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Interested committees:

Title: BS EN 1993-1-7 Eurocode 3 - Design of steel structures

Part 1-7: Plate assemblies with elements under transverse loads

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

For national standards, comments will be reviewed by the relevant UK national committee and the resulting standards published as a British Standard.

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Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

English Version

Eurocode 3 - Design of steel structures - Part 1-7: Plate assemblies with elements under transverse loads

Eurocode 3 - Calcul des structures en acier - Partie 1-7 :
Structures en plaques avec éléments sous charges
transversales

Eurocode 3 - Bemessung und Konstruktion von
Stahlbauten - Teil 1-7 : Aus Blechen zusammengesetzte
Bauteile unter Querbelastrung

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 250.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

This draft European Standard was established by CEN 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-CENELEC Management Centre has the same status as the official versions.

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Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Warning : This document is not a European Standard. It is distributed for review and comments. It is subject to change without notice and shall not be referred to as a European Standard.



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COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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European foreword

This document (prEN 1993-1-7:2023), has been prepared by Technical Committee CEN/TC250 “Structural Eurocodes”, the secretariat of which is held by BSI. CEN/TC 250 is responsible for all Structural Eurocodes and has been assigned responsibility for structural and geotechnical design matters by CEN.

This document is currently submitted to the CEN Enquiry.

This document will supersede EN 1993-1-7:2007 and its amendments.

The first generation of EN Eurocodes was published between 2002 and 2007. This document forms part of the second generation of the Eurocodes, which have been prepared under Mandate M/515 issued to CEN by the European Commission and the European Free Trade Association.

The Eurocodes have been drafted to be used in conjunction with relevant execution, material, product and test standards, and to identify requirements for execution, materials, products and testing that are relied upon by the Eurocodes.

The Eurocodes recognize the responsibility of each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level through the use of National Annexes.

0 Introduction

0.1 Introduction to the Eurocodes

The Structural Eurocodes comprise the following standards generally consisting of a number of Parts:

- EN 1990 Eurocode: Basis of structural and geotechnical design
- EN 1991 Eurocode 1: Actions on structures
- EN 1992 Eurocode 2: Design of concrete structures
- EN 1993 Eurocode 3: Design of steel structures
- EN 1994 Eurocode 4: Design of composite steel and concrete structures
- EN 1995 Eurocode 5: Design of timber structures
- EN 1996 Eurocode 6: Design of masonry structures
- EN 1997 Eurocode 7: Geotechnical design
- EN 1998 Eurocode 8: Design of structures for earthquake resistance
- EN 1999 Eurocode 9: Design of aluminium structures
- New parts are under development, e.g. Eurocode for design of structural glass

The Eurocodes are intended for use by designers, clients, manufacturers, constructors, relevant authorities (in exercising their duties in accordance with national or international regulations), educators, software developers, and committees drafting standards for related product, testing and execution standards.

NOTE Some aspects of design are most appropriately specified by relevant authorities or, where not specified, can be agreed on a project-specific basis between relevant parties such as designers and clients. The Eurocodes identify such aspects making explicit reference to relevant authorities and relevant parties.

0.2 Introduction to EN 1993 (all parts)

EN 1993 (all parts) applies to the design of buildings and civil engineering works in steel. It complies with the principles and requirements for the safety and serviceability of structures, the basis of their design and verification that are given in EN 1990 – Basis of structural design.

EN 1993 (all parts) is concerned only with requirements for resistance, serviceability, durability and fire resistance of steel structures. Other requirements, e.g. concerning thermal or sound insulation, are not covered.

EN 1993 is subdivided in various parts:

EN 1993-1, *Design of Steel Structures — Part 1: General rules and rules for buildings*;

EN 1993-2, *Design of Steel Structures — Part 2: Steel bridges*;

EN 1993-3, *Design of Steel Structures — Part 3: Towers, masts and chimneys*;

EN 1993-4, *Design of Steel Structures — Part 4: Silos and tanks*;

EN 1993-5, *Design of Steel Structures — Part 5: Piling*;

EN 1993-6, *Design of Steel Structures — Part 6: Crane supporting structures*;

EN 1993-7, *Design of steel structures — Part 7: Design of sandwich panels*.

EN 1993-1 in itself does not exist as a physical document, but comprises the following 14 separate parts, the basic part being EN 1993-1-1:

EN 1993-1-1, *Design of Steel Structures — Part 1-1: General rules and rules for buildings*;

EN 1993-1-2, *Design of Steel Structures — Part 1-2: Structural fire design*;

EN 1993-1-3, *Design of Steel Structures — Part 1-3: Cold-formed members and sheeting*;

NOTE Cold-formed hollow sections supplied according to EN 10219 are covered in EN 1993-1-1.

EN 1993-1-4, *Design of Steel Structures — Part 1-4: Stainless steel structures*;

EN 1993-1-5, *Design of Steel Structures — Part 1-5: Plated structural elements*;

EN 1993-1-6, *Design of Steel Structures — Part 1-6: Strength and stability of shell structures*;

EN 1993-1-7, *Design of Steel Structures — Part 1-7: Plate assemblies with elements under transverse loads*;

EN 1993-1-8, *Design of Steel Structures — Part 1-8: Design of joints*;

EN 1993-1-9, *Design of Steel Structures — Part 1-9: Fatigue*;

EN 1993-1-10, *Design of Steel Structures — Part 1-10: Material toughness and through-thickness properties*;

EN 1993-1-11, *Design of Steel Structures — Part 1-11: Design of structures with tension components*;

EN 1993-1-12, *Design of Steel Structures — Part 1-12: Additional rules for steel grades up to S960*;

EN 1993-1-13, *Design of Steel Structures — Part 1-13: Beams with large web openings*;

EN 1993-1-14¹, *Design of Steel Structures — Part 1-14: Design assisted by finite element analysis*.

All subsequent parts EN 1993-1-2 to EN 1993-1-14 treat general topics that are independent from the structural type such as structural fire design, cold-formed members and sheeting, stainless steels, plated structural elements, etc.

All subsequent parts numbered EN 1993-2 to EN 1993-7² treat topics relevant for a specific structural type such as steel bridges, towers, masts and chimneys, silos and tanks, piling, crane supporting structures, etc. EN 1993-2 to EN 1993-7 refer to the generic rules in EN 1993-1 and supplement, modify or supersede them.

0.3 Introduction to prEN 1993-1-7

prEN 1993-1-7 gives supplementary rules for plate assemblies with elements under transverse loads.

1 Under preparation.

2 Under preparation.

0.4 Verbal forms used in the Eurocodes

The verb “shall” expresses a requirement strictly to be followed and from which no deviation is permitted in order to comply with the Eurocodes.

The verb “should” expresses a highly recommended choice or course of action. Subject to national regulation and/or any relevant contractual provisions, alternative approaches could be used/adopted where technically justified.

The verb “may” expresses a course of action permissible within the limits of the Eurocodes.

The verb “can” expresses possibility and capability; it is used for statements of fact and clarification of concepts.

0.5 National Annex for prEN 1993-1-7

National choice is allowed in this standard where explicitly stated within notes. National choice includes the selection of values for Nationally Determined Parameters (NDPs).

The national standard implementing prEN 1993-1-7 can have a National Annex containing all national choices to be used for the design of steel structures to be constructed in the relevant country.

When no national choice is given, the default choice given in this standard is to be used.

When no national choice is made and no default is given in this standard, the choice can be specified by a relevant authority or, where not specified, agreed for a specific project by appropriate parties.

National choice is allowed in prEN 1993-1-7 through the following clauses:

4.1(5) 4.6(2) 9.2.2.2(5)

National choice is allowed in prEN 1993-1-7 on the application of the following informative annexes:

Annex A Annex B Annex C

The National Annex can contain, directly or by reference, non-contradictory complementary information for ease of implementation, provided it does not alter any provisions of the Eurocodes.

1 Scope

1.1 Scope of prEN 1993-1-7

(1) prEN 1993-1-7 provides rules for the structural design of assemblies of unstiffened and stiffened steel plates whose elements are under predominantly distributed transverse loads.

(2) prEN 1993-1-7 is applicable to containment structures such as silos, tanks, digesters and lock gates, where the external actions chiefly act transversely on their individual plates or panels. Where a plate or panel under bending is additionally subject to membrane forces that have a significant effect on the resistance, this document covers assessment of the resistance through its computational analysis procedures.

(3) prEN 1993-1-7 is applicable to structures with rectangular, trapezoidal or triangular component plate segments, each with one axis of symmetry.

(4) prEN 1993-1-7 does not apply to plates or panels where the dominant structural resistance requirement relates to membrane forces in the plates (for these, see EN 1993-1-5).

(5) prEN 1993-1-7 does not apply to plates or panels whose curvature (out of flatness) exceeds that defined in 1.1 (14). For such curved plates, see EN 1993-1-6.

(6) prEN 1993-1-7 does not apply to circular or annular plates. For such plates, see EN 1993-1-6.

(7) prEN 1993-1-7 does not apply to cold-formed sheeting. For such plates, see EN 1993-1-3.

(8) This document is only concerned with the requirements for design of plates and plate assemblies against the ultimate limit states of:

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

(9) Overall equilibrium of the structure (sliding, uplifting, or overturning) is not included in this document. Special considerations for specific applications are available in the relevant applications parts of EN 1993.

(10) The rules in this document refer to plate assemblies that are fabricated using unstiffened or stiffened plates or panels. The document is also applicable to the design of individual plates or panels that are predominantly subject to actions transverse to the plane of each plate. Both frictional actions on the plate surface and forces imposed by adjacent components of the plate assembly also induce in-plane actions in each plate.

(11) This document gives algebraic rules and guidance to account for bending with small membrane forces in the individual plates or panels. Where an unstiffened or stiffened plates or panels is subject to significant magnitudes of both bending and in-plane forces, the computational analysis procedures of this document apply.

(12) Where no application part defines a different range, this document applies to structures within the following limits:

- design metal temperatures within the range -50 °C to $+100\text{ °C}$;
- the geometry of individual plate segments is limited to rectangular, triangular and trapezoidal shapes with b/t greater than 20, or b_1/t greater than 20, as appropriate (see Figure 3.2);

- Single plate elements are treated as flat where the deviation from flatness e_0 meets the condition $e_0/t \leq 0,750$ (see Figure 9.1). Where this criterion is not met, it is appropriate to treat the plate as a shell panel (see EN 1993-1-6).

1.2 Assumptions

(1) Unless specifically stated, the provisions of EN 1990, EN 1991 (all parts) and EN 1993 (all parts) apply.

(2) The design methods given in prEN 1993-1-7 are applicable if:

- the execution quality is as specified in EN 1090-2, and
- the construction materials and products used are as specified in the relevant parts of EN 1993 (all parts), or in the relevant material and product specifications.

(3) The provisions in this document apply to materials that satisfy the brittle fracture provisions given in EN 1993-1-4 and EN 1993-1-10.

(4) In this document, it is assumed that wind loading, seismic actions and bulk solids flow can, in general, be treated as quasi-static actions.

(5) Dynamic effects are treated in other relevant application parts of EN 1993 or EN 1998, including the consequences for fatigue. The stress resultants arising from dynamic behaviour are treated in this part as quasi-static.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE See the Bibliography for a list of other documents cited that are not normative references, including those referenced as recommendations (i.e. through 'should' clauses) and permissions (i.e. through 'may' clauses).

EN 1090-2, *Execution of steel structures and aluminium structures - Part 2: Technical requirements for steel structures*

EN 1090-4, *Execution of steel structures and aluminium structures - Part 4: Technical requirements for cold-formed structural steel elements and cold-formed structures for roof, ceiling, floor and wall applications*

EN 1990, *Basis of structural and geotechnical design*

EN 1991 (all parts), *Eurocode 1: Actions on structures*

EN 1993 (all parts), *Eurocode 3: Design of steel structures*

ISO 8930, *General principles on reliability for structures - Vocabulary*

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in EN 1990, EN 1993-1-1, ISO 8930 and the following apply.

3.1 Terms and definitions

3.1.1 Structural forms and geometry

3.1.1.1

plate

structural element that, in general, has two large dimensions a and b and a uniform much smaller dimension t , and is shaped such that the two large dimensions lie in a single plane (flat plate)

Note 1 to entry: In this standard, the ratios a/t and b/t are required to exceed the value 20 (except as noted below). Where the boundary conditions and geometry are such that the plate only bends in a single direction, its treatment is not the principal role of this standard, but the provisions given here can be used.

Note 2 to entry: In special circumstances (e.g. the edge b_2 of a trapezoidal plate), the smaller dimension b can be less than $20t$.

Note 3 to entry: A plate for which the above restrictions apply is termed a thin plate.

Note 4 to entry: Typical generic forms of plate assemblies considered by this standard are illustrated in Figures 3.1 and 3.3. These are categorised as assemblies of plates of rectangular, trapezoidal or triangular shape, each plate element having at least one axis of symmetry.

3.1.1.2

plate assembly

structure that is assembled from flat plates which are joined together (see Figure 3.1) in such a way that the assembly has at least one axis of symmetry

Note 1 to entry: The individual plates may be unstiffened or stiffened

Note 2 to entry: The coordinate system indicated in Figure 3.2 only serves to indicate directions. The origin can be chosen by the user to be at any suitable location.

Note 3 to entry: The dimensions a , b and c shown in Figure 3.1 relate to the complete plate assembly to give clarity to the usage in this standard for common orientations of plate. Where an individual plate is described elsewhere in the standard, the dimension a is the longer side and the shorter side is always b , even if in the global system it is defined as c .

3.1.1.3

plate geometry

geometries of individual plates that are defined as rectangular, trapezoidal or triangular

Note 1 to entry: Where the shape is rectangular, the larger side length is defined as the dimension a . Where the shape is other than rectangular, the side(s) parallel to the axis of symmetry are defined by the dimension a (see Figure 3.2). Trapezoidal and triangular plates are only covered by this standard where they have an axis of symmetry.

3.1.1.4

panel

flat plate which may be unstiffened or stiffened

Note 1 to entry: A panel can be regarded as an individual part of a plate assembly (see Figure 3.1). The term can also be used for stiffened plates with transverse and longitudinal stiffeners, which delimit sub-panels (see 3.1.1.11).

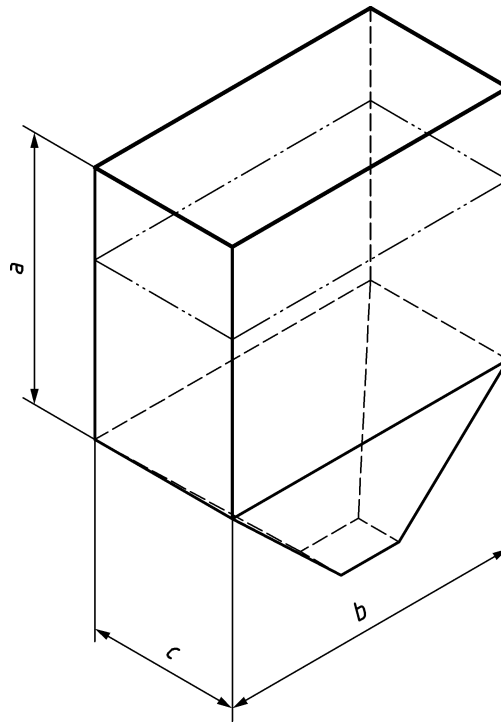


Figure 3.1 — Typical arrangement of a plate assembly, composed of individual panels, that is unstiffened or stiffened plates

3.1.1.5

aspect ratio

ratio of the shorter side length to the longer side length ($\psi = b/a \leq 1,0$) for a rectangular plate or panel

3.1.1.6

stiffener

flat plate or prismatic member attached to a panel for the purpose of increasing its bending resistance

Note 1 to entry: It can also be used to reinforce the member to support local loads.

3.1.1.7

longitudinal stiffener

stiffener on a rectangular panel in which the stiffener longitudinal axis is aligned with the longer dimension a of the panel (see Figure 6.8)

3.1.1.8

transverse stiffener

stiffener on a rectangular panel in which the stiffener longitudinal axis is aligned with the shorter dimension b of the panel (see Figure 6.8)

Note 1 to entry: The term “transverse stiffener” is commonly used in plates that are subject only to membrane forces to refer to stiffeners that are orthogonal to the direction of a main membrane force. By contrast, in this standard the terminology of 3.1.1.7 and 3.1.1.8 defines the longitudinal and transverse directions only in terms of the shape of the plate, since these plates are principally subject to bending in both directions.

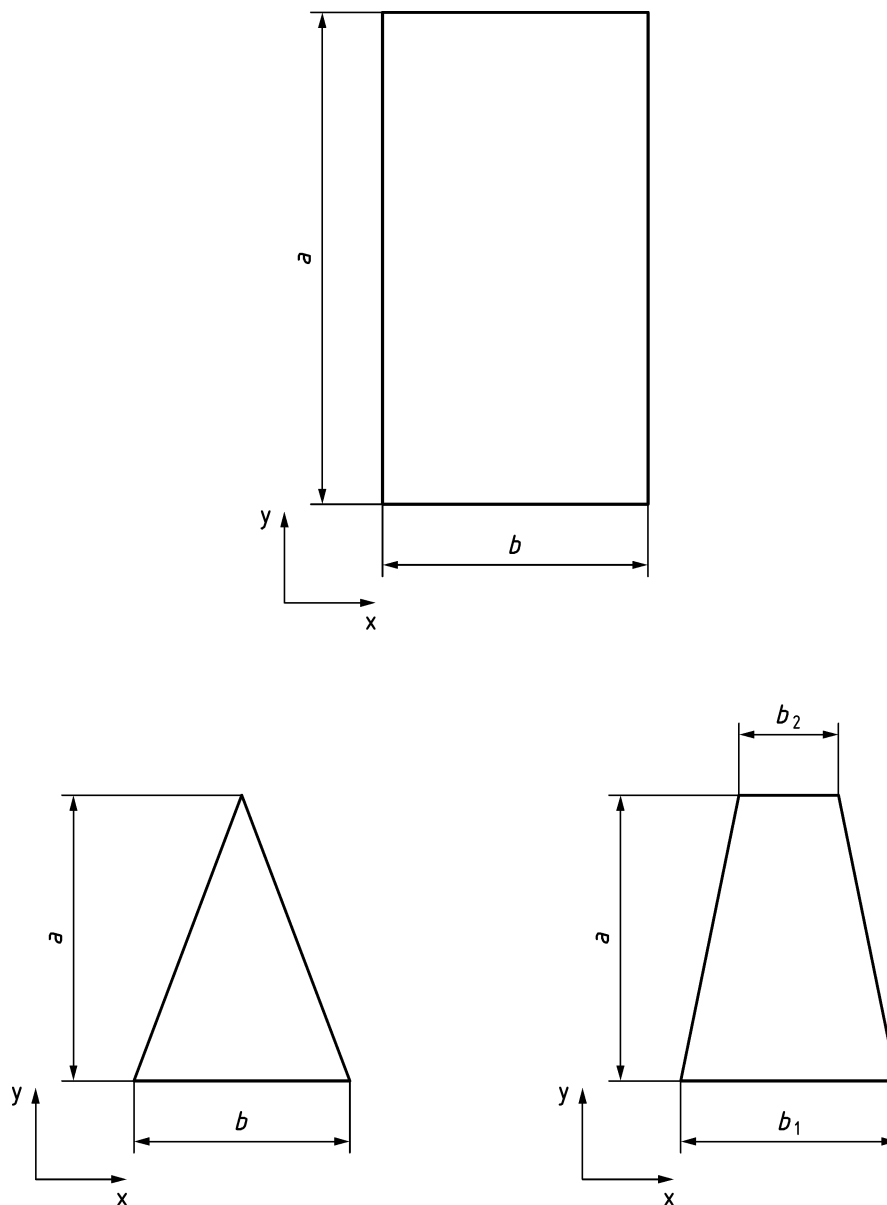


Figure 3.2 — Dimensions and local coordinate systems for rectangular, triangular and trapezoidal plates

3.1.1.9

uni-directionally stiffened plate

rectangular plate that has parallel stiffeners attached to it with their longitudinal axis in one direction

Note 1 to entry: The direction can be longitudinal or transverse.

3.1.1.10

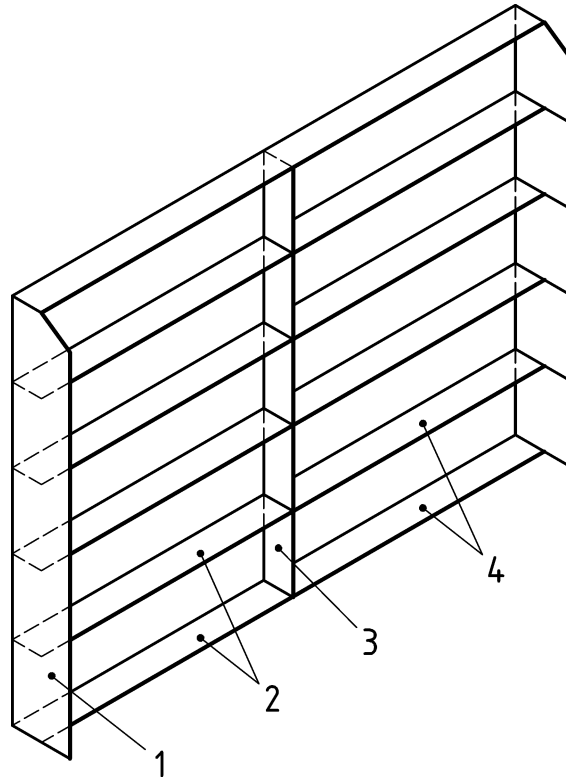
bi-directionally stiffened plate

rectangular plate that has two sets of parallel stiffeners in the two principal directions attached to it with their longitudinal axes in orthogonal directions

3.1.1.11**sub-panel**

part of a stiffened plate that lies between stiffeners, and so is locally an unstiffened plate bounded by stiffeners

Note 1 to entry: The design of sub-panels is covered within the rules of this standard in 6.6 and Clauses 9 and 10, where stiffened plates are treated.

**Key**

- 1 transverse end stiffener
- 2 longitudinal stiffeners
- 3 transverse intermediate stiffener
- 4 sub-panels

Figure 3.3 — Example of a rectangular stiffened plate

3.1.2 Failure mechanisms**3.1.2.1****buckling**

ultimate limit state where the stability of the structure is lost under compression and/or shear

3.1.2.2**cyclic plasticity**

ultimate limit state in which repeated cycles of loading lead to repeated plastic straining

Note 1 to entry: Two distinct failure modes can arise: ratcheting and low-cycle fatigue.

3.1.2.3

high cycle fatigue

ultimate limit state where a high number of cycles of loading and unloading under nominally elastic stresses induce a fatigue crack

3.1.2.4

low cycle fatigue

ultimate limit state where repeated alternating cycles of plastic strain cause exhaustion of the plasticity of the material

3.1.2.5

plastic failure

ultimate limit state where the structure loses its ability to resist increased loading due to the development of excessive plastic deformations

3.1.2.6

ratcheting

progressive increase of plastic strains up to failure in the direction of the mean stress caused by unsymmetrical cycles of stress

3.1.2.7

tensile rupture

ultimate limit state where separation of the parts of a panel or the junctions between panels occurs due to tension

3.1.3 Actions

3.1.3.1

transverse load

pressure loading applied to the plate normal to its middle surface (perpendicular to both the dimensions a and b)

3.1.3.2

in-plane loading

forces applied parallel to or in the plane of the middle surface of a plate

Note 1 to entry: The forces can be applied through the connections between panels, or by frictional loads applied to the plate surface, or by temperature effects, or where large displacements cause some of the transverse loads acting on an individual panel to be carried by forces in its plane.

3.1.4 Terms for analysis treatments

3.1.4.1

computational analysis

use of analysis software (usually finite element) to produce a numerical analysis of the structure

Note 1 to entry: This can take different forms depending on the assumptions adopted in the numerical model (see 6.1).

3.1.4.2

global analysis

analysis that includes the complete structure, rather than individual structural parts treated separately

Note 1 to entry: This is usually a computational analysis.

3.1.4.3

membrane and simple bending analysis (MSBA)

analysis using simple statics of membrane forces and simple bending analysis treating each plate or panel as separate (see 6.1)

3.2 Symbols

For the purposes of this document, the symbols given in EN 1990 and EN 1993-1-1 and the following apply.

NOTE 1 Symbols and notations which are not listed below are explained in the text where they first appear.

Latin upper case letters

E	Young's modulus of elasticity
F	generalized action
F_{Ed}	action set on a complete structure corresponding to a design situation (design values)
F_{Rd}	calculated values of the action set at the maximum resistance condition of the structure (design values)
R	resistance of the structure under the design values of loads in a specific load case
R_{cr}	critical buckling resistance ratio (defined as a load factor on design loads using LBA analysis)
R_k	characteristic reference resistance ratio (used with subscripts to identify the basis): defined as a load factor on design loads using the ratio (F_{Rk} / F_{Ed})
R_{pl}	plastic reference resistance ratio (defined as a load factor on design loads using MNA analysis)
R_{plf}	plastic failure resistance ratio (defined as a load factor on design loads using GMNA analysis)
R_{GNA}	buckling resistance ratio determined in a GNA analysis
R_{GMNA}	buckling resistance ratio determined in a GMNA analysis
R_{GMNIA}	buckling resistance ratio determined in a GMNIA analysis (normally as R_k)

Latin lower case letters

a	length of a rectangular plate or panel (longer dimension), or length of a symmetrical triangular or trapezoidal plate or panel parallel to the axis of symmetry, see Figure 3.2
b	width of a rectangular plate or panel (shorter dimension), or base of a symmetrical triangular plate or panel, see Figure 3.2
b_1	length of the longer side normal to the axis of symmetry in a symmetrical trapezoidal plate or panel, see Figure 3.2
b_2	length of the shorter side normal to the axis of symmetry in a symmetrical trapezoidal plate or panel, see Figure 3.2
e	eccentricity of the equivalent axial force N_{Ed} in the plate and stiffener assembly relative to the centroid of the effective cross-section

f_y	yield stress or 0,2% proof stress for material with a nonlinear stress-strain curve
t	uniform thickness of a plate
x_e	exclusion distance

NOTE 2 The dimension “ a ” is defined in different senses in common texts on plates, making no single notation universal. In this document the use of “ a ” as the longer side of a rectangular plate element is to provide consistency with other Eurocodes, notably with EN 1993-1-1. The notation for triangular and trapezoidal plates is only used in this document.

Greek upper case letters

Δ	Mathematical operator indicating a change in a value
----------	--

Greek lower case letters

ψ	aspect ratio of a rectangular plate or panel ($b/a \leq 1,0$)
ε	strain
ρ	reduction factor for plate buckling
ν	Poisson's ratio
γ_M	partial factor for resistance
γ_{M0}	partial factor for plastic resistance or material yielding
γ_{M1}	partial factor for resistance to stability (buckling)
γ_{M2}	partial factor for resistance to tensile rupture, including the net section in bolted construction
γ_{M4}	partial factor for resistance to cyclic plasticity
γ_{M5}	partial factor for resistance of connections
γ_{Mf}	partial factor for resistance to fatigue

Membrane stress resultants in a plate (see Figure 3.4)

n_x	membrane direct stress resultant that is the force per unit width acting in the x direction in the plane of a plate
n_y	membrane direct stress resultant that is the force per unit width acting in the y direction in the plane of a plate
n_{xy}	membrane shear stress resultant that is the shear force per unit width acting in the plane of a plate

Membrane stresses in a plate (see Figure 3.4):

σ_{mx}	membrane normal stress in the x -direction due to a membrane normal stress resultant per unit width n_x
σ_{my}	membrane normal stress in the y -direction due to membrane normal stress resultant per unit width n_y
τ_{mxy}	membrane shear stress due to membrane shear stress resultant per unit width n_{xy}

Bending and twisting stress resultants in a plate (see Figure 3.5)

m_x	bending moment per unit width inducing normal stresses in the x direction in the plane of a plate
m_y	bending moment per unit width inducing normal stresses in the y direction in the plane of a plate
m_{xy}	twisting bending moment per unit width inducing shear stresses in the plane of a plate

Transverse shear stress resultants in a plate (see Figure 3.5)

q_x	transverse shear force per unit width associated with bending stresses in the x direction
q_y	transverse shear force per unit width associated with bending stresses in the y direction

Bending and shear stresses in a plate due to bending (see Figure 3.5)

σ_{bx}	bending stress in the x direction due to bending moment per unit width m_x
σ_{by}	bending stress in the y direction due to bending moment per unit width m_y
τ_{bxy}	shear stress due to the twisting moment per unit width m_{xy}

Transverse shear stresses in a plate

τ_{bxz}	shear stress due to transverse shear forces per unit width q_x associated with bending
τ_{byz}	shear stress due to transverse shear forces q_y associated with bending

NOTE 3 In general, there are eight stress resultants in a plate at any point. In all plates within the scope of this document, the transverse shear stresses τ_{bxz} and τ_{byz} due to q_x and q_y are negligible compared to the other components of stress, and therefore they can be disregarded in the resistance assessment of an individual plate, though they are required for the analysis of the stress state. For the resistance assessment, only six stress resultants at every point are required.

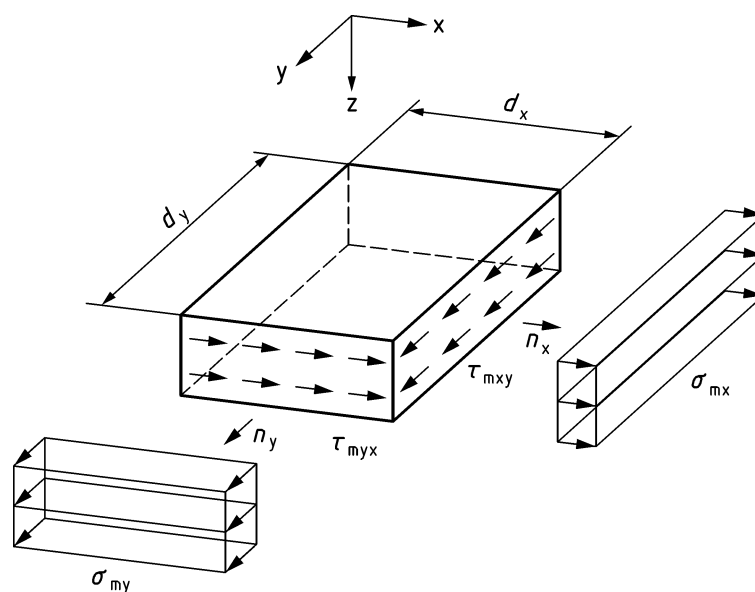


Figure 3.4 — Membrane stresses and membrane stress resultants in a plate

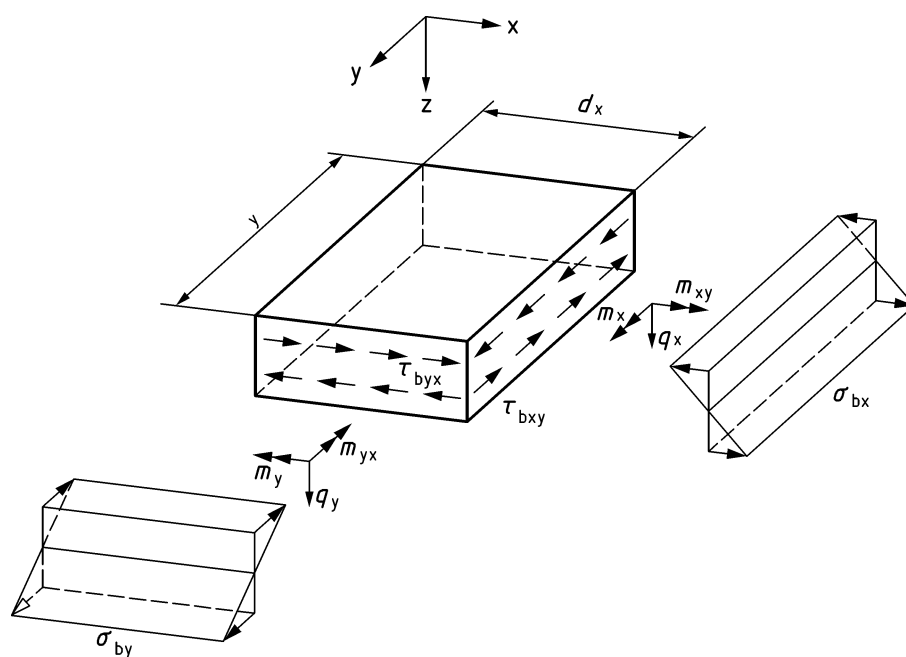


Figure 3.5 — Bending stresses and bending moments in a plate

4 Basis of design

4.1 General

(1) The design of steel structures shall be in accordance with the general rules given in EN 1990 and EN 1991 (all parts) and the specific design provisions for steel structures given in the other relevant parts of EN 1993-1 (all parts).

(2) Steel structures designed according to this document shall be executed according to EN 1090-2 and EN 1090-4 with construction materials and products used as specified in the relevant parts of EN 1993, or in the relevant material and product specifications.

(3) A plate or a plate assembly shall be designed against the ultimate limit states defined in 7.1 and against serviceability limit states in accordance with its intended use and the relevant application or product standards.

(4) This standard is intended for use in conjunction with EN 1993-1-1, EN 1993-1-2, EN 1993-1-3, EN 1993-1-4, EN 1993-1-5, EN 1993-1-9, EN 1993-1-14 and the relevant application parts of EN 1993, which include EN 1993-4-1 for silos.

(5) A plate assembly may be proportioned using design assisted by testing. Where appropriate, the requirements are set out in the appropriate application standard.

NOTE Where design is assisted by testing, additional information and application rules can be given in a National Annex.

(6) All actions should be introduced using their design values according to EN 1990.

(7) Where a stiffened plate assembly is subdivided into individual plate or panels the boundary conditions assumed for stiffeners in the design calculations should be recorded in the drawings and project specification to ensure that the connections have appropriate capacity.

4.2 Reliability management

(1) The execution classes for a plate assembly should be selected in accordance with EN 1993-1-1 or in accordance with the appropriate application or product standards.

(2) The rules for ultimate limit state design in this standard are based on a Reliability Class 2 as defined in EN 1990. If different levels of reliability are required, they should be achieved by an appropriate choice of quality management in design and execution according to EN 1990, EN 1090-2 and EN 1090-4. Where an application standard makes provisions for different Reliability Classes, these provisions may be adopted (e.g. EN 1993-4-1).

4.3 Design values of geometrical data

(1) The thickness t of any plate or part of a plate within a plate assembly should be taken as defined in the relevant application standard. If no application standard is relevant, the nominal thickness of the plate should be used, reduced by an appropriate corrosion or abrasion loss.

(2) The middle surface of each plate or panel should be taken as the reference surface for applied loads, unless stated otherwise in definitions of the load in other standards or application rules.

4.4 Geometrical tolerances and geometrical imperfections

(1) Tolerance values for the deviations of the geometry of each plate or panel surface from the nominal values are defined in EN 1090-2 and the relevant product and application standards.

(2) When the limit state of buckling (LS3, see 7.4) is the limit state to be considered, the geometrical tolerances given in EN 1090-2 should be met. The analysis of the plate assembly is not required to include these tolerances as imperfections, except where GMNIA analysis is used.

4.5 Durability

(1) The provisions of EN 1993-1-1 on durability should be used.

4.6 Verification by the partial factor method

(1) Where structural properties are determined by testing, the requirements and procedures of EN 1990 should be adopted.

(2) The partial factors γ_{Mj} for different limit states should be taken from Table 4.1.

Table 4.1 — Partial factors for resistance

Resistance to failure mode	Relevant γ
Resistance to plastic limit state or yielding	γ_{M0}
Resistance to instability / buckling	γ_{M1}
Resistance to rupture	γ_{M2}
Resistance to cyclic plasticity	γ_{M4}
Resistance to fatigue	γ_{Mf}

(3) The numerical values for γ_M defined in Table 4.2 are recommended for plates or plate assemblies that are not covered by the provisions of EN 1993-4-1, or where no application standard exists for the form of construction involved, or the application standard does not define the relevant values.

Table 4.2 (NDP) — Values of partial factors for resistance

$\gamma_{M0} = 1,00$	$\gamma_{M1} = 1,10$	$\gamma_{M2} = 1,25$	$\gamma_{M4} = 1,00$	γ_{Mf} see EN 1993-1-9
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NOTE The values of each of the partial factors γ_M are given in Table 4.2, unless the National Annex gives different values.

5 Materials and geometry

5.1 Material properties

(1) This document covers the design of plates and plate assemblies fabricated from steel conforming to the product standards listed in EN 1993-1-1 and the relevant application standards.

(2) Where cold-formed sheeting or cold-formed stiffeners are used, the material properties of cold formed sheeting and stiffeners should be obtained from EN 1993-1-3 or the appropriate product standard.

(3) The material properties of stainless steels should be obtained from EN 1993-1-4 or the appropriate product standard.

(4) In a computational analysis using materials with a nonlinear stress-strain relationship, the 0,2% proof stress should be used to represent the yield stress f_y in all relevant formulae. The stress-strain curve should be modelled in accordance with EN 1993-1-14.

(5) Where a material with a nonlinear stress-strain curve is involved and a buckling analysis is carried out under stress design (see 8.4 and 9.4) and the special provisions for stainless steel do not apply, the initial tangent value of Young's modulus E should be replaced by a reduced value. If no better method is available, the linear elastic stress state should be examined and the peak value of the von Mises equivalent stress should be found from the membrane stress components alone at a distance greater than x_e from any boundary, which may be taken as $10t$. The tangent modulus found using a uniaxial tensile test and corresponding to this stress should then be used to estimate the quasi-elastic critical load or quasi-elastic critical resistance.

NOTE Although the thickest plate treated in this document is $b/t = 20$ and $10t$ is therefore half the plate width, such thick plates are not susceptible to buckling failure so this exclusion distance for buckling is not too restrictive.

6 Structural analysis

6.1 Types of analysis

6.1.1 General

(1) This standard assumes that a complete plate assembly will often be analysed using a global computational analysis (for example, by means of computer programs based on the finite element method). However, for simple plate assemblies, the treatment using static equilibrium and membrane and simple bending analysis (MSBA) is permitted (see Annex A).

(2) One or more of the following types of analysis should be used, see Table 6.1, depending on the limit state and other considerations:

- Membrane and simple bending analysis (MSBA), see 6.1.2;
- Linear elastic structural analysis (LA), see 6.1.3;
- Linear elastic bifurcation analysis (LBA), see 6.1.4;
- Geometrically nonlinear elastic analysis (GNA), see 6.1.5;
- Materially nonlinear analysis (MNA), see 6.1.6;
- Geometrically and materially nonlinear analysis (GMNA), see 6.1.7;
- Geometrically and materially nonlinear analysis with imperfections included (GMNIA), see 6.1.8.

Table 6.1 — Types of analysis for plate or panels and plate assemblies

Type of analysis	Treatment	Material law	Geometry
Membrane and simple bending analysis (MSBA)	membrane equilibrium for membrane forces; simple bending treatment for forces normal to the plates	static equilibrium alone	perfect
Linear elastic analysis (LA)	linear bending and stretching	linear	perfect
Linear elastic bifurcation analysis (LBA)	linear bending and stretching	linear	perfect
Geometrically nonlinear elastic analysis (GNA)	nonlinear	linear	perfect
Materially nonlinear analysis (MNA)	linear bending and stretching	ideal elastic-plastic	perfect
Geometrically and materially nonlinear analysis (GMNA)	nonlinear	nonlinear	perfect
Geometrically and materially nonlinear analysis including imperfections (GMNIA)	nonlinear	nonlinear	imperfect

6.1.2 Membrane and simple bending analysis (MSBA)

(1) A membrane and simple bending analysis may be used to treat each plate or panel as separate, with a simple one-way beam bending treatment as a horizontal strip in each plate or panel and only simple end shear forces in one plate being transmitted as membrane forces into the adjacent plate or panel.

(2) A membrane and simple bending analysis should only be used provided that the plate junctions are appropriate for transfer of the forces in the plates into support reactions without causing significant local stress effects. For definitions and notes on boundary conditions, see 6.2.4.

(3) A membrane and simple bending analysis does not, in general, fulfil the compatibility of deformations at boundaries or within the plate or panel or between plate or panels either of different shape or that are subjected to different patterns of loading. However, the resulting membrane forces satisfy the equilibrium requirements for the ultimate limit state of plastic failure (LS1).

6.1.3 Linear elastic structural analysis (LA)

(1) Linear elastic structural analysis treats all components as having a linear elastic material law and assumes that the displacements of the plate or plate assembly are governed by small deflection theory (unchanged geometry under load).

(2) An LA analysis satisfies compatibility in the deformations between plate or panels as well as equilibrium. The resulting field of membrane and bending stresses satisfies the requirements for cyclic loading limit states (see 7.3 and 7.5).

(3) This analysis may be undertaken using algebraic formulae (see Annexes A and B) or a computational analysis.

(4) Where a computational analysis is undertaken, the modelling, mesh, validation and verification criteria of EN 1993-1-14 should be met.

6.1.4 Linear elastic bifurcation analysis (LBA)

(1) The result of an LBA analysis provides the elastic critical buckling resistance, which can be interpreted as a load amplification factor R_{cr} on the design value of the loads F_{Ed} and can be used in the verification of limit state LS3. Linear elastic material law and small-deflection theory are used. The lowest buckling eigenvalue R_{cr} is the lowest load amplification factor on the loads F_{Ed} at which the considered structure or component may deform into an elastic buckling mode, assuming no change of geometry, no change in the direction of action of the loads, and no material degradation. Imperfections of all kinds are ignored. The term elastic critical is reserved in this document for the outcomes of this analysis (linear elastic with unchanged geometry).

(2) This analysis may be undertaken using a computational analysis or algebraic formulae.

(3) Where a computational analysis is undertaken, the modelling, mesh, validation and verification criteria of EN 1993-1-14 should be met.

6.1.5 Geometrically nonlinear elastic analysis (GNA)

(1) A GNA analysis satisfies both equilibrium and compatibility of the deflections under conditions in which the change in the geometry of the elastic structure caused by loading is included. The resulting field of stresses satisfies the requirements for cyclic loading limit states (LS2 and LS4). It is only computational.

(2) Where changes of geometry caused by the loads produce significant redistributions in the elastic stress state, a GNA analysis may be used for determining the underlying equilibrium state while checking limit state LS1.