



Eurocodes

Background and Applications

Design of **Steel Buildings** with worked examples



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European Commission

DG Enterprise and Industry
Joint Research Centre

European Convention for Constructional Steelwork

European Committee for Standardization
CEN/TC250/SC3

Joint
Research
Centre

Overview on EN 1993

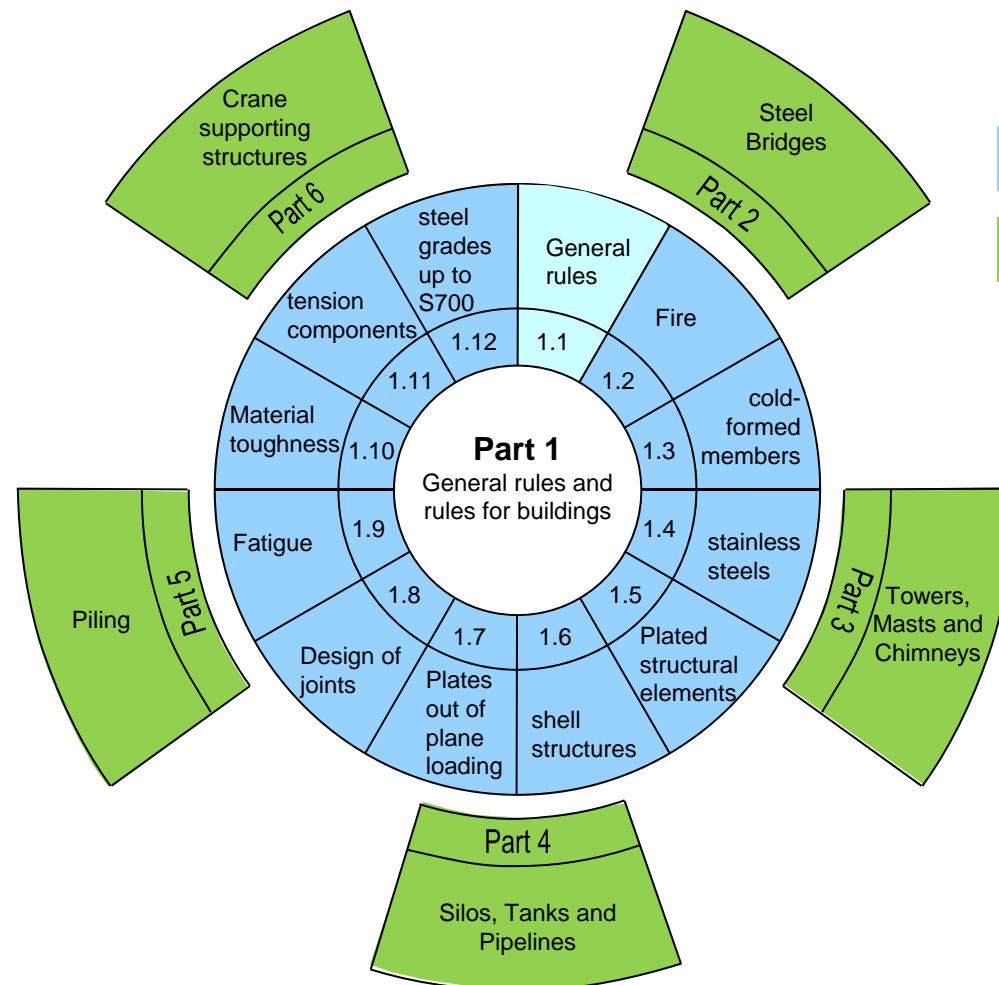
Prof. Dr.-Ing. U. Kuhlmann
(Chairperson CEN/TC250/SC3)

Content

- Structure and overview on Eurocode 3
- Organization
- Revision and further developments of Eurocode 3
- Mandate M/515
- Examples of issues for further developments
- Final remarks



Structure and overview on Eurocode 3

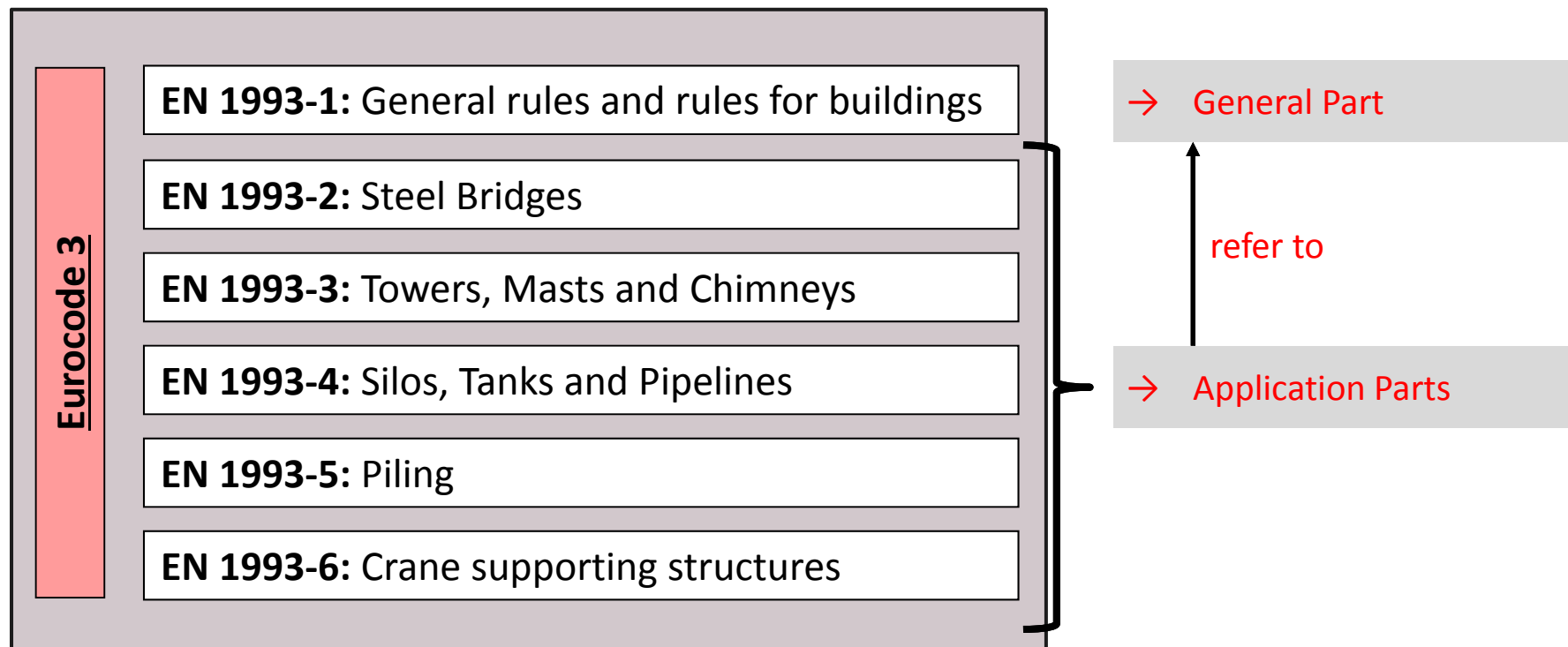


General parts (12 parts)

Application parts (8 parts)

Application parts
→ „Master“ for field of application

Structure and overview on Eurocode 3



Structure and overview on Eurocode 3

→ General Parts

EN 1993-1

EN 1993-1-1: General rules and rules for buildings

EN 1993-1-2: Structural fire design

EN 1993-1-3: Supplementary rules for cold-formed members and sheeting

EN 1993-1-4: Supplementary rules for stainless steels

EN 1993-1-5: Plated structural elements

EN 1993-1-6: Strength and stability of shell structures

EN 1993-1-7: Plated structures subject to out of plane loading

EN 1993-1-8: Design of joints

EN 1993-1-9: Fatigue

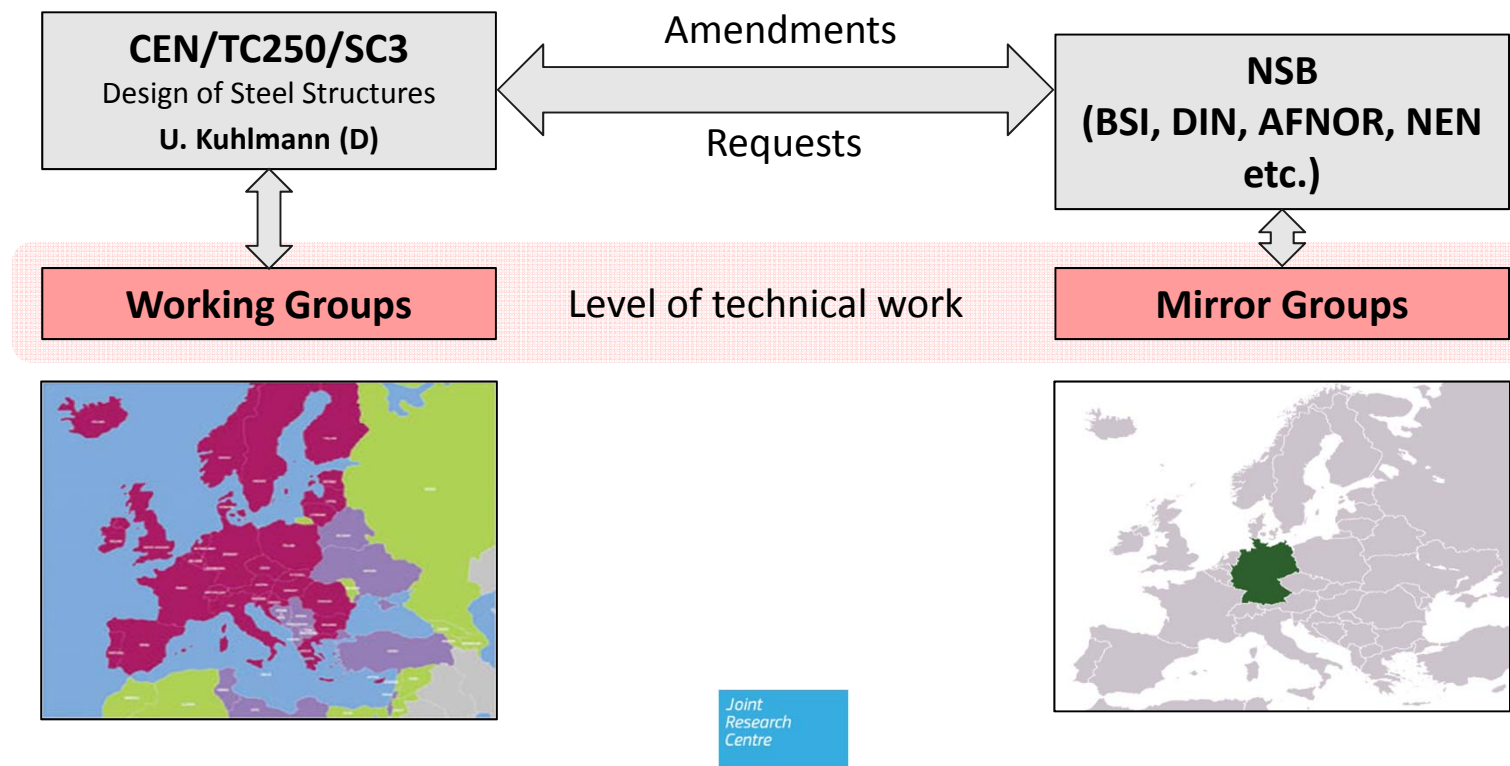
EN 1993-1-10: → EN 1993-1-1 and EN 1993-1-8 are of **central importance**

EN 1993-1-11: Design of structures with tension components

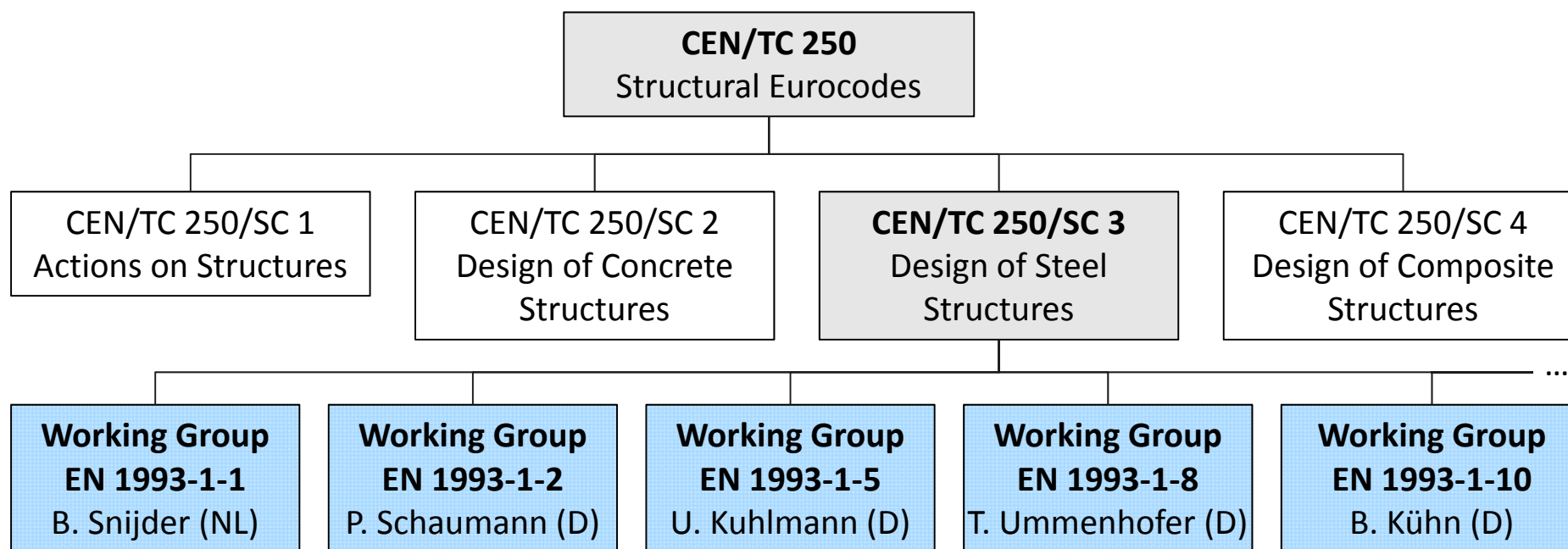
EN 1993-1-12: Additional rules for the extension of EN 1993 up to steel grades S700

Organization

- At European level CEN/TC250/SC3 „Design of Steel Structures“ involving NSBs = National Standardization Bodies (e.g. BSI, DIN, AFNOR, NEN etc.)



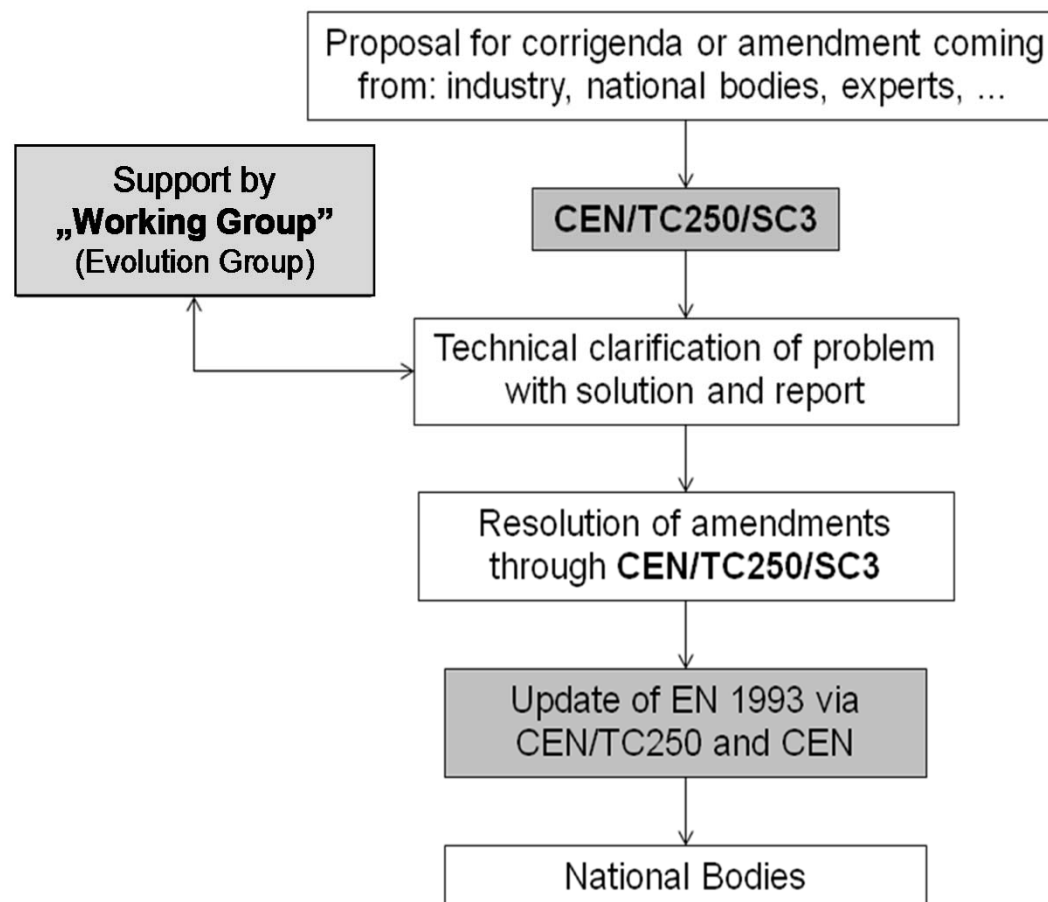
Organization



→ Technical work by **19 CEN Working Groups***

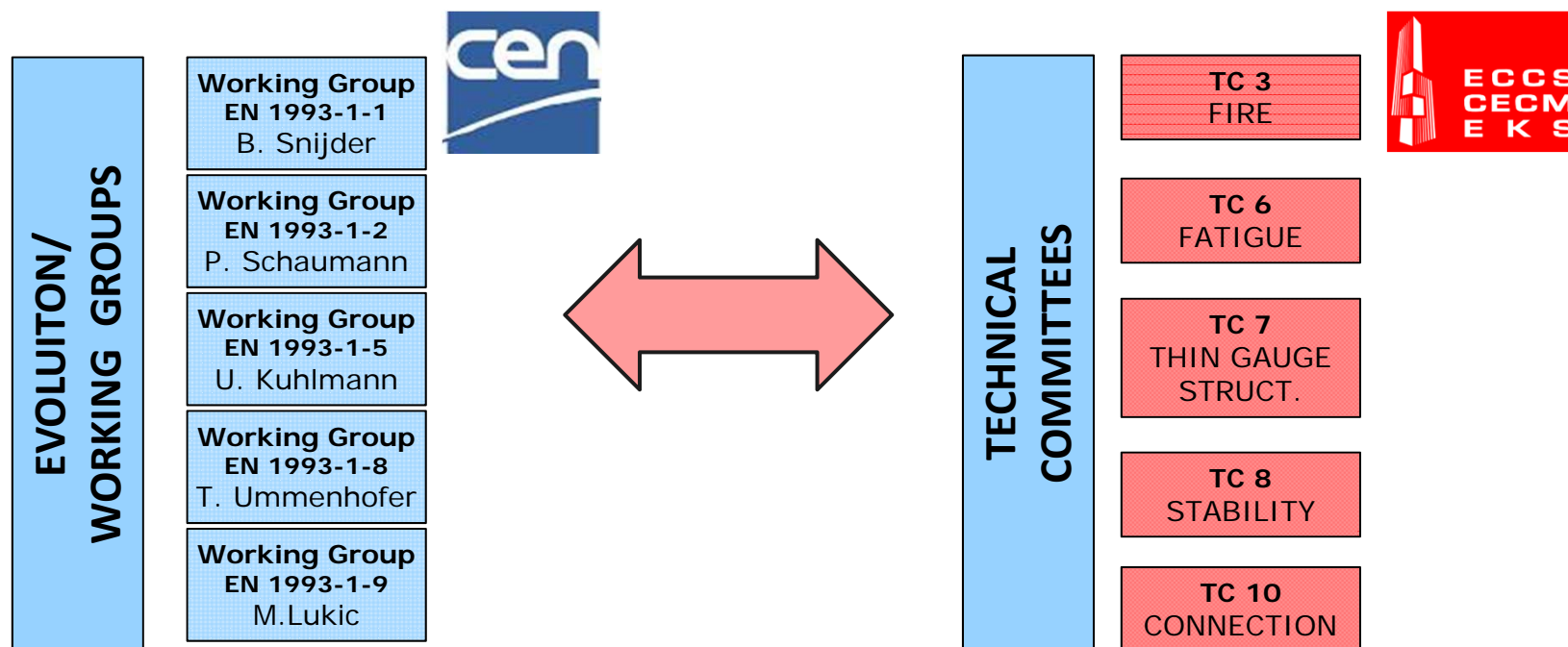
* Formerly called Evolution Groups

Organization



Organization

- CEN Evolution/Working Groups ↔ ECCS Technical Committees



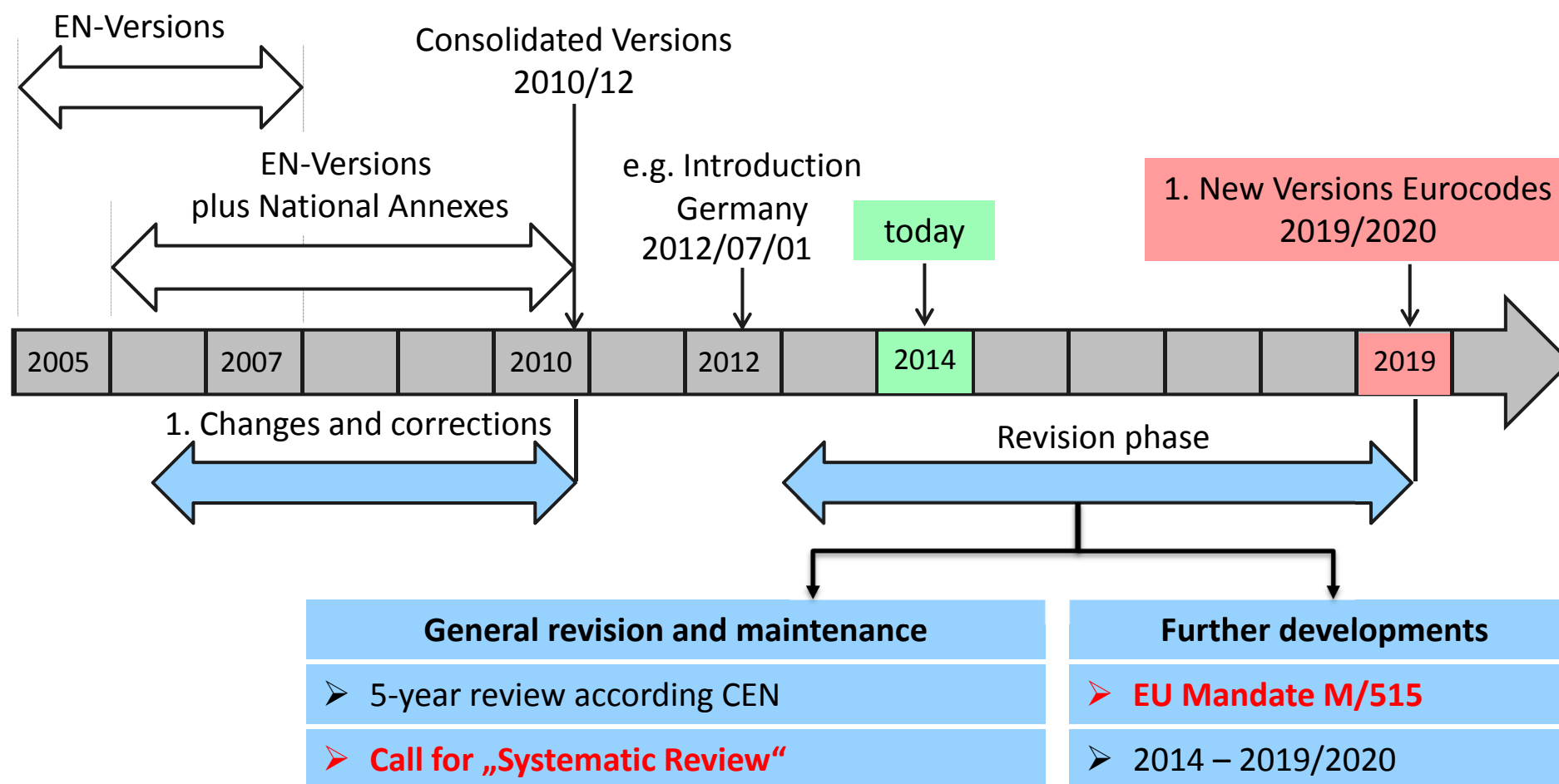
Exchange of experts - Common meetings, use of ECCS-Internet-Platform, common dissemination, common research projects

Organization

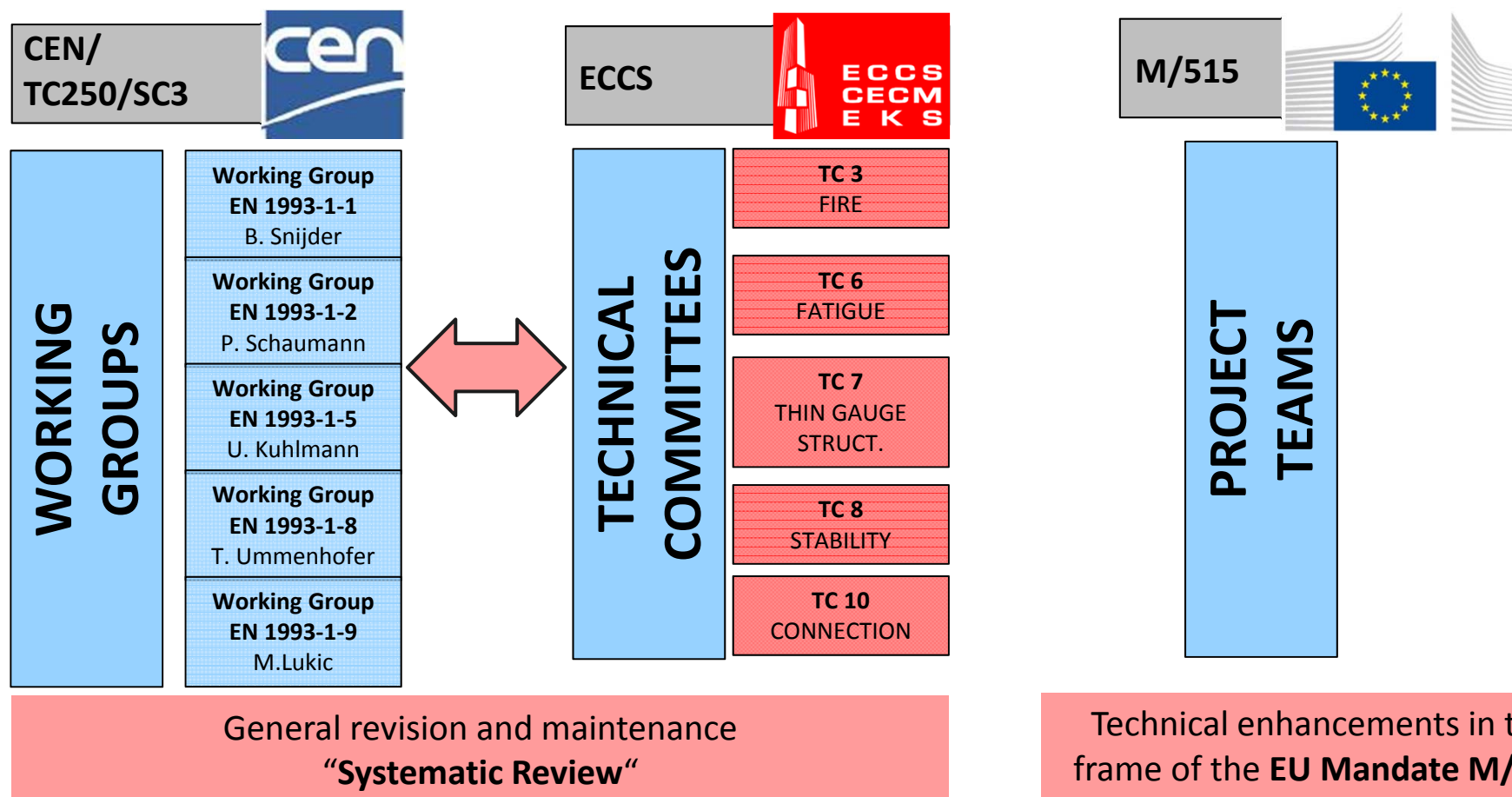
- Current list of Working Groups of SC3

Working Group CEN/TC250/SC3	Title	Convenor
WG1	Evolution of EN 1993-1-1 – General rules for buildings	B. Snijder
WG2	Evolution of EN 1993-1-2 – Fire	P. Schaumann
WG3	Evolution of EN 1993-1-3 – Cold-formed members	L. Sokol
WG4	Evolution of EN 1993-1-4 – Stainless steel	N. Baddoo
WG5	Evolution of EN 1993-1-5 – Plated structures	U. Kuhlmann
WG6	Evolution of EN 1993-1-6 – Shell Structures	M. Rotter
WG7	Evolution of EN 1993-1-7 – Plated structures subject to out of plane loading	M. Rotter
WG8	Evolution of EN 1993-1-8 – Joints and connections	T. Ummenhofer
WG9	Evolution of EN 1993-1-9 – Fatigue	M. Lukic
WG10	Evolution of EN 1993-1-10 – Material toughness and through-thickness properties	B. Kühn
WG11	Evolution of EN 1993-1-11 – Tension components	H. Friedrich
WG12	Evolution of EN 1993-1-12 – High strength steel	O. Lagerqvist
WG13	Evolution of EN 1993-2 – Bridges	L. Davaine
WG14	Evolution of EN 1993-3 – Towers, masts and chimneys	J. Rees
WG15	Evolution of EN 1993-4-1 – Silos	M. Rotter
WG16	Evolution of EN 1993-4-2 – Tanks	M. Rotter
WG17	Evolution of EN 1993-4-3 – Pipelines	M. Rotter
WG18	Evolution of EN 1993-5 – Piling	A. Schmitt
WG19	Evolution of EN 1993-6 – Crane supporting structures	U. Kuhlmann


Revision and further developments of Eurocode 3



Revision and further developments of Eurocode 3



Revision and further developments of Eurocode 3



Document : CEN/TC 250
N 1083

Date: 31 March 2014

To the Members of CEN/TC 250
Structural Eurocodes

Direct tel: +44 [0]208 996 7421
E-mail: tracey.wilkins@bsigroup.com
Web: www.bsigroup.com

Dear Member,

CEN/TC 250 SYSTEMATIC REVIEWS

In accordance with BT resolution C60/2008, the launch of systematic reviews for the 58 Eurocodes was delayed.

The systematic reviews are now being treated as a complementary activity to the execution of Mandate M/515 EN *Structural Eurocodes*, with the timing compatible with the phasing of the TC 250 work programme [CEN/TC 250 N 993]. It should be noted that the publication of the next generation of the EN Eurocodes is not planned to conclude before 2020.

The following reviews have been launched:

- **EN 1993-1-1:2005** [AC:2005 + AC:2006 + AC:2009] *Eurocode 3 - Design of steel structures - General rules and rules for buildings*
- **EN 1993-1-8:2005** [AC:2005 + AC:2009] *Eurocode 3 - Design of steel structures - Design of joints*
- **EN 1993-1-12:2007** [AC:2009] *Eurocode 3 - Design of steel structures - Additional rules for the extension of EN 1993 up to steel grades S 700*

Members are invited to register their responses to the questions below via their National Standards Body's nominated voter on the Committee Internal Ballot (CIB) no later than:

30 September 2014

➤ Current call

➤ First: EN 1993-1-1
EN 1993-1-8
EN 1993-1-12

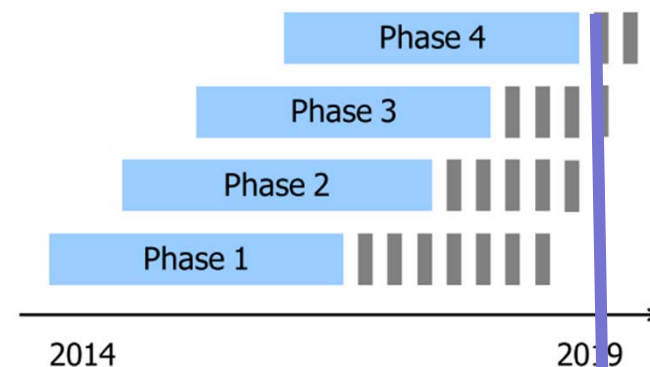
➤ Further parts later

Mandate M/515

- Title
 - Mandate for amending existing Eurocodes and extending the scope of structural Eurocodes
- Duration
 - 2014 – 2019/2020? (parallel to 1. review period of Eurocodes)
- Key Issues
 - Reduction of Nationally Determined Parameters (NPDs) of existing Eurocode parts
 - Enhancing ‘ease of use’ of existing Eurocodes by:
 - i. improving the clarity
 - ii. simplifying routes through the Eurocodes
 - iii. limiting, where possible, the inclusion of alternative application rules; and
 - iv. avoiding or removing rules of little practical use in design
- Creation of new Eurocodes, e.g. for “Glass” or “Existing Structures”

Mandate M/515

- Title
 - Mandate for amending existing Eurocodes and extending the scope of Structural Eurocodes
- Start originally March 2014 (now spring 2015?), Duration of 5 years, equal to official CEN review period of Eurocodes
- Total work program is split up into 4 overlapping phases



→ All coming amendments and corrigenda will be realized by the Mandate

1. Revision of
Eurocodes
2019/2020

Mandate M/515

- SC3 Mandate Tasks

Task-Ref.	Task-Phase	Corresponding Part of EN 1993	Task-Name	No. of Sub-tasks	No. of priority Sub-tasks	Responsible
SC3.T1	1	EN 1993-1-1	Design of Sections and Members according to EN 1993-1-1	9	6	B. Snijder
SC3.T2	1	EN 1993-1-8	Joints and Connections according to EN 1993-1-8	11	7	T. Ummenhofer
SC3.T3	2	EN 1993-1-3	Cold-formed members and sheeting - Revised EN 1993-1-3	10	7	L. Sokol
SC3.T4	2	EN 1993-1-5	Stability of Plated Structural Elements - Revised EN 1993-1-5	9	6	U. Kuhlmann
SC3.T5	2	EN 1993-1-6, -1-7	Harmonisation and Extension of Rules for Shells and Similar Structures - Revised EN 1993-1-6 and EN 1993-1-7	7	5	M. Rotter
SC3.T6	2	EN 1993-1-2	Fire design of Steel Structures - Revised EN 1993-1-2	10	6	P. Schaumann
SC3.T7	3	EN 1993-1-4	Stainless Steels - Revised EN 1993-1-4	7	5	N. Baddoo
SC3.T8	3	EN 1993-1-9	Steel Fatigue - Revised EN 1993-1-9	11	7	M. Lukic
SC3.T9	3	EN 1993-1-10	Material and Fracture - Revised EN 1993-1-10	9	6	B. Kühn
SC3.T10	4	EN 1993-2 EN1993-1-11	Steel bridges and tension components- Revised EN 1993-2 and EN 1993-1-11	9	6	L. Davaine H. Friedrich
SC3.T11	4	EN 1993-3	Consolidation and rationalisation of EN 1993-3	6	4	J. Rees
SC3.T12	4	EN 1993-4	Harmonisation and Extension of Rules for Storage Structures – Revised EN 1993-4-1 and EN 1993-4-2	8	5	M. Rotter
SC3.T13	4	EN 1993-1-12, - 4-3 EN 1993-5, -6	Evolution of existing parts of EN 1993 not included in the other parts. Revised EN 1993-1-12, -4-3, -5, -6	4	3	U. Kuhlmann

→ 13 single tasks for 20 parts of Eurocode 3

Mandate M/515

- Distribution of 13 SC3-Tasks
 - 2 Tasks (EN 1993-1-1 and EN 1993-1-8) in Phase 1 as basis where all the other parts are dependent on
 - 4 Tasks in Phase 2, mainly basic parts concerning stability
 - 3 Tasks in Phase 3, mainly basic parts concerning fatigue, toughness and material
 - 4 Tasks in Phase 4, application parts for bridges, silos, masts and tower etc.
- Main issues
 - Further development in view of reduction of NDPs, clarity and ease of use
 - Harmonizing of content, Harmonizing of different parts of Eurocode 3
 - Keep main structure and content for reliability

Mandate M/515

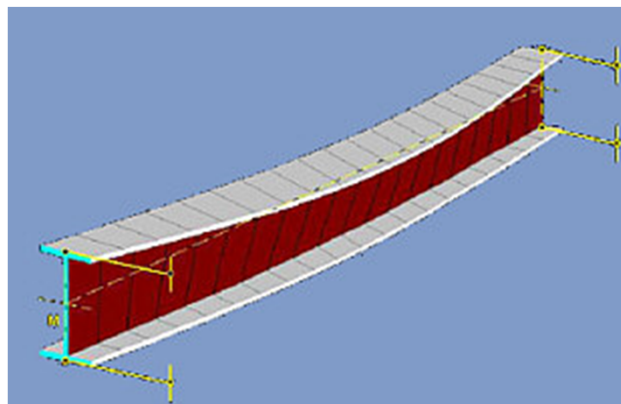
- Principles
 - After discussion the following principles for the further development of Eurocode 3 were decided within CEN/TC250/SC3

Decision 4/2013

- keep the overall structure of EN 1993 and its parts
- improve the clarity
- harmonize and simplify rules (same format, structure, notations,..) and harmonize different parts of Eurocode 3 and if possible also with other relevant Eurocodes
- reduce the overall volume (e.g. by avoiding informative annexes)
- reduce number of alternatives.

Further developments on the example of EN 1993-1-1

- Simplification of the stability rules
- Unification of the rules between general and application parts
- Reduction of the rules in particular for lateral torsional buckling



EN 1993-1-1: 2005 (E)

Annex A [informative] – Method 1: Interaction factors k_{ij} for interaction formula in 6.3.3(4)Table A.1: Interaction factors k_{ij} (6.3.3(4))

Interaction factors	Design assumptions	
	elastic cross-sectional properties class 3, class 4	plastic cross-sectional properties class 1, class 2
k_{yy}	$C_{my} C_{mLT} \frac{\mu_y}{1 - \frac{N_{Ed}}{N_{cr,y}}}$	$C_{my} C_{mLT} \frac{\mu_y}{1 - \frac{N_{Ed}}{N_{cr,y}}} \frac{1}{C_{yy}}$
k_{yz}	$C_{mz} \frac{\mu_y}{1 - \frac{N_{Ed}}{N_{cr,x}}}$	$C_{mz} \frac{\mu_y}{1 - \frac{N_{Ed}}{N_{cr,x}}} \frac{1}{C_{yz}} \frac{1}{0,6 \sqrt{\frac{w_z}{w_y}}}$
k_{zy}	$C_{my} C_{mLT} \frac{\mu_z}{1 - \frac{N_{Ed}}{N_{cr,y}}}$	$C_{my} C_{mLT} \frac{\mu_z}{1 - \frac{N_{Ed}}{N_{cr,y}}} \frac{1}{C_{zy}} \frac{1}{0,6 \sqrt{\frac{w_z}{w_y}}}$
k_{zz}	$C_{mz} \frac{\mu_z}{1 - \frac{N_{Ed}}{N_{cr,z}}}$	$C_{mz} \frac{\mu_z}{1 - \frac{N_{Ed}}{N_{cr,z}}} \frac{1}{C_{zz}}$

Auxiliary terms:

$$\mu_y = \frac{1 - \frac{N_{Ed}}{N_{cr,y}}}{1 - \chi_y \frac{N_{Ed}}{N_{cr,y}}}$$

$$\mu_z = \frac{1 - \frac{N_{Ed}}{N_{cr,z}}}{1 - \chi_z \frac{N_{Ed}}{N_{cr,z}}}$$

$$w_y = \frac{W_{pl,y}}{W_{el,y}} \leq 1,5$$

$$w_z = \frac{W_{pl,z}}{W_{el,z}} \leq 1,5$$

$$n_{pl} = \frac{N_{Ed}}{N_{Rk} / \gamma_{M1}}$$

$$C_{my} \text{ see Table A.2}$$

$$a_{LT} = 1 - \frac{I_T}{I_y} \geq 0$$

$$C_{yy} = 1 + (w_y - 1) \left[\left(2 - \frac{1,6}{w_y} C_{my}^2 \bar{\lambda}_{max} - \frac{1,6}{w_y} C_{my}^2 \bar{\lambda}_{max}^2 \right) n_{pl} - b_{LT} \right] \geq \frac{W_{el,y}}{W_{pl,y}}$$

with $b_{LT} = 0,5 a_{LT} \frac{\bar{\lambda}_0^2}{\chi_{LT} M_{pl,y,Rd} M_{z,Ed}}$

$$C_{yz} = 1 + (w_z - 1) \left[\left(2 - 14 \frac{C_{mz}^2 \bar{\lambda}_{max}^2}{w_z^5} \right) n_{pl} - c_{LT} \right] \geq 0,6 \sqrt{\frac{w_z}{w_y} \frac{W_{el,z}}{W_{pl,z}}}$$

with $c_{LT} = 10 a_{LT} \frac{\bar{\lambda}_0^2}{5 + \bar{\lambda}_z} \frac{M_{y,Ed}}{C_{my} \chi_{LT} M_{pl,y,Rd}}$

$$C_{zy} = 1 + (w_y - 1) \left[\left(2 - 14 \frac{C_{my}^2 \bar{\lambda}_{max}^2}{w_y^5} \right) n_{pl} - d_{LT} \right] \geq 0,6 \sqrt{\frac{w_y}{w_z} \frac{W_{el,y}}{W_{pl,y}}}$$

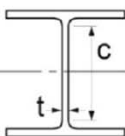
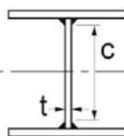
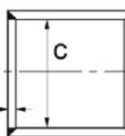
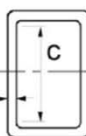
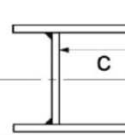
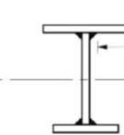
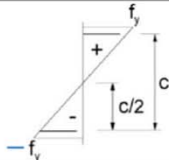
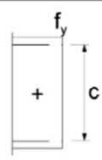
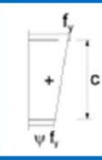
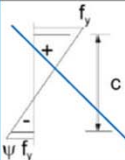
with $d_{LT} = 2 a_{LT} \frac{\bar{\lambda}_0}{0,1 + \bar{\lambda}_z} \frac{M_{y,Ed}}{C_{my} \chi_{LT} M_{pl,y,Rd} C_{mz} M_{z,Ed}}$

$$C_{zz} = 1 + (w_z - 1) \left[\left(2 - \frac{1,6}{w_z} C_{mz}^2 \bar{\lambda}_{max} - \frac{1,6}{w_z} C_{mz}^2 \bar{\lambda}_{max}^2 \right) n_{pl} - e_{LT} \right] \geq \frac{W_{el,z}}{W_{pl,z}}$$

with $e_{LT} = 1,7 a_{LT} \frac{\bar{\lambda}_0}{0,1 + \bar{\lambda}_z} \frac{M_{y,Ed}}{C_{my} \chi_{LT} M_{pl,y,Rd}}$

Further developments on the example of EN 1993-1-1

Cross-section Classification

Internal compression parts						
						Axis of bending
						
Class	Part subject to bending	Part subject to compression	Part subject to bending and compression			
Stress distribution in parts (compression positive)					$\leq \frac{38\epsilon}{0,608+0,343\psi+0,049\psi^2}$	
3	$c/t \leq 124\epsilon$ $c/t \leq 121\epsilon$	$c/t \leq 42\epsilon$ $c/t \leq 38\epsilon$	when $\psi > -1$: $c/t \leq \frac{42\epsilon}{0,67+0,33\psi}$ when $\psi \leq -1$: $c/t \leq 62\epsilon(1-\psi)\sqrt{(-\psi)}$			
$\epsilon = \sqrt{235/f_y}$	f_y	235	275	355	420	460
	ϵ	1,00	0,92	0,81	0,75	0,71

*) $\psi \leq -1$ applies where either the compression stress $\sigma \leq f_y$ or the tensile strain $\epsilon_y > f_y/E$

*) $\psi \leq -1$ and a compression stress of $\sigma_{com,Ed} = f_y$ applies when the tensile strain exceeds $\epsilon_y = f_y/E$

➤ Adaption of threshold values

➤ Adjustment with rules in EC3 Part 1-3, 1-5 and 1-6

➤ Continuous transition between Class 2 and 3

$$\leq \frac{38\epsilon}{0.608 + 0.343\psi + 0.049\psi^2}$$

$$\frac{42\epsilon}{0.67 + 0.33\psi}$$

$$c/t \leq 62\epsilon(1-\psi)\sqrt{(-\psi)}$$

$$\leq 60.5\epsilon(1-\psi)\sqrt{(-\psi)}$$

Further developments on the example of EN 1993-1-8

- Weld strength function

$$\tau_{w,Rd} = \frac{f_{u,k} / \sqrt{3}}{\beta_w \cdot \gamma_{M2}}$$

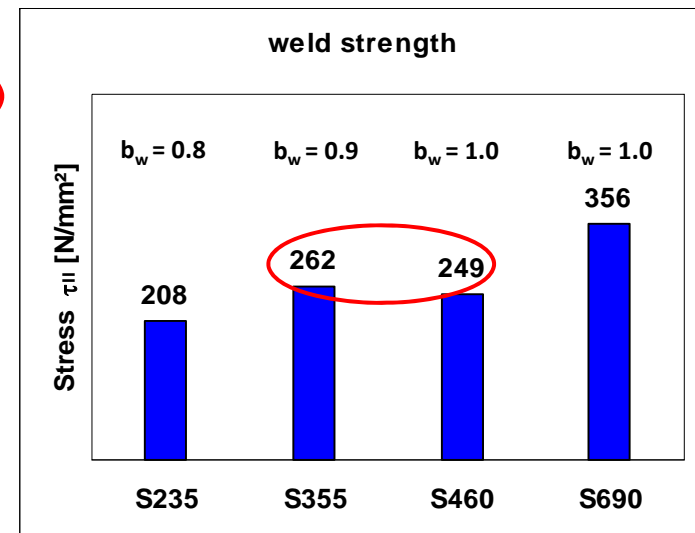
$f_{u,k}$ tensile strength of base metal
 β_w correlation factor

→ weld strength for S460 smaller than S355

→ weld strength independent of filler metal

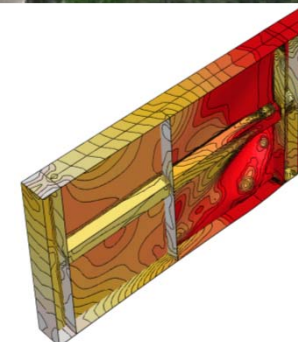
- No possibilities to cover mismatch-effects
- Undermatching may have advantages regarding ductility, weldability, quality

→ Improved design specifications also for steel grades up to 700 N/mm²



Further developments on the example of EN 1993-1-5

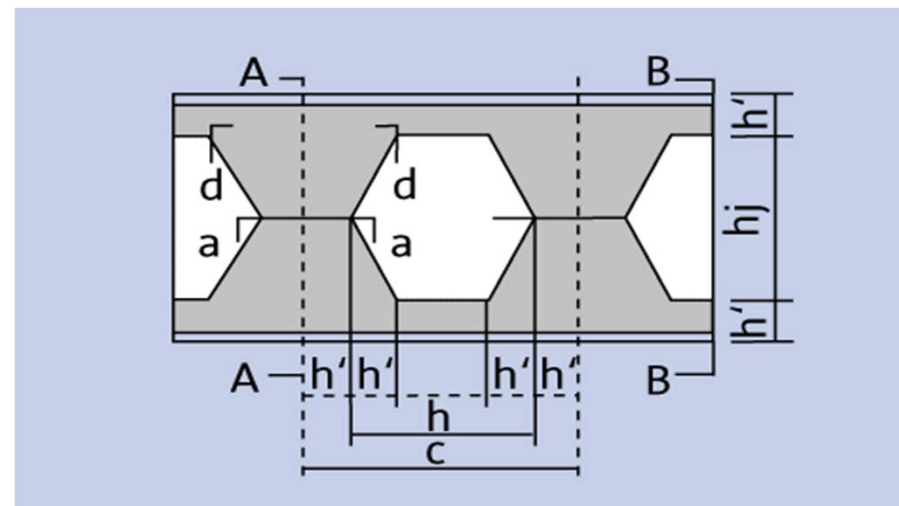
- Additional design rules and recommendations for modern stiffener design
- Additional design rules for girders with corrugated webs
- Further developments of rules for FEM-calculations and harmonization with EN 1993-1-6



Further developments

- Integration of EN 1993-1-12 for High Strength Steels up to 700N/mm^2 in the respective sections in the other general parts of EN 1993-1
- Reorganization and fundamental revision of EN 1993-1-7
Harmonization with EN 1993-1-5 (plate buckling) and EN 1993-1-6 (shell buckling)
- New design rules for girders with web-openings

	DIN EN 1993-1-12	DIN
ICS 91.010.30; 91.080.10	Ersatz für DIN EN 1993-1-12:2007-07 und DIN EN 1993-1-12 Berichtigung 1:2009-12	
Eurocode 3: Bemessung und Konstruktion von Stahlbauten – Teil 1-12: Zusätzliche Regeln zur Erweiterung von EN 1993 auf Stahlgüten bis S700; Deutsche Fassung EN 1993-1-12:2007 + AC:2009		
Eurocode 3: Design of steel structures – Part 1-12: Additional rules for the extension of EN 1993 up to steel grades S700; German version EN 1993-1-12:2007 + AC:2009		
Eurocode 3: Calcul des structures en acier – Partie 1-12: Règles additionnelles pour l'utilisation de l'EN 1993 jusqu'à la nuance d'acier S700; Version allemande EN 1993-1-12:2007 + AC:2009		



Final remarks

- How to influence the future code?

➤ Everyone

- Applying Eurocodes → Gaining experience
- Questions and comments to the mirror groups

➤ Collaboration in mirror groups

- Influence on National Annex
- Proposals for amendments

➤ Collaboration in Working Groups

- Experts nominated from National Standardization Bodies




Final remarks

- Aims
 - harmonized and user-friendly design rules
- Modern Eurocodes
 - Necessary basis for complex problems
 - Easy-to-use rules for standard cases (80%)

The application of the Eurocodes pays off

Apply rules, gather experience and influence
development
- Create codes for the future -

Thanks for attention !



Institut für Konstruktion und Entwurf

University of Stuttgart
Institute of Structural Design
Steel, Timber & Composite Constructions

Prof. Dr.-Ing. Ulrike Kuhlmann
Pfaffenwaldring 7
70569 Stuttgart

Phone: +49 711 685 66245
Facsimile: +49 711 685 66236
E-Mail: sekretariat@ke.uni-stuttgart.de