Eurocode tools for structural detailing and connections of Single Storey Buildings

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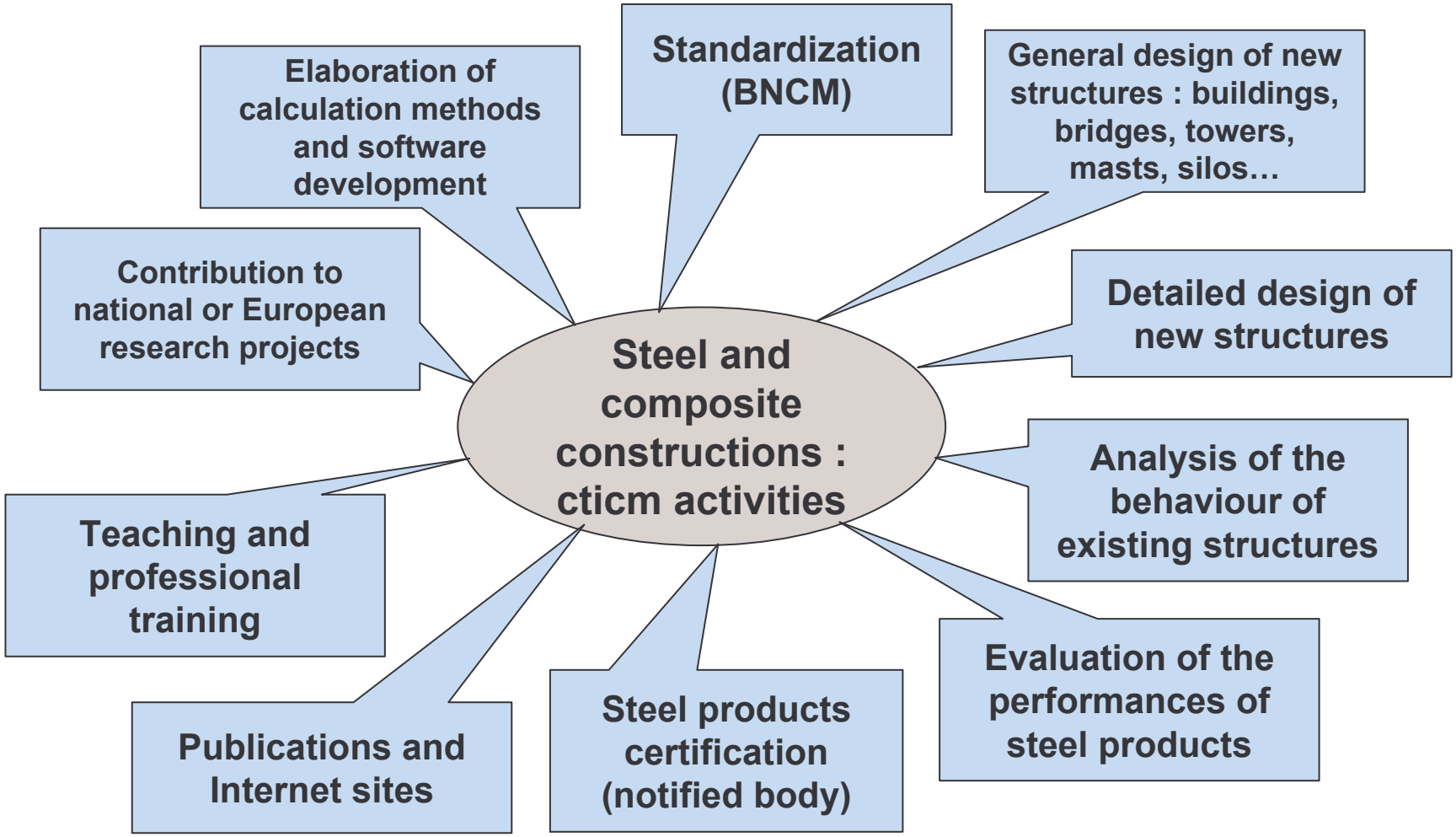
The French technical centre for steel construction

2 main fields of expert activities :
Steel and composite steel-concrete construction
Fire engineering

Cticm was a technical partner of the STEEL project and is member of the Steel Alliance association

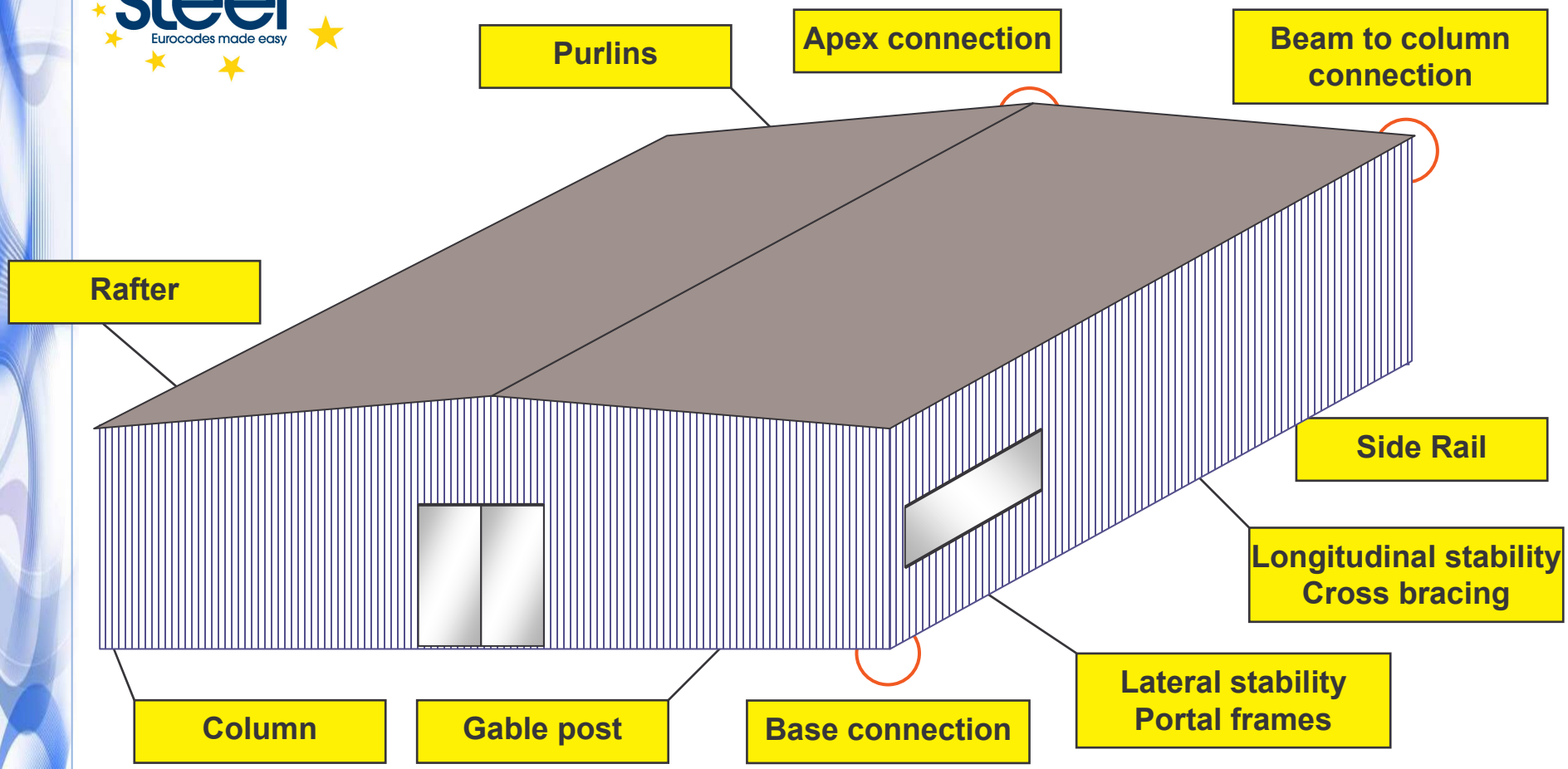
Steel Alliance


Steel and composite constructions : cticm activities
Standardization (BNCM)
Elaboration of calculation methods and software development
General design of new structures : buildings, bridges, towers, masts, silos…
Contribution to national or European research projects
Detailed design of new structures
Analysis of the behaviour of existing structures
Teaching and professional training
Evaluation of the performances of steel products
Publications and Internet sites
Steel products certification (notified body)

Introduction

- Detailed design with Access Steel
- Design of members
- Design of connections
- Different types of available documents
- Other design tools to apply the Eurocodes

Typical single storey building



Other possible general designs

Example : cross bracings in the 4 walls and roof bracings in two directions

The current single storey buildings have generally a structural Class II according to EN 1993-1-3.

Steel sheeting (roof and/or walls) generally contributes to the strength and stability of individual structural elements.

EUROPEAN STANDARD **EN 1993-1-3 -** October 2006
Eurocode 3 - Design of steel structures - Part 1-3: General rules
-Supplementary rules for cold-formed members and sheeting

2 - Basis of design

(6) For the design of structures made of cold formed members and sheeting a distinction should be made between "structural classes" associated with failure consequences according to EN 1990 – Annex B defined as follows:
Structural Class I: Construction where cold-formed members and sheeting are designed to contribute to the overall strength and stability of a structure;
Structural Class II: Construction where cold-formed members and sheeting are designed to contribute to the strength and stability of individual structural elements;
Structural Class III: Construction where cold-formed sheeting is used as an element that only transfers loads to the structure.
NOTE 1: During different construction stages different structural classes may be considered.
NOTE 2: For requirements for execution of sheeting see EN 1090.

DESIGN OF MEMBERS with access steel

Eurocodes made easy

Photo from Pr Muzeau - APK

Different types of available documents

- Extracts from the standards
- Complementary information to Eurocodes (NCCI)
- Code commentaries
- Flowcharts
- Design data
- Worked examples
- “Active” worked examples

No National Annex is considered.

Complementary Information (NCCI)

- Buckling lengths of columns
- Elastic critical moment for LTB
- Elastic critical moment of cantilevers
- Critical axial force for torsional buckling modes
- Stability of mono-symmetrical uniform members
- Torsion
- Sizing guidance for columns
- …

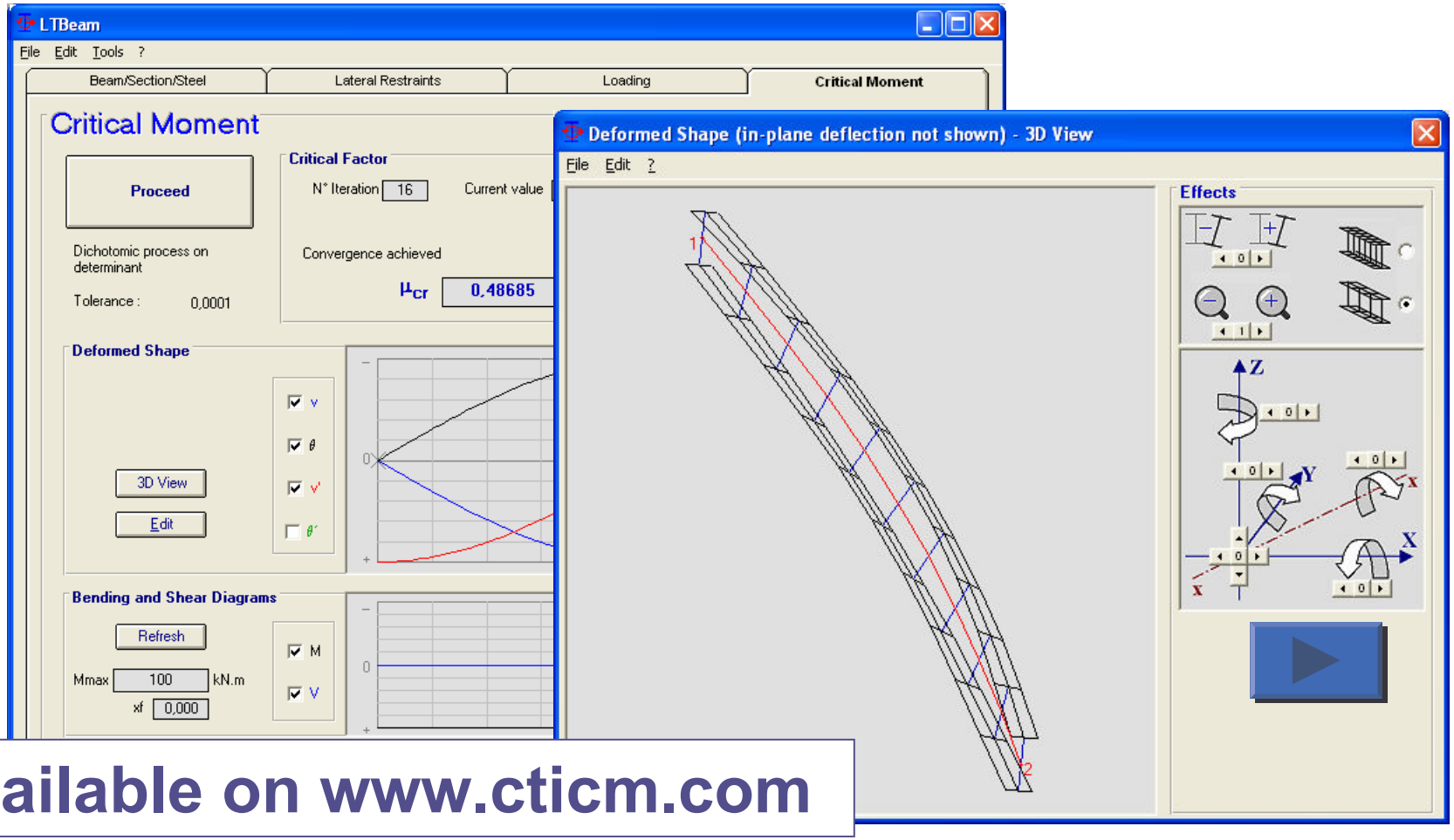
Elastic critical moment for LTB

NCCI: Elastic critical moment for lateral torsional buckling

This NCCI gives the expression of the elastic critical moment for doubly symmetric cross-sections. Values of the factors involved in the calculation are given for common cases. For a beam under a uniformly distributed load with end moments or a concentrated load at mid-span with end moments, the values for the factors are given in graphs.

Contents

LTBeam software : Calculation of the elastic critical moment



Available on www.cticm.com

Torsional and flexural-torsional buckling

NCCI: Critical axial load for torsional and flexural torsional buckling modes

This NCCI gives the expressions for the critical axial load for the torsional buckling mode and the flexural-torsional buckling mode.

Contents

Design data : Classification of cross-sections

Data: Section classification tables for European hot rolled beam profiles (IPE and HE profiles)
SD001a-EN-EU

Data: Section classification tables for European hot rolled beam profiles (IPE and HE profiles)

This NCCI contains tables giving the section classification of IPE and HE profiles, according to the Eurocode rules. Classifications are given for pure bending about both axes and for bending with axial compression. The tables cover steel grades S235, S275, S355 and S460.

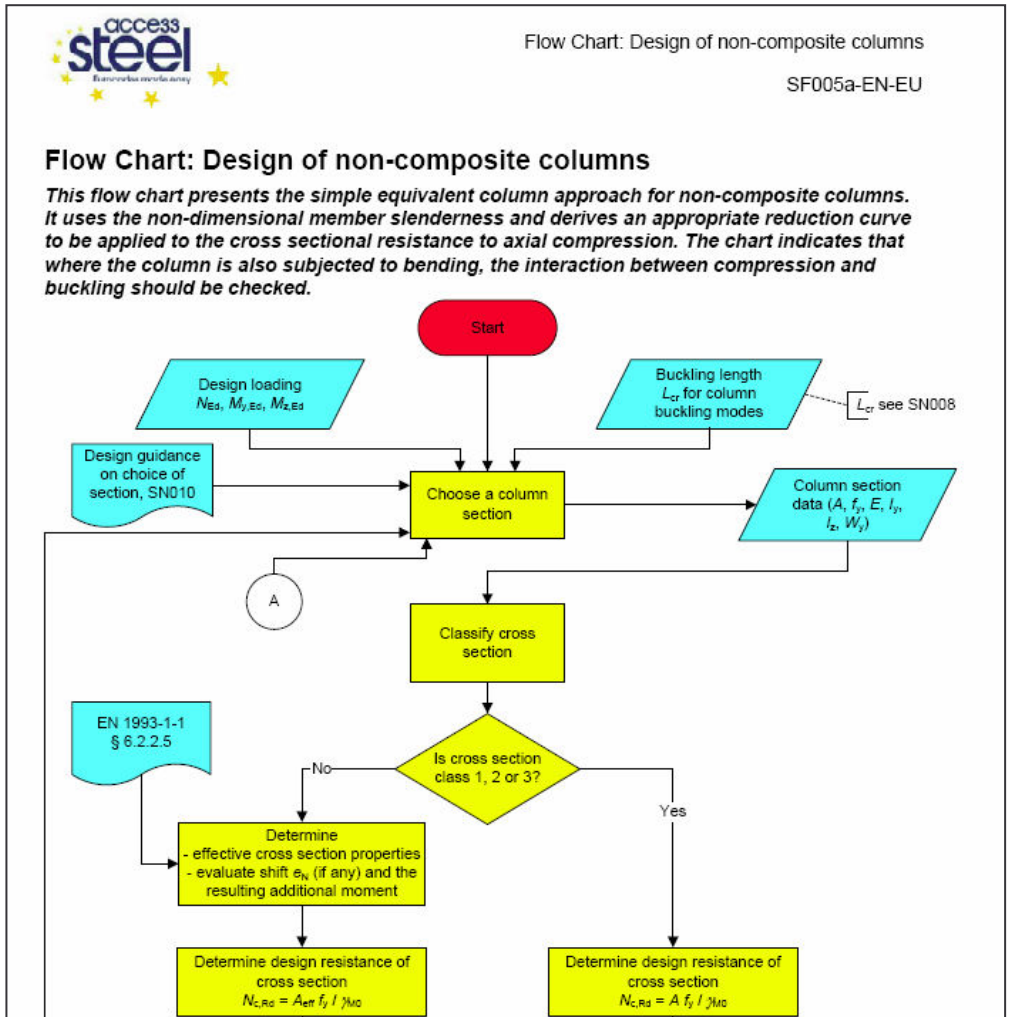
Contents

EN 1993-1-1
Table 5.2

Flowcharts …for designers

- Design of columns
- Beam under uniform loading
- Design of a wind transverse girder
- Buckling verification of non-uniform members
- Design of cold formed members
- …

Design of columns



Worked examples

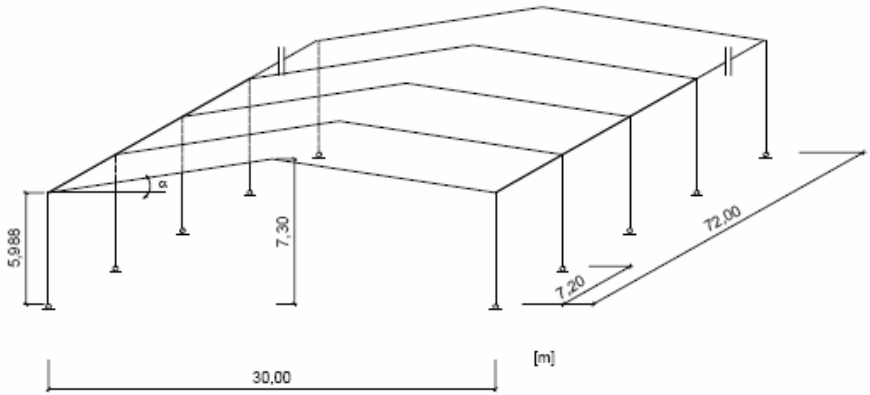
- Buckling resistance of a column
- Simply supported beam, laterally restrained
- Simply supported beam, unrestrained
- Design of a purlin (hot rolled profile)
- Design of cold formed members
- Elastic analysis of a portal frame
- …

Elastic analysis of a portal frame

CALCULATION SHEET	Document Ref:	SX029a-EN-EU	Sheet	1 of 28	
	Title	Example: Elastic analysis of a single bay portal frame			
	Eurocode Ref				
	Made by	Valérie Lemaire	Date	April 2006	
	Checked by	Alain Bureau	Date	April 2006	

Example: Elastic analysis of a single bay portal frame

A single bay portal frame made of rolled profiles is designed according to EN 1993-1-1. This worked example includes the elastic analysis of the frame using first order theory, and all the verifications of the members under ULS combinations.



“Active” worked examples

TEDDS CTICM	Project			Job Ref.	
	Section			Sheet no./rev. 4	
	Calc. by B	Date 24/01/2008	Chck'd by	Date	App'd by	Date

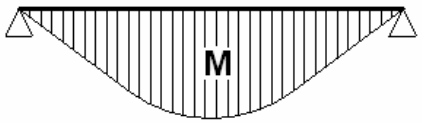
Variable loading $Q_k = w_{bay} \times F_{imp} = \mathbf{6.25}$ kN/m

ULS Combination

Total ULS load $F_{uls} = G_k \times \gamma_G + Q_k \times \gamma_Q = \mathbf{22.10}$ kN/m

EN 1990

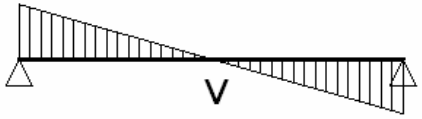
Moment diagram



Maximal moment at midspan

$M_{y,Ed} = 0.125 \times F_{uls} \times L^2 = \mathbf{89.77}$ kNm

Shear force diagram



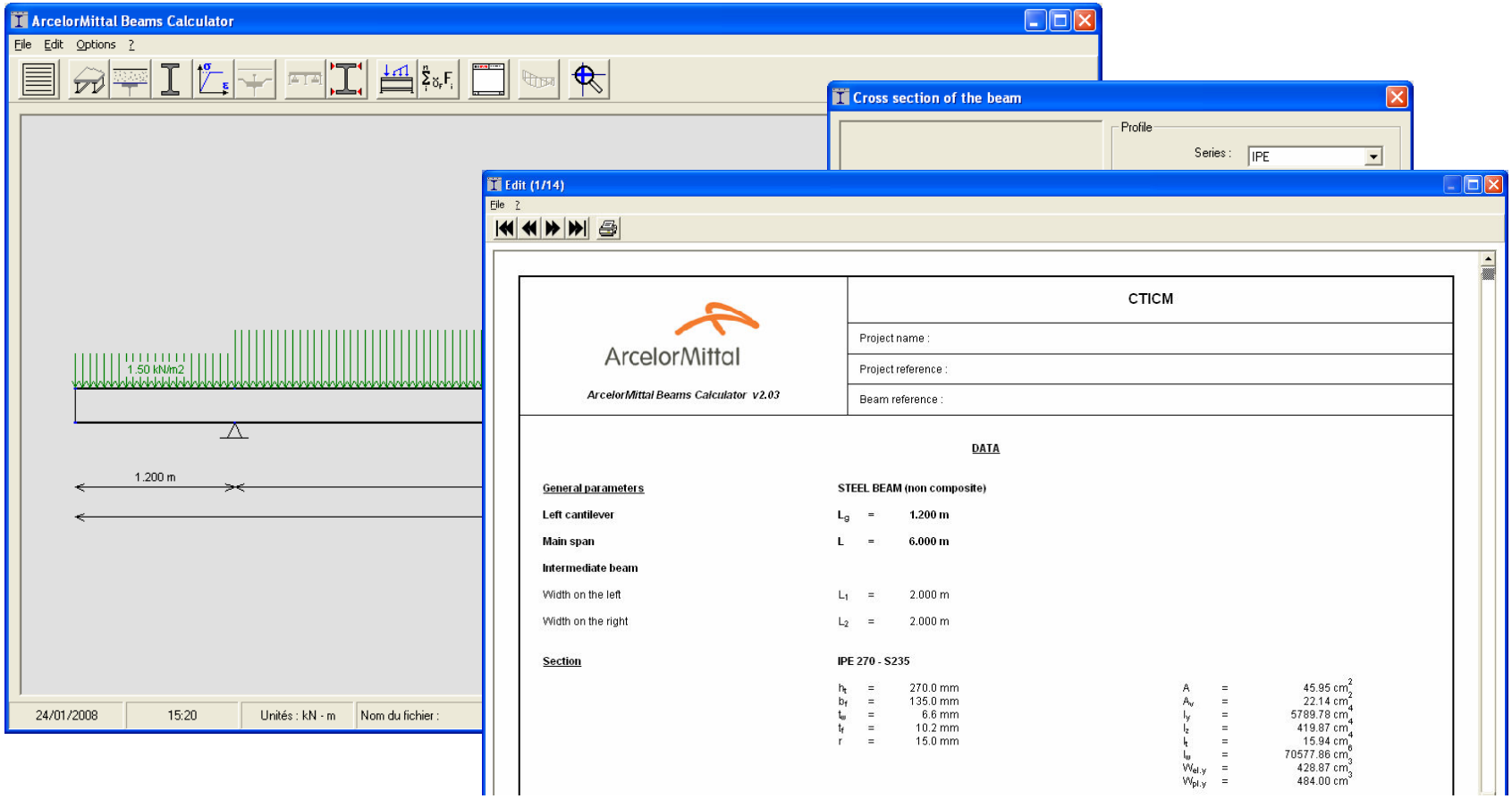
Maximal shear force at supports

$V_{Ed} = 0.5 \times F_{uls} \times L = \mathbf{63.00}$ kN

Special version of the Tedds software to download

Calculation of steel beams according EN 1993 and EN 1994

ArcelorMittal Beams Calculator



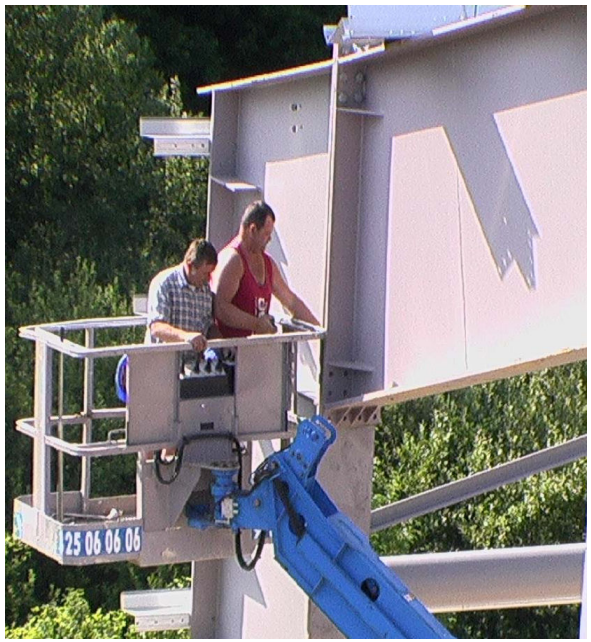
ArcelorMittal Beams Calculator

ArcelorMittal

- Composite and non composite beams
- ULS and SLS calculations
- LTB verification based on M_{cr} calculated by the *LTBeam* engine
- Detailed calculation sheet
- Available on the web site

www.arcelormittal.com/sections

DESIGN OF CONNECTIONS



For connection calculations, reference is made to EN 1998-1-8 and its national annex

List of contents of EN 1993-1-8

1 - Introduction

2 - Basis of design

3 - Connections made with **bolts**, rivets or pins

4 - **Welded** connections

5 - Analysis, classification and modelling

6 - Structural joints **connecting H or I sections**

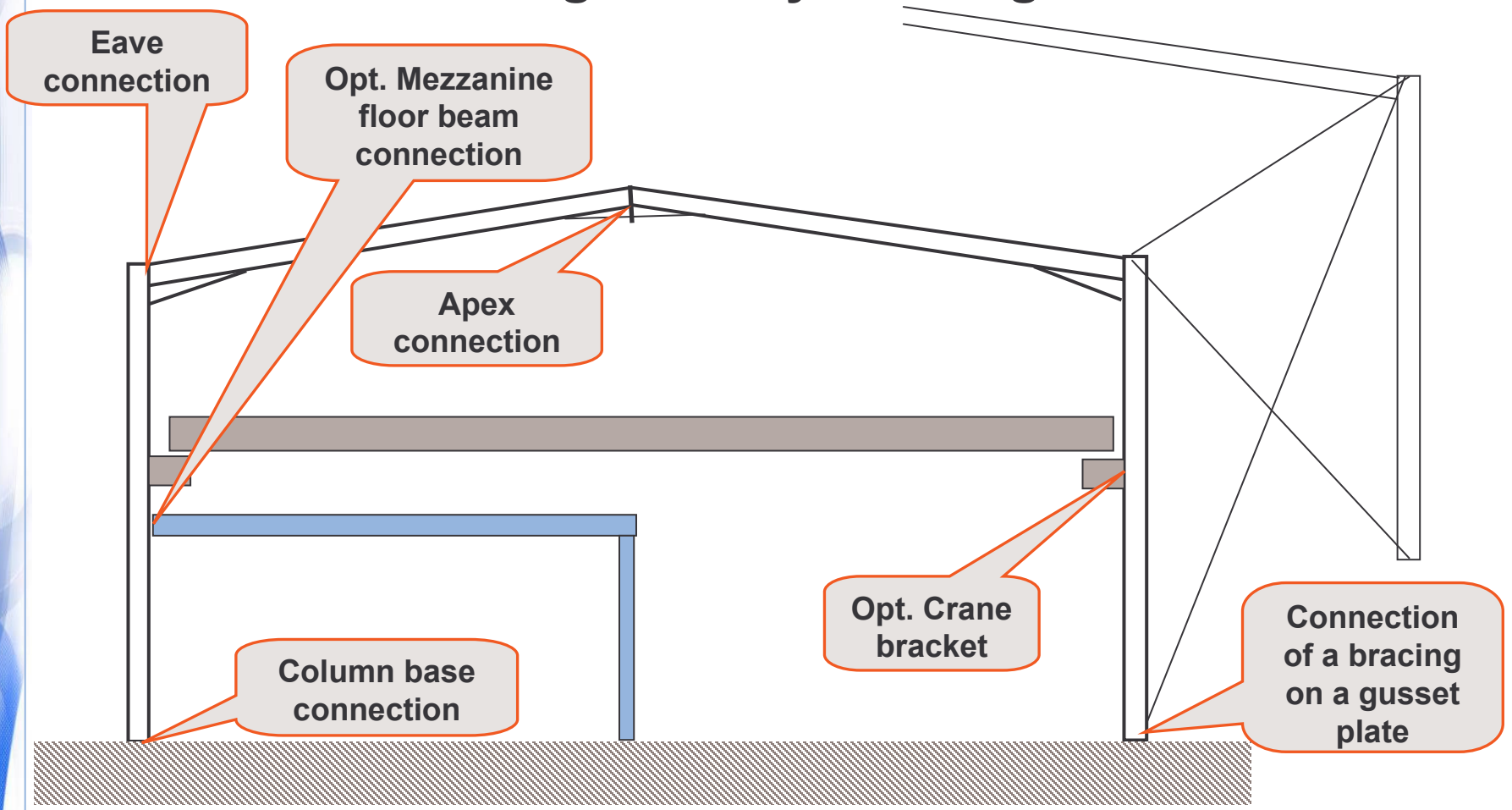
7 - Hollow section joints

All types of connections are covered by application or interpretation of EN 1993-1-8.

The general principle to determine the resistance and stiffness of any connection is to consider the connection as a series of components. The resistance of the connection is obtained from the failure modes of each component.

But a liable calculation is not sufficient to ensure the good behaviour of a connection; a careful execution is also necessary !!! See EN 1090-2.

Connections of the main structure of a typical single storey building



In general cases :

- **Apex connection :** RIGID CONNECTION – CONNECTION BY BOLTED END PLATES – CHAPTER 6 OF EN 1993-1-8 – NCCI – FLOW CHART (+ ASCAP)
- **Eave connection :** RIGID CONNECTION – CONNECTION BY BOLTED RAFTER END PLATE – CHAPTER 6 OF EN 1993-1-8 – NCCI (+ ASCAP)
- **Column base connection :** EITHER PINNED OR RIGID CONNECTION (RIGID WHERE DEFORMATIONS HAVE TO BE LIMITED : PRESENCE OF A CRANE…) – CHAPTER 6 OF EN 1993-1-8 (6.2.8 – 6.3.4) – FLOW CHART (PINNED)
- **Connection of a bracing on a gusset plate :** PINNED CONNECTION – CHAPTER 3 OF EN 1993-1-8 - EXAMPLE
- **Crane bracket :** RIGID CONNECTION – EITHER WELDED CONNECTION (CHAPTER 4 OF EN 1993-1-8) OR CONNECTION BY BOLTED BRACKET END PLATE (CHAPTER 6)
- **Mezzanine floor beam connection :** PINNED CONNECTION – EITHER BY 2 BOLTED ANGLES, OR BY FIN PLATE (NCCI – FLOW CHART – EXAMPLE), OR BY THIN PARTIAL END PLATE (NCCI – FLOW CHART)
- (+ ASCAP FOR CONNECTIONS BY 2 BOLTED ANGLES)

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NCCI (Non Contradictory Complementary Information)

- Design of portal frame eaves connections
- Design of portal frame apex connections
- Design model for non bearing column splices
- Design of bearing column splices
- Design model for splices in structural hollow sections
- Column splices not requiring full continuity of stiffness
- Column base stiffness for global analysis
- Design of a notched section at the end of a beam

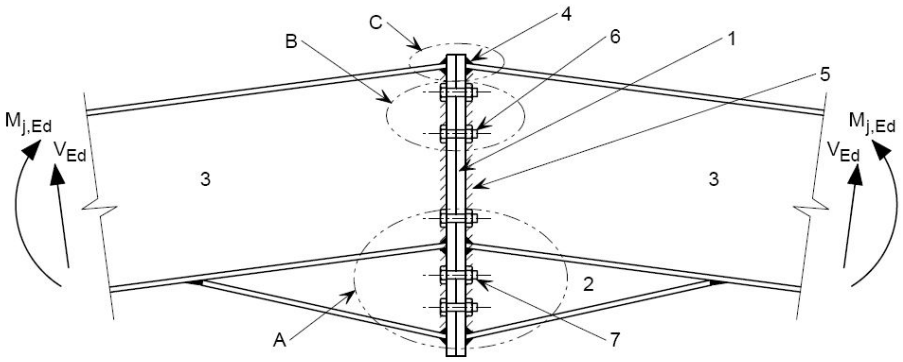
NCCI

- Design model for simple column bases
- Design of simple column bases with shear nibs
- Design of fixed column bases
- Tying resistance of a fin plate connection
- Tying resistance of a simple end plate connection
- Shear resistance of a fin plate connection
- Shear resistance of a simple end plate connection
- Initial sizing of fin plate connections
- Initial sizing of simple end plate connections
- Initial sizing of non bearing column splices

NCCI: Design of portal frame apex connections

This NCCI provides information on the design method for a bolted apex moment connection. It includes several simplifications which are explained throughout the document, to obtain simpler but conservative calculations. This NCCI references repeatedly to SN041 to benefit from the common approach to design apex and eaves connections and therefore only presents those contents specific for apex.

Contents



Key:

1. End plate	3. Rafter	6. Shear Bolts
2. Apex haunch	4. Flange Weld	7. Tension Bolts
	5. Web Weld	
A. Tension zone	B. Shear zone	C. Compression zone

Figure 1.1 Portal frame apex connection with bolted extended end plate

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Flow charts

- Portal frame eaves connection
- Portal frame apex connection
- Simple end plate connection
- Fin plate connection
- Design model for non bearing column splices
- Design of a chord splice in structural hollow sections

Flow charts

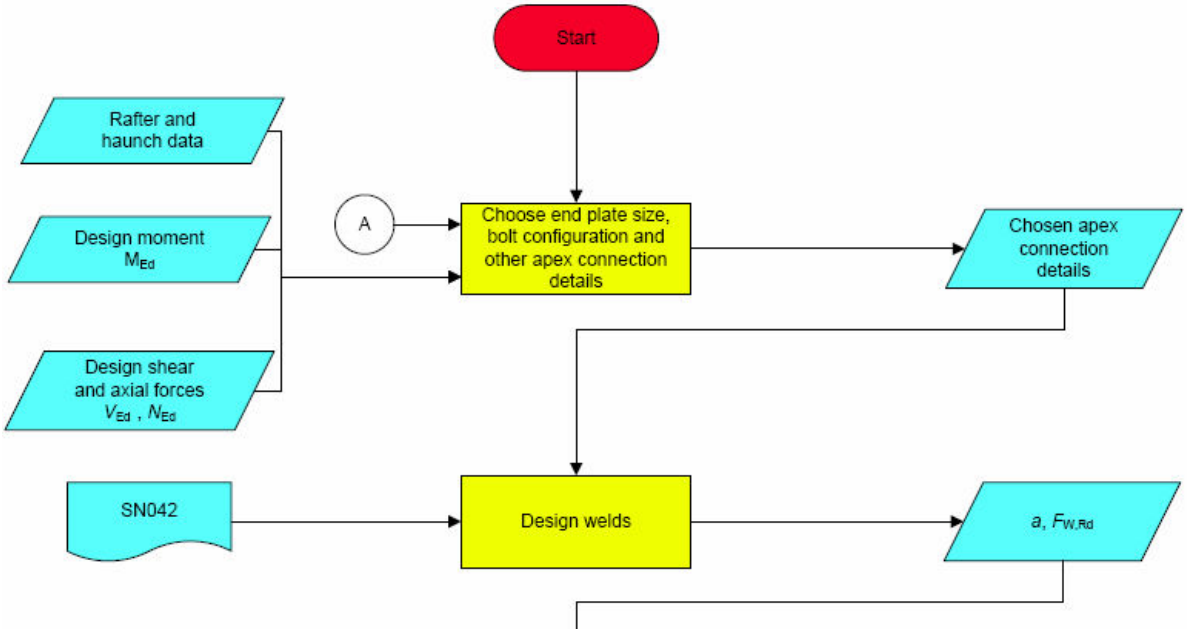
- Design model for welded joints in trusses using hollow sections
- Design resistance of screwed connections of cold-formed members
- Design of a column base under axial load
- Pinned column base connection in portal frames
- Fixed column bases

Design of a portal frame apex connection

Flow chart: Portal frame apex connection
SF026a-EN-EU

Flow chart: Portal frame apex connection

This chart sets out the process for verifying the adequacy of a bolted end plate connection for a portal frame. The resistances in the tension and the compression zones are determined before the design moment resistance of the joint is established. The vertical shear resistance is also determined.



access steel Eurocodes made easy Resources

Examples

- Portal frame eaves moment connection
- End plate beam-to-column flange simple connection
- Fin plate beam-to-column flange connection
- Column splice – non bearing splice
- Column base connection under axial compression

Examples

- Design resistance of a screwed connection of cold-formed members
- Bolted connection of an angle brace in tension to a gusset plate
- Fin plate beam-to-column-flange connection
- Truss/post end connection

CALCULATION SHEET	Document Ref:	*SX034a-EN-EU*	Sheet	*1* of *8*	
	Title	*Example: Bolted connection of an angle brace in tension to a gusset plate*			
	Eurocode Ref				
	Made by	*Edurne Nuñez*	Date	*April 2006*	
	Checked by	*Jose A Chica*	Date	*April 2006*	

Example: Bolted connection of an angle brace in tension to a gusset plate

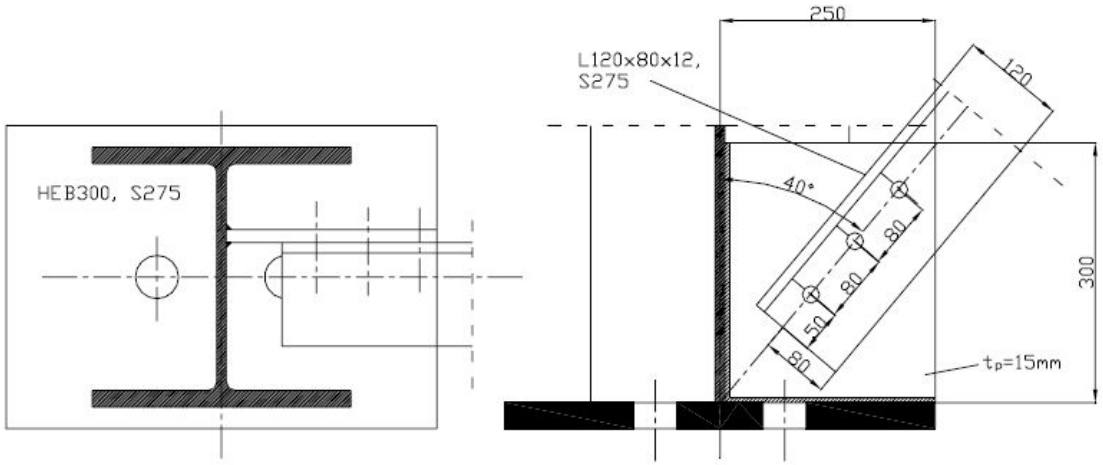


Figure 1.1 Detail of the bolted connection: plan and section view

Other tools than Access Steel also provide resources to calculate the resistance and stiffness of connections according to Eurocode EN 1993-1-8.

An example of such tools is the tables ASCAP developed by the cticm and giving the capacity of standardized connections.

For different types of connections, paper tables are edited in a book that also contains a CD with extended tables and a research engine. In the next months, the software used to produce ASCAP tables will be available on cticm internet site www.steelbizfrance.com


cticm
Assemblages de continuité
de poutres réalisés
par platines d'about
Collection
« les guides Ascap »

The first ASCAP book concerns beam-to-beam connections (bolted end plates). Paper tables give the capacity of 400 standardized connections, and the associated CD gives the capacity of 7000 connections.

IPE xxx Jx	Mpl,Rd (m.kN)	Npl,Rd (kN)	Mj,Rd+ (m.kN)	Mj,Rd- (m.kN)	Nj,Rd+ (kN)	Nj,Rd- (kN)	Sj,ini (N.mm)	Z_eq (mm)	k_eq (mm)	Lb (m)	-
tp (mm)	bp (mm)	hp (mm)	af (mm)	aw (mm)	∅ (mm)	nb	Fc,fb,Rd+ (kN)	Fc,fb,Rd- (kN)	tr (mm)	hr (mm)	ar (mm)
IPE 550	654,95	3149	**395,58**	**395,58**	**1654,7**	**3149**	498270	358,3	18,48	7,07	
25	210	580	pt	6	24	5	1229,3	1229,3	-	-	-
Ftr[r]	-	406,66	316,18	223,78	131,38	47,38	-	-	-	-	-
mode	-	PL3	PL2 T2	PL2 T2	PL2 T2	PL2 T2	-	-	-	-	-
Ftr[r]	-	47,38	131,38	223,78	316,18	406,66	-	-	-	-	-
mode	-	PL2 T2	PL2 T2	PL2 T2	PL2 T2	PL3	-	-	-	-	-
IPE 550	654,95	3149	**397,04**	**276,12**	**1432,2**	**3149**	480300	363,4	17,32	7,34	
20	210	665	pt	6	20	6	1229,3	1229,3	-	-	-
Ftr[r]	204,48	282,24	218,41	154,58	90,75	26,92	-	-	-	-	-
mode	PL2	PL3 T1	PL2 T1	PL2 T1	PL2 T1	PL2 T1	-	-	-	-	-
Ftr[r]	-	26,92	90,75	154,58	218,41	282,24	-	-	-	-	-
mode	-	PL2 T1	PL2 T1	PL2 T1	PL2 T1	PL3 T1	-	-	-	-	-
IPE 550	654,95	3149	**454,86**	**339,43**	**1647,6**	**3149**	390650	362,3	14,17	9,02	
20	210	675	pt	6	24	6	1229,3	1229,3	-	-	-
Ftr[r]	193,53	350,44	270,19	191,23	112,27	40,49	-	-	-	-	-

lons 8.8

CONCLUSION

- Various tools are now available to apply the Eurocodes
- Access Steel is the most important European web site for the application of Eurocodes to steel structures
- Access Steel provides different types of information for common single storey buildings (NCCI, Flowcharts, examples…).

Thank you for your attention