Testing Rules

of the

European Quality Assurance Association

for Panels and Profiles

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Contents

1 Determination of relevant mechanical and physical properties

Necessary mechanical and physical properties in general and depending on the intended application are presented in the following table.

No.	Type of test	External walls	Internal walls	Ceilings	Roofs
1	Density of core material	yes	yes	yes	yes
2	Cross-panel tensile strength (with faces)	yes	yes	yes	yes
3	Thickness of core and faces	yes	yes	yes	yes
4	Mass of panel	yes	yes	yes	yes
5	Compressive strength of core material	yes	yes	yes	yes
6	Shear strength and modulus of core material	yes	yes	yes	yes
7	Long term shear strength	no	no	yes	yes
8	Creep coefficient	no	no	yes	yes
9	Tensile strength and thickness of face material (or declaration - 6.3.4.2)	yes	yes	yes	yes
10	- bending resistance in span and at internal support:				
	- positive bending	yes	yes	yes	yes
	- positive bending, elevated temperature	yes	no	no	yes
	- negative bending	yes	yes	yes	yes
	- negative bending, elevated temperature	yes	no	no	yes
	- wrinkling stresses				
	- wrinkling stress, external face				
	- in span,	yes	yes	yes	yes
	- in span, elevated temperature	yes	no	no	yes
	- at internal support	yes	yes	yes	yes
	- at internal central support, elevated temperature	yes	no	no	yes
	- wrinkling stress, internal face				
	- in span	yes	yes	yes	yes
	- at central support	yes	yes	yes	yes
11	Dimentional Tolerances	yes	yes	yes	yes
12	Resistance to point and access loads	no	no	yes	yes
13	Reaction to fire - certification	yes	yes	yes	yes
14	Resistance to fire - certification	Where applicable			
15	External fire performance - certification	no	no	no	yes
16	Thermal insulation performance	yes	Where applicable		yes
17	Water permeability	yes	Where applicable		yes
18	Air permeability	yes	Where required		yes
19	Airborne sound insulation	Where applicable			
20	Sound absorption	Where applicable			
21	Durability and long term effects	yes	Where required		yes

2 Mechanical Properties

2.1 Task

The subjects of considerations of chapter B are all tests for the mechanical values, the durablility and long term effects and the resistance for point loads and repeated loads.

2.2 Composition of required values for mechanical resistance for the CE-marking and information accompanying the CE-marking

2.2.1 External walls (see EN 14509, ZA.3.3 and Fig.ZA.3.)

For external walls all nesessery mechanical values for the CE marking (see EN 14509 ZA. 3) and the accompanying documents need to be determinated acocord-ing to table 1.1, page 4, point 1 to 11 and 21

2.2.2 Internal walls (see EN 14509, ZA.3.2 and Fig.ZA.4)

The same values as under 2.2.1, however without properties for elevated temperature and uplifting loads over the central support when determining wrinkling strength and durability investigations.

Note:

In many countries there are national regulations considering the determination of impact loads on internal walls (e.g. in Germany DIN 4103). Such standards need to be considered additionally.

2.2.3 Roofs (see EN 14509, ZA.3.4 and Fig. ZA.2)

Same values as in 2.2.1 and additionally:

- shear strength after long-term loading
- creep coefficient (value at t = 2,000 h and t = 100,000 h)

2.2.4 Ceilings (see EN 14509, ZA.3.2 and Fig. ZA.4)

The same values as under 2.2.3, however without properties for elevated temperature, uplifting loads over the central support when determining wrinkling strength and dura-bility investigations. In addition tests on walkability and point loads need to be undertaken.
In the following all necessary tests and the according evaluations for a roof and for a wall panel are discussed. This then includes all necessary testing for internal walls and ceilings, where the tests mentioned above can be neglected.

2.3 General references for testing procedures and evaluation of test results

1. All mechanical properties necessary for CE-marking shall be stated as characteristic values (i.e. as 5%-fractile values) and mean values (see EN 14509, 6.2.3). The mean values are particularly necessary for the modulus values because the mean value of the shear modulus is taken into account for design (see EN 14509, E.7.1 and EN 14509, E.7.6). The mean values of tension and compression modulus are eventually used for required standardisations.

2. The 5%-fractile values should result from a statistic evaluation in accordance with EN 14509, A.16.3 following the subsequent formulas (log. distribution!)

   $$x_{\mathrm{p}} = e^{(\overline{y} - k\sigma_{\mathrm{y}})}$$

   where

x_p 5%-fractile value of population x;

$y_i = L_n(x_i)$;

$\overline{y}$ mean value of y y_i;

$\overline{y} = \frac{1}{n} \cdot \sum_{n=1}^{n} y_i$

k fractile factor given in EN 14509, table A.4;

σ_y standard deviation of y.

$\sigma_y = \sqrt{\frac{1}{n-1} \cdot \sum_{i=1}^{n} (y_i - \overline{y})^2}$

Number of specimens (n)	3	4	5	6	7	8	9	10	15	20	30	60	100
k_σ	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

Table 2.1: Fractile factor k assuming a confidence level of 75%

For clarification the evaluation is displayed for 3 virtual assumed test results (x_i):

$x_1 = 80$
$x_2 = 100$
$x_3 = 120$

mean value $\Rightarrow \overline{x} = 100$

$y_1 = lnx_1 = ln80 = 4.38203$
$y_2 = lnx_2 = ln100 = 4.60517$
$y_3 = lnx_3 = ln120 = 4.78749$

mean value $\Rightarrow \overline{y} = 4.59156$

$$\sigma_y = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (y_i - \overline{y}^2)}$$

$$= \sqrt{\frac{1}{3-1} \cdot \left[(4.38203 - 4.59156)^2 + (4.60517 - 4.59156)^2 + (4.78749 - 4.59156)^2\right]} = 0.20307$$

k_σ = 3.15 (factor in accordance to EN 14509, Tab. A.4)

3. Calculation of the related material safety factor for mechanical strength, subject to EN 14509, E.6.3.2:

$y_p = \overline{y} - k \cdot \sigma_y = 4.59156 - 0.20307 \cdot 3.15 = 3.95189$

$x_p = e^{y_p} = e^{3.95189} = 52.03$

$\gamma_m = e^{((0,8 \cdot 4.7 - 1.645) \cdot \sigma_y)} = e^{((0.8 \cdot 4.7 - 1.645) \cdot 0.20307)} = 1.54$

$\gamma_M = 1.05 \cdot 1.54 = 1.62$

4. Advice on number of tests:

The minimum number of tests are indicated for ITT in EN 14509, tab. 4 and for FPC in EN 14509, tab. 5. It is, however, strongly recommended to accomplish more than only the minimum numbers of tests for some mechanical properties. This does not necessarily apply to full scale tests (simple beam test and simulated central support tests). For these, the minimum number of 3 tests is expected to result in sensible 5 % - fractile values of the mechanical properties (e.g. wrinkling stresses). Furthermore, the performance of full scale tests is cost-intensive.

Since the determination of material values (e.g. shear, compressive and tensile strength of the core material) is carried out with small samples and relatively small effort and costs, a larger series of tests (e.g. 10 tests) can be of great benefit. This is described in the following example:

Due to real measured ultimate loads of 10 shear tests (short beam, see also chapt. 2.5.1.2 and 2.5.2.2) the following shear strengths were determined. Thereby it is expressly underlined that these values are determined on samples of a good PUR-core quality (all values range from 0.100 to 0.123) and, therefore, they do not have a great statistical scatter.

sample no.	1	2	3	4	5	6	7	8	9	10
f_{Cv} [N/mm^2]	0.123	0.121	0.104	0.108	0.113	0.106	0.107	0.109	0.113	0.100

Assuming that only 3 tests instead of 10 were carried out and duly evaluated (minimum number according to EN 14509 tab. 4) instead of 10, and this coincidentally with the samples no. 1, 3 and 10, a very low 5%-fractile value would have been found.

$f_{Cv}^{5\%} = 0.076\ N/mm^2$ with a standard deviation of "$\sigma_y = 0.1099$"

This result could possibly have a decisive impact on design, so that as a result, smaller permissible spans or loads were determined. All calculations with these small characteristic values would be uneconomic.

This is additionally intensified by the fact that the material safety factor is specified depending on the deviation found in the evaluated tests. Due to the standard deviation according to EN 14509, E.6.3.2.:

$\gamma_M = 1.05 \cdot e^{2.115 \cdot v} = 1.05 \cdot e^{2.115 \cdot 0.1099} = 1.32 \quad (\sigma_y = 0.1099)$

The design value of shear strength would then only be $f_{Cvd} = \frac{0.076}{1.32} = 0.057\ N/mm^2$ and, for the entire design, very uneconomic.

Assuming once more that only 3 tests were carried out and duly evaluated instead of 10, and, this time, coincidentally with the samples no. 1, 2 and 5, a very high 5%-fractile value would have been found:

$f_{C_v}^{5\%} = 0.076\ N/mm^2$ with a standard deviation "$\sigma_y = 0.0449$"

This result indeed would be an advantage for the design but the probability that this value is always confirmed by FPC, is very small and that would cause substantial problems. The consequence in most occasions is that all tests belonging to this test series must be repeated.

These examples clearly show that it is of advantage to accomplish more tests (e.g. n = 10) than the minimum number required in EN 14509, table 4 and 5, particularly with the small test specimens. In doing so, one receives a sufficiently well 5%-fractile value which can be kept with steady quality also throughout FPC.

It follows, with the 10 given values above:

$f_{C_v}^{5\%} = 0.096\ N/mm^2$ with a standard deviation of "$\sigma_y = 0.0648$" and with that a material safety factor of

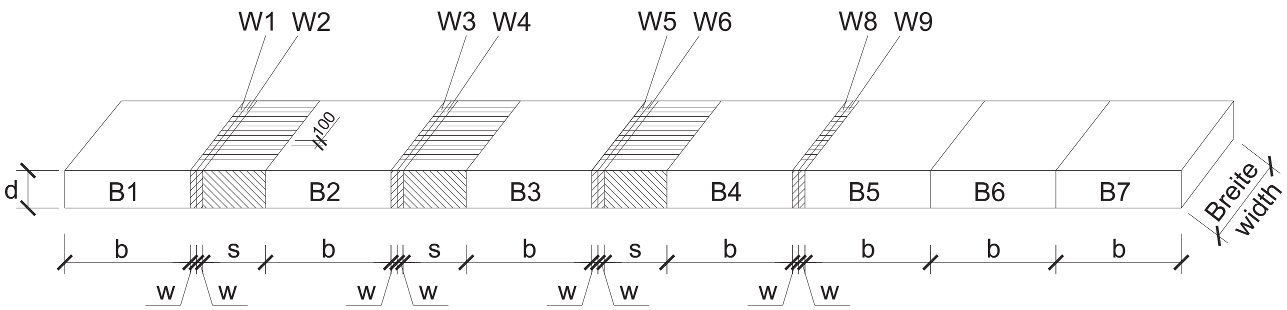
$\gamma_M = 1.05 \cdot e^{2.115 \cdot v} = 1.05 \cdot e^{2.115 \cdot 0.0648} = 1.20$ ($v = \sigma_y$ = 0.0648)

5. For ITT tests all panels and specimens shall be from the same batch (see EN 14509, 6.2.2.1). Therefore, all test specimens must be from one "batch/10t" of the current production. This is of great importance since all mechanical properties depend on each other in principle (e.g. wrinkling stresses depend on Young's Modulus) and the defined specifications of the characteristic values are only sensible if the core material is from one and the same batch.

   The removal and cutting of the samples is normally based on explicit "cutting sketches". An example is presented below:

nicht maßstäblich / no scale

B = 4000mm, w = 100mm, s = 1000



b → full scale tests
w → small scale tests (compression, tension, density etc.)
s → short beam tests

The required samples may also be taken from the unharmed areas of a panel subject to a full scale test. It is important to include both, samples from the edge as well as from the centre region of the panel.

6. Development of product families

   In order to reduce the number of necessary tests it is sensible, and in most cases also easy, to define product families as described in EN 14501, 6.1.

   In the following the expression "family" is described more thoroughly by giving the relevant criteria, which the panels belonging to one family have to fulfil. The following products can be united under one family:

   - Products sharing the same cross section, meaning that the face geometry for both faces is defined exactly.
   - The faces may consist of different steel thicknesses as long as they are within the same steel grade
   - All products are produced implementing the same PUR/PIR or phenolic foam formulation, or the same type of mineral wool or EPS.
   - All core materials have the same density.
   - For panels with slabstock or lamella cores, it is necessary that all elements are produced with the same amount of glue, the same type of glue as well as the same orientation of the lamellas or slabstock within the panel.

   If there are several thicknesses planned within a product family, it is only necessary to test the thinnest, one mid range and the biggest thickness (see EN 14509, A.5). For any thickness between those tested, the obtained results can either be interpolated or the lowest values may be used for all thicknesses.

   Note: for long term evaluation only the greatest thickness is of relevance.

   If for one family both, flat and slightly profiled ("as if flat") face geometries (according to definition in EN 14509), are planned, the results obtained for the completely flat panels may also be used for the slightly profiled panels.

2.4 General references for technical correct recording of test results

The requirements of EN 14509, A.16.1 need to be considered and followed essentially:

For each ITT test series a formal documentation (inspection report), that contains all relevant data, needs to be developed so that the test series can be reproduced accurately. In addition to test results, the specimens need to be described fully and accurately, particularely in terms of dimensions and material properties. Further-more, any observations during testing must be recorded.
The following information shall be recorded in all ITT inspection reports:

1. date and time of production;

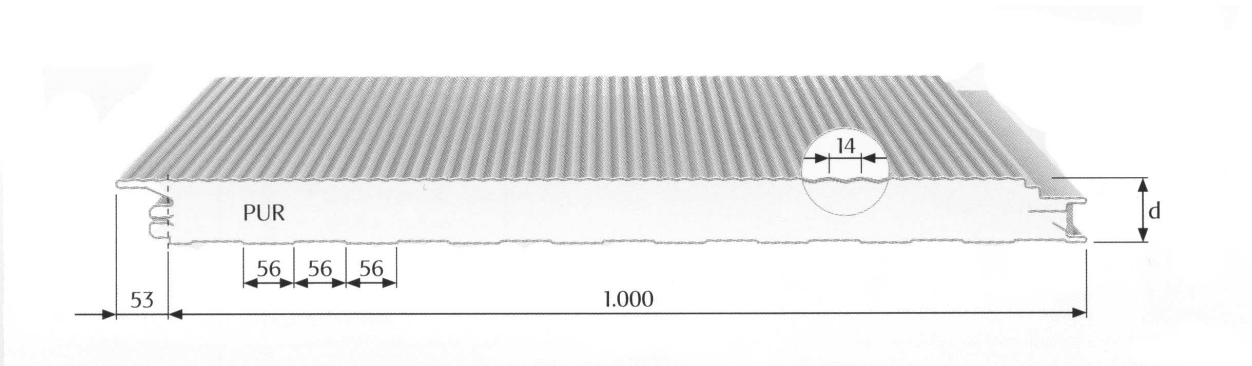
2. method of production and orientation of the panel during production e.g. for foamed PUR elements:
    - which face was on top, which was the leading edge during continuous foaming, etc);
    - for EPS panels:
      joints in the core, gluing of slabs etc. or
    - for MW panels: width and length of the lamellas, if necessary gluing of the lamellas and ori-entation of the fibres, etc.
3. date of testing;
4. conditions during testing (temperature and humidity);
5. method of loading and details of testing - including gauging device
6. support conditions (number and length of spans, width and details of supports, number and details of connections to supporting structure, etc.);
7. orientation of panel during testing (e.g. full scale tests: positive- or negative orientation);
8. type and properties of face material (thickness, yield stress, geometry, etc.);
9. type and properties of core material (density, strength, modulus, etc.);
10. type and details of adhesive;
11. gauging made during testing (load, deflection readings, temperature, etc.);
12. mode of failure (if possible with photo documentation)

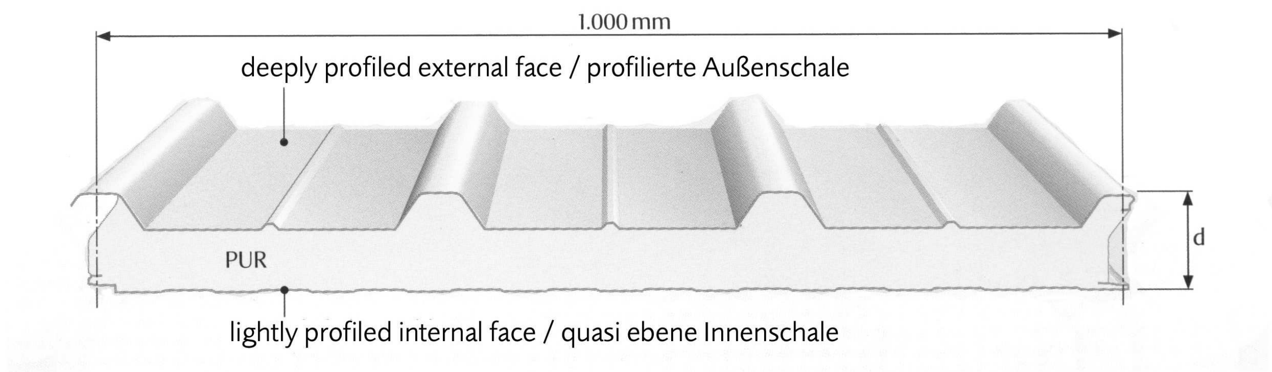
The analysis of results for a test shall be based on measured dimensions and material properties of the speci-men, unlike the design, where nominal values assumed.

General notes:

- The data provided from 2. to 12. is normally acquired directly during individual test series.
- The requirement of employing measured dimensions and material properties for the evaluation of test results is of high importance. First of all this means that every specimen must be measured exactly, i.e. the exact width, thickness, and length but also the depth of stiffeners and light profiling, the distance of stiffeners and profiles together with the height and width of ribs and valleys in trapezoidally profiled sheets must be documented.

  In addition the metal sheet thicknesses need to be taken for each specimen. For arithmetical evaluations based on sandwich theory, the determined test results, e.g. tested shear modulus of core material, must be implemented.





2.5 Presentation and explanation of tests in detail

In the following the necessary tests for a wall - and a roof panel according to EN 14509, 5.2.1 and 6.2 (in particular EN 14509, table 4) are explained separately. In addition, important notes on how to conduct the tests are given for each case. Furthermore, explanations on which relevant parameters are needed for accurate evaluation of characteristic properties and how these should be acquired is given. For more precise illustration these details are shown in both, the wall and the roof explanations. On the left general explanations with references to the related chapters of standards can be found. On the right, examples for real panels together with realistic test results can be found.
The necessary tests for different panel types and application modes together with a cost estimation can be acquired with the help of computer program (see internet: iS - Mainz).

2.5.1 Wall panels

notes:

The task is to determine all necessary mechanical values for the CE-marking and for the information accompanying the CE-marking for:

One type of wall panel with different panel and face thicknesses

note:

The following systematic of test numbering and the number of tests conducted are based on EN 14509, table 4.

2.5.1.1 Mechanical properties of metal faces

Based on: EN 14509, 5.1.2 and EN 10002-1 (annex A)

Comments:

1. Test specimen:
   metallic bright flat test pieces according to EN 10002-1 type 1 or type 2.
   The coating must be removen either in part or totally before taking the steel thickness. The removal must be in accordance with EN 10326 Annex A.

2. Test procedure is exactly defined in EN 10002-1.

3. Number of tests:
   For each coil 3 tests are sufficient

Two of the samples must be taken from the edge area (however with a minimum distance of 50 mm from the edge) and one sample must be taken from the centre of the face. All samples must be oriented parallel to the lengthwise direction of the panel.

4. Important test results:
   metal sheet thickness t_{obs} (accurancy 1/100 mm) and yield stress fyobs determined on test specimen.

   Aim of evaluation of test results:

   The values are necessary for interpretation of test results (e.g. see EN 14509, 5.2.1.2, 5.2.1.7, 5.2.1.8) and for determination of correction factors (e.g. EN 14509, A.5.5.4, equation A15).

2.5.1.2 Shear strength and shear modulus

Based on: EN 14509, 5.2.1.2 and A3
(in particular EN 14509, A.3.1 to A.3.5), A.4 and A.5.6

notes:

Comments:

There are 2 different kinds of tests which can be conducted alternatively:

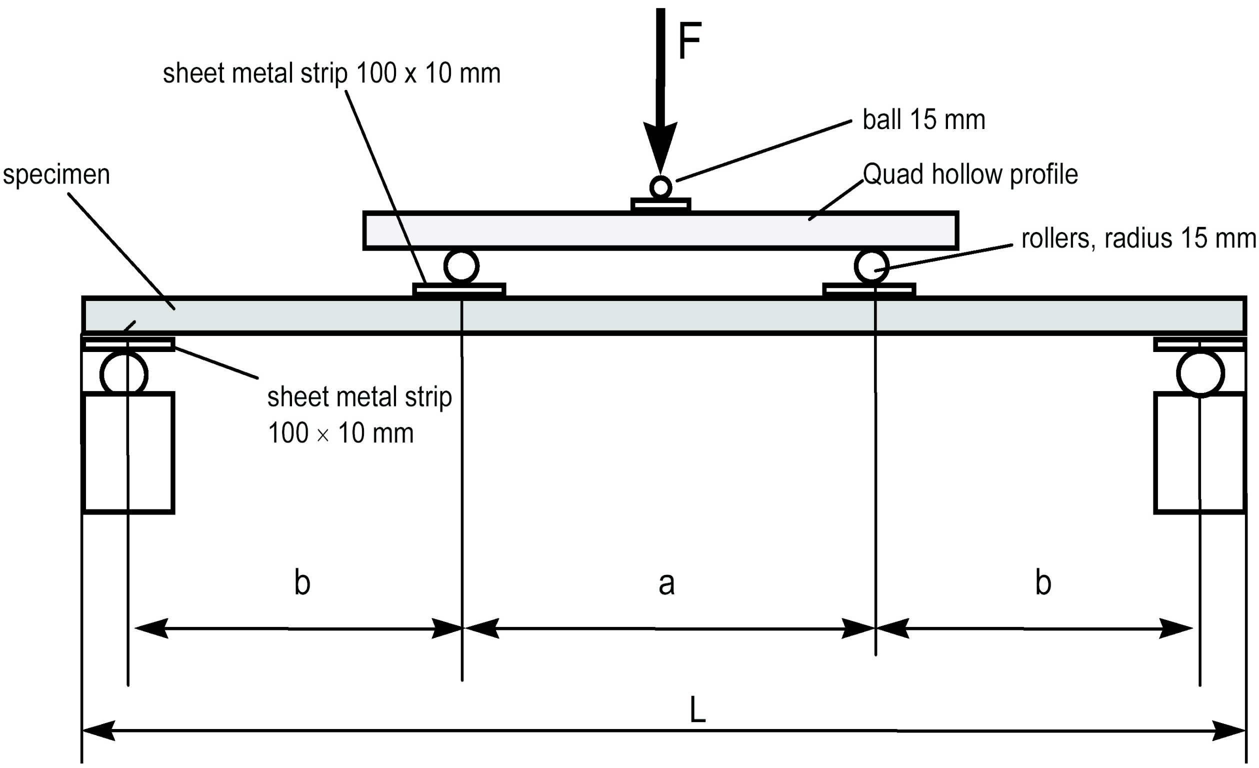
1. four-point bending test on short beams (see EN 14509, A.3.1 to A.3.4)
2. test on a complete panel (see EN 14509, A.4)

In this context it should also be remembered that ITT tests and FPC tests must be identical, i.e. if ITT shear tests are accomplished with full scale panels, the FPC shear tests must also be conducted on full scale panels.

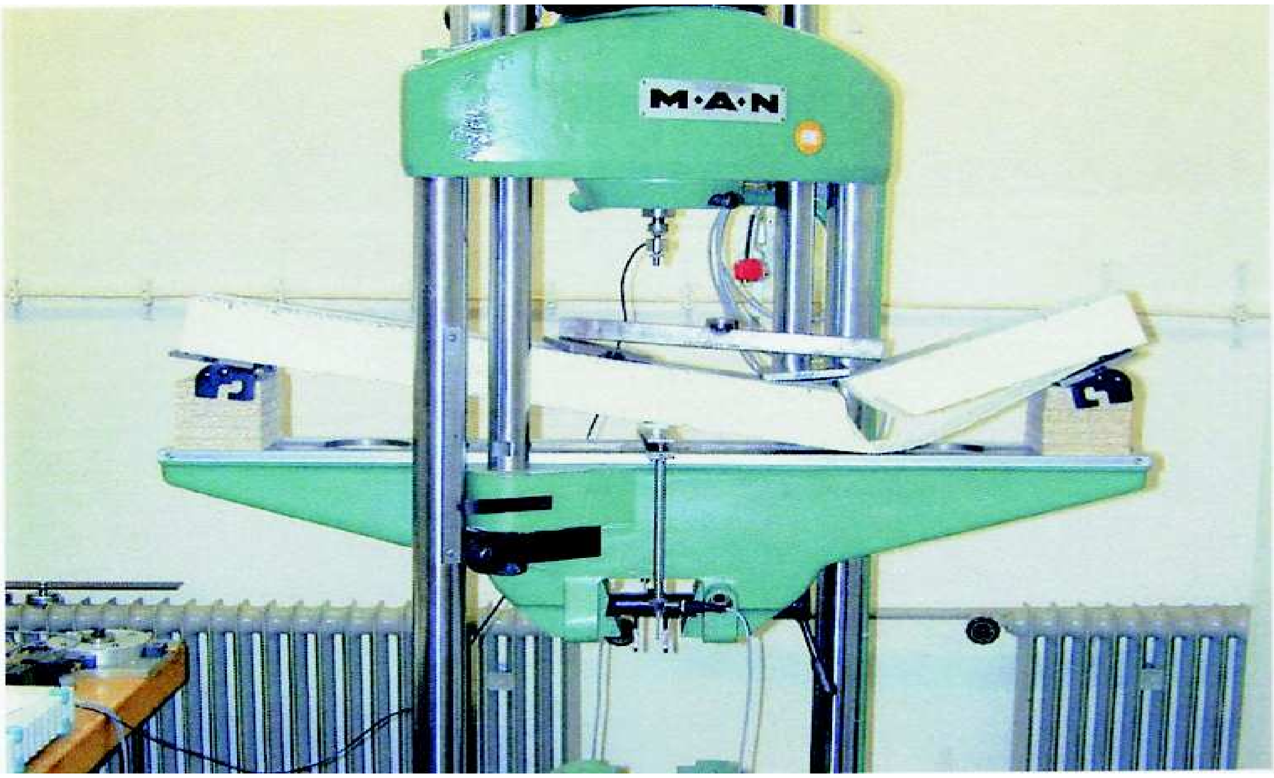
2.5.1.2.1 Test procedure on short beams :

The exact test procedure is described in EN 14509, A.3.2 to A.3.4. Comments:

1. shear failure mode:
   With PUR, PIR, EPS clear shear failure (shear crack, see photo) must occur.




M·A·N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Failure due to wrinkling or delamination of faces does not deliver real shear strength.

With MW also shear hinges (no clear shear cracks) which correspond to real shear strength can be found (see photo).
For some configurations the failure mode may be a compressive failure either at the support or under the load introduction area. The test evaluation then does not give realistic shear strength properties.

2. deflection recording:

   For determination of the shear modulus the exact load-deformation curve must be recorded. The deformation must be measured at the lower face of the sample because if it is measured at the upper side (e.g. cross head displacement) the deformation caused by compression at the supports is wrongfully included. Alternatively the displacement can be measured at the upper side, then however the compressive deformation at the supports must be taken at the same time and then subtracted from the deformation at mid span.

   Since just the difference of total deformation less bending deformation (small value!) is decisive for evaluation, the deformations must be measured very exactly.

3. sampling of test specimen:

   - For panels with profiled faces the specimens shall be cut out of the predominant thickness (analogue to EN 14509, A.1.3) which mostly occurs between the ribs. Possibly existing light profiles or micro linings should be symmetrically distributed over the width of samples if possible.
   - For specimens with PUR, PIR, EPS, PF and CG it just needs to be kept in mind that a span must be selected with which the above mentioned shear failure mode occurs.
   - With MW and EPS the following needs to be considered additionally:
     - With a core of prefabricated slabs (e.g. MW or EPS plates) and transverse joints through full (or half) panel width within the core and glued together at the front side:

       A short beam needs to be removed so that the transverse joint is situated between the support and the 1st loading point during the test.
     - With lamellas (mineral wool):

       With lamellas where longitudinal and transversal joints are not glued together, the arrangement of joints is of decisive importance for the shear strength and shear modulus. Therefore, the joints are normally not in one line.

       The following procedure is recommended:

       Sampling of a short beam in such way that no transverse joints are present, if possible (sample A).

       If not possible otherwise, a part of the cross section can include a joint (sample B) as long as the joint is situated between the two single loads.

       For evaluation of tests (also see EN 14509, A.3.5.1. equation A6) the influence of transverse joints is then considered arithmetically (also see 6.1.2 and 6.2.2).
   - Special care must be taken when cutting the specimen. Once again please refer to note 1 in chapter A.1.3 of this document.

4. number of tests:

   It is recommended to perform 10 instead of the required 3 tests per thickness (see chapter 3) . This generally leads to a smaller scatter of results and thus to better values when determining the characteristic values and the material safety factors γ_M.

   When evaluating a variety of panel thicknesses, it is necessary to test only the thinnest, a mid range and the largest thickness. This procedure is in accordance with the full scale tests (see chapter 3).

5. Documentation and test results:

   The individual test specimens must be measured exactly and the results must be documented in detail. Important test results:

   failure load, load-deflection curve and details on failure mode

6. Aim of evaluation of test results:

   shear strength f_{Cv} (characteristic value)
   shear modulus G_C (mean value and characteristic value)

   Shear strengths are needed for design against ultimate and serviceability limit states (see e.g. EN 14509, tab. E.2).

   The single values for the shear modulus are to be determined from the linear slope of the load-deflection curve.
   The shear modulus is necessary for application of the sandwich theory (design by calculation) e.g. according to EN 14509, tab. E.3 and E.10.

2.5.1.2.2 Test procedure on full panel The exact test procedure is presented in EN 14509, A.4 and/ or A5.

Comments:

1. To get a shear failure it is important that a) the width of the spreading plates both at the supports and below the load points (if not using air pressure loading) and b) the span length is appropriate. The recommended values in the standard may not be suitable for all types of panels. It is up to the manufacturer, as the best expert regarding his own products, to choose the appropriate values to be used in the tests.

2. The deflection recording, the member of tests, the documentation of test results and the evaluation of test results are in principle according to 2.5.1.2.1

3. When the shear strength and modulus are determined with a complete panel the effects of the possible joints in the core material are included in the test results. It is therefore important that the sampling of the test panels is such that the joints are situated in the most critical pattern in the shear failure area. The joint pattern in the core material must always be delivered by the manufacturer so that an evaluation of the influence can be made. It should also be noted if the joints are glued or in any other way connected to each other.

4. In this test setup it is also possible to test panels with profiled faces. The evaluation determining the shear strength and the shear modulus however has to be undertaken on the base of the sandwich theory (see EN 14509, A.4.5 and A.5.6). If ITT testing is performed on the full panel, the same test setup has to be used also for FPC, as well as for external quality control.

2.5.1.3 Reduced shear strength after long-term load

Since long-term loads do not occur on wall panels the corresponding verifications are omitted. It is not necessary to conduct long-term shear strength tests according to EN 14509, 5.2.1.5 and A.3.6 for wall panels.

2.5.1.4 Compressive strength and compressive E-modulus

based on: EN 14509, 5.2.1.4 and A.2
Comments:

1. test procedure:

   When accomplishing the tests it is important to have centric and constraint free load introduction (e.g. spherically seated mounting device). Regarding the test arrangement one ball bearing plate is sufficient.

2. Number of tests:

   It is recommended to accomplish 10 instead of 6 tests (see EN 14509, tab. 4) for each panel thickness (explanations see 2.3, point 6).

3. Sampling of test specimen:

   In case of panels with profiled faces the specimens shall be cut out of the predominant thickness (analogue to EN 14509, A.1.3) that mostly occurs between the high profiles. Possibly existing light profiles or micro linings should be symmetrically distributed over the width of samples if possible.

4. The individual test specimens must be measured exactly and the results must be documented in detail.

5. Important test results:

   failure load and load-deformation curve

6. Aim of evaluation of test results:

   compressive strength f_{Cc}
   compressive E-modulus E_{Cc} (mean value and 5%-fractile value)

   Compressive strengths are needed for proof of ultimate and serviceability limit states of stresses at the supports (see EN 14509, E.2 and E.4.3.2), (alternatively full scale tests can be accomplished according to EN 14509, A.15.5!)

   The single values of compressive E-modulus are to be determined from, the linear slope of the load-deflection curve.

   The compressive E-modulus is necessary for standardisation and for the case that the wrinkling stress should be determined arithmetically without tests (such procedure is however conservative and gives low values!) (see EN 14509, A.5.5.3. equ. A13 and A14).

2.5.1.5 Tensile strength and tensile E-modulus

based on: EN 14509, 5.2.1.6 and A.1
In general:

Comments:

1. Test procedure:

   - At accomplishment of tests it is absolute important to have centric load introduction (tensile force). Therefore e.g. metal plates, plywood or similar are glued to the faces of the specimen and these are gimbal mounted into the test device. Regarding the test arrangement one ball bearing plate is sufficient.

     In the cross panel tensile test it is important to determine the accurate deformation between the two plates. When using the cross head movement for evaluation, the deformation of the mounting devices is always included in the results. The determined elastic modulus can then not be determined accurately.

     It is in any case necessary to use the same type of test setup for both, ITT and external quality control.
   - During sampling it is important that the faces are not peeled off, not even in small areas at the edges (see EN 14509, A.1. note 1).

2. Number of tests:

   It is recommended to accomplish 10 instead of 6 tests (see EN 14509, tab. 4) for each panel thickness (explanations see 2.3, point 6).

3. Sampling of test specimen:

   In case of panels with profiled faces the specimens shall be cut out of the predominant thickness (analogue to EN 14509, A.1.3) that mostly occurs between the high profiles. Possibly existing light profiles or micro linings should be symmetrically distributed over the width of samples if possible.

4. Documentation and test results:

   - The individual test specimens must be measured exactly and the results must be documented in detail.
   - Important test results:
     tensile strength f_{Ct} at 20 °C and 80 °C (see EN 14509, A.1.6)
     tensile E-modulus E_{Ct} at 20 °C and 80 °C (see EN 14509, A.1.6)

5. Aim of evaluation of test results

   The tensile strength values are needed as control values (FPC) and for determination of the correction factor k_2 (see EN 14509, A.5.5.5) of the wrinkling stress at low tensile strengths.

   The single values of tensile E-modulus are to be determined from the linear slope of the load-deflection curve.

   The tensile E-modulus is necessary for determination of the correction factor k_1 for the wrinkling stress at increased temperature (see EN 14509, A.5.5.5, equ. A.16) and if the wrinkling stress should be determined arithmetically without tests (such procedure is however conservative and gives low values!) (see EN 14509, A.5.5.3, equ. A13 and A.14).

2.5.1.6 Bending moment capacity and wrinkling stresses of single span panels

Based on: EN 14509, 5.2.1.7 and A.5.1 to A.5.4
comments:

In general:

1. The aim of this test setup is to define the wrinkling stresses σ_w for each type of face. The determination of the bending moment capacity (M_u) is automatically included with the evaluation of the test results, even though these values are not necessary for the design calculations.

2. Test procedure:

   The exact test procedure is described in EN 14509, A.5.1 to A.5.4.

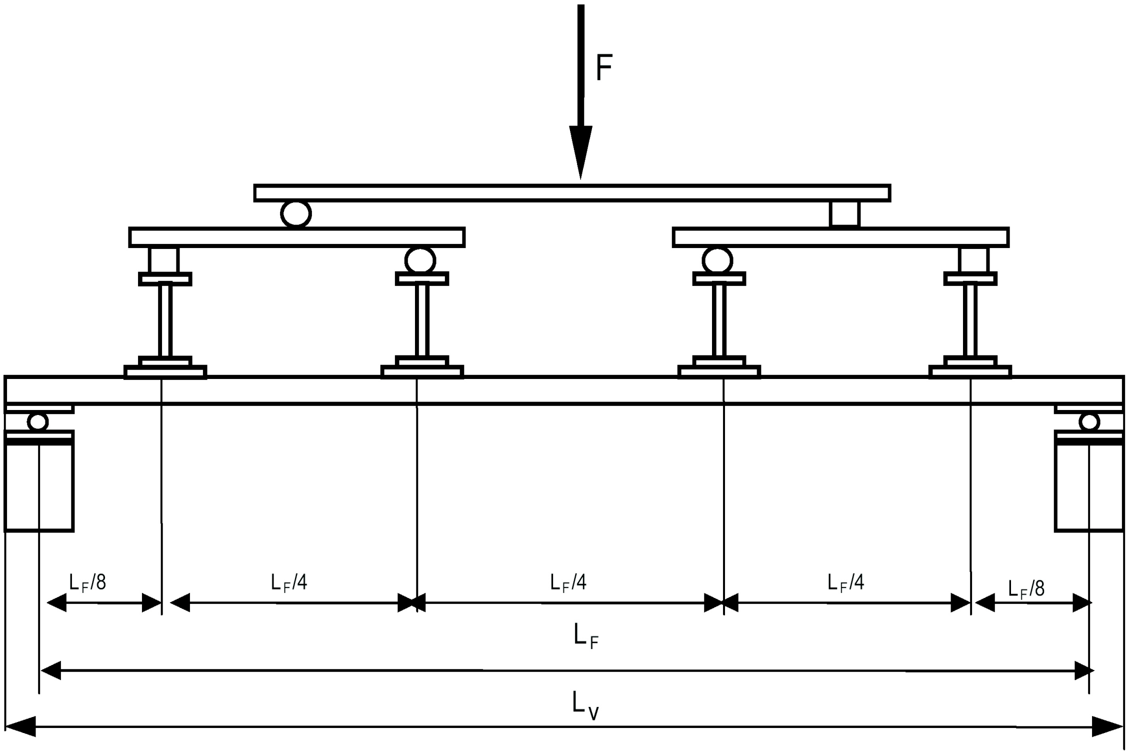
   - In principle there are 2 ways in which the test loads can be applied to the system (see EN 14509, A.5.2.1):
     - 4 line loads or
     - by air pressure, either in a vacuum chamber or with air bags.

   Only when loading with air pressure, the correction factor k_2 (see EN 14509, A.5.5.6) needs to be considered in the evaluation.

3. Test results:

   - After the ultimate load is reached the failure mode needs to be determined and documented exactly. A pure bending failure must always be obtained. This is virtually always recognizable (in the face under pressure) by wrinkling of the flat or lightly profiled faces or by buckling of the upper chord areas of the trapezoidal faces (see photo). The failure must occur in the centre part of the panel. If not, the test should be repeated. A failure can also occur through yielding of the faces (in the face under tension). This can be determined e.g. by measuring the strains (and thus the stresses) with strain gauges and possibly also through the load-deflection curve.

   - In addition to the determination of the failure load the deflection at mid span must be determined in any case and displayed in a load-deflection curve. Furthermore it is recommended to measure strains (and thus stresses) with strain gauges at the middle of the span. The obtained results should also be displayed in a load-stress curve. Compared to calculated deflections and stresses (design by calculation) both curves serve for confirmation of the calculation method with which allowable span tables are determined in the end.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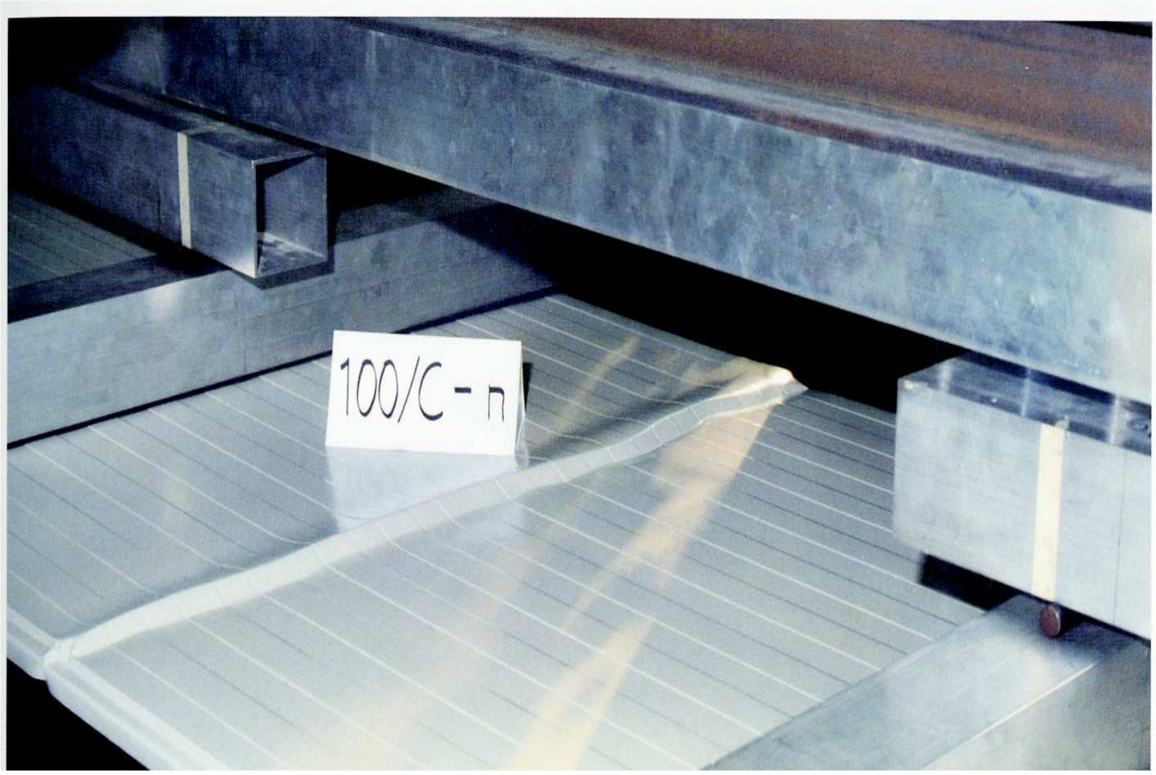


Figure 2.1: wrinkling of a lightly profiled (quasi flat) face (negative orientation)

Figure 2.2: buckling of the trapezoidal face (positive orientation)

4. Number of tests:

   For each face with a defined geometry (depth of stiffeners and profiles, distance of stiffeners and profiles) and for each panel thickness 3 full scale tests (one span panel) need to be accomplished. In these tests the face under investigation must be in the compression area (upper side) during the test.

Since the geometry of exterior - and interior faces differ, also for panels with lightly profiled faces on both sides, 3 tests need to be accomplished in positive - and negative orientation; i.e. the exterior - and interior face must be in the compression area during the tests.

If the faces are identical, concerning geometry, only 3 tests must be accomplished; the faces that were on the upper side during production (lower properties, possibly blowholes, unfavourable bonding) must be in the compression area (upper side during test). It is recommended for inspection that one additional test is also accomplished on the face that has been on the lower side during production. On this, a higher value should be recognizable.

No tests need to be arranged with different sheet thicknesses as long as the tests were accomplished with the thinnest intended thickness and the wrinkling stresses for further sheet thicknesses are determined according to EN 14509, A.5.5.3, equ. A.12. If tests for several sheet thicknesses are intended only the thinnest and thickest need to be tested and the worst case can be used for all sheet

5. Documentation:
   The test specimens dimensions must be measured exactly and the results must be documented in detail.

   Here the measured values of the metal sheet geometry and the panel thickness need to be determined most important, so that the cross-sectional values (distance between centroids of faces, areas etc.) can be determined for each individual test specimen.

6. Important test results:

   achieved ultimate load for each test, deflection at the middle of span.

   Recommended:

   Results of strain - (stress-) measurement at mid span, possibly only in few, defined tests.

7. Aim of evaluation of test results:

   The wrinkling stresses (σ_w) within span for individual types of faces at different panel thicknesses including the related values for increased temperature by application of the evaluation process according to EN 14509, A.5.5.5, equ. A.16.

   By comparing theoretical and tested deformation, the shear modulus determined in the small scale test can be scrutinized. In some cases the shear modulus can also be determined directly from the full scale bending test.

   The values are needed for design against ultimate and serviceability limit states.

2.5.1.7 Bending moment capacity and wrinkling stresses at an internal support

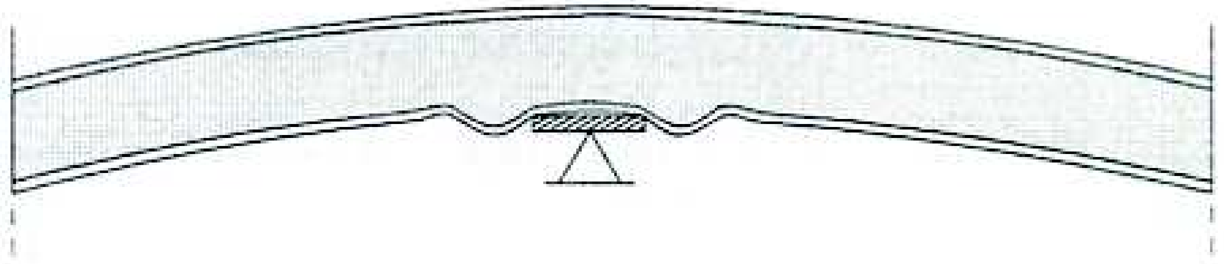
Based on: chapt. 5.2.1.8 and A.7
comments:

1. In general:

   For the design of continuous beam panels, ultimate (see EN 14509, E.5.2) and serviceability (see EN 14509, E.5.4) limit states need to be checked.

   It is allowed to assume "wrinkling hinges" above the central support for the design of the ultimate limit state. The statical system then changes to a chain of simple beam panels for which the ultimate limit state can be determined individually (see EN 14509, E.7.2.3).

For the serviceability limit state (see EN 14509, E.5.4 and E.7.2) it needs to be ensured through calculation that no yielding or wrinkling in the faces occurs above the central support. In the area of central supports an explicit reduction of the wrinkling stresses can arise due to additional deformations caused by support pressure or (under uplifting loads) due to point bearing in the area of the screw heads.



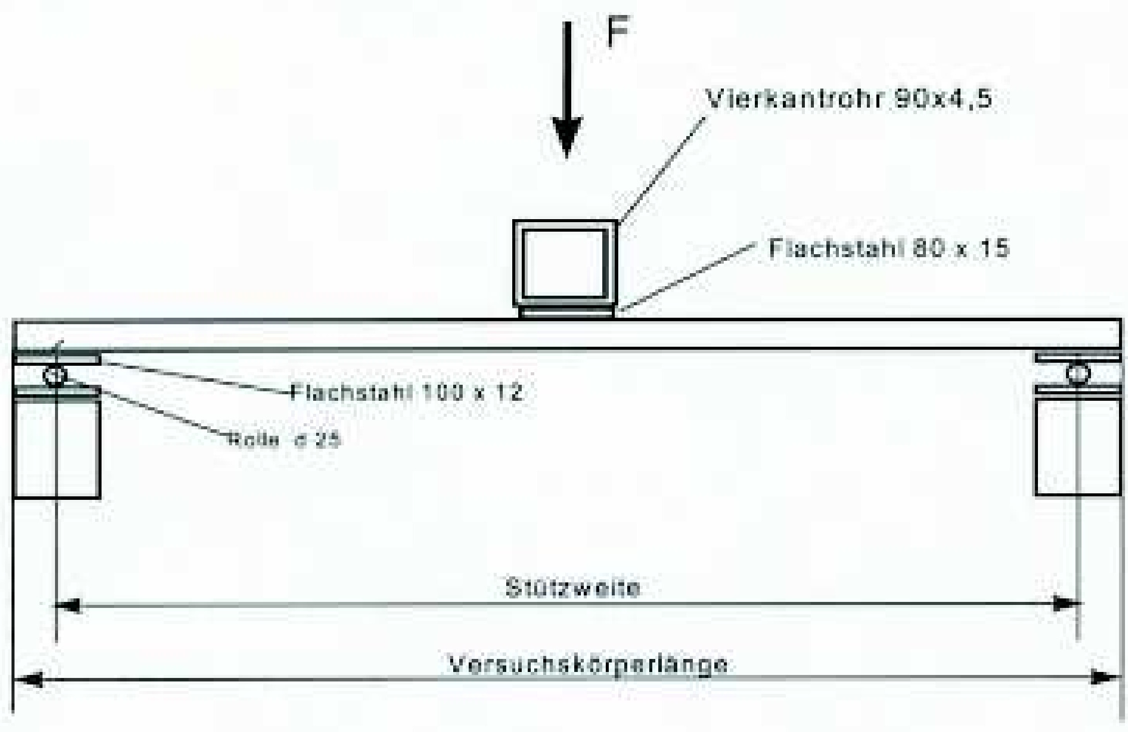
Therefore, the aim of simulated central support tests is to analyse the effects on the ultimate capability (see EN 14509, 5.2.1.8) and to determine the relevant wrinkling stresses for design in the area of central supports. Compared to wrinkling stresses within the span these can be expected to be clearly lower.

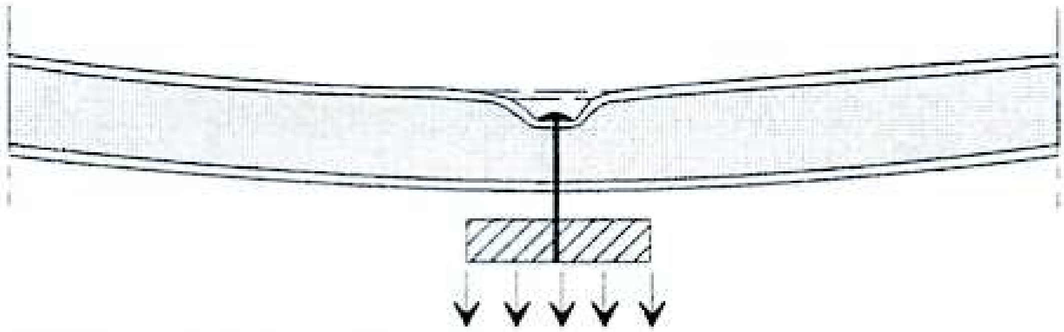
With the help of the simulated central support test load configurations that are comparable with those in the area of central support of a double span panel shall be achieved in an economic way.

Therefore, simplely supported beam panels are loaded until failure in such way, that a line load is introduced either directly through a bending stiff beam at the middle of the span or through a screwed connection to the beam.

For the load case "uplifting loads" the uplifting support reactions in the area of the central support of the continuous sandwich panel are normally transferred to the substructure with the help of a thorough screw connection.

For flat or lightly profiled exterior faces the support reactions of the panel must be transferred into the screws via the elastically supported, flexible faces. A punctual support arises in the area of the screw heads and causes relatively high, locally limited additional stresses in the exterior face.





For panels with profiled external faces, the support reactions can be transferred without a problem via the webs of the trapezoidal metal sheets and the narrow upper chord.

The resulting triangular shape of the moments in the simulated central support tests approximately correspond to the moments on a continuous beam (in reverse orientation of the points of zero-moments). Here, the transverse loading beam simulates the central support.

2. Test procedure:

   The exact test procedure is described in EN 14509, A.7. In addition for design purposes, it is necessary to not only design against the stresses in the faces, but also implement the support pressure and the fastenings into the calculations for serviceability limit state in real life design.

   Therefore, the tests setup must be chosen in a way that, in compliance with these verifications, the faces in the central support area fail at about the same loading as the compressive strength (f_{Cc}) respectively the allowable tensile force of the screws (zul F) is reached. At least the loads should be in the same range.

   Because of this relatively long spans usually need to be provided for the tests. These spans do not have to correspond with the point of zero-moments in a double span beam

3. Number of tests:

   Three tests with regular loads and always three tests with uplifting loads need to be accomplished for each panel thickness. It is recommended that tests with uplifting loads are carried out with different numbers of screws (with a defined distribution over the panel's width), e.g. 1 test with 3 screws, 1 test with 4 screws and 1 test with 5 screws.

For each panel thickness the test specimens shall be taken from the same batch as the test specimens for simple beams. Normalization can be undertaken implementing the material properties used for the single span tests. If the samples for the simulated central support test are taken from a different production lot, it is necessary to perform all material testing again.

4. documentation:

   The test specimens shall be measured exactly, analogous to the simple beam test specimens.

5. Important test results:

   achieved ultimate load per test

   recommended:
   Measuring of sinking and crushing of the support (loading beam) and the screw heads.

6. Aim of evaluation of test results:

   Wrinkling stresses (σ_w) over a central support for regular - and uplifting loads for individual types of faces at different panel thicknesses.
   Related values for increased temperature by application of the evaluation according to EN 14509, A.5.5.5, equ. A.16.

   The values are necessary for verification of serviceability limit state over central support for continuous beam panels.

7. Failure mode:

   If the panel fails in shear at the intermediate support (load introduction area) and not in wrinkling, this has to be noted. The calculation model must then be adjusted when determining the ultimate and serviceability limit state (plastic hinge at intermediate support is no longer an accurate model).

2.5.1.8 Creep coefficient

Since long term loadings do not occur in wall panels verifications concerning creep are not necessary and therefore no creep coefficients need to be determined.

2.5.1.9 Density of the core and weight of panels

Based on: EN 14509, A.8 and EN 1602

in general:

Test specimen and test procedure is exactly described in EN 14509, A.8 or in EN 1602 respectively.

Comments:

- The density shall be determined for each panel type.
- The weight of the panels shall be determined arithmetically with the nominal values of the density according to EN 14509, A.8.
- The weight of the panels for evaluation of the tests shall be measured directly (by weighing) according to chapt. 5.1.6 and 5.1.7.
- In terms of sampling of the specimens for determination of the density follow EN 14509, A.8.1.3.

2.5.1.10 Geometrical tolerances

Based on: EN 14509, 5.2.5, table 3 and annex D

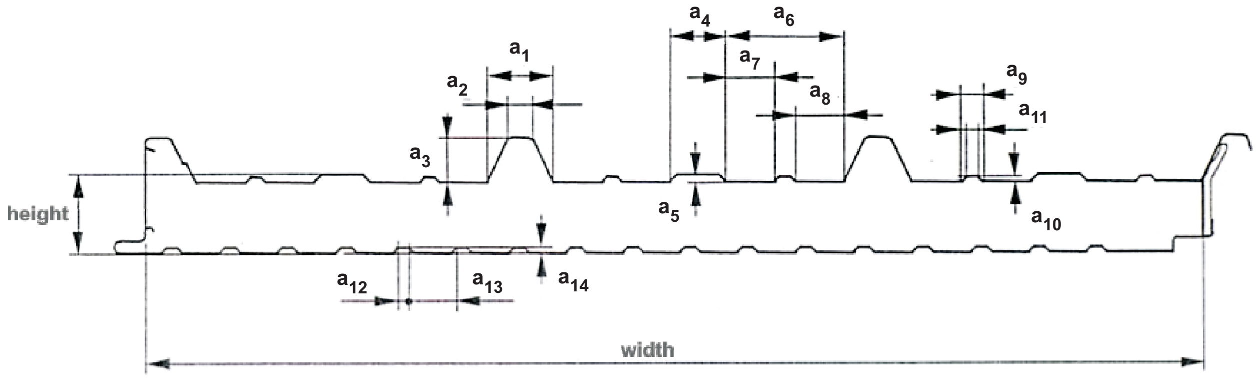
2.5.2 Roof panels

in general:

The task is to determine all necessary mechanical values for the CE marking and for the information accompanying the CE-marking need to be determined for one roof panel type with different over all and metal faces thicknesses.

note:

The following systematic of test numbering and the number of tests conducted are based on EN 14509, table 4.



2.5.2.1 Mechanical properties of faces

Based on: EN 14509, 5.1.2 and EN 10002-1 (annex A)

Comments:

1. Test specimen:

   metallic bright flat test pieces: according to EN 10002-1 type 1 or type 2.
   The coating must be removen either in part or totally before taking the steel thickness. The removal must be in accordance with EN 10326 Annex A.
   The coating and the zinc layers must be removed in advance.

2. Test procedure is exactly defined in EN 10002-1.

3. Number of tests:
   For each coil 3 tests are sufficient

   Two of the samples must be taken from the edge area (however with a minimum distance of 50 mm from the edge) and one sample must be taken from the centre of the face. All samples must be oriented parallel to the lengthwise direction of the panel.

4. Important test results:

   metal sheet thickness t_{obs} (accuracy 1/100 mm) and yield stress f_{yobs} determined on test specimen

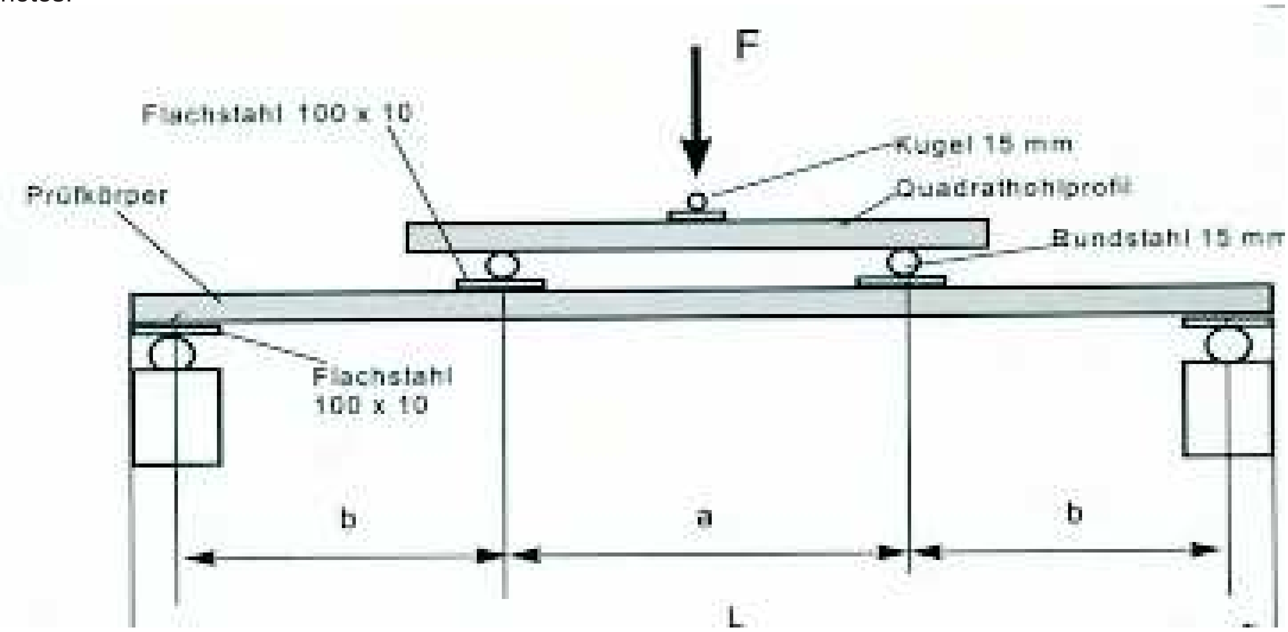
5. Aim of evaluation of test results:

   The values are necessary for interpretation of test results (e.g. see EN 14509, 5.2.1.2, 5.2.1.7, 5.2.1.8) and for determination of correction factors (e.g. EN 14509 A.5.5.4. equation A.15).

2.5.2.2 Shear strength and shear modulus

Based on: EN 14509, 5.2.1.2 and A3

notes:



There are 2 different kinds of tests which can be conducted alternatively:

1. four-point bending test on short beams (see EN 14509, A.3.1 to A.3.4)
2. test on a complete panel (see EN 14509, A.4).

It is recommended to conduct tests on short beams if possible since they are clearly less complex and can be accomplished in small test device. Only in special cases, e.g. due to unusual arrangement of lamellas or other prefabricated special core materials, the tests shall be accomplished with full scale panels.
In this context it should also be remembered that ITT tests and FPC tests must be identical, i.e. if ITT shear tests are accomplished with full scale panels, the FPC shear tests must also be conducted on full scale panels.

2.5.2.2.1 Test procedure on short beams :

The exact test procedure is described in EN 14509, A.3.2 to A.3.4. Comments:

1. shear failure mode:

   With PUR, PIR, EPS clear shear failure (shear crack, see photo) must occur.

   Failure due to wrinkling or delamination of faces does not deliver real shear strength.

   With MW also shear hinges (no clear shear cracks) which correspond to real shear strength can be found (see photo).

   For some configurations the failure mode may be a compressive failure either at the support or under the load introduction area. The test evaluation then does not give realistic shear strength properties.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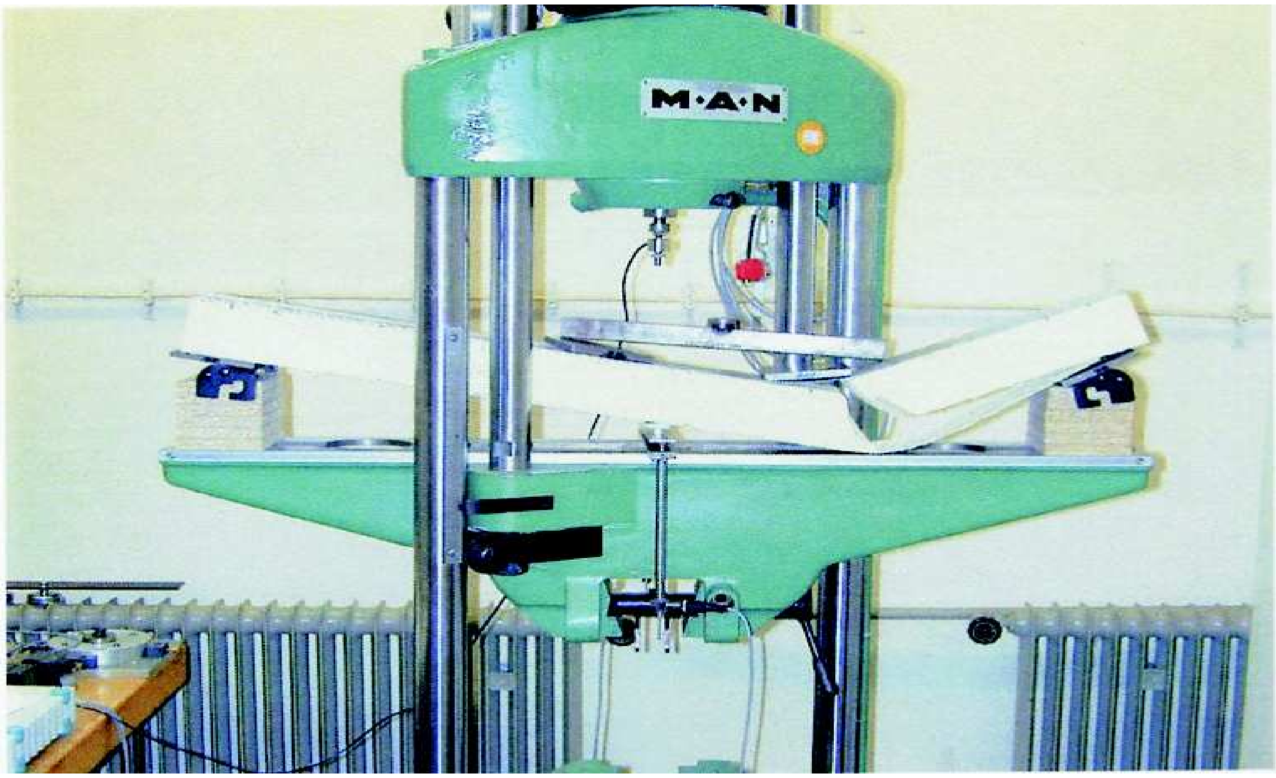
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2. deflection recording:

For determination of the shear modulus the exact load-deformation curve must be recorded. The deformation must be measured at the lower face of the sample because if it is measured at the upper side (e.g. cross head displacement) the deformation caused by compression at the supports is wrongfully included. Alternatively the displacement can be measured at the upper side, then however the compressive deformation at the supports must be taken at the same time and then subtracted from the deformation at mid span.

Since just the difference of total deformation less bending deformation (small value!) is decisive for evaluation, the deformations must be measured very exactly.

3. sampling of test specimen:
   - For panels with profiled faces the specimens shall be cut out of the predominant thickness (analogue to EN 14509, A.1.3) which mostly occurs between the ribs. Possibly existing light profiles or micro linings should be symmetrically distributed over the width of samples if possible.
   - For specimens with PUR, PIR, EPS, PF and CG it just needs to be kept in mind that a span must be selected with which the above mentioned shear failure mode occurs.
   - With MW and EPS the following needs to be considered additionally:
     - With a core of prefabricated slabs (e.g. MW or EPS plates) and transverse joints through full (or half) panel width within the core and glued together at the front side:

       A short beam needs to be removed so that the transverse joint is situated between the support and the 1^{st} loading point during the test.
     - With lamellas (mineral wool):

       With lamellas where longitudinal and transversal joints are not glued together, the arrangement of joints is of decisive importance for the shear strength and shear modulus. Therefore, the joints are normally not in one line.

       The following procedure is recommended:

       Sampling of a short beam in such way that no transverse joints are present, if possible (sample A).

       If not possible otherwise, a part of the cross section can include a joint (sample B) as long as the joint is situated between the two single loads.

       For evaluation of tests (also see EN 14509, A.3.5.1. equation A.6) the influence of transverse joints is then considered arithmetically (also see 6.1.2 and 6.2.2).
   - Special care must be taken when cutting the specimen. Once again please refer to note 1 in chapter A.1.3 of this document.

4. Number of tests:
   - - It is recommended to perform 10 instead of the required 3 tests per thickness (see chapter 2.3) per thickness tested. This generally leads to a smaller scatter of results and thus to better values when determining the characteristic values and the material safety factors γ_M

     When evaluating a variety of panel thicknesses, it is necessary to test only the thinnest, a mid range and the largest thickness. This procedure is in accordance with the full scale tests (see chapter 2.3).

5. Documentation and test results:
   - The individual test specimens must be measured exactly and the results must be documented in detail.
   - Important test results:

     failure load, load-deflection curve and details on failure mode

6. Aim of evaluation of test results:

   shear strength f_{Cv} (characteristic value)
   shear modulus G_C (mean value and characteristic value)

   Shear strengths are needed for design against ultimate and serviceability limit states (see e.g. EN 14509, tab. E.2).

   The single values for the modulus are to be determined from the linear slope of the load-deflection curve. The shear modulus is necessary for application of the sandwich theory (design by calculation) e.g. according to EN 14509, tab. E.3 and E.10.

2.5.2.2.2 Test procedure on full panel

The exact test procedure is presented in EN 14509, A.4 and/ or A5.

Comments:

1. To get a shear failure it is important that a) the width of the spreading plates both at the supports and below the load points (if not using pressure loading and b) the span length are appropriate. The recommended values in the standard may not be suitable for all types of panels. It is up to the manufacturer as the best expert regarding his own products to choose the appropriate values to be used in the tests.
2. The deflection recording, the member of tests. The documentation of test results and the evaluation of test results are in principle according to 2.5.2.2.1
3. When the shear strength and modulus are determined with a complete panel the effects of the possible joints in the core material are included in the test results. It is therefore of uppermost importance that the sampling of the test panels is such that the joints are situated in the most critical pattern in the shear failure area. The joint pattern in the core material must always be delivered by the manufacturer so that an evaluation of the influence can be made. It should also be noted if the joints are glued or in any other way connected to each other.
4. In this test setup it is also possible to test panels with profiled faces. The evaluation determining the shear strength and the shear modulus however has to be undertaken on the base of the sandwich theory (see EN 14509, A.4.5 and A.5.6). If ITT testing is performed on the full panel, the same test setup has to be used also for FPC as well as for external quality control

2.5.2.3 Reduced shear strength after long-term load

Based on: EN 14509, 5.2.1.5 and A.3.6
Comments:

1. In general:

   The tests shall be carried out as four-point bending tests (short beam) as described in chapt. 2.5.2.2, however with long term loading. In terms of test procedure all notes in chapter 2.5.2.2 need to be considered. A general description of the tests is presented in EN 14509, A.3.6.2.

   The test speciments have to be from the same lot as the test speciments for the short beam tests (see chapt. 2.5.2.2).

   It is recommended to apply a maximum load of approx. 90 % and a minimum load of approx. 50 % of the mean failure load determined in the short term tests (see chapt. 2.5.2.2).

   The long term loading usually is applied with weights.

2. Number of tests:

   Based on experience, a set of 10 tests on short beams, taken from the greatest panel thickness, is sufficient.

3. Documentation

   The individual test specimens must be measured exactly and the results must be documented in detail.

4. Important test results:

   Time of shear failure after the load was applied for different loads. The results are necessary to determine the long term shear strength at t = 100,000 h.

5. note:

   According to EN 14509, A.3.6.1 no tests need to be accomplished if a long term shear strength of $f_{v,long\ term} = 0.5 \cdot f_{v,short\ term}$ (at $\varphi \leq 2.4$ at 2000 h) or $f_{v,long\ term} = 0.3 \cdot f_{v,shortterm}$ (at $\varphi > 2.4$ at 2000 h) is specified.

   It must however be noted, that higher long term shear strengths, which can be determined with the help of the described tests, leade to significant advantages for the design of panels.

2.5.2.4 Compressive strength and compressive E-modulus

Based on: EN 14509, 5.2.1.4 and A.2

Comments:

1. test procedure:

   When accomplishing the tests it is important to have centric and constraint free load introduction (e.g. spherically seated mounting device).. Regarding the test arrangement one ball bearing plate is sufficient.

2. Number of tests:

   It is recommended to accomplish 10 instead of 6 tests (see EN 14509, tab. 4) for each panel thickness (explanations see chapt. 2.3, point 6).

3. Sampling of test specimen:

   In case of panels with profiled faces the specimens shall be cut out of the predominant thickness (analogue to EN 14509, A.1.3) that mostly occurs between the high profiles. Possibly existing light profiles or micro linings should be symmetrically distributed over the width of samples if possible.

4. The individual test specimens must be measured exactly and the results must be documented in detail.

5. Important test results:

   failure load and/or load-deformation curve

6. Aim of evaluation of test results:

   compressive strength f_{Cc}
   compressive E-modulus E_{Cc} (mean value and 5%-fractile value)

   Compressive strengths are needed for proof of ultimate and serviceability limit states of stresses at the supports (see EN 14509, E.2 and E.4.3.2), (alternatively full scale tests can be accomplished according to EN 14509, A.15.5!)

   The single values of compressive E-modulus are to be determined from the linear slope of the load-deflection curve.

   The compressive E-modulus is necessary for standardisation and for the case that the wrinkling stress should be determined arithmetically without tests (such procedure is however conservative and gives low values!) (see EN 14509,. A.5.5.3, equ. A.13 and A.14).

2.5.2.5 Tensile strength and tensile E-modulus

Based on: EN 14509, 5.2.1.6 and A.1
Comments:

1. Test procedure:

   - At accomplishment of tests it is absolute important to have centric load introduction (tensile force). Therefore e.g. metal plates, plywood or similar are glued to the faces of the specimen and these are gimbal mounted into the test device. Regaring the test arrangement one ball bearing plate is sufficient.

     In the cross panel tensile test it is important to determine the accurate deformation between the two plates. When using the cross head movement for evaluation, the deformation of the mounting devices is always included in the results. The determined elastic modulus can then not be determined accurately.

     It is in any case necessary to use the same type of test setup for both, ITT and external quality control.
   - During sampling it is important that the faces are not peeled off, not even in small areas at the edges (see EN 14509, A.1. note 1).

2. Number of tests:

   It is recommended to accomplish 10 instead of 6 tests (see EN 14509, tab. 4) for each panel thickness (explanations see chapt. 2.3, point 6).

3. Sampling of test specimen:

   In case of panels with profiled faces the specimens shall be cut out of the predominant thickness (analogue to EN 14509, A.1.3) that mostly occurs between the high profiles. Possibly existing light profiles or micro linings should be symmetrically distributed over the width of samples if possible.

4. Documentation and test results The individual test specimens must be measured exactly and the results must be documented in detail.

   - Important test results:
     tensile strength f_{Ct} at 20 °C and 80 °C (see EN 14509, A.1.6)
     tensile E-modulus E_{Ct} at 20 °C and 80 °C (see EN 14509, A.1.6)

5. Aim of evaluation of test results:

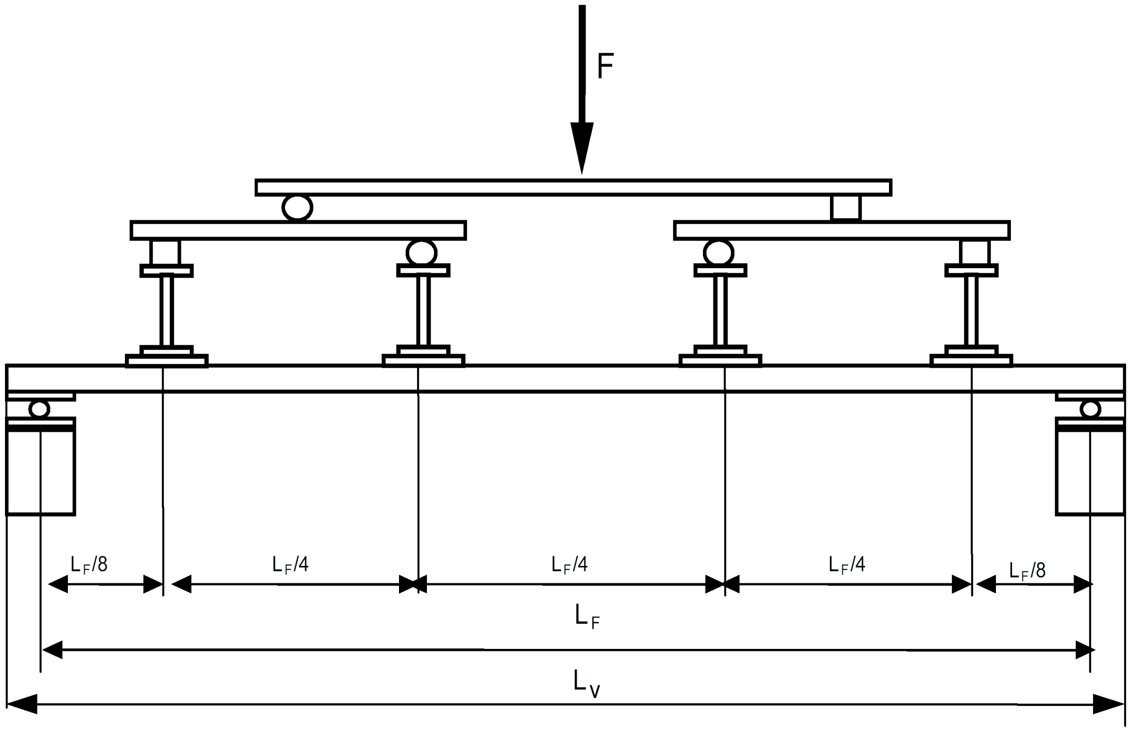
   The tensile strengths are needed as control value (FPC) and for determination of the correction factor k_2 (see EN 14509, A.5.5.5) of the wrinkling stress at low tensile strengths.

   The single values of tensile E-modulus are to be determined from the linear slope of the load-deflection curve.

   The tensile E-modulus is necessary for determination of the correction factor k_1 for the wrinkling stress at increased temperature (see EN 14509, A.5.5.5, equ. A.16) and if the wrinkling stress should be determined arithmetically without tests (such procedure is however conservative and gives low values!) (see EN 14509, A.5.5.3, equ. A.13 and A.14).

2.5.2.6 Bending moment capacity and wrinkling stress of simply supported panels

Based on: EN 14509, 5.2.1.7 and A.5.1 to A.5.5



Comments:

1. In general:

   The aim of the test setup is to define the wrinkling stresses w for each type of face. The determination of the bending moment capacity (Mu) is automatically included with the evaluation of the test results, even though these values are not necessary for the design calculations.

2. Test procedure:

   The exact test procedure is described in EN 14509, A.5.1 to A.5.4.

   - In principle there are 2 ways in which the test loads can be applied to the system (see EN 14509, A.5.2.1):
     - by 4 line loads (linear distributed loads) or
     - by air pressure, either in a vacuum chamber or with air bags

     Only when loading with air pressure the correction factor k_2 (see EN 14509, A.5.5.5) needs to be considered in the evaluation.

3. Test results

   After the ultimate load is reached the failure mode needs to be determined and documented exactly. A pure bending failure must always be obtained. This is virtually always recognizable (in the face under pressure) by wrinkling of the flat or lightly profiled faces or by buckling of the upper chord areas of the trapezoidal faces (see photo). The failure must occur in the centre part of the panel. If not, the test should be repeated. A failure can also occur by yielding of the faces (in the face under tension). This can be determined e.g. by measuring the strains (and thus the stresses) with strain gauges and possibly also through the load-deflection curve.

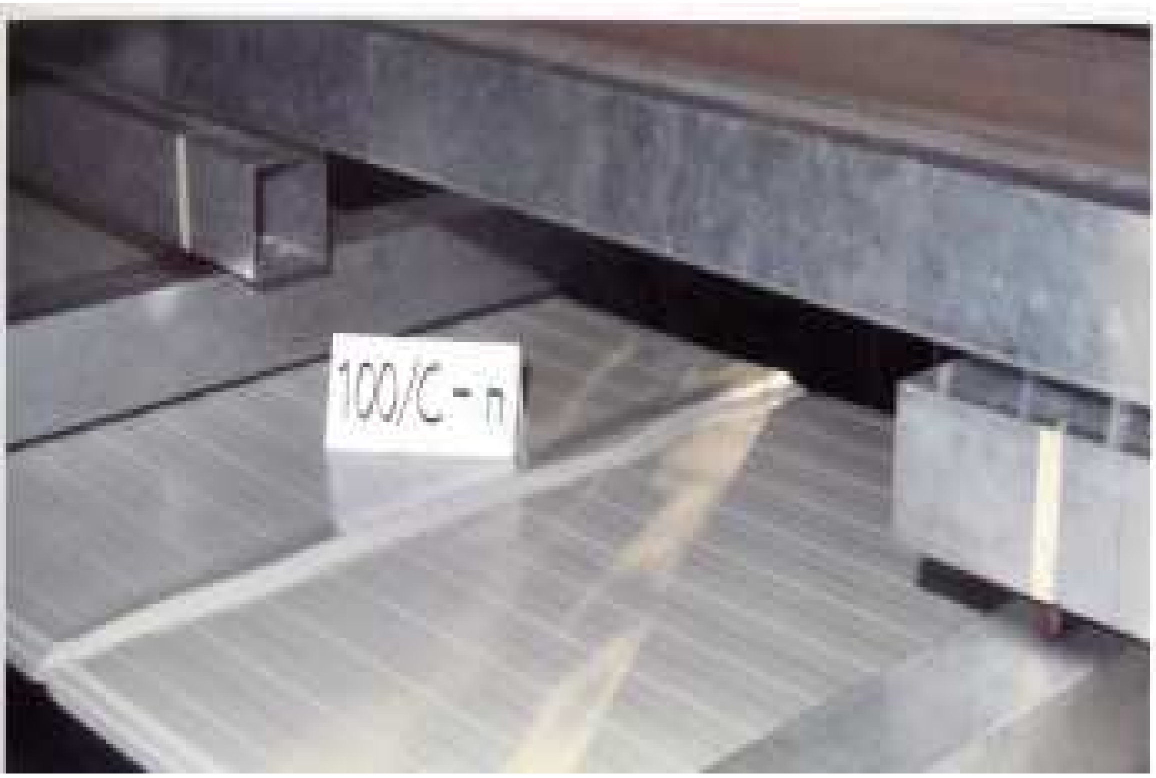


Figure 2.3: wrinkling of a lightly profiled (quasi flat) face (negative orientation)

Figure 2.4: buckling of the trapezoidal face (positive orientation)

4. In addition to the determination of the failure load the deflection at mid span must be determined in any case and displayed in a load-deflection curve. Furthermore it is recommended to measure strains (stresses) with strain gauges at the middle of the span. The obtained results should also be displayed in a load-stress curve. Compared to calculated deflections and stresses (design by calculation) both curves serve for confirmation of the calculation method with which allowable span tables are determined in the end.

5. Number of tests:

   In principle for panels with upper profiled (trapezoidal) and lower lightly profiled faces 3 full scale tests (simple beam) for each panel thickness need to be accomplished in both, positive orientation (profiled face under pressure) and in negative orientation (lightly profiled face under pressure).

   Within the scope of different panel types of one company the geometry of the inner, lightly profiled faces often correspond to the geometry of the wall panels for which the tests are accomplished also at the same time. In this case the wrinkling stress of these faces is already known in principle through the tests on the wall panels. It is recommended however to accomplish one test with each panel thickness respectively for confirmation.

   No tests need to be arranged with different sheet thicknesses as long as the tests were accomplished with the thinnest intended thickness and the wrinkling stresses for further sheet thicknesses are determined according to EN 14509, A.5.5.3, equ. A.12.
   In tests for several thicknesses are intended only the thinnest and thickest need to be tested and the worst case can be used for all thicknesses.

6. Documentation
   The test specimens dimensions must be measured exactly and the results must be documented in detail.

   Here the measured values of the metal sheet geometry and the panel thickness need to be determined most important, so that the cross-sectional values (distance between centroids of faces, areas etc.) can be determined for each individual test specimen.

7. Important test results:

   achieved ultimate load for each test, deflection at the middle of span.

   Recommended:

   Results of strain - (stress-) measurement at mid span, possibly only in few, defined tests.

8. Aim of evaluation of test results:

   Failure stresses for the upper chord of the profiled (trapezoidal) faces respectively wrinkling stresses (σ_W)
   of the lightly profiled lower faces for different panel thicknesses including the appropriate values for increased temperature by application of the evaluation process according to EN 14509, A.5.5.5, equ. A.16.

   The values are needed for design against ultimate and serviceability limit states.

2.5.2.7 Bending moment capacity and wrinkling stresses at an internal support

Based on: EN 14509, 5.2.1.8 and A.7
notes:

All general notes apply according to chapt. 2.5.1.7

For roof panels with profiled (trapezoidal) upper faces the following points should be considered additionally:

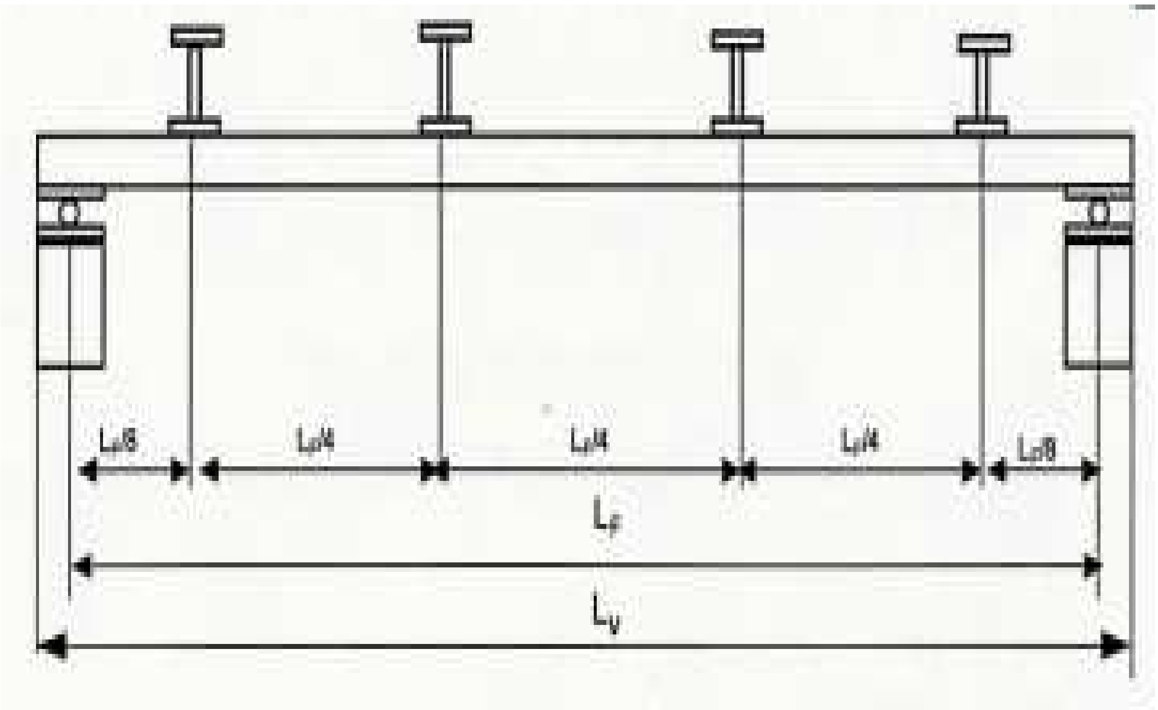
- In case of conventioanal fastenings with calottes at the high points of the profuiles, tests with uplifting loads are not necessary because a reduction of failure stresses in the upper chord is not to be expected with such fastening.
- Tests with regular loading are not necessary, as long as the inner, lightly profiled faces are similar to those of the wall panels on which simulated central support tests were accomplished already.

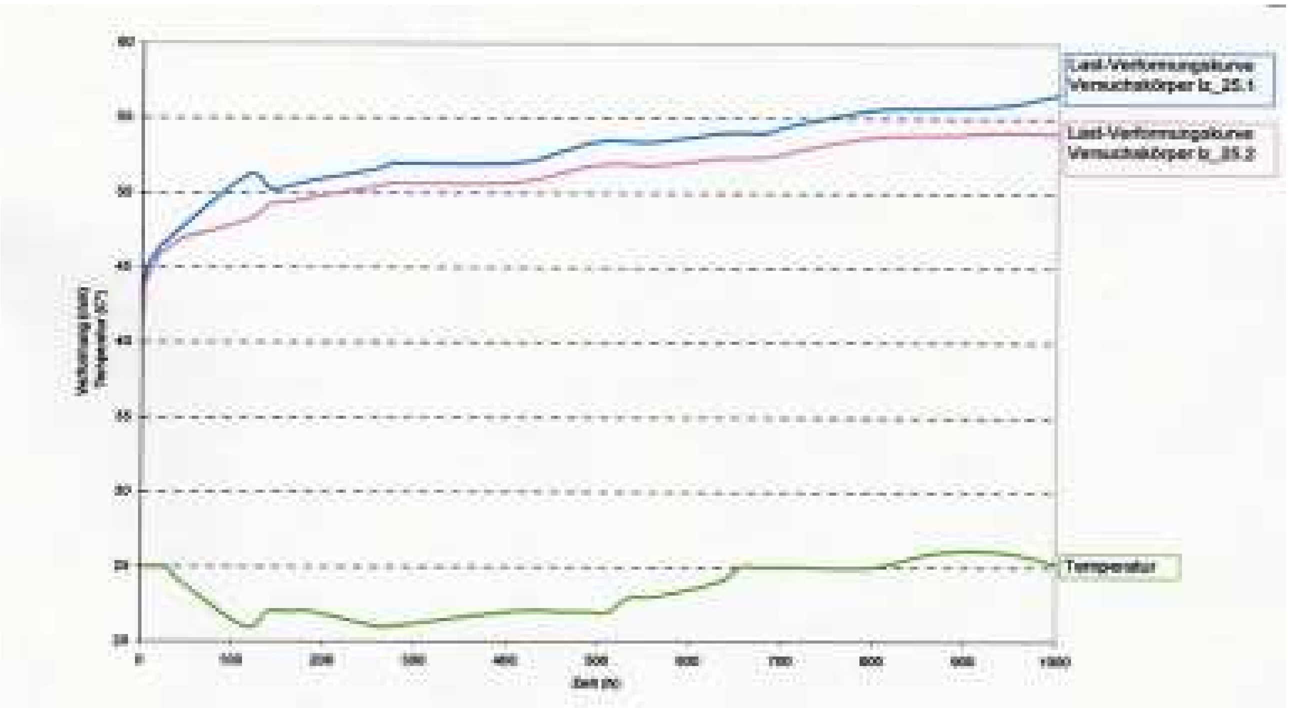
2.5.2.8 Creep coefficient

Based on: EN 14509, 5.2.1.3 and A.6

Comments:

1. In general:
   Since creep actions can occur under constant mechanical loading, the deflection of the panel can accelerate without an increase of the loading. Such an effect leads to a rearrangement of stresses within the metal sheets. This shall be considered in the design of panels.
   Because of this, long term tests need to be undertaken in which a uniformly distributed load or four linear loads are applied to a panel (simple beam loaded with weights) and the increase of deflections over time is measured.





2. Test procedure:
   In principle the tests need to be accomplished according to chapt. 2.5.2.6 (respectively EN 14509, A.5) whereas instead of an increasing load, a long term constant load shall be applied. The amount of loading must be chosen in such way, that a maximum shear loading on the core of approx. 30 % to 40 % of the mean short term shear strength according to 2.5.2.2 (respectively EN 14509, A.3) is reached. Minor diviations from the required loading are acceptable (see EN 14509, A.6.4). The loading time shall be at least 1,000 h.

3. Number of tests:
   For a range of panlled panel thicknesses one test on the greatest panel thickness is sufficied (according to EN 14509, A.6.1). Because of problems that may occur when determining the panel deformation it is recommended to perform 2 tests.

4. Documantation
   The test specimen's dimensions must be measured exactly and the results must be documented in detail.

5. Important test results:
   The deflection at mid span of a simply supported beam measured in defined time intervals so that a diagram showing deflection over time (up to 1000 h) can be drawn.

6. Aim of evaluation of test results:
   Determination of creep coefficients φ_t at 2,000 h and (by interpolation) at 100,000 h.

2.5.2.9 Density of the core and weight of the panels

Based on: EN 14509, A.8 and EN 1602
notes:

Test specimen and test procedure is exactly described in EN 14509, A.8 or in EN 1602 respectively.

Comments:

The density shall be determined for each panel type.

The weight of the panels shall be determined arithmetically with the nominal values of the density according to EN 14509, A.8.

The weight of the panels for evaluation of the tests shall be measured directly (by weighing) according to chapter 2.5.2.6 and 2.5.2.7

In terms of sampling of the specimens for determination of the density follow EN 14509, A.8.1.3.

For panels with profiled faces the specimens shall be cut out of the predominant thickness (see chapt. 2.5.2.2.1, point 3).

2.5.2.10 Geometrical tolerances

Based on: EN 14509, 5.2.5, table 3 and annex D

2.6 Evaluation of test results (ITT-Tests) for determination of mechanical values

In the following the evaluation of the test results (according to chapt. 2.5) for a wall - and a roof panel is demonstrated according to the guidelines in EN 14509. This is achieved by performing the necessary evaluation steps on the base of the previously determined test results. On the left you will find general notes for accurate evaluation with references to the related chapters in EN 14509 and on the right you will find examples. For exemplary evaluation the respective test values shown in chapt. 2.5 are assessed.

2.6.1 Wall panels

in general:

The task is to determine all necessary mechanical values for the CE-marking and for the information accompanying the CE-marking by evaluation of test results of accomplished ITT-tests for one wall panel type with different panel - and metal sheet thicknesses.
notes:

The following systematic of test numbering and corresponding notes are directly based on the information given in chapt. 2.5.

2.6.1.1 Mechanical properties of metal faces

Based on: EN 14509, 5.1.2 and EN 10002-1 (annex A)
note:

Due to the test results according to chapt. 2.5.1.1 the metal grade and the thickness of the face material must be determined on the base of the relevant standards (in this case for steel EN 10326).

A question of great importance is the classification of the steel grade in principle, since normally the tensile tests provide clearly higher values compared to the normative values of the ordered steel.

Therefore, it needs to be clarified which steel grade shall be the base for the CE-marking.

For panels with flat or slightly profiled faces (profile < 5 mm, see EN 14509, E.1.1) it is not necessary to perform normalization with regards to the yield strength of the faces. For wall panels with profiled faces, the normalization should be in accordance with chapter 6.2.6, section 2.3.1.

2.6.1.2 Shear strength and shear modulus

Based on: EN 14509, 5.2.1.2 and A.3 (in particular A.3.1 to A.3.5), A.4 and A.5.6

1. On shear strength:

    - For cores without joints or glued joints the shear strength is easy to determine from the 4-point bending test (or the full scale test) with

      $f_{Cv} = \frac{F_u}{2 \cdot B \cdot e}$ (see EN 14509, A.3.5.1. A.5)

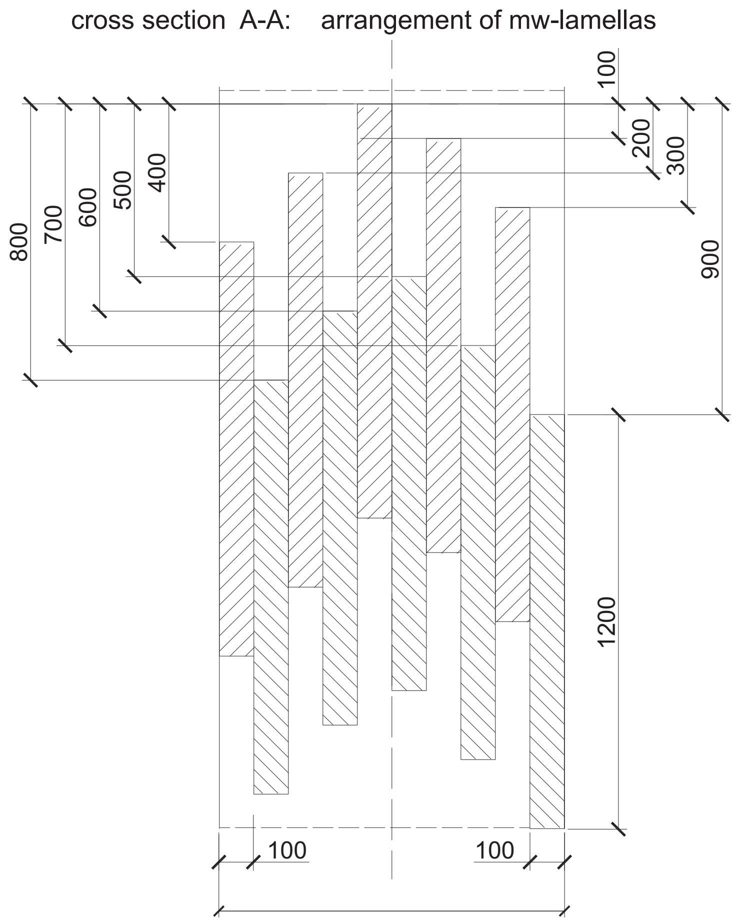
      F_u = failure load
      B = width of test specimen
      e = distance between centroids of faces

      With the individual values the fractile value needs to be determined according to EN 14509, A.16 and stated as the characteristic value of the shear strength.

    - For cores including joints, e.g. not glued mineral wool lamellas, the evaluation must be undertaken as above, as long as samples without joints (or joints in the shear force free area) were used in the 4-point bending test. But the characteristic value then needs to be reduced with the factor kv (see EN 14509, A.3.5.1 and A.6).

      $$k_v = \frac{\text{minimal width of uncut core along a line of cut ends}}{\text{over-all panel width}}$$

      e.g. in the following case:



$$k_v = \frac{900}{1000} = 0.9$$

Comment:
If the shear strength has been determined including the appropriate amount of core joints, no further reduction is necessary.

2. On shear modulus

The shear modulus is to be determined on the base of the 4-point bending test (or the full scale test) according to EN 14509, A.3.5.2. The shear modulus GC needs to be determined for each test specimen from the linear part of the load-deflection curve $\left[\frac{\Delta F}{\Delta w}\right]$ as shown below:

flexural rigidity: $$B_S = \frac{E_{F1} \cdot A_{F1} \cdot E_{F2} \cdot A_{F2}}{E_{F1} \cdot A_{F1} + E_{F2} \cdot A_{F2}} \cdot e^2$$

bending deformation: $$\Delta w_B = \frac{\Delta F \cdot L^3}{56,34 \cdot B_S}$$

shear deformation: $$\Delta w_S = \Delta w - \Delta w_B$$

shear modulus: $$G_C = \frac{\Delta F \cdot L}{6 \cdot B \cdot d_C \cdot \Delta w_S} \quad \text{(A.7)}$$

Where

E_{F1} Young's modulus of upper face;
A_{F1} cross-sectional area of upper face;
A_{F2} cross-sectional area of lower face;
E_{F2} Young's modulus of lower face;
e determined distance between centroids of faces;
w deflection at mid-span for a load increment F taken from the linear part of the load-deflection curve;

d_C height of core material (see EN 14509, D.2.1. where $d_C = D - (t_1 + t_2)$, i.e. t_1,t_2 are the thicknesses of the faces);
B determined width of test specimen;
L span of test specimen (in shear failure)

With the single values the mean - **and** fractile value needs to be determined in accordance with EN 14509, A.16. Both values must be specified for the shear modulus.

Comment:

A reduction of the shear modulus because of not glued core joints is in principle not necessary. In doing so it is however assumed, that the theoretically determined deformation for the single span test shows good correlation with the test obtained results.

2.6.1.3 Long term shear strength

In wall panels no long term loadings occur (see EN 14509, 5.2.1.5 and chapt. 5.1.3) and therefore, no test results need to be evaluated.

2.6.1.4 Compressive strength and compressive E-modulus

Based on: EN 14509, 5.2.1.4 and A.2
Comments:

1. On compressive strength

   The compressive strength is determined by

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

   F_u = failure load respectively the load at a defined compressive strain (see EN 14509, A.2.5.1) e.g. with PUR at 10 % of the core height
   A = cross-sectional area = $B \cdot L$

2. On compressive E-modulus

   The compressive E-modulus must be determined from the linear part of the load-deflection curve $\left[\frac{\Delta F}{\Delta w}\right]$ from the compression test.

   $$E_{Cc} = \frac{\Delta F \cdot d_C}{\Delta w \cdot B \cdot L} = \frac{\Delta \sigma \cdot d_C}{\Delta w} = \frac{\Delta \sigma}{\varepsilon_C}$$

   $\Delta\sigma$= stress increment within linear part
   d_C= thickness of core
   ϵ_c = compression strain

2.6.1.5 Tensile strength and tensile E-modulus

Based on: EN 14509, 5.2.1.6 and A.1
Comments:

1. On tensile strength

   The tensile strength is determined by

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

F_u = failure load respectively the load at a defined strain (see EN 14509, A.1.5.1. note 1) e.g. with PUR at 10 % of the height of the core
A = cross-sectional area = $B \cdot L$

2. On tensile E-modulus

The tensile E-modulus must be determined from the linear part of the load-deflection curve $\left[\frac{\Delta F}{\Delta w}\right]$ from the tensile test:

$$E_{Ct} = \frac{\Delta F \cdot d_C}{\Delta w \cdot B \cdot L} = \frac{F_u \cdot d_C}{w_u \cdot A} = \frac{\Delta\sigma \cdot d_C}{\Delta w} = \frac{\Delta\sigma}{\Delta\varepsilon_t}$$

$\Delta\sigma$ = stress increment within linear part
d_C = thickness of core
ϵ_t = tensile strain

2.6.1.6 Bending moment capacity and wrinkling stresses at a simple beam

Based on: EN 14509, 5.2.1.7 and A.5.5
Comments:

1. In general

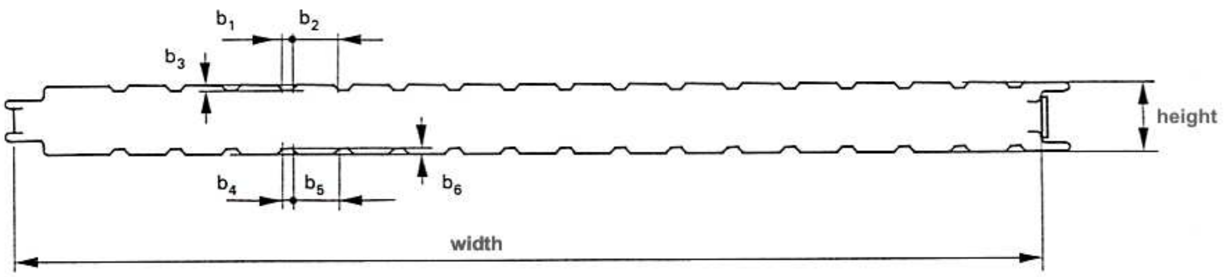
One of the most important values for the design against ultimate limit state is the wrinkling stress W at which the flat or lightly profiled face under compression fails. Therefore, the aim is to determine the

- wrinkling stress within span and the
- wrinkling stress within span at increased temperature

for each type of exterior and interior face.

The wrinkling stresses may depend on the thickness of the core. If different panel thicknesses are intended, values need to be determined for the least, a mean and the greatest thickness. If panels with a thickness between the tested thicknesses are to be evaluated, the lower properties found in one of the two surrounding thicknesses (next thicker or next thinner panel) has to be assumed. It is however unscrupulous to use liner interpolation for such cases.

The wrinkling stresses may, in addition to the thickness of the core, also depend on the metal sheet thickness and the temperature of the face. These values shall be determined by an appropriate evaluation of the determined wrinkling stresses (see following chapter).



2. Evaluation of tests

In the following it is assumed, that the faces for wall panels are either flat or lightly profiled (depth of profile < 5 mm, see EN 14509 E.1.1). For profiled faces the evaluation needs to be undertaken in accordance with chapter 2.6.2.6

The determination of wrinkling stresses of flat or lightly profiled faces is described in EN 14509, A.5.5.2 and A.5.5.3:

$$M_u = \frac{F_u \cdot L}{8}$$

M_u = ultimate bending moment
M_u = ultimate bending moment
F_u = failure load, including possible existing transverse loading beams and the self-weight of test specimen.

$$\sigma_w = \frac{M_u}{e \cdot A_1}$$

M_u = ultimate bending moment
e = Distance between the centroids of faces.
For lightly profiled and quasi flat faces, the centroids of the faces must be determined under consideration of the geometry.
A_1 = cross-sectional area of the face under compression

3. Determination of wrinkling stresses for metal sheet thicknesses that were not experimentally analysed.

   For larger metal sheet thicknesses the wrinkling stress must be reduced.

   $\sigma_{w,t2} = f \cdot \sigma_{W,t1}$

   $\sigma_{w,t2}$ = wrinkling stress of a larger metal sheet thickness t_2

   $\sigma_{w,t1}$ = wrinkling stress of metal sheet thicknesses determined in tests.

   $$f = \frac{A_1 \cdot \sqrt[3]{I_2}}{A_2 \cdot \sqrt[3]{I_1}}$$

   A_1 , I_1 = cross-sectional area and moment of inertia of a face with thickness t_1

   A_2 , I_2 = cross-sectional area and moment of inertia of a face with thickness t_2

4. Wrinkling stresses at increased temperature (see EN 14509, A.5.5.5) are determined with the help of the factor k_1:

   $$k_1 = \sqrt[3]{\left(\frac{E_{Ct,+80^\circ C}}{E_{Ct,+20^\circ C}}\right)^2}$$ see EN 14509 A.16

   $E_{Ct,+20^\circ C}$ = characteristic value of the tensile E-modulus at 20 °C

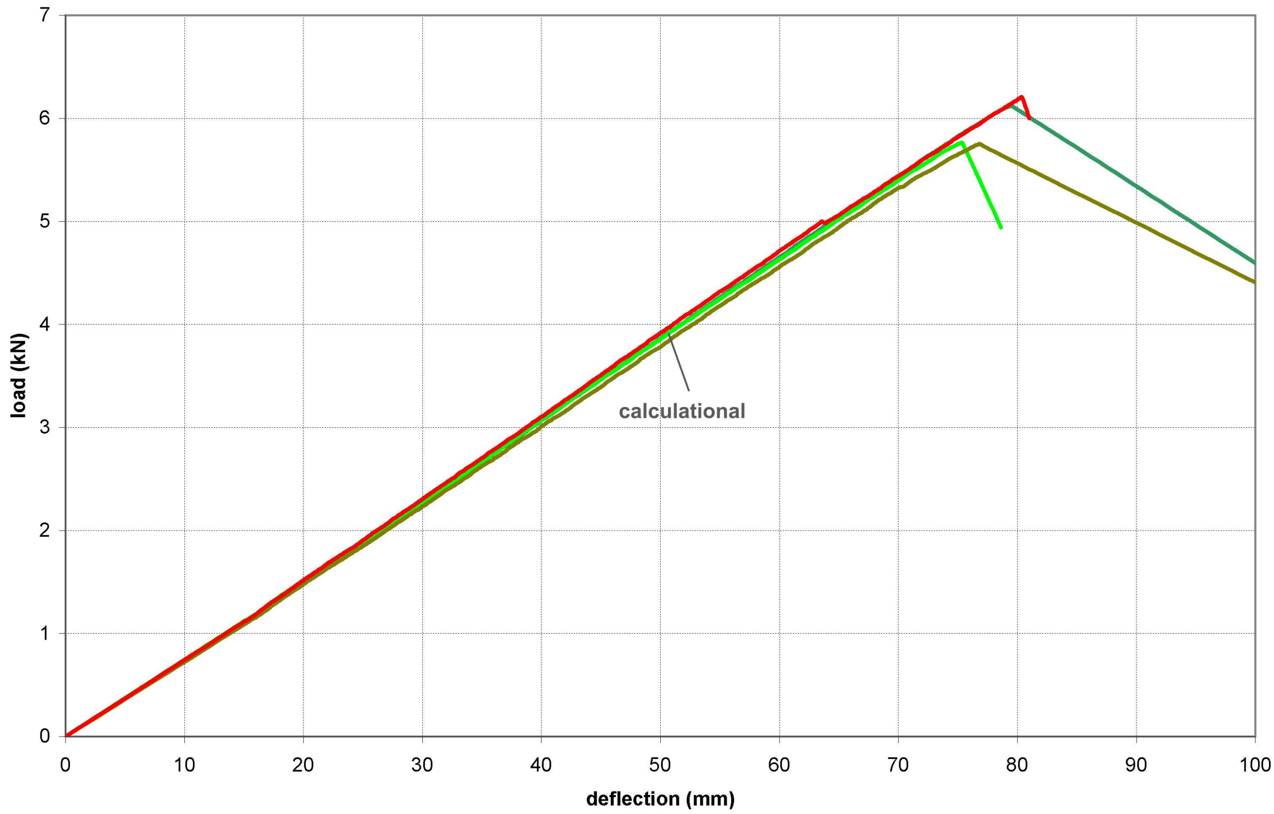
   $E_{Ct,+80^\circ C}$ = characteristic value of the tensile E-modulus at 80 °C

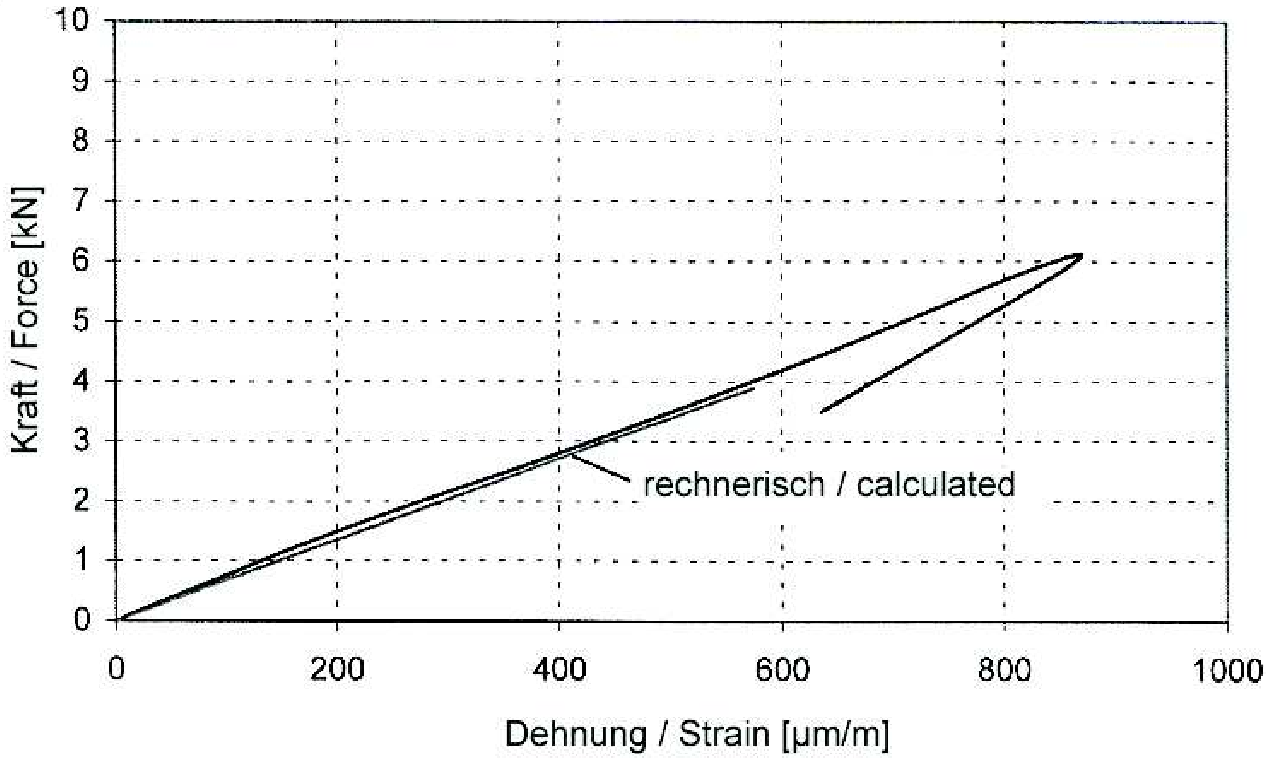
   $$\sigma_w^{80^\circ C} = k_1 \cdot \sigma W$$

   $\sigma_w^{80^\circ C}$ = wrinkling stress at increased temperature

5. Reference to the factor k_2 (EN 14509, A.5.5.5):

   With the factor k_2 the wrinkling stress must be additionally reduced if the characteristic tensile strength of the core is less than $f_{ct} = 0.1MPa$. This must only be taken into account as long as the loading in the tests was applied with air pressure, e.g. in a vacuum chamber or by air bags. For tests with 4 line loads (transverse loading beams) k_2 is never to be taken into account.





2.6.1.7 Bending moment capacity and wrinkling stresses at an internal support

Based on: EN 14509, 5.2.1.8 and A.7, in particular A.7.5
General comments:

One of the most important values for the design against serviceability limit state is the wrinkling stress W at which the flat or lightly profiled face under compression fails directly in the area of the central support due to regular or uplifting loads (more detailed explanations about ultimate capacity over a central support see chapt. 2.5.1.7).

Therefore, the aim is to determine the wrinkling stress under regular - and uplifting loads at first of each type of exterior and interior faces.

In terms of dependency of the thickness of panels and the thickness of metal sheets the same information as in chapt. 2.6.1.6 apply.

The factor k_1 implementing increased temperature can also be applied analogous to chapt. 2.6.1.6

The factor k_2 does not need to be taken into consideration as long as the characteristic tensile strength of core materials is less than $f_{Ct} \leq 0.1\ MPa$.

The determination of the wrinkling stress is described in EN 14509, A.7.5:

$$M_u = \frac{F_u}{4} + \frac{F_G}{8} \cdot L$$

F_u = failure load including transverse loading beams
F_G = self-weight of panel

$$\sigma = \frac{M}{e \cdot A_i}$$

A_i = cross-sectional area of face under compression

2.6.1.8 Creep coefficient

Since long term loadings do not occur in wall panels, creep coefficients are not necessary for the CE-marking (see also chapt. 2.5.1.8).

2.6.1.9 Density of the core and weight of the panels

Based on: EN 14509, A.8
Comments:
The density according to EN 1602 shall be stated as mean value based on the obtained test results presented in chapt. 2.5.1.9 Furthermore the least - and largest values shall be stated according to EN 14509, table 4.

The weight of the panels shall be determined arithmetically (value shown in CE-marking) based on the nominal geometry and the nominal density of the core and faces material.

2.6.1.10 Determination of dimension tolerances of the most important geometrical dimensions

Comments:

The maximum allowed dimension tolerances are shown in EN 14509, 5.2.5, table 3. These need to be checked according to EN 14509, annex D.

For wall panels with quasi flat faces on both sides these are in particular the depths of the profiles as well as the width between the profiles and the thickness of the panel.

2.6.1.11 Determination of material safety factors

Based on: EN 14509, E.6.3.2
Comments:

The variation coefficient obtained from the determined values of shear, compressive and wrinkling strength are the base for the determination of the material safety factors (see. EN 14509, E.6.3.2).

2.6.1.12 CE-Marking

The requirements of EN 14509, ZA.3.5 need to be considered and followed:
note:

With the results in chapter 2.6.1 all necessary values for the CE Marking regarding the mechanical properties, see EN 14509, figure ZA.3 for panels for use in external walls are available.

The CE Markings can be made for all the panels included in the same "productfamily", see chapter 2.3.

It is important to point out that for some properties the mean values, e.g. shear modulus of the core, have to be declared, see EN 14509, 5.2.1. For others the 5 %-fractile values have to be declared, e.g. wrinkling stresses.

Furthermore other values, as for example the thermal transmittance also have to be declared (see chapter 1 and 3).

2.6.2 Roof panels

In general:

The task is to determine all necessary mechanical values for the CE-marking and for the information accompanying the CE-marking by evaluation of test results of accomplished ITT-tests for one roof panel type with different panel - and metal sheet thicknesses.

notes:

The following systematic of test numbering and corresponding notes are directly based on the information given in chapt. 2.5.

2.6.2.1 Mechanical properties of metal faces

Based on: EN 14509, 5.1.2 and EN 10002-1 (annex A)
Note:

Due to the test results according to chapt. 2.5.1 the metal grade and the thickness of the face material must be determined on the base of the relevant standards (in this case for steel EN 10326).

A question of great importance is the classification of the steel grade in principle, since normally the tensile tests provide clearly higher values compared to the normative values of the ordered steel.

Therefore, it needs to be clarified which steel grade shall be the base for the CE-marking.

For panels with flat or slightly profiled faces (profile < 5 mm, see EN 14509, E.1.1) it is not necessary to perform normalization with regards to the yield strength of the faces. For wall panels with profiled faces, the normalization should be in accordance with chapter 2.6.2.6, section 5.

Most times the yield stress (in the upper chord) of the trapezoidal upper face is controlling for design. Therefore, the normative value of the defined steel shown in the CE-marking must be applied. This standardisation shall be accomplished according to EN 14509, A.5.5.4.

2.6.2.2 Shear strength and shear modulus

Based on: EN 14509, 5.2.1.2 and A.3 (in particular A.3.1 to A.3.5), A.4 and A.5.6
Comments:

1. On shear strength

   - For cores without joints or glued joints the shear strength is easy to determine from the 4-point bending test (or the full scale test) with (see EN 14509, A.3.5.1. A.5)

$$f_{Cv} = \frac{F_u}{2 \cdot B \cdot e}$$

F_u = failure load
B = width of test specimen
e = distances of centroids of faces

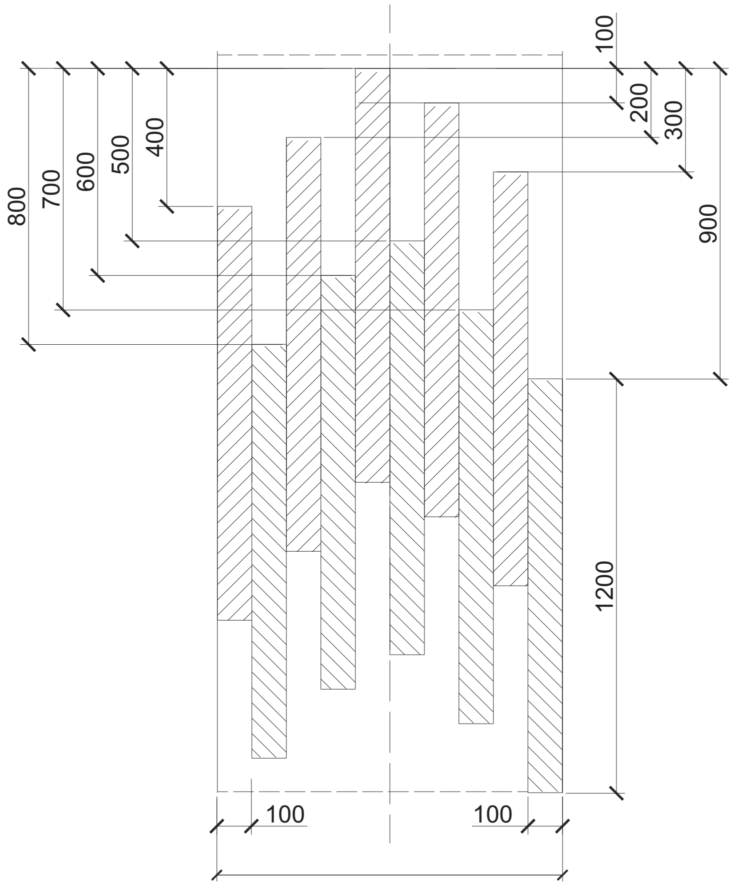
With the individual values the fractile value needs to be determined according to EN 14509, A.16 and stated as the characteristic value of the shear strength.

- For cores including joints, e.g. not glued mineral wool lamellas, the evaluation must be undertaken as in 1a) above, as long as samples without joints (or joints in the shear force free area) were used in the 4-point bending test. But the characteristic value then needs to be reduced with the factor kv (see EN 14509, A.3.5.1 and A.6).

$$k_v = \frac{\text{minimal width of uncut core material along a line of cut ends}}{\text{over-all panel width}}$$

e.g. in the following case:

cross section A-A: arrangement of mw-lamellas



$$k_v = \frac{900}{1000} = 0,9$$

Note:

If the shear strength has been determined including the appropriate amount of core joints, no further reduction is necessary.

2. On shear modulus

The shear modulus is to be determined on the base of the 4-point bending test (or the full scale test) according to EN 14509, A.3.5.2. The shear modulus G_C needs to be determined for each test specimen from the linear part of the load-deflection curve $\left[\frac{\Delta F}{\Delta w}\right]$ as shown below:

flexural rigidity $B_S = \frac{E_{F1} \cdot A_{F1} \cdot E_{F2} \cdot A_{F2}}{E_{F1} \cdot A_{F1} + E_{F2} \cdot A_{F2}} \cdot e^2$

bending deformation $\Delta w_B = \frac{\Delta F \cdot L^3}{56.34 \cdot B_S}$

shear deformation $\Delta w_S = \Delta w - \Delta w_B$

shear modulus $G_C = \frac{\Delta F \cdot L}{6 \cdot B \cdot d_C \Delta}$

Where

E_{F1} Young's modulus of upper face;
A_{F1} cross-sectional area of upper face;
A_{F2} cross-sectional area of lower face;
E_{F2} Young's modulus of lower face;
e determined distance between centroids of faces;
w deflection at mid-span for a load increment F taken from the linear part of the load-deflection curve;
d_C height of core material (see EN 14509, D.2.1. where $d_C = D - (t_1 + t_2)$, i.e. t_1, t_2 are the thicknesses of the faces);
B determined width of test specimen;
L span of test specimen (in shear failure)

With the single values the mean - and fractile value is to be determined according to EN 14509, A.16. Both values must be specified for the shear modulus.

Comment:

A reduction of the shear modulus because of not glued core joints is in principle not necessary. In doing so it is however assumed, that the theoretically determined deformation for the single span test shows good correlation with the test obtained results.

2.6.2.3 Long term shear strength

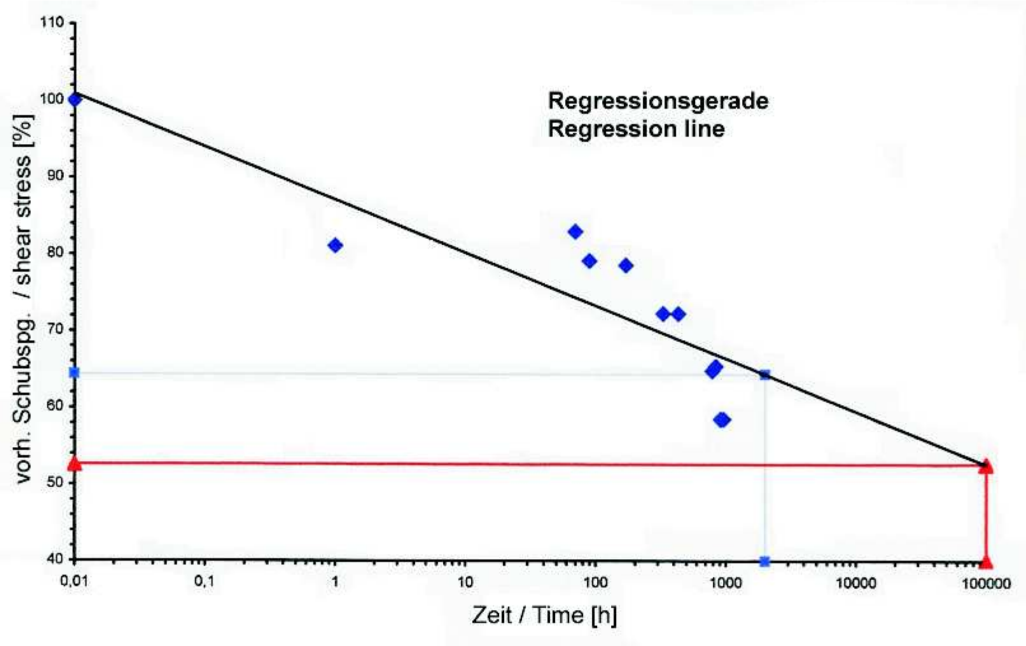
Based on: EN 14509, A.3.6.3
Comments:
For determination of the long term shear strength the obtained results shall be evaluated in such way, that the "time to failure" values obtained in the long term shear strength tests are displayed in a diagram. Here the shear stresses (τ_i) determined on the individual test specimens and determined by the applied loads shall be determined and put into relation to the short term shear strength (f_{Cv} as mean value).

In these diagrams this ratio (τ_i / f_{Cv}) is shown at the ordinate and the "time to failure" value is shown on the abscissa in a logarithmic scale.

On the basis of the obtained points in the diagram a regression line can be calculated which allows an extrapolation for 2,000 and 100,000 hours.

From this the following fraction results: $\frac{f_{Cv,long\ term}}{f_{Cv}}$.

The shear strengths of short term loads are to be multiplied with this factor and accepted as long term value in the CE-marking.



2.6.2.4 Compressive strenght and compressive E-modulus

Based on: EN 14509, A.5.2.1.4 and A.2
Comments:

1. On compressive strength

   The compressive strength is determined by

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

   F_u = failure load respectively the load at a defined compressive strain (see EN 14509, A.2.5.1) e.g. with PUR at 10 % of the core height.
   A = cross-sectional area = $B \cdot L$

2. On compressive E-modulus

   The compressive E-modulus must be determined from of the linear part of the load-deflection curve $[\frac{\Delta F}{\Delta w}]$ from the compression test:

   $$E_{Cc} = \frac{\Delta F \cdot d_c}{\Delta w \cdot B \cdot L} = \frac{\Delta \sigma \cdot d_c}{\Delta w} = \frac{\Delta \sigma}{\varepsilon_c}$$

   $\Delta\sigma$ = stress within linear range
   d_C = thickness of core
   ϵ_C = compression strain

2.6.2.5 Tensile strength and tensile E-modulus

Based on: EN 14509, 5.2.1.6 and A.1
Comments:

1. On tensile strength

   The tensile strength is determined by

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

F_u = failure load respectively the load at a defined strain
(see EN 14509, A.1.5.1. note 1) e.g. with PUR at 10 % of the heightof the core.
A = cross-sectional are = $B \cdot L$

2. On tensile E-modulus

The tensile E-modulus must be determined of the linear slope of the load-deflection curve $\left[\frac{\Delta F}{\Delta w}\right]$ from the tensile test

$$E_{Ct} = \frac{\Delta F \cdot d_C}{\Delta w \cdot B \cdot L} = \frac{F_u \cdot d_C}{w_u \cdot A} = \frac{\Delta\sigma \cdot d_C}{\Delta w} = \frac{\Delta\sigma}{\Delta\varepsilon_t}$$

$\Delta\sigma$ = stress increment within linear part
d_C = thickness of core
ϵ_t = tensile strain

2.6.2.6 Bending moment capacity and wrinkling stresses at a simple beam

Based on: EN 14509, 5.2.1.7 and A.5.5
Comments:

1. In general

The most important values for the design against ultimate limit state are the failure stress (compressive stress) in the upper chord of the upper profiled face under regular loading together with the wrinkling stress σ_w of the lower quasi flat face under uplifting loads. Therefore, the aim is to determine the

- failure stress of the upper, profiled face and the
- wrinkling stress of the lower quasi flat face within span

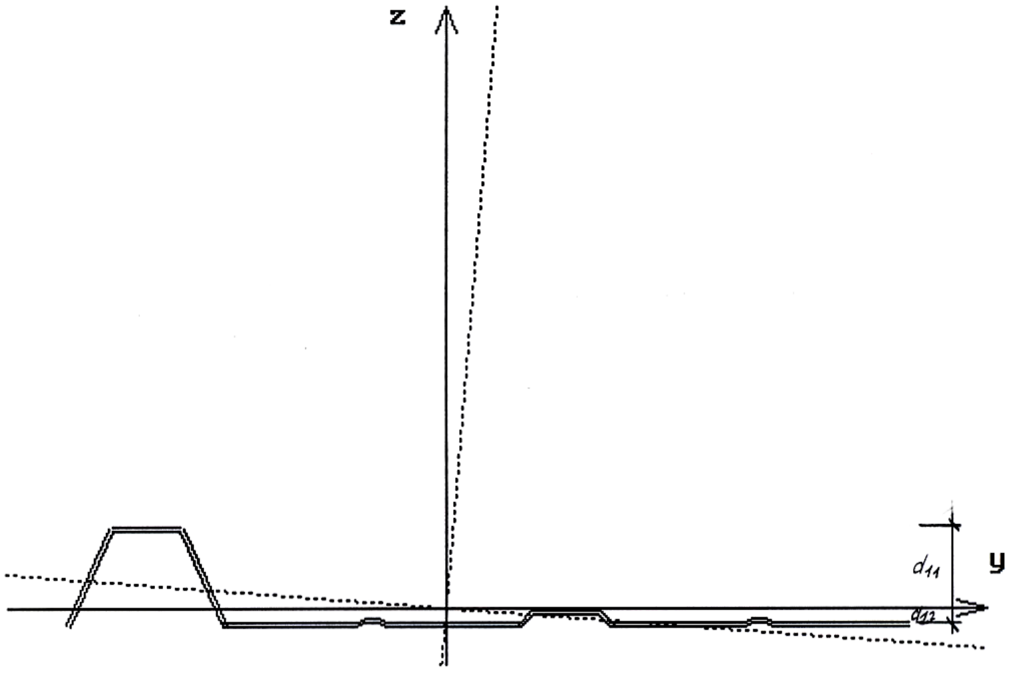
for each type of exterior and interior face.

The wrinkling stresses may depend on the thickness of the core. If different panel thicknesses are intended, values need to be determined for the least, a mean and the greatest thickness. If panels with a thickness between the tested thicknesses are to be evaluated, the lower properties found in one of the two surrounding thicknesses (next thicker or next thinner panel) has to be assumed. It is however unscrupulous to use liner interpolation for such cases.

The wrinkling stresses may, in addition to the thickness of the core, also depend on the metal sheet thickness and the temperature of the face. These values shall be determined by an appropriate evaluation of the determined wrinkling stresses (see following chapter).

2. Evaluation of tests

For the determination of the failure stresses in the upper as well as in the lower face on the base of the achieved test results , the sandwich theory (consideration of the shear flexibility of the core) must be taken into account (see EN 14509, A.5.5.3. A.11 respectively E.7.2).



The following principle procedure is recommended:

- First of all the stresses in the faces caused by unit load of $\bar{q}$=1 kN/m shall be determined. Here the cross-sectional values of the measured geometry and the thickness of the metal sheets shall be applied.
- The failure stresses measured in a test can than easily be determined by multiplying the obtained failure loads with the ratio of failure load to unit load.

3. Determination of stresses caused by unit load

- The stresses due to the unit load of for panels with profiled faces can be calculated directly according to EN 14509, E.7.5.2 and making use of table E.10.2 in prEN 14509. Or, a little easier, with the help of a computer program (see homepage iS-mainz).Compilation of formulas according to EN 14509, table E.10.2

$$M_{F1} = \frac{q \cdot L^2}{8} \cdot \beta$$

$$M_{F1} = \frac{q \cdot L^2}{8} \cdot \beta$$

$$M_S = \frac{q \cdot L^2}{8} \cdot (1 - \beta)$$

$$w = \frac{5 \cdot q \cdot L^4}{384 \cdot B_S} \cdot (1 - 3.2 \cdot k) \cdot (1 - \beta)$$

M_{F1} Face bending moment fraction at mid-span
M_S Sandwich bending moment fraction at mid-span
w maximum deflection at mid-span

for a uniform load:

$$\beta = \frac{B_{F1}}{B_{F1} + \frac{B_s}{1+3.2k}}$$

flexural rigidity:
(terms see also EN 14509, E.1.1)

$$B_{F1} = E_{F1} \cdot I_{F1}$$

$$B_S = \frac{E_{F1} \cdot A_{F1} \cdot E_{F2} \cdot A_{F2}}{(E_{F1} \cdot A_{F1} + E_{F2} \cdot A_{F2}) \cdot B} \cdot e^2$$

$$k = \frac{3 \cdot B_S}{L^2 \cdot G_C \cdot A_C}$$

stresses in faces:

stresses in the upper chord of the profiled face:

$$\sigma_{F1} = -\frac{M_s}{e \cdot A_{F1}} - \frac{M_{F1}}{I_{F1}} \cdot d_{11}$$

stresses in the lower, quasi flat face:

$$\sigma_{F2} = +\frac{M_s}{e \cdot A_{F2}}$$

- Compilation of input data for computer program

Besides the geometrical values (thickness of panels and faces) just the following values are necessary for input:

$A_{F1},\ I_{F1},\ d_{11},\ (d_{12}),\ E_{F1},\ A_{F2},\ (d_{21}),\ d_{22},\ E_{F2},\ D,\ G_c,\ L,\ q\ =\ 1\ kN/m$

4. Determination of failure stresses

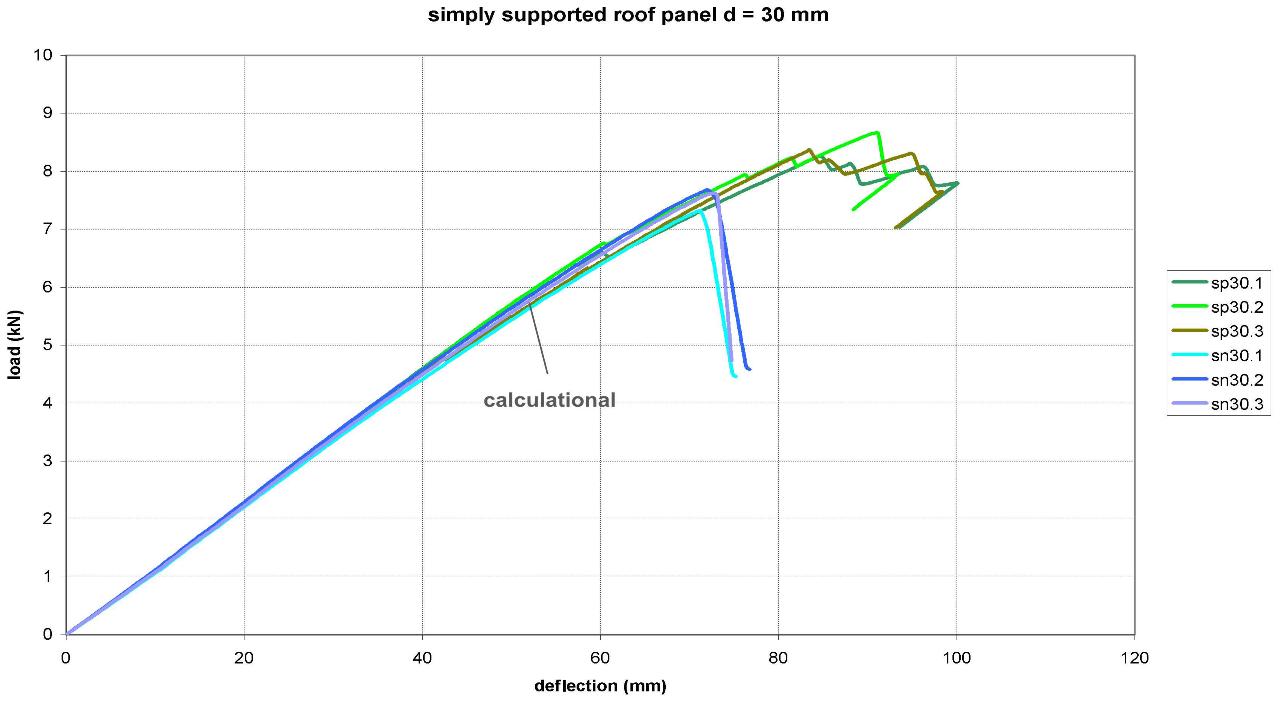
The determining failure stresses in the upper chord of the profiled face σ^u_{F1} and the wrinkling stress w in the lower quasi flat face shall be determined by multiplying the calculated stresses caused by a unit load with the following factor:

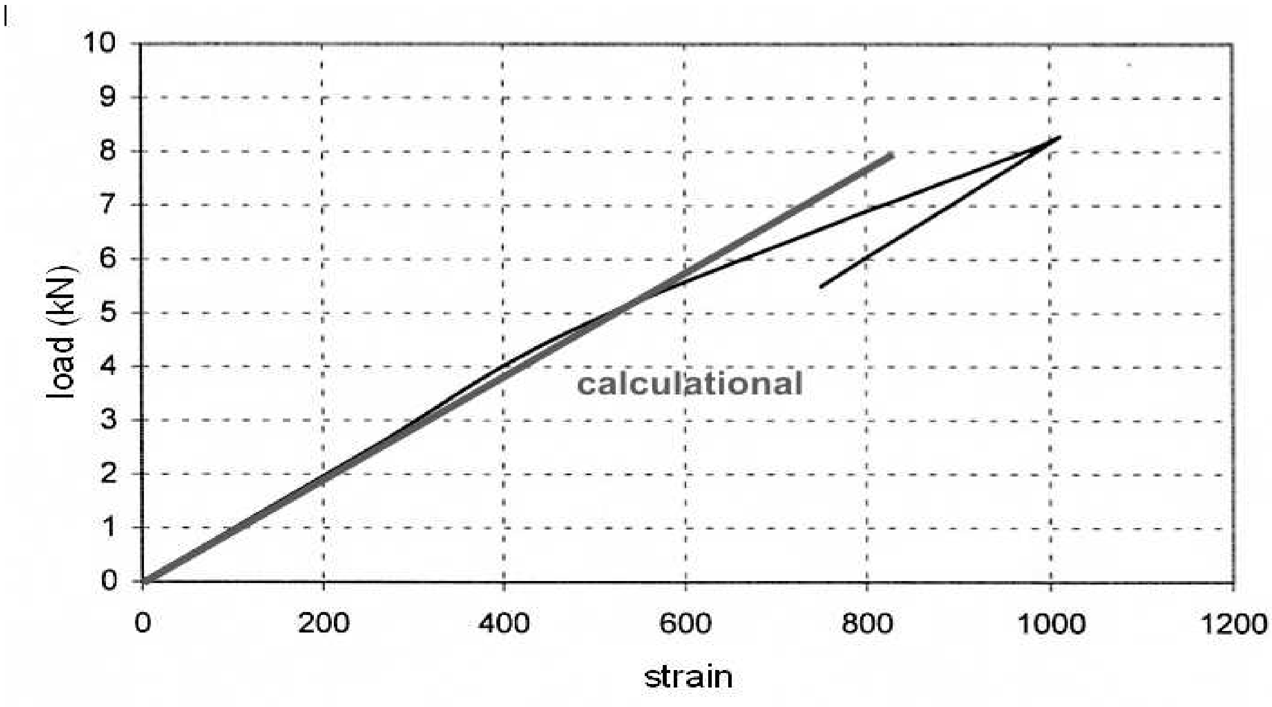
$$f = \frac{failure\ load}{regular\ loading} = \frac{q^u + weight\ of\ panel\,[kN/m]}{1}$$

$$q^u = \frac{F^u}{L}$$

F_u = failure load measured in the test
L = span
$\sigma^u_{F1} = f \cdot \sigma_{F1}$
$\sigma_w = f \cdot \sigma_{F2}$

In doing so it must be mentioned that in principle only the failure stresses of the face under compression is of interest. This means that for σ^u_{F1} only tests with positive orientation and for σ_w only test with negative orientation must be evaluated.





note 1:

Most of the times the yield stresses of metallic materials can be applied as failure stresses for the faces under tension.

note 2:

The lightly profiled quasi flat lower faces of roof panels often equals those of the wall panels

For cases with similar material properties only confirmation tests with negative orientation must be accomplished, to proof that the wrinkling stresses measured in such tests are higher than those values determined in wall panel tests. The values for wall panels are than also applied as the wrinkling stresses of the lower face of roof panels, all panels are produced in the same production line.

5. correction coefficient for the upper profiled face

For normalisation of the failure stress, deterimined in the tests, with regards to the standard values of the facing material, the formulas in EN 14509, A.5.5.4 are to be implemented:

$$R_{adj,i} = R_{obs,i} \left(\frac{f_y}{f_{y,obs}}\right)^{\alpha} \cdot \left(\frac{t}{t_{obs}}\right)^{\beta} \qquad \text{(A.15)}$$

Where:

$R_{obs,i}$ test result of test no. i;
$R_{adj,i}$ test result modified to corresponmd to the nominal values of metal thickness and yield stress;
f_y nominal yield strength according to CE-marking;
$f_{y,obs}$ measured yield strength of test specimen;
t nominal thickness of face;
t_{obs} measured thickness of face at test specimen;

$\alpha = 0$ if $f_{y,obs} \leq f_y$
$\alpha = 1$ if $f_{y,obs} > f_y$

but for compressive failure of a profiled face:

$\alpha = 0.5$ if $f_{y,obs} > f_y$ and $\frac{b}{t} > 1,27\sqrt{\frac{E_F}{f_y}}$.

For β applies:

$\beta = 1.0$

but for compressive failure of a profiled face:
$\beta = 1.0$ if $t_{obs} \leq t$
$\beta = 2.0$ if $t_{obs} > t$ and $\frac{b}{t} > 1,27\sqrt{\frac{E_F}{f_y}}$.

The mentioned formulas can also be used for determination of failure stresses in metal sheet thicknesses that were not tested. However, the following limits must be considered:

$$\frac{b}{t} > 1,27\sqrt{\frac{E_F}{f_y}}$$

notes:

- The normalization specified in EN 14509, A.5.5.4 (formula A.15) is based on knowledge about trapezoidal metal sheets (see also DIN 18807, part 2). Since for design of trapezoidal metal sheets for acceptable moments and forces are not based on stress values, EN 14509, formula A.15 refers to the actual capacity of moments. If the stresses are used as basis, the metal sheet thickness is already taken into account and the scale factors according to EN 14509, A.5.5.4 result as follows:
  In general:
  $\beta = 0$ if $t_{obs} \leq t$

  If a profiled face fails under pressure, the following evaluation needs to be applied: $\beta = 0$ if $t_{obs} > t$ and $\frac{b}{t} \leq 1,27\sqrt{\frac{E_F}{f_y}}$

  $\beta = 1$ if $t_{obs} > t$ and $\frac{b}{t} > 1,27\sqrt{\frac{E_F}{f_y}}$

- A reduction of the maximum allowable stresses for the upper chord because of elevated temperature only needs to be considered if the determined normalized failure stresses are lower than the yield stresses of the applied face material.

  If a reduction is necessary the factor k_1 needs to be applied according to EN 14509, A.5.5.5 (see also chapt. 2.6.1.6).

6. Correction factors for the lower quasi flat faces

If the values for wrinkling stresses of wall panels (see also note 2 in chapt. 2.3) can not be adopted for the reason that e.g. the lightly profiles of the faces are not similar, the correction factors determined in tests with **negative orientation** shall be applied analogous to

chapter 2.6.1.6	(determination of wrinkling stresses of sheet thicknesses that were not checked experimental)
chapter 2.6.1.6	(factor k1 at increased temperature)
chapter 2.6.1.6	(factor k2 at core materials with $f_{ct} \leq 0.1\ MPa$)

2.6.2.7 Bending moment capacity and wrinkling stresses at an internal support

Based on: EN 14509, 5.2.1.8 and A.7
Comments:

As already mentioned in chapt. 2.5.2.7 only simulated central support tests for regular loading are necessary for roof panels with a profiled upper face and a quasi flat lower face.

For roof panels with a lower face similar to the face of a wall panel the values of wrinkling stresses over the central support can be adopted.

Also with related, lightly profiled lower faces, comparable but not identical with those of wall panels, it is possible to reduce the wrinkling stresses within span (negative orientation) of the lower face of roof panels proportionately to the wrinkling stresses of wall panels (wrinkling stress above central support / wrinkling stress within span). This reduced value can be implemented as design value of the lower face in the area of central supports.

2.6.2.8 Creep coefficient

Based on: EN 14509, A.6.5
Comments:

Theoretical basics and compilation of formulas for roof panels with upper profiled (trapezoidal) faces and lower quasi flat (lightly profile) faces:

Depending on time the deformation of sandwich panels increases due to long term loading. The increase in deformation depends on the creep of the core due to permanently existing shear stresses.

The deformation of sandwich panels can be described as follows:

$$\epsilon_t = \epsilon_0 \cdot (1 + \varphi_t)$$
$$\gamma_t = \gamma_0 \cdot (1 + \varphi_t)$$

By means of the creep coefficient φ_t, long term calculations can be accomplished, e.g. by implementing a time dependant shear modulus

$$G_t = \frac{G_0}{1 + \varphi_t}$$

For evaluation of long term tests of panels with profiled faces the following formulas are given in EN 14509, A.6.5.3:

$$\varphi_t = \frac{\beta \cdot (C_D - 1)}{\beta_1 \cdot [1 - \beta - \beta \cdot \rho (C_D - 1)]} \qquad C_D = \frac{w_t}{w_0} \qquad \rho = 0.5$$

w_t = deflection at time t
w_0 = deflection at time t = 0
w_b = deflection due to axial forces in the faces

$$\begin{aligned} \beta &= \frac{I_F}{I_F + \frac{I_S}{1+k}} = \frac{I_F}{I_w} \\ k &= \frac{\pi^2 E_{F2} A_{F2} e^2}{\left(\frac{A_{F1}}{A_{F2}} + 1\right) G_C \cdot A_C \cdot L^2} \\ \beta_1 &= \frac{k \cdot \beta}{1+k} \\ I_w &= I_F + \frac{I_S}{1+k} \end{aligned}$$

I_S = moment of inertia of the faces
I_S = moment of inertia of the sandwich fraction

$$\gamma = \frac{1}{1+k}$$

With the formulas in EN 14509, A.6.5.2 the creep coefficients φ_{10^5} and $\varphi_{2 \cdot 10^3}$ shall be extrapolated from the test results:

$$\begin{aligned} \varphi_{10^5} &= 3,86 \cdot \varphi_{10^3} - 2,86 \cdot \varphi_{2 \cdot 10^2} \\ \varphi_{2 \cdot 10^3} &= 1,2 \cdot (1,43 \cdot \varphi_{10^3} - 0,43 \cdot \varphi_{2 \cdot 10^2}) \end{aligned}$$

The time dependant shear modulus can be determined with the following:

$$G_{10^5} = \frac{G_0}{1 + \varphi_{10^5}} \text{ und } G_{2 \cdot 10^3} = \frac{G_0}{1 + \varphi_{2 \cdot 10^3}}.$$

note:
The evaluation of roof panels with flat faces on both sides (rare application!) can easily be done according to EN 14509, A.6.5.2.

2.6.2.9 Density of the core and weight of the panels

Based on: EN 14509, A.8

Comments:

Due to the test results according to chapt. 2.5.2.9 the density shall be stated as mean value according to EN 1602. Furthermore the smallest and greatest value shall be stated according to EN 14509, table 4.

The weight of the panels (value in CE-marking) shall be determined arithmetically with the nominal geometry and the nominal density of the core- and facing material.

2.6.2.10 Determination of dimension tolerances of the most important geometrical dimensions

Based on: EN 14509, 5.2.5, table 3

Comments:
The maximum allowed dimension tolerances are shown in EN 14509, 5.2.5, table 3. These need to be checked according to EN 14509, annex D.

For wall panels with quasi flat faces on both sides these are in particular the depth and width of profiling together with the thickness of the panel.

2.6.2.11 Determination of material safety factors

Based on: EN 14509, E.6.3.2

Comments:
The variation coefficient obtained from the determined values of shear, compressive and wrinkling strength are the base for the determination of the material safety factors (see. EN 14509, E.6.3.2).

2.6.2.12 CE Marking

The requirements of EN 14509, ZA.3.5 need to be considered and followed essentially:
note:

With the results in chapter 2.6.2 there are all necessary values for the CE Marking regarding the mechanical properties, see EN 14509, figure ZA.2 for panels for use in roofs are available.

The CE Markings can be made for all the panels included in the same "productfamily", see chapter 2.3.

It is important to point out that for some properties the mean values, e.g. shear modulus of the core, have to be declared, see EN 14509, 5.2.1. For others the 5 %-fractile values have to be declared, e.g. wrinkling stresses.

Furthermore other values, as for example the thermal transmittance also have to be declared, see chapter 1 and 3.

2.7 Support reaction capacity at the end of a panel

Based on EN 14509, A.15

- In general End support reaction capacity tests are used to determine the value of the parameter k that is used in the calculation of support reaction capacity in cases where a plain or lightly profile face is in contact with the support (see E.4.3.2 in prEN 14509). The principle of test arrangement is shown in Fig. A.22 in prEN 14509. Three tests should be made for each support width. The analysis of the test results is given in A.15.5.
- Test arrangement and comments

  The support reaction FR should be measured directly with load cells placed under the support beam to achieve better accuracy (see Fig. 2.7).

  The support beam should be aligned with the lower face of the panel so that the crushing is uniform along the support.

  The width of the other support should be wide enough to avoid failure there.

  The loading rate should be slow enough (preferably 1 %/min to 3 %/min) so that the test reflects the true nature of crushing failure on a support in practice. Crushing of MW fibres is an irreversible slow process in real panels (fibres break gradually). The ultimate compressive strains are only some percents. Plastic foams are more resilient and the deformation somewhat reversible.

  It is not always possible to obtain crushing failure in the tests because the ration between shear and compression strengths may be low. The use of thick panels lowers the possibility of shear failure. The failure may start as crushing of the core but may then turn into shear failure (see Figs. 2.7 and 2.7). This can be seen if the rate of deflection is also monitored.

  The assumption that the parameter k is a material constant does not actually hold true. While repeating the same test series one might get different results.

  It is advisable to determine the compression strength of each end tested using three compression test specimens. These should be taken as close to the end as possible (from undamaged parts) and to use the average of the tests as fC, while adjusting the test results. It is also advisable to determine the density.

3. Test results Identify the tests panels, information of the geometry (measurements), faces (geometry, steel grade, thickness) and core (type, nominal values). Present the test arrangement (test layout, loading, measurements) and procedure (rate of loading). Give the results of the compression tests (place of the specimens, loading rate, compression strengths). Show the analysis of the test results (values of k obtained).

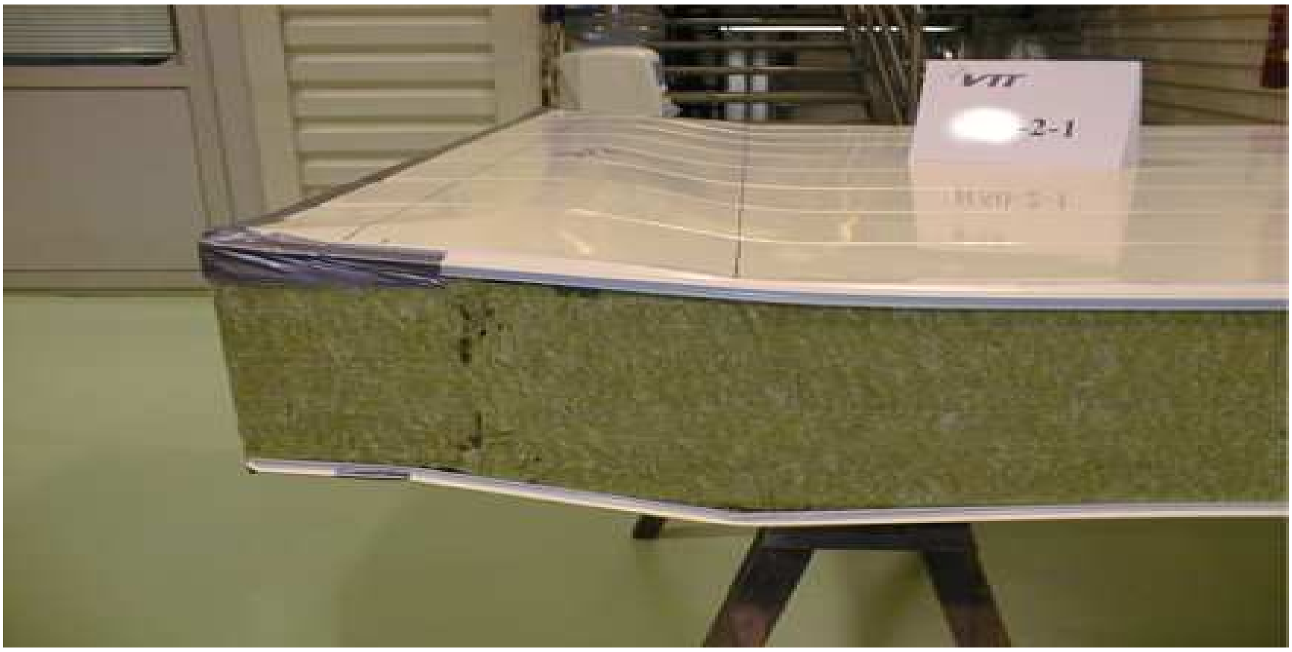


Figure 2.5: specimen 2-1 after the failure. The final failure was shear.

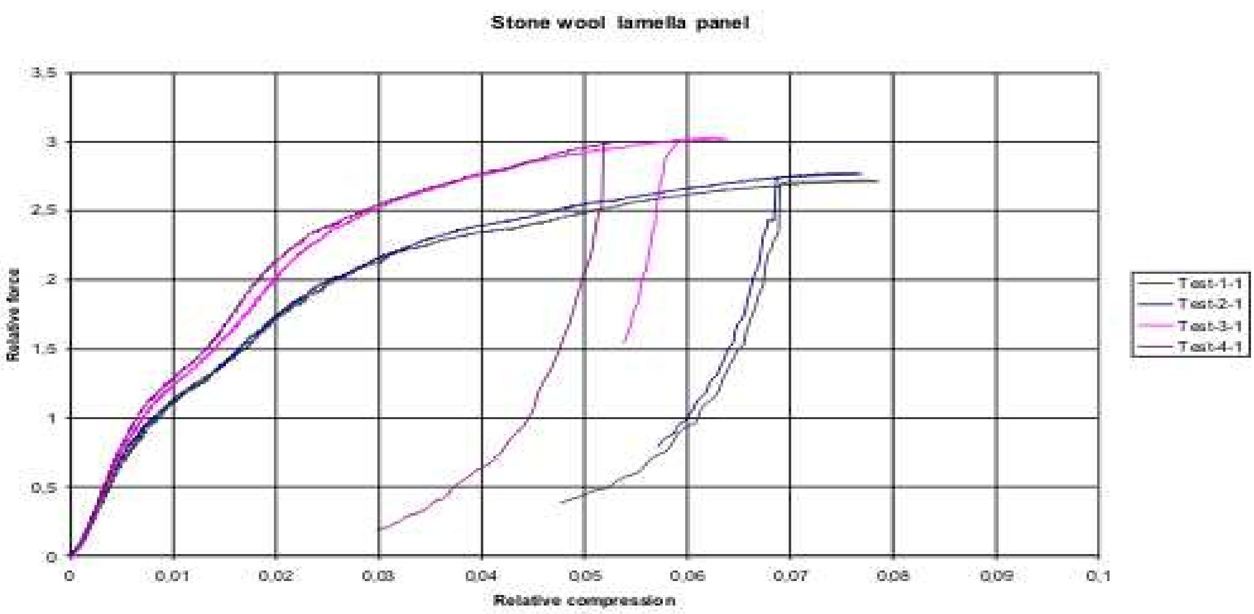


Figure 2.6: Support reaction tests on stone wool lamella. Four similar tests were carried out. In all tests shear failure occurred before the relative compression of 0.10. The relative force is $F_{REL} = \dfrac{F_{R1}}{f_{Cc} \cdot L_s \cdot B}$

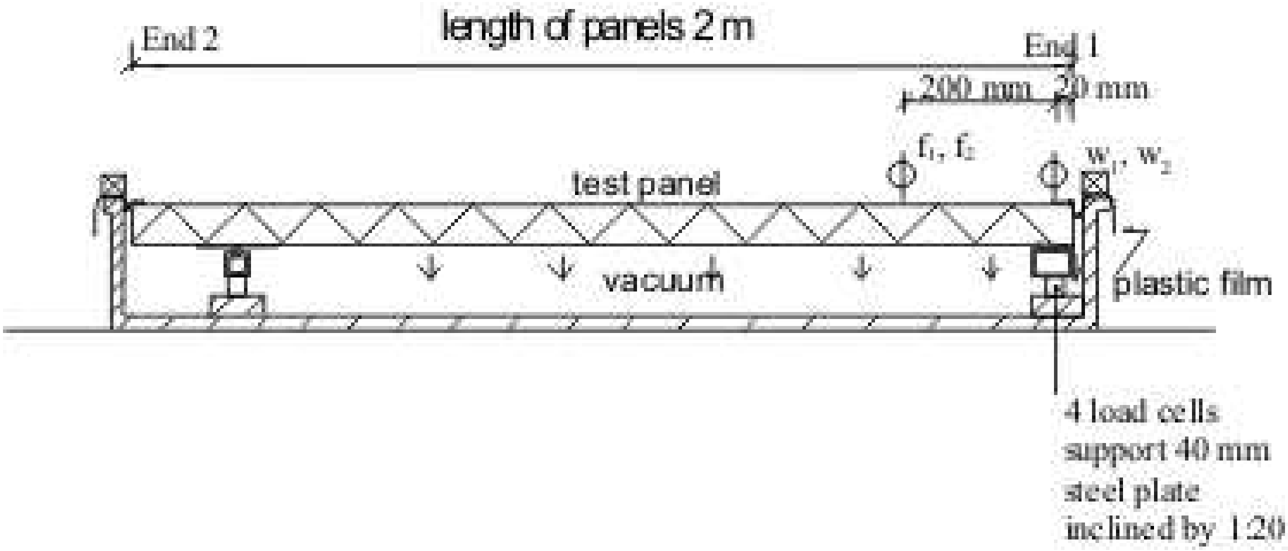


Figure 2.7: Principle when using a vacuum chamber in support reaction tests. The width of support by end 2 is 200mm. The displacement transducers f1 and f2 are used to monitor possible shear failure

2.8 Durability and long term effects

Based on: EN 14509, 5.2.3 and Annex B

In general:

Comments:

1. In general

   All together there are 5 different test methods in this chapter:

   - DUR 1 (see EN 14509, B.2)
   - DUR 2 (see EN 14509, B.3)
   - Wedge test (see EN 14509, B.5)
   - Repeated loading test (see EN 14509, B.6
   - Thermal shock test (see EN 14509, B.7)

2. Necessary testing for different material combinations

   The necessary testing is defined in table 2 (EN 14509, 5.2) and also presented in the following table.

Test according to	a)	b)	c)	d)	e)
MW		x	x		
EPS/XPS	x		x		
PUR (auto adhesive)	x				
PUR (laminated)	x		x		
PF	x		x	x	
CG	x		x	x	x

For PUR foam systems that are included in EN 13165 and which do not employ CO_2 as a blowing agent, the tests according to DUR 1 can be omitted.

Comment:
The, at the moment predominantly employed, PUR foams are within the scope of EN 13165 and therefore no durability testing is needed in most cases.

3. Test accomplishment

   The influence of ageing on sandwich panels or their constituent materials is tested by measuring changes in the cross panel tensile strength of the panel. The durability is defined by the change in the tensile strength of a test specimen that is subject to climatic test cycles, which are denoted as DUR 1 and DUR 2 and have to be chosen depending on the core material employed.

   The cross panel tensile tests are, in principle, performed as described in 5.1.5 resp. 5.2.5 (EN 14509, 5.2.1.6 and A.1).

2.8.1 DUR 1 based on EN 14509, B.2

The test accomplishment, as well as the corresponding test conditions (e.g. choice of temperature according to colour group of panel face) and the necessary evaluations are defined in EN 14502, B.2. The evaluation must be undertaken in accordance with EN 14509, B.2.5 and is recapitulated in the following:

The lowest average value found in a set of specimen is denoted as fCtDUR1. The test is passed, it the following requirements are met:

- $f_{CtDUR1} \;\geq\; 0.50\; f_{Ct0}$
- $f_{CtDUR1} \;\geq\; 0.02$ MPa
- change in dimension = 5 %

Notes:

- With the temperatures required in the test, it can be assumed that the relative humidity is always lower than the requested 15 %. In most cases it is not necessary to control this parameter.
- It is recommended to age more than the requested 5 specimen per set. Specimen that are excluded from the evaluation can the easily be replaced without having to repeat the complete test cycle.
- It is recommended to perform the test on the thickest and thinnest panel planned for one product family (procedure analogous to DUR 2).

2.8.2 DUR 2 based on EN 14509, B.3

The test accomplishment, as well as the corresponding test conditions (e.g. 65 $_{\circ}$C air temperature and 100 % relative humidity) and the necessary evaluations are defined in EN 14502, B.3.

The evaluation must be undertaken in accordance with EN 14509, B.3.5 and is recapitulated in the following:

- $f_{Ct7} - f_{Ct28} \;\leq\; 3 \cdot (f_{Ct0} - f_{Ct7})$
- $f_{Ct28} \;\geq\; 0,4 \cdot f_{Ct0}$
- or, if one of the previous criteria is not met
  $f_{Ct28} - f_{Ct56} \;<\; f_{Ct7} - f_{Ct28}$ and $f_{Ct56} \geq 0,4 \cdot f_{Ct0}$

Notes:

- It is strongly recommended to protect the cut edges of the samples by applying a silicone layer. This layer then protects the sample from moisture penetration into the adhesive layer between face and core. Such penetration can lead to oxidation of the zinc layer (formation of "white rust") which reduces the cross panel tensile strength in an unnatural way.
- It is recommended to include one set for 56 days of ageing from the beginning of the test. If the test becomes necessary during the evaluation process, this reduces testing time as the necessary results are on hand.

2.8.3 Adhesive bond between faces and prefabricated core material (wedge test)

based on EN 14509, B.5

1. In general This test is used to asses the suitability of the glue on the back-coat ('primer coating') of the steel sheet. It is of qualitative nature, it gives an indication whether the bond between the glue and the primer coating and the adhesive layer itself are resilient enough.
2. Test procedure and comments
   a) Cut at least 10 strips of size 20 x 100 mm^2.Clean the surfaces well.
   b) Weight five (or more) pairs of strips.
   c) Mix the components according to the instructions from the glue manufacturer and apply glue on the surfaces aiming at the real amount of glue used in the production of panels.. NOTE: This generally has to be done manually in a very short time. It is of great importance to have the ratio between the components right and the amount of glue as close to the target amount as possible.
   d) Keep the strips in pressure for the time given by the glue manufacturer. Let the specimens cure for the time given by the glue manufacturer
   e) Remove excessive glue (burrs) along the edges.
   f) Weight the specimens and calculate the amount of glue per area.
   g) Smoothly insert the wedges between the strips, measure the initial crack length l on both edges using a loupe. It should not be more than 30 mm.
   h) Immerse the specimens for 24 h in water heated to 70 °C while loading the wedges with force of 3 N.
   NOTE This may be done with plummets (see Figure 2.8.3)
   i) Remove the specimens and measure the crack growth 2. It should not be more than 20 mm. (see Figs. 2.8.3 and 2.10).
   j) Examine the type of cracking. It should be cohesive (in glue only)
   k) In the report give the details of metal sheet used:
      - Grade, thickness, manufacturer, identification (coil/charge number), type and thickness of back coat and
      - the details of the glue:
        Trade names of components, ratio of mixture, identification (lot number) and
      - the test results:
        Cure time used, amount of glue, initial crack length l, crack growth 2 , type of cracking for each specimen and
      - the conclusions (test passed/failed)

Figure 2.8: The test arrangement

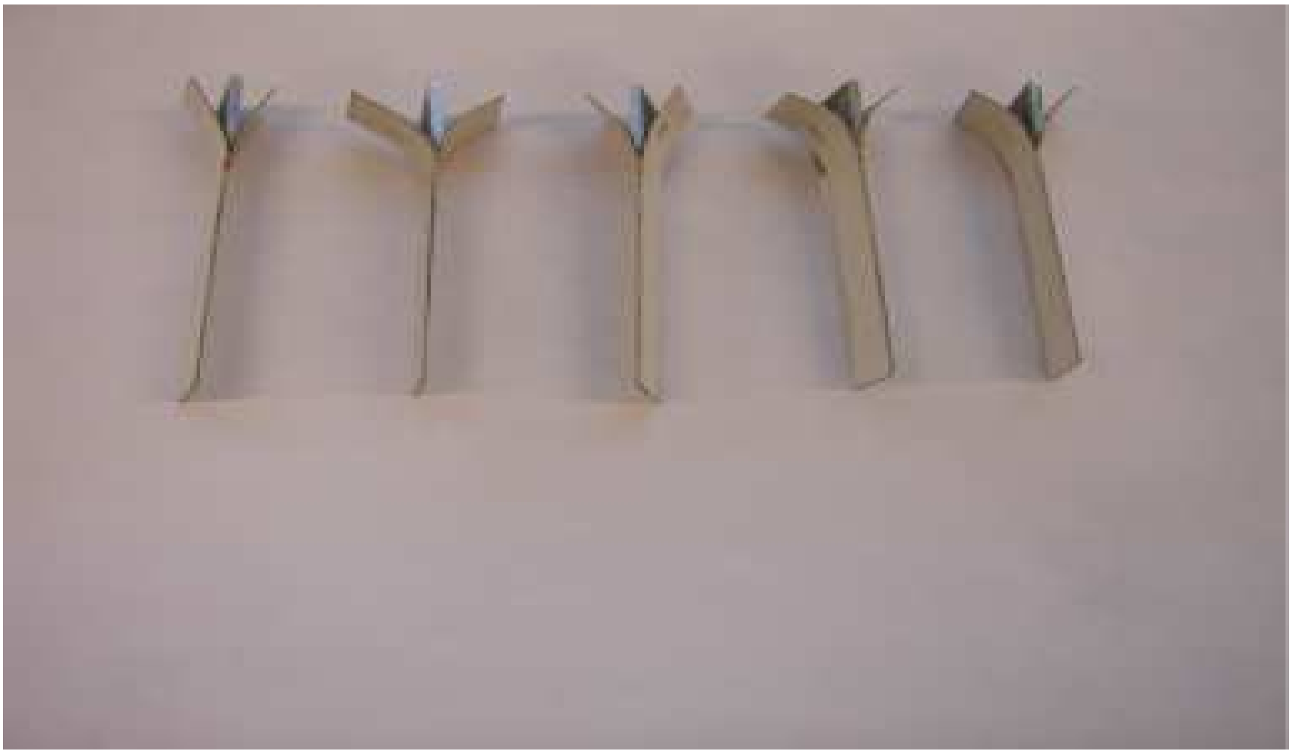


Figure 2.9: The specimens after exposure

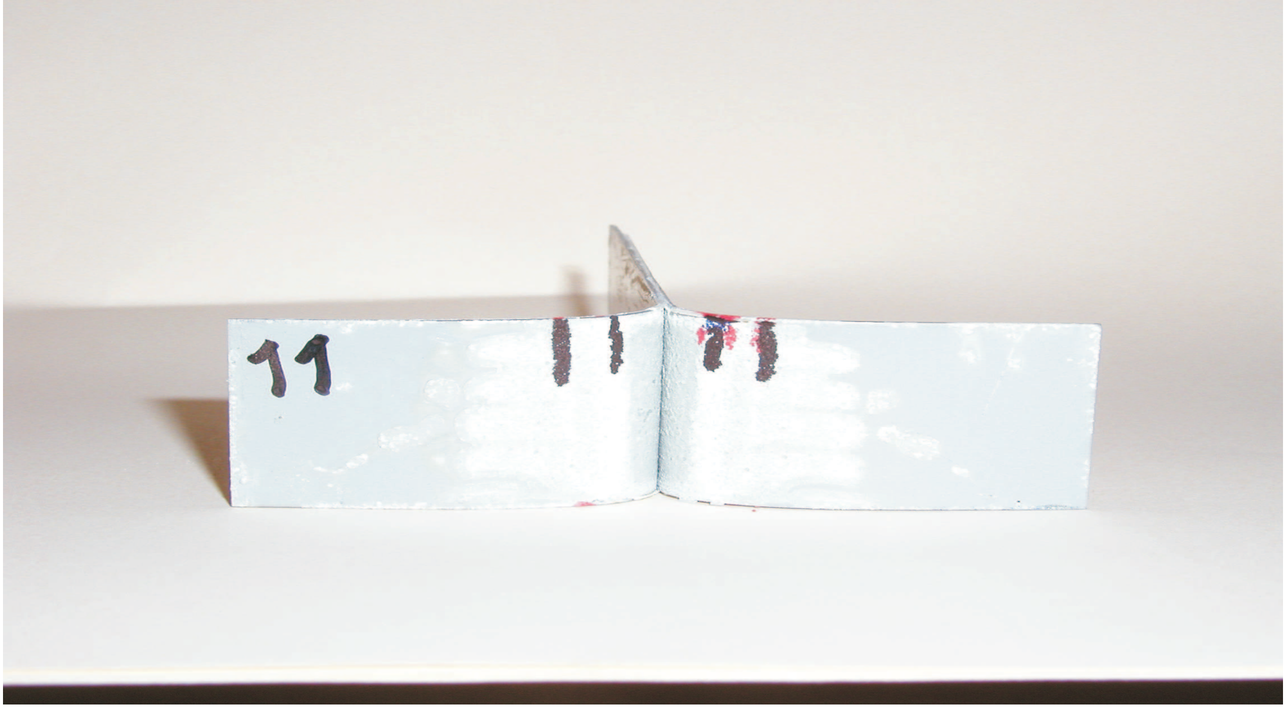


Figure 2.10: The specimen 11 after exposure. The crack tips are marked on the strips.

2.9 Resistance to point loads and repeated loads

1. General

Panels within the scope of prEN14509 with thin metal faces are generally accepted as unsuitable for regular foot traffic and applications of this type (like floors) are outside the scope of the standard. For applications like ceilings and roofs where there is occasional or repeated access on the panel there are rules for classification of the panels for which type of access they are suitable. The rules in prEN 14509 (see prEN 14509 chapters 5.2.3. & A.9) are written for ceilings only (fig. 2.11), but it is recommended to also follow these rules for roofs.

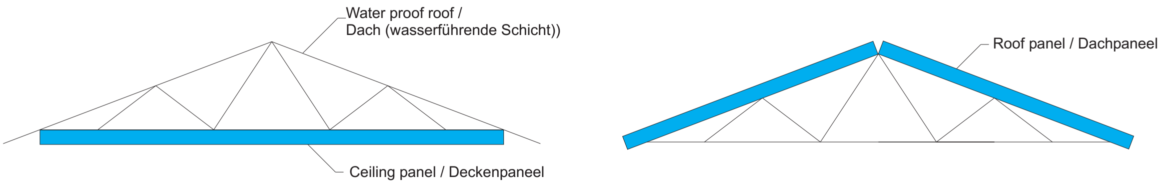


Figure 2.11: Insulated sandwich panel used in ceilings and roofs

The resistance to point load and access load is subject to initial type testing (ITT) only. The connection to the factory production control (FPC) is through control of the compression strength. Therefore, also the compression strength of the panel tested for access load is recommended to be determined according to procedures in A.2 in prEN 14509 (see chapt. 2.6.1.4 and 2.6.2.4).

The resistance to point and access loads of the panel shall be noticed on the CE mark (see prEN 14509 chapter Z.A.3.2 and fig. Z.A.4) and based on a **pass/fail** criteria given in chapter A.9 of pr EN 14509.
There are **two cases** for type of application:

Case 1: **occasional access** to be tested according to A.9.1 in prEN 14509
or
Case 2: **repeated access** to be tested according to A.9.2 in prEN 14509

There is no further information given in prEN 14509 on the definition of occasional access and repeated access.

Based on experience the following guidelines can be used if nothing else is specified (see fig. 2.12):

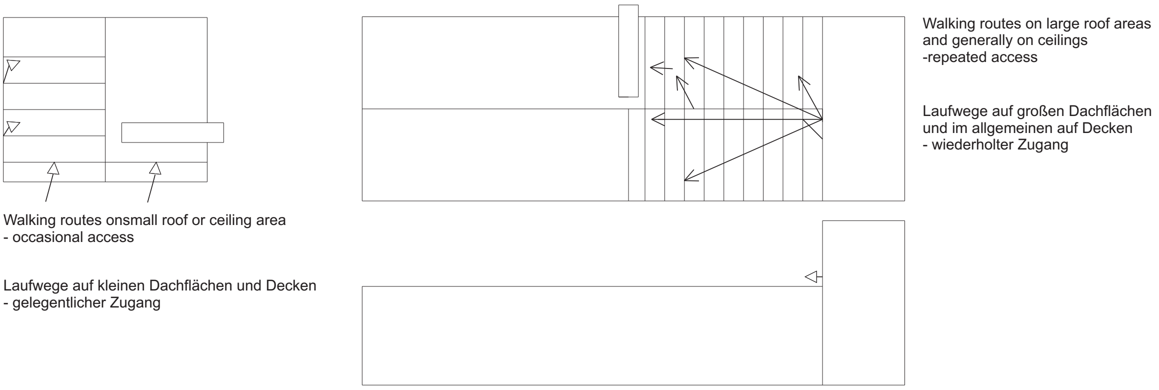


Figure 2.12: Walking pattern on ceilings, small roofs and on large roofs

- if there is access to the panels during erection, only on the area which is to be mounted, an area that is moving during the progress of the installation and there is not foreseen any planned regular service of devices placed on the tope of the panels, this type of access is **occasional**
- if the access to the erection area of the panels is given by permanent ladders or doors and the area is more than approximately 1000 m^2 (for roofs) and if the service access to devices placed on the top of the panels is regular, the access is of **repeated** nature.

Generally the case for repeated access is more frequent in ceilings than for roofs, as the frame structure above the ceiling hinders free access on the ceiling.

In Note 1 in chapter 5.2.3 of prEN 14509 there is a comment on the span capability to be checked and in chapter A.9.1.3 it is said that the length of the panel to be tested shall be of the maximum span used in practice.

In prEN 14509 there is no recommendation on the loads for ceilings. The following guideline can be followed if national regulations do not require otherwise:

The span is calculated in normal procedure according to chapter E in prEN 14509 with the **safety factors** as defined in chapter E and with the following **loads**:

- roofs: snow load (according to national rules) + self-weight + eventual other permanent loads

- ceilings: point load 0.9 kN in the critical position (one man walking) + surface load of 0.25 kN/m2 (tools and equipments)+ self-weight + eventual other permanent loads

Note: For ceilings only one man is allowed to walk on a panel at one time

CE-marking:
The testing required in order to get a CE mark for a ceiling panel (CE label or accompanying document), will lead to one of the following classifications of the panel:

If passing the tests according to both chapter 2 and chapter 3, the following notation shall be made:

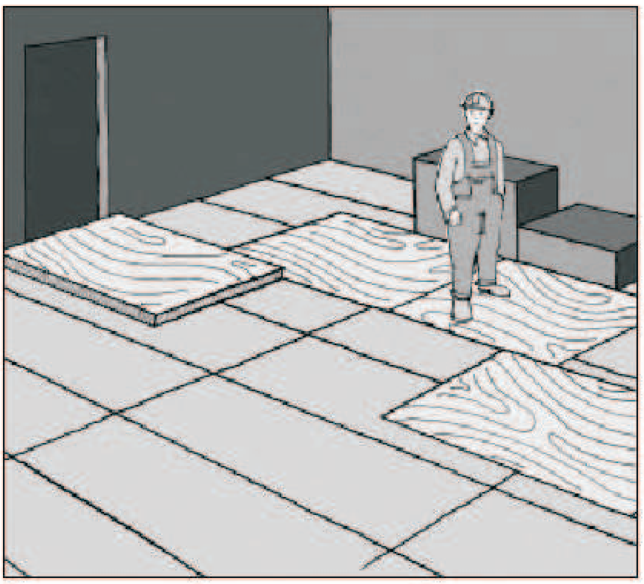
a) **Resistance to point and access loads: Suitable for repeated access**
   or
   If passing the tests according to chapter 2 without visible damages but not passing the tests according to chapter 3, the following notation shall be made:

b) **Resistance to point and access load: Suitable for occasional access for erection and service. Unsuitable for repeated access without additional protection**
or
If passing the tests according to chapter 2 but with visible damages, and not passing the tests according to chapter 3, the following notation shall be made on the CE-document:

c) Resistance to point and access loads: Suitable for occasional access for erection only when using protection for the surface. Unsuitable for service and repeated access without permanent walk ways installed and supported through the frame of the building.
or
If not passing the tests according to chapter 2 or 3, the following notation shall be made on the panel:

d) **Resistance to point and access loads: Suitable for non walk on ceilings only**

Protection In the Note 3 in prEN 14509 it is noticed generally that the panel should be protected where repeated walking is expected. For manufacturers having not all the time control over what happens during and after the erection phase this should be a general recommendation. In the figure below one example from one producers manual on the need for protection is shown:



Protection of the surface with a board.

In case of frequent walking a mineral wool board is placed beneath the protection board

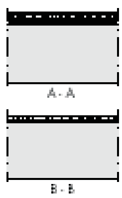


Figure 2.13: protection of the panels, example

Practical recommendations:

Recommendation on core material to be used:

There are no requirements on the materials used in roof and ceiling panels from the accessibility point of view in prEN 14509. The principle is to determine the resistance of the panel by testing.

The test methods described in prEN 14509 are anyhow not used frequently and especially the test method in A.9.2 is new and there is little experience so far on its suitability. Therefore it is from a practical point of view and based on experience and in order to increase the safety of ceiling and roof panels for access recommend using core materials with compression strengths not lower than 100 kPa (characteristic value) in all other cases than non-walk-on ceiling panels.

Fixing of panel ends

In order to avoid panels falling down even in case of failure, it is highly recommended to use screws penetrating the panel fixing both skins to the frame or fixing both skins directly with metal stripes and screws to the frame. This makes membrane action possible which is also of great importance with regards to fire safety.

2. Testing Case 1: Occasional access during erection and service (prEN 14509 A.9.1)

The target in this test is to check the safety and serviceability of roof or ceiling panels with respect to a single person walking on the panel, for occasional access both during and after erection.

There are three different classification categories that can be reached based on this test:

- panels are suitable for occasional access and point loads
- panels are suitable for occasional access and point loads during erection only if protection of the panel surface is used (i.e. boards spreading the compression force on a bigger area)
- panels are not suitable for access or point loads, the panels are regarded as non-walk-on panels

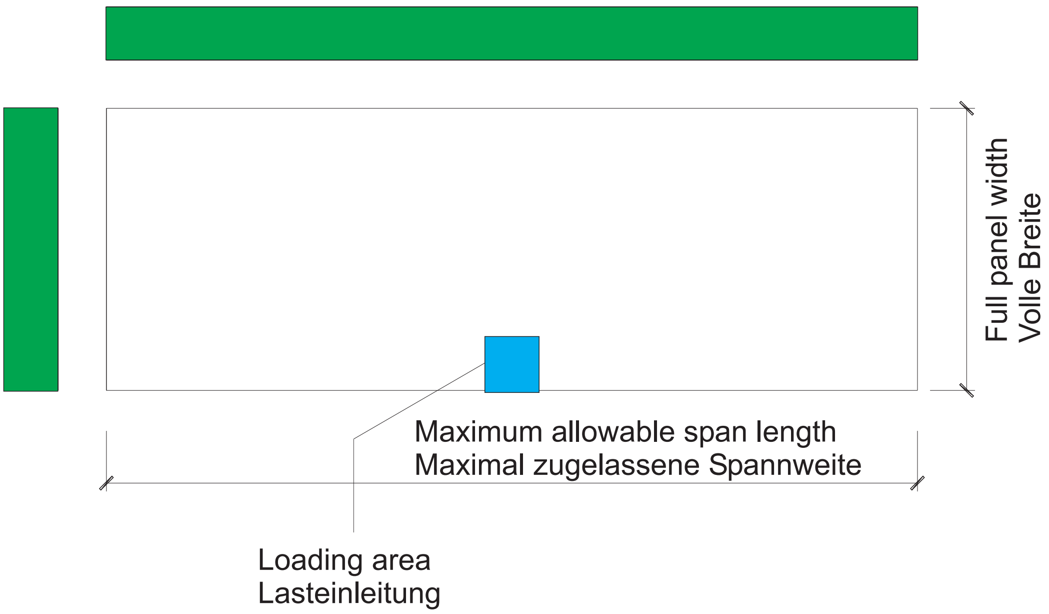


Figure 2.14: Sampling for testing panel resistance to point loads

a) Sampling

The panel sample is of full panel width. The samples chosen for testing are checked for the compression strength of the core not to be higher than 10 % over the declared compression strength for the panel (see fig. 2.14and 2.15).

At least the following two panels per each core type shall be tested:

- a panel of the minimum panel thickness and minimum steel thickness and
- a panel with the maximum panel thickness and minimum steel thickness

b) Testing

A test report according to chapter A.16.1 (ITT tests) in prEN 14509 shall be written.
The loading procedure is as following:

i. Cut a minimum of three specimen from the undamaged zone of the panel close to the loaded area for determining the compression strength of the core in the tested panel. The procedure for determining the compression strength shall follow chapter A.2 in prEN 14509 (see 2.6.2.4).

ii. Place the panel on two end supports (simply supported; i.e. free to rotate and one end free to move in the direction of the span) with a maximum distance determined by the procedure in Annex E in prEN 14509 and loads according to national regulations.
In case there is no defined loads for ceilings in the national regulations, the following loads to determine the maximum allowable span can be used (see above):

- an uniform surface load (variable) of 0.25 kN/m^2 all over the panel representing tool box etc., plus
- a point load (variable) of 0.9 kN to be placed in the most unfavourable position representing a person walking over the panel.

iii. Apply a point load of 1.2 kN through a 100 mm x 100 mm timber block on the edge of the panel in the middle of the span (see fig. 2.15 and 2.16):

- measure the deflection at the mid point of the panel under the loading point by using e.g. a line spanning in the middle of the upper surface from support to support and measuring the mid point deflection before and after the testing. An accuracy of $\pm$ 1 mm is sufficient.
- place the timber block on the edge rib if this is closer to the edge than 100 mm or
- place the timber block close to the edge of the panel in case of flat surfaces
A rubber felt shall be placed between the timber block and the panel.
Keep the maximum load for 6 s and release the load.
Release the timber block and the felt.
Make visual inspection of the loaded area.

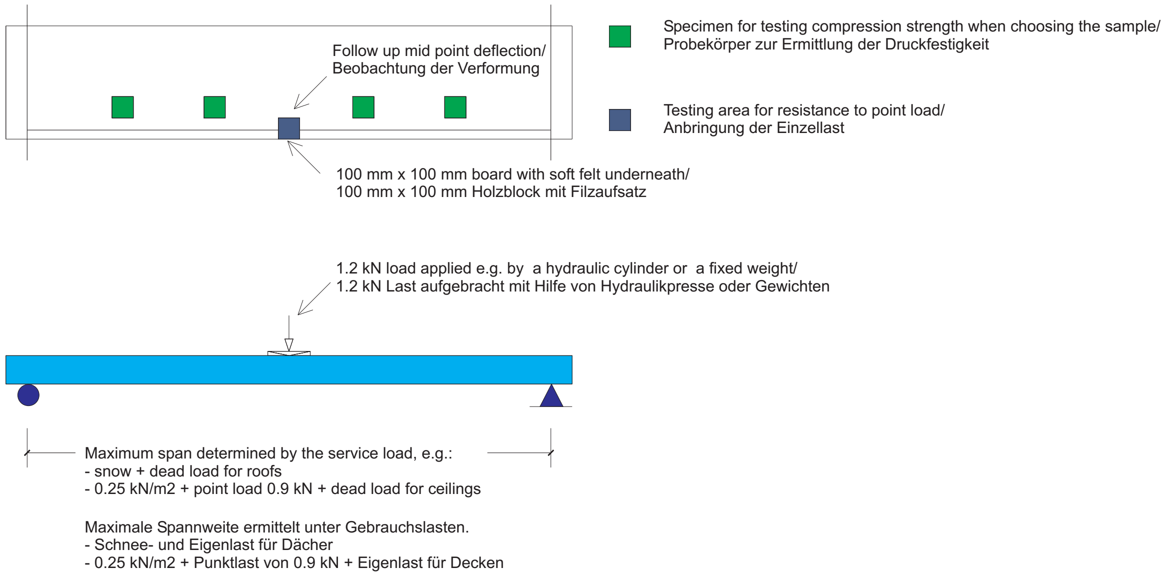


Figure 2.15: Test arrangement for testing panel resistance to point load (Case 1)

The details are shown below:

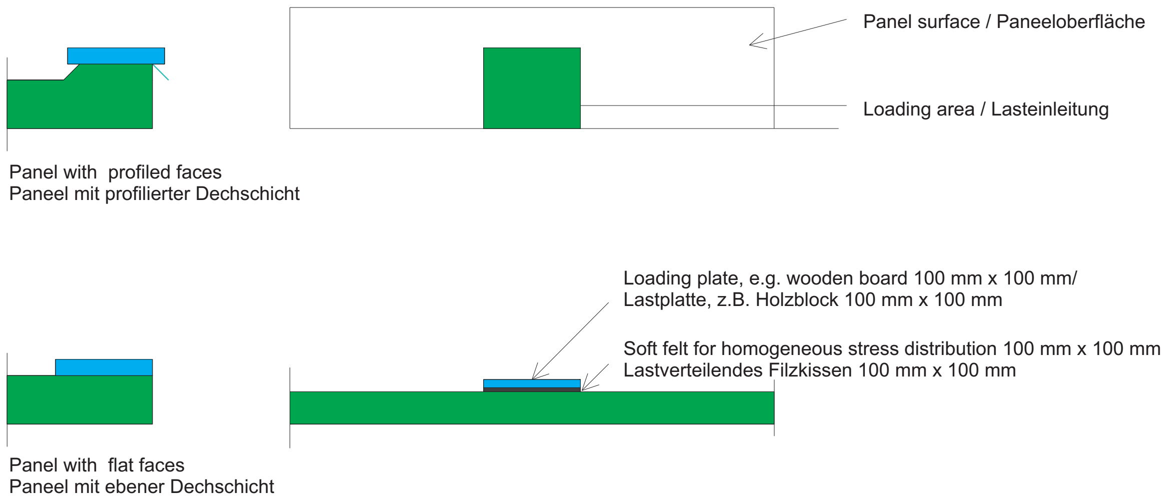


Figure 2.16: Detail on loading arrangement

c) **Evaluation of test results**

The result shall be one of the following:

i. If the panel supports the load without clearly visible damages after releasing the timber block and the felt (possible damages are: yielding of the face or a permanent deformation of the face; e.g. over 0.1 mm) there is no restriction for occasional access onto the roof or ceiling neither during the erection phase nor during occasional service work on the panel or other devices on top of the panel. The notation in the CE mark in this case is:

   Resistance to point and access loads: Suitable for occasional access for erection and service.
   For clarification of the suitability for repeated access these panels shall be further tested according to chapter 3.

   If the panel supports the load without failure but with clearly visible permanent damages the panel can only be allowed for access during erection if protection boards are used. For further access permanent walking ways supported by the frame structure of the building are to be installed. The notation in the CE mark in this case is:
   Resistance to point and access loads: Suitable for occasional access for erection only when using protection of the surface. Unsuitable for service and repeated access without permanent walk ways installed.

ii. If the panel fails to support the load, i.e. there is a clear collapse of the panel (a permanent deflection at the loading point of the panel, of size e.g. greater than span/100, measured e.g. with the help of a line spanning over the panel length in the middle of the upper face, is noticed), no access to the panel neither during erection or thereafter is allowed. Access on the panel is allowed only via walk ways fixed to the supporting frame of the building. The notation in the CE mark in this case is:
   Resistance to point and access load: Access not allowed, suitable as non-walk-on ceilings only.

3. Testing case 2: Repeated access for erection and service (prEN 14509 A.9.2)

If the panel has passed testing according to 2.2 the panel has to be tested for suitability to repeated access. The target of this test is to check the safety and serviceability of roof or ceiling panels with respect to a single person walking on the panel for repeated access both during and after erection.

This can be the case where installation groups are walking over already installed panels to areas to be installed, or where the routes to the erection area is passing through doors, fixed ladders. Such may also be applicable in case of necessary service work on devices on the top of the panels after erection where the personnel is expected to repeatedly pass along one and the same route.

This is simulated by repeatedly pressing a 100 mm x 100 mm loading plate (e.g. wooden board) on the surface of the panel. The evaluation of the resistance is done by comparing tensile strength of the samples after repeated compression loading to the initial tensile strength measured on reference samples.

a) **Samples**

The panel sample of full width chosen for testing is checked for compression strength of the core not to be higher than 10 % over the declared compression strength for the panel (see fig. 2.17).

From one panel six samples with the length of 500 mm and the full panel width are extracted.

On five of these samples, chosen for repeated compression testing, a square of 100 mm by 100 mm is marked in the middle of the panel. The sixth sample is chosen for testing reference tensile strength. Three specimen of size 100 mm by 100 mm are marked and cut out from this sample.

All the samples are kept in laboratory conditions for 6 hours.

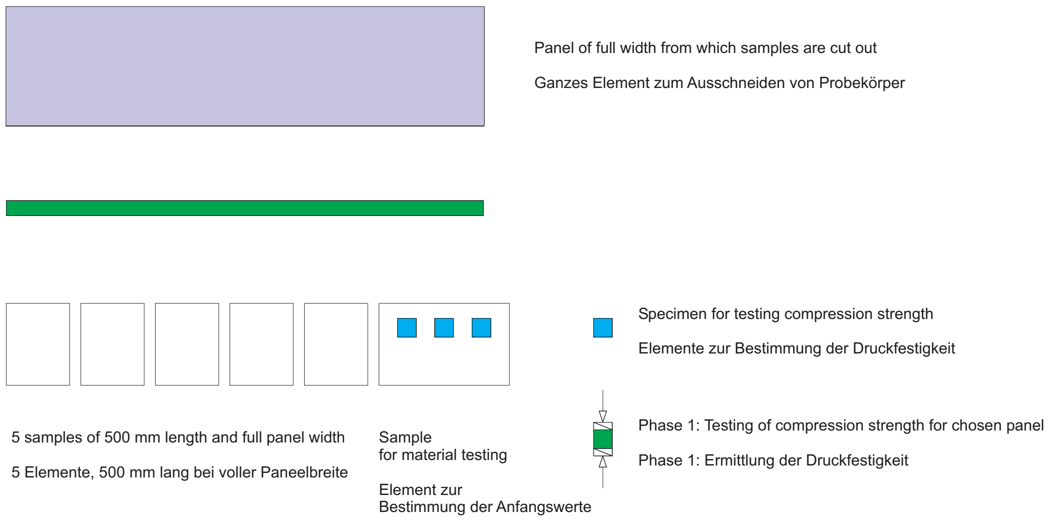


Figure 2.17: 5 samples for testing strength to repeated compression loads and 1 sample for testing material strength

b) **Testing**

i. **Initial tensile strength**
The reference value for tensile strength is determined on three specimens in accordance with A.1 (phase 2 in fig. 2.18).

ii. **Repeated compression test**

On the five sample (500 mm x panel width) compression tests are done as follows (phase 3 in fig. 2.18):
The sample is placed on a rigid base covering the entire sample. On the marked square 100 mm x 100 mm a loading plate (e.g. wooden board) is placed. A load of 600 N is applied and kept for 6 s. The load is dropped to zero and kept for 2 s. This is repeated for 40 cycles.

After these cycles the loading plate is removed and the marked square 100 mm x 100 mm where the compression load was applied is cut out.

This procedure is repeated for all five specimens.

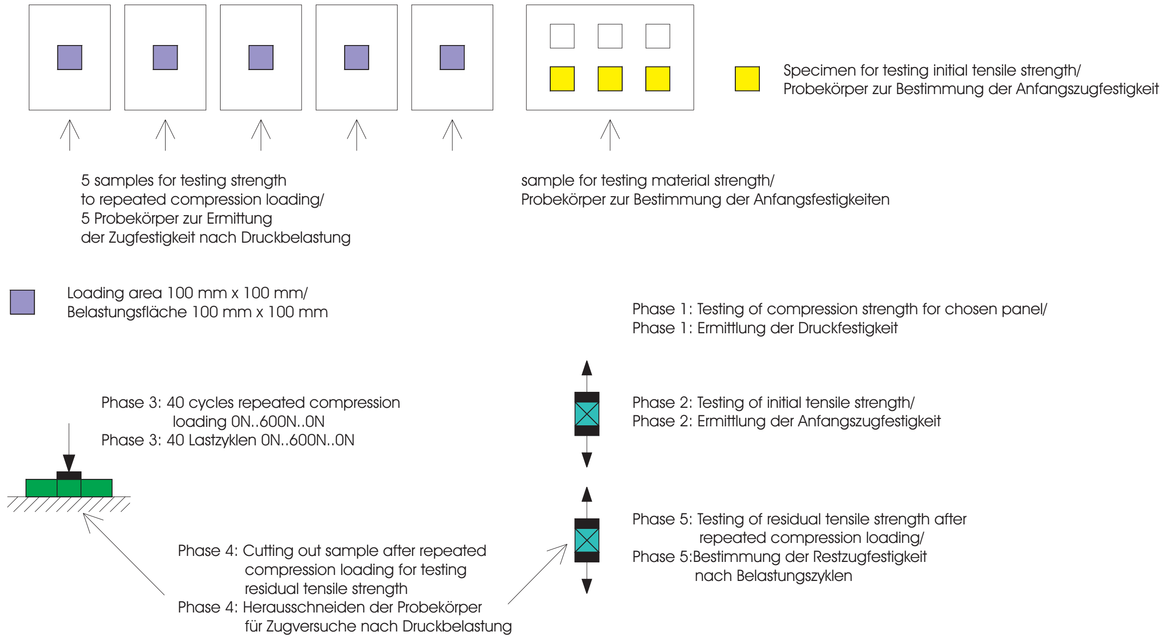


Figure 2.18: Testing procedure

iii. **Tensile strength after repeated compression testing**
The tensile strength is measured on all five specimens subject to repeated compression loading (phase 5 in fig. 2.18).

c) **Evaluation of test results**

As described in A.1 (see chapt. 2.6.2.5) the tensile strength is determined as $f_{Ct} = F_u/A$.
The mean value from the reference tests f_{Ct0} is compared to the mean value for the tensile strength f_{Cta} for the specimens subject to repeated compression loads. When calculating the mean value for the specimen subject to repeated loading the best and worst result is eliminated.

If the ratio f_{Cta}/f_{Ct0} is ≥ 0.8 the panels are suitable for repeated access.
The notation in the CE-mark is in this case:
Resistance to point and access loads: Suitable for repeated access

If the ratio $f_{Cta}/f_{Ct0} < 0.8$ the panels are not suitable for repeated access.
The notation in the CE-Mark in this case is:
Resistance to point and access load: Suitable for occasional access for erection and service. Unsuitable for repeated access without additional protection

3 Building physics properties

3.1 General

All properties that are handled and described in this section are not only dependent on the sandwich panel but the function of the whole system consisting of panels, fixings, sealants, flashings, details and workmanship during installation. There are different options for the manufacturer to deal with these aspects.

Generally the specimens should therefore include both longitudinal joints between the panels and transversal joints with fixings to connect the panels to the building frame. Normal sealant systems and details should be used in the joints mentioned above according to the end use conditions the manufacturer will use in practice.

All details used in the different tests shall be recorded in the test reports and the test results are valid only for the same family of structure that the tested one according to the field of direct and/or extended applications given for the different test methods.

Openings (windows, doors, etc.) shall not be included in the test specimen.

3.2 Installation on the building site

Because the installation will affect the properties of the system the installation of a quality marked product shall always be made by an installation company that has enough knowledge of the product and its function. The manufacturer is obliged to give clear installation rules and details to ensure a correct installation on the building site. These rules must also be followed to ensure the properties declared.

3.3 Determination of product properties in final applications

3.3.1 Reaction to fire

Based on: EN 14509, 5.2.4.1, 5.2.4.2 and C1

Family of products shall be established using the rules for direct field of application given in the product standard.

The tests shall be made according to the relevant test methods and the additional instructions given in the product standard.

Where the test EN ISO 11925-2 is needed the method for unprotected applications without flashings shall be used.

In case of A1 or A2 classified panels the amount of adhesive shall be checked at least once per day and the rolling mean value of the amount shall be below the value given in the certificate. This shall also be checked together with the strength properties in ITT and third party control tests.

3.3.2 Fire Resistance

Based on: EN 14509, 5.2.4.1, 5.2.4.3 and C2

Family of products shall be established using the rules for direct field of application given in the product standard.

The tests shall be made according to the relevant test methods and the additional instructions given in the product standard.

Additional measurements can be used for further EXAP examinations and classifications.

3.3.3 External fire exposure

Based on: EN 14509, 5.2.4.1, 5.2.4.4 and C3

Family of products shall be established.

The tests shall be made according to the relevant test methods and the additional instructions given in the product standard if the panels do not have a CWFT. It is up to the manufacturer to choose what test method(s) he wants to use depending on the requirements in the different countries.

3.3.4 Thermal insulation performance

Based on: EN 14509, 5.2.2 and A10

The declared thermal conductivity shall be determined in accordance with the procedures described in the appropriate product standard for the core material in the direction used in the sandwich panel. For preformed core materials the values and results from the manufacturer of the core material can be used. For other materials than core materials (eg. metal sheets) tabulated values in accordance with EN 12524 shall be used.

Design thermal conductivity shall be determined and the thermal transmittance value (U) for the panel system excluding the end fixings but taking into account the effects of all joints shall be calculated according to EN 14509.

The influence of the fixings shall be given separately and calculated according to standard EN-ISO 10211-1.

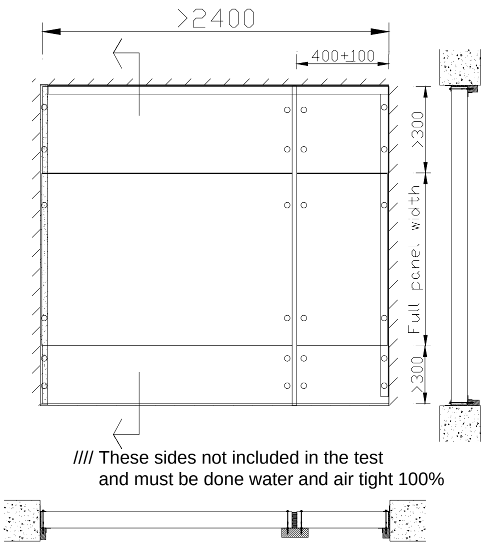
3.3.5 Water permeability

Based on: EN 14509, 5.2.6 and A11

Water permeability tests can be made on the same assembly used for air permeability.

The tests shall be made according to the relevant test methods, the additional instructions given in the product standard and the following rules:

- The dimensions of the test assembly shall be large enough to be representative of the intended use. This means that it shall consist of at least one full width panel and two cut panels (width ≥ 300 mm) to include a minimum of two longitudinal joints in the assembly. The length/height of the assembly shall not be less than 2400 mm.
- Both horizontal and vertical joints shall be incorporated in the test assembly together with the fixing to the floor. Corners and fixing to the roof construction is not included in the test assembly.
- If both horizontal and vertical installations are used in practice both configurations shall be tested. Be sure to seal the 3 sides air and rain tight according to figures 1 and 2.
- Principal drawings of the test assemblies are given figures 1 – 2.



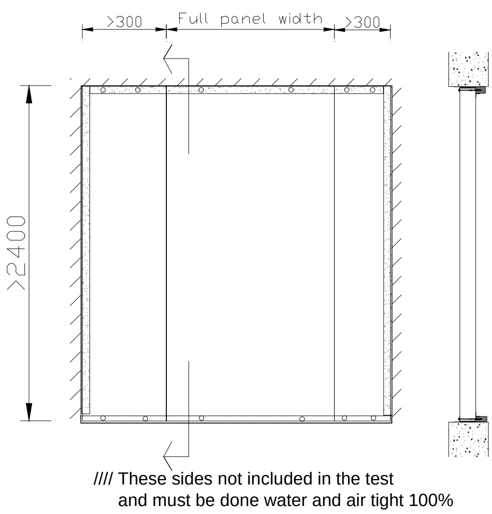


Figure 1: Test arrangement for horizontal installation

Figure 2: Test arrangement for vertical installation

Family of products shall be established taking into account the following extended application rules:

- Results for horizontally installed wall panels are not valid for vertically installed panels and vice versa.
- Roof panels shall be tested as wall panels. If the longitudinal panel joints in the roof are in the slope direction test arrangements according to figure 2 shall be used. In all other cases test arrangements according to figure 1 shall be used. Results are valid for the tested direction only.
- If panels of different thicknesses are manufactured only thinnest panel shall be tested and the results are valid for all thicker panels.
- Lowest amount of fixings/panel end used in practice shall be used in the test. Results are then valid for all higher amounts of fixings.
- Results for one type of core material are valid only for that type of core material (e.g. if PUR is tested it is valid only for PUR cores not for MW or others). If different core materials are used within the same family (e. g. different densities) only the material with the lowest stiffness needs to be tested and the results are valid for all other stiffer core materials within the same family.
- If different types of face materials are used only the thinnest type needs to be tested and the results are valid for all thicker face materials within the same family. For different types of metals a result for a metal giving a lower panel stiffness is always valid for a metal face giving a higher stiffness.
- Because the permeability is totally depending on the joint system a result for one type of joint is valid for that joint type only within the tolerances for the joint in question.
- Results for one type of sealant are valid for other sealants within the same family with same material properties within given tolerances. A joint system can be constructed with or without sealants. Results for joints without sealants are always valid for the same type of joint with sealants. Regarding the question of one or several sealants the results are depending on where the sealants are situated and any general assumptions can not be given so the results are valid for the tested type only.

3.3.6 Air permeability

Based on: EN 14509, 5.2.7 and A12

The tests shall be made according to the relevant test methods, the additional instructions given in the product standard and the following rules:

- The dimensions of the test assembly shall be large enough to be representative of the intended use. This means that it shall consist of at least one full width panel and two cut panels (width ≥ 300 mm) to include a minimum of two longitudinal joints in the assembly. The length of the assembly shall not be less than 2400 mm.

- Both horizontal and vertical joints shall be incorporated in the test assembly together with the fixing to the floor. Corners and fixing to the roof construction is not included in the test assembly.
- Only a horizontal installation as used in practice shall be tested. Results are then valid for all other configurations with the same type of panels and joint constructions. Be sure to seal the 3 sides air tight according to figure 1.
- The test specimen shall be tested both for under and over pressure. Worst result is valid for the test specimen.
- The test shall be performed and the test results given in such a way that the air permeability for the horizontal longitudinal joints, vertical joint and fixing to the floor all as (m^3/m h) are measured and given. The recommended way to do this is first to measure the air permeability for the complete assembly totally sealed to get the leakage of the equipment and the 3 sides not included in the test. Then unseal the panel joints to get a result for the longitudinal joints between the panels only, unseal also the vertical joint and make a new measurement and at last unseal also the joint between the panel and the floor to get results for the whole assembly. From these results the air permeability (m^3/m^2 h) for the whole assembly can be calculated for different applications. The calculation should be made for a 10 by 10 m^2 wall assembly. Even if the product standard requires air permeability to be measured only for a pressure difference of 50 Pa it is recommended to perform the test according to the test method standard also for the given other pressure differences. An example of calculations is given in figure 3.
- Principal drawing of the test assembly is given in figure 1.

From the test we have the following results at air pressure 50 Pa:

- Longitudinal joint between panels: mean value for both joints — 1 m^3/m h
- Vertical joint between panels: calculated on the total joint length — 5 m^3/m h
- Joint between panel and floor: calculated on the total joint length — 3 m^3/m h

For a horizontally mounted wall with 1 m panel width and 10 m span this will give the following result:
$(10*3 + 10*5 + 9*10*1)/100 = 1.7$ m^3/m^2 h
For a vertically mounted wall with the same panels we do not have any vertical joints so the result will be:
$(10*3 + 9*10*1)/100 = 1.2$ m^3/m^2 h

Figure 3: Example of air permeability calculations

Family of products shall be established taking into account the following extended application rules:

- Roof panels shall be tested as wall panels according to figure 1.
- If panels of different thicknesses are manufactured only thinnest panel shall be tested and the results are valid for all thicker panels.
- Lowest amount of fixings/panel end used in practice shall be used in the test. Results are then valid for all higher amounts of fixings.
- Results for one type of core material are valid only for that type of core material (e.g. if PUR is tested it is valid only for PUR cores not for MW or others). If different core materials are used within the same family (e. g. different densities) only the material with the lowest stiffness needs to be tested and the results are valid for all other stiffer core materials within the same family.
- If different types of face materials are used only the thinnest type needs to be tested and the results are valid for all thicker face materials within the same family. For different types of metals a result for a metal giving a lower panel stiffness is always valid for a metal face giving a higher stiffness.
- Because the permeability is totally depending on the joint system a result for one type of joint is valid for that joint type only within the tolerances for the joint in question.
- Results for one type of sealant are valid for other sealants within the same family with same material properties within given tolerances. A joint system can be constructed with or without sealants. Results for joints without sealants are always valid for the same type of joint with sealants. Regarding the question of one or several sealants the results are depending on where the sealants are situated and any general assumptions can not be given so the results are valid for the tested type only.

3.3.7 Airborne sound insulation

Based on: EN 14509, 5.2.9 and A13

The tests shall be made according to the relevant test methods and the additional instructions given in the product standard.

Family of products shall be established taking into account the following rules:

- Longitudinal joints between the panels shall be incorporated in the test assembly and end fixings.
- Results for horizontally installed wall panels are valid for vertically installed panels and vice versa.
- If panels of different thicknesses are manufactured thinnest panel shall be tested and test results are valid for all thicknesses.
- Results for one core material are valid for the tested core material only.
- If different types of face materials are used only the thinnest type needs to be tested and the results are valid for all thicker face materials within the same family. For different types of metals a result for a metal with lower density is always valid for a metal face with a higher density.
- Tests should be made for one type of joint construction. Results are then valid for other joint constructions with the same type of sealing system. Results for constructions without sealants are also valid for constructions with sealants.

3.3.8 Sound absorption

Based on: EN 14509, 5.2.10 and A14

Perforated panels are not within the scope of the standard. For non-perforated panels it can be assumed that the sound absorption for normal metal faces and coatings is 0 without any tests.

3.4 Quality control

The factory production control shall be made according to the rules given in EN 14509 and the following additional requirements:

- The precise specifications of all components shall be recorded during manufacturing or a sufficient statement shall be provided by the manufacturer of the component.
- The panel design/type shall be recorded to confirm the panel to panel joint detail. The dimensions of the joint shall be measured at least once per month and always when a change in the production affecting the joint is made.