BRITISH STANDARD

BS EN 13031-1:2001

Greenhouses — Design and construction —

Part 1: Commercial production greenhouses

The European Standard EN 13031-1:2001 has the status of a British Standard

ICS 65.040.30

National foreword

This British Standard is the official English language version of EN 13031-1:2001. It partially supersedes BS 5502-22:1993 (subclause **15.3.3**).

The UK participation in its preparation was entrusted by Technical Committee B/549, Agricultural buildings and structures, to Subcommittee B/549/1, Structural considerations, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled "International Standards Correspondence Index", or by using the "Find" facility of the BSI Standards Electronic Catalogue.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Contents

Foreword

This European Standard has been prepared by Techical Committee CEN/TC 284 “Greenhouses”, the secretariat of which is held by NEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at te latest by June 2002, and conflicting national standards shall be withdrawn at the latest by June 2002.

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

Introduction

Part 1 of this standard relates specifically to greenhouses used for the professional production of plants and crops where human occupancy is restricted to low levels of authorised personnel. Other parts of this European Standard are to be prepared that relate to greenhouses where general access by the public is permitted (such as those in garden centres or expositions), and to small domestic greenhouses.

This European Standard gives rules for structural design and construction of greenhouse structures for the professional production of plants and crops.

It is based on ENV 1991 "Eurocode 1: Basis of design and actions on structures" as regards the general principles and requirements for actions, mechanical resistance and stability, serviceability and durability considerations. For structural design considerations, it is similarly based on the relevant parts of ENV 1992 to ENV 1999 (Eurocodes 2 to 9).

Complementary information is provided to account for the particular requirements, functions and forms of commercial production greenhouses that distinguish them from ordinary buildings. Amongst the distinguishing functional requirements of greenhouses are the desire to optimise solar radiation transmission to create and maintain an optimal environment for the growth of plants and crops, and commonly, to support the weight of growing plants. These have implications on the form and structural design of commercial greenhouses. Greenhouse designs, based on this European Standard providing specific information about load distributions, deformation criteria and tolerances, adapting rules of Structural Eurocodes, ENV 1991 to ENV 1999, result in adequate structural safety. This is justified because in contrast to normal buildings, greenhouses have specific design working lives and human occupancy is restricted to low levels of authorised personnel.

As rules and requirements of this Standard may become adopted by other European Standards, for example the Structural Eurocodes or codes for Glass in Building - Design of glass panes, these will be replaced by a reference to the adopting European Standard.

Design criteria for the accessibility of the greenhouses, e.g. ascents, workways, walkways, or roof ladders may be part of national legislation.

1 Scope

This European Standard specifies principles and requirements for the mechanical resistance and stability, serviceability and durability for design and construction of commercial production greenhouse structures irrespective of material, including their foundations, for the professional production of plants and crops.

Fire resistance-related aspects are not covered in this standard.

2 Normative references

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

EN 572-1, *Glass in building - Basic soda lime silicate glass products - Part 1: Definitions and general physical and mechanical properties*

EN 572-2, *Glass in building - Basic soda lime silicate glass products - Part 2: Float glass*

EN 572-3, *Glass in building - Basic soda lime silicate glass products - Part 3: Polished wired glass*

EN 572-4, *Glass in building - Basic soda lime silicate glass products - Part 4: Drawn sheet glass*

EN 572-5, *Glass in building - Basic soda lime silicate glass products - Part 5: Patterned glass*

EN 572-6, *Glass in building - Basic soda lime silicate glass products - Part 6: Wired patterned glass*

ENV 1090-1, *Execution of steel structures - Part 1: General rules and rules for buildings*

EN 1096-1, *Glass in building - Coated glass - Part 1: Definitions and classification*

prEN 1279-1:1998, *Glass in building - Insulating glass units - Part 1: Generalities, dimensional tolerances and rules for the system description*

EN 1863-1, *Glass in building - Heat strengthened soda lime silicate glass – Part 1: Definition and description*

ENV 1991-1:1994, *Eurocode 1 - Basis of design and actions on structures - Part 1: Basis of design*

ENV 1991-2-1, *Eurocode 1: Basis of design and actions on structures - Part 2-1: Densities, self-weight and imposed loads*

ENV 1991-2-3, *Eurocode 1: Basis of design and actions on structures - Part 2-3: Actions on structures - Snow loads*

ENV 1991-2-4, *Eurocode 1: Basis of design and actions on structures - Part 2-4: Actions on structures - Wind actions*

ENV 1992-1-1:1991, *Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings*

ENV 1993-1-1:1992, *Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings*

ENV 1993-1-3:1999, *Eurocode 3: Design of steel structures - Part 1-3: General rules – Supplementary rules for cold formed thin gauge members and sheeting*

ENV 1995-1-1:1993, *Eurocode 5: Design of timber structures - Part 1-1: General rules and rules for buildings*

ENV 1997-1:1994, *Eurocode 7: Geotechnical design- Part 1: General rules*

ENV 1998-1-1:1994, *Eurocode 8: Design provisions for earthquake resistance of structures - Part 1-1: General rules - Seismic actions and general requirements for structures*

ENV 1999-1-1:1998, *Eurocode 9: Design of aluminium structures - Part 1-1: General rules - General rules and rules for buildings*

EN 12150-1 – *Glass in building - Thermally toughened soda lime silicate safety glass – Part 1: Definition and description*

EN 12337-1 – *Glass in building - Chemically strengthened soda lime silicate glass – Part 1: Definition and description*

EN ISO 12543-5:1998, *Glass in building - Laminated glass and laminated safety glass - Part 5: Dimensions and edge finishing (ISO 12543-5:1998)*

prEN 13474-1:1999, *Glass in building - Design of glass panes - Part 1: General basis of design*

3 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in ENV 1991-1 and ENV 1090-1 and the following apply

3.1
greenhouse
structure used for cultivation and/or protection of plants and crops, that optimises solar radiation transmission under controlled conditions, to improve the growing environment of a size that enables people to work within it.

3.2
commercial production greenhouse
greenhouse (3.1) for professional production of plants and crops, where human occupancy is restricted to low levels of authorised personnel. Other people shall be accompanied by authorised personnel.

3.3
clearance
difference between the distance between two opposite cladding bars in their nominal position and the relevant nominal dimension enlarged with the tolerance of a cladding panel.

3.4
dominant permanent opening
opening which cannot be closed under extreme wind conditions and which has a significant influence on the internal pressure.

3.5
deflection
the deformation perpendicular to the surface on which the action acts.

3.6
deformation
change of shape from a building structure or part of it.

3.7
displacement
change in the position of a point.

4 Symbols and abbreviations

The following symbols and abbreviations are used in this European Standard.

A_i	accidental action
a	largest span of a glass panel, distance between wires
B	width
b	smallest span of a glass panel, distance in width direction
c	clearance, coefficient
D	cross sectional dimension of the foundation hole
d	distance, diameter
E	modulus of elasticity
F	force
f	strength of a material
G_i	permanent action
H	height of the ridge above ground level
h	length of column (between foundation and gutter)
L	length, span
l	span, distance in length direction
M	moment
N	normal force
n	number
p	permanent action
Q_i	variable action
q	variable action
s	span of a roof
t	thickness
u	displacement or deflection
v_{int}	intended fall of the gutter
w	width
z_{e}, z_{i}	reference height of a greenhouse
α	angle of pitch
α_{cr}	second-order elastic critical load factor
α_{u}	second-order elastic-plastic critical load factor
γ	partial factor (for actions)
Δ	deviation
$\Delta\varphi$	deviation from intended inclination
λ_{cr}	lowest positive eigenvalue from linear buckling analysis (Euler)
μ	shape coefficient
φ	intended inclination
ϕ_{x}	rotation angle of the cladding bar
ψ	combination coefficient (for actions)

SLS	serviceability limit states
ULS	ultimate limit states

indices

a	arch
c	cladding
cb	column base
f	friction
gh	greenhouse
gl	glass
gw	gable wall
h	horizontal
lim	limit
pe	external pressure
pi	internal pressure
r	roof
s	section length, span
sup	support
sw	side wall
v	vertical
wire	wire

5 Design of greenhouse structures

5.1 General

5.1.1 Greenhouses shall be designed by verifying that no relevant limit state is exceeded. The relevant limit states to be considered depend on the class of the greenhouse, which is detailed in 5.2.

5.1.2 Serviceability limit states shall be verified in accordance with clause 6, and ultimate limit states in accordance with clause 7.

5.1.3 Greenhouses shall be designed such that the requirements for tolerances, durability, maintenance and repair given in clause 8 and clause 9 are satisfied.

5.2 Classes of greenhouse structures

5.2.1 General

Greenhouses shall be classified in accordance with a minimum design working life for the structure as given in 5.2.2 and the tolerance to frame displacements of the cladding system as given in 5.2.3. The classification is given in 5.2.4.

5.2.2 Minimum design working life for the structure

Greenhouse structures shall have a minimum design working life of 15 years, 10 years or 5 years.

5.2.3 Tolerance to frame displacements of the cladding system

5.2.3.1 Greenhouses shall be designated as Class A or Class B depending upon the tolerance to frame displacements of the cladding system, as described in 5.2.3.2, 5.2.3.3 and 5.2.3.4.

5.2.3.2 Greenhouses in which the cladding system is not tolerant to frame displacements, resulting from the design actions, shall be designated as Class A. Class A greenhouses shall be designed by considering serviceability limit states (SLS) as well as ultimate limit states (ULS).

5.2.3.3 Greenhouses in which the cladding system is tolerant to frame displacements, resulting from the design actions, may be designated as Class B. Class B greenhouses may be designed by considering ultimate limit states (ULS) only.

5.2.3.4 In cases where only a part of the greenhouse cladding system is not tolerant to frame displacements, the greenhouse structure shall be designated as Class A. The local displacements of structural components directly carrying only parts of the cladding system that are tolerant to frame displacements need not be checked against serviceability limit state (SLS) criteria.

5.2.4 Greenhouse classification

Greenhouses shall be classified as shown in Table 1.

Table 1 - Greenhouse classification

Classification [c]	**Minimum design working life**		
	15 year	10 year	5 year
Class A [a]	A15	A10	-
Class B [b d]	B15	B10	B5

[a] Class A greenhouses shall have a minimum design working life for the structure of either 15 years or 10 years and shall be designated as Class A15 or A10 greenhouse accordingly.
[b] Class B greenhouses shall have a minimum design working life for the structure of 15 years, 10 years or 5 years and shall be designated as Class B15, B10 or B5 greenhouses accordingly.
[c] Greenhouses clad in glass shall have a minimum design working life of not less than 15 years.
[d] Where expensive crops and/or equipment are present in the greenhouse a design working life of at least 10 years is recommended.

6 Serviceability limit states

6.1 Requirements

6.1.1 The serviceability of Class A greenhouses, determined in accordance with 6.2 or 6.3, shall be such that the serviceability limit states with respect to displacements and deflections, presented in clause 11, are not exceeded under the design values of actions determined in accordance with clause 10.

6.2 Design calculations

6.2.1 The design calculation methods for serviceability limit states shall be performed in accordance with:

- 4.4 of ENV 1992-1-1:1991 for concrete structures;
- Clause 4 of ENV 1993-1-1:1992 for steel structures;
- Clause 4 of ENV 1993-1-3:1999 for cold formed steel members;
- Clause 4 of ENV 1995-1-1:1993 for timber structures;
- Clause 2 of ENV 1997-1:1994 for geotechnical design;
- Clause 4 of ENV 1999-1-1:1998 for aluminium structures.

6.2.2 The material properties shall conform to:

- Clause 3 of ENV 1992-1-1:1991 for concrete structures;
- Clause 3 of ENV 1993-1-1:1992 for steel structures;
- Clause 3 of ENV 1993-1-3:1999 for cold formed steel members;
- Clause 3 of ENV 1995-1-1:1993 for timber structures;
- Clause 3 of ENV 1997-1:1994 for geotechnical design;
- Clause 3 of ENV 1999-1-1:1998 for aluminium structures.

6.2.3 The design calculation methods for and properties of other materials may be used provided it can be demonstrated that the resulting design is suitable for the intended purpose and leads to safe results.

6.3 Testing

The serviceability may be determined by testing, provided that the tests are carried out and the test results are evaluated, both in accordance with the procedures described in clause 8 of ENV 1991-1:1994.

7 Ultimate limit states

7.1 Requirements

7.1.1 The structural capacity of Class A and Class B greenhouses, determined in accordance with 7.2 or 7.3, shall be such that the ultimate limit states are not exceeded under the design values of actions determined in accordance with clause 10.

7.1.2 Clamping connections that operate by friction between structural members shall be able to transmit the ultimate limit state design forces without slipping.

7.2 Design calculations

7.2.1 The design calculation methods for ultimate limit states shall be performed in accordance with:

- 4.3 of ENV 1992-1-1:1991 for concrete structures;
- Clause 5 of ENV 1993-1-1:1992 for steel structures;
- Clause 5 of ENV 1993-1-3:1999 for cold formed steel members;
- Clause 5 of ENV 1995-1-1:1993 for timber structures;
- Clause 2 of ENV 1997-1:1997 for geotechnical design;
- Clause 5 of ENV 1999-1-1:1998 for aluminium structures;
- ENV 1991-1 for steel arches;
- Annex A for cladding.

NOTE For steel arches it is referred to ENV 1991-1 because ENV 1993-1-1 does not contain design calculation methods for arches. In Annex D a design calculation method is given based on research results from tests on tubular steel arches for film plastic covered tunnels.

7.2.2 The material properties shall conform to:

- Clause 3 of ENV 1992-1-1:1991 for concrete structures;
- Clause 3 of ENV 1993-1-1:1992 for steel structures;
- Clause 3 of ENV 1993-1-3:1999 for cold formed steel members;
- Clause 3 of ENV 1995-1-1:1993 for timber structures;
- Clause 3 of ENV 1997-1:1997 for geotechnical design;
- Clause 3 of ENV 1999-1-1:1998 for aluminium structures;
- Annex A for cladding.

7.2.3 The design calculation methods for and properties of other materials may be used provided it can be demonstrated that the resulting design is suitable for the intended purpose and leads to safe results.

7.3 Testing

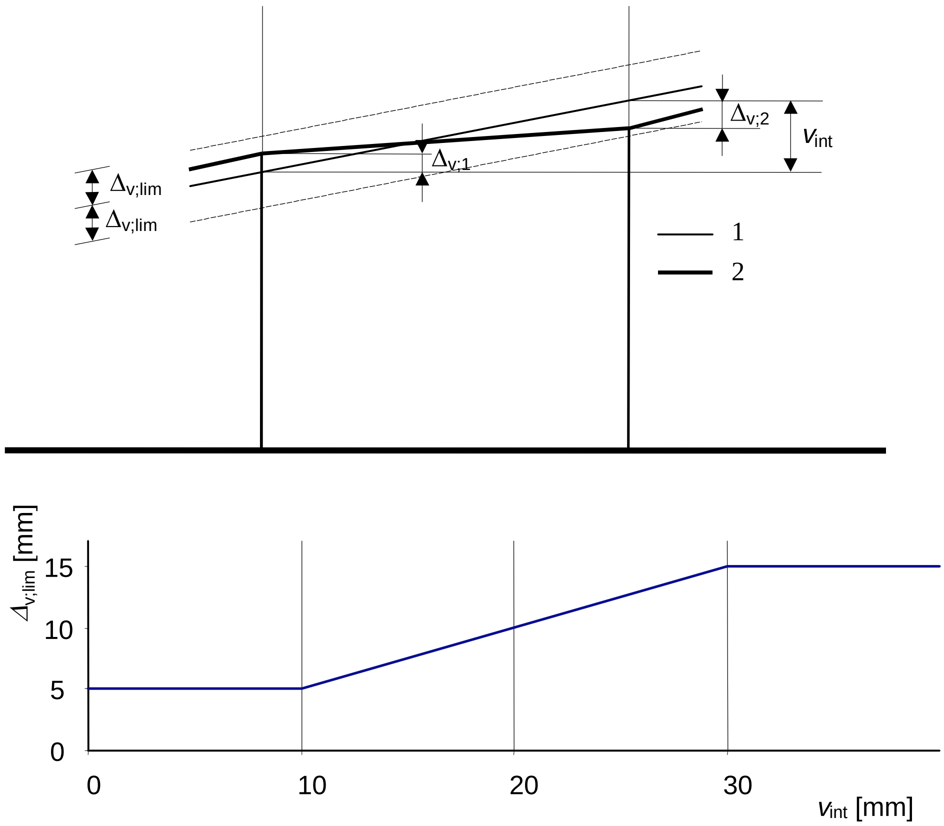
The structural capacity may be determined by testing, provided that the tests are carried out and the test results are evaluated, both in accordance with the procedures described in clause 8 of ENV 1991-1:1994.

8 Tolerances

8.1 General

8.1.1 The design calculation methods for greenhouses are valid only if the greenhouse structure conform to 8.1, 8.2 and 8.3.

8.1.2 The vertical deviation Δ_v from the intended position of the gutter at column ends shall be not more than $\Delta_{v;lim}$, where $\Delta_{v;lim}$ is equal to half the intended fall v_{int} of the gutter per bay, with a minimum upper limit of 5 mm and a maximum upper limit of 15 mm (see Figure 1).



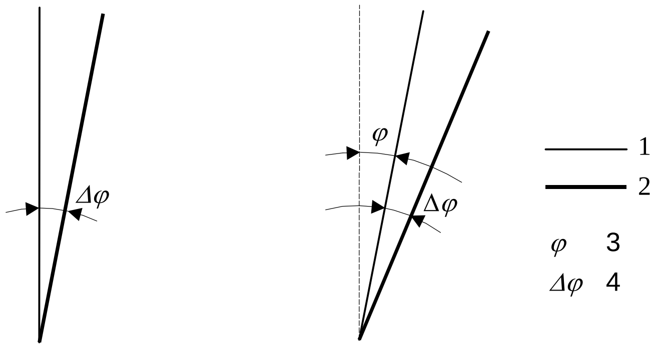
Key

1 Intented position
2 Actual position

Figure 1 - Limit for the vertical deviation from the intended position of the gutter at column ends

8.1.3 The deviation from the intended inclination of columns in any direction shall be not more than 1/200 or 20/*h*, whichever is smaller, where *h* is the column length measured between foundation and gutter in millimetres (see Figure 2).

In case the deviation from the intended inclination shall be measured the influence of thermal actions may be taken into account. Unless specified in annex E, the temperature under which the components are made can be taken as 20 °C.



Key

1 Intended position in design
2 Actual position
3 Intended inclination
4 Deviation from the intended inclination

Figure 2 - Deviation from the intended inclination of a column

8.1.4 The deviation from the intended inclination of a foundation pile shall be not more than 1/50.

8.1.5 The position of the prefabricated foundation pile within the foundation hole shall be such that (see Figure 3):

- its centre lies within a circle with radius equal to *D*/5 or 100 mm, whichever is less, of the centre of the foundation hole;

- the distance between the face of the pile and the face of the foundation hole is at least 50 mm or *D*/8, whichever is larger;

where *D* is the cross sectional dimension of the foundation hole.

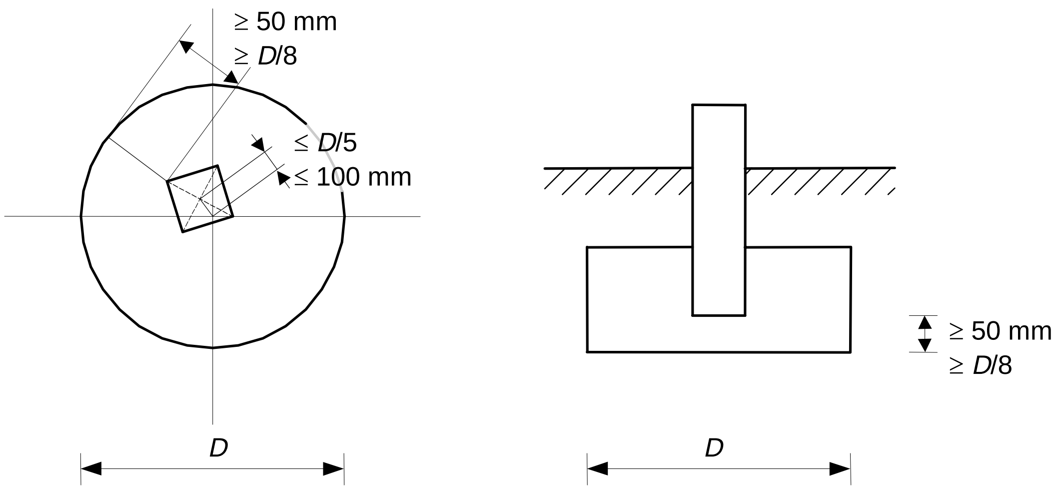


Figure 3 - Position of the prefabricated foundation pile within the foundation hole

8.1.6 The tolerances of glass panels, made of basic soda-lime silicate glass conforming EN 572-1 to EN 572-6, and which are not coated or coated in accordance with EN 1096-1, shall be as follows:

a) Single glass panels

The tolerance on nominal dimensions for thickness, length and width shall conform as follows:

- annealed glass (float glass and drawn sheet glass also known as normal flat glass, patterned glass and wired glass) shall conform to EN 572-1 to EN 572-6;
- heat strengthened glass shall conform to EN 1863-1;
- thermally toughened safety glass shall conform to EN 12150-1
- chemically strengthened glass shall conform to EN 12337-1.

The tolerance on nominal dimensions for length and width of annealed glass may deviate from the values mentioned in EN 572-1 to EN 572-6, but shall be taken not less than:

- ±1 mm for float and drawn sheet glass;
- ±2 mm for patterned glass;
- ±3 mm for wired glass.

b) Laminated glass

The tolerance on nominal dimensions for thickness, length and width shall conform to EN ISO 12543-5.

The tolerance on nominal dimensions for length and width may deviate from the values mentioned in

EN ISO 12543-5, but shall be taken not less than ±3 mm.

c) Insulating glass units

The tolerance on nominal dimensions for thickness, length and width shall conform to prEN 1279-1:1998.

The tolerance on nominal dimensions for length and width may deviate from the values mentioned in prEN 1279-1:1998, but shall be taken not less than ±2 mm.

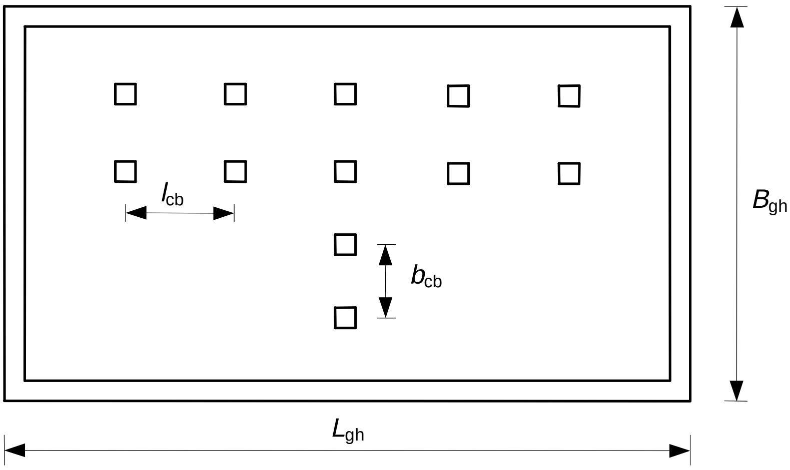
8.1.7 Fabrication tolerances of structural steel components shall be in accordance with ENV 1090-1.

8.2 Tolerances specific to Class A greenhouses

8.2.1 The deviation in horizontal spacing between column bases shall be not more than the values given in Table 2.

Table 2 - Maximum allowable deviation in horizontal measures between column bases

Measure (see Figure 4)	**Maximum deviation**
Distance between column bases in length l_{cb} and width b_{cb} direction	15 mm
Total length of greenhouse L_{gh}	$\frac{1}{3\,000}$ L_{gh} or 30 mm, whichever is greater
Total width of greenhouse B_{gh}	$\frac{1}{3\,000}$ B_{gh} or 30 mm, whichever is greater



Key

B_{gh} width of the greenhouse

b_{cb} distance between column bases in the width direction of the greenhouse

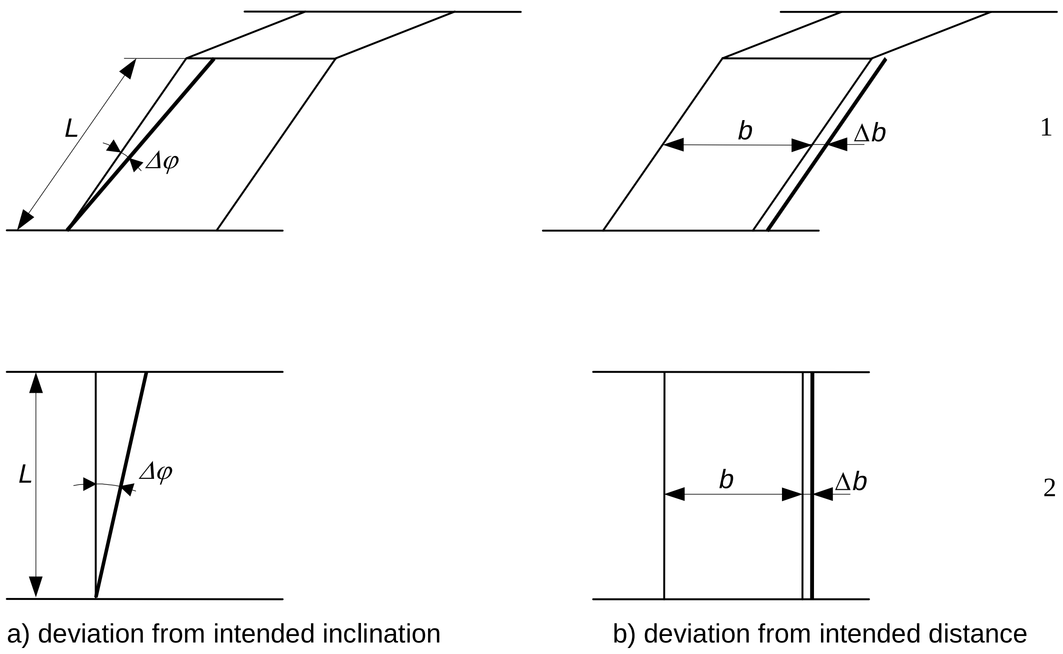
L_{gh} length of the greenhouse

l_{cb} distance between column bases in the length direction of the greenhouse

Figure 4 - Horizontal spacing between column bases

8.2.2 The deviation from the intended inclination of cladding bars in the plane of the cladding $\Delta\varphi$ shall be not more than 1/150 or 12/L, whichever is smaller, where L is the span of the cladding bar in millimetres (see Figure 5a)).

8.2.3 The deviation Δb from the intended centre-to-centre distance b of the cladding bars on average along the bar shall be not more than the value of the tolerance on the nominal dimensions for length and width of the cladding panels (see Figure 5b)).



Key

1 Roof
2 Wall

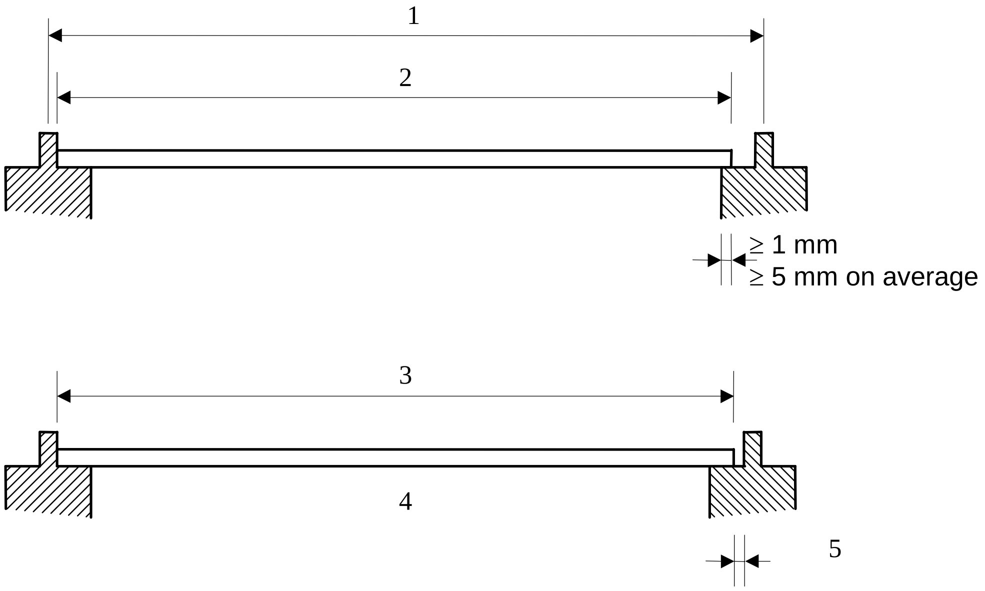
Figure 5 - Deviation from the intended position of cladding bars

8.2.4 During installation of cladding panels, the position of the cladding bars shall be such that the cladding panels can be installed in a way that damage to those panels is avoided. This can be reached by having a clearance of at least 1 mm to pass any relevant part of the cladding bars.

8.2.5 Cladding panels in installed condition shall conform to the following requirements on the support widths and clearances (see Figure 6):

- The distance between the edge of the cladding panel and the further edge of the supporting face of the cladding bar shall be at least 5 mm on average, but nowhere less than 1 mm in any position of the cladding panel.
This condition shall be checked taking account of the position of the panel on the cladding bars, the tolerances on the nominal dimensions for length and width of the cladding panel, the tolerance on the position of the cladding bars and the panel deformations under actions in accordance with clause 10. For glass panels these deformations may be neglected.

- The value of the clearance between the net distance of two opposite cladding bars and the according dimension of the cladding panel shall be taken not less than 2 mm in both directions.
This condition shall be checked taking account of the tolerances on the nominal dimensions for length and width of the cladding panel, the position of the cladding bars and the panel deformations under actions in accordance with clause 10. For glass panels these deformations may be neglected.
For the position of the cladding bars it is allowed to take the nominal position provided that the design of the connections of the cladding bars to the supporting structure makes it possible that the cladding bars can shift to their nominal position after erection.



Key

1 Nominal distance + limit for deviation (see 8.2.5)
2 Nominal dimension cladding panel - tolerance
3 Nominal dimension cladding panel + tolerance
4 Cladding bars on nominal position
5 Clearance

Figure 6 - Requirements on the support widths and clearances of cladding panels

8.3 Tolerances specific to Class B greenhouses

8.3.1 The deviation in horizontal spacing between column bases shall be not more than the values given in Table 3.

Table 3 - Maximum allowable deviation in horizontal measures between column bases

Measure (see Figure 4)	**Maximum deviation**
Distance between column bases in both length and width direction	30 mm
Total length of greenhouse L_{gh}	$\frac{1}{1500} L_{gh}$ or 60 mm, whichever is greater
Total width of greenhouse B_{gh}	$\frac{1}{1500} B_{gh}$ or 60 mm, whichever is greater

8.3.2 For monospan arches of Class B5, the deviation from the intended inclination of the arch-plane shall be not more than 1/50.

NOTE These larger tolerances are allowed based on the fact that larger imperfections are used in the design. See annex D.

9 Durability, maintenance and repair

9.1 General

The design calculation methods for greenhouses are valid only if the greenhouse structure conform to 9.2. The paragraphs in 9.3 are related to considerations for safe execution of maintenance and repair.

9.2 Durability

Greenhouse structures shall be protected against corrosion and deterioration such that the structural safety is maintained for a period of not less than the minimum design working life as specified in 5.2.4.

9.3 Maintenance and repair

9.3.1 Concentrated loads on the cladding needs shall be avoided.

NOTE This clause is meant to say that people should not step on cladding panels to seek equilibrium when being on the roof.

9.3.2 Systems should be devised so as to avoid hazardous situations during human access to the roofs and for the transportation across the roofs of heavy materials and equipment required for cleaning, maintenance or repair.

9.3.3 In order to reduce the overall hazards involved in roof working, bulk materials, heavy components and equipment required for repairs should either be moved to the location of the repair inside the greenhouse and then lifted through the roof, or be transported over the roof on a special device.

9.3.4 Greenhouse manufacturers/constructors shall supply, for use by those working in these greenhouses, a manual detailing the specification of the greenhouse including servicing and maintenance loads used for design and an instruction to avoid a concentration of materials on the roof (see annex F and annex G).

NOTE Design criteria for the accessibilty of the greenhouses, e.g. ascents, workways, walkways, on roof ladders, are not a normative part of this standard. The specifications given in the informative annex G are recommendations.

10 Actions on greenhouses

10.1 General

10.1.1 All actions and influences likely to occur during the minimum design working life of the greenhouse shall be considered in the design in accordance with the procedures described in ENV 1991-1. In the following subclauses of this clause these procedures are adapted for greenhouses.

10.1.2 The minimum reference periods (recurrence intervals) and annual probabilities of exceedance for determining the characteristic values of the variable actions to be used in the design of each Class of greenhouse shall be as shown in Table 4.

Table 4 - Minimum reference periods for actions and annual probability of exceedence of actions

	Greenhouse Class		
	A15 and B15	A10 and B10	B5
Minimum reference period for actions	15 years	10 years	5 years
Annual probability of exceedance of actions corresponding to the minimum reference period	0,07	0,10	0,20
NOTE Probability of exceedance of the reference period actions during the minimum reference period	0,64	0,65	0,67

10.1.3 The selected design situations shall be considered and critical load cases identified. For each critical load case, the design values of the effects of combinations of actions shall be determined.

10.1.4 Rules for the combination of independent actions in design situations are given in the following subclauses of this clause. Actions which cannot occur simultaneously, for example, due to physical reasons, should not be considered together in combinations.

The combinations of actions to be considered in design are to be taken from 10.2.

10.2 Combinations of actions

10.2.1 All design values of actions that may occur simultaneously shall be considered in combination. In verifying the serviceability and ultimate limit states, the effects of the most onerous combinations of design values of actions shall be considered and shall include the combinations of actions given in Table 5.

Table 5 - Combinations of actions

a) Permanent actions + permanently-present installation actions + wind actions + snow actions + crop actions

	Permanent actions		Permanently-present installation actions		Wind actions		Snow actions		Crop actions
a1)	$\gamma_{G1}\ G_{k1}$	+	$\gamma_{G2}\ G_{k2}$	+	$\gamma_{Q1}\ Q_{k1}$	+	$\psi_{0Q2}\ \gamma_{Q2}\ Q_{k2}$	+	$\psi_{0Q3}\ \gamma_{Q3}\ Q_{k3}$
a2)	$\gamma_{G1}\ G_{k1}$	+	$\gamma_{G2}\ G_{k2}$	+	$\psi_{0Q1}\ \gamma_{Q1}\ Q_{k1}$	+	$\gamma_{Q2}\ Q_{k2}$	+	$\psi_{0Q3}\ \gamma_{Q3}\ Q_{k3}$
a3)	$\gamma_{G1}\ G_{k1}$	+	$\gamma_{G2}\ G_{k2}$	+	$\psi_{0Q1}\ \gamma_{Q1}\ Q_{k1}$	+	$\psi_{0Q2}\ \gamma_{Q2}\ Q_{k2}$	+	$\gamma_{Q3}\ Q_{k3}$

b) Permanent actions + wind actions

	Permanent actions		Wind actions
b1)	$\gamma_{G1}\ G_{k1}$	+	$\gamma_{Q1}\ Q_{k1}$

c) Permanent actions + permanently-present installation actions + crop actions + concentrated vertical action + incidentally-present installation actions

	Permanent actions		Permanently-present installation actions		Crop actions		Concentrated vertical action		Incidentally-present installation actions
c1)	$\gamma_{G1}\ G_{k1}$	+	$\gamma_{G2}\ G_{k2}$	+	$\psi_{0Q3}\ \gamma_{Q3}\ Q_{k3}$	+	$\gamma_{Q4}\ Q_{k4}$	+	$\psi_{0Q5}\ \gamma_{Q5}\ Q_{k5}$
c2)	$\gamma_{G1}\ G_{k1}$	+	$\gamma_{G2}\ G_{k2}$					+	$\gamma_{Q5}\ Q_{k5}$

d) Permanent actions + permanently-present installation actions + snow actions + crop actions + seismic actions

	Permanent actions		Permanently-present installation actions		Snow actions		Crop actions		Seismic actions
d1)	G_{k1}	+	G_{k2}			+	$\psi_{2Q3}\ Q_{k3}$	+	$\gamma_{AE}\ A_{Ek}$
d2)	G_{k1}	+	G_{k2}	+	$\psi_{2Q2}\ Q_{k2}$	+	$\psi_{2Q3}\ Q_{k3}$	+	$\gamma_{AE}\ A_{Ek}$

e) Permanent actions + permanently-present installation actions + thermal actions

	Permanent actions		Permanently-present installation actions		Thermal actions
e1)	$\gamma_{G1}\ G_{k1}$	+	$\gamma_{G2}\ G_{k2}$	+	$\gamma_{Q6}\ Q_{k6}$

f) Permanent actions + permanently-present installation actions + crop actions + accidental snow actions

	Permanent actions		Permanently-present installation actions		Crop actions		Accidental snow actions
f1)	$\gamma_{G1}\ G_{k1}$	+	$\gamma_{G2}\ G_{k2}$	+	$\psi_{1Q3}\ \gamma_{Q3}\ Q_{k3}$	+	$\gamma_A\ A_k$

where

A_{Ek} is the characteristic value of the seismic actions, in accordance with 10.4.9;
A_k is the characteristic value of the accidental snow actions, in accordance with 10.4.10.
G_{k1} is the characteristic value of the permanent actions, in accordance with 10.4.1;
G_{k2} is the characteristic value of the permanently present installation actions, in accordance with 10.4.2;
Q_{k1} is the characteristic value of the wind actions, in accordance with 10.4.3;
Q_{k2} is the characteristic value of the snow actions, in accordance with 10.4.4;
Q_{k3} is the characteristic value of the crop actions, in accordance with 10.4.5;
Q_{k4} is the characteristic value of the concentrated vertical action, in accordance with 10.4.6;
Q_{k5} is the characteristic value of the incidentally present installation actions, in accordance with 10.4.7;
Q_{k6} is the characteristic value of the thermal actions, in accordance with 10.4.8;
γ is the partial factor, in accordance with 10.3.1;
ψ is the combination coefficient, in accordance with 10.3.2.

10.2.2 In verifying the serviceability limit states all combinations of actions as given in Table 5 shall be taken into account except for c1), d1), d2) and f1), unless otherwise specified in annex E.

10.2.3 Non-uniform snow actions, as specified in C.3, should be taken into account only in the combinations with wind actions, in accordance with 10.2.1 a).

10.3 Partial factors and combination coefficients

10.3.1 Partial factors

Partial factors γ shall be as given in annex E.

NOTE Partial factors are related to the safety level of the greenhouse. This safety level may be lower than for normal building structures because human occupancy is restricted to low levels of authorised personnel.

10.3.2 Combination coefficients

Combination coefficients ψ shall be as given in annex E.

NOTE Combination coefficients depend on the combinations of actions for greenhouses. Combination coefficients are determined regionally due to the variation in wind, snow and seismic actions and the probability of simultaneous action occurrences.

10.4 Characteristic value of actions

10.4.1 Permanent actions G_{k1}

10.4.1.1 Permanent actions are actions due to the self-weight of structural and non-structural elements, excluding the installations even if they are permanently present.

10.4.1.2 Characteristic values of the self-weight of construction elements shall be assessed in accordance with ENV 1991-2-1.

10.4.2 Permanently-present installation actions G_{k2}

10.4.2.1 Permanently-present installation actions are actions due to permanently installed equipment such as that for heating, cooling, lighting, shading, irrigation, ventilation and insulation.

10.4.2.2 Characteristic values of the self-weight of fixed equipment shall be assessed in accordance with ENV 1991-2-1.

10.4.2.3 For Class A15 greenhouses the characteristic action due to installations for heating, shading, cooling, lighting, ventilation and insulation shall be determined in accordance with 10.4.2.2 but shall be not less than 70 N/m^2 on plan area.

10.4.2.4 The characteristic value of the actions due to main supply and return heating pipes shall be taken as the self-weight of the insulated pipes when filled.

10.4.2.5 Where greenhouse structures support horizontal wires and cables of shading and irrigation equipment, the effects of the forces resulting from the system and use of these wires and cables, shall be taken into account, but shall be taken not less than:

- shading systems
  - supporting wires: 250 N per wire
  - drive cables: 500 N per wire
- irrigation equipment
  - supporting wires: 1 250 N per wire

10.4.3 Wind actions Q_{k1}

10.4.3.1 Wind actions are actions imposed on the structure by wind.

10.4.3.2 Characteristic values of wind actions shall be calculated in accordance with ENV 1991-2-4.

10.4.3.3 Annex B provides complementary information for 10.4.3.2 to take account of the special case of greenhouse structures.

10.4.4 Snow actions Q_{k2}

10.4.4.1 Snow actions are actions imposed on the structure by snow.

10.4.4.2 Characteristic values of snow actions shall be calculated in accordance with ENV 1991-2-3.

10.4.4.3 Annex C provides complementary information for 10.4.4.2 to take account of the special case of greenhouse structures.

10.4.5 Crop actions Q_{k3}

10.4.5.1 Crop actions are actions due to plants and crops supported by the structure.

10.4.5.2 Where greenhouse structures support plants and crops, the actions due to plants and crops, and the growing medium if this is also supported, shall be considered in the design. Characteristic values of the self-weight of plants, crops and growing medium shall be assessed in accordance with ENV 1991-2-1 but shall be taken not less than the minimum actions given in Table 6. The minimum actions of Table 6 should be considered to be uniformly distributed on plan and to act vertically.

Table 6 - Minimum values for crop actions

Crop	**Minimum value for crop action q_{k3}** kN/m^2
Crops, such as tomatoes and cucumbers	0,15
Crops in lightweight containers, such as strawberries	0,30
Crops in heavy containers, such as pot plants	1,00

10.4.5.3 Where crop actions are transmitted to the structure through horizontal wires, allowance should be made for the wire forces where they are reacted by the structure.

NOTE The horizontal force per wire may be taken as:

$$F_{\text{wire}} = q_{k3}\, a \frac{l^2_{\text{wire,sup}}}{8\, u_{\text{wire}}}$$

where

F_{wire} is the value of the horizontal force per wire;

q_{k3} is the characteristic crop action, in accordance with 10.4.5.2;

a is the distance between the wires;

$l_{\text{wire;sup}}$ is the distance between the wire supports (section length);

u_{wire} is the deflection of the loaded wire.

It is recommended to take u_{wire} at least larger than $l_{\text{wire;sup}}/30$ at a load level of 0,15 kN/m^2.

10.4.6 Concentrated vertical action Q_{k4}

10.4.6.1 Concentrated vertical actions are actions arising from maintenance and repair operations.

10.4.6.2 Minimum values of concentrated vertical actions which shall be taken to act over a surface area of 100 mm by 100 mm, or over a length of 100 mm and over the full width of a structural member narrower than 100 mm, are given in Table 7.

NOTE Concentrated vertical actions need not be taken into account in verifying the serviceability limit states, unless otherwise specified in annex E.

Table 7 - Minimum values for concentrated vertical action

Concentrated vertical action	Minimum value for concentrated vertical action Q_{k4} kN
Action on structural frame and gutter	1,0
Action on a secondary structural member such as a cladding bar or ridge bar	0,35 [a]
[a] For Class A15, A10, B15 and B10 greenhouses only. For single span greenhouses without gutter Q_{k4} may be taken equal to 0.	

10.4.7 Incidentally-present installation actions Q_{k5}

10.4.7.1 Incidentally-present installation actions are actions of variable magnitude due to mobile equipment such as gantries running on rails supported by the structure, and cleaning equipment running along the roof, including service personnel.

10.4.7.2 Characteristic values of actions for moveable installations shall be assessed from data provided by the manufacturer on the self-weight of the equipment and the maximum design action carrying capacity of the equipment. Braking and acceleration forces of transportation equipment shall be taken into account.

10.4.8 Thermal actions Q_{k6}

10.4.8.1 Thermal actions are actions due to temperature effects.

10.4.8.2 Characteristic values of thermal actions shall be derived from the deviations in temperature, that can occur within a 24 h period. Characteristic values for ranges in temperature are given in annex E.

10.4.8.3 For Class B greenhouses, thermal actions need not be taken into account when the length and the width of the greenhouse are less than 150 m.

10.4.8.4 H.2 gives guidance on structural detailing which accommodates the effects due to temperature changes.

10.4.9 Seismic actions A_{Ek}

10.4.9.1 Seismic actions are actions due to earthquakes.

10.4.9.2 Characteristic values of seismic actions shall be assessed in accordance with ENV 1998-1-1.

10.4.10 Accidental snow actions A_k

10.4.10.1 Accidental snow actions are actions imposed by snow with extreme values, that cannot be treated by the usual statistical methods used to evaluate the characteristic value.

10.4.10.2 Characteristic values of accidental snow actions shall be calculated in accordance with ENV 1991-2-3.

10.4.10.3 Annex C provides complementary information for 10.4.10.2 to take account of the special case of greenhouse structures.

10.4.10.4 Accidental snow actions may be adjusted for the return period in the same way as for the ground snow action, in accordance with ENV 1991-2-3.

11 Displacements and deflections (SLS)

11.1 Displacements of Class A greenhouses

11.1.1 Displacements of connecting points of columns with foundations

Displacements, either in horizontal and/or vertical direction, of those points on top of the foundations where the columns are connected to the foundations, shall be not more than 5 mm.

11.1.2 Displacements at gutter level

11.1.2.1 The horizontal displacements of the greenhouse at gutter level, in the direction of the gutter, shall conform to the following requirement (see Figure 7):

$$u_{h;//} \leq u_{h;sw;//;lim} + u_{h;r;//;lim}$$

where

$u_{h;//}$ is the calculated horizontal displacement of the greenhouse at gutter level, in the direction of the gutter;

$u_{h;sw;//;lim}$ is the limiting value of the horizontal displacement of the side wall at gutter level in the direction of the gutter, due to the clearances of the cladding panels in the side wall, in accordance with 11.1.2.3;

$u_{h;r;//;lim}$ is the limiting value of the horizontal displacement of the roof in the direction of the gutter, due to the clearances of the cladding panels in the roof, in accordance with 11.1.2.5.

NOTE Displacements of a greenhouse might also be limited by the use of equipment moving through the greenhouse.

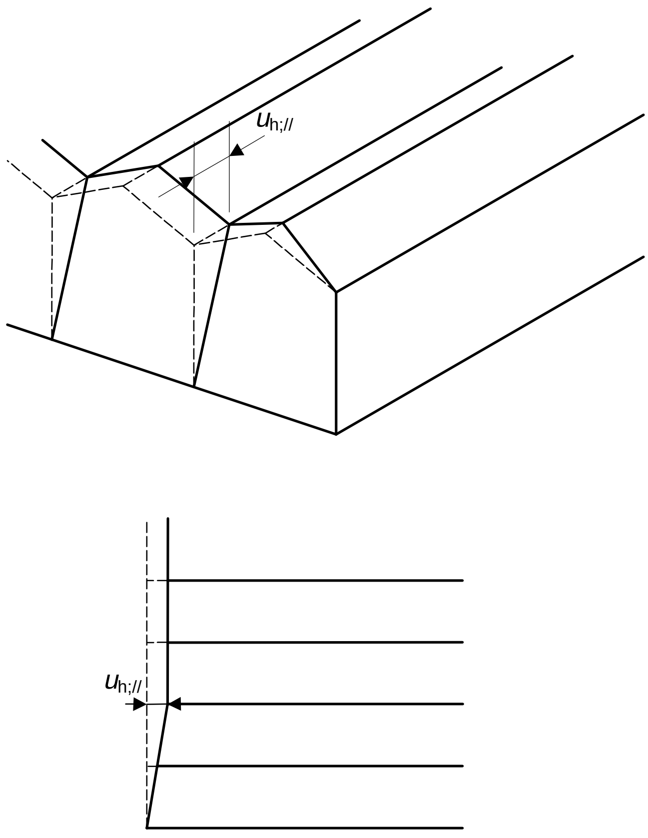


Figure 7 - Horizontal displacements of the greenhouse at gutter level in the direction of the gutter

11.1.2.2 The horizontal displacements of the greenhouse at gutter level, perpendicular to the gutter, shall conform to the following requirement (see Figure 8):

$$u_{h;\perp} \leq u_{h;gw;\perp;lim} + u_{h;r;\perp;lim}$$

where

$u_{h;\perp}$ is the calculated horizontal displacement of the greenhouse at gutter level, perpendicular to the gutter;

$u_{h;gw;\perp;lim}$ is the limiting value of the horizontal displacement of the gable wall at gutter level perpendicular to the gutter, due to the clearance of the cladding panels in the gable wall, in accordance with 11.1.2.4;

$u_{h;r;\perp;lim}$ is the limiting value of the horizontal displacement of the roof perpendicular to the gutter, due to the clearances of the cladding panels in the roof, in accordance with 11.1.2.6.

NOTE Displacements of a greenhouse might also be limited by the use of equipment moving through the greenhouse.

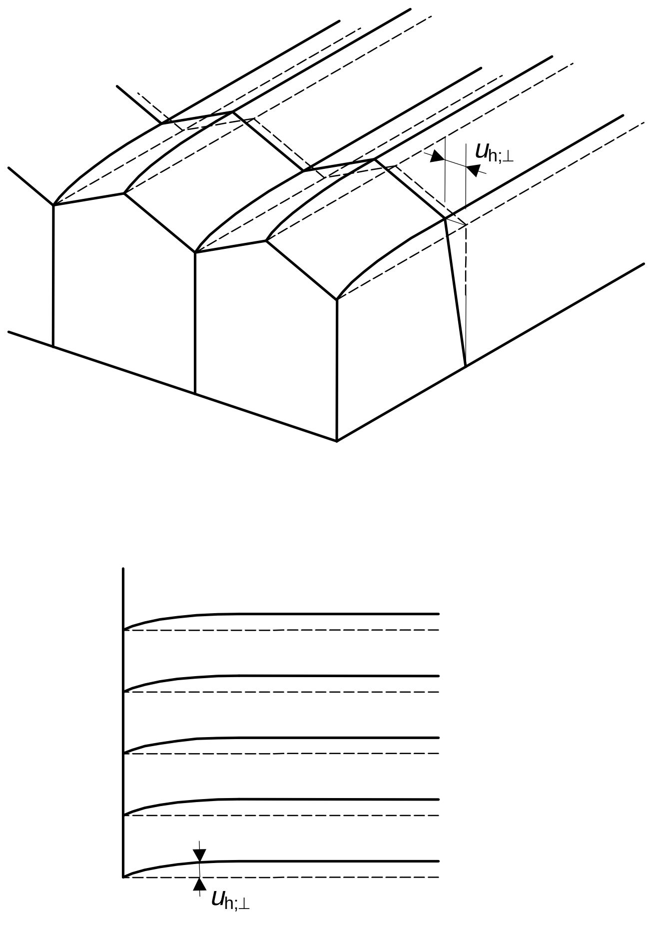


Figure 8 - Horizontal displacements of the greenhouse at gutter level perpendicular to the gutter

11.1.2.3 The limiting value of the horizontal displacement of the side wall at gutter level in the direction of the gutter $u_{h;sw;//;lim}$ shall be determined from the possibility to movements of the cladding panel within its cladding bars (see Figure 9).

This limiting value shall be calculated taking account of the nominal dimensions for length and width of the cladding panel and the clearances as described in 8.2.5.

For side walls with bracings the limiting value $u_{h;sw;//;lim}$ near the bracings shall be taken equal to 0.

NOTE For four sides supported cladding panels the limiting value $u_{h;sw;//;lim}$ may be taken as:

$$u_{h;sw;//;lim} = \left(c_{w;c;sw} + c_{h;c;sw} \frac{h_{c;sw}}{w_{c;sw}} \right) \frac{h}{h_{c;sw}}$$

or

$$u_{h;sw;//;lim} = \frac{h}{w_{c;sw}} \sqrt{2 c_{w;c;sw} w_{c;sw}}$$

whichever is less

where

$c_{h;c;sw}$ is the clearance of the cladding panel perpendicular to the length direction of the side wall;

$c_{w;c;sw}$ is the clearance of the cladding panel in the length direction of the side wall;

$h_{c;sw}$ is the height of the largest cladding panel perpendicular to the length direction of the side wall;

$w_{c;sw}$ is the width of the largest cladding panel in the length direction of the side wall;

h is the column length measured between foundation and gutter.

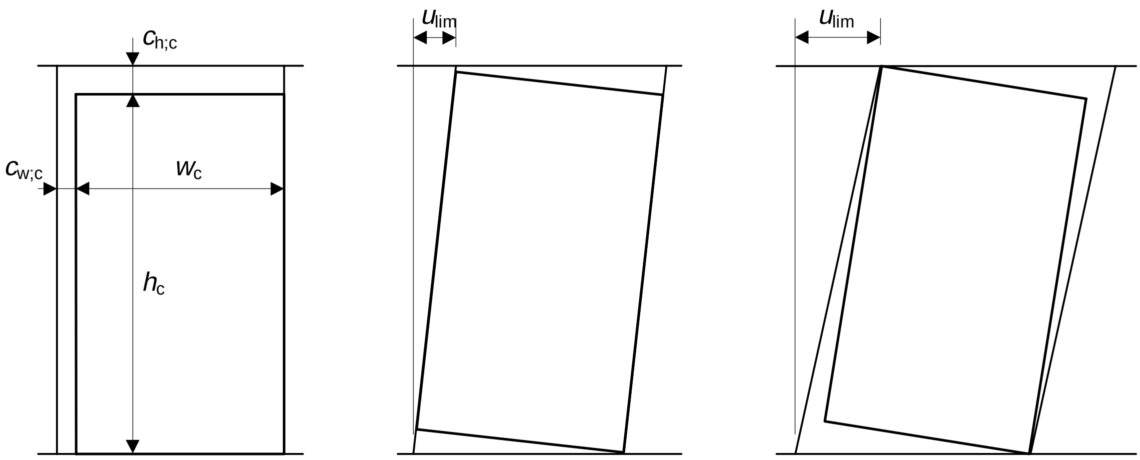


Figure 9 - Limits to the possibility to movements of the cladding panel

11.1.2.4 The limiting value of the horizontal displacement of the gable wall at gutter level perpendicular to the gutter $u_{h;gw;\perp;lim}$ shall be determined from the possibility to movements of the cladding panel within its cladding bars (see Figure 9).

This limiting value shall be calculated taking account of the nominal dimensions for length and width of the cladding panel and the clearances as described in 8.2.5.

For gable walls with bracings the limiting value $u_{h;gw;\perp;lim}$ near the bracings shall be taken equal to 0.

NOTE For four sides supported cladding panels the limiting value $u_{h;gw;\perp;lim}$ may be taken as:

$$u_{h;gw;\perp;lim} = \left(c_{w;c;gw} + c_{h;c;gw} \frac{h_{c;gw}}{w_{c;gw}} \right) \frac{h}{h_{c;gw}}$$

or

$$u_{h;gw;\perp;lim} = \frac{h}{w_{c;gw}} \sqrt{2 c_{w;c;gw} w_{c;gw}}$$

whichever is less

where

$c_{h;c;gw}$	is the clearance of the cladding panel perpendicular to the length direction of the gable wall;
$c_{w;c;gw}$	is the clearance of the cladding panel in the length direction of the gable wall;
$h_{c;gw}$	is the height of the largest cladding panel perpendicular to the length direction of the gable wall;
$w_{c;gw}$	is the width of the largest cladding panel in the length direction of the gable wall;
h	is the column length measured between foundation and gutter.

11.1.2.5 The limiting value of the horizontal displacement of the roof, in the direction of the gutter $u_{h;r;//;lim}$ shall be determined from the possibility to movements of the cladding panel within its cladding bars (see Figure 9).

This limiting value shall be calculated taking account of the nominal dimensions for length and width of the cladding panel and the clearances as described in 8.2.5.

NOTE For four sides supported cladding panels the limiting value $u_{h;r;//;lim}$ may be taken as:

$$u_{h;r;//;lim} = \left(c_{w;c;r} + c_{h;c;r} \frac{h_{c;r}}{w_{c;r}} \right) \frac{n_r d_r}{h_{c;r}}$$

or

$$u_{h;r;//;lim} = \frac{n_r d_r}{w_{c;r}} \sqrt{2 c_{w;c;r} w_{c;r}}$$

whichever is less

where

$c_{h;c;r}$	is the clearance of the cladding panel perpendicular to the length direction of the pitch of the roof;
$c_{w;c;r}$	is the clearance of the cladding panel in the length direction of the pitch of the roof;
$h_{c;r}$	is the height of the largest cladding panel perpendicular to the length direction of the pitch of the roof;
$w_{c;r}$	is the width of the largest cladding panel in the length direction of the pitch of the roof;
d_r	is the distance between the gutter and the ridge;
n_r	is the number of pitches between gutters supported by columns.

11.1.2.6 The limiting value of the horizontal displacement of the roof, perpendicular to the gutter $u_{h;r;\perp;lim}$ shall be determined from the possibility to movements of the cladding panel within its cladding bars (see Figure 9).

This limiting value shall be calculated taking account of the nominal dimensions for length and width of the cladding panel and the clearances as described in subclause 8.2.5.

NOTE For four sides supported cladding panels the limiting value $u_{h;r;\perp;lim}$ for one gutter span may be taken as:

$$u_{h;r;\perp;lim} = \left(c_{w;c;r} + c_{h;c;r} \frac{h_{c;r}}{w_{c;r}} \right) \frac{d_g}{h_{c;r}}$$

or

$$u_{h;r;\perp;lim} = \frac{d_g}{w_{c;r}} \sqrt{2 c_{w;c;r} w_{c;r}}$$

whichever is less

where

$c_{h;c;r}$ is the clearance of the cladding panel perpendicular to the length direction of the pitch of the roof;

$c_{w;c;r}$ is the clearance of the cladding panel in the length direction of the pitch of the roof;

$h_{c;r}$ is the height of the largest cladding panel perpendicular to the length direction of the pitch of the roof;

$w_{c;r}$ is the width of the largest cladding panel in the length direction of the pitch of the roof;

d_g is the distance between the considered frame and the gable wall. This distance may not be taken larger than twice the distance between two adjacent frames.

11.1.3 Displacements of arches

The horizontal and vertical displacements of arches shall conform to the following requirements:

$$u_h \leq \frac{1}{100} h_a$$

$$u_v \leq \frac{1}{100} h_a$$

where

h_a is the height of the arch excluding any column height;

u_h is the horizontal displacement of the arch;

u_v is the vertical displacement of the arch.

11.2 Deflections of Class A greenhouses

11.2.1 General

Unless it is demonstrated by a rigorous analysis, including dynamic effects when relevant, that due to deformations the cladding panels or other structural components do not fail and rainwater drainage is not obstructed, the deflections are subject to 11.2.2 to 11.2.4.
The limiting criterion of cladding panels is that they are stuck tight between the cladding bars.

11.2.2 Deflections of gutters, girders and ridges

11.2.2.1 The vertical deflection of gutters and ridges and the deflections of girders perpendicular to the cladding surface, either downward or upward, shall conform the following requirements:

$$u_v \leq \frac{l_s}{650 - 100 n_{c;r}}$$

$$u_v \leq \frac{l_s}{150}$$

$$u_v \leq 30 \text{ mm}$$

$$u_v \leq \frac{l_s}{750}$$ (for gutters only under permanent actions)

$$u_v \leq 6 \text{ mm}$$ (for gutters only under permanent actions)

where

l_s is the section length of the gutter, girder or ridge;

$n_{c;r}$ is the number of cladding panels placed beside each other in one section length;

u_v is the vertical deflection of the gutter, girder or ridge.

11.2.2.2 The horizontal deflection of gutters and ridges shall conform to the following requirements:

$$u_h \le \frac{l_s/2}{650 - 100 n_{c;r}}$$

$$u_h \le \frac{l_s}{300}$$

where

l_s is the section length of the gutter or ridge;

$n_{c;r}$ is the number of cladding panels placed beside each other in one section length;

u_h is the horizontal deflection of the gutter or ridge.

11.2.3 Deflections of rafters and trellis girders

11.2.3.1 The deflections of rafters and trellis girders, in the plane of the frame either downward or upward, shall conform to the following requirements:

$$u_v \le \frac{l_s}{150},$$

where

l_s is the span of the rafter or trellis girder;

u_v is the vertical deflection of the rafter or trellis girder.

11.2.3.2 The deflections of gutter supporting trellis girders, in the plane of the frame either downward or upward, shall conform to the following requirements:

$$u_v \le \frac{l_s}{250},$$

$$u_v \le 30 \text{ mm},$$

where

l_s is the span of the trellis girder;

u_v is the vertical deflection of the trellis girder.

11.2.3.3 The deflections of rafters and trellis girders, out of the plane of the frame, shall conform to the following requirements:

$$u_h \le \frac{l_s}{300}$$

$$u_h \le 12 \text{ mm},$$

where

l_s is the span of the rafter or trellis girder;

u_h is the horizontal deflection of the rafter or trellis girder.

11.2.4 Deflections of structural components directly supporting cladding panels of gable walls and side walls

11.2.4.1 The deflection of structural components, perpendicular to the cladding surface, shall conform to the following requirements:

$$u_\perp \le \frac{l_s}{150},$$

$$u_\perp \le 30 \text{ mm},$$

where

$u_{\perp}$ is the deflection of the structural component, perpendicular to the cladding surface;

l_s is the span of the structural component.

11.2.4.2 In case the structural component is loaded by crop supporting wires the second requirement in 11.2.4.1 may be omitted.

11.2.4.3 The deflection of structural components, in the direction of the cladding surface, shall conform to the following requirement:

$$u_{//} \leq \frac{l_s}{300},$$

where

l_s is the span of the structural component;

$u_{//}$ is the deflection of the structural component, in the direction of the cladding surface.

11.2.5 Deflections of cladding (glazing) bars

11.2.5.1 The out of plane deflection of cladding bars shall conform to the following requirements:

- cladding bars for single glass or cladding panels:

$$u_{\perp} \leq \frac{l_s}{100},$$

$$u_{\perp} \leq 25 \text{ mm}$$

- cladding bars for insulating glass panels:

$$u_{\perp} \leq \frac{l_s}{200},$$

$$u_{\perp} \leq 12 \text{ mm}$$

where

l_s is the span of the cladding bar;

$u_{\perp}$ is the out of plane deflection of the cladding bar.

11.2.5.2 The in plane deflection of cladding bars shall conform to the following requirements:

$$u_{//} \leq \frac{l_s}{200},$$

$$u_{//} \leq 6 \text{ mm}$$

where

l_s is the span of the cladding bar.

$u_{//}$ is the in plane deflection of the cladding bar;

11.2.5.3 The rotation angle of cladding bars shall conform to the following requirement:

$$\phi_x \leq 0{,}1 \text{ rad}$$

where

ϕ_x is the rotation angle of the cladding bar.

Annex A
(normative)

Structural capacity of cladding

A.1 General

A.1.1 The structural capacity of cladding shall be determined in accordance with:

- A.3 for glass panels, which are made of basic soda-lime silicate glass in conforming to EN 572-1 to EN 572-6;
- A.4 for film plastics;
- By testing in accordance with 6.3 respectively 7.3 for other types of cladding.

NOTE It is intended to replace the calculation method for glass panels by a reference to the forthcoming EN 13474 series. However, prior to making any reference, the EN 13474 series should:
- be completed;
- be publicly available;
- demonstrate by calibration calculations the applicability of the calculation method for commercial greenhouses.

A.1.2 For normal flat glass, patterned glass, smooth surfaces of rigid plastics and film plastics, the in plane loading component may be ignored. In cases where the surface is unusually rough the in plane loading component shall be taken into account.

A.2 Materials

A.2.1 The material properties given in A.2.2 are nominal values that shall be adopted as characteristic values in design calculations.

A.2.2 The nominal value of the ultimate strength of basic soda-lime silicate glass shall be taken to be:

- annealed glass:
  - normal flat glass $f_{gl;u} = 25\ N/mm^2$
  - patterned glass $f_{gl;u} = 20\ N/mm^2$
  - wired glass $f_{gl;u} = 16\ N/mm^2$
- heat strengthened glass:
  - normal flat glass $f_{gl;u} = 25\ N/mm^2$
  - patterned glass $f_{gl;u} = 20\ N/mm^2$
- thermally toughened glass:
  - normal flat glass $f_{gl;u} = 62\ N/mm^2$
  - patterned glass $f_{gl;u} = 50\ N/mm^2$
- chemically toughened glass:
  - normal flat glass $f_{gl;u} = 62\ N/mm^2$

A.2.3 The design value $f_{gl;t;d}$ of the ultimate strength of basic soda-lime silicate glass dependant on the duration of the actions shall be taken to be:

$$f_{gl;t;d} = \frac{f_{gl;u}}{\gamma_{M;t}}$$

where

$f_{gl;u}$ is the nominal value of the ultimate strength of basic soda-lime silicate glass;

$\gamma_{M;t}$ is the partial factor for glass depending on the duration of the actions, and shall be taken to be, unless otherwise specified in annex E:

- permanent actions $\gamma_{M;t=G1}$ = 2,4 or 1,2 [1])
- wind actions $\gamma_{M;t=Q1}$ = 1,2
- snow actions $\gamma_{M;t=Q2}$ = 1,6 or 1,2 [1])

A.3 Calculation method for glass panels

A.3.1 The calculation method is applicable only to flat glass panels uniformly loaded perpendicular to their surface, simply supported along the edges and with a nominal thickness not less than 4 mm.

A.3.2 Glass panels shall satisfy:

$$\frac{p_{gl;Sd}}{p_{gl;Rd}} \leq 1,0$$

where

$p_{gl;Sd}$ is the design value of the total loading component perpendicular to the surface of the glass panel;

$p_{gl;Rd}$ is the design value of the ultimate resistance for glass panels, in accordance with A.3.4.

A.3.3 The design value of the ultimate strength of basic soda-lime silicate glass $f_{gl;d}$ shall be taken to be:

$$f_{gl;d} = \frac{p_{gl;G1;Sd}}{p_{gl;Sd}} \cdot f_{gl;t=G1;d} + \frac{p_{gl;Q1;Sd}}{p_{gl;Sd}} \cdot f_{gl;t=Q1;d} + \frac{p_{gl;Q2;Sd}}{p_{gl;Sd}} \cdot f_{gl;t=Q2;d}$$

where

$p_{gl;Sd}$ is the design value of the total loading component perpendicular to the surface of the glass panel;

$p_{gl;G1;Sd}$ is the design value of the permanent loading component perpendicular to the surface of the glass panel;

$p_{gl;Q1;Sd}$ is the design value of the wind loading component perpendicular to the surface of the glass panel;

$p_{gl;Q2;Sd}$ is the design value of the snow loading component perpendicular to the surface of the glass panel;

$f_{gl;t=x;d}$ is the design value of the ultimate strength of basic soda-lime silicate glass, due to loading type x, in accordance with A.2.3.

A.3.4 The design ultimate resistance of glass panels shall be calculated based on an elastic plate theory taking into account the design value $f_{gl;d}$ of the ultimate strength of basic soda-lime silicate glass according to A.3.3. Geometrical non-linearity's may be taken into account for single glass panels only.

NOTE The design ultimate resistance may be taken to be:

- for two-sided and three-sided simply supported rectangular single glass panels:

$$p_{gl;Rd} = \frac{f_{gl;d} t^2}{6 \beta b^2}$$

- for four-sided simply supported rectangular single glass panels:

$$p_{gl;Rd} = \sqrt{\frac{\left(\sqrt{B^2 + 4C} - B\right)}{2}} E \left(\frac{4t^2}{ab}\right)^2 \text{ but: } p_{gl;Rd} \leq 40E \left(\frac{4t^2}{ab}\right)^2$$

- for rectangular laminated glass and insulated glass panels:

$$p_{gl;Rd} = \frac{f_{gl;d}\left(t_1^3 + t_2^3\right)/t_1}{6 \beta b^2}$$

[1]) The higher value should be used when the actions work in the unfavourable sense, the lower value should be used when the actions work in the favourable sense

where

a is the largest span of the glass panel;

$$B = \left(\frac{k_3}{k_4}\right)^2 - \left(\frac{f_{gl;d}ab}{4k_4Et^2}\right)^2 - \left(\frac{f_{gl;d}ab}{4k_2Et^2}\right)^2$$

b is the smallest span of the glass panel;

$$C = \left(\frac{k_3 f_{gl;d}ab}{4k_2k_4Et^2}\right)^2$$

where

$$k_2 = \frac{24\beta}{a/b}$$

$$k_3 = 4{,}75\left(\frac{a}{b} - 1\right)^2 + 4$$

$k_4 = 0{,}8$

E is the modulus of elasticity of the glass panel.

$f_{gl;u}$ is the nominal value of the ultimate strength of glass, in accordance with A.2;

$p_{gl;Rd}$ is the design value of the ultimate resistance of the glass panel;

t is the thickness of the glass panel;

t_1 is the thickness of the thickest pane of insulating glass units;

t_2 is the thickness of the thinnest pane of insulating glass units;

β is a factor depending on the dimensions and support conditions of the glass panel;

- for two-sided simply supported $\beta = 0{,}125$

- for three-sided simply supported $\beta = 0{,}125$

- for four-sided simply supported β shall conform to Table A.1.

Table A.1 - Factor β for a four-sided simply supported glass panel

$\frac{a}{b}$	β[a]
1,0	0,0447
1,1	0,0524
1,2	0,0597
1,3	0,0666
1,4	0,0730
1,5	0,0788
1,6	0,0840
1,8	0,0930
2,0	0,1002
2,5	0,1121
3,0	0,1184
3,5	0,1216
4,0	0,1241
5,0	0,1245
∞	0,1250

where

a is the largest span of the glass panel;

b is the smallest span of the glass panel.

[a] an approaching formula is:

$\beta = 0{,}0447 + 0{,}0803\left(1 - e^{-1{,}117(a/b-1)^{1{,}073}}\right)$

A.4 Calculation method for film plastics

No calculation method is given because there is not sufficient established knowledge on the design calculations for film plastics.

Annex B
(normative)

Wind actions

B.1 General

B.1.1 Wind actions shall be calculated in accordance with ENV 1991-2-4, using the complementary information specific to greenhouses given in this annex and in E.1.7.

B.1.2 The mean return period used to determine the reference wind speed shall be taken as the value of the minimum reference period given in Table 4, corresponding to the Class of the greenhouse.

B.1.3 Aerodynamic coefficients for greenhouses are given in B.2.

B.1.4 Dynamic coefficients for gust wind response of greenhouses are given in B.3.

B.1.5 Where ventilators are capable of being opened or closed, the greenhouse shall be designed for wind actions corresponding to the ventilators closed.

B.1.6 Ventilators and their opening mechanisms shall be designed in the following two positions:

a) Semi-open position
Ventilators and their opening mechanisms shall be designed to resist the effects of the wind actions at 65% of the reference wind velocity.

b) Maximum open position
Ventilators and their opening mechanisms shall be designed to resist the effects of the wind actions at 40% of the reference wind velocity.

NOTE It is intended to replace this annex B by a reference to the forthcoming Eurocode on wind actions for the calculation of wind actions. However, prior to making any reference to the forthcoming Eurocode on wind actions this Eurocode should:
- be completed;
- be publicly available;
- be provided with appropriate data specific for greenhouses;
- demonstrate by calibration calculations the applicability for commercial greenhouses.

B.2 Aerodynamic coefficients

B.2.1 General

B.2.1.1 Aerodynamic coefficients are given for:

- greenhouses with planar pitched roofs in B.2.2;

- greenhouses with vaulted roofs in B.2.3;

- ventilators in B.2.4;

- permeable cladding in B.2.5.

B.2.1.2 These aerodynamic coefficients relate specifically to greenhouse structures.

B.2.1.3 These aerodynamic coefficients are based on a reference wind velocity as defined in 7.2 of ENV 1991-2-4:1995 (10 min mean wind velocity at 10 m above ground of terrain category II).

B.2.2 Greenhouses with planar pitched roofs

B.2.2.1 The reference height, z_e, for greenhouses with planar pitched roofs shall be taken equal to the height of the ridge above ground level (see Figure B.1).

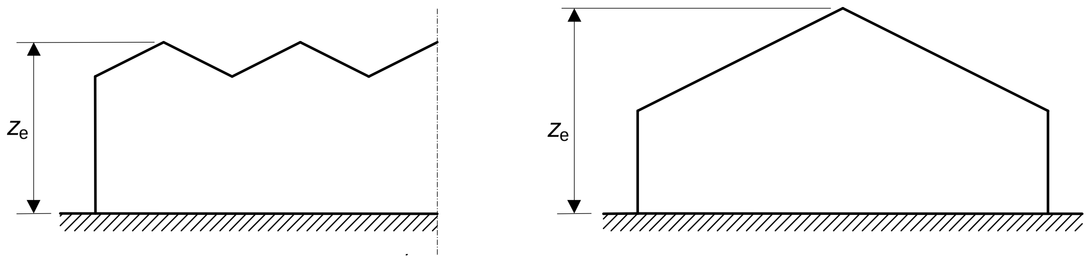
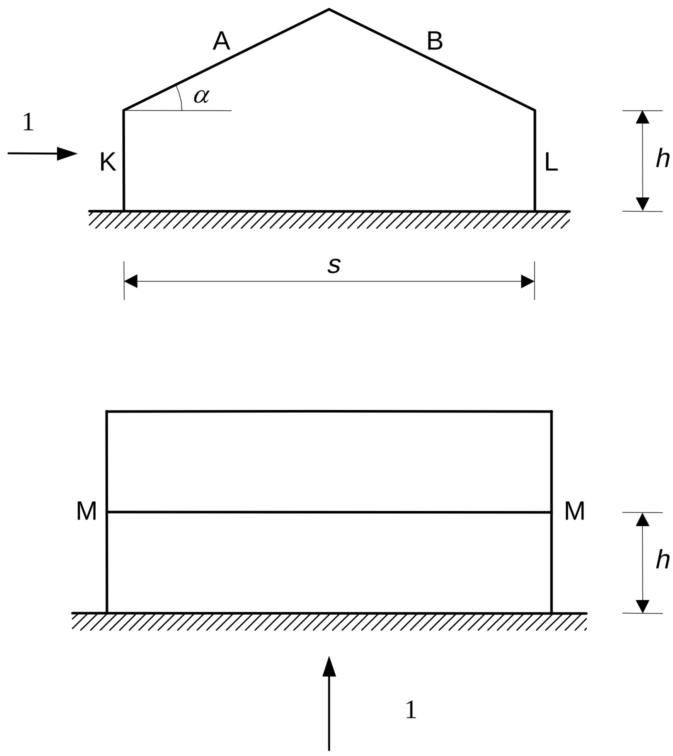


Figure B.1 - Reference height z_e for greenhouses

B.2.2.2 The reference height z_i shall be taken to be equal to the reference height z_e.

B.2.2.3 External pressure coefficients c_{pe} for the walls and roofs of duo pitched greenhouses with roof pitches of 20° to 26° for wind in the direction perpendicular to the ridge, 0° wind, shall be as given in Table B.1 and Figure B.3, depending on the ratio h/s. Zones A, B, K, L and M are defined in Figure B.2. For intermediate values of h/s the values of the external pressure coefficients shall be interpolated linearly.



Key
1 0° wind

Figure B.2 - Zones for the walls and roofs of duo pitched greenhouses

Table B.1 - External pressure coefficients c_{pe} for the walls and roofs of duo pitched greenhouses for wind in the direction perpendicular to the ridge

h/s	A	B	K	L	M
≤ 0,3	see Figure B.4	-0,5	+0,6	-0,3	-0,3
0,4	see Figure B.4	-0,6	+0,6	-0,3	-0,3
≥ 0,6	see Figure B.4	-0,8	+0,6	-0,6	-0,4

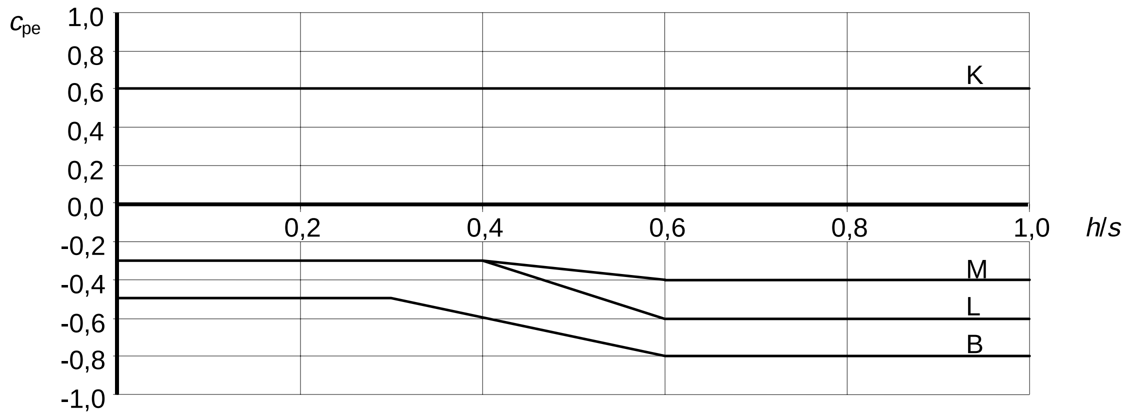
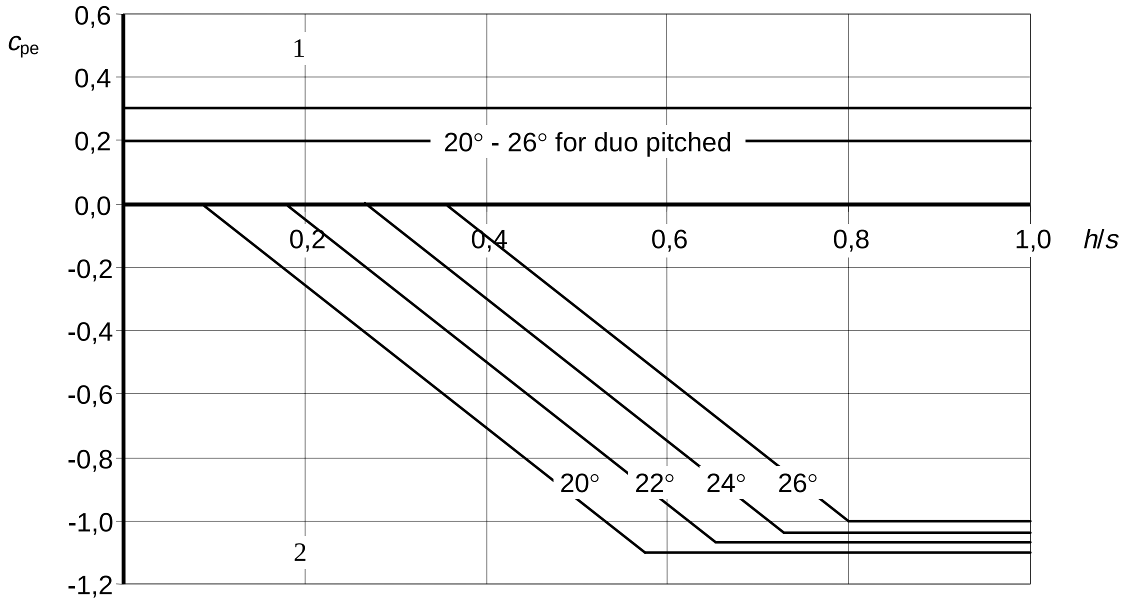


Figure B.3 - External pressure coefficients c_{pe} for the walls and roofs of duo pitched greenhouses for wind in the direction perpendicular to the ridge



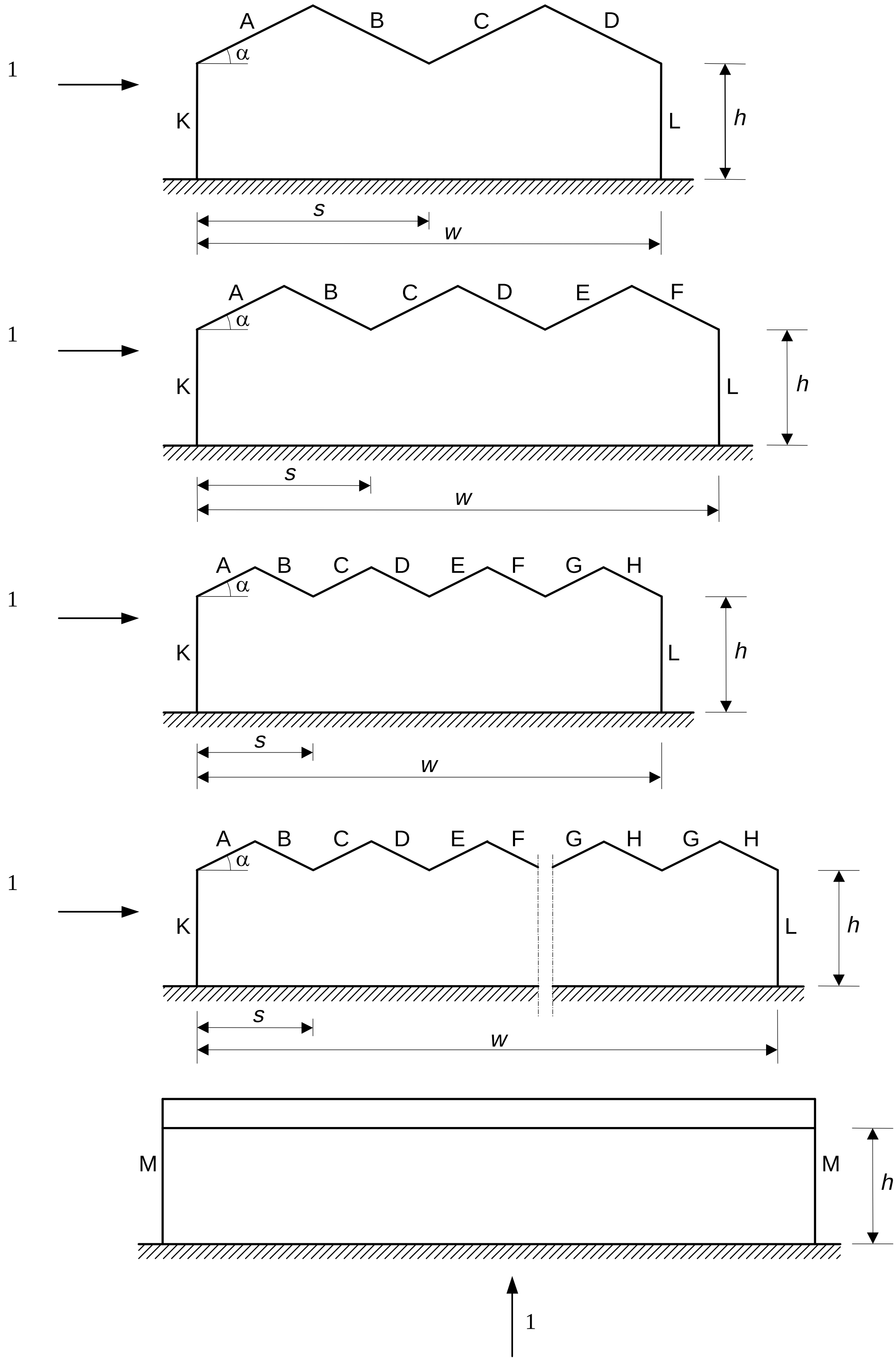
- C_{pe} = +0,2 in case of single span greenhouses
- C_{pe} = +0,3 in case of multi span greenhouses

Key
1 Overpressure
2 Underpressure

Pressure as well as suction shall be taken into account.
Interpolation may be used over the range 20° ≤ roof pitch α ≤ 26°

Figure B.4 - External pressure coefficients c_{pe} for the windward roof slope of planar pitched greenhouses

B.2.2.4 External pressure coefficients c_{pe} for the walls and roofs of multispan greenhouses with roof pitches of 20° to 26° for wind in the direction perpendicular to the ridge, 0° wind, shall be as given in Table B.2 and Figure B.6, depending on the ratios h/s and h/w. Zones A, B, C, D, E, F, G, H, K, L and M are defined in Figure B.5. For intermediate values of *h*/*s* and *h*/*w* the values of the external pressure coefficients shall be interpolated linearly.



Key
1 0° wind

Figure B.5 - Zones for the walls and roofs of multispan greenhouses

Table B.2 - External pressure coefficients c_{pe} for the walls and roofs of multispan greenhouses for wind in the direction perpendicular to the ridge

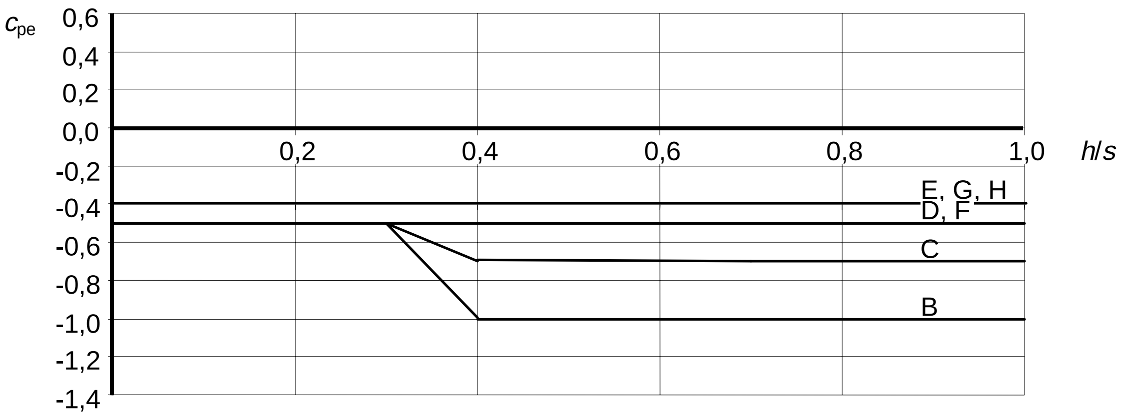
h/*s*	A	B	C	D	E [a]	F [a]	G [a]	H [a]
≤ 0,3	see Figure B.4	-0,5	-0,5	-0,5	-0,4	-0,5	-0,4	-0,4
≥ 0,4	see Figure B.4	-1,0	-0,7	-0,5	-0,4	-0,5	-0,4	-0,4

[a] For greenhouses with more than five spans, the pressure coefficients for roof faces E and F shall be repeated on subsequent faces by the number of times indicated below. For subsequent spans the pressure coefficients for faces G and H shall apply.

Maximum number of subsequent faces with pressure coefficients for roof faces E and F:

- 3 x faces E and F for $h/s \leq 0,4$
- 4 x faces E and F for $0,4 < h/s \leq 0,5$
- 5 x faces E and F for $0,5 < h/s \leq 0,6$
- 6 x faces E and F for $0,6 < h/s \leq 0,7$
- 7 x faces E and F for $h/s > 0,7$

h/*w*	K	L	M
≤ 0,4	+0,6	-0,3	-0,3
≥ 0,6	+0,6	-0,6	-0,4



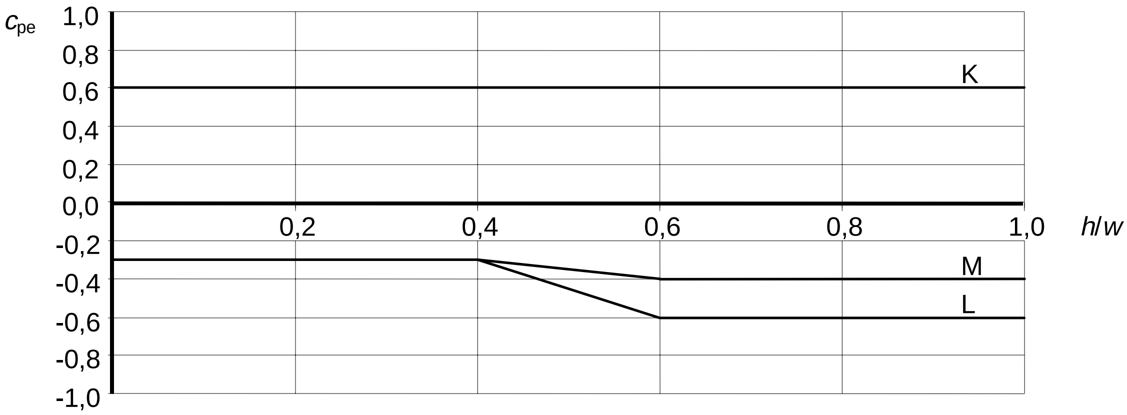
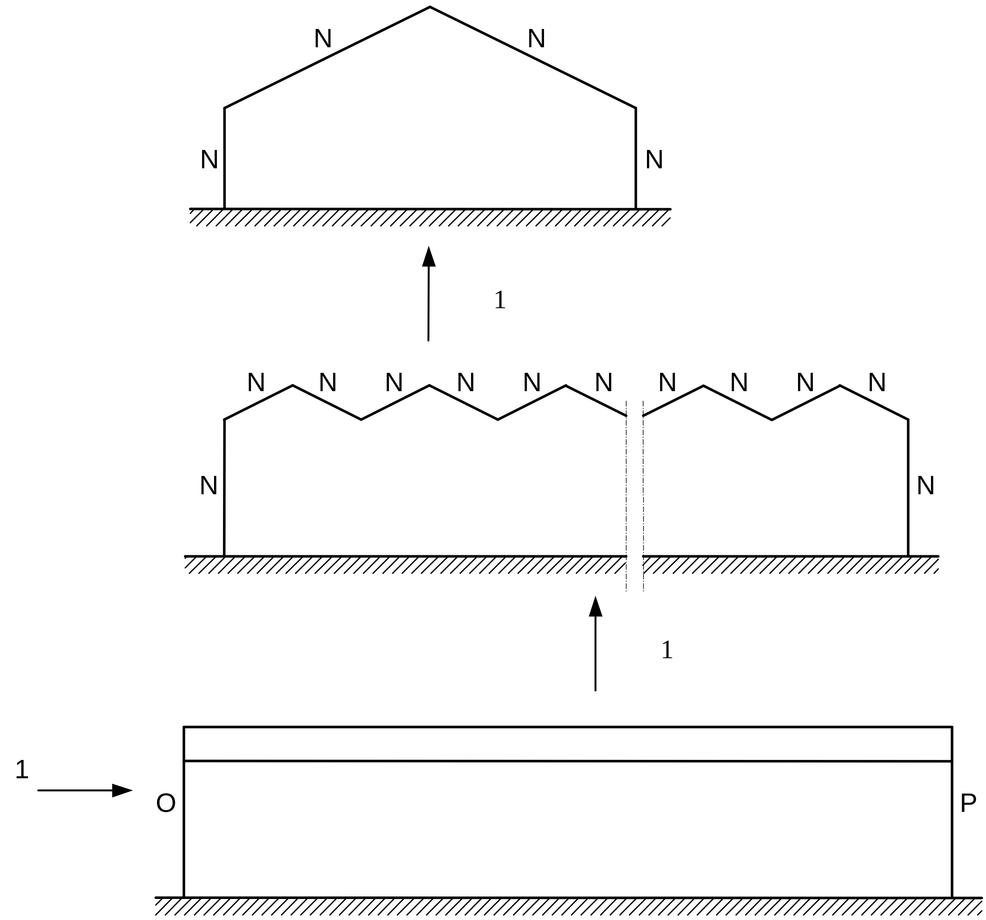


Figure B.6 - External pressure coefficients c_{pe} for the walls and roofs of multispan greenhouses for wind in the direction perpendicular to the ridge

B.2.2.5 External pressure coefficients c_{pe} for the walls and roofs of duo pitched and multispan greenhouses with roof pitches of 20° to 26° for wind in the direction of the ridge, 90° wind, shall be as given in Table B.3 and Figure B.8. Zones N, O and P are defined in Figure B.7.



Key
1 90° wind

Figure B.7 - Zones for the walls and roofs of duo pitched and multispan greenhouses

Table B.3 - External pressure coefficients c_{pe} for the walls and roofs of duo pitched and multispan greenhouses for wind in the direction of the ridge

h*/*s	**N**	**O**	**P**
All	-0,2	+0,7	-0,3

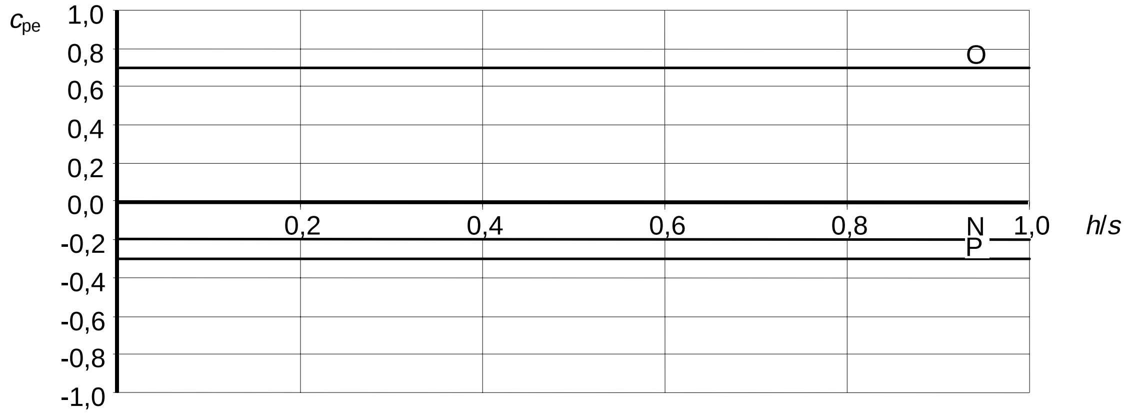
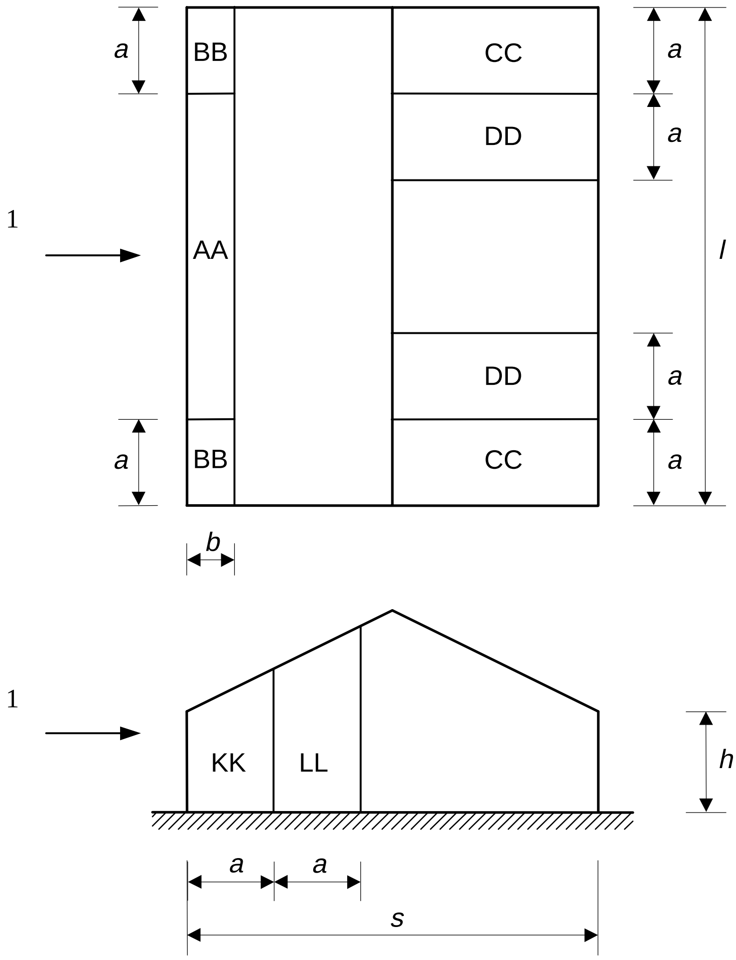


Figure B.8 - External pressure coefficients c_{pe} for the walls and roofs of duo pitched and multispan greenhouses for wind in the direction of the ridge

B.2.2.6 Local pressure coefficients c_{pe} for the walls and roofs of duo pitched greenhouses with roof pitches of 20° to 26° for wind in the direction perpendicular to the ridge, 0° wind, shall be as given in Table B.4. Zones AA, BB, CC, DD, KK and LL are defined in Figure B.9. Local coefficients only apply to the covering, glazing bars and their connections.



a = *h* or *l*/5, whichever smaller

b = 2,0 m

Key

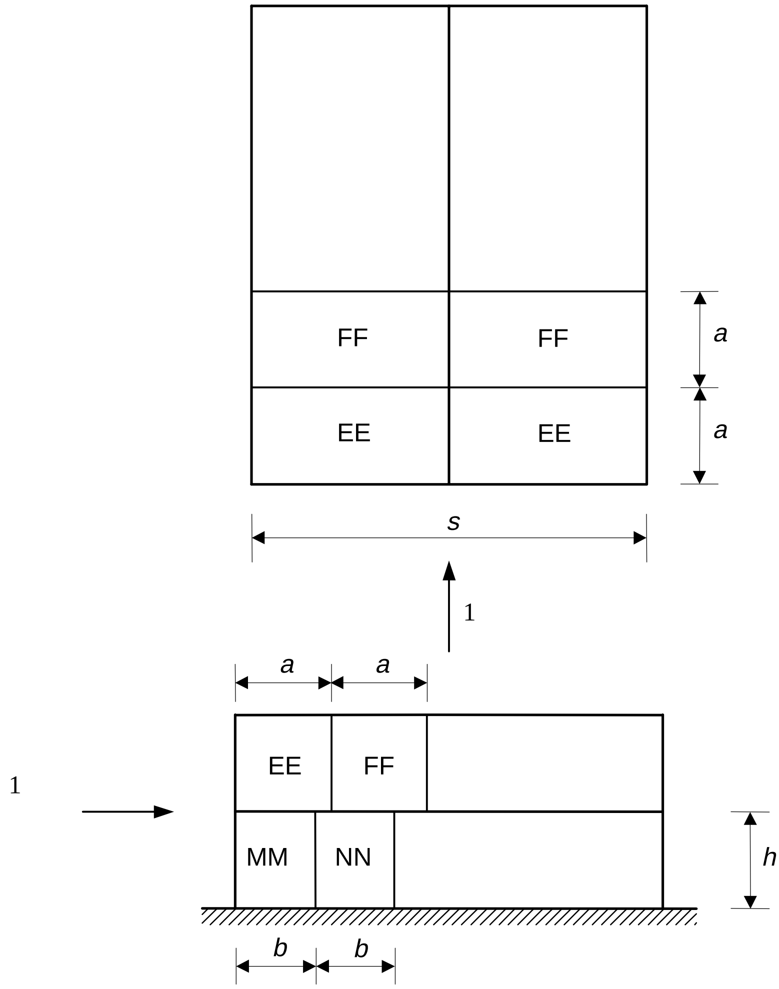
1 0° wind

Figure B.9 - Zones for the walls and roofs of duo pitched greenhouses

Table B.4 - Local pressure coefficients c_{pe} for the walls and roofs of duo pitched greenhouses for wind in the direction perpendicular to the ridge

h/*s*	AA	BB	CC	DD	KK	LL
All	-1,2	-1,6	-1,0	-0,8	-1,0	-0,6

B.2.2.7 Local pressure coefficients c_{pe} for the walls and roofs of duo pitched greenhouses with roof pitches of 20° to 26° for wind in the direction of the ridge, 90° wind, shall be as given in Table B.5 and Figure B.11, depending on the ratio *h*/*s*. Zones EE, MM and NN are defined in Figure B.10. For intermediate values of *h*/*s* the values of the local pressure coefficients shall be interpolated linearly. Local coefficients only apply to the covering, glazing bars and their connections.



a = *h* or *s*/2, whichever smaller

b = *h* or *s*/5, whichever smaller

Key
1 90° wind

Figure B.10 - Zones for the walls and roofs of duo pitched greenhouses

Table B.5 - Local pressure coefficients c_{pe} for the walls and roofs of duo pitched greenhouses for wind in the direction of the ridge

h/*s*	EE	FF	MM	NN
≤ 0,4	-1,2	-0,5	-0,8	-0,5
≥ 0,6	-1,2	-0,5	-1,0	-0,6

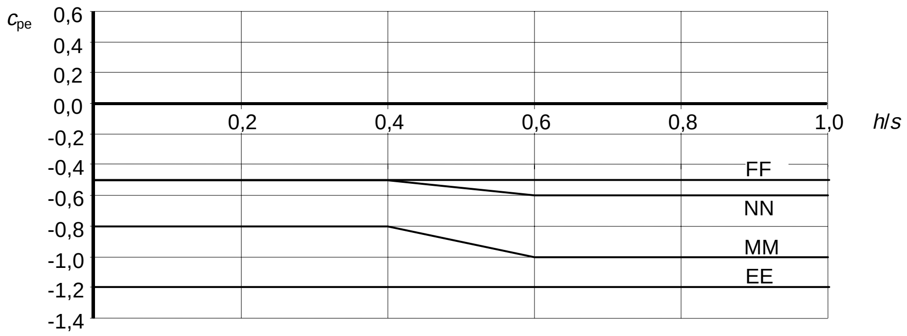
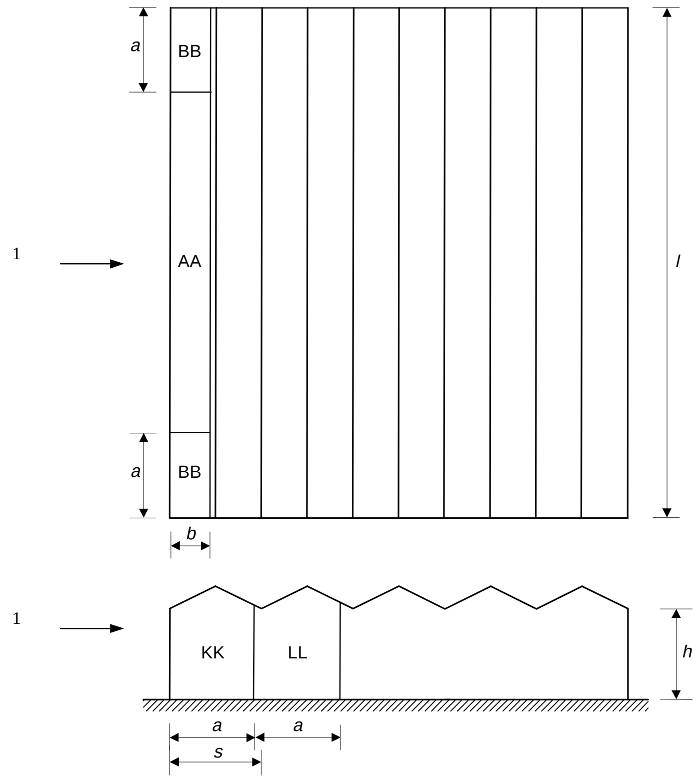


Figure B.11 - Local pressure coefficients c_{pe} for the walls and roofs of duo pitched greenhouses for wind in the direction of the ridge

B.2.2.8 Local pressure coefficients c_{pe} for the walls and roofs of multispan greenhouses with roof pitches of 20° to 26° for wind in the direction perpendicular to the ridge, 0° wind, shall be as given in Table B.6. Zones AA, BB, KK and LL are defined in Figure B.12. Local coefficients only apply to the covering, glazing bars and their connections.



a = *h* or *l*/5, whichever smaller

b = 2,0 m or *s*/2, whichever smaller

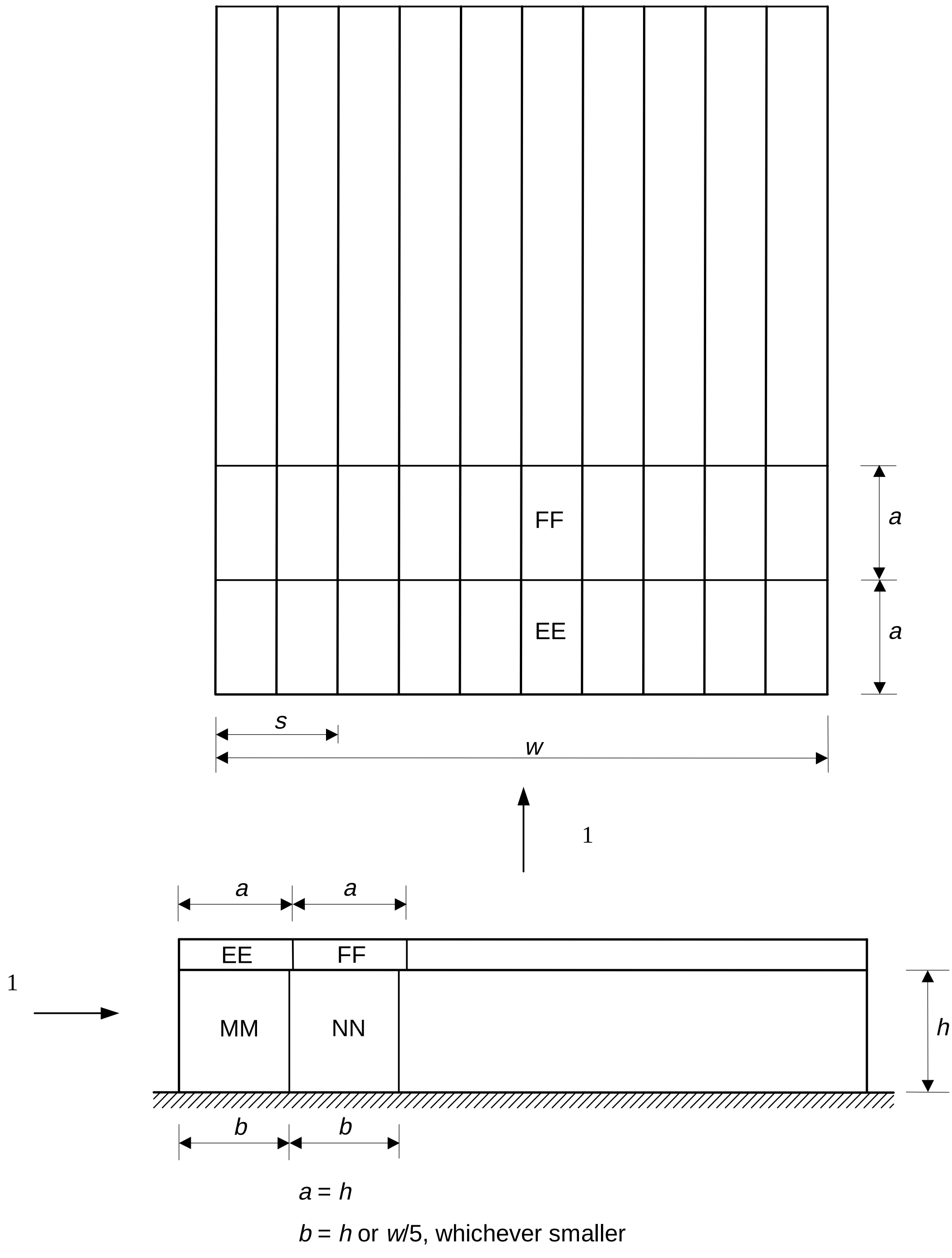
Key
1 0° wind

Figure B.12 - Zones for the walls and roofs of multispan greenhouses

Table B.6 - Local pressure coefficients c_{pe} for the walls and roofs of multispan greenhouses for wind in the direction perpendicular to the ridge

h/*s*	AA	BB	KK	LL
All	-1,2	-1,6	-1,0	-0,6

B.2.2.9 Local pressure coefficients c_{pe} for the walls and roofs of multispan greenhouses with roof pitches of 20° to 26° for wind in the direction of the ridge, 90° wind, shall be as given in Table B.7 and Figure B.14, depending on the ratio *h*/*s*. Zones EE, FF, MM and NN are defined in Figure B.13. For intermediate values of *h*/*s* the values of the local pressure coefficients shall be interpolated linearly. Local coefficients only apply to the covering, glazing bars and their connections.



Key
1 90° wind

Figure B.13 - Zones for the walls and roofs of multispan greenhouses

Table B.7 - Local pressure coefficients c_{pe} for the walls and roofs of multispan greenhouses for wind in the direction of the ridge

h/*s*	EE	FF	MM	NN
≤ 0,4	-1,2	-0,5	-0,8	-0,5
≥ 0,6	-1,2	-0,5	-1,0	-0,6

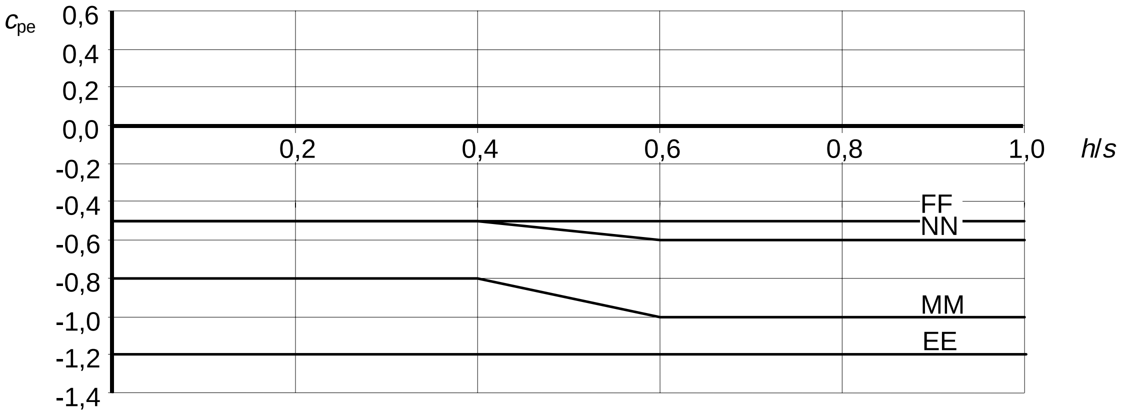


Figure B.14 - Local pressure coefficients c_{pe} for the walls and roofs of multispan greenhouses for wind in the direction of the ridge

B.2.2.10 Internal pressure coefficients c_{pi} for greenhouses with planar pitched roofs shall be as given in Table B.8.

Table B.8 - Internal pressure coefficient c_{pi} for greenhouses with planar pitched roofs

Wind direction	Single span	Multispan
0°	c_{pi} = 0,2 c_{pi} = -0,4	c_{pi} = 0,2 c_{pi} = -0,3
90°	c_{pi} = 0,2 c_{pi} = -0,2	c_{pi} = 0,2 c_{pi} = -0,2
For the case of a dominant permanent opening on a windward wall, an internal pressure coefficient of +0,6 shall be used.		

B.2.2.11 Frictional wind forces shall be calculated using a friction coefficient c_f = 0,01. Frictional forces shall be calculated over the face area of side walls aligned parallel to the wind, excluding zones KK, LL, MM and NN shown in Figures B.9, B.10, B.12 and B.13. Frictional forces should also be calculated over the face area of the roof for the 90° wind direction only, excluding zones EE and FF shown in Figures B.11 and B.13.

B.2.3 Greenhouses with vaulted roofs

B.2.3.1 The reference height, z_e, for greenhouses with vaulted roofs shall be taken equal to the average of the height of the ridge and the height of the gutter above ground level, but not less than 0,75 *H*, where *H* is the height of the ridge above ground level (see Figure B.15).

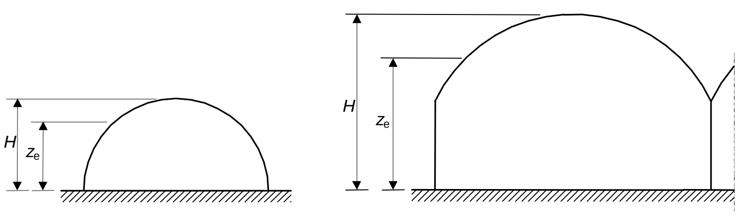
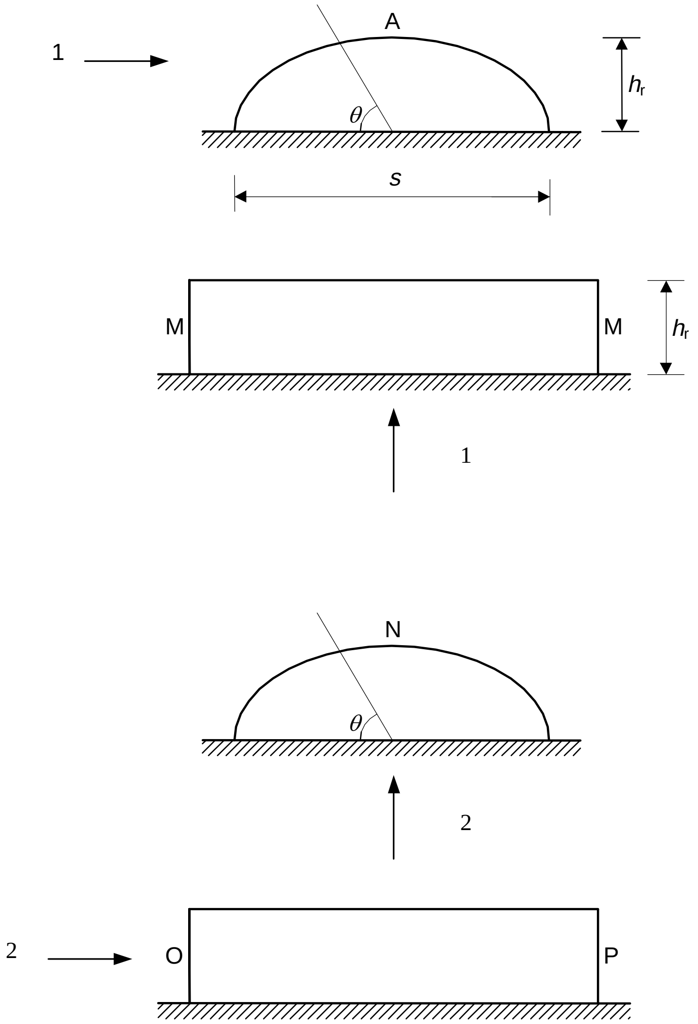


Figure B.15 - Reference height z_e for greenhouses

B.2.3.2 The reference height z_i shall be taken to be equal to the reference height z_e.

B.2.3.3 External pressure coefficients c_{pe} for the vaulted roof and walls of single span greenhouses without eaves shall be as given in Table B.9. Zones A, M, N, O and P are defined in Figure B.16.



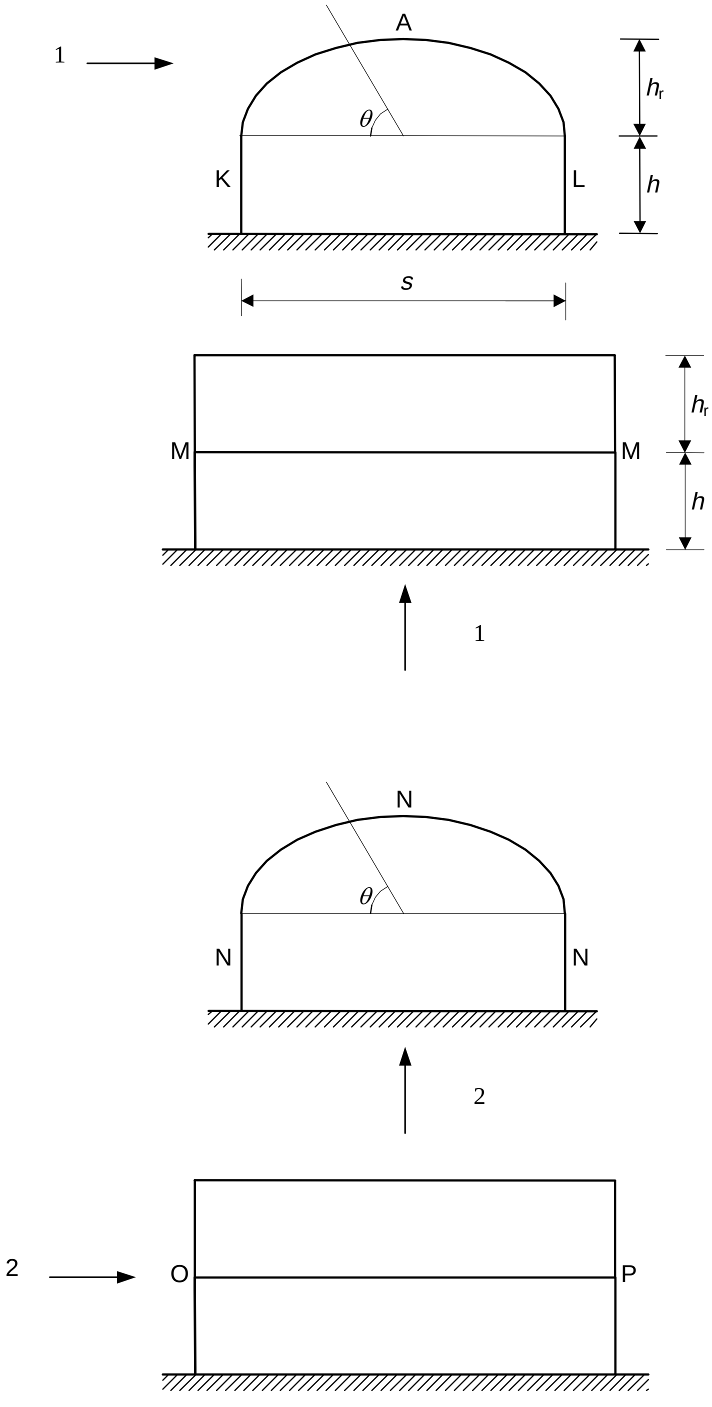
Key
1 0° wind
2 90° wind

Figure B.16 - Zones for the vaulted roof and walls of single span greenhouses without eaves

Table B.9 - External pressure coefficients c_{pe} for the vaulted roof and walls of single span greenhouses without eaves

Wind direction	**θ**	**A**	**A [a]**	**M**
0°	0° to 35°	+0,4	+0,4	-0,3
	35° to 55°	-0,1	-0,1	
	55° to 75°	-0,8	-1,1	
	75° to 95°	-1,3	-1,8	
	95° to 115°	-0,8	-0,9	
	115° to 180°	-0,4	-0,4	
[a] For h_r/s < 0,35 and film plastic cladding unrestrained against uplifting over ridge.				
Wind direction	θ	N	O	P
90°	All	-0,3	+0,7	-0,3

B.2.3.4 External pressure coefficients c_{pe} for the vaulted roof and walls of single span greenhouses with eaves and with $h/s \geq 0,2$ shall be as given in Table B.10, depending on the ratio h/s. Zones A, K, L, M, N, O and P are defined in Figure B.17. For intermediate values of h/s the values of the external pressure coefficients shall be interpolated linearly. Vaulted roofs of single span greenhouses with eaves and with $h/s < 0,2$ shall be treated as greenhouses without eaves in accordance with B.2.3.3.



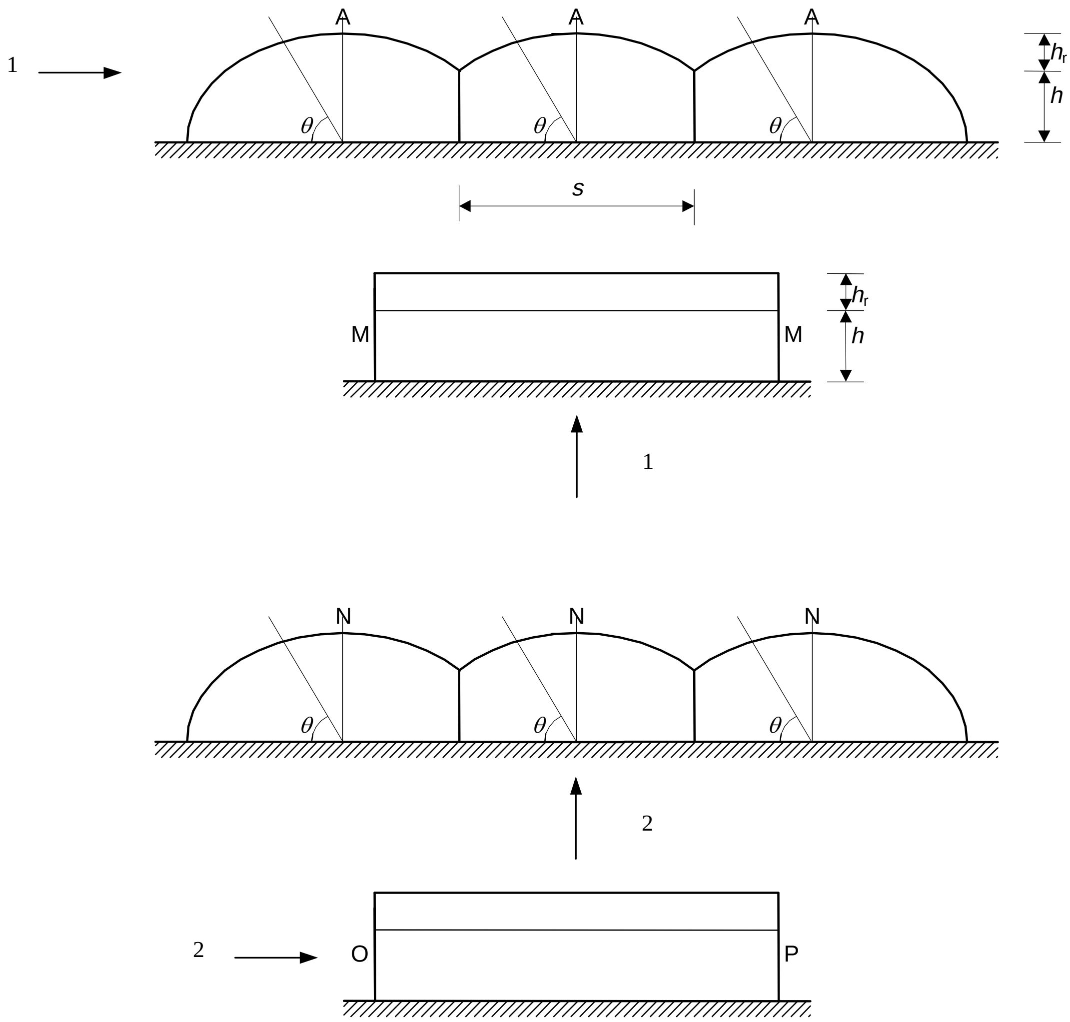
Key
1 0° wind
2 90° wind

Figure B.17 - Zones for the vaulted roof and walls of single span greenhouses with eaves and with $h/s \geq 0,2$

Table B.10 - External pressure coefficients c_{pe} for the vaulted roof and walls of single span greenhouses with eaves and with $h/s \geq 0{,}2$

<table>
<tr><th>Wind direction</th><th>θ</th><th colspan="3">A</th><th colspan="3">A [a]</th></tr>
<tr><td>0°</td><td>0° to 55°
55° to 115°
115° to 180°</td><td colspan="3">+0,3
-1,0
-0,4</td><td colspan="3">+0,3
-1,2
-0,4</td></tr>
<tr><td colspan="8">[a] For h_r/s < 0,2 and film plastic cladding unrestrained against uplifting over ridge.</td></tr>
<tr><td>Wind direction</td><td>h/s</td><td colspan="2">K</td><td colspan="2">L</td><td colspan="2">M</td></tr>
<tr><td>0°</td><td>≤ 0,4
≥ 0,6</td><td colspan="2">+0,6
+0,6</td><td colspan="2">-0,3
-0,6</td><td colspan="2">-0,3
-0,4</td></tr>
<tr><td>Wind direction</td><td>θ</td><td colspan="2">N</td><td colspan="2">O</td><td colspan="2">P</td></tr>
<tr><td>90°</td><td>All</td><td colspan="2">-0,2</td><td colspan="2">+0,7</td><td colspan="2">-0,3</td></tr>
</table>

B.2.3.5 External pressure coefficients c_{pe} for the vaulted roofs and walls of multispan greenhouses without eaves shall be as given in Table B.11. Zones A, M, N, O and P are defined in Figure B.18.



Key
1 0° wind
2 90° wind

Figure B.18 - Zones for the vaulted roofs and walls of multispan greenhouses without eaves

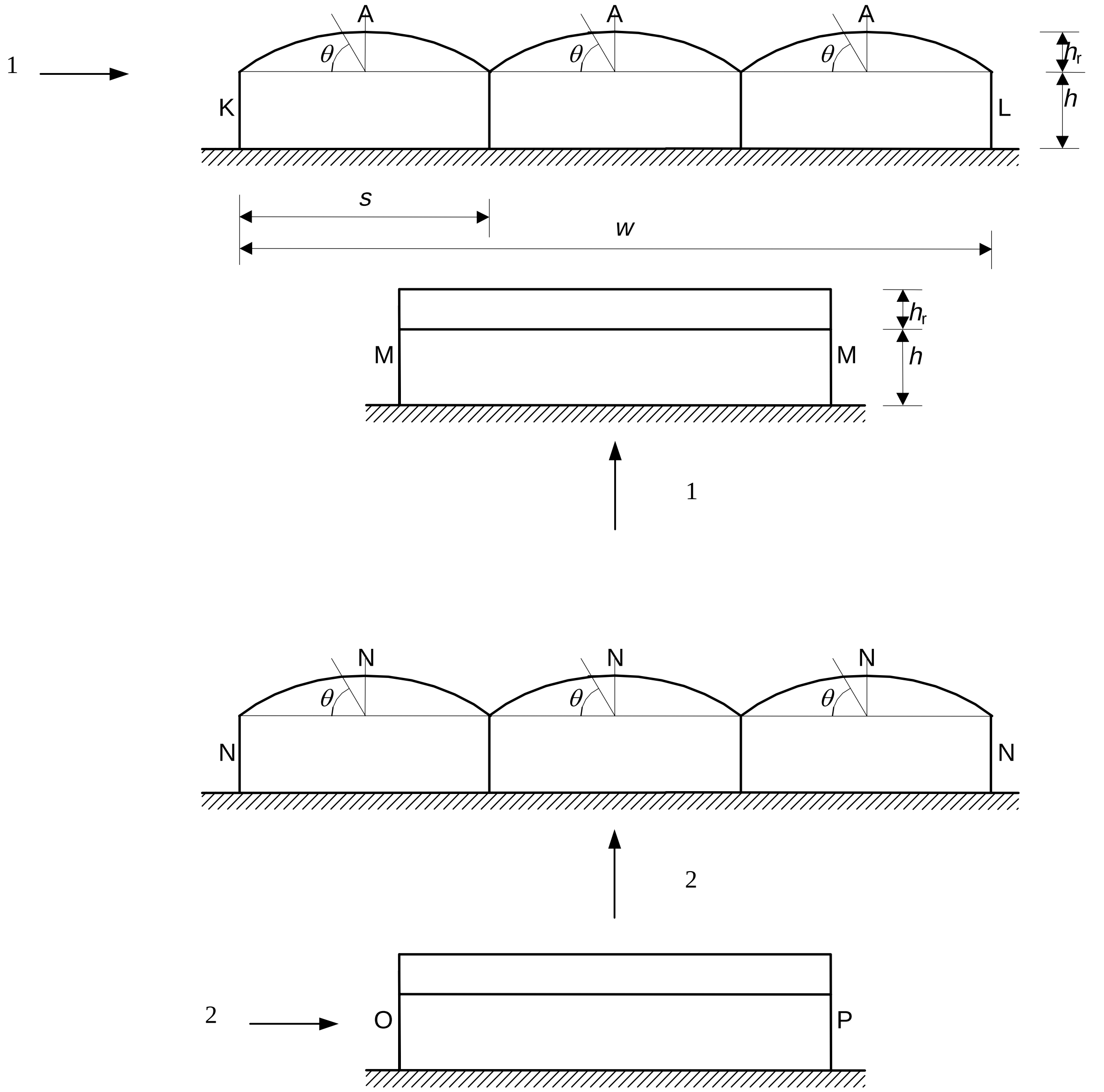
Table B.11 - External pressure coefficients c_{pe} for the vaulted roofs and walls of multispan greenhouses without eaves

Wind direction	Span	θ	A	A [a]	M
0°	First	0° to 35°	+0,4	+0,4	-0,3
		35° to 55°	-0,1	-0,1	
		55° to 75°	-0,8	-1,1	
		75° to 95°	-1,3	-1,8	
		95° to 105°	-0,8	-0,9	
		105° to gutter	-0,4	-0,4	
	Second	gutter to 85°	-0,3	-0,3	
		85° to 100°	-0,9	-1,0	
		100° to gutter	-0,2	-0,2	
	Third and subsequent	gutter to 85°	-0,1	-0,1	
		85° to 100°	-0,7	-0,8	
		100° to gutter	-0,1	-0,1	
	Leeward [b]	gutter to 85°	0,0	0,0	
		85° to 100°	-0,6	-0,6	
		100° to 180°	-0,2	-0,2	

[a] For h_r/s < 0,2 and film plastic cladding unrestrained against uplifting over ridge.
[b] For the leeward span of twin-span greenhouses the pressure coefficients of the second span shall be used for $\theta \leq 100°$. For $100° < \theta \leq 180°$ a pressure coefficient equal to -0,4 shall be used.
For the leeward span of three-span greenhouses the pressure coefficients of the second span shall be used for $\theta \leq 100°$. For $100° < \theta \leq 180°$ a pressure coefficient equal to -0,4 shall be used.

Wind direction	θ	N	O	P
90°	All	-0,3	+0,7	-0,3

B.2.3.6 External pressure coefficients c_{pe} for the vaulted roofs and walls of multispan greenhouses with eaves and with $h/s \geq 0,2$ shall be as given in Table B.12, depending on the ratio h/w. Zones A, K, L, M, N, O and P are defined in Figure B.19. For intermediate values of h/s the values of the external pressure coefficients shall be interpolated linearly. Vaulted roofs of multispan greenhouses with eaves and with h/s < 0,2 shall be treated as greenhouses without eaves in accordance with B.2.3.5.



Key
1 0° wind
2 90° wind

Figure B.19 - Zones for the vaulted roofs and walls of multispan greenhouses with eaves and with $h/s \geq 0{,}2$

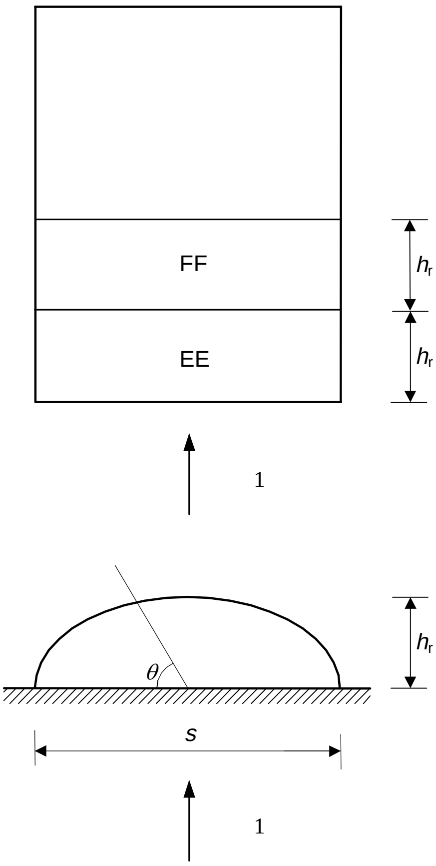
Table B.12 - External pressure coefficients c_{pe} for the vaulted roofs and walls of multispan greenhouses with eaves

Wind direction	Span	θ	A	A [a]
0°	First	0° to 55° 55° to 70° 70° to 115° 115° to gutter	+0,3 -1,0 -1,0 -0,4	+0,3 -1,0 -1,2 -0,4
	Second	gutter to 80° 80° to 100° 100° to gutter	-0,2 -0,9 -0,3	-0,2 -0,9 -0,3
	Third and subsequent	gutter to 80° 80° to 100° 100° to gutter	0,6 c_{pe} Of second span	

[a] For h_r/s < 0,2 and film plastic cladding unrestrained against uplifting over ridge.

Wind direction	h/w	K	L	M
0°	≤ 0,4 ≥ 0,6	+0,6 +0,6	-0,3 -0,6	-0,3 -0,4
Wind direction	θ	N	O	P
90°	All	-0,2	+0,7	-0,3

B.2.3.7 Local pressure coefficients c_{pe} for the vaulted roof of single span greenhouses without eaves shall be as given in Table B.13. Zones EE and FF are defined in Figure B.20. Local coefficients only apply to the covering, glazing bars and their connections.



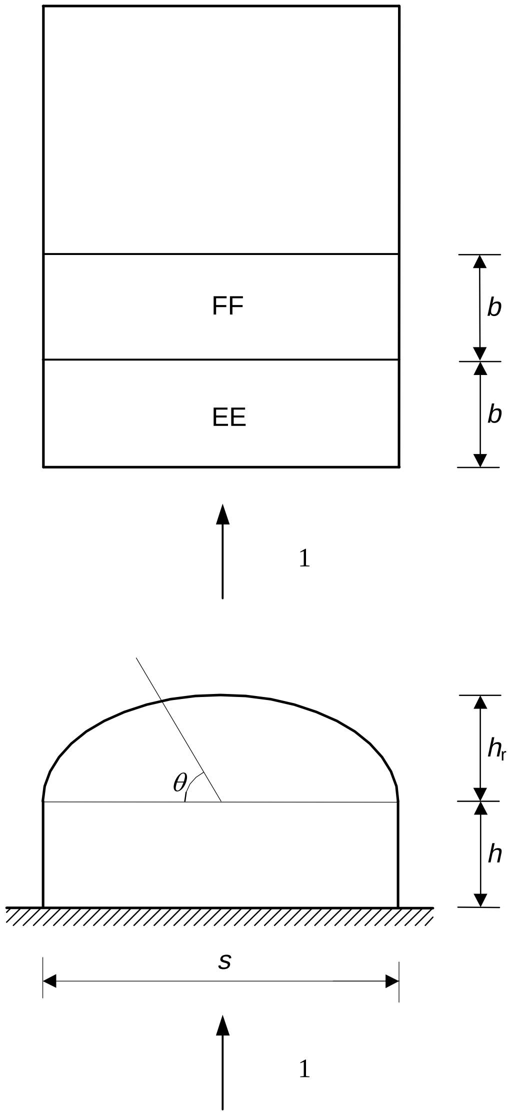
Key
1 90° wind

Figure B.20 - Zones for the vaulted roof of single span greenhouses without eaves

Table B.13 - Local pressure coefficients c_{pe} for the vaulted roof of single span greenhouses without eaves

Wind direction	θ	EE	FF
90°	All	-1,0	-0,6

B.2.3.8 Local pressure coefficients c_{pe} for the vaulted roof of single span greenhouses with eaves and with $h/s \geq 0,2$ shall be as given in Table B.14. Zones EE and FF are defined in Figure B.21. Local coefficients only apply to the covering, glazing bars and their connections. Vaulted roofs of single span greenhouses with eaves and with $h/s < 0,2$ shall be treated as greenhouses without eaves in accordance with B.2.3.7.



$b = h$ or $s/2$, whichever smaller

Key
1 90° wind

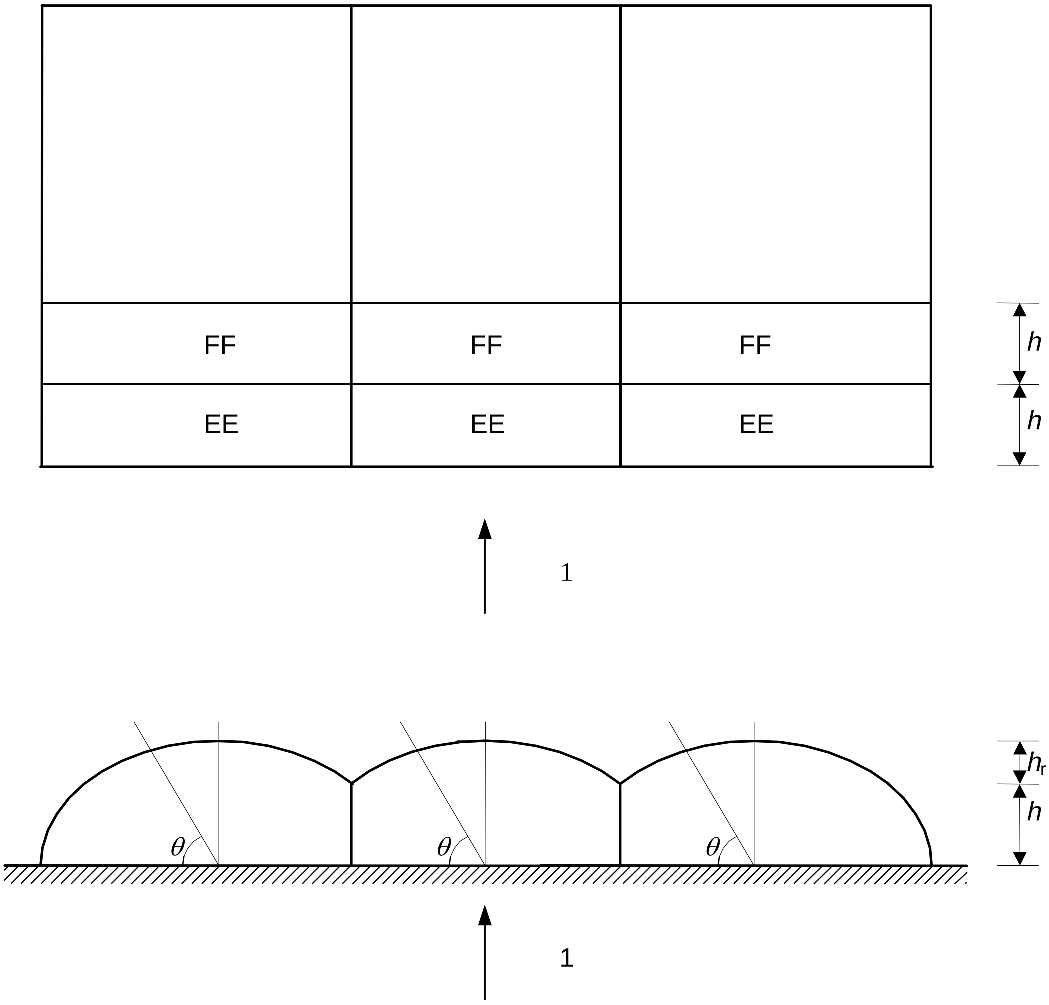
Figure B.21 - Zones for vaulted roofs of single span greenhouses with eaves and with $h/s \geq 0,2$

Table B.14 - Local pressure coefficients c_{pe} for the vaulted roofs of single span greenhouses with eaves and with $h/s \geq 0,2$

Wind direction	θ	EE	FF
90°	All	-1,2	-0,5

B.2.3.9 Local pressure coefficients c_{pe} for the walls of single span greenhouses with vaulted roofs shall be taken equal to the local pressure coefficients as given in B.2.2.6 and B.2.2.7 for duo pitched greenhouses.

B.2.3.10 Local pressure coefficients c_{pe} for the vaulted roofs of multispan greenhouses without eaves shall be as given in Table B.15. Zones EE and FF are defined in Figure B.22. Local coefficients only apply to the covering, glazing bars and their connections.



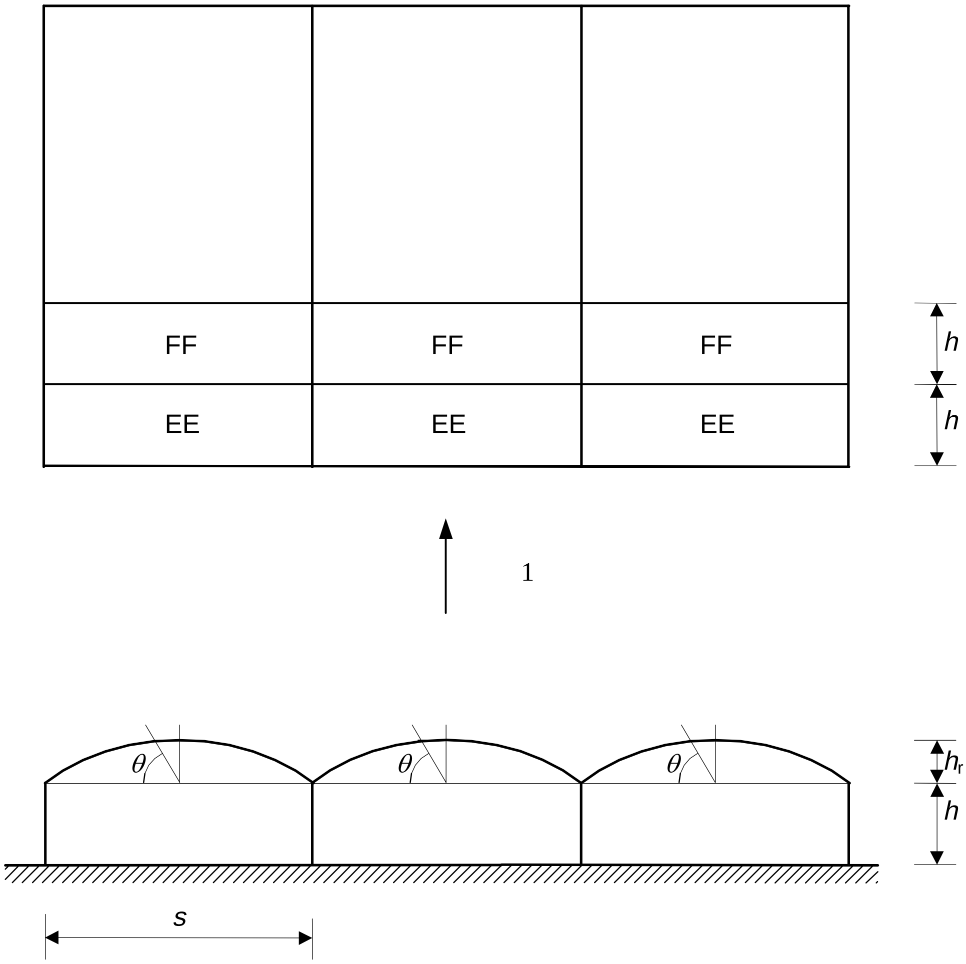
Key
1 90° wind

Figure B.22 - Zones for the vaulted roof of multispan greenhouses without eaves

Table B.15 - Local pressure coefficients c_{pe} for the vaulted roofs of multispan greenhouses without eaves

Wind direction	θ	EE	FF
90°	All	-1,0	-0,6

B.2.3.11 Local pressure coefficients c_{pe} for the vaulted roofs of multispan greenhouses with eaves and with $h/s \geq 0{,}2$ shall be as given in Table B.16. Zones EE and FF are defined in Figure B.23. Local coefficients only apply to the covering, glazing bars and their connections. Vaulted roofs of multispan greenhouses with eaves and with *h*/*s* < 0,2 shall be treated as greenhouses without eaves in accordance with B.2.3.10.



Key
1 90° wind

Figure B.23 - Zones for the vaulted roof of multispan greenhouses with eaves and with *h*/*s* ≥ 0,2

Table B.16 - Local pressure coefficients c_{pe} for the vaulted roofs of multispan greenhouses with eaves and with *h*/*s* ≥ 0,2

Wind direction	θ	EE	FF
90°	All	-1,3	-0,6

B.2.3.12 Local pressure coefficients c_{pe} for the walls of multispan greenhouses with vaulted roofs shall be taken equal to the local pressure coefficients as given in subclauses B.2.2.8 and B.2.2.9 for multispan greenhouses.

B.2.3.13 Internal pressure coefficients c_{pi} for greenhouses with vaulted roofs shall be as given in Table B.17.

Table B.17 - Internal pressure coefficient c_{pi} for greenhouses with vaulted roofs

Wind direction	Single span		Multispan
	Impermeable sides [a]	Vented or permeable sides [b]	
0°	c_{pi} = 0,2 c_{pi} = -0,4	c_{pi} = 0,2 c_{pi} = -0,2 [c]	c_{pi} = 0,2 c_{pi} = -0,3
90°	c_{pi} = 0,2 c_{pi} = -0,1	c_{pi} = 0,2 c_{pi} = 0,0	c_{pi} = 0,2 c_{pi} = -0,1

[a] Greenhouses with closed vents and/or doors in end walls but impermeable side walls
[b] Greenhouses with closed vents and/or doors in end walls and vented or permeable side walls
[c] Where permanent ridge ventilation is present c_{pi} = -0,3 should be used

B.2.3.14 For the case of a dominant permanent opening on a windward wall, an internal pressure coefficient of +0,6 shall be used.

B.2.3.15 Frictional wind forces shall be calculated using a friction coefficient c_f = 0,01. Frictional forces shall be calculated over the face area of side walls aligned parallel to the wind, excluding zones KK, LL, MM and NN shown in Figures B.9, B.10, B.12 and B.13. Frictional forces shall also be calculated over the face area of the roof for the 90° wind direction only, excluding zones EE and FF shown in Figures B.20, B.21, B.22 and B.23.

B.2.4 Ventilators

B.2.4.1 The reference height z_e for ventilators shall be taken to be equal to either:

- the reference height z_e in accordance with B.2.2.1 for greenhouses with planar pitched roofs or
- the reference height z_e in accordance with B.2.3.1 for greenhouses with vaulted roofs.

B.2.4.2 The net pressure coefficient $c_{p;net}$ of ventilators in the opened position shall be taken as $c_{p;net}$ = +1,25 and $c_{p;net}$ = -1,25.

B.2.5 Permeable cladding

For greenhouses covered with permeable cladding the external pressure coefficient c_{pe} and the internal pressure coefficient c_{pi} shall be determined from test results based on an appropriate method. In the absent of test data it is allowed to take the pressure coefficients for non-permeable clad greenhouses.

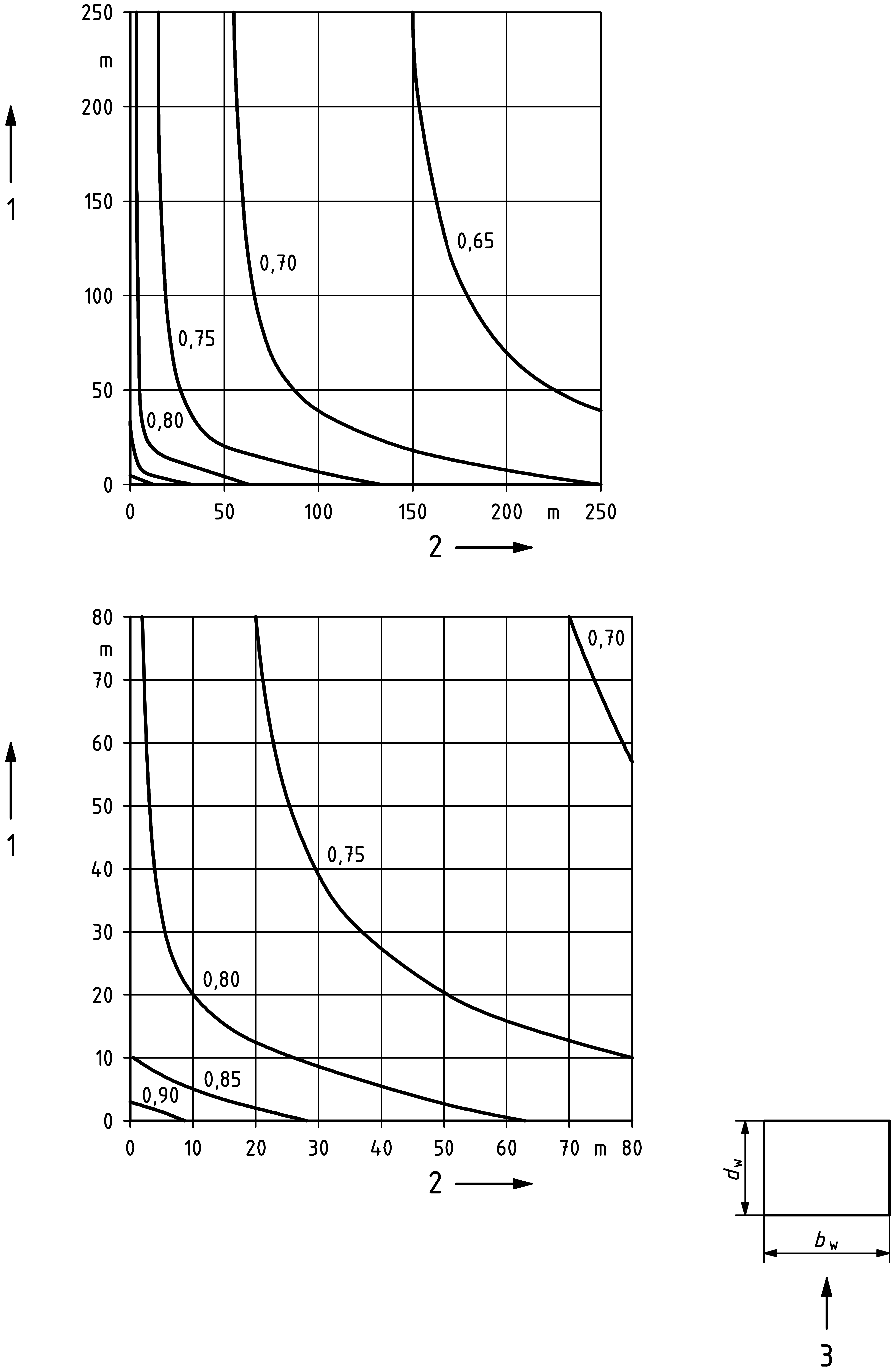
B.3 Dynamic coefficients for gust wind response

B.3.1 The dynamic coefficient for gust wind response, c_d, of cladding panels, cladding supporting profiles and their connections may be taken as c_d = 1,0.

B.3.2 Values of the dynamic coefficient for gust wind response, c_d, of bearing frames and bracings of greenhouses set out in Figure B.24 are based on typical values of the relevant parameters. This reduction is only allowed for horizontal forces if the structure is able to redistribute horizontal forces. The effect of expansion joints needs to be taken into account into the determination of length and width of the greenhouse.

NOTE In Figure B.24 the c_d values are given representing the following two phenomena:
Firstly the resonance of the structure due to the dynamic character of the wind. The high damping of the greenhouse results in a value for the dynamic amplification equal to 1,0.
Secondly the influence of the ratio between the size of the greenhouse and the dimensions of the gust. Dependant on the size of the greenhouse this phenomena results in a reduction of the wind action on the complete greenhouse structure.
The values for c_d given in Figure B.24 may be used in design for all reference wind speeds, for all terrain categories and for heights of the ridge not larger than 10 m.

B.3.3 Values of c_d for gutters, girders, ridges and structural component supporting gable walls and side walls of greenhouses may be taken to be c_d = 1,0.



NOTE Values of parameters used in Figure B.24:

(i) v_{ref} = 23 m/s

(ii) terrain category II

(iii) *H* = 5 m (height of ridge)

Key

1 Depth, d_w

2 Width, b_w

3 Wind direction

Figure B.24 - Dynamic coefficients for gust wind response of greenhouses

Annex C
(normative)

Snow actions

C.1 General

C.1.1 Snow actions shall be calculated in accordance with ENV 1991-2-3, but using the complementary information specific to greenhouses given in this annex.

C.1.2 The return period used to determine the ground snow load shall be taken as the minimum reference period conforming to Table 4.

C.1.3 A thermal coefficient C_t for greenhouses shall be taken in accordance with C.2, to account for the effect of heat loss through the roof.

C.1.4 Snow load shape coefficients μ_i for greenhouses shall be as given in C.3. In cases where the greenhouse is situated near to a building of different shape or height, redistribution of snow due to drifting and sliding shall be taken into account, in accordance with ENV 1991-2-3.

NOTE It is intended to replace this annex C by a reference to the forthcoming Eurocode on Snow actions for the calculation of snow actions. However, prior to making any reference to the forthcoming Eurocode on Snow actions this Eurocode should:
- be completed;
- be publicly available;
- be provided with appropriate data specific for greenhouses;
- demonstrate by calibration calculations the applicability for commercial greenhouses.

C.2 Thermal coefficient C_t

C.2.1 The thermal coefficient C_t reflects the effects of heat loss through the greenhouse roof and the reduction of snow load on the greenhouse roof as a result of this heat loss.

C.2.2 The reduction of snow load on the greenhouse roof is due to melting of the snow which is dependent on:

- heating of the greenhouse;

- thermal insulation (heat loss);

- thermal radiation;

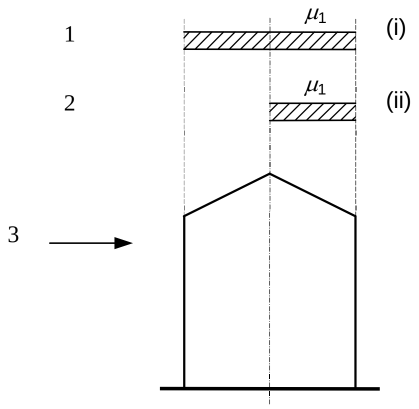
- regionally determined conditions such as wind conditions and rate of snowfall.

C.2.3 Thermal coefficients C_t are given in annex E.

C.3 Snow load shape coefficients

C.3.1 Duo pitched roofs

C.3.1.1 For duo pitched roofs two cases of snow loads shall be considered as shown in Figure C.1.



Key
1 Uniform load
2 Non-uniform load
3 Wind direction

Figure C.1 - Snow load shape coefficients for duo pitched roofs

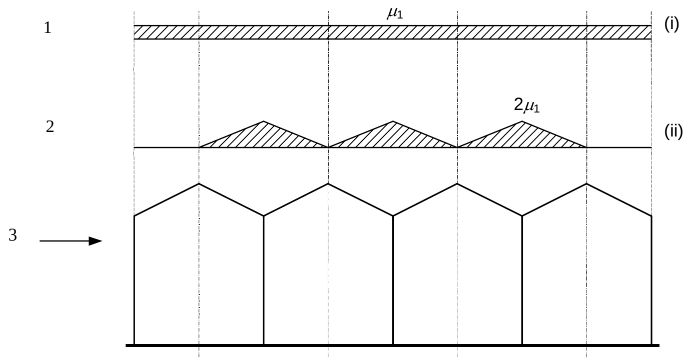
C.3.1.2 The values of the snow load shape coefficients μ_i for duo pitched roofs shall be as given in Table C.1.

Table C.1 - Snow load shape coefficients for duo pitched roofs

	Angle of pitch α		
	$0° \leq \alpha \leq 30°$	$30° < \alpha < 60°$	$\alpha \geq 60°$
Shape coefficient μ_1	0,8	0,8(60 - α)/30	0,0
NOTE α is the angle of pitch of the roof.			

C.3.2 Multipitch roofs

C.3.2.1 For multipitch roofs two cases of snow loads shall be considered as shown in Figure C.2.



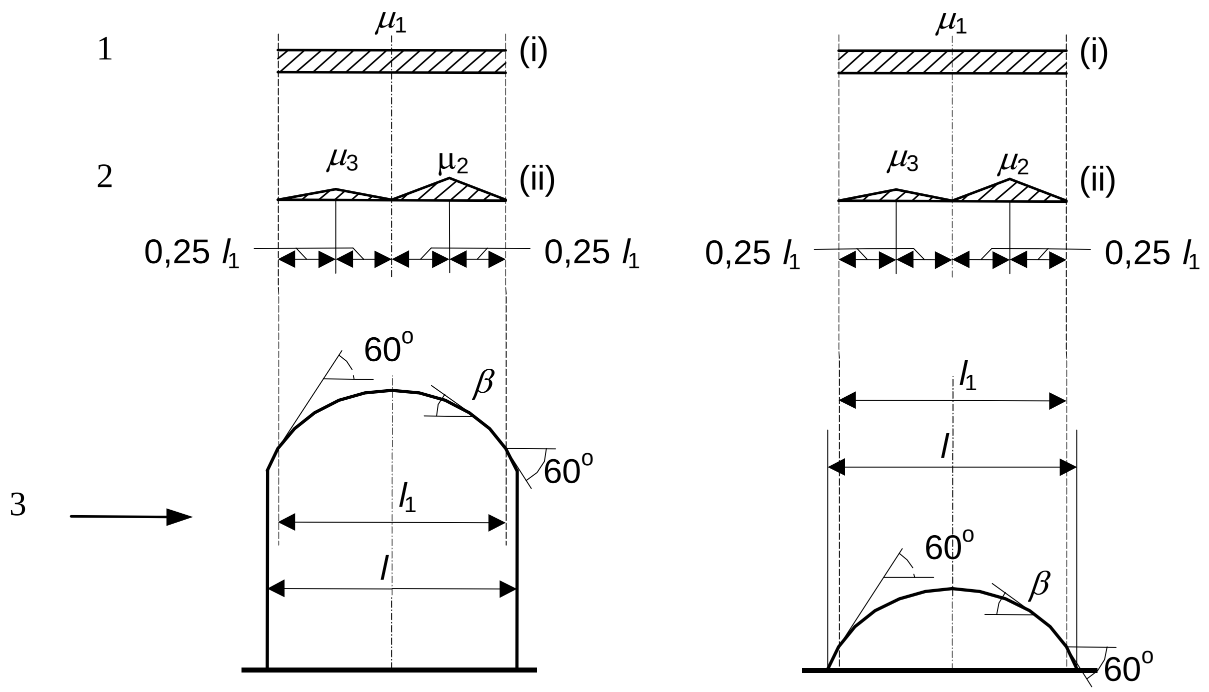
Key
1 Uniform load
2 Non-uniform load
3 Wind direction

Figure C.2 - Snow load shape coefficients for multipitch roofs

C.3.2.2 The value of the snow load shape coefficient μ_1 for multipitch roofs shall be taken to be:
$\mu_1 = 0,8$

C.3.3 Monospan arches

C.3.3.1 For monospan arches two cases of snow loads shall be considered as shown in Figure C.3.



Key
1 Uniform load
2 Asymmetric load
3 Wind direction

Figure C.3 - Snow load shape coefficients for monospan arches

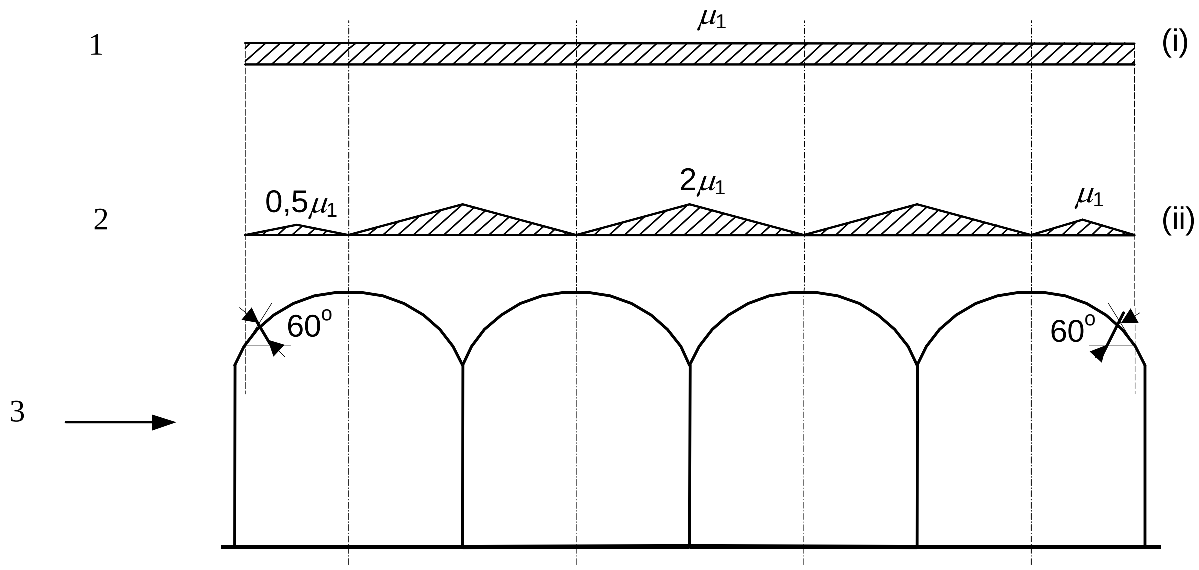
C.3.3.2 The values of the snow load shape coefficients μ_i for monospan arches shall be as given in Table C.2.

Table C.2 - Snow load shape coefficients for monospan arches

	Angle of pitch β	
	$0° \leq \beta \leq 60°$	$\beta > 60°$
Shape coefficient μ_1	0,8	0,0
Shape coefficient μ_2	$\mu_2 = 0,2 + 10\ h_r/l \leq 1,0$	
Shape coefficient μ_3	$\mu_3 = 0,5\ \mu_2$	
NOTE β is the angle of the arch tangent with the horizontal.		

C.3.4 Multispan arches

C.3.4.1 For multispan arches two cases of snow loads shall be considered as shown in Figure C.4.



Key
1 Uniform load
2 Non-uniform load
3 Wind direction

Figure C.4 - Snow load shape coefficients for multispan arches

C.3.4.2 The value of the snow load shape coefficient μ_1 for multispan arches shall be taken to be:

$\mu_1 = 0,8$

Annex D
(normative)

Ultimate limit states of arches

D.1 General

D.1.1 Arches shall be verified in accordance with the procedures described in ENV 1991-1. In the following subclauses of this annex these procedures are adapted to arches of greenhouses.

NOTE 1 The procedure described is necessary because ENV 1993-1-1 does not contain design rules for slender mono tubular arches (e.g. no rules given for geometrical imperfections, buckling lengths and amplified sway moment expressions for arches).
Any other procedure may be used provided that it takes account of imperfections and effects of the thin walled tubular sections specific for tubular steel arches of film plastic covered tunnels. The geometrical imperfections of tubular steel arches of film plastic covered tunnels are larger than those for normal buildings.

NOTE 2 The load distribution on the arch results from external actions on the film and the pretension in the film plastic. In annex I a procedure is given to determine the load distribution on the arch.

D.1.2 The ultimate limit state of arches shall be verified in accordance with one of the following methods of analysis:

- First order elastic and linear buckling (Euler buckling);
- Second order elastic;
- Second order elastic-plastic.

D.1.3 The requirements to be satisfied for each method of analysis are given in D.3 to D.5. These requirements for the ultimate limit states are summarised in Table D.1 and Figure D.1.

Table D.1 - Arch ultimate limit state requirements

Method of analysis in accordance with D.1.2	**Geometrical equivalent imperfections**	**Criteria to be checked**	
		Cross-section resistance	Stability
First order elastic and linear buckling [a]	Yes	Yes	$\lambda_{cr} \geq 3,6$
Second order elastic [b]	Yes	Yes	$\alpha_{cr} \geq 3,0$
Second order elastic-plastic [c]	Yes	No [d]	$\alpha_u \geq 1,0$

[a] See D.3 First order elastic and linear buckling (Euler buckling).
[b] See D.4 Second order elastic.
[c] See D.5 Second order elastic-plastic.
[d] The cross-section resistance is included in the analysis.

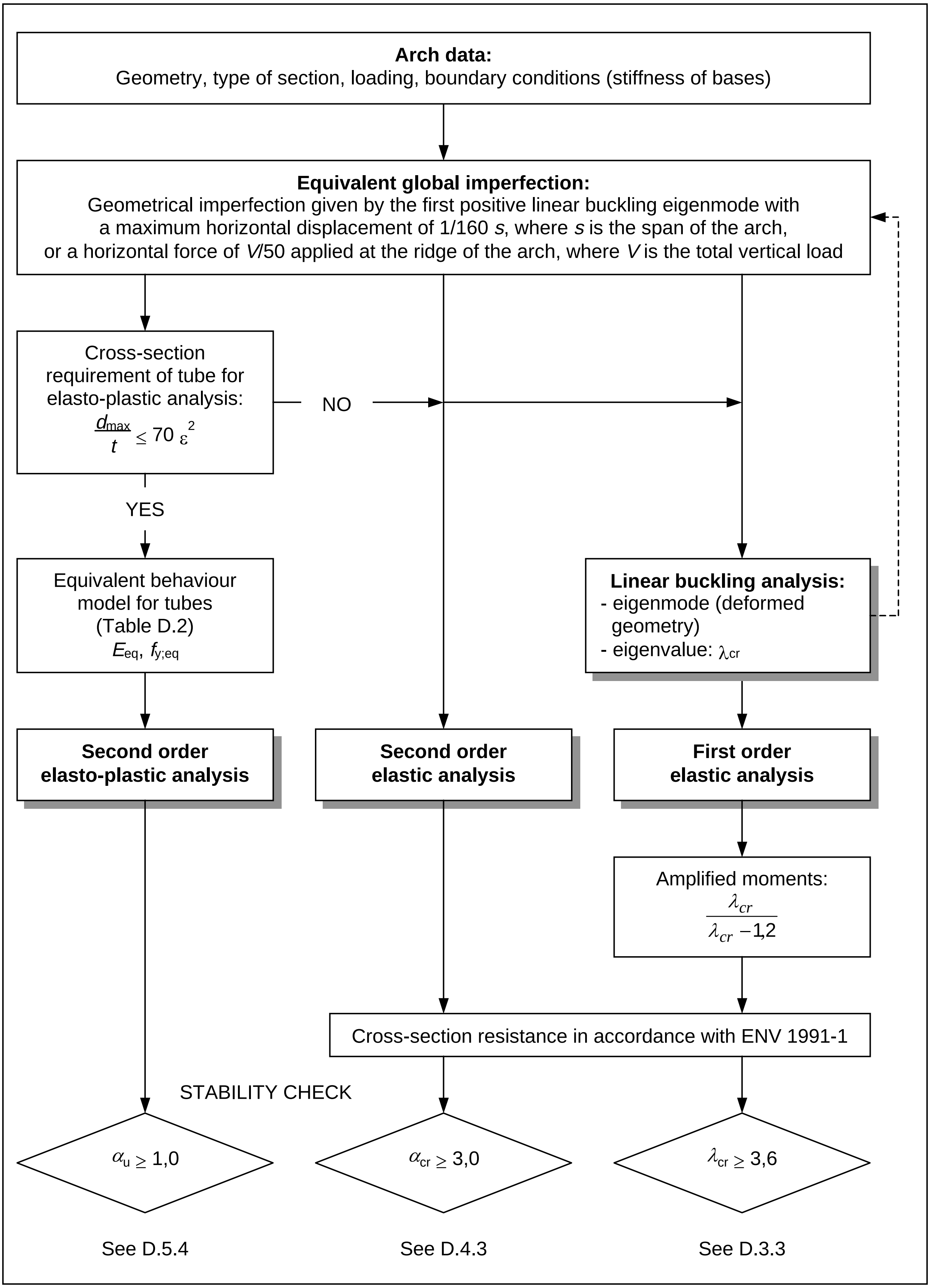


Figure D.1 - Design methodology for greenhouse arches

D.2 Equivalent imperfections

D.2.1 The effects of imperfections shall be taken into account in analysis by means of an equivalent geometric imperfection taken equal to the most unfavourable shape based on the first positive linear buckling eigenmode amplified by a factor. This amplification factor shall be taken in such a way that the maximum displacement of the equivalent geometric imperfection is equal to 1/160 *s*, where *s* is the span of the arch.

D.2.2 The geometrical equivalent imperfection may be replaced by an equivalent horizontal force applied at the crown of the arch. The value of this force shall be taken equal to 1/50 *V*, where *V* is the total vertical action applied to the arch.

D.3 First order elastic and linear buckling (Euler buckling)

D.3.1 For the first order elastic and the linear buckling (Euler buckling) analysis, equivalent imperfections as defined in D.2 shall to be taken into account.

D.3.2 The cross-section resistance shall be checked in accordance with 5.4 of ENV 1993-1-1:1992. In these verification rules the moment found by the first order elastic analysis shall be amplified by:

$$\frac{\lambda_{cr}}{\lambda_{cr} - 1{,}2}$$

where

λ_{cr} is the lowest positive eigenvalue from linear buckling analysis (Euler).

D.3.3 The load level at which the structure becomes unstable (lowest positive eigenvalue from linear buckling analysis) λ_{cr} shall meet the following requirement:

$\lambda_{cr} \geq 3{,}6$

D.4 Second order elastic

D.4.1 For the second order elastic analysis, an equivalent imperfections as defined in D.2 shall to be taken into account.

D.4.2 The cross-section resistance must be checked in accordance with D.6 and 5.4 of ENV 1993-1-1:1992.

D.4.3 The load level at which the structure becomes unstable (equilibrium divergence) α_{cr} shall meet the following requirement:

$\alpha_{cr} \geq 3{,}0$

D.5 Second order elastic-plastic

D.5.1 For the second order elastic-plastic analysis, an equivalent imperfections as defined in D.2 shall to be taken into account.

D.5.2 In order to use the second order elastic-plastic calculation method, the cross-section shall fulfil the requirement of subclause 5.3.3 of ENV 1993-1-1:1992.

D.5.3 For the specific case of thin tubular sections, the second order elastic-plastic calculation method shall be carried out in accordance with D.6, if the cross-section fulfils the requirements given in D.6.1, or shall be based on behaviour models resulting from experiments on the cross-section.

D.5.4 The load level at which the structure becomes unstable (elastic-plastic equilibrium divergence) α_u shall meet the following requirement:

$\alpha_u \geq 1{,}0$

D.6 Equivalent model for the behaviour of cross-sections of thin walled tubes

D.6.1 For circular sections and oval tubular sections with a ratio of the maximum and minimum outer diameter $d_{outer;max}/d_{outer;min} \leq 1{,}5$ and 50 mm $\leq d_{outer;max} \leq$ 70 mm, an equivalent behaviour model may be used for second order elastic-plastic analysis. This equivalent model, given in Table D.2, is based on an equivalent yield strength $f_{y;eq}$ and an equivalent modulus of elasticity E_{eq}.

Table D.2 - Equivalent model for the behaviour of the cross-section

Maximum diameter to thickness ratios d_{max}/t	Equivalent yield strength $f_{y;eq}$ and equivalent modulus of elasticity E_{eq}
$d_{max}/t \leq 25\ \varepsilon^2$	$E_{eq} = E$ $f_{y;eq} = f_y$
$25\ \varepsilon^2 < d_{max}/t \leq 50\ \varepsilon^2$	$E_{eq} = 0{,}85\ E$ $f_{y;eq} = f_y$
$50\ \varepsilon^2 < d_{max}/t \leq 70\ \varepsilon^2$	$E_{eq} = 0{,}85\ E$ $f_{y;eq} = f_y\ (f_{ref}/f_y)^{0{,}45}$
$70\ \varepsilon^2 \leq d_{max}/t$	No second order elastic-plastic analysis allowed

where:

d_{max} is the maximum outer diameter;

E is the modulus of elasticity for cold formed steel;

f_y is the average yield strength of the steel cross-section after cold forming and bending (for arches);

f_{ref} is the reference yield strength. For tubular sections: $f_{ref} = 11750\ (t/d_{max})$ in Newtons per millimetres (N/mm^2);

t is the wall thickness;

$\varepsilon = \sqrt{235/f_y}$

D.6.2 The resistance of cross-sections in case of bending and axial force for Class 1 and 2 cross-sections $(d_{max}/t) \leq 50\ \varepsilon^2$) of circular and oval tubular sections with $d_{outer;max}/d_{outer;min} \leq 1{,}5$ may be approximated by:

$$M_{N;Rd} = 1{,}20 M_{pl;Rd}\left(1 - \frac{N_{Sd}}{N_{pl;Rd}}\right) \quad \text{but} \quad M_{N;Rd} \leq M_{pl;Rd}$$

where

$M_{N;Rd}$ is the design value of the ultimate plastic resistance for moments of the cross-section reduced by the effects of normal forces;

$M_{pl;Rd}$ is the design value of the ultimate plastic resistance for moments of the cross-section;

N_{Sd} is the design value of the normal force due to actions;

$N_{pl;Rd}$ is the design value of the ultimate plastic resistance for normal forces of the cross-section.

Annex E
(normative)

Country related factors, coefficients and formulas

E.1 General

E.1.1 This annex gives the combinations of actions and numerical values for the partial factors, combination coefficients, temperature ranges, thermal coefficients and terrain categories and related parameters that shall be used.

NOTE In annex E information specific per CEN member state is given. In the absent of authorised information provided by CEN member states table E.1 gives default values.

E.1.2 Unless specified to the contrary by a CEN member state, the following combinations of actions, as defined in 10.2, shall be taken into account:

a1, a2, a3, b1, c1, c2, d1, d2, e1

E.1.3 Unless specified to the contrary by a CEN member state, the partial factors given in Table E.1 shall be used.

Table E.1 - Partial factors γ

Limit state classification		Serviceability limit states	Ultimate limit states
Name	Symbol		
Permanent actions	γ_{G1}	1,0	1,5/1,0 [a]
Permanently-present installation actions	γ_{G2}	1,0	1,5/1,0 [a]
Wind actions	γ_{Q1}	1,0	1,5
Snow actions	γ_{Q2}	1,0	1,5
Crop actions	γ_{Q3}	1,0	1,5
Concentrated vertical action	γ_{Q4}		1,5
Incidentally-present installation actions	γ_{Q5}	1,0	1,5
Thermal actions	γ_{Q6}	1,0	1,0
Seismic actions	γ_{AE}		1,0

[a] The higher value shall be used when G_k acts in the unfavourable sense, the lower value shall be used when G_k acts in the favourable sense.

NOTE In the table for partial factors γ a shaded area means that the partial factor γ does not exist in the combination of actions because that action is not considered in verifying the serviceability limit state.

E.1.4 Unless specified to the contrary by a CEN member state, the combination coefficients given in Table E.2 shall be used.

Table E.2 - Combination coefficients ψ

Combination of actions	Combination coefficients ψ			
	wind ψ_{0Q1}	snow ψ_{0Q2} or ψ_{2Q2}	crop ψ_{0Q3} or ψ_{2Q3}	incidentally-present installation ψ_{0Q5}
a1	-	1,0	1,0	
a2	0,0	-	1,0	
a2	1,0	-	1,0	
a3	1,0	1,0	-	
c1			1,0	1,0
d1			1,0	
d2		0,5	1,0	

NOTE In the table for combination coefficients ψ a shaded area means that the combination coefficient ψ does not exist in that combination of actions because that action is not considered in that combination of actions.
In the table for combination coefficients ψ a dash means that the combination coefficient ψ does not exist in that combination of actions because that action is the main action in that combination of actions.

E.1.5 Unless specified to the contrary by a CEN member state, the characteristic values for ranges in temperature given in Table E.3 shall be considered.

Table E.3 - Characteristic values for ranges in temperature within a period of 24 h

Structural component	**Temperature range within a period of 24 h**
Temperature ranges for gutters	a) 20 °C to 60 °C for dark coloured surfaces 20 °C to 40 °C for light coloured surfaces b) 20 °C to -10 °C
Temperature ranges structural component inside the greenhouse	a) 20 °C to 40 °C b) 20 °C to -10 °C

E.1.6 Unless specified to the contrary by a CEN member state, the thermal coefficients C_t given in Table E.4 shall be considered.

Table E.4 - Thermal coefficient C_t dependent on the roof cladding

Roof cladding	**Thermal coefficient C_t**	
	Heated greenhouses [a]	Unheated greenhouses
Single glass sheets	0,6	1,0
Sealed double-glazed panels	0,7	1,0
Single plastic sheets	0,6	1,0
Multi-layer plastic sheets	0,7	1,0
Single film-plastic layers	0,6	1,0
Double inflated layers	0,9	1,0

[a] Greenhouses may only be considered as heated in cases where heating equipment including an automatic back-up system capable of melting snow from the roof is present. Greenhouses with a warning system as well as an emergency electrical power supply system may be considered as heated. In other cases the greenhouse shall be considered as unheated.

E.1.7 Unless specified to the contrary by a CEN member state, the terrain categories and related parameters shall be taken from ENV 1991-2-4.

E.2 Belgium

E.2.1 For Belgium the following combinations of actions, as defined in 10.2, shall be taken into account:

a1, a2, b1, c1, c2, e1

E.2.2 For Belgium the partial factors shall be taken from Table E.5.

Table E.5 - Partial factors γ

Limit state classification		Serviceability limit states	Ultimate limit states
Name	Symbol		
Permanent actions	γ_{G1}	1,0	1,2/1,0 [a]
Permanently-present installation actions	γ_{G2}	1,0	1,2/1,0 [a]
Wind actions	γ_{Q1}	1,0	1,2
Snow actions	γ_{Q2}	1,0	1,2
Crop actions	γ_{Q3}	1,0	1,2
Concentrated vertical action	γ_{Q4}		1,2
Incidentally-present installation actions	γ_{Q5}	1,0	1,2
Thermal actions	γ_{Q6}	1,0	1,0
[a] The higher value shall be used when G_k acts in the unfavourable sense, the lower value shall be used when G_k acts in the favourable sense.			

E.2.3 For Belgium the combination coefficients shall be taken from Table E.6.

Table E.6 - Combination coefficients ψ

Combination of actions	Combination coefficients ψ			
	wind ψ_{0Q1}	snow ψ_{0Q2}	crop ψ_{0Q3}	incidentally-present installation ψ_{0Q5}
a1	-	0,0	1,0	
a2	0,0	-	0,0	
c1			1,0	0,0

E.2.4 For Belgium the characteristic values for ranges in temperature given in Table E.7 shall be considered.

Table E.7 - Characteristic values for ranges in temperature within a period of 24 h

Structural component	Temperature range within a period of 24 h
Temperature ranges for gutters	a) 20 °C to 60 °C for dark coloured surfaces 20 °C to 40 °C for light coloured surfaces b) -10 °C to 20 °C [a]
Temperature ranges structural component inside the greenhouse	a) 20 °C to 40 °C b) 0 °C to 20 °C
[a] The value of -10 °C may be chosen differently, based on the actual thermal behaviour of the gutter profile, which can be influenced by the use of insulation material.	

E.2.5 For Belgium the thermal coefficients C_t given in Table E.8 shall be considered.

Table E.8 - Thermal coefficient C_t dependent on the roof cladding

Roof cladding	**Thermal coefficient C_t**	
	Heated greenhouses [a]	Unheated greenhouses
Single glass sheets	0,5	1,0
Sealed double-glazed panels	0,6	1,0
Single plastic sheets	0,5	1,0
Multi-layer plastic sheets	0,6	1,0
Single film-plastic layers	0,5	1,0
Double inflated layers	0,8	1,0

[a] Greenhouses may only be considered as heated in cases where heating equipment including an automatic back-up system capable of melting snow from the roof is present. Greenhouses with a warning system as well as an emergency electrical power supply system may be considered as heated. In other cases the greenhouse shall be considered as unheated.

E.2.6 For Belgium the terrain categories and related parameters for wind actions shall be taken as given in Table E.9.

Table E.9 - Terrain categories and related parameters

Terrain category	k_T	z_0 **[m]**	z_{min} **[m]**	ε
Greenhouses in Belgium	0,208	0,2	2	0,35

E.3 Finland

E.3.1 For Finland the following combinations of actions, as defined in 10.2, shall be taken into account:

a1, a2, a3, b1, c1, c2, e1, f1

E.3.2 For Finland the partial factors shall be taken from Table E.10.

Table E.10 - Partial factors γ

Limit state classification		Serviceability limit states	Ultimate limit states
Name	Symbol		
Permanent actions	γ_{G1}	1,0	1,2/1,0 [a]
Permanently-present installation actions	γ_{G2}	1,0	1,2/1,0 [a]
Wind actions	γ_{Q1}	1,0	1,5
Snow actions	γ_{Q2}	1,0	1,5
Crop actions	γ_{Q3}	1,0	1,5
Concentrated vertical action	γ_{Q4}		1,5
Incidentally-present installation actions	γ_{Q5}	1,0	1,0
Thermal actions	γ_{Q6}	1,0	1,0

[a] The higher value shall be used when G_k acts in the unfavourable sense, the lower value shall be used when G_k acts in the favourable sense.

E.3.3 For Finland the combination coefficients shall be taken from Table E.11.

Table E.11 - Combination coefficients ψ

Combination of actions	Combination coefficients ψ			
	wind ψ_{0Q1}	snow ψ_{0Q2}	crop ψ_{0Q3}	incidentally-present installation ψ_{0Q5}
a1	-	0,6	1,0	
a2	0,25	-	0,2	
a2	0,5	-	0,5	
a3	0,25	0,6	-	
c1			1,0	0,6
f1			1,0	

E.3.4 For Finland the characteristic values for ranges in temperature given in Table E.12 shall be considered.

Table E.12 - Characteristic values for ranges in temperature within a period of 24 h

Structural component	Temperature range within a period of 24 h
Temperature ranges for gutters	a) 20 °C to 60 °C for dark coloured surfaces 20 °C to 40 °C for light coloured surfaces b) 20 °C to -40 °C
Temperature ranges structural component inside the greenhouse	a) 20 °C to 40 °C b) 20 °C to -20 °C

E.3.5 For Finland the thermal coefficients C_t given in Table E.13 shall be considered.

Table E.13 - Thermal coefficient C_t dependent on the roof cladding

Roof cladding	**Thermal coefficient C_t**	
	Heated greenhouses [a b]	Unheated greenhouses
Single glass sheets	0,45	1,0
Sealed double-glazed panels	0,55	1,0
Single plastic sheets	0,45	1,0
Multi-layer plastic sheets	0,55	1,0
Single film-plastic layers	0,45	1,0
Double inflated layers	0,60	1,0

[a] Greenhouses may only be considered as heated in cases where heating equipment including an automatic back-up system capable of melting snow from the roof is present. Greenhouses with a warning system as well as an emergency electrical power supply system may be considered as heated. In other cases the greenhouse shall be considered as unheated.

[b] For values of thermal coefficients it is assumed that the lowest inside temperature in a heated greenhouse is 10 °C and roof structure is duo pitched 27 °C.

E.3.6 The ground snow load for Finland with a return period of *n* years shall be calculated from:

$$s_n = s_k \left[0{,}0564 - 0{,}5554 \log_{10} \left(\frac{1}{n} \right) \right],$$

where

s_n is the ground snow load with a return period of n years;

s_k is the ground snow load with a return period of 50 years;

n is the return period.

E.3.7 For Finland the snow load on the roof of a heated greenhouse may be reduced using an exposure coefficient C_e equal to 0,5.

E.4 France

E.4.1 For France the following combinations of actions, as defined in 10.2, shall be taken into account:

- ULS (Ultimate limit state): a1, a2, a3, b1, c1, c2, e1, f1
- SLS (Serviceability limit state): a1, a2, a3, b1, c1, c2, e1

E.4.2 For France the partial factors shall be taken from Table E.14.

Table E.14 - Partial factors γ

Limit state classification		Serviceability limit states	Ultimate limit states
Name	Symbol		
Permanent actions	γ_{G1}	1,0	1,0
Permanently-present installation actions	γ_{G2}	1,0	1,2
Wind actions	γ_{Q1}	1,0	1,2
Snow actions	γ_{Q2}	1,0	1,2
Crop actions	γ_{Q3}	1,0	1,2
Concentrated vertical action	γ_{Q4}		1,0
Incidentally-present installation actions	γ_{Q5}	1,0	1,2
Thermal actions	γ_{Q6}	1,0	1,0
Accidental snow actions	γ_{A}		0,8

E.4.3 For France the combination coefficients shall be taken from Table E.15.

Table E.15 - Combination coefficients ψ

Combination of actions	Combination coefficients ψ			
	wind ψ_{0Q1}	snow ψ_{0Q2} or ψ_{2Q2}	crop ψ_{0Q3}, ψ_{1Q3} or ψ_{2Q3}	incidentally-present installation ψ_{0Q5}
a1	-	0,6	1,0 [a]	
a2	0,0	-	1,0 [a]	
a2	0,6	-	1,0 [a]	
a3	0,6	0,6 [a]	-	
c1			1,0	0,6
f1			1,0 [a]	

[a] For Class B5 greenhouses , the loads linked to Qk3 (crop actions) have not to be taken into account in the combination a1, a2, a3, and f1.

E.4.4 For France the thermal coefficients C_t given in Table E.16 shall be considered.

Table E.16 - Thermal coefficient C_t dependent on the roof cladding

Roof cladding	Thermal coefficient C_t	
	Heated greenhouses [a]	Unheated greenhouses
Single glass sheets	1,0	1,0
Sealed double-glazed panels	1,0	1,0
Single plastic sheets	1,0	1,0
Multi-layer plastic sheets	1,0	1,0
Single film-plastic layers	1,0	1,0
Double inflated layers	1,0	1,0

[a] Greenhouses may only be considered as heated in cases where heating equipment including an automatic back-up system capable of melting snow from the roof is present. Greenhouses with a warning system as well as an emergency electrical power supply system may be considered as heated. In other cases the greenhouse shall be considered as unheated.

E.4.5 The ground snow load for France with a return period of *n* years shall be calculated from:

$$s_n = s_k\left[0{,}0564 - 0{,}5554\,\log_{10}\left(\frac{1}{n}\right)\right],$$

where

s_n is the ground snow load with a return period of *n* years;

s_k is the ground snow load with a return period of 50 years;

n is the return period.

E.4.6 For France the geographical zones for snow loads shall be taken in accordance with ENV 1991-2-3, but adapted using the complementary information specific to greenhouses given in Table E.17.

Table E.17 - Geographical zones for snow loads on greenhouses

Snow zone	Department	Canton
1A	In accordance with ENV 1991-2-3	In accordance with ENV 1991-2-3
1B	In accordance with ENV 1991-2-3	In accordance with ENV 1991-2-3
2A	In accordance with ENV 1991-2-3	In accordance with ENV 1991-2-3
2B	In accordance with ENV 1991-2-3	In accordance with ENV 1991-2-3
3	In accordance with ENV 1991-2-3	In accordance with ENV 1991-2-3
4	In accordance with ENV 1991-2-3	In accordance with ENV 1991-2-3

E.4.7 For France the reference wind velocity $v_{ref}(p)$ for annual probabilities of exceedence *p* shall be calculated according to ENV 1991-2-4 using $K_1 = 0{,}33$.

E.4.8 For France the terrain categories and related parameters for wind actions shall be taken as given in Table E.18. In addition, wichever the dimension of the greenhouse, the dynamic coefficient for gust wind reponse c_d defined in B.3 must not be lower than 0.75.

Table E.18 - Terrain categories and related parameters

Terrain category		$k_T = k_r$	z_0 [m]	z_{min} [m]	ε
I	Greenhouses situated at a distance less than 2 km from the open sea or a lake (only lakes where the wind covers a distance of at least 5 km are concerned)	0,16	0,045	1	0,13
II	Greenhouses situated in terrain category other than as specified in category I (Farmland, suburban)	0,21	0,32	2	0,32

E.5 Germany

E.5.1 For Germany the following combinations of actions, as defined in 10.2, shall be taken into account:

a1, a2, b1, c1, d1, e1

E.5.2 For Germany the partial factors shall be taken from Table E.19.

Table E.19 - Partial factors γ

Limit state classification		Serviceability limit states	Ultimate limit states
Name	Symbol		
Permanent actions	γ_{G1}	1,0	1,2/1,0 [a]
Permanently-present installation actions	γ_{G2}	1,0	1,2/1,0 [a]
Wind actions	γ_{Q1}	1,0	1,2
Snow actions	γ_{Q2}	1,0	1,2
Crop actions	γ_{Q3}	1,0	1,2
Concentrated vertical action	γ_{Q4}		1,2
Incidentally-present installation actions	γ_{Q5}	1,0	1,2
Thermal actions	γ_{Q6}	1,0	1,0
Seismic actions	γ_{AE}		1,0

[a] The higher value shall be used when G_k acts in the unfavourable sense, the lower value shall be used when G_k acts in the favourable sense.

E.5.3 For Germany the combination coefficients shall be taken from Table E.20.

Table E.20 - Combination coefficients ψ

Combination of actions	Combination coefficients ψ			
	wind ψ_{0Q1}	snow ψ_{0Q2}	crop ψ_{0Q3}	incidentally-present installation ψ_{0Q5}
a1	-	0,0	1,0	
a2	0,0	-	0,0	
c1			1,0	0,0
d1 [a]			0,6	

[a] Only in seismic zones.

E.5.4 For Germany the snow actions according to ENV 1991-2-3 may be multiplied by a reduction factor according to Table E.21 to take into account the maximum day-rate for the snowfall.

Table E.21 - Reduction factor for maximum day-rate of the snowfall

National snow-zone	I	II	III	IV
Reduction factor	0,6	0,5	0,4	0,3

E.5.5 For Germany the thermal coefficients C_t given in Table E.22 shall be considered.

Table E.22 - Thermal coefficient C_t dependent on the roof cladding

Roof cladding	**Thermal coefficient C_t**		
	Maximum heated greenhouses [b]	Regular heated greenhouses [a]	Unheated greenhouses
Single glass sheets	0,3	0,6	1,0
Sealed double-glazed panels	0,4	0,7	1,0
Single plastic sheets	0,3	0,6	1,0
Multi-layer plastic sheets	0,4	0,7	1,0
Single film-plastic layers	0,3	0,6	1,0
Double inflated layers	0,4	0,7	1,0

[a] The lowest inside temperature is 12 °C (single sheets) or 17 °C (double/multi sheets).
[b] In case of snowfall the heating system shall be switched to full power (through a snow sensor).

E.5.6 The ground snow load for Germany with a return period of n years shall be calculated from:

$$s_n = s_k \left[0{,}0564 - 0{,}5554 \log_{10} \left(\frac{1}{n} \right) \right],$$

where

s_n is the ground snow load with a return period of n years;

s_k is the ground snow load with a return period of 50 years;

n is the return period.

The minimum snow load is 250 N/m^2.

E.5.7 For Germany the reference wind velocity v_{ref} according to ENV 1991-2-4 and the resulting reference impact pressure q_{ref} for different minimum design working life and wind zones can be taken from table E.23. For the specific density of the air a simplified value of 1,25 kg/m^3 can be used.

Table E.23:reference wind velocity and reference impact pressure

wind zone	Zone 1		Zone 2		Zone 3	
Minimum Design working life	v_{ref} [m/s]	q_{ref} [N/m^2]	v_{ref} [m/s]	q_{ref} [N/m^2]	v_{ref} [m/s]	q_{ref} [N/m^2]
50 years (informative)	24,3	369	27,6	476	32,0	640
15 years	22,5	316	25,5	408	29,6	548
10 years	21,9	301	24,9	388	28,9	521
5 years	20,8	269	23,6	348	27,3	467

E.6 Greece

E.6.1 For Greece the following combinations of actions, as defined in 10.2, shall be taken into account:

a1, a2, a3, b1, c1, d1, d2, e1

E.6.2 For Greece the partial factors shall be taken from Table E.24.

Table E.24 - Partial factors γ

Limit state classification		Serviceability limit states	Ultimate limit states
Name	Symbol		
Permanent actions	γ_{G1}	1,0	1,2/1,0 [a]
Permanently-present installation actions	γ_{G2}	1,0	1,2/1,0 [a]
Wind actions	γ_{Q1}	1,0	1,2/0,0
Snow actions	γ_{Q2}	1,0	1,2/0,0
Crop actions	γ_{Q3}	1,0	1,2/0,0
Concentrated vertical action	γ_{Q4}		1,2/0,0
Incidentally-present installation actions	γ_{Q5}	1,0	1,2/0,0
Thermal actions	γ_{Q6}	1,0	1,0/0,0
Seismic actions	γ_{AE}		0,8/0,0

[a] The higher value shall be used when G_k acts in the unfavourable sense, the lower value shall be used when G_k acts in the favourable sense.

E.6.3 For Greece the combination coefficients shall be taken from Table E.25.

Table E.25 - Combination coefficients ψ

Combination of actions	Combination coefficients ψ			
	wind ψ_{0Q1}	snow ψ_{0Q2}	crop ψ_{0Q3} or ψ_{2Q3}	incidentally-present installation ψ_{0Q5}
a1	-	0,6/0,0	1,0/0,0	
a2	0,6/0,0	-	1,0/0,0	
a3	0,6/0,0	0,6/0,0	-	
c1			1,0/0,0	0,0
d1 [a]			1,0/0,0	
d2 [a]		0,3	1,0/0,0	

[a] Only in seismic zones.

E.7 Italy

E.7.1 For Italy the following combinations of actions, as defined in 10.2, shall be taken into account:

a1, a2, a3, b1, c1, c2, d1, d2, e1

E.7.2 For Italy the partial factors shall be taken from Table E.26.

Table E.26 - Partial factors γ

Limit state classification		Serviceability limit states	Ultimate limit states
Name	Symbol		
Permanent actions	γ_{G1}	1,0	1,2/1,0 [a]
Permanently-present installation actions	γ_{G2}	1,0	1,2/1,0 [a]
Wind actions	γ_{Q1}	1,0	1,2
Snow actions	γ_{Q2}	1,0	1,2
Crop actions	γ_{Q3}	1,0	1,2
Concentrated vertical action	γ_{Q4}		1,2
Incidentally-present installation actions	γ_{Q5}	1,0	1,2
Thermal actions	γ_{Q6}	1,0	1,0
Seismic actions	γ_{AE}		1,0

[a] The higher value shall be used when G_k acts in the unfavourable sense, the lower value shall be used when G_k acts in the favourable sense.

E.7.3 For Italy the combination coefficients shall be taken from Table E.27.

Table E.27 - Combination coefficients ψ

Combination of actions	Combination coefficients ψ			
	wind ψ_{0Q1}	snow ψ_{0Q2}	crop ψ_{0Q3} or ψ_{2Q3}	incidentally-present installation ψ_{0Q5}
a1	-	0,6	1,0	
a2	0,0	-	1,0	
a2	0,6	-	1,0	
a3	0,8	0,8	-	
c1			1,0	0,0
d1			1,0	
d2		0,5	1,0	

E.8 The Netherlands

E.8.1 For The Netherlands the following combinations of actions, as defined in 10.2, shall be taken into account:

a1, a2, b1, c1, c2, e1

E.8.2 For The Netherlands the partial factors shall be taken from Table E.28.

Table E.28 - Partial factors γ

Limit state classification		Serviceability limit states	Ultimate limit states
Name	Symbol		
Permanent actions	γ_{G1}	1,0	1,2/1,0 [a]
Permanently-present installation actions	γ_{G2}	1,0	1,2/1,0 [a]
Wind actions	γ_{Q1}	1,0	1,2
Snow actions	γ_{Q2}	1,0	1,2
Crop actions	γ_{Q3}	1,0	1,2
Concentrated vertical action	γ_{Q4}		1,2
Incidentally-present installation actions	γ_{Q5}	1,0	1,2
Thermal actions	γ_{Q6}	1,0	1,0

[a] The higher value shall be used when G_k acts in the unfavourable sense, the lower value shall be used when G_k acts in the favourable sense.

E.8.3 For The Netherlands the combination coefficients shall be taken from Table E.29.

Table E.29 - Combination coefficients ψ

Combination of actions	Combination coefficients ψ			
	wind ψ_{0Q1}	snow ψ_{0Q2}	crop ψ_{0Q3}	incidentally-present installation ψ_{0Q5}
a1	-	0,0	1,0	
a2	0,0	-	0,0	
c1			1,0	0,0

E.8.4 For The Netherlands the characteristic values for ranges in temperature given in Table E.30 shall be considered.

Table E.30 - Characteristic values for ranges in temperature within a period of 24 h

Structural component	Temperature range within a period of 24 h
Temperature ranges for gutters	a) 20 °C to 60 °C for dark coloured surfaces 20 °C to 40 °C for light coloured surfaces b) -10 °C to 20 °C [a]
Temperature ranges structural component inside the greenhouse	a) 20 °C to 40 °C b) 0 °C to 20 °C

[a] The value of -10 °C may be chosen differently, based on the actual thermal behaviour of the gutter profile, which can be influenced by the use of insulation material.

E.8.5 For The Netherlands the thermal coefficients C_t given in Table E.31 shall be considered.

Table E.31 - Thermal coefficient C_t dependent on the roof cladding

Roof cladding	Thermal coefficient C_t	
	Heated greenhouses [a]	Unheated greenhouses
Single glass sheets	0,5	1,0
Sealed double-glazed panels	0,6	1,0
Single plastic sheets	0,5	1,0
Multi-layer plastic sheets	0,6	1,0
Single film-plastic layers	0,5	1,0
Double inflated layers	0,8	1,0

[a] Greenhouses may only be considered as heated in cases where heating equipment including an automatic back-up system capable of melting snow from the roof is present. Greenhouses with a warning system as well as an emergency electrical power supply system may be considered as heated. In other cases the greenhouse shall be considered as unheated.

E.8.6 For The Netherlands the reference wind speed with a return period of 50 years shall be taken to be:

v_{ref} = 27,3 m/s and the shape parameter K_1 to be taken as 0,243.

E.8.7 For The Netherlands the terrain categories and related parameters for wind actions shall be taken as given in Table E.32.

Table E.32 - Terrain categories and related parameters

Terrain category	k_T	z_0 [m]	z_{min} [m]	ε
I Greenhouses in The Netherlands	0,208	0,2	2	0,35

E.9 Norway

E.9.1 For Norway the following combinations of actions, as defined in 10.2, shall be taken into account:

a1, a2, b1, c1, c2, e1

E.9.2 For Norway the partial factors shall be taken from Table E.33.

Table E.33 - Partial factors γ

Limit state classification		Serviceability limit states	Ultimate limit states
Name	Symbol		
Permanent actions	γ_{G1}	1,0	1,2/1,0 [a]
Permanently-present installation actions	γ_{G2}	1,0	1,2/1,0 [a]
Wind actions	γ_{Q1}	1,0	1,2
Snow actions	γ_{Q2}	1,0	1,2
Crop actions	γ_{Q3}	1,0	1,5
Concentrated vertical action	γ_{Q4}		1,5
Incidentally-present installation actions	γ_{Q5}	1,0	1,2
Thermal actions	γ_{Q6}	1,0	1,0

[a] The higher value shall be used when G_k acts in the unfavourable sense, the lower value shall be used when G_k acts in the favourable sense.

E.9.3 For Norway the combination coefficients shall be taken from Table E.34.

Table E.34 - Combination coefficients ψ

Combination of actions	Combination coefficients ψ			
	wind ψ_{0Q1}	snow ψ_{0Q2}	crop ψ_{0Q3}	incidentally-present installation ψ_{0Q5}
a1	-	0,6	1,0	
a2	0,0	-	0,0	
a2	0,6	-	1,0	
c1			1,0	0,6

E.9.4 For Norway, in greenhouses where the combination of the heating system, the U-value of roof cladding, and the possibility for snow to slide off is such that the user can clear the roof of snow within one day after the most recent snowfall, the thermal coefficient C_t may be taken to be equal to 0,2 if the following requirements are fulfilled:

- the roof cladding shall have a U-value of 3,0 W/m^{2}K or more (surface resistance to outside air not taken into account);

- the heating system shall be able to bring the inside air temperature to 18 °C at any time of the year;

- the roof pitch shall be more than 15°;

- no obstacles prevent snow from sliding off the roof;

- internal gutters of multispan greenhouses shall be heated sufficiently so that snow sliding into these gutters will melt within one day after the end of a snowfall;

- the water downlets of multispan greenhouses are secured against freezing;

- the resulting snow load s (= $\mu C_t s_o$) shall be taken not less than 500 N/m^2.

E.9.5 Where any of the requirements in E.9.4 are not met, the thermal coefficient C_t shall be taken from Table E.35, considering that the resulting snow load s (= $\mu\ C_t\ s_o$) shall be taken not smaller than 500 N/m^2, that internal gutters of multispan greenhouses are heated sufficiently that snow sliding into them will melt and that the water downlets of multi-span greenhouses are protected against freezing.

Table E.35 - Thermal coefficient C_t dependent on the roof cladding

Roof cladding	Thermal coefficient C_t	
	Heated greenhouses [a]	Unheated greenhouses
Single glass sheets	0,5	1,0
Sealed double-glazed panels	0,7	1,0
Single plastic sheets	0,5	1,0
Multi-layer plastic sheets	0,7	1,0
Single film-plastic layers	0,6	1,0
Double inflated layers	0,8	1,0

[a] Greenhouses may only be considered as heated in cases where heating equipment including an automatic back-up system capable of melting snow from the roof is present. Greenhouses with a warning system as well as an emergency electrical power supply system may be considered as heated. In other cases the greenhouse shall be considered as unheated.

E.9.6 For Norway the characteristic values for ranges in temperature given in Table E.36 shall be considered.

Table E.36 - Characteristic values for ranges in temperature within a period of 24 h

Structural component	Temperature range within a period of 24 h
temperature ranges for gutters	a) 20 °C to 60 °C for dark coloured surfaces 20 °C to 40 °C for light coloured surfaces b) -20 °C to 20 °C
temperature ranges structural component inside the greenhouse	a) 10 °C to 40 °C

E.10 Portugal

E.10.1 For Portugal the following combinations of actions, as defined in 10.2, shall be taken into account:

a1, a2, a3, b1, c1, c2

E.10.2 For Portugal the partial factors shall be taken from Table E.37.

Table E.37 - Partial factors γ

Limit state classification		Serviceability limit states	Ultimate limit states
Name	Symbol		
Permanent actions	γ_{G1}	1,0	1,2/1,0 [a]
Permanently-present installation actions	γ_{G2}	1,0	1,2/1,0 [a]
Wind actions	γ_{Q1}	1,0	1,2
Snow actions	γ_{Q2}	1,0	1,2
Crop actions	γ_{Q3}	1,0	1,2
Concentrated vertical action	γ_{Q4}		1,2
Incidentally-present installation actions	γ_{Q5}	1,0	1,2
Thermal actions	γ_{Q6}	1,0	1,0

[a] The higher value shall be used when G_k acts in the unfavourable sense, the lower value shall be used when G_k acts in the favourable sense.

E.10.3 For Portugal the combination coefficients shall be taken from Table E.38.

Table E.38 - Combination coefficients ψ

Combination of actions	Combination coefficients ψ			
	wind ψ_{0Q1}	snow ψ_{0Q2}	crop ψ_{0Q3}	incidentally-present installation ψ_{0Q5}
a1	-	0,6	1,0	
a2	0,0	-	1,0	
a2	0,6	-	1,0	
a3	0,6	0,6	-	
c1			1,0	0,6

E.11 Spain

E.11.1 For Spain the following combinations of actions, as defined in 10.2, shall be taken into account:

a1, a2, a3, b1, c1, c2

E.11.2 For Spain the partial factors shall be taken from Table E.39.

Table E.39 - Partial factors γ

Limit state classification		Serviceability limit states	Ultimate limit states
Name	Symbol		
Permanent actions	γ_{G1}	1,0	1,2/1,0 [a]
Permanently-present installation actions	γ_{G2}	1,0	1,2/1,0 [a]
Wind actions	γ_{Q1}	1,0	1,2
Snow actions	γ_{Q2}	1,0	1,2
Crop actions	γ_{Q3}	1,0	1,2
Concentrated vertical action	γ_{Q4}		1,2
Incidentally-present installation actions	γ_{Q5}	1,0	1,2

[a] The higher value shall be used when G_k acts in the unfavourable sense, the lower value shall be used when G_k acts in the favourable sense.

E.11.3 For Spain the combination coefficients shall be taken from Table E.40.

Table E.40 - Combination coefficients ψ

Combination of actions	Combination coefficients ψ			
	wind ψ_{0Q1}	snow ψ_{0Q2}	crop ψ_{0Q3}	incidentally-present installation ψ_{0Q5}
a1	-	0,5	1,0	
a2	0,0	-	1,0	
a3	1,0	0,0	-	
c1			1,0	0,6

E.12 United Kingdom

E.12.1 For United Kingdom the following combinations of actions, partial factors and combination coefficients are valid for greenhouses used for professional production of plants and crops, where human access is restricted to low levels of authorised personnel to the inside of the greenhouse (for the tending and harvesting of the crop), and to within an area to the outside of the greenhouse in any direction, extending 1,5 times the overall height of the greenhouse.

E.12.2 For United Kingdom the following combinations of actions, as defined in 10.2, shall be taken into account:

a1, a2, a3, b1, c1, c2, e1

E.12.3 For United Kingdom the partial factors shall be taken from Table E.41.

Table E.41 - Partial factors γ

Limit state classification		Serviceability limit states	Ultimate limit states
Name	Symbol		
Permanent actions	γ_{G1}	1,0	1,2/1,0 [a]
Permanently-present installation actions	γ_{G2}	1,0	1,2/1,0 [a]
Wind actions	γ_{Q1}	1,0	1,2
Snow actions	γ_{Q2}	1,0	1,2
Crop actions	γ_{Q3}	1,0	1,2
Concentrated vertical action	γ_{Q4}		1,2
Incidentally-present installation actions	γ_{Q5}	1,0	1,2
Thermal actions	γ_{Q6}	1,0	1,0

[a] The higher value shall be used when G_k acts in the unfavourable sense, the lower value shall be used when G_k acts in the favourable sense.

E.12.4 For United Kingdom the combination coefficients shall be taken from Table E.42.

Table E.42 - Combination coefficients ψ

Combination of actions	**Combination coefficients ψ**			
	wind ψ_{0Q1}	snow ψ_{0Q2}	crop ψ_{0Q3}	incidentally-present installation ψ_{0Q5}
a1	-	0,6	0,5	
a2	0,0	-	0,5	
a2	0,6	-	0,5	
a3	0,6	0,6	-	
c1			0,5	0,6

E.12.5 For United Kingdom the minimum reference height z_{min} shall be taken to be 2 m for all terrain categories.

Annex F
(normative)

Owner's manual and identification plaque

F.1 General

F.1.1 The contractor shall supply a manual as specified in F.2 with each greenhouse to the owner.

F.1.2 An identification plaque shall be installed inside the greenhouse as specified in F.3

F.2 Owner's manual

The following information shall be included in the owner's manual:

- the Class of greenhouse;
- the manufacturer;
- the erection date (delivery date if the greenhouse is erected by the owner);
- the covered area;
- the place where the greenhouse is designed for (optional);
- design characteristic actions;
- whether a cleaning machine can be carried on the roof;
- specifications for foundations or anchoring (in cases where the greenhouse is not constructed by the manufacturer);
- instructions for maintenance and repair, as an example, see instructions given in annex G informative;
- instructions for maintaining the durability (definition of any maintenance procedures implicit in maintaining the durability of the greenhouse throughout its working life);
- instructions that openable ventilators should be closed whenever the wind speed exceeds '*x*' m/s, where '*x*' corresponds to 65 % of the reference wind velocity but corrected to the height above ground and time average period for which meteorological information on wind speeds is normally given in the country in which the greenhouse is to be erected;
- instructions that in case where the design is based on the phenomena that heating relieves snow loading the heating system and its automatic back-up system shall be serviceable and enabled to operate at all times snow may fall, even if the greenhouse is empty;
- instructions about the deflections of wires loaded by crop. It is recommended to take the deflection of the loaded wire at least larger than the distance between the wire supports divided by 30 at a load level of 0,15 kN/m^2;
- a note saying that this greenhouse has been designed in accordance with EN 13031-1 "Greenhouses: Design and construction - Part 1: Commercial production greenhouses".

F.3 Identification plaque

F.3.1 For Class A15, A10, B15 and B10 greenhouses, a plaque shall be installed inside the greenhouse displaying at least the following information:

- the Class of greenhouse;
- the manufacturer;
- the date of erection;
- the characteristic crop load;
- the covered area.

F.3.2 For Class B5 greenhouses a plaque shall be supplied displaying the following information:

- the class of greenhouse;
- the manufacturer;
- the date of delivery.

Annex G
(informative)

Instructions for maintenance and repair

G.1 General

Instructions for maintenance and repair should contain at least the information given in G.2 to G.4.

G.2 Access to the roof

G.2.1 A means should be provided so that ladders used to gain access to the roof can rest squarely against, and can be securely attached to, the greenhouse structure at points that can resist the actions due to the process.

G.2.2 For safe transition from the ladder to the valley roof slopes, provision should be available for the ladder to be positioned to one side of the valley gutter and a handhold, that is within reaching distance when standing on the ladder, should be provided at a height of 1 m above the gutter.

G.3 Moving and working on the roof

G.3.1 Provision should be made for safe movement along the roof, including balancing aids, means of moving these aids, and provision of non slip hard locations along roofs against which they can be rested.

G.3.2 A device (such as for instance a working platform, scaffolding, planks, ladders, etc.) should be provided so that a maintenance operator working on the roof can maintain balance with both hands free to carry out the work.

G.4 Cleaning and whitewashing of the roof

It is recommended to carry out roof cleaning and whitewashing by a cleaning machine.

Annex H
(informative)

Structural detailing

H.1 General

This informative annex gives information about structural detailing. The following subjects are considered:

- forces due to temperature effects;
- contact forces between glass panels and cladding bars;
- rainwater capacities of gutters, gutter outlets and downpipes;
- aperture ratio;
- light interception ratio.

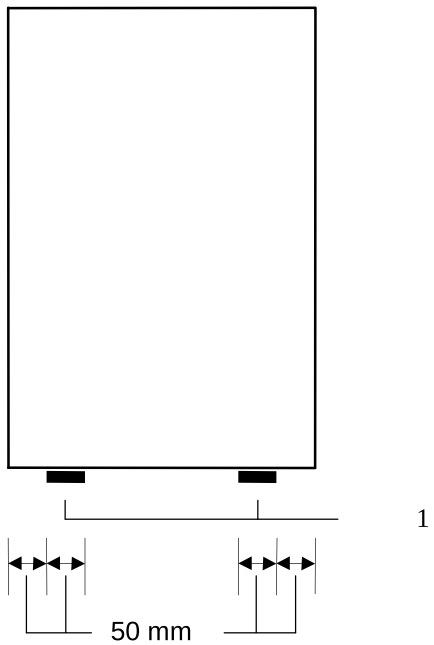
H.2 Forces due to temperature effects

H.2.1 In order to avoid forces due to temperature effects, vertical bracings between the columns and bracings in the roof should be placed near the centre of the greenhouse.

H.2.2 To prevent damage to the cladding due to thermal elongation's of structural components, expansion joints may be used.

H.3 Contact forces between glass panels and cladding bars

In order to avoid in plane concentrated contact forces between the glass panel and the cladding bars it is advised to apply a pressure spreading layer for the lower horizontal supporting cladding bar (see Figure H.1).



Key
1 Neoprene

Figure H.1 - Example of pressure spreading layer

H.4 Rainwater capacities of gutters, gutter outlets and downpipes

H.4.1 The rainwater capacities of gutters, gutter outlets and downpipes depend on many parameters including:

- the hydraulic properties of the gutter sections, outlets and downpipes;
- the fall of the gutter in relation to its length;
- the number of end and intermediate outlets and downpipes;
- the effects of wind on waterflow in the gutter.

H.4.2 Requirements for the rainwater capacities of gutters, gutter outlets and downpipes should be related to the chosen reference period to determine the design value for the rainfall intensity and the acceptance of the risk of overflow from the system into the greenhouse.

H.4.3 For information on rainwater capacities of gutters, gutter outlets and downpipes refer to EN 12056-3.

H.5 Aperture ratio

H.5.1 Measuring and characterising the performance of ventilation for a greenhouse is a difficult task that depends on many parameters including:

- ventilation (natural or mechanical);
- the aperture ratio and aperture areas as defined in H.5.2 and H.5.3;
- the speed and direction of the wind;
- the position of ventilators in the roof and walls;
- the temperature and humidity inside and outside the greenhouse;
- the shape of the ventilators;
- the internal volume of the greenhouse;
- the volume and type of crops inside the greenhouse;
- internal equipment.

H.5.2 The aperture ratio R_{ap} is equal to the ratio between the total aperture area ΣA_{ap}, as defined in H.5.3, and the ground area A_{gr} of the greenhouse. The aperture ratio is equal to:

$$R_{ap} = \frac{\Sigma A_{ap}}{A_{gr}}$$

where

ΣA_{ap} is the total aperture area of the greenhouse;

A_{gr} is the ground area of the greenhouse.

H.5.3 The total aperture area of a greenhouse ΣA_{ap} is the sum of the aperture area of all the vents of the greenhouse. The aperture area A_{ap} is equal to the smallest area of $A_{ap;V}$ and $A_{ap;R}$:

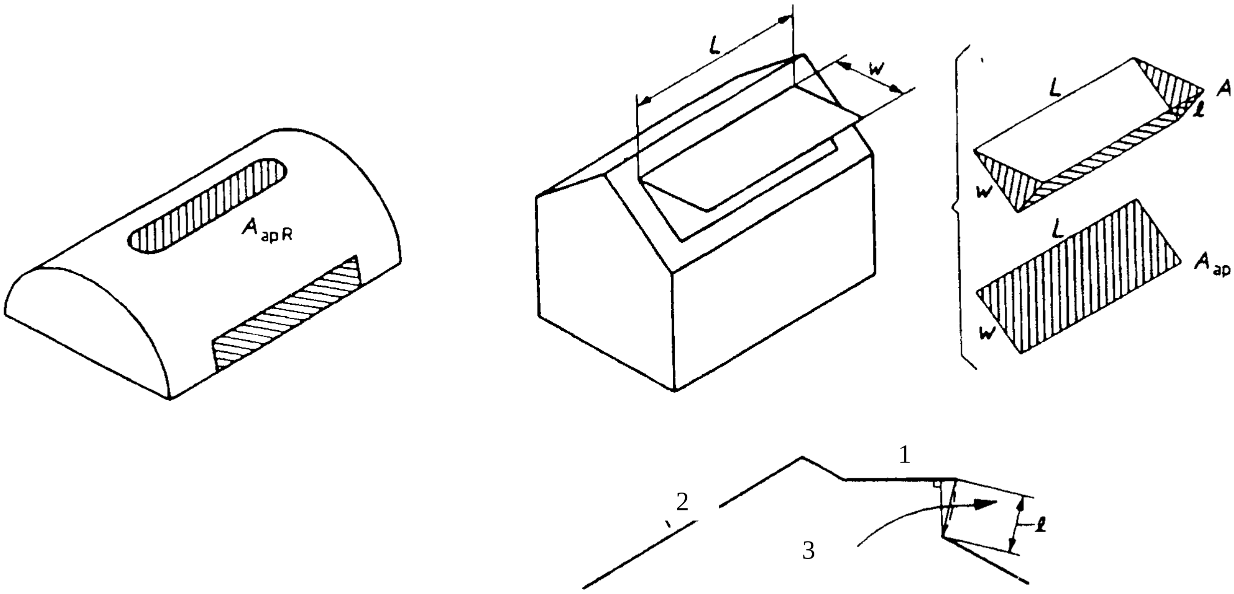
$$A_{ap} = \min(A_{ap;V};A_{ap;R})$$

where

$A_{ap;V}$ is the opening area made by the vent in its maximum opening position;

$A_{ap;R}$ is the area of the ventilator opening in the cladding surface of the greenhouse.

H.5.4 The aperture areas $A_{ap;V}$ and $A_{ap;R}$ of some different types of apertures are summarised in Figure H.2.



Key
1 Vent
2 Roof
3 Inside

Figure H.2 - Aperture areas for some typical apertures

H.6 Light interception ratio

H.6.1 Light entrance into the greenhouse is a difficult phenomenon to calculate and depends on many parameters including:

- light absorption by the cladding;

- light interception by all components of the greenhouse;

- light reflections.

H.6.2 The light interception ratio is equal to the ratio between the total light interception area A_{li} and the ground area A_{gr}. The light interception ratio can be determined from:

$$R_{li} = \frac{A_{li}}{A_{gr}},$$

where

A_{li} is the total light interception area of the greenhouse (see H.6.3);

A_{gr} is the ground area of the greenhouse.

H.6.3 The total light interception area of the greenhouse A_{li} should be taken as the sum of the light interception of all components, from a representative part of the greenhouse. The total light interception is equal to:

$$A_{li} = \sum_{i=1}^{n} l_i \frac{l_{A;i}}{2} \xi_i,$$

where

$l_{A;i}$ is the length of the smallest enveloping polygon of component i;

l_i is the length of component i;

ξ_i is a correction coefficient (see H.6.4).

H.6.4 The correction coefficient ξ_i for the light interception of component *i* is equal to:

$$\xi_i = 1 - \frac{\alpha_i}{\pi},$$

where

α_i is the smallest angle between the component *i* and the ground surface (in radians).

Annex I
(informative)

Calculation method for film covered greenhouses

I.1 General

I.1.1 Introduction

There is no simple calculation method available to determine the distribution of forces and moments in the arches and film cover of tunnels. At present the actions are taken from the wind and snow actions working on the film assuming that the film remains in complete contact with the arches. The actions due to pre-stressing in the film are mostly neglected.

This situation does not accord with real behaviour. In cases where the film is not attached to the arches, transmission of tensile forces between film and arch is not possible. Pre-tension in the film may not be disregarded because this leads to compression in the arches. Pre-tension in the film increases when the film comes loose from the arch due to external actions.

Real behaviour may differ greatly from the assumed distribution of forces and moments resulting from external actions only.

I.1.2 The calculation method for film covered greenhouses given in this annex is valid for single skin films as well as twin skin air inflated films. For planar pitched roofs, a calculation method based on the same principles should be used.

NOTE This annex gives a possible method allowing the assessment of the load transfer between the film and the structure. This phenomenon is highly dependent on the pre-tension in the film, which itself depends on several parameters such as outdoor temperature, film attachment, etc.

I.2 Actions on films of film covered greenhouses

Actions on films of film covered tunnels are due to initial pre-tension and external actions. The initial pre-tension in the film is caused by the way the film is mounted on the arches. External actions should be calculated in accordance with clause 10. The resulting normal force in the film depends on both action types. Because the external actions differs for each loading case the resulting normal force depends on the loading case.

I.3 Transmission of forces from the film to the supporting structure

I.3.1 The actions on the supporting arches should be determined from the actions on the film and the resulting normal forces in the film. A suggested strategy to determine the transmission of forces from the film to the supporting arches is described in I.3.2 to I.3.12.

I.3.2 Determine the actions on the cover film per section resulting from wind and/or snow as specified in clause 10 (see Figure I.1).

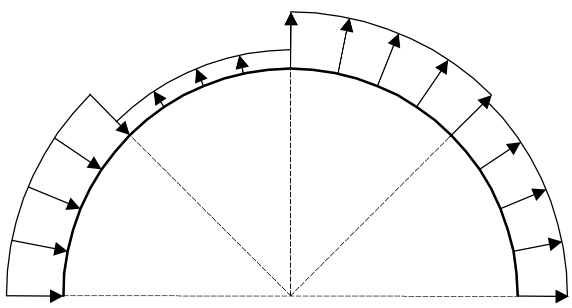


Figure I.1 - Actions on the cover film resulting from wind and/or snow

I.3.3 Determine the actions on the supporting arch resulting from the pre-tension in the film (see Figure I.2).

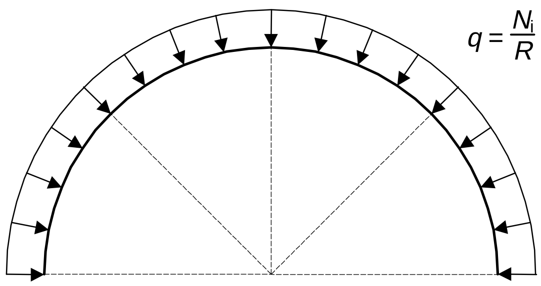


Figure I.2 - Actions on the supporting arch resulting from the pre-tension

I.3.4 Add together the actions from I.3.2 and I.3.3 (see Figure I.3).

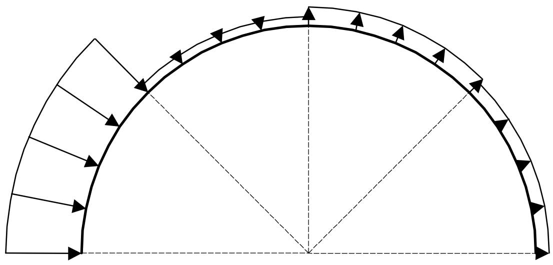
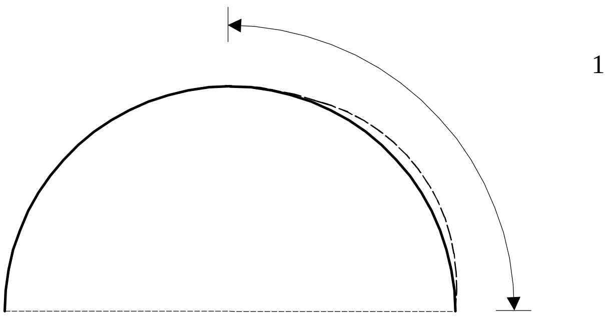


Figure I.3 - Actions resulting from wind and/or snow and pre-tension

I.3.5 If the result of I.3.4 leads to contact compression forces everywhere between film and arch, the transmission of forces between film and arch is identical to the added actions in I.3.4 (see Figure I.3).

In other cases the film may come loose from the arch over a specific length. If so, continue the procedure from I.3.6.

I.3.6 Assume that the film is loose over the length where the result of the added actions (see I.3.4) leads to contact tension forces (suction) on the arch (see Figure I.4).



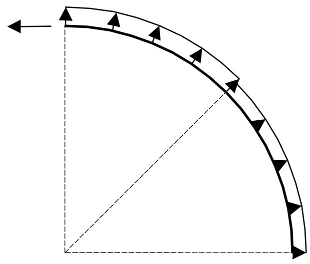
Key
1 Length over which the film is loose from the arch (suction).

Figure I.4 - Length over which the film is loose from the arch

I.3.7 Determine the normal force in the film based on the equilibrium of the part of the film that is loose from the arch (see Figure I.5), taking the following assumptions into account.

- The geometry of this part of the film is almost the same as that of the arch. From this assumption it can be deduced that the external actions on the film are not changed.

- At the points where the film touches the arch, the direction of the normal forces in the film is the same as the tangent to the arch at those points.



Key
1 Normal force N_t in the film

Figure I.5 - Normal force in the film

I.3.8 Determine the actions on the supporting arch due to the normal forces in the film only resulting from I.3.7. To do so the normal force in the film should to be taken as a pre-tension force (see Figure I.6).

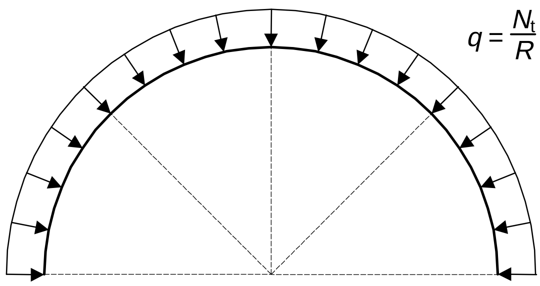


Figure I.6 - Actions on the supporting arch resulting from normal forces in the film

I.3.9 Add together the actions from I.3.2 and I.3.8 (see Figure I.7).

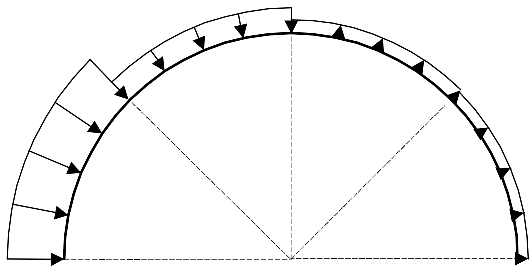


Figure I.7 - Actions resulting from wind and/or snow and normal forces in the film

I.3.10 Assume that the film is loose where the result of the added actions (see I.3.9) leads to contact tension forces (suction) on the arch.

I.3.11 Compare the result of I.3.10 with the result of I.3.6 or previous I.3.10.

If the result of I.3.10 is the same as that of I.3.6 or previous I.3.10, the actions on the supporting arch should be determined in accordance with I.3.12.

If the result of I.3.10 differs from that of I.3.6 or previous I.3.10, repeat the steps in I.3.7 to I.3.11.

I.3.12 The actions on the supporting arch should be determined as follows:

Take the actions from I.3.9 for those parts of the supporting arch where the contact compression forces are present. Where contact tension forces are present no forces are transmitted from the film to the arch (see Figure I.8).

NOTE The influence of a normal force in an eventually present tightening rope parallel to the arch, should be taken into account as an increase of the pre-tension force.

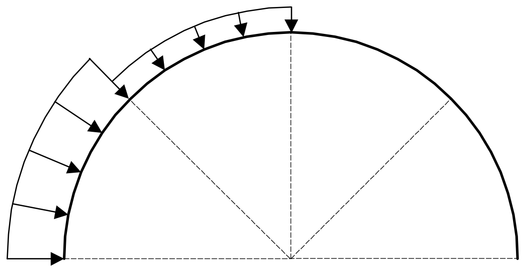


Figure I.8 - Actions on the supporting arch

I.4 Verification of the film

I.4.1 The film should resist the normal forces in the film (membrane forces). The normal forces in the direction parallel to the arches as well as perpendicular to the arches should to be taken into account.

I.4.2 The normal force in the direction parallel to the arches should be taken to be at least equal to the pre-tension force. If the normal force in the film (see I.3.7) is larger than the pre-tension force, the larger force has to be taken into account.

I.4.3 In the direction perpendicular to the arches the maximum value of the normal force follows from the uniformly distributed actions on the film and the pre-tension force in the same direction.

I.4.4 The normal forces should be checked against the bearing capacity of the film.

In determining the bearing capacity of the film the long term behaviour should be taken into account, such as ageing, creep and relaxation. Forces due to pre-tension are long term effects, whereas effects due to wind are short term effects. Ageing has influence on both long term and short term effects.

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