Overview of R&D programmes

Prof. Dr. Olivier Vassart

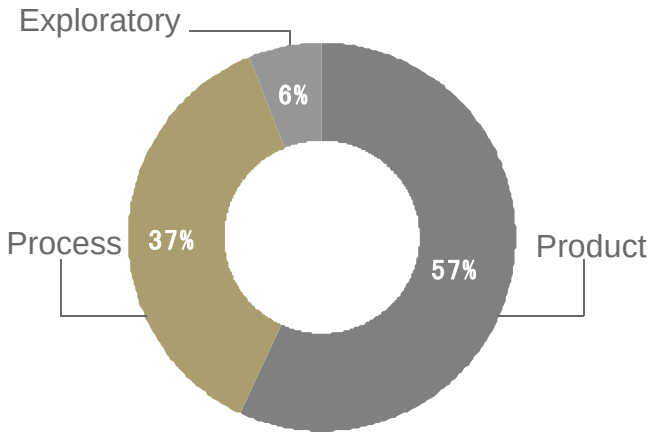
ArcelorMittal

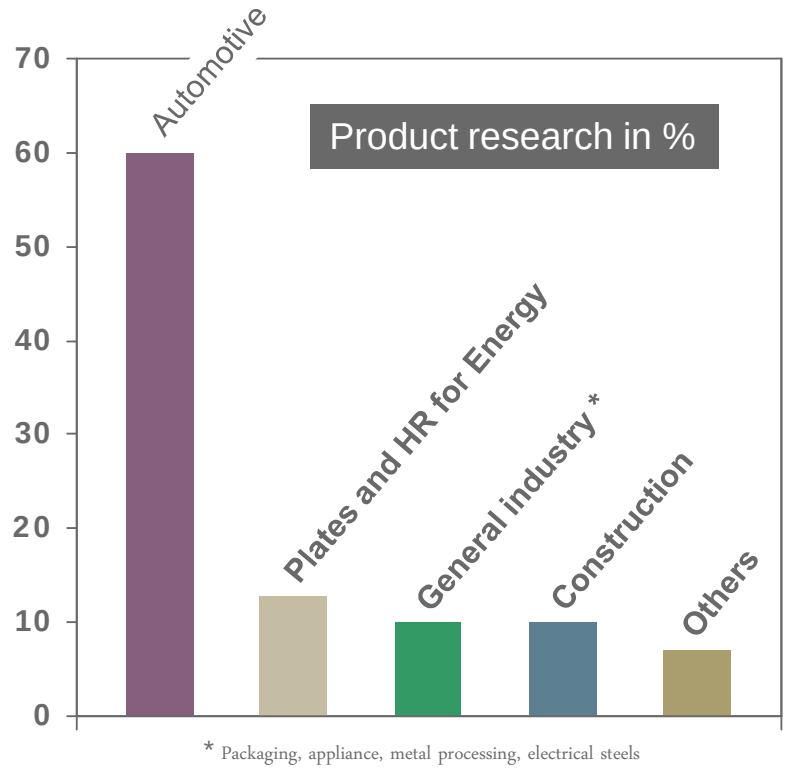
$$\frac{\partial f_{i,j}(\vec{x},\vec{c})}{\partial x_i} = \sum_{k \neq i} c_{k,j}$$

The right formula
for the steels of the future

Global R&D Key Facts and Figures

- 1,300 full time researchers
- 2014 spending of $260m
- Broad, comprehensive portfolio and programmes addressing business needs
- Worldwide network of laboratories: 12 labs in Europe and Americas
- Budget spending by focus area:



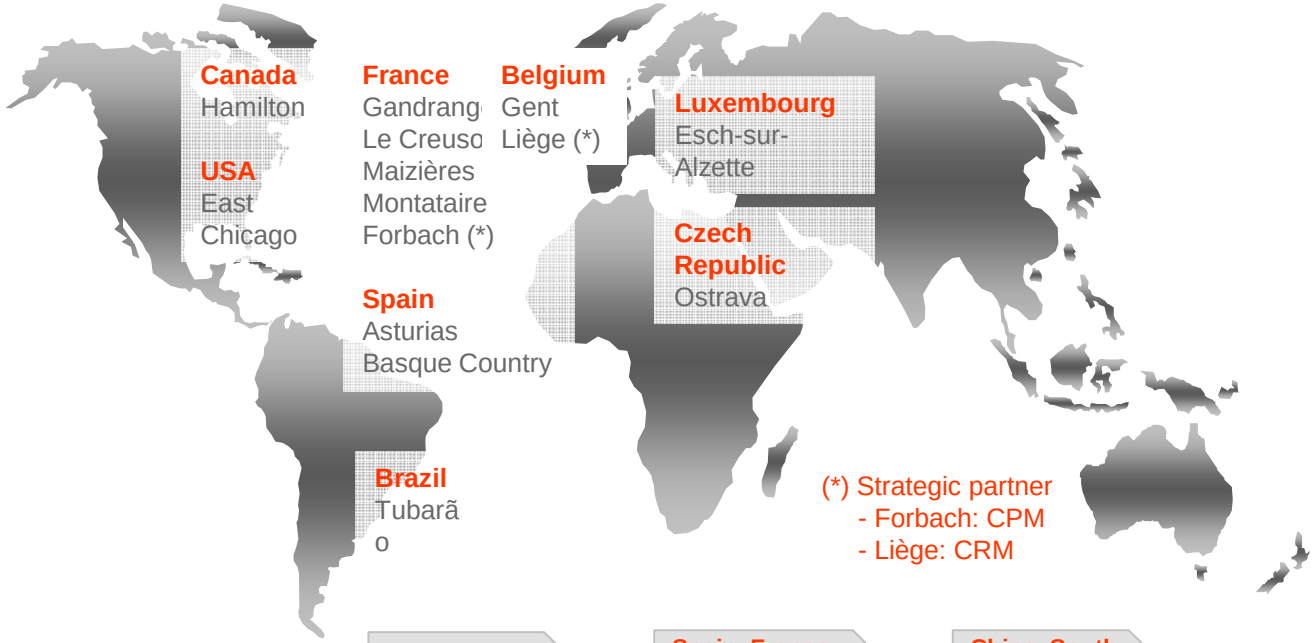


R&D effort fully aligned with group strategy: geography, value chain, product differentiation

… across 12 research centres and at customer locations on 3 continents…





Canada, USA | **Spain, France, Germany, Italy** | **China, South Korea, Japan**

On-site product-portfolio deployment: Product Development Engineers Automotive Residents, Process Development & Deployment Specialists



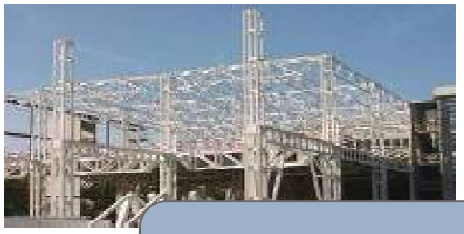

February 2016

ArcelorMittal

Construction Portfolio

R&D Review - Long Products

R&D Construction Long Products



Sections

Bars & Wires Fiber

Sheet Piles

AM approach towards market needs and requests

MARKET NEEDS			R&D ANSWERS New Products and Concept	Example of applications
Regulations	Safety	SEISMIC	Energy Absorption Connections ☞"Dog Bone"	High Rise Buildings
		FIRE	Structural Fire Engineering ☞Natural Fire Safety Concept	AM Flemalle, Turquish scholl, AOB, CACTUS ESCH;
	Sustainability		New Products to minimize Energy & Carbon Foot Print	HISTAR, ARCOROX L300 Wind Tower
Architecture	Flexibility		Slimfloor	Hollerich
	Transparancy		Cellular Beams	Airport Limasol
Design	Innovative design improvements		Advanced Design Methods implemented in userfriendly design tools	Download Center *www.arcelormittal.com/sections*
Economical performing			Composite Construction	Bridges PreCoBeam
			HISTAR Gr 70	High rise buildings
			Jumbo / HD sections	

AM approach towards market needs and requests

MARKET NEEDS			R&D ANSWERS New Products and Concept	Example of applications
Regulations	Safety	SEISMIC	Energy Absorption Connections ☞"Dog Bone"	High Rise Buildings
		FIRE	Structural Fire Engineering ☞Natural Fire Safety Concept	AM Flemalle, Turquish scholl, AOB, CACTUS ESCH;
	Sustainability		New Products to minimize Energy & Carbon Foot Print	HISTAR, ARCOROX L300 Wind Tower
Architecture	Flexibility		Slimfloor	Hollerich
	Transparancy		Cellular Beams	Airport Limasol
Design	Innovative design improvements		Advanced Design Methods implemented in userfriendly design tools	Download Center *www.arcelormittal.com/sections*
Economical performing			Composite Construction	Bridges PreCoBeam
			HISTAR Gr 70	High rise buildings
			Jumbo / HD sections	

VERSATILITY OF STEEL

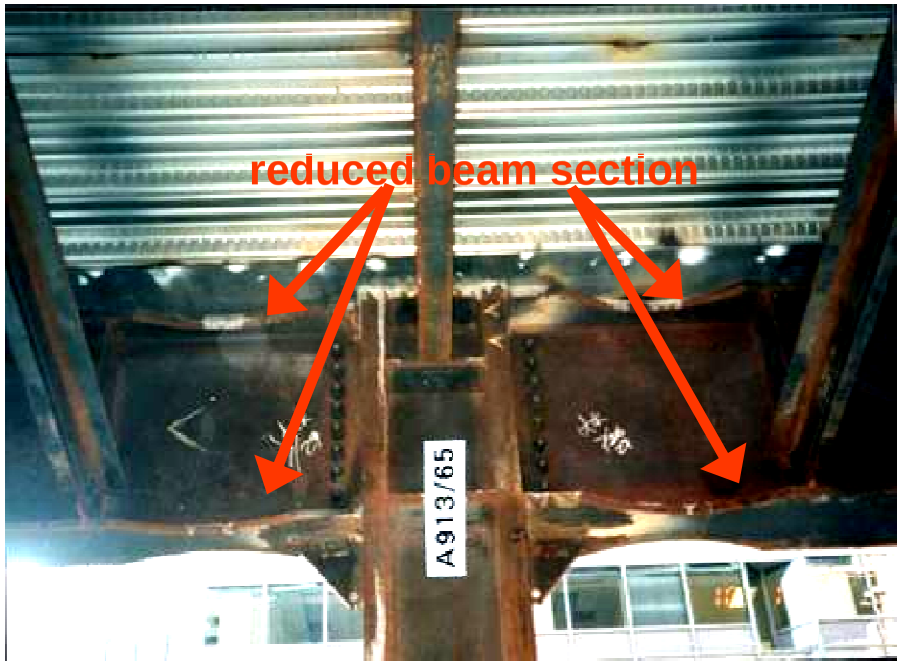
- High rise buildings / Seismic safety

"Strong column - weak beam" Concept with "reduced section beam"

199 Fremont, San Francisco, USA Courtesy KMD architects

Column: A913 Grade 65

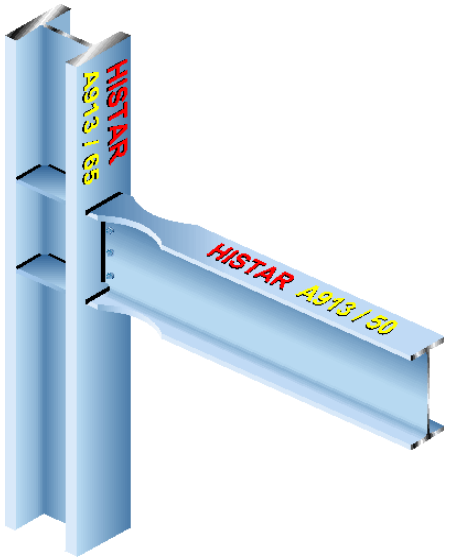
Beam: Grade 50

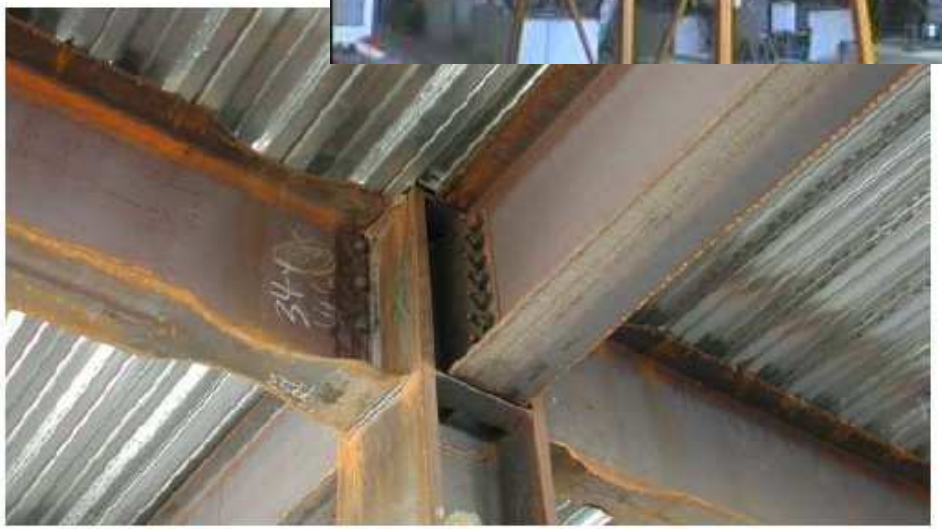


Courtesy EQE International

EARTHQUAKE RESISTANCE - New Product

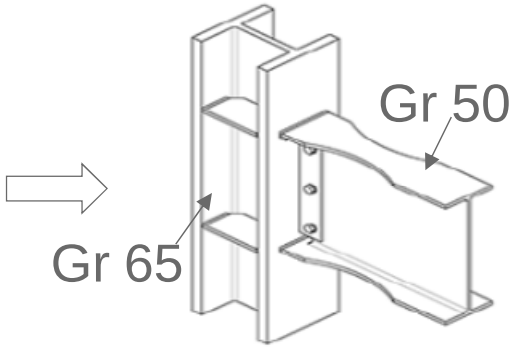
Investigation Field		Deliverables			
		Standards	Design aids	Promotion	New Prod/Sol
	Fire Resistance Design				
	Composite Construction				
	Earthquake Resistance				
	ACB				
	Other (Eurocode)				
	Composite Bridges				

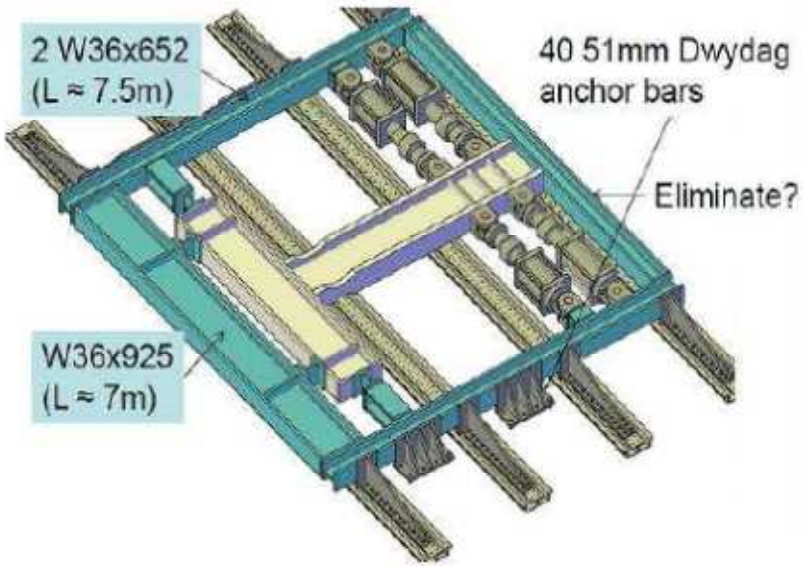


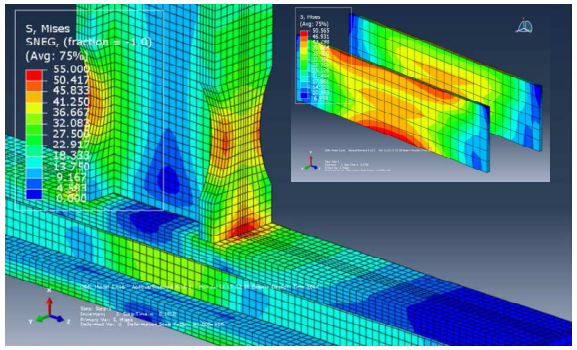


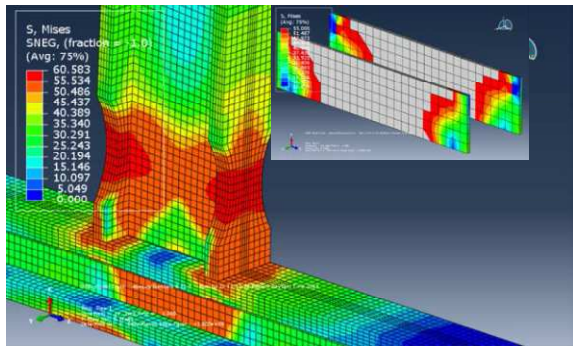
Testing Frame Design

- Dog-bone connections and test frame:







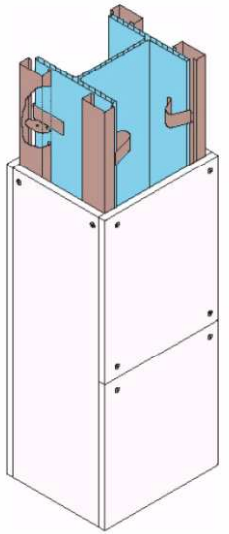


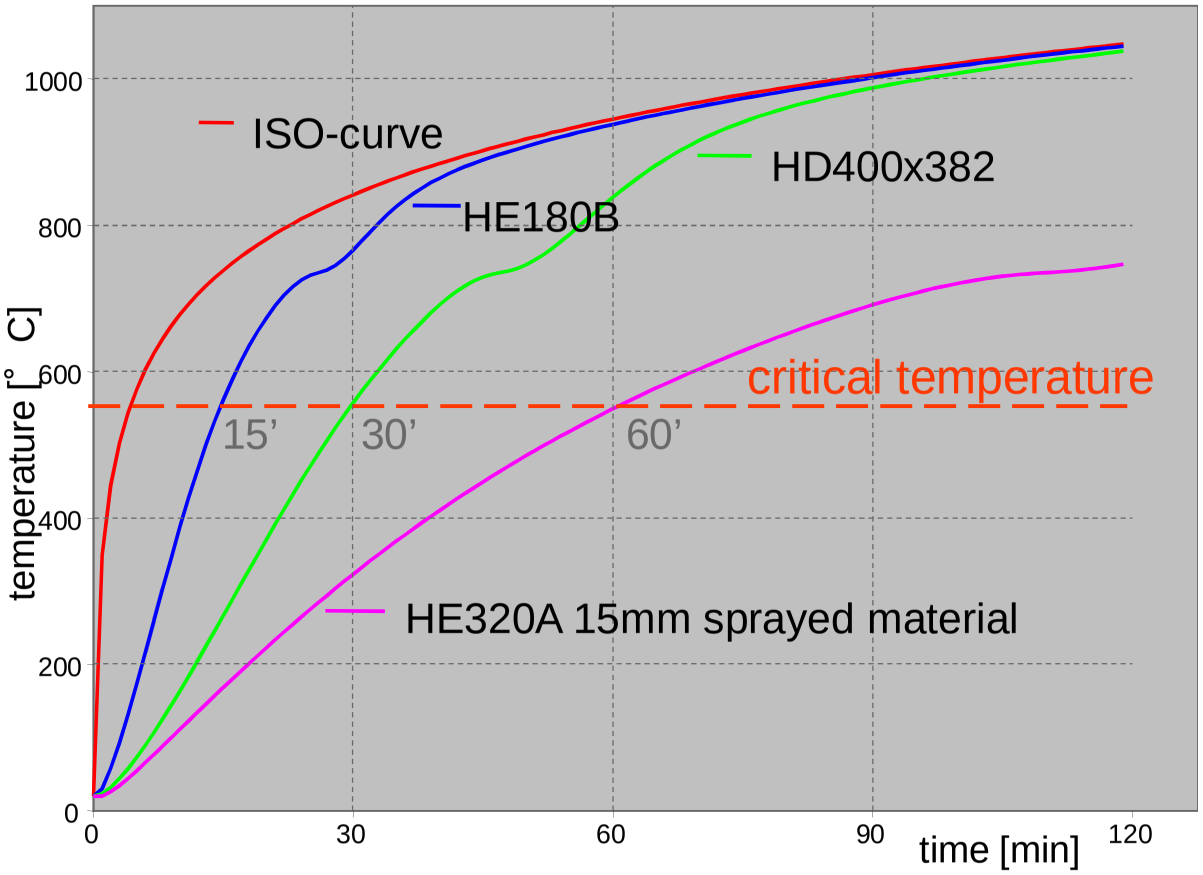
- So far, FEA performed on specimens before fabrication to ensure correct behaviour:

AM approach towards market needs and requests

MARKET NEEDS			R&D ANSWERS New Products and Concept	Example of applications
Regulations	Safety	SEISMIC	Energy Absorption Connections ☞"Dog Bone"	High Rise Buildings
		FIRE	Structural Fire Engineering ☞Natural Fire Safety Concept	AM Flemalle, Turquish scholl, AOB, CACTUS ESCH;
	Sustainability		New Products to minimize Energy & Carbon Foot Print	HISTAR, ARCOROX L300 Wind Tower
Architecture	Flexibility		Slimfloor	Hollerich
	Transparancy		Cellular Beams	Airport Limasol
Design	Innovative design improvements		Advanced Design Methods implemented in userfriendly design tools	Download Center *www.arcelormittal.com/sections*
Economical performing			Composite Construction	Bridges PreCoBeam
			HISTAR Gr 70	High rise buildings
			Jumbo / HD sections	

Classical approach to single elements
ISO-834 heating curve

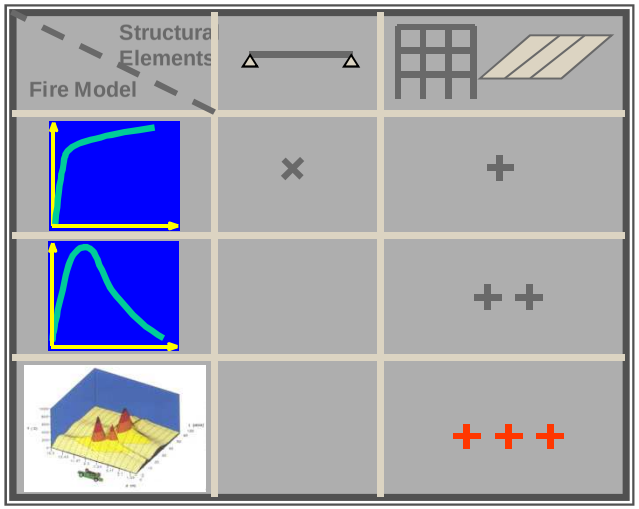


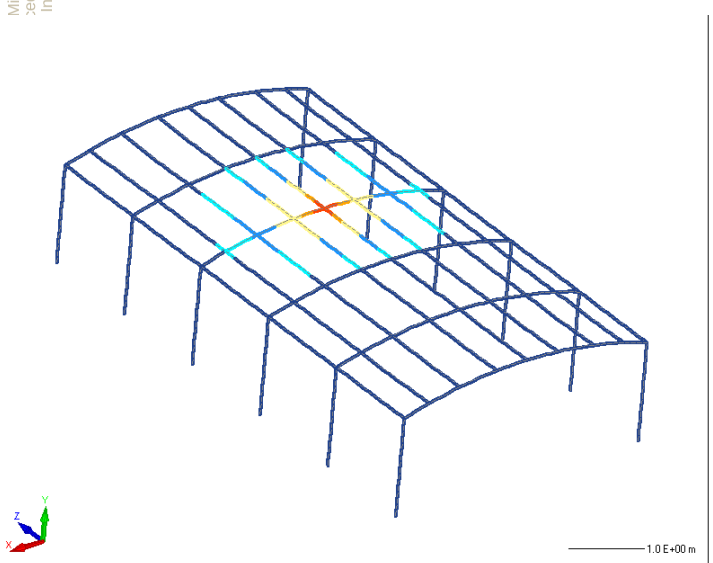


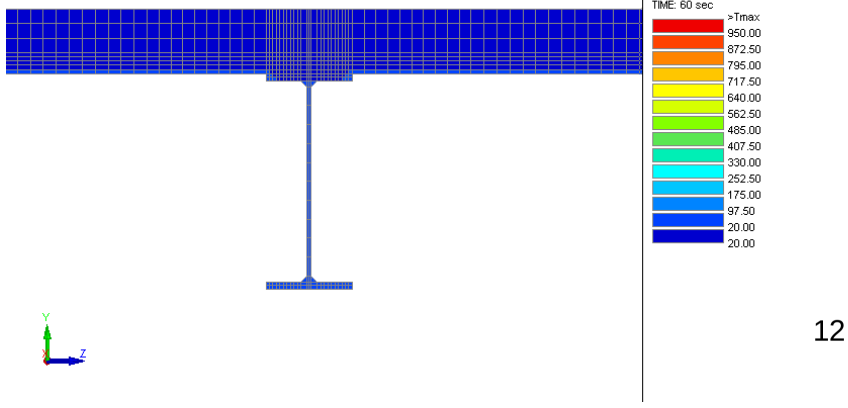
Additionnal cost of the protection > 40% of the cost of finished steel

The protection must be optimized and applied where it is really needed.

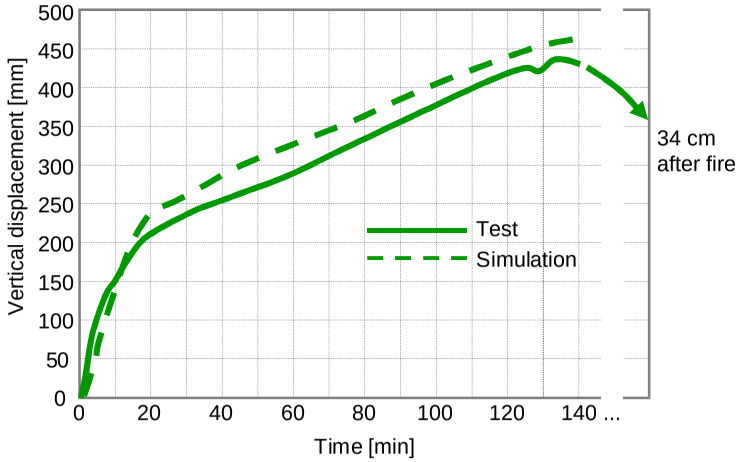
The “structural fire safety engineering” approach Eurocodes 1, 3 et 4



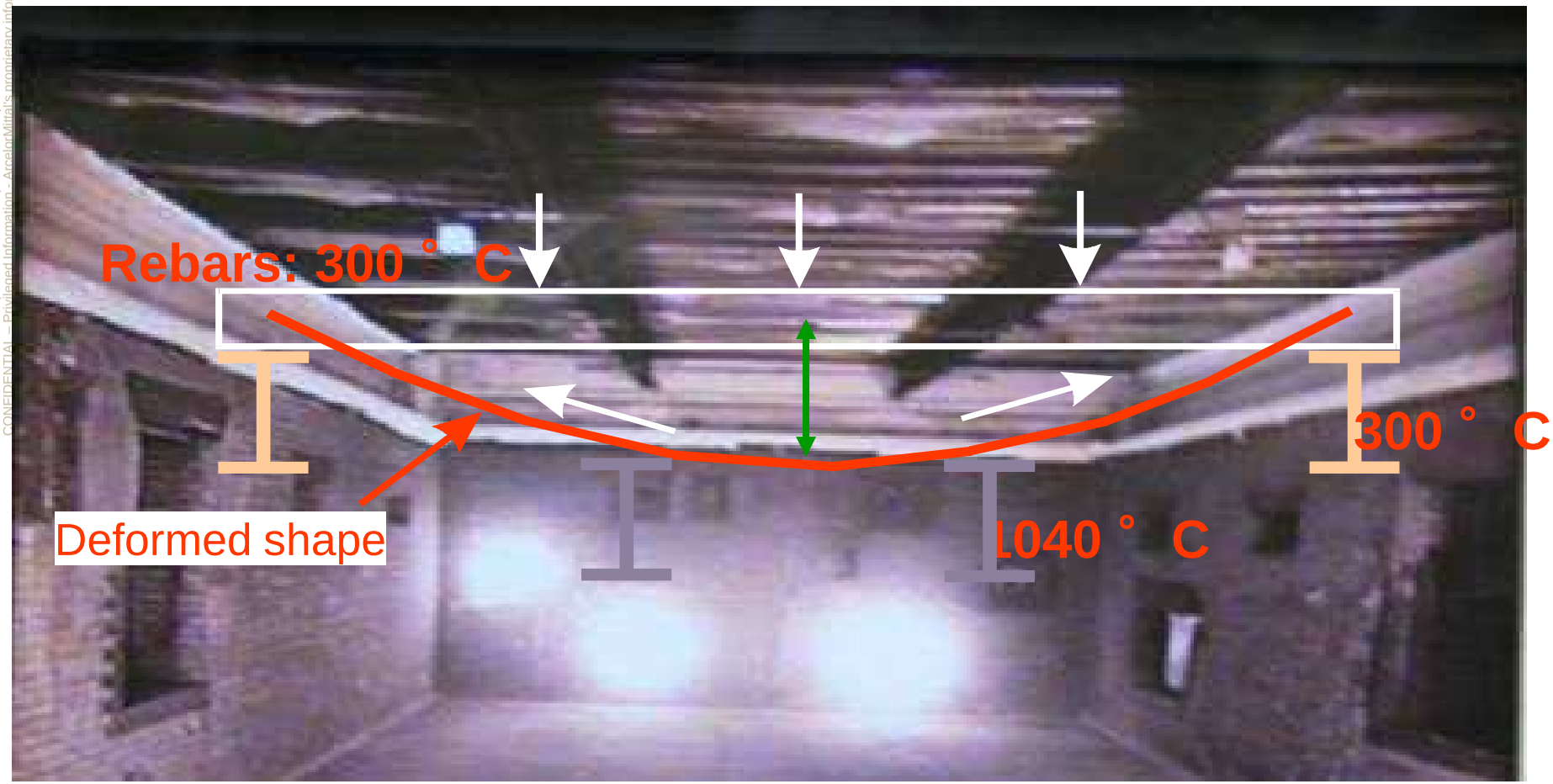


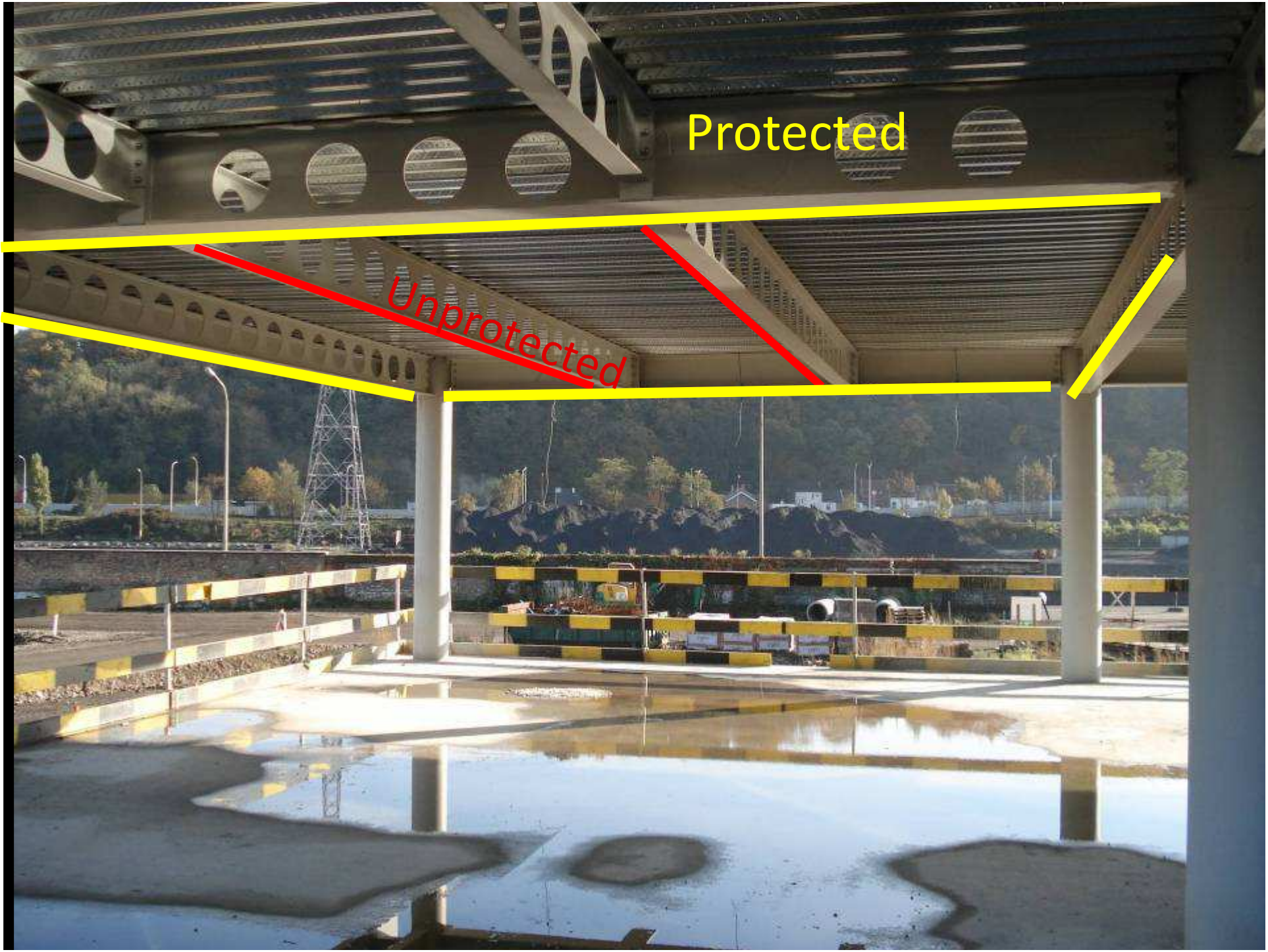


Test results
R > 120 minutes



ArcelorMittal




Protected
Unprotected

ArcelorMittal

FireSERT - University of Ulster

Primary beams protected
Secondary beams unprotected

Reference Buildings

School in Turkey

Switzerland

BOBST Building in Lausanne
Offices + Production

INGENIEURS CONSEILS SA

Switzerland

Congress centre of EPFL in Lausanne

Crédit Suisse / HRS / Richter-Dahl&Rocha

INGENI
INGENIERIE
STRUCTURALE

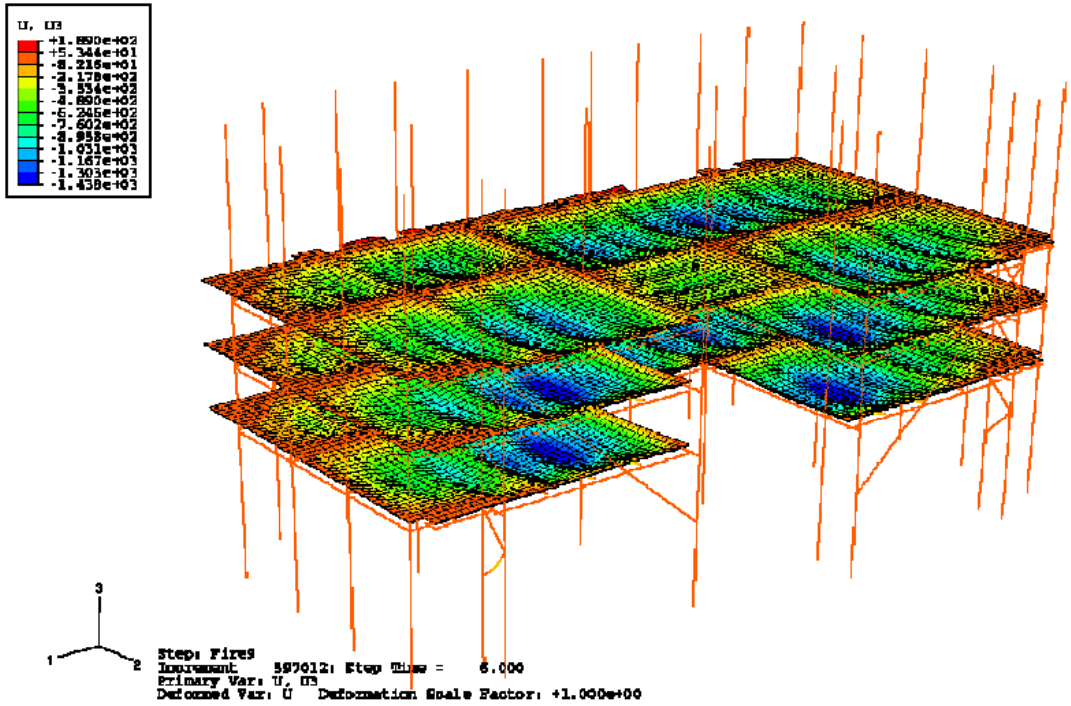
France

Car park of Toulouse Blagnac Airport

Belgium

Greich Office Building in Liège

United Kingdom



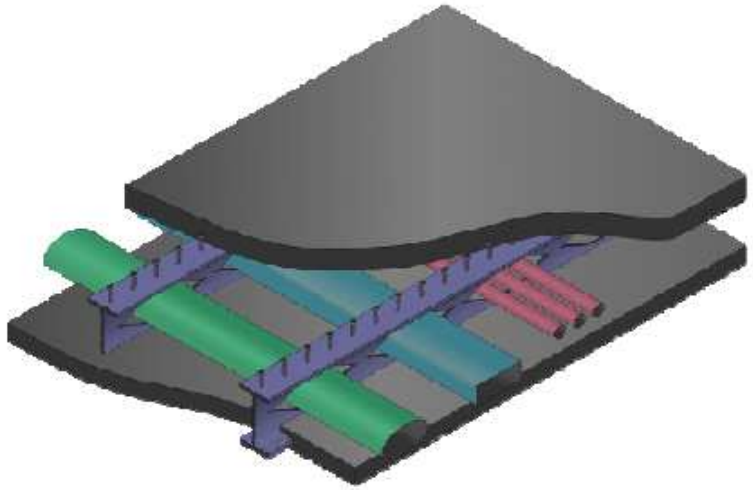
Heron Tower – Arup Fire London

AM approach towards market needs and requests

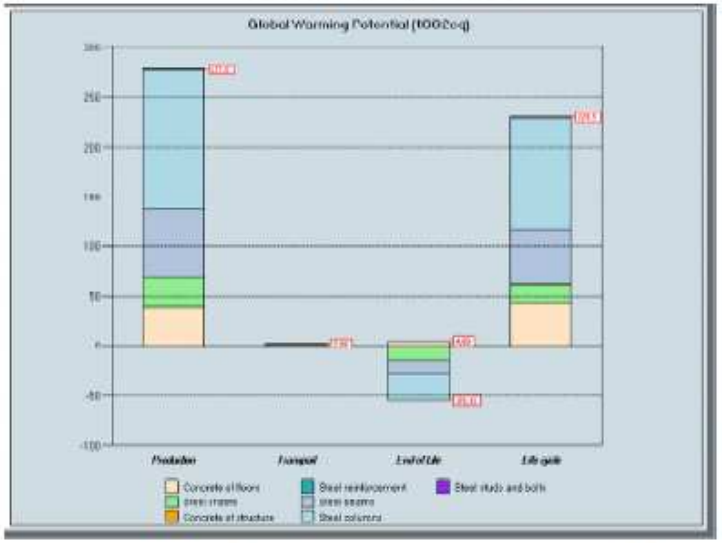
MARKET NEEDS			R&D ANSWERS New Products and Concept	Example of applications
Regulations	Safety	SEISMIC	Energy Absorption Connections ☞"Dog Bone"	High Rise Buildings
		FIRE	Structural Fire Engineering ☞Natural Fire Safety Concept	AM Flemalle, Turquish scholl, AOB, CACTUS ESCH;
	Sustainability		New Products to minimize Energy & Carbon Foot Print	HISTAR, ARCOROX L300 Wind Tower
Architecture	Flexibility		Slimfloor	Hollerich
	Transparancy		Cellular Beams	Airport Limasol
Design	Innovative design improvements		Advanced Design Methods implemented in userfriendly design tools	Download Center *www.arcelormittal.com/sections*
Economical performing			Composite Construction	Bridges PreCoBeam
			HISTAR Gr 70	High rise buildings
			Jumbo / HD sections	

Environemental optimisation of buildings

Passiv House SIEEB – Beijing, CNY

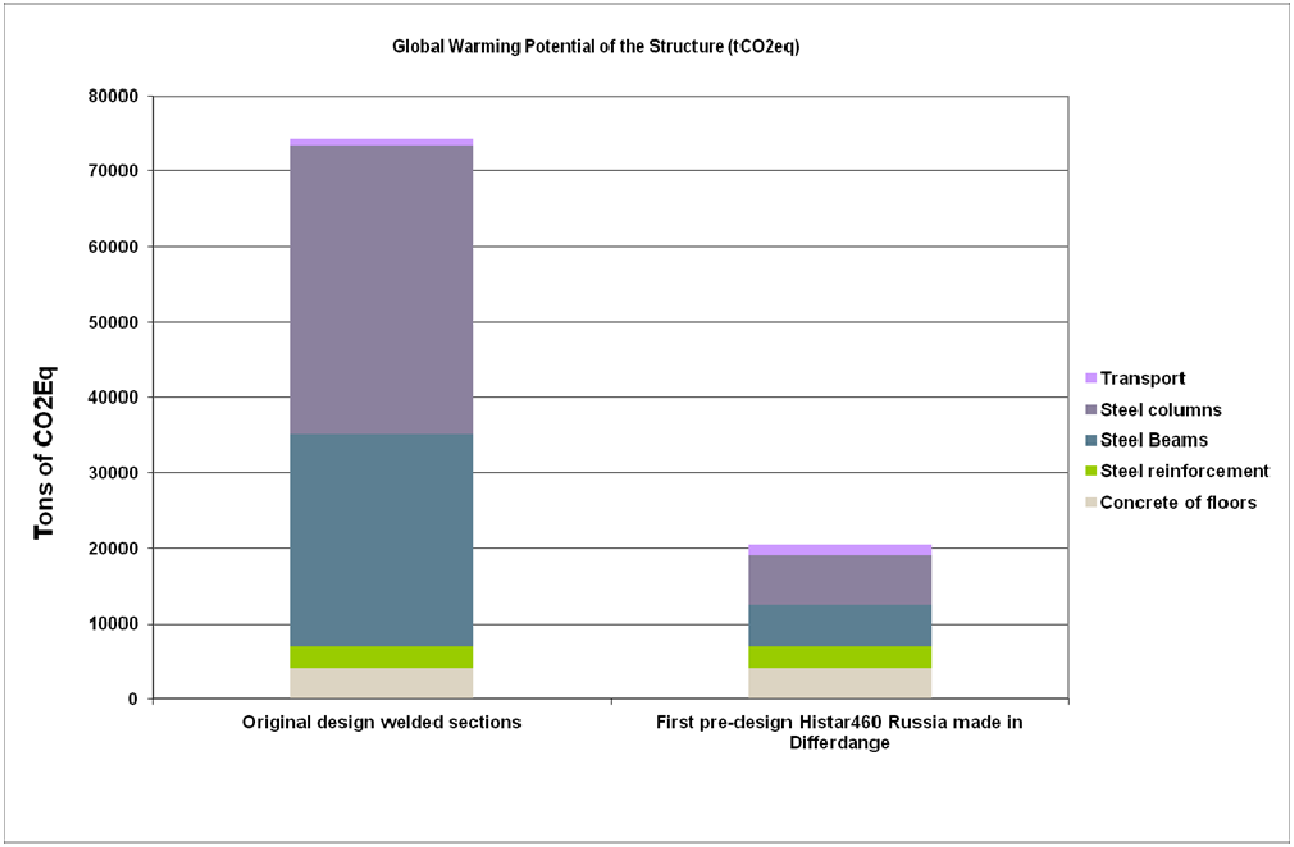


Recycled steel



Calculation of CO_2 impact using AMECO

Life Cycle Assessment of the Laktha Tower



AM approach towards market needs and requests

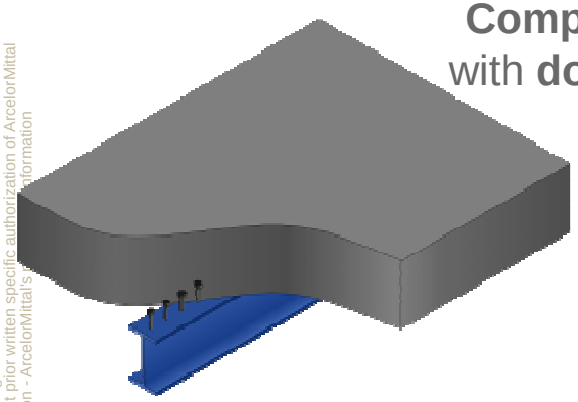
MARKET NEEDS			R&D ANSWERS New Products and Concept	Example of applications
Regulations	Safety	SEISMIC	Energy Absorption Connections ☞"Dog Bone"	High Rise Buildings
		FIRE	Structural Fire Engineering ☞Natural Fire Safety Concept	AM Flemalle, Turquish scholl, AOB, CACTUS ESCH;
	Sustainability		New Products to minimize Energy & Carbon Foot Print	HISTAR, ARCOROX L300 Wind Tower
Architecture	Flexibility		Slimfloor	Hollerich
	Transparancy		Cellular Beams	Airport Limasol
Design	Innovative design improvements		Advanced Design Methods implemented in userfriendly design tools	Download Center *www.arcelormittal.com/sections*
Economical performing			Composite Construction	Bridges PreCoBeam
			HISTAR Gr 70	High rise buildings
			Jumbo / HD sections	

VERSATILITY OF STEEL

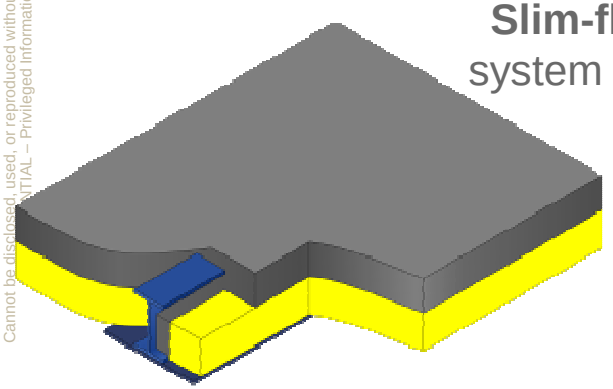
- CoSFB / Economical performing

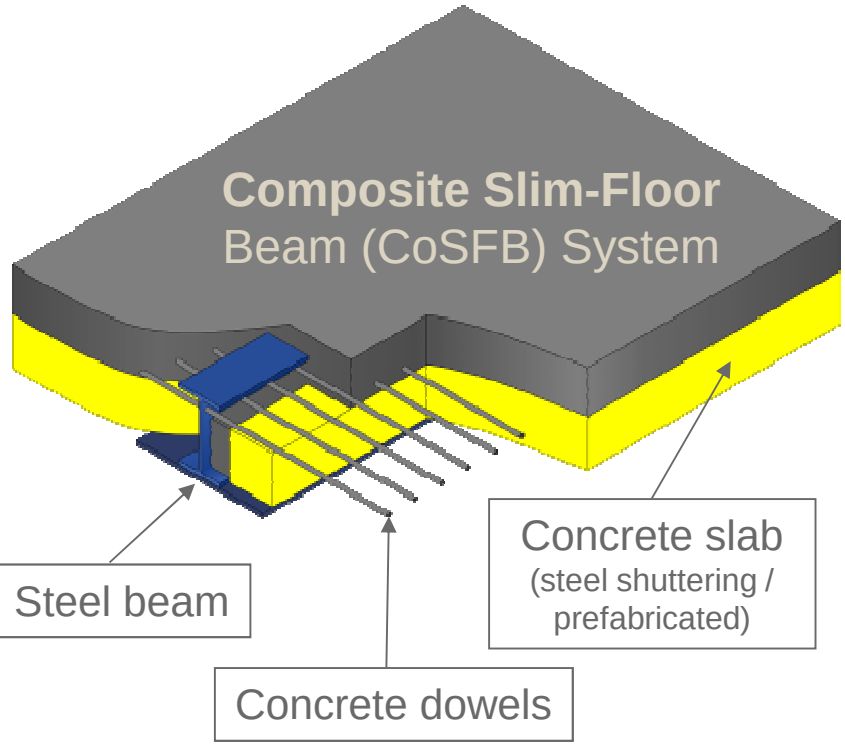
CoSFB – Composite Slim-Floor Beam

Composite floor system with **downstanding** beam



Slim-floor beam (SFB) system – **non composite**



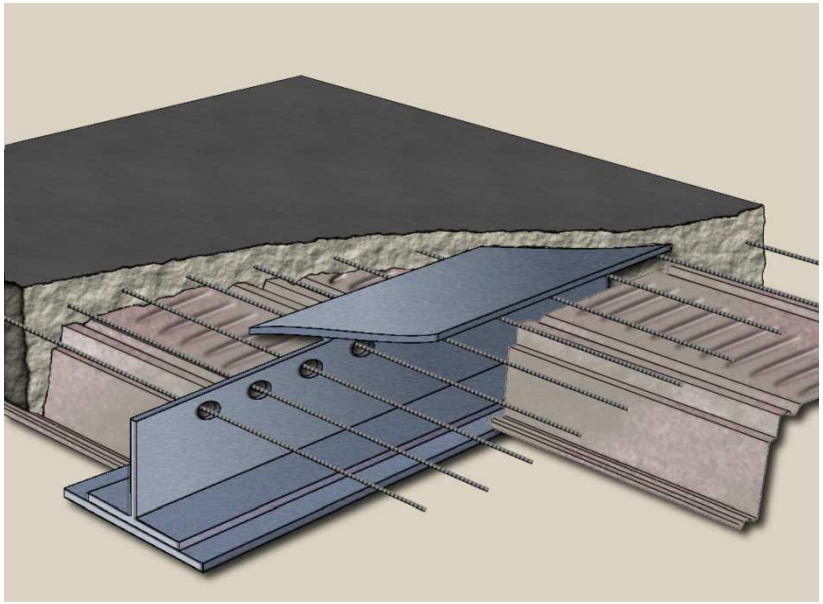


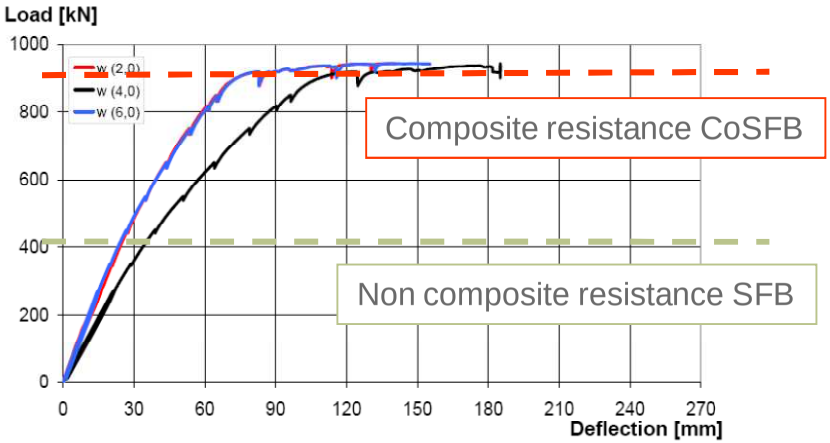
2 existing systems → 1 Innovative system

Major benefits without adding to the complexity of the fabrication or compromising of the cost

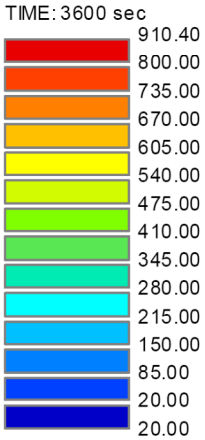
VERSATILITY OF STEEL

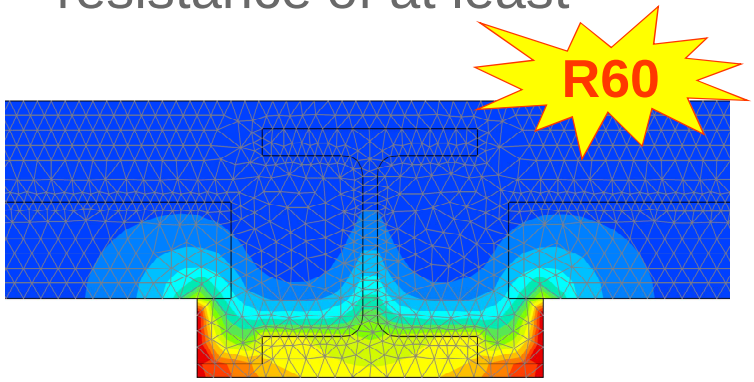
- CoSFB / Economical performing





With integrated fire resistance of at least





In normal conditions it covers a span gap between SFB applications and ACB application

February 2nd, 2016

Advanced Steels for Engineered Solutions

Short presentation of CRM Construction activities in the Flat Carbon segment

Meeting with Academics

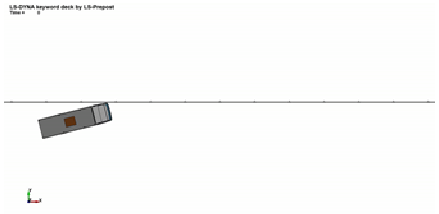
ArcelorMittal

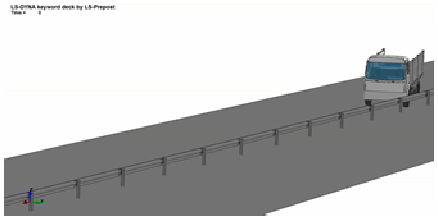
- **Example 1: Safety barriers**

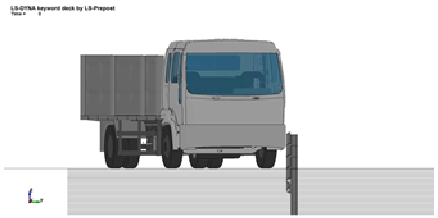
Design of structures | Mechanical testing | Numerical computation

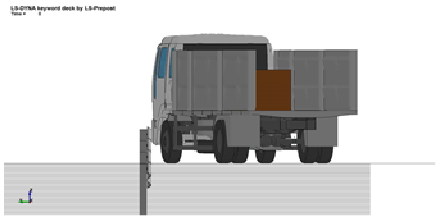
- Weight: 16kg/m → *One of the lightest barriers of this category* ✓
- Steel: S420MC;
- Coating: MAGNELIS®.

- Vehicle mass: 10tons;
- Impact speed: 70km/h;
- Impact angle: 15° .





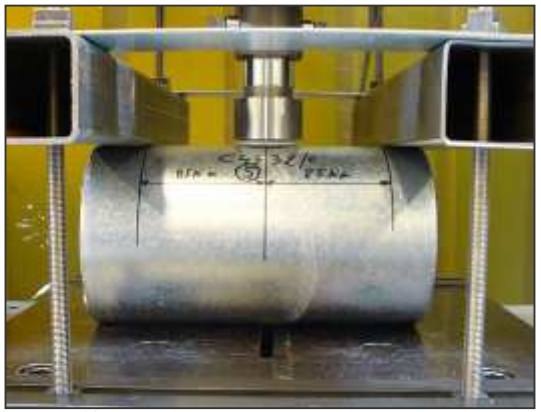




ArcelorMittal

- **Example 1: Safety barriers**

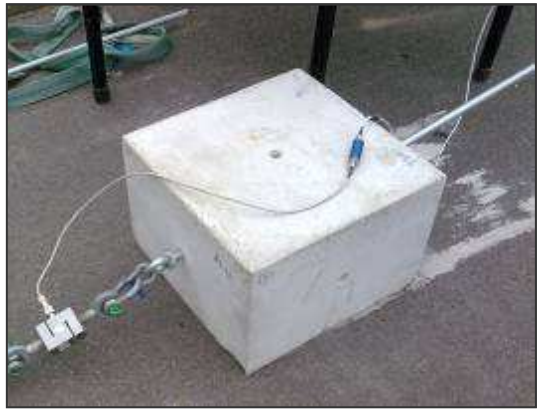
Design of structures | Mechanical testing | Numerical computation



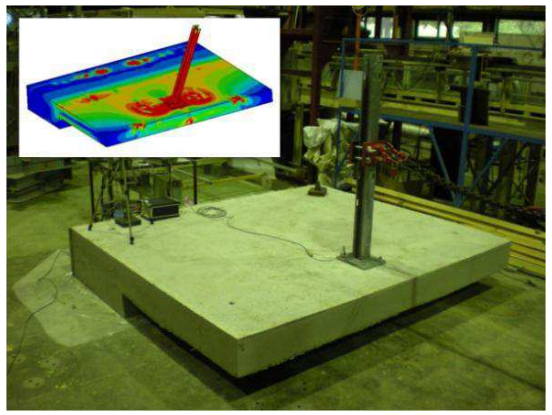
↳ Connection pull-out tests

↳ Beam bending tests

↳ Beam-Beam resistance test



↳ Friction coefficients tests

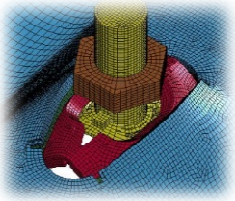


ArcelorMittal

- **Example 1: Safety barriers**

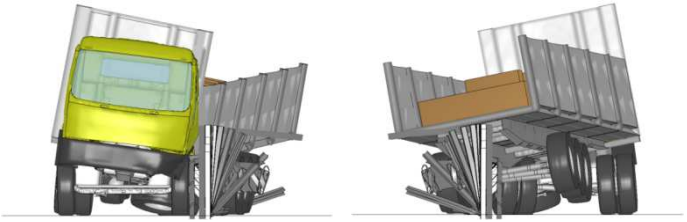
Design of structures | Mechanical testing | Numerical computation

Advanced modeling of bolted connections



High containment system – Design 1 = KO

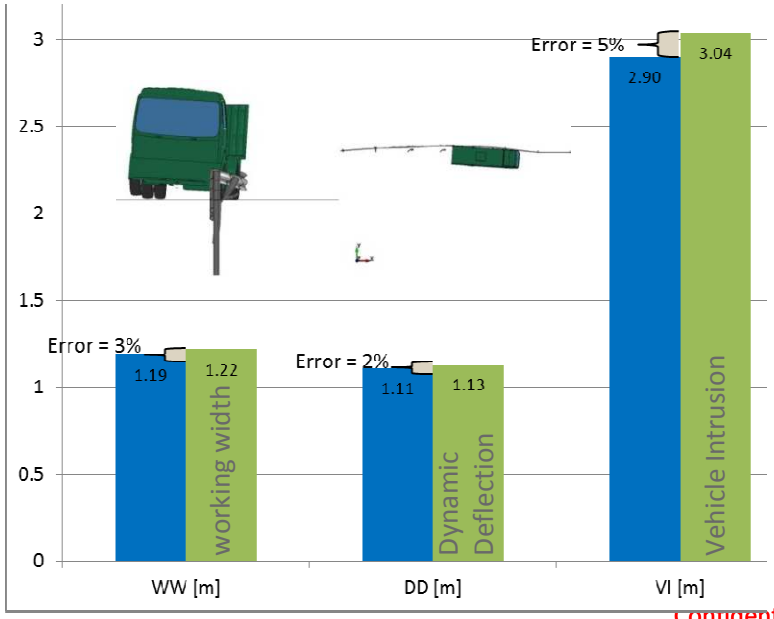
High containment system – Design 2 = OK



Computation of a 10 ton truck impact:

Very good prediction ✓

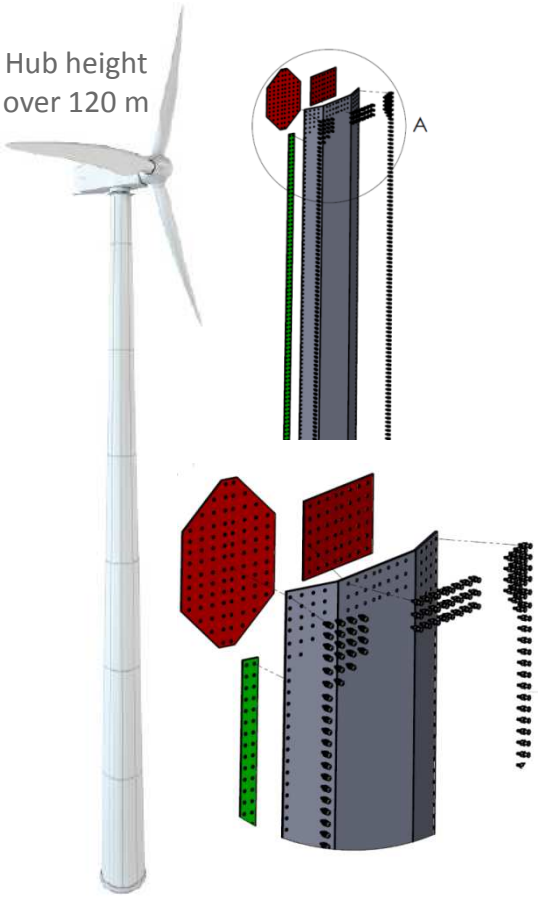
Relative difference between **Crash-testing (blue)** and **Numerical computation (green)**



ArcelorMittal

- **Example 2: Wind turbine Towers**

Design of structures | Mechanical testing | Numerical computation



Primary Objective:

• Alternative to conventional welded wind towers

Other advantages :

• No transportation limitations (components fit on conventional trucks) and without special size requirements, can be shipped to even the most difficult sites ;

• Components can be transported by truck, rail, boat, or containers ;

• The design can be adapted to any specific top or bottom diameter with no limitation on bottom diameter size ;

• No welds and thus no heat affected zones (improve fatigue endurance) ;

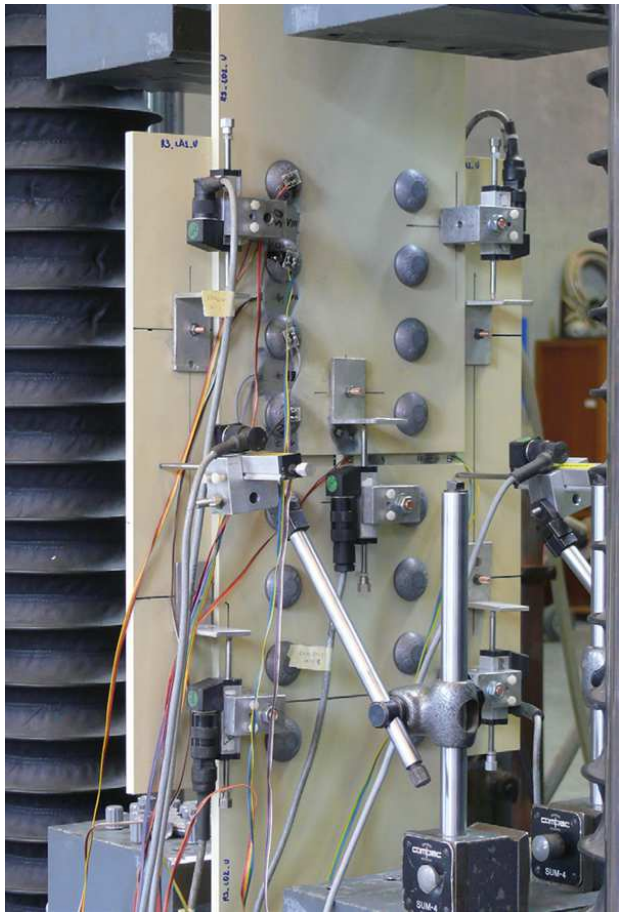
• The design can be adapted to higher hub heights and/or more powerful wind turbines requirements ;

• The tower is fully recyclable and can be easily dismantled at end of life ;

• Use of maintenance-free bolting system minimizes maintenance operations

- **Example 2: Wind turbine Towers**

Design of structures | Mechanical testing | Numerical computation

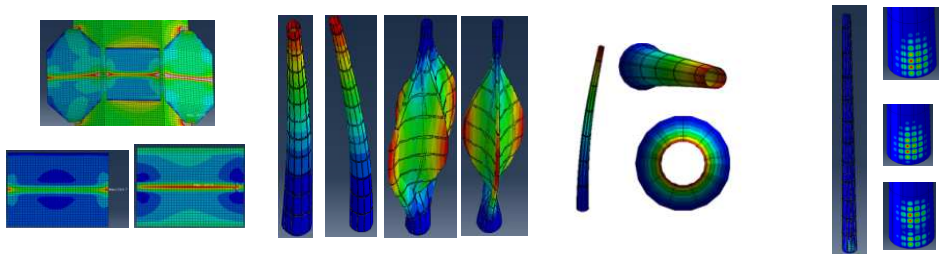


ArcelorMittal

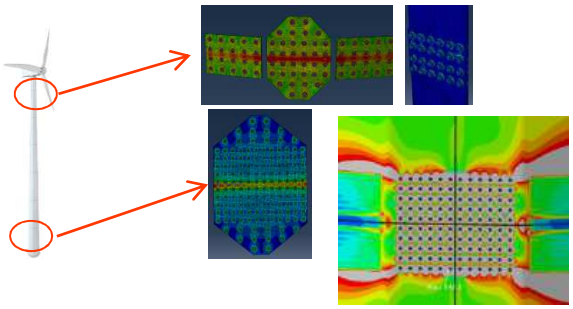
- **Example 2: Wind turbine Towers**

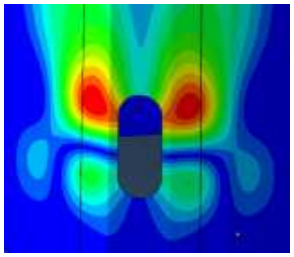
Design of structures | Mechanical testing | Numerical computation

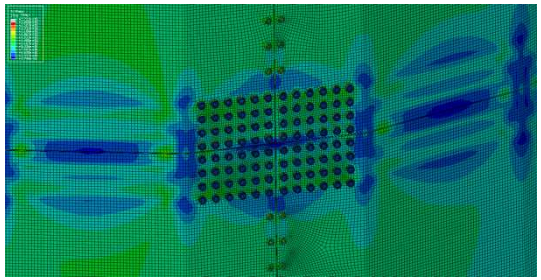
Global tower analysis:
- Strength
- Resonance
- Buckling
- Fatigue



Specific analysis:
- Detailed bolted connection analysis
- Door opening + reinforcement
- Other analysis



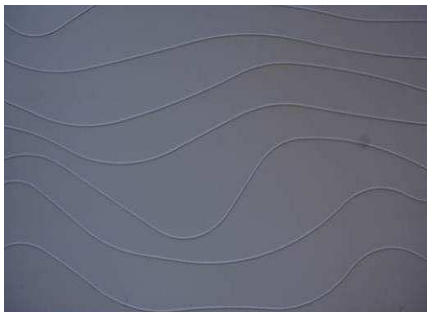




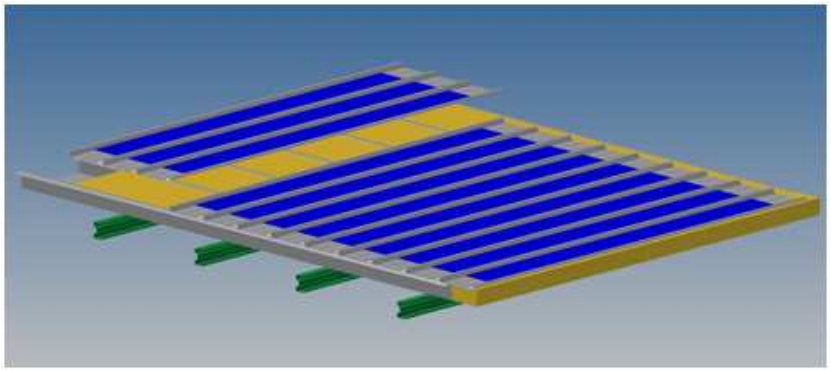
ArcelorMittal

- **Example 3: Facades and Roofing**

- Development of New aesthetic Facade

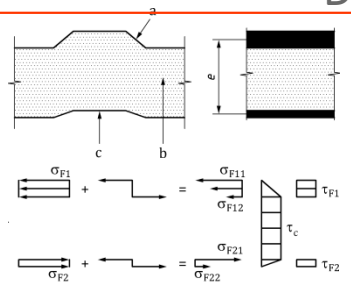

- Development of highly efficient eco-designed building integrated photovoltaic (BI-PV) roofing element using innovative and greener manufacturing process.



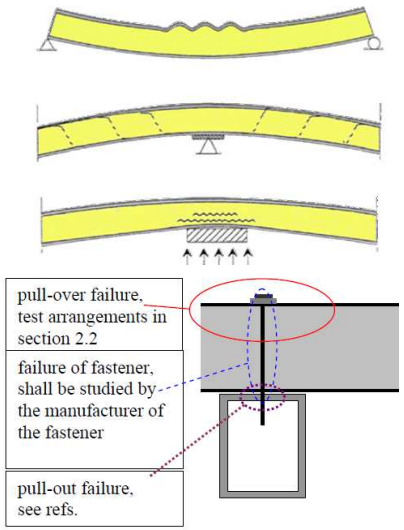
ArcelorMittal

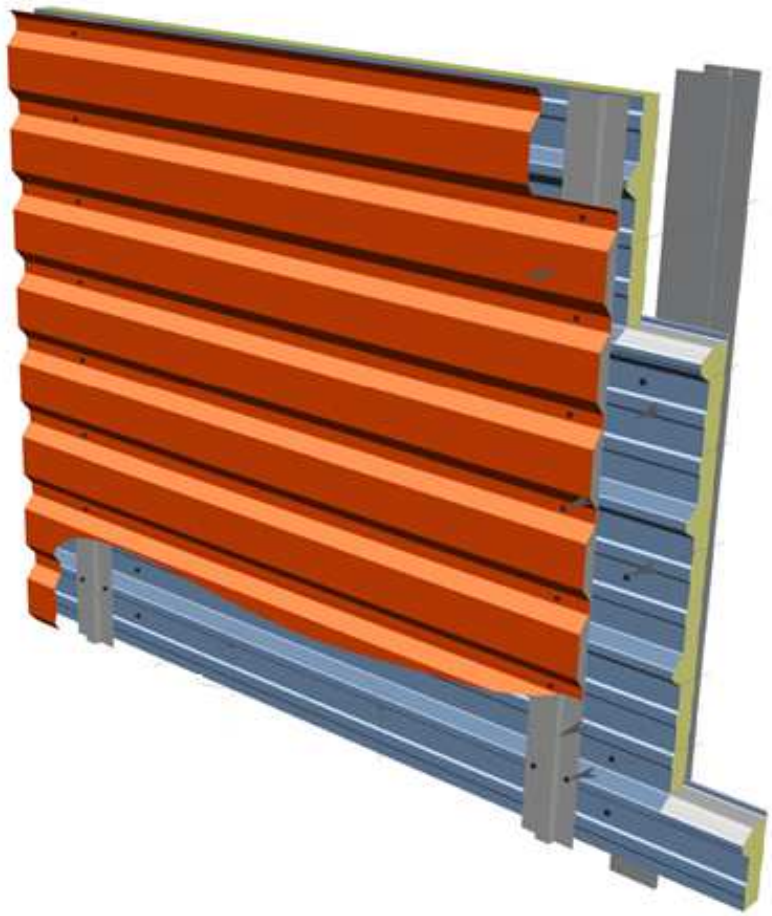
- **Example 4: Sandwich panels**

Development and characterization of new solutions



Analytical analysis of the mechanical behaviour of the solution, according EN 14509 , inc. fastening system acc. ECCS n° 320





From chemical analysis to large scale mechanical test (EN 14509)

ArcelorMittal

- **Example 4: Sandwich panels**

Development and characterization of new solutions

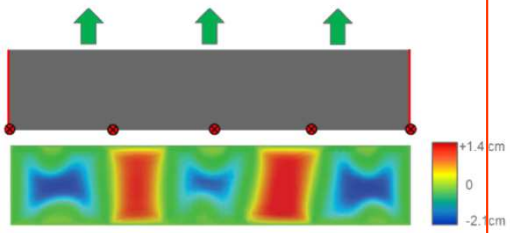
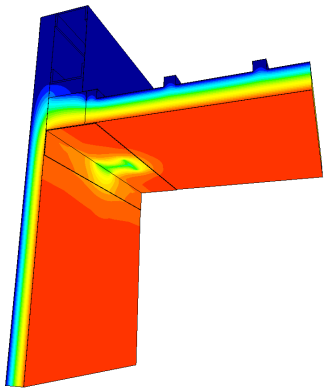
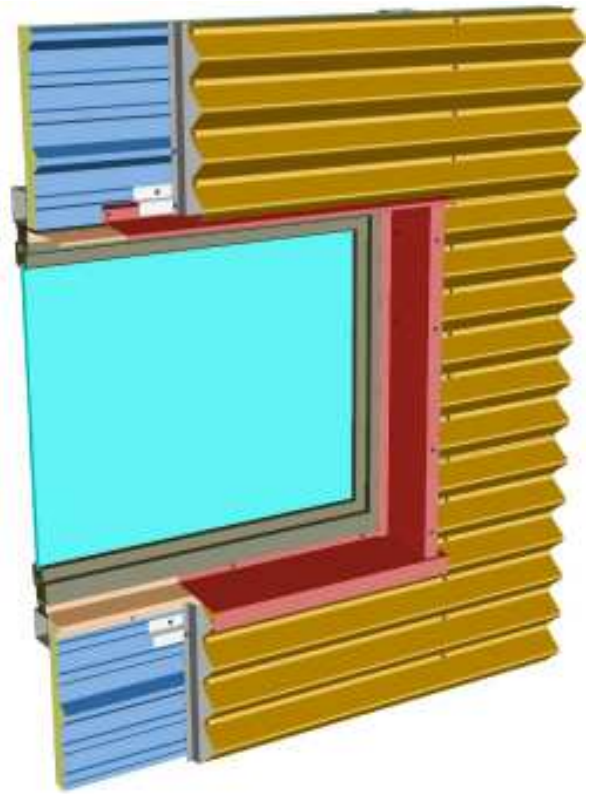


Figure 19 Modélisation 2: Bord supérieur libre

Numerical simulations to assess the mechanical and thermal behaviour (EN 10211) of the solution





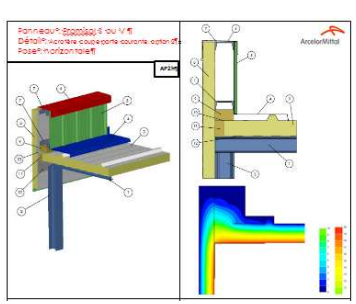
Development of energy efficient accessories and technical support for certification (EN 12114)

ArcelorMittal

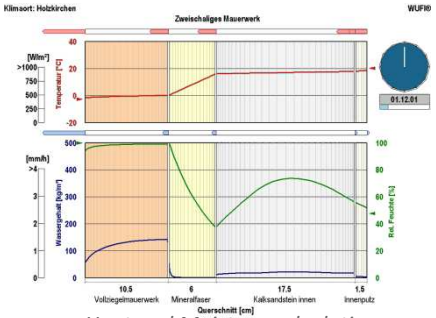
• Example 5: Building Physics

- R&D response to the real-performance challenge to better understand how to deliver buildings that actually perform and tailor efficient envelope solutions. The expertise is focalized mainly on airtightness, thermal bridges and laboratory testing and we are using the results to push for **better building components and systems**
- **Thermal and hygrothermal performance**
  - Improvement of junction and details for steel buildings
    detect and reduce the heat losses due to the thermal bridging phenomenon in order to thermally improve building envelopes
  - Dynamic calculation of the thermal behaviour of the whole building

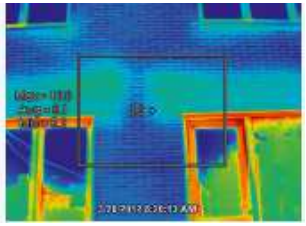
  - In situ testing

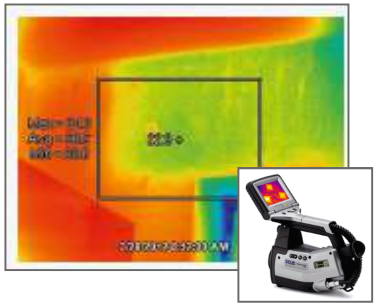


Thermal bridge calculations



Heat and Moisture calculations

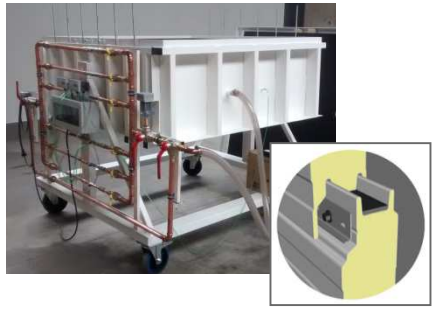




- **Air tightness performance**

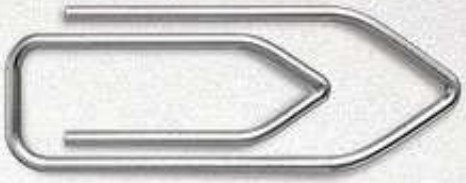
Today, air tightness is not calculated, but measured EN 12114 - Air permeability of building components and building elements - Laboratory test method

➔ R&D performs orientation tests to identify the best configuration (joint details) before getting the certification



Futur trends

Lightweight, ...



sustainable design

Our constant goal

3D printing with steel welding wires

MX3D, Bridge project in Amsterdam

ArcelorMittal

AUTODESK

heijmans

ArcelorMittal

Power and productivity for a better world™ ABB

AIR LIQUIDE Creative Oxygen

Lenovo

Delcam

JUNGHEINRICH

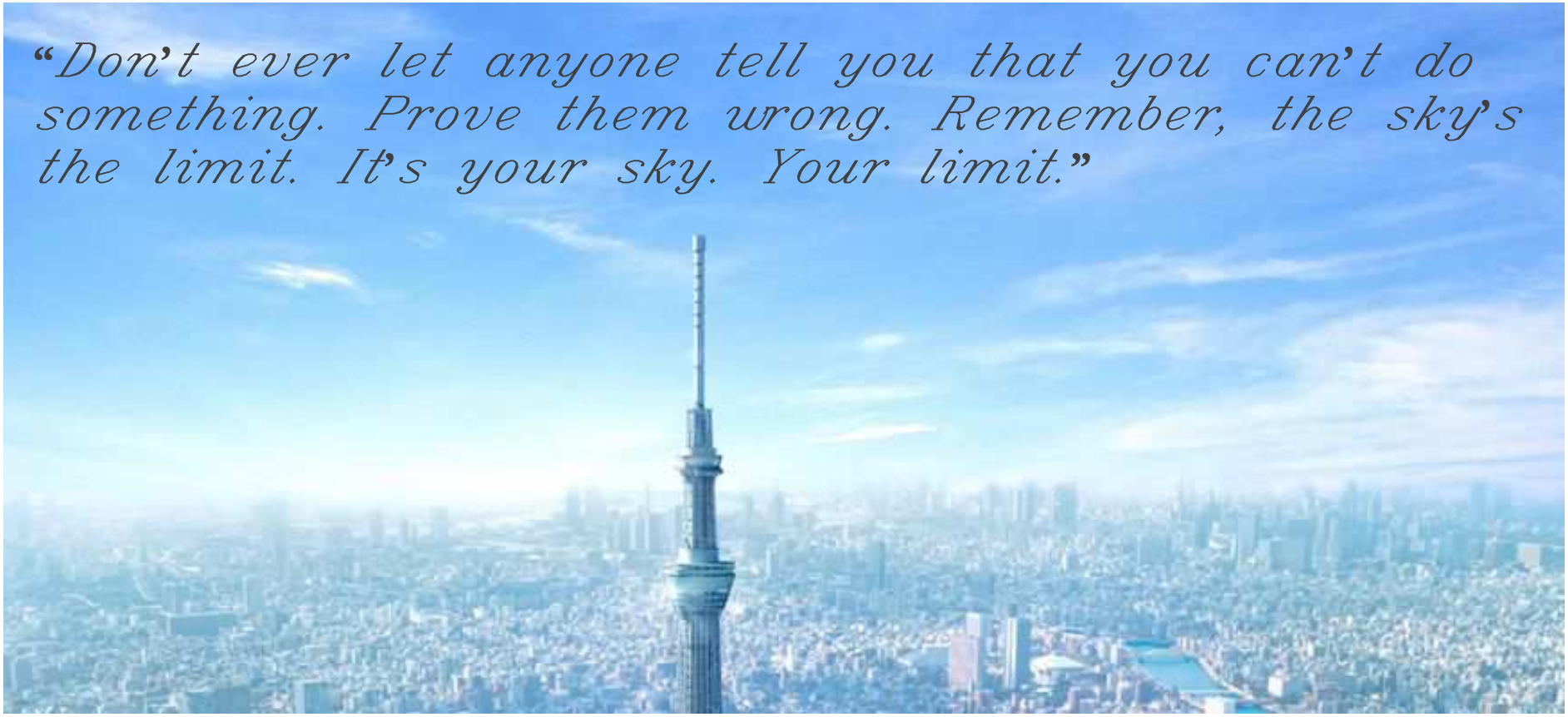
STV WELDINGSUPPLIES.NL

PLYMOVENT

Gemeente Amsterdam

AMS AMSTERDAM INSTITUTE FOR ADVANCED METROPOLITAN SOLUTIONS

TU Delft Delft University of Technology



olivier.vassart@arcelormittal.com