BRITISH STANDARD

BS EN
1991-1-4:2005
+A1:2010
Incorporating corrigenda July 2009 and January 2010

Eurocode 1: Actions on structures —

Part 1-4: General actions — Wind actions

ICS 91.010.30

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BSI Documents Document Sharing Hub British Standards

Full document details: BS EN 1991-1-4:2005+A1:2010

National foreword

This British Standard is the UK implementation of EN 1991-1-4:2005+A1:2010, incorporating corrigendum January 2010. It supersedes BS EN 1991-1-4:2005 which is withdrawn. Details of superseded British Standards are given in the table below.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to CEN text carry the number of the CEN amendment. For example, text altered by CEN amendment A1 is indicated by ⟦A1⟩ ⟨A1⟧.

The start and finish of text introduced or altered by corrigendum is indicated in the text by ⟦AC2⟩ ⟨AC2⟧.

NOTE The content of CEN corrigendum January 2010 replaced the content of CEN corrigendum July 2009.

The structural Eurocodes are divided into packages by grouping Eurocodes for each of the main materials: concrete, steel, composite concrete and steel, timber, masonry and aluminium; this is to enable a common date of withdrawal (DOW) for all the relevant parts that are needed for a particular design. The conflicting national standards will be withdrawn at the end of the coexistence period, after all the EN Eurocodes of a package are available.

Following publication of the EN, there is a period allowed for national calibration during which the National Annex is issued, followed by a co-existence period of a maximum three years. During the co-existence period Member States are encouraged to adapt their national provisions. At the end of this co-existence period, the conflicting parts of national standard(s) will be withdrawn.

In the UK, the following national standards are superseded by the Eurocode 1 series and, based on this transition period, these standards have now been withdrawn.

Eurocode	**Superseded British Standards**
EN 1991-1-1	BS 6399-1:1996
EN 1991-1-2	none
EN 1991-1-3	BS 6399-3:1988
EN 1991-1-4	BS 6399-2:1997, BS 5400-2:1978*
EN 1991-1-5	BS 5400-2:1978*
EN 1991-1-6	none
EN 1991-1-7	none
EN 1991-2	BS 5400-1:1988, BS 5400-2:1978*
EN 1991-3	none
EN 1991-4	none

* BS 5400-2:1978 will not be fully superseded until publication of Annex **A.2** to BS EN 1990:2002.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 25 April 2005

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Amendments/corrigenda issued since publication

Date	Comments
31 December 2009	Implementation of CEN corrigendum July 2009
31 August 2010	Implementation of CEN corrigendum January 2010
31 January 2011	Implementation of CEN amendment A1:2010

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The UK participation in its preparation was entrusted by Technical Committee B/525, Building and civil engineering structures, to Subcommittee B/525/1, Actions (loadings) and basis of design.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Where a normative part of this EN allows for a choice to be made at the national level, the range and possible choice will be given in the normative text, and a note will qualify it as a Nationally Determined Parameter (NDP). NDPs can be a specific value for a factor, a specific level or class, a particular method or a particular application rule if several are proposed in the EN.

To enable EN 1991-1-4 to be used in the UK, the NDPs have now been published in a National Annex.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 1991-1-4:2005+A1

April 2010

ICS 91.010.30

Supersedes ENV 1991-2-4:1995
Incorporating corrigendum January 2010

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.

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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 agreement[1] 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).

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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 Documents[2] referred to in Article 12 of the CPD, although they are of a different nature from harmonised product standards[3]. 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.

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[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.

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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 works[4]. 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:

1.5 (2)

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

[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.

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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
7.2.3 (2)
7.2.3 (4)
7.2.4 (1)
7.2.4 (3)
7.2.5 (1)
7.2.5 (3)
7.2.6 (1)
7.2.6 (3)
7.2.7
7.2.8 (1)
7.2.9 (2)
7.2.10 (3) Notes 1 and 2
7.3 (6)
7.4.1 (1)
7.4.3 (2)
7.6 (1) Note 1
7.7 (1) Note 1
7.8 (1)
7.9.2 (2)
7.10 (1) Note 1
7.11 (1) Note 2
7.13 (1)
7.13 (2)
Table 7.14

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)

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)

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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.

〈AC2〉 (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 (12) and 8.2. 〈AC2〉

(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.

〈AC2〉 (11) Guyed masts and lattice towers are treated in EN 1993-3-1 and lighting columns in EN 40.

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

- torsional vibrations, e.g. tall buildings with a central core
- bridge deck vibrations from transverse wind turbulence
- wind actions on cable supported bridges
- vibrations where more than the fundamental mode needs to be considered. 〈AC2〉

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

1.4 Distinction between Principles and Application Rules

(1)P 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)

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1.6.3
mean wind velocity
the basic wind velocity modified to account for the effect of terrain roughness and orography

1.6.4
pressure coefficient
external pressure coefficients give the effect of the wind on the external surfaces of buildings; internal pressure coefficients give the effect of the wind on the internal surfaces of buildings.

The external pressure coefficients are divided into overall coefficients and local coefficients. Local coefficients give the pressure coefficients for loaded areas of 1 m^2 or less e.g. for the design of small elements and fixings; overall coefficients give the pressure coefficients for loaded areas larger than 10 m^2.

Net pressure coefficients give the resulting effect of the wind on a structure, structural element or component per unit area.

1.6.5
force coefficient
force coefficients give the overall effect of the wind on a structure, structural element or component as a whole, including friction, if not specifically excluded

1.6.6
background response factor
the background factor allowing for the lack of full correlation of the pressure on the structure surface

1.6.7
resonance response factor
the resonance response factor allowing for turbulence in resonance with the vibration mode

1.7 Symbols

(1) For the purposes of this European standard, the following symbols apply

NOTE The notation used is based on ISO 3898:1999. In this Part the symbol dot in expressions indicates the multiplication sign. This notation has been employed to avoid confusion with functional expressions.

(2) A basic list of notations is provided in EN 1990, 1.6 and the additional notations below are specific to EN 1991-1-4.

Latin upper case letters

A	area
A_{fr}	area swept by the wind
A_{ref}	reference area
B^2	background response part
C	wind load factor for bridges
E	Young's modulus
F_{fr}	resultant friction force
F_j	vortex exciting force at point j of the structure
F_w	resultant wind force
H	height of a topographic feature
I_v	turbulence intensity
K	mode shape factor; shape parameter
AC2 K_a	aerodynamic damping parameter AC2

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K_{iv}	interference factor for vortex shedding
K_{rd}	reduction factor for parapets
K_w	correlation length factor
K_x	non dimensional coefficient
L	length of the span of a bridge deck; turbulent length scale
L_d	actual length of a downwind slope
L_e	effective length of an upwind slope
L_j	correlation length
L_u	actual length of an upwind slope
N	number of cycles caused by vortex shedding
N_g	number of loads for gust response
R^2	resonant response part
Re	Reynolds number
R_h, R_b	aerodynamic admittance
S	wind action
Sc	Scruton number
S_L	non dimensional power spectral density function
St	Strouhal number
W_s	weight of the structural parts contributing to the stiffness of a chimney
W_t	total weight of a chimney

Latin lower case letters

a_G	factor of galloping instability
a_{IG}	combined stability parameter for interference galloping
b	width of the structure (the length of the surface perpendicular to the wind direction if not otherwise specified)
c_{alt}	altitude factor
c_d	dynamic factor
c_{dir}	directional factor
$c_e(z)$	exposure factor
c_f	force coefficient
$c_{f,o}$	force coefficient of structures or structural elements without free-end flow
$c_{f,l}$	lift force coefficient
c_{fr}	friction coefficient
c_{lat}	aerodynamic exciting coefficient
c_M	moment coefficient
c_p	pressure coefficient
[AC2] c_{pe}	external pressure coefficient
c_{pi}	internal pressure coefficient
$c_{p,net}$	net pressure coefficient [AC2]
c_{prob}	probability factor
c_r	roughness factor
c_o	orography factor

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c_s	size factor
c_{season}	seasonal factor
d	depth of the structure (the length of the surface parallel to the wind direction if not otherwise specified)
e	eccentricity of a force or edge distance
f_L	non dimensional frequency
h	height of the structure
h_{ave}	obstruction height
h_{dis}	displacement height
k	equivalent roughness
[AC2⟩ k_I	turbulence factor ⟨AC2]
k_p	peak factor
k_r	terrain factor
k_Θ	torsional stiffness
l	length of a horizontal structure
m	mass per unit length
m_1	equivalent mass per unit length
n_i	natural frequency of the structure of the mode i
$n_{1,x}$	fundamental frequency of along wind vibration
$n_{1,y}$	fundamental frequency of cross-wind vibration
n_0	ovalling frequency
p	annual probability of exceedence
q_b	reference mean (basic) velocity pressure
q_p	peak velocity pressure
r	radius
s	factor; coordinate
t	averaging time of the reference wind speed, plate thickness
v_{CG}	onset wind velocity for galloping
v_{CIG}	critical wind velocity for interference galloping
v_{crit}	critical wind velocity of vortex shedding
v_{div}	divergence wind velocity
v_m	mean wind velocity
$v_{b,0}$	fundamental value of the basic wind velocity
v_b	basic wind velocity
w	wind pressure
x	horizontal distance of the site from the top of a crest
x-direction	horizontal direction, perpendicular to the span
y-direction	horizontal direction along the span
y_{max}	maximum cross-wind amplitude at critical wind speed
z	height above ground
z_{ave}	average height
z-direction	vertical direction

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z_0	roughness length
z_e, z_i	reference height for external wind action, internal pressure
z_g	distance from the ground to the considered component
z_{max}	maximum height
z_{min}	minimum height
z_s	reference height for determining the structural factor

Greek upper case letters

Φ	upwind slope
$\Phi_{1,x}$	fundamental alongwind modal shape

Greek lower case letters

α_G	galloping instability parameter
α_{IG}	combined stability parameter of interference galloping
δ	logarithmic decrement of damping
δ_a	[AC2] logarithmic decrement of aerodynamic damping 〈AC2〉
δ_d	logarithmic decrement of damping due to special devices
δ_s	[AC2] logarithmic decrement of structural damping 〈AC2〉
ε	coefficient
ε_0	bandwidth factor
ε_1	frequency factor
η	variable
φ	solidity ratio, blockage of canopy
λ	slenderness ratio
μ	opening ratio, permeability of a skin
ν	up-crossing frequency; Poisson ratio; kinematic viscosity
θ	torsional angle; wind direction
ρ	air density
σ_v	standard deviation of the turbulence
$\sigma_{a,x}$	standard deviation of alongwind acceleration
ψ_{mc}	reduction factor for multibay canopies
ψ_r	reduction factor of force coefficient for square sections with rounded corners
ψ_λ	reduction factor of force coefficient for structural elements with end-effects
$\psi_{\lambda\alpha}$	end-effect factor for circular cylinders
ψ_s	shelter factor for walls and fences
ζ	exponent of mode shape

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Indices

crit	critical
e	external ; exposure
fr	friction
i	internal ; mode number
j	current number of incremental area or point of a structure
m	mean
p	peak; parapet
ref	reference
v	wind velocity
x	alongwind direction
y	cross-wind direction
z	vertical direction

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Section 2 Design situations

(1)P The relevant wind actions shall be determined for each design situation identified in accordance with EN 1990, 3.2.

(2) In accordance with EN 1990, 3.2 (3)P other actions (such as snow, traffic or ice) which will modify the effects due to wind should be taken into account.

〚AC2〛 NOTE See also EN 1991-1-3, EN 1991-2 and ISO 12494 〚AC2〛

(3) In accordance with EN 1990, 3.2 (3)P, the changes to the structure during stages of execution (such as different stages of the form of the structure, dynamic characteristics, etc.), which may modify the effects due to wind, should be taken into account.

NOTE See also EN 1991-1-6

(4) Where in design windows and doors are assumed to be shut under storm conditions, the effect of these being open should be treated as an accidental design situation.

NOTE See also EN 1990, 3.2 (2) (P)

(5) Fatigue due to the effects of wind actions should be considered for susceptible structures.

NOTE The number of load cycles may be obtained from Annex B, C and E.

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Section 3 Modelling of wind actions

3.1 Nature

(1) Wind actions fluctuate with time and act directly as pressures on the external surfaces of enclosed structures and, because of porosity of the external surface, also act indirectly on the internal surfaces. They may also act directly on the internal surface of open structures. Pressures act on areas of the surface resulting in forces normal to the surface of the structure or of individual cladding components. Additionally, when large areas of structures are swept by the wind, friction forces acting tangentially to the surface may be significant.

3.2 Representations of wind actions

(1) The wind action is represented by a simplified set of pressures or forces whose effects are equivalent to the extreme effects of the turbulent wind.

3.3 Classification of wind actions

(1) Unless otherwise specified, wind actions should be classified as variable fixed actions, see EN 1990, 4.1.1.

3.4 Characteristic values

(1) The wind actions calculated using EN 1991-1-4 are characteristic values (See EN 1990, 4.1.2). They are determined from the basic values of wind velocity or the velocity pressure. In accordance with EN 1990 4.1.2 (7)P the basic values are characteristic values having annual probabilities of exceedence of 0,02, which is equivalent to a mean return period of 50 years.

NOTE All coefficients or models, to derive wind actions from basic values, are chosen so that the probability of the calculated wind actions does not exceed the probability of these basic values.

3.5 Models

(1) The effect of the wind on the structure (i.e. the response of the structure), depends on the size, shape and dynamic properties of the structure. This Part covers dynamic response due to along-wind turbulence in resonance with the along-wind vibrations of a fundamental flexural mode shape with constant sign.

The response of structures should be calculated according to Section 5 from the peak velocity pressure, q_p, at the reference height in the undisturbed wind field, the force and pressure coefficients and the structural factor $c_s c_d$ (see Section 6). q_p depends on the wind climate, the terrain roughness and orography, and the reference height. q_p is equal to the mean velocity pressure plus a contribution from short-term pressure fluctuations.

(2) Aeroelastic response should be considered for flexible structures such as cables, masts, chimneys and bridges.

NOTE Simplified guidance on aeroelastic response is given in Annex E.

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Section 4 Wind velocity and velocity pressure

4.1 Basis for calculation

(1) The wind velocity and the velocity pressure are composed of a mean and a fluctuating component.

The mean wind velocity v_m should be determined from the basic wind velocity v_b which depends on the wind climate as described in 4.2, and the height variation of the wind determined from the terrain roughness and orography as described in 4.3. The peak velocity pressure is determined in 4.5.

The fluctuating component of the wind is represented by the turbulence intensity defined in 4.4.

NOTE The National Annex may provide National climatic information from which the mean wind velocity v_m, the peak velocity pressure q_p and additional values may be directly obtained for the terrain categories considered.

4.2 Basic values

(1)P The fundamental value of the basic wind velocity, $v_{b,0}$, is the characteristic 10 minutes mean wind velocity, irrespective of wind direction and time of year, at 10 m above ground level in open country terrain with low vegetation such as grass and isolated obstacles with separations of at least 20 obstacle heights.

NOTE 1 This terrain corresponds to terrain category II in Table 4.1.

NOTE 2 The fundamental value of the basic wind velocity, $v_{b,0}$, may be given in the National Annex.

(2)P The basic wind velocity shall be calculated from Expression (4.1).

$$v_b = c_{dir} \cdot c_{season} \cdot v_{b,0} \tag{4.1}$$

where:

v_b is the basic wind velocity, defined as a function of wind direction and time of year at 10 m above ground of terrain category II

$v_{b,0}$ is the fundamental value of the basic wind velocity, see (1)P

c_{dir} is the directional factor, see Note 2.

c_{season} is the season factor, see Note 3.

NOTE 1 Where the influence of altitude on the basic wind velocity v_b is not included in the specified fundamental value $v_{b,0}$ the National Annex may give a procedure to take it into account.

NOTE 2 The value of the directional factor, c_{dir}, for various wind directions may be found in the National Annex. The recommended value is 1,0.

NOTE 3 The value of the season factor, c_{season}, may be given in the National Annex. The recommended value is 1,0.

NOTE 4 The 10 minutes mean wind velocity having the probability p for an annual exceedence is determined by multiplying the basic wind velocity v_b in 4.2 (2)P by the probability factor, c_{prob} given by Expression (4.2). See also EN 1991-1-6.

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$$c_{prob} = \left(\frac{1 - K \cdot \ln(-\ln(1-p))}{1 - K \cdot \ln(-\ln(0{,}98))} \right)^n \quad (4.2)$$

where:

K is the shape parameter depending on the coefficient of variation of the extreme-value distribution.

n is the exponent.

NOTE 5 The values for K and n may be given in the National Annex. The recommended values are 0,2 for K and 0,5 for n.

(3) For temporary structures and for all structures in the execution phase, the seasonal factor c_{season} may be used. For transportable structures, which may be used at any time in the year, c_{season} should be taken equal to 1,0.

NOTE See also EN 1991-1-6.

4.3 Mean wind

4.3.1 Variation with height

(1) The mean wind velocity $v_m(z)$ at a height z above the terrain depends on the terrain roughness and orography and on the basic wind velocity, v_b, and should be determined using Expression (4.3)

$$v_m(z) = c_r(z) \cdot c_o(z) \cdot v_b \quad (4.3)$$

where:

$c_r(z)$ is the roughness factor, given in 4.3.2

$c_o(z)$ is the orography factor, taken as 1,0 unless otherwise specified in 4.3.3

NOTE 1 Information on c_O may be given in the National Annex. If the orography is accounted for in the basic wind velocity, the recommended value is 1,0.

NOTE 2 Design charts or tables for $v_m(z)$ may be given in the National Annex.

The influence of neighbouring structures on the wind velocity should be considered (see 4.3.4).

4.3.2 Terrain roughness

(1) The roughness factor, $c_r(z)$, accounts for the variability of the mean wind velocity at the site of the structure due to:

the height above ground level

the ground roughness of the terrain upwind of the structure in the wind direction considered

NOTE The procedure for determining $c_r(z)$ may be given in the National Annex. The recommended procedure for the determination of the roughness factor at height z is given by Expression (4.4) and is based on a logarithmic velocity profile.

$$c_r(z) = k_r \cdot \ln\left(\frac{z}{z_0}\right) \quad \text{for} \quad z_{min} \le z \le z_{max} \quad (4.4)$$

$$c_r(z) = c_r(z_{min}) \quad \text{for} \quad z \le z_{min}$$

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where:

z_0 is the roughness length

k_r terrain factor depending on the roughness length z_0 calculated using

$$k_r = 0{,}19 \cdot \left(\frac{z_0}{z_{0,II}} \right)^{0{,}07} \tag{4.5}$$

where:

$z_{0,II}$ = 0,05 m (terrain category II, Table 4.1)

z_{min} is the minimum height defined in Table 4.1

z_{max} is to be taken as 200 m

z_0, z_{min} depend on the terrain category. Recommended values are given in Table 4.1 depending on five representative terrain categories.

Expression (4.4) is valid when the upstream distance with uniform terrain roughness is long enough to stabilise the profile sufficiently, see (2).

Table 4.1 — Terrain categories and terrain parameters

Terrain category		z_0 m	z_{min} m
0	Sea or coastal area exposed to the open sea	0,003	1
I	Lakes or flat and horizontal area with negligible vegetation and without obstacles	0,01	1
II	Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights	0,05	2
III	Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)	0,3	5
IV	Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m	1,0	10
NOTE: The terrain categories are illustrated in A.1.			

(2) The terrain roughness to be used for a given wind direction depends on the ground roughness and the distance with uniform terrain roughness in an angular sector around the wind direction. Small areas (less than 10% of the area under consideration) with deviating roughness may be ignored. See Figure 4.1.

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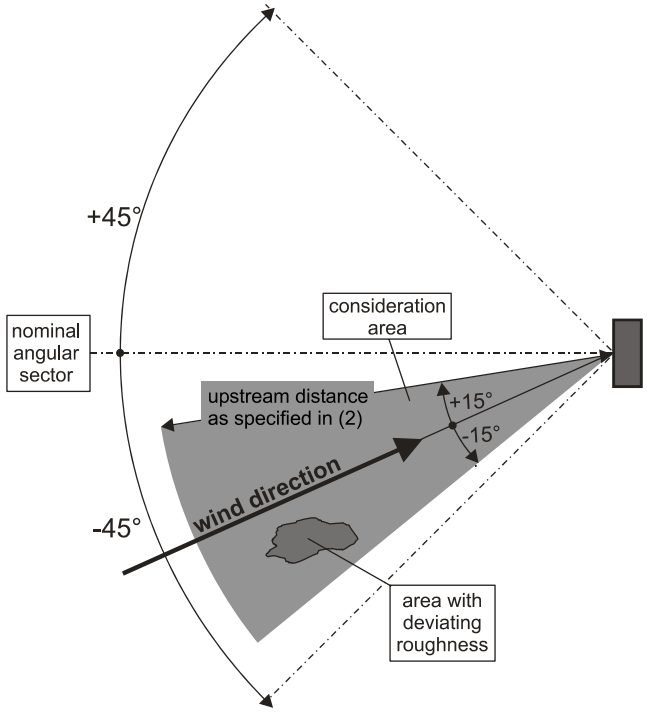

Figure 4.1 — Assessment of terrain roughness

NOTE The National Annex may give definitions of the angular sector and of the upstream distance. The recommended value of the angular sector may be taken as the 30º angular sector within ±15° from the wind direction. The recommended value for the upstream distance may be obtained from A.2.

(3) When a pressure or force coefficient is defined for a nominal angular sector, the lowest roughness length within any 30° angular wind sector should be used.

(4) When there is choice between two or more terrain categories in the definition of a given area, then the area with the lowest roughness length should be used.

4.3.3 Terrain orography

(1) Where orography (e.g. hills, cliffs etc.) increases wind velocities by more than 5% the effects should be taken into account using the orography factor c_O.

NOTE The procedure to be used for determining c_O may be given in the National Annex. The recommended procedure is given in A.3.

(2) The effects of orography may be neglected when the average slope of the upwind terrain is less than 3°. The upwind terrain may be considered up to a distance of 10 times the height of the isolated orographic feature.

4.3.4 Large and considerably higher neighbouring structures

(1) If the structure is to be located close to another structure, that is at least twice as high as the average height of its neighbouring structures, then it could be exposed (dependent on the properties of the structure) to increased wind velocities for certain wind directions. Such cases should be taken into account.

NOTE The National Annex may give a procedure to take account of this effect. A recommended conservative first approximation is given in A.4.

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4.3.5 Closely spaced buildings and obstacles

(1) The effect of closely spaced buildings and other obstacles may be taken into account.

NOTE The National Annex may give a procedure. A recommended first approximation is given in A.5. In rough terrain closely spaced buildings modify the mean wind flow near the ground, as if the ground level was raised to a height called displacement height h_{dis}.

4.4 Wind turbulence

(1) The turbulence intensity $I_v(z)$ at height z is defined as the standard deviation of the turbulence divided by the mean wind velocity.

NOTE 1 The turbulent component of wind velocity has a mean value of 0 and a standard deviation σ_v. The standard deviation of the turbulence σ_v may be determined using Expression (4.6).

$$\sigma_v = k_r \cdot v_b \cdot k_I \tag{4.6}$$

For the terrain factor k_r see Expression (4.5), for the basic wind velocity v_b see Expression (4.1) and for turbulence factor k_I see Note 2.

NOTE 2 The recommended rules for the determination of $I_v(z)$ are given in Expression (4.7)

$$\begin{aligned} I_v(z) &= \frac{\sigma_v}{v_m(z)} = \frac{k_I}{c_o(z)\cdot \ln(z/z_0)} \quad \text{for} \quad z_{min} \le z \le z_{max} \\ I_v(z) &= I_v(z_{min}) \quad \text{for} \quad z < z_{min} \end{aligned} \tag{4.7}$$

where:

k_I is the turbulence factor. The value of k_I may be given in the National Annex. The recommended value for k_I is 1,0.

c_o is the orography factor as described in 4.3.3

z_0 is the roughness length, given in Table 4.1

4.5 Peak velocity pressure

(1) The peak velocity pressure $q_p(z)$ at height z, which includes mean and short-term velocity fluctuations, should be determined.

NOTE 1 The National Annex may give rules for the determination of $q_p(z)$. The recommended rule is given in Expression (4.8).

$$q_p(z) = \left[1 + 7 \cdot I_v(z)\right] \cdot \tfrac{1}{2} \cdot \rho \cdot v_m^2(z) = c_e(z) \cdot q_b \tag{4.8}$$

where:

ρ is the air density, which depends on the altitude, temperature and barometric pressure to be expected in the region during wind storms

$c_e(z)$ is the exposure factor given in Expression (4.9)

$$c_e(z) = \frac{q_p(z)}{q_b} \tag{4.9}$$

q_b is the basic velocity pressure given in Expression (4.10)

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$$q_b = \frac{1}{2} \cdot \rho \cdot v_b^2 \qquad (4.10)$$

NOTE 2 The values for ρ may be given in the National Annex. The recommended value is 1,25 kg/m^3.

NOTE 3 The value 7 in Expression (4.8) is based on a peak factor equal to 3,5 and is consistent with the values of the pressure and force coefficients in Section 7.

For flat terrain where $c_O(z)$ = 1,0 (see 4.3.3), the exposure factor $c_e(z)$ is illustrated in Figure 4.2 as a function of height above terrain and a function of terrain category as defined in Table 4.1.

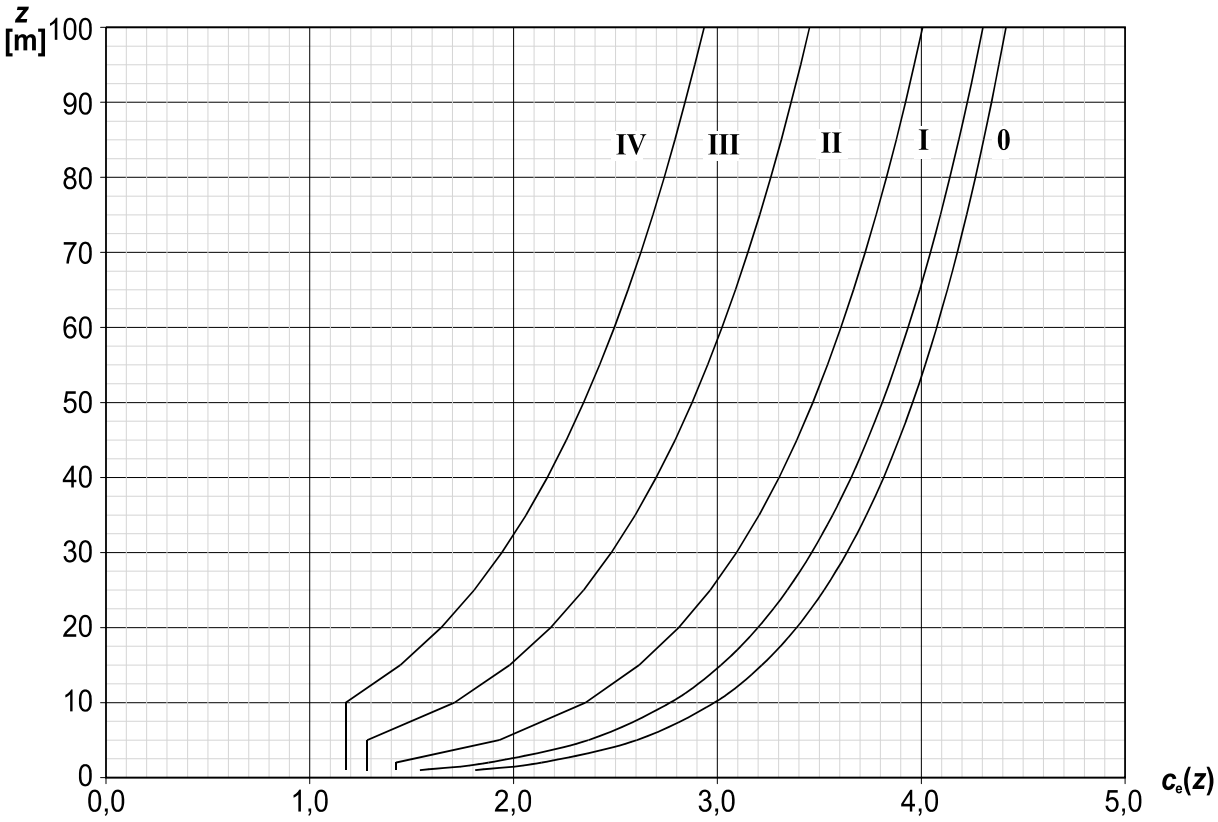

Figure 4.2 — Illustrations of the exposure factor $c_e(z)$ for c_O=1,0, k_I=1,0

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Section 5 Wind actions

5.1 General

(1)P Wind actions on structures and structural elements shall be determined taking account of both external and internal wind pressures.

NOTE A summary of calculation procedures for the determination of wind actions is given in Table 5.1.

Table 5.1 —Calculation procedures for the determination of wind actions

Parameter	Subject Reference
peak velocity pressure q_p	
basic wind velocity v_b	4.2 (2)P
reference height z_e	Section 7
terrain category	Table 4.1
characteristic peak velocity pressure q_p	4.5 (1)
turbulence intensity I_v	4.4
mean wind velocity v_m	4.3.1
orography coefficient $c_o(z)$	4.3.3
roughness coefficient $c_r(z)$	4.3.2
Wind pressures, e.g. for cladding, fixings and structural parts	
external pressure coefficient c_{pe}	Section 7
internal pressure coefficient c_{pi}	Section 7
net pressure coefficient $c_{p,net}$	Section 7
external wind pressure: $w_e=q_p\ c_{pe}$	5.2 (1)
internal wind pressure: $w_i=q_p\ c_{pi}$	5.2 (2)
Wind forces on structures, e.g. for overall wind effects	
structural factor: $c_s c_d$	6
wind force F_w calculated from force coefficients	5.3 (2)
wind force F_w calculated from pressure coefficients	5.3 (3)

5.2 Wind pressure on surfaces

(1) The wind pressure acting on the external surfaces, w_e, should be obtained from Expression (5.1).

$$w_e = q_p(z_e) \cdot c_{pe} \tag{5.1}$$

where:

$q_p(z_e)$ is the peak velocity pressure

z_e is the reference height for the external pressure given in Section 7

c_{pe} is the pressure coefficient for the external pressure, see Section 7.

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NOTE $q_p(z)$ is defined in 4.5

(2) The wind pressure acting on the internal surfaces of a structure, w_i , should be obtained from Expression (5.2)

$$w_i = q_p(z_i) \cdot c_{pi} \tag{5.2}$$

where:

$q_p(z_i)$ is the peak velocity pressure

z_i is the reference height for the internal pressure given in Section 7

c_{pi} is the pressure coefficient for the internal pressure given in Section 7

NOTE $q_p(z)$ is defined in 4.5

(3) The net pressure on a wall, roof or element is the difference between the pressures on the opposite surfaces taking due account of their signs. Pressure, directed towards the surface is taken as positive, and suction, directed away from the surface as negative. Examples are given in Figure 5.1.

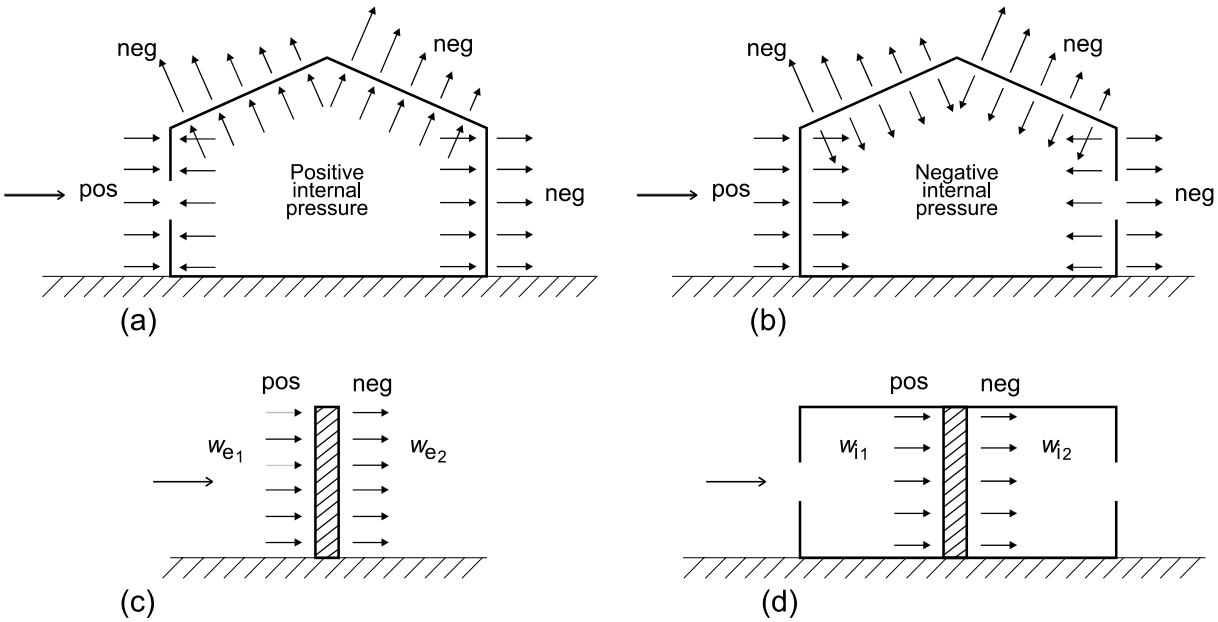

Figure 5.1 — Pressure on surfaces

5.3 Wind forces

(1) The wind forces for the whole structure or a structural component should be determined:

by calculating forces using force coefficients (see (2)) or

by calculating forces from surface pressures (see (3))

(2) The wind force F_w acting on a structure or a structural component may be determined directly by using Expression (5.3)

$$F_w = c_s c_d \cdot c_f \cdot q_p(z_e) \cdot A_{ref} \tag{5.3}$$

or by vectorial summation over the individual structural elements (as shown in 7.2.2) by using Expression (5.4)

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$$F_w = c_s c_d \cdot \sum_{\text{elements}} c_f \cdot q_p(z_e) \cdot A_{ref} \quad (5.4)$$

where:

$c_s c_d$ is the structural factor as defined in Section 6

c_f is the force coefficient for the structure or structural element, given in Section 7 or Section 8

$q_p(z_e)$ is the peak velocity pressure (defined in 4.5) at reference height z_e (defined in Section 7 or Section 8)

A_{ref} is the reference area of the structure or structural element, given in Section 7 or Section 8

NOTE Section 7 gives c_f values for structures or structural elements such as prisms, cylinders, roofs, signboards, plates and lattice structures etc. These values include friction effects. Section 8 gives c_f values for bridges.

(3) The wind force, F_w acting on a structure or a structural element may be determined by vectorial summation of the forces $F_{w,e}$, $F_{w,i}$ and F_{fr} calculated from the external and internal pressures using Expressions (5.5) and (5.6) and the frictional forces resulting from the friction of the wind parallel to the external surfaces, calculated using Expression (5.7).

external forces:

$$F_{w,e} = c_s c_d \cdot \sum_{\text{surfaces}} w_e \cdot A_{ref} \quad (5.5)$$

internal forces:

$$F_{w,i} = \sum_{\text{surfaces}} w_i \cdot A_{ref} \quad (5.6)$$

friction forces:

$$F_{fr} = c_{fr} \cdot q_p(z_e) \cdot A_{fr} \quad (5.7)$$

where:

$c_s c_d$ is the structural factor as defined in Section 6

w_e is the external pressure on the individual surface at height z_e, given in Expression (5.1)

w_i is the internal pressure on the individual surface at height z_i, given in Expression (5.2)

A_{ref} is the reference area of the individual surface

c_{fr} is the friction coefficient derived from 7.5

A_{fr} is the area of external surface parallel to the wind, given in 7.5.

NOTE 1 For elements (e.g. walls, roofs), the wind force becomes equal to the difference between the external and internal resulting forces.

NOTE 2 Friction forces F_{fr} act in the direction of the wind components parallel to external surfaces.

(4) The effects of wind friction on the surface can be disregarded when the total area of all surfaces parallel with (or at a small angle to) the wind is equal to or less than 4 times the total area of all external surfaces perpendicular to the wind (windward and leeward).

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(5) In the summation of the wind forces acting on building structures, the lack of correlation of wind pressures between the windward and leeward sides may be taken into account.

NOTE The National Annex may determine whether this lack of correlation may be applied generally or be restricted to walls as applied in 7.2.2 (3). It is recommended to consider the lack of correlation only for walls (see 7.2.2 (3)).

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Section 6 Structural factor $c_s c_d$

6.1 General

(1) The structural factor $c_s c_d$ should take into account the effect on wind actions from the non-simultaneous occurrence of peak wind pressures on the surface (c_s) together with the effect of the vibrations of the structure due to turbulence (c_d).

NOTE The structural factor $c_s c_d$ may be separated into a size factor c_S and a dynamic factor c_d, based on 6.3. Information on whether the structural factor $c_s c_d$ should be separated or not may be given in the National Annex.

6.2 Determination of $c_s c_d$

(1) $c_s c_d$ may be determined as follows:

a) For buildings with a height less than 15 m the value of $c_s c_d$ may be taken as 1.

b) For facade and roof elements having a natural frequency greater than 5 Hz, the value of $c_s c_d$ may be taken as 1.

c) For framed buildings which have structural walls and which are less than 100 m high and whose height is less than 4 times the in-wind depth, the value of $c_s c_d$ may be taken as 1.

d) For chimneys with circular cross-sections whose height is less than 60 m and 6,5 times the diameter, the value of $c_s c_d$ may be taken as 1.

e) Alternatively, for cases a), b), c) and d) above, values of $c_s c_d$ may be derived from 6.3.1.

f) For civil engineering works (other than bridges, which are considered in Section 8), and chimneys and buildings outside the limitations given in c) and d) above, $c_s c_d$ should be derived either from 6.3 or taken from Annex D.

NOTE 1 Natural frequencies of facade and roof elements may be calculated using Annex F (glazing spans smaller than 3 m usually lead to natural frequencies greater than 5 Hz)

NOTE 2 The figures in Annex D give values of $c_s c_d$ for various types of structures. The figures give envelopes of safe values calculated from models complying with the requirements in 6.3.1.

6.3 Detailed procedure

6.3.1 Structural factor $c_s c_d$

(1) The detailed procedure for calculating the structural factor $c_s c_d$ is given in Expression (6.1). This procedure can only be used if the conditions given in 6.3.1 (2) apply.

$$c_s c_d = \frac{1 + 2 \cdot k_p \cdot I_v(z_s) \cdot \sqrt{B^2 + R^2}}{1 + 7 \cdot I_v(z_s)} \tag{6.1}$$

where:

z_s is the reference height for determining the structural factor, see Figure 6.1. For structures where Figure 6.1 does not apply z_s may be set equal to h, the height of the structure.

k_p is the peak factor defined as the ratio of the maximum value of the fluctuating part of the response to its standard deviation

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I_v is the turbulence intensity defined in 4.4

B^2 is the background factor, allowing for the lack of full correlation of the pressure on the structure surface

R^2 is the resonance response factor, allowing for turbulence in resonance with the vibration mode

NOTE 1 The size factor c_s takes into account the reduction effect on the wind action due to the non-simultaneity of occurrence of the peak wind pressures on the surface and may be obtained from Expression (6.2):

$$c_s = \frac{1+7\cdot I_v(z_s)\cdot\sqrt{B^2}}{1+7\cdot I_v(z_s)} \tag{6.2}$$

NOTE 2 The dynamic factor c_d takes into account the increasing effect from vibrations due to turbulence in resonance with the structure and may be obtained from Expression (6.3):

$$c_d = \frac{1+2\cdot k_p\cdot I_v(z_s)\cdot\sqrt{B^2+R^2}}{1+7\cdot I_v(z_s)\cdot\sqrt{B^2}} \tag{6.3}$$

NOTE 3 The procedure to be used to determine k_p, B and R may be given in the National Annex. A recommended procedure is given in Annex B. An alternative procedure is given in Annex C. As an indication to the users the differences in $c_s c_d$ using Annex C compared to Annex B does not exceed approximately 5%.

(2)P Expression (6.1) shall only be used if all of the following requirements are met:

– the structure corresponds to one of the general shapes shown in Figure 6.1,

– only the along-wind vibration in the fundamental mode is significant, and this mode shape has a constant sign.

NOTE The contribution to the response from the second or higher alongwind vibration modes is negligible.

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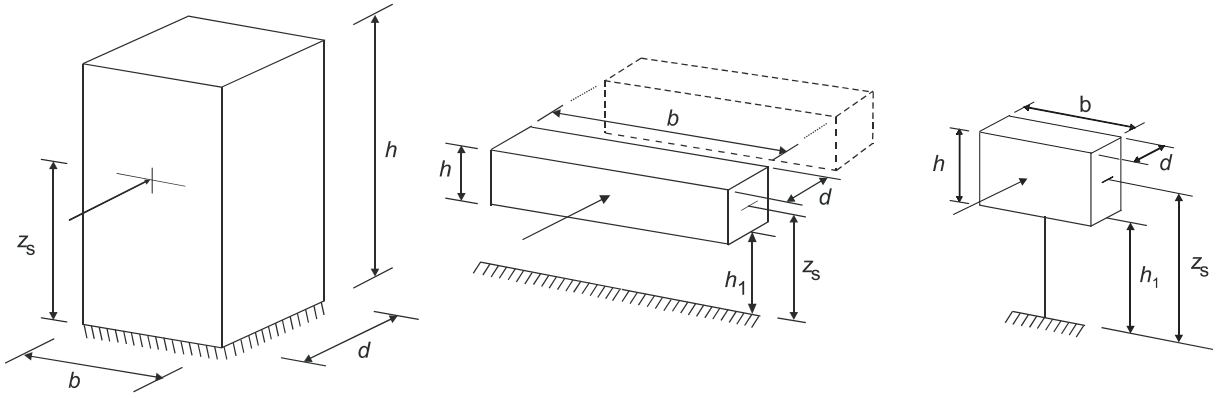
a) vertical structures such as buildings etc.

b) parallel oscillator, i.e. horizontal structures such as beams etc.

c) pointlike structures such as signboards etc.



NOTE Limitations are also given in 1.1 (2)

$$z_s = 0{,}6 \cdot h \geq z_{min} \qquad z_s = h_1 + \frac{h}{2} \geq z_{min} \qquad z_s = h_1 + \frac{h}{2} \geq z_{min}$$

Figure 6.1 — General shapes of structures covered by the design procedure. The structural dimensions and the reference height used are also shown.

6.3.2 Serviceability assessments

(1) For serviceability assessments, the maximum along-wind displacement and the standard deviation of the characteristic along-wind acceleration of the structure at height z should be used. For the maximum along-wind displacement the equivalent static wind force defined in ⟩AC2⟨ 5.3 ⟩AC2⟨ should be used.

NOTE The National Annex may give a method for determining the along-wind displacement and the standard deviation of the along-wind acceleration. The recommended method is given in Annex B. An alternative method is given in Annex C.

6.3.3 Wake buffeting

(1) For slender buildings (h/d > 4) and chimneys (h/d > 6,5) in tandem or grouped arrangement, the effect of increased turbulence in the wake of nearby structures (wake buffeting) should be taken into account.

(2) Wake buffeting effects may be assumed to be negligible if at least one of the following conditions applies:

– The distance between two buildings or chimneys is larger than 25 times the cross wind dimension of the upstream building or chimney.

– The natural frequency of the downstream building or chimney is higher than 1 Hz.

NOTE If none of the conditions in 6.3.3 (2) is fulfilled wind tunnel tests or specialist advice is recommended.

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Section 7 Pressure and force coefficients

7.1 General

(1) This section should be used to determine the appropriate aerodynamic coefficients for structures. Depending on the structure the appropriate aerodynamic coefficient will be:

– Internal and external pressure coefficients, see 7.1.1 (1),

– Net pressure coefficients, see 7.1.1 (2),

– Friction coefficients, see 7.1.1 (3),

– Force coefficients, see 7.1.1 (4).

7.1.1 Choice of aerodynamic coefficient

(1) Pressure coefficients should be determined for:

– Buildings, using 7.2 for both internal and external pressures, and for

– Circular cylinders, using 7.2.9 for the internal pressures and 7.9.1 for the external pressures

NOTE 1 External pressure coefficients give the effect of the wind on the external surfaces of buildings; internal pressure coefficients give the effect of the wind on the internal surfaces of buildings.

NOTE 2 The external pressure coefficients are divided into overall coefficients and local coefficients. Local coefficients give the pressure coefficients for loaded areas of 1 m^2 . They may be used for the design of small elements and fixings. Overall coefficients give the pressure coefficients for loaded areas of 10 m^2. They may be used for loaded areas larger than 10 m^2.

(2) Net pressure coefficients should be determined for:

– Canopy roofs, using 7.3

– Free-standing walls, parapets and fences using 7.4

NOTE Net pressure coefficients give the resulting effect of the wind on a structure, structural element or component per unit area.

(3) Friction coefficients should be determined for walls and surfaces defined in 5.3 (3) and (4), using 7.5.

(4) Force coefficients should be determined for:

– Signboards, using 7.4.3,

– Structural elements with rectangular cross section, using 7.6,

– Structural elements with sharp edged section, using 7.7,

– Structural elements with regular polygonal section, using 7.8,

– Circular cylinders, using 7.9.2 and 7.9.3,

– Spheres, using 7.10,

– Lattice structures and scaffoldings, using 7.11,

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– Flags, using 7.12.

A reduction factor depending on the effective slenderness of the structure may be applied, using 7.13.

NOTE Force coefficients give the overall effect of the wind on a structure, structural element or component as a whole, including friction, if not specifically excluded.

7.1.2 Asymmetric and counteracting pressures and forces

(1) If instantaneous fluctuations of wind over surfaces can give rise to significant asymmetry of loading and the structural form is likely to be sensitive to such loading (e.g. torsion in nominally symmetric single core buildings) then their effect should be taken into account.

(2) For free-standing canopies and signboards, 7.3 and 7.4 should be applied.

NOTE The National Annex may give procedures for other structures. The recommended procedures are:

a) For rectangular structures that are susceptible to torsional effects the pressure distribution given in Figure 7.1 should be applied for the representation of the torsional effects due to an inclined wind or due to lack of correlation between wind forces acting at different places on the structure.

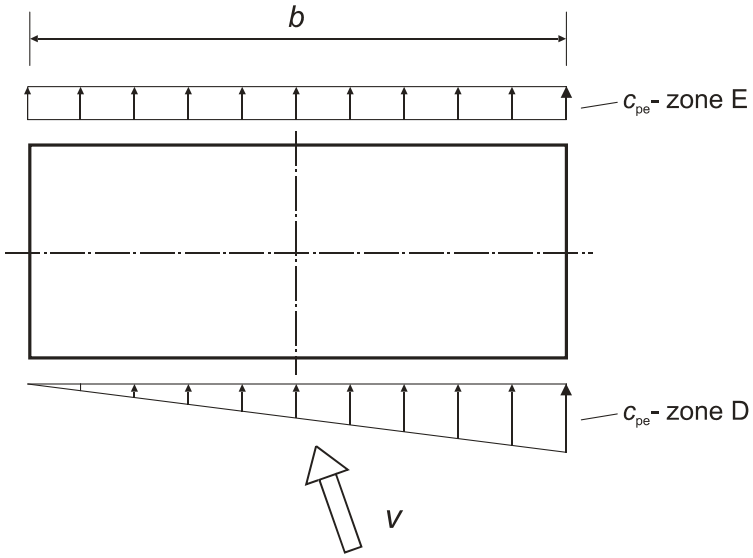

Figure 7.1 — Pressure distribution used to take torsional effects into account. The zones and values for c_{pe} are given in Table 7.1 and Figure 7.5.

b) For other cases an allowance for asymmetry of loading should be made by completely removing the design wind action from those parts of the structure where its action will produce a beneficial effect.

7.1.3 Effects of ice and snow

(1) If ice or snow alters the geometry of a structure so that it changes the reference area or shape, this should be taken into account.

NOTE Further information may be given in the National Annex.

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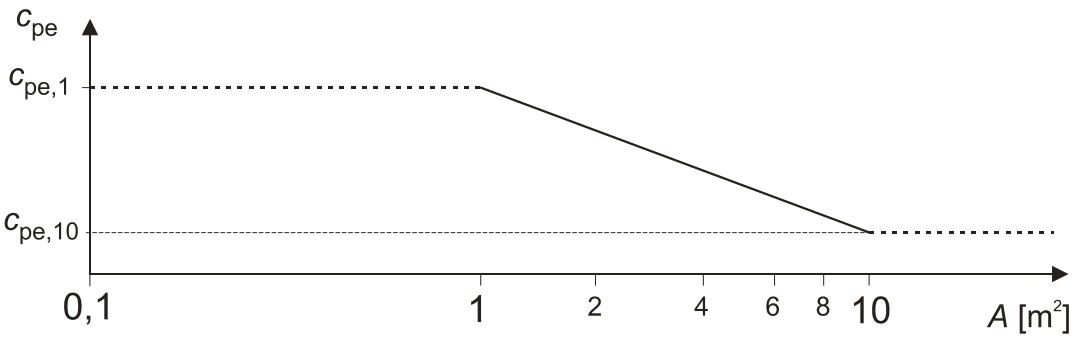
7.2 Pressure coefficients for buildings

7.2.1 General

(1) The external pressure coefficients c_{pe} for buildings and parts of buildings depend on the size of the loaded area A, which is the area of the structure, that produces the wind action in the section to be calculated. The external pressure coefficients are given for loaded areas A of 1 m^2 and 10 m^2 in the tables for the appropriate building configurations as $c_{pe,1}$, for local coefficients, and $c_{pe,10}$, for overall coefficients, respectively.

NOTE 1 Values for $c_{pe,1}$ are intended for the design of small elements and fixings with an area per element of 1 m^2 or less such as cladding elements and roofing elements. Values for $c_{pe,10}$ may be used for the design of the overall load bearing structure of buildings.

NOTE 2 The National Annex may give a procedure for calculating external pressure coefficients for loaded areas above 1 m^2 based on external pressure coefficients $c_{pe,1}$ and $c_{pe,10}$. The recommended procedure for loaded areas up to 10 m^2 is given in Figure 7.2.



The figure is based on the following:
for 1 $m^2 < A < 10$ m^2 $\quad c_{pe} = c_{pe,1} - (c_{pe,1} - c_{pe,10}) \log_{10} A$

Figure 7.2 — Recommended procedure for determining the external pressure coefficient c_{pe} for buildings with a loaded area A between 1 m^2 and 10 m^2

(2) The values $c_{pe,10}$ and $c_{pe,1}$ in Tables 7.1 to 7.5 should be used for the orthogonal wind directions 0°, 90°, 180°. These values represent the most unfavourable values obtained in a range of wind direction $\theta = \pm 45°$ either side of the relevant orthogonal direction.

(2) For protruding roof corners the pressure on the underside of the roof overhang is equal to the pressure for the zone of the vertical wall directly connected to the protruding roof; the pressure at the top side of the roof overhang is equal to the pressure of the zone, defined for the roof.

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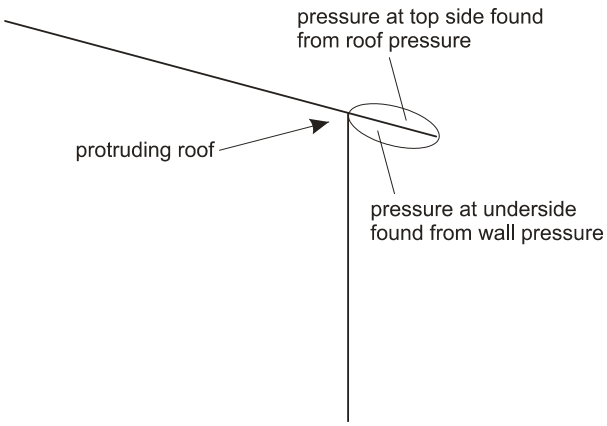

Figure 7.3 — Illustration of relevant pressures for protruding roofs

7.2.2 Vertical walls of rectangular plan buildings

(1) The reference heights, z_e, for windward walls of rectangular plan buildings (zone D, see Figure 7.5) depend on the aspect ratio h/b and are always the upper heights of the different parts of the walls. They are given in Figure 7.4 for the following three cases:

– A building, whose height h is less than b should be considered to be one part.

– A building, whose height h is greater than b, but less than $2b$, may be considered to be two parts, comprising: a lower part extending upwards from the ground by a height equal to b and an upper part consisting of the remainder.

– A building, whose height h is greater than $2b$ may be considered to be in multiple parts, comprising: a lower part extending upwards from the ground by a height equal to b; an upper part extending downwards from the top by a height equal to b and a middle region, between the upper and lower parts, which may be divided into horizontal strips with a height h_{strip} as shown in Figure 7.4.

NOTE The rules for the velocity pressure distribution for leeward wall and sidewalls (zones A, B, C and E, see Figure 7.5) may be given in the National Annex or be defined for the individual project. The recommended procedure is to take the reference height as the height of the building.

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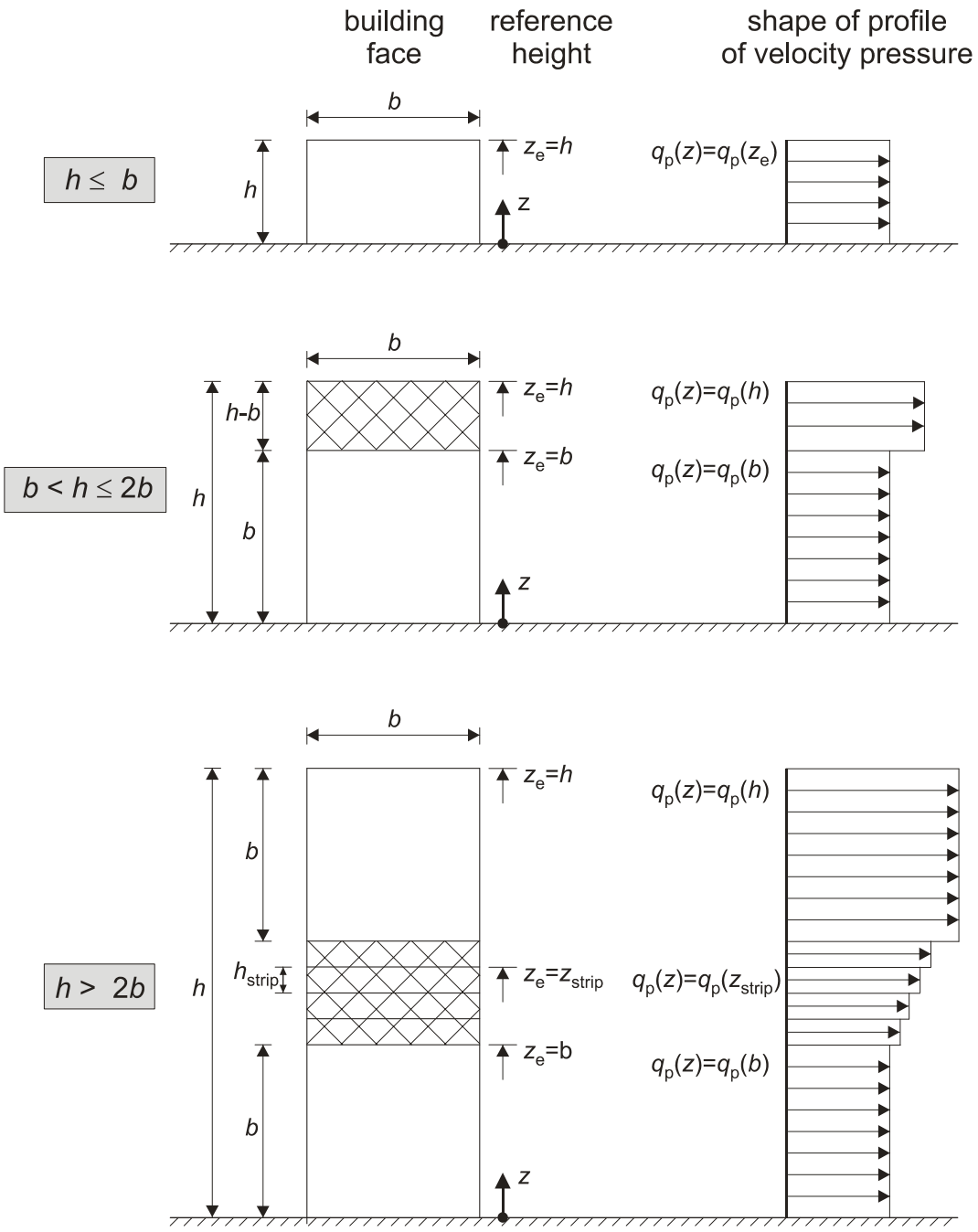

NOTE The velocity pressure should be assumed to be uniform over each horizontal strip considered.

Figure 7.4 — Reference height, z_e, depending on *h* and *b*, and corresponding velocity pressure profile

(2) The external pressure coefficients $c_{pe,10}$ and $c_{pe,1}$ for zone A, B, C, D and E are defined in Figure 7.5.

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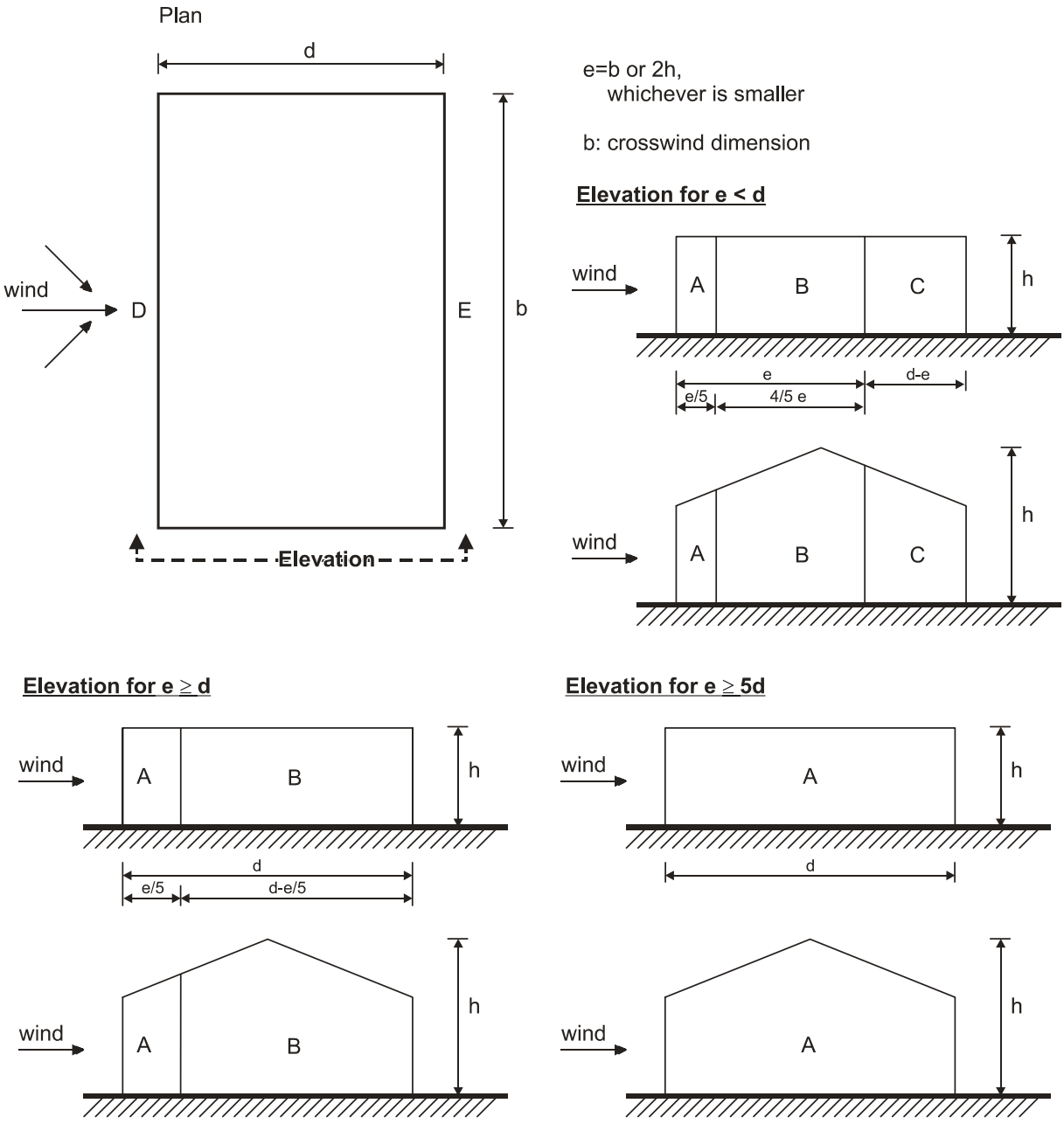

Figure 7.5 — Key for vertical walls

NOTE 1 The values of $c_{pe,10}$ and $c_{pe,1}$ may be given in the National Annex. The recommended values are given in Table 7.1, depending on the ratio h/d. For intermediate values of h/d, linear interpolation may be applied. The values of Table 7.1 also apply to walls of buildings with inclined roofs, such as duopitch and monopitch roofs.

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Table 7.1 — Recommended values of external pressure coefficients for vertical walls of rectangular plan buildings

Zone	A		B		C		D		E	
h/*d*	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,7	
1	-1,2	-1,4	-0,8	-1,1	-0,5		+0,8	+1,0	-0,5	
≤ 0,25	-1,2	-1,4	-0,8	-1,1	-0,5		+0,7	+1,0	-0,3	

NOTE 2 For buildings with $h/d > 5$, the total wind loading may be based on the provisions given in 7.6 to 7.8 and 7.9.2.

(3) In cases where the wind force on building structures is determined by application of the pressure coefficients c_{pe} on windward and leeward side (zones D and E) of the building simultaneously, the lack of correlation of wind pressures between the windward and leeward side may have to be taken into account.

NOTE The lack of correlation of wind pressures between the windward and leeward side may be considered as follows. For buildings with $h/d \geq 5$ the resulting force is multiplied by 1. For buildings with $h/d \leq 1$, the resulting force is multiplied by 0,85. For intermediate values of *h*/*d*, linear interpolation may be applied.

7.2.3 Flat roofs

(1) Flat roofs are defined as having a slope (α) of $-5° < \alpha < 5°$

〈A1〉 (2) The roof should be divided in zones.

NOTE The zones may be defined by the National Annex.
The recommended zones are given in Figure 7.6. 〈A1〉

(3) The reference height for flat roof and roofs with curved or mansard eaves should be taken as h. The reference height for flat roofs with parapets should be taken as $h + h_p$, see Figure 7.6.

〈A1〉 (4) Pressure coefficients should be defined for each zone.

NOTE 1 The pressure coefficients may be set by the National Annex.
The recommended values are given in Table 7.2

NOTE 2 The resulting pressure coefficient on the parapet should be determined using 7.4. 〈A1〉

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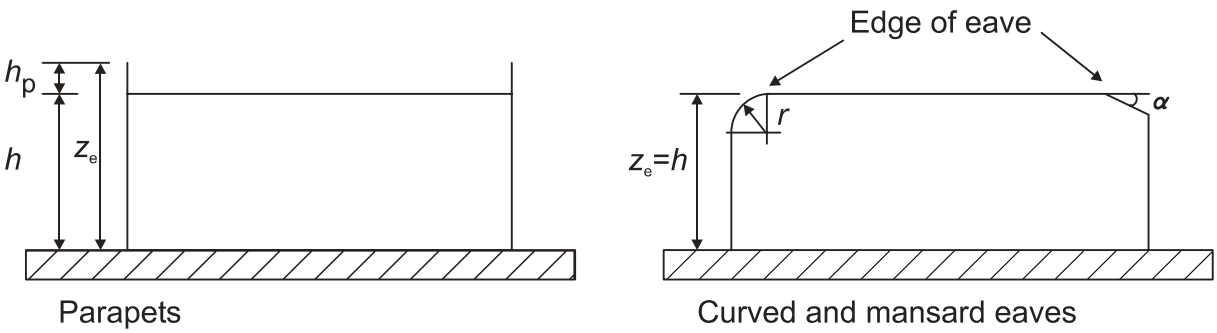

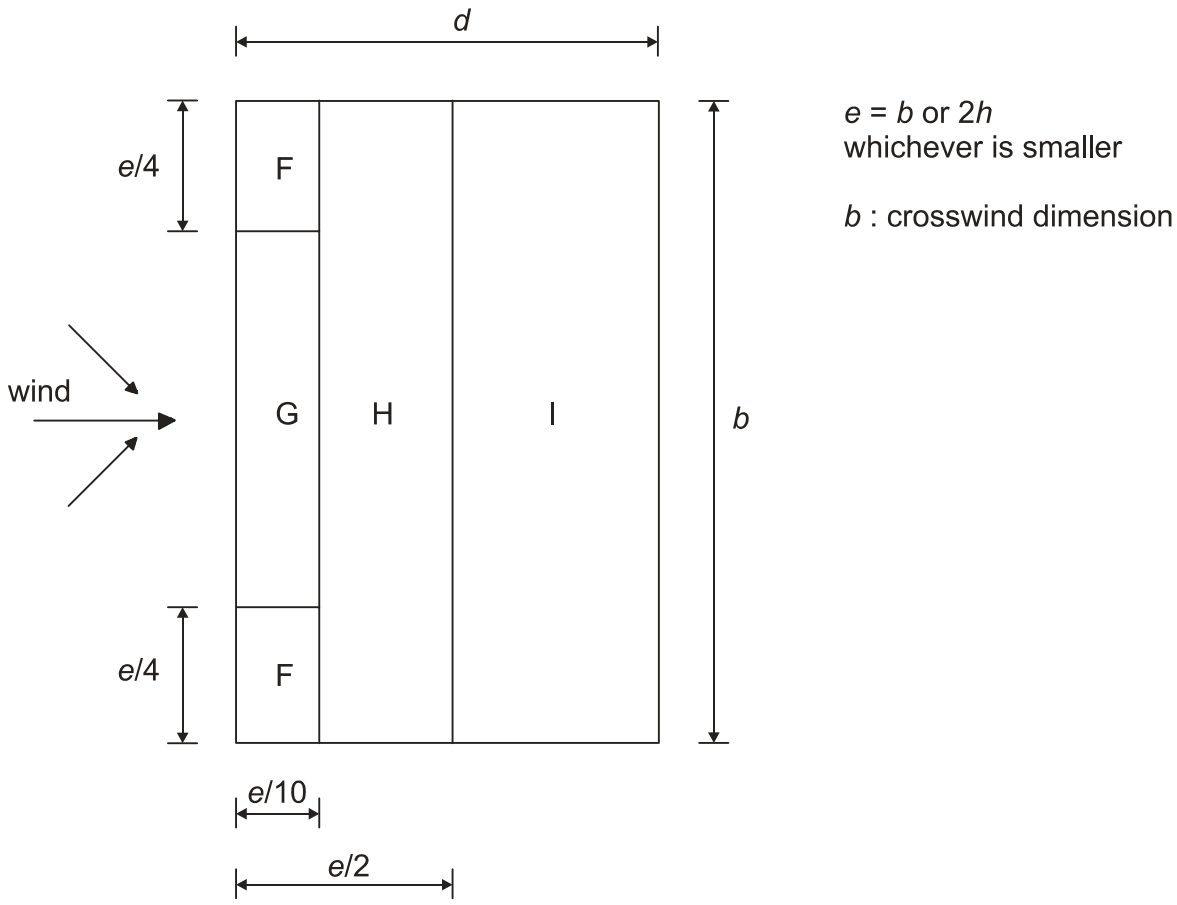

Figure 7.6 — Key for flat roofs

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Table 7.2 — Recommended values of external pressure coefficients for flat roofs

Roof type		Zone							
		F		G		H		I	
		$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
Sharp eaves		-1,8	-2,5	-1,2	-2,0	-0,7	-1,2	+0,2	
								-0,2	
With Parapets	h_p/h=0,025	-1,6	-2,2	-1,1	-1,8	-0,7	-1,2	+0,2	
								-0,2	
	h_p/h=0,05	-1,4	-2,0	-0,9	-1,6	-0,7	-1,2	+0,2	
								-0,2	
	h_p/h=0,10	-1,2	-1,8	-0,8	-1,4	-0,7	-1,2	+0,2	
								-0,2	
Curved Eaves	r/h = 0,05	-1,0	-1,5	-1,2	-1,8	-0,4		+0,2	
								-0,2	
	r/h = 0,10	-0,7	-1,2	-0,8	-1,4	-0,3		+0,2	
								-0,2	
	r/h = 0,20	-0,5	-0,8	-0,5	-0,8	-0,3		+0,2	
								-0,2	
Mansard Eaves	α = 30°	-1,0	-1,5	-1,0	-1,5	-0,3		+0,2	
								-0,2	
	α = 45°	-1,2	-1,8	-1,3	-1,9	-0,4		+0,2	
								-0,2	
	α = 60°	-1,3	-1,9	-1,3	-1,9	-0,5		+0,2	
								-0,2	

NOTE 1 For roofs with parapets or curved eaves, linear interpolation may be used for intermediate values of h_p/h and r/h.

NOTE 2 For roofs with mansard eaves, linear interpolation between α = 30°, 45° and α = 60° may be used. For α > 60° linear interpolation between the values for α = 60° and the values for flat roofs with sharp eaves may be used.

NOTE 3 In Zone I, where positive and negative values are given, both values should be considered.

NOTE 4 For the mansard eave itself, the external pressure coefficients are given in Table 7.4a "External pressure coefficients for duopitch roofs: wind direction 0° ", Zone F and G, depending on the pitch angle of the mansard eave.

NOTE 5 For the curved eave itself, the external pressure coefficients are given by linear interpolation along the curve, between values on the wall and on the roof.

NOTE 6 For mansard eaves with horizontal dimension less than $e/10$,the values for sharp eaves should be used. For the definition of e see Figure 7.6.

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7.2.4 Monopitch roofs

(1) The roof, including its protruding parts, should be divided in zones.

NOTE The zones may be defined by the National Annex. The recommended zones are given in Figure 7.7.

(2) The reference height z_e should be taken equal to h.

(3) Pressure coefficients should be defined for each zone.

NOTE The pressure coefficients may be set by the National Annex. The recommended values are given in Table 7.3a and Table 7.3b.

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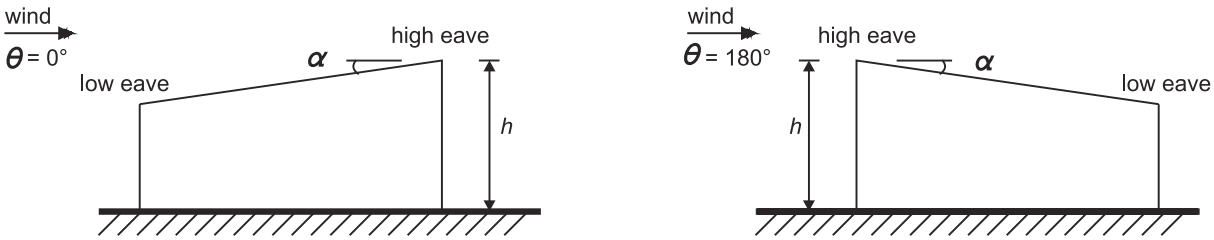
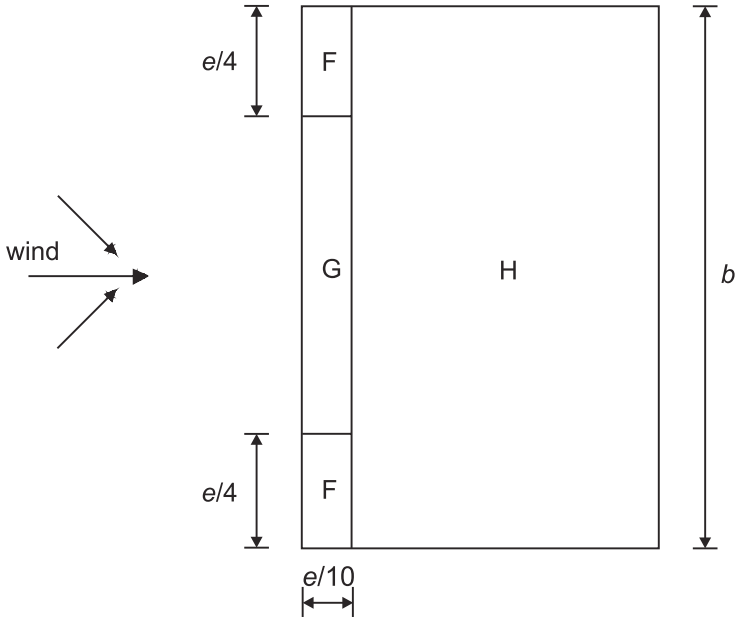


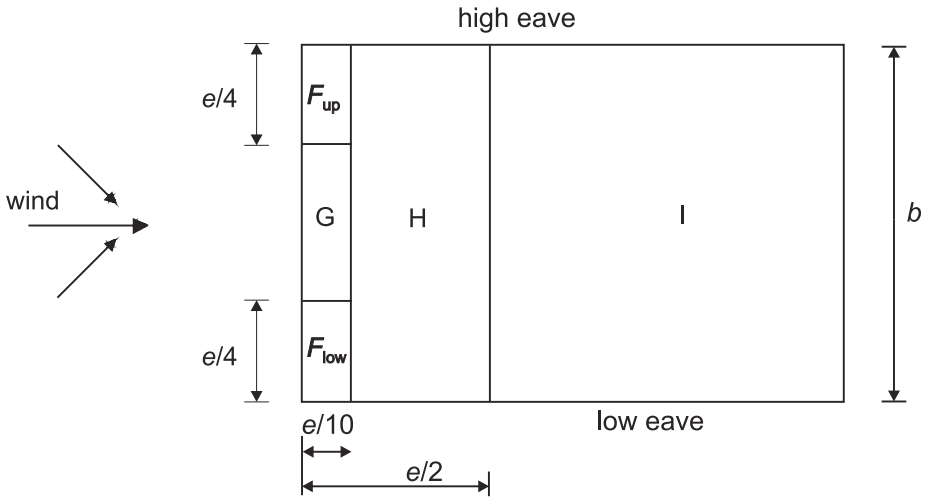
(a) general



(b) wind directions $\theta = 0°$ and $\theta = 180°$

$e = b$ or $2h$
whichever is smaller

b : crosswind dimension



(c) wind direction $\theta = 90°$

Figure 7.7 — Key for monopitch roofs

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Table 7.3a — Recommended values of external pressure coefficients for monopitch roofs

Pitch Angle α	Zone for wind direction θ = 0 °						Zone for wind direction θ = 180 °					
	F		G		H		F		G		H	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5°	-1,7	-2,5	-1,2	-2,0	-0,6	-1,2	-2,3	-2,5	-1,3	-2,0	-0,8	-1,2
	+0,0		+0,0		+0,0							
15°	-0,9	-2,0	-0,8	-1,5	-0,3		-2,5	-2,8	-1,3	-2,0	-0,9	-1,2
	+0,2		+0,2		+ 0,2							
30°	-0,5	-1,5	-0,5	-1,5	-0,2		-1,1	-2,3	-0,8	-1,5	-0,8	
	+0,7		+0,7		+0,4							
45°	-0,0		-0,0		-0,0		-0,6	-1,3	-0,5		-0,7	
	+0,7		+0,7		+0,6							
60°	+0,7		+0,7		+0,7		-0,5	-1,0	-0,5		-0,5	
75°	+0,8		+0,8		+0,8		-0,5	-1,0	-0,5		-0,5	

Table 7.3b — Recommended values of external pressure coefficients for monopitch roofs

Pitch Angle α	Zone for wind direction θ = 90°									
	F_{up}		F_{low}		G		H		I	
	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$	$c_{pe,10}$	$c_{pe,1}$
5°	-2,1	-2,6	-2,1	-2,4	-1,8	-2,0	-0,6	-1,2	-0,5	
15°	-2,4	-2,9	-1,6	-2,4	-1,9	-2,5	-0,8	-1,2	-0,7	-1,2
30°	-2,1	-2,9	-1,3	-2,0	-1,5	-2,0	-1,0	-1,3	-0,8	-1,2
45°	-1,5	-2,4	-1,3	-2,0	-1,4	-2,0	-1,0	-1,3	-0,9	-1,2
60°	-1,2	-2,0	-1,2	-2,0	-1,2	-2,0	-1,0	-1,3	-0,7	-1,2
75°	-1,2	-2,0	-1,2	-2,0	-1,2	-2,0	-1,0	-1,3	-0,5	

NOTE 1 At θ = 0° (see table a)) the pressure changes rapidly between positive and negative values around a pitch angle of α = +5° to +45°, so both positive and negative values are given. For those roofs, two cases should be considered: one with all positive values, and one with all negative values. No mixing of positive and negative values is allowed on the same face.

NOTE 2 Linear interpolation for intermediate pitch angles may be used between values of the same sign. The values equal to 0.0 are given for interpolation purposes

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