

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.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

This British Standard, having been prepared under the direction of the Building and Civil Engineering Sector Policy and Strategy Committee, was published under the authority of the Standards Policy and Strategy Committee on 06 April 2002

Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 94, an inside back cover and a back cover.

The BSI copyright date displayed in this document indicates when the document was last issued.

Amendments issued since publication

Amd. No.	Date	Comments

© BSI 06 April 2002

ISBN 0 580 39462 X

English version

Greenhouses: Design and construction - Part 1: Commercial production greenhouses

Serres: Calcul et construction - Partie 1: Serres de production

Gewächshäuser: Bemessung und Konstruktion - Teil 1: Kulturgewächshäuser

This European Standard was approved by CEN on 7 April 2001.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.



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

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

Contents

Page

Foreword.....	3
Introduction	4
1 Scope.....	5
2 Normative references	5
3 Terms and definitions	6
4 Symbols and abbreviations.....	7
5 Design of greenhouse structures	9
6 Serviceability limit states	10
7 Ultimate limit states.....	11
8 Tolerances	12
9 Durability, maintenance and repair	18
10 Actions on greenhouses	18
11 Displacements and deflections (SLS).....	23
Annex A (normative) Structural capacity of cladding	30
Annex B (normative) Wind actions	34
Annex C (normative) Snow actions.....	56
Annex D (normative) Ultimate limit states of arches.....	60
Annex E (normative) Country related factors, coefficients and formulas.....	64
Annex F (normative) Owner's manual and identification plaque.....	83
Annex G (informative) Instructions for maintenance and repair	85
Annex H (informative) Structural detailing	86
Annex I (informative) Calculation method for film covered greenhouses	90
Bibliography	94

Foreword

This European Standard has been prepared by Technical 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 the 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, Spain, 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

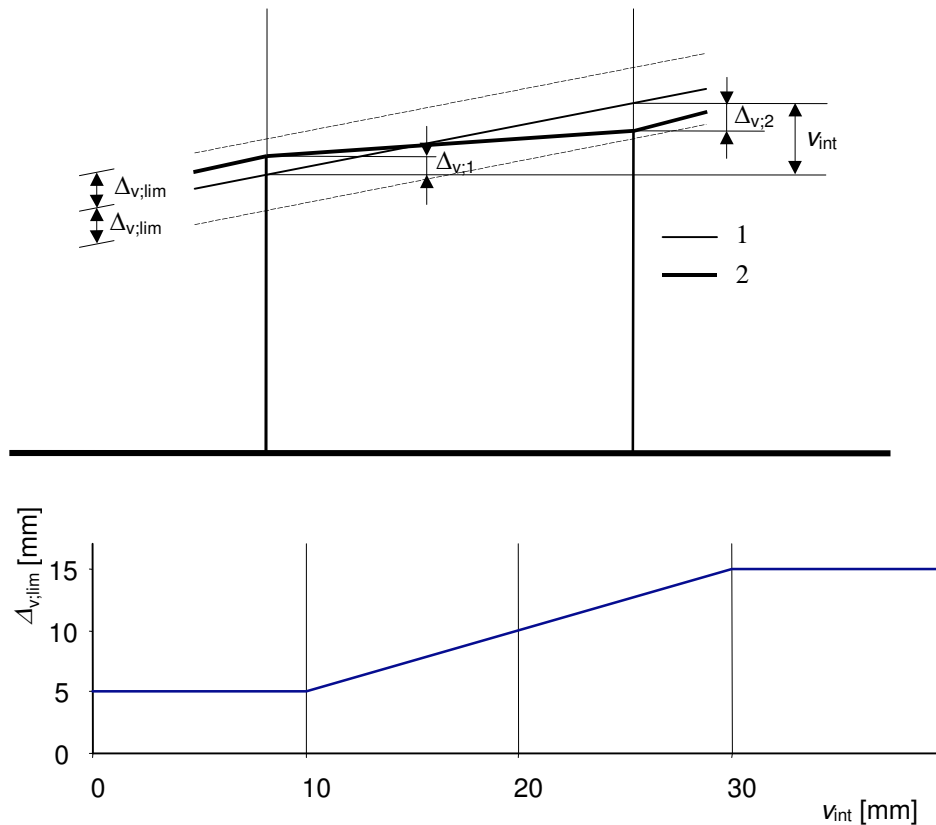
The structural capacity may be determined by testing, provided that the tests are carried out and the test results are evaluated, both in accordance with the procedures described in clause 8 of ENV 1991-1:1994.

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).



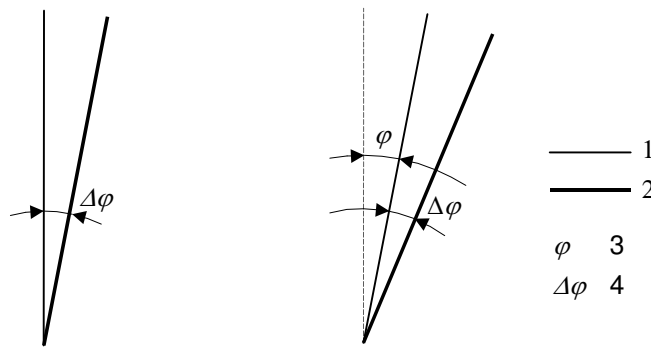
Key

- 1 Intended 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.

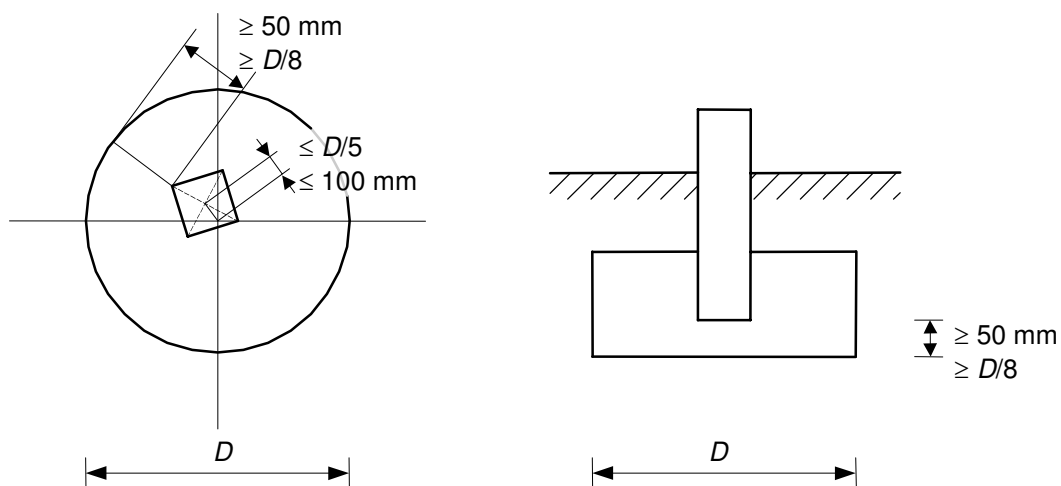


Figure 3 - Position of the prefabricated foundation pile within the foundation hole

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.

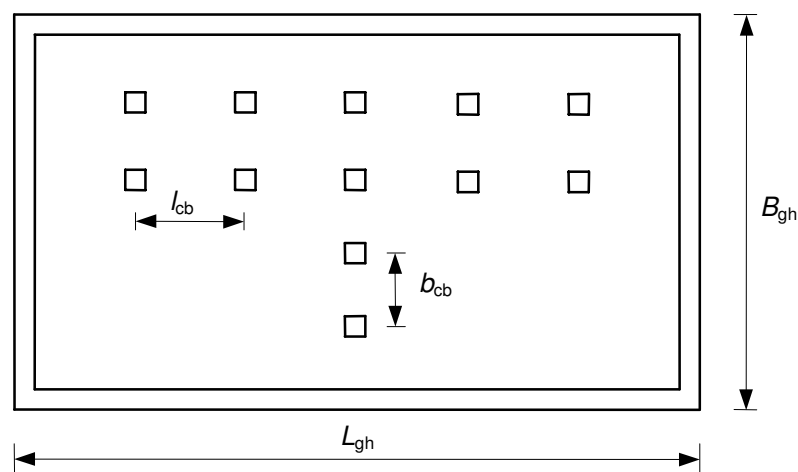
8.1.7 Fabrication tolerances of structural steel components shall be in accordance with ENV 1090-1.

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



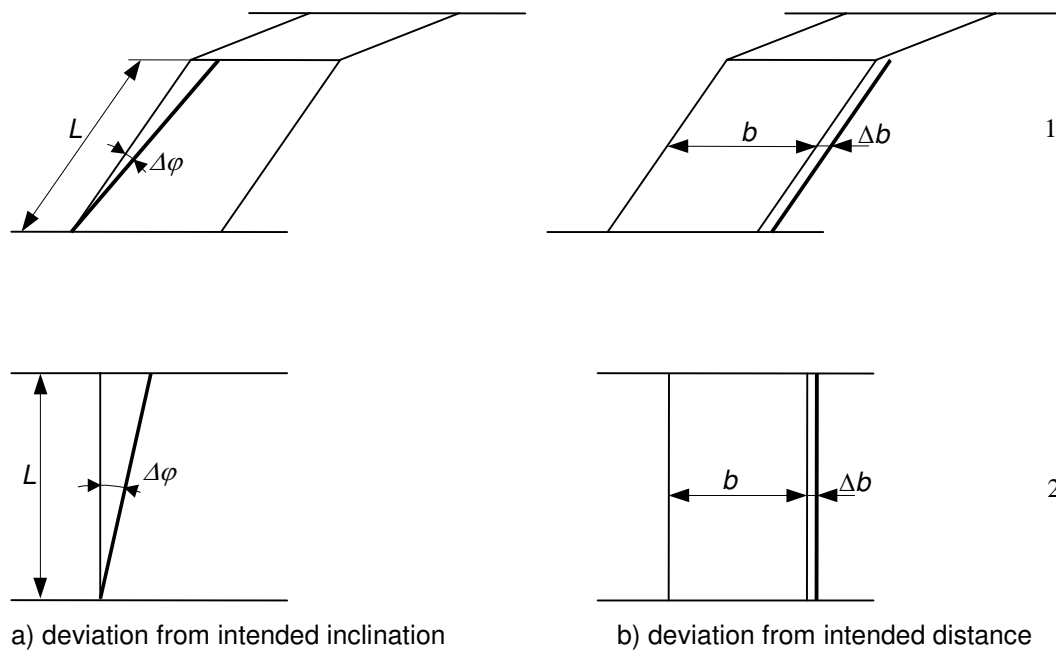
Key

- 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):

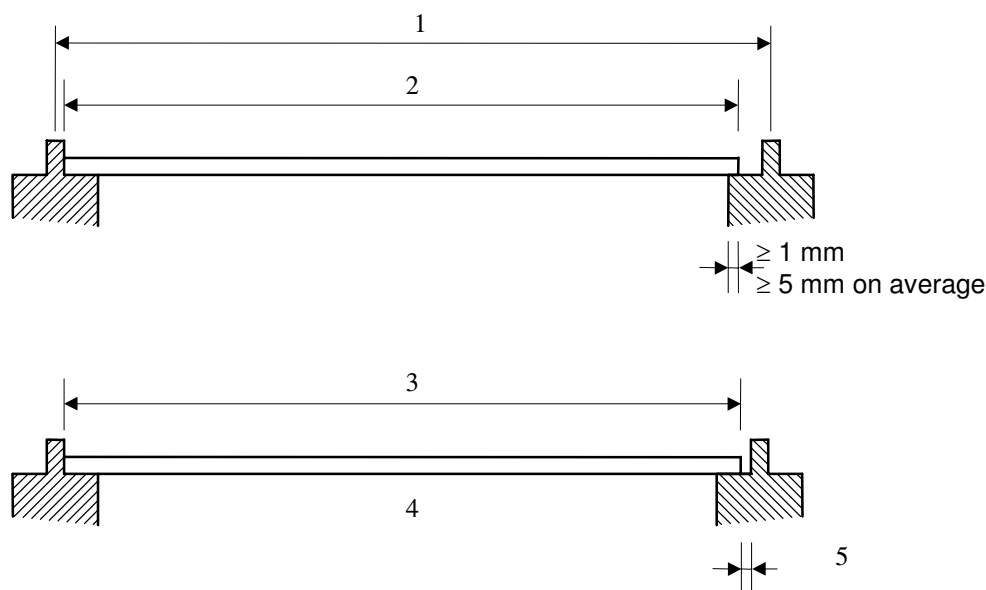
- The distance between the edge of the cladding panel and the further edge of the supporting face of the cladding bar shall be at least 5 mm on average, but nowhere less than 1 mm in any position of the cladding panel.

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 accessibility 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 exceedance 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)	γ_{G1}	G_{k1}	+	γ_{G2}	G_{k2}	+	γ_{Q1}	Q_{k1}	+	$\psi_{0Q2} \gamma_{Q2} Q_{k2}$	+	$\psi_{0Q3} \gamma_{Q3} Q_{k3}$
a2)	γ_{G1}	G_{k1}	+	γ_{G2}	G_{k2}	+	$\psi_{0Q1} \gamma_{Q1} Q_{k1}$	+	$\gamma_{Q2} Q_{k2}$	+	$\psi_{0Q3} \gamma_{Q3} Q_{k3}$	
a3)	γ_{G1}	G_{k1}	+	γ_{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)	γ_{G1}	G_{k1}	+	γ_{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)	γ_{G1}	G_{k1}	+	γ_{G2}	G_{k2}	+	$\psi_{0Q3} \gamma_{Q3} Q_{k3}$	+	$\gamma_{Q4} Q_{k4}$	+	$\psi_{0Q5} \gamma_{Q5} Q_{k5}$	
c2)	γ_{G1}	G_{k1}	+	γ_{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)	γ_{G1}	G_{k1}	+	γ_{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)	γ_{G1}	G_{k1}	+	γ_{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/m² 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:

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

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/m².

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):

$$U_{h;g} \leq U_{h;sw;g;lim} + U_{h;r;g;lim}$$

where

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

$U_{h;sw;g;lim}$ 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;

$U_{h;r;g;lim}$ 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.

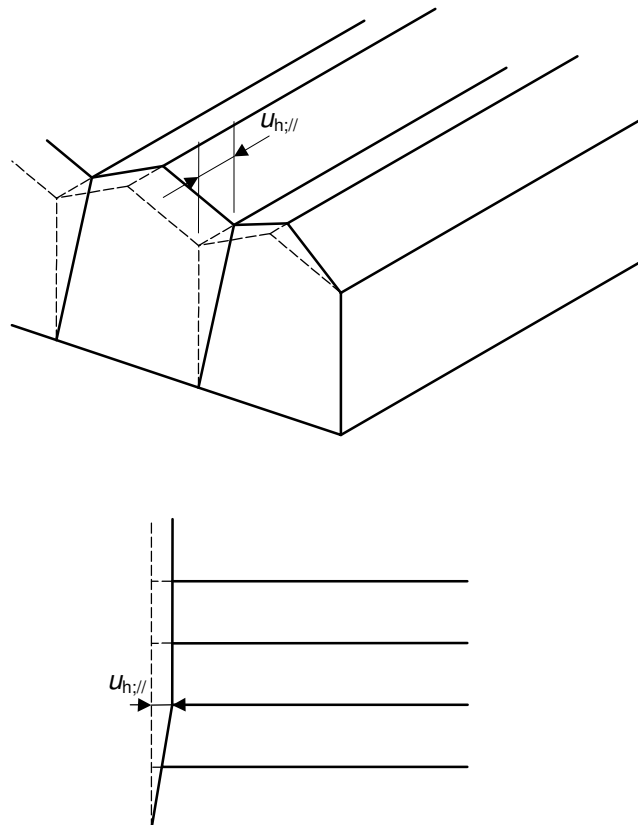


Figure 7 - Horizontal displacements of the greenhouse at gutter level in the direction of the gutter

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.

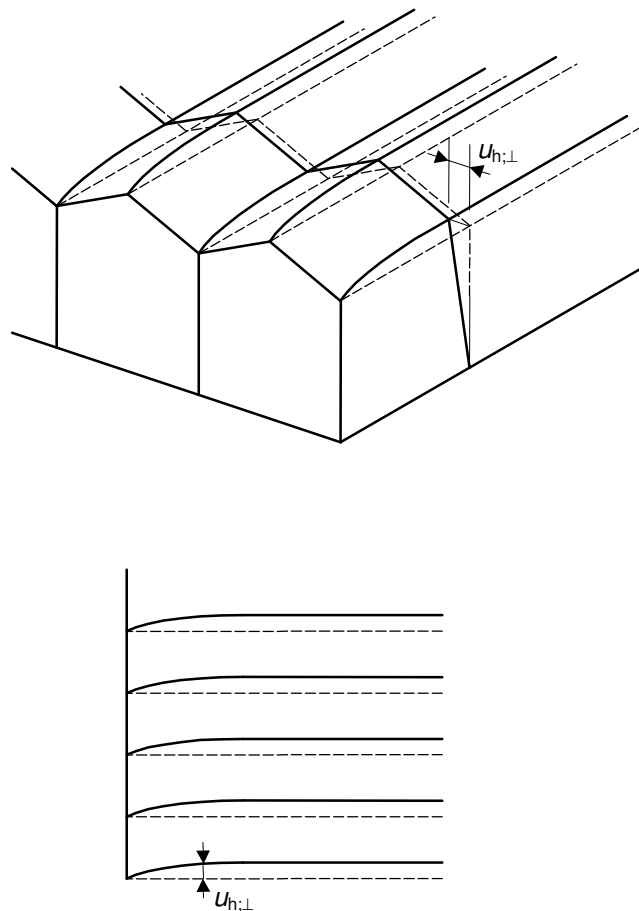


Figure 8 - Horizontal displacements of the greenhouse at gutter level perpendicular to the gutter

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

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

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.

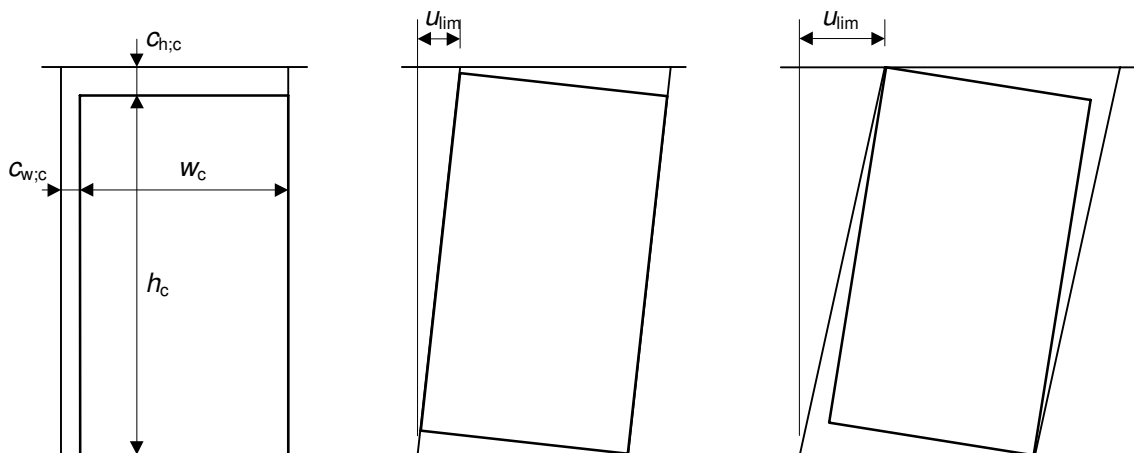


Figure 9 - Limits to the possibility to movements of the cladding panel

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

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

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 $u_{h;r;\parallel;lim}$ 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 $u_{h;r;\parallel;lim}$ may be taken as:

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

or

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

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

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

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:

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

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

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

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

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

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:

$$u_h \leq \frac{l_s/2}{650 - 100n_{c,r}}$$

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

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:

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

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:

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

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

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:

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

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

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:

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

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