EUROPEAN ASSESSMENT DOCUMENT

EAD 140022-00-0304

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PREFABRICATED WOOD-BASED LOADBEARING STRESSED SKIN PANELS

This European Assessment Document (EAD) has been developed taking into account up-to-date technical and scientific knowledge at the time of issue and is published in accordance with the relevant provisions of Regulation (EU) 305/2011 as a basis for the preparation and issuing of European Technical Assessments (ETA).

Contents

1 SCOPE OF THE EAD

1.1 Description of the construction product

This EAD covers prefabricated wood-based loadbearing stressed skin panels for use in roofs, external walls, structural partitions and floors (including the joints/ connections between the stressed skin panels where jointing is part of the product).

These stressed skin panels are composed of single or double skin(s), made of wood-based materials (at least one skin), with or without internal reinforcement (wooden ribs), with or without a rigid insulating core and with or without a vapour control layer or breather membrane. The exact composition of the product and materials of its layers are specified in the ETA.

The stressed skin panel contributes to the mechanical resistance or to the stability of the works or it supports other structural elements of the works or it has a positive influence on the racking resistance of the works (horizontally and/or vertically).

Roof coverings, claddings, external façade insulating systems and rain/snow protection and fixings to the substructure are sometimes attached to the stressed skin panels in the manufacturing process. These roof coverings, claddings, external façade insulating systems and rain/snow protection and fixings to the substructure are not in the scope of this EAD, they are covered by harmonised European standards or other harmonised technical specifications.

This EAD considers the following components:

- Skins or flanges made of wood based panels for load bearing applications hEN13986[1], solid wood hEN14081-1, finger jointed solid wood hEN15497, LVL hEN14374, CLT, gypsum plasterboard EN 520, gypsum fibre board EN 15283-2 or ETA's for similar products.
- Ribs made of wood based panels, solid wood, finger jointed solid wood, glulam, LVL, CLT
- Isolation made of flexible (e.g. mineral wool) or rigid insulation (e.g. EPS, XPS, or PU), standards: hEN 13162, hEN 13163, hEN 13164, hEN 13165, hEN 13166, hEN 13167, hEN 13168, hEN 13169, hEN 13170, hEN 13171, hEN 16069
- Adhesives as described below

This EAD applies for products where the following adhesives are used:

- Adhesives type I according to EN 301, subclasses GP or GF, M or S

- Adhesives type I according to EN 15425, subclasses GP or SP

In case of finger jointed wooden skins or ribs the following adhesives are used:

- Adhesives type I according to EN 301, subclass FJ, M or S

- Adhesives type I according to EN 15425, subclass FJ

The characteristic and mean values of density of the components can be considered representative for the product.

1 All undated references to standards or to EADs in this Chapter are to be understood as references to the dated versions listed in clause 4.

Loads are transferred to the main structure of the works in both the plane of and or at right angles with the plane of the stressed skin panels.

The stressed skin panels (see figure 1) can be either:

1. Double-skin construction, such as:
   - Sandwich type (without ribs);
   - Closed box type (so called double T- or I-beams),
2. Single-skin construction:
   - Open box type (so called T-beams or stiffened stressed skin panels).

The stressed skin effect is achieved:

- For stressed skin panels, sandwich type and closed/open box type with rigid insulation material (see Figure 1 – type A, respectively both types B1 and B2): By rigidly bonding the skins throughout the whole skin interface to both the *rigid* insulation and the ribs where present, by gluing or foam injection
- For other types of stressed skin panels (see Figure 1 – types C1 and C2): By rigidly bonding the skin to the whole length of the ribs or by gluing and mechanical fixing (only for positioning or realisation of the pressure) with nails, staples or screws.

The stressed skin panels can be treated to give improved fire and biological resistance.

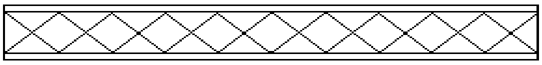
Principles of prefabricated wood-based loadbearing stressed skin panels

I. Double-skin construction

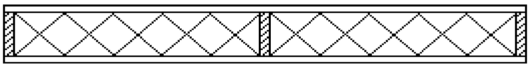
I.1 Insulation of *rigid* material which contributes to the loadbearing properties of the stressed skin panels.

Skins: wood-based boards Insulation, glued to the skins: *rigid* materials such as: expanded/extruded polystyrene or polyurethane.

A. Sandwich type (without wooden ribs)



B1. Closed box type (with or without intermediate wooden ribs)

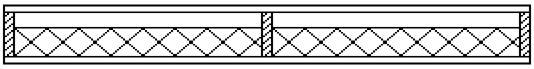


I.2 Insulation of flexible (soft) material which does not contribute to the loadbearing properties of the stressed skin panels.

Skin(s): wood-based board(s)

Insulation (if any): *flexible* (soft) materials such as mineral wool, sheep's wool, polyurethane, etc.

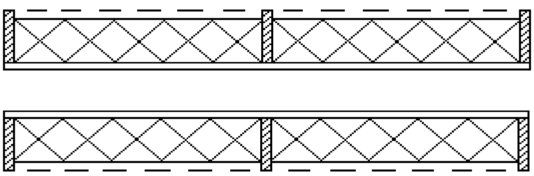
C1. Closed box type (with wooden ribs)



II. Single-skin construction

II.1 Insulation of *rigid* material which contributes to the loadbearing properties of the stressed skin panels

B2. Open box type (with or without a membrane)



II.2 Insulation of *flexible* (soft) material which does not contribute to the loadbearing properties of the stressed skin panels

C2. Open box type (with or without a membrane)

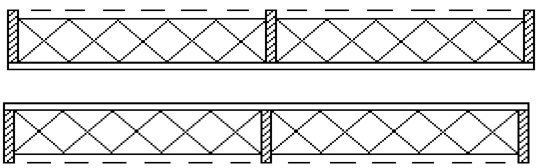


Figure 1: Principles of prefabricated wood-based loadbearing stressed skin panels

Concerning product packaging, transport, storage, maintenance, replacement and repair it is the responsibility of the manufacturer to undertake the appropriate measures and to advise his clients on the transport, storage, maintenance, replacement and repair of the product as he considers necessary.

It is assumed that the product will be installed according to the manufacturer's instructions or (in absence of such instructions) according to the usual practice of the building professionals.

Relevant manufacturer's stipulations having influence on the performance of the product covered by this European Assessment Document shall be considered for the determination of the performance and detailed in the ETA.

1.2 Information on the intended use(s) of the construction product

1.2.1 Intended uses

Prefabricated wood-based loadbearing stressed skin panels are intended to be used as a structural element for load-bearing applications in buildings and civil engineering structures such as roofs, internal and external walls, structural partitions and floors (including the joints/ connections between the stressed skin panels where jointing is part of the product).

The product is only intended to be used subject to static or quasi-static actions. In seismic areas the behaviour factor of Prefabricated wood-based loadbearing stressed skin panels used for the design is limited to non-dissipative or low-dissipative structures ($q \leq 1.5$), defined according to Eurocode 8 (EN 1998-1 clauses 1.5.2 and 8.1.3 b).

Note: Products intended for higher class of dissipative structure need further assessment.

The products are intended to be used in service class 1 and 2 according to EN 1995-1-1.

1.2.2 Working life/ Durability

The assessment methods included or referred to in this EAD have been written based on the manufacturer's request to take into account a working life of the prefabricated wood-based loadbearing stressed skin panels for the intended use of 50 years when installed in the works. These provisions are based upon the current state of the art and the available knowledge and experience.

When assessing the product the intended use as foreseen by the manufacturer shall be taken into account. The real working life may be, in normal use conditions, considerably longer without major degradation affecting the basic requirements for works[2].

The indications given as to the working life of the construction product cannot be interpreted as a guarantee neither given by the product manufacturer or his representative nor by EOTA when drafting this EAD nor by the Technical Assessment Body issuing an ETA based on this EAD, but are regarded only as a means for expressing the expected economically reasonable working life of the product.

1.3 Specific terms used in this EAD

1.3.1 Prefabricated

Manufactured in a factory and brought on to site for installation into the works.

[2] The real working life of a product incorporated in a specific works depends on the environmental conditions to which that works is subject, as well as on the particular conditions of the design, execution, use and maintenance of that works. Therefore, it cannot be excluded that in certain cases the real working life of the product may also be shorter than referred to above.

1.3.2 Wood-based

Natural wood : solid timber.

Processed wood : plywood, LVL, OSB, particle board, laminated timber, CLT, wood fibre board, etc.

1.3.3 Loadbearing

Property that:

- Forces on stressed skin panels are directly transferred to the (loadbearing structure of the) works, without an intermediate structure or substructure;
- A stressed skin panel contributes to stability of the works.

1.3.4 Stressed skin panel

Stressed skin panels are structural elements comprising internal (core) and external (skin) elements, bonded together. The core elements may consist of reinforcement (wooden ribs) in the direction of the span and/or a solid form of insulation while the skins normally comprise wood-based panels on one or both sides of the core element(s). The bonding between the core and outer skin(s) are adhesives or gluing by foam blowing; mechanical fasteners can be used for (only) positioning or realisation of the pressure. Skins carry a large proportion of the stresses generated by bending, shear, compression and racking loads depending on their end use.

1.3.5 T-beams

A T-beam is a theoretical model of a beam to be used for calculation purposes only. Such a T-beam consists of a wooden rib which is (at one side) rigidly bonded to a skin with a limited effective width. The effective width has to be calculated according to Figure 9.2 of EN 1995-1-1.

1.3.6 Double T- or I-beams

A double T- or I-beam is a theoretical model of a beam to be used for calculation purposes only. Such a beam consists of a rib which is (at both sides) rigidly bonded to skins with limited effective widths. The effective skin width of each skin has to be calculated according to Figure 9.2 of EN 1995-1-1.

1.3.7 Core

Material positioned between two skins.

1.3.8 Skin

Sheathing or boarding covering made of flat wood-based sheet, solid wood, gypsum plaster boards or gypsum fibre boards.

2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

2.1 Essential characteristics of the product

Table 1 shows how the performance of prefabricated wood-based loadbearing stressed skin panels is assessed in relation to the essential characteristics.

Table 2.1 **Essential characteristics of the product and methods and criteria for assessing the performance of the product in relation to those essential characteristics**

No	Essential characteristic	Assessment method	Type of expression of product performance
Basic Works Requirement 1: Mechanical resistance and stability			
1.	Bending strength and/or bending moment resistance perpendicular to the skin (flatwise bending of the product)	2.2.2	Description, level
2.	Compression strength and/or resistance parallel to the skin (parallel and perpendicular to the grain as applicable)	2.2.3	Description, level
3.	Compression strength and/or resistance perpendicular to the skin (support reaction)	2.2.4	Description, level
4.	Shear strength and/or resistance perpendicular to the skin (flatwise bending of the product)	2.2.5	Description, level
5.	Racking resistance	2.2.6	Description, level
6.	Resistance to concentrated loads	2.2.7	Description, level
7.	Density	2.2.8	Description, level
8.	Creep and duration of the load	2.2.9	Description, level
9.	Dimensional stability	2.2.10	Description, level
Basic Works Requirement 2: Safety in case of fire			
10.	Reaction to fire	2.2.11	Class
11.	Resistance to fire	2.2.12	levels
Basic Works Requirement 3: Hygiene, health and the environment			
12.	Content, emission and/or release of dangerous substances	2.2.13	Description
13.	Water vapour permeability and moisture resistance	2.2.14	Description, level
Basic Works Requirement 4: Safety and accessibility in use			
14.	Impact/shock resistance	2.2.15	Description, level

No	Essential characteristic	Assessment method	Type of expression of product performance
Basic Works Requirement 5: Protection against noise			
15.	Airborne sound insulation	2.2.16	Description, level
16.	Impact sound insulation	2.2.17	Description, level
17.	Sound absorption	2.2.18	Description, level
Basic Works Requirement 6: Energy economy and heat retention			
18.	Thermal conductivity	2.2.19	Description, level
19.	Air permeability	2.2.20	Description, level
20.	Thermal inertia	2.2.21	Description, level
Aspects of durability			
21.	Natural Durability	2.2.22	Description, level

2.2 Methods and criteria for assessing the performance of the product in relation to essential characteristics of the product

Testing will be limited only to the essential characteristics which the manufacturer intends to declare. If for any components covered by harmonised standards or European Technical Assessments the manufacturer of the component has included the performance regarding the relevant characteristic in the Declaration of Performance, retesting of that component for issuing the ETA under the current EAD is not required

This chapter is intended to provide instructions for TABs. Therefore, the use of wordings such as “shall be stated in the ETA” or “it has to be given in the ETA” shall be understood only as such instructions for TABs on how results of assessments shall be presented in the ETA. Such wordings do not impose any obligations for the manufacturer and the TAB shall not carry out the assessment of the performance in relation to a given essential characteristic when the manufacturer does not wish to declare this performance in the Declaration of Performance.

2.2.1 Mechanical resistance and stiffness in general

The prefabricated wood-based loadbearing stressed skin panels are assessed to resist static and dynamic loads, structural collapse and inadmissible deformations.

The mechanical resistance and stability of the prefabricated wood-based loadbearing stressed skin panels can be assessed using:

- Calculation,
- Calculation assisted by testing as of EN1990, clause 5 and Annex D,
- Testing.

Calculation is an economical way to establish the performance of characteristics, but it may give conservative results. Testing or calculation assisted by testing alternatives are more expensive to perform, but they may give advantages in end results.

If calculation is used, the strength and stiffness values of the components and a calculation method (or software) that utilizes these values shall be presented in the ETA. In addition it is possible to define effective (characteristic) strength values (or resistance values) for predefined cross sections.

TAB shall review the calculation method and the conditions where the method is applicable. Relevant information about the method and its validation shall be presented in the ETA.

2.2.1.1 Calculation

In general, the calculation method is suitable when the strength and stiffness properties of the components are well known and documented in their declarations of performance. Furthermore, the theoretical model used to estimate the mechanical resistance and stability shall be well established. EN 1995-1-1:2004; A1 A2 AC 2014 assumes linear elastic behaviour of the timber materials and the performance of other composite cross sections is calculated on the basis of the strength and stiffness properties of the components (clauses 3.1.2 and 9.1). When the properties are not defined in DoPs, the methods in chapters 2.2.1.2 or 2.2.1.3 shall be used.

The calculation method is only suitable for XPS, EPS or PU used as loadbearing rigid insulation and for non-loadbearing insulation.

In case rigid insulation shall contribute to the loadbearing performance of the product, the performance values of the insulation (k_{mod}, k_{def}, etc.) can be taken from Annex A.6.

The composite effect of glued panels only relies on the adhesive bond between the components. When using the calculation method for products with loadbearing insulation, chapter 3.1.1 shall be taken into account to assure the bonding quality. The performance of the panels is calculated from the strength and stiffness properties of the components. For this purpose, the strength and stiffness values of the component manufacturer's declaration of performance shall be given in the ETA. If several types of components are used, all of them shall be specified.

EN 1995-1-1 shall also be applied in the calculation of the details of the structural members made of the stressed skin panels. Partial factor γ_M for material properties and resistance for components given in EN 1995-1-1 shall be used in absence of nationally determined parameters. Reference to this shall be given in the ETA.

Size effect of prefabricated wood-based loadbearing stressed skin panels shall be taken into account in the tension and bending moment resistance by reduction of the tension strength of skins on the tensile side of the cross section EN1995-1-1, clause 9.1.2, equation (9.16). In the case of LVL flanges the size effect factor k_l of EN 1995-1-1:2004 clause 3.4 is used. For other flange materials the size effect factor shall be assessed according to 2.2.3.

In case of calculation, the performance of the product can also be represented by the properties of the components and geometrical data (strength, stiffness, k_{mod}, $k_{def,}$ embedment strength and arrangement of fasteners where applicable). These shall then be presented in the ETA instead of or in addition to the characteristics assessed using the methods of the clause 2.2.1.2 or 2.2.1.3. In this case at least one type of the product according to figure 1 shall be calculated as an example and given in the ETA.

<u>Calculation models</u>

Sandwich type A can be calculated by using the classical beam theory taking account of the shear deformation of the core, if the skins can be considered for themselves as rigid composite compound units. Annex A, section A.2, contains calculations formulas from EN 14509:2013, Annex E, for single-span beams and multi-span beams. Alternatively, sandwich type A may be calculated according to the calculation model by Kreuzinger, see Annex A, sections A.4 and A.4.3 , or with the method using programmes for "statics of a lattice frame", see Annex A, section A.5..

Closed box type B1 can be calculated by using the flexible bond theory according to EN 1995-1-1:2004, Clause 9.1.3, if the skins can be considered for themselves as rigid composite compound units. For single-span beams Annex A, section A.3, contains a calculation formulas from EN 1995-1-1:2004, Clause 9.1.3 and Annex B, with an adaptation to the situation of the sandwich panel of type B1 for single-span beams. Alternatively, box type B1 may be calculated according to the calculation model by Kreuzinger, see Annex A, section A.4 and A.4.4 or with the method using programmes for "statics of a lattice frame", see Annex A, section A.5..

Closed box type C1 can be calculated according to EN 1995-1-1:2004, Clause 9.1.2, considering the effective skin width (EN1995-1-1:2004, Figure 9.2). Alternatively, box type C1 may be calculated according to the calculation model by Kreuzinger, Annex A, section A.4 and A.4.4..

Open box types C2 and B2 can be calculated according to the calculation model by Kreuzinger, see Annex A, section A.4 and A.4.5.

The calculation method by Kreuzinger shall be the reference method in all cases of dispute between alternative methods.

The used calculation model shall be given in the ETA.

2.2.1.2 Calculation assisted by testing

The principles described in section 2.2.1.1 apply. In general, the calculation assisted by testing can be used when

- Tests are expected to show a better performance compared to the calculation according to 2.2.1.1 due to performance characteristics of components given in a conservative way in their DoPs. In this case correlation factors or adapted values for the components performance can be derived from calculation assisted by testing. Tests for the components according to their respective standards are advised to determine, which product characteristics differ in value from those given in the DoP of the component.
- A specific calculation model other than those described in 2.2.1.1 shall be used. In this case testing is needed both for the components (if their properties are used in the calculation) and the panels to validate the results of calculation according to that model.

Calculation assisted by testing is described in EN 1990, clause 5 and Annex D. It is recommended that at least 3 sets of 4 tests are made for each characteristic performance value to be determined [3] . The number of specimens used and the results shall be stated in the ETA.

In case the insulation core shall be used as loadbearing, but not all performance characteristics are given in Annex A or not all performance characteristics are well known and documented in their declaration of the material, the performance characteristics of the insulation core shall be derived according to EN 14509 as described in Annex A. At least 30 tests per missing property are advised..

The performance of other sizes of given variant of the product can be calculated according to the validated calculation model within the tested limits.

In case of calculation assisted by testing the performance of the product can also be represented by the properties of the components and geometrical data (strength, stiffness, k_{mod}, k_{def}, embedment strength and arrangement of fasteners where applicable, correlation factors). These shall then be presented in the ETA instead of or in addition to the characteristics assessed using the methods of the clause 2.2.1.1 or 2.2.1.3. In this case at least one type of the product according to figure 1 shall be calculated as an example and given in the ETA.

2.2.1.3 Testing

When a theoretical model and the material values of the components are not utilised, the characteristic values of the mechanical properties can be determined directly from tests specified later on. Moisture content and density of the specimens shall be determined, as well as the specification of the components.

At least 10 tests for each product shall be conducted for each characteristic strength and stiffness value to be determined. Characteristic strength values shall be calculated as provided for in EN 14358, lognormal or normal distribution can be assumed. The test specimens should normally be conditioned to constant mass and moisture content in an atmosphere having a relative humidity of 65% and a temperature of 20°C.

For all values derived by testing the following applies: As the tests only describe short term loading, the geometrical data and the material values k_{mod}, k_{def} for all materials shall be given in the ETA.

[3] For small number of specimens, the calculation methods in EN 14358 imply a punishment. In case of normal distribution and the minimum standard deviation of 0,05 assumed, the same mean value gives for 5 specimens a characteristic strength 0,98 times the one for 10 specimens, while for 15 specimens the characteristic strength would be 1,01 times the one for 10 specimens. This effect is larger if the standard deviation is larger, what it often is for small number of specimens.

While testing a product, where the insulation is defined as "non-loadbearing" it has to be assured, that the insulation does not contribute to the test results.

In case of testing products with ribs, these shall be arranged in a way that the lowest performance occur. The boundary conditions (length, position of ribs, position of supports, etc.) covered by the tests shall be given in the ETA.

2.2.2 Bending strength and/or bending moment resistance perpendicular to the skin (flatwise bending of the product)

Calculation:

The flatwise bending strength of the product with loads uniformly distributed along the panel width can be derived from those for the components calculated as beam structures according to the elastic bond theory. The calculated stress values must not exceed the strength of the components in any point of the cross section. Principle of the stress distribution is shown in EN 14509:2013, Figure E.4, for sandwich type A, and EN1995-1-1, Figure 9.1, for closed box types B1 and C1, as well as in Annex A, section A.4. Effective bending strength or bending moment resistance for a given whole cross section can thus be calculated. It is usually user friendly to define bending moment resistance of the cross section. The size effect can be taken into consideration in design value of tensile strength in the EN 1995-1-1, clause 9.1.2, equation (9.16).

The calculation models according to Clause 2.2.1.1 for the different types (A, B1, B2, C1, C2) apply.

Characteristic bending strength values as well as size effect parameters and reference heights or bending moment resistance of the cross sections shall be given in the ETA and clarified in form of equations. Alternatively the results shall be given in the ETA as characteristic bending moment resistance for the whole cross section [kNm].

Additionally, the deflection [mm] can be given for scenarios defined by loading conditions, the geometry of the product, the arrangement of supports and the material properties of the components.

Testing or calculation assisted by testing:

Tests with whole cross sections of specimens type A, B1, B2, C1 or C2 arranged in flatwise orientation shall be carried out according to the principle of EN 408:2010+A1:2012, Clause 19, with measurement of local and global deformations according to EN 408:2010+A1:2012, Clause 9 and 10, and analysed according to EN 408 and EN 14358. Hereby, the whole cross sections of specimens type B1, B2, C1 or C2 shall be tested. Specimens of type A shall be tested with the whole height and a specified width of at least half a meter or full element width. Further information for testing is also given in the section A.2.2 of EAD 130367-00-0304/Annex A..

Size effect shall be calculated from the bending test results of the product. It is possible to determine the value for the size effect factor from the tests with whole cross sections (e.g. small, medium, and large). The results may be analysed by curve fitting equation

$$\ln(f) = s \ln(1/h) + C \qquad \text{(Eq. 1)}$$

in the results. s is the size effect, f is the strength, h is the height of the specimen and C is constant derived from the test results so that the equation gives safe side results for the height range of the product.

Characteristic bending strength values as well as size effect parameters and reference heights or bending moment resistance of the cross sections shall be given in the ETA and clarified in form of equations. Alternatively the results shall be given in the ETA as characteristic bending moment resistance for the whole cross section [kNm].

Additionally, the deflection [mm] can be given for scenarios defined by loading conditions, the geometry of the product, the arrangement of supports and the material properties of the components.

Note: The bending moment resistance of the skin in perpendicular to the ribs shall be considered separately.

2.2.3 Compression strength and/or resistance parallel to the skin (parallel and perpendicular to the grain as applicable)

Calculation:

Compression strength parallel to the product is the same as the one for the weakest component. In case of several types of components in the same product, stress distribution of the cross section shall be calculated assuming linear elasticity. The calculated stress values must not exceed the strength of the components in any point of the cross section. The calculation models according to Clause 2.2.1.1 for the different types (A, B1, B2, C1, C2) apply. Effective compression strength for a given whole cross section or compression resistance to compressive axial forces can thus be calculated.

Testing or calculation assisted by testing:

Tests with the grain in the skins arranged parallel and/or perpendicular shall be carried out according to EN 408:2010+A1:2012, Clause 15, and analysed according to EN 408 and EN 14358. Hereby, the whole cross sections of specimens type B1, B2, C1 or C2 shall be tested. Specimens of type A shall be tested with the whole height and a specified width of at least half a meter or full element width. Further information for testing is also given in the section A.2.5 of EAD 130367-00-0304/Annex A., whereas the transverse load H is optional in the test.

The results shall be given in the ETA as characteristic compression resistance in kN/m (homogenized value for the cross section). The geometry and the wall height of the specimens shall be given in the ETA.

2.2.4 Compression strength and/or resistance perpendicular to the skin (support reaction)

Calculation:

Compression strength perpendicular to the product of type A may be assumed to be the same as the one for the weakest component.

Stress distribution of the cross section may be calculated assuming linear elasticity. Compression strength perpendicular to the product of type B1, B2, C1, C2 shall be verified for every rib area according to EN 1995-1-1, Clause 6.1.5. The results can be given in the ETA as characteristic compression perpendicular to the skin resistance for the support area in kN/(m of product width) or kN/rib. The geometry of the support area shall be given in the ETA.

Testing or calculation assisted by testing:

The test method is specified in EAD 130367-00-0304/Annex A., section A.2.3. When the product is supported and primarily uniform loaded as a beam, test type D of figure 3 shall be used. When the product is line loaded directly on the support, test types A and B shall be used. Specimens of type A shall be tested with the whole height and a specified width of at least half a meter or full element width. The position of the ribs of specimens type B1, B2, C1 or C2 shall be documented. The maximum resistance of the support is to be considered as the force at final (brittle) failure or the force at 10 % deformation.

The results can be given in the ETA as characteristic compression perpendicular to the skin resistance for the support area in kN/(m of product width) or kN/rib. The geometry of the support area shall be given in the ETA.

2.2.5 Shear strength and/or resistance perpendicular to the skin (flatwise arrangement of the product)

Calculation:

Stress distribution of the cross section may be calculated assuming linear elasticity.

Shear strength for product of type A may be calculated and verified by the calculation model by Kreuzinger, see Annex A, section A.4.

Shear strength of product of type B1, B2, C1, C2 shall be verified according to EN 1995-1-1, Clause 9.1.2, Equation (9.14). In addition the shear strength in the centre of gravity of the rib needs to be verified. The results shall be given in the ETA as characteristic shear resistance in kN per product or kN/(m of product width).

Testing or calculation assisted by testing:

Test method is specified EAD 130367-00-0304/Annex A. section A.2.4. Specimens shall be arranged in flatwise orientation. Hereby, the whole cross sections of specimens type B1, B2, C1 or C2 shall be tested. Specimens of type A shall be tested with the whole height and a specified width of at least half a meter or full element width using a test equipment and load application according to EN 14509:2013, Clause A.3. The position of the ribs of specimens type B1, B2, C1 or C2 shall be documented. Strength reducing characteristics e.g. butt joints, finger joints or holes shall be taken into consideration. Tests can be made simultaneously with shear modulus tests; the test may be interrupted for removing the deformation measurement equipment at about 60 % the ultimate load.

In the case of calculation assisted by testing, the characteristic shear strength of the connection area between the components shall be derived from the test results. All calculation methods specified in Annex A are based on the assumption that the bonding is stronger than the shear values of the materials.

The results shall be given in the ETA as characteristic shear resistance in kN/rib per product or kN/(m of product width).

2.2.6 Racking resistance

The racking resistance of prefabricated wood-based loadbearing stressed skin panels shall be assessed by one off the following equivalent methods:

a) The racking resistance of the product is represented by the properties of the components: nominal thickness of the skins, embedment strength, information on studs, fasteners and geometrical data. These shall be presented in the ETA. In this case at least one type of the product according to figure 1 shall be calculated according to b) and given in the ETA.

b) Calculated for the specific end-use situations according to EN1995-1-1, clause 9.2.4 (method A or B depending on the national annex of the country of destination). Based on nominal thickness of the skins, embedment strength, information on studs, fasteners and geometrical data. Calculation is only possible when the isolation does not contribute to the loadbearing properties. The racking resistance $F_{v,Rd}$ [N] shall be given in the ETA with information of the used method.

c) Tested and evaluated according to EN 594 and expressed as characteristic value of racking resistance in [N] and mean value of racking stiffness in [N/mm] under point load and relevant test parameters (complete description of the timber frame wall panel being tested, especially regarding material properties, geometry, fasteners and spacings). The test configuration is specified in figure 2.

The reference method in all cases of dispute is method c).

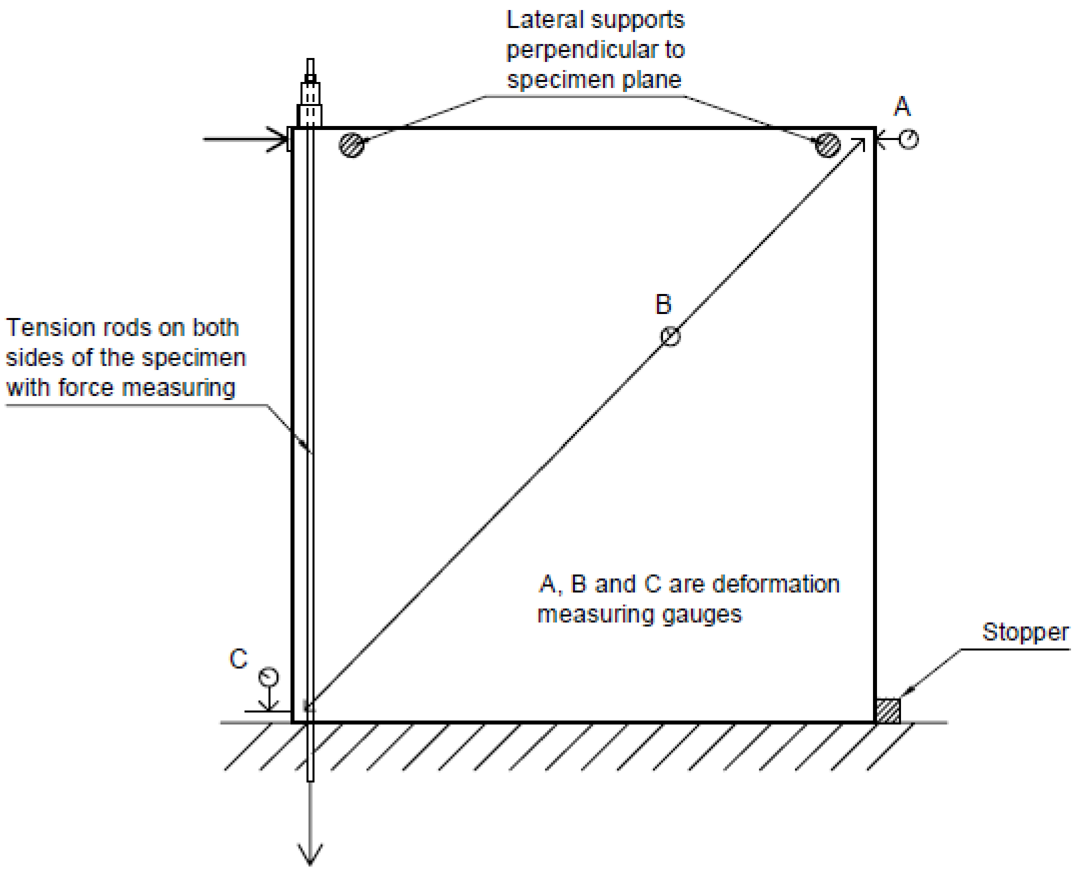


Figure 2: Racing resistance test configuration. Load is applied at the upper left corner of the specimen which is vertically tied with tension rods to the foundation. In horisontal direction the specimen is supported with a stopper at the bottom right corner. A, B and C are deformations measurement gauges.

2.2.7 Resistance to concentrated loads

Testing shall be done according to EN 12871 in conjunction with EN 1195. The serviceability characteristic strength $F_{ser,k}$, the mean stiffness in bending R_{mean} and the ultimate characteristic strength $F_{max,k}$. and Impact Class shall be given in the ETA.

2.2.8 Density of components

Density of the components shall be assessed according to EN323, EN384, chapter 5.3.4, or EN1602 depending on the material of the components, and they shall be stated as characteristic value and mean value of the density.

In case of CE-marked components the value declared by the manufacturer of the component is to be used and retesting is not required.

2.2.9 Creep and duration of the load

For structural wood products the influence of creep and duration of load are taken into account for according to EN1995-1-1 clauses 2.2.3 , equations (2.3) –(2.5) by parameter k_{def} and 2.4.1 , equation (2.14) by the parameter k_{mod}. Their values are given in the EN1995-1-1, tables 3.1 for k_{mod} and 3.2 for k_{def}. For loadbearing insulation materials the values are given in Annex A, section A.6. The parameters shall be given in the ETA. Unless the values are determined from product specific tests, the following applies:

- For the resistance on bending moment, axial forces and bearing capacity and flexural rigidity, the parameters k_{def} and k_{mod} are defined according the skin material.

- For the resistance on shear forces and shear rigidity and bending moment of the rib, the parameters k_{def} and k_{mod} are defined according the rib or loadbearing isolation materials

NOTE: When LVL with cross veneers is used as skin material and the shear rigidity of the product is assesses only based on the shear rigidity of rib and/or rigid isolation properties, the k_{def} of LVL without cross veneers maybe used for the flexural stiffness assessment of the product, since the skins are primarily subjected to axial stresses.

2.2.10 Dimensional stability

2.2.10.1 Tolerances, swelling and shrinkage

Dimensional stability of the element shall be dealt with by its swelling and shrinkage values. The swelling and shrinkage values shall be tested according to EN 318 for a specific layup and species or species combination and declared as presence of soft- or hardwood and mean values of percentile change of dimension related to one percent change in moisture content. In case of CE-marked components the value declared by the manufacturer of the component is to be used and retesting is not required.

Nominal dimensions of the products depend on the individual design referred to under clause 1.1. No standard product sizes normally exist. In the ETA, dimension limits depending on the manufacturing method should be given. Tolerances used by the manufacturer as well as swelling and shrinkage values determined for the parts of the elements shall be given in the ETA.

2.2.10.2 Deformation due to hygroscopicity difference of components

For new products or for specific uses, if permanent or non-permanent deflection is expected considering the hygroscopicity / non- hygroscopicity of the different components, this deflection can be measured as follows.

a) Behavior in homogeneous humidity conditions:

- Two stressed skin panels are placed in a room regulated at 23 ± 2°C and 15 or 20 ± 5 % RH (relative humidity) during 3 weeks, then in a room regulated at 23 ± 2°C and 90 % RH (alternative stressed skin panels can be used, two at 15-20 % RH and two at 90 % RH in the same time)
- The stressed skin panels shall be stored free for/to any deformation, e.g. vertically on a long side, without effect of their own weight, the main faces exposed to the same air ambience.
- Measure every week the maximum deflection against horizontal or vertical reference line in the length and the width direction, using premarked points located in the middle of each edge.
- If a global curving is observed, measure also the diagonal deflection.

b) Behavior between two different humidity conditions:

- A test specimen comprising one or several stressed skin panels free for deformation in the length direction and sealed to a frame, is placed between two climates regulated during 3 weeks.
- The measurements are made as in clause a).
- The choice of ambiences is defined according to the most severe conditions expected in the considered field of application. In absence of specific conditions use (according to EN 1121):
  - External side at 3 + 2°C and 85 + 5 % RH;
  - Internal side at 23 + 2°C and 30 + 5 % RH.

The results shall be expressed in the ETA as an equation u = L / C, where L is the span of the product and C = mean value of the ratios of the tested specimens: span of the tested specimen [mm] / deformation [mm] of the test specimen in the middle of the span.

2.2.11 Reaction to fire

The skin/rib materials of structural timber are considered to satisfy the requirements for performance class D-s2,d0 of the characteristic reaction to fire in accordance with the EC Decision 2003/593/EC as amended without the need for testing on the basis of it fulfilling the conditions set out in that Decision and its intended use being covered by that Decision.

Therefore the performance of the rib/skin materials of structural timber is D-s2,d0.

The skin materials of gypsum plasterboards are considered to satisfy the requirements for performance class A2-s1,d0 or B-s1,d0 of the characteristic reaction to fire in accordance with the EC Decision 2003/593/EC as amended without the need for testing on the basis of it fulfilling the conditions set out in that Decision and its intended use being covered by that Decision.

Therefore the performance of the skin materials of gypsum plasterboards is A2-s1,d0 or B-s1,d0.

The skin/rib materials of glulam are considered to satisfy the requirements for performance class D-s2,d0 of the characteristic reaction to fire in accordance with the EC Decision 2005/610/EC as amended without the need for testing on the basis of it fulfilling the conditions set out in that Decision and its intended use being covered by that Decision.

Therefore the performance of the rib/skin materials of glulam is D-s2,d0.

The skin/rib materials of LVL and CLT are considered to satisfy the requirements for performance class D-s2,d0 of the characteristic reaction to fire in accordance with the EC Decision 2017/2293/EC as amended without the need for testing on the basis of it fulfilling the conditions set out in that Decision and its intended use being covered by that Decision.

Therefore the performance of the rib/skin materials of LVL and CLT is D-s2,d0.

The skin/rib materials of wood-based materials are considered to satisfy the requirements for performance class B-s1,d0, D-s2,d0, D-s2,d1 or D-s2,d2 of the characteristic reaction to fire in accordance with the EC Decision 2003/43/EC as amended without the need for testing on the basis of it fulfilling the conditions set out in that Decision and its intended use being covered by that Decision.

Therefore the performance of the rib/skin materials of wood-based materials is B-s1,d0, D-s2,d0, D-s2,d1 or D-s2,d2.

The isolation materials of mineral wool, cellular glass and expanded perlite are considered to satisfy the requirements for performance class A1 of the characteristic reaction to fire in accordance with the EC Decision 96/603 as amended without the need for testing on the basis of it fulfilling the conditions set out in that Decision and its intended use being covered by that Decision.

Therefore the performance of the aforementioned isolation materials is A1.

The performance regarding reaction to fire of materials not mentioned above shall be taken from the DoP of this component if available.

When the components / the product do not meet the provisions of the aforementioned EC Decisions or when a higher classification is sought, testing shall be done using the procedures/test method(s) according to EN 13501-1 and relevant for the corresponding reaction to fire class. The product shall be classified according to Commission Delegated Regulation (EU) No 2016/364.

2.2.12 Resistance to fire

The resistance to fire of roofs, floors or walls in which the prefabricated wood-based loadbearing stressed skin panels are intended to be incorporated, installed or applied, shall be tested and classified using the test method relevant for the corresponding fire resistance class, in order to be classified according to EN 13501-2. The tests shall be performed in accordance with EN 1365-1 (walls) or EN 1365-2 (roofs and floors).

All boundary conditions in the tests and other provisions for the level shall be given in the ETA.

In case the parts of the works in which the prefabricated wood-based loadbearing stressed skin panels are intended to be incorporated, installed or applied fall within the scope of EN 1995-1-1, fire design may be calculated in accordance with EN 1995-1-2. For the determination of the performance of the product in relation to this essential characteristic the following parameters shall be assessed:

- *Charring rates β_0 and β_n of the components according to/applying EN 1995-1-2*
- *t_{ch} and t_f times of the fire protection layers according to/applying FprEN13381-7:2017*
- *k_2 and k_3 factors for modified charring rates according to/applying FprEN13381-7:2017*
- *k_n and k_s factors for modified charring rates according to/applying FprEN13381-7:2017*
- *$k_{mod,fm,fi}$ and $k_{mod,c,fi}$, when the method of Annex C of EN1995-1-2:2004 is applied*
- *Zero strength layer d_0, when the method of Annex C of EN1995-1-2:2004 is applied*

The levels shall be given in the ETA.

When calculation is used as the assessment method without any testing, it shall be assumed that the adhesive bonding doesn't contribute to the mechanical resistance of the element in the case of fire. When the resistance of fire of the product is tested, the contribution of the adhesive bonding to the mechanical resistance can be assessed applying the methods defined in EN 1365-1 (walls) or EN 1365-2 (roofs and floors) or FprEN 13381-7 (Applied fire protection to timber structures).

The assessment method of the above mentioned characteristics shall be stated in the ETA.

2.2.13 Content, emission and/or release of dangerous substances

The performance of the panels related to the emissions and/or release and, where appropriate, the content of dangerous substances will be assessed on the basis of the information provided by the manufacturer[4] after identifying the release scenarios (in accordance with EOTA TR 034, October 2015) taking into account the intended use of the product and the Member States where the manufacturer intends his product to be made available on the market.

The identified intended release scenarios for this product and intended use with respect to dangerous substances are:

IA1: Product with direct contact to indoor air

IA2: Product with indirect contact to indoor air (e.g. covered products) but possible impact on indoor air.

2.2.13.1 SVOC and VOC

For the intended use covered by the release scenario IA1/IA2 semi-volatile organic compounds (SVOC) and volatile organic compounds (VOC) are to be determined in accordance with EN 16516. The loading factor to be used for emission testing shall be taken from EN 16516 depending on the intended use of the product. Only panels with skins made of oriented strand boards (OSB), particle boards or high-pressure decorative laminates (HPL) have to be tested.

The preparation of the test specimen is performed by using a representative sample of the product installed in accordance with the manufacturer's product installation instructions or in absence of such instructions the usual practice of the product installation. The size of the test specimen has to be chosen in consideration

4 The manufacturer may be asked to provide to the TAB the REACH related information which he must accompany the DoP with (cf. Article 6(5) of Regulation (EU) No 305/2011).

The manufacturer is **not** obliged:
- to provide the chemical constitution and composition of the product (or of constituents of the product) to the TAB, or
- to provide a written declaration to the TAB stating whether the product (or constituents of the product) contain(s) substances which are classified as dangerous according to Directive 67/548/EEC and Regulation (EC) No 1272/2008 and listed in the "Indicative list on dangerous substances" of the SGDS.

Any information provided by the manufacturer regarding the chemical composition of the products may not be distributed to EOTA or to TABs.

of the test chamber size and the intended loading factor (see above). As stated in the EN 16516, product samples shall be collected at the point of manufacture after the normal production processes are completed (including drying or curing if applicable) and immediately be placed in the emission test chamber[5]. This time is considered the starting time of the emission test.

Once the test specimen has been produced, as described above, it should immediately be placed in the emission test chamber. This time is considered the starting time of the emission test.

The test results have to be reported for the relevant parameters (e.g. chamber size, temperature and relative humidity, air exchange rate, loading factor, size of test specimen, conditioning, production date, arrival date, test period, test result) after 3 and 28 days testing.

The product performance shall be expressed in [mg/m³] and stated in the ETA.

2.2.13.2 Formaldehyde

Release of formaldehyde shall be assessed based on tests according to EN 717-1 and classification is E1 or E2. Statement of class shall be given in the ETA.

Release of formaldehyde shall be assessed based on tests according to EN 717-1 and classification according to EN 14734[6]. Simplified rules presented in Table 2 apply.

Table 2.2. Simplified rules for assessment of formaldehyde emission of the product

Class of the product	Class of component with poorest performance	Adhesive
E1	E1	E1*
E1	E1	adhesive contains no formaldehyde
Product contains no added formaldehyde	Component adhesive contains no formaldehyde	adhesive contains no formaldehyde
E2	Other than mentioned above	Other than mentioned above

*Class of softwood glulam made with the adhesive is taken as a reference

Statement of class E1 or “product contains no added formaldehyde" shall be given in the ETA.

2.2.14 Water vapour permeability and moisture resistance

The water vapour resistance of the product is represented by the properties each single component. From the water vapour resistance of the components, the hygrothermal performance of the product can be calculated, e.g. according to EN ISO 13788. The performance of water vapour resistance of each single component shall be expressed as an individual value of wet cup factor μ [-] and dry cup factor μ [-], either:

- Testing of water vapour resistance for thermal insulating products shall be according to EN 12086 and for other building materials according to EN ISO 12572, or
- taken from the manufacturers DoP.

The water vapour resistance of the relevant layers shall be given in the ETA as wet cup factor μ [-] and dry cup factor μ [-].

Note: The water vapour resistance of the product as a whole is normally not assessed.

[5] If specified in the relevant product standard a conditioning period shall be applied to test specimens before starting the test to enable the product to acquire properties representing in use conditions.

[6] Class E1 in EN 14374 is defined similarly as in EN 14080. Usually, only class E1 applies.

2.2.15 Impact/shock resistance

The impact resistance of the product is represented by the properties of the components. Impact resistance of the skin acting as a floor or roof decking on the ribs or rigid isolation is represented by the impact resistance of the skin and shall be assessed according to EN 12871. Impact resistance of the skin acting as a wall sheeting on the studs or rigid isolation is represented by the impact resistance of the skin and shall be assessed according to EN 12871. The performance shall be given in the ETA.

Note: Stressed skin panels (to be used in walls, floors and roofs) with well-known lining materials, such as gypsum boards, wood-based board products and solid timber boards with suitable rib spacing (e.g. at maximum 60 cm), have satisfactory impact/ shock resistance for normal use in residential housing, office buildings, etc. and they don't need not to be tested separately.

Testing and assessment of stressed skin panels to be used in walls not covered by the conditions above has to be undertaken according to the EAD 340308-00-0301/Annex C. .

2.2.16 Airborne sound insulation

The airborne sound insulation performance of the assembled stressed skin panels shall be assessed by laboratory tests according to EN-ISO 10140-2. The rating of airborne sound insulation shall be undertaken according to EN ISO 717-1.

The airborne sound insulation shall be given in the ETA as: Weighted apparent sound reduction index $R_{w.}$

2.2.17 Impact sound level (insulation)

The impact sound insulation performance of the assembled stressed skin panels to be used in floors shall be assessed by laboratory tests according to EN ISO 10140-3 and the rating of impact sound insulation shall be undertaken according to EN ISO 717-2.

Impact sound level shall be given in the ETA as: Weighted normalized impact sound pressure level $L_{n\ w}$ (Band width 1/3 octave).

2.2.18 Sound absorption

Sound absorption of the product to be used in walls, roofs or floors shall be assessed according to EN ISO 354. Test specimen mounting type A shall be used. The sound absorption coefficient α_s of product shall be given in the ETA.

2.2.19 Thermal conductivity

Calculation:

The thermal conductivity of the product is represented by the performance of the components. The performance of thermal conductivity of the components shall be expressed as an individual value of thermal conductivity λ [W/mK] taken from the manufacturers DoP.

The thermal conductivity of the components shall be given in the ETA.

The thermal resistance value R of an product can be calculated according to EN ISO 6946 or, where appropriate EN ISO 10211. In case a design value for R shall be given (as it is common), the material safety factors used in calculation shall be given in the ETA as a footnote to the thermal resistance value. The thermal resistance value R shall be a effective value for the whole product, including thermal bridges.

The thermal resistance value shall be given in the ETA for each element calculated.

Testing:

The thermal resistance value may also be tested according to EN ISO 8990. The results as a homogenized value for the whole element (including thermal bridges) shall be given in the ETA for each element tested.

2.2.20 Air permeability

Air permeability shall be assessed according to EN 12114 and of results shall be given in the ETA according to EN 12207.

Note: Assessment of the air permeability of the roofs, external walls and ground floors is normally undertaken by judgement of the construction details. Where joints are part of the stressed skin panels e.g. when non-traditional joints are applied, the air permeability shall be assessed by testing.

2.2.21 Thermal inertia

The specific heat capacity (thermal inertia) of the product is represented by the performance of the components. The performance of thermal inertia of the components shall be expressed as an individual value of specific heat capacity cp [J/kg K]], either:

- based on testing where ISO 22007-2 or ISO 11357-4 are applied, or
- taken from the manufacturers DoP.

Design values for specific heat capacity (thermal inertia) of components shall be given in the ETA.

Note: The specific heat capacity of the product as a whole is normally not assessed. Value according to EN ISO 10456 may be used for the components in the DoPs. Density variation of the products shall be taken into account.

1.1.1 Natural durability

Natural durability of prefabricated wood-based loadbearing stressed skin panels is assessed as the performance of the material of the product with poorest performance as given in the associated standards of the components. If the natural durability is not addressed in the standard of a component, the natural durability shall be assessed according to EN 350.

The natural durability of the component with the poorest performance shall be given in the ETA as the performance of the prefabricated wood-based loadbearing stressed skin panel.

3 ASSESSMENT AND VERIFICATION OF CONSTANCY OF PERFORMANCE

3.1 System of assessment and verification of constancy of performance to be applied

For the products covered by this EAD the applicable European legal act is: Decision 97/176/EC

The system is: 1

3.2 Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of the product in the procedure of assessment and verification of constancy of performance are laid down in Table 3.1.

Table 3.1 Control plan for the manufacturer; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Factory production control (FPC) including testing of samples taken at the factory in accordance with a prescribed test plan					
1	*Checking of incoming components:* panels, ribs, isolation, adhesive and connectors	Checking of technical data sheet and DoP or, when relevant: supplier certificates or supplier tests	Control plan*	Testing is not required	Each delivery to factory
2	Gluing conditions	EN 14080	Control plan*	N/A	Continuous
3	Dimensions	2.2.10	Control plan *	Control plan *	Once / day or production lot
4	Bonding quality	3.4.1	Control plan	**	Once / day or production lot
5	Moisture content	3.4.2	Control plan*	Control plan*	Once / day or production lot

* Control plan shall be defined in the detail for each individual ETA
** One / each glue line of the considered product

3.3 Tasks of the notified body

The cornerstones of the actions to be undertaken by the notified body in the procedure of assessment and verification of constancy of performance for the Prefabricated wood-based loadbearing stressed skin panels are laid down in Table 3.2

Table 3.2 Control plan for the notified body; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Initial inspection of the manufacturing plant and of factory production control					
1	*Checking of incoming components*	Checking of technical data sheet and DoP or, when relevant: supplier certificates or supplier tests	Control plan	Testing is not required	N/A
2	Gluing conditions and equipment	Inspection, EN14080	Control plan	Control plan	2/year
3	Dimensions, tolerances and control equipment	Inspection, 2.2.10	Control plan	Control plan	2/year
4	Bonding quality and control equipment	Inspection, 3.4.1	Control plan	Control plan	Once / day or production lot
5	Moisture content	Inspection, 3.4.2	Control plan	Control plan	Once / day or production lot
6	Documentation and the templates for the records of the subjects in table 3.1	Inspection	Control plan	N/A	N/A
Continuous surveillance, assessment and evaluation of factory production control					
7	Checking of incoming components	Checking of technical data sheet and DoP or, when relevant: supplier certificates or supplier tests	Control plan	Testing is not required	2/year
8	Gluing conditions and equipment	Inspection, EN14080	Control plan	Control plan	2/year
9	Dimensions, tolerances and control equipment	Inspection, 2.2.10	Control plan	Control plan	2/year
10	Bonding quality and control equipment	Inspection, 3.4.1	Control plan	Control plan	2/year
11	Moisture content	Inspection, 3.4.2	Control plan	Control plan	2/year
12	Records of the subjects in table 3.1	Inspection	Control plan	Control plan	2/year

3.4 Special methods of control and testing used for the verification of constancy of performance

3.4.1 Bonding quality

Bonding quality shall be determined as for LVL according to EN 14374 (cleaving test) or as for glulam according to EN 14080, annex D (shear test). The glue bond between the panels and ribs and/or panels and rigid insulation material shall be equally strong as for components. Thickness of the glue line as well as the amount of wood failure shall be considered.

The requirements shall be formulated according to wood products that have been used. E.g. if the drill core test like EN 14080 Fig D7 a) is used, the following criteria apply:

- The measured glue line thickness on the surface of the drill core shall fulfil the requirement for the adhesive used
- The strength measured shall exceed the one for wood product or insulation for the element types A, B1 and B2 measured by the same method
- The amount of wood failure shall normally be more than 80 %. If the strength of the glue line is 1,2 times the one of the wood product, then the amount of wood failure may be smaller.

For the assessment, bonding quality shall be tested for each intended combination of manufacturing method, adhesive, wood product and insulation (for element types A, B1 and B2). The specimen product for bonding tests shall reflect the largest intended product size implying worst case from the manufacturing point of view. The ETA shall have a size limit based on that specimen product size, facilities and production methods.

For the assessment, bonding test specimens shall be taken of the specimen product from every glue line. When determining the reference values for FPC the specimens shall be taken from both ends and at least in third points or one per 3 m (≥ 4 per glue line). If the product is manufactured in a hydraulic press, the specimens shall be taken in the middle between each cylinder. Any other critical points shall be taken into account in sampling.

3.4.2 Moisture content of timber and wood-based materials

The moisture content of the components during manufacturing of the prefabricated wood-based loadbearing stressed skin panel shall be adequate according to the specification of adhesives. Differing moisture contents of glued components shall not cause shear. All components shall be technically dried before gluing.

The moisture content has to be checked according to:

- EN 322 for wood-based materials;
- ISO 3130 for solid timber.

4 REFERENCE DOCUMENTS

EN 301:2017	Adhesives, phenolic and aminoplastic, for load-bearing timber structures – Classification and performance requirements
EN 318:2002	Wood based panels – Determination of dimensional changes associated with changes in relative humidity
EN 322:1993	Wood-based panels – Determination of moisture content
EN 323:1993	Wood-based panels – Determination of density
EN 335:2013	Durability of wood and wood-based products – Use classes: definitions, application to solid wood and wood-based products
EN 350:2016	Durability of wood and wood-based products – Testing and classification of the durability to biological agents of wood and wood-based materials
EN 384:2018	Structural timber – Determination of characteristic values of mechanical properties and density
EN 408:2012	Timber structures – Structural timber and glued laminated timber – Determination of some physical and mechanical properties
EN 520:2004+A1:2009	Gypsum plasterboards – Definitions, requirements and test methods
EN 594:2011	Timber structures – Test methods – Racking strength and stiffness of timber frame wall panels
EN 717-1:2004	Wood-based panels – Determination of formaldehyde release – Part 1: Formaldehyde emission by the chamber method
EN 1121:2000	Doors – Behaviour between two different climates – Test method
EN 1195:1997	Timber structures – Test methods – Performance of structural floor decking
EN 1365-1: 2012 +AC:2013	Fire resistance tests for loadbearing elements – Part 1: Walls
EN 1365-2:2014	Fire resistance tests for loadbearing elements – Part 2: Floors and roofs
EN 1602:2013	Thermal insulating products for building applications – Determination of the apparent density
EN 1990: 2002 +AC:2008 +AC 2010	Eurocode – Basis of structural design
EN 1995-1-1: 2004 +AC:2006 +A1:2008 +A2:2014	Eurocode 5: Design of timber structures – Part 1-1: General – Common rules and rules for buildings
EN 1995-1-2: 2004 +AC:2006 +AC:2009	Eurocode 5: Design of timber structures – Part 1 2: General – Structural fire design
EN 1998-1: 2004 +AC:2009 +A1:2013	Eurocode 8: Design of structures for earthquake resistance – Part 1: General rules, seismic actions and rules for buildings
EN 12086:2013	Thermal insulating products for building applications – Determination of water vapour transmission properties
EN 12114:2000	Thermal performance of buildings – Air permeability of building components and building elements – Laboratory test method
EN 12207:2016	Windows and doors – Air permeability – Classification
EN 12572:2016	Hygrothermal performance of building materials and products – Determination of water vapour transmission properties – Cup method
EN 12871:2013	Wood-based panels – Determination of performance characteristics for load bearing panels for use in floors, roofs and walls
EN 13162:2012+A1: 2015	Thermal insulation products for buildings – Factory made mineral wool (MW) products – Specification
EN 13163:2012+A2: 2016	Thermal insulation products for buildings – Factory made expanded polystyrene (EPS) products – Specification
EN 13164:2012+A1: 2015	Thermal insulation products for buildings – Factory made extruded polystyrene foam (XPS) products – Specification

EN 13165:2012+A2: 2016	Thermal insulation products for buildings – Factory made rigid polyurethane foam (PU) products – Specification
EN 13166:2012+A2: 2016	Thermal insulation products for buildings – Factory made phenolic foam (PF) products – Specification
EN 13167:2012+A1: 2015	Thermal insulation products for buildings – Factory made cellular glass (CG) products – Specification
EN 13168:2012+A1: 2015	Thermal insulation products for buildings – Factory made wood wool (WW) products – Specification
EN 13169:2012+A1: 2015	Thermal insulation products for buildings – Factory made expanded perlite board (EPB) products – Specification
EN 13170:2012+A1: 2015	Thermal insulation products for buildings – Factory made products of expanded cork (ICB) – Specification
EN 13171:2012+A1: 2015	Thermal insulation products for buildings – Factory made wood fibre (WF) products – Specification
FprEN 13381-7:2017	Test methods for determining the contribution to the fire resistance of structural members - Part 7: Applied protection to timber members
EN 13501-1: 2007+A1:2009	Fire classification of construction products and building elements – Part 1: Classification using data from reaction to fire tests
EN 13501-2:2016	Fire classification of construction products and building elements – Part 2: Classification using data from fire resistance tests, excluding ventilation services
EN 13986:2015	Wood-based panels for use in construction – Characteristics, evaluation of conformity and marking
EN 14080:2013	Timber structures – Glued laminated timber and glued solid timber – Requirements
EN 14081-1:2016	Timber structures – Strength graded structural timber with rectangular cross section – Part 1: General requirements
EN 14358:2016	Timber structures – Calculation and verification of characteristic values
EN 14374:2004	Timber structures – Structural laminated veneer lumber – Requirements
EN 14509:2013	Self-supporting double skin metal faced insulating panels — Factory made products — Specifications
EN 15283-2:2008+A1: 2009	Gypsum boards with fibrous reinforcement – Definitions, requirements and test methods – Part 2: Gypsum fibre boards
EN 15425:2017	Adhesives – One component polyurethane (PUR) for load-bearing timber structures – Classification and performance requirements
EN 15497:2014	Structural finger jointed solid timber – Performance requirements and minimum production requirements
EN 16069:2012+A1: 2015	Thermal insulation products for buildings – Factory made products of polyethylene foam (PEF) – Specification
EN 16516:2017	Construction products – Assessment of release of dangerous substances – Determination of emissions into indoor air
EN ISO 354:2003	Acoustics – Measurement of sound absorption in a reverberation room
EN ISO 6946:2017	Building components and building elements – Thermal resistance and thermal transmittance – Calculation methods
EN ISO 717-1:2013	Acoustics – Rating of sound insulation in buildings and of building elements – Part 1: Airborne sound insulation
EN ISO 717-2:2013	Acoustics – Rating of sound insulation in buildings and of building elements – Part 2: Impact sound insulation
EN ISO 8990: 1996	Thermal insulation – Determination of steady-state thermal transmission properties – Calibrated and guarded hot box
EN ISO 10140-2: 2010	Acoustics – Laboratory measurement of sound insulation of building elements – Part 2: Measurement of airborne sound insulation

EN ISO 10140-3:2010+A1: 2015	Acoustics – Laboratory measurement of sound insulation of building elements – Part 3: Measurement of impact sound insulation
EN ISO 10211: 2017	Thermal bridges in building construction – Heat flows and surface temperatures – Detailed calculations
EN ISO 10456:2007 +AC:2009	Building materials and products – Hygrothermal properties – Tabulated design values and procedures for determining declared and design thermal values
EN ISO 11357-4:2014	Plastics – Differential scanning calorimetry (DSC) – Part 4: Determination of specific heat capacity
EN ISO 13788:2012	Hygrothermal performance of building components and building elements. Internal surface temperature to avoid critical surface humidity and interstitial condensation. Calculation methods
EN ISO 22007-2:2015	Plastics – Determination of thermal conductivity and thermal diffusivity – Part 2: Transient plane heat source (hot disc) method
ISO 3130:1994	Wood – Determination of moisture content for physical and mechanical tests
EOTA TR 034	General BWR3 Checklist for EADs/ETAs – Dangerous substances, October 2015

ANNEX A - CALCULATION MODELS FOR PREFABRICATED WOOD-BASED LOADBEARING STRESSED SKIN PANELS FOR USE IN ROOFS AND FLOORS[7]

A.1 General

This annex specifies the theoretical background of the several models for the assessment by calculation of prefabricated wood-based loadbearing stressed skin panels for use in roofs.

This annex shall be used in the following way:
An action E_d [8] will be applied to the assessed product and the inner stresses resulting will be calculated as shown in this annex.
From comparing the design stresses with the design material resistances the utilization percentage for this component resistance value can be derived. The most critical resistance value can then be used to calculate the product performance as a design resistance value R_d against the action E_d. The material safety factors and other factors used in the calculation should be stated together with the design resistance value.

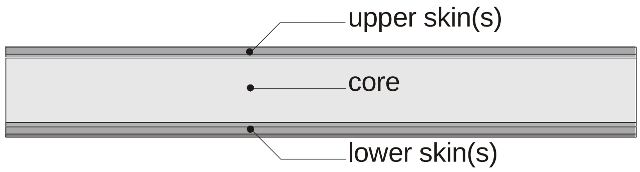
Input for calculations, the material characteristics of the components, are taken from the product to be assessed. They can be taken from DoPs or established by testing. For the insulation materials load bearing characteristics given at chapter A.6.2 may be used.

The outcomes of the assessments are design values of the resistance of the product to be used as an input for users and designers.

This annex is applicable for the assessment by calculation of the following types stressed skin panels:

Type A

Stressed skin panels, closed box type double-skin, *without* wooden ribs, *with* loadbearing insulation:

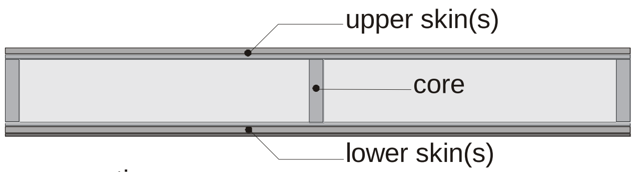


cross section

upper skin(s) : wood-based skin(s) (e.g. particleboard, oriented strand board, plywood)
core : loadbearing insulation (e.g. expanded/extruded polystyrene, polyurethane)
lower skin(s) : wood-based skin(s) (e.g. particleboard, oriented strand board, plywood)

Type B1

Stressed skin panels, closed box type double-skin, *with* wooden ribs and loadbearing insulation:



cross section

upper skin(s) : wood-based skin(s) (e.g. particleboard, oriented strand board, plywood)
core : wooden ribs and loadbearing insulation (e.g. expanded/extruded polystyrene, polyurethane)
lower skin(s) : wood-based skin(s) (e.g. particleboard, oriented strand board, plywood)

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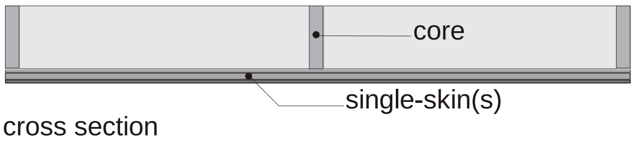
[7] This Annex replace the outdated EOTA TR 019 with modifications

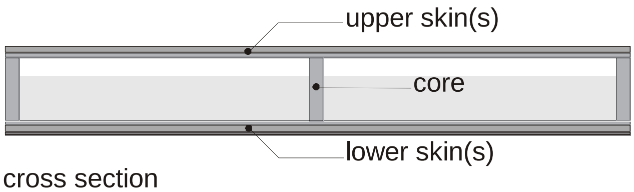
[8] It is necessary to perform this calculation on the design level when different material safety factors have to be taken into account for wood and insulation components (for example Type A products).

Type B2
Stressed skin panels, open box type single-skin, *with* wooden ribs and loadbearing insulation:



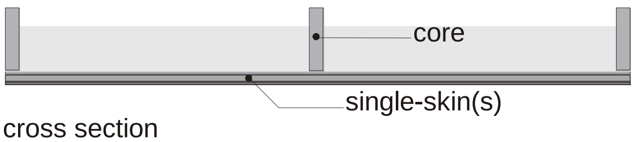
core : wooden ribs and loadbearing insulation (e.g. expanded/extruded polystyrene, polyurethane)
single-skin(s) : wood-based skin(s) (e.g. particleboard, oriented strand board, plywood);
could be beneath or above the wooden ribs

Type C1
Stressed skin panels, closed box type double-skin, *with* wooden ribs and non-loadbearing insulation or without insulation:



upper skin(s) : wood-based skin(s) (e.g. particleboard, oriented strand board, plywood)
core : wooden ribs and non-loadbearing insulation (e.g. mineral wool) or without insulation
lower skin(s) : wood-based skin(s) (e.g. particleboard, oriented strand board, plywood)

Type C2
Stressed skin panels, open box type single-skin, *with* wooden ribs and non-loadbearing insulation or without insulation:



core : wooden ribs and non-loadbearing insulation (e.g. mineral wool) or without insulation
single-skin(s) : wood-based skin(s) (e.g. particleboard, oriented strand board, plywood);
could be beneath or above the wooden ribs

A.1.1 List of symbols

Main symbols

A area (of cross-section)
E modulus of elasticity
G shear modulus
I second moment of area
K modulus of subgrade reaction
M bending moment
N axial force
Q shear force
R reaction force at support
S section modulus
W moment of resistance
a distance between the centers of the two outer layers; variable concerning effective flange width
b width of certain layer; width of support
c factor of co-operation; variable concerning effective flange width

d thickness
f strength of a material; factor
h height
i certain layer in stressed skin panel
k factor
ℓ span; length
n total of layers in stressed skin panel
z distance from the center of a certain layer to the neutral axis
α factor for EPS core at support; angle
γ partial factor
λ slenderness ratio; variable concerning effective flange width
μ Poisson's ratio
ρ mass density
σ stress
τ shear stress

Subscripts
A virtual beam A
B virtual beam B
M material
c compression
d design
f flange
i i^{th} layer in stressed skin panel
k characteristic
m bending
n enlarging
o at support
t tension
v shear
def deformation
ef effective concerning flange width
eff effective
mean mean
mod modification
red reduction
0 along the grain (timber); along the grain of face veneer (wood-based skin)
90 perpendicular to the grain (timber); perpendicular to the grain of face veneer (wood-based skin)
$\perp$ planar
// in-plane

A.1.2 Failure modes and deformation behavior considered in the assessment by calculation

When assessing the resistance of the product the most critical of the following failure modes either individually or in combination shall be presented:

- Wrinkling (local buckling) of a face of the panel with consequential failure.
- Shear failure of the core.
- Shear failure of the bond between the face and the core.
- Crushing of the core at a support.
- Failure of the panels at the points of attachment to the supporting structure.
- A combination of bending and compression failure of a face of the panel.
- A combination of bending and tension failure of a face of the panel.
- A combination of bending and compression failure of the core.
- A combination of bending and tension failure of the core.

Deformations of sandwich panels of type A may increase with time as a consequence of creep of the core. Creep also causes a change in the stresses with time and this shall be taken into account in the assessment.

A.1.3 Calculation method for determining the characteristic loads

The behaviour of sandwich panels with loads uniformly distributed along the panel width can normally be calculated according to the elastic bond theory as beam structures. In the case of local loading due to man load the effective width used for the load transfer shall be considerably reduced (for loading at the panel edge to b_m<b/3), or the sandwich panels shall be designed for local loadings as surface elements by taking the flexible bond into account. All calculation methods can be approximately used, with a "creep modulus", for the calculation of the redistributed stresses due to creep of the core under the actions.

a) The behaviour of sandwich panels of type A can be calculated by using the classical beam theory taking account of the shear deformation of the core, if the skins can be considered for themselves as rigid composite compound units (always given for one-piece floor layers). Chapter A.2 contains calculations formulas from EN 14509 for single-span beams and multi-span beams.

b) The behaviour of sandwich panels of type B1 can be calculated as single-span beam in good approximation and as multi-span beam approximately by using the flexible bond theory, which is proposed in Eurocode 5 for timber structures with flexible bond, if the skins can be considered for themselves as rigid composite compound units (always given for one-piece floor layers). For single-span beams and multi-span beams chapter A.3 contains calculation methods from Eurocode 5 with an adaptation to the situation of the sandwich panel of type B1.

c) The behaviour of the sandwich panels of type A and type B1 can be calculated by using the Kreuzinger method, if the skins can be considered for themselves as rigid composite compound units (always given for one-piece floor layers). The calculation formulas are given inchapter A.4.

d) The behaviour of the sandwich panels of type A and type B1 can be calculated with the method using programs for "statics of a lattice frame". This model can also be applied for multi-layer sandwich panels or for sandwich panels with skins being for themselves components with a flexible bond. This model is shown in chapter A.5, and can also be used for surface structures.

e) Furthermore, the solutions of the differential equations of the elastic bond or the differential method can be used for the calculation of the behaviour of the sandwich panels.

If shrinkage or swelling of the skins has to be taken into account, the resulting deformations or restraints can be calculated from an equivalent temperature gradient.

When a partial safety factor is not given, γ_M = 1,5 may be used as a default value for safeguarding the material properties of the core.

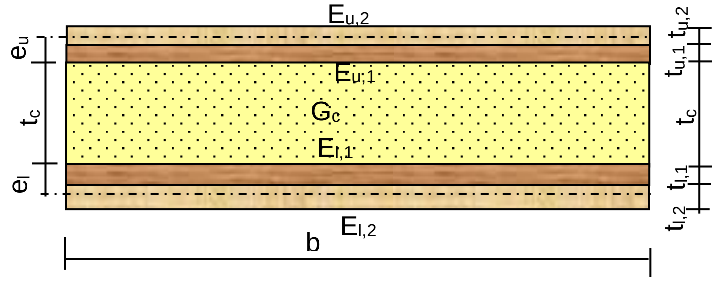
The modification factors shall be determined experimentally.

A.1.3.1 Assessment of shear failure of the bond between the face and the core

Due to the co-action of the core the following peculiarities result, which have to be considered in the assessment.
In the case of sandwich panel type A without wooden ribs and in the case of sandwich panel type B1 with wooden ribs with big spacing, which cannot be used for mere wood constructions because of the required buckling verification, the compressed skin is stabilized by the core. Because of the imperfections of the skin this stabilization is long-term-depending.

Note: Sufficient stability can be approximately verified by establishing that the design value of the bond stress between core and skins does not exceed the time-depending design value of the shear strength of the materials.

Example bond stress between upper skin and core:



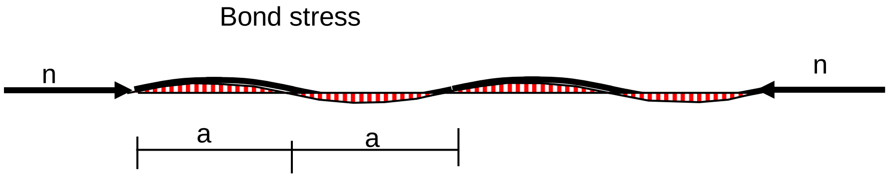
Bending stiffness of skin:

$$B_u = E_{u,1}\frac{t_{u,1}^3}{12} + E_{u,2}\frac{t_{u,1}^3}{12} + \frac{E_{u,1}t_{u,1}E_{u,2}t_{u,2}}{E_{u,1}t_{u,1} + E_{u,2}t_{u,2}}\frac{\left(t_{u,1} + t_{u,2}\right)^2}{4}$$

$$a = \pi\sqrt[3]{\frac{2B_u}{\sqrt{E_c G_c}}}$$

$$n_{ki} = 1{,}8899\sqrt[3]{B_u E_c G_c}$$

$$\sigma_c = \frac{\pi}{a}\sqrt{E_c G_c}\, f_0\left(1 + k_{def}\right)\frac{n}{n_{ki} - n}$$



a = half of wrinkling wave length [mm]
n_{ki} = mathematical wrinkling load [N/mm]
n = normal force in the skin [N/mm]
f_0 = imperfection of the skin with a being half the wave length [mm]
σ_c = bond stress [N/mm²]

In the area of intermediate supports the skin has additionally to resist the transverse compression resulting from the reaction. This leads to a reduction of the acceptable longitudinal compression force. The bedding of the skin can be calculated with

$$c = \frac{\pi}{a}\sqrt{E_c G_c}$$

The calculation shall be carried out according to the second order theory.
The long term behaviour is to be taken into account.

The acceptance of the transverse reaction shall be verified without spreading in the core. For type A the core must resist the reaction. For type B1 the wooden ribs must resist almost the entire reaction by pressing vertically to the fibre direction.

If, the system with wooden ribs resists the long-term bond stresses, the buckling verification may be omitted without taking the bedding by the core into account.
For mere wood constructions in panel system, which are designed only on the basis of EN 1995-1-1, it is allowed to use the core for the stabilization of the skins, when the resistance of the bond strength is verified.

A.1.3.2 Wrinkling of the skin at a support

The wrinkling phenomenon of the skin is caused by the local influence of the shear force on the wood-based skin in combination with the compression force in the skin.

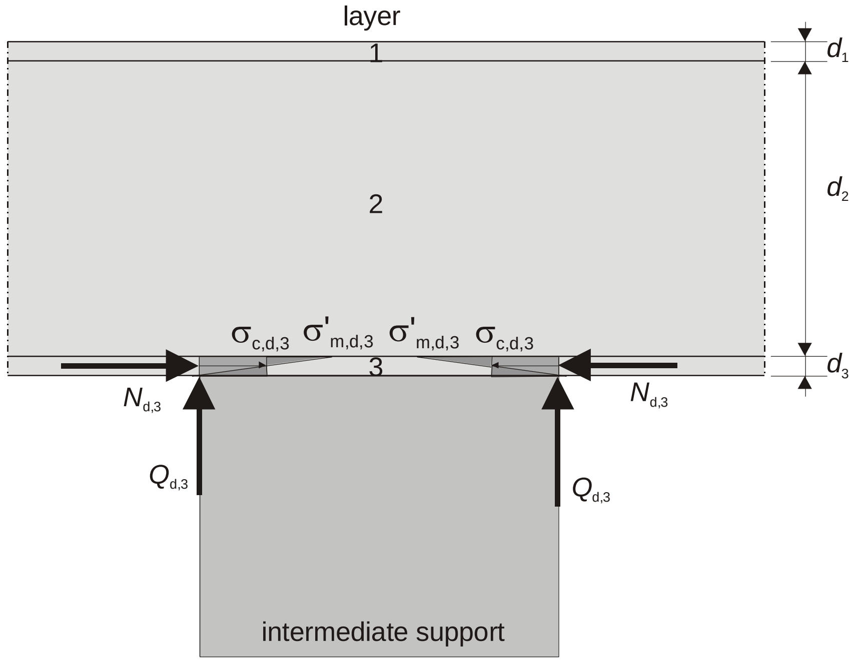


Figure A.1.1 - E.g. local design 'wrinkling' stresses in the lower wood-based skin at an intermediate support

Modulus of subgrade reaction K underneath the lower wood-based skin:

$$K = \max \begin{cases} \dfrac{E_{t(c),fin,2}}{d_2} \\ 0{,}27 \cdot E_{t(c),fin,2} \cdot \sqrt[3]{\dfrac{E_{t(c),fin,2}}{E_{m,\perp,0,fin,3} \cdot I_3 / b_3}} \end{cases}$$

where:

$$I_3 = \frac{b_3 \cdot d_3^3}{12}$$

concerning the loadbearing insulation core:

$E_{t(c),fin,2}$ the final modulus of elasticity for compression or tension.

concerning the lower wood-based skin:

$E_{m,\perp,0,fin,3}$ the <u>planar</u> final modulus of elasticity for bending along the grain of face veneer.

The local design moment $M'_{0,d}$ for an elastic supported wood-based skin with an own bending stiffness ($E_{m,\perp,0,fin,3} \cdot I_3$) and a modulus of subgrade reaction K, loaded by the design shear force $Q_{d,3}$ in layer 3:

$$\lambda = \sqrt[4]{\frac{K}{4 \cdot E_{m,\perp,0,fin,3} \cdot I_3 / b_3}}$$

$$M'_{0,d} = \frac{Q_{d,3}}{4 \cdot \lambda}$$

The design compression force $N_{d,3}$ in the lower wood-based skin increases the design moment $M'_{0,d}$ with the factor f_n:

$$f_n = \frac{1}{\sqrt{1 - \dfrac{N_{d,3}}{4 \cdot E_{m,\perp,0,fin,3} \cdot I_3 \cdot \lambda^2}}}$$

$$M'_{d,3} = f_n \cdot M'_{0,d}$$

<u>Local design compression and bending stress in layer 3 (lower wood-based skin) at a support:</u>

$$\sigma_{c,d,3} = \frac{N_{d,3}}{A_3}$$

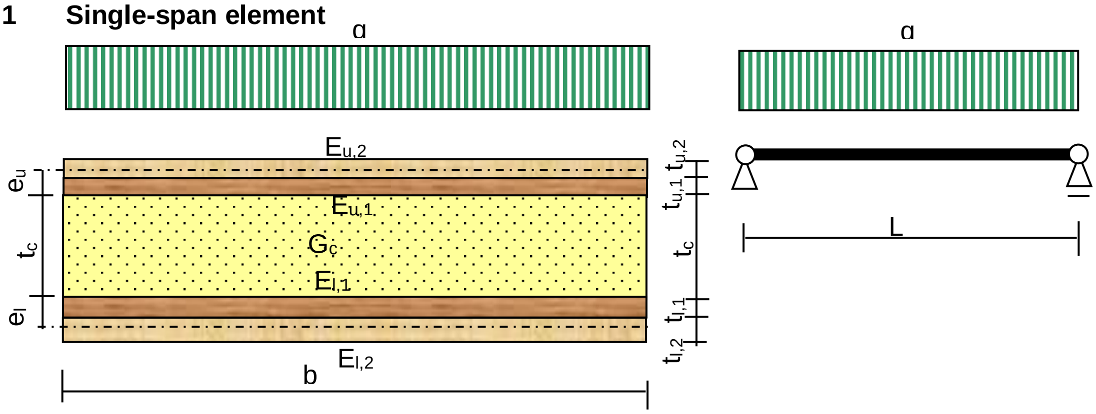
$$\sigma'_{m,d,3} = \frac{M'_{d,3}}{W_3}$$

The maximum design compression and bending stress must be compared to the design in-plane compression strength along the grain of face veneer and the design planar bending strength along the grain of face veneer of the lower wood-based skin.

$$\frac{\sigma_{c,d,3}}{f_{c,//,0,d,3}} + \frac{\sigma'_{m,d,3}}{f_{m,\perp,0,d,3}} \leq 1{,}00$$

A.2 Beam theory by taking account of the shear deformations of the core

A.2.1 Single-span element



$$e_u = \frac{E_{u,1} b t_{u,1} \frac{t_{u,1}}{2} + E_{u,2} b t_{u,2} \left(t_{u,1} + \frac{t_{u,2}}{2} \right)}{E_{u,1} b t_{u,1} + E_{u,2} b t_{u,2}}$$

$$e_l = \frac{E_{l,1} b t_{l,1} \frac{t_{l,1}}{2} + E_{l,2} b t_{l,2} \left(t_{l,1} + \frac{t_{l,2}}{2} \right)}{E_{l,1} b t_{l,1} + E_{l,2} b t_{l,2}}$$

$$B_u = E_{u,1} b \frac{t_{u,1}^3}{12} + E_{u,2} b \frac{t_{u,1}^3}{12} + \frac{E_{u,1} b t_{u,1} E_{u,2} b t_{u,2}}{E_{u,1} b t_{u,1} + E_{u,2} b t_{u,2}} \frac{\left(t_{u,1} + t_{u,2}\right)^2}{4}$$

$$B_l = E_{l,1} b \frac{t_{l,1}^3}{12} + E_{l,2} b \frac{t_{l,1}^3}{12} + \frac{E_{l,1} b t_{l,1} E_{l,2} b t_{l,2}}{E_{l,1} b t_{l,1} + E_{l,2} b t_{l,2}} \frac{\left(t_{l,1} + t_{l,2}\right)^2}{4}$$

$$B_s = B_u + B_l + \frac{\left(E_{u,1} b t_{u,1} + E_{u,2} b t_{u,2}\right)\left(E_{l,1} b t_{l,1} + E_{l,2} b t_{l,2}\right)}{\left(E_{u,1} b t_{u,1} + E_{u,2} b t_{u,2}\right) + \left(E_{l,1} b t_{l,1} + E_{l,2} b t_{l,2}\right)} \left(e_u + t_c + e_l\right)^2$$

$$Q = \frac{qbL}{2}$$

$$M = \frac{qbL^2}{8}$$

$$\max f = \frac{5qbL^4}{384 B_s} + \frac{qbL^2}{8 G_c b t_c}$$

$$N = \pm \frac{M}{(e_u + t_c + e_l)}$$

$$M_u = M \frac{B_u}{B_s}$$

$$M_l = M \frac{B_l}{B_s}$$

$$\theta = \frac{\alpha_l T_l - \alpha_u T_u}{(e_u + t_c + e_l)}$$

$$f_T = \frac{\theta L^2}{8}$$

A.2.2 Two-span element

$$f_3 = \frac{qb(L_1+L_2)^4}{24B_s}\left(\frac{a_3}{L_1+L_2} - 2\left(\frac{a_3}{L_1+L_2}\right)^3 + \left(\frac{a_3}{L_1+L_2}\right)^4\right) -$$

$$- \frac{R_2(L_1+L_2)^2 L_1}{6B_s}\frac{a_3}{L_1+L_2}\left(1 - \left(\frac{L_1}{L_1+L_2}\right)^2 - \left(\frac{a_3}{L_1+L_2}\right)^2\right) + \frac{M_3}{G_c b t_c}$$

$$\theta = \frac{\alpha_l T_l - \alpha_u T_u}{(e_u + t_c + e_l)}$$

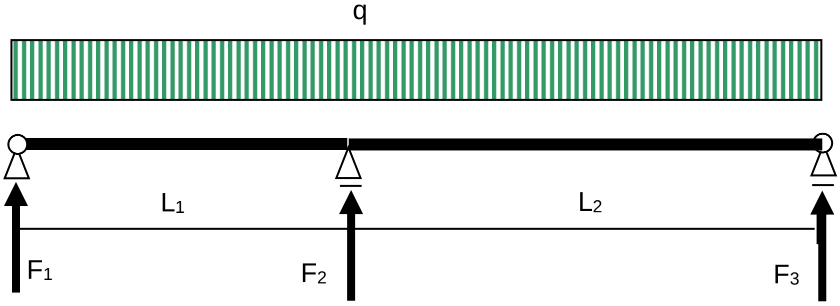
$$f_{2,T} = \frac{\theta(L_1+L_2)^2}{2}\left(\frac{L_1}{L_1+L_2} - \left(\frac{L_1}{L_1+L_2}\right)^2\right)$$

$$R_{2,T} = \frac{f_{2,T}}{f_{2,1}}$$

$$M_{2,T} = -R_{2,T}\frac{L_1 L_2}{L_1+L_2}$$

$$F_{1,T} = -R_{2,T}\frac{L_2}{L_1+L_2}$$

$$F_{3,T} = -R_{2,T}\frac{L_1}{L_1+L_2}$$



$$f_{2,0} = \frac{qb(L_1 + L_2)^4}{24B_s}\left(\frac{L_1}{L_1 + L_2} - 2\left(\frac{L_1}{L_1 + L_2}\right)^3 + \left(\frac{L_1}{L_1 + L_2}\right)^4\right) + \frac{qbL_1L_2}{2G_c b t_c}$$

$$f_{2,1} = \frac{L_1^2 L_2^2}{3(L_1 + L_2)B_s} + \frac{L_1 L_2}{(L_1 + L_2)G_c b t_c}$$

$$R_2 = \frac{f_{2,0}}{f_{2,1}}$$

$$R_1 = \frac{qb(L_1 + L_2)}{2} - R_2 \frac{L_2}{(L_1 + L_2)}$$

$$R_3 = \frac{qb(L_1 + L_2)}{2} - R_2 \frac{L_1}{(L_1 + L_2)}$$

$$M_2 = R_1 L_1 - \frac{qbL_1^2}{2}$$

$$\max M_1 = \frac{R_1^2}{2qb}$$

$$\max M_3 = \frac{R_3^2}{2qb}$$

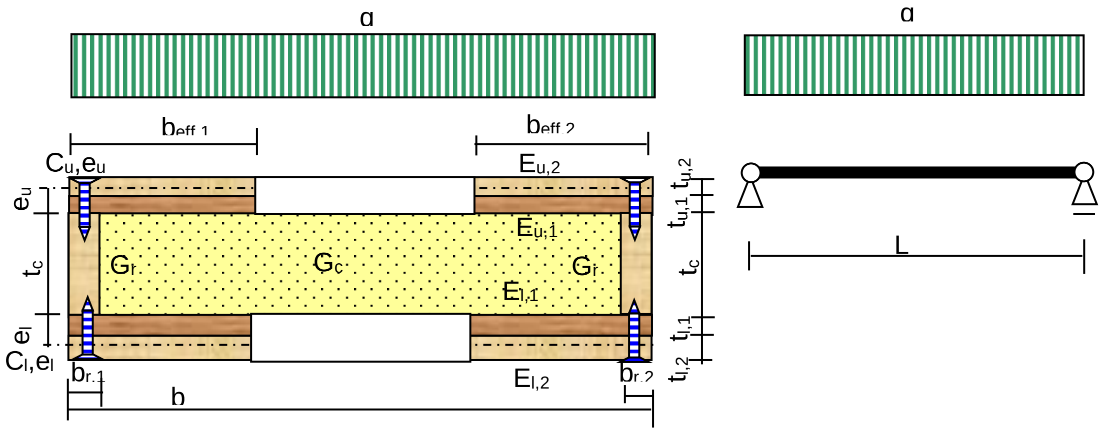
$$a_1 = \frac{R_1}{qb}$$

$$a_3 = \frac{R_3}{qb}$$

$$f_1 = \frac{qb(L_1 + L_2)^4}{24B_s}\left(\frac{a_1}{L_1 + L_2} - 2\left(\frac{a_1}{L_1 + L_2}\right)^3 + \left(\frac{a_1}{L_1 + L_2}\right)^4\right) - \frac{R_2(L_1 + L_2)^2 L_2}{6B_s}\frac{a_1}{L_1 + L_2}\left(1 - \left(\frac{L_2}{L_1 + L_2}\right)^2 - \left(\frac{a_1}{L_1 + L_2}\right)^2\right) + \frac{M_1}{G_c b t_c}$$

A.3 Approximation method for sandwich panels with wooden ribs according to EN 1995-1-1

A.3.1 Single-span element



Shear spring stiffness:

$$Sf_{u,1} = \frac{1}{\frac{e_u}{C_u} + \frac{t_c}{G_r b_{r,1}}} + G_c \frac{b_{eff,1} - b_{r,1}}{t_c}$$

$$Sf_{l,1} = \frac{1}{\frac{e_l}{C_l} + \frac{t_c}{G_r b_{r,1}}} + G_c \frac{b_{eff,1} - b_{r,1}}{t_c}$$

$$Sf_{u,2} = \frac{1}{\frac{e_u}{C_u} + \frac{t_c}{G_r b_{r,2}}} + G_c \frac{b_{eff,2} - b_{r,2}}{t_c}$$

$$Sf_{l,2} = \frac{1}{\frac{e_l}{C_l} + \frac{t_c}{G_r b_{r,2}}} + G_c \frac{b_{eff,2} - b_{r,2}}{t_c}$$

$$\gamma_{u,1} = \frac{1}{1 + \frac{\pi^2 b_{eff,1}\left(E_{u,1}t_{u,1} + E_{u,2}t_{u,2}\right)}{Sf_{u,1}L^2}}$$

$$\gamma_{l,1} = \frac{1}{1 + \frac{\pi^2 b_{eff,1}\left(E_{l,1}t_{l,1} + E_{l,2}t_{l,2}\right)}{Sf_{l,1}L^2}}$$

γ

$$\gamma_{u,2} = \frac{1}{1 + \frac{\pi^2 b_{eff,2}\left(E_{u,1}t_{u,1} + E_{u,2}t_{u,2}\right)}{Sf_{u,2}L^2}}$$

$$\gamma_{u,2} = \frac{1}{1 + \frac{\pi^2 b_{eff,2}\left(E_{l,1}t_{l,1} + E_{l,2}t_{l,2}\right)}{Sf_{l,2}L^2}}$$

Effective bending stiffnesses

$$e_{u,1} = \frac{E_{u,1}b_{eff,1}t_{u,1}\frac{t_{u,1}}{2} + E_{u,2}b_{eff,1}t_{u,2}\left(t_{u,1} + \frac{t_{u,2}}{2}\right)}{E_{u,1}b_{eff,1}t_{u,1} + E_{u,2}b_{eff,1}t_{u,2}}$$

$$e_{l,1} = \frac{E_{l,1}b_{eff,1}t_{l,1}\frac{t_{l,1}}{2} + E_{l,2}b_{eff,1}t_{l,2}\left(t_{l,1} + \frac{t_{l,2}}{2}\right)}{E_{l,1}b_{eff,1}t_{l,1} + E_{l,2}b_{eff,1}t_{l,2}}$$

$$B_{u,1} = E_{u,1}b_{eff,1}\frac{t_{u,1}^3}{12} + E_{u,2}b_{eff,1}\frac{t_{u,1}^3}{12} + \frac{E_{u,1}b_{eff,1}t_{u,1}E_{u,2}b_{eff,1}t_{u,2}}{E_{u,1}b_{eff,1}t_{u,1} + E_{u,2}b_{eff,1}t_{u,2}}\frac{\left(t_{u,1} + t_{u,2}\right)^2}{4}$$

$$B_{l,1} = E_{l,1}b_{eff,1}\frac{t_{l,1}^3}{12} + E_{l,2}b_{eff,1}\frac{t_{l,1}^3}{12} + \frac{E_{l,1}b_{eff,1}t_{l,1}E_{l,2}b_{eff,1}t_{l,2}}{E_{l,1}b_{eff,1}t_{l,1} + E_{l,2}b_{eff,1}t_{l,2}}\frac{\left(t_{l,1} + t_{l,2}\right)^2}{4}$$

$$B_{s,w,1} = B_{u,1} + B_{l,1} + E_r\frac{b_{r,1}t_c^3}{12} + \frac{\gamma_{u,1}\left(E_{u,1}b_{eff,1}t_{u,1} + E_{u,2}b_{eff,1}t_{u,2}\right)\gamma_{l,1}\left(E_{l,1}b_{eff,1}t_{l,1} + E_{l,2}b_{eff,1}t_{l,2}\right)}{\gamma_{u,1}\left(E_{u,1}b_{eff,1}t_{u,1} + E_{u,2}b_{eff,1}t_{u,2}\right) + \gamma_{l,1}\left(E_{l,1}b_{eff,1}t_{l,1} + E_{l,2}b_{eff,1}t_{l,2}\right)}\left(e_u + t_c + e_l\right)^2$$

$$e_{r,1} = \frac{\gamma_{u,1}\left(E_{u,1}b_{eff,1}t_{u,1} + E_{u,2}b_{eff,1}t_{u,2}\right)\left(\frac{t_c}{2} + e_{u,1}\right) - \gamma_{l,1}\left(E_{l,1}b_{eff,1}t_{l,1} + E_{l,2}b_{eff,1}t_{l,2}\right)\left(\frac{t_c}{2} + e_{l,1}\right)}{\gamma_{u,1}\left(E_{u,1}b_{eff,1}t_{u,1} + E_{u,2}b_{eff,1}t_{u,2}\right) + \gamma_{l,1}\left(E_{l,1}b_{eff,1}t_{l,1} + E_{l,2}b_{eff,1}t_{l,2}\right) + E_r b_{r,1} t_r}$$

$$e_{r,2} = \frac{\gamma_{u,2}\left(E_{u,1}b_{eff,2}t_{u,1} + E_{u,2}b_{eff,2}t_{u,2}\right)\left(\frac{t_c}{2} + e_{u,2}\right) - \gamma_{l,2}\left(E_{l,1}b_{eff,2}t_{l,1} + E_{l,2}b_{eff,2}t_{l,2}\right)\left(\frac{t_c}{2} + e_{l,2}\right)}{\gamma_{u,2}\left(E_{u,1}b_{eff,2}t_{u,1} + E_{u,2}b_{eff,2}t_{u,2}\right) + \gamma_{l,2}\left(E_{l,1}b_{eff,2}t_{l,1} + E_{l,2}b_{eff,2}t_{l,2}\right) + E_r b_{r,2} t_r}$$

$$B_{u,2} = E_{u,1}b_{eff,2}\frac{t_{u,1}^3}{12} + E_{u,2}b_{eff,2}\frac{t_{u,1}^3}{12} + \frac{E_{u,1}b_{eff,2}t_{u,1}E_{u,2}b_{eff,2}t_{u,2}}{E_{u,1}b_{eff,2}t_{u,1} + E_{u,2}b_{eff,2}t_{u,2}}\frac{\left(t_{u,1} + t_{u,2}\right)^2}{4}$$

$$B_{l,2} = E_{l,1}b_{eff,2}\frac{t_{l,1}^3}{12} + E_{l,2}b_{eff,2}\frac{t_{l,1}^3}{12} + \frac{E_{l,1}b_{eff,2}t_{l,1}E_{l,2}b_{eff,2}t_{l,2}}{E_{l,1}b_{eff,2}t_{l,1} + E_{l,2}b_{eff,2}t_{l,2}}\frac{\left(t_{l,1} + t_{l,2}\right)^2}{4}$$

$$B_{s,w,2} = B_{u,2} + B_{l,2} + E_r\frac{b_{r,2}t_c^3}{12} + \frac{\gamma_{u,2}\left(E_{u,1}b_{eff,2}t_{u,1} + E_{u,2}b_{eff,2}t_{u,2}\right)\gamma_{l,2}\left(E_{l,1}b_{eff,2}t_{l,1} + E_{l,2}b_{eff,2}t_{l,2}\right)}{\gamma_{u,2}\left(E_{u,1}b_{eff,2}t_{u,1} + E_{u,2}b_{eff,2}t_{u,2}\right) + \gamma_{l,2}\left(E_{l,1}b_{eff,2}t_{l,1} + E_{l,2}b_{eff,2}t_{l,2}\right)}\left(e_u + t_c + e_l\right)^2$$

$$Q_{1,2} = \frac{1}{2}\frac{qbL}{2}$$

$$M_{1,2} = \frac{1}{2}\frac{qL^2}{8}$$

$$f = \frac{5qbL^4}{384\left(B_{s,w,1} + B_{s,w,2}\right)}$$

$$\min\ \sigma_{u,1} = -\frac{M_1}{B_{s,w,1}}\left[\gamma_{u,1}\left(\frac{t_c}{2} + e_{u,1} - e_{r,1}\right) + t_{u,1} + t_{u,2} - e_{u,1}\right]$$

$$max\,\sigma_{l,1} = \frac{M_1}{B_{s,w,1}}\left[\gamma_{l,1}\left(\frac{t_c}{2} + e_{l,1} + e_{r,1}\right) + t_{l,1} + t_{l,2} - e_{l,1}\right]$$

$$min\,\sigma_{u,2} = -\frac{M_2}{B_{s,w,2}}\left[\gamma_{u,2}\left(\frac{t_c}{2} + e_{u,2} - e_{r,2}\right) + t_{u,1} + t_{u,2} - e_{u,2}\right]$$

$$max\,\sigma_{l,2} = \frac{M_2}{B_{s,w,2}}\left[\gamma_{l,2}\left(\frac{t_c}{2} + e_{l,2} + e_{r,2}\right) + t_{l,1} + t_{l,2} - e_{l,2}\right]$$

This applies correspondingly to multi-span beams. The shear effect coefficients $\gamma_{u,1}$, $\gamma_{u,2}$, $\gamma_{l,1}$, $\gamma_{l,2}$ shall be calculated, instead with L, with 0.8 of the smaller one of two adjacent spans.

A.4 Calculation model by Kreuzinger

A.4.1 General

The stiffness matrix takes into account equilibrium in the deformed state (linear static).

A.4.1.1 Shear deflection

The model Kreuzinger contains the following assumptions for the shear deflections:

To determine the shear stiffness the shear stress line (product of shear stress and layer width) between the center of the two outer layers is assumed to have a constant course. The course of the shear deflection of the total cross-section is assumed to be linear (figure A.4.1). Thus the total shift *u* is related to the thickness of the composite beam, between the center of the two outer layers. Therefore, an effective shear modulus or shear stiffness for the whole cross-section can be given.

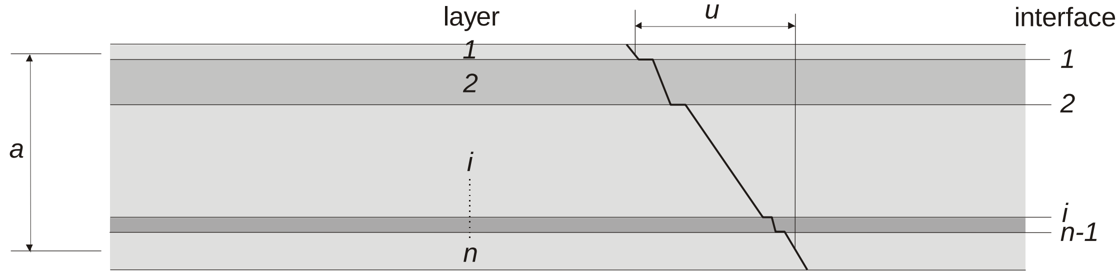


Figure A.4.1: Linearity of the shear deflections

A.4.1.2 Stiffness

Besides the shear stiffness, the composite element also has two types of bending stiffness: the own bending stiffness and the Steiner bending stiffness.

These two types of stiffness will be described by two virtual beams A and B.

A.4.1.3 Stresses

1. Axial forces cause axial stress in each layer *i*, which could be of a different thickness, width and material. The distance from the neutral axis to the layer center also influences the axial stress in each different layer. Therefore, the axial stress in each different layer also depends on the Steiner bending stiffness.
2. From the curvature of each layer a bending stress occurs in each different layer. The bending stress in each different layer depends on the own bending stiffness of each different layer *i* ($E_i \cdot I_i$).
3. Shear forces causes shear stresses in each layer *i*.
4. From the shear force transfer at the interface of the adjoining layers, each layer contains planar shear stresses at the interface of the adjoining layers. This results in a linear shear stress distribution over the depth of each layer due to the shear force transfer at the interface.

A.4.2 Analytical Kreuzinger model

A.4.2.1 Neutral axis

The neutral axis depends on the relation of the partial stiffness under axial load ($E_i \cdot A_i$) of each different layer *i* to the total stiffness under axial load $\left(\sum_{i=1}^{n} E_i \cdot A_i\right)$ of the cross section.

A.4.2.2 Virtual beam A

The own bending stiffness of *n* layers is represented by virtual beam A:

$$(EI)_A = \sum_{i=1}^{n} E_i \cdot I_i \qquad \text{(own bending stiffness)}$$

The shear stiffness of virtual beam A is assumed to be infinite. The shear stiffness of the composite element is described in virtual beam B.

A.4.2.3 Virtual beam B

The composite action of *n* cross-sections is represented by the Steiner bending stiffness in virtual beam B. Also represented in virtual beam B is the composite action at the interface of the adjoining layers and the finite shear stiffness.

The following assumptions are valid:

$$(EI)_{\mathrm{B}} = \sum_{i=1}^{n} E_i \cdot A_i \cdot z_i^2 \qquad \text{(Steiner bending stiffness)}$$

$$\frac{1}{(GA)_{\mathrm{B}}} = \frac{1}{S} = \frac{1}{a^2} \cdot \left(\sum_{i=1}^{n-1} \frac{1}{c_i} + \frac{d_1}{2 \cdot G_1 \cdot b_1} + \sum_{i=2}^{n-1} \frac{d_i}{G_i \cdot b_i} + \frac{d_n}{2 \cdot G_n \cdot b_n} \right) \qquad \text{(finite shear stiffness)}$$

The first term in parentheses deals with the slip deflection, depending on the connection between the layers.

The last three terms in parentheses deal with the shear deflection, depending on the shear moduli of the layers. The two outer layers are only partially accounted for.

A.4.2.4 Kreuzinger beam

All the relevant stiffnesses are now systematic applied to two virtual beams A and B. In figure A.4.2 the model of this new virtual Kreuzinger beam is shown. Hereby the important requirement is: both virtual beams A and B must experience the same deflection, as, in reality, both beams are neither spatial nor substantially separated from each other. This can be achieved in the model by placing the beams parallel to each other and connecting them with mutual nodes.

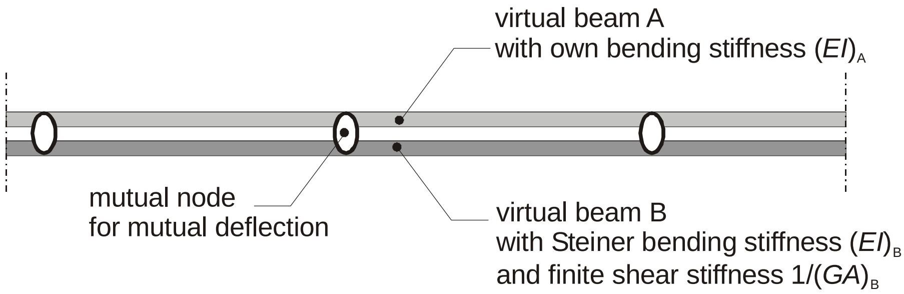


Figure A.4.2: Model of the Kreuzinger beam

The Kreuzinger beam can now be loaded by action which results in deflection and internal virtual forces (M_A, Q_A, N_A, M_B, Q_B, N_B). Then these virtual forces are translated to the internal forces in each different layer of the composite element.
The forces M_A and Q_A of virtual beam A are divided among the different layers proportionally to the own bending stiffness of layer *i* ($E_i \cdot I_i$) and the total own bending stiffness $(EI)_A$. Each different layer takes into account a bending stress and a parabolic shear stress distribution.
The forces M_B and Q_B of virtual beam B deliver the constant axial stress in each layer *i* and the shear stress distribution at the interface of the adjoining layers, with which the total shear stress in layer *i* can be calculated.

In figure A.4.3 the axial, bending and shear stresses in a five layer composite element are shown. By the names A or B one can recognize the virtual beam and the stresses which belong to that beam.

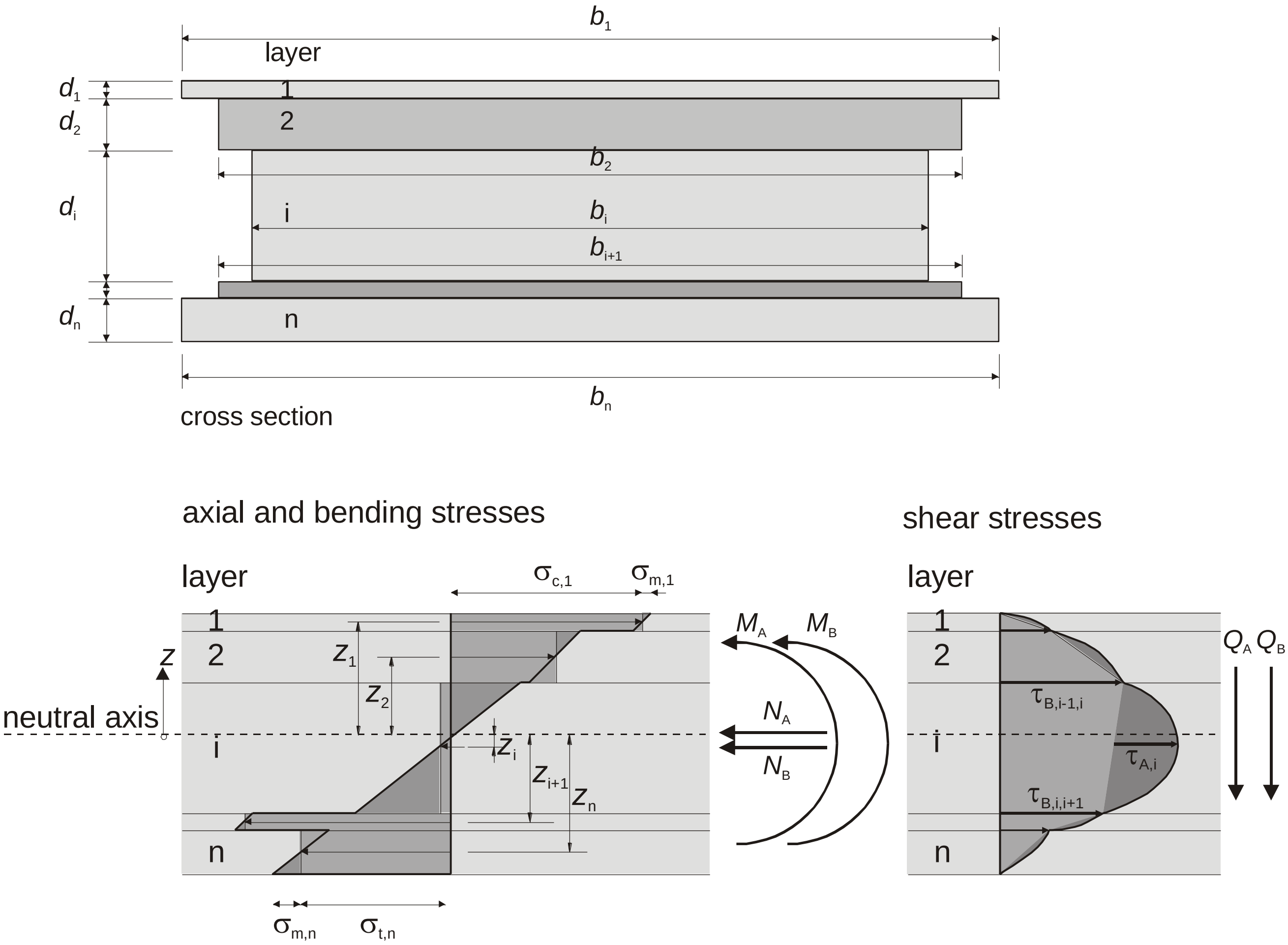


Figure A.4.3: Stresses in the composite element

Bending stress in layer *i*:

$$M_A \Rightarrow M_i = \frac{E_i \cdot I_i}{(EI)_A} \cdot M_A \quad \Rightarrow \quad \sigma_{m,i} = \frac{M_i}{W_i}$$

(e.g. shown in figure A.4.3 as $\sigma_{m,n}$ or $\sigma_{m,1}$)

where:

$$I_i = \frac{b_i \cdot d_i^3}{12}$$

$$W_i = \frac{b_i \cdot d_i^2}{6}$$

b_i width of layer *i*

d_i thickness of layer *i*

Axial stress in layer *i*:

$$M_B \text{ and } N \Rightarrow N_i = \frac{E_i \cdot A_i \cdot z_i}{(EI)_B} \cdot M_B + \frac{E_i \cdot A_i}{\sum_{i=1}^{n} E_i \cdot A_i} \cdot N \Rightarrow \sigma_{c,i} \text{ or } \sigma_{t,i} = \frac{N_i}{A_i}$$

(e.g. shown in figure A.4.3 as $\sigma_{t,n}$ or $\sigma_{c,1}$)

where:

$$N = N_A + N_B$$

$$A_i = b_i \cdot d_i$$

The axial force N from the actions on the structure is distributed on the partial cross-sections of the stressed skin panel according to the longitudinal stiffness values of the partial cross-sections.

Shear stress in layer *i*:

$$\tau_{max,i} = \tau_{A,i} + \tau_{1,i} + \frac{\tau_{2,i}}{2} + \frac{\tau_{2,i}^2}{16 \cdot \tau_{A,i}} \qquad \text{if } \tau_{A,i} > \frac{\tau_{2,i}}{4}$$

$$\tau_{max,i} = \tau_{1,i} + \tau_{2,i} \qquad \text{if } \tau_{A,i} \leq \frac{\tau_{2,i}}{4}$$

where:

$$Q_A \Rightarrow \tau_{A,i} = \frac{E_i \cdot I_i}{(EI)_A} \cdot Q_A \cdot \frac{3}{2} \cdot \frac{1}{d_i \cdot b_i}$$ (e.g. shown in figure A.4.3 as $\tau_{A,i}$)

$$Q_B \Rightarrow \tau_{B,i\text{-}1,i} = \frac{Q_B}{(EI)_B} \cdot \frac{\sum_{i=1}^{i-1} E_i \cdot A_i \cdot z_i}{\min\begin{cases} b_{i-1} \\ b_i \end{cases}}$$ (e.g. shown in figure A.4.3 as $\tau_{B,i\text{-}1,i}$)

$$Q_B \Rightarrow \tau_{B,i,i+1} = \frac{Q_B}{(EI)_B} \cdot \frac{\sum_{i=1}^{i} E_i \cdot A_i \cdot z_i}{\min\begin{cases} b_i \\ b_{i+1} \end{cases}}$$ (e.g. shown in figure A.4.3 as $\tau_{B,i,i+1}$)

$$\tau_{1,i} = \min\begin{cases} \tau_{B,i\text{-}1,i} \\ \tau_{B,i,i+1} \end{cases}$$

$$\tau_{2,i} = \left|\tau_{B,i\text{-}1,i} - \tau_{B,i,i+1}\right|$$

Shear stress at the interface of the adjoining layers between layer *i* and *i+1*:

$$Q_B \Rightarrow \tau_{B,i,i+1} = \frac{Q_B}{(EI)_B} \cdot \frac{\sum_{i=1}^{i} E_i \cdot A_i \cdot z_i}{\min\begin{cases} b_i \\ b_{i+1} \end{cases}}$$ (e.g. shown in figure A.4.3 as $\tau_{B,i,i+1}$)

A.4.3 Model for a glued stressed skin panel, closed box type double-skin, *without* wooden ribs, *with* loadbearing insulation (type A)

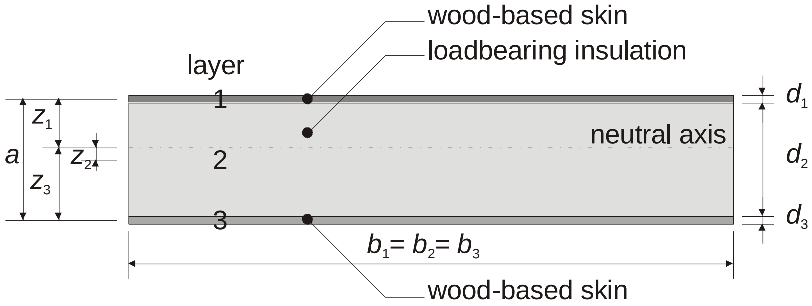


Figure A.4.4 - E.g. cross-section of the three layers stressed skin panel *without* wooden rib, *with* loadbearing insulation

In this example the main direction of the wood-based skin (the grain direction of face veneer) is parallel to the span direction. For wood-based skins like OSB or plywood the material properties parallel and perpendicular to the grain direction of face veneer are different.

A.4.3.1 Assessment of resistance at ultimate limit states

A.4.3.1.1 Virtual beam A

The own bending stiffness, represented by virtual beam A, appears to be a factor of 100 to 200 times smaller than the Steiner bending stiffness, represented by virtual beam B. As there is no effect in the load distribution and singularity errors are caused by the large difference in stiffness, virtual beam A plays no part and is ignored.

A.4.3.1.2 Virtual beam B

Virtual beam B contains the Steiner bending stiffness and a finite shear stiffness resulting in a noticeable shear deflection:

$$(EI)_B = \sum_{i=1}^{3} E_{t(c),//,0,mean,i} \cdot A_i \cdot z_i^2$$ (Steiner bending stiffness)

The wood-based skins are glued to the core. Therefore the connection between flange and web is assumed to be infinitely stiff. Because the factor of cooperation is assumed to be 1,00 the term

$\sum_{i=1}^{n-1} \frac{1}{c_i}$ in the general equation for the shear stiffness (see also A.4.2.3) is neglected.

$$\frac{1}{(GA)_B} = \frac{1}{S} = \frac{1}{a^2} \cdot \left(\frac{d_1}{2 \cdot G_{\perp,0,mean,1} \cdot b_1} + \frac{d_2}{G_{mean,2} \cdot b_2} + \frac{d_3}{2 \cdot G_{\perp,0,mean,3} \cdot b_3} \right)$$ (finite shear stiffness)

where:

$A_i = b_i \cdot d_i$

concerning the wood-based skin:

$E_{t(c),//,0,mean,i}$ the in-plane mean modulus of elasticity along the grain of face veneer for compression or tension.

$G_{\perp,0,mean,1(3)}$ the planar mean shear modulus along the grain of face veneer.

concerning the insulation core:

$E_{t(c),//,0,mean,i}$ the mean modulus of elasticity for compression or tension $E_{t(c),mean}$.

$G_{mean,2}$ the mean shear modulus.

Note: Default values of the material values of the insulation core can be found at A.6.

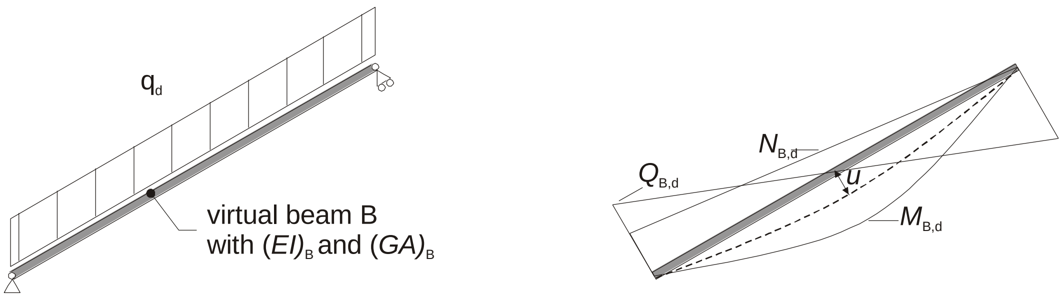


Figure A.4.5 - E.g. a simply supported Kreuzinger beam of type A

In figure A.4.5 a design example is given. The stressed skin panel of type A is now described as a virtual beam B with the Steiner bending stiffness $(EI)_B$ and a finite shear stiffness $(GA)_B$.

The resistance of the virtual beam B can now be calculated to determine the maximum design internal forces.
The calculated virtual design bending, shear and axial forces ($M_{d,B}$, $Q_{d,B}$, $N_{d,B}$) are then translated to the design axial and shear stresses in each different layer *i*. Bending stress in each layer *i* do not occur, because the own bending stiffness is neglected.

Virtual design bending moment $M_{d,B}$ is translated to design axial stress in each different layer *i* by ratio of the Steiner bending stiffness.

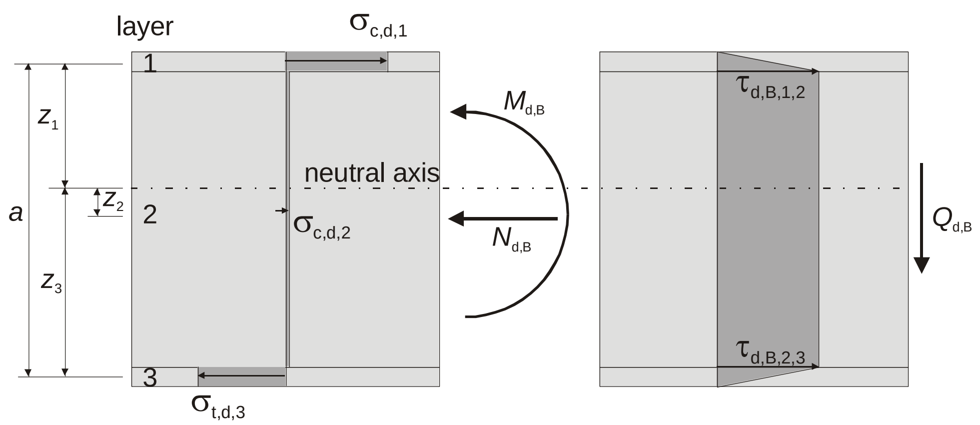


Figure A.4.6 - Design stresses in the stressed skin panel of type A

A.4.3.1.3 Compression or tension resistance

Depending on the direction of the moment $M_{d,B}$ and the axial force $N_{d,B}$ in the structure, each layer can experience compression or tension stress. In this example we assume that the upper wood-based skin and the loadbearing insulation core experience compression and the lower wood-based skin experiences tension.

<u>Design compression stress in layer 1 (upper wood-based skin):</u>

$$N_{d,1} = \frac{E_{t(c),//,0,mean,1} \cdot A_1 \cdot z_1}{(EI)_B} \cdot M_{d,B} + \frac{E_{t(c),//,0,mean,1} \cdot A_1}{\sum_{i=1}^{3} E_{t(c),//,0,mean,i} \cdot A_i} \cdot N_{d,B} \Rightarrow \sigma_{c,d,1} = \frac{N_{d,1}}{A_1}$$ (shown in figure A.4.6 as $\sigma_{c,d,1}$)

The maximum design compression stress must be compared to the design in-plane compression strength along the grain of face veneer of the upper wood-based skin.

$$\sigma_{c,d,1} \leq f_{c,//,0,d,1}$$

Design compression stress in layer 2 (loadbearing insulation core):

$$N_{d,2} = \frac{E_{t(c),mean,2} \cdot A_2 \cdot z_2}{(EI)_B} \cdot M_{d,B} + \frac{E_{t(c),mean,2} \cdot A_2}{\sum_{i=1}^{3} E_{t(c),//,0,mean,i} \cdot A_i} \cdot N_{d,B} \Rightarrow \sigma_{c,d,2} = \frac{N_{d,2}}{A_2}$$ (shown in figure A.4.6 as $\sigma_{c,d,2}$)

The maximum design compression stress must be compared to the design compression strength of the loadbearing insulation core.

$$\sigma_{c,d,2} \leq f_{c,d,2}$$

Design tension stress in layer 3 (lower wood-based skin):

$$N_{d,3} = \frac{E_{t(c),//,0,mean,3} \cdot A_3 \cdot z_3}{(EI)_B} \cdot M_{d,B} + \frac{E_{t(c),//,0,mean,3} \cdot A_3}{\sum_{i=1}^{3} E_{t(c),//,0,mean,i} \cdot A_i} \cdot N_{d,B} \Rightarrow \sigma_{t,d,3} = \frac{N_{d,3}}{A_3}$$ (shown in figure A.4.6 as $\sigma_{t,d,3}$)

The maximum design tension stress must be compared to the design in-plane tension strength along the grain of face veneer of the lower wood-based skin.

$$\sigma_{t,d,3} \leq f_{t,//,0,d,3}$$

A.4.3.1.4 Shear resistance at interface of adjoining layers

Design shear stress at the interface of adjoining layers 1 and 2:

$$\tau_{d,B,1,2} = \frac{\sum_{i=1}^{1} E_{t(c),//,0,mean,i} \cdot A_i \cdot z_i}{(EI)_B} \cdot \frac{Q_{d,B}}{\min\begin{cases} b_1 \\ b_2 \end{cases}}$$ (shown in figure A.4.6 as $\tau_{d,B,1,2}$)

The maximum design shear stress at the interface of adjoining layers 1 and 2 must be compared to the minimum value of the design planar shear strength along the grain of face veneer of layer 1 (upper wood-based skin) or the design shear strength of layer 2 (loadbearing insulation core).

$$\tau_{d,B,1,2} \leq \min\begin{cases} f_{v,\perp,0,d,1} \\ f_{v,d,2} \end{cases}$$

Design shear stress at interface of adjoining layers 2 and 3:

$$\tau_{d,B,2,3} = \frac{\sum_{i=1}^{2} E_{t(c),//,0,mean,i} \cdot A_i \cdot z_i}{(EI)_B} \cdot \frac{Q_{d,B}}{\min\begin{cases} b_2 \\ b_3 \end{cases}}$$ (shown in figure A.4.6 as $\tau_{d,B,2,3}$)

The maximum design shear stress at interface of adjoining layers 2 and 3 must be compared to the minimum value of the design shear strength of layer 2 (loadbearing insulation core) or the design planar shear strength along the grain of face veneer of layer 3 (lower wood-based skin).

$$\tau_{d,B,2,3} \leq \min\begin{cases} f_{v,d,2} \\ f_{v,\perp,0,d,3} \end{cases}$$

A.4.3.1.5 Shear resistance

Design shear stress in layer 1 (upper wood-based skin):

$$\tau_{d,B,0,1} = 0$$

$$\tau_{d,B,1,2} = \frac{\sum_{i=1}^{1} E_{t(c),//,0,mean,i} \cdot A_i \cdot z_i}{(EI)_B} \cdot \frac{Q_{d,B}}{\min\begin{cases} b_1 \\ b_2 \end{cases}}$$ (shown in figure A.4.6 as $\tau_{d,B,1,2}$)

$$\tau_{1,d,1} = \min\begin{cases} \tau_{d,B,0,1} \\ \tau_{d,B,1,2} \end{cases} = 0$$

$$\tau_{2,d,1} = \left|\tau_{d,B,0,1} - \tau_{d,B,1,2}\right| = \tau_{d,B,1,2}$$

$$\tau_{max,d,1} = \tau_{1,d,1} + \tau_{2,d,1} = \tau_{d,B,1,2}$$

The maximum design shear stress must be compared to the design planar shear strength along the grain of face veneer of the upper wood-based skin.

$$\tau_{max,d,1} \leq f_{v,\perp,0,d,1}$$

Design shear stress in layer 2 (loadbearing insulation core):

$$\tau_{d,B,1,2} = \frac{\sum_{i=1}^{1} E_{t(c),//,0,mean,i} \cdot A_i \cdot z_i}{(EI)_B} \cdot \frac{Q_{d,B}}{\min\begin{cases} b_1 \\ b_2 \end{cases}}$$ (shown in figure A.4.6 as $\tau_{d,B,1,2}$)

$$\tau_{d,B,2,3} = \frac{\sum_{i=1}^{2} E_{t(c),//,0,mean,i} \cdot A_i \cdot z_i}{(EI)_B} \cdot \frac{Q_{d,B}}{\min\begin{cases} b_2 \\ b_3 \end{cases}}$$ (shown in figure A.4.6 as $\tau_{d,B,2,3}$)

$$\tau_{1,d,2} = \min\begin{cases} \tau_{d,B,1,2} \\ \tau_{d,B,2,3} \end{cases}$$

$$\tau_{2,d,2} = \left|\tau_{d,B,1,2} - \tau_{d,B,2,3}\right|$$

$$\tau_{max,d,2} = \tau_{1,d,2} + \tau_{2,d,2}$$

The maximum design shear stress must be compared to the design shear strength of the loadbearing insulation core.

$$\tau_{max,d,2} \leq f_{v,d,2}$$

Design shear stress in layer 3 (lower wood-based skin):

$$\tau_{d,B,2,3} = \frac{\sum_{i=1}^{2} E_{t(c),//,0,mean,i} \cdot A_i \cdot z_i}{(EI)_B} \cdot \frac{Q_{d,B}}{\min\begin{cases} b_2 \\ b_3 \end{cases}}$$ (shown in figure A.4.6 as $\tau_{d,B,2,3}$)

$$\tau_{d,B,3,4} = 0$$

$$\tau_{1,d,3} = \min\begin{cases} \tau_{d,B,2,3} \\ \tau_{d,B,3,4} \end{cases} = 0$$

$$\tau_{2,d,3} = \left|\tau_{d,B,2,3} - \tau_{d,B,3,4}\right| = \tau_{d,B,2,3}$$

$$\tau_{max,d,3} = \tau_{1,d,3} + \tau_{2,d,3} = \tau_{d,B,2,3}$$

The maximum design shear stress must be compared to the design planar shear strength along the grain of face veneer of the lower wood-based skin.

$$\tau_{max,d,3} \leq f_{v,\perp,0,d,3}$$

A.4.3.1.6 Local compression resistance in layer 2 (loadbearing insulation core) at a support

The verification is following:

$$\sigma_{c,d,2} = \frac{R_d}{A_{eff}}$$

where:

R_d the maximum design reaction force at a support.
A_{eff} the effective support area of loadbearing insulation core at a support.

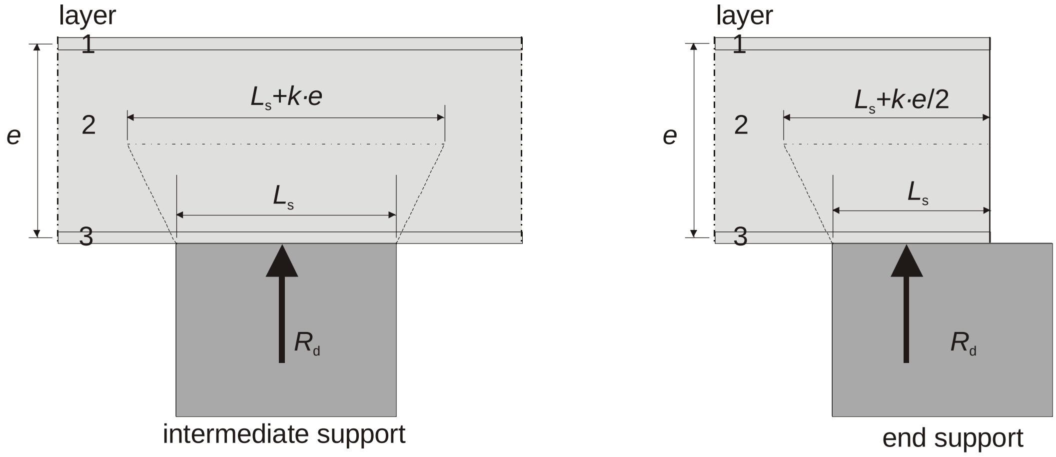


Figure A.4.7 – Effective support length of the loadbearing insulation core

Effective support area of the loadbearing insulation core:

Intermediate support:

$$A_{eff} = B \cdot (L_s + k \cdot e)$$

End support:

$$A_{eff} = B \cdot \left(L_s + k \cdot e/2\right)$$

where:

B the supported width of the loadbearing insulation core.
k a distribution parameter; k = 0,50 for loadbearing insulation core.
e the distance between the centers of the face layers; $e \leq 100$ mm.

For sandwich panels with e > 100 mm, e = 100 mm should be used.
The maximum design compression stress must be compared to the reduced design compression strength of the loadbearing insulation core.

$$\frac{\sigma_{c,d,2}}{f_{c,d,2}} \leq 1{,}00$$

A.4.3.1.7 Wrinkling resistance

The wrinkling phenomenon in the wood-based skin due to compression stress in the field or due to compression and bending stress at the support is described in A.1.3.2.

A.4.3.1.8 Fastening of the stressed skin panel to the supporting structure

In case the stressed skin panel is supported by a timber structure, metal fasteners can be used to connect the stressed skin panel to the supporting structure. The panel-to-timber connection must be calculated according to EN 1995-1-1.

A.4.3.2 Assessment of deflection at of serviceability limit states

As the loadbearing insulation core has a small finite shear stiffness, the shear deflection is of great influence. Besides a deflection caused by the elastic stiffness, an extra noticeable deflection caused by the small finite shear stiffness shall be calculated.

A.4.3.2.1 Design value of the stiffness properties of each layer *i*

Virtual beam B can now be loaded by combination of actions to be used for verification in the serviceability limit state to determine the maximum total deflection.

The final deformation of the stressed skin panel fabricated from members which have different creep properties should be calculated using modified final stiffness moduli ($E_{fin,i}$ and $G_{fin,i}$), which are determined by dividing the instantaneous values of the modulus for each member ($E_{mean,i}$ and $G_{mean,i}$) by the appropriate value of ($1+k_{def,i}$).
A load combination which consists of actions belonging to different load duration classes, the contribution of each action to the total deflection should be calculated separately using the appropriate k_{def} values.

Final stiffness properties of each action using the appropriate k_{def} values for <u>virtual beam B</u>:

$$E_{fin,i} = \frac{E_{mean,i}}{1+\psi_2 \cdot k_{def,i}}$$

$$G_{fin,i} = \frac{G_{mean,i}}{1+\psi_2 \cdot k_{def,i}}$$

concerning the wood-based skin with the grain of face veneer parallel to the span direction:
$E_{mean,i}$ the <u>in-plane</u> mean modulus of elasticity for compression or tension along the grain of face veneer $E_{t(c),//,0,mean}$.
$G_{mean,i}$ the <u>planar</u> mean shear modulus along the grain of face veneer $G_{\perp,0,mean}$.
concerning the loadbearing insulation core:
$E_{mean,i}$ the mean modulus of elasticity for compression or tension $E_{t(c),mean}$.
$G_{mean,i}$ the mean shear modulus G_{mean}.
ψ_2 a factor for the quasi-permanent value of a variable action. For permanent actions, ψ_2 should be taken equal to 1,00.

A.4.4 Model for a stressed skin panel, closed box type double-skin, *with* wooden ribs and (non)-loadbearing insulation (type B1 and C1)

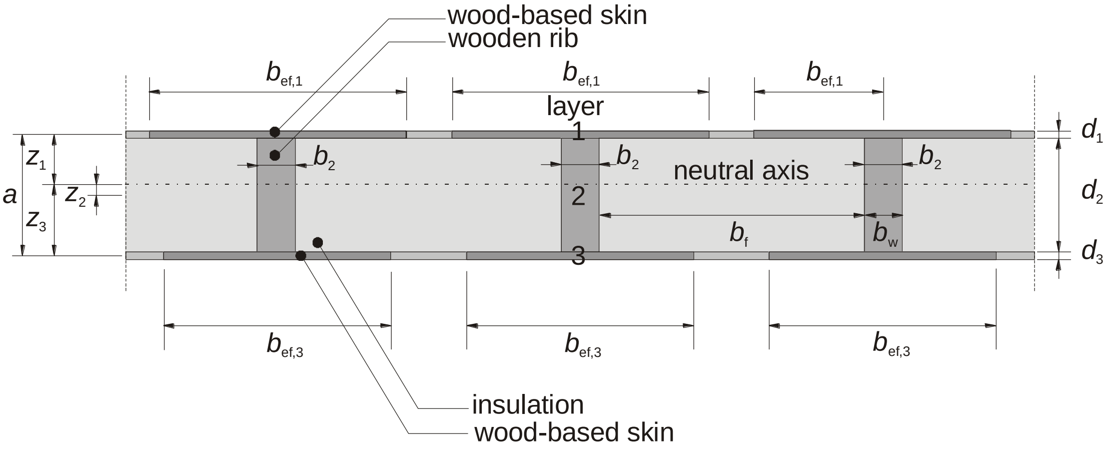


Figure A.4.8 - E.g. cross-section of the three layers stressed skin panel *with* wooden ribs and (non)- loadbearing insulation

In this example the main direction of the wood-based skin (the grain direction of face veneer) is parallel to the span direction. For wood-based skins like OSB or plywood the material properties parallel and perpendicular to the grain direction of face veneer are different.

A.4.4.1 Assessment of resistance at ultimate limit states

A.4.4.1.1 Effective flange width b_{ef} of wood-based skins

With non-loadbearing (unstiff) insulation (type C1)

In case the space between the wooden ribs consists of non-loadbearing (unstiff) insulation the effective flange width should be taken from table 9.1 of the EN 1995-1-1. The minimum value between the columns due to the shear lag and due to the plate buckling should be taken.

With loadbearing (stiff) insulation, glued to the wood-based skins (type B1)

The space between the wooden ribs forms a stressed skin panel of type A. Therefore the wood-based skins of type B1 are supported by the loadbearing (stiff) insulation core. The effect of plate buckling may be disregarded. The analytical solution for the maximum effective flange widths due to the effect of shear lag is independent of the type of insulation because it only takes into account shear lag and no plate buckling and therefore may be used in all cases. Effective flange width of the wood-based skins:

$$\frac{b_{ef,i} - b_w}{b_f} = \frac{2 \cdot \ell \cdot \left(\lambda_{1,i} \cdot \tanh\alpha_{1,i} - \lambda_{2,i} \cdot \tanh\alpha_{2,i}\right)}{\pi \cdot b_f \cdot \left(\lambda_{1,i}^2 - \lambda_{2,i}^2\right)}$$

where:

$$\alpha_{1,i} = \frac{\lambda_{1,i} \cdot \pi \cdot b_f}{2 \cdot \ell}$$

$$\alpha_{2,i} = \frac{\lambda_{2,i} \cdot \pi \cdot b_f}{2 \cdot \ell}$$

$$\lambda_{1,i} = \sqrt{a_i + \sqrt{a_i^2 - c_i}}$$

$$\lambda_{2,i} = \sqrt{a_i - \sqrt{a_i^2 - c_i}}$$

$$a_i = \frac{E_{t(c),//,90,mean,i}}{2 \cdot G_{//,mean,i}} - \mu_i$$

$$c_i = \frac{E_{t(c),//,90,mean,i}}{E_{t(c),//,0,mean,i}}$$

ℓ	the span of the beam.
b_f	the web spacing.
b_w	the rib width.
$E_{t(c),//,0,mean,i}$	the in-plane mean modulus of elasticity along the grain of face veneer for compression or tension of wood-based skin layer *i*.
$E_{t(c),//,90,mean,i}$	the in-plane mean modulus of elasticity perpendicular to the grain of face veneer for compression or tension of wood-based skin layer *i*.
$G_{//,mean,i}$	the in-plane mean shear modulus of wood-based skin layer *i*.
μ_i	the in-plane Poisson's ratio of wood-based skin layer *i*.

A.4.4.1.2 Virtual beam A

Virtual beam A contains the own bending stiffness of the three layers:

$$(EI)_A = \sum_{i=1}^{3} E_{m,\perp,0,mean,i} \cdot I_i$$

where:

$$I_i = \frac{b_{ef,i} \cdot d_i^3}{12} \qquad \text{(for the wood-based skins and } b_{ef,i} \text{ according to A.4.4.1.1)}$$

$$I_i = \frac{b_i \cdot d_i^3}{12} \qquad \text{(for the wooden rib core)}$$

concerning the wood-based skin:
$E_{m,\perp,0,mean,i}$ the planar mean modulus of elasticity along the grain of face veneer for bending.

concerning the wooden rib core:
$E_{m,\perp,0,mean,i}$ the mean modulus of elasticity along the grain $E_{0,mean}$.

The shear stiffness of virtual beam A is assumed to be infinite.

A.4.4.1.3 Virtual beam B

Virtual beam B contains the Steiner bending stiffness:

$$(EI)_B = \sum_{i=1}^{3} E_{t(c),//,0,mean,i} \cdot A_i \cdot z_i^2 \qquad \text{(Steiner bending stiffness)}$$

The shear stiffness should also be taken into account for slender webs and small ℓ/h-ratios. In these cases, the shear stiffness might influence the stress distribution and the deformation.
In this example the wood-based skins are glued to the wooden ribs. Therefore the connection between flange and web is assumed to be infinitely stiff. Because the factor of co-operation is assumed to be 1,00 the term

$\sum_{i=1}^{n-1} \frac{1}{c_i}$ in the general equation for the shear stiffness (see also A.4.2.3) is neglected.

If the connection between skin and wooden rib is made of mechanical fasteners, the factor of co-operation is less than 1,00 and the slip stiffness due to mechanical fastening has to be taken into account by the term $\sum_{i=1}^{n-1} \frac{1}{c_i}$. The slip stiffness can be calculated according to EC 5. The total number of layers should then not exceed 5.

$$\frac{1}{(GA)_B} = \frac{1}{S} = \frac{1}{a^2} \cdot \left(\frac{d_1}{2 \cdot G_{\perp,0,\text{mean},1} \cdot b_{\text{ef},1}} + \frac{d_2}{G_{\text{mean},2} \cdot b_2} + \frac{d_3}{2 \cdot G_{\perp,0,\text{mean},3} \cdot b_{\text{ef},3}} \right) \quad \text{(finite shear stiffness)}$$

where:

$A_i = b_{\text{ef},i} \cdot d_i$ (for the wood-based skins and $b_{\text{ef},i}$ according to A.4.4.1.1)

$A_i = b_i \cdot d_i$ (for the wooden rib core)

concerning the wood-based skins:

$E_{t(c),//,0,\text{mean},i}$ the in-plane mean modulus of elasticity along the grain of face veneer for compression or tension.

$G_{\perp,0,\text{mean},1(3)}$ the planar mean shear modulus along the grain of face veneer.

concerning the wooden rib core:

$E_{t(c),//,0,\text{mean},i}$ the mean modulus of elasticity along the grain $E_{0,\text{mean}}$.

$G_{\text{mean},2}$ the mean shear modulus.

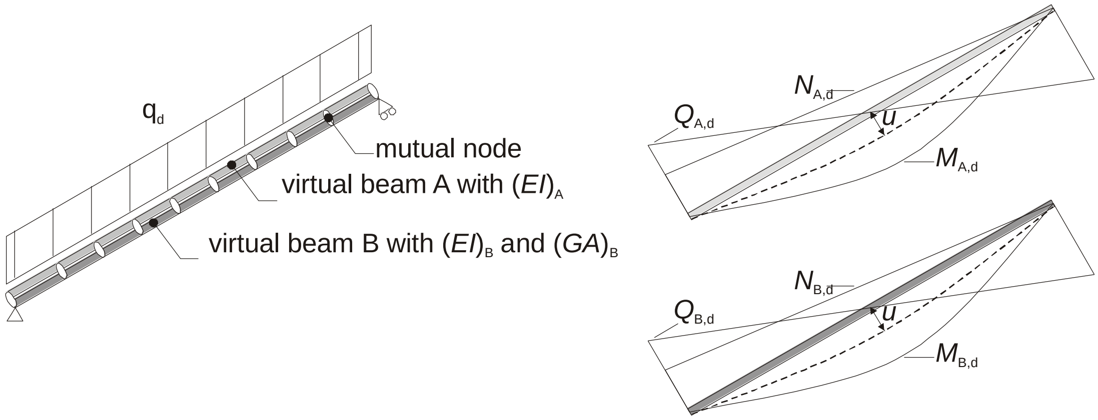


Figure A.4.9 - E.g. a simply supported Kreuzinger beam of type B1 or C1

In figure A.4.9 a design example is given. The stressed skin panel of type B1 or C1 is now described as a virtual beam A with the own bending stiffness $(EI)_A$ and a virtual beam B with the Steiner bending stiffness $(EI)_B$. Both beams are placed parallel to each other and they are connected with mutual nodes.

The resistance of the combined virtual beams A and B can now be calculated to determine the maximum design internal forces.

The calculated virtual design bending, shear and axial forces ($M_{d,A}$, $Q_{d,A}$, $N_{d,A}$, $M_{d,B}$, $Q_{d,B}$, $N_{d,B}$) are then translated to the design bending, axial and shear stresses in each different layer *i*.

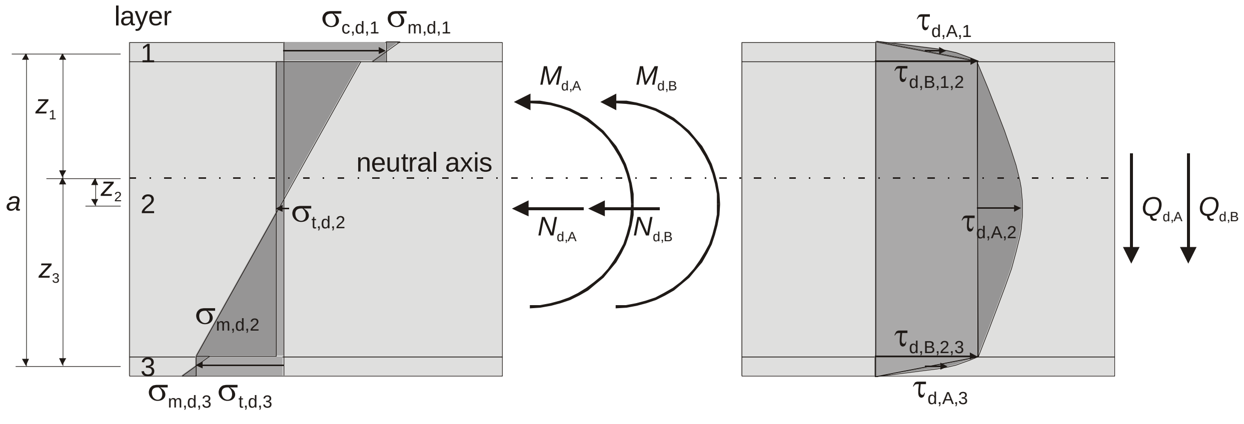


Figure A.4.10 - Stresses in the stressed skin panel of type B1 or C1

A.4.4.1.4 Compression or tension resistance in combination with bending

Depending on the direction of the moment $M_{d,B}$ and the axial forces $N_{d,A}$ and $N_{d,B}$ in the structure, every layer can havee compression or tension stress. In this example we assume that the upper wood-based skin has compression stress and the lower wood-based skin and the wooden rib core has tension stress.

Design bending stress in layer 1 (upper wood-based skin):

$$M_{d,1} = \frac{E_{m,\perp,0,mean,1} \cdot I_1}{(EI)_A} \cdot M_{d,A} \quad \Rightarrow \quad \sigma_{m,d,1} = \frac{M_{d,1}}{W_1}$$ (shown in figure A.4.10 as $\sigma_{m,d,1}$)

where:

$$W_1 = \frac{b_{ef,1} \cdot d_1^2}{6}$$ (for the wood-based skins and $b_{ef,1}$ according to A.4.4.1.1)

Design compression stress in layer 1 (upper wood-based skin):

$$N_{d,1} = \frac{E_{t(c),//,0,mean,1} \cdot A_1 \cdot z_1}{(EI)_B} \cdot M_{d,B} + \frac{E_{t(c),//,0,mean,1} \cdot A_1}{\sum_{i=1}^{3} E_{t(c),//,0,mean,i} \cdot A_i} \cdot \left(N_{d,A} + N_{d,B}\right) \Rightarrow \sigma_{c,d,1} = \frac{N_{d,1}}{A_1}$$

(shown in figure A.4.10 as $\sigma_{c,d,1}$)

The maximum combined design compression and bending stress must be compared to the combined design in-plane compression strength along the grain of face veneer and the design planar bending strength along the grain of face veneer of the upper wood-based skin.

$$\frac{\sigma_{c,d,1}}{f_{c,//,0,d,1}} + \frac{\sigma_{m,d,1}}{f_{m,\perp,0,d,1}} \leq 1{,}00$$

Design bending stress in layer *2* (wooden rib core):

$$M_{d,2} = \frac{E_{0,mean,2} \cdot I_2}{(EI)_A} \cdot M_{d,A} \quad \Rightarrow \quad \sigma_{m,d,2} = \frac{M_{d,2}}{W_2}$$ (shown in figure A.4.10 as $\sigma_{m,d,2}$)

where:

$$W_2 = \frac{b_2 \cdot d_2^2}{6}$$ (for the wooden rib core)

Design tension stress in layer 2 (wooden rib core):

$$N_{d,2} = \frac{E_{0,mean,2} \cdot A_2 \cdot z_2}{(EI)_B} \cdot M_{d,B} + \frac{E_{0,mean,2} \cdot A_2}{\sum_{i=1}^{3} E_{t(c),//,0,mean,i} \cdot A_i} \cdot \left(N_{d,A} + N_{d,B}\right) \Rightarrow \sigma_{t,d,2} = \frac{N_{d,2}}{A_2}$$

(shown in figure A.4.10 as $\sigma_{t,d,2}$)

The maximum combined design tension and bending stress must be compared to the combined design tension and bending strength along the grain of the wooden rib core.

$$\frac{\sigma_{t,d,2}}{f_{t,0,d,2}} + \frac{\sigma_{m,d,2}}{f_{m,d,2}} \leq 1{,}00$$

Design bending stress in layer 3 (lower wood-based skin):

$$M_{d,3} = \frac{E_{m,\perp,0,mean,3} \cdot I_3}{(EI)_A} \cdot M_{d,A} \quad \Rightarrow \quad \sigma_{m,d,3} = \frac{M_{d,3}}{W_3}$$ (shown in figure A.4.10 as $\sigma_{m,d,3}$)

where:

$W_3 = \frac{b_{ef,3} \cdot d_3^2}{6}$ (for the wood-based skins and $b_{ef,3}$ according to A.4.4.1.1)

Design tension stress in layer 3 (lower wood-based skin):

$$N_{d,3} = \frac{E_{t(c),//,0,mean,3} \cdot A_3 \cdot z_3}{(EI)_B} \cdot M_{d,B} + \frac{E_{t(c),//,0,mean,3} \cdot A_3}{\sum_{i=1}^{3} E_{t(c),//,0,mean,i} \cdot A_i} \cdot \left(N_{d,A} + N_{d,B}\right) \Rightarrow \sigma_{t,d,3} = \frac{N_{d,3}}{A_3}$$

(shown in figure A.4.10 as $\sigma_{t,d,3}$)

The maximum combined design tension and bending stress must be compared to the combined design in-plane tension strength along the grain of face veneer and the design planar bending strength along the grain of face veneer of the lower wood-based skin.

$$\frac{\sigma_{t,d,3}}{f_{t,//,0,d,3}} + \frac{\sigma_{m,d,3}}{f_{m,\perp,0,d,3}} \le 1{,}00$$

A.4.4.1.5 Shear resistance at interface of adjoining layers

Design shear stress at interface of adjoining layers 1 and 2:

$$\tau_{d,B,1,2} = \frac{Q_{d,B}}{(EI)_B} \cdot \frac{\sum_{i=1}^{1} E_{t(c),//,0,mean,i} \cdot A_i \cdot z_i}{\min\begin{cases} b_{ef,1} \\ b_2 \end{cases}}$$

(shown in figure A.4.10 as $\tau_{d,B,1,2}$)

The maximum design shear stress at interface of adjoining layers 1 and 2 must be compared to the minimum value of the design planar shear strength along the grain of face veneer of layer 1 (upper wood-based skin) or the design shear strength layer 2 (wooden rib core).

$$\tau_{d,B,1,2} \le \min\begin{cases} f_{v,\perp,0,d,1} \\ f_{v,d,2} \end{cases}$$

Design shear stress at interface of adjoining layers 2 and 3:

$$\tau_{d,B,2,3} = \frac{Q_{d,B}}{(EI)_B} \cdot \frac{\sum_{i=1}^{2} E_{t(c),//,0,mean,i} \cdot A_i \cdot z_i}{\min\begin{cases} b_2 \\ b_{ef,3} \end{cases}}$$

(shown in figure A.4.10 as $\tau_{d,B,2,3}$)

The maximum design shear stress at interface of adjoining layers 2 and 3 must be compared to the minimum value of the design shear strength of layer 2 (wooden rib core) or the design planar shear strength along the grain of face veneer of layer 3 (lower wood-based skin).

$$\tau_{d,B,2,3} \le \text{minimum of} \begin{cases} f_{v,d,2} \\ f_{v,\perp,0,d,3} \end{cases}$$

A.4.4.1.6 Shear resistance

Design shear stress in layer 1 (upper wood-based skin):

$$\tau_{d,A,1} = \frac{E_{m,\perp,0,mean,1} \cdot I_1}{(EI)_A} \cdot Q_{d,A} \cdot \frac{3}{2} \cdot \frac{1}{d_1 \cdot b_{ef,1}}$$ (shown in figure A.4.10 as $\tau_{d,A,1}$)

$$\tau_{d,B,0,1} = 0$$

$$\tau_{d,B,1,2} = \frac{Q_{d,B}}{(EI)_B} \cdot \frac{\sum_{i=1}^{1} E_{t(c),//,0,mean,i} \cdot A_i \cdot z_i}{\min\begin{cases} b_{ef,1} \\ b_2 \end{cases}}$$ (shown in figure A.4.10 as $\tau_{d,B,1,2}$)

$$\tau_{1,d,1} = \min\begin{cases} \tau_{d,B,0,1} \\ \tau_{d,B,1,2} \end{cases} = 0$$

$$\tau_{2,d,1} = \left|\tau_{d,B,0,1} - \tau_{d,B,1,2}\right| = \tau_{d,B,1,2}$$

if $\tau_{d,A,1} > \frac{\tau_{2,d,1}}{4} \Leftrightarrow$ if $\tau_{d,A,1} > \frac{\tau_{d,B,1,2}}{4}$:

$$\tau_{max,d,1} = \tau_{d,A,1} + \tau_{1,d,1} + \frac{\tau_{2,d,1}}{2} + \frac{\tau_{2,d,1}^2}{16 \cdot \tau_{d,A,1}} \Leftrightarrow \tau_{max,d,1} = \tau_{d,A,1} + \frac{\tau_{d,B,1,2}}{2} + \frac{\tau_{d,B,1,2}^2}{16 \cdot \tau_{d,A,1}}$$

if $\tau_{d,A,1} \le \frac{\tau_{2,d,1}}{4} \Leftrightarrow$ if $\tau_{d,A,1} \le \frac{\tau_{d,B,1,2}}{4}$:

$$\tau_{max,d,1} = \tau_{1,d,1} + \tau_{2,d,1} \Leftrightarrow \tau_{max,d,1} = \tau_{d,B,1,2}$$

The maximum design shear stress must be compared to the design planar shear strength along the grain of face veneer of the upper wood-based skin.

$$\tau_{max,d,1} \le f_{v,\perp,0,d,1}$$

Design shear stress in layer 2 (wooden rib core):

$$\tau_{d,A,2} = \frac{E_{0,mean,2} \cdot I_2}{(EI)_A} \cdot Q_{d,A} \cdot \frac{3}{2} \cdot \frac{1}{d_2 \cdot b_2}$$ (shown in figure A.4.10 as $\tau_{d,A,2}$)

$$\tau_{d,B,1,2} = \frac{Q_{d,B}}{(EI)_B} \cdot \frac{\sum_{i=1}^{1} E_{t(c),//,0,mean,i} \cdot A_i \cdot z_i}{\min\begin{cases} b_{ef,1} \\ b_2 \end{cases}}$$ (shown in figure A.4.10 as $\tau_{d,B,1,2}$)

$$\tau_{d,B,2,3} = \frac{Q_{d,B}}{(EI)_B} \cdot \frac{\sum_{i=1}^{2} E_{t(c),//,0,mean,i} \cdot A_i \cdot z_i}{\min\begin{cases} b_2 \\ b_{ef,3} \end{cases}}$$ (shown in figure A.4.10 as $\tau_{d,B,2,3}$)

$$\tau_{1,d,2} = \min\begin{cases} \tau_{d,B,1,2} \\ \tau_{d,B,2,3} \end{cases}$$

$$\tau_{2,d,2} = \left|\tau_{d,B,1,2} - \tau_{d,B,2,3}\right|$$

if $\tau_{d,A,2} > \frac{\tau_{2,d,2}}{4}$:

$$\tau_{max,d,2} = \tau_{d,A,2} + \tau_{1,d,2} + \frac{\tau_{2,d,2}}{2} + \frac{\tau_{2,d,2}^2}{16 \cdot \tau_{d,A,2}}$$

if $\tau_{d,A,2} \leq \frac{\tau_{2,d,2}}{4}$:

$$\tau_{max,d,2} = \tau_{1,d,2} + \tau_{2,d,2}$$

The maximum design shear stress must be compared to the design shear strength of the wooden rib core.

$$\tau_{max,d,2} \leq f_{v,d,2}$$

Design shear stress in layer 3 (lower wood-based skin):

$$\tau_{d,A,3} = \frac{E_{m,\perp,0,mean,3} \cdot I_3}{(EI)_A} \cdot Q_{d,A} \cdot \frac{3}{2} \cdot \frac{1}{d_3 \cdot b_{ef,3}}$$ (shown in figure A.4.10 as $\tau_{d,A,3}$)

$$\tau_{d,B,2,3} = \frac{Q_{d,B}}{(EI)_B} \cdot \frac{\sum_{i=1}^{2} E_{t(c),//,0,mean,i} \cdot A_i \cdot z_i}{\min\begin{cases} b_2 \\ b_{ef,3} \end{cases}}$$ (shown in figure A.4.10 as $\tau_{d,B,2,3}$)

$$\tau_{d,B,3,4} = 0$$

$$\tau_{1,d,3} = \min\begin{cases} \tau_{d,B,2,3} \\ \tau_{d,B,3,4} \end{cases} = 0$$

$$\tau_{2,d,3} = \left|\tau_{d,B,2,3} - \tau_{d,B,3,4}\right| = \tau_{d,B,2,3}$$

if $\tau_{d,A,3} > \frac{\tau_{2,d,3}}{4} \Leftrightarrow$ if $\tau_{d,A,3} > \frac{\tau_{d,B,2,3}}{4}$:

$$\tau_{max,d,3} = \tau_{d,A,3} + \tau_{1,d,3} + \frac{\tau_{2,d,3}}{2} + \frac{\tau_{2,d,3}^2}{16 \cdot \tau_{d,A,3}} \Leftrightarrow \tau_{max,d,3} = \tau_{d,A,3} + \frac{\tau_{d,B,2,3}}{2} + \frac{\tau_{d,B,2,3}^2}{16 \cdot \tau_{d,A,3}}$$

if $\tau_{d,A,3} \leq \frac{\tau_{2,d,3}}{4} \Leftrightarrow$ if $\tau_{d,A,3} \leq \frac{\tau_{d,B,2,3}}{4}$:

$$\tau_{max,d,3} = \tau_{1,d,3} + \tau_{2,d,3} \Leftrightarrow \tau_{max,d,3} = \tau_{d,B,2,3}$$

The maximum design shear stress must be compared to the design planar shear strength along the grain of face veneer of the lower wood-based skin.

$$\tau_{d,max,3} \leq f_{v,\perp,0,d,3}$$

The wood-based skins are supported by the relatively rigid wooden rib core. Therefore the local wrinkling effect of the skin doesn't occur in the stressed skin panel of type B1 or C1.

A.4.4.1.7 Fastening of the stressed skin panel to the supporting structure

In case the stressed skin panel is supported by a timber structure, metal fasteners can be used to connect the stressed skin panel to the supporting structure. The panel-to-timber connection must be calculated according to EN 1995-1-1.

A.4.4.2 Assessment of deflection at of serviceability limit states

A.4.4.2.1 Design value of the stiffness properties of each layer *i*

Both virtual beams A and B can now be loaded by combination of actions to be used for verification in the serviceability limit state to determine the maximum total deflection.

The final deformation of the stressed skin panel fabricated from members which have different creep properties should be calculated using modified final stiffness moduli ($E_{fin,i}$ and $G_{fin,i}$), which are determined by dividing the instantaneous values of the modulus for each member ($E_{mean,i}$ and $G_{mean,i}$) by the appropriate value of ($1+k_{def,i}$).
A load combination which consists of actions belonging to different load duration classes, the contribution of each action to the total deflection should be calculated separately using the appropriate k_{def} values.

Final stiffness properties of each action using the appropriate k_{def} values for <u>virtual beam A</u>:

$$E_{fin,i} = \frac{E_{mean,i}}{1+\psi_2 \cdot k_{def,i}}$$

concerning the wood-based skin with the grain of face veneer parallel to the span direction:
$E_{mean,i}$ the <u>planar</u> mean modulus of elasticity for bending along the grain of face veneer $E_{m,\perp,0,mean}$.
concerning the wooden rib core:
$E_{mean,i}$ the mean modulus of elasticity along the grain $E_{0,mean}$.

Final stiffness properties of each action using the appropriate k_{def} values for <u>virtual beam B</u>:

$$E_{fin,i} = \frac{E_{mean,i}}{1+\psi_2 \cdot k_{def,i}}$$

The shear moduli and the slip moduli of the connections should also be modified using the modification factor k_{def}.

$$G_{fin,i} = \frac{G_{mean,i}}{1+\psi_2 \cdot k_{def,i}} ; \quad c_{fin,i} = \frac{\sum_{i=1}^{n-1} c_i}{1+\psi_2 \cdot k_{def}}$$

concerning the wood-based skin:
$E_{mean,i}$ the <u>in-plane</u> mean modulus of elasticity for compression or tension along the grain of face veneer $E_{t(c),//,0,mean}$.
$G_{mean,i}$ the <u>planar</u> mean shear modulus along the grain of face veneer $G_{\perp,0,mean}$.
concerning the wooden rib core:
$E_{mean,i}$ the mean modulus of elasticity along the grain $E_{0,mean}$.
$G_{mean,i}$ the mean shear modulus G_{mean}.
ψ_2 a factor for the quasi-permanent value of a variable action. For permanent actions, ψ_2 should be taken equal to 1,00.
c_i the slip modulus between the layers of the stressed skin panel.

A.4.5 Model for a stressed skin panel, open box type single-skin, *with* wooden ribs and (non)-loadbearing insulation (type B2 and C2)

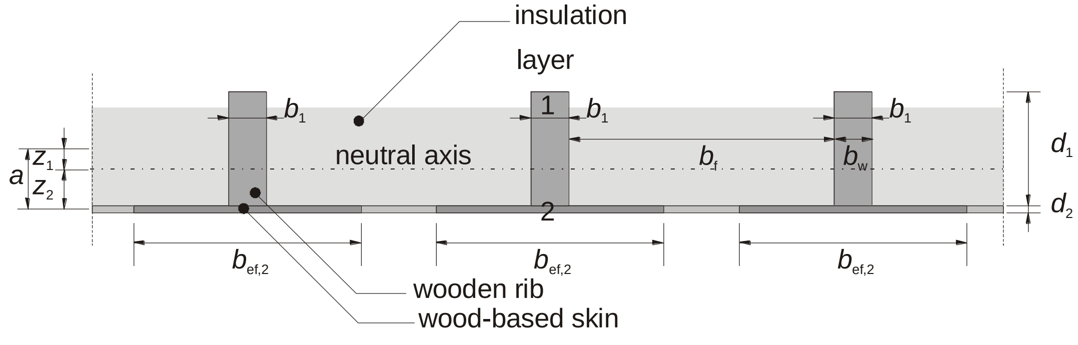


Figure A.4.11 - E.g. cross-section of the two layers single-skin stressed skin panel *with* wooden ribs and (non)-loadbearing insulation

In this example the main direction of the wood-based skin (the grain direction of face veneer) is parallel to the span direction. For wood-based skins like OSB or plywood the material properties parallel and perpendicular to the grain direction of face veneer are different.

A.4.5.1 Assessment of resistance at ultimate limit states

A.4.5.1.1 Effective flange width b_{ef} of wood-based skins

With non-loadbearing (unstiff) insulation (type C2)

In case the space between the wooden ribs consists of non-loadbearing (unstiff) insulation the effective flange width should be taken from table 9.1 of the EN 1995-1-1. The minimum value between the columns due to the shear lag and due to the plate buckling should be taken.

With loadbearing (stiff) insulation, glued to the wood-based skins (type B2)

The wood-based skin is supported by the loadbearing (stiff) insulation core. The effect of plate buckling may be disregarded. The analytical solution for the maximum effective flange widths due to the effect of shear lag is independent of the type of insulation because it only takes into account shear lag and no plate buckling and therefore may be used also for open box type single-skin stressed skin panels. Effective flange width of the wood-based skins:

$$\frac{b_{ef,i} - b_w}{b_f} = \frac{2 \cdot \ell \cdot \left(\lambda_{1,i} \cdot \tanh\alpha_{1,i} - \lambda_{2,i} \cdot \tanh\alpha_{2,i}\right)}{\pi \cdot b_f \cdot \left(\lambda_{1,i}^2 - \lambda_{2,i}^2\right)}$$

where:

$$\alpha_{1,i} = \frac{\lambda_{1,i} \cdot \pi \cdot b_f}{2 \cdot \ell}$$

$$\alpha_{2,i} = \frac{\lambda_{2,i} \cdot \pi \cdot b_f}{2 \cdot \ell}$$

$$\lambda_{1,i} = \sqrt{a_i + \sqrt{a_i^2 - c_i}}$$

$$\lambda_{2,i} = \sqrt{a_i - \sqrt{a_i^2 - c_i}}$$

$$a_i = \frac{E_{t(c),//,90,mean,i}}{2 \cdot G_{//,mean,i}} - \mu_i$$

$$c_i = \frac{E_{t(c),//,90,mean,i}}{E_{t(c),//,0,mean,i}}$$

ℓ	the span of the beam.
b_f	the web spacing.
b_w	the rib width.
$E_{t(c),//,0,mean,i}$	the in-plane mean modulus of elasticity along the grain of face veneer for compression or tension of wood-based skin layer *i*.
$E_{t(c),//,90,mean,i}$	the in-plane mean modulus of elasticity perpendicular to the grain of face veneer for compression or tension of wood-based skin layer *i*.
$G_{//,mean,i}$	the in-plane mean shear modulus of wood-based skin layer *i*.
μ_i	the in-plane Poisson's ratio of wood-based skin layer *i*.

A.4.5.1.2 Virtual beam A

Virtual beam A contains the own bending stiffness of the two layers:

$$(EI)_A = \sum_{i=1}^{2} E_{m,\perp,0,mean,i} \cdot I_i$$

where:

$I_1 = \frac{b_1 \cdot d_1^3}{12}$ (for the wooden rib)

$I_2 = \frac{b_{ef,2} \cdot d_2^3}{12}$ (for the wood-based skin and $b_{ef,2}$ according to A.4.5.1.1)

concerning the upper wooden rib:

$E_{m,\perp,0,mean,i}$ the mean modulus of elasticity along the grain $E_{0,mean}$.

concerning the lower wood-based skin:

$E_{m,\perp,0,mean,i}$ the planar mean modulus of elasticity along the grain of face veneer for bending.

The shear stiffness of virtual beam A is assumed to be infinite.

A.4.5.1.3 Virtual beam B

Virtual beam B contains the Steiner bending stiffness:

$$(EI)_B = \sum_{i=1}^{2} E_{t(c),//,0,mean,i} \cdot A_i \cdot z_i^2 \quad \text{(Steiner bending stiffness)}$$

The shear stiffness should also be taken into account for slender webs and small ℓ/h-ratios. In these cases, the shear stiffness might influence the stress distribution and the deformation.
In this example the wood-based skins are glued to the wooden ribs. Therefore the connection between flange and web is assumed to be infinitely stiff. Because the factor of co-operation is assumed to be 1,00 the term
$\sum_{i=1}^{n-1} \frac{1}{c_i}$ in the general equation for the shear stiffness (see also A.4.2.3) is neglected.
If the connection between skin and wooden rib is made of mechanical fasteners, the factor of co-operation is less than 1,00 and the slip stiffness due to mechanical fastening has to be taken into account by the term $\sum_{i=1}^{n-1} \frac{1}{c_i}$. The slip stiffness can be calculated according to EC 5. The total number of layers should then not exceed 5.

$$\frac{1}{(GA)_B} = \frac{1}{S} = \frac{1}{a^2} \cdot \left(\frac{d_1}{2 \cdot G_{mean,1} \cdot b_1} + \frac{d_2}{2 \cdot G_{\perp,0,mean,2} \cdot b_{ef,2}} \right) \quad \text{(finite shear stiffness)}$$

where:

$A_1 = b_1 \cdot d_1$ (for the wooden rib)

$A_2 = b_{ef,2} \cdot d_2$ (for the wood-based skin and $b_{ef,2}$ according to A.4.5.1.1)

concerning the upper wooden rib:

$E_{t(c),//,0,mean,i}$ the mean modulus of elasticity along the grain $E_{0,mean}$.

$G_{mean,1}$ the mean shear modulus.

concerning the lower wood-based skin:

$E_{t(c),//,0,mean,i}$ the in-plane mean modulus of elasticity along the grain of face veneer for compression or tension.

$G_{\perp,0,mean,2}$ the planar mean shear modulus along the grain of face veneer.

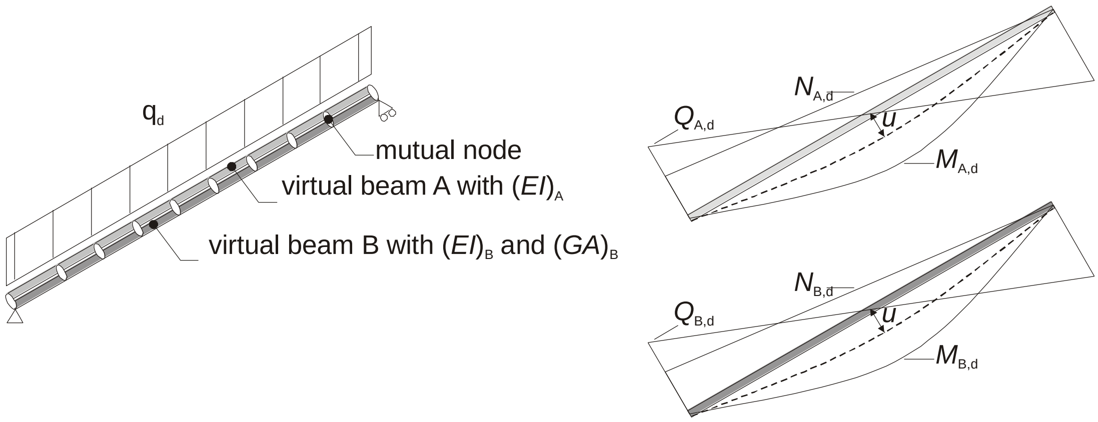


Figure A.4.12 - E.g. a simply supported Kreuzinger beam of type B2 or C2

In figure A.4.12 a design example is given. The stressed skin panel of type B2 or C2 is now described as a virtual beam A with the own bending stiffness $(EI)_A$ and a virtual beam B with the Steiner bending stiffness $(EI)_B$. Both beams are placed parallel to each other and they are connected with mutual nodes.

The resistance of the combined virtual beams A and B can now calculated to determine the maximum design internal forces.
The calculated virtual design bending, shear and axial forces ($M_{d,A}$, $Q_{d,A}$, $N_{d,A}$, $M_{d,B}$, $Q_{d,B}$, $N_{d,B}$) are then translated to the design bending, axial and shear stresses in each different layer *i*.

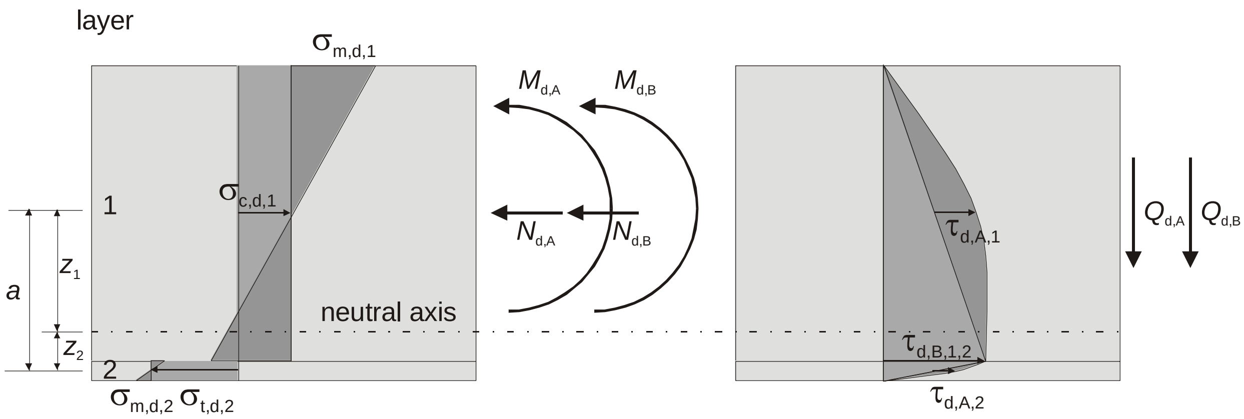


Figure A.4.13 - Stresses in the stressed skin panel of type B2 or C2

A.4.5.1.4 Compression or tension resistance in combination with bending

Depending on the direction of the moment $M_{d,B}$ and the axial forces $N_{d,A}$ and $N_{d,B}$ in the structure, every layer can experience compression or tension stress. In this example we assume that the upper wooden rib experiences compression and the lower wood-based skin experiences tension.

Design bending stress in layer 1 (upper wooden rib):

$$M_{d,1} = \frac{E_{0,mean,1} \cdot I_1}{(EI)_A} \cdot M_{d,A} \quad \Rightarrow \quad \sigma_{m,d,1} = \frac{M_{d,1}}{W_1}$$ (shown in figure A.4.13 as $\sigma_{m,d,1}$)

where:

$$W_1 = \frac{b_1 \cdot d_1^2}{6}$$ (for the wooden rib)

Design compression stress in layer 1 (upper wooden rib):

$$N_{d,1} = \frac{E_{0,mean,1} \cdot A_1 \cdot z_1}{(EI)_B} \cdot M_{d,B} + \frac{E_{0,mean,1} \cdot A_1}{\sum_{i=1}^{2} E_{t(c),//,0,mean,i} \cdot A_i} \cdot \left(N_{d,A} + N_{d,B}\right) \Rightarrow \sigma_{c,d,1} = \frac{N_{d,1}}{A_1}$$

(shown in figure A.4.13 as $\sigma_{c,d,1}$)

The maximum combined design compression and bending stress must be compared to the combined design compression and bending strength along the grain of the upper wooden rib.

$$\left(\frac{\sigma_{c,d,1}}{f_{c,0,d,1}}\right)^2 + \frac{\sigma_{m,d,1}}{f_{m,d,1}} \leq 1{,}00$$

Design bending stress in layer 2 (lower wood-based skin):

$$M_{d,2} = \frac{E_{m,\perp,0,mean,2} \cdot I_2}{(EI)_A} \cdot M_{d,A} \quad \Rightarrow \quad \sigma_{m,d,2} = \frac{M_{d,2}}{W_2}$$

(shown in figure A.4.13 as $\sigma_{m,d,2}$)

where:

$$W_2 = \frac{b_{ef,2} \cdot d_2^2}{6}$$ (for the wood-based skin and $b_{ef,2}$ according to A.4.5.1.1)

Design tension stress in layer 2 (lower wood-based skin):

$$N_{d,2} = \frac{E_{t(c),//,0,mean,2} \cdot A_2 \cdot z_2}{(EI)_B} \cdot M_{d,B} + \frac{E_{t(c),//,0,mean,2} \cdot A_2}{\sum_{i=1}^{2} E_{t(c),//,0,mean,i} \cdot A_i} \cdot \left(N_{d,A} + N_{d,B}\right) \Rightarrow \sigma_{t,d,2} = \frac{N_{d,2}}{A_2}$$

(shown in figure A.4.13 as $\sigma_{t,d,2}$)

The maximum combined design tension and bending stress must be compared to the combined design in-plane tension strength along the grain of face veneer and the design planar bending strength along the grain of face veneer of the lower wood-based skin.

$$\frac{\sigma_{t,d,2}}{f_{t,//,0,d,2}} + \frac{\sigma_{m,d,2}}{f_{m,\perp,0,d,2}} \leq 1{,}00$$

A.4.5.1.5 Shear resistance at interface of adjoining layers

Design shear stress at interface of adjoining layers 1 and 2:

$$\tau_{d,B,1,2} = \frac{Q_{d,B}}{EI_B} \cdot \frac{\sum_{i=1}^{1} E_{t(c),//,0,mean,i} \cdot A_i \cdot z_i}{\min\begin{cases} b_1 \\ b_{ef,2} \end{cases}}$$

(shown in figure A.4.13 as $\tau_{d,B,1,2}$)

The maximum design shear stress at interface of adjoining layers 1 and 2 must be compared to the minimum value of the design shear strength of layer 1 (upper wooden rib) or the design planar shear strength along the grain of face veneer of layer 2 (lower wood-based skin).

$$\tau_{d,B,1,2} \leq \min\begin{cases} f_{v,d,1} \\ f_{v,\perp,0,d,2} \end{cases}$$

A.4.5.1.6 Shear resistance

Design shear stress in layer 1 (upper wooden rib):

$$\tau_{d,A,1} = \frac{E_{0,mean,1} \cdot I_1}{(EI)_A} \cdot Q_{d,A} \cdot \frac{3}{2} \cdot \frac{1}{d_1 \cdot b_1}$$ (shown in figure A.4.13 as $\tau_{d,A,1}$)

$$\tau_{d,B,0,1} = 0$$

$$\tau_{d,B,1,2} = \frac{Q_{d,B}}{EI_B} \cdot \frac{\sum_{i=1}^{1} E_{t(c),//,0,mean,i} \cdot A_i \cdot z_i}{\min\begin{cases} b_1 \\ b_{ef,2} \end{cases}}$$ (shown in figure A.4.13 as $\tau_{d,B,1,2}$)

$$\tau_{1,d,1} = \min\begin{cases} \tau_{d,B,0,1} \\ \tau_{d,B,1,2} \end{cases} = 0$$

$$\tau_{2,d,1} = \left|\tau_{d,B,0,1} - \tau_{d,B,1,2}\right| = \tau_{d,B,1,2}$$

if $\tau_{d,A,1} > \frac{\tau_{2,d,1}}{4} \Leftrightarrow$ if $\tau_{d,A,1} > \frac{\tau_{d,B,1,2}}{4}$:

$$\tau_{max,d,1} = \tau_{d,A,1} + \tau_{1,d,1} + \frac{\tau_{2,d,1}}{2} + \frac{\tau_{2,d,1}^2}{16 \cdot \tau_{d,A,1}} \Leftrightarrow \tau_{max,d,1} = \tau_{d,A,1} + \frac{\tau_{d,B,1,2}}{2} + \frac{\tau_{d,B,1,2}^2}{16 \cdot \tau_{d,A,1}}$$

if $\tau_{d,A,1} \leq \frac{\tau_{2,d,1}}{4} \Leftrightarrow$ if $\tau_{d,A,1} \leq \frac{\tau_{d,B,1,2}}{4}$:

$$\tau_{max,d,1} = \tau_{1,d,1} + \tau_{2,d,1} \Leftrightarrow \tau_{max,d,1} = \tau_{d,B,1,2}$$

The maximum design shear stress must be compared to the design shear strength of the upper wooden rib.

$$\tau_{max,d,1} \leq f_{v,d,1}$$

Design shear stress in layer 2 (lower wood-based skin):

$$\tau_{d,A,2} = \frac{E_{m,\perp,0,mean,2} \cdot I_2}{(EI)_A} \cdot Q_{d,A} \cdot \frac{3}{2} \cdot \frac{1}{d_2 \cdot b_2}$$ (shown in figure A.4.13 as $\tau_{d,A,2}$)

$$\tau_{d,B,1,2} = \frac{Q_{d,B}}{EI_B} \cdot \frac{\sum_{i=1}^{1} E_{t(c),//,0,mean,i} \cdot A_i \cdot z_i}{\min\begin{cases} b_1 \\ b_{ef,2} \end{cases}}$$ (shown in figure A.4.13 as $\tau_{d,B,1,2}$)

$$\tau_{d,B,2,3} = 0$$

$$\tau_{1,d,2} = \min\begin{cases} \tau_{d,B,1,2} \\ \tau_{d,B,2,3} \end{cases} = 0$$

$$\tau_{2,d,2} = \left|\tau_{d,B,1,2} - \tau_{d,B,2,3}\right| = \tau_{d,B,1,2}$$

if $\tau_{d,A,2} > \frac{\tau_{2,d,2}}{4} \Leftrightarrow$ if $\tau_{d,A,2} > \frac{\tau_{d,B,1,2}}{4}$:

$$\tau_{max,d,2} = \tau_{d,A,2} + \tau_{1,d,2} + \frac{\tau_{2,d,2}}{2} + \frac{\tau_{2,d,2}^2}{16 \cdot \tau_{d,A,2}} \Leftrightarrow \tau_{max,d,2} = \tau_{d,A,2} + \frac{\tau_{d,B,1,2}}{2} + \frac{\tau_{d,B,1,2}^2}{16 \cdot \tau_{d,A,2}}$$

if $\tau_{d,A,2} \le \frac{\tau_{2,d,2}}{4} \Leftrightarrow$ if $\tau_{d,A,2} \le \frac{\tau_{d,B,1,2}}{4}$:

$$\tau_{max,d,2} = \tau_{1,d,2} + \tau_{2,d,2} \Leftrightarrow \tau_{max,d,2} = \tau_{d,B,1,2}$$

The maximum design shear stress must be compared to the design planar shear strength along the grain of face veneer of the lower wood-based skin.

$$\tau_{d,max,2} \le f_{v,\perp,0,d,2}$$

The wood-based skin is supported by the relatively stiff wooden rib. Therefore the local wrinkling effect of the skin doesn't occur in the stressed skin panel of type B2 or C2.

A.4.5.1.7 Fastening of the stressed skin panel to the supporting structure

In case the stressed skin panel is supported by a timber structure, metal fasteners can be used to connect the stressed skin panel to the supporting structure. The stressed skin panel of type B2 or C2 should be fastened by connecting the wooden ribs to the supporting timber structure. The timber-to-timber connection must be calculated according to EN 1995-1-1.

A.4.5.2 Assessment of deflection at of serviceability limit states

A.4.5.2.1 Design value of the stiffness properties of each layer *i*

Both virtual beams A and B can now be loaded by combination of actions to be used for verification in the serviceability limit state to determine the maximum total deflection.

The final deformation of the stressed skin panel fabricated from members which have different creep properties should be calculated using modified final stiffness moduli ($E_{fin,i}$ and $G_{fin,i}$), which are determined by dividing the instantaneous values of the modulus for each member ($E_{mean,i}$ and $G_{mean,i}$) by the appropriate value of ($1+k_{def,i}$).
A load-combination which consists of actions belonging to different load duration classes, the contribution of each action to the total deflection should be calculated separately using the appropriate k_{def} values.

Final stiffness properties of each action using the appropriate k_{def} values for <u>virtual beam A</u>:

$$E_{fin,i} = \frac{E_{mean,i}}{1 + \psi_2 \cdot k_{def,i}}$$

concerning the wood-based skin with the grain of face veneer parallel to the span direction:
$E_{mean,i}$ the <u>planar</u> mean modulus of elasticity for bending along the grain of face veneer $E_{m,\perp,0,mean}$.
concerning the wooden rib core:
$E_{mean,i}$ the mean modulus of elasticity along the grain $E_{0,mean}$.

Final stiffness properties of each action using the appropriate k_{def} values for <u>virtual beam B</u>:

$$E_{fin,i} = \frac{E_{mean,i}}{1 + \psi_2 \cdot k_{def,i}}$$

The shear moduli and the slip moduli of the connections should also be modified using the modification factor k_{def}.

$$G_{fin,i} = \frac{G_{mean,i}}{1 + \psi_2 \cdot k_{def,i}} ; \quad c_{fin,i} = \frac{\sum_{i=1}^{n-1} c_i}{1 + \psi_2 \cdot k_{def}}$$

concerning the wood-based skin:

$E_{mean,i}$ the in-plane mean modulus of elasticity for compression or tension along the grain of face veneer $E_{t(c),//,0,mean}$.

$G_{mean,i}$ the planar mean shear modulus along the grain of face veneer $G_{\perp,0,mean}$.

concerning the wooden rib core:

$E_{mean,i}$ the mean modulus of elasticity along the grain $E_{0,mean}$.

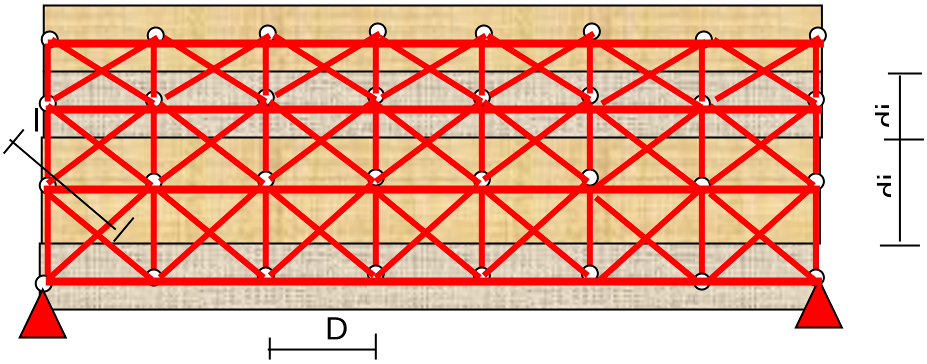
$G_{mean,i}$ the mean shear modulus G_{mean}.

ψ_2 a factor for the quasi-permanent value of a variable action. For permanent actions, ψ_2 should be taken equal to 1,00.

c_i the slip modulus between the layers of the stressed skin panel.

A.5 Model N

A somewhat more complicated, but universal calculation model for the composite cross-section could be as follows:



If the posts of this multi-member truss are designed to be rigid, for example by calculating with Ap=Dl*(di+di+1)/2, and if the influence of the expansions of the truss flanges on the shear stiffness is neglected, the shear stiffness between two layers is

$$S = G\frac{2t_{ideell}}{(d_i + d_{i+1})}$$

$$t_{ideell} = \frac{E}{G}\frac{\Delta l(d_i + d_{i+1})}{2\frac{l_d^3}{2A_d}}$$

$$S = E\frac{2\Delta l A_d}{l_d^3}$$

$$\frac{1}{S} = \frac{1}{C_{i,i+1}} + \frac{d_i}{2G_i b_i} + \frac{d_{i+1}}{2G_{i+1} b_{i+1}}$$

$$A_d = \frac{l_d^3}{2\Delta l E}\frac{1}{\frac{1}{C_{i,i+1}} + \frac{d_i}{2G_i b_i} + \frac{d_{i+1}}{2G_{i+1} b_{i+1}}}$$

l_d= length of diagonals

A_d= area of diagonals

E= E-modulus of the diagonals (free to chose)

By means of the area of the diagonals each truss plane can be adapted to the shear stiffness between two loadbearing layers of the composite cross-section. The skins pass through the entire length of the composite beam without intermediate hinge.

The fact that more time and work is needed for the system is partly compensated by the result, which means that the stresses calculated with this system are already the resulting stresses.
Further, by entering a shear stiffness of the "layered beams", it is possible to take account of the shear deformation resulting from the proportionate transverse force of the relevant layers.

It is pointed out that for all systems, where the flexibility of the bond does not affect the action-effects of the composite beam, or for sandwich beams with two skins having a small own bending stiffness, the complicated calculation with the equivalent truss system and the decomposition of the system into virtual beams can be omitted.

A.6 Material properties

A.6.1 Wood-based skins

The material characteristics of the components, are taken from the product to be assessed. They can be taken from DoPs or established by testing.

A.6.2 Loadbearing insulation

The appropriate material factors (γ_M, k_{mod}, k_{def}) are missing in the Eurocodes, so the default values given in this chapter may be used. The material characteristics shall be determined by testing according to EN 14509 or the default values given in this chapter may be used.

A.6.2.1 Testing of load bearing insulation (EPS, XPS, PUR and PIR)

Testing shall be performed according to EN 14509 for the following material characteristics:

- Compression according to section A.2
- Tension according to section A.1
- Shear according to section A.3
- Compression or tension E-modulus according to section A.2
- Shear modulus according to section A.3
- Density according to section A.8
- Creep coefficient according to section A.6

The *G*-modulus for EPS can also be measured by tests according to EN 12090.

A.6.2.2 Default values for EPS (expanded polystyrene)

EPS class names are based on the compression strength of the EPS.

EPS acc. EN 13163		Strength class					
Material properties		EPS60	EPS80	EPS100	EPS120	EPS150	EPS200
Strength in N/mm²							
compression	$f_{c,k}$	0,060	0,080	0,100	0,120	0,150	0,200
tension	$f_{t,k}$	0,100	0,125	0,150	0,170	0,200	0,250
shear	$f_{v,k}$	0,050	0,060	0,075	0,085	0,100	0,125
Stiffness in N/mm²							
E-modulus	$E_{t(c),mean}$	4	5	6	7	9	11
G-modulus	G_{mean}	1,82	2,27	2,73	3,18	4,09	5,00
Density in kg/m³							
density	ρ_k	15	17,5	20	22,5	27,5	32,5

A.6.2.2.1 Ultimate limit states

The partial factor for material properties of the insulation materials can be taken from EN 14509, Table E.9. An assessment acc. to Eurocode is necessary in case of test results with $v>0,1$.

Strength modification factor: k_{mod}, effecting the strength parameters and depending on the load duration and the moisture content in the structure.

Load duration class	Service class 1	Service class 2
permanent	0,25	0,25
long-term	0,50	0,50
medium-term	0,75	0,75
short-term	1,00	1,00
instantaneous	1,00	1,00

A.6.2.2.2 Serviceability limit states

The deformation modification factor of the insulation materials can be taken from EN 14509, clause E.7.6. k_{def}, is equivalent to the creep coefficient φ_t (long-term) in EN 14509.

Deformation modification factor of EPS, XPS, PUR and PIR:

k_{def} = 7,00

A.6.3 Wooden ribs

The material characteristics of the components, are taken from the product to be assessed. They can be taken from DoPs or established by testing.