



EUROCODES

EN 1999

# Design of aluminium structures



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# Half century of research and codification on aluminium structures

1972, ECCS-TC2 “Aluminium Alloy Structures” – Chair F.M. Mazzolani;

1978, Issue of the The ECCS “European Recommendations for Aluminium Alloy Structures”;

1992, CEN/TC250/SC9 “Eurocode 9: Design of Aluminium Structures” – Chair F.M. Mazzolani;

2007, Issue of the first edition of EC9 (EN1999), revised in 2009;

2022, Issue of the Second Generation EC9;

2023, A. Mandara new Chairman of CEN/TC250/SC9.



# What is new in EN1999 Second Generation

- According to the project for the new generation of Eurocode 9, all the new items were planned just for Part 1-1
- Anyway, important maintenance operations have been done for the other Parts 1-2, 1-3, 1-4 1-5, including upgrading, updating and simplifying, with some new additions where necessary
- Significant reduction of Nationally Determined Parameters has been done, from 89 to 49 (main clauses, all parts)

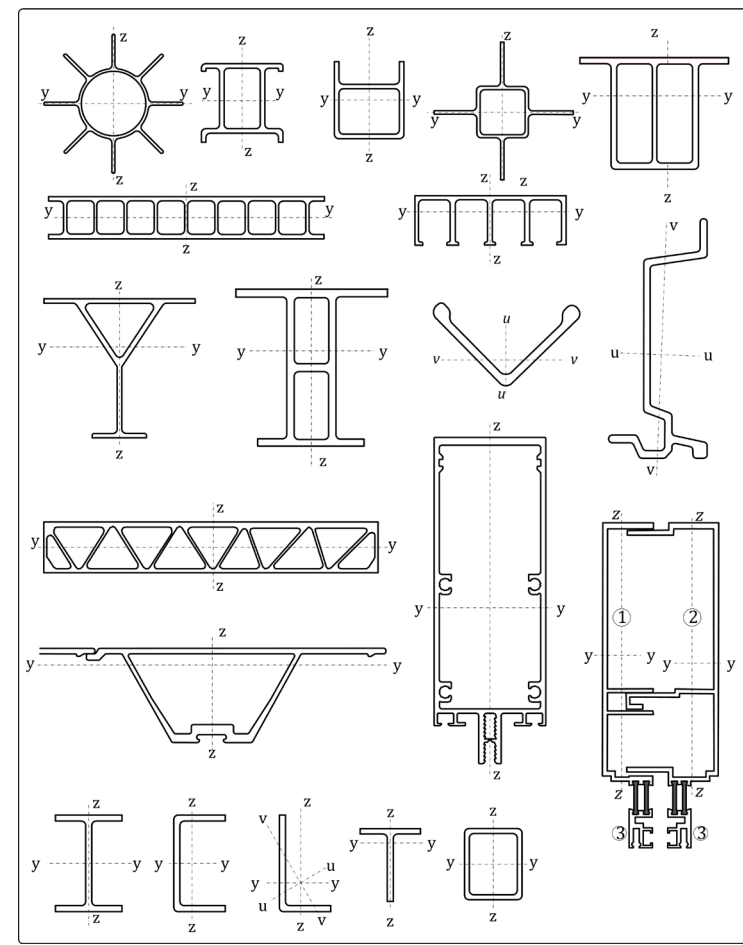
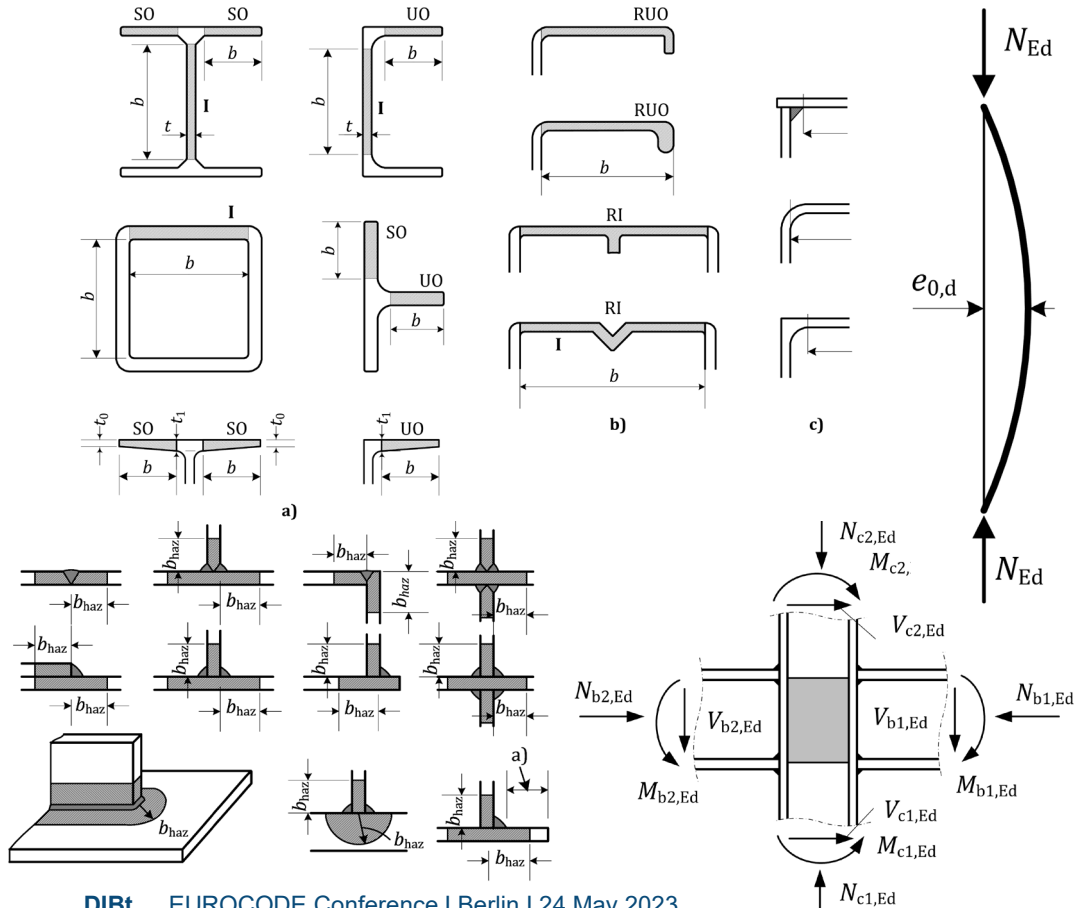


# How ease of use has been enhanced in the new EN1999

- Optimization of editorial layout and general improvement of wording
- Improvement of some figure
- The calculation methods have been simplified as far as possible
- Clear distinction between buckling of members with longitudinal welds and members with transverse welds
- Clear rules if the initial bow imperfection  $L/1000$  for members is not fulfilled
- Reduction of NDPs



# EN 1999-1-1: General Structural Rules



# EN 1999-1-1: General Structural Rules - Major changes

- Introduction of new material, alloy EN-AW 5383
- Introduction of structural typologies (bridging, roofing, composite aluminium-concrete)
- Introduction of a new buckling material class (Class B), intermediate between the previous classes with the corresponding new buckling curves
- Introduction of new connection types (FSW, bolt-channels, screw grooves)
- Improvement and addendum of the rules for equivalent T-stub in tension
- Addition of out-of-plane loading on stiffened plating
- Introduction of additional structural typologies (bridging, roofing, composite aluminium-concrete)
- Definition of improved buckling curves according to the new material classes ( $L/1000$ )



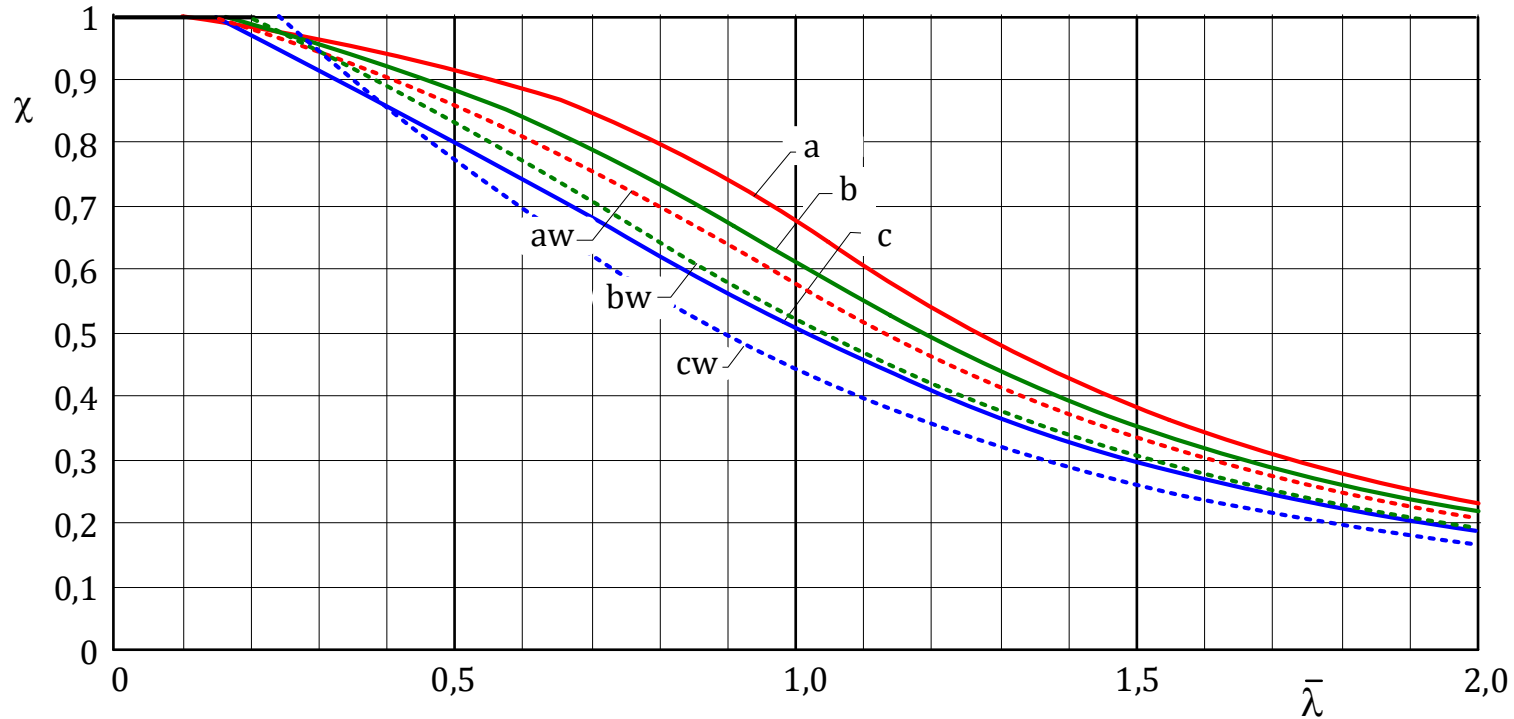
# EN 1999-1-1: General Structural Rules - New contents

- New buckling curves
- Special types of connections (bolt-channel, screw-groove, friction-stir welding)
- Bridges (Annex S)
- Lattice space roof structures (Annex T)
- Composite aluminium concrete beams (Annex U)
- Modified buckling conditions (Annex V)
- Determining the extent of HAZ from hardness tests (Annex Q)
- Weld studs connected by arc stud welding with tip ignition (annex R)



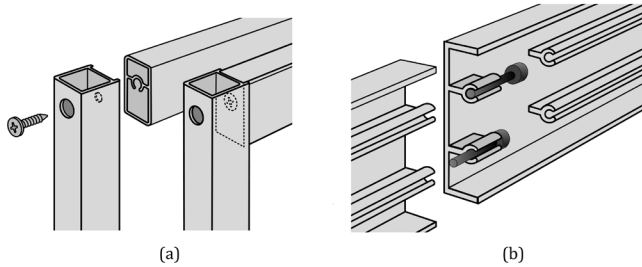


# New buckling curves: reduction factor $\chi$ for flexural buckling

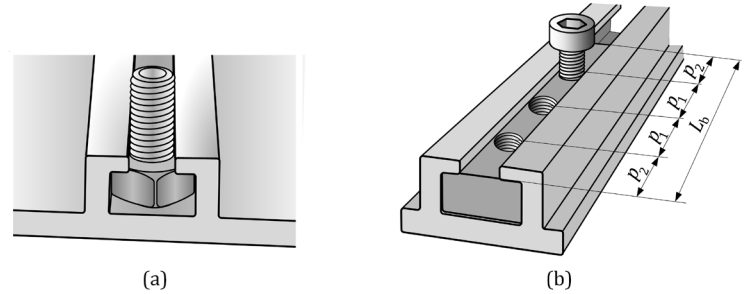


# New connections types

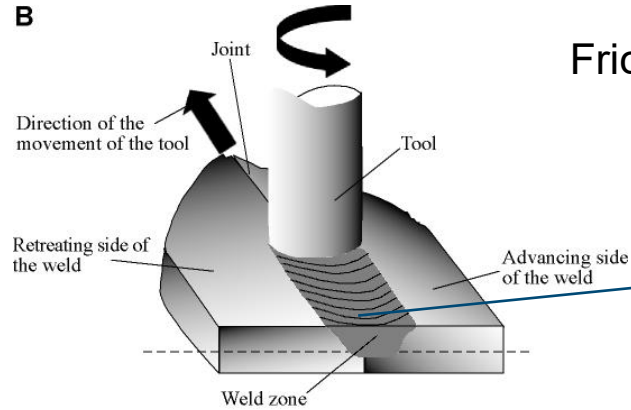
## Screw-groove



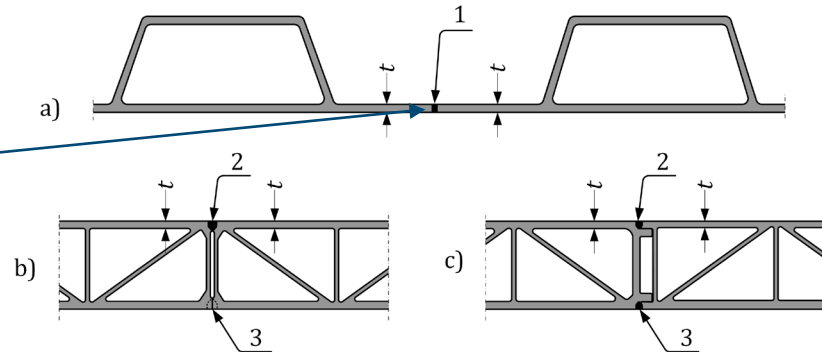
## Bolt-channel



B

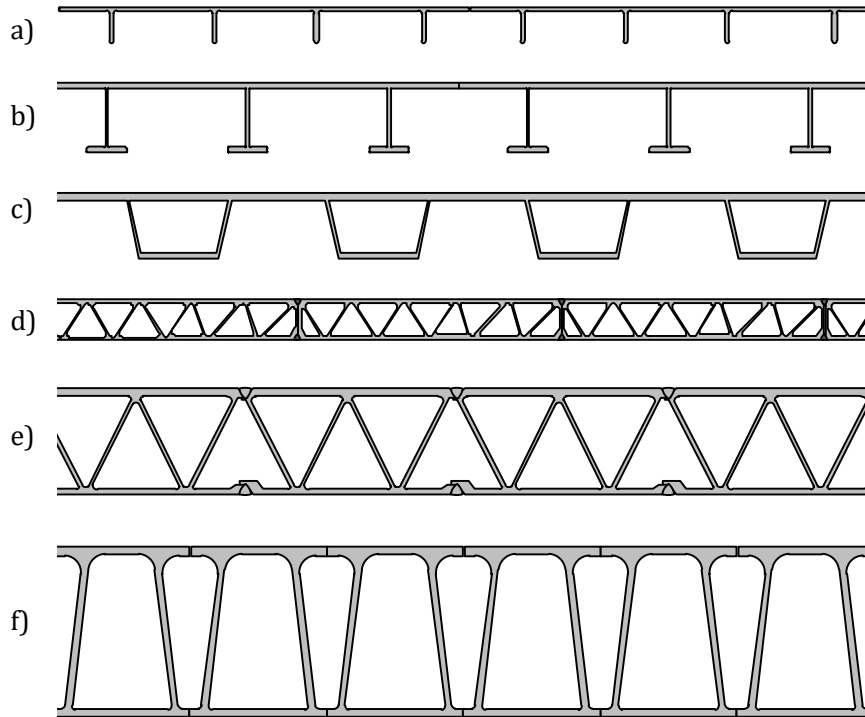


## Friction Stir Weld, FSW

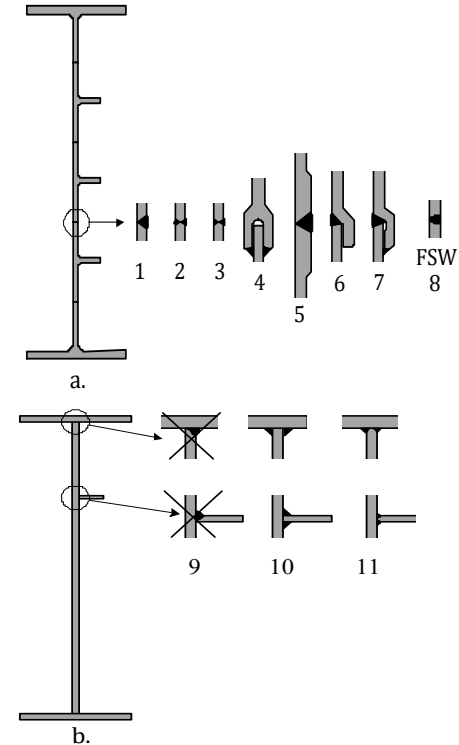


# Details of aluminium decks

## Extruded decks

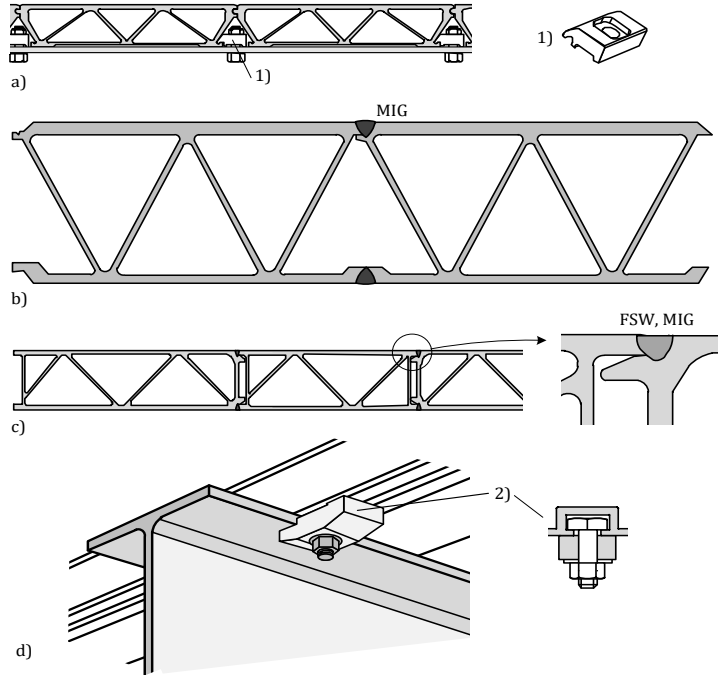


## Deep girders

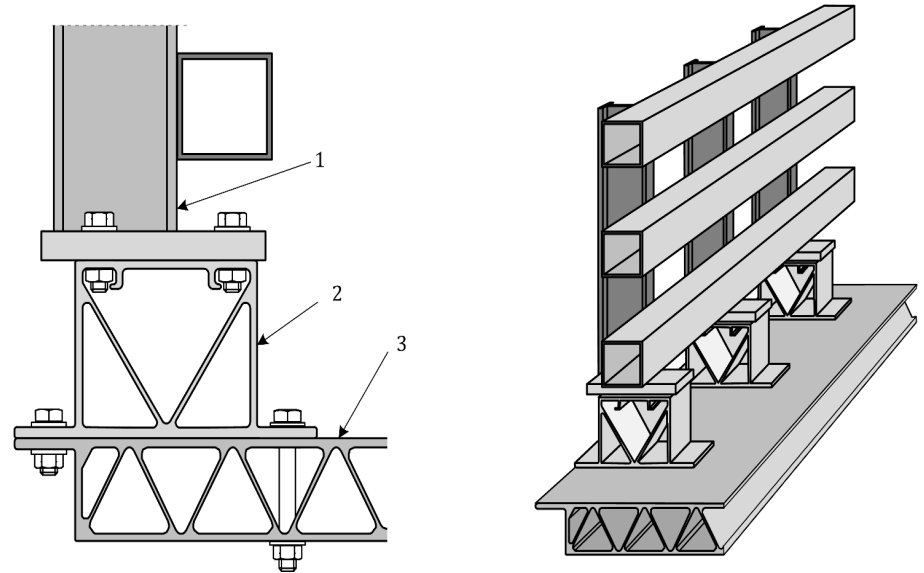


# Details of aluminium briges

## Details of splices of deck section



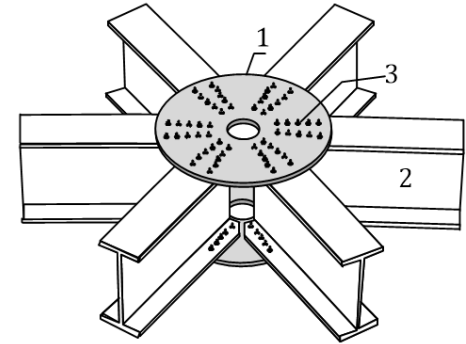
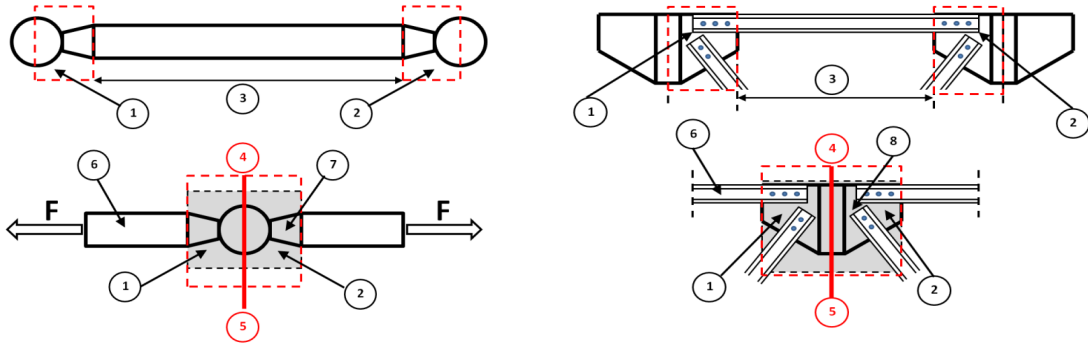
## Connection of traffic barrier to aluminium deck



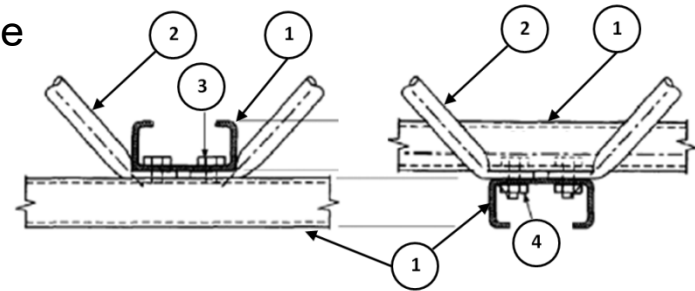
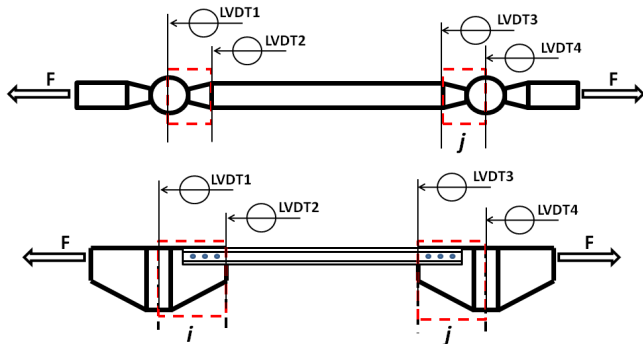
# Lattice Spatial Roof Structures

Joints requiring the testing of a complete sub-assembly

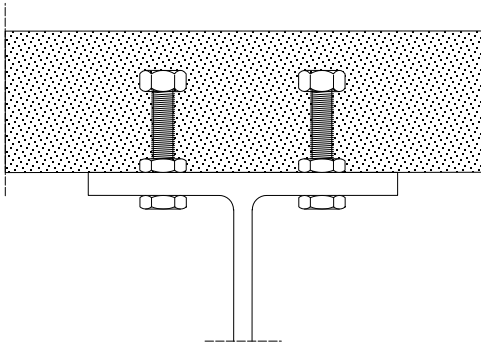
## Definition of joint and connection



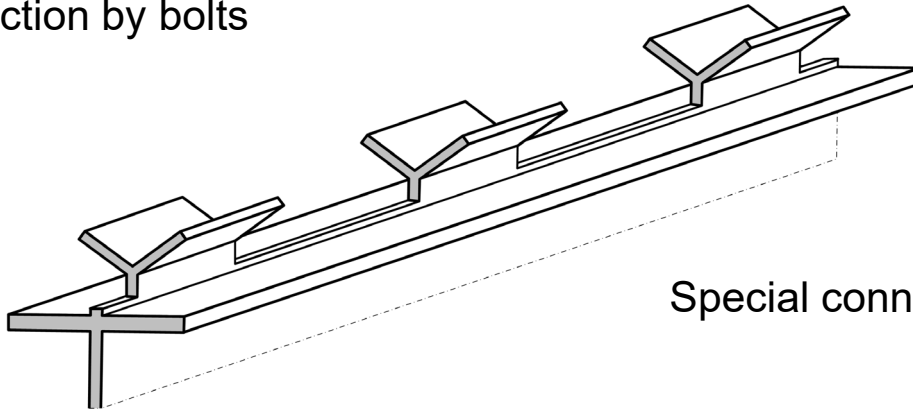
## Testing of a complete connection-to-member sub-assembly



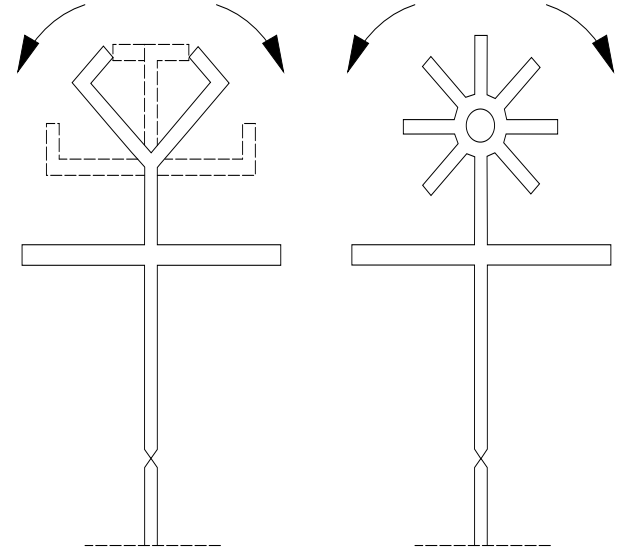
# Composite aluminium-concrete beams



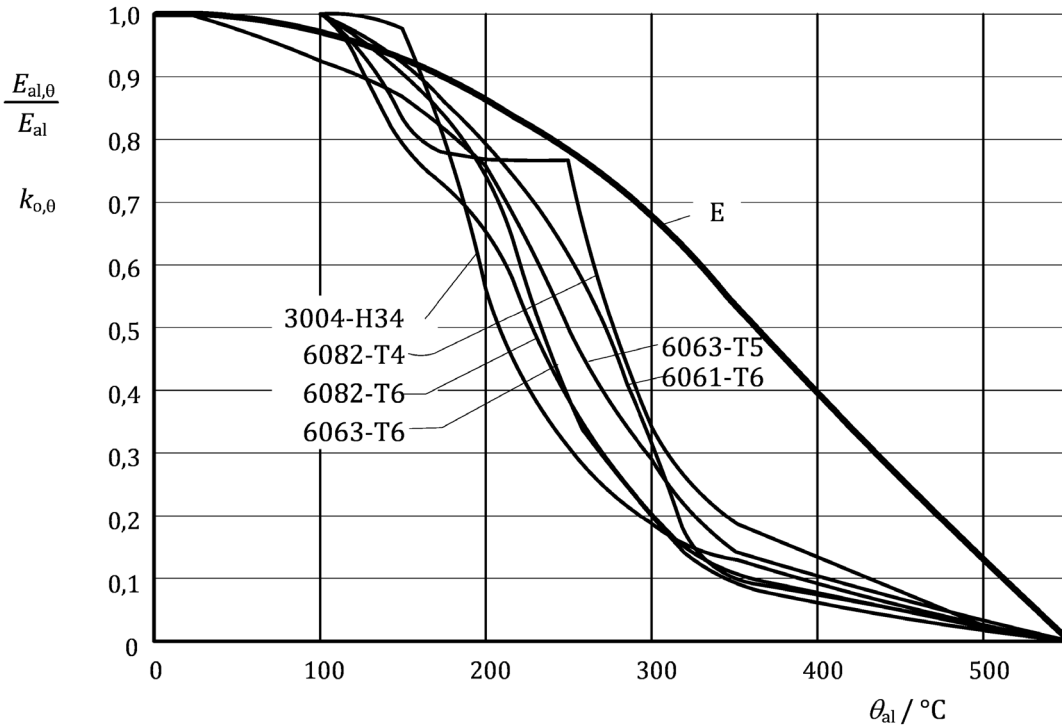
Connection by bolts



Special connectors by extrusion



# EN1999-1-2: Structural Fire Design



Aluminium alloy temperature, $\theta$ (°C)	Modulus of elasticity, $E_{al,\theta}$ (N/mm <sup>2</sup> )
20	70 000
50	69 300
100	67 900
150	65 100
200	60 200
250	54 600
300	47 600
350	37 800
400	28 000
550	0



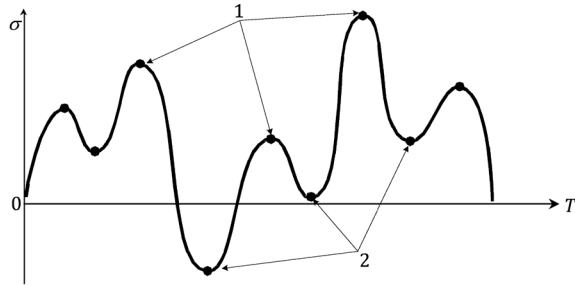
# EN1999-1-2: Structural Fire Design – Major changes

- No significant modifications have been included in the content of EN1999-1-2
- Light modifications with respect to the old version, which include:
  - Some reorganization of the text and its coherence with other Eurocodes (EN199x-1-2 and EN1991)
  - Improvement of some figures
  - Updating of symbols
- Improved clarity and consistency and harmonisation of existing contents according to the new template provided by HGF (Horizontal Group Fire), which has been applied for the Fire Part of all Eurocodes (EN 199x-1-2)
- Updating of many symbols according to Eurocodes related to other structural materials (EN 199x-1-2) and Eurocode 1

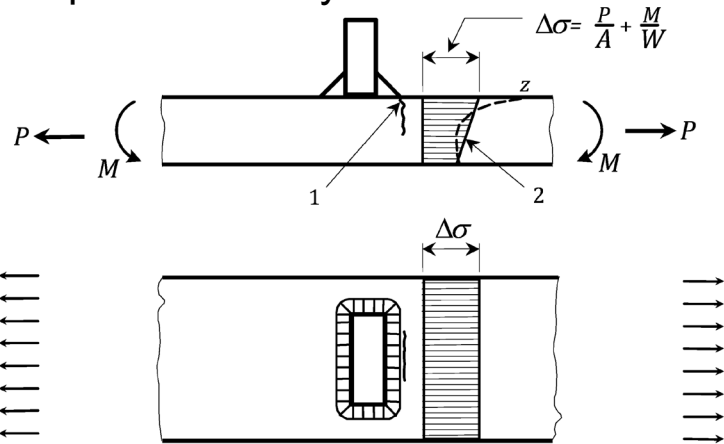




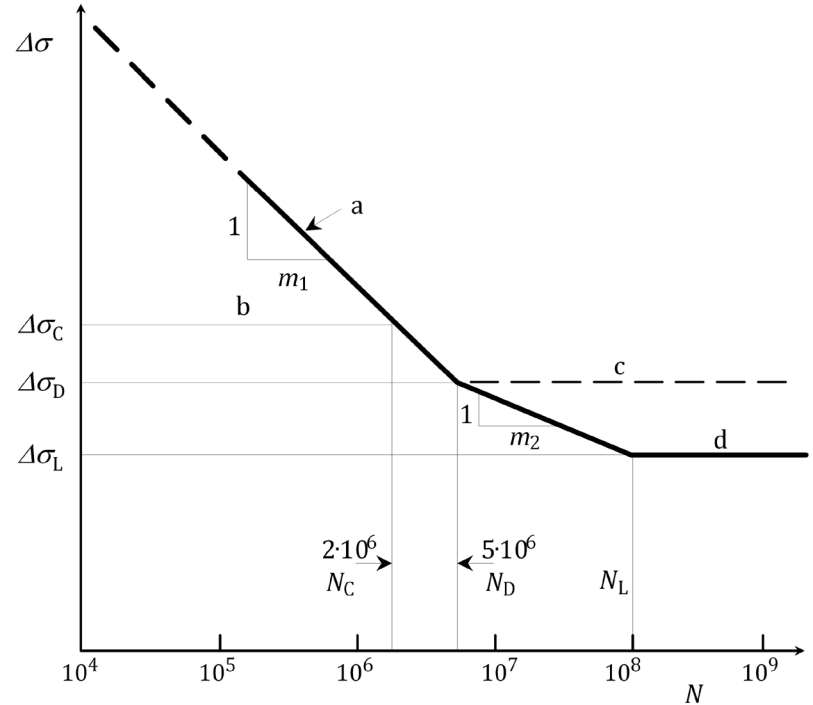
# EN1999-1-3: Structures susceptible to fatigue



Variable amplitude load cycle



Local stress concentration at weld toe



Fatigue strength curve  
 $\log\Delta\sigma - \log N$

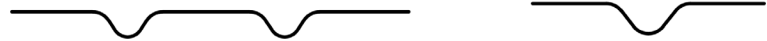
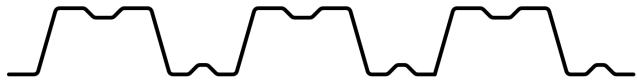


## EN1999-1-3: Structures Susceptible to Fatigue – Major changes

- The changes mainly about improving clarity and scope:
  - Some reorganization of the text and its coherence with the general part EN1999-1-1
  - Improvement of some figures
  - Improvement of detail categories for fillet-welded joints between members
  - Improvement of detail categories for bolted joints
- Inclusion of Friction Stir Welding:
  - Inclusion of Friction Stir Welding (FSW) in the scope
  - Inclusion of detail categories for members with FSW

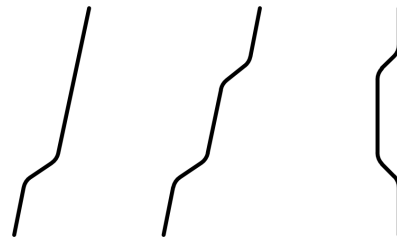


# EN1999-1-4: Cold-formed structural sheeting



Grooves in flanges

Examples of cold-formed profiled sheeting

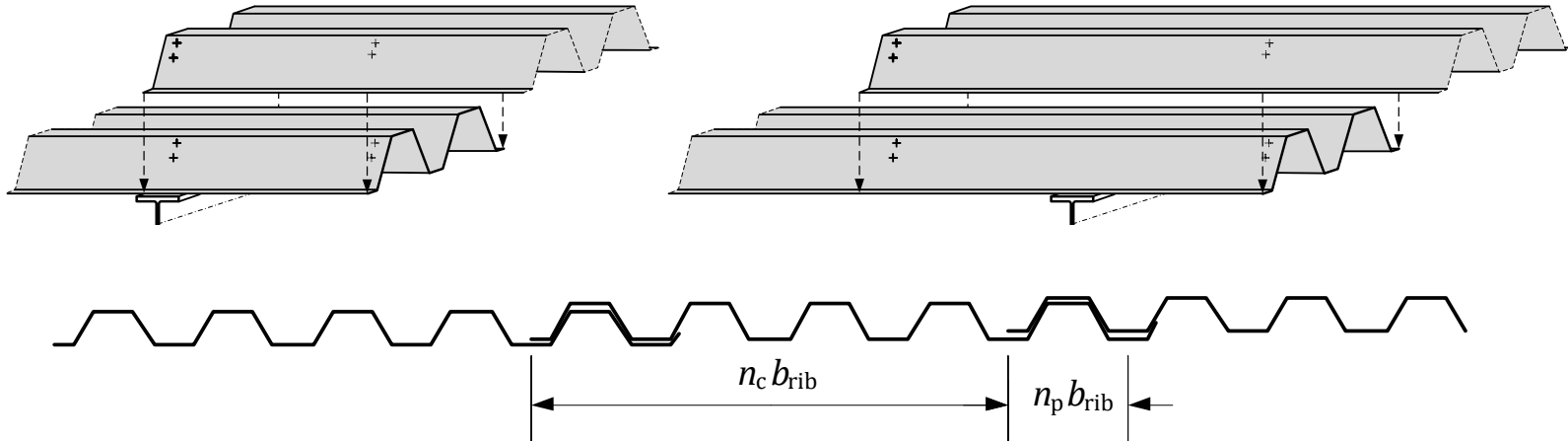


Folds in webs



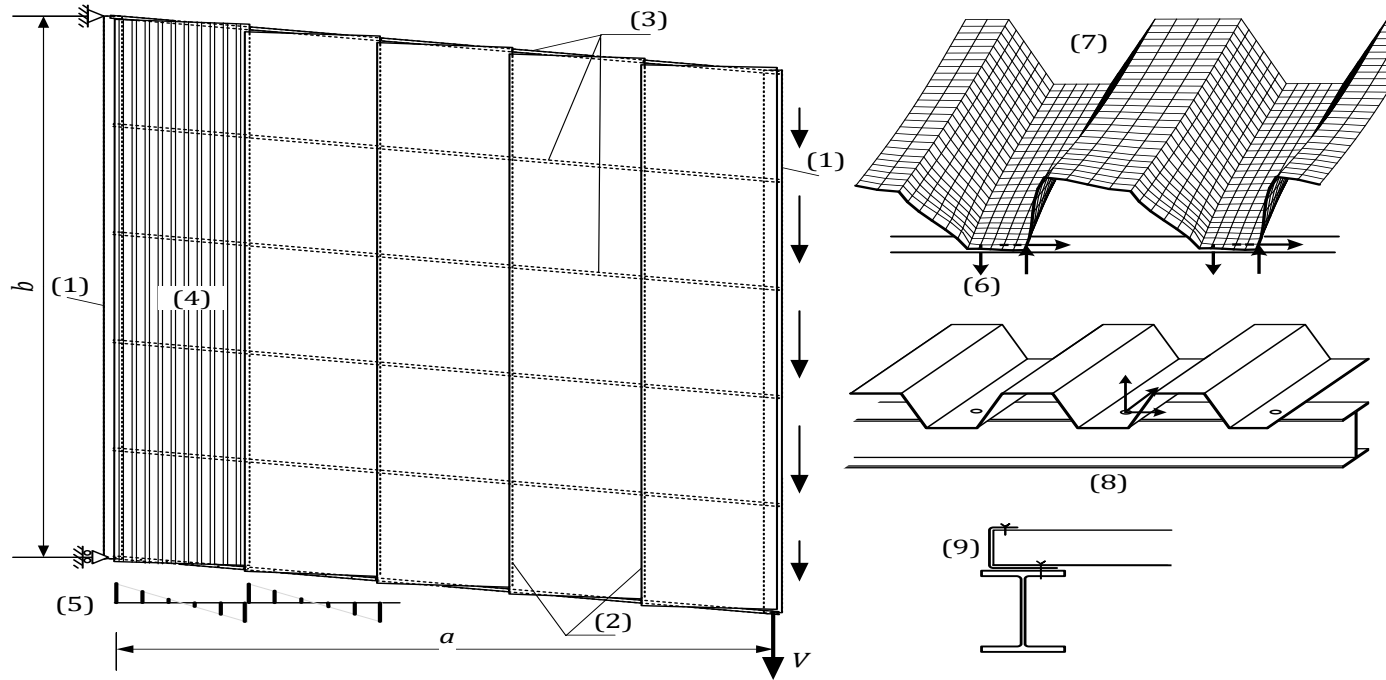
# New content included in the scope of EN1999-1-4

- New general rules for cold-formed profiles (not only profiled sheeting)
- New rules for static overlapping system of sheeting with single or double overlap
- New rules for trapezoidal sheeting with side overlaps

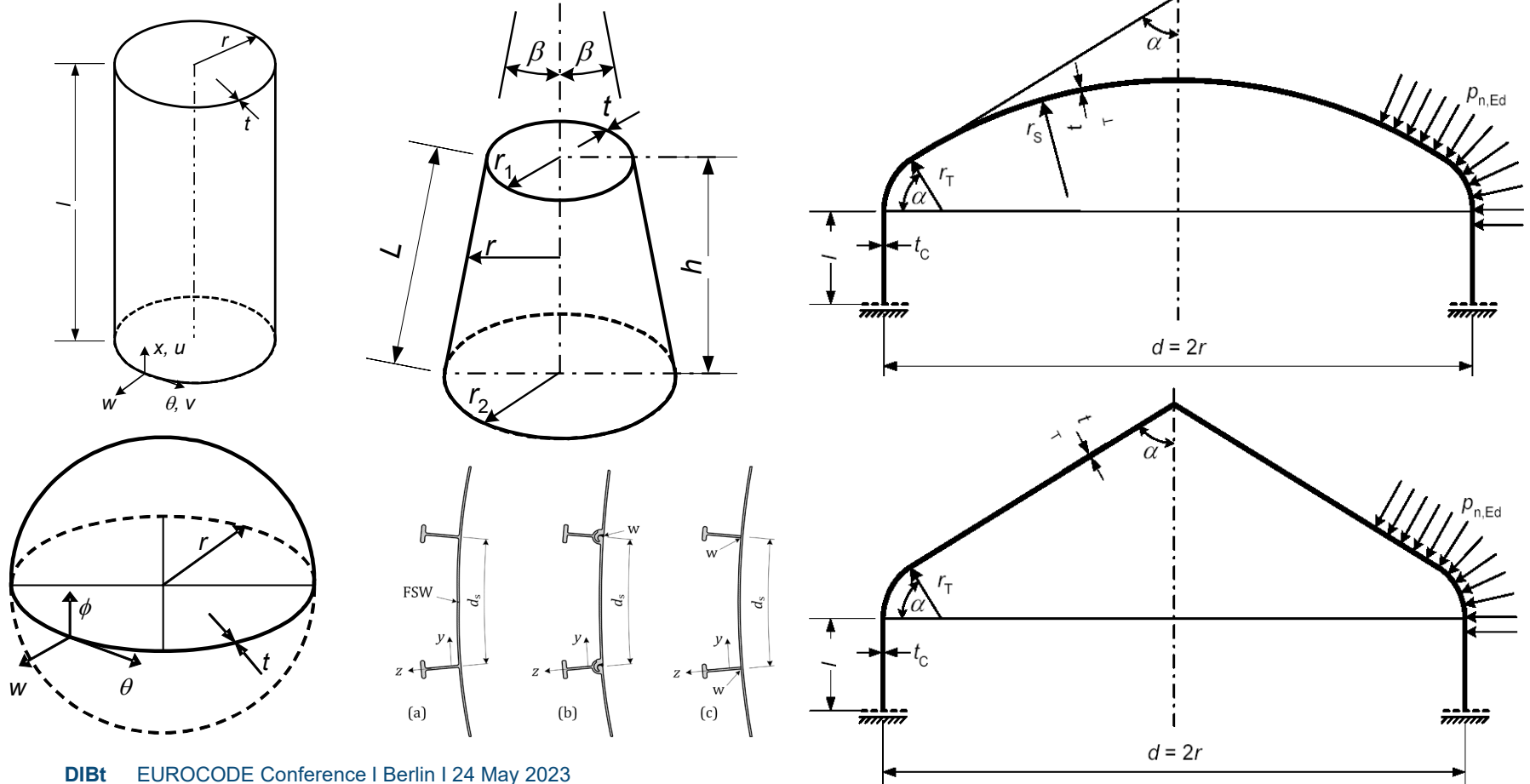


# New content included in the scope of EN1999-1-4

## ■ Clarification of behavior of diaphragm at the end of building



# EN1999-1-5: Shell Structures



# EN1999-1-5: Shell Structures – Major changes

- New, more accurate formulation for imperfection reduction factors given in Annex A, related to unstiffened and stiffened shells under axial load, circumferential pressure and shear, including the case of axial compression with coexistent internal pressure
- Better fitting of buckling curves against benchmarked available data, also considering the addition of a new material class in EN1999, which led to three buckling classes A, B and C
- Minor changes has been made in the content list of EN1999-1-5.
- Major changes have been done to Annex A dealing with buckling formulae for cylinders, cones and spheres
- Improved consistency with corresponding document of EC3 (EN1993-1-6)



# Conclusions

- Since its first EN issue in 2007, EC9 marked a valuable development in codification on Aluminium Structures for civil and industrial applications;
- A number of topics involving Aluminium Structures (e.g. Cold Formed Sheetings, Shell Structures, etc.) have been for the first time included into codification accepted at European level;
- In December 2022 the final draft of EN1999 Second Generation has been unanimously approved for publication;
- The New Generation EC9 embodies a further extension and refinement of the previous version, including additional structural typologies (bridging, roofing, composite aluminium-concrete, etc.) alongside with many changes making the code more effective and user-friendly;
- In March 2023 A. Mandara took over F.M. Mazzolani in the Chair of CEN/TC250/SC9. EC9 enters a new stage of maintenance and feedback from users.







**Presented by**

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