Tampereen yliopisto

Kylmämuovattujen teräsrakenteiden suunnittelu ja mitoitus

Toisen sukupolven standardi EN 1993-1-3

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EN 1993-1-3 – YLEISTÄ

- Standardin kehitystyö on käynyt läpi kaikki tavanomaiset vaiheet.
  - Viimeinen, ns. Formal Vote –vaihe alkaa lokakuussa 2023.
- TC250/SC3/WG3 –työryhmä on vastannut standardin päivityksestä
  - Aktiivisimpina Saksa, Ranska, BeNeLux-maat, UK sekä Suomi ja Ruotsi.
  - Tavallisesti kokouksissa on ollut edustajia n. 10 maasta

EN 1993-1-3 – SISÄLTÖ

EN 1993-1-3:2005

1. Introduction
2. Basis of design
3. Materials
4. Durability
5. Structural analysis
6. Ultimate limit state
7. Serviceability limit state
8. Design of joints
9. Design assisted by testing
10. Special considerations for purlins, liner trays and sheeting

132 sivua (englanninkielinen versio)

FprEN 1993-1-3:2023

1. Scope
2. Normative references
3. Terms, definitions and symbols
4. Basis of design
5. Materials
6. Durability
7. Structural analysis
8. Ultimate limit states
9. Serviceability limit states
10. Design of joints
11. Special considerations for purlins, liner trays and sheeting
12. Design assisted by testing

214 sivua (+62%, termejä 7 sivua, symboleja 18 sivua)

EN 1993-1-3 – SISÄLTÖ

EN 1993-1-3:2005
Liitteet

A. Testing procedures
B. Durability of fasteners
C. Cross section constants for thin-walled cross sections
D. Mixed effective width/effective thickness method for outstand elements
E. Simplified design for purlins

FprEN 1993-1-3:2023
Liitteet

A. Testing procedures
B. Durability of fasteners
C. Mixed effective width/effective thickness method for outstand elements

KANSALLISET VALINNAT

EN 1993-1-3:2005

National choice is allowed in EN 1993-1-3 through clauses:

- 2(3)P
- 2(5)
- 3.1(3) Note 1 and Note 2
- 3.2.4(1)
- 5.3(4)
- 8.3(5)
- 8.3(13), Table 8.1
- 8.3(13), Table 8.2
- 8.3(13), Table 8.3
- 8.3(13), Table 8.4
- 8.4(5)
- 8.5.1(4)
- 9(2)
- 10.1.1(1)
- 10.1.4.2(1)
- A.1(1), NOTE 2
- A.1(1), NOTE 3
- A.6.4(4)
- E(1)

FprEN 1993-1-3:2023

National choice is allowed in FprEN 1993-1-3 through notes to the following clauses:

4.2(3)	4.2(4)	4.2(5)	5.2.1(3)
7.1(2)	7.2.1(6)	8.2.5(2)	10.3(3)
10.3(3)	10.3(3)	10.3(3)	12(1)
A.1(1)	A.9.4(3)		

- Osavarmuuskertoimet (4.2(3) ja 4.2(4))
- Rakenneluokat (4.2(5))
- Plastisuusteorian käyttö rakenneanalyysissä (5.2.1(3))
- Suurin sallittu plastinen venymä FEM-analyysissä (7.1(2))
- Ekvivalentin sauvan menetelmän käyttö (7.2.1(6))
- Puristus-taivutuksessa käytetyt eksponentit (8.2.5.(2))
- Kiinnittimien kestävyys (10.3(3))
- Kylmämuovattujen rakenteiden testaus (12(1))
- Olemassa olevien testitulosten muuntaminen standardin mukaisiksi (A.1(1))
- Kestävyyden mitoitusarvon määrityksessä käytettävä osavarmuuskerroin (A.9.4(3))

Standardin EN 1993-1-3 päivitys

- Yleiset periaatteet pysyvät ennallaan
- Yksityiskohdissa paljon pieniä muutoksia
  - Koko standardi on luettava huolella läpi.
- Tässä keskitytään seuraaviin muutoksiin
  1) Rakenneluokat (4.2(5))
  2) Nimellispaksuus t_{nom} (5.2.4(6))
  3) Rakenneanalyysi (7.2)
  4) Puristus-taivutus (8.2.5)
  5) Muotolevyjä ja orsia koskevia lisäsääntöjä (11)

MUUTOS 1

RAKENNELUOKAT

RAKENNELUOKAT

EN 1993-1-3:2005 2(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:

		KÄYTTÖTARKOITUS
Structural Class I:	Construction where cold-formed members and sheeting are designed to **contribute to the overall strength and stability of a structure**;	**LEVYJÄYKISTYS**
Structural Class II:	Construction where cold-formed members and sheeting are designed to **contribute to the strength and stability of individual structural elements**;	**YKSITTÄISEN SAUVAN TUENTA**
Structural Class III:	Construction where cold-formed sheeting is used as an element that **only transfers loads to the structure**.	**EI VUOROVAIKUTUSTA RUNGON KANSSA**

NOTE 1: During different construction stages different structural classes may be considered.

NOTE 2: For requirements for execution of sheeting see EN 1090.

RAKENNELUOKAT

FprEN 1993-1-3:2023 4.2(5)

In the design of structures, a distinction shall be made between various ‘structural classes’, based on the level of contribution of cold-formed steel members, sheeting or sandwich panels to the strength and stability of the overall structure or that of individual structural elements. These **structural classes are associated with different requirements in the applicable product and execution standards for cold-formed steel members, sheeting and sandwich panels**, and shall be determined as follows:

— Applications in which cold-formed steel members, sheeting or sandwich panels are designed to contribute to the overall strength and stability of a structure shall be classified as **Structural Class I**;

— Applications in which cold-formed steel members, sheeting or sandwich panels are designed to contribute to the strength and stability of individual structural elements shall be classified as **Structural Class II**;

— Sheeting or sandwich panels providing stabilizing support to purlins or side rails which are designed as part of the bracing system of the main structure (e.g. as compression members, struts, or tie beams) **may be** classified as **Structural Class II**.

— Applications in which cold-formed steel members, sheeting or sandwich panels are used as elements which only transfer loads to the structure shall be classified as **Structural Class III**. Sheeting and sandwich panels in Structural Class III can be further differentiated into **‘structural’** or **‘non-structural’** applications.

NOTE Permitted applications of non-structural cold-formed steel sheeting or non-structural sandwich panels in Structural Class III can be set by the **National Annex**.

RAKENNELUOKAT

FprEN 1993-1-3:2023 4.2(5)

EN 1090-4 and EN 1090-2 cover the requirements for execution of structural sheeting and cold-formed steel members. **EN 14782 covers non-structural** cold-formed sheeting in Structural Class III. EN 14509-1 covers non-structural sandwich panels in Structural Class III and EN 14509-2 covers structural sandwich panels in Structural Class II.

(6) The classification into structural classes is particularly relevant for sheeting and sandwich panels to establish their relation with the overall structure, as well as with their supporting members.

NOTE

Structural Class I: The **designer of the structure** assumes bracing of the structure by the sheeting.

Structural Class II: The **designer of the members** directly supporting the sheeting or sandwich panels assumes that the latter provide restraint with regard to global buckling or bending parallel to the plane of the sheeting or sandwich panel.

Structural Class III: The **designer of the members** directly supporting the sheeting or sandwich panels assumes that the latter do not provide restraint with regard to global buckling or bending parallel to the plane of the sheeting or sandwich panel.

RAKENNELUOKAT

KESKEINEN MUUTOS

- Selkiytetään rakenneluokkien 2 ja 3 eroa.
- Luokassa 3 erotellaan ”ei-rakenteelliset” (non-structural, itsekantantavat) ja ”rakenteelliset (structural) tapaukset
  - Näillä on merkitystä toteutusstandardin valinnassa ja loppukädessä rakenteellisen turvallisuuden takaamisessa.
- Korostetaan suunnittelijoiden välistä viestintää ja vastuita.

MUUTOS 2

NIMELLISPAKSUUS

NIMELLISPAKSUUS

EN 1993-1-3:2005
3.2.4(5)

t_{nom} is the **nominal sheet thickness** **after cold forming**. It may be taken as the value to t_{nom} of the original sheet, if the calculative cross-sectional areas before and after cold forming do not differ more than 2%; otherwise the notional dimensions should be changed.

ONGELMA:

1. Suunnittelijan on erittäin vaikeaa (*suht' mahotonta*) tietää, toteutuuko ”2% sääntö” vai ei.
2. Jos sääntö ei toteudu, standardi ei kerro, miten käsitteellisiä mittoja (*notional dimensions*) pitäisi muuttaa.

NIMELLISPAKSUUS

FprEN 1993-1-3:2023
5.2.4(6)

t_{nom} is the nominal sheet thickness after cold-forming. It may be taken as the value t_{nom} of the original sheet, if

— the cross-sectional area A before cold-forming (equal to the nominal sheet width times the nominal thickness) and the cross-sectional area A_{calc} after cold-forming (as calculated from the specified cross-sectional shape) do not differ by more than 2%, or

*— the design of the members is based on the **basic yield strength** f_{yb}.*

Otherwise, the specified nominal thickness t_{nom} of the original sheet material should be reduced correspondingly.

Käytännössä levynpaksuuskysymys voidaan sivuuttaa, koska mitoitus perustuu pääosin perusaineen myötörajaan f_{yb}.

MUUTOS 3

RAKENNEANALYYSI

RAKENNEANALYYSI

FprEN 1993-1-3:2023
7.2

- EN 1993-1-3 on “harmonisoitu” EN 1993-1-1:n kanssa rakenneanalyysin ohjeistuksen osalta.
  - Analyysimenetelmät M0-M5, EM
  - Ensimmäisen ja toisen kertaluvun analyysi
  - Epätarkkuudet
- Kylmämuovatuilla rakenteilla erilaiset stabiilisuusilmiöt korostuvat.
  - Näihin liittyvien epätarkkuuksien kanssa on oltava tarkkana, EN 1993-1-1:n sääntöjä on haluttu täsmentää.
- Mahdollisuus soveltaa elementtimenetelmää EN 1993-1-14 mukaisesti on avattu.

RAKENNEANALYYSI

Table 7.1 — Methods of structural analysis applicable to ultimate limit state design checks of cold-formed steel structures and members

Method acc. to. EN 1993-1-1: 2022, 7.2.2	Additional requirements for cold-formed steel sections	1st/2nd order effects for global analysis	Imperfections to be considered in the global analysis	Design check according to Clause 8.1 or 8.2
M0 7.2.2(4)	In-plane and out-of-plane buckling may be neglected	1st order effects	None	8.1: Cross-sectional resistance
M1 7.2.2(5)	In-plane buckling may be neglected, Out-of-plane buckling (Flexural, torsional, torsional-flexural or lateral-torsional buckling) shall not be neglected	1st order effects	None	8.1: Cross-sectional resistance and 8.2: Out-of-plane member buckling check
EM 7.2.2(9)	None	1st order effects	None	8.1: Cross-sectional resistance and 8.2: In-plane and out-of-plane member buckling check acc. to 8.2 based on an appropriate buckling length of "Equivalent Members"

RAKENNEANALYYSI

Method acc. to. EN 1993-1-1: 2022, 7.2.2	Additional requirements for cold-formed steel sections	1st/2nd order effects for global analysis	Imperfections to be considered in the global analysis	Design check according to Clause 8.1 or 8.2
M2 7.2.2(6)	None	1st order effects	Sway imperfections	8.1: Cross-sectional resistance and 8.2: In-plane and out-of-plane member buckling check
M3 7.2.2(7)a	None	2nd order effects	Sway imperfections	8.1: Cross-sectional resistance using γ_{M1} and 8.2: In-plane and out-of-plane member buckling check

RAKENNEANALYYSI

Method acc. to. EN 1993-1-1: 2022, 7.2.2	Additional requirements for cold-formed steel sections	1st/2nd order effects for global analysis	Imperfections to be considered in the global analysis	Design check according to Clause 8.1 or 8.2
M4 7.2.2(7)b	None	2nd order effects	Sway imperfections and in-plane member bow imperfections	8.1: Cross-sectional resistance using γ_{M1} and 8.2: Out-of-plane member buckling check
M5 7.2.2(8)	None	2nd order effects	Sway imperfections and in-plane and out-of-plane member bow imperfections and torsional effects (torsional, torsional-flexural or lateral-torsional buckling modes)	8.1: Verification of the cross-sectional resistance using γ_{M1} or Stress verification e.g. based on FE-analysis acc. to EN 1993-1-14 using γ_{M1}

MUUTOS 4

PURISTUS-TAIVUTUS

PURISTUS-TAIVUTUS

EN 1993-1-3:2005
6.2.5

(1) The interaction between axial force and bending moment may be obtained from a second-order analysis of the member as specified in EN 1993-1-1, based on the properties of the effective cross-section obtained from Section 5.5. See also 5.3.

(2) As an alternative the interaction formula (6.36) may be used

$$\left(\frac{N_{Ed}}{N_{b,Rd}}\right)^{0,8} + \left(\frac{M_{Ed}}{M_{b,Rd}}\right)^{0,8} \leq 1,0$$

where $N_{b,Rd}$ is the design buckling resistance of a compression member according to 6.2.2 (flexural, torsional or torsional-flexural buckling) and $M_{b,Rd}$ is the design bending moment resistance according to 6.2.4 and M_{Ed} includes the effects of shift of neutral axis, if relevant.

PURISTUS-TAIVUTUS

FprEN 1993-1-3:2023
8.2.5

(2) As an alternative to (1) the criteria in Formulae (8.73) and (8.74) should be satisfied in each cross-section along the member:
For major principal axis buckling:

$$\left(\omega_{x,y}\frac{N_{Ed}}{\chi_y N_{c,Rd}}\right)^{\alpha_y} + \left(\omega_{x,LT}\frac{M_{y,Ed}+\Delta M_{y,Ed}}{\chi_{LT} M_{cy,Rd}}\right)^{\beta_y} + \left(\frac{M_{z,Ed}+\Delta M_{z,Ed}}{M_{cz,Rd}}\right)^{\delta_y} \leq 1 \qquad (8.73)$$

For minor principal axis buckling:

$$\left(\omega_{x,z}\frac{N_{Ed}}{\chi_z N_{c,Rd}}\right)^{\alpha_z} + \left(\omega_{x,LT}\frac{M_{y,Ed}+\Delta M_{y,Ed}}{\chi_{LT} M_{cy,Rd}}\right)^{\beta_z} + \left(\frac{M_{z,Ed}+\Delta M_{z,Ed}}{M_{cz,Rd}}\right)^{\delta_z} \leq 1 \qquad (8.74)$$

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PURISTUS-TAIVUTUS

FprEN 1993-1-3:2023
8.2.5

$$\left(\omega_{x,y}\frac{N_{Ed}}{\chi_y N_{c,Rd}}\right)^{\alpha_y}+\left(\omega_{x,LT}\frac{M_{y,Ed}+\Delta M_{y,Ed}}{\chi_{LT} M_{cy,Rd}}\right)^{\beta_y}+\left(\frac{M_{z,Ed}+\Delta M_{z,Ed}}{M_{cz,Rd}}\right)^{\delta_y}\leq 1$$

$$\left(\omega_{x,z}\frac{N_{Ed}}{\chi_z N_{c,Rd}}\right)^{\alpha_z}+\left(\omega_{x,LT}\frac{M_{y,Ed}+\Delta M_{y,Ed}}{\chi_{LT} M_{cy,Rd}}\right)^{\beta_z}+\left(\frac{M_{z,Ed}+\Delta M_{z,Ed}}{M_{cz,Rd}}\right)^{\delta_z}\leq 1$$

NOTE 1 Formulae (8.73) and (8.74) reduce to a **single stability check for members**, if, conservatively, the maximum design values of the compressive force N_{Ed} and the maximum design values of the bending moments $M_{y,Ed}$, $M_{z,Ed}$ are used in combination with the conservative values of the interpolation factors $\omega_{x,i}$ = 1,0 according to Table 8.10.

NOTE 2 The interaction Formulae (8.73) and (8.74) can also be used for **hot-rolled and welded members**.

NOTE 3 For **cold-formed I-shaped members** (e.g. two back-to-back channels) the interaction formula of **EN 1993-1-1 can be used**.

PURISTUS-TAIVUTUS

FprEN 1993-1-3:2023
8.2.5

$$\left(\omega_{x,y}\frac{N_{Ed}}{\chi_y N_{c,Rd}}\right)^{\alpha_y} + \left(\omega_{x,LT}\frac{M_{y,Ed}+\Delta M_{y,Ed}}{\chi_{LT} M_{cy,Rd}}\right)^{\beta_y} + \left(\frac{M_{z,Ed}+\Delta M_{z,Ed}}{M_{cz,Rd}}\right)^{\delta_y} \leq 1$$

$$\left(\omega_{x,z}\frac{N_{Ed}}{\chi_z N_{c,Rd}}\right)^{\alpha_z} + \left(\omega_{x,LT}\frac{M_{y,Ed}+\Delta M_{y,Ed}}{\chi_{LT} M_{cy,Rd}}\right)^{\beta_z} + \left(\frac{M_{z,Ed}+\Delta M_{z,Ed}}{M_{cz,Rd}}\right)^{\delta_z} \leq 1$$

NOTE 1 Formulae (8.73) and (8.74) reduce to a **single stability check for members**, if, conservatively, the maximum design values of the compressive force N_{Ed} and the maximum design values of the bending moments $M_{y,Ed}$, $M_{z,Ed}$ are used in combination with the conservative values of the interpolation factors $\omega_{x,i}$ = 1,0 according to Table 8.10.

NOTE 2 The interaction Formulae (8.73) and (8.74) can also be used for **hot-rolled and welded members**.

NOTE 3 For **cold-formed I-shaped members** (e.g. two back-to-back channels) the interaction formula of **EN 1993-1-1 can be used**.

PURISTUS-TAIVUTUS

FprEN 1993-1-3:2023
8.2.5

Table 8.10 — Interpolation factors $\omega_{x,y}$, $\omega_{x,z}$ and $\omega_{x,LT}$

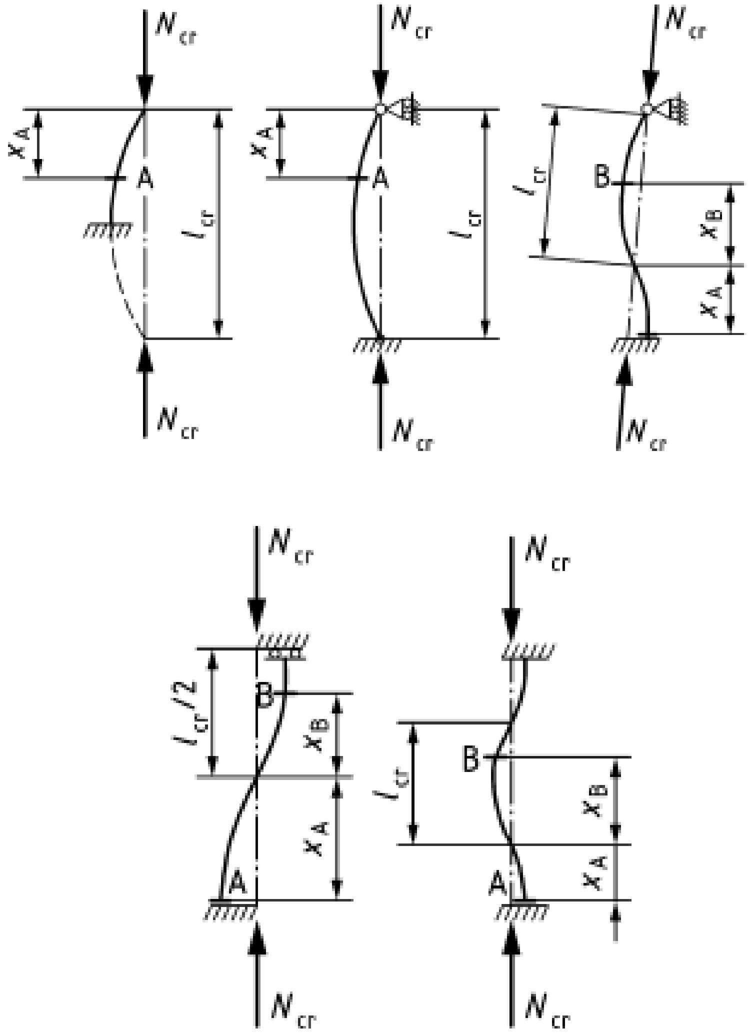
Factor	**For a specific cross-section location along a uniform member and special loading cases**		**Conservative for all cross-section locations and for all loading cases**
$\omega_{x,y}$	Constant or equivalent axial force N [a,b,c]	$\chi_y + (1 - \chi_y)\sin\frac{\pi x_s}{l_{cr,y}}$	1,0
$\omega_{x,z}$		$\chi_z + (1 - \chi_z)\sin\frac{\pi x_s}{l_{cr,z}}$	
$\omega_{x,LT}$	Constant or equivalent bending moment M_y [b,c]	$\chi_{LT} + (1 - \chi_{LT})\sin\frac{\pi x_s}{l_{cr,LT}}$	

where

$l_{cr,y}$, $l_{cr,z}$, $l_{cr,LT}$ are the buckling lengths for the relevant buckling mode;

x_s (= x_A or x_B) is the distance from the cross-section under consideration to a simple support or a point of contraflexure in the elastically buckled shape of the relevant mode based on the sinusoidal buckling shape, see Figure 8.13 for examples.

Figure 8.13



PURISTUS-TAIVUTUS

FprEN 1993-1-3:2023
8.2.5

$$\left(\omega_{x,y}\frac{N_{Ed}}{\chi_y N_{c,Rd}}\right)^{\alpha_y} + \left(\omega_{x,LT}\frac{M_{y,Ed}+\Delta M_{y,Ed}}{\chi_{LT} M_{cy,Rd}}\right)^{\beta_y} + \left(\frac{M_{z,Ed}+\Delta M_{z,Ed}}{M_{cz,Rd}}\right)^{\delta_y} \leq 1$$

$$\left(\omega_{x,z}\frac{N_{Ed}}{\chi_z N_{c,Rd}}\right)^{\alpha_z} + \left(\omega_{x,LT}\frac{M_{y,Ed}+\Delta M_{y,Ed}}{\chi_{LT} M_{cy,Rd}}\right)^{\beta_z} + \left(\frac{M_{z,Ed}+\Delta M_{z,Ed}}{M_{cz,Rd}}\right)^{\delta_z} \leq 1$$

Table 8.9 — Exponents to be used in the interaction Formulae (8.73) and (8.74)

Exponents	General provisions (NDP)	Conservative
α_y [a]	$\chi_y/\omega_{x,y}$ but $\alpha_y, \beta_y, \gamma_y \geq 0{,}85$	0,85
β_y [a]		
δ_y [a]		
α_z [a]	$\chi_z/\omega_{x,z}$ but $\alpha_z, \beta_z, \gamma_z \geq 0{,}85$	0,85
β_z [a]		
δ_z [a]		

[a] In the case of torsional-flexural buckling, the relevant reduction factor for flexural buckling χ_y or χ_z should be replaced with χ_{TF}

NOTE The general provisions for the exponents of cold-formed sections are given in the second column of Table 8.9-unless the National Annex specifies different values.

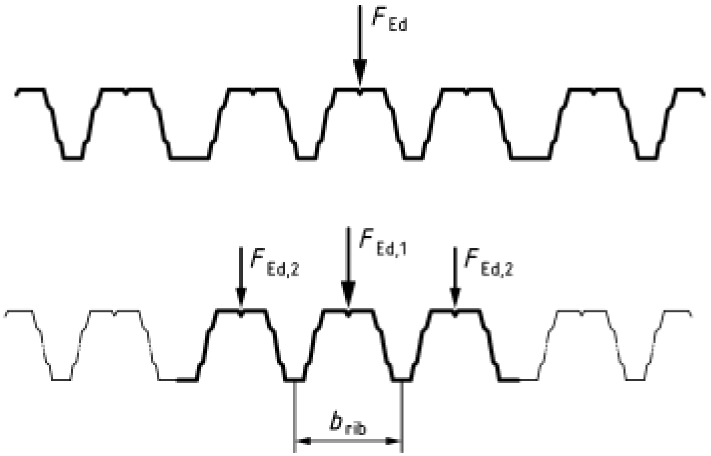
MUUTOS 5

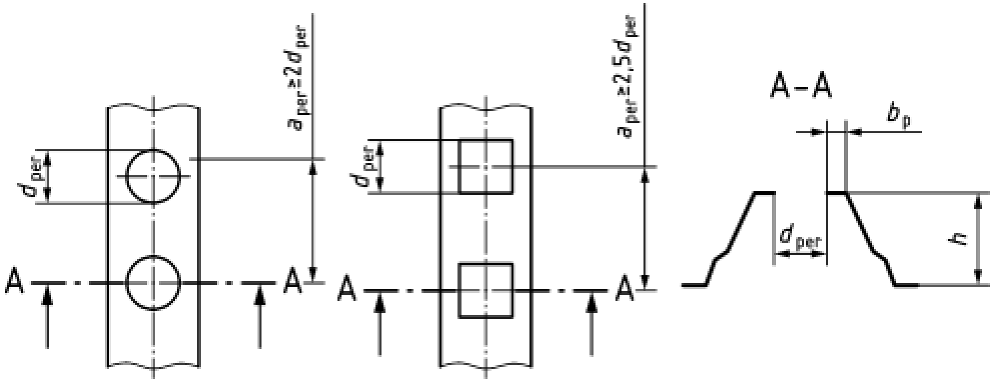
LISÄSÄÄNTÖJÄ MUOTOLEVYILLE, SANDWICH-PANEELEILLE JA KASETEILLE

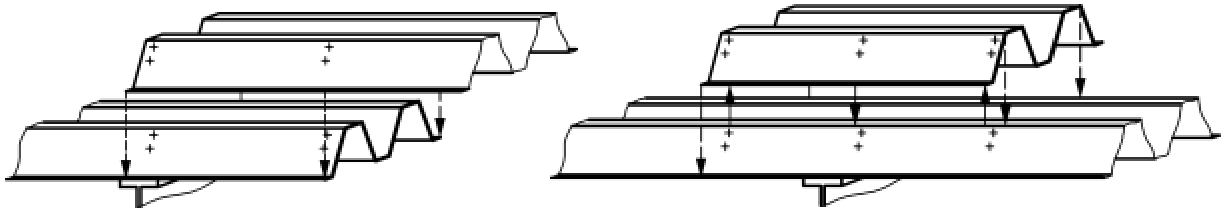
LISÄSÄÄNTÖJÄ

FprEN 1993-1-3:2023
11

- Sauvan poikittainen tuenta sandwich-paneeleilla (11.1)
- Muotolevyn viiva- ja pistekuormat (11.3.1)
- Aukot muotolevyjen laipoissa (11.3.3)
- Muotolevyjen limitykset (overlap) (11.3.4)
- Levyjäykistys (11.5)







Tampereen yliopisto

YHTEENVETO

YHTEENVETO

- EN 1993-1-3 on päivitetty perusteellisesti.
  - Monia kohtia on pyritty selkiyttämään
  - Uutta tutkimustietoa on sisällytetty standardiin
  - Kytkentä EN 1993:n muihin osiin sekä EN 1090-4:en.
- Kylmämuovattujen teräsrakenteiden suunnittelun ja mitoituksen perusasioihin ei kuitenkaan tule merkittäviä muutoksia.
  - Stabiilisuusilmiöt ja avointen poikkileikkausten erityispiirteet hallitsevat suunnittelua.
- Standardi on menossa **Formal Vote** –äänestykseen lokakuussa 2023.
  - METSTA SR.103 muodostaa Suomen kannan, näköpiirissä ei kuitenkaan ole syitä vastustaa standardin hyväksymistä.