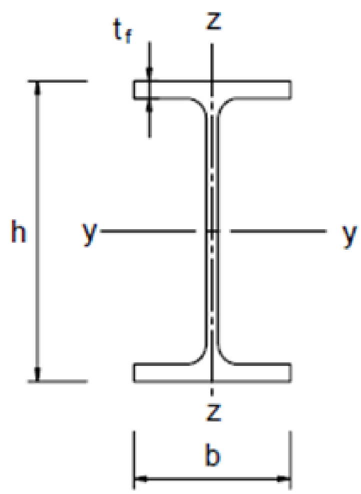
Boundary conditions

- Extension of population by FEA
- Statistical analyses to obtain buckling curves

Design - New structural shapes

Analyses to obtain buckling curves

- Proposal for amendment in EN 1993-1-1 to expert group

Cross section		Limits		Buckli ng about axis	Buckling curve	
					S235 S275 S355 S420	S460 / S500
Rolled sections		h/b > 1,2	$t_f \leq 40$ mm	y-y	a	a_0
				z-z	b	a_0
			40mm < $t_f \leq 100$ mm	y-y	b	a
				z-z	c	a
			t_f > 100 mm	**y-y**	**b**	**a**
				z-z	**c**	**b**
		h/b ≤ 1,2	$t_f \leq 100$ mm	y-y	b	a
				z-z	c	a
			t_f > 100 mm	y-y	d	c
				z-z	d	c

BP4, Canary Wharf, London (UK)

Predesign tender stage

Height 108 m – 25 floors

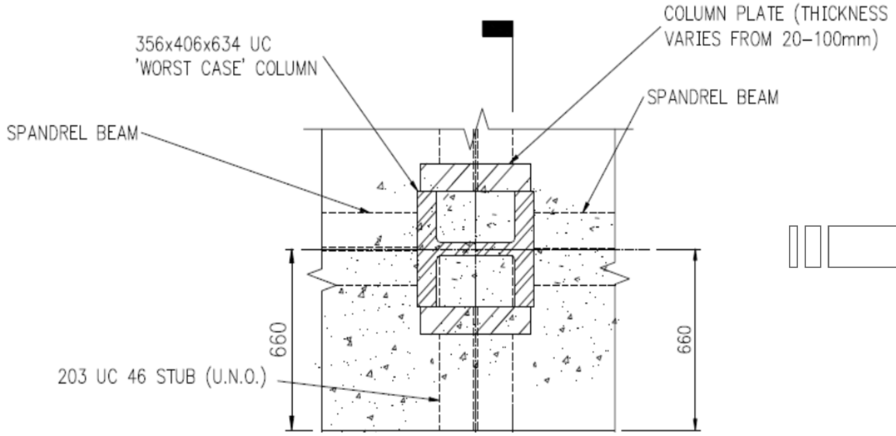
General contractor:
Canary Wharf Contractors Ltd

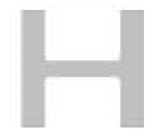
Steel fabricator:
JV Victor Buyck (B) / Hollandia (NL)

1.1 kT of UC column sections in HISTAR355

BP4, Canary Wharf, London (UK)

Predesign tender stage





UC356x406x1202

Column section in tender

- Dimensions 474.6x624mm
- Welded section out of UC356x406x634 and 100mm plates in S355
- Yield strength 315MPa
- Weight 1341kg/m
- Scrap due to plate cutting
- Web to flange welding
- Milling and preheating before welding
- Ultrasonic Testing of Welds
- Lead time heavy plates?

Column section proposal ArcelorMittal

- Dimensions 580x471mm
- UC356x406x1202 hot-rolled section in HISTAR460
- Yield strength 450MPa
- Weight 1202kg/m / **-10%**
- No scrap / **-100%**
- No welding / **-100%**
- No milling, no preheating / **-100%**
- No ultrasonic testing / **-100%**
- Monthly rollings of UC356 sections

Stadskantoor Utrecht (NL)

Under construction …

Height 92m – 22 floors - +/- 65000m^2

+ Design: Kraaivanger architecten

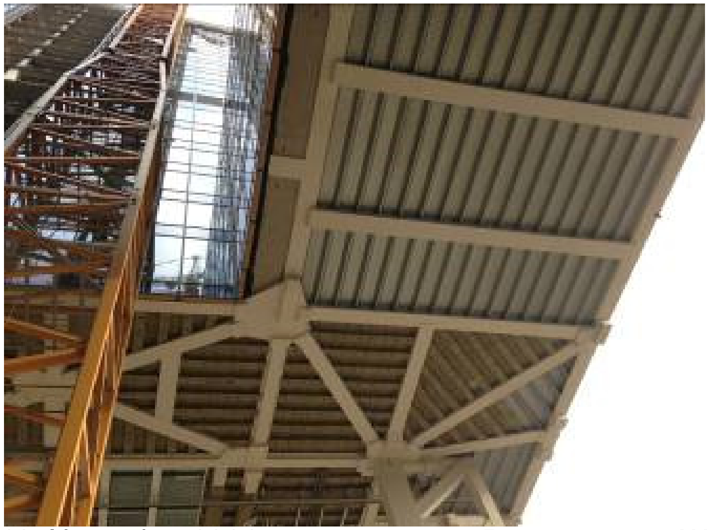
+ Engineering: Zonneveld Ingenieurs

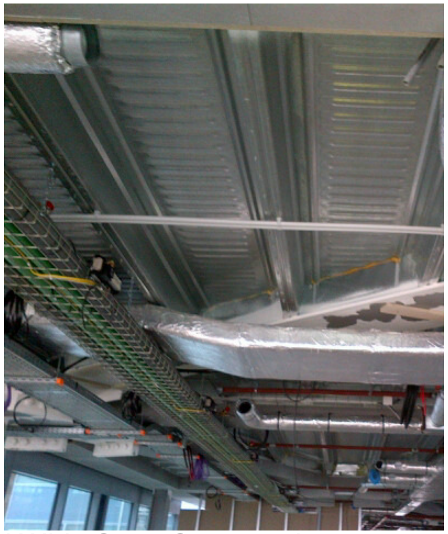
+ General contractor:
Boele&van Eesteen and G&S Bouw

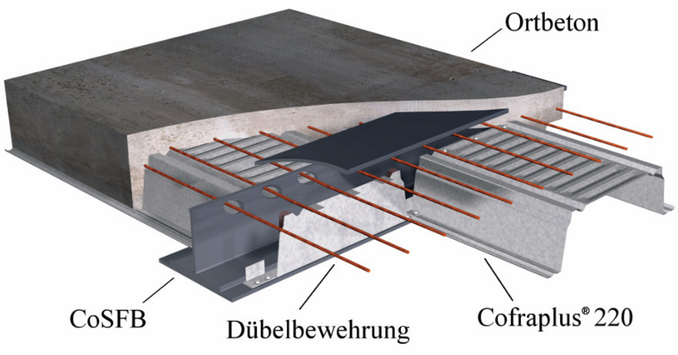
+ Steel fabricator:
ASK Romein – Oostingh Staalbouw

+/- 8000to sections delivered
+/- 5000to colunms as HD-beams in
HISTAR 460

Stadskantoor Utrecht (NL)







Design: CoSFB – Composite slim-floor beam

Request of modern architecture:

- Energy efficient design and use
- Transparent structural envelopes with column free ground floor design
- Flexibility for sustainable conversion of use
- Possibility to upgrade services for multifunctional living

ArcelorMittal Office Building, Luxembourg

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Slim-floor construction (SFB / IFB):

- Combines advantages of prefabricated slab elements with steel-framed construction

⇒ Economic solutions fulfilling the above specified demands

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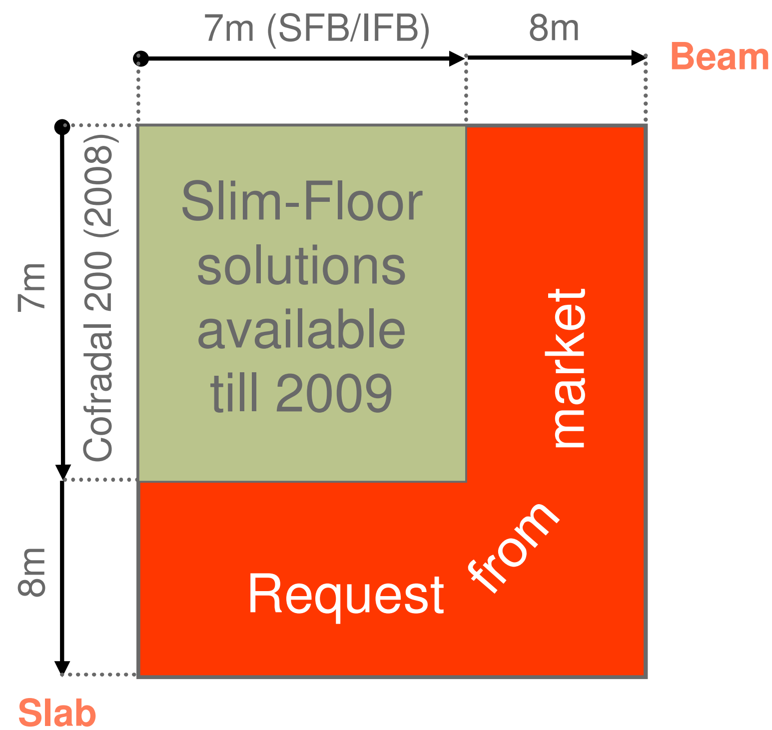
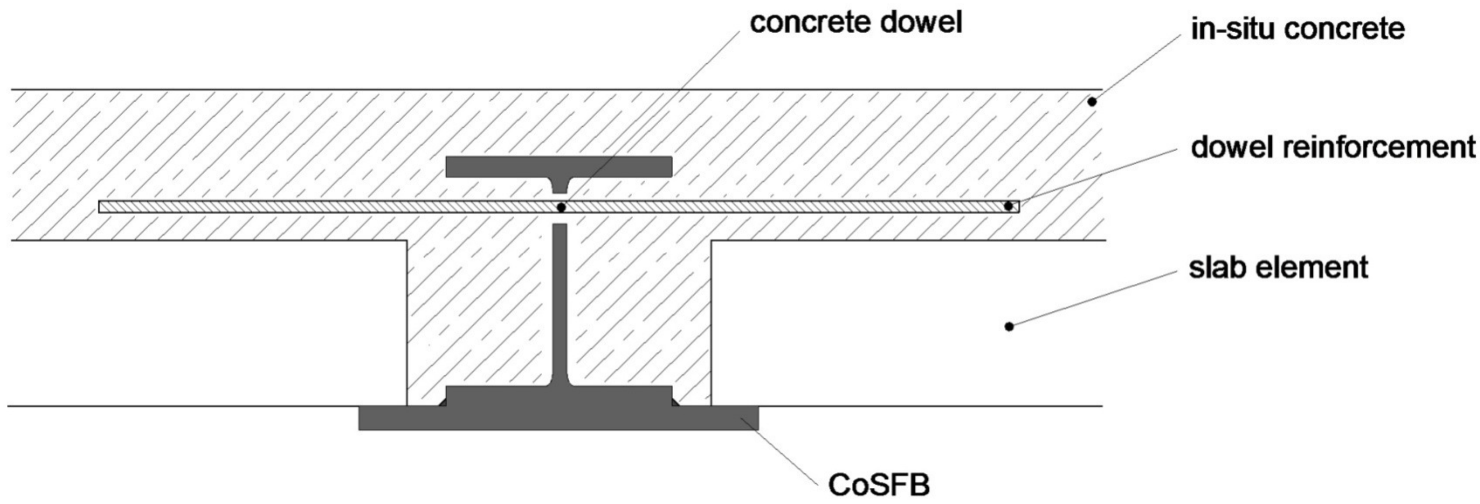


Limitations in ground floor design

Design: CoSFB – Composite slim-floor beam

German Technical Approval “CoSFB-Betondübel”



CoSFB-Betondübel = reinforced concrete dowel, new method to assure composite action

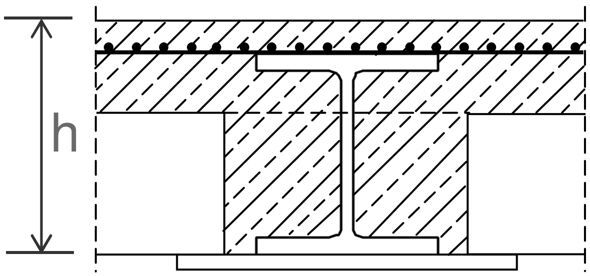
Fits perfectly to slim-floor construction (= integrated beams)

Allows for significant increase of the beam span (up to 14m)

Design: CoSFB – Composite slim-floor beam

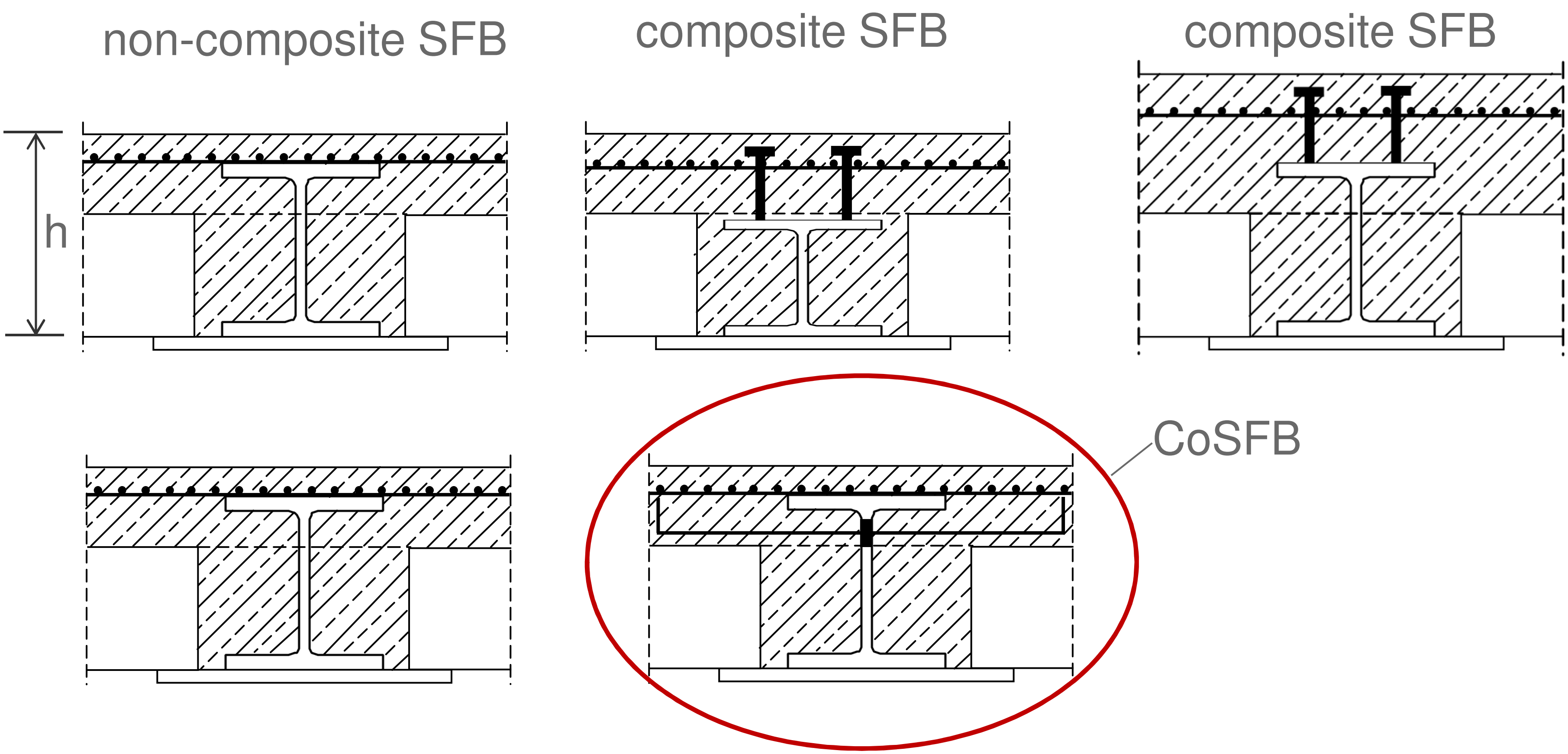
CoSFB – Why not imply shear studs?

non-composite SFB



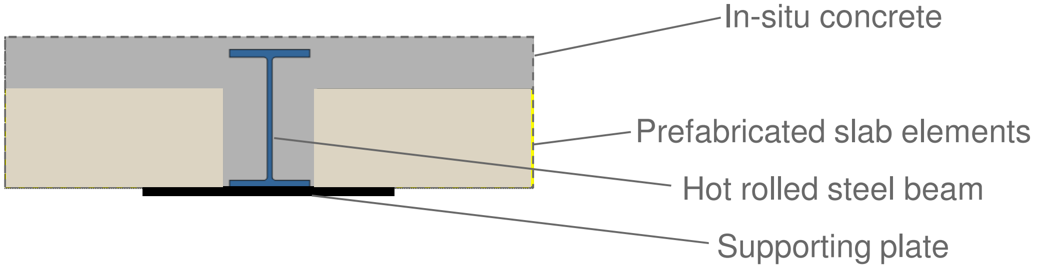
Design: CoSFB – Composite slim-floor beam

CoSFB – Why not imply shear studs?



Design: CoSFB – Composite slim-floor beam

Standard SFB



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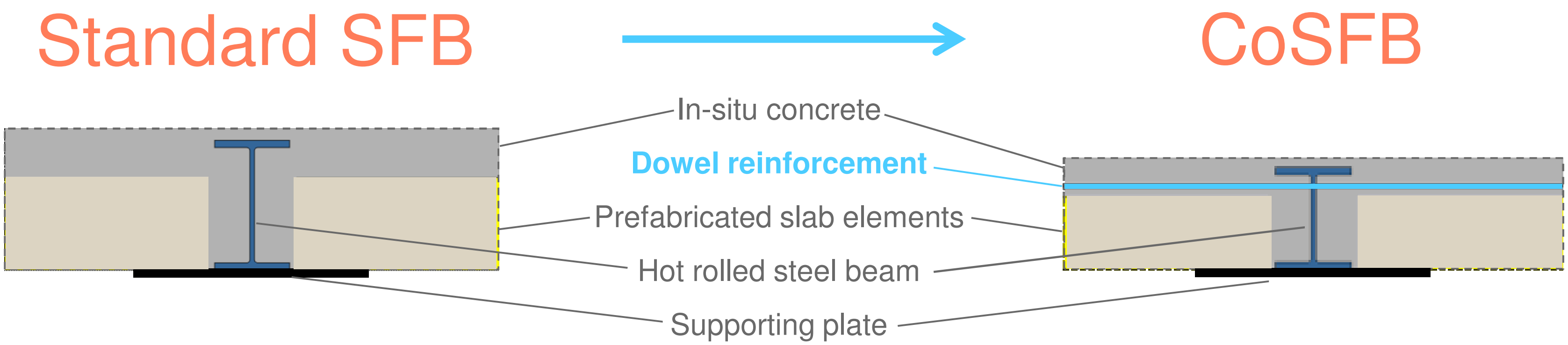
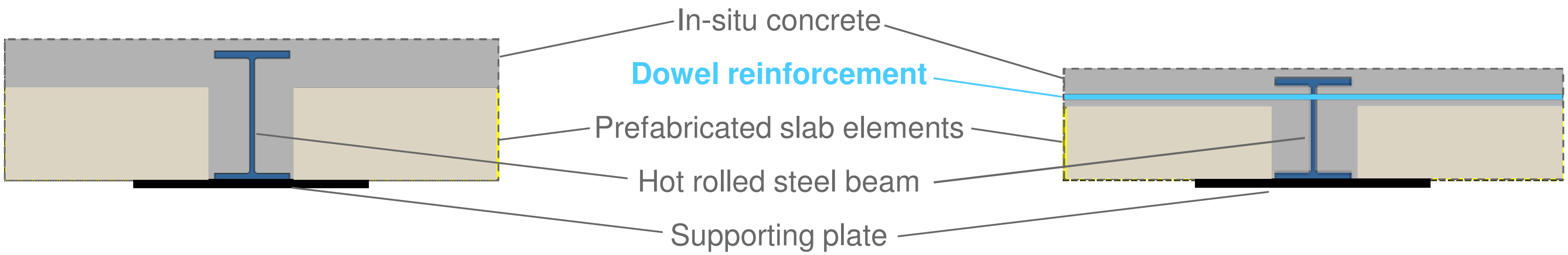
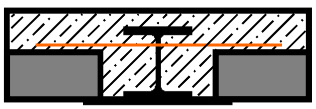


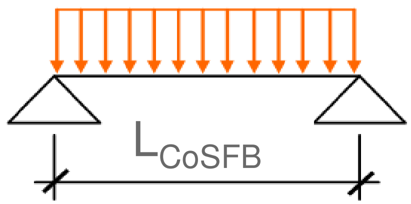
Design: CoSFB – Composite slim-floor beam

Standard SFB → CoSFB





HE320B + 500x25, S355



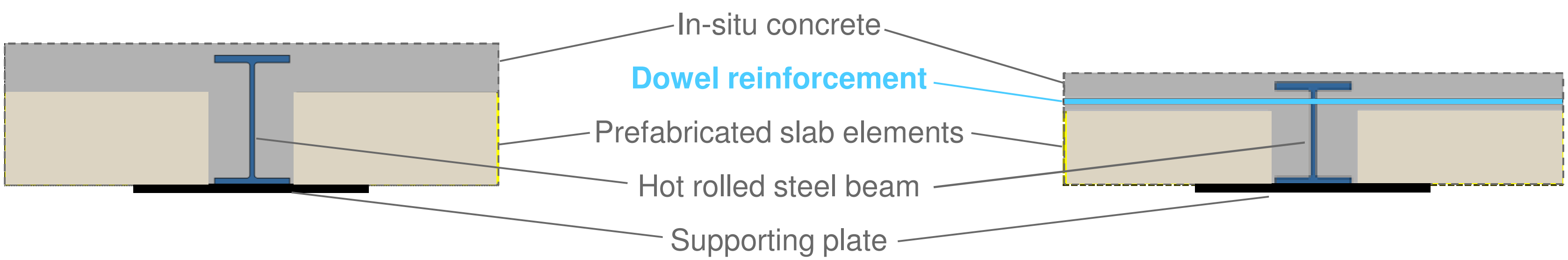
ULS: $1.35 \times g_k + 1.50 \times q_k$

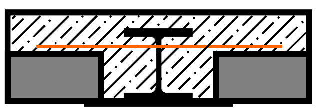
SLS: $1.00 \times g_k + 0.20 \times q_k$

Beam type	ULS - Moment	SLS - n. Frequency	Max. Span
SFB (non-composite) $M_{pl,Rd} = 890kNm$ $I_y \approx 52000cm^4$	$\mathbf{M_{Ed} / M_{pl,Rd} = 0.99 < 1.00}$	F = 3.6Hz > 3.0Hz	
CoSFB (C30/37, $b_{eff} = 2.75m$) $M_{pl,Rd} = 2000kNm$ $I_{y,0} \approx 140000cm^4$ Dowel reinf.: 8∅12 per meter	$M_{Ed} / M_{pl,Rd} = 0.82 < 1.00$	**F = 3.0Hz > 3.0Hz**	

Design: CoSFB – Composite slim-floor beam

Standard SFB → CoSFB





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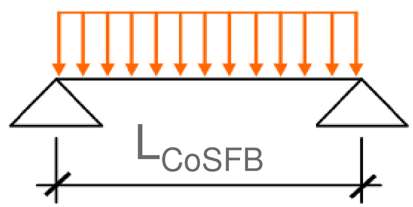

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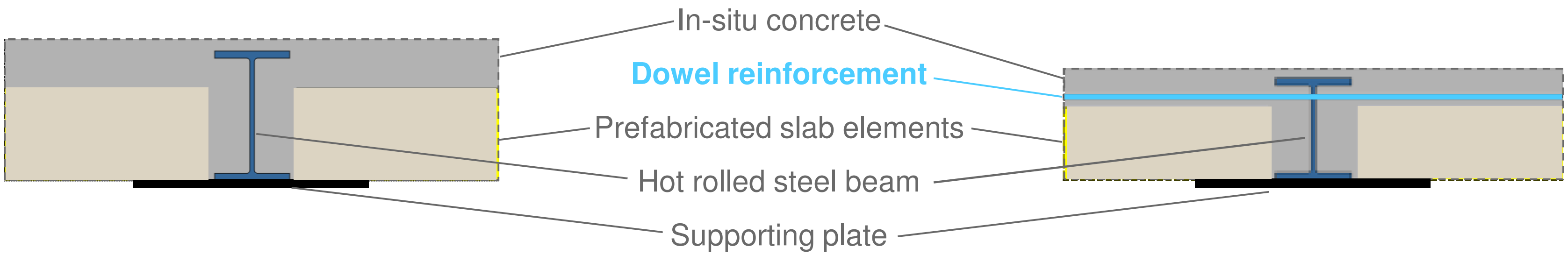
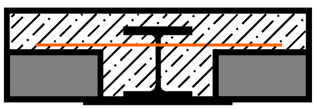
Design: CoSFB – Composite slim-floor beam

Standard SFB → CoSFB





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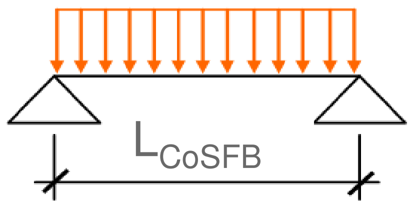

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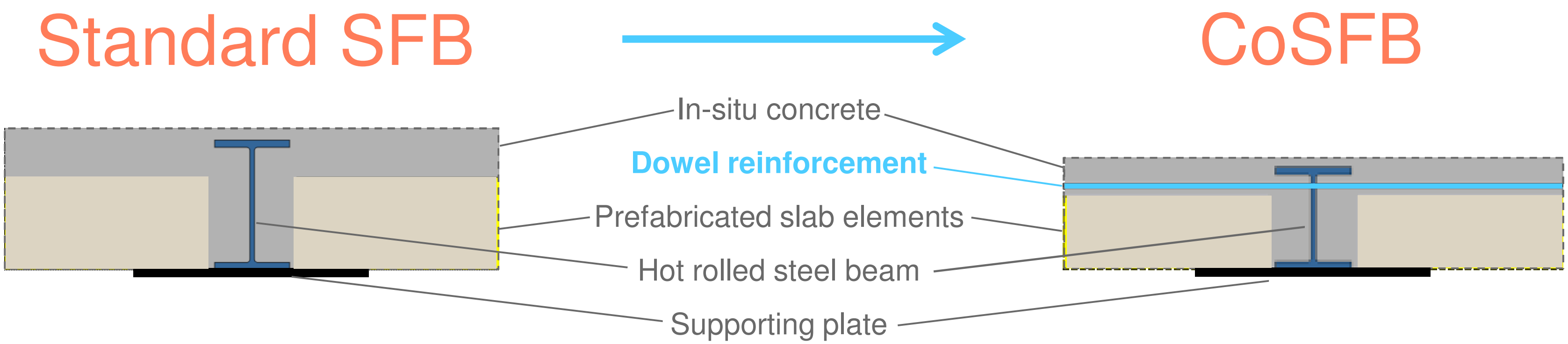
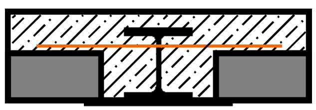
Design: CoSFB – Composite slim-floor beam





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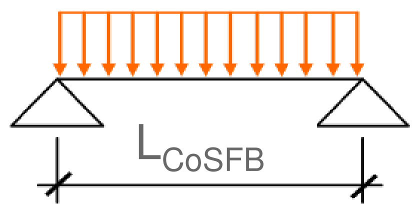

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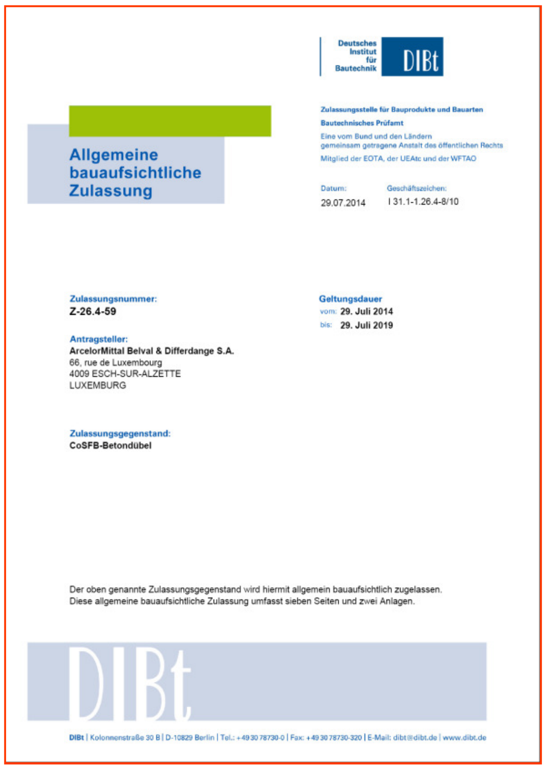
Design: CoSFB – Composite slim-floor beam

Test program:

- Global structural behaviour
  (load-deformation, effective width, vibration) (**Beam Tests**)
- Capacity of the shear connection
  (Push-Out Tests & **Shear Beam Tests**)



Deutsches Institut für Bautechnik DIBt

Allgemeine bauaufsichtliche Zulassung

Zulassungsstelle für Bauprodukte und Bauarten
Bautechnisches Prüfamt
Eine vom Bund und den Ländern gemeinsam getragene Anstalt des öffentlichen Rechts
Mitglied der EOTA, der UEAtc und der WFTAO

Datum: 29.07.2014
Geschäftszeichen: I 31.1-1.26.4-8/10

Zulassungsnummer:
Z-26.4-59

Geltungsdauer
vom: 29. Juli 2014
bis: 29. Juli 2019

Antragsteller:
ArcelorMittal Belval & Differdange S.A.
66, rue de Luxembourg
4009 ESCH-SUR-ALZETTE
LUXEMBURG

Zulassungsgegenstand:
CoSFB-Betondübel

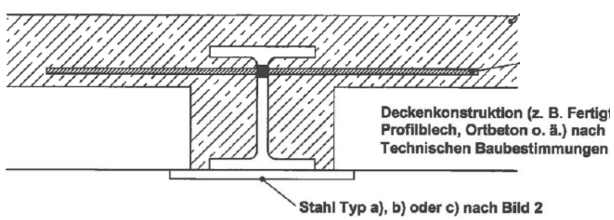
Der oben genannte Zulassungsgegenstand wird hiermit allgemein bauaufsichtlich zugelassen.
Diese allgemeine bauaufsichtliche Zulassung umfasst sieben Seiten und zwei Anlagen.

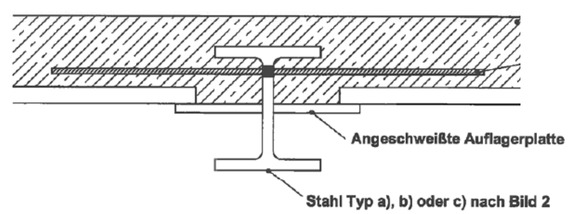
DIBt

DIBt | Kolonnenstraße 30 B | D-10829 Berlin | Tel.: +49 30 78730-0 | Fax: +49 30 78730-320 | E-Mail: dibt@dibt.de | www.dibt.de

P_{Rk} in [kN] $\gamma_V = 1,25$

Concrete class / web thickness	C25/30	C30/37	C35/45	C40/50 - C55/67
7,5 mm $\leq t_w <$ 15,5 mm	117	125	135	122
15,5 mm $\leq t_w$	148	157	166	122





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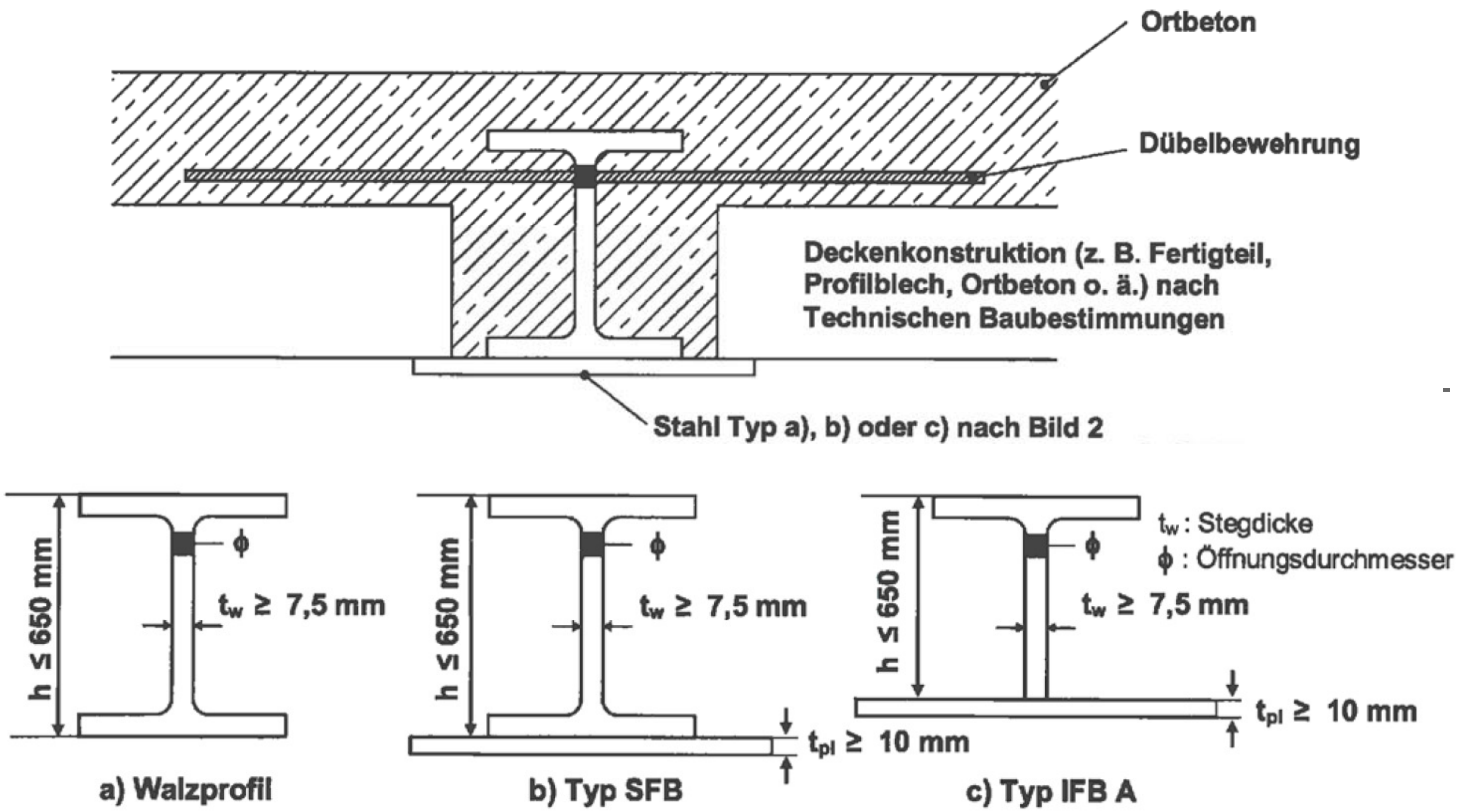
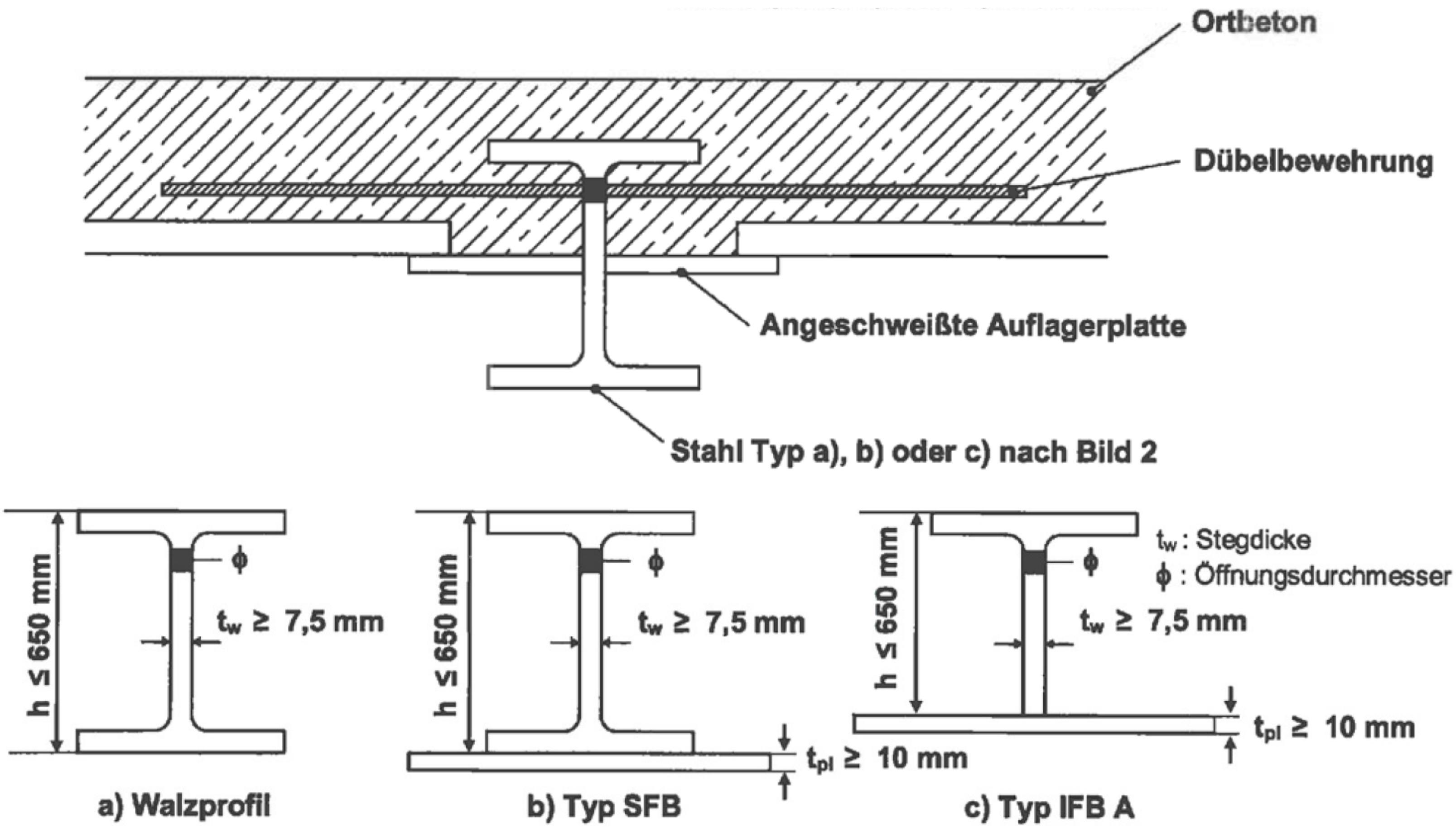


Bild 2 : Zulässige Querschnittsformen der Stahlträger

Design: CoSFB – Composite slim-floor beam



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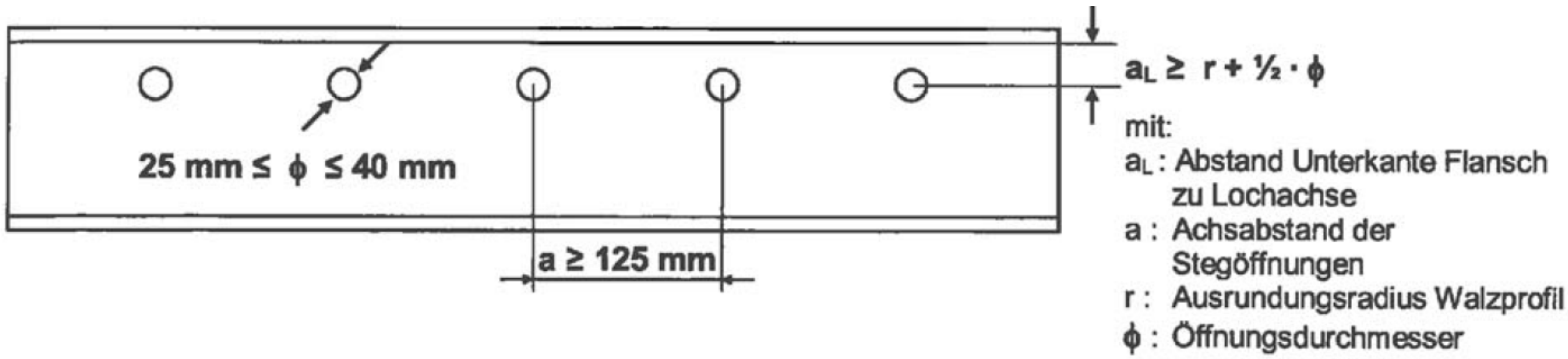
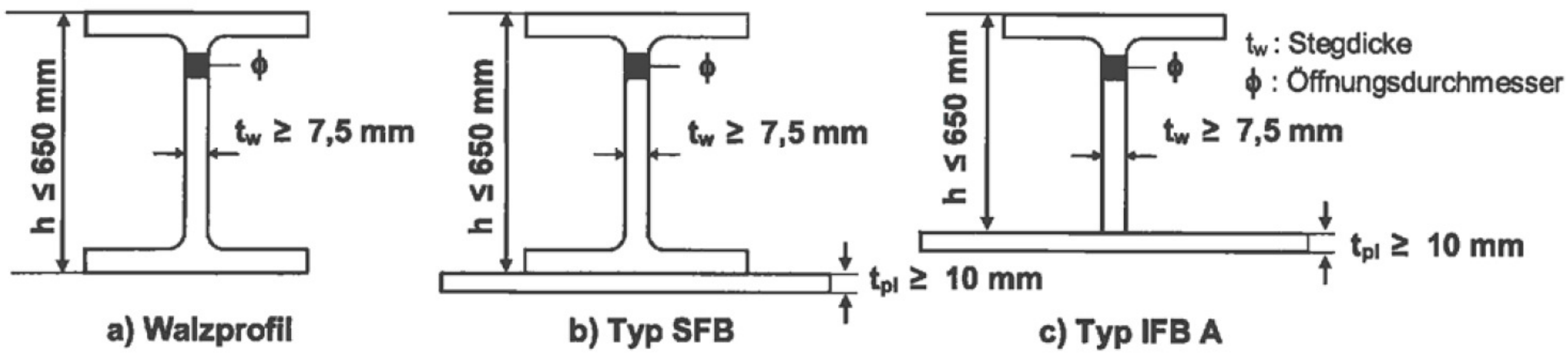


Bild 3 : Position der Bohrungen im Steg der Stahlträger



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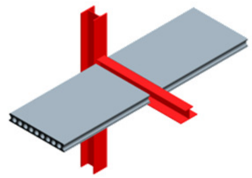
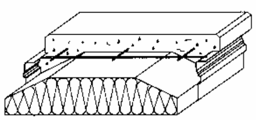
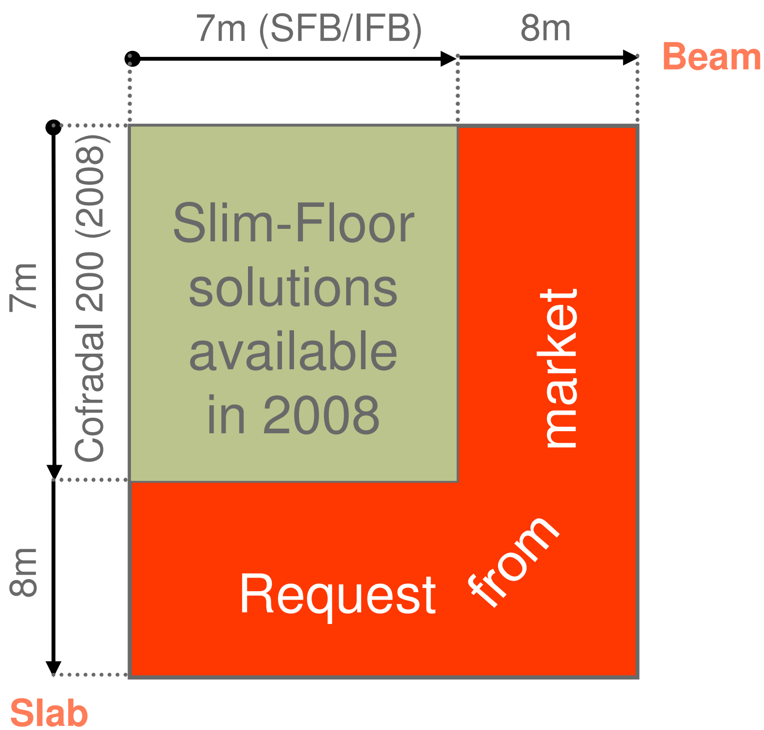
Design: CoSFB – Composite slim-floor beam

Standard SFB







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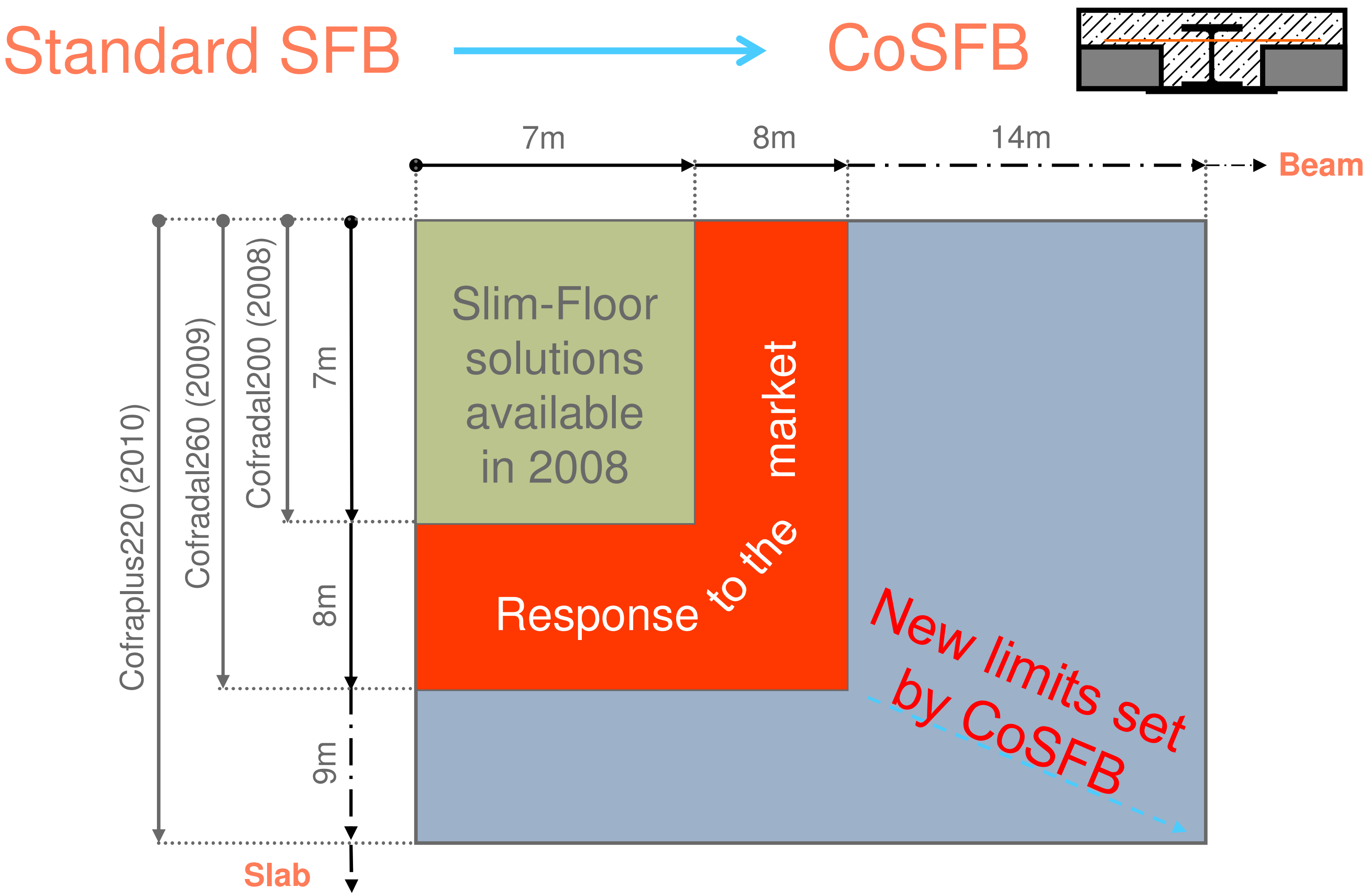
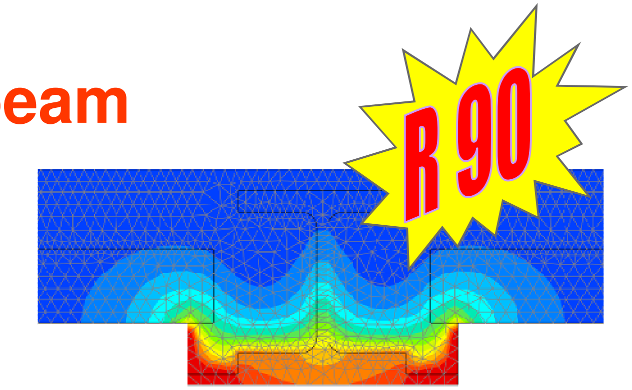


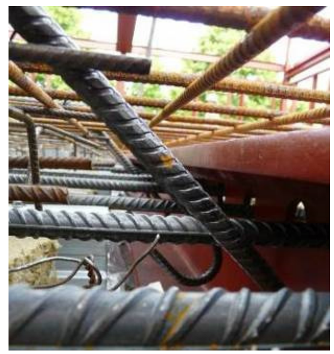
Design: CoSFB – Composite slim-floor beam

AM Building in Maizières-les-Metz (R+1):

- Area > 400m² / floor (12.3m x 33.7m)
- Tonnage >11to of CoSFB
- Section HE260B, S355M
- Slab system Cofradal®260



⇒ Integrated fire protection

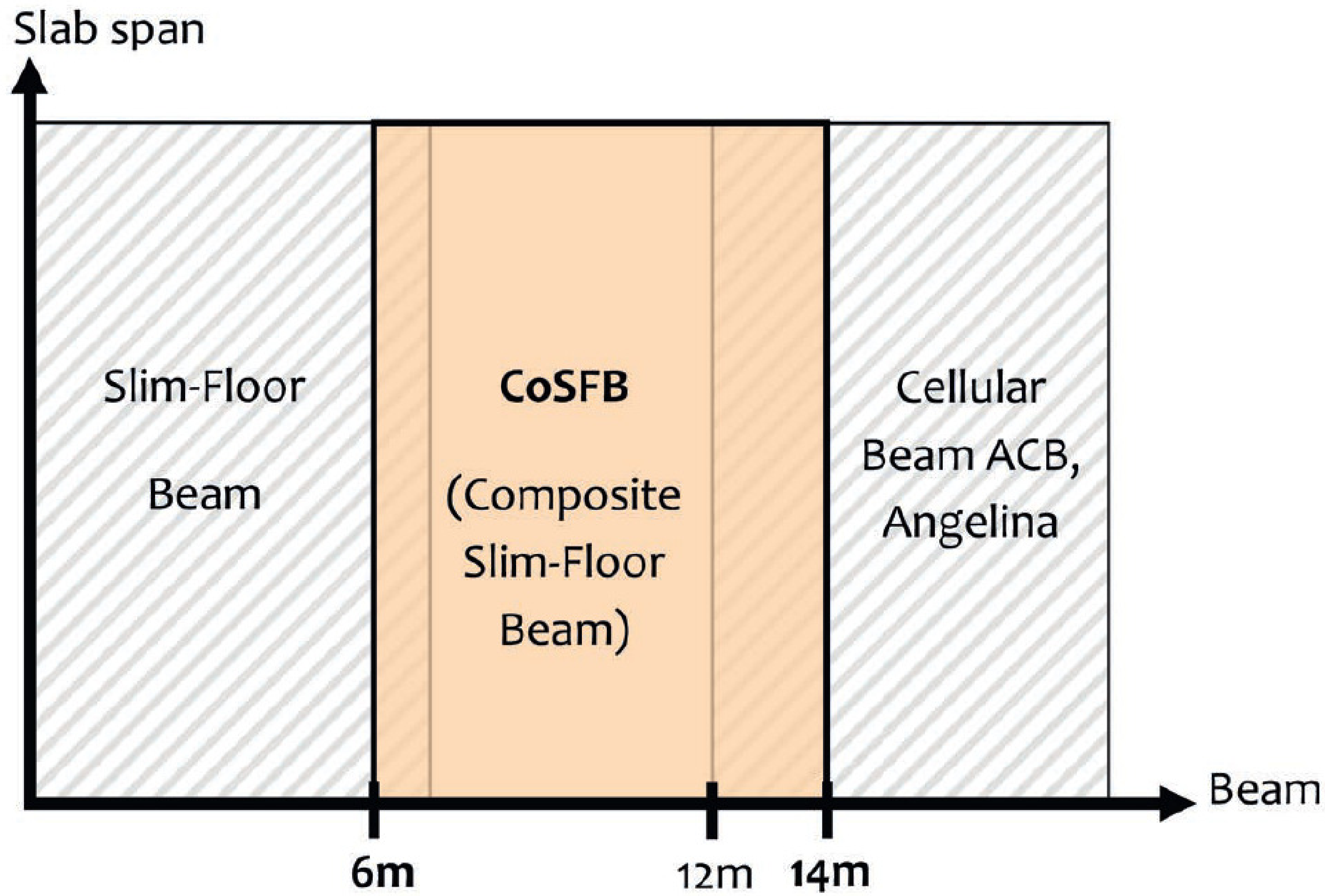


Collège de Gignac, F

Plein ciel - St. Nazaire, F

Hoche - Nimes, F

Concept: Floors



⇒ CoSFB fills the gap between non-composite SFB and Long span solutions (e.g. ACB, Angelina…)

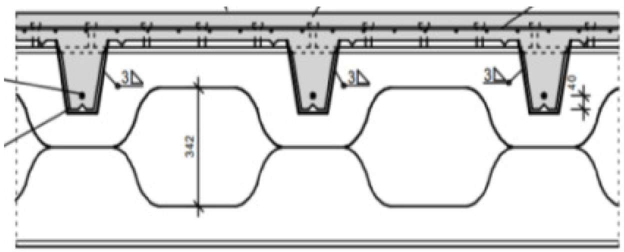
Concept: Cellular Beams

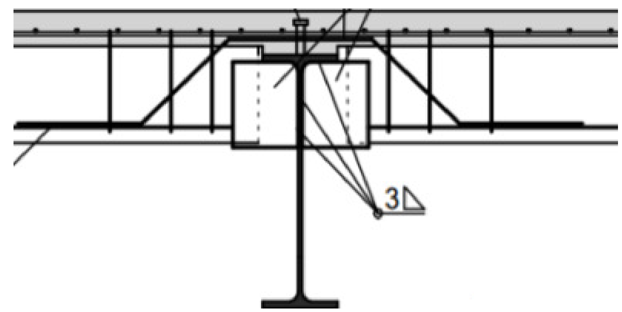
Angelina beam

C. Vasconi

ENOVOS Parking (LU)

Efficient erection as part of the system





ENOVOS Parking (LU)

Steel framed car parks

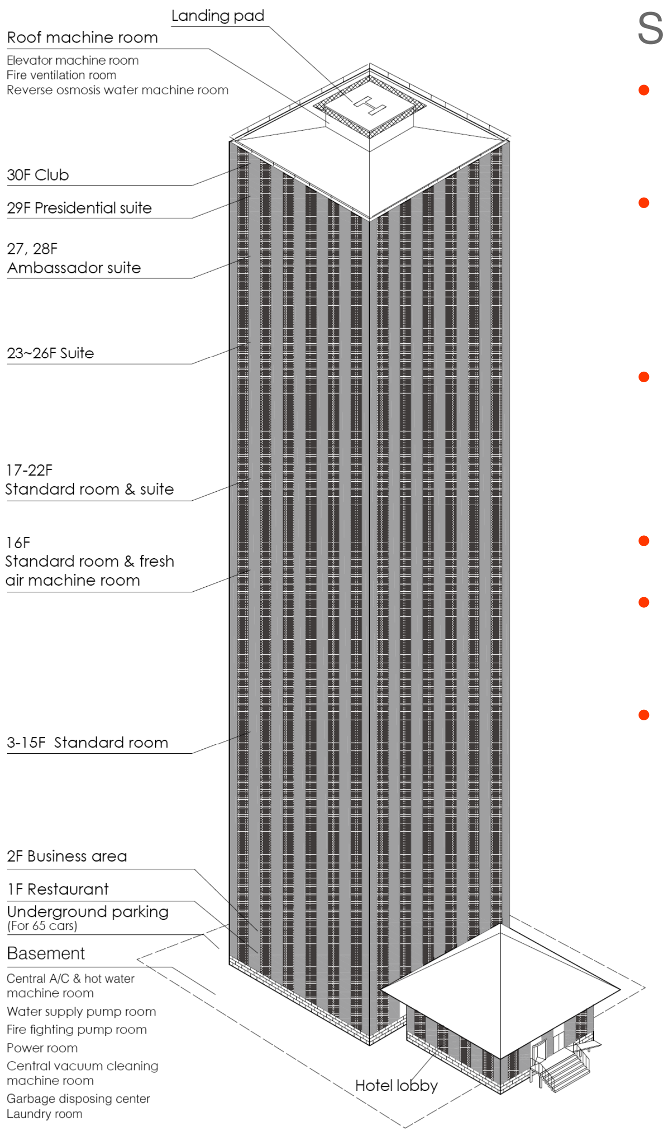
- Fast construction progress
- Flexible design of parking space without columns
- Aligned level of user comfort (i.e. commercial, airport, P&R, city centre)
- Low weight of the entire structure
- Less & smaller foundation works
- Possibility to extend existing buildings
- Material efficient construction methods including de-construction & recycling

Usual disposal of columns avoided

Steel Tower T30 by Broad

BROAD SUSTAINABLE BUILDING
远大可建科技有限公司

30 floors hotel build in 15 days



Sustainability (compared with conventional buildings):

- Prefabricated steel building with construction waste less than 1%
- 9 magnitude earthquake resistance
  - 10~20% less steel consumption
  - 80~90% less concrete consumption
- 5 times energy efficiency,
  20 times purer air,
  10%~30% lower in cost
- Low cost due to high automation level (use phase)
- Amazing construction speed, while zero injury during construction process (360 hours)
- Perfect construction quality, while no fire, no water & no dust (no welding, no concrete, and no polish with emery cloth)

Steel Tower T30 by Broad

BROAD SUSTAINABLE BUILDING
远大可建科技有限公司

World Wide Inspiration on Steel Construction

ArcelorMittal

Matthias BRAUN
Oliver HECHLER
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Broad Film

youtube.com

[redacted]

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Thank You!