a) design for the ultimate limit state has been carried out in accordance with A.3 or A.5;

b) minimum reinforcement provisions of 5.2.7.2 are satisfied;

c) detailing is carried out in accordance with A.10.

(3) Long term effects may be taken into account by assuming a modulus of elasticity reduced by the factor $1/(1 + \varphi)$ (where φ is the creep coefficient according to 4.2.11) for situations where more than 50 % of the stress arise from quasi-permanent actions. Otherwise, they may be ignored.

(4) Stresses are checked employing section properties corresponding to either the uncracked or the fully cracked condition, whichever is appropriate.

(5) Normally, components may be considered to be uncracked if the bending moment under the frequent combination of loading, M_{f}, does not exceed the cracking moment of the section, M_{cr}, anywhere within the component. For the calculation M_{cr} the modulus of elasticity of AAC may be taken as $E_{\mathrm{c,eff}}$ (see Formula (A.43)) and its mean flexural strength 0,8 f_{cflm} derived from tests according to EN 1351 or determined by Formulae (5a) and (5b), see 4.2.5, respectively.

(6) Where an uncracked cross-section is used, the whole of the AAC section is assumed to be active, and both AAC and steel are assumed to be elastic in both tension and compression.

(7) Where a cracked cross-section is used, the AAC is assumed to be elastic in compression but to be incapable of sustaining any tension.

(8) At least the minimum area of reinforcement given by A.10.3 is required to satisfy the limitation of the stress in ordinary bonded reinforcement under the action of restrained imposed deformations.

A.9.3 Serviceability limit states of cracking

(1)P Cracking shall be limited to a level that will not impair the proper functioning of the structure or cause its appearance to be unacceptable.

(2)P Calculation of crack widths in order to ensure sufficient corrosion protection of the reinforcement is not necessary for AAC components, as this is achieved in connection with the requirement on the corrosion protective coating.

(3)P In order to achieve a general crack control, the requirements on minimum structural tensile reinforcement area in 5.2.7.2 shall be fulfilled for components under predominantly transverse load.

NOTE Cracking can occur in reinforced AAC components due to bending, shear, torsion or tension, resulting from either direct loading or restraint of imposed deformations. Different cracks can also arise from other causes, such as chemical attacks from the environment. Such cracks may be unacceptable, but their avoidance and control lie outside the scope of this clause.

A.9.4 Serviceability limit states of deformation

A.9.4.1 Basic considerations

(1)P The deformation of a component should not be such that it adversely affects its proper functioning or appearance.

(2)P Appropriate limiting values of deflection, taking into account the function of the structure and the nature of finishes, partitions and fixings, should be clearly defined, either as values declared by the manufacturer for current standard components or as values agreed with the client for components with specific purposes.

(3)P Generally, compliance with deflection limits should be checked by calculation. In many cases it is possible to employ the calculation method to formulate simple rules, such as limits to span/depth ratio which will be adequate to ensure compliance for a whole range of components. In such cases an explicit calculation for a specific component is not deemed necessary.

(4) The limiting deflection values given in (5) and (6) below are derived from ISO 4356 and may be considered as appropriate for buildings such as dwellings, offices, public buildings or factories.

(5) The calculated sag of roof and floor components subjected to quasi-permanent loads should be limited. The sag is assessed relative to the supports. Precamber may be used to compensate for some or all of the deflections.

NOTE 1 The above limit value for use in a country may be found in a national application document. The recommended value for the calculated sag of roof and floor components subjected to quasi-permanent loads is span/250.

(6) Deflections that may cause damage to partitions or other elements in contact with the component and occurring after installation of such members ("active" deflection) should be limited. This limit may be relaxed in cases where the elements which might suffer damage are known to be capable of withstanding greater deflections without being impaired.

NOTE 2 The above limit value for use in a country may be found in a national application document. The recommended value for the deflections that may cause damage to partitions or other elements in contact with the component and occurring after installation of such members ("active deflection") is span/500.

A.9.4.2 Checking deflections by calculation

(1)P Where a calculation is deemed necessary, the deflections shall be calculated under load conditions which are appropriate to the purpose of the check.

(2)P The calculation method shall represent the true behaviour of the component under relevant actions to an accuracy appropriate to the objectives of the calculation. In particular, where components are expected to be cracked, the influence of the cracks on the deformations should be taken into account.

(3)P Where appropriate, the following shall be considered:

— effects of creep and shrinkage;

— stiffening effect of the AAC in tension between the cracks;

— cracking resulting from previous loadings;

— possible slip of reinforcement due to poor bond properties;

— effects of prestrain if declared.

(4) When assessing cracking, the loadings to be taken into account should be at least those defined as “persistent design situation”. For the calculation of deflections it will normally be satisfactory to consider the deflections under the quasi-permanent combination of loading and assuming this load to be of long duration. For the calculation of “active” deflection, due consideration should also be taken to the additional loading that can occur under the frequent combination of loading and assuming this to be of short duration.

(5) Slip of reinforcement shall be taken into account in the cracked zone of the component, in accordance with A.9.2.2 (5), if the bond stresses under frequent combination of loading exceed f_{bd}, where f_{bd} is the design bond strength (see A.10.2.2).

A.9.4.3 Calculation method

(1) Two limiting conditions are assumed to exist for the deformation:

— uncracked condition:

In this state, steel and AAC act together elastically in both tension and compression.

— cracked condition:

In this state, the influence of the AAC in tension is ignored.

(2) The curvature κ can be determined using the Formulae (A.40), (A.41), and (A.42).

$$\kappa = \frac{M}{E_c I_i} \quad \text{(A.40)}$$

$$I_i = I_c + n I_s \quad \text{(A.41)}$$

$$n = \frac{E_s}{E_c} \quad \text{(A.42)}$$

where

E_c is the modulus of elasticity taken as E_{cm} for the short-term part of the load and as $E_{c,eff}$ for the long term part of the load, also when determining n;

I_i is the second moment of area (moment of inertia) of the reinforced AAC cross-section in the uncracked or cracked state depending on the load. In the cracked state only the compression zone of AAC and the reinforcement are taken into account.

(3) For loads of long duration creep should be allowed for by using an effective modulus of elasticity, $E_{c,eff}$, calculated from Formula (A.43).

$$E_{c,eff} = E_{cm} / (1 + \phi) \quad \text{(A.43)}$$

where

φ is the creep coefficient in accordance with 4.2.11;

E_{cm} is the mean modulus of elasticity of AAC.

(4) For creep classes ≤ 0,7 (see Table 3) the long term deflection can be calculated from Formula (A.43a)

$$y_\infty = 1{,}35 y_{el} \quad \text{(A.43a)}$$

where

y_∞ is the long term deflection under the quasi-permanent combination of loading;

y_{el} is the elastic short-term deflection; in case of pre-stressed components having precamber the precamber shall be considered in the determination of y_{el}.

(5) If M_f is greater than M_{cr}, the component is considered to behave in a manner intermediate between uncracked and cracked condition. For components subjected predominantly to flexure, an adequate prediction of behaviour is given by Formula (A.44).

$$p = k p_{II} + (1 - k) p_I \quad \text{(A.44)}$$

where

p is the parameter considered which may be, for example, a strain, a curvature or a deflection;

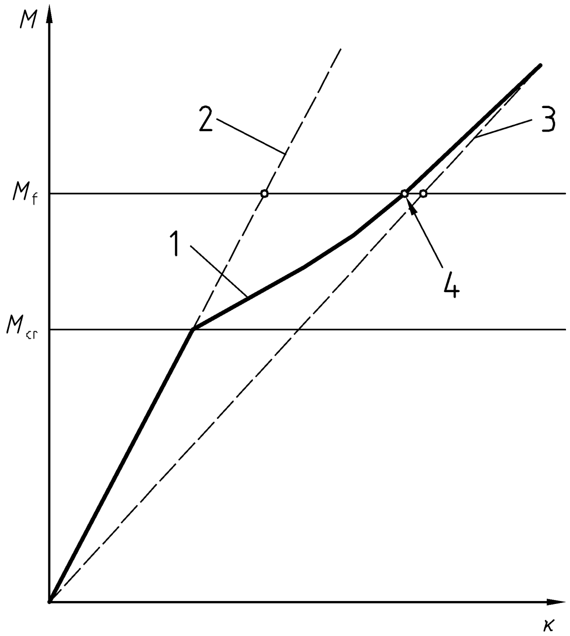
p_I and p_{II} are the values of this parameter calculated for the uncracked and fully cracked section, respectively;

k is a distribution coefficient given by Formulae (A.45a) and (A.45b).

$k = 1 - 0{,}8\ (M_{cr}/M_f)^2$ if slip may be ignored (see A.9.4.2 (5)); (A.45a)

$k = 1 - 0{,}4\ (M_{cr}/M_f)^2$ if slip may not be ignored (see A.9.4.2 (5)). (A.45b)

(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).

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

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):

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

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

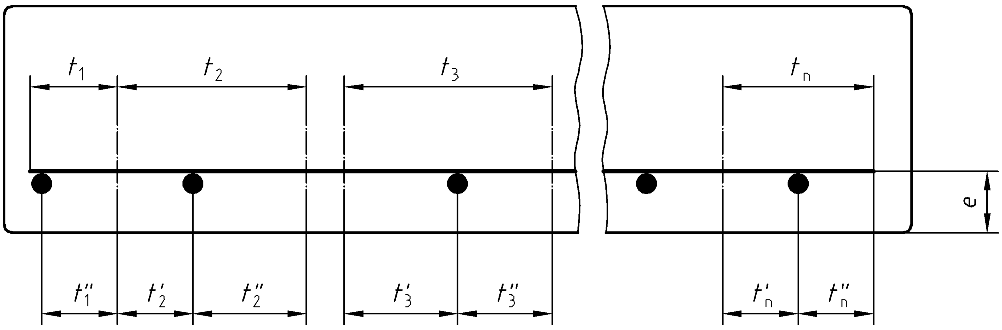


Figure A.15 — Effective length of transverse anchorage bars

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

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

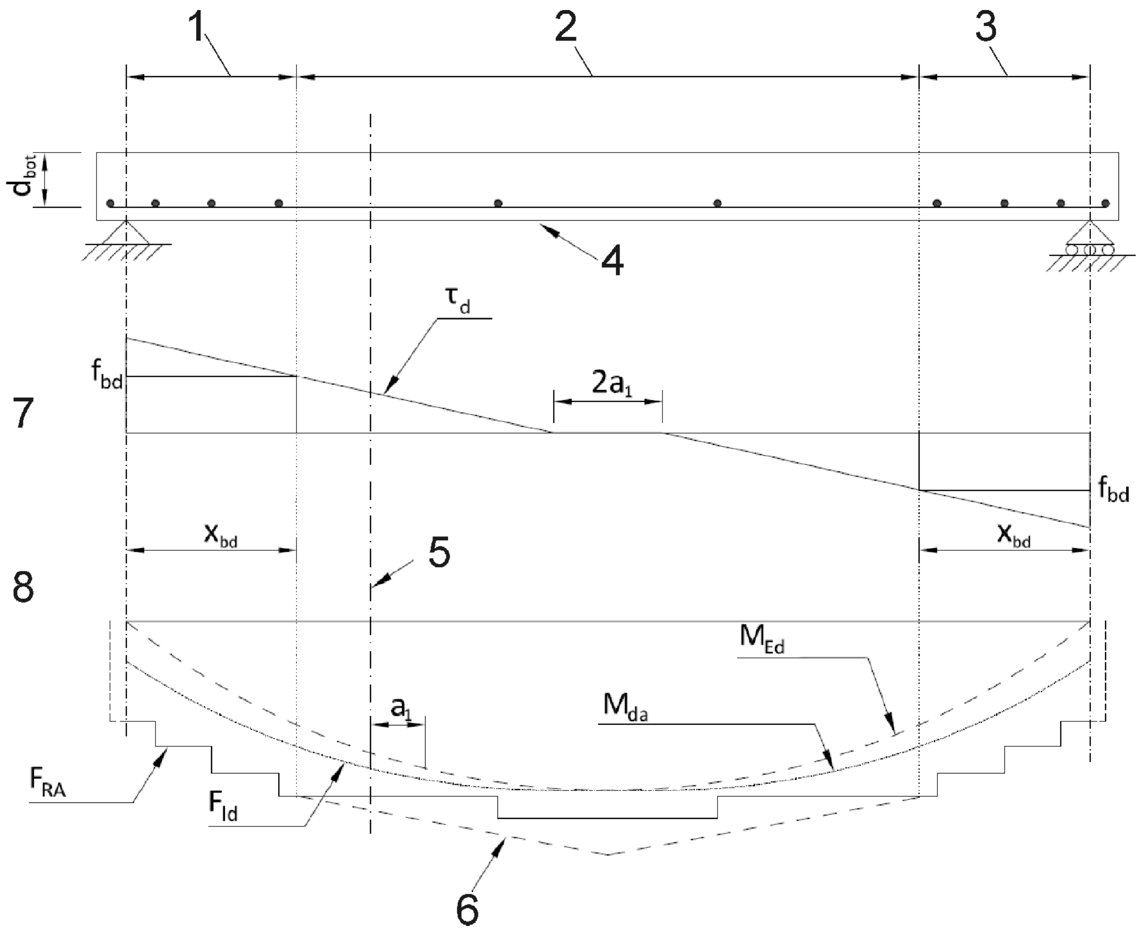
where

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:

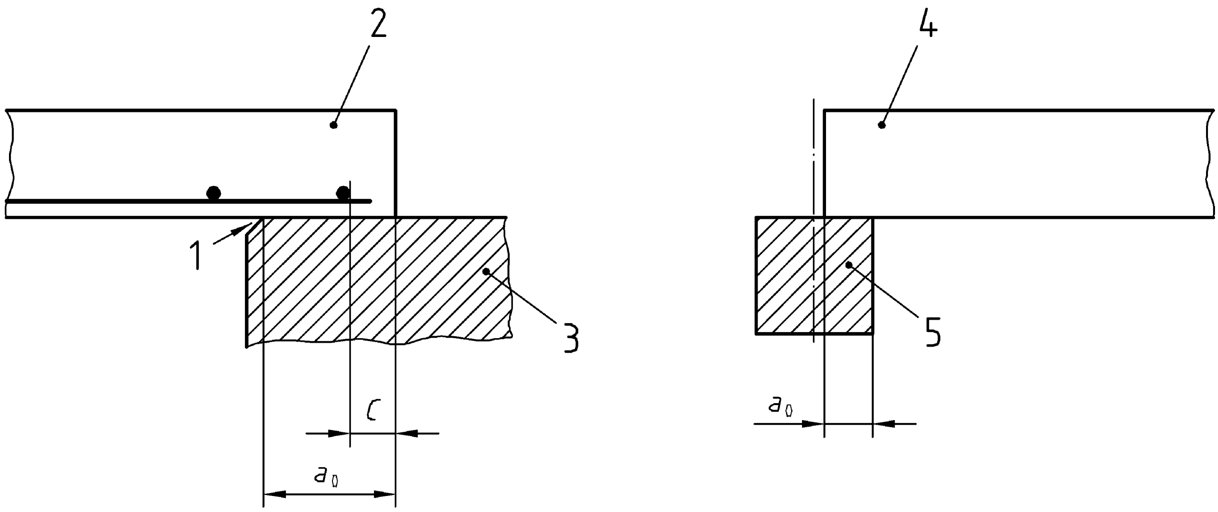
— beams: 60 mm;

— 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.