

Geregistreeerde Belgische norm

NBN EN 1993-1-6

2e uitg., augustus 2007

Normklasse: B 51

Eurocode 3 - Ontwerp en berekening van staalconstructies - Deel 1-6: Algemene regels - Sterkte en stabiliteit van schaalconstructies (+ AC:2009)

Eurocode 3 - Calcul des structures en acier - Partie 1-6: Résistance et stabilité des structures en coque (+ AC:2009)

Eurocode 3 - Design of steel structures - Part 1-6: Strength and Stability of Shell Structures (+ AC:2009)

Toelating tot publicatie: 30 mei 2007

Vervangt NBN ENV 1993-1-6 (1999).

Deze Europese norm EN 1993-1-6:2007 heeft de status van een Belgische norm.

Deze Europese norm bestaat in drie officiële versies (Duits, Engels, Frans).

Er is bij het NBN ook een Nederlandstalige versie beschikbaar, die dezelfde status heeft als de officiële versies.

Deze norm mag in België slechts samen met zijn nationale bijlage (ANB) worden toegepast. Deze laatste legt hoofdzakelijk de waarden van de parameters vast die op nationaal vlak worden bepaald.



Bureau voor Normalisatie - Birminghamstraat 131 - 1070 Brussel - België

Tel: +32 2 738 01 12 - Fax: +32 2 733 42 64 - E-mail: info@nbn.be - NBN Online: www.nbn.be
Bank 000-3255621-10 IBAN BE41 0003 2556 2110 BIC BPOTBEB1 BTW BE0880857592

***norme belge
enregistrée***

NBN EN 1993-1-6

2e éd., août 2007

Indice de classement: B 51

Eurocode 3 - Calcul des structures en acier - Partie 1-6: Résistance et stabilité des structures en coque (+ AC:2009)

Eurocode 3 - Ontwerp en berekening van staalconstructies - Deel 1-6: Algemene regels - Sterkte en stabiliteit van schaalconstructies (+ AC:2009)

Eurocode 3 - Design of steel structures - Part 1-6: Strength and Stability of Shell Structures (+ AC:2009)

Autorisation de publication: 30 mai 2007

Remplace NBN ENV 1993-1-6 (1999).

La présente norme européenne EN 1993-1-6:2007 a le statut d'une norme belge.

La présente norme européenne existe en trois versions officielles (allemand, anglais, français).

Une version en néerlandais, ayant le même statut que les versions officielles, est également disponible au NBN.

Cette norme ne peut être utilisée en Belgique qu'en combinaison avec son annexe nationale (ANB) qui fixe principalement la valeur des paramètres à déterminer au niveau national.



Bureau de Normalisation - Rue de Birmingham 131 - 1070 Bruxelles - Belgique

Tél: +32 2 738 01 12 - Fax: +32 2 733 42 64 - E-mail: info@nbn.be - NBN Online: www.nbn.be
Banque 000-3255621-10 IBAN BE41 0003 2556 2110 BIC BPOTBEB1 TVA BE0880857592

NATIONAAL VOORWOORD VAN NBN EN 1993-1-6:2007

1. De norm NBN EN 1993-1-6:2007 «Eurocode 3 – Ontwerp en berekening van staalconstructies – Deel 1-6: Algemene regels - Sterkte en stabiliteit van schaalconstructies» omvat de nationale bijlage NBN EN 1993-1-6 ANB:2011 met een normatief karakter in België. Hij vervangt vanaf de datum van de publicatie in het Belgische Staatsblad van de bekrachtiging van de norm NBN EN 1993-1-6 ANB:2011 de volgende norm:

NBN ENV 1993-1-6:1999 Eurocode 3 – Ontwerp van stalen draagsystemen -
Deel 1-6: Algemene regels – Aanvullende regels
voor schalenbouw

Het corrigendum EN 1993-1-6/AC:2009, zoals door CEN gepubliceerd, is na deze norm toegevoegd.

2. De Europese normen (EN) waarnaar de tekst van deze norm met hun Engelse titel verwijst, dragen in België de volgende Nederlandstalige titels:

Vermelde norm	Nederlandstalige titel (NBN)
EN 1090-2 Execution of steel structures and aluminium structures Part 2: Technical requirements for steel structures	NBN EN 1090-2 Uitvoering van staalconstructies en aluminiumconstructies Deel 2: Technische eisen voor staalconstructies
EN 1990 Basis of structural design	NBN EN 1990 Eurocode - Grondslagen van het constructief ontwerp
EN 1991 Eurocode 1: Actions on structures	NBN EN 1991 Eurocode 1 : Belastingen op constructies
EN 1993 Eurocode 3 : Design of steel structures Part 1.1: General rules and rules for buildings	NBN EN 1993 Eurocode 3: Ontwerp en berekening van staalconstructies Deel 1-1: Algemene regels en regels voor gebouwen
EN 1993 Eurocode 3 : Design of steel structures Part 1.3: Cold formed thin gauged members and sheeting	NBN EN 1993 Eurocode 3: Ontwerp en berekening van staalconstructies Deel 1-3: Algemene regels - Aanvullende regels voor koudgevormde profielen en platen

<p>EN 1993 Eurocode 3 : Design of steel structures</p> <p>Part 1.4: Stainless steels</p>	<p>NBN EN 1993 Eurocode 3: Ontwerp en berekening van staalconstructies</p> <p>Deel 1-4: Algemene regels - Aanvullende regels voor roestvast staal</p>
<p>EN 1993 Eurocode 3 : Design of steel structures</p> <p>Part 1.5: Plated structural steels</p>	<p>NBN EN 1993 Eurocode 3: Ontwerp en berekening van staalconstructies</p> <p>Deel 1-5: Algemene regels - Constructieve plaatvelden</p>
<p>EN 1993 Eurocode 3 : Design of steel structures</p> <p>Part 1.9: Fatigue strength of steel structures</p>	<p>NBN EN 1993 Eurocode 3: Ontwerp en berekening van staalconstructies</p> <p>Deel 1-9: Algemene regels - Vermoeiing</p>
<p>EN 1993 Eurocode 3 : Design of steel structures</p> <p>Part 1.10: Selection of steel for fracture toughness and through-thickness properties</p>	<p>NBN EN 1993 Eurocode 3: Ontwerp en berekening van staalconstructies</p> <p>Deel 1-10: Algemene regels - Materiaaltaaiheid en eigenschappen in de dikterichting</p>

AVANT-PROPOS NATIONAL À LA NBN EN 1993-1-6:2007

1. La norme NBN EN 1993-1-6:2007 "Eurocode 3 – Calcul des structures en acier - Partie 1-6 : Résistance et stabilité des structures en coque" comprend l'annexe nationale NBN EN 1993-1-6 ANB:2011 qui a un caractère normatif en Belgique. Elle remplace à partir de la date de publication au Moniteur Belge de l'homologation de la norme NBN EN 1993-1-6 ANB:2011 la norme suivante:

NBN ENV 1993-1-6:1999 Eurocode 3 : Calcul des structures en acier –
Partie 1-6 : Règles générales - Règles supplémentaires pour la résistance et la stabilité des structures en coque".

Le corrigendum EN 1993-1-6/AC:2009, tel que publié par le CEN, est joint à cette norme.

2. La version en langue française de l'EN 1993-1-6:2007 a été rédigée en France par l'AFNOR.
En conséquence, on peut y rencontrer certaines expressions d'usage moins courant en Belgique.

Une liste de termes équivalents est donnée ci-après :

Terme de l'EN 1993-1-6	Terme équivalent en Belgique
Aucun terme n'est repris.	

English Version

Eurocode 3 - Design of steel structures - Part 1-6: Strength and Stability of Shell Structures

Eurocode 3 - Calcul des structures en acier - Partie 1-6:
Résistance et stabilité des structures en coque

Eurocode 3 - Bemessung und Konstruktion von
Stahlbauten - Teil 1-6: Festigkeit und Stabilität von Schalen

This European Standard was approved by CEN on 12 June 2006.

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. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN Management Centre or to any CEN member.

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.

CEN members are the national standards bodies of 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.



EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

Contents	Page
1. General	4
1.1 Scope	4
1.2 Normative references	5
1.3 Terms and definitions	6
1.4 Symbols	11
1.5 Sign conventions	15
2 Basis of design and modelling	15
2.1 General	15
2.2 Types of analysis	15
2.3 Shell boundary conditions	17
3 Materials and geometry	18
3.1 Material properties	18
3.2 Design values of geometrical data	18
3.3 Geometrical tolerances and geometrical imperfections	18
4 Ultimate limit states in steel shells	19
4.1 Ultimate limit states to be considered	19
4.2 Design concepts for the limit states design of shells	20
5 Stress resultants and stresses in shells	23
5.1 Stress resultants in the shell	23
5.2 Modelling of the shell for analysis	23
5.3 Types of analysis	26
6 Plastic limit state (LS1)	26
6.1 Design values of actions	26
6.2 Stress design	26
6.3 Design by global numerical MNA or GMNA analysis	27
6.4 Direct design	28
7 Cyclic plasticity limit state (LS2)	28
7.1 Design values of actions	28
7.2 Stress design	29
7.3 Design by global numerical MNA or GMNA analysis	29
7.4 Direct design	30
8 Buckling limit state (LS3)	30
8.1 Design values of actions	30
8.2 Special definitions and symbols	30
8.3 Buckling-relevant boundary conditions	31
8.4 Buckling-relevant geometrical tolerances	31
8.5 Stress design	38
8.6 Design by global numerical analysis using MNA and LBA analyses	40
8.7 Design by global numerical analysis using GMNIA analysis	43
9 Fatigue limit state (LS4)	48
9.1 Design values of actions	48
9.2 Stress design	48

9.3	Design by global numerical LA or GNA analysis	49
ANNEX A (normative)		50
Membrane theory stresses in shells		50
A.1	General	50
A.2	Unstiffened cylindrical shells	51
A.3	Unstiffened conical shells	52
A.4	Unstiffened spherical shells	53
ANNEX B (normative)		54
Additional expressions for plastic collapse resistances		54
B.1	General	54
B.2	Unstiffened cylindrical shells	55
B.3	Ring stiffened cylindrical shells	57
B.4	Junctions between shells	59
B.5	Circular plates with axisymmetric boundary conditions	62
ANNEX C (normative)		63
Expressions for linear elastic membrane and bending stresses		63
C.1	General	63
C.2	Clamped base unstiffened cylindrical shells	64
C.3	Pinned base unstiffened cylindrical shells	66
C.4	Internal conditions in unstiffened cylindrical shells	68
C.5	Ring stiffener on cylindrical shell	69
C.6	Circular plates with axisymmetric boundary conditions	71
ANNEX D (normative)		73
Expressions for buckling stress design		73
D.1	Unstiffened cylindrical shells of constant wall thickness	73
D.2	Unstiffened cylindrical shells of stepwise variable wall thickness	83
D.3	Unstiffened lap jointed cylindrical shells	88
D.4	Unstiffened complete and truncated conical shells	90

Foreword

This European Standard EN 1993-1-6, Eurocode 3: Design of steel structures: Part 1-6 Strength and stability of shell structures, 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 August 2007, and conflicting National Standards shall be withdrawn at latest by March 2010.

This Eurocode supersedes ENV 1993-1-6.

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,

EN 1993-1-6: 2007 (E)

Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

National annex for EN 1993-1-6

This standard gives alternative procedures, values and recommendations with notes indicating where national choices may have to be made. Therefore the National Standard implementing EN 1993-1-6 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 1993-1-6 through:

- 3.1.(4)
- 4.1.4 (3)
- 5.2.4 (1)
- 6.3 (5)
- 7.3.1 (1)
- 7.3.2 (1)
- 8.4.2 (3)
- 8.4.3 (2)
- 8.4.3 (4)
- 8.4.4 (4)
- 8.4.5 (1)
- 8.5.2 (2)
- 8.5.2 (4)
- 8.7.2 (7)
- 8.7.2 (16)
- 8.7.2 (18) (2 times)
- 9.2.1 (2)P

1. General**1.1 Scope**

(1) EN 1993-1-6 gives basic design rules for plated steel structures that have the form of a shell of revolution.

(2) This Standard is intended for use in conjunction with EN 1993-1-1, EN 1993-1-3, EN 1993-1-4, EN 1993-1-9 and the relevant application parts of EN 1993, which include:

- Part 3.1 for towers and masts;
- Part 3.2 for chimneys;
- Part 4.1 for silos;
- Part 4.2 for tanks;
- Part 4.3 for pipelines.

(3) This Standard defines the characteristic and design values of the resistance of the structure.

- (4) This Standard is concerned with the requirements for design against the ultimate limit states of:
- plastic limit;
 - cyclic plasticity;
 - buckling;
 - fatigue.
- (5) 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 are included in the relevant application parts of EN 1993.
- (6) The provisions in this Standard apply to axisymmetric shells and associated circular or annular plates and to beam section rings and stringer stiffeners where they form part of the complete structure. General procedures for computer calculations of all shell forms are covered. Detailed expressions for the hand calculation of unstiffened cylinders and cones are given in the Annexes.
- (7) Cylindrical and conical panels are not explicitly covered by this Standard. However, the provisions can be applicable if the appropriate boundary conditions are duly taken into account.
- (8) This Standard is intended for application to steel shell structures. Where no standard exists for shell structures made of other metals, the provisions of this standards may be applied provided that the appropriate material properties are duly taken into account.
- (9) The provisions of this Standard are intended to be applied within the temperature range defined in the relevant EN 1993 application parts. The maximum temperature is restricted so that the influence of creep can be neglected if high temperature creep effects are not covered by the relevant application part.
- (10) The provisions in this Standard apply to structures that satisfy the brittle fracture provisions given in EN 1993-1-10.
- (11) The provisions of this Standard apply to structural design under actions that can be treated as quasi-static in nature.
- (12) In this Standard, it is assumed that both wind loading and bulk solids flow can, in general, be treated as quasi-static actions.
- (13) Dynamic effects should be taken into account according to the relevant application part of EN 1993, including the consequences for fatigue. However, the stress resultants arising from dynamic behaviour are treated in this part as quasi-static.
- (14) The provisions in this Standard apply to structures that are constructed in accordance with EN 1090-2.
- (15) This Standard does not cover the aspects of leakage.
- (16) This Standard is intended for application to structures within the following limits:
- design metal temperatures within the range -50°C to $+300^{\circ}\text{C}$;
 - radius to thickness ratios within the range 20 to 5000.

NOTE: It should be noted that the stress design rules of this standard may be rather conservative if applied to some geometries and loading conditions for relatively thick-walled shells.

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