SIST

SLOVENSKI STANDARD
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Steklo v gradbeništvu - Določevanje bočne nosilnosti steklenih plošč z izračunom

Glass in building - Determination of the lateral load resistance of glass panes by calculation

Glas im Bauwesen - Bestimmung des Belastungswiderstandes von Glasscheiben durch Berechnung und Prüfung

Verre dans la construction - Détermination par calcul de la résistance des vitrages aux charges latérales

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Glass in building - Determination of the lateral load resistance of glass panes by calculation

Verre dans la construction - Determination de la resistance des feuilles de verre par calcul et par essai

Glas im Bauwesen - Bestimmung des Belastungswiderstandes von Glasscheiben durch Berechnung und Prüfung

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European foreword

This document (EN 16612:2019) has been prepared by Technical Committee CEN/TC 129 "Glass in Building", the secretariat of which is held by NBN.

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of an identical text or by endorsement, at the latest by April 2020 and conflicting national standards shall be withdrawn at the latest by April 2020.

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Introduction

This document gives a method of determining the lateral load resistance of linearly supported glass elements.

The method of determining the load resistance of glass is in accordance with the principles of structural Eurocode EN 1990: Basis of structural design. The actions are determined in accordance with the structural Eurocode 1 series for actions on structures, e.g. EN 1991-1-1, EN 1991-1-3 and EN 1991-1-4, including the National annexes. In the design processes, the reliability is part of national competency. For that reason, this document foresees that, to conform with the rules applied by the Eurocodes, the following parameters are subject to national determination:

— material partial factors, $\gamma_{M;A}$ and $\gamma_{M;v}$;

— factors for the load duration, k_{mod} ;

— factor for stressed edges, k_e.

1 Scope

This document gives a method of determining the design value of the bending strength of glass. It gives the general method of calculation, and guidance for lateral load resistance of linearly supported glazed elements used as infill panels.

NOTE Examples of lateral loads are wind loads, snow loads, self weight of sloping glass, and cavity pressure variations on insulating glass units.

This document gives recommended values for the following factors for glass as a material:

— material partial factors, $\gamma_{M;A}$ and $\gamma_{M;v}$;

— factors for the load duration, k_{mod} ;

— factor for stressed edges, k_e.

Most glass in buildings is used as infill panels. This document covers those infill panels that are in a class of consequence lower than those covered in EN 1990, so proposed values for the partial load factors, γ_Q and γ_G, are given for these infill panels.

The action of cavity pressure variations on insulating glass units is not covered by Eurocodes, so this document also gives proposed values of combination factors, ψ_0, ψ_1 and ψ_2, for this action.

This document does not determine suitability for purpose. Resistance to lateral loads is only one part of the design process, which could also need to take into account:

- in-plane loading, buckling, lateral torsional buckling, and shear forces,
- environmental factors (e.g. sound insulation, thermal properties),
- safety characteristics (e.g. fire performance, mode of breakage in relation to human safety, security).

This document does not apply to channel shaped glass, glass blocks and pavers, or vacuum insulated glass units.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 410, *Glass in building — Determination of luminous and solar characteristics of glazing*

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

EN 673, *Glass in building — Determination of thermal transmittance (U value) — Calculation method*

EN 1279-5, *Glass in building — Insulating glass units — Part 5: Product standard*

EN 1288-2, *Glass in building — Determination of bending strength of glass — Part 2: Coaxial double ring test on flat specimens with large test surface areas*

EN 1288-3, *Glass in building — Determination of the bending strength of glass — Part 3: Test with specimen supported at two points (four point bending)*

EN 1748-1-1, *Glass in building — Special basic products — Borosilicate glasses — Part 1-1: Definition and general physical and mechanical properties*

EN 1748-2-1, *Glass in building — Special basic products —Glass ceramics — Part 2-1: Definitions and general physical and mechanical properties*

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

EN 1990:2002[1], *Eurocode — Basis of structural design*

EN 1991-1-1, *Eurocode 1: Actions on structures — Part 1-1: General actions — Densities, self-weight, imposed loads for buildings*

EN 1991-1-3, *Eurocode 1: Actions on structures — Part 1-3: General actions - Snow loads*

EN 1991-1-4, *Eurocode 1: Actions on structures — Part 1-4: General actions - Wind actions*

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 13024-1, *Glass in building — Thermally toughened borosilicate safety glass — Part 1: Definition and description*

EN 14178-1, *Glass in building — Basic alkaline earth silicate glass products — Part 1: Float glass*

EN 14179-1, *Glass in building — Heat soaked thermally toughened soda lime silicate safety glass — Part 1: Definition and description*

EN 14321-1, *Glass in building — Thermally toughened alkaline earth silicate safety glass — Part 1: Definition and description*

EN 14449, *Glass in building — Laminated glass and laminated safety glass — Evaluation of conformity/Product Standard*

EN 15681-1, *Glass in building — Basic alumino silicate glass products — Part 1: Definitions and general physical and mechanical properties*

EN 15682-1, *Glass in building — Heat soaked thermally toughened alkaline earth silicate safety glass — Part 1: Definition and description*

EN 16613, *Glass in building — Laminated glass and laminated safety glass — Determination of interlayer mechanical properties*

1 This document is impacted by the amendment EN 1990:2002/A1:2005 and the corrigendum EN 1990:2002/A1:2005/AC:2010.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

• IEC Electropedia: available at http://www.electropedia.org/

• ISO Online browsing platform: available at http://www.iso.org/obp

3.1
infill panel
panel that closes openings in buildings but does not contribute to the stability of the load bearing members

3.2
annealed glass
glass which has been treated during manufacture to minimise the residual stress in the glass, allowing it to be cut by scoring and snapping

Note 1 to entry: Examples are float glass, drawn sheet glass, patterned glass and wired glass.

3.3
prestressed glass
glass which has been subjected to a strengthening treatment, by heat or chemicals, which induces a compressive surface stress into the whole surface of the glass, balanced by a tensile stress within the body of the glass

Note 1 to entry: Examples are thermally toughened safety glass, heat strengthened glass and chemically strengthened glass.

3.4
enamelled glass
glass which has a ceramic frit applied to the surface, by e.g. painting or screen printing, which is subsequently fired into the surface of the glass

Note 1 to entry: Examples are enamelled heat strengthened glass, enamelled toughened glass and enamelled heat soaked toughened glass.

3.5
equivalent thickness (of laminated glass)
thickness calculated for laminated glass which, when used in place of the glass thickness in an engineering formula, will result in a reasonably accurate determination of the deflection of and / or stress in the laminated glass

3.6
lateral load resistance
resistance to forces applied normal to the glass surface (i.e. at right angles to it)

3.7
cavity pressure variation
pressure applied to the panes of insulating glass units due to the internal volume of the hermetically sealed cavity or cavities being affected by changes in temperature and changes in the ambient atmospheric pressure in service

3.8
altitude load
cavity pressure change solely resulting from a difference in altitude between the place of assembly (sealing) and the place of use

4 Symbols and abbreviations

A	Surface area of the pane *(= a x b)*
a	Shorter dimension of the pane
a^*	Characteristic length of a double insulating glass unit
b	Longer dimension of the pane
C_d	Limiting design value of the relevant serviceability criterion
c_H	Coefficient for the effect of altitude change on isochore pressure (=0,12 kPa/m)
c_T	Coefficient for the effect of cavity temperature change on isochore pressure (=0,34 kPa/K)
E	Young's modulus of glass
E_L	Tensile modulus of an interlayer material
F_d	Design value of the action
$F_{d;e}$	Design value of the action on pane 1 of a double insulating glass unit
$F_{d;i}$	Design value of the action on pane 2 of a double insulating glass unit
$F_{d;1}$	Design value of the action on pane 1 of a triple insulating glass unit
$F_{d;3}$	Design value of the action on pane 3 of a triple insulating glass unit
f	Frequency (of vibration)
$f_{b;k}$	Characteristic value of the bending strength of prestressed glass
$f_{g;d}$	Design value of bending strength for the surface of glass panes
$f_{g;k}$	Characteristic value of the bending strength of annealed glass
g	Self weight load
g_1	Self weight load of pane 1
g_2	Self weight load of pane 2
g_3	Self weight load of pane 3
G	Permanent action
G_L	Shear modulus of an interlayer material
H	Altitude
H_P	Altitude of production of insulating glass unit
h	Nominal thickness of the pane
h_1	Nominal thickness of pane 1 of an insulating glass unit or ply 1 of a laminated glass

h_2	Nominal thickness of pane 2 of an insulating glass unit or ply 2 of a laminated glass
h_3	Nominal thickness of pane 3 of an insulating glass unit or ply 3 of a laminated glass
h_e	External heat transfer coefficient
$h_{eq;w}$	Equivalent thickness of a laminated glass for calculating out-of-plane bending deflection
$h_{eq;\sigma}$	Equivalent thickness of a laminated glass for calculating out-of-plane bending stress
$h_{eq;\sigma;j}$	Equivalent thickness of a laminated glass for calculating out-of-plane bending stress of ply *j*
h_i	Internal heat transfer coefficient
h_j	Nominal thickness of pane *j* of an insulating glass unit or ply *j* of a laminated glass
h_k	Nominal thickness of pane *k* of an insulating glass unit or ply *k* of a laminated glass
$h_{m;1}$	The distance of the mid-plane of the glass ply 1 from the mid-plane of the laminated glass
$h_{m;2}$	The distance of the mid-plane of the glass ply 2 from the mid-plane of the laminated glass
$h_{m;3}$	The distance of the mid-plane of the glass ply 3 from the mid-plane of the laminated glass
$h_{m;j}$	The distance of the mid-plane of the glass ply *j* from the mid-plane of the laminated glass
$h_{m;k}$	The distance of the mid-plane of the glass ply *k* from the mid-plane of the laminated glass
h_s	Cavity heat transfer coefficient
h_{s1}	Cavity heat transfer coefficient - cavity 1
h_{s2}	Cavity heat transfer coefficient - cavity 2
J_A	Variable used in calculations of cavity temperatures for triple glazed insulating glass units
J_B	Variable used in calculations of cavity temperatures for triple glazed insulating glass units
J_C	Variable used in calculations of cavity temperatures for triple glazed insulating glass units
J_D	Variable used in calculations of cavity temperatures for triple glazed insulating glass units
k_1	Coefficient used in the calculation of large deflection: stresses
k_4	Coefficient used in the calculation of large deflection: deflections
k_5	Coefficient used in the calculation of large deflection: volume changes
k_6	Coefficient used in the calculation of insulating glass unit edge seal force
k_e	Factor for edge strength

k_{FI}	Coefficient of class of consequence expressing the reduction of safety applicable to the secondary structures and infill panels compared to that applicable for the main structures
k_{mod}	Factor for the load duration
$k_{\text{mod;1}}$	Factor for the load duration of the dominant action in a load combination
$k_{\text{mod;c}}$	Factor for the load duration when there are combined loads
$k_{\text{mod;G}}$	Factor for the load duration of a permanent action in a load combination
$k_{\text{mod;i}}$	Factor for the load duration of a non-dominant action in a load combination
k_{sp}	Factor for the glass surface profile
k_v	Factor for strengthening of prestressed glass
n	coefficient used in the formula for static fatigue (stress corrosion) of glass. The normally used value is 16.
p	Pressure
p_0	Isochore pressure for an insulating glass unit
$p_{0;1}$	Isochore pressure for cavity 1 of an insulating glass unit
$p_{0;2}$	Isochore pressure for cavity 2 of an insulating glass unit
p_a	Meteorological air pressure (air pressure at sea level)
$p_{a;m}$	Average meteorological air pressure = 100 kN/m^2
$p_{C;0}$	Isochore pressure due to the effect of change in cavity temperature and air pressure
$p_{ex;1}$	Externally applied uniformly distributed load on pane 1 of a triple insulating glass unit
$p_{ex;1;S}$	Externally applied snow load on pane 1 of a triple insulating glass unit
$p_{ex;1;W}$	Externally applied wind load on pane 1 of a triple insulating glass unit
$p_{ex;3}$	Externally applied uniformly distributed load on pane 3 of a triple insulating glass unit
$p_{H;0}$	Isochore pressure due to the effect of change in altitude
p_P	Meteorological air pressure (air pressure at sea level) at the time of production of insulating glass unit
$p_{res;1}$	Load partition for pane 1 of a triple insulating glass unit
$p_{res;2}$	Load partition for pane 2 of a triple insulating glass unit
$p_{res;3}$	Load partition for pane 3 of a triple insulating glass unit
$p_{res;C;k}$	Load partition of cavity pressure variation for pane k of a triple insulating glass unit
$p_{res;G;k}$	Load partition of dead load for pane k of a triple insulating glass unit
$p_{res;S;k}$	Load partition of snow + dead load for pane k of a triple insulating glass unit
$p_{res;W;k}$	Load partition of wind + snow + dead load for pane k of a triple insulating glass unit

p^*	Non-dimensional uniformly distributed load
$Q_{k,1}$	Single action or dominant action
$Q_{k,i}$	Actions which are not dominant
q_e	Insulating glass unit edge seal force
R_d	Design value of the resistance to the actions
s	Nominal cavity width of a double glazed insulating glass unit
s_1	Nominal cavity width of cavity 1 in a triple glazed insulating glass unit
s_2	Nominal cavity width of cavity 2 in a triple glazed insulating glass unit
T_C	Insulating glass unit cavity temperature
$T_{C;1}$	Insulating glass unit cavity temperature - cavity 1
$T_{C;2}$	Insulating glass unit cavity temperature - cavity 2
T_{ext}	External air temperature
$T_{g;cen}$	Glass temperature of the central pane of a triple glazed insulating glass unit
$T_{g;ext}$	Glass temperature of the outer pane of an insulating glass unit
$T_{g;int}$	Glass temperature of the inner pane of an insulating glass unit
T_{int}	Internal (room) air temperature
T_P	Temperature of production of insulating glass unit
t	Load duration (in hours)
V	Volume displaced due to the deflection of a pane
$V_{pr;1}$	Nominal volume of cavity 1 in an insulating glass unit
$V_{pr;2}$	Nominal volume of cavity 2 in an insulating glass unit
$V_{pr;k}$	Nominal volume of cavity k in an insulating glass unit
w_d	Design value of deflection
$w_{\max}$	Maximum deflection calculated for the design load
z_1	Coefficient used in the approximate calculation of k_4
z_2	Coefficient used in the approximate calculation of k_1
z_3	Coefficient used in the approximate calculation of k_1
z_4	Coefficient used in the approximate calculation of k_1
α_1, α_1^+	Relative volume changes for the panes on either side of cavity 1 of a triple insulating glass unit
α_2, α_2^+	Relative volume changes for the panes on either side of cavity 2 of a triple insulating glass unit
α_k, α_k^+	Relative volume changes for the panes on either side of cavity k of a triple insulating glass unit

α_{e1}	Solar direct effective absorptance of the outer pane of an insulating glass unit
α_{e2}	Solar direct effective absorptance of the second pane of an insulating glass unit
α_{e3}	Solar direct effective absorptance of the third pane of an insulating glass unit
β	Factor used in calculating internal pressure differences in triple insulating glass units
$\Delta p_{1;\mathrm{j}}$	Internal pressure difference for cavity 1 of a triple insulating glass unit
$\Delta p_{2;\mathrm{j}}$	Internal pressure difference for cavity 2 of a triple insulating glass unit
$\Delta p_{C;\mathrm{i;j}}$	Internal pressure difference due to cavity pressure variations for cavity *i* of a triple insulating glass unit
$\Delta p_{G;\mathrm{i;j}}$	Internal pressure difference due to dead loads for cavity *i* of a triple insulating glass unit
$\Delta p_{\mathrm{i;j}}$	Internal pressure difference for cavity *i* of a triple insulating glass unit
$\Delta p_{S;\mathrm{i;j}}$	Internal pressure difference due to snow + dead loads for cavity *i* of a triple insulating glass unit
$\Delta p_{W;\mathrm{i;j}}$	Internal pressure difference due to wind + snow + dead loads for cavity *i* of a triple insulating glass unit
δ_1	Stiffness partition for pane 1 of a double insulating glass unit
δ_2	Stiffness partition for pane 2 of a double insulating glass unit
ϕ	Insulating glass unit factor for a double insulating glass unit
ϕ_1	Insulating glass unit factor for cavity 1 of a triple insulating glass unit
ϕ_2	Insulating glass unit factor for cavity 2 of a triple insulating glass unit
ϕ_e	Incident solar radiant flux
γ	Partial factor
γ_G	Partial factor for permanent actions, also accounting for model uncertainties and dimensional variations
$\gamma_{M;A}$	Material partial factor for annealed glass
$\gamma_{M;v}$	Material partial factor for surface prestress
γ_Q	Partial factor for variable actions, also accounting for model uncertainties and dimensional variations
λ	Aspect ratio of the pane ($= a/b$)
μ	Poisson number
$v_{p;1}$	Volume change of glass pane 1 when subjected to unit uniform pressure
$v_{p;2}$	Volume change of glass pane 2 when subjected to unit uniform pressure
$v_{p;3}$	Volume change of glass pane 3 when subjected to unit uniform pressure
$v_{p;k}$	Volume change of glass pane *k* when subjected to unit uniform pressure

$v_{p;k+1}$	Volume change of glass pane k+1 when subjected to unit uniform pressure
θ	Temperature
ρ	Glass density
σ	Stress
σ_{all}	Allowable stress
$\sigma_{all;i}$	Allowable stress associated with load type i
$\sigma_{calc;i}$	Calculated stress from load type i
σ_G	Calculated stress from dead load
$\sigma_{\max}$	Maximum stress calculated for the design load
σ_S	Calculated stress from snow load
σ_W	Calculated stress from wind load
ψ	Combination factor
ψ_0	Combination factors for the actions which are not dominant
$\psi_{0,i}$	Factors for combination value of accompanying variable actions
ψ_1	Combination factor for a frequent value of a variable action Note 1 to entry: This value is determined - in so far as it can be fixed on statistical bases - so that either the total time, within the reference period, during which it is exceeded is only a small given part of the reference period, or the frequency of it being exceeded is limited to a given value. It may be expressed as a determined part of the characteristic value by using a factor $\psi_1 \leq 1$
ψ_2	Combination factor for a quasi-permanent value of a variable action Note 1 to entry: This value is determined so that the total period of time for which it will be exceeded is a large fraction of the reference period. It may be expressed as a determined part of the characteristic value by using a factor $\psi_2 \leq 1$
$\psi_{2,i}$	Combination factor for a quasi-permanent value of a variable action Note 1 to entry: This value is determined so that the total period of time for which it will be exceeded is a large fraction of the reference period. It may be expressed as a determined part of the characteristic value by using a factor $\psi_{2;i} \leq 1$
ω	Coefficient for the shear transfer of an interlayer in laminated glass

5 Requirements

5.1 Basis of determination of load resistance of glass

The process shall follow the principles of EN 1990: Eurocode – Basis of structural design.

The determination of actions shall be in accordance with the relevant parts of EN 1991-1-1, EN 1991-1-3 and EN 1991-1-4. Where relevant or required, other codes shall also be taken into account.