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ICS

First Edition

**Self-supporting double skin metal faced insulating
panels — Factory made products — Specification**



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Self-supporting double skin metal faced insulating panels — Factory made products — Specification

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Foreword

This Kenya Standard was prepared by the KEBS TC 121 Steel and Aluminium and Metallurgy Technical Committee under the guidance of the Standards Projects Committee, and it is in accordance with the procedures of the Kenya Bureau of Standards.

Kenya Bureau of Standards (KEBS) has established Technical Committees (TCs) mandated to develop Kenya Standards (KS). The Committees are composed of representatives from the public and private sector organizations in Kenya.

Kenya Standards are developed through Technical Committees that are representative of key stakeholders including government, academia, consumer groups, private sector and other interested parties. Draft Kenya Standards are circulated to stakeholders through the KEBS website and notifications to World Trade Organization (WTO). The comments received are discussed and incorporated before finalization of the standards, in accordance with the Procedures for Development of Kenya Standards.

Kenya Standards are subject to review, to keep pace with technological advances. Users of the Kenya Standards are therefore expected to ensure that they always have the latest versions of the standards they are implementing.

During the preparation of this Standard, reference was made to the following documents:

EN 14509 Self-supporting double skin metal faced insulating panels - Factory made products - Specifications

Acknowledgement is hereby made for the assistance derived from these sources.

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Self-supporting double skin metal faced insulating panels — Factory made products — Specification

1 Scope

This Draft Kenya Standard specifies requirements for 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;
- c) walls (including partitions) and ceilings within the building envelope.

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).

Panels with edge details that utilize different materials from the main insulating core are included in this Standard.

This Draft Kenya Standard does not cover the following:

- i. sandwich panels with a declared thermal conductivity for the insulating core greater than 0.06 W/m·K at 10 °C;
- ii. products consisting of two or more clearly defined layers of different insulating core materials (multi-layered);
- iii. panels with perforated facing(s);
- iv. curved panels.

2 Normative references

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

KS ISO 6361-2, *Aluminium and aluminium alloys — Sheet, strip and plate — Part 2: Mechanical properties*

KS ISO 6361-2, *Wrought aluminium and aluminium alloys — Sheets, strips and plates — Part 2: Mechanical properties*

KS ISO 6361-2, *Wrought aluminium and aluminium alloys — Sheets, strips and plates — Part 4: Sheets and plates: Tolerances on shape and dimensions*

KS ISO 6361-3, *Wrought aluminium and aluminium alloys — Sheets, strips and plates — Part 3: Strips: Tolerances on shape and dimensions*

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

EN 508-1, *Roofing products from metal sheet — Specification for self-supporting products of steel, aluminium or stainless steel sheet — Part 1: Steel*

KS ISO 29469, *Thermal insulating products for building applications — Determination of compression behaviour*

KS ISO 9229, *Thermal insulation — Vocabulary*

EN 1172, *Copper and copper alloys — Sheet and strip for building purposes*

KS ISO/TR 12468-3, *External exposure of roofs to fire — Part 3: Commentary*

KS ISO 834-1, *Fire-resistance tests — Elements of building construction — Part 1: General requirements*

KS ISO 834-1, *Fire-resistance tests — Elements of building construction — Part 1: General requirements*

KS 566, *Specification for fire resistance tests - Elements of building construction*

KS ISO 834-8, *Fire resistance tests for non-loadbearing elements — Part 1: Walls*

ISO 834-8:2002 Fire-resistance tests — Elements of building construction — Part 8: Specific requirements for non-loadbearing vertical separating elements

KS ISO 834-8/Cor 1, *Fire-resistance tests — Elements of building construction — Part 8: Specific requirements for non-loadbearing vertical separating elements — Technical Corrigendum 1*

KS ISO/TR 12470-2, *Fire-resistance tests — Guidance on the application and extension of results from tests conducted on fire containment assemblies and products — Part 2: Non-loadbearing elements*

KS ISO 834-9, *Fire resistance tests for non-loadbearing elements — Part 2: Ceilings*

KS ISO 834-9, *Fire-resistance tests — Elements of building construction — Part 9: Specific requirements for non-loadbearing ceiling elements*

KS ISO 834-9/Cor 1, *Fire-resistance tests — Elements of building construction — Part 9: Specific requirements for non-loadbearing ceiling elements — Technical Corrigendum 1*

EN 1365-2, *Fire resistance tests for loadbearing elements — Part 2: Floors and roofs*

KS ISO 5000, *Aluminium and aluminium alloys — Coil coated sheet and strip for general applications — Specifications to be replaced by*

ISO 5000:2019 *Steel sheet, aluminium-silicon alloy-coated by the continuous hot-dip process, of commercial and drawing qualities*

KS ISO 29470, *Thermal insulating products for building applications — Determination of the apparent density*

KS ISO 29766, *Thermal insulating products for building applications — Determination of tensile strength parallel to faces*

KS EN 1990, *Eurocode — Basis of structural design*

KS EN 1991, *Eurocode 1: Actions on structures (all parts)*

KS ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

KS ISO 15510, *Stainless steels — Chemical composition*

KS EAS 410, *Hot-dip aluminium-zinc coated plain and corrugated steel sheets — Specification*

- EN 10169-1, *Continuously organic coated (coil coated) steel flat products — Part 1: General information (definitions, materials, tolerances, test methods)*
- EN 10169-2, *Continuously organic coated (coil coated) steel flat products — Part 2: Products for building exterior applications*
- EN 10169-3, *Continuously organic coated (coil coated) steel flat products — Part 3: Products for building interior applications to be replaced by*
- KS ISO 10474, *Steel and steel products — Inspection documents*
- KS ISO 4998, *Steel sheet, zinc-coated and zinc-iron alloy-coated by the continuous hot-dip process, of structural quality*
- EN 10327, *Continuously hot-dip coated strip and sheet of low carbon steels for cold forming — Technical delivery conditions*
- KS ISO 29768,
- KS ISO 29768, *Thermal insulating products for building applications — Determination of linear dimensions of test specimens*
- KS ISO 9972, *Thermal performance of buildings — Determination of air permeability of buildings — Fan pressurization method*
- KS ISO 10456,
- KS ISO 10456, *Building materials and products — Hygrothermal properties — Tabulated design values and procedures for determining declared and design thermal values*
- EN 12865, *Hygrothermal performance of building components and building elements — Determination of the resistance of external wall systems to driving rain under pulsating air pressure*
- KS ISO 8145, *Thermal insulation — Mineral wool board for overdeck insulation of roofs — Specification*
- KS ISO 12576-1, *Thermal insulation — Insulating materials and products for buildings — Conformity control systems — Part 1: Factory-made products*
- KS ISO 24285, *Thermal insulation for building equipment and industrial installations — Cellular glass products — Specification*
- KS ISO 834-10:2014, *Fire resistance tests Elements of building construction Part 10: Specific requirements to determine the contribution of applied fire protection materials to structural steel elements*
- KS ISO 834-1, *Fire-resistance tests — Elements of building construction — Part 1: General requirements*
- KS ISO/TR 834-3, *Fire-resistance tests — Elements of building construction — Part 3: Commentary on test method and guide to the application of the outputs from the fire-resistance test*
- KS ISO 12468-1, *External exposure of roofs to fire — Part 1: Test method*
- KS ISO 13784-1, *Reaction to fire test for sandwich panel building systems — Part 1: Small room test*
- KS ISO 13784-2, *Reaction-to-fire tests for sandwich panel building systems — Part 2: Test method for large rooms*
- KS ISO 834-11 *Fire resistance tests — Elements of building construction — Part 11: Specific requirements for the assessment of fire protection to structural steel elements*

KS ISO 140-3, *Acoustics — Measurement of sound insulation in buildings and of building elements — Part 3: Laboratory measurements of airborne sound insulation of building elements (ISO 140-3:1995)*

KS ISO 354, *Acoustics — Measurement of sound absorption in a reverberation room (ISO 354:2003)*

KS ISO 717-1, *Acoustics — Rating of sound insulation in buildings and of building elements — Part 1: Airborne sound insulation (ISO 717-1:1996)*

KS ISO 1182, *Reaction to fire tests for building products — Non-combustibility test (ISO 1182:2002)*

KS ISO 1716, *Reaction to fire tests for building products — Determination of the heat of combustion*

KS ISO 6946, *Building components and building elements — Thermal resistance and thermal transmittance — Calculation method*

KS ISO 9001, *Quality management systems — Requirements*

KS ISO 9445, *Continuously cold-rolled stainless steel narrow strip, wide strip, plate-sheet and cut lengths — Tolerances on dimensions and form*

KS ISO 10211-1, *Thermal bridges in building construction — Heat flows and surface temperatures — Part 1: General calculation methods*

KS ISO 10211-2, *Thermal bridges in building construction — Calculation of heat flows and surface temperatures — Part 2: Linear thermal bridges*

KS ISO 10456, *Building materials and products — Procedures for determining declared and design thermal values*

KS ISO 11654, *Acoustics — Sound absorbers for use in buildings — Rating of sound absorption*

KS ISO 11925-2, *Reaction to fire tests — Ignitability of building products subjected to direct impingement of flame — Part 2: Single-flame source test*

KS ISO 12491, *Statistical methods for quality control of building materials and components*

3 Terms and definitions

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

3.1

auto-adhesion

self-adhesion of the core to the face(s) occurring automatically without the use of an adhesive

3.2

bending moment capacity

maximum bending moment recorded during a test of an individual panel

3.3

bending resistance

characteristic value of bending Moment Capacity determined on the basis of a test series

3.4

bond, bonding

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, having thermal insulating properties, which is bonded between two metal faces

3.7**durability**

ability of the panel to withstand the environmental effects and 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**flat facing**

facing without any rolled or pressed profile, or raised strengthening rib

3.11**incompletely bonded face**

metal face whose bond to the core is inadequate for sandwich action but does not include the entire surface of the core

3.12**incompletely bonded panel**

panel in which one or both faces is incompletely bonded

3.13**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 to entry 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 to entry 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.

3.14**lamella**

core material consisting of mineral wool that has been cut and orientated with the fibres perpendicular to the facings prior to bonding

3.15**lightly profiled facing**

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

3.16**pre-manufactured, pre-formed**

component or material that is supplied to the manufacturer ready for direct incorporation into the sandwich panel

3.17

sandwich panel

building product consisting 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

3.18

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 (e.g. snow, wind, internal air pressure), and transmitting these loadings to the supports

3.19

side lap

folded area of one or both of the facing materials along the longitudinal edge of the panel which engages with the adjacent panel to form an interlocking or overlapping joint

3.20

wrinkling stress

stress in the compressed face of a panel undergoing failure in bending where the failure mode takes the form of a 'wrinkle' extending over the full width of the panel near the section of maximum bending moment

3.21

wrinkling strength

characteristic value of wrinkling stress

3.22

rib

fabricated fold that bends upward from a flat steel sheet and is made of one corrugation

3.23

trough

fabricated fold that remains down after formation of a rib

4 Symbols and abbreviations

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

A - cross-sectional area

B - flexural rigidity, overall width of the panel/specimen, width of support (B_s)

C - ratio

D - overall depth of the panel

E - modulus of elasticity

F - force, load, support reaction

G - shear modulus, permanent action

I - moment of inertia

L - span, distance
M - bending moment
N - axial compressive force
Q - variable action
R - resistance, sound reduction index (R_w), reflectivity (R_G), tensile strength (R_{DUR} , R_{24}) S shear rigidity, value of a load effect, effect of an action
T - temperature
U - thermal transmittance
V - shear force
a - distance apart of clips (A.10.4)
b - width of test specimen, width of plate, width of ribs/valleys, bowing
d - depth of face profile or stiffeners, depth of core (d_c)
e - distance between centroids of faces, base of natural logarithms ($e = 2,718\ 282$)
f - strength, yield stress, thermal transmittance contribution factor (f_{joint})
h - height of profile, thickness (e.g. glue)
k - parameter (E.4.3.2 support reaction capacity), correction factor
l - length, deviation
m - mass
n - number of tests, number of screws, number of webs
p - pitch of profile
q - live load
r - radius
s - length of web (s_{w1})
t - thickness of face sheet
v - variance factor
w - deflection, displacement, compression, cover width
x, y, z - coordinates
 α - parameter (A.5.5.4), coefficient of thermal expansion, sound absorption (α_w)

β - parameter (A.5.5.4 and Table E.10.2 design equations)

δ - deviation

φ - angle

γ - shear strain, partial safety factor

λ - thermal conductivity, λ_{Design} (design value)

ϕ - creep coefficient

θ - parameter (Table E.10.1 design equations)

σ - stress, compressive strength σ_m , standard deviation

τ - shear stress

ψ - combination coefficient (Annex E), linear thermal transmittance of joints (A.10.3)

ρ - coefficient, density

Subscripts

C - core

D - declared value (R_D)

F - ace, action (γ_F)

G - self-weight, degree

M - material (γ_M)

Q - variable action

S - sandwich part of the cross-section

adj - adjusted

b - bending, elastic extension

c - compression, core, carrier (C.4.3.2), clip ($f_{\text{joint,c}}$)

d - design

e - external, additional thickness of main profiles (Δe)

eff - effective

f - load, facing (λ_{fi})

i - internal (λ_{fi})

i, j - index

k - characteristic value

lin - linear

m - material

n - nominal

nc - without clip ($f_{joint,nc}$)

obs - observed (e.g. result)

q - uniform load

s - support (L_s = support width), stiffeners, surface (R_{s1})

t - tension, time

tol - tolerance (normal or special)

tr - traffic (C_{tr})

u - ultimate (F_u)

v - shear, variance

w - wind, web, wrinkling (σ_w), weighted (R_w)

y - yield

0 - basic value, unit width, time (e.g. $t = 0$)

1 - external face, upper face

2 - internal face, lower face

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

PCS - gross calorific potential

PUR - rigid polyurethane foam (the abbreviation PUR includes polyisocyanurate foam (PIR)) PF phenolic foam

XPS - extruded polystyrene foam

5 Requirements, properties and test methods

5.1 Requirements for component materials

5.1.1 General

The product shall be manufactured with materials and components conforming to

5.1.2 Metal Facings

5.1.2.1 Steel Faces

Steel faces (other than stainless steel) shall meet the requirements in KS EAS 468, KS EAS 11 and KS EAS 410.

5.1.2.2 Stainless Steel Faces

Stainless steel facings shall meet the requirements of KS ISO 15510.

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 ISO 9445.

The minimum coating mass for terne coated stainless steel shall be 40 g/m².

5.1.2.3 Aluminium Faces

The chemical composition, temper and mechanical properties of aluminium faces shall conform to requirements of KS ISO 6361-1, KS ISO 6361-2, KS ISO 6361-3 and KS ISO 6361-4.

Organic coated aluminium sheets shall conform to the requirements of ISO 18768-1 and ISO 18768-2.

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 aluminium facing sheets shall be determined in accordance with EN 485-4 or ISO 5000.

NOTE Not all aluminium alloys covered by KS ISO 6361-2 or ISO 5000 are suitable for sandwich panels in all the intended end uses.

5.1.2.4 Copper Faces (WILFRED to act on this)

Copper facings shall have a minimum design value of the stress at the 0.2%-strainlimit (for simplification called "yield strength") of 180 N/mm². The chemical composition, temper, mechanical properties and thickness tolerances of copper faces shall conform to EN 1172.

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 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 Material

5.1.3.1 Thermal Performance

The declared and design thermal conductivity of core materials shall be determined in accordance with A 10.2

5.1.3.2 Thermal Stability of Core Materials

The insulating core materials shall conform to the thermal stability and shrinkage requirements specified in the relevant standards EN 13162 to EN 13167.

5.1.4 Adhesives and bonding

Adhesives and bonding shall conform to 5.2.1.6 and 5.2.3.1. to check.

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 according to ISO 12491. verify

Declared values shall be given to two significant figures.

5.2.1.2 Shear strength (f_{cv}) and shear modulus (G)

The characteristic value of the shear strength of the core shall be determined in accordance with A.3 or A.4, A.5.6 verify and shall be declared by the manufacturer in megapascals (MPa).

NOTE 1 Test A.3 is the standard test which 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. Test A.4 should be used wherever the incidence of joints is considered to be significant. Test A.5.6 may be used to determine a more reliable value of the shear modulus for all core materials.

The declared value shall be less than or equal to the characteristic value. To verify

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

5.2.1.3 Creep coefficient (ϕ_t)

The creep coefficient shall be determined according to 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 e.g. snow and self-weight.

5.2.1.4 Compressive strength (σ_m) or compressive stress (σ_{10})

The compressive strength of the core σ_m or its compressive stress at 10 % deformation σ_{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_{cv} 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 e.g. snow and self-weight. The declared value shall be less than or equal to the characteristic value (f_{cv}) 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 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 (σ_w)

The bending moment capacity shall be obtained by testing according to 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.

NOTE 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 according to 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 is 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 (λ_{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 Annexure 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.

Where 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 covered within EN 13165:2001 including Amendments A1 and A2:2004 and a combination of these blowing agents, to verify 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 according to test DUR1 and the colour reflectivity levels shall be declared (B.2.5).

Table 2 – Durability tests and deemed to satisfy criteria

Insulating Core Material	Test method (Annexure B)	Note
Mineral wool (MW)	DUR2	DUR2 including the wedge test (B.5)
Polystyrene (EPS or XPS)	DUR1	DUR1 including wedge test (B.5)
Polyurethane (PUR) – auto-adhesive bond	DUR1	No test required for panels manufactured using the blowing agents covered within EN 13165:2001 including Amendments A1 and A2:2004 and combinations of these agents, but excluding CO ₂ blown foams. Other blowing agents shall be tested to DUR1.

Polyurethane (PUR) - adhesive bond	DUR1	No test required for panels manufactured using the blowing agents covered within EN 13165:2001 including Amendments A1 and A2:2004 and combinations of these agents, but excluding CO2 blown foams. Other blowing agents shall be tested to DUR1 including the wedge test (B.5) The wedge test (B.5) shall be carried out
Phenolic (PF)	DUR1 and repeated loading B.6	PF panels with an adhesive bond shall be tested to DUR1 including the wedge test (B.5)
Cellular Glass (CG)	DUR1, thermal shock B.7 and repeated loading B.6	Including the wedge test (B.5)

5.2.3.2 Resistance to point loads and access loads – ceiling panels

Where 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 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 Reaction to fire

The reaction to fire classification of the product shall be determined according to EN 13501-1. The classification shall apply to panel applications defined in Clause 1 (Scope) of this European Standard.

Test arrangements for reaction to fire tests shall be in accordance with the following, as appropriate for the intended class:

- ISO 1182;
- ISO 1716 including determination of adhesives set out in C.4;
- EN 13823 and ISO 11925-2 together with the additions set out in C.1.

5.2.4.3 Fire resistance

Where required, the fire resistance classification of the product shall be determined according to EN 13501-2.

The test methods for sandwich panels shall be in accordance with the following standards:

- EN 1364-1 (non-loadbearing walls) together with the additions set out in C.2.1;
- ISO 834-9 (ceilings) together with the additions set out in C.2.1;
- CEN/TS 13381-1 (ceilings – horizontal protection) together with the additions set out in C.2.1;
- EN 1365-2 (loadbearing roofs) together with the additions set out in C.2.1 and C.2.2;
- ISO 834-11 Fire resistance tests — Elements of building construction — Part 11: Specific requirements for the assessment of fire protection to structural steel elements

5.2.4.4 External fire performance – roofs

Where the manufacturer wishes to declare external fire performance (e.g. when subject to regulatory requirements), the product shall be tested and classified in accordance with EN 13501-5.

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 panels

Dimension	Tolerance (maximum permissible)	Measurement method
Thickness of the panel ^a	$D \leq 100$ mm ± 2 mm $D > 100$ mm ± 2 %	D.2.1
Deviation from flatness (according to the length of measurement L)	For $L = 200$ mm – Deviation from flatness 0,6 mm For $L = 400$ mm – Deviation from flatness 1,0 mm For $L > 700$ mm – Deviation from flatness 1,5 mm	D.2.2
Depth of metal profile (ribs) (mm)	$5 < h \leq 50$ mm ± 1 mm $50 < h \leq 100$ mm $\pm 2,5$ mm	D.2.3
Depth of stiffeners and light profiling	$d_s \leq 1$ mm ± 30 % of d_s 1 mm $< d_s \leq 3$ mm $\pm 0,3$ mm 3 mm $< d_s \leq 5$ mm ± 10 % of d_s	D.2.4
Length of the panel	$L \leq 3$ m ± 5 mm $L > 3$ m ± 10 mm	D.2.5
Cover width of the panel	$w \pm 2$ mm	D.2.6
Deviation from squareness	$0,006 \times w$ (nominal cover width)	D.2.7
Deviation from straightness (on length)	1 mm per metre, maximum 5 mm	D.2.8
Bowing	2 mm per metre length, maximum 10 mm 8,5 mm per metre width for flat profiles – $h \leq 10$ mm 10 mm per metre width for profiles – $h > 10$ mm	D.2.9
Pitch of the profile (p)	If $h \leq 50$ mm $p: \pm 2$ mm If $h > 50$ mm $p: \pm 3$ mm	D.2.10
Width of the ribs (b_1) and width of the valleys (b_2)	For b_1 ± 1 mm For b_2 ± 2 mm	D.2.11
^a For calculation of the thickness of panels with profiled facings, see Figure D.1.		

5.2.6 Water Permeability

Where required, the water permeability (resistance to driving rain) 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 resistance classification of a sandwich panel assembly to driving rain under pulsating air pressure shall be determined according to A.11. 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 water. The water tightness of the assembly is a function of its installation. Water permeability is only relevant to the joints and fixings.

5.2.7 Air permeability ($\text{m}^3/\text{m}^2\cdot\text{h}$ 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 conform to A.12. The test method shall be used for both external wall and roof applications.

Sandwich panels covered by this European 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 ($R_w(C;C_{tr})$)

Where required, the airborne sound insulation of a sandwich panel assembly shall be determined according to A.13. The result shall be declared as a $R_w(C;C_{tr})$ rating to ISO 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 (α_w)

Where required, the sound absorption of a sandwich panel assembly shall be determined according to A.14. The result shall be declared as single number rating to ISO 11654.

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 selfweight, 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' shall 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 Annexure E.

Information shall be produced which gives 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. For the purpose of this Standard provision of this information shall be regarded as part of the product.

5.3.2 Actions and combinations of actions

In design for mechanical resistance the following actions: 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 Annexure E.

6 Evaluation of conformity, testing, assessment and sampling methods

6.1 General

The conformity of a sandwich panel to the requirements of this Standard and to the stated values including classes shall be demonstrated by:

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

Where 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 Initial Type Testing – ITT

6.2.1 Initial type evaluation

Initial type testing shall be conducted to show conformity to 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 conformity of the product.

Characteristics which are required for specific applications, e.g. permeabilities or acoustics, shall be tested on a 'where 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 conformity 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 factory production control.

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. panel, shall be a simple random sample, drawn from a finite panel population.

Where 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 initial type tests 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 should 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

All samples intended for ITT purposes shall be marked as follows:

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

The sampling records shall provide at least the following information:

- manufacturing plant;
- place of sampling;
- stock or batch quantity (from which the samples have been taken);
- quantity of samples;
- reference to this European Standard, i.e. EN 14509;
- marking of the product by the manufacturer;
- identification mark of the samples;
- properties to be tested;
- place and date;
- signature(-s) of the person(-s) responsible for 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.

Table 4 – Test methods, test specimens, type of the test and conditions for ITT

Characteristic	Test method	Type of test	Min. number of ITT specimens	Compliance criteria and specifications	
5.1.2 Mechanical properties of a face	EN 10002-1 ^a		3 ^a		
Mechanical properties of a panel and its core material:					
5.2.1.2 Shear strength and modulus	A.3 or A.4 or A.5.6	ITT	3	Statement of declared values	
5.2.1.4 Compressive strength and modulus	A.2	ITT	6		
5.2.1.5 Reduced shear strength ^c	A.3.2	ITT	1/10 ^d		
5.2.1.6 Cross panel tensile strength: (and modulus ^b)	A.1	ITT	6		
5.2.1.7 Bending moment capacity and wrinkling stress	A.5	ITT	3		
5.2.1.8 Bending moment capacity over a central support	A.7	ITT	3		
5.2.1.3 Creep coefficient ^c	A.6	ITT	1		[Number]
Cross panel tensile modulus at elevated temperatures ^{b,f}	A.1.6	ITT	3		
Density	A.8	ITT record		Max, Min, and average densities	
5.2.2 Thermal transmittance	A.10	ITT	See A.10	Limit value according to A.10	
5.2.3 Durability ^e	Annex B	ITT		Pass (see 5.2.3 and Annex B)	
5.2.4.2 Reaction to fire	EN ISO 1716, EN ISO 1182	ITT	As specified in EN 13501-1	Classification in accordance with EN 13501-1	Specific conditions see C.1
	EN 13823 (SBI) EN ISO 11925-2				
5.2.4.3 Fire resistance ^e	EN 1364-1 or 1364-2	ITT	1	Classification in accordance with Specific conditions see C.2	
	EN 1365-2 or CEN/TS 13381-1		1		
	EN 14135		1		
5.2.4.4 External fire performance-roofs ^e	ENV 1187	CWFT or ITT	see ENV 1187	Classification in accordance with Specific conditions see C.3	
5.2.6 Water permeability ^e	EN 12865	ITT	1	EN 12865 and in accordance with	
5.2.7 Air permeability ^e	EN 12114	ITT	1	EN 12114 and in accordance with	
5.2.9 Airborne sound insulation ^e	EN ISO 140-3	ITT	1	Declaration $R_{w}(C;C_{tr})$ (see A.13)	
5.2.10 Sound absorption ^e	EN ISO 354	ITT	1	EN ISO 11654 (see A.14)	
5.2.5 Dimensional tolerances	Annex D	ITT	1	-	

^a These values are required to adjust test results in accordance with A.5.5.4.
^b Required for design purposes only – not declared.
^c Roof/ceiling applications only.
^d 1/10 = a single test series with 10 specimens.
^e Where required.
^f Not declared. Required to calculate the wrinkling stress at elevated temperatures.

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 according to ISO 12491 using the equation and fractile factors in A.16.3.

The results of all type tests shall be recorded and held by the manufacturer for at least 10 years after the last date of production of the product(s) to which they belong.

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 conform to the stated performance characteristics. The FPC system shall consist of procedures, regular inspections and tests and/or assessments 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 conforming to the requirements of ISO 9001, and made specific to the requirements of this European 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 providing conformity can be shown, in which case factory production control 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:

- date and time of manufacture;
- type of product;
- 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 conformity of the finished product to 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, conformity shall be calibrated or verified and regularly inspected according to documented procedures, frequencies and criteria.

Calibration and/or checking 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 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 is maintained.

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

The calibration of all test equipment shall be repeated if any repair or failure occurs which 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 conformity.

The manufacturer shall have written procedures which 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.

Conformity for metal facings shall be in accordance with 6.3.4.2, pre-manufactured core components with 6.3.4.3 and adhesives with 6.3.4.4.

6.3.4 .1.1 Metal facings

Where provided by the facing manufacturer, declarations shall be according to EN 10204, document Type 3.1, and shall be provided for every 50 t of coil material.

6.3.4 .1.2 Prefabricated lamella and preformed core material

Pre-formed material for the cores of sandwich panels shall undergo factory production control 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 (EN 13162 to EN 13167):

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

NOTE In the context of this European Standard, declaration means the supplier's formal declaration of the properties.

6.3.4 .1.3 Adhesives

The panel manufacturer shall obtain the supplier's declaration for the following:

- description and specification;
- viscosity/speed;
- 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 factory production control 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 the Standard 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 factory production control procedure for the manufacture of panels shall include testing according to Table 5.

Factory production control 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 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 should 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

Type of test	Test method	Minimum number of specimens	Minimum frequency
Density of core material	A.8	3	1 per shift/6 or 8h ^a
Cross-panel tensile strength and modulus (with faces)	A.1	3	1 per shift/6 or 8h ^a
Compressive strength and modulus of core material	A.2	3	1 per week ^a
Shear strength and modulus of core material	A.3	3	1 per week ^a
Tensile strength of face material (or declaration – 6.3.4.2)	-	3	All deliveries
Thickness of face material (or declaration – 6.3.4.2)	-	3	All deliveries
Shear strength of complete panel ^b	A.4	1	1 per 2 weeks ^a
Wrinkling stress (optional see text above)	A.5	1	1 per week ^a
Dimensional control:	-		
— Panel thickness	D.2.1		
— Deviation from flatness	D.2.2		
— Depth of profile	D.2.3		
— Depth of stiffeners	D.2.4		
— Length of panel	D.2.5		
— Cover width	D.2.6	1	1 per shift/6 h or 8 h
— 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		
Reaction to fire – (6.3.5.3) ^c			
Resistance to fire – (6.3.5.3) ^c	-	-	Specification Record
External fire performance – (6.3.5.3) ^c or CWFT			
Thermal insulation performance	A.10.2.1.1 ^d	1	1 per month
Water permeability – 5.2.6			
Air permeability – 5.2.7	Visual inspection ^a	-	-
Water vapour permeability – 5.2.8			



Table 5 (concluded)

<p>^a 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.</p> <p>^b Panels with MW lamella insulating cores only.</p> <p>^c Manufacturer's specification record (see 6.3.5.3) or supplier's statement of fire performance of components.</p> <p>^d Procedure tests λ_i (single test result of thermal conductivity) in accordance with the appropriate product standard for the core material (A.10.2.1.1) and shall be representative of the material at the time of manufacture of the panel.</p> <p>NOTE 1 The control of the thickness of pre-formed 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).</p> <p>NOTE 2 Typical allowable difference in cutting thickness between adjacent pre-manufactured pieces for fabrication with stiff platens is $\pm 0,5$ mm.</p>

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 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 pre-formed or lamella insulation produced by bonding shall be controlled by recording the precise specification of all pre-formed 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 pre-formed 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.

Indirect tests on components shall be carried out according to Table 6.

Table 6 – Minimum testing frequencies for components for reaction to fire characteristics

Component	Test method	Frequency
Core material	Check of raw material or chemical formulation, and density (A.8)	1 per day
Adhesive	Check for maximum amount and thickness of adhesive layer (C.4)	1 per day
Facings	Manufacturer's declaration	1 per week

6.3.6 Conformity of Factory Production Control – supplier purchases

6.3.6.1 General

Where a supplier purchases the product from a manufacturer whose production plant is outside the EEA, the supplier shall take full responsibility for demonstrating conformity for the product in accordance with 6.3.6.2.

Where 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

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

Conformity shall be based on product testing of the whole panel or specimens taken from a panel in accordance with Table 7.

Values of the following characteristics shall also be provided in accordance with 6.3.4.2 and 6.3.4.3:

- Compressive strength and modulus of the core material;
- Shear strength and modulus of the core material;
- Tensile strength of the face material (or declaration – 6.3.4.2);
- Thickness of face material (or declaration – 6.3.4.2).

The frequency of testing for these characteristics shall be every 2 000 m² and at least once per delivery.

Table 7 – Supplier purchases: FPC system requirements for panels

Type of test	Test method	Minimum number of specimens	Minimum frequency
Density of core material	A.8	3	All deliveries
Cross-panel tensile strength and modulus (with faces)	A.1	3	
Shear strength of complete panel ^a	A.4	1	
Dimensional control:	-	-	-
— Panel thickness	D.2.1	1	All deliveries
— Deviation from flatness	D.2.2		
— Depth of profile	D.2.3		
— Depth of stiffeners	D.2.4		
— Length of panel	D.2.5		
— Cover width	D.2.6		
— 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		
Reaction to fire – (6.3.5.3) ^b	-	-	Specification Record
Resistance to fire – (6.3.5.3) ^b	-	-	
External fire performance – (6.3.5.3) ^b or CWFT	-	-	
Thermal insulation performance – 5.2.2	A.10		Every 3 months
Water permeability – 5.2.6	Visual inspection	-	All deliveries
Air permeability – 5.2.7			
Water vapour permeability – 5.2.8			
^a Panels with MW lamella insulating cores only.			
^b Manufacturer's specification record (see 6.3.5.3) or supplier's statement of fire performance of components.			

7 Classification and designation

Sandwich panels shall be classified and designated in accordance with Table 8 where required, for example when subject to regulatory requirements. Declared values shall be given to two significant figures.

Table 8 – Classification and designation

Clause	Designation	Units or class
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 ^c — wrinkling stress ^c	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	Reaction to fire	See EN 13501-1
5.2.4.3	Fire resistance	See EN 13501-2 ^b
5.2.4.4	External fire performance for roofs	B _{ROOF} (CWFT) or EN 13501-5 ^b
5.2.6	Water permeability	Class: e.g. A (1 200 Pa); B (600 Pa); C (300 Pa). ^b
5.2.7	Air permeability	m ³ /m ² ·h at 50 Pa ^b
5.2.9	Airborne sound insulation	Rating: R _w (C;C _{tr}) ^b
5.2.10	Sound absorption	Single value rating: α _w ^b
^a Characteristic only required for panels used as roofs and ceilings. ^b These characteristics may be designated NPD (No Performance Determined, see ZA.3) where the intended use is not subject to regulatory requirements. ^c 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 (A.5.5.3).		

8 Marking, labelling and packaging

8.1 Marking and labelling

The following information shall be supplied by the manufacturer with or attached to every pack, or bundle of sandwich panels:

- a) Name or registered identification of the manufacturer and address of production plant.
- b) Number of this Kenyan Standard;
- c) Information on the type of product including product reference/name;
- d) Mass of the product in kg/m^2 ;
- e) Thickness of the product;
- f) Description of the metal faces and coatings as applicable;
- g) Description of the core material including material identification, thickness, density etc.;
- h) Values of the characteristics in Table 8.

Where ZA.3 covers the same information as in 8.1, the requirements of this subclause are met.

Manufacturers may wish to supply additional information with the product as appropriate.

8.2 Packaging, transport, storage and handling

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

NOTE 1 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.

NOTE 2 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 the following sub-clauses.

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).

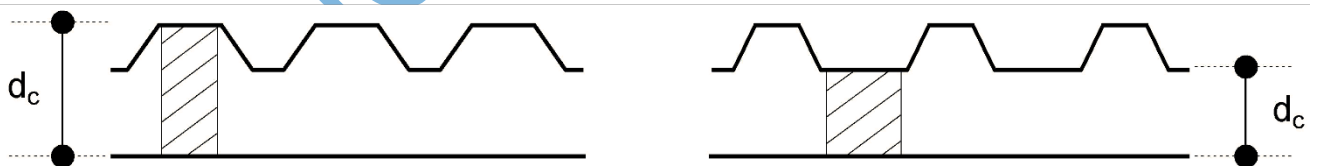


Figure A.1 – Cutting of specimens

Test specimens shall be of square cross-section having 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 ISO 29768. The tolerance on 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 should 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, due 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.



Figure A.2 – Examples of specimens with shaped filling pieces

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 $10 \text{ mm} \pm 10 \%$ 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 (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 elevated temperature (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 shall be calculated as follows. The tensile strength f_{ct} is given by Equation (A.1):

f_{ct}

= F_u

A

(A.1)

where F_u is the ultimate load;

A is the cross-sectional area of the specimen determined from the measured dimensions.

NOTE 1 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.

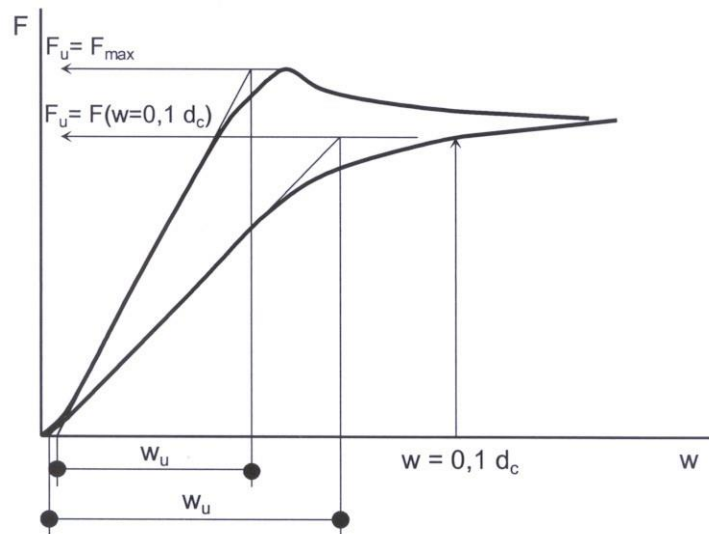


Figure A.3 – Load against deflection curve (F_u against displacement 'w')

Recording and interpretation of test results shall comply with A.16.

The test report shall state the characteristic value (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 2 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):

$$E_{ct} = \frac{F_u d_c}{w_u A}$$

(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 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 which have been heated for 20 h to 24 h in a heating chamber at a temperature of 80_{-1}^{+3} °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_{-1}^{+3} °C).

The characteristic 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 the following sub-clauses.

A.2.2 Apparatus

The apparatus shall be in accordance with EN 826.

A.2.3 Test Specimen

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):

$$f_{cc} = \frac{F_u}{A}$$

A

(A.3)

The compressive strength f_{cc} of the core material shall be calculated using Equation (A.3):

$$f_{cc} = \frac{F_u}{A}$$

(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 which 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):

$$E_{Cc} = \frac{F_u d_c}{w_u A} \quad (\text{A.4})$$

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 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 (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.

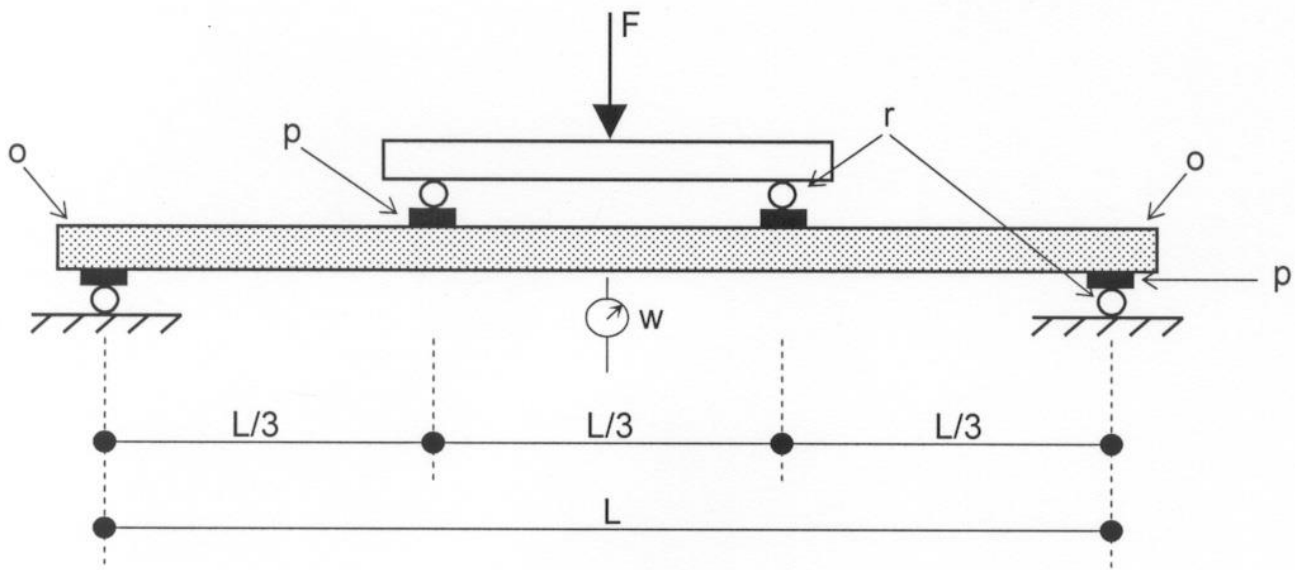
A.3.2 Apparatus

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.

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**Key**

F applied load

r rollers, radius 15 mm

w measured deflection

p metal load spreading plates of width L_s

o overhang not exceeding 50 mm

Figure A.4 – Four point bending test

A.3.3 Test Specimens

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

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 1 Faces may incorporate light profiling.

For all core materials except MW lamellas, the width of the specimen shall be $100 \text{ mm} \pm 2 \text{ mm}$. For MW lamellas the width to be used shall be $\geq 100 \text{ mm}$ and shall be chosen to incorporate at least one full width of lamellas. There shall be no cut ends of lamellas or pre-formed core material within the length of the test specimen.

NOTE 2 It is preferable to use the test described in A.4 to determine the shear strength and modulus of panels with lamellas.

Span L shall be chosen so that a shear failure is obtained. The recommended span is 1000 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.

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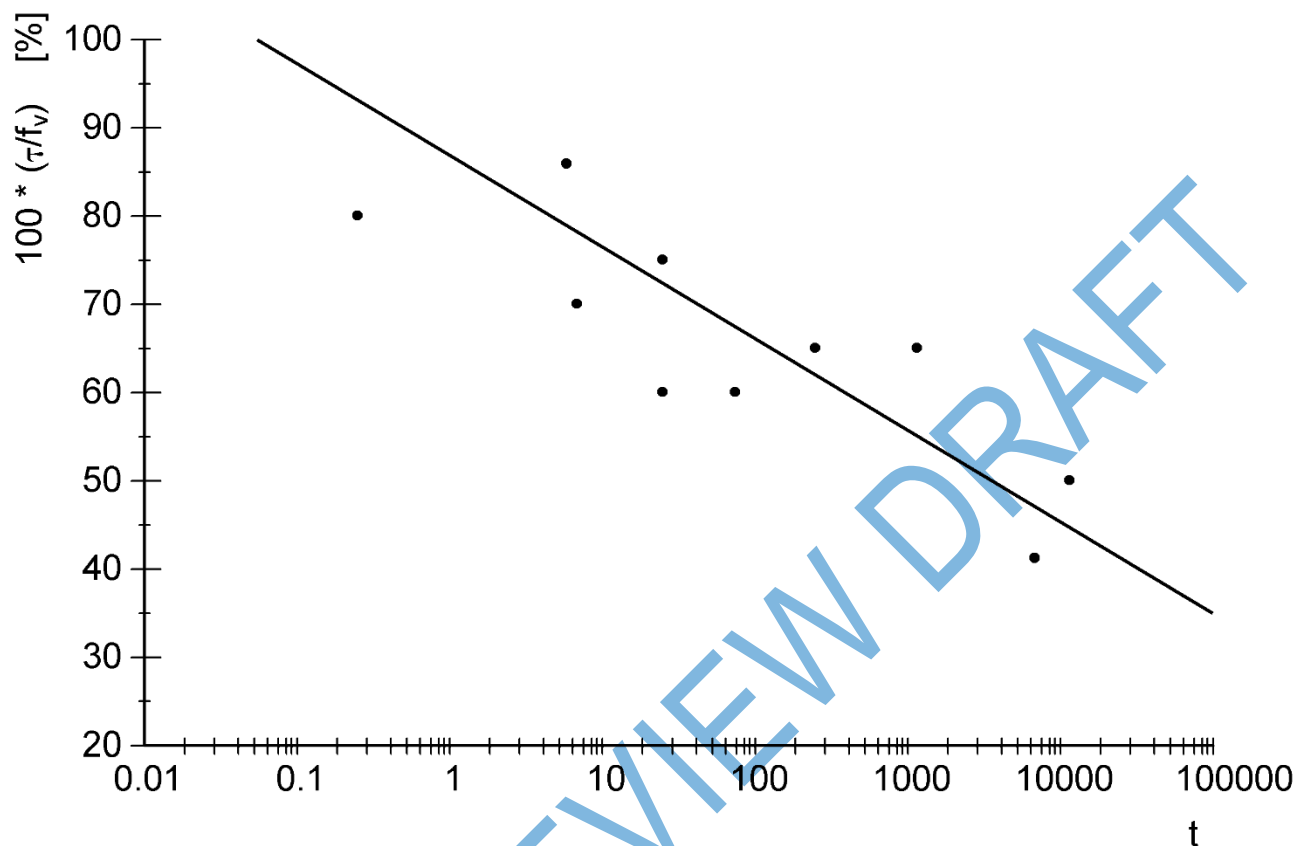


Figure A.5 – Typical shear failure

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 (A.5):

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

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

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- 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 pre-formed or lamella cores.

The shear strength for panels with offset pre-formed 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 pre-formed cores, no reduction in shear strength shall be considered when the joints are adhered.

For panels with the core material foamed in-situ or pre-formed in a single piece, or for panels with cut ends which are adhered, $k_v = 1.0$. For other panels with pre-formed 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):

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

Recording and interpretation of test results shall comply with A.16.

The test report shall state the characteristic value (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 as follows (A.7):

$$\text{Flexural rigidity} \quad B_s = \frac{E_{F1} \cdot A_{F1} \cdot E_{F2} \cdot A_{F2}}{e^2}$$

$$\text{Bending deflection} \quad \Delta w_B = \frac{E_{F1} \cdot A_{F1} + E_{F2} \cdot A_{F2}}{2}$$

$$= \frac{\Delta F L^3}{56,34 B_s}$$

$$\text{Shear deflection} \quad \Delta w_S = \Delta w - \Delta w_B$$

Shear modulus

$$G_c = \frac{\Delta F L}{6 B d_c \Delta w_s}$$

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;

Δw is the deflection at mid-span for a load increment ΔF 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);

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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.16.

The test report shall state both the mean and characteristic values (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 2000 h and 100 000 h shall be calculated as:

50 % of the short term value, if the ϕ_t is less or equal than 2.4 at 2000 h

30 % of the short term value, if the ϕ_t is higher than 2.4 at 2000 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 $6 \text{ min} \leq t \leq 1\,000 \text{ h}$. Specimens failing after $t > 1\,000 \text{ h}$ may also be incorporated into the analysis.

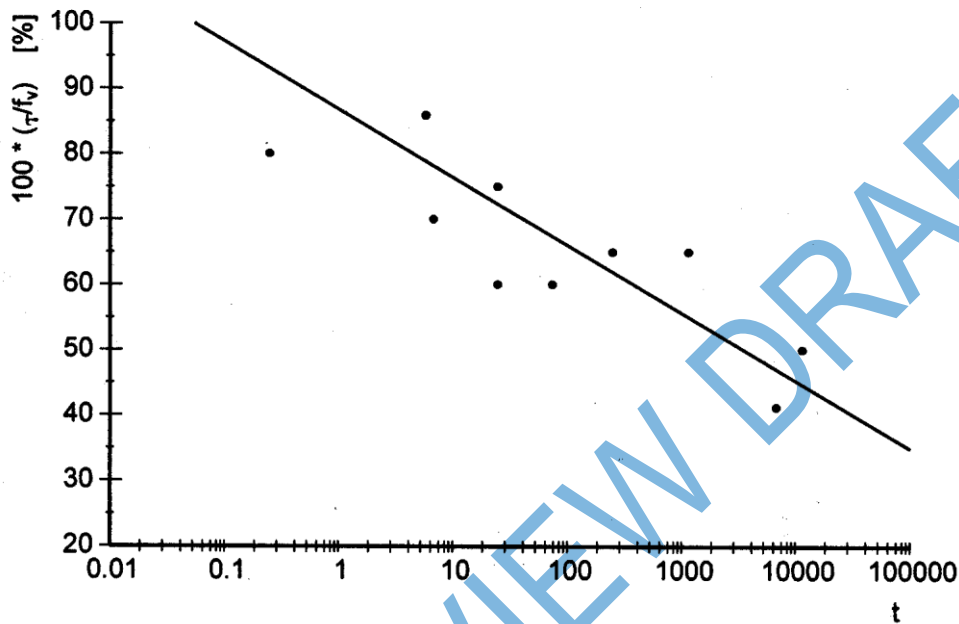
Deformation measurements are not required.

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)
- τ 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 A.3 and offers a more reliable method of determining the shear strength and tested shear modulus of panels with lamella and pre-formed cores where joints between the core elements may 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_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 by using the test method in A.5.6.

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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 1000 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

$$\left(\frac{w_{s1} + w_{s2}}{2} \right) \text{ from the measured deflection } w.$$

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 \pm 25 %, per minute. The loading rate shall be uniform and sufficient to cause failure within three minutes 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_{cv} shall be calculated as follows (A.8):

$$f_{cv} = \frac{F_u}{2B/e}$$

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

(A.8)

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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 and/or other loading systems, 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.

NOTE [2] can be used for calculation purposes.

Recording and interpretation of test results shall comply with A.16.

The test report shall state the characteristic value (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 which 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 Figure 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.

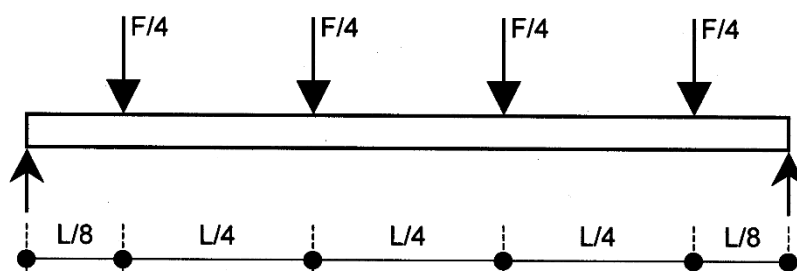


Figure A.7 – Simply supported panel: 4 line loads

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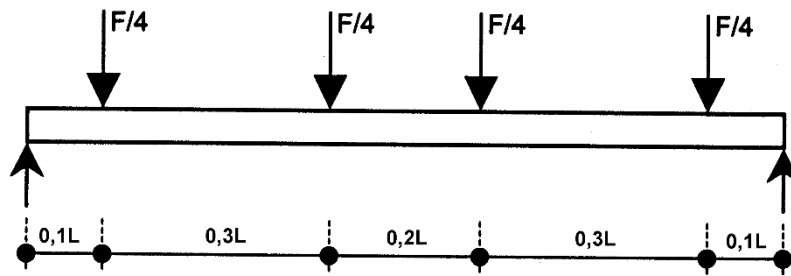
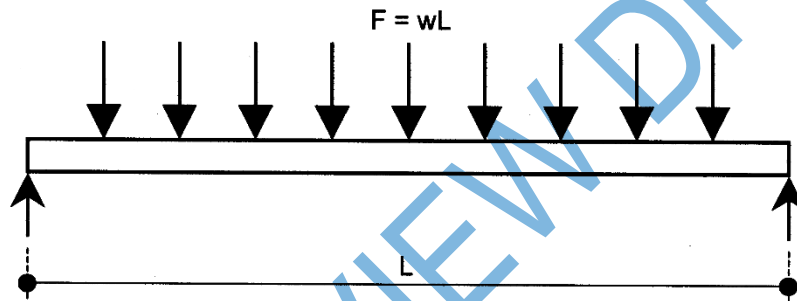


Figure A.8 – Simply supported panel: 4 line loads (alternative)



Key

w load per unit length

Figure A.9 – Simply supported panel: Air pressure

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 which 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.

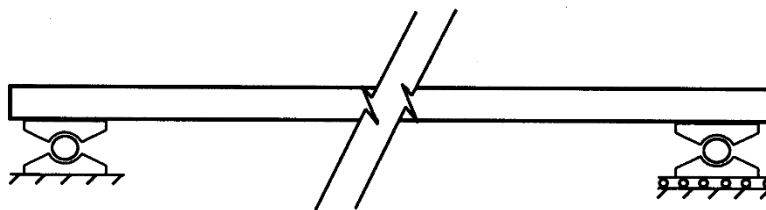


Figure A.10 – Panel support detail

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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.

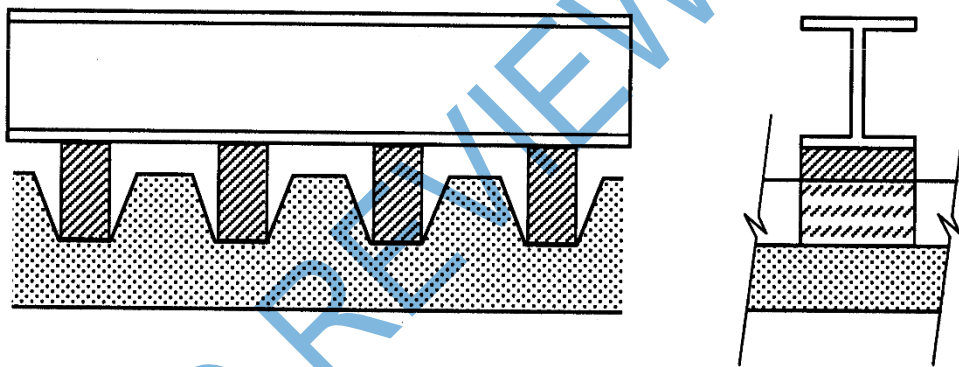


Figure A.11 – Loading platens for profiled facings

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.

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NOTE The values in Table A.1 are offered for guidance.

Table A.1 – Indicative span criteria to obtain bending failure

Overall depth of panel (<i>D</i>)	Indicative span (<i>L</i>)
$D < 40 \text{ mm}$	3.0 m
$40 \text{ mm} \leq D < 60 \text{ mm}$	4.0 m
$60 \text{ mm} \leq D < 100 \text{ mm}$	5.0 m
$D \geq 100 \text{ mm}$	6.0 m

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.

Prior to the test a small load, which shall be not greater than 10 % of the failure load, shall be applied for no more than five minutes 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.16.

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):

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$$M_u = \frac{F_u L}{8} \quad (\text{A.9})$$

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 prior to obtaining the characteristic values to be declared.

A.5.5.3 Determination of the Wrinkling Stress (σ_w)

The wrinkling stress σ_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 σ_w shall be given by Equation (A.10):

$$\sigma_w = \frac{M_u}{e A_1} \quad (\text{A.10})$$

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 σ_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 prior to 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):

$$\sigma_{w,t_2} = f \cdot \sigma_{w,t_1} \quad (\text{A.12})$$

where σ_{w,t_2} is the wrinkling stress of a thicker face, t_2 ;

$\sigma_{w,t1}$ is the wrinkling stress of the thinnest face, t_1 ;

$$A_1 \times 3 \sqrt{I_1}$$

f is the reduction factor = $\frac{1}{2}$

$$A_2 \times 3 \sqrt{I_2}$$

A_1, I_1 is the cross-sectional area and moment of inertia of the face with t_1 ;

A_2, I_2 is the cross-sectional area and moment of inertia of the face with t_2 .

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

$$\sigma_w = 0.5 \times 3 \sqrt{G_c \times E_C \times E_F} \quad (A.13)$$

where E_C is the mean of the characteristic values of the tensile and compressive moduli of the core material (A.14).

$$E_C = \frac{E_{Ct} + E_{Cc}}{2} \quad (A.14)$$

G_c is the characteristic shear modulus of the core material;

E_F 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 $R_{obs,i}$ is the result of test number i ;

$R_{adj,i}$ is the test result modified to correspond to the design values of metal thickness and yield stress;

f_y is the design yield stress;

$f_{y,obs}$ is the yield stress measured in the test specimen;

t is the design metal thickness;

t_{obs} is the metal thickness measured in the test specimen;

$\alpha = 0$ if $f_{y,obs} \leq f_y$

$\alpha = 1$ if $f_{y,obs} > f_y$

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

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

In general:

$$\beta = 1.0$$

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

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

$$\beta = 1.0 \quad \text{if } t_{\text{obs}} > t \quad \text{and} \quad \frac{b}{t} \leq 1.27 \sqrt{\frac{E_F}{f_y}}$$

$$\beta = 2.0 \quad \text{if } t_{\text{obs}} > t \quad \text{and} \quad \frac{b}{t} > 1.27 \sqrt{\frac{E_F}{f_y}}$$

b

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

t

The values $R_{\text{adj},i}$ 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 (E.3), the individual test results shall be reduced according to Equation (A.16):

$$k_1 = \sqrt[3]{\left(\frac{E_{Ct,+80^\circ C}}{E_{Ct,+20^\circ C}}\right)^2}$$

(A.16)

where $E_{Ct,+20^\circ C}$ is the tensile characteristic cross panel E-modulus at 20 °C;

$E_{Ct,+80^\circ C}$ 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:

$$k_2 = (6.10 \times f_{Ct} + 0.39)$$

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 (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:

$$w = w_b + w_v$$

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_v is the deflection due to shear deformation of the core material.

The shear modulus of the core shall be determined from w_v .

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):

$$w_b = \frac{5 FL^3}{384 B_s} \quad \text{and} \quad G_c = \frac{FL}{8 A_c (w - w_b)} \quad (\text{A.17}) \quad (\text{A.18})$$

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):

$$w_b = \frac{41 FL^3}{3072 B_s} \quad \text{and} \quad G_c = \frac{FL}{8 A_c (w - w_b)} \quad (\text{A.19}) \quad (\text{A.20})$$

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):

$$w_b = \frac{1.24 FL^3}{96 B_S} \quad \text{and} \quad G_c = \frac{FL}{8 A_c (w - w_b)} \quad \text{(A.21) (A.22)}$$

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:

$$B_S = \frac{E_{F1} \cdot A_{F1} \cdot E_{F2} \cdot A_{F2}}{E_{F1} \cdot A_{F1} + E_{F2} \cdot A_{F2}} e^2 \quad \text{and} \quad A_c = B \cdot e$$

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

A.6 Determination of the creep coefficient (ϕ_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 (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 according to 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 commence 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.16.

On the basis of the results of the tests within the time range $0 < t \leq 1\,000$ 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 (ϕ_t)

The creep coefficient for the core of a lightly profiled sandwich panel shall be determined using Equation (A.23):

$$\varphi_t = \frac{w_t - w_0}{w_0 - w_b} \quad (\text{A.23})$$

where w_t is the deflection measured at time t ,

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

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:

$$\phi_{2000} = 1,2(1,43\phi_{1000} - 0,43\phi_{200}) = 1,7(\phi_{1000} - 0,3\phi_{200})$$

$$\phi_{100000} = 3,86\phi_{1000} - 2,86\phi_{200}$$

A.6.5.3 Creep coefficient (core) for deeply profiled panels (ϕ_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).

$$\varphi_t = \frac{\beta(C_D - 1)}{\beta_1(1 - \beta - \beta\rho(C_D - 1))} \quad (\text{A.24})$$

where $C_D = \frac{w_t}{w_0}$ 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);

$$k = \frac{\pi^2 \times E_{F2} \times A_{F2} \times e^2}{\left(\frac{A_{F2}}{A_{F1}} + 1 \right) \times G_C \times A_C \times L^2}$$

$$\beta_1 = \frac{k \beta}{1+k}$$

where e 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: Note.

For declaration, ϕ_{2000} shall be declared for applications where snow lies for significant periods and ϕ_{100000} shall be declared for general roof and ceiling applications.

A.7 Interaction Between Bending Moment and Support Force

A.7.1 Principle

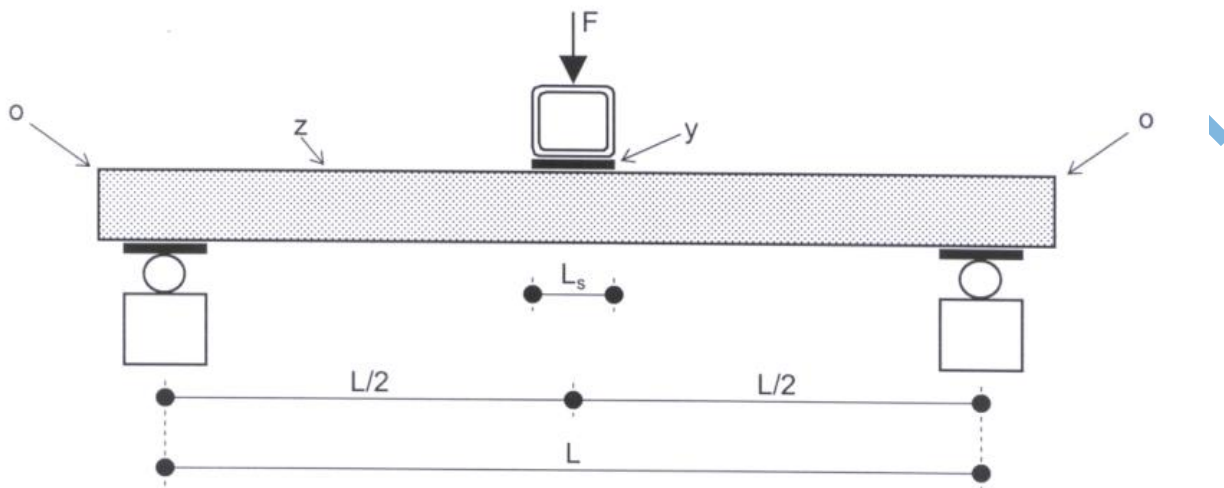
This test is generally used to determine the bending strength at an internal support of a panel which is continuous over two or more spans. The corresponding wrinkling stress for flat or lightly profiled faces or the buckling or yield stress for profiled faces shall then be determined by calculation.

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

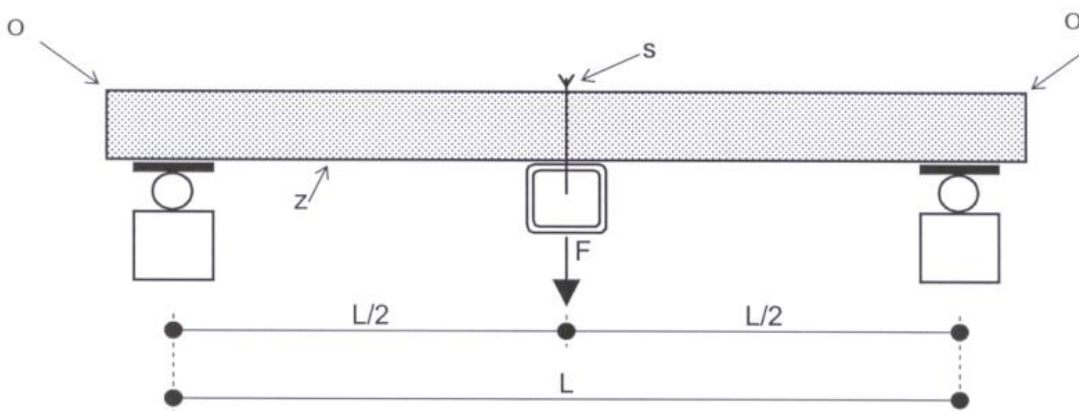
z face against support in practice

y sheet metal strip approximately 60 mm x 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



Key

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

A.7.3 Test specimens

The tests shall be carried out on a full panel width and span according to A.7.4.

For the uplift load test the fixing detail and the number and type of screws and washers shall conform to those used in practice.

A.7.4 Procedure

In order to determine the wrinkling stress at an intermediate support two types of test shall be carried out:

- a) Tests which simulate downward load (see Figure A.13);
- b) Tests which simulate uplift load (see Figure A.14).

It is important that the span shall 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 according to 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.16.

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):

$$M_u = \left[\frac{F_u}{4} + \frac{F_G}{8} \right] L \quad (\text{A.25})$$

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 prior to 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 ρ_c shall be determined according to ISO 29470.

A.8.1.2 Apparatus

The apparatus shall be as defined in ISO 29470.

A.8.1.3 Test specimens

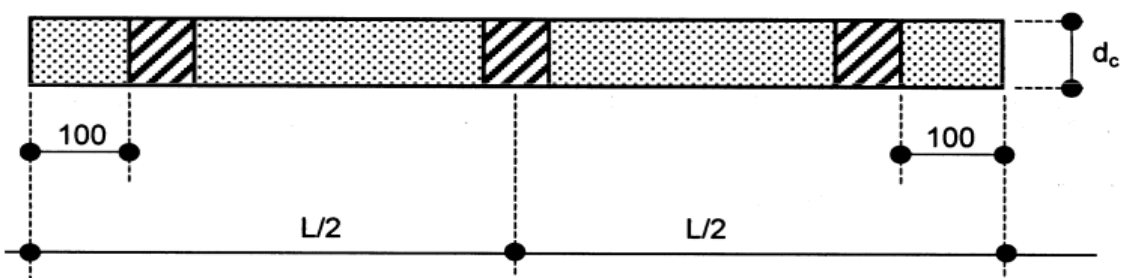
Specimens shall be taken during the production of the sandwich panels as follows:

- a) Panels with core material from slabstock or lamella bonded to faces:

Three specimens of the core material with the dimensions 100 mm x 100 mm x thickness shall be taken before bonding.

- b) Panels with auto-adhesive bonded PUR core:

Three specimens including the faces with the dimensions 100 mm x 100 mm x thickness shall be cut from positions covering the width of the panel (see Figure A.15).



Dimensions in mm

Figure A.15 – Location of test specimens – density test

The faces shall be removed carefully (e.g. 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.

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 ISO 29470.

A.8.1.5 Calculations and Results

Calculations shall be as defined in ISO 29470. Recording and interpretation of test results shall comply with A.16.

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 checks the safety and serviceability of roof or ceiling panels e.g. 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 x 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 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)
- c) If the panel supports the load but with permanent visible damage, measures shall be taken to avoid damage during erection (e.g. walking boards). Furthermore, there shall be no provision for access to the roof after building work is completed;
- d) 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.16.

A.9.2 Panels subject to repeated loads

A.9.2.1 Principle

This test checks the safety and serviceability of roof or ceiling panels e.g. 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 x 100 mm.

A.9.2.3 Specimen

Three reference specimens measuring 100 mm x 100 mm shall be taken and tested according to A.1.

For the cyclical test five sample panels shall be used each of 500 mm x nominal width x 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 x 100 mm marked according to 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 x 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 x 1 200 mm and place the rigid base and the sample panel on the lower plate of the compression machine.

Adjust the 100 mm x 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

The declared thermal conductivity ($\lambda_{\text{Declared}}$) shall be determined in accordance with the procedures described in the appropriate product standard for the core material:

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

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;
- 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 (λ_{design}) shall be determined according to ISO 10456, except in the case where the declared value is the aged value, when it is not necessary to use the ageing calculations in ISO 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 (λ_{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 13165:2001 including Amendments A1 and A2, 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 13165:2001 including Amendments A1 and A2, 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 programme in accordance with ISO 10211-1 and ISO 10211-2 (Finite Element Method).

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

$$U = \frac{1}{R_{si} + \frac{t_{ni}}{\lambda_{fi}} + \frac{d_c + \Delta e}{\lambda_{\text{design}}} + \frac{t_{ne}}{\lambda_{fe}} + R_{se}} + \frac{\psi}{B} \quad (\text{A.26})$$

where;

d_c is the nominal thickness of the core (ignoring the thickness of the facings) (m);

t_{ni} is the nominal thickness of the internal facing (m);

t_{ne} is the nominal thickness of the external facing (m);

λ_{design} is the design thermal conductivity of the core (W/m·K);

λ_{fi} is the design thermal conductivity of the internal facing (W/m·K);

λ_{fe} is the design thermal conductivity of the external facing (W/m·K);

Δe is the additional thickness due to the main profiles (m);

ψ is the linear thermal transmittance of the joints per metre length of panel (W/m·K);

B is the overall width of the panel (m);

R_{si} is the internal surface resistance (m²K/W);

R_{se} is the external surface resistance (m²K/W).

The design thermal conductivity (λ_{design}) for the core material shall be determined according to A.10.2.1.2.

The design thermal conductivity for the facing, sealant and fixing materials shall be determined according to A.10.2.2.

The linear thermal transmittance of the joints (ψ) shall be determined according to A.10.4.

The internal surface resistance (R_{si}) and the external surface resistance (R_{se}) shall be determined according to ISO 6946.

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

Table A.2 – Additional thickness due to the main profiles (Δe), m

Coverage of ribs	Height h of ribs (mm)			
	$10 \leq h \leq 25$	$25 \leq h \leq 50$	$50 \leq h \leq 70$	$h > 70^a$
$r < 25\%$	0	0	0	0
$25\% < r \leq 50\%$	0,003	0,005	0,006	0,007
$50\% < r \leq 60\%$	0,005	0,009	0,012	0,014
$60\% < r \leq 70\%$	0,007	0,012	0,016	0,019
$70\% < r \leq 85\%$	0,008	0,015	0,020	0,024
^a Where $h > 120$ mm, a more accurate calculation is necessary.				

Where r in Table A.2 is defined by Equation (A.27)

$$r = \frac{0,5 \times (b_1 + b_2)}{p} \quad (\text{A.27})$$

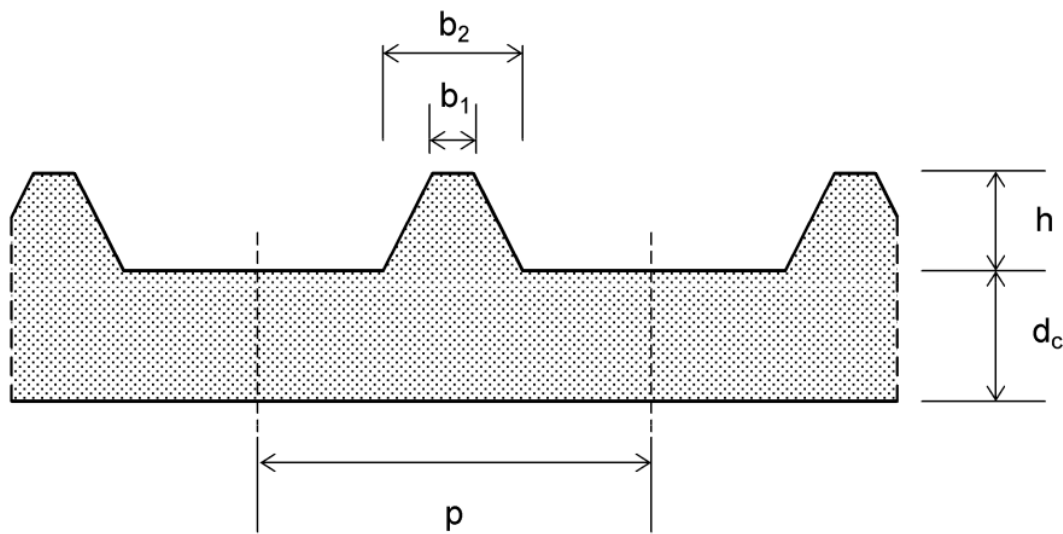


Figure A.16 – Definition of symbols in Table A.2 and Equation (A.27)

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 according to Equation (A.26) shall be determined according to ISO 10211-2 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).

$$U = \frac{1}{R_{si} + \frac{t_{ni}}{\lambda_{fi}} + \frac{d_c + \Delta e}{\lambda_{design}} + \frac{t_{ne}}{\lambda_{fe}} + R_{se}} \left(1 + f_{\text{joint}} \frac{1,0}{B} \right) \quad (\text{A.28})$$

where f_{joint} the linear thermal transmittance contribution factor of the joints calculated for a joint distance of 1m.

Table A.3 – Thermal transmittance contribution factor (f_{joint}) for steel faces

f_{joint}						
Thickness (mm)	Type I	Type II		Type III	Type IV	Type V
		no clip ($f_{\text{joint,nc}}$)	clip ($f_{\text{joint,c}}$)			
60	0,04	0,14	1,156	0,16	0,04	0,02
80	0,04	0,08	1,389	0,10	0,04	0,02
120	0,03	0,06	1,719	0,06	0,04	0,01
160	0,03	0,05	1,948	0,05	0,04	0,01
200	0,03	0,04	2,106	0,04	0,03	0,01

NOTE 1 Equation (A.29) for determination of f_{joint} of joint type II (see Table A.3):

$$f_{\text{joint}} = f_{\text{joint,nc}} \frac{a - b_c}{a} + f_{\text{joint,c}} \frac{b_c}{a} \quad (\text{A.29})$$

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.

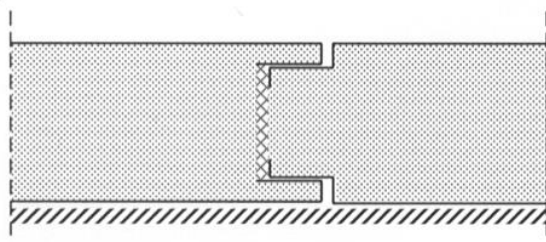


Figure A.17 – Joint type I

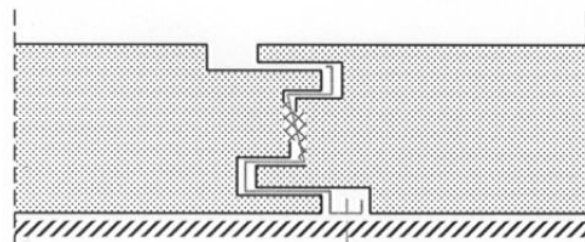


Figure A.18 – Joint type II

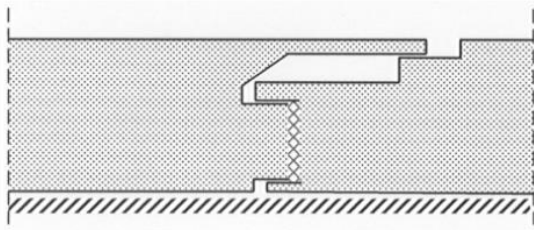


Figure A.19 – Joint type III

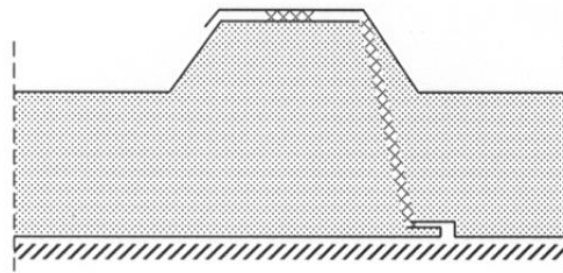


Figure A.20 – Joint type IV

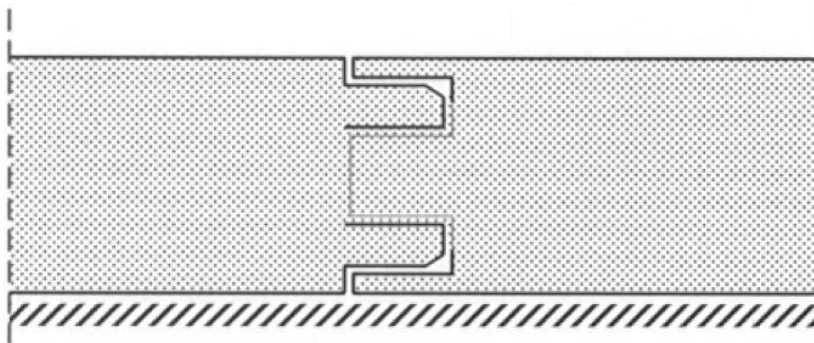


Figure A.21 – Joint type V (similar to type I but with a cut-to-shape joint without sealant)

A.11 Water permeability – resistance to driving rain under pulsating pressure

A.11.1 Principle

Where required, the resistance of a sandwich panel assembly to driving rain under pulsating air pressure shall be tested according to EN 12865.

A.11.2 Apparatus

The test apparatus shall be in accordance with EN 12865.

A.11.3 Test specimens

The dimensions of the test specimen shall be as specified in EN 12865. Both horizontal and vertical joints shall be incorporated where these are an intrinsic part of the panel assembly.

A.11.4 Procedure

The test shall be carried out in accordance with EN 12865 – procedure A.

A.11.5 Calculations and results

The following criteria shall be used to define water tightness:

A.11 Water Permeability – Resistance to Driving Rain Under Pulsating Pressure

A.11.1 Principle

Where required, the resistance of a sandwich panel assembly to driving rain under pulsating air pressure shall be tested according to EN 12865.

A.11.2 Apparatus

The test apparatus shall be in accordance with EN 12865.

A.11.3 Test specimens

The dimensions of the test specimen shall be as specified in EN 12865. Both horizontal and vertical joints shall be incorporated where these are an intrinsic part of the panel assembly.

A.11.4 Procedure

The test shall be carried out in accordance with EN 12865 – procedure A.

A.11.5 Calculations and Results

The following criteria shall be used to define water tightness:

- No water penetrates 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;
- Any water penetrating through the joint system or fixings is of the order of a few small drops and is estimated to dry out.

One of the following three test classes shall be used:

- Class A: Demanding applications with heavy rain and wind. The assembly shall be watertight up to 1 200 Pa;
- Class B: Normal applications. The assembly shall be watertight up to 600 Pa;
- Class C: Low requirement applications. The assembly shall be watertight up to 300 Pa.

A.12 Air Permeability

A.12.1 Principle

Where required, the air tightness of a sandwich panel assembly shall be tested according to EN 12114 including the following additional requirements.

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 x 2 400 mm.

The joints of the modules comprising the test assembly shall be representative, i.e. the same length per m² as in 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 m³/m²·h at 50 Pa.

A.13 Airborne Sound Insulation

A.13.1 Principle

Where required, the airborne sound insulation of a sandwich panel assembly shall be tested in accordance with ISO 140-3 including the following additional requirements.

A.13.2 Apparatus

The test apparatus shall be in accordance with ISO 140-3.

A.13.3 Test Specimens

The mounting of the test specimens in the test opening shall conform to 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 ISO 140-3.

A.13.5 Calculations and results

The following single number rating shall be declared in accordance with ISO 717-1: $R_W(C;C_{tr})$.

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 conform to 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 (α_w) in accordance with ISO 11654.

A.15 Support Reaction Capacity at the End of a Panel

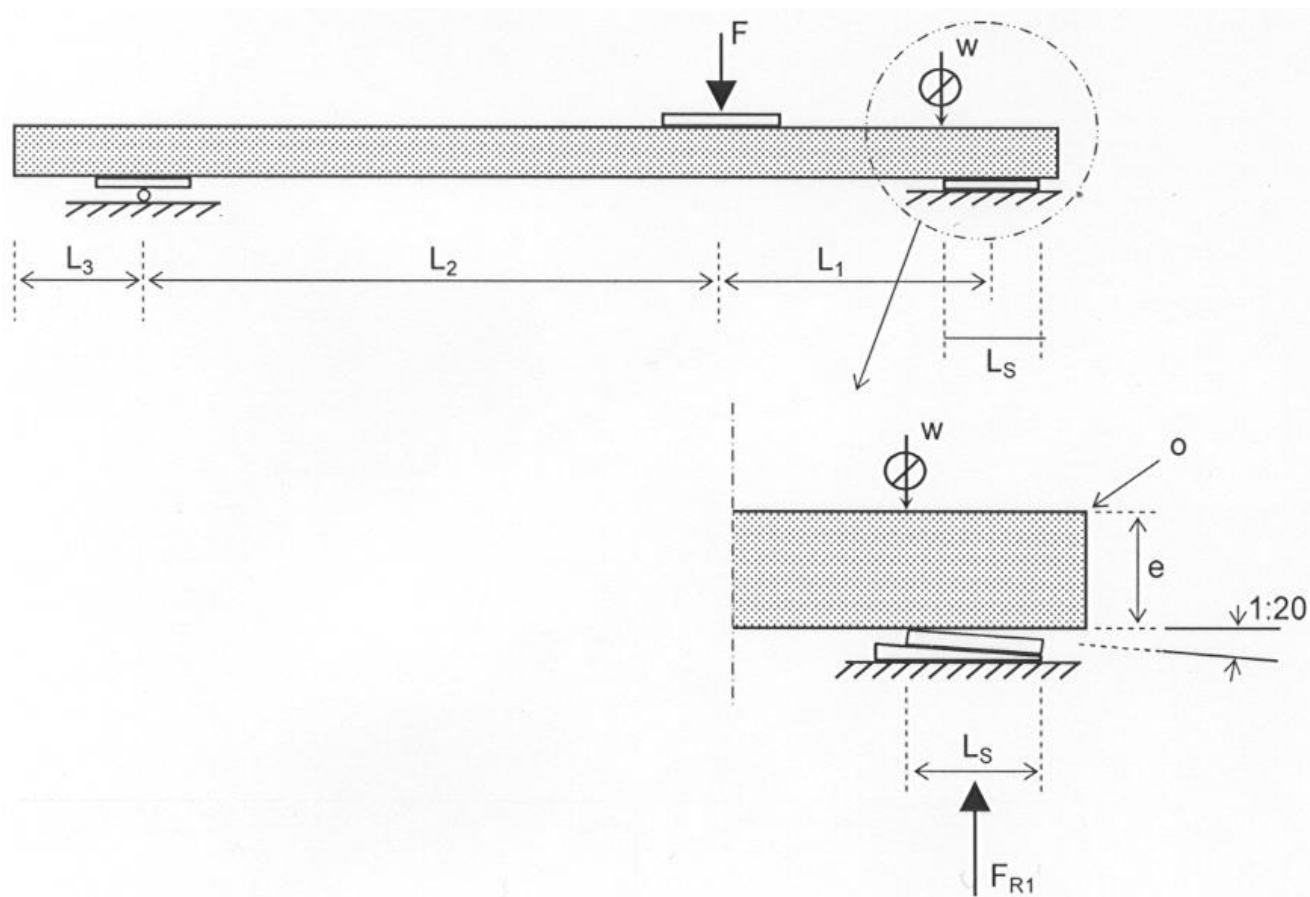
A.15.1 Principle

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 according to 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_1 shall be $> 1.5e$.

**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

Figure A.22 – Test arrangement for the determination of the resistance for the end support reaction

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

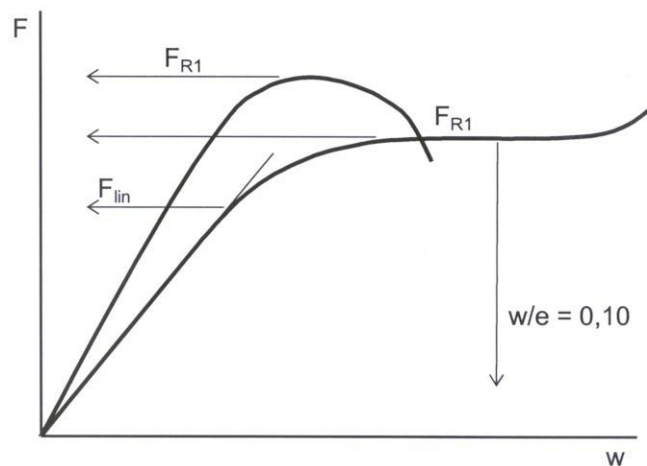
The rate of loading shall be such that the ratio w/e rises by between 1 % and 3 % per minute. A minimum of three tests shall be carried out at each support width. The compressive strength f_{cc} of the core material of the test specimen shall be determined according to A.2.

The test value of reaction capacity, F_{R1} , shall either be measured by a load cell or calculated by

Equation (A.30):

$$F_{R1} = \frac{L_2}{L_1 + L_2} F_u$$

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).



Key

- F support reaction
- F_{in} 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_{cd}/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 :

$$F_{R1} = B (L_s + 0.5 k e) f_{Cc} \quad (\text{A.31})$$

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 of the core following initial type testing;

k is the distribution parameter.

Therefore, the distribution parameter k shall be determined according to Equation (A.32):

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$$k = \frac{2(F_{R1} - f_{Cc} B L_s)}{f_{Cc} B e}$$

(A.32)

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A.16 Recording and Interpretation of Test Results

A.16.1 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) Date and time of manufacture;
- b) Method of manufacture and orientation of panel during manufacture (e.g. which face was uppermost, which was the leading edge during continuous foaming);
- c) Date of testing;
- d) Conditions during testing (temperature and humidity);
- e) Method of loading and details of instrumentation;
- f) Support conditions (number and length of spans, width and details of supports, number and details of connections to supporting structure etc.);
- g) Orientation of panel during testing;
- h) Type and properties of face material (thickness, yield stress, geometry etc.);
- i) Type and properties of core material (density, strength, moduli etc.);
- j) Type and details of adhesive;
- k) Measurements made during testing (load, deflection readings, temperature etc.); and
- l) 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.16.2 FPC Tests

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

- a) Date of manufacture;
- b) Method of manufacture and orientation of panel during manufacture;
- c) Date of testing;
- d) Orientation of panel during testing;
- e) Type and properties of face material (thickness, yield stress, geometry etc.);

- f) Type and properties of core material (density, strength, moduli etc.);
- g) Type and details of adhesive;
- h) Measurements made during testing (load, deflection readings, temperature etc.);
- i) 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.16.3 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 following procedure. 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 according to Equation (A.33):

$$x_p = e^{(\bar{y} - k\sigma_y)} \tag{A.33}$$

where x_p is the 5% fractile value of population x ;

$$y = L_n(x)$$

\bar{y} is the mean value of y (A.34);

k is the fractile factor given in Table A.4;

σ_y is the standard deviation of y (A.35).

$$\bar{y} = \frac{1}{n} \sum_{i=1}^n L_n(x_i) \tag{A.34}$$

$$\sigma_y = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (L_n(x_i) - \bar{y})^2}$$

(A.35)

Table A.4 – Fractile factor *k* assuming a confidence level of 75%

Number of specimens (<i>n</i>)	3	4	5	6	7	8	9	10	15	20	30	60	100
<i>k_σ</i>	3,15	2,68	2,46	2,34	2,25	2,19	2,14	2,10	1,99	1,93	1,87	1,80	1,76

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. The 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 ISO 29766 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, Table 2).

The test shall be carried out at one of the three temperature levels (T) that reflect the maximum temperatures that may be reached in end use, according to the colour of the exposed facing:

- test temperature 90 °C for dark colours;
- test temperature 75 °C for light colours;
- test temperature 65 °C for very light colours.

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

B.2.2 Apparatus

- 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 %).
- 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 x 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 commencing 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 according to ISO 29768.

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_{C10} 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, $T = 90\text{ °C}$, 75 °C , or 65 °C , as defined in B.2.1.

The test program shall be as follows:

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

Set 2: Condition for 6 weeks at $T\text{ °C}$ followed by tensile test;

Set 3: Condition for 24 weeks at $T\text{ °C}$ followed by 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_{C16} or f_{C124} , whichever is lowest, shall not be less than 50 % of the initial tensile strength value f_{C10} ;
- the mean value of tensile strength f_{C16} or f_{C124} , whichever is lowest, of the samples with T °C shall be not less than 0,02 MPa;
- the change of thickness of the sections at T °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 ($T = 90$ °C test);
- Durability pass: suitable for light and very light colours. Reflectivity 40-90. ($T = 75$ °C test);
- Durability pass: suitable for very light colours only. Reflectivity 75-90. ($T = 65$ °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, Table 2).

The effect of ageing (durability) shall be measured by determining the change in tensile strength in accordance with ISO 29766 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

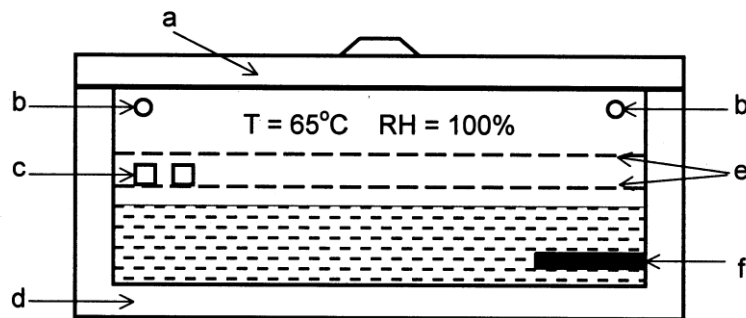
The humidity test shall be carried out using the DUR2 test chamber.

B.3.2.1.1 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.



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 ISO 29768 having 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 commencing 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 according to ISO 29768.

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_{C10} 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

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

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

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

Set 4: Maintain under constant conditions for 56 d at (65 ± 3) °C and 100 % RH (B.3.2.1) followed by 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 7, 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_{C10} ; after conditioning for seven days as f_{C17} ; and after 28 days as f_{C28} .

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 days shall be tested. The strength value obtained shall be denoted as f_{C156} .

B.3.5 Test results and acceptance criteria – DUR2

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

- $f_{C17} - f_{C28}$ shall be equal to or smaller than $3 (f_{C10} - f_{C17})$;
- f_{C28} shall not be less than 40 % of f_{C10} .

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

$f_{C28} - f_{C156}$ shall be less than $f_{C17} - f_{C28}$ and

f_{C156} shall not be less than 40 % of f_{C10} .

B.4 Test report on durability tests

The test report shall include the following information:

- a) reference to this European Standard, i.e. EN 14509;
- b) 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;
 - 8) other information as appropriate, e.g. nominal thickness, nominal density, the conditions under which the product was stored and transported before arriving at the laboratory;
- c) test procedure:
 - 1) conditioning;
 - 2) any deviations from this European Standard (B.2 and B.3);

- 3) 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;
- 5) factors which may have affected the results:
 - i) corrosion of the exposed samples;
 - ii) interruptions in the cycling test programme and the treatment of specimens during these;
 - 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) 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.);
 - ii) any corrosion of the test specimens;
 - 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.

Dimensions in millimetres

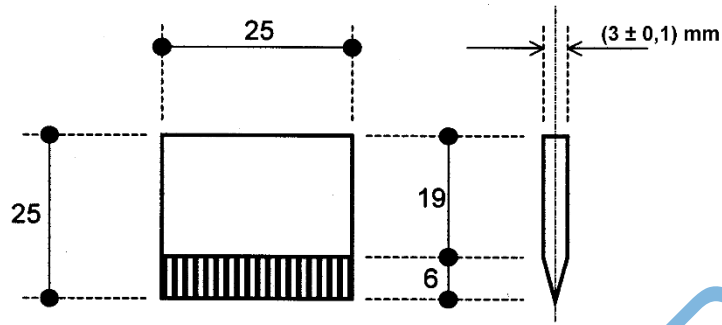


Figure B.2 – Wedge test – aluminium or stainless steel wedge

B.5.3 Test specimens

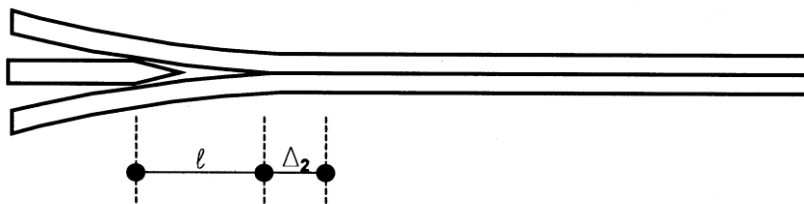
Five specimens shall be used for the wedge test. The test specimens shall be fabricated from two strips of the face material with a width of 20 mm and a length of 100 mm.

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, the strips shall be cut 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 (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.



Key

l	initial crack length (mm)
Δ_2	crack growth after exposure (mm)

Figure B.3 – Wedge test using aluminium or stainless steel wedge

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 (Table 2). 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 according to A.5 (5 % fractile value) to reach the wrinkling stress at the serviceability limit state, i.e. the characteristic value divided by $\gamma_F \gamma_M$, where γ_F is the load factor for variable actions and γ_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 γ_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.

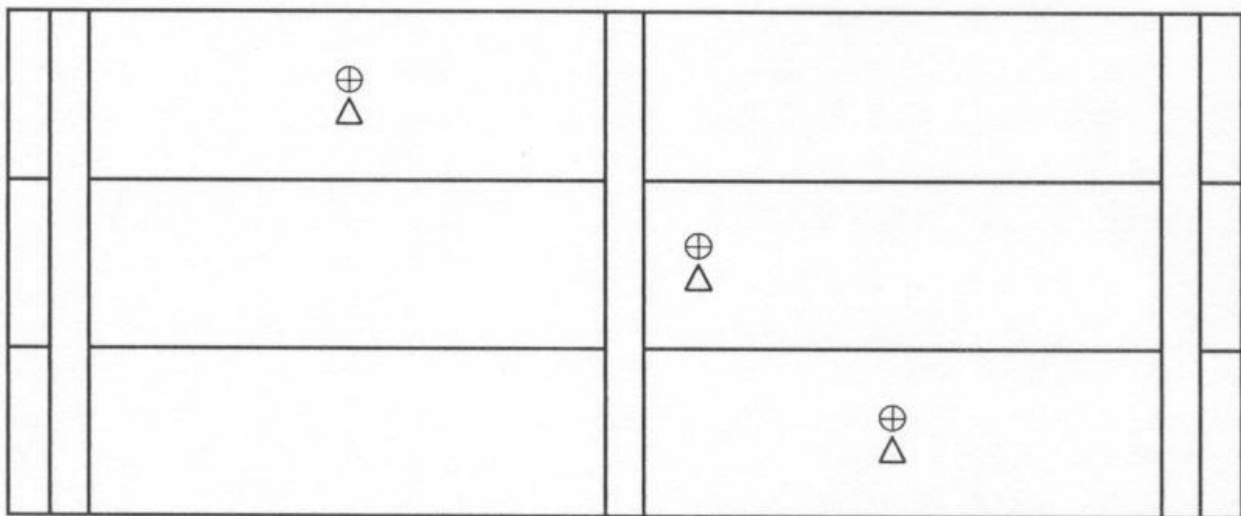
B.7 Thermal shock test

B.7.1 Principle

The thermal shock test is part of the durability assessment procedure for sandwich panels identified in 5.2.3.1 (Table 2). 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
 Δ 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.

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 Reaction to fire

C.1.1 Fire test EN 13823 (SBI) – specimens and mounting and fixing

C.1.1.1 General

All sandwich panel products, including roof, ceiling and horizontal wall types, shall be tested vertically in the test rig with a vertical panel-to-panel joint on the long wing.

For sandwich panels used in external roof and wall applications, the internal face and/or the external face shall be tested, depending on the end use conditions and the regulatory requirements in the Member State of use.

For internal end use applications, where both faces may be exposed to the internal fire, the following shall apply:

- products with similar facings (e.g. same metal type, profile and coating – see Table C.1) shall be tested on one side only;
- products with asymmetrical or dissimilar facings (e.g. different types of material, profile geometry, or coating – see Table C.1) shall be tested at both sides.

C.1.1.2 Specimen

The dimensions of the specimens shall be:

Short wing.	Panel size:	(495 ± 5) mm	x 1,5 m \pm 5 mm (height)
Long wing.	Panel sizes:	a) $(200 + D \pm 5)$ mm	x 1,5 m \pm 5 mm (height)
		b) (795 ± 5) mm	x 1,5 m \pm 5 mm (height)
		and $(a + b) (1\,000 + D)_{-5}^{+0}$ mm	

where D is the thickness of panel.

NOTE The maximum panel thickness that can be accommodated in the rig is 150 mm. This is measured at the thickest point of the panel and allows for a minimum 35 mm gap between specimen and backing board behind the panel.

The test specimen shall always include both panel facings.

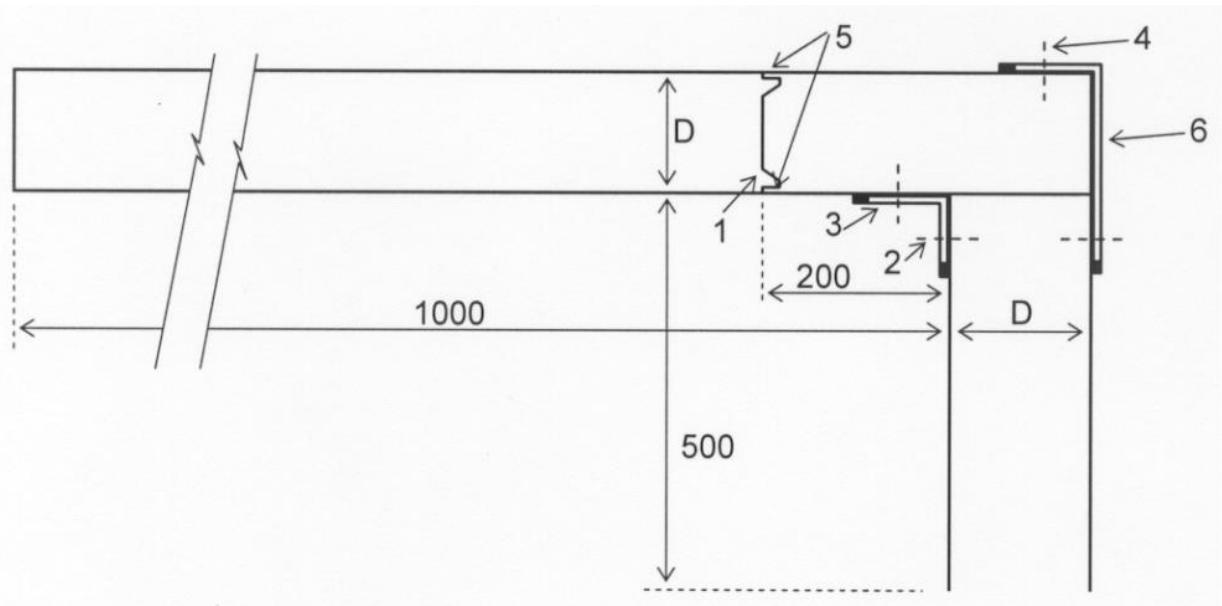
In cases where the profile depth of the face to be tested is between 10 mm and 50 mm, the facing shall be cut away to extend over the U-profile – see C.1.1.3.1.4 and Figure C.2.

C.1.1.3 Mounting and fixing

C.1.1.3.1 General configuration

C.1.1.3.1.1 General

Sandwich panels shall either be installed and fixed as described in EN 13823 in the configuration shown in Figure C.1 and in accordance with C.1.1.3.1 and C.1.1.3.2, or installed in a manner representative of their end use application(s).



Dimensions in mm

Key

D- panel thickness

1- panel joint with factory applied seals

2- screws or pop rivets every 400 mm

3- internal corner flashing

4- screws or pop rivets every 400 mm

5- screws, pop rivets or fixing plate

6- external corner flashing

Figure C.1 – Assembly and corner detail for standard assembly, fire test EN 13823

C.1.1.3.1.2 Corner flashings and seals

- a) Standard assembly – steel corner flashings:
 - The two panels forming the long wing shall be assembled with the joint secured according to C.1.1.3.2;
 - The cut edge of the short wing panel shall be placed against the long wing assembly to form an internal corner so that the vertical joint on the long wing is 200 mm from the internal corner. The two wings shall then be secured at 90° to each other using internal and external corner flashings and steel screws or 'pop' type rivets at 400 mm spacing. Positioning of the fixings measured from the bottom of the specimen shall be at the following centres: 50 mm; 450 mm; 850 mm; 1 250 mm and 1 450 mm (see Figure C.1);
 - Steel corner flashings shall have the following dimensions:
 - internal flashing: 50 mm x 50 mm x 0,5 mm or 0,6 mm thickness;
 - external flashing: 50 mm x (*D* + 50) mm x 0,5 mm or 0,6 mm thickness;

- The internal corner flashing shall have the same coating as the panel specimen;
- The cut panel edges at the top and sides and bottom of the specimen shall not be covered by flashings, foil or other materials.

b) Alternative corner flashings and seals – assembly in end use configuration:

Where required for specific end use applications, alternative corner flashings i.e. aluminium, plastic shall be used in the EN 13823 test. Internal seals, e.g. cold store vapour seals which are normally applied on site, shall also be incorporated into the assembly. The materials used in the tests shall be representative of those used in the end use application.

The type of alternative materials, dimensions, fixing centres, coatings etc shall be recorded on the test report.

Panels used without corner flashings in end use shall be tested in accordance with EN 13823 without flashings. This shall be recorded on the test report.

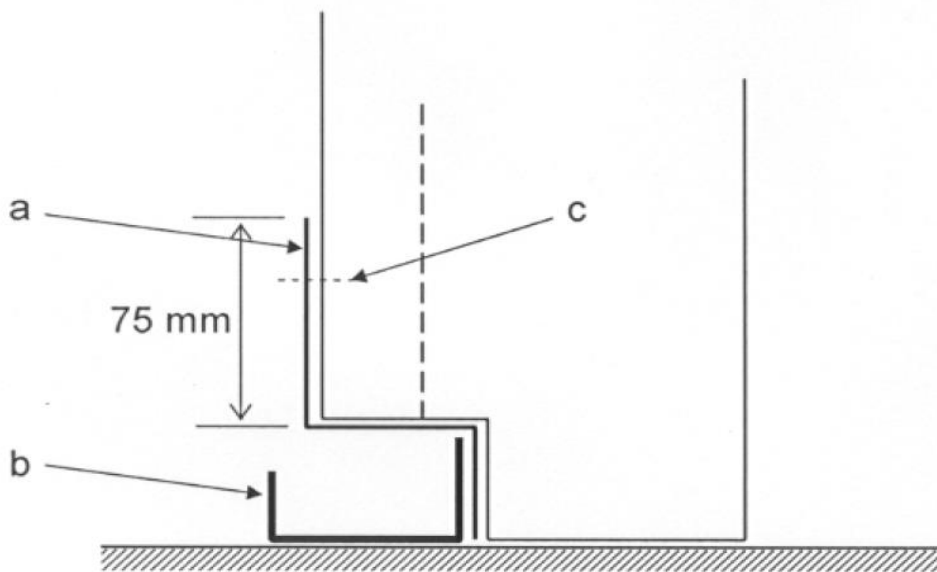
NOTE The assembly may be prepared and fixed together away from the test chamber. The complete assembly can then be placed on the trolley.

C.1.1.3.1.3 Backing boards and air gap

Backing boards shall be placed in accordance with EN 13823 with a minimum 35 mm distance between board and the panel specimen using a spacer bar at top and bottom. The frame between backing board and specimen shall be open to allow ventilation into the gap.

C.1.1.3.1.4 Profiled facings

Non-flat products, where the facing to be tested is profiled, shall be tested in such a way that not more than 30% of a representative area of 250 mm "square" of the facing to be tested, i.e. $B > 0.7 \times A$ in Figure D.1, is more than 10 mm behind the vertical plane through the rear side of the U-profile. Non-flat products shall be reshaped (cut-back) to partly extend over the U-profile to the side of the burner to fulfil this requirement (see Figure C.2). A product shall not extend over the burner (i.e. maximum extension over the U-profile is 40 mm). The cut section shall be covered with a flashing manufactured from the same material as the face to be tested.



Key

a - Cover flashing

b - U-profile

c - fixing

Figure C.2 – Cut-back of profiled facing over U-profile

C.1.1.3.2 Securing the panel to panel joint

The following principles shall apply when securing the panel joint on the long wing:

- Panels that are normally fixed to spaced structural supports i.e. in external roof and wall applications, shall be mounted in one of the following ways:
 - by using rivets or screw fixings to hold the panel joint in place. This represents the tight joint achieved in end use. Fixings shall be placed 40 mm from the top and bottom of the specimen (within the aperture dimensions formed by the upper board and lower 'U' section). Both internal and external facings shall be secured. The internal face shall be secured first;
 - for panels where the joint design does not allow a screw type of fixing to be used, a thin plate fixing of maximum size 100 mm x 20 mm x 2 mm may be used to hold the joint tightly together.
- Sandwich panels that are normally held together with an internal locking system, i.e. some cold store panels, shall be fixed together using the locking method.

NOTE If the locking system does not hold the joint together over the whole length of the specimen, an additional fixing may be used at either the top or bottom of the specimen.

C.1.2 Fire test ISO 11925-2 (ignitability test)

C.1.2.1 Specimen

The dimensions of the specimens shall be in accordance with ISO 11925-2.

Where the thickness of the sandwich panel is greater than 60 mm, the specimen shall be prepared by reducing the thickness to 60 mm by cutting away the unexposed external face of the panel and some of the insulation. The facing may be replaced with a flat steel sheet adhesively bonded to the 60 mm specimen.

For applications where the cut edges are protected in end use, metal flashings may be used in the test to cover the cut edge and shall be prepared to suit the thickness of the specimen (see C.1.2.2 b)).

In certain end use applications the cut edges are protected by flashings manufactured from other materials, e.g. plastics, that are different to the metal facings of the sandwich panel. For these applications specimens shall be prepared with the end use flashing covering the cut edge to be tested (see C.1.2.2 b)).

C.1.2.2 Method

Testing shall be in accordance with end use conditions, where the insulating core may be unprotected or protected by flashings.

- a) Method for unprotected applications without flashings:

The flame shall be applied both to the end (cut edge) representing all applications and to the surface of the specimen.

The surface flame attack shall be as described in ISO 11925-2.

The cut-edge flame attack shall be carried out on the middle of the thickness of the insulating core (specimen turned 90°). For this European Standard, other layers i.e. adhesive shall be considered non-substantial and shall not be tested individually.

b) Method for applications with protective flashings:

The flame shall be applied both to the surface of the specimen and to the protected cut edge of the specimen.

C.1.2.3 Results

The results shall be recorded for both surface and edge flame attack test methods.

The results shall be valid as follows:

- a) For tests where the edge flame attack is on the unprotected edge, the classification shall be valid for all end use applications;
- b) For tests where the edge flame attack is on an edge protected by steel flashings, the classification shall be valid for all steel protective flashings;
- c) For tests where the edge flame attack is on an edge protected by other types of flashings e.g. plastic, aluminium, the classification shall be valid for the type of flashing tested and also for steel protective flashings.

NOTE 1 The manufacturer may declare any number of alternative classification values with associated definitions.

The classification shall be accompanied by a note describing the materials tested:

- In case a) above - 'Classification result' (all end use applications);
- In case b) above - 'Classification result' (with steel protective flashings);
- In case c) above - 'Classification result' (with (e.g. plastic PVC 2 mm) protective flashings).

NOTE 2 Protected edge flashings should be of the same material as the corner flashings, where they are used in EN 13823.

C.1.3 Direct field of application of reaction to fire test results

The direct field of application of the reaction to fire tests for the standard parameters for sandwich panels described in Table C.1 shall apply.

Table C.1 – Reaction to fire: Direct field of application of test results

Parameter	Factors	Validity of test
Metal facings	Grade of metal	Valid for all grades of tested metal type
	Thickness of metal facing excluding organic coatings	Valid for all thicknesses between tested thickness and up to +100 % of the tested thickness
	Profile geometry of inside facing a) flat or light profiling up to 5 mm b) profiles greater than 5 mm	Valid for other types of flat or light profile Valid for any profiles of greater profile depth
	Surface coating – tested face a) PCS value 0 to 4 MJ/m ² b) PCS value > 4 MJ/m ² c) colour of coating	Valid for all coatings in the range 0 to 4 MJ/m ² Valid for PCS values lower than that tested within manufacturing tolerances Valid for all colours
Joint design		Valid within normal tolerances (see 5.2.5). Not valid for changes of shape or configuration
Adhesive (where relevant)	Amount and type of adhesive	Valid for same amount of adhesive (same PCS) or lower Valid for PCS values lower than the tested adhesive within manufacturing tolerances
Seals and gaskets	Seals and gaskets (integral with panel)	Valid only for the types of joint seals and gaskets tested and for those of equal or lower PCS value
MW insulating core	a) density ^a	Valid for ± 15 % of tested density
	b) orientation of fibres – lamella or slabs	Not valid for change of orientation
	c) joints between lamellas	Valid for change in the number of joints
	d) MW fibres and binders	Valid for same type of fibre with same PCS or lower of the tested binder
PUR, XPS, EPS, PF insulating core	a) chemical composition	Valid for the same chemical system and blowing agent
	b) density ^a	Valid for ± 15 % of tested density

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Table C.1 (concluded)

Thickness of panel (<i>D</i>)	a) panels < 100 mm thickness	Valid for ± 15 % of tested thickness (single test) Where the same panels are produced in different thicknesses, both the maximum and minimum thickness shall be tested and the lowest classification declared
	b) panels ≥ 100 mm thickness	The results from specimens $100 \leq D < 150$ mm in thickness shall be valid for any panel greater than 100 mm in thickness
Orientation of panels	Vertical or horizontal application of sandwich panels	Test (vertical) is also valid for horizontally installed all panels and ceiling applications
Metal corner flashings ^b		Valid for end use flashings of same material as that tested and of at least the same width and thickness Tests carried out with no corner flashings or steel flashings shall be valid for all types of steel flashings
Plastic corner flashings		Valid for end use flashings of the same material; no flashings; or metal flashings
Protection over cut edges (C.1.2)	a) no flashings in EN ISO 11925-2	Valid for all end use applications
	b) plastic or other flashings	Only valid for the same material as that tested
Fixings for metal flashings	Standard spacing is 400 mm	Valid for fixing spacing of 400 mm or less
Seals ^c	Seals which are applied in end use but not part of the manufactured panel	Valid for seals of the same type as tested or seals with the same or lower PCS
<p>^a Density: Where the same panels are produced in different densities, the maximum and minimum density shall be tested. The lowest classification or a classification together with its associated density shall be declared.</p> <p>^b Flashings: The flashing dimensions and metal thickness stated in C.1.1.3.3 represent the minimum thickness and dimension in end use. Results are valid for any metal flashing of greater thickness or dimension used in practice.</p> <p>^c Seals: Where seals are incorporated during the manufacture of the sandwich panel they shall be tested as part of the product in accordance with EN 13823.</p>		

C.2 Fire resistance

C.2.1 Test thermocouples and time temperature curve

Additional thermocouples of a conventional type shall be used during the first five minutes in accordance with the procedure specified in the note to 5.1.2 of EN 1363-1:1999.

NOTE Ideally, a smooth transition should be made taking a maximum of five minutes before full control by plate thermometers. If the furnace control system does not allow this, then a sudden transition can be made. With care, if both control systems are set to follow the time temperature curve specified in EN 1363-1, the resulting time-temperature curve, as measured by the plate thermometers, should be within the tolerances allowed by EN 1363-1.

C.2.2 Fire resistance test EN 1365-2 – Roofs

C.2.2.1 General

Sandwich panel roofs may be subject to superimposed loads. Only in exceptional designs (e.g. acting as diaphragms) do they carry part of the primary load of the building structure.

Loading in accordance with the EN 1363-1 and EN 1365-2 test refers to superimposed loads only.

C.2.2.2 Apparatus

The framework shall be designed to support the panel assembly as in end use. Panels shall be fixed to the framework on two sides at either end of the panel. The other two sides shall be unrestrained.

The specimen shall be tested in the horizontal position.

C.2.2.3 Procedure

The applied load shall be in accordance with national regulations valid in the country of use and determined according to EN 1365-2 for the end use condition or without loading.

C.2.2.4 Results and declaration

The load shall be declared with the fire resistance classification.

C.2.3 Field of application of fire resistance test results

The field of application of the fire resistance test results for the standard parameters for sandwich panels described in Table C.2 shall apply.

Table C.2 – Fire resistance: Direct field of application of test results

Parameter	Factors	Validity of test
Metal facings	Grade of metal	Valid for all grades of tested metal type
	Thickness of metal facing	Valid up to $\pm 50\%$ of the tested thickness
	Profile geometry of facing	Valid for any profile change Valid for variations $+ 50\%$ of profile depth
	a) flat or small profiling up to 5 mm b) profiles greater than 5 mm	
	Surface coating – tested side	Valid for all coatings
a) colour of coating b) un-coated facings	Valid for all colours Tests on coated facings are not valid for un-coated facings	
Joint design		Valid within normal tolerances (see 5.2.5) Not valid for changes of shape or configuration

Table C.2 (concluded)

Adhesive (where relevant)	Amount and type of adhesive a) PCS value 0 to 4 MJ/m ² b) PCS value > 4 MJ/m ² c) PCS > 4MJ/m ² and > 1,15*PCS	Valid for all adhesives ± 50 % of mass tested Valid for PCS values lower than the tested adhesive within manufacturing tolerances Test results reduced by the same % as the PCS value over the initial tested adhesive
Seals and gaskets (integral with panel)		Valid only for the types of joint seals and gaskets tested and for those of equal or lower PCS value
MW	a) MW fibres and binders b) density c) orientation of fibres – lamella or slabs d) joints between lamellas	Not valid if the MW fibres or binders used differ from the original tested materials Valid for increase in binder content + 20 % or for lower quantities of binder Valid for all densities greater than that tested in the density range 50 kg/m ³ to 150 kg/m ³ Valid to down to –10 % of tested density Not valid for change of orientation Valid for reduction in the number of joints
PUR	Chemical composition	Valid for the same chemical system and blowing agent Valid for ± 10 % of tested density
PF	Chemical composition	Valid for same chemical composition, density and blowing agent
Thickness of panel	Increase of panel thickness	Valid for any increase in thickness using the same insulating core material
Orientation of panels	Vertical or horizontal joints between sandwich panels	Valid for both orientations (EN1364-1:1999, 13.1 i))
Fixing distance and spans	a) External applications b) Internal applications	Valid for fixing centres and spans less than those tested Panels tested at 3 m are valid for applications up to 4 m spans providing the conditions in EN 1364-1 are satisfied
Width	a) decrease in panel width b) increase in panel width	Test valid (see EN 1364-1) Valid for increases not greater than + 20 %
Seals	Seals which are applied in end use but not part of the manufactured panel	Valid for that type of seal only and for those of equal or lower PCS value Valid for the same panels without seals for MW and CG cores. Not valid for other core materials

C.3 Fire tests ENV 1187 - external fire performance for roofs

C.3.1 Classification without further testing (CWFT)

The following types of roof panel have been approved for CWFT providing they are designed for external roof applications satisfying the specifications below and are subject to FPC controls for safety in fire characteristics (6.3.5.3).

Panels with a profiled external metal facing and a core material of PUR or MW incorporating:

- A return overlap extending 15 mm minimum down the opposite face of the crown (sidelap – longitudinal joint);
Or a metal cover cap completely covering the joint crowns at the longitudinal joint;
Or a raised standing seam at the longitudinal joint;
- Where applicable, an end overlap greater than or equal to 75 mm;
- A minimum nominal thickness for the external facing of 0,4 mm (steel and stainless steel) and 0,9 mm (aluminium) in accordance with 5.1.2.1, 5.1.2.2 and 5.1.2.3;
- A protective weather coating comprising a liquid applied PVC paint of maximum nominal dry film thickness 0,200 mm, a PCS of not greater than 8,0 MJ/m² and a maximum dry mass of 300 g/m²,
Or any thin paint coating less than the above;
- Minimum reaction to fire classification of the panel of D-s3,d0 without edge protection in accordance with EN 13501-1;
- A nominal core density > 35 kg/m³ for PUR insulating cores;
- A nominal core density > 80 kg/m³ for MW with lamella cores;
- A nominal core density > 110 kg/m³ for MW with full width board cores.

C.3.2 ENV 1187 Method 1 test

C.3.2.1 Specimens and mounting – side lap test

The specimens shall be cut so that the end of the overlap sheet is at least 250 mm from cut edge of panel.

Panels shall be fixed to three support sections (Top-hat or angles) at top, centre and bottom and side laps shall be stitched every 400 mm.

C.3.2.2 Specimens and mounting – end lap test

The specimens shall be cut to create an end lap so that the cut edge of the upper panel is positioned 750 mm from the lower edge of the specimen.

The panel at the end lap shall be fixed in each trough to a support angle with a minimum bearing surface of 75 mm and the overlap sheet shall be stitched in each trough 50 mm from the cut edge.

C.3.3 ENV 1187 Method 2 test

Specimens and their mounting shall be as specified in ENV 1187.

C.3.4 ENV 1187 Method 3 test

C.3.4.1 Specimens

a) Side lap plus end lap test:

The test specimen shall be made up from two part-panels with a central standard side-lap joint. The central line shall be the edge of the overlap not the edge of the panel. The left hand panel shall have a standard end lap situated 500 mm from the bottom edge.

b) Side lap test only:

The test specimen shall be made up from two full-length part-panels with a standard side-lap joint. The dimension to the cut edge of the overlap, not the edge of the panel, shall be 785 mm from the left hand edge.

C.3.4.2 Mounting and fixing

a) Side lap plus end lap test:

The panel at the end lap shall be fixed in each trough to a support angle with a minimum bearing surface of 75 mm and the overlap sheet shall be stitched in each trough 50 mm from the cut edge.

Panels shall be fixed to three support sections (Top-hat or angles) at top, centre and bottom and side laps shall be stitched every 400 mm.

b) Side lap test only:

Panels shall be fixed to three support sections (Top-hat or angles) at top, centre and bottom and side laps shall be stitched every 400 mm.

NOTE For the ENV 1187 tests, the position of the cut edge stated in the test requirements refers to the position of the edge of the overlapping top sheet and not the position of the panel joint underneath.

C.3.5 ENV 1187 Method 4 test

The specimen shall be prepared with a longitudinal panel joint positioned centrally.

Specimens shall be secured to a non combustible framework using standard fixings so that the joint is held rigidly, as in end use.

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 according to C.4.2.2 to C.4.2.5.

C.4.2.2 Specimen

A 500 mm x 500 mm specimen of the panel facing shall be cut (e.g. 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):

$$m_{\text{glue}} = (m_1 - m_2)/A \quad (\text{C.1})$$

where

m_{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); and

A is the area of facing sheet in square metres (m^2).

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

$$h_{\text{glue}} = m_{\text{glue}} / \rho$$

where

h_{glue} is the thickness of adhesive in millimetres (mm);

m_{glue} is the amount of glue in grams per square metre (g/m^2); and

ρ is the density of used glue in kilograms per cubic metre, i.e. density of uncured glue mixture, (kg/m^3).

C.4.2.5 Reporting

The test report shall contain the following information:

- a) Date of the test;
- b) Test method used;
- c) Panel code or specification;
- d) Place of the sample in the panel;
- e) Type of glue, glue batch (if known), density of the glue;
- f) Dimensions and area of the facing sheet; and
- g) 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 according to C.4.3.2 to C.4.3.3.

C.4.3.2 Procedure

Weigh a suitable carrier e.g. 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):

$$m_{(\text{adhesive})} = (m_{a+c} - m_c) / A \quad (\text{C.2})$$

where

m_{a+c} is the mass of the carrier and adhesive;

m_c is the mass of the carrier; and

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, Table 3 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. Prior to 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.

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

$D > 100 \text{ mm} \pm 2 \%$.

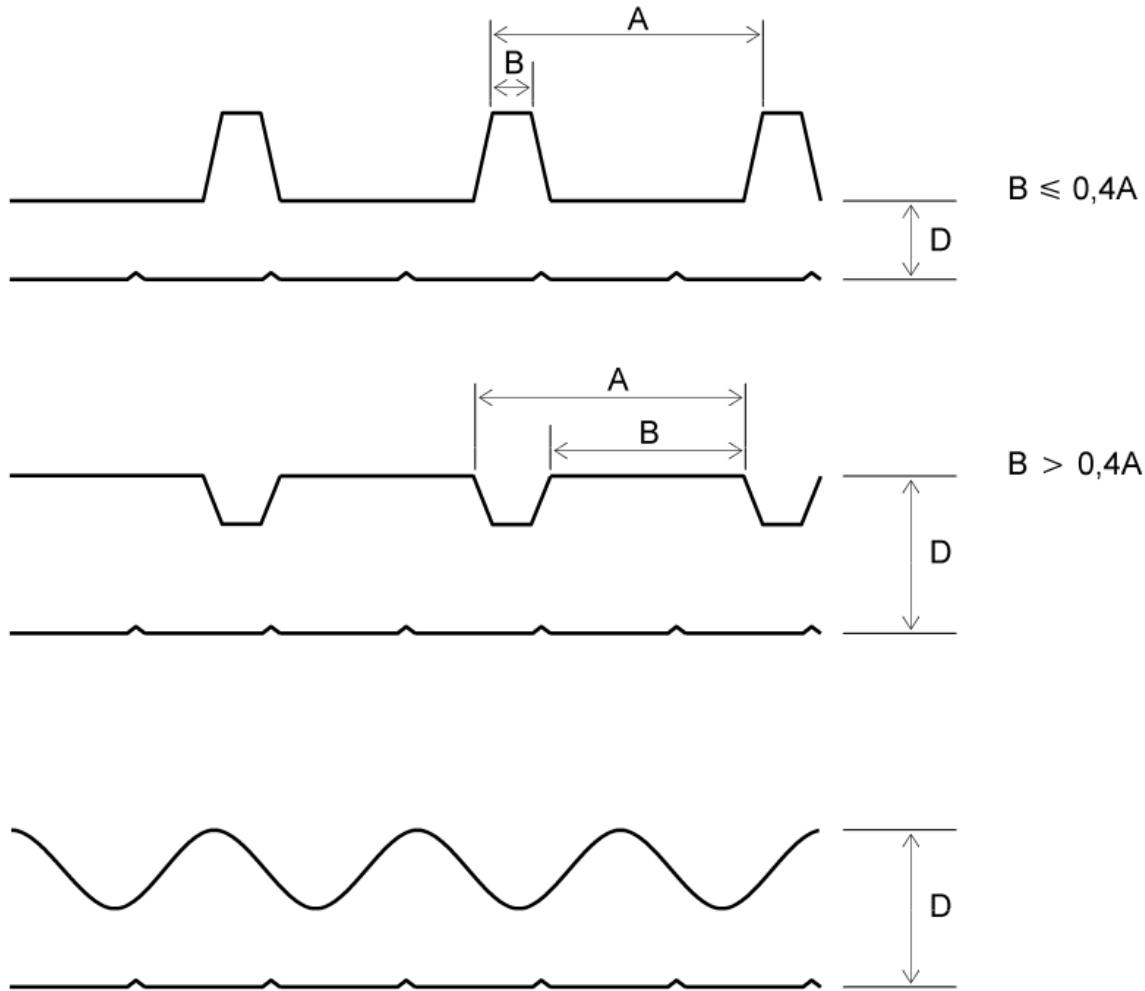


Figure D.1 – Thickness of panels

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 (l) 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.

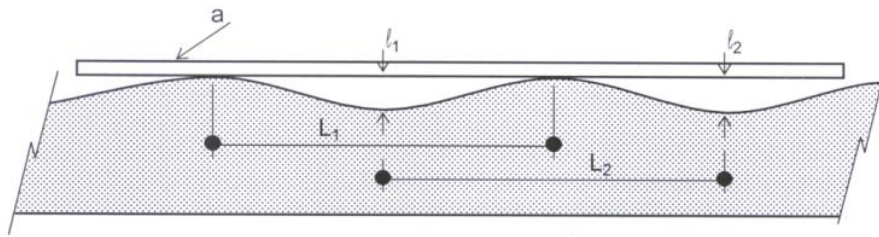
The location of the measured distance L shall be at least 100 mm from the edge of the panel and 200 mm from the end of the panel.

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 $l = 0,6$ mm;

For $L = 400$ mm $l = 1,0$ mm;

For $L > 700$ mm $l = 1,5$ mm.



Key

- L measured distance on flat plane
- l deviation from flatness
- a straight metal bar

Figure D.2 – Flatness

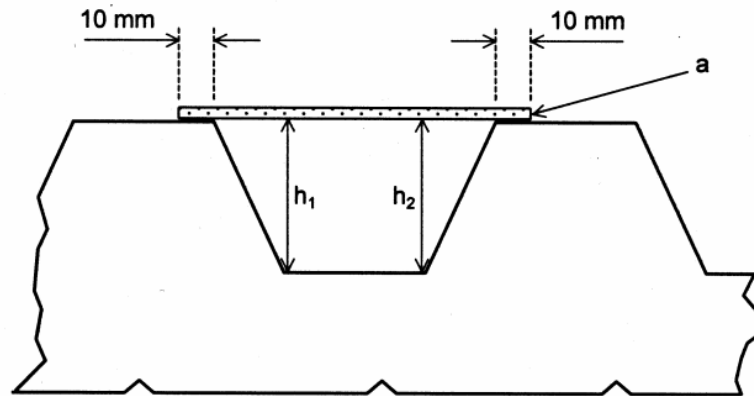
D.2.3 Depth of metal profile

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.

Tolerances:

$5 \text{ mm} < h \leq 50 \text{ mm} \pm 1 \text{ mm}$;

$50 \text{ mm} < h \leq 100 \text{ mm} \pm 2,5 \text{ mm}$.



Key

- a straight metal bar

Figure D.3 – Dimensional check for depth of profile h

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 , see Figure D.4), 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).

Tolerances:

$d_s \leq 1 \text{ mm} \pm 30\%$ of d_s ,

$1 \text{ mm} < d_s \leq 3 \text{ mm} \pm 0,3 \text{ mm}$,

$3 \text{ mm} < d_s \leq 5 \text{ mm} \pm 10\%$ of d_s .



Figure D.4 – Depth of stiffeners and light profiling

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.

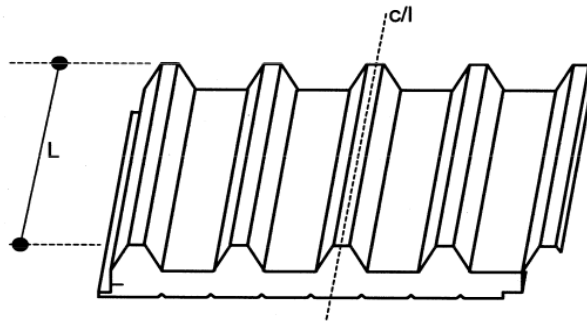
Tolerances:

$L \leq 3\,000 \text{ mm} \pm 5 \text{ mm}$;

$L > 3\,000 \text{ mm} \pm 10 \text{ mm}$.

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.



Key

c/l centre line of the panel

Figure D.5 – Sheet length

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 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 (see Figure D.14 for example of method).

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: ± 2 mm for all profiles.

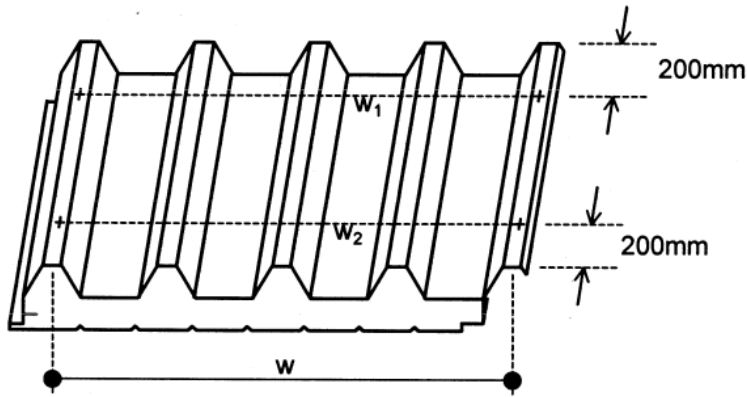


Figure D.6 – Cover width (w) of profiled panels

 Dimensions in millimetres

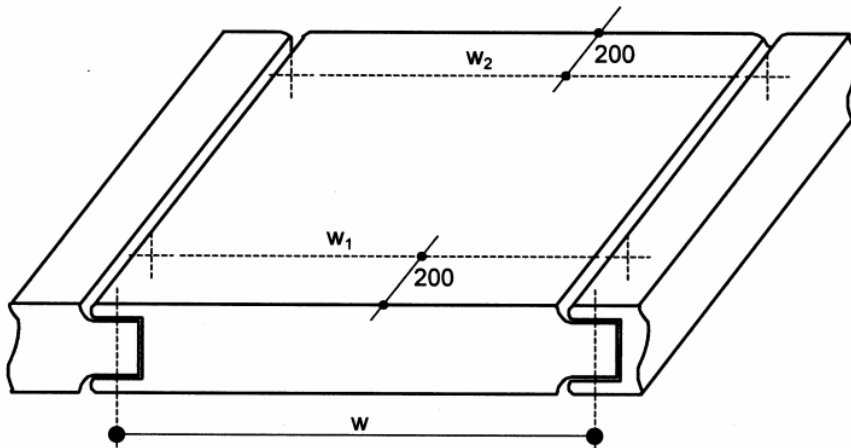


Figure D.7 – Design width (w) in the case of a male and female joint

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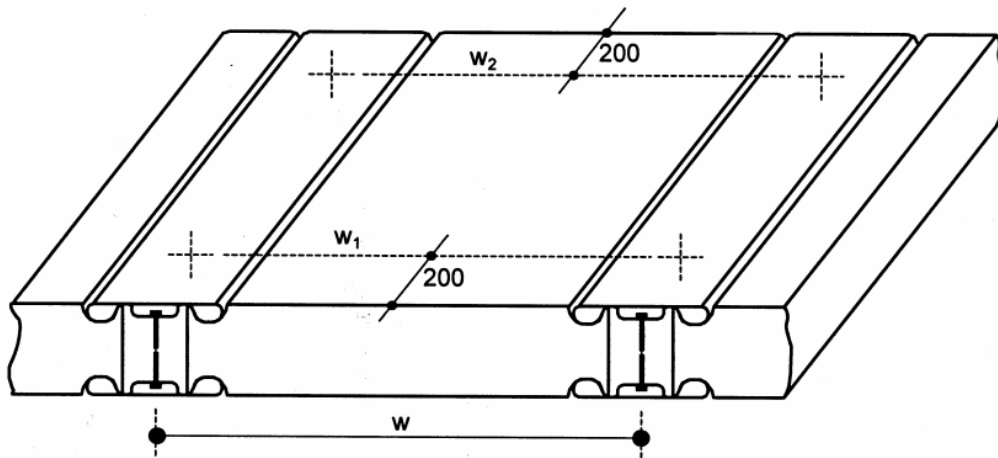
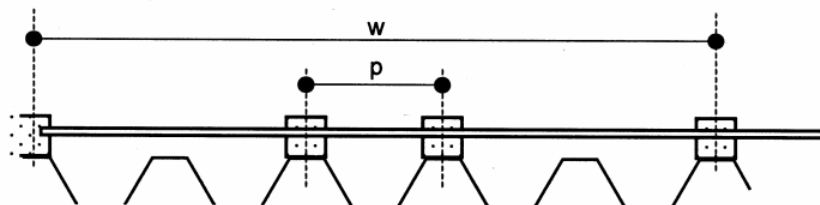


Figure D.8 – Measurement of cover width (w)



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 dimensions in Figure D.10.

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

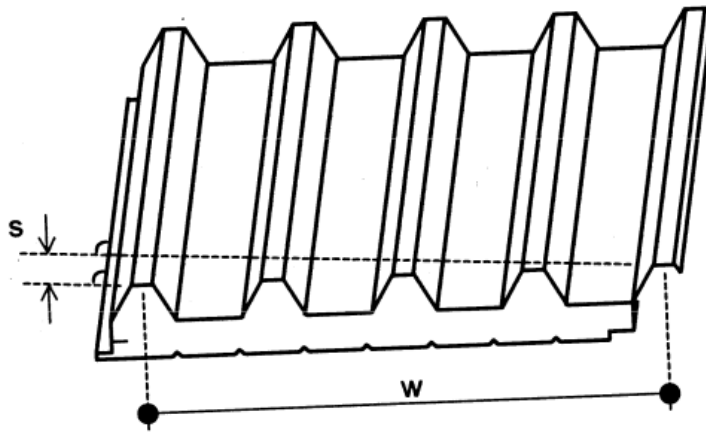


Figure D.10 – Squareness

D.2.8 Deviation from straightness

The deviation of straightness from the theoretical straight line is defined as the dimension δ 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.

Dimensions in millimetres

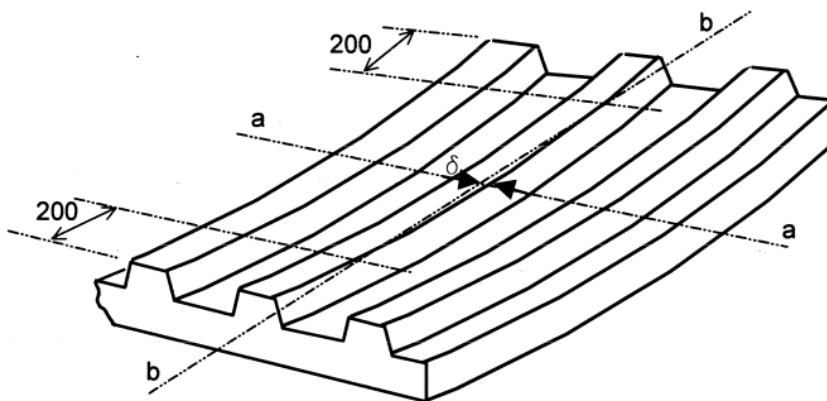


Figure D.11 – Deviation of straightness

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.

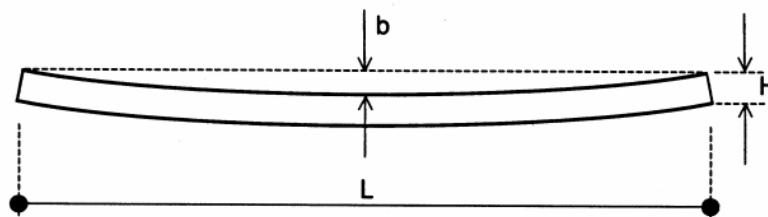
Tolerance: 2.0 mm for each metre length but not greater than 10 mm;

8.5 mm for each metre width for flat profiles – $h \leq 10$ mm (see D.2.3);

10 mm for each metre width for other depths of profile – $h > 10$ 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 e.g. 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 preferred:

- As the distance measured between two plates placed on the webs, as illustrated in Figure D.14;
- As the deviation from a template;
- By means of a profile gauge (see Figure D.9).

Tolerances:

where

$h \leq 50$ mm \pm 2 mm;

$h > 50$ mm \pm 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.

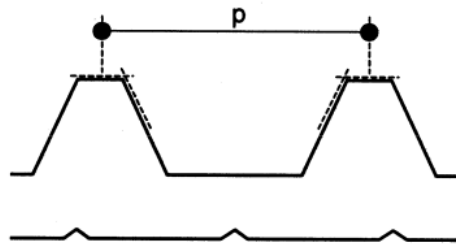


Figure D.13 – Pitch (p)

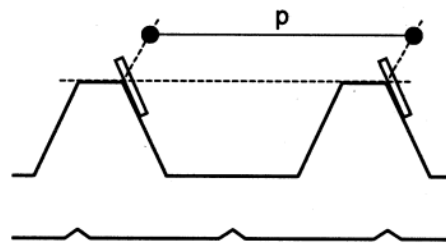


Figure D.14 – Dimensional check for pitch

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.

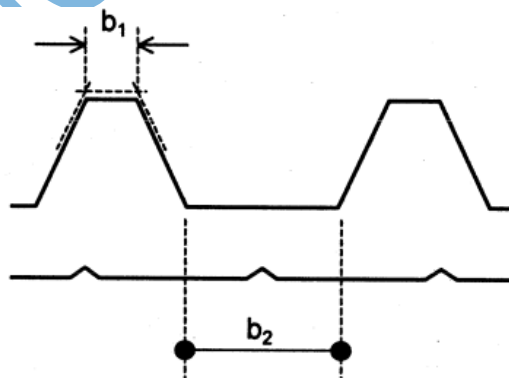


Figure D.15 – Widths of rib and valley

Annex E

(normative)

Design Procedures

NOTE This Annex supports mechanical resistance characteristics required by the 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 Figures E.1 a) and E.1 b) and Table E.1.

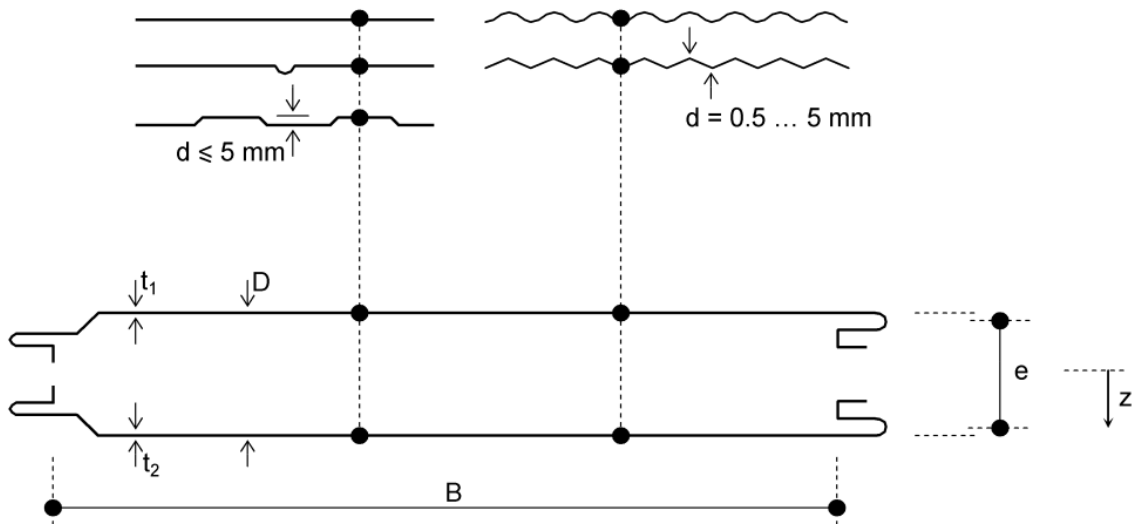


Figure E.1 a) – Panel cross-section, flat, lightly profiled or microprofile face

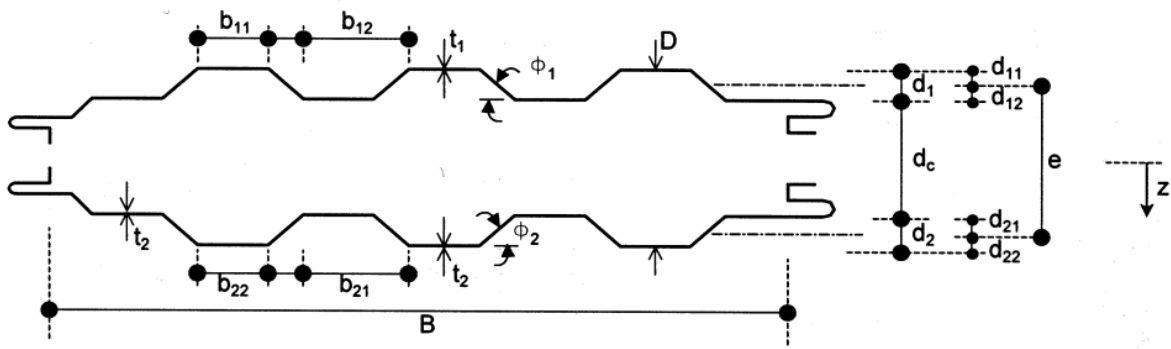


Figure E.1 b) – Panel cross-section, profiled face and material properties of a sandwich panel

Table E.1 – Panel properties

Layer	Geometry	Material properties	Structural properties
Face 1	$t_1, d_1, d_{11}, d_{12}, A_{F1}, I_{F1}$	E_{F1}, α_{F1}	B_{F1}
Core	d_c	E_c, G_c	S
Face 2	$t_2, d_2, d_{21}, d_{22}, A_{F2}, I_{F2}$	E_{F2}, α_{F2}	B_{F2}

E.1.2 Symbols used in Annex E

The following symbols apply to this Annex.

- 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_G)
- S shear rigidity, characteristic value of an action

- T temperature
- V shear force
- D depth of face profile or stiffeners, depth of core (d_c)
- 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 (Table E.10.2 design equations)
- φ angle
- γ partial safety factor, load factor (γ_F)
- ϕ creep coefficient
- θ parameter (Table E.10.1 design equations)
- σ stress, compressive strength σ_m , standard deviation τ shear stress
- ψ combination coefficient

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
- 1 external face, upper face
- 2 internal face, lower 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 γ_M .

It shall be verified by means of calculation and/or testing 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.

$E_d =$ the effect of $\sum \gamma_f \psi S_{ki}$ (E.3)

$R_d = \frac{R_k}{\gamma_M} =$ design value of the resistance at the ultimate limit state (E.4)

$C_d =$ 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 γ_M .

$S_{ki} =$ characteristic value of an action;

$\gamma_f =$ relevant load factor;

$\psi =$ relevant combination factor;

$\gamma_M =$ relevant material partial factor;

$R_k =$ calculated or experimental value of the characteristic resistance.

NOTE 1 The procedures which follow conform to the “European Recommendations for Sandwich Panels: Part 1: Design” [2] and present a sub-set of the more detailed procedures which are given in these Recommendations.

NOTE 2 This product standard is primarily concerned with the values of R_d and C_d . The load levels and the levels of safety may be specific to each Member State.

E.3 Actions

E.3.1 General

The actions in E.3.2 to E.3.4 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:

- Self-weight of the panel (calculated from the nominal dimensions and mean densities);
- Mass of any permanent components of the structure and installation that apply load to the panel;
- Permanent imposed deformations, e.g. 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 (e.g. due to access to a roof or ceiling);
- Wind loads;
- Construction loads;
- Climatic effects (e.g. 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.

NOTE The following characteristic resistance values are required in order to carry out design by calculation in accordance with this annex – see Table E.2.

Table E.2 – Characteristic resistance values

Characteristic resistance values	Clause	Test
Yield strength of the faces	5.1.2	
Shear strength of the core material	5.2.1.2	A.3 or A.4
Compressive strength of the core material (and/or support reaction capacity)	5.2.1.4	A.2 (A.15)
Shear strength after long-term loading (roof and ceiling panels only)	5.2.1.5	A.3.6
Wrinkling stress (positive and negative bending) at normal and higher temperature (or bending moment capacity for panels with one or two profiled faces)	5.2.1.7	A.5 and A.5.5.5
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)	5.2.1.8	A.7 and A.5.5.5

In addition, the following are required in order to carry out the necessary calculations – see Table E.3.

Table E.3 – Additional calculation requirements

Characteristic values	Clause	Test
Design thickness of the faces	E.7.3	
Shear modulus of the core material	5.2.1.2	A.3, A.4 or A.5.6
Creep coefficient (roof and ceiling panels only)	5.2.1.3	A.6

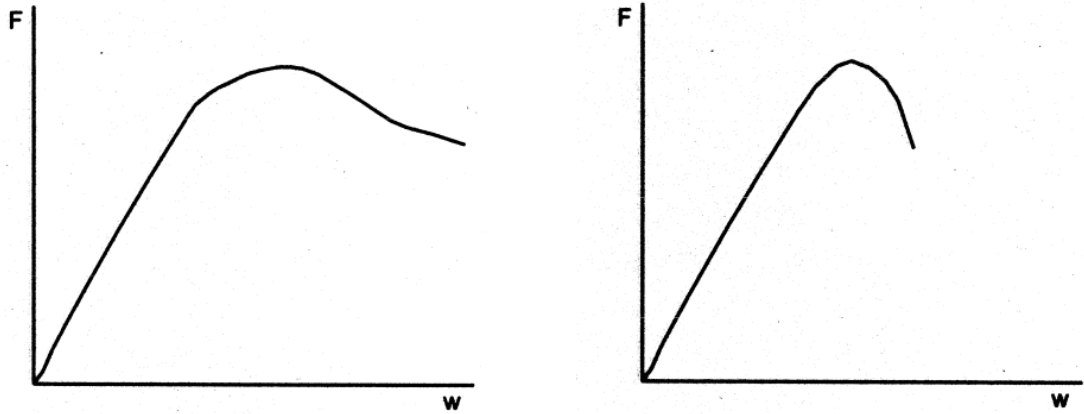
The comparison of the design values of actions and the design values of resistance according to E.2 is usually carried out in terms of stresses, which are determined from the stress resultants according to E.7.2.5 and E.7.2.6. Determination of the compressive strength (wrinkling stress) of a profiled face from the bending moment capacity of the panel requires a calculation for which the equations are given in E.7.5.2 (Table E.10.2).

E.4.2 Residual (rest) bending resistance at an intermediate support

If the load-deflection curve, determined according to 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° .



Key
F load
w deflection

**Figure E.2 a) – Load deflection curve
 (gradual failure with long drooping portion)**

**Figure E.2 b) – Load deflection curve
 (sudden failure with rapid loss of load)**

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.

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 according to E.4.3.2 or by tests on full width panels according to A.15.5.

The reaction capacity at an internal support shall be determined by calculation according to 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):

$$F_{R1} = B \times (L_S + 0,5 \times k \times e) \times f_{cc} \quad (E.5)$$

The capacity at an internal support shall be given by Equation (E.6):

$$F_{R2} = B \times (L_S + k \times e) \times f_{cc} \quad (E.6)$$

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 according to A.15.5, or the following values shall be used:

- For rigid plastic foams and cellular glass cores where $e < 100$ mm, $k = 0,5$;
- For rigid plastic foams and cellular glass cores where $e \geq 100$ mm, $k = 0,5$ with $e = 100$ 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 according to 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 and/or deflections 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;
- 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 according to EN 1990

Permanent actions G_d (self-weight etc.)	Variable actions Q_d	
	Dominant with its characteristic value	Others with their combination value
$\gamma_G \times G_k$	$\gamma_{Q1} \times Q_{k1}$	$\gamma_{Qi} \times \psi_{0i} \times Q_{ki}$

The design values in Table E.4 shall be combined in the following way according to Equation (E.7):

$$S_d = \gamma_G G_k + \gamma_{Q1} Q_{k1} + \sum_{i>1} \gamma_{Qi} \psi_{0i} Q_{ki} \quad (E.7)$$

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 $i (i > 1)$;
- γ_G is the partial safety factor for the permanent action;
- γ_{Qi} is the partial safety factor for the variable action i ;
- ψ_0 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 characterised 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;
- 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 γ_G and γ_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

Combination	Permanent actions G_d	Variable actions Q_d	
		Dominant	Others
Characteristic (rare)	G_k	Q_{k1}	$\psi_{0i} \times Q_{ki}$
Frequent	G_k	$\psi_{11} \times Q_{k1}$	$\psi_{0i} \times \psi_{1i} \times Q_{ki}$

a) Characteristic (rare) combination (for resistance at intermediate supports) according to Equation (E.8):

$$S_d = \sum_{j \geq 1} G_{kj} + Q_{k1} + \sum_{i > 1} \psi_{0i} Q_{ki} \tag{E.8}$$

b) Frequent combination (for deflections) according to Equation (E.9):

$$S_d = \sum_{j \geq 1} G_{kj} + \psi_{11} Q_{k1} + \sum_{i > 1} \psi_{0i} \psi_{1i} Q_{ki} \tag{E.9}$$

where

ψ_{0i} is the combination coefficient of a variable action i ($i > 1$) to be used in characteristic combinations;

ψ_{11} is the combination coefficient of the dominant action effect Q_{k1} to be used in frequent combinations; and

ψ_{1i} is the combination coefficient of the other action effects Q_{ki} ($i > 1$) to be used in frequent combinations.

Values for combination coefficients ψ_{0i} and ψ_{1i} 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 ψ_0 and ψ_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 E.6 – Values of combination coefficients ψ_0 and ψ_1

Combination coefficients	Factors		
	Snow	Wind	Temperature
ψ_0	0,6	0,6	0,6 / 1,0 ^a
ψ_1	0,75 / 1,0 ^b	0,75 / 1,0 ^b	1,0

^a Coefficient $\psi_0 = 1,0$ is used if the winter temperature $T_1 = 0$ °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 according to EN 1990, may be used when required by national regulatory requirements.

Table E.7 – Alternative values of combination coefficients ψ_0 and ψ_1

Combination coefficients	Factors		
	Snow	Wind	Temperature
ψ_0	0,5 or 0,7 ^a	0,6	0,6
ψ_1	0,2 or 0,5 ^a	0,2	0,5

^a The higher values of snow load coefficient are applicable to Finland, Iceland, Norway and Sweden (see EN 1991-1-3) and to the remainder of CEN Member States for sites at an altitude greater than 1 000 metres above sea level.

E.6.2 Load factors

Values of the load factors γ_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 γ_f

Actions	Limit state	
	Ultimate limit state	Serviceability limit state
Permanent actions G	1,35 (1,00)	1,00
Variable actions	1,50	1,00
Temperature actions	1,50 ^a	1,00
Creep effects	1,00	1,00

^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 γ_M shall reflect the variability of the mechanical properties of sandwich panels, as indicated by the results of initial type testing and factory production control. Two alternative approaches, together with indicative values, are given in E.6.3.2 and E.6.3.3 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” v of the relevant test results. Initially, v shall be based on initial type testing of a single product batch. Subsequently, the value of v used in design shall be checked against the results of factory production control and the material safety factors updated as necessary.

E.6.3.2 Determination of γ_M

The material safety factors γ_M for the ultimate and serviceability limit states shall be determined according to EN 1990. The following equations may be used:

For the ultimate limit state (E.10):

$$\gamma_M = 1,05e^{(0,8 \times 4,7 - 1,645)v} = 1,05e^{2,115v} \quad (\text{E.10})$$

For the serviceability limit state (E.11):

$$\gamma_M = 1,0e^{(0,8 \times 3,0 - 1,645)v} = 1,0e^{0,755v} \quad (\text{E.11})$$

where

v is the variance of $\ln(x)$; and

x is the population of test results (see E.6.3.1).

NOTE The material safety factors γ_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 γ_M

Property to which γ_M applies	Limit state	
	Ultimate limit state	Serviceability limit state
Yielding of a metal face	1,1	1,0
Wrinkling of a metal face in the span ($v \leq 0,09$)	1,25	1,1
Wrinkling of a metal face at an intermediate support (interaction with support reaction)	1,25 ^a	1,1
Shear of the core ($v \leq 0,16$)	1,5	1,1
Shear failure of a profiled face	1,1	1,0
Crushing of the core ($v \leq 0,13$)	1,4	1,1
Support reaction capacity of a profiled face	1,1	1,0
Failure of a fastener	1,33 ^b	1,0 ^b
Failure of an element at a point of connection	1,33 ^b	1,0 ^b

^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 or other of the following methods of analysis shall be used:

- Elastic analysis;
- 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;
- 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.

NOTE 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 according to 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 two components (see Figures E.3 and E.4):

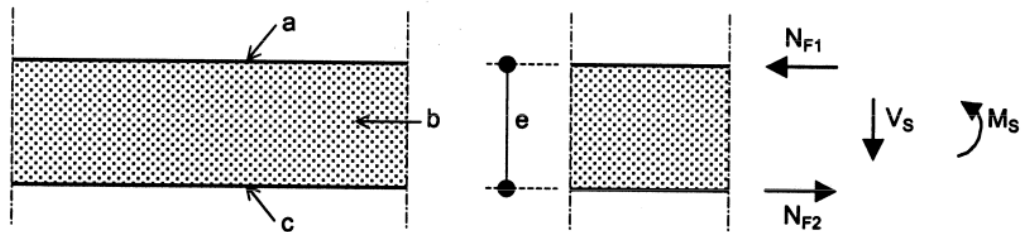
- a) For bending moments:
 - Into a moment component M_F in the metal faces and a moment component M_S (the sandwich part) arising from the normal forces N_{F1} and N_{F2} in the faces multiplied by the distance between the centroids e .
- b) For shear forces:
 - Into a shear force component V_F in the 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, 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_s causes a constant shear stress distribution τ_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 τ_{F1} , τ_{F2} in the face layers with non-vanishing bending rigidity.

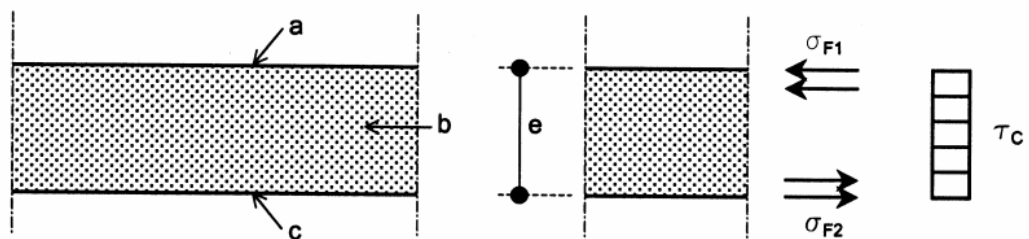
These shear stresses τ_{F1} , τ_{F2} shall be assumed to be a constant over the depths of the webs of the metal face.



Key

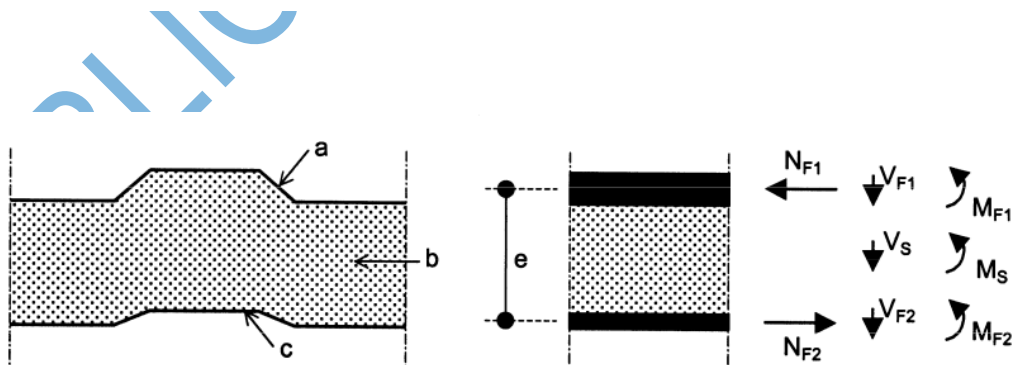
- a face 1
- b core
- c face 2

Figure E.3 – Stress resultants in a thin (flat or lightly profiled) faced sandwich panel



Key as Figure E.3

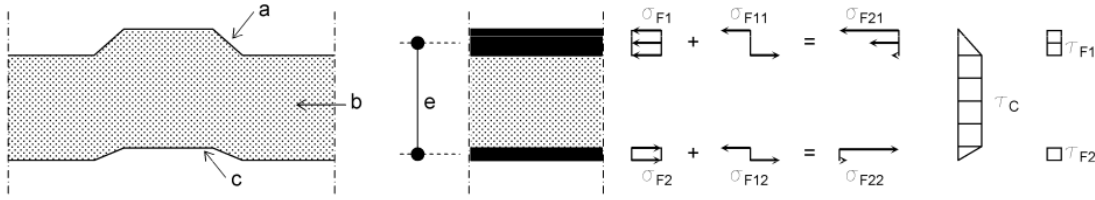
Figure E.4 – Stress distribution over the cross-section in a thin faced sandwich panel



Key as 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 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 according to 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):

$$\sigma_{F1} = -\frac{N_{F1}}{A_{F1}} = -\frac{M_S}{e A_{F1}}, \quad \sigma_{F2} = \frac{N_{F2}}{A_{F2}} = \frac{M_S}{e A_{F2}} \quad (\text{E.12a,b})$$

$$\sigma_{F11} = \sigma_{F1} - \frac{M_{F1}}{I_{F1}} d_{11}, \quad \sigma_{F12} = \sigma_{F1} + \frac{M_{F1}}{I_{F1}} d_{12} \quad (\text{E.13a,b})$$

$$\sigma_{F21} = \sigma_{F2} - \frac{M_{F2}}{I_{F2}} d_{21}, \quad \sigma_{F22} = \sigma_{F2} + \frac{M_{F2}}{I_{F2}} d_{22} \quad (\text{E.14a,b})$$

where

A_{F1} and A_{F2} are the cross-sectional areas of the faces;

I_{F1} , 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 according to 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):

$$\tau_C = \frac{V_S}{eB} \quad (\text{E.15})$$

$$\tau_{F1} = \frac{V_{F1}}{n_1 s_{w1} t_1}, \quad \tau_{F2} = \frac{V_{F2}}{n_2 s_{w2} t_2} \quad (\text{E.16a,b})$$

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 according to 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 which 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 zinc layers (or similar protective coating) and t_{tol} the normal or special tolerance according to EN 10143. The design thickness of other metal facing sheets, such as those made of 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.10.1.

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.10.1.

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, e.g. 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.10.2.

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 (e.g. 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'. Editor J M Davies. [3].

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 which may be considered 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_{Ct} .

Where relevant, the reduced value of the shear modulus, G_{Ct} , 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):

$$G_{Ct} = \frac{G_C}{1 + \phi_t} \quad (E.17)$$

where ϕ_t is the creep coefficient.

ϕ_t shall be determined by test according to A.6 or by using the following values:

For rigid plastic foams (PUR, EPS, XPS):

$\phi t = 2.4$ for $t = 2\,000$ h;

7.0 for $t = 100\,000$ h.

For mineral wool:

$\phi t = 1.5$ 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 ϕt 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.

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Table E.10.2 – Design equations for single span panels with one profiled face and one flat or lightly profiled face

	Shear at end support	Shear at internal support	Face bending moment in span M_{F1}	Sandwich bending moment in span M_S	Maximum deflection in span
Single span of L Uniform load q	$\frac{qL}{2}$		$\frac{qL^2}{8}\beta$	$\frac{qL^2}{8}(1-\beta)$	$\frac{5qL^4}{384B_S}(1+3,2k)(1-\beta)$
Temperature difference $T_1 - T_2$	0		$-B_{F1}\theta(1-\beta)$	$B_{F1}\theta(1-\beta)$	$\frac{\theta L^2}{8}(1-\beta)$

For uniform load, $\beta = \frac{B_{F1}}{B_{F1} + \frac{B_S}{1+3.2k}}$ For temperature difference, $\beta = \frac{B_{F1}}{B_{F1} + \frac{B_S}{1+2.67k}}$

$\sigma_{F1} = -\frac{M_S}{e} \frac{1}{A_{F1}} + \frac{M_{F1}h}{I_{F1}}$ $\sigma_{F2} = -\frac{M_S}{A_{F2}e}$

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.

Table E.10.1 – Design equations for one-, two- and three-span panels with plane or lightly profiled faces

	Shear at end support	Shear at internal support	Intermediate support reaction	Bending moment in (end) span	Bending moment at internal support	Maximum deflection in span
Single span of L Uniform load q	$\frac{qL}{2}$			$\frac{qL^2}{8}$		$\frac{5qL^4}{384B_S}(1+3,2k)$
Temperature difference $T_1 - T_2$						$\frac{\theta L^2}{8}$
Two equal spans of L Uniform load q	$\frac{qL}{2} \left(1 - \frac{1}{4(1+k)}\right)$	$\frac{qL}{2} \left(1 + \frac{1}{4(1+k)}\right)$	$qL \left(1 + \frac{1}{4(1+k)}\right)$	$\frac{qL^2}{8} \left(1 - \frac{1}{4(1+k)}\right)^2$	$-\frac{qL^2}{8} \frac{1}{1+k}$	$\frac{qL^4}{48B_S} \frac{0,26+2,6k+2k^2}{1+k}$
Temperature difference $T_1 - T_2$	$-\frac{3B_S\theta}{2L} \frac{1}{1+k}$	$\frac{3B_S\theta}{2L} \frac{1}{1+k}$	$\frac{3B_S\theta}{L} \frac{1}{1+k}$	$-\frac{3B_S\theta}{4} \frac{1}{1+k}$	$-\frac{3B_S\theta}{2} \frac{1}{1+k}$	$\frac{\theta L^2}{32} \frac{1,1+4k}{1+k}$
Three spans of L Uniform load q	$\frac{qL}{2} \left(1 - \frac{1}{5+2k}\right)$	$\frac{qL}{2} \left(1 + \frac{1}{5+2k}\right)$	$qL \left(1 + \frac{1}{2(5+2k)}\right)$	$\frac{qL^2}{8} \left(1 - \frac{1}{5+2k}\right)^2$	$-\frac{qL^2}{10+4k}$	$\frac{qL^4}{24B_S} \frac{0,83+5,6k+2k^2}{5+2k}$
Temperature difference $T_1 - T_2$	$-\frac{6B_S\theta}{L} \frac{1}{5+2k}$	$\frac{6B_S\theta}{L} \frac{1}{5+2k}$	$\frac{6B_S\theta}{L} \frac{1}{5+2k}$	$-3B_S\theta \frac{1}{5+2k}$	$-6B_S\theta \frac{1}{5+2k}$	$\frac{\theta L^2}{4} \frac{1,06+k}{5+2k}$

$B_S = \frac{E_{F1}A_{F1}E_{F2}A_{F2}e^2}{(E_{F1}A_{F1} + E_{F2}A_{F2})B}$ $k = \frac{3B_S}{L^2G_cA_c}$ $\theta = \frac{\alpha_2T_2 - \alpha_1T_1}{e}$

A_c = cross-sectional area of the core ($G_cA_c = S$ = shear rigidity of the core)

NOTE For geometry and section properties see Figure E.1. For stress systems see Figures E.3 and E.4.