

Eurocode 1: Actions on structures

Part 1-4: General actions

Wind actions

Eurokoodeks 1: Ehituskonstruksioonide koormused

Osa 1-4: Üldkoormused

Tuulekoormus

EESTI STANDARDI EESSÕNA

NATIONAL FOREWORD

Käesolev Eesti standard
EVS-EN 1991-1-4:2005+NA:2007 sisaldab Euroopa
standardi identset ingliskeelset teksti ning rahvuslikku
lisa NA:2007.

Standard on kinnitatud Eesti Standardikeskuse
29.10.2007 käskkirjaga nr 161 ja on jõustunud
sellekohase teate avaldamisel EVS Teatajas.

Euroopa standardimisorganisatsioonide poolt
rahvuslikele liikmetele Euroopa standardi teksti
kättesaadavaks tegemise kuupäev on 13.04.2005.

Standard on kättesaadav Eesti Standardikeskusest.

This Estonian Standard
EVS-EN 1991-1-4:2005+NA:2007 consists of the
identical English text of the European Standard and
the Estonian National Annex NA.

This standard is ratified with order nr 161 of Estonian
Centre for Standardisation dated 29.10.2007 and is
endorsed with the notification published in the official
bulletin of the Estonian centre for Standardisation.!

Date of Availability of the European Standard is
13.04.2005.

This standard is available from the Estonian Centre
for Standardisation.

ICS 91.010.30

Standardite reprodutseerimis- ja levitamiseõigus kuulub Eesti Standardikeskusele

Andmete paljundamine, taastekitamine, kopeerimine, salvestamine elektroonilisse süsteemi või edastamine ükskõik millises vormis või
millisel teel on ilma Eesti Standardikeskuse kirjaliku loata keelatud.

Kui Teil on küsimusi standardite autorikaitse kohta, võtke palun ühendust Eesti Standardikeskusega:
Aru 10, 10317 Tallinn, Eesti; www.evs.ee; telefon: 605 5050; e-post: info@evs.ee

The right to reproduce and distribute standards belongs to the Estonian Centre for Standardisation

No part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying,
without a written permission from the Estonian Centre for Standardisation.

If you have any questions about standards copyright, please contact the Estonian Centre for Standardisation:
Aru 10, 10317 Tallinn, Estonia; www.evs.ee; phone: 605 5050; e-mail: info@evs.ee

English version

**Eurocode 1: Actions on structures - Part 1-4: General actions -
Wind actions**

Eurocode 1: - Actions sur les structures - Partie 1-4:
Actions générales - Actions du vent

Eurocode 1: Einwirkungen auf Tragwerke - Teil 1-4:
Allgemeine Einwirkungen - Windlasten

This European Standard was approved by CEN on 4 June 2004.

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 Central Secretariat 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 Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, 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

Section 1	General	9
1.1	Scope	9
1.2	Normative references	10
1.3	Assumptions	10
1.4	Distinction between Principles and Application Rules	10
1.5	Design assisted by testing and measurements	10
1.6	Definitions	10
1.7	Symbols	11
Section 2	Design situations	16
Section 3	Modelling of wind actions	17
3.1	Nature	17
3.2	Representations of wind actions	17
3.3	Classification of wind actions	17
3.4	Characteristic values	17
3.5	Models	17
Section 4	Wind velocity and velocity pressure	18
4.1	Basis for calculation	18
4.2	Basic values	18
4.3	Mean wind	19
4.3.1	Variation with height	19
4.3.2	Terrain roughness	19
4.3.3	Terrain orography	21
4.3.4	Large and considerably higher neighbouring structures	21
4.3.5	Closely spaced buildings and obstacles	22
4.4	Wind turbulence	22
4.5	Peak velocity pressure	22
Section 5	Wind actions	24
5.1	General	24
5.2	Wind pressure on surfaces	24
5.3	Wind forces	25
Section 6	Structural factor $c_s c_d$	28
6.1	General	28
6.2	Determination of $c_s c_d$	28
6.3	Detailed procedure	28
6.3.1	Structural factor $c_s c_d$	28
6.3.2	Serviceability assessments	30
6.3.3	Wake buffeting	30
Section 7	Pressure and force coefficients	31
7.1	General	31
7.1.1	Choice of aerodynamic coefficient	31
7.1.2	Asymmetric and counteracting pressures and forces	32
7.1.3	Effects of ice and snow	32
7.2	Pressure coefficients for buildings	33
7.2.1	General	33
7.2.2	Vertical walls of rectangular plan buildings	34
7.2.3	Flat roofs	37
7.2.4	Monopitch roofs	40
7.2.5	Duopitch roofs	43
7.2.6	Hipped roofs	47
7.2.7	Multispan roofs	48
7.2.8	Vaulted roofs and domes	50

7.2.9 Internal pressure	51
7.2.10 Pressure on walls or roofs with more than one skin	53
7.3 Canopy roofs	54
7.4 Free-standing walls, parapets, fences and signboards	61
7.4.1 Free-standing walls and parapets	61
7.4.2 Shelter factors for walls and fences	63
7.4.3 Signboards	63
7.5 Friction coefficients	64
7.6 Structural elements with rectangular sections	65
7.7 Structural elements with sharp edged section	67
7.8 Structural elements with regular polygonal section	67
7.9 Circular cylinders	69
7.9.1 External pressure coefficients	69
7.9.2 Force coefficients	71
7.9.3 Force coefficients for vertical cylinders in a row arrangement	74
7.10 Spheres	74
7.11 Lattice structures and scaffoldings	76
7.12 Flags	78
7.13 Effective slenderness λ and end-effect factor ψ_λ	80
Section 8 Wind actions on bridges	82
8.1 General	82
8.2 Choice of the response calculation procedure	85
8.3 Force coefficients	85
8.3.1 Force coefficients in x-direction (general method)	85
8.3.2 Force in x-direction – Simplified Method	88
8.3.3 Wind forces on bridge decks in z-direction	89
8.3.4 Wind forces on bridge decks in y-direction	90
8.4 Bridge piers	91
8.4.1 Wind directions and design situations	91
8.4.2 Wind effects on piers	91
Annex A (informative) Terrain effects	92
A.1 Illustrations of the upper roughness of each terrain category	92
A.2 Transition between roughness categories 0, I, II, III and IV	93
A.3 Numerical calculation of orography coefficients	95
A.4 Neighbouring structures	100
A.5 Displacement height	101
Annex B (informative) Procedure 1 for determining the structural factor $c_s c_d$	102
B.1 Wind turbulence	102
B.2 Structural factor	103
B.3 Number of loads for dynamic response	105
B.4 Service displacement and accelerations for serviceability assessments of a vertical structure	105
Annex C (informative) Procedure 2 for determining the structural factor $c_s c_d$	108
C.1 Wind turbulence	108
C.2 Structural factor	108
C.3 Number of loads for dynamic response	109
C.4 Service displacement and accelerations for serviceability assessments	109
Annex D (informative) $c_s c_d$ values for different types of structures	111
Annex E (informative) Vortex shedding and aeroelastic instabilities	114
E.1 Vortex shedding	114
E.1.1 General	114
E.1.2 Criteria for vortex shedding	114
E.1.3 Basic parameters for vortex shedding	115
E.1.4 Vortex shedding action	118
E.1.5 Calculation of the cross wind amplitude	118
E.1.6 Measures against vortex induced vibrations	128
E.2 Galloping	129
E.2.1 General	129

E.2.2	Onset wind velocity	129
E.2.3	Classical galloping of coupled cylinders	131
E.3	Interference galloping of two or more free standing cylinders	133
E.4	Divergence and Flutter	134
E.4.1	General	134
E.4.2	Criteria for plate-like structures	134
E.4.3	Divergency velocity	134
Annex F (informative)	Dynamic characteristics of structures	136
F.1	General	136
F.2	Fundamental frequency	136
F.3	Fundamental mode shape	141
F.4	Equivalent mass	143
F.5	Logarithmic decrement of damping	143
Bibliography		146

Foreword

This document EN 1991-1-4:2005 has been prepared by Technical Committee CEN/TC250 "Structural Eurocode", the secretariat of which is held by BSI.

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 2005, and conflicting national standards shall be withdrawn at the latest by March 2010.

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

This European Standard supersedes ENV 1991-2-4: 1995.

CEN/TC 250 is responsible for all Structural Eurocodes.

Background of the Eurocode programme

In 1975, the Commission of the European Community decided on an action programme in the field of construction, based on article 95 of the Treaty. The objective of the programme was the elimination of technical obstacles to trade and the harmonisation of technical specifications.

Within this action programme, the Commission took the initiative to establish a set of harmonised technical rules for the design of construction works which, in a first stage, would serve as an alternative to the national rules in force in the Member States and, ultimately, would replace them.

For fifteen years, the Commission, with the help of a Steering Committee with Representatives of Member States, conducted the development of the Eurocodes programme, which led to the first generation of European codes in the 1980s.

In 1989, the Commission and the Member States of the EU and EFTA decided, on the basis of an agreement¹ between the Commission and CEN, to transfer the preparation and the publication of the Eurocodes to the CEN through a series of Mandates, in order to provide them with a future status of European Standard (EN). This links *de facto* the Eurocodes with the provisions of all the Council's Directives and/or Commission's Decisions dealing with European standards (e.g. the Council Directive 89/106/EEC on construction products - CPD - and Council Directives 93/37/EEC, 92/50/EEC and 89/440/EEC on public works and services and equivalent EFTA Directives initiated in pursuit of setting up the internal market).

The Structural Eurocode programme comprises the following standards generally consisting of a number of Parts :

EN 1990	Eurocode :	Basis of Structural Design
EN 1991	Eurocode 1:	Actions on structures
EN 1992	Eurocode 2:	Design of concrete structures
EN 1993	Eurocode 3:	Design of steel structures

¹ Agreement between the Commission of the European Communities and the European Committee for Standardisation (CEN) concerning the work on EUROCODES for the design of building and civil engineering works (BC/CEN/03/89).

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

Eurocode standards recognise the responsibility of regulatory authorities in each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level where these continue to vary from State to State.

Status and field of application of Eurocodes

The Member States of the EU and EFTA recognise that Eurocodes serve as reference documents for the following purposes :

- as a means to prove compliance of building and civil engineering works with the essential requirements of Council Directive 89/106/EEC, particularly Essential Requirement N°1 – Mechanical resistance and stability – and Essential Requirement N°2 – Safety in case of fire ;
- as a basis for specifying contracts for construction works and related engineering services ;
- as a framework for drawing up harmonised technical specifications for construction products (ENs and ETAs)

The Eurocodes, as far as they concern the construction works themselves, have a direct relationship with the Interpretative Documents² referred to in Article 12 of the CPD, although they are of a different nature from harmonised product standards³. Therefore, technical aspects arising from the Eurocodes work need to be adequately considered by CEN Technical Committees and/or EOTA Working Groups working on product standards with a view to achieving full compatibility of these technical specifications with the Eurocodes.

The Eurocode standards provide common structural design rules for everyday use for the design of whole structures and component products of both a traditional and an innovative nature. Unusual forms of construction or design conditions are not specifically covered and additional expert consideration will be required by the designer in such cases.

² According to Art. 3.3 of the CPD, the essential requirements (ERs) shall be given concrete form in interpretative documents for the creation of the necessary links between the essential requirements and the mandates for harmonised ENs and ETAGs/ETAs.

³ According to Art. 12 of the CPD the interpretative documents shall :

- a) give concrete form to the essential requirements by harmonising the terminology and the technical bases and indicating classes or levels for each requirement where necessary ;
- b) indicate methods of correlating these classes or levels of requirement with the technical specifications, e.g. methods of calculation and of proof, technical rules for project design, etc. ;
- c) serve as a reference for the establishment of harmonised standards and guidelines for European technical approvals.

The Eurocodes, *de facto*, play a similar role in the field of the ER 1 and a part of ER 2.

National Standards implementing Eurocodes

The National Standards implementing Eurocodes will comprise the full text of the Eurocode (including any annexes), as published by CEN, which may be preceded by a National title page and National foreword, and may be followed by a National annex.

The National annex may only contain information on those parameters which are left open in the Eurocode for national choice, known as Nationally Determined Parameters, to be used for the design of buildings and civil engineering works to be constructed in the country concerned, *i.e.* :

- values and/or classes where alternatives are given in the Eurocode,
- values to be used where a symbol only is given in the Eurocode,
- country specific data (geographical, climatic, etc.), e.g. wind map,
- the procedure to be used where alternative procedures are given in the Eurocode.

It may also contain

- decisions on the use of informative annexes, and
- references to non-contradictory complementary information to assist the user to apply the Eurocode.

Links between Eurocodes and harmonised technical specifications (ENs and ETAs) for products

There is a need for consistency between the harmonised technical specifications for construction products and the technical rules for works⁴. Furthermore, all the information accompanying the CE Marking of the construction products which refer to Eurocodes should clearly mention which Nationally Determined Parameters have been taken into account.

Additional information specific for EN 1991-1-4

EN 1991-1-4 gives design guidance and actions for the structural design of buildings and civil engineering works for wind.

EN 1991-1-4 is intended for the use by clients, designers, contractors and relevant authorities.

EN 1991-1-4 is intended to be used with EN 1990, the other Parts of EN 1991 and EN 1992-1999 for the design of structures.

National annex for EN 1991-1-4

This standard gives alternative procedures, values and recommendations for classes with notes indicating where National choice may be made. Therefore the National Standard implementing EN 1991-1-4 should have a National Annex containing Nationally Determined Parameters to be used for the design of buildings and civil engineering works to be constructed in the relevant country.

National choice is allowed for EN 1991-1-4 through clauses:

- 1.1 (11) Note 1
- 1.5 (2)

⁴ see Art.3.3 and Art.12 of the CPD, as well as clauses 4.2, 4.3.1, 4.3.2 and 5.2 of ID 1.

4.1 (1)
4.2 (1)P Note 2
4.2 (2)P Notes 1, 2, 3 and 5
4.3.1 (1) Notes 1 and 2
4.3.2 (1)
4.3.2 (2)
4.3.3 (1)
4.3.4 (1)
4.3.5 (1)
4.4 (1) Note 2
4.5 (1) Notes 1 and 2

5.3 (5)

6.1 (1)
6.3.1 (1) Note 3
6.3.2 (1)

7.1.2 (2)
7.1.3 (1)
7.2.1 (1) Note 2
7.2.2 (1)
7.2.2 (2) Note 1
7.2.8 (1)
7.2.9 (2)
7.2.10 (3) Notes 1 and 2
7.4.1 (1)
7.4.3 (2)
7.6 (1) Note 1
7.7 (1) Note 1
7.8 (1)
7.10 (1) Note 1
7.11 (1) Note 2
7.13 (1)
7.13 (2)

8.1 (1) Notes 1 and 2
8.1 (4)
8.1 (5)
8.2 (1) Note 1
8.3 (1)
8.3.1 (2)
8.3.2 (1)
8.3.3 (1) Note 1
8.3.4 (1)
8.4.2 (1) Notes 1 and 2

A.2 (1)

E.1.3.3 (1)
E.1.5.1 (1) Notes 1 and 2
E.1.5.1 (3)
E.1.5.2.6 (1) Note 1
E.1.5.3 (2) Note 1
E.1.5.3 (4)
E.1.5.3 (6)
E.3 (2)

Section 1 General

1.1 Scope

(1) EN 1991-1-4 gives guidance on the determination of natural wind actions for the structural design of building and civil engineering works for each of the loaded areas under consideration. This includes the whole structure or parts of the structure or elements attached to the structure, e. g. components, cladding units and their fixings, safety and noise barriers.

(2) This Part is applicable to:

- Buildings and civil engineering works with heights up to 200 m. See also (11).
- Bridges having no span greater than 200 m, provided that they satisfy the criteria for dynamic response, see (11) and 8.2.

(3) This part is intended to predict characteristic wind actions on land-based structures, their components and appendages.

(4) Certain aspects necessary to determine wind actions on a structure are dependent on the location and on the availability and quality of meteorological data, the type of terrain, etc. These need to be provided in the National Annex and Annex A, through National choice by notes in the text as indicated. Default values and methods are given in the main text, where the National Annex does not provide information.

(5) Annex A gives illustrations of the terrain categories and provides rules for the effects of orography including displacement height, roughness change, influence of landscape and influence of neighbouring structures.

(6) Annex B and C give alternative procedures for calculating the structural factor $c_s c_d$.

(7) Annex D gives $c_s c_d$ factors for different types of structures.

(8) Annex E gives rules for vortex induced response and some guidance on other aeroelastic effects.

(9) Annex F gives dynamic characteristics of structures with linear behaviour

(10) This part does not give guidance on local thermal effects on the characteristic wind, e.g. strong arctic thermal surface inversion or funnelling or tornadoes.

(11) This part does not give guidance on the following aspects:

- wind actions on lattice towers with non-parallel chords
- wind actions on guyed masts and guyed chimneys
- torsional vibrations, e.g. tall buildings with a central core
- bridge deck vibrations from transverse wind turbulence
- cable supported bridges
- vibrations where more than the fundamental mode needs to be considered

NOTE 1 The National Annex may provide guidance on these aspects as non contradictory complementary information.

NOTE 2 For wind actions on guyed masts, guyed chimneys and lattice towers with non-parallel chords, see EN 1993-3-1, Annex A.

NOTE 3 For wind actions on lighting columns, see EN 40.

1.2 Normative references

The following normative documents contain provisions which, through references in this text, constitute provisions of this European standard. For dated references, subsequent amendments to, or revisions of any of these publications do not apply. However, parties to agreements based on this European standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references the latest edition of the normative document referred to applies.

EN 1990 Eurocode: Basis of structural design

EN 1991-1-3 Eurocode 1: Actions on structures: Part 1-3: Snow loads

EN 1991-1-6 Eurocode 1: Actions on structures: Part 1-6: Actions during execution

EN 1991-2 Eurocode 1: Actions on structures: Part 2: Traffic loads on bridges

EN 1993-3-1 Eurocode 3: Design of steel structures: Part 3-1: Masts and towers

1.3 Assumptions

(1) The general assumptions given in EN 1990, 1.3 apply.

1.4 Distinction between Principles and Application Rules

(1) The rules in EN 1990, 1.4 apply.

1.5 Design assisted by testing and measurements

(1) In supplement to calculations wind tunnel tests and proven and/or properly validated numerical methods may be used to obtain load and response information, using appropriate models of the structure and of the natural wind.

(2) Load and response information and terrain parameters may be obtained from appropriate full scale data.

NOTE: The National Annex may give guidance on design assisted by testing and measurements.

1.6 Definitions

For the purposes of this European Standard, the definitions given in ISO 2394, ISO 3898 and ISO 8930 and the following apply. Additionally for the purposes of this Standard a basic list of definitions is provided in EN 1990, 1.5.

1.6.1

fundamental basic wind velocity

the 10 minute mean wind velocity with an annual risk of being exceeded of 0,02, irrespective of wind direction, at a height of 10 m above flat open country terrain and accounting for altitude effects (if required)

1.6.2

basic wind velocity

the fundamental basic wind velocity modified to account for the direction of the wind being considered and the season (if required)