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Evrokod 3: Projektiranje jeklenih konstrukcij - 1-7.del: Predmet ploļ evinaste konstrukcije obremenjen s preļ no obteģbo

Eurocode 3 - Design of steel structures - Part 1-7: Plated structures subject to out of plane loading

Eurocode 3 - Bemessung und Konstruktion von Stahlbauten - Teil 1-7: Plattenförmige Bauteile mit Querbelastung

Eurocode 3 - Calcul des structures en acier - Partie 1-7: Résistance et stabilité des structures en plaques planes chargées hors de leur plan

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ICS:

91.010.30	Tehniļ ni vidiki	Technical aspects
91.080.10	Kovinske konstrukcije	Metal structures

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN Management Centre has the same status as the official versions.

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Foreword

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This European Standard EN 1993-1-7, Eurocode 3: Design of steel structures: Part 1-7 Plated structures subject to out of plane loading, has been prepared by Technical Committee CEN/TC250 « Structural Eurocodes », the Secretariat of which is held by BSI. CEN/TC250 is responsible for all Structural Eurocodes.

This European Standard shall be given the status of a National Standard, either by publication of an identical text or by endorsement, at the latest by October 2007, and conflicting National Standards shall be withdrawn at latest by March 2010.

This Eurocode supersedes ENV 1993-1-7.

According to the CEN-CENELEC Internal Regulations, the National Standard Organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

National annex for EN 1993-1-7

This standard gives alternative procedures, values and recommendations with notes indicating where national choices may have to be made. The National Standard implementing EN 1993-1-7 should have a National Annex containing all Nationally Determined Parameters to be used for the design of steel structures to be constructed in the relevant country.

National choice is allowed in EN 1993-1-7 through:

– 6.3.2(4)

1 General

1.1 Scope

(1)P EN 1993-1-7 provides basic design rules for the structural design of unstiffened and stiffened plates which form part of plated structures such as silos, tanks or containers, that are loaded by out of plane actions. It is intended to be used in conjunction with EN 1993-1-1 and the relevant application standards.

(2) This document defines the design values of the resistances: the partial factor for resistances may be taken from National Annexes of the relevant application standards. Recommended values are given in the relevant application standards.

(3) This Standard is concerned with the requirements for design against the ultimate limit state of:

- plastic collapse;
- cyclic plasticity;
- buckling;
- fatigue.

(4) Overall equilibrium of the structure (sliding, uplifting, overturning) is not included in this Standard, but is treated in EN 1993-1-1. Special considerations for specific applications may be found in the relevant applications parts of EN 1993.

(5) The rules in this Standard refer to plate segments in plated structures which may be stiffened or unstiffened. These plate segments may be individual plates or parts of a plated structure. They are loaded by out of plane actions.

(6) For the verification of unstiffened and stiffened plated structures loaded only by in-plane effects see EN 1993-1-5. In EN 1993-1-7 rules for the interaction between the effects of inplane and out of plane loading are given.

(7) For the design rules for cold formed members and sheeting see EN 1993-1-3.

(8) The temperature range within which the rules of this Standard are allowed to be applied are defined in the relevant application parts of EN 1993.

(9) The rules in this Standard refer to structures constructed in compliance with the execution specification of EN 1090-2.

(10) Wind loading and bulk solids flow should be treated as quasi-static actions. For fatigue, the dynamic effects must be taken into account according to EN 1993-1-9. The stress resultants arising from the dynamic behaviour are treated in this part as quasi-static.

1.2 Normative references

(1) This European Standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 1993	Eurocode 3:	Design of steel structures:
	Part 1.1:	General rules and rules for buildings
	Part 1.3:	Cold-formed members and sheeting
	Part 1.4:	Stainless steels
	Part 1.5:	Plated structural elements

Part 1.6: Strength and stability of shell structures

Part 1.8: Design of joints

Part 1.9: Fatigue strength of steel structures

Part 1.10: Selection of steel for fracture toughness and through-thickness properties

Part 1.12: Additional rules for the extension of EN 1993 up to steel grades S700

Part 4.1: Silos

Part 4.2: Tanks

1.3 Terms and definitions

(1) The rules in EN 1990, clause 1.5 apply.

(2) The following terms and definitions are supplementary to those used in EN 1993-1-1:

1.3.1 Structural forms and geometry

1.3.1.1 Plated structure

A structure that is built up from nominally flat plates which are joined together. The plates may be stiffened or unstiffened, see Figure 1.1.

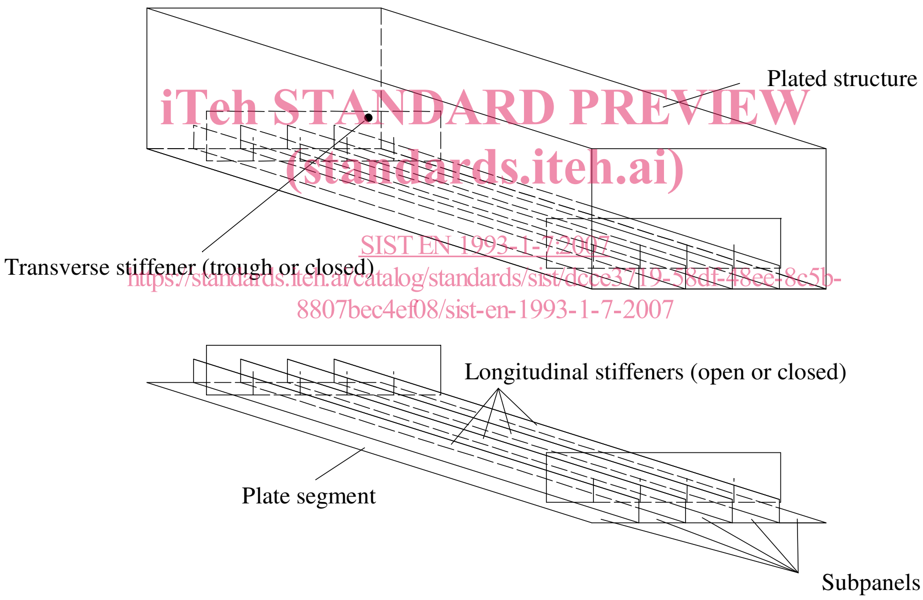

Figure 1.1: Components of a plated structure

1.3.1.2 Plate segment

A plate segment is a flat plate which may be unstiffened or stiffened. A plate segment should be regarded as an individual part of a plated structure.

1.3.1.3 Stiffener

A plate or a section attached to the plate with the purpose of preventing buckling of the plate or reinforcing it against local loads. A stiffener is denoted:

- longitudinal if its longitudinal direction is in the main direction of load transfer of the member of which it forms a part.
- transverse if its longitudinal direction is perpendicular to the main direction of load transfer of the member of which it forms a part.

1.3.1.4 Stiffened plate

Plate with transverse and/or longitudinal stiffeners.

1.3.1.5 Sub-panel

Unstiffened plate surrounded by stiffeners or, on a web, by flanges and/or stiffeners or, on a flange, by webs and/or stiffeners.

1.3.2 Terminology

1.3.2.1 Plastic collapse

A failure mode at the ultimate limit state where the structure loses its ability to resist increased loading due to the development of a plastic mechanism.

1.3.2.2 Tensile rupture

A failure mode in the ultimate limit state where failure of the plate occurs due to tension.

1.3.2.3 Cyclic plasticity

Where repeated yielding is caused by cycles of loading and unloading.

1.3.2.4 Buckling

Where the structure looses its stability under compression and/or shear.

1.3.2.5 Fatigue

Where cyclic loading causes cracking or failure.

1.3.3 Actions

1.3.3.1 Out of plane loading

The load applied normal to the middle surface of a plate segment.

1.3.3.2 In-plane forces

Forces applied parallel to the surface of the plate segment. They are induced by in-plane effects (for example temperature and friction effects) or by global loads applied at the plated structure.

1.4 Symbols

(1) In addition to those given in EN 1990 and EN 1993-1-1, the following symbols are used:

(2) Membrane stresses in rectangular plate, see Figure 1.2:

σ_{mx} is the membrane normal stress in the x-direction due to membrane normal stress resultant per unit width n_x;

σ_{my} is the membrane normal stress in the y-direction due to membrane normal stress resultant per unit width n_y;

τ_{mxy} is the membrane shear stress due to membrane shear stress resultant per unit width n_{xy}.

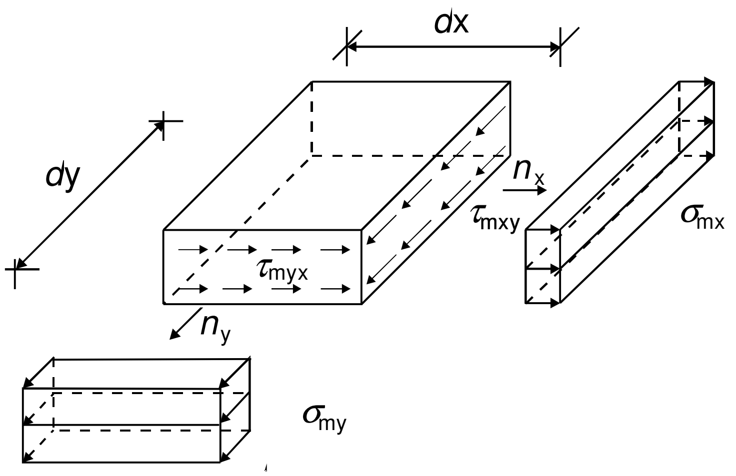

Figure 1.2: Membrane stresses

(3) Bending and shear stresses in rectangular plates due to bending, see Figure 1.3:

σ_{bx} is the stress in the x-direction due to bending moment per unit width m_x;

σ_{by} is the stress in the y-direction due to bending moment per unit width m_y;

τ_{bxy} is the shear stress due to the twisting moment per unit width m_{xy};

τ_{bxz} is the shear stress due to transverse shear forces per unit width q_x associated with bending;

τ_{byz} is the shear stress due to transverse shear forces q_y associated with bending.

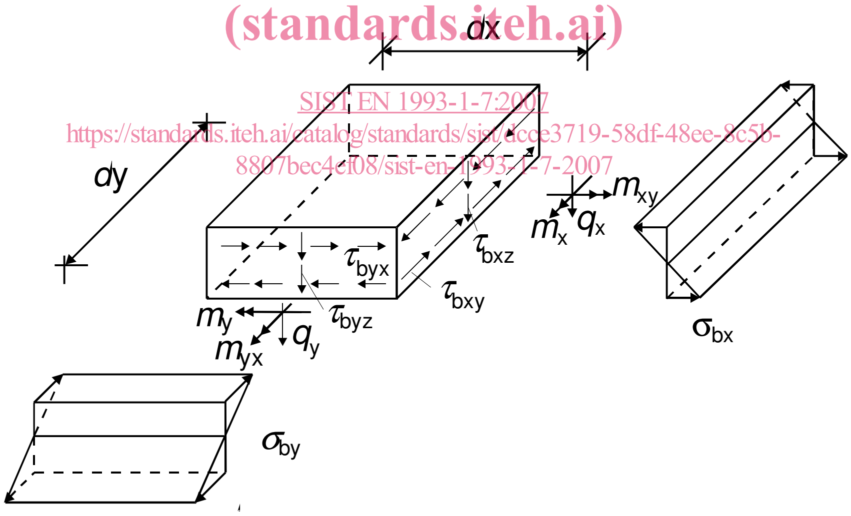

Figure 1.3: Normal and shear stresses due to bending

NOTE: In general, there are eight stress resultants in a plate at any point. The shear stresses τ_{bxz} and τ_{byz} due to q_x and q_y are in most practical cases insignificant compared to the other components of stress, and therefore they may normally be disregarded for the design.

(4) Greek lower case letters:

α aspect ratio of a plate segment (a/b);

ε strain;

α_R load amplification factor;

ρ reduction factor for plate buckling;

σ_i Normal stress in the direction i, see Figure 1.2 and Figure 1.3;

τ Shear stress, see Figure 1.2 and Figure 1.3;

ν Poisson's ratio;

γ_M partial factor.

(5) Latin upper case letter:

E Modulus of elasticity

(6) Latin lower case letters:

a length of a plate segment, see Figure 1.4 and Figure 1.5;

b width of a plate segment, see Figure 1.4 and Figure 1.5;

f_{yk} yield stress or 0,2% proof stress for material with non linear stress-strain curve;

n_i membrane normal force in the direction i [kN/m];

n_{xy} membrane shear force [kN/m}

m bending moment [kNm/m];

q_z transverse shear force in the z direction [kN/m];

t thickness of a plate segment, see figure 1.4 and 1.5.

NOTE: Symbols and notations which are not listed above are explained in the text where they first appear.

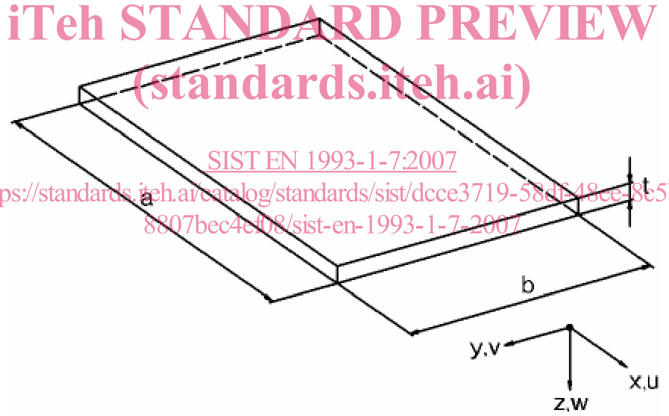

Figure 1.4: Dimensions and axes of unstiffened plate segments

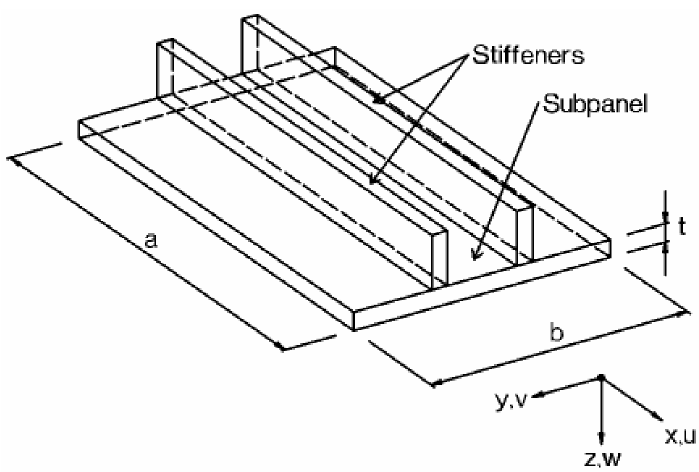

Figure 1.5: Dimensions and axes of stiffened plate segments; stiffeners may be open or closed stiffeners

2 Basis of design

2.1 Requirements

(1)P The basis of design shall be in accordance with EN 1990.

(2)P The following ultimate limit states shall be checked for a plated structure:

- plastic collapse, see 2.2.2;
- cyclic plasticity, see 2.2.3;
- buckling, see 2.2.4;
- fatigue, see 2.2.5.

(3) The design of a plated structure should satisfy the serviceability requirements set out in the appropriate application standards.

2.2 Principles of limit state design

2.2.1 General

(1)P The principles for ultimate limit state given in section 2 of EN 1993-1-1 and EN 1993-1-6 shall also be applied to plated structures.

2.2.2 Plastic collapse

(1) Plastic collapse is defined as the condition in which a part of the structure develops excessive plastic deformations, associated with development of a plastic mechanism. The plastic collapse load is usually derived from a mechanism based on small deflection theory.

2.2.3 Cyclic plasticity

(1) Cyclic plasticity should be taken as the limit condition for repeated cycles of loading and unloading produce yielding in tension or in compression or both at the same point, thus causing plastic work to be repeatedly done on the structure. This alternative yielding may lead to local cracking by exhaustion of the material's energy absorption capacity, and is thus a low cycle fatigue restriction. The stresses which are associated with this limit state develop under a combination of all actions and the compatibility conditions for the structure.

2.2.4 Buckling

(1) Buckling should be taken as the condition in which all or parts of the structure develop large displacements, caused by instability under compressive and/or shear stresses in the plate. It leads eventually to inability to sustain an increase in the stress resultants.

(2) Local plate buckling, see EN 1993-1-5.

(3) For flexural, lateral torsional and distortional stability of stiffeners, see EN 1993-1-5

2.2.5 Fatigue

(1) Fatigue should be taken as the limit condition caused by the development and / or growth of cracks by repeated cycles of increasing and decreasing stresses.

2.3 Actions

(1) The characteristic values of actions should be determined from the appropriate parts of EN 1991.

2.4 Design assisted by testing

(1) For design assisted by testing reference should be made to section 2.5 of EN 1993-1-1 and where relevant, Section 9 of EN 1993-1-3.

3 Material properties

(1) This Standard covers the design of plated structures fabricated from steel material conforming to the product standards listed in EN 1993-1-1 and EN 1993-1-12.

(2) The material properties of cold formed members and sheeting should be obtained from EN 1993-1-3.

(3) The material properties of stainless steels should be obtained from EN 1993-1-4.

4 Durability

(1) For durability see section 4 of EN 1993-1-1.

5 Structural analysis

5.1 General

(1)P The models used for calculations shall be appropriate for predicting the structural behaviour and the limit states considered.

(2) If the boundary conditions can be conservatively defined, i.e. restrained or unrestrained, a plated structure may be subdivided into individual plate segments that may be analysed independently.

(3)P The overall stability of the complete structure shall be checked following the relevant parts of EN 1993.

5.2 Stress resultants in the plate

5.2.1 General

(1) The calculation model and basic assumptions for determining internal stresses or stress resultants should correspond to the assumed structural response for the ultimate limit state loading.

(2) Structural models may be simplified such that it can be shown that the simplifications used will give conservative estimates of the effects of actions.

(3) Elastic global analysis should generally be used for plated structures. Where fatigue is likely to occur, plastic global analysis should not be used.

(4) Possible deviations from the assumed directions or positions of actions should be considered.

(5) Yield line analysis may be used in the ultimate limit state when inplane compression or shear is less than 10% of the corresponding resistance. The bending resistance in a yield line should be taken as

$$m_{Rd} = \frac{0{,}25 \cdot f_y \cdot t^2}{\gamma_{M0}}$$

5.2.2 Plate boundary conditions

(1) Boundary conditions assumed in analyses should be appropriate to the limit states considered.