Selection Guide
Self-supporting double-skin metal-faced insulating panels
Specifications - Factory-made products

March 2013

Endorsed by

TP MA
Thermal Panel Manufacturers Association
Introduction

Compliance of panels with the requirements of this standard is in itself not proof that such panels are suitable for a specific application. Such suitability is established by comparing the properties of the panels with the requirements of the National Building Regulations and more specifically regulations B, K and T. Unconventional building systems comply with the requirements of Agrément South Africa.

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1. **Scope**

1.1 This standard specifies requirements for factory-made, self-supporting, double-skin metal-faced insulating sandwich panels, which are intended for discontinuous laying in the following applications:

a) roofs and roof cladding;
b) external walls and wall cladding; and
c) walls (including partitions) and ceilings within the building envelope.

1.2 Panels intended to be used as structural elements are not included in this standard, but the properties listed in this standard may be utilized by the specifying engineer to ensure durable and functional structures should panels be used as structural elements. Guidance is also given in respect of the fire resistance of structural elements incorporated in sandwich panels.

1.3 The insulating core materials covered by this standard are rigid polyurethane, expanded polystyrene, extruded polystyrene foam, phenolic foam, cellular glass and mineral wool.

**NOTE:** Polyurethane (PUR) includes polyisocyanurate (PIR).

1.4 Panels with edge details of different materials from the main insulating core are included in this standard.

1.5 This standard does not cover the following:
a) sandwich panels with a declared thermal conductivity for the insulating core greater than 0.06 W/(m·k) at 10 °C;
b) products that consist of two or more clearly defined layers of different insulating core materials (multilayered);
c) panels with perforated facings;
d) curved panels; and
e) panels that are intended to be used as structural elements.

1.6 Compliance of panels with the requirements of this standard is in itself not proof that equivalent panels are suitable for a specific application. Suitability of the panels for a specific application is established by comparing their properties with the requirements of the National Building Regulations and more specifically regulations B, K and T.

**NOTE:** When panels are fixed to a structure additional testing might need to be done on the system. A South African National Standard in respect of construction with thermal insulation panels does not currently exist and applicable South African National Standards need to be used for structural design. The manufacturer's guidelines and local industry standards should therefore be consulted for detail.
2. Normative references

The following referenced documents are indispensable for the application 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. Information on currently valid national and international standards can be obtained from the SABS Standards Division.

ASTM E822, Standard practice for determining resistance of solar collector covers to hail by impact with propelled ice balls.

EN 485-2, Aluminium and aluminium alloys – Sheet, strip and plate – Part 2: Mechanical properties.

EN 485-4, Aluminium and aluminium alloys – Sheet, strip and plate – Part 4: Tolerances on shape and dimensions for cold-rolled products.

EN 502, Roofing products from metal sheet – Specification for fully supported roofing products of stainless steel sheet.


EN 826, Thermal insulating products for building applications – Determination of compression behaviour.

EN 1172, Copper and copper alloys – Sheet and strip for building purposes.

EN 1396, Aluminium and aluminium alloys – Coil coated sheet and strip for general applications – Specifications.

EN 1602, Thermal insulating products for building applications – Determination of the apparent density.

EN 1607, Thermal insulating products for building applications – Determination of tensile strength perpendicular to faces.

EN 1990, Eurocode – Basis of structural design.

EN 10143, Continuously hot-dip coated steel sheet and strip – Tolerances on dimensions and shape.

EN 10169, Continuously organic coated (coil coated) steel flat products – Technical delivery conditions.

EN 12085, Thermal insulating products for building applications – Determination of linear dimensions of test specimens.

EN 12114, Thermal performance of buildings – Air permeability of building components and building elements – Laboratory test method.

EN 12524, Building materials and products – Hygrothermal properties – Tabulated design values.


EN 13164, Thermal insulation products for buildings – Factory made products of extruded polystyrene foam (XPS) – Specification.


EN 13166, Thermal insulation products for buildings – Factory made products of phenolic foam (PF) – Specification.


ISO 6892-1, Metallic materials – Tensile testing – Part 1: Method of test at room temperature.
SANS 428, *Fire performance classification of thermal insulated building envelope systems.*
SANS 10177-3, *Fire testing of materials, components and elements used in buildings – Part 3: Surface fire index of finishing materials.*
SANS 1 0400-K:201 1, *The application of the National Building Regulations – Part K: Walls.*
SANS 10456/ISO 10456, *Building materials and products – Procedures for determining declared and design thermal values.*
3. Terms and definitions
For the purposes of this document, the following terms and definitions apply.

3.1 Associated Joint
structure that is not an integral part of the panel but that is used to join two or more panels in order to form part of an assembly

3.2 Auto-adhesive
self-adhesive quality that occurs automatically without the use of an adhesive

3.3 Blistering
paintwork defect in which local areas become detached from their substrate while still cohering with the rest of the paint

3.4 Bond
adhesion between the face(s) and the core normally provided by an adhesive

3.5 Ceiling
covering over an internal area

3.6 Core
layer of material that has thermal insulating properties and that is bonded between two metal faces

3.7 Durability
ability of the panel to withstand the environmental effects and to accommodate the consequent decrease in mechanical strength with time caused by factors such as temperature, humidity, freeze-thaw cycles and their various combinations

3.8 Edge
longitudinal edge
side of the panel where adjacent panels join together in the same plane

3.9 Face
facing
flat, lightly profiled or profiled thin metal sheet firmly bonded to the core

3.10 Joint
interface between two panels where the meeting edges have been designed to allow the panels to join together in the same plane

NOTE 1: The joint may incorporate interlocking parts that enhance the mechanical properties of the system as well as improving the thermal, acoustic and fire performance and restricting air movement.

NOTE 2: The term “joint” does not refer to a junction between cut panels or a junction where the panels are not installed in the same plane.

3.11 Lamella
core material that consists of mineral wool that has been cut and orientated with the fibres perpendicular to the facings before bonding

3.12 Lightly profiled facing
facing with a rolled or pressed profile not exceeding 5 mm in depth

3.13 Preformed
pre-manufactured
ready for direct incorporation into the sandwich panel

3.14 Sandwich panel
building product that consists of two metal faces positioned on either side of a core that is a thermally insulating material, which is firmly bonded to both faces so that the three components act compositely when under load

3.15 Self-supporting panel
panel capable of supporting, by virtue of its materials and shape, its self-weight and in the case of panels fixed to spaced structural supports all applied loadings, and transmitting these loadings to the supports
NOTE: Examples of applied loadings are snow, wind and internal air pressure.

3.16 Shift
period of production during a working day, normally 6 h to 8 h but can be less

3.17 Side lap
folded area of one or both of the facing materials along the longitudinal edge of the panel that engages with the adjacent panel to form an interlocking or overlapping joint
4. Symbols, subscripts and abbreviations

For the purposes of this document, the following symbols, subscripts and abbreviations apply.

4.1 Symbols

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>cross-sectional area</td>
</tr>
<tr>
<td>B</td>
<td>flexural rigidity, overall width of the panel/specimen, width of support ((B_w))</td>
</tr>
<tr>
<td>C</td>
<td>ratio</td>
</tr>
<tr>
<td>D</td>
<td>overall depth of the panel</td>
</tr>
<tr>
<td>E</td>
<td>modulus of elasticity</td>
</tr>
<tr>
<td>F</td>
<td>force, load, support reaction</td>
</tr>
<tr>
<td>G</td>
<td>shear modulus, permanent action</td>
</tr>
<tr>
<td>I</td>
<td>moment of inertia</td>
</tr>
<tr>
<td>L</td>
<td>span, distance</td>
</tr>
<tr>
<td>M</td>
<td>bending moment</td>
</tr>
<tr>
<td>N</td>
<td>axial compressive force</td>
</tr>
<tr>
<td>Q</td>
<td>variable action</td>
</tr>
<tr>
<td>R</td>
<td>resistance, sound reduction index ((R_w)), reflectivity ((R_G)), tension</td>
</tr>
<tr>
<td>S</td>
<td>shear rigidity, value of a load effect, effect of an action</td>
</tr>
<tr>
<td>T</td>
<td>temperature</td>
</tr>
<tr>
<td>U</td>
<td>thermal transmittance</td>
</tr>
<tr>
<td>V</td>
<td>shear force</td>
</tr>
<tr>
<td>a</td>
<td>distance apart of clips (see A.10.4)</td>
</tr>
<tr>
<td>b</td>
<td>width of test specimen, width of plate, width of ribs/valleys, bowing</td>
</tr>
<tr>
<td>d</td>
<td>depth of face profile or stiffeners, depth of core ((d_c))</td>
</tr>
<tr>
<td>e</td>
<td>distance between centroids of faces, base of natural logarithms ((e = 2.718282))</td>
</tr>
<tr>
<td>f</td>
<td>strength, yield stress, thermal transmittance contribution factor ((f_{joint}))</td>
</tr>
<tr>
<td>h</td>
<td>height of profile, thickness (for example glue)</td>
</tr>
<tr>
<td>k</td>
<td>parameter (see E.4.3.2 support reaction capacity), correction factor</td>
</tr>
<tr>
<td>l</td>
<td>length, deviation</td>
</tr>
<tr>
<td>m</td>
<td>mass</td>
</tr>
<tr>
<td>n</td>
<td>number of tests, number of screws, number of webs</td>
</tr>
<tr>
<td>p</td>
<td>pitch of profile</td>
</tr>
<tr>
<td>q</td>
<td>live load</td>
</tr>
<tr>
<td>r</td>
<td>radius</td>
</tr>
<tr>
<td>s</td>
<td>length of web ((S_{wl}))</td>
</tr>
<tr>
<td>t</td>
<td>thickness of face sheet</td>
</tr>
<tr>
<td>v</td>
<td>variance factor</td>
</tr>
<tr>
<td>x, y, z</td>
<td>coordinates</td>
</tr>
<tr>
<td>α</td>
<td>parameter (see A.5.5.4), coefficient of thermal expansion, sound absorption ((\alpha_w))</td>
</tr>
<tr>
<td>β</td>
<td>parameter (see A.5.5.4 and table E.10.2 design equations)</td>
</tr>
<tr>
<td>δ</td>
<td>deviation</td>
</tr>
<tr>
<td>φ</td>
<td>angle</td>
</tr>
<tr>
<td>γ</td>
<td>shear strain, partial safety factor</td>
</tr>
<tr>
<td>λ</td>
<td>thermal conductivity, (\lambda_{design}) (design value)</td>
</tr>
<tr>
<td>Φ</td>
<td>creep coefficient</td>
</tr>
<tr>
<td>θ</td>
<td>parameter (see table E.10.1 design equations)</td>
</tr>
<tr>
<td>σ</td>
<td>stress, compressive strength</td>
</tr>
<tr>
<td>(\sigma_m)</td>
<td>standard deviation i shear stress</td>
</tr>
<tr>
<td>ψ</td>
<td>combination coefficient (see annex E), linear thermal transmittance of joints (see A.10.3)</td>
</tr>
<tr>
<td>ρ</td>
<td>coefficient, density</td>
</tr>
</tbody>
</table>
4.2 Subscripts
C  core
D  declared value ($R_b$)
F  face, action ($\gamma_F$)
G  self-weight, degree M material ($\gamma_M$)
Q  variable action
S  sandwich part of the cross-section
adj  adjusted
b  bending, elastic extension
c  compression, core, carrier (see C.4.3.2), clip ($f_{\text{joint,c}}$)
d  design
e  external, additional thickness of main profiles ($\Delta e$)
eff  effective
f  load, facing ($\lambda_{fi}$)
i  internal ($\lambda_{fi}$)
i, j  index
k  characteristic value
lin  linear
m  material
n  nominal
nc  without clip ($f_{\text{joint,nc}}$)
obs  observed (for example result)
q  uniform load
s  support ($L_z = \text{support width}$), stiffeners, surface ($R_{st}$)
t  tension, time
tol  tolerance (normal or special)
tr  traffic ($C_{tr}$)
u  ultimate ($F_u$)
v  shear, variance
w  wind, web, wrinkling ($\sigma_w$), weighted ($R_w$)
y  yield
0  basic value, unit width, time (for example $t = 0$)
1  external face, upper face
2  internal face, lower face

4.3 Abbreviations
CG  cellular glass
CWFT  classified without further testing EPS expanded polystyrene
FPC  factory production control
ITT  initial type test
MW  mineral wool
NPD  no performance determined
PUR  rigid polyurethane foam (includes polyisocyanurate foam (PIR))
PF  phenolic foam
XPS  extruded polystyrene foam
5. Requirements, properties and actions

5.1 Requirements for component materials

5.1.1 General
The product shall be manufactured with materials and components that comply with 5.1.2 to 5.1.4.

5.1.2 Metal facings

5.1.2.1 Steel faces
Steel (other than stainless steel) faces shall have a minimum yield strength of 220 N/mm$^2$ and shall comply with the requirements of the appropriate standard given in table 1.

Table 1 - Standards for steel with metallic coating

<table>
<thead>
<tr>
<th>1</th>
<th>Metallic coating</th>
<th>2</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc, 5 % Al-Zn, 55 % Al-Zn and aluminium-silicon</td>
<td>EN 10169</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>EN 10346</td>
<td></td>
</tr>
</tbody>
</table>

The minimum nominal metallic coating masses shall be as specified in EN 508-1. If the metal face is bonded over its whole area to a rigid foam core with a closed cell structure, the reverse side metallic coating mass shall be a minimum of 50 g/m$^2$.

Organic protective coatings shall be selected according to their durability in the application environment. Organic coated steel sheets shall comply with the requirements of EN 10169. Multilayer coatings shall comply with EN 508-1.

The panel manufacturer shall state the metal grade, thickness and tolerance system of each face. Tolerances on thickness shall be according to "special" or "normal" tolerances as described in the relevant standards. The thickness of steel facing sheets shall be determined in accordance with EN 10143.

NOTE: Not all steels in table 1 are suitable for sandwich panels in all the intended end uses.

5.1.2.2 Stainless steel faces
Stainless steel facings shall have a minimum yield strength of 220 N/mm$^2$. The chemical composition of stainless steel faces and their physical properties shall comply with EN 10088-1.

The panel manufacturer shall state the metal grade, thickness and tolerance system of each face. Tolerances on thickness shall be in accordance with "special" or "normal" tolerances as described in the relevant standards. The thickness of steel facing sheets shall be determined in accordance with ISO 9445-1 and ISO 9445-2.

NOTE: Not all steels in EN 10088-1 are suitable for sandwich panels in all the intended end uses.

The coating properties of terne coated stainless steel shall comply with EN 502. The nominal coating mass shall be the total mass including both sides and shall be at least 40 g/m$^2$.

5.1.2.3 Aluminium faces
Aluminium facings shall have a minimum design value of the stress at the 0.2 % strain limit (for simplification called "yield strength") of 140 N/mm$^2$. The chemical composition, temper and mechanical properties of aluminium shall comply with EN 485-2 or EN 1396.

Organic coated aluminium sheets shall comply with the requirements of EN 1396.

The panel manufacturer shall state the metal grade, thickness and tolerance system of each face. Tolerances on thickness shall be in accordance with "special" or "normal" tolerances as described in the relevant standards. The thickness of aluminium facing sheets shall be determined in accordance with EN 485-4 or EN 1396.

NOTE: Not all aluminium alloys covered by EN 485-2 or EN 1396 are suitable for sandwich panels in all the intended end uses.
5.1.2.4 Copper faces
Copper facings shall have a minimum design value of the stress at the 0.2 % strain limit (for simplification called "yield strength") of 180 N/mm². The chemical composition, temper, mechanical properties and thickness tolerances of copper faces shall comply with EN 1172.

The panel manufacturer shall state the metal grade, thickness and tolerance system of each face. Tolerances on thickness shall be in accordance with "special" or "normal" tolerances as described in the relevant standards. The thickness of copper facing sheets shall be determined in accordance with EN 1172.

NOTE: Not all copper facings in EN 1172 are suitable for sandwich panels in all the intended end uses.

5.1.3 Core materials

5.1.3.1 Thermal performance
The declared and design thermal conductivity of core materials shall be determined in accordance with 5.2.2.

5.1.3.2 Thermal stability of core materials
The insulating core materials shall comply with the thermal stability and shrinkage requirements specified in EN 13162 to EN 13167.

5.1.4 Adhesives and bonding
Adhesives and bonding shall comply with 5.2.1.6 and 5.2.3.1.

The adhesion between the core and the faces of the panel has a fundamental role in the satisfactory performance of the panel. The surface preparation of the facing material shall be appropriate for the adhesive or the method of adhesion.

5.2 Properties of panels

5.2.1 Mechanical resistance of the panel

5.2.1.1 General
For mechanical properties, unless stated otherwise, the mean value and the characteristic value (5 %-fractile value assuming a confidence level of 75 % for each population of test results) shall be determined in accordance with ISO 12491.

Declared values shall be given to two significant figures.

5.2.1.2 Shear strength (f_{c,0}) and shear modulus (G)

5.2.1.2.1 The characteristic value of the shear strength of the core shall be determined in accordance with A.3 or A.4 and shall be declared by the manufacturer in megapascals (MPa).

NOTE The test in A.3 is the standard test that should be used for core materials without joints. It may be used for materials with joints when allowance is made for the influence of joints on both stiffness and strength. The test in A.4 should be used wherever the incidence of joints is considered to be significant. The test in A.5.6 may be used to determine a more reliable value of the shear modulus for all core materials.

5.2.1.2.2 The declared value shall be less than or equal to the characteristic value. The mean value of the shear modulus of the core shall be declared and the 5 %-fractile value recorded for FPC purposes in accordance with A.3, A.4 or A.5.6. Only the mean value of the shear modulus obtained from the available test results shall be declared.

NOTE: The mean value of shear modulus is used for calculation. Low values of the shear modulus may be associated with low values of wrinkling stress.

5.2.1.3 Creep coefficient (\(\phi_t\))
The creep coefficient shall be determined in accordance with A.6 and expressed as a number.

The creep coefficient shall be determined for all panels used as a roof or ceiling designed to carry long-term or permanent loads, for example snow and self-weight.
5.2.1.4 Compressive strength ($\sigma_m$) or compressive stress ($\sigma_{10}$)
The compressive strength of the core $\sigma_m$ or its compressive stress at 10 % deformation $\sigma_{10}$ (whichever is reached first) shall be determined in accordance with the method given in A.2 and shall be declared by the manufacturer in megapascals (MPa).

5.2.1.5 Shear strength after long-term loading ($f_{ct}$-long term)
Where required, the shear strength after long-term loading shall be determined in accordance with A.3.6.

This value shall be determined for all panels used as a roof or ceiling designed to carry long-term or permanent loads, for example snow and self-weight. The declared value shall be less than or equal to the characteristic value ($f_{ct}$) and shall be declared by the manufacturer in megapascals (MPa).

5.2.1.6 Cross panel tensile strength ($f_{ct}$)
The cross panel tensile strength perpendicular to the panel faces shall be greater than 0.018 MPa when tested in accordance with A.1 and shall be declared by the manufacturer in megapascals (MPa).

The characteristic value for tensile strength shall be at least 0.018 MPa. The declared values shall be less than or equal to the characteristic value.

NOTE: A low tensile strength can reduce the wrinkling strength and increase its variability. Account is taken of this in A.5.5.5 ($k_2$ factor).

5.2.1.7 Bending moment capacity ($M_u$) and wrinkling stress ($\sigma_{wr}$)
The bending moment capacity shall be obtained by testing in accordance with A.5 and shall be declared by the manufacturer in kilonewton metres per metre width (kNm/m).

For panels with flat or lightly profiled faces, the wrinkling stress shall be calculated in accordance with A.5.5 and shall be declared by the manufacturer in megapascals (MPa).

5.2.1.8 Bending moment capacity and wrinkling stress over a central support
Where required, the bending moment capacity over a central support shall be determined in accordance with A.7. For panels with flat or lightly profiled faces, the wrinkling stress shall then be calculated in accordance with A.5.5.

The bending moment capacity over a central support is required when panels, which are continuous over two or more spans, are to be designed by calculation in accordance with annex E. In such cases, the comparison of the design values of resistance in accordance with E.2 is usually carried out in terms of stresses. If the panel has one or more profiled faces, the determination of the ultimate compressive (wrinkling) stress from the bending moment capacity requires calculation in accordance with E.7.5. It is recommended that this calculation be carried out at the time of testing.

5.2.2 Thermal transmittance
The thermal transmittance value for the panel ($U$), incorporating the design thermal conductivity for the core material ($\lambda_{design}$) and the joints and any profiled facings, shall be determined in accordance with A.10.

5.2.3 Durability and other long-term effects

5.2.3.1 Reduction of tensile strength with time as a consequence of ageing (durability)
Panels shall satisfy the criteria for reduction in tensile strength in accordance with the relevant test method DUR1 and DUR2 (see table 2) as described in annex B.

Durability tests shall be applied to panels designed for external applications. They are based on the accelerated ageing effect of temperature or humidity, which from long-term experience are critical for each core material. The use of EPS and XPS panels is restricted to applications where temperatures do not exceed +80 °C. When required, the durability tests may be used to assess the performance of internal sandwich panels.

NOTE: These tests evaluate the reduction of tensile strength as a result of temperature or humidity on a pass/fail basis.

PUR panels manufactured using the blowing agents such as hydrocarbons (namely pentanes) and hydro fluorocarbons (namely HFC 134a, 245fa, 227ea and 365mfc), and a combination of these blowing agents, but excluding CO₂ blown foams, shall be considered to satisfy the durability requirements without testing. PUR panels manufactured with other blowing agents shall be tested in accordance with test DUR1 and the colour reflectivity levels shall be declared (see B.2.5).
Table 2 - Durability tests

<table>
<thead>
<tr>
<th>Insulating core material</th>
<th>Test method (see annex B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral wool (MW)</td>
<td>DUR2 a</td>
</tr>
<tr>
<td>Polystyrene (EPS or XPS)</td>
<td>DUR1 b</td>
</tr>
<tr>
<td>Polystyrene (PUR), – auto-adhesive bond</td>
<td>DUR1 c</td>
</tr>
<tr>
<td>Polystyrene (PUR), – adhesive bond</td>
<td>DUR1 d</td>
</tr>
<tr>
<td>Phenolic foam (PF)</td>
<td>DUR1 and repeated loading in B.6 e</td>
</tr>
<tr>
<td>Cellular glass (CG)</td>
<td>DUR1, thermal shock B.7 and repeated loading in B.6 f</td>
</tr>
</tbody>
</table>

a  DUR2 including the wedge test (see B.5).

b  DUR1 including wedge test (see B.5).

c  No test is required for panels manufactured using the blowing agents covered within EN 13165 and combinations of these agents, but excluding CO2 blown foams. Other blowing agents shall be tested to DUR1.

d  No test is required for panels manufactured using the blowing agents covered within EN 13165 and combinations of these agents, but excluding CO2 blown foams. Other blowing agents shall be tested to DUR1 including the wedge test (see B.5). The wedge test shall be carried out.

e  PF panels with an adhesive bond shall be tested in accordance with DUR1 including the wedge test (see B.5).

f  Including the wedge test (see B.5).

5.2.3.2 Resistance to point loads and access loads - Ceiling panels
When required, the ability of a sandwich panel to resist point loads and access loads shall be determined in accordance with A.9.1. For applications where there will be more frequent access than occasional foot traffic (see note 2), the procedure described in A.9.2 shall also be carried out.

NOTE 1: The span capabilities of a ceiling panel and its supporting system should be checked before access is allowed.

NOTE 2: Ceiling panels are generally unsuitable for regular foot traffic.

NOTE 3: Panels should be protected when used on regular walking routes or working areas both during installation and in end use. Panels should allow a wide and safe support for a foot and should not be subject to permanent deformations under occasional foot traffic for access or maintenance. For maintenance purposes, only one person at a time should be allowed to walk on a panel.

5.2.4 Fire characteristics

5.2.4.1 General
Sandwich panels shall be tested in the end use application as far as possible. This means the performance of an assembly shall be assessed, i.e. the assembly that is to be installed in a building, including the product and its coatings, factory applied seals, standard joints, representative flashings, and a method of fixing as appropriate to the test.

5.2.4.2 Fire resistance rating as applicable to fire separating elements (non-load bearing)
When determined in accordance with C.1, the fire-resistance rating, as applicable to a fire separation element, of a panel assembly shall be as stated. The determination can be of non-load bearing nature and of load-bearing nature in which the failing temperature of load-bearing members shall be less than 376 °C.

5.2.4.3 Fire performance classification of thermal insulated building envelope systems
When determined in accordance with C.2, the fire performance classification of a panel system shall be as stated.

5.2.4.4 Surface fire index classification
When determined in accordance with C.3, the surface fire index classification of a panel shall be as stated.

The surface fire index classification shall only be done in respect of the metal face if the face is coated with an organic material exceeding 0.5 mm in thickness.

5.2.5 Dimensional tolerances for sandwich panels
The dimensional tolerances for sandwich panels shall be in accordance with table 3.
Table 3 - Dimensional tolerances for sandwich panels

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Tolerance (maximum permissible)</th>
<th>Measurement method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness of the panel</td>
<td>$D \leq 100 \text{ mm} \pm 2 \text{ mm}$</td>
<td>D.2.1</td>
</tr>
<tr>
<td></td>
<td>$D &gt; 100 \text{ mm} \pm 2 %$</td>
<td></td>
</tr>
<tr>
<td>Deviation from flatness (according to the length of measurement $L$)</td>
<td>For $L = 200 \text{ mm}$ – Deviation from flatness $0,6 \text{ mm}$</td>
<td>D.2.2</td>
</tr>
<tr>
<td></td>
<td>For $L = 400 \text{ mm}$ – Deviation from flatness $1,0 \text{ mm}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>For $L &gt; 700 \text{ mm}$ – Deviation from flatness $1,5 \text{ mm}$</td>
<td></td>
</tr>
<tr>
<td>Depth of metal profile (ribs) (mm)</td>
<td>$5 &lt; h &lt; 50 \text{ mm} \pm 1 \text{ mm}$</td>
<td>D.2.3</td>
</tr>
<tr>
<td></td>
<td>$50 &lt; h &lt; 100 \text{ mm} \pm 2,5 \text{ mm}$</td>
<td></td>
</tr>
<tr>
<td>Depth of stiffeners and light profiling</td>
<td>$d_s \leq 1 \text{ mm} \pm 30 %$ of $d_s$</td>
<td>D.2.4</td>
</tr>
<tr>
<td></td>
<td>$1 \text{ mm} &lt; d_s \leq 3 \text{ mm} \pm 0,3 \text{ mm}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$3 \text{ mm} &lt; d_s \leq 5 \text{ mm} \pm 10 %$ of $d_s$</td>
<td></td>
</tr>
<tr>
<td>Length of the panel</td>
<td>$L \leq 3 \text{ m} \pm 5 \text{ mm}$</td>
<td>D.2.5</td>
</tr>
<tr>
<td></td>
<td>$L &gt; 3 \text{ m} \pm 10 \text{ mm}$</td>
<td></td>
</tr>
<tr>
<td>Cover width of the panel</td>
<td>$w \pm 2 \text{ mm}$</td>
<td>D.2.6</td>
</tr>
<tr>
<td>Deviation from squareness</td>
<td>$0,006 \times w$ (nominal cover width)</td>
<td>D.2.7</td>
</tr>
<tr>
<td>Deviation from straightness (on length)</td>
<td>$1 \text{ mm/m, maximum 5 mm}$</td>
<td>D.2.8</td>
</tr>
<tr>
<td>Bowing</td>
<td>$2 \text{ mm/m length, maximum 10 mm}$</td>
<td>D.2.9</td>
</tr>
<tr>
<td></td>
<td>$8,5 \text{ mm/m width for flat profiles}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$h \leq 10 \text{ mm}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$10 \text{ mm/m width for profiles}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$h &gt; 10 \text{ mm}$</td>
<td></td>
</tr>
<tr>
<td>Pitch of the profile ($p$)</td>
<td>$2 \text{ mm/m}$ if $h \leq 50 \text{ mm}$</td>
<td>D.2.10</td>
</tr>
<tr>
<td></td>
<td>$p: \pm 2 \text{ mm}$ if $h &gt; 50 \text{ mm}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$p: \pm 3 \text{ mm}$</td>
<td></td>
</tr>
<tr>
<td>Width of the ribs ($b_1$) and width of the valleys ($b_2$)</td>
<td>$b_1: \pm 1 \text{ mm}$</td>
<td>D.2.11</td>
</tr>
<tr>
<td></td>
<td>$b_2: \pm 2 \text{ mm}$</td>
<td></td>
</tr>
</tbody>
</table>

For calculation of the thickness of panels with profiled facings, see figure D.1.

5.2.6 Resistance to rain penetration
When a joint in a panel system is tested in accordance with A.11 the joint shall be watertight for the selected period chosen from table 8 as given in SANS 10400-K:2011. The selected period shall be stated by the manufacturer.

The following criteria shall be used to determine water tightness:

a) there shall be not more than 100 g increase in mass of the specimen;

b) no water shall penetrate through the panel assembly to the inside of the building, which would continuously or repeatedly wet the inside face of the assembly or any part of the specimen intended to remain dry; and

c) any water penetrating through the joint system or fixings that is of the order of a few drops and that is estimated to dry out shall be acceptable if the weight gain criteria are met.

5.2.7 Air permeability (in cubic metres per square meter hour (m$^3$/m$^2$·h) at 50 Pa)
Where required, the air permeability of a complete assembly of sandwich panels shall be assessed, i.e. the assembly that is to be installed in a building, including the product and its coatings; factory applied seals, standard joints, site applied seals, representative flashings and a method of fixing as appropriate to the test.

The measurement of air permeability of a sandwich panel assembly shall comply with A.12. The test method shall be used for both external wall and roof applications.

Sandwich panels covered by this standard are metal faced. When correctly manufactured and if satisfying an appropriate visual inspection they may be deemed to be impermeable to air. The air tightness of the assembly is a function of its installation. Air permeability is only relevant to the joints and fixings.

5.2.8 Water vapour permeability
For the purposes of this standard, the water vapour transmission coefficient for the metal facings used is considered to be infinity. Metal faced sandwich panels are therefore considered to be impermeable to water vapour.

5.2.9 Airborne sound insulation ($R_w(C; C_{t,p})$)
When required, the airborne sound insulation of a sandwich panel assembly shall be determined in accordance with A.13. The result shall be declared as a ($R_w(C; C_{t,p})$) rating in accordance with SANS 717-1.
C is a spectrum adaptation term calculated with A-weighted pink noise. \( C_{tr} \) is a spectrum adaptation term calculated with A-weighted urban traffic noise.

### 5.2.10 Sound absorption (\( \alpha_w \))
When required, the sound absorption of a sandwich panel assembly shall be determined in accordance with A.14. The result shall be declared as single number rating in accordance with ISO 11654.

### 5.2.11 Resistance to hail
When a panel is tested in accordance with A.16, it shall show no sign of structural damage and the metal sheet shall not delaminate from the substrate.

### 5.3 Actions and safety level requirements

#### 5.3.1 Mechanical resistance to design loads
The product shall have sufficient mechanical resistance to the design loads arising from the actions of self-weight, snow, wind, temperature and pressure gradients and access, where these loads shall be factored such that, either alone or in combination, they do not impair the performance of the product in service.

The safety of the product shall be verified by design procedures based on the limit state concept. This requires that the "design value of the resistance" be greater than the "design value of the effect of the actions" and shall be satisfied at both the serviceability limit state and the ultimate limit state. Verification shall be by calculation in accordance with annex E.

Information on all values necessary for the production of design load tables together with the corresponding characteristic values obtained during initial type testing and factory production control (FPC) shall be provided. For the purpose of this standard the provision of such information shall be regarded as part of the product.

#### 5.3.2 Actions and combinations of actions
In design for mechanical resistance permanent actions, variable actions and actions due to long term effects shall be taken into account in the calculations. They shall be considered either individually or in combination using the combination factors in annex E.
6. Evaluation of compliance, testing, assessment and sampling methods

6.1 General
The compliance of a sandwich panel with the requirements of this standard and the stated values, including classes, shall be demonstrated by the following:

- initial type testing (ITT);
- factory production control (FPC) by the manufacturer, including product assessment; - when required, initial inspection (FPC); and
- when required, continuous surveillance (FPC).

The principle of grouping of products into families may be applied to reduce testing costs. A family is a group of products for which the test results for one or more characteristics of one product in the family are valid for all other products within the family. There may be different families for different characteristics as defined by the manufacturer. For the application of families in accordance with this product standard, the principle of "worst case" situation shall apply.

When the manufacturer produces products that have the same physical and chemical characteristics on more than one production line or in more than one factory, there shall be no need to repeat ITT for the different production lines.

If there is a difference between the characteristic values for products from two different lines, the worst values shall be used.

6.2 Type testing - ITT

6.2.1 Initial type evaluation
Initial type testing shall be conducted to show compliance with this standard in accordance with table 4.

Whenever a change occurs in the product, raw material or supplier of the components, or the production process (subject to the definition of a family), which would change significantly one or more characteristics, the type tests shall be repeated for the appropriate characteristic(s).

In addition, initial type testing shall be performed at the beginning of the production of a new panel type (unless a member of the same family) or at the beginning of a new method of production where this may affect the declared properties or compliance of the product.

Characteristics that are required for specific applications, for example permeabilities or acoustics, shall be tested on a "when–required" basis.

Data from tests previously performed in accordance with the provisions of this standard (same product, same characteristics, test method, sampling procedure, system of attestation of compliance, etc.) may be used.

6.2.2 Sampling for ITT and audit testing purposes

6.2.2.1 General
Samples shall be representative of the product to be placed on the market and the manufacturer shall keep satisfactory records as part of his/her FPC.

All samples shall preferably be from the same batch or, if this is not practicable, the manufacturer shall ensure availability of sufficient proof allowing comparison of the ITT or audit test results with those for samples from other batches.

The number of test specimens (for ITT) shall be in accordance with the test methods in table 4. The sample taken, i.e. the panel, shall be a simple random sample, drawn from a finite panel population.

When test specimens are obtained from a single panel, the specimens shall be taken from a range of positions covering the width of the panel. At least one specimen shall be taken from the middle of the panel and at least one specimen from close to the edge of the panel, with the first cut edge not greater than 10 % of the cover width of the panel from an outside edge.
Conditioning of the test specimens, before or after the test, shall not be carried out unless otherwise specified in the test method.

The minimum age of specimens for ITTs shall be at least 24 h. The date and time of production shall be recorded at the time of sampling.

NOTE: Test specimens are very sensitive to the process of cutting and the accuracy of testing, in particular for tensile test measurements. Considerable care is required in the cutting process, especially if the core material is relatively weak or has brittle tendencies. The cutting can be carried out with a band saw with a fine-toothed blade. It may be advantageous to sandwich the specimen between two pieces of plywood or similar material in order to reduce vibration during the cutting process. It is suggested that specimens be carefully inspected after cutting. Specimens that show evidence of delamination caused by the cutting process should be rejected (up to a maximum of 30% of those cut for any family of tests).

6.2.2.2 Sampling marking and records

6.2.2.2.1 Marking of all samples intended for ITT purposes shall contain the following:

- the date and time of sampling;
- the production line or unit; and
- an identification mark.

6.2.2.2.2 The sampling records shall provide at least the following information:

- the name of the manufacturing plant;
- the place of sampling;
- the stock or batch quantity (from which the samples have been taken);
- the quantity of samples;
- a reference to this standard, i.e. SANS 54509;
- the marking of the product by the manufacturer;
- the identification mark of the samples;
- the properties to be tested;
- the place and date of testing; and
- the signature(s) of the person(s) responsible for the sampling.

NOTE: If a third party is responsible for sampling, the sampling records of that third party may be used.

6.2.3 Testing and compliance criteria - ITT

All characteristics in table 4, where relevant, shall be subject to ITT tests with the exception of external fire performance when using the CWFT option, where measurement in accordance with C.3.1 is required to ensure that the product meets the definition required for CWFT.

Unless the test method requires otherwise, all testing shall be carried out under ambient laboratory conditions, without any special conditions.

For mechanical properties, unless stated otherwise, the mean value and the characteristic value (5%-fractile value assuming a confidence level of 75%) for each population of the test results shall be determined in accordance with ISO 12491 using the equation and fractile factors in A.17.3.

The results of all type tests shall be recorded and held by the manufacturer for at least five years after the last date of production of the product(s) to which they belong.
Table 4 - Test methods, test specimens, type of the test and conditions for ITT

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Test method</th>
<th>Type of test</th>
<th>Min. number of ITT specimens</th>
<th>Compliance criteria and specific conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1.2 Mechanical properties of a face</td>
<td>ISO 6892-1⁹</td>
<td>ITT</td>
<td>3 ⁹</td>
<td></td>
</tr>
<tr>
<td>Mechanical properties of a panel and its core material:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.2.1.2 Shear strength and modulus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.2.1.4 Compressive strength and stress</td>
<td>A.3 or A.4 or A.5.6, A.2</td>
<td>ITT</td>
<td>3</td>
<td>Statement of declared values</td>
</tr>
<tr>
<td>5.2.1.5 Reduced shear strength⁵</td>
<td>A.3.6, A.1, A.5</td>
<td>ITT</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>5.2.1.6 Cross panel tensile strength (and modulus⁰)</td>
<td>A.3.6</td>
<td>ITT</td>
<td>1/10⁵</td>
<td></td>
</tr>
<tr>
<td>5.2.1.7 Bending moment capacity and wrinkling stress</td>
<td>A.7, A.6</td>
<td>ITT</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>5.2.1.8 Bending moment capacity over a central support</td>
<td>A.7</td>
<td>ITT</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Cross panel tensile modulus at elevated temperatures⁶, ⁷</td>
<td>A.1 .6</td>
<td>ITT</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>A.8</td>
<td>ITT record</td>
<td></td>
<td>Maximum, minimum and average densities to be recorded</td>
</tr>
<tr>
<td>5.2.2 Thermal transmittance</td>
<td>A.10</td>
<td>ITT</td>
<td>See A.10</td>
<td>Limit value in accordance with A.10</td>
</tr>
<tr>
<td>5.2.3 Durability</td>
<td>Annex B, ITT pass</td>
<td>ITT</td>
<td>Pass (see 5.2.3 and annex B)</td>
<td></td>
</tr>
<tr>
<td>5.2.5 Dimensional tolerances</td>
<td>Annex D</td>
<td>ITT</td>
<td>1</td>
<td>Statement of declared classification</td>
</tr>
<tr>
<td>5.2.6 Resistance to rain penetration</td>
<td>A.1 1</td>
<td>ITT</td>
<td>Assembly</td>
<td>Statement of declared classification</td>
</tr>
<tr>
<td>5.2.7 Air permeability</td>
<td>EN 12114</td>
<td>ITT</td>
<td>1</td>
<td>EN 12114 and in accordance with A.12</td>
</tr>
<tr>
<td>5.2.9 Airborne sound insulation</td>
<td>SANS 140-3</td>
<td>ITT</td>
<td>1</td>
<td>Declaration $R_{p}(C;G_{tr})$ (see A.13)</td>
</tr>
<tr>
<td>5.2.10 Sound absorption</td>
<td>ISO 354</td>
<td>ITT</td>
<td>1</td>
<td>ISO 11654 (see A.14)</td>
</tr>
<tr>
<td>5.2.11 Resistance to hail</td>
<td>A.16</td>
<td>ITT</td>
<td>1</td>
<td>Compliance as in this standard</td>
</tr>
<tr>
<td>5.2.4.2 Fire resistance</td>
<td>SANS 10177-2</td>
<td>ITT</td>
<td>1</td>
<td>Statement of declared classification</td>
</tr>
<tr>
<td>5.2.4.3 Fire performance classification</td>
<td>SANS 428</td>
<td>ITT</td>
<td>Assembly</td>
<td>Statement of declared classification</td>
</tr>
<tr>
<td>5.2.4.4 Fire index</td>
<td>SANS 10177-3</td>
<td>ITT</td>
<td>3 × sheets</td>
<td>Statement of declared classification</td>
</tr>
</tbody>
</table>

⁹ These values are required to adjust test results in accordance with A.5.5.4.
⁵ Roof/ceiling applications only.
¹⁵ 1/10 = a single test series with 10 specimens.
⁲ Required for design purposes only - not declared.
⁷ Not declared. Required to calculate the wrinkling stress at elevated temperature.
⁸ Where required.
⁹ Roof and side cladding only.
6.3 Factory production control (FPC)

6.3.1 General
The manufacturer shall establish, document and maintain an FPC system to ensure that the products placed on the market comply with the stated performance characteristics. The FPC system shall consist of procedures, regular inspections and tests or assessments (or both) and the use of the results to control raw and other incoming materials or components, equipment, the production process and the product.

An FPC system that complies with the requirements of SANS 9001, and that is made specific to the requirements of this standard, shall be considered to satisfy the above requirements.

The results of inspections, tests or assessments requiring action shall be recorded, as shall any action taken. The procedure and action to be taken in cases of non-conformity shall be clearly stated.

When products of the same family (see 6.1) are produced using the same process equipment, the manufacturer may use common ITT results provided compliance can be shown, in which case FPC procedures shall be the same.

Where a manufacturer operates different production lines or units in the same factory or production lines or units in different factories and these are covered by a single overall FPC system, the manufacturer shall keep control records for each separate production line or unit.

In addition to the test results, the following minimum information shall also be recorded: - the date and time of manufacture;
- the type of product; and
- the product specification, including materials and components.

6.3.2 Results of FPC tests
Each individual value of a declared mechanical property determined by FPC shall be equal to or higher than the value declared as a result of ITT. If one or more values are lower, a statistical evaluation of this property shall either be carried out over the previous year and the 5 %-fractile value determined or, if FPC of this property has been carried out for less than one year, all available results shall be included in the evaluation. This 5 %-fractile value shall be equal to or higher than the declared value.

For each declared value, if the fractile value is lower than the declared value, additional FPC tests shall be carried out on material from the same batch and a corrected 5 %-fractile value determined. If this value is lower than the declared value, the batch shall be rejected.

If sustained FPC results indicate that the declared value cannot be attained, either the declared value shall be reduced on the basis of the existing ITT tests, or a new set of ITT tests shall be carried out and a new value for the relevant property shall be declared.

NOTE 1: The number of additional tests required is at the discretion of the manufacturer.

NOTE 2: Where the results of FPC consistently exceed the declared value these results may be used to determine a 5 %-fractile value, which may be used as the basis for an increase in the declared value.

6.3.3 Equipment
Tests to demonstrate compliance of the finished product with this standard shall be carried out using equipment described in the relevant test methods referred to in this standard.

All weighing, measuring and testing equipment necessary to achieve, or produce evidence of, compliance shall be calibrated or verified and regularly inspected in accordance with documented procedures, frequencies and criteria. Calibration or checking (or both) shall be against equipment or test specimens traceable to relevant international or nationally recognized reference test specimens (standards). Where no such reference test specimens exist, the basis used for internal checks and calibration shall be documented.

All equipment used in the manufacturing process shall be regularly inspected and maintained to ensure that use, wear or failure does not cause inconsistency in the manufacturing process.
Inspections and maintenance shall be carried out and recorded in accordance with the manufacturer’s written procedures and the records retained for the period defined in the manufacturer’s FPC procedures.

The manufacturer shall ensure that handling, preservation and storage of test equipment is such that its accuracy and fitness for purpose are maintained.

When production is intermittent, the manufacturer shall ensure that any test equipment which may be affected by the interruption is suitably checked or calibrated (or both) before use.

The calibration of all test equipment shall be repeated if any repair or failure occurs that could upset the calibration of the test equipment.

6.3.4 Raw materials and components

6.3.4.1 General
The specifications of all incoming raw materials and components shall be documented, as shall the inspection scheme for verifying their compliance.

The manufacturer shall have written procedures that specify how non-conforming raw materials and components shall be dealt with. Any such events shall be recorded as they occur and these records shall be kept for the period defined in the manufacturer’s written procedures.

Compliance for metal facings shall be in accordance with 6.3.4.2, preformed core components with 6.3.4.3 and adhesives with 6.3.4.4.

6.3.4.2 Metal facings
When provided by the facing manufacturer, declarations shall be in accordance with SANS 31, document type 3.1, and shall be provided for every 50 t of coil material.

6.3.4.3 Prefabricated lamella and preformed core material
Preformed material for the cores of sandwich panels shall undergo FPC testing (see table 5). The panel manufacturer shall determine or obtain a manufacturer’s declaration for the following properties in accordance with the relevant insulation product standard (see EN 13162 and EN 13167):

- tolerances (particularly consistency of thickness); and
- thermal conductivity.

NOTE: In the context of this standard, declaration means the supplier’s formal declaration of the properties.

6.3.4.4 Adhesives
The panel manufacturer shall obtain the supplier’s declaration for the following: - the description and specification;

- the viscosity/speed; and

- the shelf life.

6.3.5 Product testing and assessment - FPC

6.3.5.1 General
The manufacturer shall establish procedures to ensure that the stated values of all of the characteristics are maintained in accordance with 6.3.5.2 and 6.3.5.3.

The FPC procedures shall be organized so that every product type appears in the statistical control in approximate proportion to the volume of production.

Suppliers who purchase the product from a manufacturer whose production plant is outside South Africa shall establish procedures to ensure that the stated values of all of the characteristics are maintained in accordance with 6.3.6.

6.3.5.2 FPC procedures for panels
The minimum FPC procedure for the manufacture of panels shall include testing in accordance with table 5.
FPC tests shall be carried out either on aged specimens or on specimens taken immediately after production.

The number of test specimens for FPC shall be in accordance with the test methods in table 5.

The specimens shall be taken from a range of positions covering the width of the panel. At least one specimen shall be taken from the middle of the panel and at least one specimen from close to the edge of the panel, with the first cut edge not greater than 10% of the cover width of the panel from an outside edge.

NOTE: Test specimens are very sensitive to the process of cutting and the accuracy of testing in particular for tensile test measurements. Considerable care is required in the cutting process, especially if the core material is relatively weak or has brittle tendencies. The cutting can be carried out with a band saw with a fine-toothed blade. It may be advantageous to sandwich the specimen between two pieces of plywood or similar material in order to reduce vibration during the cutting process. It is suggested that specimens be carefully inspected after cutting. Those that show evidence of delamination caused by the cutting process may be rejected (up to a maximum of 30% of those cut for any family of tests).

If the wrinkling stress is determined by calculation, the FPC control of the tension and compression moduli shall be carried out in accordance with table 5.

If the wrinkling stress is not controlled at least once per week then the FPC control of the tension and compression moduli shall be carried out in accordance with table 5.
### Table 5 - FPC procedures for panels

<table>
<thead>
<tr>
<th>Type of test</th>
<th>Test method</th>
<th>Minimum number of specimens</th>
<th>Minimum frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density of core material</td>
<td>A.8</td>
<td>3</td>
<td>1 per shift/6 h or 8 h</td>
</tr>
<tr>
<td>Cross-panel tensile strength and modulus (with faces)</td>
<td>A.1</td>
<td>3</td>
<td>1 per shift/6 h or 8 h</td>
</tr>
<tr>
<td>Compressive strength and modulus of core material</td>
<td>A.2</td>
<td>3</td>
<td>1 per week</td>
</tr>
<tr>
<td>Shear strength and modulus of core material</td>
<td>A.3</td>
<td>3</td>
<td>1 per week</td>
</tr>
<tr>
<td>Tensile strength of face material (or declaration – see 6.3.4.2)</td>
<td>–</td>
<td>3</td>
<td>All deliveries</td>
</tr>
<tr>
<td>Thickness of face material (or declaration – see 6.3.4.2)</td>
<td>–</td>
<td>3</td>
<td>All deliveries</td>
</tr>
<tr>
<td>Shear strength of complete panelb</td>
<td>A.4</td>
<td>1</td>
<td>1 per 2 weeks</td>
</tr>
<tr>
<td>Wrinkling stress (optional, see text above)</td>
<td>A.5</td>
<td>1</td>
<td>Per week</td>
</tr>
<tr>
<td>Dimensional control:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Panel thickness</td>
<td>D.2.1</td>
<td>1</td>
<td>1 per shift/6 h or 8 h</td>
</tr>
<tr>
<td>- Deviation from flatness</td>
<td>D.2.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Depth of profile</td>
<td>D.2.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Depth of stiffeners</td>
<td>D.2.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Length of panel</td>
<td>D.2.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Cover width</td>
<td>D.2.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Deviation from squareness</td>
<td>D.2.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Deviation from straightness</td>
<td>D.2.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Bowing (curvature)</td>
<td>D.2.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Pitch of profile</td>
<td>D.2.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Width of valleys/ribs</td>
<td>D.2.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire performance classificationc</td>
<td></td>
<td></td>
<td>Specification record</td>
</tr>
<tr>
<td>Resistance to fire</td>
<td>–</td>
<td></td>
<td>Specification record</td>
</tr>
<tr>
<td>Hail resistance</td>
<td>–</td>
<td></td>
<td>Specification record</td>
</tr>
<tr>
<td>Rain penetration</td>
<td>–</td>
<td></td>
<td>Specification record</td>
</tr>
<tr>
<td>Thermal insulation performance</td>
<td>A.10.2.1.1a</td>
<td>1</td>
<td>1 per month</td>
</tr>
<tr>
<td>Air permeability - see 5.2.7</td>
<td>Visual</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water vapour permeability - see 5.2.8</td>
<td>Visual</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Where production volumes are below 2 000 m² per shift, the manufacturer shall only test every 2 000 m² or at least every three months. Dimensional control tests and permeability inspections, however, shall be carried out every shift.
- Panels with MW lamella insulating cores only.
- Manufacturer’s specification record (see 6.3.5.3).
- Procedure tests λₖ (single test result of thermal conductivity) in accordance with the appropriate product standard for the core material (see A.10.2.1.1) and shall be representative of the material at the time of manufacture of the panel.

**NOTE 1:** The control of the thickness of preformed core material or lamellas and the positioning of the joints between individual slabs are of fundamental importance and should be frequently checked (e.g. every 2 h).

**NOTE 2:** Typical allowable difference in cutting thickness of core material between adjacent preformed pieces for fabrication with stiff platens is ±0.5 mm.
6.3.5.3 FPC controls for fire characteristics

FPC controls for fire characteristics shall be carried out as follows:

a) Panels with insulation created by foaming (chemical action) during the manufacturing process shall be controlled by recording the precise specification of all chemical components, fire retardants, etc. for each production batch, including the origin of supply, proportions used, etc. In the case of chemical systems supplied by an external manufacturer a sufficient statement of the specification shall be provided. The panel design/type shall be recorded to confirm the panel to panel joint detail.

b) Panels with preformed or lamella insulation produced by bonding shall be controlled by recording the precise specification of all preformed or lamella components for each production batch, including, as applicable, the full chemical specification, density, fire retardants, binders, adhesives, or other organic material, including backing coats, etc. In the case of preformed or lamella and other components (i.e. adhesives) supplied by an external manufacturer a sufficient statement of the specification shall be provided. The panel design/type shall be recorded to confirm the panel to panel joint detail.

6.3.6 Compliance of factory production control - Supplier purchases

6.3.6.1 General

When a supplier purchases the product from a manufacturer whose production plant is outside South Africa, the supplier shall take full responsibility for demonstrating compliance for the product in accordance with 6.3.6.2.

When a supplier purchases the product from a manufacturer who does not operate an FPC system as described in 6.3, either the manufacturer shall be obliged to operate such a system or the supplier shall take full responsibility for the product in accordance with 6.3.6.2.

6.3.6.2 FPC procedures - Products purchased by suppliers

When a product is purchased by a supplier under the conditions given in 6.3.6.1, the supplier shall take full responsibility for demonstrating compliance of the product and shall operate an FPC system, including test equipment and non-compliance procedures, to ensure that compliance is maintained with the same degree of certainty as if a full FPC system in accordance with 6.3 had been operated.

Compliance shall be based on product testing of the whole panel or specimens taken from a panel in accordance with table 6.

Values of the following characteristics shall also be provided in accordance with 6.3.4.2 and 6.3.4.3: – the compressive strength and modulus of the core material;

- the shear strength and modulus of the core material;
- the tensile strength of the face material (or declaration – see 6.3.4.2); and
- the thickness of the face material (or declaration – see 6.3.4.2).

The frequency of testing for these characteristics shall be every 2 000 m$^2$ and at least once per delivery.
Table 6 - Supplier purchases: FPC system requirements for panels

<table>
<thead>
<tr>
<th>Type of test</th>
<th>Test method</th>
<th>Minimum number of specimens</th>
<th>Minimum frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density of core material</td>
<td>A.8</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Cross-panel tensile strength and modulus (with faces)</td>
<td>A.1</td>
<td>3</td>
<td>All deliveries</td>
</tr>
<tr>
<td>Shear strength of complete panel(^a)</td>
<td>A.4</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Dimensional control:
- Panel thickness                                  | –           |                               |                   |
- Deviation from flatness                           | D.2.1       |                               |                   |
- Depth of profile                                  | D.2.2       |                               |                   |
- Depth of stiffeners                               | D.2.4       |                               |                   |
- Length of panel                                   | D.2.5       |                               |                   |
- Cover width                                       | D.2.6       | 1                            | All deliveries    |
- Deviation from squareness                         | D.2.7       |                               |                   |
- Deviation from straightness                       | D.2.8       |                               |                   |
- Bowing (curvature)                                | D.2.9       |                               |                   |
- Pitch of profile                                  | D.2.10      |                               |                   |
- Width of valleys/ribs                            | D.2.11      |                               |                   |

Fire performance classification                     | –           | –                            | Specification record\(^b\) |
Fire resistance classification                       | –           | –                            | Specification record\(^b\) |
Fire index classification                            | –           | –                            | Specification record\(^b\) |
Resistance to hail                                  | –           | –                            | Specification record\(^b\) |
Resistance to rain penetration                      | –           | –                            | Specification record\(^b\) |
Thermal insulation performance – see 5.2.2          | A.10        |                               | Every three months |
Air permeability – see 5.2.7                        | Visual inspection | –                        | All deliveries    |
Water vapour permeability – see 5.2.8               | –           |                               |                   |

\(^a\) Panels with MW lamella insulating cores only.
\(^b\) Manufacturer’s specification record (see 6.3.5.3).
7. Classification and designation

Sandwich panels shall be classified and designated in accordance with table 7 where required, for example when subject to regulatory requirements. Declared values shall be given to two significant figures.

Table 7 - Classification and designation

<table>
<thead>
<tr>
<th>Clause</th>
<th>Designation</th>
<th>Unit or class</th>
</tr>
</thead>
</table>
| 5.2.1  | Mechanical properties:  
- metal grade/thickness/tolerance system  
- cross panel tensile strength  
- shear strength (core)  
- shear modulus (core)  
- creep coefficient\(^a\)  
- compressive strength (core)  
- long term shear strength\(^a\)  
- bending resistance\(^b\)  
- wrinkling stress\(^b\) | Statement  
MPa  
MPa  
MPa  
(number)  
MPa  
MPa  
kNm/m  
MPa | |
| 5.2.2  | Thermal transmittance | W/m\(^2\)·K |
| 5.2.3  | Long-term mechanical properties – Durability | Pass (colours – see annex B)/Fail |
| 5.2.4.2 | Fire resistance | Minutes, load bearing/non-load bearing |
| 5.2.4.3 | Fire performance classification | Classification code |
| 5.2.4.4 | Fire index classification | Fire index |
| 5.2.6  | Resistance to rain penetration | Annual rainfall category |
| 5.2.7  | Air permeability | m\(^3\)/m\(^2\)·h at 50 Pa\(^c\) |
| 5.2.9  | Airborne sound insulation | Rating: \(R_w (C; C_{10})\)\(^c\) |
| 5.2.10 | Sound absorption | Single value rating: \(\alpha_w\)\(^c\) |
| 5.2.11 | Hail resistance | Complies/does not comply\(^c\) |

\(^a\) Characteristic only required for panels used as roofs and ceilings.
\(^b\) The bending resistance shall be declared for both positive and negative bending. Where one or both faces are flat or lightly profiled, the wrinkling stress shall be declared for such faces (see A.5.5.3).
\(^c\) These characteristics may be designated NPD where the intended use is not subject to regulatory requirements.
8. Marking, labelling and packaging

8.1 Marking of panels
The following information shall be supplied by the manufacturer with or attached to every package, or bundle of sandwich panels, or on each panel, or on a name plate or label securely attached to the panel:

a) Certification marks, if applicable
b) The manufacturer’s name or trade name or trademark.
c) The nature of the core material.
d) The nature of the metal facings.
e) The nature of the coating.
f) The nominal dimensions of the panel.
g) The batch number of the panel or date of manufacture.

8.2 Marking of the packaging
The following information shall be included in every package or delivery:

a) The manufacturer’s name or trade name or trademark.
b) The thermal insulation designation.
c) The metal facing sheet designation.
d) The coating description.
e) The batch identification or date of manufacture.
f) The nominal length of the panel, in millimetres.
g) The nominal width of the panel, in millimetres.
h) The nominal thickness of the panel, in millimetres.
i) The applicable properties listed in table 7.

8.3 Data sheets
The following data on the system manufactured, given in a data sheet, shall be available from the manufacturer:

a) The manufacturer’s name or trade name or trademark.
b) The thermal insulation designation.
c) The metal facing sheet designation.
d) The coating description.
e) The nominal length of the panels and the tolerance on length, in millimetres.
f) The nominal width of the panels and the tolerance on the width, in millimetres.
g) The nominal thickness in millimetres.
h) The applicable properties listed in table 7.
i) Instructions for installation of the panels, including a diagram or figure showing jointing details.
j) The mass of the panels, in kilograms per square metre.
k) Warning of any health hazard.
l) Recommendations for the transportation and storage of the panels.

8.4 Packaging, transport, storage and handling
Any instructions regarding transport, storage and handling shall be clearly visible on the package or in the accompanying documentation.

If severe service conditions are expected during transportation, storage or processing, the product may be supplied with an additional protection of a temporary, strippable film, wax or oil.

The type, thickness, adhesion properties, formability, tear strength and light fastness should be taken into consideration when choosing protective films. All protective films can be exposed to outdoor weathering for only a limited period without deterioration.
Annex A
(normative)

Testing procedures for material properties

A.1 Cross panel tensile test

A.1.1 Principle
This test measures the cross panel tensile strength and the E-modulus of the core material.

The characteristic value of the cross panel tensile strength shall be determined in accordance with EN 1607 and A.1.2 to A.1.6.

A.1.2 Apparatus
The tensile test apparatus shall be in accordance with EN 1607.

A.1.3 Test specimens
Sampling and conditioning of the test specimens shall comply with 6.2.2 and 6.2.3.

The test shall be performed with the faces of the panel intact (in place) in order to include the tensile bond strength between the faces and the core or to demonstrate adequate bond.

For panels with profiled faces the specimens shall be cut from the predominant thickness (see examples in figure A.1).

Figure A.1 - Cutting of specimens

Test specimens shall be of square cross-section with side dimensions between 100 mm and 300 mm. Where applicable the test specimen shall include the full width of lamellas.

The dimensions of the specimen shall be measured in accordance with EN 12085. The tolerance on the side dimension shall be ± 3 mm.

NOTE 1: Test specimens are very sensitive to the process of cutting and the accuracy of testing in particular for tensile test measurements. Considerable care is required in the cutting process, especially if the core material is relatively weak or has brittle tendencies. The cutting can be carried out with a band saw with a fine toothed blade. It may be advantageous to sandwich the specimen between two pieces of plywood or similar material in order to reduce vibration during the cutting process. It is suggested that specimens be carefully inspected after cutting. Those that show evidence of delamination caused by the cutting process shall be rejected (up to a maximum of 30 % of those cut for any family of tests).

Where it is not possible to cut a specimen with two plain faces, owing to the profile of the faces, the specimen shall be prepared with an appropriately shaped filling piece, which is glued to the profiled face (see examples in figure A.2).

NOTE 2: Additional thin layers may be adhered to the faces in order to ensure that the loading platens of the testing machine are parallel at the commencement of the tensile test.

NOTE 3: As an alternative to the use of shaped filling pieces and if the shape of the profiled face is suitable, it may be possible to glue two specimens together in such a way that the profiled faces mate.
A.1.4 Procedure
The test shall be carried out by loading the specimen continuously, or in at least 10 increments, using a tensile testing machine. The strain rate shall be 10 mm ± 10 % per minute. During the test the extension shall be measured with a precision of 1 %.

The test shall be continued until the ultimate load \( F_u \) is reached (see figure A.3). If the specimen does not exhibit a clearly defined ultimate load the test shall be discontinued when the relative deformation exceeds 20 %.

The tests shall be performed under normal laboratory conditions of temperature and humidity except when carrying out the test at an elevated temperature (see A.1.6).

A.1.5 Calculations and results

A.1.5.1 Cross panel tensile strength \( (f_{ct}) \)

A load-deflection curve shall be drawn (see figure A.3) and the tensile strength \( f_{ct} \) shall be calculated as follows by equation (A.1):

\[
f_{ct} = \frac{F_u}{A}
\]

where

\( F_u \) is the ultimate load;
\( A \) is the cross-sectional area of the specimen determined from the measured dimensions.

NOTE: For specimens that do not exhibit a well-defined ultimate load, \( F_u \) may alternatively be defined as the load at a specified relative deformation. For polyurethane foams, 10 % relative deformation (0,1 \( d_c \)) may be an appropriate limit. For materials with a more rigid cell structure or of non-cellular structure, a lower value may be used.
Recording and interpretation of test results shall comply with A.16.

The test report shall state the characteristic value (see 6.2.3) for tensile strength and shall state the failure mode, i.e. whether failure was in the adhesion layer or in the core.

NOTE: Special attention should be given in cases where the failure is close to the adhesion layer to determine the location of the failure.

A. 1.5.2 Tensile E-modulus of the core ($E_{ct}$)
The test report shall also give the characteristic E-modulus for the core material. The tensile modulus $E_{ct}$ is given by equation (A.2):

$$E_{ct} = \frac{F_u d_c}{w_u A}$$  \hspace{1cm} (A.2)

where

- $F_u$ is the ultimate load;
- $d_c$ is the thickness;
- $w_u$ is the ideal displacement at ultimate load based on the linear part of the curve as shown in figure A.3;
- $A$ is the cross-sectional area of the specimen determined from the measured dimensions.

A.1.6 Cross panel tensile modulus at an elevated temperature
Where required for design and ITT but not for FPC procedures of external panels, the test described in A.1.1 to A.1.5 shall also be carried out on specimens that have been heated for 20 h to 24 h in a heating chamber at a temperature of 80 $^\circ$C $\pm$ 1 $^\circ$C. The tensile test shall be carried out immediately, before the specimen has cooled.

NOTE: The test may be carried out by heating the specimens together with the load distributing platens to a temperature a little above 80°C and then carrying out the tensile test before the specimen has cooled below 80°C (limits 80 $^\circ$C $\pm$ 1 $^\circ$C).

The characteristics value for the E-modulus at elevated temperature shall be added to the test report.

A.2 Compressive strength and modulus of the core material

A.2.1 Principle
This test measures the compressive strength and E-modulus in compression of the core material.

The characteristic value of the compressive strength of the core material shall be determined in accordance with EN 826 and A.2.2 to A.2.5.

A.2.2 Apparatus
The apparatus shall be in accordance with EN 826.

A.2.3 Test specimens
Sampling and conditioning of the test specimens shall comply with 6.2.2 and 6.2.3.

Test specimens shall be prepared as described in A.1.3. If the profile of the face(s) requires the use of filling pieces then these shall not be glued to the loading platen.

A.2.4 Procedure
The specimen shall be placed between the two parallel stiff loading plates of a compression testing machine. The loading rate shall be sufficient to cause a displacement equivalent to 10 % of thickness $\pm$ 25 % per minute. During the test the displacement shall be measured with a precision of 1 % and a load-deflection curve drawn (see figure A.3).

The tests shall be performed under normal laboratory conditions of temperature and humidity.
A.2.5 Calculations and results

A.2.5.1 Compressive strength \( f_{Cc} \)
The compressive strength \( f_{Cc} \) of the core material shall be calculated using equation (A.3):

\[
f_{Cc} = \frac{F_u}{A} \tag{A:3}
\]

where

- \( F_u \) is the ultimate load;
- \( A \) is the cross-sectional area of the specimen determined from the measured dimensions.

**NOTE:** For specimens that do not exhibit a well-defined ultimate load, \( F_u \) may alternatively be defined as the load at a specified relative deformation. For polyurethane foams, 10% relative deformation (0.1 \( d_c \)) may be an appropriate limit (see figure A.3). For materials with a more rigid cell structure or of non-cellular structure, a lower value may be used.

A.2.5.2 Compressive E-modulus of the core \( E_{Cc} \)
The test report shall also give the characteristic E-modulus for the core material.

The compressive modulus \( E_{Cc} \) of the core material shall be calculated using equation (A.4):

\[
E_{Cc} = \frac{F_u d_c}{W_u a} \tag{A:4}
\]

where

- \( F_u \) is the ultimate load;
- \( d_c \) is the thickness;
- \( W_u \) is the ideal displacement at ultimate load based on the linear part of the curve as shown in figure A.3;
- \( A \) is the cross-sectional area of the specimen determined from the measured dimensions. Recording and interpretation of test results shall comply with A.16.

The test report shall state the characteristic value (see 6.2.3) for compressive strength and modulus of the core material.

A.3 Shear test on the core material

A.3.1 Principle

The shear strength and shear modulus of the core material shall be determined using the four-point bending test (see figure A.4). The ultimate load carried by the specimen failing in shear shall be measured and the shear modulus calculated from the load deflection curve.

A.3.2 Apparatus

The four-point bending test apparatus is illustrated in figure A.4.

Steel load spreading plates \( p \) are required below the load points and over the supports. The thickness of the load spreading plates shall be between 8 mm and 12 mm.

The width \( L_s \) of the load spreading plates at the support and load points shall be a minimum of 60 mm. This value shall be increased up to 100 mm, if necessary, in order to avoid local crushing of the core. If \( L_s \) is greater than 100 mm a more precise determination of the shear modulus \( G_c \) shall be made for the purposes of ITT, i.e. by using the test method in A.5.6.
A.3.3 Test specimens

A.3.3.1 Conditioning of the test specimens shall comply with 6.2.2 and 6.2.3.

A.3.3.2 The specimens shall be cut in the lengthwise direction of the panel. The position shall be chosen so that the faces of the specimen are flat and parallel.

NOTE: Faces may incorporate light profiling.

A.3.3.3 For all core materials except MW lamellas, the width of the specimen shall be 100 mm ± 2 mm. For MW lamellas the width to be used shall be > 100 mm and shall be chosen to incorporate at least one full width of lamellas. There shall be no cut ends of lamellas or preformed core material within the length of the test specimen.

NOTE: It is preferable to use the test described in A.4 to determine the shear strength and modulus of panels with lamellas.

A.3.3.4 Span L shall be chosen so that a shear failure is obtained. The recommended span is 1 000 mm. If the recommended span does not result in a shear failure similar to that illustrated in figure A.5, the span shall be reduced in increments of 100 mm until a shear failure is obtained. Subsequent tests shall then be carried out at the reduced span.

Figure A.4 - Four-point bending test

Figure A.5 - Typical shear failure
A.3.4 Procedure
The specimen shall be loaded as shown in figure A.4. The loading rate shall be sufficient to cause an increase in the maximum deflection equivalent to 10 % of thickness ± 25 % per minute. During the test the deflection shall be measured with a precision of 1 %. The loading shall be continued until failure and a load-deflection curve shall be drawn.

The tests shall be performed under normal laboratory conditions of temperature and humidity.

The metal thickness, excluding all protective coatings, of both faces of each test specimen shall be measured and recorded.

A.3.5 Calculations and results - Short-term loading
A.3.5.1 Shear strength of the core material ($f_{cv}$)
The ultimate shear strength $f_{cv}$ of the core material shall be calculated from the maximum load attained in a specimen failing in shear as follows using equation (A.5):

$$f_{cv} = k_v \frac{F_u}{2Be}$$  \hspace{1cm} (A.5)

where

- $F_u$ is the ultimate load carried by the specimen failing in shear;
- $B$ is the measured width of the specimen;
- $e$ is the measured depth between the centroids of the faces;
- $k_v$ is the reduction factor for cut ends in preformed or lamella cores.

The shear strength for panels with offset preformed or lamella cores shall be reduced to take account of the fact that the cut ends of the core materials have little or no shear strength. For non-lamella panels with preformed cores, no reduction in shear strength shall be considered when the joints are adhered.

For panels with the core material foamed in-situ or preformed in a single piece, or for panels with cut ends that are adhered, $k_v = 1.0$. For other panels with preformed or lamella cores, unless a better result can be justified by testing a full cover width of panel to A.4, $k_v$ shall be calculated by equation (A.6):

$$k_v = \frac{\text{the minimum width of uncut core material across a line of cut ends}}{\text{the full width of the panel}}$$  \hspace{1cm} (A.6)

Recording and interpretation of test results shall comply with A.17.

The test report shall state the characteristic value (see 6.2.3) for the shear strength in megapascals (MPa). The span shall be declared in the test report.

A.3.5.2 Shear modulus of the core material ($G_c$)
For each test specimen, the shear modulus $G_c$ shall be calculated from the slope of the straight part of the load-deflection curve $\frac{\Delta F}{\Delta w}$ as follows using equation (A.7):

- Flexural rigidity
  $$B_x = E$$

- Bending deflection
  $$\Delta w_B = \frac{\Delta F L^3}{56.34 B_x}$$

- Shear deflection
  $$\Delta w_s = \Delta w - \Delta w_B$$

- Shear modulus
  $$G_c = \frac{\Delta F L}{6B_d \Delta w_s}$$
where

\[ E_{F1} \] is the E-modulus of the top face;
\[ A_{F1} \] is the measured area of cross-section of the top face;
\[ A_{F2} \] is the measured area of cross-section of the bottom face;
\[ E_{F2} \] is the E-modulus of the bottom face;
\[ e \] is the measured depth between the centroids of the faces;
\[ \Delta w \] is the deflection at mid-span for a load increment \( AF \) taken from the slope of the linear part of the load-deflection curve;
\[ d_c \] is the depth of the core material (see D.2.1 where \( d_c = D - (t_1 + t_2) \) i.e. the thickness of the two facings);
\[ B \] is the measured width of the specimen;
\[ L \] is the span of test specimen at shear failure.

Recording and interpretation of test results shall comply with A.1.6.

The test report shall state both the mean and characteristic values (see 6.2.3) of the shear modulus in megapascals (MPa). The span shall be declared in the test report.

A.3.6 Test procedures, calculations and results - Long-term loading

A.3.6.1 Principle

Where required for design purposes for roof and ceiling applications, and if no tests are available, the long-term shear strength at 2 000 h and 100 000 h shall be calculated as:

- 50 % of the short term value, if the \( \phi_t \) is less or equal than 2,4 at 2 000 h
- 30 % of the short term value, if the \( \phi_t \) is higher than 2,4 at 2 000 h.

A.3.6.2 Procedure

Using the apparatus described in figure A.4 at least 10 long-term loading tests shall be carried out. These tests shall be carried out on nominally identical specimens subject to a range of loads, which shall be held constant after initial application. The loads shall be chosen such that the failures of \( n \geq 10 \) specimens are spread over the time interval \( 6 \text{ min} \leq t \leq 1 \text{ 000 h} \). Specimens failing after \( t > 1 \text{ 000 h} \) may also be incorporated into the analysis.

Deformation measurements are not required.

The tests shall be performed under normal laboratory conditions of temperature and humidity.

A.3.6.3 Results and calculations

Based on the test results for the failure loads, a straight regression line shall be drawn (see figure A.6), in order to show the relationship of the mean long-term shear strength to the initial shear strength (short-term strength) as a function of the loading time plotted on a logarithmic scale.

The long-term shear strength at 2 000 h or 100 000 h shall be determined by extrapolation using the mean-value regression line.
Key
\( t \)  time (hours)
\( \tau \)  shear stress in specimen
\( f_v \)  shear strength (short term)

Figure A. 6 - Regression line showing long-term shear strength

A.4 Test to determine the shear properties of a complete panel

A.4.1 Principle

This test is an alternative to the test in A.3 and offers a more reliable method of determining the shear strength and tested shear modulus of panels with lamella and preformed cores where joints between the core elements might affect the shear properties. The value determined by the test takes account of the influence of the end joint on the shear modulus.

NOTE 1: This test may be used for panels with profiled faces.

NOTE 2: This test is similar to the test described in A.5 when carried out on sufficiently small spans. The test in A.5 may offer a more reliable determination of the shear strength and the shear modulus when the results are influenced by compression of the core at the supports or below line loads.

A.4.2 Apparatus

The test apparatus is illustrated in figure A.4. The span shall be sufficiently short to ensure a shear failure. When using air pressure loading, the load shall be measured by means of load cells, not air pressure.

Steel load spreading plates are required below the load points and over the supports. The thickness of the load spreading plates shall be between 8 mm and 12 mm.

The width \( L_x \) of the load spreading plates at the support and load points shall be a minimum of 60 mm. This value shall be increased up to 100 mm, if necessary, in order to avoid local crushing of the core. If \( L_x \) is greater than 100 mm a more precise determination of the shear modulus \( G_c \) shall be made for the purposes of ITT by using the test method in A.5.6.

A.4.3 Test specimens

Sampling and conditioning of the test specimens shall comply with 6.2.2 and 6.2.3. Span \( L \) shall be chosen so that a shear failure is obtained.

For panels with discontinuous core material, tests shall be carried out on the full cover width of the panel with joints in the core material in the worst arrangement that may arise in practice.
NOTE 1: The recommended span is 1 000 mm. If the recommended span does not result in a shear failure similar to that illustrated in figure A.5, the span should be reduced in increments of 100 mm until a shear failure is obtained. Subsequent tests should then be carried out at the reduced span.

NOTE 2: Joints in the core material near the support are more critical than joints near mid-span.

NOTE 3: In order to avoid large compressive deformations of the core at the supports compared to the deflection of the specimens, the span $L$ should not be reduced more than is necessary to ensure a shear failure. If it is not possible to obtain a shear failure without visible compressive deformation of the core material at the supports, the deflections $w_{s1}$ and $w_{s2}$ at the supports should be measured. The deflection $w$ to be used in the calculations of the shear modulus should then be modified by subtracting

$$\left(\frac{w_{s1} + w_{s2}}{2}\right)$$

from the measured deflection $w$

where

$w_{s1}$ and $w_{s2}$ are the measured deflections of the top face of the specimen over the left- and right-hand supports respectively.

The net metal thickness, excluding all protective coatings, of both faces of each test specimen shall be measured and recorded. The joint arrangement used in the tests shall be described in the test report.

A.4.4 Procedure
The test shall be carried out by subjecting a short simply supported panel of full cover width to two line loads either equally spaced, or applied at the 1/4 points, or to air pressure caused by either a partial vacuum chamber test apparatus or air bags.

The specimen shall be loaded as shown in figure A.4. The loading rate shall be sufficient to cause an increase in the maximum deflection equivalent to 10% of thickness ± 25% per minute. The loading rate shall be uniform and sufficient to cause failure within 3 min of the commencement of loading. During the test the extension shall be measured with a precision of 1%. The loading shall be continued until failure and a load-deflection curve shall be drawn.

The tests shall be performed under normal laboratory conditions of temperature and humidity.

A.4.5 Calculations and results
The load $F_u$ at failure gives the shear strength of the complete panel including the contribution of both the core and faces.

For panels with flat or lightly profiled faces subject to two line loads applied at the third points of the span the calculation for shear strength $f_{CP}$ shall be calculated as follows using equation (A.8):

$$f_{CP} = \frac{F_u}{2B'e}$$  \hspace{1cm} (A.8)

where

$F_u$ is the ultimate load carried by the specimen failing in shear;

$B$ is the measured width of the specimen;

$e$ is the measured depth between the centroids of the faces.

and shear modulus $G_C$ shall be as given in A.3.5.2 (equation (A.7)).

For panels with profiled faces or other loading systems (or both), the shear strength and modulus of the core material shall be determined by calculation (see also A.5.6). Where relevant, this calculation shall take account of the profiled faces.

Recording and interpretation of test results shall comply with A.17.

The test report shall state the characteristic value (see 6.2.3) for the shear strength.
A.5 Test to determine the bending moment capacity and stiffness of a simply supported panel

A.5.1 Principle
This test is used to determine the bending strength of panels in which the span \( L \) is sufficiently large to ensure a bending failure, i.e. wrinkling, yielding or face buckling. The wrinkling stress for flat or lightly profiled faces, or the buckling or yield stress for profiled faces, shall then be determined by calculation.

**NOTE 1:** There are a number of alternative load systems that simulate a uniformly distributed load on a panel. These all give similar results for the bending strength and stiffness of the panel.

**NOTE 2:** This bending test may also be used in order to determine a reliable value for the shear modulus of the core material.

A.5.2 Apparatus

A.5.2.1 Loading arrangement
The test shall be carried out by subjecting a simply supported panel to four line loads (see figures A.7 or A.8) extending across the full width of the panel, or to air pressure caused by either a partial vacuum chamber test apparatus or air bags (see figure A.9).

The load shall be measured by load cells located below the supports.

![Figure A.7 - Simply supported panel: Four-line loads](image1)

![Figure A.8 - Simply supported panel: Four-line loads (alternative)](image2)
A.5.2.2 Support conditions
A suitable panel support detail is shown in figure A.10. The width of the supports shall be within the range 50 mm to 100 mm and shall be sufficiently large to prevent local crushing of the core.

The tested panel shall be attached to the supports through either the profile valleys or crests as in practice.

**NOTE:** Timber blocks may be used to avoid deformation of a side rib that does not contain foam.

Where this test is used to determine the wrinkling stress for use in design calculations, the support conditions shall be such as to apply no restraint to the rotation of the panel about the line of support.

**A.5.2.3 Application of load to panel facings**
Where line loads are applied to panels with lightly profiled faces, they shall be applied through loading platens (see figure A.4).

Steel load spreading plates are required below the load points and over the supports. The thickness of the load spreading plates shall be between 8 mm and 12 mm.

The width $L_s$ of the load spreading plates at the support and load points shall be a minimum of 60 mm. This value shall be increased up to 100 mm, if necessary, in order to avoid local crushing of the core.

Where line loads are applied to a profiled face, they shall be applied through timber or steel transverse loading beams together with timber loading platens placed in the troughs of the profile (see figure A.11). The width of the loading platens shall be sufficient to avoid compressive failure of the core below the platens.

**NOTE:** A layer of felt, rubber or other similar material may be placed between the loading platens and the panel in order to reduce the possibility of local damage.

The loads shall be maintained perpendicular to the panel throughout the test.
Figure A. 11 - Loading platens for profiled facings

If the trough of the profile includes rolled-in stiffeners, the loading platens shall be shaped appropriately (see figure A. 12).

Figure A. 12 - Loading platens for facings with stiffeners

A.5.3 Test specimens

The necessary span is dependent on several factors including the overall depth $D$ of the panel and shall be chosen to give a bending failure.

The values in table A.1 are provided for guidance.

<table>
<thead>
<tr>
<th>Overall depth of panel ($D$)</th>
<th>Indicative span ($L$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D &lt; 40$ mm</td>
<td>3.0 m</td>
</tr>
<tr>
<td>$40$ mm $&lt; D &lt; 60$ mm</td>
<td>4.0 m</td>
</tr>
<tr>
<td>$60$ mm $&lt; D &lt; 100$ mm</td>
<td>5.0 m</td>
</tr>
<tr>
<td>$D &gt; 100$ mm</td>
<td>6.0 m</td>
</tr>
</tbody>
</table>

If the span values in table A.1 are found to give rise to a shear failure, they shall be increased in increments of 1.0 m until a bending failure is obtained.

In the case of panels from the same family (design) only panels of the greatest and least thickness shall be tested together with a panel from the middle of the range. The worst result shall apply to all products of intermediate thickness.

In the case of panels of the same type but with different face-thickness, at least panels with the thinnest face shall be tested.

A.5.4 Procedure

For all panels, including those with similar upper and lower faces, this test shall be carried out on both orientations of the panel because the wrinkling stress may be greatly influenced by whether the face was at the top or bottom of the panel during manufacture.

Before the test a small load, which shall be not greater than 10 % of the failure load, shall be applied for no more than 5 min and then removed.

The tests shall be performed under normal laboratory conditions of temperature and humidity.
The panel shall be loaded steadily in at least 10 increments until failure occurs. The deflection speed shall not exceed 1/50 of the span per minute at any time during the test. Both the load and the central deflection shall be recorded. Displacement transducers shall have an accuracy of 0,1 mm.

After completion of the test, the net metal thickness excluding all protective coatings and yield stress of each face shall also be determined from a minimum of three specimens per panel and recorded.

A.5.5 Calculations and results

A.5.5.1 General

Recording and interpretation of test results shall comply with A.17.

The failure load and the nature and location of the failure shall be recorded. A load-deflection curve shall be drawn for the central displacement.

A.5.5.2 Determination of the bending moment capacity \( M_u \)

The bending moment capacity \( M_u \) shall be given by equation (A.9):

\[
M_u = \frac{F_u d}{b} \\
(A.9)
\]

where

- \( M_u \) is the ultimate bending moment recorded in the test including the effect of the self-weight of the specimen and the mass of the loading equipment;
- \( F_u \) is the total load recorded in the test including an allowance for the self-weight of the panel and the weight of the loading equipment.

The bending moment values determined from the tests shall additionally be corrected by the correction factors set out in A.5.5.4 and A.5.5.5 before obtaining the characteristic values to be declared.

A.5.5.3 Determination of the wrinkling stress \( \sigma_w \)

The wrinkling stress \( \sigma_w \) is only directly relevant for panels with flat or lightly profiled faces.

The wrinkling stress of a panel shall be obtained by determining the ultimate bending moment. The face stress at failure shall then be obtained by calculation.

For panels with similar profiled inner and outer faces, the design shall be based on the least favourable wrinkling stress.

If the face under tension is flat or lightly profiled the wrinkling stress \( \sigma_w \) shall be given by equation (A.10):

\[
\sigma_w = \frac{M_u}{e A_1} \\
(A.10)
\]

where

- \( M_u \) is the ultimate bending moment recorded in the test, after correcting for the effect of the self-weight of the panel and the weight of the loading equipment;
- \( e \) is the depth between centroids of the faces;
- \( A_1 \) is the cross-sectional area of the face in compression.

If the face under tension in this test is profiled, the wrinkling stress \( \sigma_w \) of the flat or lightly profiled face in compression shall be determined using equation (A.11):

\[
\sigma_w = \frac{M_u - M_{f2}}{e A_1} \\
(A.11)
\]

where

- \( M_{f2} \) is the bending moment carried by the profiled face. The value of \( M_{f2} \) shall be determined by calculation (see E.7).
The wrinkling stress values determined from the tests shall additionally be corrected by the correction factors set out in A.5.5.4 and A.5.5.5 before obtaining the characteristic values to be declared.

In the case of panels of the same type but with different face thickness, where only panels with the thinnest face have been tested the wrinkling stresses for thicker faces shall be determined using equation (A.12):

\[
\sigma_{w,t2} = f \cdot \sigma_{w,t1}
\]  

(A.12)

where

\[
\sigma_{w,t2} \quad \text{is the wrinkling stress of a thicker face, } t2;
\]

\[
\sigma_{w,t1} \quad \text{is the wrinkling stress of the thinnest face, } t1;
\]

\[
f \quad \text{is the reduction factor} = \frac{A_1 \times \frac{3}{\sqrt{I_2}}}{A_2 \times \frac{3}{\sqrt{I_1}}}
\]

\[
A_1, I_1 \quad \text{is the cross-sectional area and moment of inertia of the face with } t1;
\]

\[
A_2, I_2 \quad \text{is the cross-sectional area and moment of inertia of the face with } t2.
\]

**NOTE 1:** For panels without joints in the core the wrinkling stress \(\sigma_w\) may be determined, as an alternative to testing, by equation (A.13):

\[
\sigma_w = 0.5 \times \frac{G_C \times E_C \times E_F}{G_C}
\]  

(A.13)

where

\[
E_C \quad \text{is the mean of the characteristic values of the tensile and compressive moduli of the core material} \text{ (A.14)}.
\]

\[
E_C = \frac{E_{ct} + E_{cc}}{2}
\]  

(A.14)

\[
G_C \quad \text{is the characteristic shear modulus of the core material;}
\]

\[
E_F \quad \text{is the modulus of elasticity of the face material in compression.}
\]

**NOTE 2:** Although, in most cases, the design value of the wrinkling stress may be calculated, more favourable values of the wrinkling stress will generally be obtained by testing.

### A.5.5.4 Correction factors to be applied to test results for bending moment and wrinkling strength

For the failure of the profiled metal face in compression [wrinkling] the individual test results shall be adjusted according to the following equation (A. 15):

\[
R_{adj,i} = R_{obs,i} \left( \frac{f_y}{f_{y,obs}} \right)^\alpha \left( \frac{t}{t_{obs}} \right)^\beta
\]  

(A.15)

where

\[
R_{obs,i} \quad \text{is the result of test number } I;
\]

\[
R_{adj,i} \quad \text{is the test result modified to correspond to the design values of metal thickness and yield stress;}
\]

\[
f_y \quad \text{is the design yield stress;}
\]

\[
f_{y,obs} \quad \text{is the yield stress measured in the test specimen;}
\]

\[
t \quad \text{is the design metal thickness;}
\]

\[
t_{obs} \quad \text{is the metal thickness measured in the test specimen;}
\]

\[
\alpha = 0 \quad \text{if } f_{y,obs} \leq f_y
\]

\[
\alpha = 1 \quad \text{if } f_{y,obs} > f_y
\]
except that, for the compression failure mode of a profiled face:

\[
\alpha = 0.5 \quad \text{if} \quad f_{y, obs} > f_y \quad \text{and} \quad \frac{b}{t} > 1.27 \frac{\sqrt{E}}{f_y}
\]

In general:

\[
\beta = 1.0
\]

except that, for the compression failure mode of a profiled face:

\[
\beta = 1.0 \quad \text{if} \quad t_{obs} \leq t
\]

\[
\beta = 1.0 \quad \text{if} \quad t_{obs} > t \quad \text{and} \quad \frac{b}{t} > 1.27 \frac{\sqrt{E}}{f_y}
\]

\[
\beta = 2.0 \quad \text{if} \quad t_{obs} > t \quad \text{and} \quad \frac{b}{t} > 1.27 \frac{\sqrt{E}}{f_y}
\]

where \(\frac{b}{t}\) = width to thickness ratio of the widest part of the profiled face.

The values \(R_{adj,i}\) shall be used to represent the individual test results in the evaluation of characteristic strengths and resistances.

### A.5.5.5 Correction factors for bending moment capacity and wrinkling stress

The wrinkling stress or the bending moment capacity obtained from original tests shall be corrected with the following correction factor \(k\) in order to obtain the value to be declared:

**NOTE:** This factor takes account of the reduction in the wrinkling stress caused by higher temperatures \((k_1)\) and the additional variability in the case of low cross-panel tensile strength \((k_2)\).

\[
k = k_1 \cdot k_2
\]

For panels in external end use applications with a lightly profiled or flat face in compression (wrinkling) and with a face temperature higher than +20 °C according to the design procedure (see E.3), the individual test results shall be reduced according to equation (A.16):

\[
k_1 = 3 \sqrt{\frac{E_{ct,+20\,^\circ\text{C}}}{E_{ct,+80\,^\circ\text{C}}}}
\]

where

- \(E_{ct,+20\,^\circ\text{C}}\) is the tensile characteristic cross panel E-modulus at 20 °C;
- \(E_{ct,+80\,^\circ\text{C}}\) is the tensile characteristic cross panel E-modulus at 80 °C.

In all other cases \(k_1 = 1.0\).

For the failure of the lightly profiled or flat face in compression (wrinkling) the individual test results shall be adjusted additionally according to the following procedure:

\[
k_2 = (6.110 \times f_{ct} + 0.39)
\]

and \(k_2 \leq 1.0\)

where

- \(f_{ct}\) is the characteristic cross panel tensile strength (MPa).

\(k_2\) shall only be used in the case of a uniformly distributed load, i.e. vacuum chamber, air bag or similar.
A.5.6 Determination of the shear modulus of the core material

Where the tests in A.3 or A.4 do not result in a clearly defined shear failure, the test to determine the bending moment capacity (see A.5) shall be used in order to determine a reliable value for the shear modulus of the core material of a panel with flat or lightly profiled faces.

The span shall be chosen to be as large as possible consistent with a reliable shear failure. Otherwise the test procedure is unchanged.

NOTE: This is a valid method when there is a problem with the crushing of the core material below the loads or at the supports.

If both faces of the test panel are flat or lightly profiled, the total deflection at the centre of the test panel shall be divided into two parts:

\[ w = w_b + w_c \]

where

- \( w \) is the measured deflection at mid-span of the test panel;
- \( w_b \) is the deflection due to axial deformation in the faces (bending deflection);
- \( w_c \) is the deflection due to shear deformation of the core material.

The shear modulus of the core shall be determined from \( w_c \).

If a partial vacuum chamber or air bag test apparatus is used in order to provide a uniformly distributed load over the surface of the specimen, the bending deflection at mid-span \( w_b \) and the shear modulus of the core \( G_C \) shall be calculated using equations (A.17) and (A.18):

\[
W_b = \frac{5}{384} \frac{FL^3}{b_s} \quad \text{and} \quad G_C = \frac{FL}{8A_C (w - w_b)} \tag{A.17} \tag{A.18}
\]

If the total load is applied as four equal line loads \( F/4 \) at positions 1/8, 3/8, 5/8, 7/8 of the span, the expressions for the bending deflection at mid-span and the shear modulus of the core shall be calculated using equations (A.19) and (A.20):

\[
W_b = \frac{41}{3072} \frac{FL^3}{b_s} \quad \text{and} \quad G_C = \frac{FL}{8A_C (w - w_b)} \tag{A.19} \tag{A.20}
\]

If the total load is applied as four equal line loads \( F/4 \) at positions 0, 1L, 0.4L, 0.6L, 0.9L of the span, the expressions for the bending deflection at mid-span and the shear modulus of the core shall be calculated using equations (A.21) and (A.22):

\[
W_b = \frac{1.24}{96} \frac{FL^3}{b_s} \quad \text{and} \quad G_C = \frac{FL}{8A_C (w - w_b)} \tag{A.21} \tag{A.22}
\]

In these expressions, the deflection \( w \) shall be taken from the linear part of the load deflection curve; \( F \) shall be the corresponding applied load and:

\[
B_s = \frac{\varepsilon_{F_1}}{\varepsilon_{F_1}} \times \frac{A_{F_1}}{A_{F_1}} \times \frac{\varepsilon_{F_2}}{\varepsilon_{F_2}} \times \frac{A_{F_2}}{A_{F_2}} \quad \text{and} \quad e^2 \quad \text{and} \quad A^c = B \times e
\]

based on the measured dimensions of the panel and its components.

A.6 Determination of the creep coefficient (\( \sigma t \))

A.6.1 Principle

Where required for the design of roof or ceiling panels, a single test on a simply supported panel with a constant uniform load shall be sufficient to determine the creep coefficient for a particular core material.
A.6.2 Apparatus
The test shall be carried out by subjecting a simply-supported panel (see figure A.9) to a uniformly distributed dead load.

A.6.3 Test specimens
The test shall be carried out on a complete panel of span equal to that used for the bending test in A.5. Panels of the greatest thickness within the sandwich panel product family shall be used for the test.

A.6.4 Procedure
The test shall be carried out by subjecting a simply-supported panel to uniformly distributed dead load. The load used for the creep test shall correspond to between 30 % and 40 % of the average load for shear failure at ambient temperature determined from the tests carried out in accordance with A.3.

NOTE: The load used for creep tests is not unduly critical and similar results will be obtained for any load in the range 30 % to 40 % of the failure load.

During the placing of the load, the panel shall be propped from below in such a way that the propping can be removed quickly and smoothly in order to initiate the test. Deflection measurements at mid-span shall start as soon as the full load is applied.

As an alternative procedure, the initial deflection shall be calculated from the slope of the load deflection curve obtained during the corresponding bending test in A.5, in which case, the dead load shall be applied more gradually in the conventional manner.

The test shall be carried out under a constant load, which shall be sustained undisturbed for a minimum of 1 000 h. During this time, the deflection shall be regularly monitored to give a continuous relationship between deflection and time.

A.6.5 Calculations and results

A.6.5.1 Recording and interpretation
Recording and interpretation of test results shall comply with A.17.

On the basis of the results of the tests within the time range $0 > t \geq 1\,000\,h$, the creep coefficients required for design shall be determined by extrapolation using a linear approximation to the deflection versus time curve on a semi-logarithmic diagram.

NOTE 1: Creep behaviour and its treatment for the purposes of design is described in annex E.

NOTE 2: The creep coefficient is generally required at $t = 2\,000\,h$ for snow load and $t = 100\,000\,h$ for permanent actions (self-weight) (see E.7.6).

A.6.5.2 Creep coefficient (core) for lightly profiled panels ($\varphi t$)
The creep coefficient for the core of a lightly profiled sandwich panel shall be determined using equation (A.23):

$$\varphi t = \frac{w_1 - w_0}{w_0 - w_b}$$  \hspace{1cm} (A.23)

where

$w_t$ is the deflection measured at time $t$;

$w_0$ is the initial deflection at the time $t = 0$;

$w_b$ is the deflection caused by the elastic extension of the faces (without shear deformation).

NOTE: If the deflections are determined from the graph of deflection versus time at $t_1 = 200\,h$ and $t_2 = 1\,000\,h$, the required creep coefficients may be determined as follows:

$$\varphi_{2000} = 1,2 \,(1,43\varphi_{1\,000} - 0,43\varphi_{2\,000}) = 1,7 \,(\varphi_{1\,000} - 0,3\varphi_{2\,000})$$

$$\varphi_{100\,000} = 3,86\varphi_{1\,000} - 2,86\varphi_{2\,000}$$
A.6.5.3 Creep coefficient (core) for deeply profiled panels (\(\varphi_t\))

The deflections caused by the bending and shear deformations of a sandwich panel with strongly profiled faces cannot be separated in the expression for the deflection because the distribution of the bending moment into the sandwich component \(M_s\) and the facing components \(M_{F1}, M_{F2}\) depends on the shear stiffness of the core (see E.7.2.4). The creep coefficient shall be evaluated on the basis of the measured deflections as a function of the time.

If one or both faces of a sandwich panel are profiled, the creep coefficient shall be evaluated from equation (A.24).

\[
\varphi_t = \frac{\beta (C_p - 1)}{\beta_1 (1 - \beta - \beta \rho (C_D - 1))}
\]  

(A.24)

where

\[C_D = \frac{w_t}{w_{t0}}\]  
is the relationship between the deflection after a loading time of \(t\) and the initial deflection;

\[\rho = 0.5\]  
is a relaxation coefficient, having here the value of 0.5.

\[\beta = \frac{I_F}{I_w}\]

\[I_w = I_F + \frac{I_s}{1 + k}\]

where

\[I_F\]  
is the moment of inertia of the profiled face(s) (sum if both faces are profiled);

\[I_s\]  
is the moment of inertia of the sandwich part (see Annex E);

\[k = \frac{\pi^2 E_{F2} A_{F2} \epsilon^2}{(A_{F2} + 1) \times G_C \times \epsilon C \times L^2}\]

\[\beta_1 = \frac{k \rho}{1 + k}\]

where

\[\epsilon\]  
is the measured depth between centroids of the faces;

\[L\]  
is the span of panel used in creep test.

NOTE: If the deflections are determined from the graph of deflection versus time at \(t_1 = 200\) h and \(t_2 = 1\,000\) h, the required creep coefficients may be determined with the equations given in A.6.5.2.

For declaration, \(\varphi_{2\,000}\) shall be declared for applications where snow lies for significant periods and \(\varphi_{100\,000}\) shall be declared for general roof and ceiling applications.

A.7 Interaction between bending moment and support force

A.7.1 Principle

This test is generally used to determine the bending strength at an internal support of a panel that is continuous over two or more spans. The corresponding wrinkling stress for flat or lightly profiled faces or the buckling or yield stress for profiled faces shall then be determined by calculation.

The interaction between bending moment and support reaction force shall be determined from a single-span panel subject to a line load.

NOTE: This is often referred to as the "simulated central support test" because it simulates the conditions in the central support of a two-span beam (see figures A.13 and A.14).
A.7.2 Apparatus
The test arrangement for the interaction between bending moment and support reaction force shall be a single-span panel subject to a line load.

**Key**
- $z$ face against support in practice
- $y$ sheet metal strip approximately 60 mm × 4 mm
- $L$ span
- $o$ overhang beyond the end of the support plate not exceeding 50 mm

![Figure A. 13 - Simulated central support test - Downward load](image1)

**Figure A. 13 - Simulated central support test - Downward load**

- $z$ face against support in practice
- $s$ screws
- $L$ span
- $o$ overhang beyond the end of the support plate not exceeding 50 mm

![Figure A. 14 - Simulated central support test - Uplift load](image2)

**Figure A. 14 - Simulated central support test - Uplift load**

A.7.3 Test specimens
The tests shall be carried out on a full panel width and span in accordance with A.7.4. For the uplift load test the fixing detail and the number and type of screws and washers shall comply with those used in practice.

A.7.4 Procedure
In order to determine the wrinkling stress at an intermediate support, the following two types of test shall be carried out:

a) a test that simulates a downward load (see figure A.13);
b) a test that simulates an uplift load (see figure A.14). It is important that the span be sufficient to ensure that

- for test (a), the compressive force between the panel and the support (under the line load) at the time of wrinkling failure shall be less than the support reaction capacity of the panel. For the purposes of this test, the support reaction capacity shall be determined either as the product of the characteristic compressive strength of the core material and the contact surface area of the loading platen simulating the support, or the resistance $f_{R2}$ determined in accordance with E.4.3, and
- for test (b), the forces in the fasteners at wrinkling failure of the panel are less than their design values.

**NOTE 1:** This ensures that all failure modes (wrinkling of the face, compressive failure of the core and tensile failure of the connection) are designed for approximately equal levels of safety.

**NOTE 2:** If the test is carried out on a shorter specimen than that described, the failure mode is likely to be dominated by core crushing and a conservative value of the wrinkling stress will be obtained.

### A.7.5 Calculations and results

Recording and interpretation of test results shall comply with A.17.

The failure load and the nature and location of the failure shall be recorded. A load-deflection curve shall be drawn for the displacement at the load position.

The bending moment capacity shall be given by equation (A.25):

\[
M_u = \left[ \frac{F_u}{4} + \frac{F_G}{8} \right] L \tag{A.25}
\]

where

- \(F_u\) is the ultimate load including the weight of the loading system;
- \(F_G\) is the self-weight of the panel.

The bending moment values determined in this way shall additionally be corrected by the correction factors set out in A.5.5.4 and A.5.5.5 before obtaining the characteristic values to be used in design (see E.4.2).

If the face in compression is flat or lightly profiled, the wrinkling stress shall be determined in accordance with A.5.5.3.

### A.8 Determination of apparent core density and mass of panel

#### A.8.1 Determination of apparent core density

##### A.8.1.1 Principle

The apparent density \(\rho_c\) shall be determined in accordance with EN 1602.

##### A.8.1.2 Apparatus

The apparatus shall be as defined in EN 1602.

##### A.8.1.3 Test specimens

Specimens shall be taken during the production of the sandwich panels as follows:

a) Panels with core material from slabstock or lamella bonded to faces: Three specimens of the core material with the dimensions 100 mm × 100 mm × thickness shall be taken before bonding.

b) Panels with auto-adhesive bonded PUR core: Three specimens including the faces with the dimensions 100 mm × 100 mm × thickness shall be cut from positions covering the width of the panel (see figure A.15).

![Figure A. 15 - Location of test specimens - Density test](image)

The faces shall be removed carefully (for example by cutting) with the remaining core specimens to be orthogonal. The thickness of the cut-off core material shall not exceed 3 mm at each face.

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For panels with profiled faces specimens shall be cut from the predominant thickness (see examples in figure A.1).

A.8.1.4 Procedure
The procedure shall be as defined in EN 1602.

A.8.1.5 Calculations and results
Calculations shall be as defined in EN 1602. Recording and interpretation of test results shall comply with A.17.

A.8.2 Determination of mass of a panel
The mass of the panel shall be determined by calculation based on the nominal dimensions and nominal densities of the core material and faces.

The mass of the panel is required for the design of roofs and ceilings and also for handling purposes and shall be recorded on the accompanying documentation.

A.9 Test for resistance to point loads and repeated loads

A.9.1 Panels subject to point loads

A.9.1.1 Principle
This test determines the safety and serviceability of roof or ceiling panels, for example with respect to a single person walking on the panel, for occasional access both during and after erection.

A.9.1.2 Apparatus
Simply supported panel with central load.

A.9.1.3 Test specimens
The test specimen shall be a single panel of full width. The length (span) shall be the largest envisaged in practice.

A.9.1.4 Procedure
The tests shall be carried out on single span panels of full width.

A load of 1,2 kN shall be applied unless required otherwise by national regulatory requirements. The load shall be applied at mid-span on the edge rib or on the edge of a flat panel through a timber block measuring 100 mm × 100 mm. In order to avoid local stresses, a 10 mm thick layer of rubber or felt shall be placed between the timber block and the metal skin of the panel.

A.9.1.5 Calculations and results
Panels shall sustain a point load giving rise to the following three possible outcomes:

a) if the panel carries the applied load without permanent visible damage, there are no restrictions for occasional access onto the roof or ceiling either during or after erection;
b) if the panel supports the load but with permanent visible damage, measures shall be taken to avoid damage during erection (for example walking boards). Furthermore, there shall be no provision for access to the roof after building work is completed; and

c) if the panel fails to support the load it shall be used only on roofs or ceilings where no walking access is possible/ permitted. This limitation shall be clearly indicated on the panel (or elsewhere).

Recording and interpretation of test results shall comply with A.17.

A.9.2 Panels subject to repeated loads

A.9.2.1 Principle
This test determines the safety and serviceability of roof or ceiling panels, for example with respect to a single person walking on the panel, for repeated access both during and after erection.

A.9.2.2 Apparatus
A universal compressive-tensile strength testing machine with cyclic loading capability shall be used. The machine shall be provided with a compression loading platen of dimensions 100 mm × 100 mm.
A.9.2.3 Specimen
Three reference specimens measuring 100 mm × 100 mm shall be taken and tested in accordance with A.1.

For the cyclical test five sample panels shall be used each of 500 mm × nominal width × nominal thickness. The sample panels shall be conditioned for at least 6 h under normal laboratory conditions before the test.

After the test, the five specimens of dimensions 100 mm × 100 mm marked in accordance with A.9.2.4 shall be carefully cut from the sample panels and tested in accordance with A.1.

A.9.2.4 Repeated loading procedure
The test measures the adhesion between the faces and the insulating core (tensile strength) following a cyclical compressive loading test, which simulates repeated access on the roof or ceiling. This shall be compared with the values obtained for the normal panel.

Mark a square of dimensions 100 mm × 100 mm in the centre of each of the five sample panels. Stick the internal face of the panel to a rigid surface 500 mm × 1 200 mm and place the rigid base and the sample panel on the lower plate of the compression machine.

Adjust the 100 mm × 100 mm loading platen of the testing machine in such a way that when it comes down it pushes exactly on the marked square.

Apply 40 cycles to the sample panel, each cycle consisting of a load of 600 N for 6 s followed by zero load for 2 s.

On completion of the 40 cycles cut the marked specimen from the centre of the test panel.

Bond the metal faces to the tensile plates with an adhesive. Test the specimens to failure in tension in accordance with A.1.4.

Repeat the test for the remaining four sample panels.

A.9.2.5 Calculations and results
Calculate the tensile strength \( f_{ct} \) as in A.1.5.1 using

\[
 f_{ct} = \frac{F_u}{A}
\]

Eliminate the best and the worst tensile strength results and take the mean of the other three results. Compare the results with the mean tensile strength results obtained for the panel without cyclical loading.

If the mean of the tensile strength results obtained after cyclic loading falls below 80 % of the mean value obtained without cyclic loading, the panels shall be considered to be unsuitable for repeated loads without added protection.

A. 10 Calculation method for the determination of the thermal transmittance of a panel (U)

A.10.1 General
The thermal transmittance \( U \) of metal faced insulating sandwich panels shall be determined in accordance with the procedures in A.10.2, A.10.3 and A.10.4.

A. 10.2 Determination of the thermal conductivity of component materials

A.10.2.1 Core material

A.10.2.1.1 Declared thermal conductivity
A.10.2.1.1.1 The declared thermal conductivity \( \lambda_{\text{declared}} \) shall be determined in accordance with the procedures described in the following appropriate product standards for the core material:

- EN 13162 for MW;
- EN 13163 for EPS;
- EN 13164 for XPS;
- EN 13165 for PUR;
- EN 13166 for PF; and
- EN 13167 for CG.

**A.10.2.1.2** The following variations from the conditions described in the product standard procedures shall be taken into account:

- the core material surface shall have the same orientation, relative to the direction of heat flow, that it would have in the panel; and
- the core material surface shall be normal to the direction of heat flow in the test equipment.

**A. 10.2.1.2 Design thermal conductivity**

The design thermal conductivity \((\lambda_{\text{design}})\) shall be determined in accordance with SANS 10456, except in the case where the declared value is the aged value, when it is not necessary to use the ageing calculations in SANS 10456.

The value of the declared thermal conductivity value \((\lambda_{\text{declared}})\) for the core, determined in the correct orientation, shall be used in determining the design thermal conductivity value \((\lambda_{\text{design}})\).

Where preformed core products, which are subject to thermal conductivity ageing in the absence of the metal faces, are used in the manufacture of the sandwich panel, the correct aged core design value shall be used. For panels created by separately bonding metal faces to a preformed core, values in accordance with EN 13165 shall be determined using either the actual thermal conductivity of the core determined at the time of lamination in accordance with C.3, or alternatively the aged value quoted by the manufacturer for the core product.

For auto-adhesively bonded PUR cores, the correctly aged core design thermal conductivity value shall be derived from EN 13165, annex C, either by applying the ageing procedure given in C.4.2, or the fixed increment procedure given in C.5.

**A. 10.2.2 Facing, sealant and fixing materials**

For materials, other than the core material, for which no design thermal conductivity is given, tabulated values in accordance with EN 12524 shall be used.

**A. 10.3 Calculation of the thermal transmittance of a panel \((U)\)**

When determining the thermal transmittance for the panel the following conditions apply:

- tests and calculations shall take account of the thermal effect of the profiles of the external and internal faces;
- calculations shall take account of the panel-to-panel edge joints (A. 10.4).

The thermal transmittance \((U)\) of the panel shall either be determined by calculation (equation (A.26)), or using a computer program in accordance with ISO 10211 (finite element method).

The thermal transmittance \((U)\) of the panel determined by calculation:

\[
U = \frac{1}{\frac{1}{R_{si}} \frac{d_{si}}{\lambda_{fi}} + \frac{d_{ne}}{\lambda_{fe}} + \frac{\Delta_{e}}{\lambda_{fe}} + \frac{\Delta_{b}}{\lambda_{fe}} + R_{se}} + \frac{\Psi}{B} \tag{A.26}
\]

where

- \(d_{c}\) is the nominal thickness of the core (ignoring the thickness of the facings), expressed in meters (m);
- \(t_{si}\) is the nominal thickness of the internal facing, expressed in metres (m);
- \(t_{se}\) is the nominal thickness of the external facing (m); \(\lambda_{\text{design}}\) is the design thermal conductivity of the core, expressed in watts per metre kelvin (W/m·K);
- \(\lambda_{fi}\) is the design thermal conductivity of the internal facing, expressed in watts per metre kelvin (W/m·K);
- \(\lambda_{fe}\) is the design thermal conductivity of the external facing, expressed in watts per metre kelvin (W/m·K);
- \(\Delta_{e}\) is the additional thickness due to the main profiles, expressed in metres (m);
- \(\Psi\) is the linear thermal transmittance of the joints per metre length of panel, expressed in watts per metre kelvin (W/m·K);
- \(B\) is the overall width of the panel, expressed in metres (m);
- \(R_{si}\) is the internal surface resistance, expressed in square metres kelvin per watt (m²K/W);
- \(R_{se}\) is the external surface resistance, expressed in square metres kelvin per watt (m²K/W);

The design thermal conductivity \((\lambda_{\text{design}})\) for the core material shall be determined in accordance with A.10.2.1.2.
The design thermal conductivity for the facing, sealant and fixing materials shall be determined in accordance with A.10.2.2.

The linear thermal transmittance of the joints (ψ) shall be determined in accordance with A. 10.4.

The internal surface resistance ($R_{si}$) and the external surface resistance ($R_{se}$) shall be determined in accordance with SANS 6946.

For profiled panels the additional thickness due to the main profiles ($\Delta_e$) shall be obtained from table A.2. For flat and lightly profiled (profile height less than 10 mm) panels $\Delta_e$ is zero.

### Table A.2 - Additional thickness due to the main profiles ($\Delta_e$), m

<table>
<thead>
<tr>
<th>Coverage of ribs</th>
<th>Height $h$ of ribs (mm)</th>
<th>10 ≤ $h$ ≤ 25</th>
<th>25 ≤ $h$ ≤ 50</th>
<th>50 ≤ $h$ ≤ 80</th>
<th>$h$ &gt; 70</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r &lt; 25%$</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>$25% &lt; r ≤ 50%$</td>
<td></td>
<td>0.003</td>
<td>0.005</td>
<td>0.006</td>
<td>0.007</td>
</tr>
<tr>
<td>$50% &lt; r ≤ 60%$</td>
<td></td>
<td>0.005</td>
<td>0.009</td>
<td>0.012</td>
<td>0.014</td>
</tr>
<tr>
<td>$60% &lt; r ≤ 70%$</td>
<td></td>
<td>0.007</td>
<td>0.012</td>
<td>0.016</td>
<td>0.019</td>
</tr>
<tr>
<td>$70% &lt; r ≤ 80%$</td>
<td></td>
<td>0.008</td>
<td>0.015</td>
<td>0.020</td>
<td>0.024</td>
</tr>
</tbody>
</table>

where $r$ in table A.2 is defined by equation (A.27) (see figure A.16)

$$r = \frac{0.5 \times (b_1 + b_2)}{p} \quad \text{(A.27)}$$

*Where $h > 120$ mm, a more accurate calculation is necessary.*

![Figure A.16 - Definition of symbols in table A.2 and equation (A.27)](image)

### A. 10.4 Determination of the effect of the joints

The linear thermal transmittance of the joints (ψ) for the calculation of thermal transmittance $U$ in accordance with equation (A.26) shall be determined in accordance with ISO 10211 and given per metre length of panel.

Alternatively the linear thermal transmittance contribution factor of the joints ($f_{joint}$) shall be obtained from table A.3 for steel faces according to the generic type of joint (see figures A.17 to A.21) and used to determine the thermal transmittance $U$ in accordance with equation (A.28), as follows:

$$U = \frac{1}{R_{si} + \frac{1}{\frac{1}{R_{se} + R_{design}}}} + \left(1 + f_{joint} \frac{1.0}{B}\right) \quad \text{(A.28)}$$
where

\[ f_{\text{joint}} \] is the linear thermal transmittance contribution factor of the joints calculated for a joint distance of 1 m.

### Table A.3 - Thermal transmittance contribution factor \((f_{\text{joint}})\) for steel faces

<table>
<thead>
<tr>
<th>Thickness (mm)</th>
<th>Type I</th>
<th>Type II</th>
<th>Type III</th>
<th>Type IV</th>
<th>Type V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>no clip ((f_{\text{joint,nc}}))</td>
<td>clip ((f_{\text{joint,c}}))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>0.04</td>
<td>0.14</td>
<td>1.156</td>
<td>0.16</td>
<td>0.04</td>
</tr>
<tr>
<td>80</td>
<td>0.04</td>
<td>0.08</td>
<td>1.389</td>
<td>0.10</td>
<td>0.04</td>
</tr>
<tr>
<td>120</td>
<td>0.03</td>
<td>0.06</td>
<td>1.719</td>
<td>0.06</td>
<td>0.04</td>
</tr>
<tr>
<td>160</td>
<td>0.03</td>
<td>0.05</td>
<td>1.948</td>
<td>0.05</td>
<td>0.04</td>
</tr>
<tr>
<td>200</td>
<td>0.03</td>
<td>0.04</td>
<td>2.106</td>
<td>0.04</td>
<td>0.03</td>
</tr>
</tbody>
</table>

**NOTE 1:** See equation (A.29) for determination of \(f_{\text{joint}}\) of joint type II (see table A.3):

\[
f_{\text{joint}} = f_{\text{joint,nc}} \left(1 - \frac{b_c}{a}\right) = f_{\text{joint,c}} \frac{b_c}{a}
\]

where

- \(f_{\text{joint,nc}}\) is the thermal transmittance contribution factor of the joints with no clips;
- \(f_{\text{joint,c}}\) is the thermal transmittance contribution factor of the joints with clips;
- \(a\) is the distance of the clips;
- \(b_c\) is the width of the clips.

**NOTE 2:** It is allowed to interpolate between the thicknesses in table A.3.

![Figure A.17 - Joint type I](image)

![Figure A.18 - Joint type II](image)
A.11 Rain penetration

A.11.1 Apparatus
A water spraying apparatus capable of spraying a fine spray of water, at a pressure of 150 kPa ± 5 kPa, over a vertical area of approximately 2 m² (in still air), at a rate of 40 mm to 50 mm depth of water per hour.

NOTE: The apparatus may be equipped with a frame in order to define the correct spraying area and to establish and maintain a still atmosphere during the test period. For further information see SANS 10400-K.

A.11.2 Test specimen
Use two joined panels (jointed with associated joints) of total width at least 1.5 m and height at least 2 m.

A.11.3 Procedure

A.11.3.1 Allow the specimen to air-dry thoroughly.

A.11.3.2 Weigh the specimen on a scale accurate to 10 g.

A.11.3.3 Place the frame (if any) of the apparatus against the surface of the specimen intended to face the outside of the building. Ensure that a vertical joint is included in the test area.

A.11.3.4 Ensure that the bottom of the panel assembly is waterproofed in accordance with the installation instructions of the test sponsor.

A.11.3.5 Spray the outer surface area of the test specimen continuously on the face of the specimen that will normally be exposed to the outside of the building. Terminate the tests after the period chosen from in table 8 of SANS 1 0400-K:2011 expired or until dampness on the face of the panel that will normally be exposed to the inside of a building shows signs of dampness exceeding the criteria given under 5.2.6. Note the duration of resistance to rain penetration.

A.11.3.6 Reweigh the specimen and calculate the mass gained.

A.12 Air permeability

A.12.1 Principle
Where required, the air tightness of a sandwich panel assembly shall be tested in accordance with EN 12114, including the additional requirements in A.12.2 to A.12.5.
A.12.2 Apparatus
The test apparatus shall be in accordance with EN 12114.

A.12.3 Test specimens
The dimensions of the test assembly shall be as large as necessary to be representative of the intended use. The assembly shall not be less than 1 200 mm × 2 400 mm.

The joints of the modules comprising the test assembly shall be representative, i.e. the same length per square metre as in the end use. Both horizontal and vertical joints shall be incorporated where these are an intrinsic part of the panel assembly.

A.12.4 Procedure
The test shall be carried out in accordance with EN 12114.

A.12.5 Calculations and results
The air permeability shall be measured with a pressure difference of 50 Pa between the inside and outside of the test assembly. The air permeability (air loss) shall be determined in terms of cubic metres per square metres hour at 50 Pa.

A.13 Airborne sound insulation

A.13.1 Principle
When required, the airborne sound insulation of a sandwich panel assembly shall be tested in accordance with SANS 140-3 including the additional requirements in A.13.2 to A.13.5.

A.13.2 Apparatus
The test apparatus shall be in accordance with SANS 140-3.

A.13.3 Test specimens
The mounting of the test specimens in the test opening shall comply with the normal assembly in a building with the same connections and seals between the elements.

A.13.4 Procedure
The sound reduction indices R in each one-third octave band in the range from 100 Hz to 3 150 Hz shall be determined using the method described in SANS 140-3.

A.13.5 Calculations and results
The single number rating $R_{w0}(C;C_r)$ shall be declared in accordance with SANS 717-1.

A. 14 Sound absorption

A.14.1 Principle
Where required, sound absorption shall be determined in accordance with ISO 354.

A.14.2 Apparatus
The test apparatus shall be in accordance with ISO 354.

A.14.3 Test specimens
The mounting of the test specimens shall comply with the normal assembly in a building with the same connections and seals between the elements. The test specimen shall be placed directly against one of the internal surfaces (wall, ceiling or floor) of the chamber. A reflective frame shall be installed round the test specimen.

A.14.4 Procedure
The test shall be carried out in accordance with ISO 354.

A.14.5 Calculations and results
The result shall be declared as a single number rating ($\alpha_w$) in accordance with ISO 11654.

A. 15 Support reaction capacity at the end of a panel
A. 15.1 Principle
Where required for design purposes and as an alternative to calculation in accordance with E.4.3.2, the reaction capacity at the end of a panel where the contact face is either plain or lightly profiled shall be determined by tests on full width panels in accordance with A.15.5.

A.15.2 Apparatus
The test apparatus shall be as shown in figure A.22.

The right-hand support shall be a 10 mm thick steel plate held firmly at an inclination of 1:20. The support width $L_s$ shall either be the minimum used in practice or tests shall be carried out for each support width used in practice. The dimensions $L_1$, $L_2$ and $L_3$ shall either be chosen so that the test specimen fails in compression at the right-hand support, or, if the failure mode is a shear failure between the loading platen ($F$) and the support platen ($F_{R1}$), the reaction capacity shall be taken to be the support reaction force at the time of shear failure. $L_3$ shall be $> 1.5 \, e$.

![Figure A.22 - Test arrangement for the determination of the resistance for the end support reaction](image)

Key

- $w$ compressive deflection
- $L_s$ support width
- $o$ overhang beyond the end of the support plate not exceeding 50 mm
- $e$ distance between centroids of the faces

A.15.3 Test specimens
Sampling and conditioning of the test specimens shall comply with 6.2.2 and 6.2.3.

The test shall be carried out on test specimens of length $L$, where the length is as specified in A.15.2. Three tests are carried out for each support width.

A.15.4 Procedure
The rate of loading shall be such that the ratio $w/e$ rises by between 1 % and 3 % per minute. A minimum of three tests shall be carried out at each support width. The compressive strength $f_{Ce}$ of the core material of the test specimen shall be determined in accordance with A.2.
The test value of reaction capacity, $F_{R1}$, shall either be measured by a load cell or calculated by equation (A.30):

$$F_{R1} = \frac{L_2}{L_2 + L_2} F_u$$  \hspace{1cm} (A.30)

where

- $F_u$ is the maximum load measured in the test or the load corresponding to a compressive deflection of $w = 0.1\, e$ (where $e$ is the depth between the centroids of the faces) if this deflection is attained on the rising part of the load-deflection curve and is less than the maximum load (see figure A.23).

![Diagram](image)

**Key**
- $F$ support reaction
- $F_{lin}$ load at the end of the linear part of the curve
- $w$ compression

**Figure A.23 - Definition of the ultimate load from the load-deflection curve in an end support reaction test**

**A.15.5 Calculation and results**

The test results shall be adjusted by multiplying them by the ratio $f_{cc}/f_c$.

The adjusted characteristic value of $F_{R1}$ shall be the value to be used in design (see E.4.3). The following equation (A.31) for the end support capacity defines the distribution parameter $k$:

$$F_{R1} = B \left(L_2 + 0.5\, ke\right)f_{cc}$$  \hspace{1cm} (A.31)

where

- $B$ is the width of panel;
- $L_2$ is the width of support;
- $e$ is the distance between centroids of the faces;
- $f_{cc}$ is the declared value of the compressive strength of the core following initial type testing;
- $k$ is the distribution parameter.

Therefore, the distribution parameter $k$ shall be determined in accordance with equation (A.32):

$$k = \frac{2F_{R1} - f_{cc} B L_2}{f_{cc} Be}$$  \hspace{1cm} (A.32)
A.16 Resistance to hail

A16.1 Use the method given in ASTM E822 and conduct the test with a nominal ball diameter of 38 mm and energy of 10 \( J \pm 2 \) J.

A 16.2 The angle of incidence of the ice ball shall be 90° in respect of roofing panels and 45° in respect of wall panels.

A16.3 Check for compliance with 5.2.11.

A.17 Recording and interpretation of test results

A.17.1 ITT tests
For each ITT test series, formal documentation shall be prepared giving all the relevant data so that the test series can be accurately reproduced. In particular, in addition to the results of the tests, the specimens shall be fully and accurately described in terms of dimensions and material properties. Any observations made during the tests shall also be recorded.

The following information shall be recorded in all ITT test reports:

a) the date and time of manufacture;
b) the method of manufacture and orientation of panel during manufacture (for example which face was uppermost, which was the leading edge during continuous foaming);
c) the date of testing;
d) the conditions during testing (temperature and humidity);
e) the method of loading and details of instrumentation;
f) the support conditions (number and length of spans, width and details of supports, number and details of connections to supporting structure, etc.);
g) the orientation of the panel during testing;
h) the type and properties of face material (thickness, yield stress, geometry, etc.);
i) the type and properties of core material (density, strength, moduli, etc.);
j) the type and details of the adhesive;
k) the measurements made during testing (load, deflection readings, temperature, etc.); and
l) the mode of failure.

The analysis of the results of a test shall be based on the measured dimensions and material properties of the test specimens rather than the nominal values assumed in the design.

A.17.2 FPC tests
The following information shall be recorded in all FPC test reports:

a) the date of manufacture;
b) the method of manufacture and orientation of panel during manufacture;
c) the date of testing;
d) the orientation of panel during testing;
e) the type and properties of face material (thickness, yield stress, geometry, etc.);
f) the type and properties of core material (density, strength, moduli, etc.);
g) the type and details of adhesive;
h) the measurements made during testing (load, deflection readings, temperature, etc.); and
i) the mode of failure.

The analysis of the results of a test shall be based on the measured dimensions and material properties of the test specimens rather than the nominal values assumed in the design.

A.17.3 Determination of characteristic values from tests
The characteristic values of the relevant properties, for each of the test procedures that result in quantified design parameters, shall be determined in accordance with the procedure given below. This statistical treatment shall be used unless defined otherwise in a horizontal standard.

For each population of test results, the mean value and the 5 % fractile value shall be determined assuming a confidence limit of 75 % in accordance with ISO 12491.
The 5 %-fractile value shall be used as the characteristic value and determined in accordance with equation (A.33):

$$\chi_p = e^{(\bar{y} - k\sigma_y)}$$  \hspace{1cm} (A.33)

where

- $\chi_p$ is the 5 %-fractile value of population $x$;
- $\bar{y}$ is equal to $L_n (\chi)$;
- $\bar{y}$ is the mean value of $y$ (A.34);
- $k$ is the fractile factor given in table A.4;
- $\sigma_y$ is the standard deviation of $y$ (A.35).

$$\bar{y} = \frac{1}{n} \sum_{i=1}^{n} L_n (\chi_i)$$  \hspace{1cm} (A.34)

$$\sigma_y = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (L_n (\chi_i) - \bar{y})^2}$$  \hspace{1cm} (A.35)

### Table A.4 - Fractile factor $k$ assuming a confidence level of 75%

<table>
<thead>
<tr>
<th>Number of specimens ($n$)</th>
<th>Fractile factor $k_\sigma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3.15</td>
</tr>
<tr>
<td>4</td>
<td>2.68</td>
</tr>
<tr>
<td>5</td>
<td>2.46</td>
</tr>
<tr>
<td>6</td>
<td>2.34</td>
</tr>
<tr>
<td>7</td>
<td>2.25</td>
</tr>
<tr>
<td>8</td>
<td>2.19</td>
</tr>
<tr>
<td>9</td>
<td>2.14</td>
</tr>
<tr>
<td>10</td>
<td>2.10</td>
</tr>
<tr>
<td>15</td>
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<td>20</td>
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<td>30</td>
<td>1.87</td>
</tr>
<tr>
<td>60</td>
<td>1.80</td>
</tr>
<tr>
<td>100</td>
<td>1.76</td>
</tr>
</tbody>
</table>
Annex B
(normative)
Durability testing method for sandwich panels

B.1 Principle
The influence of ageing on sandwich panels or their constituent materials is tested by measuring changes in the tensile strength across the depth of the panel. The durability is defined by the change in the tensile strength of a test specimen that is subjected to climatic test cycles denoted as DUR1 and DUR2. Cycle DUR1 is defined in B.2 and cycle DUR2 in B.3.

B.2 Test DUR1

B. 2.1 Principle
The effect of ageing (durability) shall be measured by determining the change in tensile strength in accordance with EN 1607, performed on panel samples that have been subject to durability test cycle DUR1.

The test shall be used on panel types where the effect of temperature is known to be the main cause of ageing (see 5.2.3.1).

The test shall be carried out at one of the following three temperature levels ($T$) that reflect the maximum temperatures that may be reached in the end use, according to the colour of the exposed facing:
- test temperature 90 °C for dark colours;
- test temperature 75 °C for light colours; and
- test temperature 65 °C for very light colours.

The reflectivity definition of the three colour ranges is listed in the note to E.3.3.

B.2.2 Apparatus

B.2.2.1 Test apparatus for the durability test in accordance DUR1 comprising a test chamber with constant temperature of ($T \pm 2$) °C (see B.2.1) and dry conditions (relative humidity not greater than 15 %).

B.2.2.2 Test apparatus for the tensile strength test in accordance with EN 1607.

B.2.3 Test specimens

B.2.3.1 Dimensions of test specimens
The thickness of the specimens shall be the full product thickness including, where applicable, any irregular profile.

The specimens shall be cut from sandwich panel sections of 500 mm × 500 mm, taken from the central area of the panels four weeks after production. All test specimens for the test programme shall be cut from the same panel in accordance with A. 1.3.

B.2.3.2 Number of test specimens
Six test specimens shall be used for the determination of the initial tensile strength (initial test) and a minimum of five test specimens shall be used for each subsequent part of the test sequence:

DUR1 specimens: Set 1 (initial set) + two sets of five specimens.

NOTE: Where there is a wide scatter in the tensile strength results in the initial test, it may be necessary to test more than five specimens.

If panels are produced in more than one thickness, the tests shall be conducted with samples from panels of both maximum and minimum thickness. The worst result shall apply to panels of all intermediate thickness.

B.2.3.3 Preparation of test specimens
Before starting the tests, the specimens shall be stored for at least 24 h under normal laboratory conditions.
B.2.4 Procedure

B.2.4.1 General
The dimensions of all test specimens shall be measured before and after the tests and shall be in accordance with EN 12085.

The tensile strength of the product shall be determined in accordance with A.1 using the initial set of the test specimens (see B.2.4.2). The strength value obtained shall be denoted $f_{c0}$ and shall be determined as the mean strength of the tested specimens.

After testing, the specimens shall be visually inspected, paying special attention to the failure type (cohesive failure of the core, adhesive bond failure in any of the bonded surfaces, proportional area of the adhesive failure, etc.). A description of the results of these observations shall be included in the test report.

If the metal faces of any of the specimens have suffered from general edge corrosion during exposure, and if the corrosion has propagated deeper than 10 mm into the joint between the surface sheet and the core over an edge length longer than 50% of the specimen perimeter, the specimen shall be rejected and its results shall not be included in the calculation of the test results. A note on this rejection shall be included in the test report.

Tensile strength statistics shall refer to mean values.

B.2.4.2 DUR1 temperature test
The test shall be carried out at the selected temperature level, $T = 90 \, ^\circ\text{C}$, 75 °C, or 65 °C, as defined in B.2.1. The test programme shall be as follows:

Set 1 (initial set): Condition for one week in normal laboratory conditions followed by the tensile test;

Set 2: Condition for six weeks at $T \, ^\circ\text{C}$ followed by the tensile test;

Set 3: Condition for 24 weeks at $T \, ^\circ\text{C}$ followed by the tensile test;

where $T$ is the selected test temperature.

B.2.4.3 Tensile strength test
The tensile strength tests shall be conducted under normal laboratory conditions. The tensile strength shall be determined with both metal faces intact.

B.2.5 Test results and acceptance criteria - DUR1
If panels are produced in more than one thickness, the tests shall be conducted with samples from panels of both maximum and minimum thickness. The worst result shall apply to panels of all intermediate thickness.

The durability criteria shall be satisfied providing the following conditions are met:

- $f_{c26}$ or $f_{c24}$, whichever is lowest, shall not be less than 50 % of the initial tensile strength value $f_{c0}$;
- the mean value of tensile strength $f_{c26}$ or $f_{c24}$, whichever is lowest, of the samples with $T \, ^\circ\text{C}$ shall be not less than 0,02 MPa; and
- the change of thickness of the sections at $T \, ^\circ\text{C}$ in test procedure DUR1 shall not be greater than 5 %, in the central and edge regions.

The test report shall state the temperature at which the specimen passed the DUR1 test. The colour limitation and reflectivity range shall be declared according to the following acceptance criteria:

- Durability pass: suitable for all colours ($T = 90 \, ^\circ\text{C}$ test).
- Durability pass: suitable for light and very light colours. Reflectivity 40 to 90. ($T = 75 \, ^\circ\text{C}$ test). – Durability pass: suitable for very light colours only. Reflectivity 75 to 90. ($T = 65 \, ^\circ\text{C}$ test).
B.3 Test DUR2

B.3.1 Principle
The test shall be used on panel types where the effect of humidity is known to be the main cause of ageing (see 5.2.3.1). The effect of ageing (durability) shall be measured by determining the change in tensile strength in accordance with EN 1607, performed on panel samples that have been subject to durability test cycle DUR2.

B.3.2 Apparatus

B.3.2.1 Test apparatus for the humidity test
The humidity test shall be carried out using the DUR2 test chamber. Test apparatus for the humidity test in accordance with DUR2 comprises a test chamber with constant conditions: air temperature of (65 ± 3) °C and relative humidity of 100 % achieved by heating up water at the bottom of the chamber.

The test chamber shall consist of a box in which the water is heated up to roughly +70 °C, (see figure B.1). Uniform air temperature shall be achieved before starting the test.

NOTE: Normally it is not necessary to provide any accelerated thermal exchange by means of fans in the test chamber. However, circulation of the water may be required.

![Diagram of test chamber for durability test DUR2](image)

Key

a sealed cover - insulated
b air temperature thermometers - (25 ± 10) mm above water level
c specimens
d insulated box
e grid for specimens - above water level
f heating element

Figure B.1 - Test chamber for durability test DUR2

B.3.2.2 Test apparatus for the tensile strength test
Test apparatus for the tensile strength test shall be in accordance with EN 1607.

B.3.3 Test specimens

B.3.3.1 Dimensions of test specimens
All test specimens shall be cut from the same panel and shall be in accordance with A.1.3.

The thickness of the specimens shall be the full product thickness including, where applicable, any irregular profile.

Specimens taken from panels with other core materials shall have a square plan form with squarely cut edges in accordance with EN 12085, with sides of 100 mm and an accuracy of 0,5 %.

B.3.3.2 Number of test specimens
Six test specimens shall be used for the determination of the initial tensile strength (initial test) and a minimum of five test specimens shall be used for each subsequent part of the test sequence:
DUR2 specimens: Set 1 (initial set) + three sets of five specimens.

NOTE: Where there is a wide scatter in the tensile strength results in the initial test, it may be necessary to test more than five specimens.

If panels are produced in more than one thickness, the tests shall be conducted with samples from panels of both maximum and minimum thickness. The worst result shall apply to panels of all intermediate thickness.

B.3.3.3 Preparation of test specimens

The cut edges of the metal facing sheets in the samples shall be protected from the effects of corrosion by the application of a layer of water resistant neutral silicone.

Before starting the tests, the specimens shall be stored for at least 24 h under normal laboratory conditions.

B.3.4 Procedure

B.3.4.1 General

The exact dimensions of all test specimens shall be measured before and after the tests and the dimensional changes for all three directions shall be in accordance with EN 12085.

The tensile strength of the product shall be determined in accordance with A.1 using the initial set of the test specimens (see B.3.4.2). The mean strength value obtained shall be denoted $f_{cto}$ and shall be determined as the average strength of the tested specimens.

After testing, the specimens shall be visually inspected, paying special attention to the failure type (cohesive failure of the core, adhesive bond failure in any of the bonded surfaces, proportional area of the adhesive failure, etc.). A description of the results of these observations shall be included in the test report.

If the metal faces of any of the specimens have suffered from general edge corrosion during exposure, and if the corrosion has propagated deeper than 10 mm into the joint between the surface sheet and the core over an edge length longer than 50% of the specimen perimeter, the specimen shall be rejected and its results shall not be included in the calculation of the test results. A note on this rejection shall be included in the test report.

Tensile strength statistics shall refer to mean values.

B.3.4.2 DUR2 Humidity test

The test programme shall be as follows:

Set 1 (initial set): Condition for one week in normal laboratory conditions followed by the tensile test.

Set 2: Maintain under constant conditions for 7 d at $(65 \pm 3)$ °C and 100 % RH (B.3.2.1) followed by the tensile test.

Set 3: Maintain under constant conditions for 28 d at $(65 \pm 3)$ °C and 100 % RH (B.3.2.1) followed by the tensile test. If required, see B.3.4.3.

Set 4: Maintain under constant conditions for 56 d at $(65 \pm 3)$ °C and 100 % RH (B.3.2.1) followed by the tensile test.

B.3.4.3 Tensile strength ($f_{ct}$) test - DUR2

The tensile strength tests shall be conducted under normal laboratory conditions. The tensile strength shall be determined with both metal faces intact.

The tensile strength test after the seven, 28 and 56 day cycles shall be carried out on stabilized samples. After the ageing test, the samples shall be stored until the mass has stabilized under ambient laboratory conditions. Constant mass shall be fulfilled when the change in mass between two subsequent weighings with a 24 h interval is smaller than 1 % of the total mass.

The mean tensile strength values obtained from the initial samples shall be denoted as $f_{cto}$; after conditioning for seven days as $f_{ct7}$; and after 28 d as $f_{ct28}$. 
If the test results illustrate a continuing decline in tensile strength with time a further set of test specimens that have been exposed to the DUR2 test cycle for 56 d shall be tested. The strength value obtained shall be denoted as $f_{\text{C}56}$.

**B.3.5 Test results and acceptance criteria - DUR2**

The durability criteria shall be satisfied providing the following conditions are met:

- $f_{\text{C}17} - f_{\text{C}28}$ shall be equal to or smaller than $3 (f_{\text{C}10} - f_{\text{C}17})$; and
- $f_{\text{C}28}$ shall not be less than 40 % of $f_{\text{C}10}$.

If this is not fulfilled, specimens shall be exposed to the DUR2 test for 56 d. The criteria for acceptance shall be that:

$$f_{\text{C}28} - f_{\text{C}56} \text{ shall be less than } f_{\text{C}17} - f_{\text{C}28}, \text{ and } f_{\text{C}56} \text{ shall not be less than } 40 \% \text{ of } f_{\text{C}10}.$$ 

**B.4 Test report on durability tests**

The test report shall include the following information:

a) Reference to this standard, i.e. SANS 54509.

b) The product identification:

1) product name, factory, manufacturer and supplier;
2) type of product;
3) packaging;
4) the form in which the product arrived at the laboratory;
5) presence of facing or coating;
6) type of adhesive;
7) type of core material; and
8) other information as appropriate, for example nominal thickness, nominal density, the conditions under which the product was stored and transported before arriving at the laboratory.

c) The test procedure:

1) conditioning;
2) any deviations from this standard (B.2 and B.3);
3) the date of testing;
4) general information related to the testing:
   i) the basic test cycle used;
   ii) use, where applicable, of the additional 56 days exposure; and
5) factors that might have affected the results:
   i) corrosion of the exposed samples;
   ii) interruptions in the cycling test programme and the treatment of specimens during these interruptions; and
   iii) rejection of individual test specimens due to the failure of the edge corrosion protection.

Information about the apparatus and identity of the technician shall be available in the laboratory, but does not need to be recorded in the test report.

d) Results:

1) all individual and mean values;
2) any visual observations of the specimens after testing:
   i) the type of failure of the specimens in tensile testing (cohesive failure of the core, adhesive failure between the surface sheet and core, failure between the surface sheet and its coating, etc.); and
   ii) any corrosion of the test specimens; and
3) a statement as to whether the product has passed or failed the acceptance criteria.
B.5 Adhesive bond between faces and prefabricated core material (wedge test)

B.5.1 Principle
The wedge test shall be used to control the adhesion between the adhesives and the normal internal coated surface of the facings.

B.5.2 Apparatus
Test apparatus for the wedge test comprises a small aluminium or stainless steel wedge as shown in figure B.2.

![Figure B.2 - Wedge test aluminium or stainless steel wedge](image)

B.5.3 Test specimens
Five specimens shall be used for the wedge test. The test specimens shall be fabricated from two strips of the face material with a width of 20 mm and a length of 100 mm.

These strips shall either be cut from the coil material to be used in the manufacturing process or, in the case of panels produced using auto-adhesive bonding, from the manufactured panels. When cutting from completed panels, the core material shall be carefully removed without damaging the bonding layer with the surface of the metal face.

The strips of face material shall then be bonded together.

B.5.4 Procedure
The wedge shall be pressed between the two faces, thus causing an initial crack whose length shall be measured (see figure B.3). The wedge shall be loaded with a force of 3 N. The specimen shall then be immersed for 24 h in water heated to 70 °C.

![Figure B.3 - Wedge test using aluminium or stainless steel wedge](image)

**Key**

- $l$: initial crack length, in millimetres (mm)
- $\Delta_2$: crack growth after exposure, in millimetres (mm)
B.5.5 Test results and acceptance criteria
The initial crack shall not extend for more than 30 mm and shall not grow by more than a further 20 mm after immersion for 24 h in heated water.

If the crack appears in the bond with the face material and not within the adhesive material itself, this shall be classed as a failure of the wedge test.

B.6 Repeated loading test

B.6.1 Principle
The repeated loading test is part of the durability assessment procedure for sandwich panels identified in 5.2.3.1. The requirement is that the wrinkling stress shall not be reduced by more than the allowed limit in B.6.5.

B.6.2 Apparatus
The loading arrangements and support conditions for subjecting a simply supported panel to four line loads shall be in accordance with A.5.2.

B.6.3 Test specimens
A single test shall be carried out for each product family.

Sampling and conditioning of the test specimens shall comply with 6.2.2 and 6.2.3.

The specimens shall be in accordance with A.5.3. The test shall be carried out on the thickest panel of the product family.

B.6.4 Procedure
The applied load shall be applied cyclically between upper and lower limits. The lower limit shall be not more than the weight of the panel + 0.5 kN. The upper limit shall be the load determined in accordance with A.5 (5 %-fractile value) to reach the wrinkling stress at the serviceability limit state, i.e. the characteristic value divided by $\gamma_p \gamma_M$, where $\gamma_p$ is the load factor for variable actions and $\gamma_M$ is the material safety factor for wrinkling failure. This upper limit shall be applied with a tolerance of $\pm 5\%$.

The load shall be applied for 5 000 cycles with a load frequency not less than $(1 \pm 0.25)$ Hz.

If the frequency coincides with the natural frequency of the specimen, the load frequency shall be reduced until no effect takes place.

After cyclic loading, the load shall be increased statically until failure occurs.

The deflection at the centre of the specimen shall be continuously measured by means of a suitable transducer during both cyclic loading and static loading to failure.

The tests shall be performed under normal laboratory conditions of temperature and humidity.

B.6.5 Calculations and results
Panels shall satisfy the test providing that the reduction in the characteristic wrinkling strength of the panel after repeated loading is less than the initial characteristic value divided by $\gamma_M$.

The increase in the maximum deflection as a result of cyclic loading shall be less than 5 % of the maximum deflection observed during the first cycle.

B.7 Thermal shock test

B.7.1 Principle
The thermal shock test is part of the durability assessment procedure for sandwich panels identified in 5.2.3.1. The requirement is that shear failure, blistering or delamination does not occur.
B.7.2 Apparatus
A vertical framework designed to support an assembly of three panels as shown in figure B.4 with a central support beam.

Key
Temperature sensors ⊕ sensors on the hot side
△ sensors on the cool side

Figure B.4 - Test arrangement with load sensors

B.7.3 Test specimens
Sampling and conditioning of the test specimens shall comply with 6.2.2 and 6.2.3.

The test shall be carried out on the thickest panel of the product family with the thinnest facing. The tests shall be carried out on an assembly of one or more two-span panels with two equal spans between 2 m and 3.5 m. Fixings shall be as in practice.

B.7.4 Procedure
The panel assembly shall be subject to four cycles of thermal loading, which shall be applied in sequence, after which the panels shall be subject to thermal shock.

In cycles 1, 2 and 3 the panels shall be heated in five steps such that the average temperature difference between the two faces is 10 °C, 20 °C, 30 °C, 40 °C and 50 °C respectively. At each step, the temperature shall be kept constant for one hour and the displacements measured.

In the fourth cycle there shall be a sixth step with a temperature difference of 60 °C. The final temperature shall then be maintained for a further two hours, after which the panels shall be subjected to thermal shock by spraying water until the temperature difference between the facings has reduced to less than 5 °C in less than 10 min.

Panels shall be carefully inspected during each cycle and the location and size of any shear failure, blistering or delamination recorded.

NOTE: Blisters are most easily observed when the panel is hot. Delamination can often be detected by tapping the panel with a hard object.

B.7.5 Calculations and results
Panels shall satisfy the test providing that no shear failure, blistering or delamination is observed at the conclusion of the test cycles.

A clearly defined wrinkle at the internal support shall not be classed as a failure.
Annex C
(normative)

Fire performance tests - Additional instructions and direct field of application

C.1 Fire resistance
If required, the fire resistance of a thermal insulation panel system shall be determined in accordance with SANS 101 77-2.

The construction detail of the assembly shall be clearly described in the test report, complete with fasteners, structure, sealants and size.

The fire safety classification shall be given in multiples of 30 min. The test report shall clearly state whether or not the fire safety classification is valid from both sides or from one side only, in which instance the exposed side shall be defined clearly.

The fire resistant classification shall comply with the value stated by the manufacturer. (See 5.2.4.2.)

The fire resistance test may be load bearing or non-load bearing. If the fire resistance classification of the system is intended to be load bearing the maximum temperature reached by load-bearing members shall be less than 376 °C.

C.2 Fire performance classification
Test and classify sandwich panel assemblies in accordance with SANS 428 to determine the fire performance classification and check for compliance with 5.2.4.3.

C.3 Fire index classification
If the coating of the panels exceeds 0,5 mm in thickness, test the relevant coating on the metal sheet, mounted to a rigid non-combustible backing plate, to determine its fire index in accordance with SANS 10177-3. Check for compliance with 5.2.4.4.

C.4 Determination of the amount and thickness of the adhesive layer

C.4.1 General
Where required, the amount and thickness of the adhesive layer shall be determined in accordance with C.4.2 for panels after production, or in accordance with C.4.3 for control measurements during production.

C.4.2 Measurements on a manufactured panel

C.4.2.1 Principle
The method to collect and calculate the amount and thickness of adhesive used in the manufacture of sandwich panels shall be determined in accordance with C.4.2.2 to C.4.2.5.

C.4.2.2 Specimen
A 500 mm × 500 mm specimen of the panel facing shall be cut (for example by sawing) from the panel. The length and width of the facing sheet shall be measured with 1 mm accuracy at three places in both directions and the area A shall be calculated using the measured mean values. The place of the sample in the panel shall be documented.

C.4.2.3 Procedure
The insulation material shall be removed from the facing. Any wool fluff or insulant shall be carefully removed with a steel brush so that a clean adhesive surface is visible.

The facing sheet shall be weighed with adhesive to an accuracy of 0,1 g.

A paint remover shall be spread over the adhesive and the softened adhesive removed with a steel trowel. The facing sheet shall be weighed without adhesive, on the same scales.
C.4.2.4 Calculation of results
The amount of adhesive shall be calculated from equation (C.1):

\[ m_{\text{glue}} = \frac{(m_1 - m_2)}{A} \]  

(C.1)

where

- \( m_{\text{glue}} \) is the amount of adhesive in grams per square metre (g/m\(^2\));
- \( m_1 \) is the mass of facing + glue in grams (g);
- \( m_2 \) is the mass of facing in grams (g);
- \( A \) is the area of facing sheet in square metres (m\(^2\)).

The mean thickness of the adhesive layer shall be calculated from:

\[ h_{\text{glue}} = \frac{m_{\text{glue}}}{\rho} \]

where

- \( h_{\text{glue}} \) is the thickness of adhesive in millimetres (mm);
- \( m_{\text{glue}} \) is the amount of glue in grams per square metre (g/m\(^2\));
- \( \rho \) is the density of used glue in kilograms per cubic metre (kg/m\(^3\)), i.e. density of uncured glue mixture.

C.4.2.5 Reporting
The test report shall contain the following information:

a) the date of the test;

b) the test method used;
c) the panel code or specification;
d) the place of the sample in the panel;
e) the type of glue, glue batch (if known), density of the glue;
f) the dimensions and area of the facing sheet; and
g) the mass of the facing sheet with and without glue.

C.4.3 Measurements during production C.4.3.1 Principle
The method to collect and calculate the amount and thickness of adhesive used in the manufacture of sandwich panels shall be determined in accordance with C.4.3.2 to C.4.3.3.

C.4.3.2 Procedure
Weigh a suitable carrier, for example an A3 size piece of paper (\( m_c \)). The length and width of the carrier shall be measured with 1 mm accuracy at three places in both directions and the area shall be calculated using the measured values.

Place the carrier on the lower sheet of the sandwich panel over which the adhesive dispensing head passes. The place of the carrier on the facing sheet shall be documented.

Coat the carrier as part of the normal application process and remove from the line. Weigh the carrier and adhesive (\( m_{a+c} \)).

C.4.3.3 Calculation of results
Calculation of the amount of the adhesive (C.2):

\[ m_{(\text{adhesive})} = \frac{m_{a+c} - m_c}{A} \]  

(C.2)

where

- \( m_{a+c} \) is the mass of the carrier and adhesive;
- \( m_c \) is the mass of the carrier;
- \( A \) is the area of the carrier.
Annex D  
(normative)  
Dimensional tolerances

D.1 General

Tolerances have an impact on the strength of a panel and its safety in use. The tolerances defined in 5.2.5 are the maximum permissible.

The following tolerances shall apply to measurements made in the factory, before delivery, on panels that have reached a stable condition. Before measurement for ITT only, foamed panels shall be kept fully supported on a flat surface at ambient temperature for at least 24 h. The measurements shall be corrected for temperature variations to 20 °C where appropriate.

Measurements of pitch, crown, valley and cover width shall be carried out at 200 mm from the end of the panel. When measurements are taken, the panel shall be placed on at least three equally spaced supports, which are on a rigid flat surface.

D.2 Dimensional tolerances

D.2.1 Thickness of panel and joint conformity

The measured thickness ($D$) of the panel shall be the nominal distance between the external flat surfaces of the faces, excluding from the measurement any trapezoidal profiles or stiffeners and including the thickness of both metal faces (see figure D.1).

These measurements shall be taken at each end of the panel on lines 200 mm from the ends of the panel and at a minimum distance of 100 mm from the longitudinal edge. Two of these measurements shall be at the opposite edges of the panel and one at the centre.

In the case of panels that have profiled faces, the measurement shall be made at the position of predominant thickness. FPC records shall indicate where, within the geometry of the panel, this measurement is to be made and a consistent measurement location shall be used.

Tolerance: $D \leq 100 \text{ mm} \pm 2 \text{ mm},$

$D > 100 \text{ mm} \pm 2 \%.$
D.2.2 Deviation from flatness
This measurement is only relevant in the case of panels with nominally flat or lightly profiled facings.

Deviation from flatness ($\ell$) shall be defined as the distance between any point in the surface and the theoretical flat plane as shown in figure D.2. Flatness shall be measured in both the longitudinal and transverse directions over a minimum distance of $L = 200$ mm.

The location of the measured distance $L$ shall be at least 100 mm from the edge of the panel and 200 mm from the end of the panel.

A straight metal bar shall be placed on the surface of the panel and the maximum gap between the bar and the panel measured with a precision gauge.

Tolerance:  
For $L = 200$ mm $\ell = 0.6$ mm;  
For $L = 400$ mm $\ell = 1.0$ mm;  
For $L > 700$ mm $\ell = 1.5$ mm.

**Key**
- $L$ measured distance on flat plane
- $\ell$ deviation from flatness
- a straight metal bar
D.2.3 Depth of metal profile

The depth of the profile \((h)\) shall be the distance between the crown and valley measured on the same side of the sheet (see figure D.3), at 200 mm from the sheet end. This measurement shall only be taken for panels that have at least one lightly profiled or profiled face.

Tolerance:
- \(5 \text{ mm} < h \leq 50 \text{ mm} \pm 1 \text{ mm}\);
- \(50 \text{ mm} < h \leq 100 \text{ mm} \pm 2.5 \text{ mm}\)

**Key**
- \(a\) straight metal bar

![Figure D.3 - Dimensional check for depth of profile \(h\)](image)

The depth of each valley across the sheet shall be measured by means of a template or a measuring rule at both sides of the valley (see figure D.3). The tolerances shall apply to the average value for each valley:

\[
h = \frac{h_1 + h_2}{2} \text{ mm}
\]

D.2.4 Depth of stiffeners on lightly profiled facings

The depth of any stiffeners \((d_s)\), on crown, valley or web, or the depth of light profiling, shall be measured across the sheet on a line at 200 mm from the end by means of a template or measuring rule and a precision gauge.

The average depth obtained in ITT tests shall be the value used for the depth of stiffeners \((d_s)\).

Tolerance:
- \(d_s \leq 1 \text{ mm} \pm 30 \% \text{ of } d_s\),
- \(1 \text{ mm} < d_s \leq 3 \text{ mm} \pm 0.3 \text{ mm}\),
- \(3 \text{ mm} < d_s \leq 5 \text{ mm} \pm 10 \% \text{ of } d_s\).

![Figure D.4 - Depth of stiffeners and light profiling](image)

Where flat faced panel properties are used as the basis of design for mechanical resistance, the tolerance of the stiffeners or light profiling need not be considered.
D.2.5 Length

The length \( L \) shall be measured along the centre axis of the panel (see figure D.5) with the panel continuously supported on a flat surface. The panel length shall be verified at least once during each shift (6 h or 8 h).

If the length over the foam is different from the length over the steel sheet, the tolerance shall be based on the length of the metal sheet. A separate tolerance shall be applied to the overlap.

Tolerance:
- \( L \leq 3\,000 \text{ mm} \pm 5 \text{ mm} \);
- \( L > 3\,000 \text{ mm} \pm 10 \text{ mm} \).

**NOTE 1:** Specific requirements may be agreed between the manufacturer and the purchaser at the time of ordering.

**NOTE 2:** Panels for cold store applications generally require tighter tolerances.

![Figure D.5 - Sheet length](image)

**Key**
- \( c/l \) centre line of the panel

**D. 2.6 Cover width**

The cover width, \( w \), shall be stated by the manufacturer. For profiled panels with a side lap, the cover width is the distance between the centre lines of the two outer profiles as shown in figure D.6.

For flat panels or panels with a male and female joint or panels with a joint built up on site, the cover width is the distance between the axes of the joints. In such cases, the points of measurement depend on the details of the joint. The manufacturer shall clearly define the measurement points and the same points shall be used every time a measurement is made (see the examples in figures D.7 and D.8).

The cover width of the sheet shall be measured across the sheet by means of a purpose-made gauge (see figure D.9) or as the distance between two plates placed on the side webs.

Measurements of cover width \( w_1 \) and \( w_2 \) shall be taken at a distance of 200 mm from the panel ends (see figure D.6). Both measurements shall be within the specified tolerance.

A third measurement \( w_3 \) of cover width shall be made across the centre line of the sheet to determine the contraction or bulging of the panel. This \( w_3 \) measurement shall be within the stated tolerance referred to the average value for \( w_1 \) and \( w_2 \):

\[
    w_3 = \frac{w_1 + w_2}{2}
\]

Tolerances: \( \pm 2 \text{ mm} \) for all profiles.
Figure D.6 - Cover width (w) of profiled panels

Figure D.7 - Design width (w) in the case of a male and female joint

Figure D.8 - Measurement of cover width (w)

Key

- p  pitch
- w  cover width

Figure D.9 - Dimensional check for cover width w and pitch p using a calibrated gauge
D.2.7 Deviation from squareness

The deviation from squareness of the profiled sheet end is defined as the dimension $s$ in figure D.10.

Tolerance: $s < 0.6\%$ of the nominal cover width $w$.

![Figure D.10 - Squareness](image)

D.2.8 Deviation from straightness

The deviation of straightness from the theoretical straight line is defined as the dimension $\delta$ in figure D.11.

The straightness of a panel shall be measured from a thin steel wire tightly stretched between two points on the same edge at 200 mm from each end of the panel. The measurement shall be made at the centre of the panel.

Tolerance: 1.0 mm/m, not exceeding 5 mm.

![Figure D.11 - Deviation of straightness](image)

D.2.9 Bowing

The bowing of the panel is a measure of the displacement between the surface of the panel and the straight line connecting the two ends (see figure D.12).

A thin steel wire shall be tightly stretched between two ends of the panel along the longitudinal centre line or across the width. The maximum displacement between the wire and the panel surface shall be measured using a graduated metal scale. Alternatively, the straight line between the two ends of the panel may be defined by means of a laser beam.

The location of the measured tolerance $b$ shall be at least 100 mm from the edge of the panel and 200 mm from the end of the panel.

Care shall be taken that no transverse load is applied to the panel during the measurement. Advantageously, this test may be carried out with the panel on its side in order to eliminate the influence of self-weight.
Tolerance: 2.0 mm for each metre length but not greater than 10 mm; 8.5 mm for each metre width for flat profiles \( h \leq 10 \text{ mm} \) (see D.2.3); 10 mm for each metre width for other depths of profile \( h > 10 \text{ mm} \) (see D.2.3).

**NOTE 1:** Continuously laminated panels may bow in this way during curing. The measurement should not be carried out until the panel is cured to ambient temperature.

**NOTE 2:** Panels with dissimilar faces, for example steel/aluminium in particular should be checked for bowing.

### Key

- \( b \) bowing displacement

**Figure D. 12 - Panel bowing**

**D.2.10 Pitch of profile**

The pitch \( p \) of the profile (see figure D.13) shall be the distance between the centres of adjacent ribs, measured at 200 mm from the sheet ends.

The measurements shall be made by one of the following methods, of which (a) is the preferred method:  
- a) as the distance measured between two plates placed on the webs, as illustrated in figure D.14;  
- b) as the deviation from a template; or  
- c) by means of a profile gauge (see figure D.9).

Tolerances: where  
- \( h \leq 50 \text{ mm} \) ± 2 mm;  
- \( h > 50 \text{ mm} \) ± 3 mm.

**NOTE:** This measurement may also be related to D.2.6 cover width. Problems may arise in practice if the relationship of the profile to the edge of the panel is not correct.

**Figure D. 13 - Pitch \( (p) \)**

**Figure D.14 - Dimensional check for pitch**
D.2. 11 Widths of rib and valley

The widths of a rib ($b_1$) and valley ($b_2$) (see figure D.15) shall be measured at 200 mm from the sheet ends. The widths of ribs and valleys shall be measured on a line across the sheet by means of a template.

Tolerances: ribs ± 1 mm, valleys ± 2 mm.

Figure D.15 - Widths of rib and valley
Annex E

(normative)

Design procedures

NOTE: This annex supports mechanical resistance characteristics required by this standard and describes the methods required for their calculation. The mechanical resistance characteristics can equally be obtained by testing.

E. 1 Definitions and symbols

E. 1.1 Properties of a sandwich panel

The cross-section and material properties of a sandwich panel shall be as shown in figure E.1 and table E.1.

![Diagram of sandwich panel cross-section](image)

**Table E.1 - Panel properties**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Geometry</th>
<th>Material properties</th>
<th>Structural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face 1</td>
<td>( t_1, d_1, d_{11}, d_{12}, A_{F1}, I_{F1} )</td>
<td>( E_{F1}, \sigma_{F1} )</td>
<td>( B_{F1} )</td>
</tr>
<tr>
<td>Core</td>
<td>( d_c )</td>
<td>( E_C, G_C )</td>
<td>( S )</td>
</tr>
<tr>
<td>Face 2</td>
<td>( t_2, d_2, d_{21}, d_{22}, A_{F2}, I_{F2} )</td>
<td>( E_{F2}, \sigma_{F2} )</td>
<td>( B_{F2} )</td>
</tr>
</tbody>
</table>
E.1.2 Symbols and subscripts used in this annex

The following symbols and subscripts apply to this annex.

E.1.2.1 Symbols

A  cross-sectional area
B  overall width of the panel
C  design value of a serviceability criterion
D  overall depth of the panel
E  modulus of elasticity, design value of the effect of an action
F  force, load
G  shear modulus, permanent action
I  moment of inertia
L  span, distance
M  bending moment
N  axial compressive force
Q  variable action
R  resistance, reflectivity ($R_c$)
S  shear rigidity, characteristic value of an action
T  temperature
V  shear force
d  depth of face profile or stiffeners, depth of core ($d_e$)
e  distance between centroids of faces, base of natural logarithms ($e = 2.718 282$)
f  strength, yield stress
h  height of profile
k  parameter (E.4.3.2 support reaction capacity), correction factor
n  number of webs
q  live load
s  length of web ($S_{w1}$)
t  thickness of face sheet
v  variance factor
α  coefficient of thermal expansion
β  parameter (see table E.10.2 design equations)
ϕ  angle
γ  partial safety factor, load factor ($γ_F$)
ψ  creep coefficient
θ  parameter (see table E.10.1 design equations)
σ  stress, compressive strength $σ_{s1}$, standard deviation
τ  shear stress
Ψ  combination coefficient

E.1.2.2 Subscripts

C  core
F  face, action ($γ_F$)
G  permanent load, degree
M  material ($γ_M$)
Q  variable action
S  sandwich part of the cross-section
c  compression, core
d  design
f  load
i, j  index
k  characteristic value
nom  nominal
s  support ($L_s = $ support width), surface ($R_{s1}$)
t  time
tol  tolerance (normal or special)
0  basic value
l  external face, upper face
E.2 General
The design values $E_d$ of the effects of the actions shall be calculated and shall be compared with the design values of the corresponding resistance $R_d$ or the relevant serviceability criterion $C_d$ taking into account the appropriate material partial factors $\gamma_M$.

It shall be verified by means of calculation or testing (or both) that that the equations (E.1 to E.4) are satisfied using the procedures in E.3 to E.7.

Ultimate limit state: $E_{ULS,d} \leq R_d$ (E.1)
Serviceability limit state: $E_{SLS,d} \leq C_d$ (E.2)

Where $E_{ULS,d}$ and $E_{SLS,d}$ are the design values of the effects of the actions, i.e.

$$E_d = \text{the effect of } \sum \gamma_f \psi S_{ki}$$ (E.3)

$$R_d = \frac{R_k}{\gamma_m} = \text{design value of the resistance at the ultimate limit state}$$ (E.4)

$$C_d = \text{limiting design value of the relevant serviceability criterion expressed as the maximum serviceability limit state design stress or limit on deflection taking into account the material partial factor for serviceability limit state design } \gamma_m$$

$S_{ki} = \text{characteristic value of an action}$;

$\gamma_f = \text{relevant load factor}$;

$\psi = \text{relevant combination factor}$;

$\gamma_M = \text{relevant material partial factor}$;

$R_k = \text{calculated or experimental value of the characteristic resistance}$.

NOTE 1: The procedures that follow comply with the Recommendations for sandwich panels – Part 1: Design, and present a sub-set of the more detailed procedures that are given in these recommendations.

NOTE 2: This product standard is primarily concerned with the values of $R_d$ and $C_d$.

E.3 Actions

E.3.1 General
The actions in E.3.2 to E3.4 shall be taken into account in the calculations. They shall be considered either individually or in combination using the combination factors in E.5 and E.6.

E.3.2 Permanent actions
The permanent actions to be taken into account in the design shall include the following:

- the self-weight of the panel (calculated from the nominal dimensions and mean densities);
- the mass of any permanent components of the structure and installation that apply load to the panel;
- permanent imposed deformations, for example due to temperatures in cold stores (calculated using nominal values relevant to the specific application).

E.3.3 Variable actions
The variable actions shall include the following, where they are relevant:

- snow (quasi-permanent action);
- live loads (for example owing to access to a roof or ceiling);
- wind loads;
- construction loads; and
- climatic effects (for example due to a temperature difference between the faces of a panel).

The temperature gradients resulting from the difference between the outside temperature $T_1$ and the inside temperature $T_2$ are variable actions.

**NOTE:** If national specifications do not give values for external temperatures, the following values for the temperature of the outside face may be used:

Depending on the latitude, the height above sea level and the distance from the sea, four different minimum winter temperature levels ($T_1$) are used throughout the continent of Europe: 0, −10 °C, −20 °C and −30 °C. The temperature of the outer face of a roof panel with an over layer of snow is 0 °C.

The temperature $T_1$ of the outside face has a maximum summer value, which depends upon the colour and reflectivity of its surface. Values of $T_1$, which are minimum for ultimate state calculations and which are suitable for serviceability calculations, may be taken as follows:

i) very light colours $R_g = 75-90$ $T_1 = +55 °C$

ii) light colours $R_g = 40-74$ $T_1 = +65 °C$

iii) dark colours $R_g = 8-39$ $T_1 = +80 °C$

where $R_g$ is the degree of reflection relative to magnesium oxide $= 100 \%$.

In special cases, the maximum temperature of a face exposed to the sun may be determined more precisely on the basis of the actual colour used.

**E.3.4 Actions due to long-term effects**

Where relevant, creep of the core material shall be taken into account in the design. NOTE 1 Creep of the core may cause a change in both stresses and deformations with time. NOTE 2 Creep is only relevant for panels used as a roof or ceiling.

**E.4 Resistance**

**E.4.1 General**

The values of resistance necessary for design shall be determined in accordance with 5.2. In addition, depending on the application, the procedures in E.4.1 and E.4.2 may be required.

The characteristic resistance values given in table E.2 are required in order to carry out design by calculation in accordance with this annex.

**Table E.2 - Characteristic resistance values**

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Characteristic resistance values</strong></td>
<td><strong>Clause</strong></td>
<td><strong>Test</strong></td>
</tr>
<tr>
<td>Yield strength of the faces</td>
<td>5.1.2</td>
<td></td>
</tr>
<tr>
<td>Shear strength of the core material</td>
<td>5.2.1.2</td>
<td>A.3 or A.4</td>
</tr>
<tr>
<td>Compressive strength of the core material (or support reaction capacity (or both))</td>
<td>5.2.1.4</td>
<td>A.2 (A.15)</td>
</tr>
<tr>
<td>Shear strength after long-term loading (roof and ceiling panels only)</td>
<td>5.2.1.5</td>
<td>A.3.6</td>
</tr>
<tr>
<td>Wrinkling stress (positive and negative bending) at normal and higher temperature (or bending moment capacity for panels with one or two profiled faces)</td>
<td>5.2.1.7</td>
<td>A.5 and A.5.5.5</td>
</tr>
<tr>
<td>Wrinkling stress over a central support (positive and negative bending, at normal and higher temperature) determined from the bending moment capacity (only for panels continuous over two or more spans)</td>
<td>5.2.1.8</td>
<td>A.7 and A.5.5.5</td>
</tr>
</tbody>
</table>

In addition, the calculation requirements in table E.3 are required in order to carry out the necessary calculations.
Table E.3 - Additional calculation requirements

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristic resistance values</td>
<td>Clause</td>
<td>Test</td>
</tr>
<tr>
<td>Design thickness of the faces</td>
<td>E.7.3</td>
<td></td>
</tr>
<tr>
<td>Shear modulus of the core material</td>
<td>5.2.1.2</td>
<td>A.3, A.4 or A.5.6</td>
</tr>
<tr>
<td>Creep coefficient (roof and ceiling panels only)</td>
<td>5.2.1.3</td>
<td>A.6</td>
</tr>
</tbody>
</table>

The comparison of the design values of actions and the design values of resistance in accordance with E.2 is usually carried out in terms of stresses, which are determined from the stress resultants in accordance with E.7.2.5 and E.7.2.6. Determination of the compressive strength (wrinkling stress) of a profiled face from the bending moment capacity of the panel requires a calculation for which the equations are given in E.7.5.2.

**E.4.2 Residual (rest) bending resistance at an intermediate support**

If the load-deflection curve, determined in accordance with A.7, is as shown in figure E.2(a), the attainment of maximum bending moment at an internal support corresponds to a serviceability limit state. Furthermore, where required, a non-zero rest moment shall be determined and incorporated into the calculations at the ultimate limit state. If the load-deflection curve falls away suddenly, as shown in figure E.2(b), the attainment of maximum bending moment at an internal support shall be deemed to correspond to the ultimate limit state.

A suitable value for the non-zero rest moment $M_{rest}$ shall be determined from a load-deflection curve type (a) by subtracting the elastic component of deflection and choosing $M_{rest}$ as the moment on the drooping part of the curve corresponding to a "plastic hinge" rotation of 3°.

**NOTE** An assessment of the residual bending resistance may be made by considering the reduction in the ultimate support moment at a "plastic hinge" rotation of 3°. If this reduction is greater than 40 % of the maximum moment attained, this may be regarded as a "sudden failure" and the rest moment should be considered to be zero.

![Load deflection curve](image)

**Key**

$F$ - load

$w$ - deflection

a) - Load deflection curve (gradual failure with long drooping portion)  
b) - Load deflection curve (sudden failure with rapid loss of load)

**Figure E.2 - Load deflection curve**

**E.4.3 End support reaction capacity**

**E.4.3.1 General**

The reaction capacity at the end of a panel where the contact face is either plain or lightly profiled shall be determined either by calculation in accordance with E.4.3.2 or by tests on full width panels in accordance with A.15.5.

The reaction capacity at an internal support shall be determined by calculation in accordance with E.4.3.2.
E.4.3.2 Calculation of the support reaction capacity

The capacity at an end support shall be given by equation (E.5):

\[ F_{R1} = B \times (L_S + 0.5 \times k \times e) \times f_{cc} \] (E.5)

The capacity at an internal support shall be given by equation (E.6):

\[ F_{R2} = B \times (L_S + k \times e) \times f_{cc} \] (E.6)

where
- \( B \) is the width of panel;
- \( L_S \) is the width of support;
- \( e \) is the distance between centroids of the faces;
- \( f_{cc} \) is the declared value of the compressive strength following initial type testing;
- \( k \) is the distribution parameter.

\( k \) shall either be determined by testing in accordance with A.15.5, or the following values shall be used:

- for rigid plastic foams and CG cores where \( e < 100 \text{ mm} \), \( k = 0.5 \);
- for rigid plastic foams and CG cores where \( e > 100 \text{ mm} \), \( k = 0.5 \) with \( e = 100 \text{ mm} \) in equations (E.4) and (E.5);
- for all other cases, \( k = 0 \).

E.5 Combination rules

E.5.1 General

The principles by which the relevant combinations of actions shall be compared with the corresponding resistances to give appropriate safety levels at both the ultimate and serviceability limit states shall be in accordance with E.5.2 to E.5.5.

The principles and procedures in this annex are in accordance with EN 1990. However, the recommended values of combination factors and material partial factors are particular to sandwich panels and reflect the special characteristics of this product, notably the increased importance of temperature stresses and deflections, the potentially highly variable nature of characteristics influenced by the properties of the core material and the influence of creep.

NOTE 1: Values determined in accordance with national regulatory requirements of any of these factors may be used provided that these have been formally declared as being appropriate for sandwich panels.

NOTE 2: Temperature is often the dominant load case and may cause greater stresses or deflections (or both) than wind, snow or imposed load.

E.5.2 Ultimate limit state

The ultimate limit state, which corresponds to the maximum load-carrying capacity of the panel, shall be characterized by the most critical of the following failure modes either individually or in combination:

- yielding of a face of the panel with consequential failure;
- wrinkling (local buckling) of a face of the panel with consequential failure; - shear failure of the core;
- failure of the bond between the face and the core;
- shear failure of a profiled face layer;
- crushing of the core at a support; and
- failure of the panels at the points of attachment to the supporting structure.

E.5.3 Combination of the effects of actions for the ultimate limit state

For each load case, the design value for the effects of actions at the ultimate limit state shall be obtained by summing the effects of the separate actions multiplied by their appropriate load factors and combination coefficients as shown in table E.4.
Table E.4 - Design values of effects of actions for use when combining actions for the ultimate limit state in accordance with EN 1990

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent actions $G_d$ (self-weight etc.)</td>
<td>$\gamma_G \times G_k$</td>
<td>$\gamma_{Q1} \times Q_{k1}$</td>
<td>$\gamma_{Qi} \times \psi_{oi} \times Q_{ki}$</td>
</tr>
<tr>
<td>Variable actions $Q_d$</td>
<td>$\gamma_{Q1} \times Q_{k1}$</td>
<td>$\gamma_{Qi} \times \psi_{oi} \times Q_{ki}$</td>
<td></td>
</tr>
</tbody>
</table>

The design values in table E.4 shall be combined in the following way in accordance with equation (E.7):

$$S_d = \gamma_G G_k + \gamma_{Q1} Q_{k1} + \sum_{i>1} \gamma_{Qi} \psi_{oi} Q_{ki}$$

(E.7)

where

- $G_k$ is the characteristic value of the permanent action;
- $Q_{k1}$ is the characteristic value of the dominant variable action;
- $Q_{ki}$ is the characteristic value of the non-dominant variable action $i$ ($i > 1$);
- $\gamma_G$ is the partial safety factor for the permanent action;
- $\gamma_{Qi}$ is the partial safety factor for the variable action $i$;
- $\psi_{oi}$ is the combination coefficient of a variable action $i$ (see table E.6).

E.5.4 Serviceability limit state

The verification of the serviceability limit state shall be sufficient to ensure the proper functioning of the panels under the serviceability loads. The serviceability limit state shall be characterized by one of the following:

- yielding of a face of the panel without consequential failure;
- wrinkling (local buckling) of a face of the panel without consequential failure;
- shear failure of the core;
- failure of the bond between face and core; or
- the attainment of a specified deflection limit.

NOTE: In the absence of any other information from national standards, the following indicative deflection limits may be used.

- Roofs and ceilings
  - short term loading: span/200
  - long term loading (including creep): span/100
- Walls: span/100

E.5.5 Combination of the effects of actions for the serviceability limit states

For each load case, the design value for the effects of actions at the serviceability limit state shall be obtained by summing the effects of the separate actions multiplied by their appropriate load factors and combination coefficients as shown in table E.5.

Verification of the serviceability limit state shall include consideration of both stresses and deflections.

The first (rare) combination shall be used to ensure that there is no visible damage to the panel at the serviceability limit state.

NOTE: For this purpose, it is usually sufficient to check that there is no wrinkling or yielding of the face material in compression at an intermediate support.

The second (frequent) combination shall be used to control deflections.

The load factors $\gamma_G$ and $\gamma_Q$ shall be taken as 1.0 except where specified otherwise.
Table E.5 - Design values of effects of actions for use when combining actions for serviceability limit states

<table>
<thead>
<tr>
<th>Combination</th>
<th>Permanent actions $G_d$</th>
<th>Variable actions $Q_d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics (rare)</td>
<td>$G_k$</td>
<td>$Q_{k1}$ $\psi_{Q1} \times Q_{k1}$</td>
</tr>
<tr>
<td>Frequent</td>
<td>$G_k$</td>
<td>$\psi_{Q1} \times Q_{k1}$ $\psi_{Q1} \times \psi_{Q1} \times Q_{k1}$</td>
</tr>
</tbody>
</table>

Calculate the combinations as follows:

a) Characteristic (rare) combination (for resistance at intermediate supports) in accordance with equation (E.8):

$$S_d = \sum_{j=1} G_{kj} + Q_{k1} + \sum_{i>1} \psi_{0i} Q_{ki}$$

(E.8)

b) Frequent combination (for deflections) in accordance with equation (E.9):

$$S_d = \sum_{j=1} G_{kj} + \psi_{Q1} Q_{k1} + \sum_{i>1} \psi_{Q1} \psi_{Q1} Q_{ki}$$

(E.9)

where

- $\psi_{Q1}$ is the combination coefficient of a variable action $i (i > 1)$ to be used in characteristic combinations;
- $\psi_{Q1}$ is the combination coefficient of the dominant action effect $Q_{k1}$ to be used in frequent combinations; and
- $\psi_{Q1}$ is the combination coefficient of the other action effects $Q_{ki} (i > 1)$ to be used in frequent combinations.

Values for combination coefficients $\psi_{0i}$ and $\psi_{Q1}$ shall be as given in table E.6.

E.6 Combination coefficients and safety factors

E.6.1 Combination coefficients

Values of the combination coefficients $\psi_0$ and $\psi_1$ defined in E.5.3 and E.5.5 shall be as given in table E.6 unless these are given in whole or in part in national regulatory requirements concerning sandwich panels (table E.7). It is not permissible to remove the combination factor for temperature if no value is given in the national regulatory requirements.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combination coefficients</td>
<td>Factors</td>
<td>Snow</td>
<td>Wind</td>
</tr>
<tr>
<td>$\psi_0$</td>
<td>0,6</td>
<td>0,6</td>
<td>6 / 1,0$^a$</td>
</tr>
<tr>
<td>$\psi_1$</td>
<td>0,75 / 1,0$^b$</td>
<td>0,75 / 1,0$^b$</td>
<td>1,0</td>
</tr>
</tbody>
</table>

$^a$ Coefficient $\psi_0 = 1,0$ is used if the winter temperature $T_1 = 0 \, ^\circ C$ is combined with snow.

$^b$ Coefficient $\psi_1 = 0,75$ for snow and wind is used if the combination includes the action effects of two or more variable actions and coefficient $\psi_1 = 1,0$ for snow and wind is used if there is, in the combination, only a single action effect representing the variable actions and it is caused by either the sole snow load or the sole wind load, acting alone.

NOTE: Table E.6 should be read in conjunction with table E.8
As an alternative to the values in table E.6, the values in table E.7, which are in accordance with EN 1990, may be used when required by national regulatory requirements.

**Table E.7 - Alternative values of combination coefficients $\psi_0$ and $\psi_1$**

<table>
<thead>
<tr>
<th>Combination coefficients</th>
<th>$\psi_0$</th>
<th>Factors</th>
<th>$\psi_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factors</td>
<td>Snow</td>
<td>Wind</td>
<td>Temperature</td>
</tr>
<tr>
<td>$\psi_0$</td>
<td>0.5 or 0.7$^a$</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>$\psi_1$</td>
<td>0.2 or 0.5$^a$</td>
<td>0.2</td>
<td>0.5</td>
</tr>
</tbody>
</table>

**E.6.2 Load factors**

Values of the load factors $\gamma_f$ given in table E.8 shall be used unless national regulatory requirements require other values. It is not permissible to remove the temperature action if no load factor is given in the national regulatory requirements. The factor in parentheses for permanent actions shall be used if the effect of the action is favourable.

**Table E.8 - Load factors $\gamma_f$**

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actions</td>
<td>Limit state</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ultimate limit state</td>
<td>Serviceability limit state</td>
</tr>
<tr>
<td>Permanent actions $G$</td>
<td>1.35 (1.00)</td>
<td>1.00</td>
</tr>
<tr>
<td>Variable actions</td>
<td>1.50</td>
<td>1.00</td>
</tr>
<tr>
<td>Temperature actions</td>
<td>1.50$^a$</td>
<td>1.00</td>
</tr>
<tr>
<td>Creep effects</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

$^a$Temperature actions may be replaced by 1.35 when regulatory provisions valid in the country of use of the panel so require.

**E. 6.3 Material factors**

**E. 6.3.1 General**

Material safety factors $\gamma_M$ shall reflect the variability of the mechanical properties of sandwich panels, as indicated by the results of initial type testing and FPC. Two alternative approaches together with indicative values are given in E.6.3.2 and these shall be used if no relevant values are available in national regulatory requirements.

In each case, it is necessary to determine the "variance" $\nu$ of the relevant test results. Initially, $\nu$ shall be based on initial type testing of a single product batch. Subsequently, the value of $\nu$ used in design shall be checked against the results of FPC and the material safety factors updated as necessary.

**E.6.3.2 Determination of $\gamma_M$**

The material safety factors $\gamma_M$ for the ultimate and serviceability limit states shall be determined in accordance with EN 1990. The following equations may be used:

For the ultimate limit state (E.10):

$$\gamma_M = 1.05e^{(0.8 \times 4.7 - 1.645)\nu} = 1.05e^{2.115\nu}$$

For the ultimate limit state (E.10):

$$\gamma_M = 1.0e^{(0.8 \times 3.0 - 1.645)\nu} = 1.0e^{0.755\nu}$$

where

$\nu$ is the variance of Ln(x);

$x$ is the population of test results (see E.6.3.1).
NOTE: The material safety factors $\gamma_M$ for the ultimate and serviceability limit states given in table E.9 are examples of values that may be obtained for a product with the (relatively small) property variance values shown.

### Table E.9 - Material safety factors $\gamma_M$

<table>
<thead>
<tr>
<th>Property to which $\gamma_M$ applies</th>
<th>Limit state</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ultimate</td>
<td>Serviceability</td>
<td></td>
</tr>
<tr>
<td>Yielding of a metal face</td>
<td>1.1</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Wrinkling of a metal face in the span ($v \leq 0.09$)</td>
<td>1.25</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Wrinkling of a metal face at an intermediate support (interaction with support reaction)</td>
<td>$1.25^a$</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Shear of the core ($v \leq 0.16$)</td>
<td>1.5</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Shear failure of a profiled face</td>
<td>1.1</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Crushing of the core ($v \leq 0.13$)</td>
<td>1.4</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Support reaction capacity of a profiled face</td>
<td>1.1</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Failure of a fastener</td>
<td>$1.33^b$</td>
<td>1.0$b$</td>
<td></td>
</tr>
<tr>
<td>Failure of an element at a point of connection</td>
<td>$1.33^b$</td>
<td>1.0$b$</td>
<td></td>
</tr>
</tbody>
</table>

$^a$ The material factor for wrinkling at the ultimate limit state is needed if the design is based on elastic analysis or if a non-zero bending resistance at intermediate supports is utilized in a design based on plastic analysis.

$^b$ If the characteristic value of the strength of a fastening is not based on a sufficient number of tests for a statistically reliable value to be obtained, higher values of the material safety factors shall be used.

### E.7 Calculation of the effects of actions

#### E.7.1 General

In the determination of the internal stress resultants and deflections, the shear flexibility of the core shall be taken into account. For this purpose, a constant value of the shear modulus of the core, corresponding to an average value at normal indoor temperature, shall be used. The stress resultants shall then be determined using the methods described in E.7.2.

#### E.7.2 Methods of analysis

##### E.7.2.1 General

One of the following methods of analysis shall be used:

- elastic analysis; or
- plastic analysis.

Elastic analysis shall be used for the serviceability limit state and may be used for the ultimate limit state.

Plastic analysis shall only be used for the ultimate limit state and shall be used whenever the design is controlled by bending stresses at an internal support. Plastic analysis shall not be used when the first failure mode is a shear failure of the core, unless the core material has adequate plastic shear capacity.

##### E.7.2.2 Elastic analysis

The action effects $S$ (bending moments, normal and shear forces) resulting from the combination of all actions applied to the sandwich panels shall be found by using the theory of elasticity taking into account the shear flexibility of the core material.

Equations for some frequently encountered cases are given in

- E.7.4 for panels with lightly profiled faces, and
- E.7.5 for panels with profiled faces.
E.7.2.3 Plastic analysis
The bending moment distribution at the ultimate state in a continuous sandwich element may be chosen arbitrarily, provided that the internal stress resultants are in equilibrium with the actions, which shall be equal to or higher than the most unfavourable combination of factored actions, and that the internal stress resultants nowhere exceed the plastic resistance of the cross-section.

In plastic analysis calculations at the ultimate limit state, a continuous multi-span sandwich panel may be replaced by a series of simply supported panels with zero bending resistance at intermediate supports. In this calculation model, stresses caused by the temperature difference between the faces vanish in sandwich panels with flat or lightly profiled faces.

Alternatively, the test procedure in E.4.2 allows a non-zero rest moment to be determined at an internal support. The bending moments at internal supports at the ultimate limit state may be chosen to be equal to or less than the inelastic moment of resistance determined in this way and reduced by a material safety factor in accordance with table E.9.

E.7.2.4 General structural principles
It shall be assumed that, for the range of deformations to be considered, except where "plastic hinges" are assumed in plastic design, the materials of the core and faces remain linearly elastic. It shall also be assumed that the extensional stiffness of the core is so small in comparison to that of the faces that the influence of longitudinal normal stresses in the core may be neglected. The load bearing capacity of a sandwich panel shall then be divided into the following two components (see figures E.3 and E.4):

a) For bending moments: into a moment component $M_F$ in the metal faces and a moment component $M_S$ (the sandwich part) arising from the normal forces $N_{F1}$ and $N_{F2}$ in the faces multiplied by the distance between the centroids $e$.

b) For shear forces: into a shear force component $V_F$ in the faces and a shear force component $V_S$ in the sandwich part of the section.

If the faces of a sandwich panel are thin and flat or they are lightly profiled, the bending stiffness of the faces ($B_{F1} = E_{F1} \cdot I_{F1}, B_{F2} = E_{F2} \cdot I_{F2}$) is small and has a negligible effect on the stress distributions and deflections of the panel, in which case, the bending stiffness of the faces shall be neglected ($B_{F1} = B_{F2} = 0$) in the analysis and the calculations shall be based on the stress resultants $M_S = e \times N_{F1} = e \times N_{F2}$ and $V_S$ only (see figures E.3 and E.4, and equations (E.12) and (E.15)).

NOTE 1: Normal forces $N_{F1}$ and $N_{F2}$ cause a uniform compressive and tensile stress distribution over the external and internal faces, while the bending moments $M_{F1}$ and $M_{F2}$ result in normal stresses, which vary linearly over the depths of the faces. Local buckling of a compressed web of a face profile makes the normal stress distribution in the face non-linear.

NOTE 2: The shear force $V_F$ causes a constant $V_C$ causes a constant shear stress distribution $\tau_C$ over the depth of the core, when the compressive and tensile rigidity of the core layer in the longitudinal direction of the sandwich panel is ignored. The shear forces $V_{F1}$ and $V_{F2}$ cause shear stresses $\tau_{F1}, \tau_{F2}$ in the face layers with non-vanishing bending rigidity.

These shear stresses $\tau_{F1}, \tau_{F2}$ shall be assumed to be a constant over the depths of the webs of the metal face profiles (see figure E.6 and equation (E.16)).

Key
a face 1
b core
c face 2

Figure E.3 - Stress resultants in a thin (flat or lightly profiled) faced sandwich panel
Key as for figure E.3

Figure E.4 - Stress distribution over the cross-section in a thin faced sandwich panel

Key as for figure E.3

Figure E.5 - Stress resultants in a sandwich panel with profiled faces

In panels with one or both profiled (thick) faces, the bending stiffness of the faces shall not be neglected \((B_{F1} + B_{F2} \neq 0)\). The stress resultants in the cross-section shall be \(M = M_S + M_{F1} + M_{F2}\) and \(V = V_S + V_{F1} + V_{F2}\) (see figures E.5 and E.6 and equations (E.13), (E.15) and (E.16)).

Key as for figure E.3

Figure E.6 - Stress distribution over the cross-section in a sandwich panel with profiled faces

E.7.2.5 Bending stresses

After carrying out a suitable analysis in accordance with E.7.2, E.7.3 and E.7.4, the bending stresses in the faces shall be determined using equations (E.12 to E.14):

\[
\sigma_{F1} = - \frac{N_{F1}}{A_{F1}} = - \frac{M_S}{e_{A_{F1}}}, \quad \sigma_{F2} = - \frac{N_{F2}}{A_{F2}} = - \frac{M_S}{e_{A_{F2}}}
\]

\[
\sigma_{F11} = \sigma_{F1} \frac{M_{F1}}{I_{F1}} d_{11}, \quad \sigma_{F12} = \sigma_{F1} \frac{M_{F2}}{I_{F2}} d_{12}
\]

\[
\sigma_{F21} = \sigma_{F2} \frac{M_{F2}}{I_{F2}} d_{21}, \quad \sigma_{F22} = \sigma_{F2} \frac{M_{F2}}{I_{F2}} d_{22}
\]

where

\(A_{F1}\) and \(A_{F2}\) are the cross-sectional areas of the faces;
\(I_{F1}\) and \(I_{F2}\) are the second moments of area of the faces
and other symbols are defined in figure E.1 and figures E.3 to E.6
E.7.2.6 Shear stresses

After carrying out a suitable analysis in accordance with E.7.2, E.7.3 and E.7.4, the shear stresses in the core and faces respectively shall be determined using equations (E.15) and (E.16):

\[
\tau_c = \frac{V_c}{eb} \quad (E.15)
\]

\[
\begin{align*}
\tau_{F1} &= \frac{V_{F1}}{n_1 s_{w1} f_1}, \\
\tau_{F2} &= \frac{V_{F2}}{n_2 s_{w2} f_2}
\end{align*} \quad (E.16(a, b))
\]

where

- \(s_{w1}\) and \(s_{w2}\) are lengths of the webs of the profiled faces,
- \(n_1\) and \(n_2\) are the numbers of the webs in the profiled faces of the panel.

E.7.2.7 Support reactions

The reactions at internal and end supports shall be determined by testing or analysis in accordance with E.7.3.

E.7.3 Static system, geometry and thickness

The static system used in the calculation of sandwich panels shall be in accordance with the number and location of supports in the practical application for both pressure and uplift loads. The lengths of spans are determined as being the distances between the mid-lines of the supports. Sandwich panels are usually assumed to rotate and to move axially on the supports without restraint, thus corresponding to 'simple' support conditions between the sandwich panel and the support. If partial or full rigidity against the rotation at supports is utilized in design calculations, the validity of the assumption shall be verified experimentally.

Dimensions that are of significance for the static behaviour and resistance, such as the depth and width and the dimensions of the face profiles, shall correspond to the actual dimensions of the sandwich panel product in question. If nominal dimensions are used in calculations, the real dimensions shall agree with the dimensions used in the calculations within the tolerances given in 5.2.5.

The design thickness of a steel facing sheet shall be taken as \(t_d = t_{nom} - t_{zinc} - 0.5 t_{tol}\), where \(t_{nom}\) is the nominal thickness of the steel sheet \(t_{zinc}\) the total thickness of the three layers (or similar protective coating) and \(t_{tol}\) the normal or special tolerance in accordance with EN 10143. The design thickness of other metal facing sheets, such as those made from aluminium, stainless steel or copper shall be determined so that they represent statistically reliable minimum thickness values. For these materials the design thickness shall be taken as \(t_d = t_{nom} - 0.5 t_{tol}\). In all equations in this standard, the design thickness is denoted by \(t\).

E.7.4 Sandwich panels with plane or lightly profiled faces

E.7.4.1 General

In sandwich panels with flat faces or with faces which are only lightly profiled, the bending stiffness of the faces shall be neglected in comparison with the bending stiffness of the sandwich part of the cross-section. No division of the global stress resultants into components shall be conducted.

NOTE: The total bending moment is carried by normal forces in the faces and the total shear force by shear stresses in the core.

E.7.4.2 Single span panels

The static behaviour of single span sandwich panels shall be illustrated by the expressions for the stress resultants and deflections caused by a uniformly distributed load and a temperature difference (stress resultants per unit width) given in table E.10.

E.7.4.3 Continuous multi-span panels

NOTE: With continuous sandwich panels (multi-span panels), the shear flexibility of the core gives rise to smaller moments at the internal supports than would arise with a shear-stiff connection between the faces.
The static behaviour of continuous sandwich panels shall be illustrated by the expressions for the bending moment, support reaction and shear force at mid-support and the deflection in the spans caused by a uniformly distributed load and a temperature difference on a continuous two or three span sandwich panel (stress resultants per unit width) given in table E.10.

E. 7.5 Sandwich panels with strongly profiled faces

E. 7.5.1 General

NOTE: When the bending stiffness of a face in a sandwich panel cannot be neglected, the panel is itself statically indeterminate in addition to any global structural indeterminacy that may be present. Explicit solutions are given in the references for a few simple cases but, in general, numerical methods of analysis, for example the finite element method, shall be used.

E.7.5.2 Single span panels

Solutions for a simply supported sandwich beam with strongly profiled faces or with faces having large material thickness and loaded by a uniformly distributed load or temperature difference shall be as given in table E.11. The stress resultants are defined per unit width.

E.7.5.3 Continuous multi-span panels

Multi-span sandwich panels with profiled (thick) faces shall be designed either by calculation (see note 2) or by testing.

NOTE 1: The stress resultants and deflections of continuous sandwich panels with thick faces can be determined analytically for the most important simple cases. However, in many cases (for example panels with unequal spans) the expressions become relatively complicated and require the use of either design charts or computer software to find numerical solutions for practical design.

NOTE 2: Additional information on the design calculations for sandwich panels of all types, including multi-span, thick-faced panels, is given in a number of texts, for example Lightweight sandwich construction.

E. 7.6 The influence of time on shear deformations of the core

NOTE 1: Typical core materials, especially the plastic foams, are visco-elastic materials in which the deformations increase in the course of time even if the loads remain constant. In the core, long-term loading causes shear creep that may be regarded as a reduction in the shear modulus $G_c$ of the core.

NOTE 2: The stresses and deflections due to shear creep of the core require a separate calculation in accordance with E.7 using the reduced value of the shear modulus $G_{cl}$.

Where relevant, the reduced value of the shear modulus, $G_{cl}$, shall be determined for a time period of 2 000 h for snow load and 100 000 h for permanent actions (dead load). The reduced shear modulus is given by equation (E.17):

$$G_{cl} = G_c (1 - \varphi_t)$$

where

- $\varphi_t$ is the creep coefficient.
- $\varphi_t$ shall be determined by test according to A.6 or by using the following values:

For rigid plastic foams (PUR, EPS, XPS):
- $\varphi_t = 2.4$ for $t = 2$ 000 h;
- $7.0$ for $t = 100$ 000 h.

For MW:
- $\varphi_t = 1.5$ for $t = 2$ 000 h;
- $4.0$ for $t = 100$ 000 h.

Creep under snow load shall be neglected in regions where snow does not regularly lie for more than a few days.

If $\varphi_t$ is less than 0.5, creep effects shall be neglected in thin faced sandwich panels, i.e. in panels with flat or micro or lightly profiled faces.
Table E. 10 - Design equations for one-, two- and three-span panels with plane or lightly profiled faces

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single-span of L:</strong> Uniform load q</td>
<td>( \frac{ql}{2} )</td>
<td>( \frac{ql^2}{8} )</td>
<td>( \frac{5ql^4}{384E_s} )</td>
<td>( 1 + 3.2k )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature difference ( T_1 - T_2 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Two equal spans of L:</strong> Uniform load q</td>
<td>( \frac{ql}{2} \left( 1 - \frac{1}{4(1+k)} \right) )</td>
<td>( \frac{ql}{2} \left( 1 + \frac{1}{4(1+k)} \right) )</td>
<td>( qL \left( 1 + \frac{1}{4(1+k)} \right) )</td>
<td>( \frac{ql^2}{8} \left( 1 - \frac{1}{4(1+k)} \right)^2 )</td>
<td>( \frac{-ql^2}{8} \left( 1 + \frac{1}{1+k} \right) )</td>
<td>( \frac{-ql^4}{48E_s} )</td>
</tr>
<tr>
<td>Temperature difference ( T_1 - T_2 )</td>
<td>( \frac{3B_s \theta}{2L} \left( 1 + \frac{1}{1+k} \right) )</td>
<td>( \frac{3B_s \theta}{2L} \left( 1 + \frac{1}{1+k} \right) )</td>
<td>( \frac{3B_s \theta}{2L} \left( 1 + \frac{1}{1+k} \right) )</td>
<td>( \frac{3B_s \theta}{2L} \left( 1 + \frac{1}{1+k} \right) )</td>
<td>( \frac{3B_s \theta}{2L} \left( 1 + \frac{1}{1+k} \right) )</td>
<td>( \frac{\theta l^2}{8} \left( 1 + \frac{1}{1+k} \right) )</td>
</tr>
<tr>
<td><strong>Three spans of L:</strong> Uniform load q</td>
<td>( \frac{ql}{2} \left( 1 - \frac{1}{5 + 2k} \right) )</td>
<td>( \frac{ql}{2} \left( 1 + \frac{1}{5 + 2k} \right) )</td>
<td>( qL \left( 1 + \frac{1}{5 + 2k} \right) )</td>
<td>( \frac{ql^2}{8} \left( 1 - \frac{1}{5 + 2k} \right)^2 )</td>
<td>( \frac{-ql^2}{8} \left( 1 + \frac{1}{5 + 2k} \right) )</td>
<td>( \frac{-ql^4}{24E_s} )</td>
</tr>
<tr>
<td>Temperature difference ( T_1 - T_2 )</td>
<td>( \frac{6B_s \theta}{L} \left( 1 + \frac{1}{5 + 2k} \right) )</td>
<td>( \frac{6B_s \theta}{L} \left( 1 + \frac{1}{5 + 2k} \right) )</td>
<td>( \frac{6B_s \theta}{L} \left( 1 + \frac{1}{5 + 2k} \right) )</td>
<td>( \frac{6B_s \theta}{L} \left( 1 + \frac{1}{5 + 2k} \right) )</td>
<td>( \frac{6B_s \theta}{L} \left( 1 + \frac{1}{5 + 2k} \right) )</td>
<td>( \frac{\theta l^2}{8} \left( 1 + \frac{1}{5 + 2k} \right) )</td>
</tr>
</tbody>
</table>

For Uniform Load, \( \beta = \frac{B_{F1}}{B_{F1} + \frac{B_S}{1+3.2k}} \)

For temperature difference, \( \beta = \frac{B_{F1}}{B_{F1} + \frac{B_S}{1+2.7k}} \)

**NOTE:** For geometry and section properties see figure E.1. For stress systems see figures E.3 and E.4.

Table E. 11 — Design equations for single span panels with one profiled face and one flat or lightly profiled face

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single-span of L:</strong> Uniform load q</td>
<td>( \frac{ql}{2} )</td>
<td>( qL^2 )</td>
<td>( qL \left( 1 + \frac{1}{4(1+k)} \right) )</td>
<td>( \frac{ql^2}{8} \left( 1 - \frac{1}{4(1+k)} \right)^2 )</td>
<td>( \frac{-ql^2}{8} \left( 1 + \frac{1}{1+k} \right) )</td>
</tr>
<tr>
<td>Temperature difference ( T_1 - T_2 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sandwich bending Moment in Span</strong></td>
<td>( \frac{M_S}{e} )</td>
<td>( \frac{1}{A_F} )</td>
<td>( \frac{M_{F1} h_1}{l_{F1}} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum deflection in span</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For Uniform Load, \( \beta = \frac{B_{F1}}{B_{F1} + \frac{B_S}{1+3.2k}} \)

For temperature difference, \( \beta = \frac{B_{F1}}{B_{F1} + \frac{B_S}{1+2.7k}} \)

**NOTE 1:** Other quantities are as for table E.10.1.

**NOTE 2:** For geometry and section properties see figure E.1. For stress systems see figures E.5 and E.6.
Bibliography

SANS 10400, The application of the National Building Regulations.