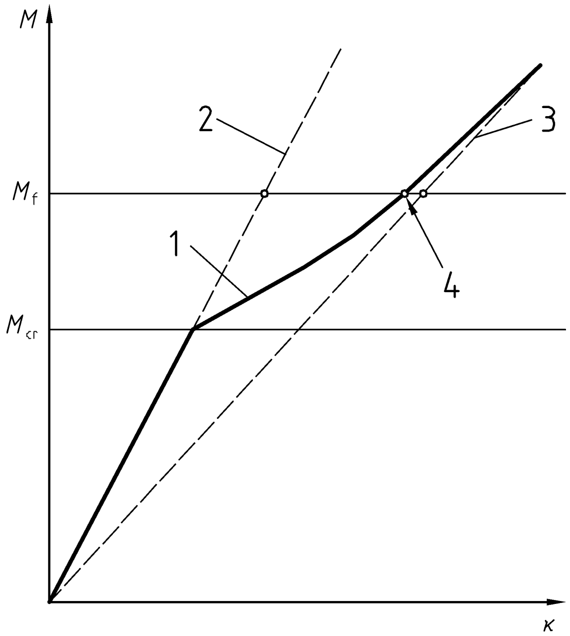
(6) For partly cracked components a rigorous method of assessing deflections using the method given in (3) above is to compute the curvatures at several sections along the component and then calculate deflection by numerical integration. When the effort involved in this is not deemed justified, it will be acceptable to compute the deflection twice, assuming the whole member to be in the uncracked and cracked condition in turn and then employ Formula (A.44).



Key

1 partly cracked state

2 uncracked state

3 cracked state

4 curvature given by Formula (A.40)

M bending moment

M_f bending moment under the frequent combination of loading

M_{cr} cracking moment of the section

κ curvature

Figure A.14 — Moment curvature relationship

A.10 Detailing of reinforcement

A.10.1 General

(1)P Minimum requirements are given in 5.2.7.

(2)P Anchorage of the longitudinal tensile or compressive reinforcing bars shall be provided by bond and in such parts of components, where the bond stress under design loads (in ULS) exceeds the design bond strength f_{bd}, exclusively by welded transverse bars. For the tensile bars there shall be always at least one welded transverse bar within the support length of the component.

A.10.2 Bond

A.10.2.1 Characteristic bond strength

(1)P If bond shall be taken into account in design, the characteristic bond strength f_{bk} shall be derived from results of tests carried out in accordance with EN 12269-1. This value may be used for all cases where the cover is at least that of the test specimens.

A.10.2.2 Design bond strength

(1)P The design bond strength shall be derived from the characteristic short-term bond strength according to Formula (A.46).

$$f_{bd} = k_1\, k_2\, f_{bk}/\gamma_C \tag{A.46}$$

where

k_1 is a reduction factor (short-term effect) taking into account the relationship between the component and the test specimen (geometrical parameters). In absence of more accurate test results, k_1 can be put equal to 0,8;

k_2 is a reduction factor (long term effect) taking into account influences (long term and temperature). In absence of more accurate test results, k_2 can be put equal to 0,2;

f_{bd} is the design bond strength;

f_{bk} is the characteristic short-term bond strength determined in accordance with EN 12269-1;

γ_C is the partial safety factor of AAC for brittle failure.

NOTE The value of γ_C for use in a country may be found in its national application document. The recommended values for use are given in Table D.4.

(2)P If the characteristic bond strength has not been declared, f_{bd} shall be taken as zero, i.e. bond may not be taken into account in design.

A.10.3 Anchorage

(1)P Anchorage of longitudinal reinforcing bars shall be provided by means of welded transverse bars in such parts of the components where the bond stress under design load (ULS) exceeds the design bond strength. The number and distribution of transverse bars in these parts shall be such that in any section Formula (A.47) is satisfied for all reinforcing bars.

$$F_{RA} \geq F_{ld} \tag{A.47}$$

where

F_{RA} is the anchorage capacity of the transverse anchorage bars;

F_{ld} is the design tensile force in the longitudinal reinforcement.

(2) F_{RA} and F_{ld} may be determined according to Formulae (A.48) and (A.51).

$$F_{RA} = \sum_{i=1}^{n_t} \min\left[0{,}83\Phi_{tot} t_t f_{ld}(n_t); 0{,}60 n_l F_{wg}/\gamma_s\right] \tag{A.48}$$

where

F_{wg} is the declared shear strength of a welded joint, see Formula (8);

n_l is the number of longitudinal bars;

n_t is the number of transverse bars between the section concerned and the end of the component;

ϕ_{tot} is the effective diameter of the transverse anchorage bars. Declared mean outer diameter of the transverse bar and corrosion protection coating $\phi_{tot,g}$, see 4.3.1, may be used as the effective diameter ϕ_{tot} when the applicability of $\phi_{tot,g}$ is verified by test (according to EN 15361). Otherwise $\phi_{tot} = \phi_t$, where ϕ_t is the diameter of the transverse anchorage bar. Effective diameter ϕ_{tot} shall not be taken greater than the following values: $\phi_{tot} \leq 1{,}5\ \phi_l$ in case of tension in the longitudinal bar and $\phi_{tot} \leq 1{,}0\ \phi_l$ in case of compression in the longitudinal bar, where ϕ_l is the diameter of the longitudinal reinforcement bars.

NOTE 1 The value of ϕ_{tot} ($\phi_{tot} = \phi_t$ obtained by testing according to EN 15361) to be introduced in Formula (A.48) for design may be found in the national application document in the country of use.

t_t is the total effective length of the transverse anchorage bars, see Formula (A.50);

$f_{ld}\ (n_t)$ is the design bearing strength of AAC depending on n_t, see Formula (A.49);

γ_S is the partial safety factor for reinforcing steel, see NOTE 2.

NOTE 2 The value of γ_S for use in a country may be found in its national application document. The recommended value for use is given in Table D.4.

The design bearing strength f_{ld} of AAC (resistance against transverse pressure under a transverse bar) is determined according to Formula (A.49):

$$f_{ld} = K_{c1} m \left(e / \varphi_{tot}\right)^{1/3} \alpha\ f_{ck} / \gamma_C \leq K_{c2} f_{ck} / \gamma_C \qquad (A.49)$$

where

f_{ck} is the characteristic compressive strength of AAC;

γ_C is the partial safety factor of ACC for brittle failure. However, safety factor γ_C may be taken for ductile failure when calculating the anchorage capacity of the transverse bars which all are at the support, see NOTE 3;

m is a factor for consideration of existing transverse compression (e.g. support pressure) in the anchorage zone, to be taken as

$$m = 1 + 0{,}3 \cdot \frac{n_p}{n_t}$$

where

n_p is the number of transverse anchorage bars within the zone of transverse pressure (e.g. at the support);

e is the distance of the axis of the transverse bars in the anchorage zone to the nearest surface of the component (see Figure A.15);

K_c is the factor for maximum AAC bearing strength. K_{c1} and K_{c2} (see Table A.1) are depending on the bond class B1 and B2, see 4.4.

Table A.1 — Bond Classes

Bond class	K_{c1}	K_{c2}
B1	1,35	2,20
B2	1,50	2,70

For Bond class B2 K_{c2} may normally be taken as 2,70. It may be increased to 3,20 for the calculation of the anchorage capacity of cross bars at the support subjected to transverse pressure.

NOTE 3 The value of γ_C for use in a country may be found in its national application document. The recommended value for use is given in Table D.4.

The total effective length t_t of the transverse anchorage bar is determined according to Formula (A.50).

$$t_t = (t_1 + t_2 + \ldots + t_n) \tag{A.50}$$

where every $t_i^{'} + t_i^{''} = t_i \leq 14\varphi_t$ and every $t_i^{'} + t_i^{''} \leq 8\varphi_t$ (see Figure A.15).

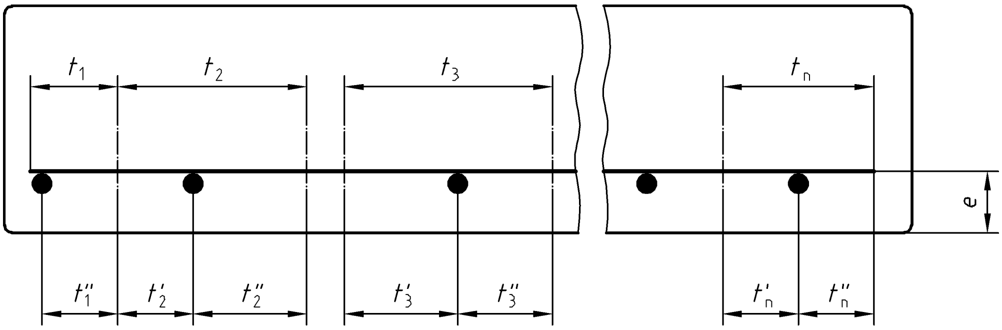


Figure A.15 — Effective length of transverse anchorage bars

The tensile force F_{ld} in the longitudinal reinforcement under design load is determined according to Formula (A.51):

$$F_{ld} = M_{da} / z \tag{A.51}$$

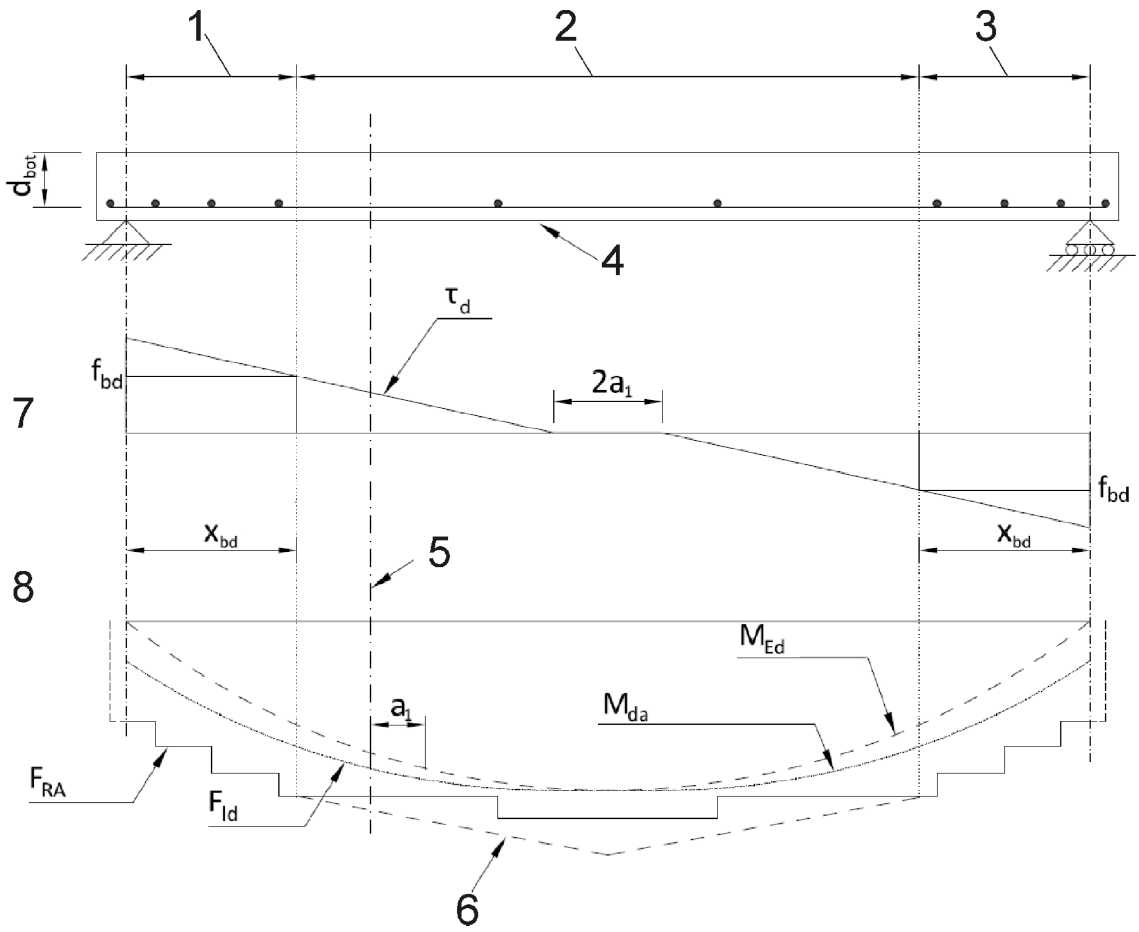
where

M_{da} is the design bending moment at the section concerned obtained by a horizontal displacement a_1, of the envelope line of the design bending moment distribution, see Figure A.16;

For shear reinforced and non shear reinforced components: $a_1 = d$

d is the effective depth of the cross section;

z is the internal lever arm; in the anchorage analysis the approximate value $z = 0,9\ d$ can normally be used.



Key

1 anchorage using cross bars

2 anchorage using cross bars or bond strength

3 anchorage using cross bars

4 cross bars in the middle zone

5 section concerned

6 anchorage using bond strength in the middle zone

7 bond stress of longitudinal reinforcement

f_{bd} design bond strength according to Formula (A.49)

8 tensile force compared to the anchorage capacity

d_{bot} effective depth of cross section

F_{ld} tensile force

F_{RA} anchorage capacity

M_{da} enlarged design bending moment curve

M_{Ed} design bending moment curve

τ_d bond stress under design loads

x_{bd} distance from support where bond stress exceeds design bond strength

Figure A.16 — Envelope line for determining the tensile force in the longitudinal reinforcement

(3)P When bond is not taken into account, the welded transverse bars within a distance d from the end of the component shall be able to resist a tensile force equal to V_{Sd}. V_{Sd} may not be reduced in accordance with A.4.1.1 (8).

A.11 Support length

The manufacturer shall declare the minimum support length when relevant.

The support length a_0 (see Figure A.17) shall be designed taking into account the following influences:

— support pressure;

— tolerances;

— splitting or spalling of support material;

— distance *c* between the last transverse bar necessary for anchorage and the end of the component;

— splays.

There shall always be at least one welded transverse bar within the support length of the component.

The support length a_0 (minimum values) shall not be less than (tolerances considered) the following recommended values:

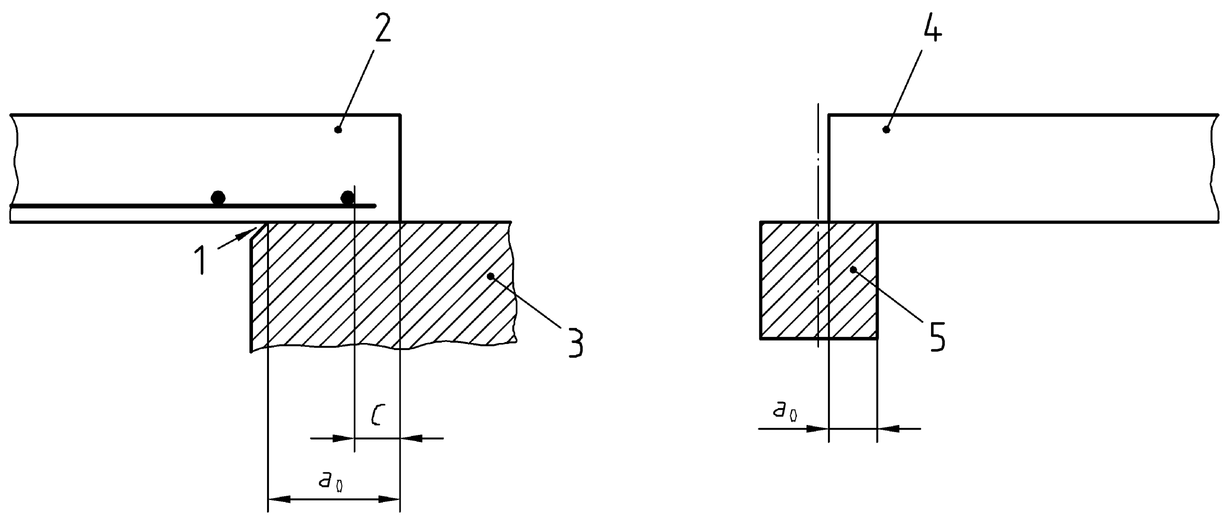
— beams: 60 mm;

— floor components: 40 mm;

— roof components: 35 mm.

NOTE Larger support lengths than given above can be required to avoid the failure in the supporting structure.

Dimensions in millimetres



Key

1 Splay
2 Roof/floor component
3 Support
4 wall component
5 column

Figure A.17 — Support length a_0

Annex B
(normative)

Design by testing

NOTE 1 The design by testing is based on the concept of EN 1990:2002 and its Annex D as far as possible.

NOTE 2 Design values to be used can be determined according to the provision of this Annex B, using the relevant partial safety factors.

NOTE 3 Values of the properties can be determined on the basis of tests and be given as declared values in the CE-marking, according to the relevant provision in Annex ZA. The declared values are based on one of the three methods expressed in Guidance Paper L, Clause 3.3.3.2 (a).

NOTE 4 For the choice of design method see 5.2.4.1.

B.1 General

(1)P Depending on the character of the individual clauses, distinction is made in this Annex B between Principles and Application rules.

(2)P The Principles comprise

— general statements and definitions for which there is no alternative, as well as

— requirements and analytical models for which no alternative is permitted unless specifically stated.

(3)P In this Annex B the Principles are marked by a number in brackets followed by the letter P.

(4)P The Application Rules are generally recognized rules which follow the principles and satisfy their requirements.

(5)P In this Annex B Application Rules are those paragraphs marked by a number in brackets which is not followed by the letter P.

(6)P In this annex it is presumed that the manufacturer declares the characteristic loadbearing capacities, type of failure and/or other characteristic properties of the component subject to initial type testing and factory production control by testing.

(7)P The loadbearing capacity shall be declared either by the load and/or by cross section capacities, e.g. moment and shear capacity, derived from the test results.

(8)P The declared values shall be established (by statistical interpretation) on the basis of the initial type testing and factory production testing of components for a direct application or derived from a model including testing for an extended application.

(9) A direct application presumes that a single product or a range of products, subjected to initial type testing and factory production testing of components, is covered by the declared values.

(10) An extended application presumes that the range of products or related products is covered by a declared tentative model, based on a calculation method (theoretical or empirical), verified by testing of samples representative for the range of products.

(11)P The manufacturer shall demonstrate compliance, in accordance with 4.2.3, between declared values and the characteristic values derived from testing of the finished product in accordance with 6.3.3 and Table 13 and Table 14.

(12)P For structural components representative test results from the factory production control shall be utilized by qualified personnel to establish the statistical basis for the characteristic values in accordance with 4.2.3.

(13) Compliance may be demonstrated in accordance with Annex F.

B.2 Safety evaluation

B.2.1 General

(1)P Safety evaluation is carried out in accordance with Annex D.

(2)P In analysis of ultimate limit states the partial safety factors shall consider any relevant safety aspect, i.e. safety classes from consequences of failure, level of factory production control, long term effects, reliability of test or design methods and type of failure.

B.2.2 Brittle and ductile failure

(1)P It is necessary to differentiate between ductile and brittle failure. Ductile failure is a failure with an early warning. Other types of failure are considered as brittle. The evaluation of the type of failure shall be made on the basis of observations in the tests performed in accordance with EN 1356 and EN 1740.

(2)P The manufacturer shall state the type of failure for the component as ductile or brittle.

(3) Ductile failure is assumed when at least one of the following states is achieved:

— failure of the component due to yielding of the reinforcement without decrease of the loadbearing capacity,

— failure of the component recognized by the appearance of visible cracks distributed in a pattern anticipating the failure mode without instant decrease of loadbearing capacity,

— for transversally loaded components, if deflection before failure is ≥ (3/200) L, where L is the span length (between the centre points of the supports).

In all other cases the failure type shall be considered as brittle. If the failure type is not consistently ductile for a type of samples subjected to testing, it shall be declared as brittle.

B.3 Ultimate limit state

B.3.1 General

(1)P In the ultimate limit state the components shall possess an adequate safety level in relation to the effect of specified actions and type of failure.

(2)P It shall be verified that the design loadbearing capacity determined in accordance with this clause is higher than or equal to the design effects of the actions applied.

(3)P For all types of failure the loadbearing capacity shall be determined in relation to the magnitude and position of the applied loads at testing.

(4)P The actual failure type shall be declared together with the loadbearing capacity. If the position of the applied loads differs from that in the test methods given in this B.3, it shall be declared which load case the declared capacity is valid for.

B.3.2 Transversely loaded components

B.3.2.1 Loadbearing capacity

(1)P The characteristic loadbearing capacity of transversely loaded components shall be determined on the basis of the performance test method according to EN 1356. The declared loadbearing capacity may be used to derive the equivalent uniformly distributed loads and/or separate values for bending and shear capacity.

(2)P In design, the bending and shear capacity derived from the test results shall always be conservative to all other combinations of loads considering their positions and magnitude.

(3) The shear capacity is always conservative when determined and declared from the performance test according to EN 1356 with loads positioned in the outer quarter points of the span length. To determine the maximum shear capacity by the performance test EN 1356, other positions of actions may be chosen. The load position in the test shall be shown to give a conservative shear capacity compared to all other possible positions and types of actions.

(4)P For determination of the shear capacity of components without shear reinforcement, actions are not allowed to be positioned closer to the support than 5d, where d is the component thickness.

(5) The characteristic value for shear capacity of a component may be fully used for all shear spans smaller than that tested, provided that the cross section and the number, diameter and position of transverse bars in the anchorage zones are the same (see Figure B.1).

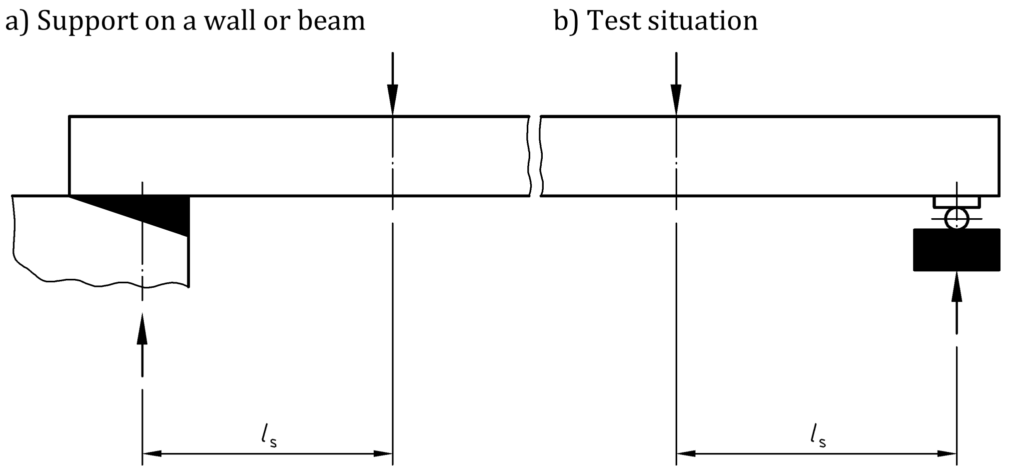


Figure B.1 — Definition of shear span l_s

(6)P Components may be designed without stirrups or with stirrups for improved shear capacity (see Figure B.2). If stirrups are used, they shall be welded to the longitudinal bars.

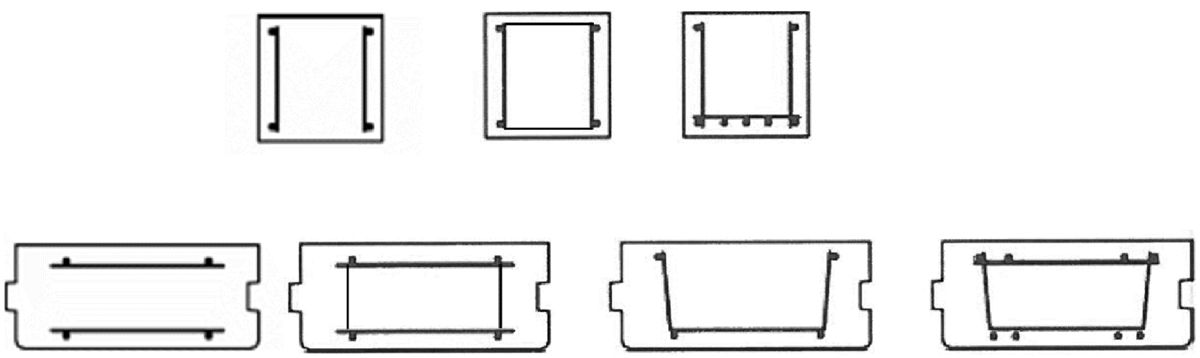


Figure B.2 — Typical reinforcement layouts in AAC-components

B.3.2.2 Design values for bending and shear capacity

(1)P Design values for bending capacity and shear capacity shall be determined from the declared characteristic values derived from test results according to B.3.2.1 taking into account the partial factors.

(2)P The design value of bending capacity shall be determined as follows:

$$M_\mathrm{d} = \frac{1}{\gamma_\mathrm{comp}} M_\mathrm{k} \tag{B.1}$$

where

M_k is the declared characteristic value of bending capacity (see 4.2.3) calculated from the results of a test series, using the test method described in EN 1356, including the dead weight and with loads normally positioned at the outer quarter points of the span;

γ_comp is the partial safety factor for components.

NOTE 1 The value of γ_comp for use in a country may be found in its national application document. The recommended values for use are given in Table D.4.

(3)P The design value of shear capacity shall be calculated as follows:

$$V_\mathrm{d} = \frac{1}{\gamma_\mathrm{comp}} V_\mathrm{k} \tag{B.2}$$

where

V_k is the declared characteristic value of shear capacity (see 4.2.3) calculated from the results of a test series, using the test method described in EN 1356, including the dead weight and with loads in stated positions. Normally the loads are positioned at the outer quarter points of the span.

γ_comp is the partial safety factor for components.

NOTE 2 The value of γ_comp for use in a country may be found in its national application document. The recommended values for use are given in Table D.4.

B.3.2.3 Multilayer components

(1)P The loadbearing capacity and the design values for a transversely loaded multilayer component, with interaction between the layers, shall be determined in accordance with B.3.2.1 and B.3.2.2. The design criteria in B.3.2.4. shall be considered.

(2)P The shear resistance between the layers shall, if it is utilized in design, be declared on the basis of testing according to EN 1742.

(3)P The first recognized failure mode in one of the structural layers shall be considered as being the failure for the whole component.

(4)P Long term effects shall be considered.

B.3.2.4 Design criteria

(1)P For design purposes the manufacturer shall give necessary information based on detailing, assumptions and results, from initial type-testing of the component (see 6.2) and factory production control (see 6.3). Performance tests shall be executed in accordance with EN 1356 and EN 1740.

(2)P Holes, grooves or chases shall only be allowed without detailed analysis if

1) they have the same or smaller dimensions than those used in the test situation and if they are placed in less critical positions,

2) they are in accordance with 5.2.7.3.