Deutsches Institut für Bautechnik

Zulassungsstelle für Bauprodukte und Bauarten

Bautechnisches Prüfamt

Eine vom Bund und den Ländern gemeinsam getragene Anstalt des öffentlichen Rechts

Mitglied der EOTA, der UEAtc und der WFTAO

National technical approval / General construction technique permit

Date: 8 Jul 2019

Reference: I 16-1.1.6-15/19

Number:
Z-1.6-238

Validity
from: **8 July 2019**
to: **1 January 2024**

Applicant:
Schöck Bauteile GmbH
Vimbucher Straße 2
76534 Baden-Baden (Steinbach), Germany

Subject of decision:
Schöck Combar reinforcing bar made from glass fibre reinforced plastic,
Nominal diameters: 8, 12, 16, 20, 25 and 32 mm

The subject named above is herewith granted a national technical approval (*allgemeine bauaufsichtliche Zulassung*)/general construction technique permit (*allgemeine Bauartgenehmigung*).
This decision contains 18 pages and one annex.
This national technical approval/general construction technique permit replaces national technical approval/general construction technique permit no. Z-1.6-238 of 10 January 2019.

Translation authorised by DIBt

I GENERAL PROVISIONS

1 This decision confirms the fitness for use and application of the subject concerned within the meaning of the Building Codes of the federal states (*Landesbauordnungen*).

2 This decision does not replace the permits, approvals and certificates required by law for carrying out construction projects.

3 This decision is granted without prejudice to the rights of third parties, in particular private property rights.

4 Without prejudice to further provisions in the 'Special Provisions', copies of this decision shall be made available to the user and installer of the subject concerned. The user and installer of the subject concerned shall also be made aware that this decision must be made available at the place of use or place of application. Upon request, copies of the decision shall be provided to the authorities involved.

5 This decision shall be reproduced in full only. Partial publication requires the consent of DIBt. Texts and drawings in promotional material shall not contradict this decision. In the event of a discrepancy between the German original and this authorised translation, the German version shall prevail.

6 This decision may be revoked. The provisions contained therein may subsequently be supplemented and amended, in particular if this is required by new technical findings.

7 This decision is based on the information and documents provided by the applicant. Alterations to this basis are not covered by this decision and shall be notified to DIBt without delay.

8 The general construction technique permit included in this decision also serves as a national technical approval for the construction technique.

II SPECIAL PROVISIONS

1 Subject concerned and field of use and application

The subject of the decision is Schöck Combar straight reinforcing bars made from a unidirectional glass fabric reinforced reaction resin (glass fibre reinforced plastic) with nominal diameters 8, 12 16, 20, 25 and 32 mm.

The reinforcing bars have a trapezoidal threaded profile (see Annex 1). The cross section is circular.

The Schöck Combar is corrosion-resistant for all exposure classes XC, XD and XS in accordance with DIN EN 1992-1-1[1] in conjunction with DIN EN 1992-1-1/NA, Clause 4.2 and is non-magnetic and electrically insulating.

Schöck Combar reinforcing bars may be used as tensile reinforcement for concrete members under the following conditions:

- The concrete members with the Schöck Combar for flexural tension or axial tension reinforcement shall be designed and dimensioned as described in Section 3 of this national technical approval/general construction technique permit. The simultaneous use of Schöck Combar rebars and steel rebars for flexural tension or axial tension reinforcement is not permissible.
- Only members not requiring design shear reinforcement shall be reinforced with Schöck Combar rebars.
- Lap joints with Schöck Combars are not permissible.
- Normal strength concrete in accordance with DIN EN 206-1 in conjunction with DIN 1045-2 with concrete strength classes C12/15 to C50/60 shall be used. Application with higher concrete strengths than C50/60 is possible if the values for a C50/60 concrete are used for the compressive strength and the bond strength.
- The members shall be predominantly statically loaded.
- For concrete attack, the specifications set out in DIN EN 1992-1-1, in conjunction with DIN EN 1992-1-1/NA, Table 4.1, Subheadings 5 and 6 (exposure classes XF and XA) as well as Clause 4.4.1.2 (13) (exposure classes XM) shall apply.
- The member temperature shall not exceed 40 °C. This temperature may be exceeded temporarily if the Schöck Combar remains unloaded during hardening of the concrete.
- Use of the Schöck Combar as a compressive reinforcement is not permissible. Positioning of the Schöck Combar in the flexural compression zone of a concrete member subjected to bending loads for anchoring or for structural reasons (e.g. installation reinforcement) is permissible.

2 Provisions for the construction product

2.1 Properties and composition

2.1.1 Surface finishing and cross-sectional area

The surfaces of the Schöck Combar rebars shall be protected from alkaline environments by means of a protective coating. The formulation of the protective coating is deposited with DIBt. Special measures to be taken for uncoated end cross sections produced as a result of cutting of the Schöck Combar are specified in Section 3.7.1.

The geometry of the profile, the nominal cross-sectional area and the nominal weight shall correspond to the specifications provided in Annex 1.

[1] Detailed information on all references to standards are listed following Section 3.7.2.

2.1.2 Mechanical and technological properties

The requirements pertaining to mechanical and technological properties given in Annex 1 and deposited with DIBt as well as the external surveillance body shall be met.

2.1.3 Chemical composition

The specifications deposited with DIBt and the external surveillance body shall be complied with.

2.2 Manufacture, marking, transport and storage

2.2.1 Manufacture

The terms and conditions of manufacture deposited with DIBt and the external surveillance body shall apply.

2.2.2 Transport and storage

During transport and storage of the Schöck Combar, the following shall be observed:

- no dragging,
- storage away from transport routes so that the bars cannot be driven over.
- no pull-out of bars from bar bundles or other friction causing surface damage,
- no impact loads, hammer blows or blows by sharp objects,
- no storage of sharp-edged objects directly on the Schöck Combar,
- no storage on rough surfaces,
- no contact with oils or solvents,
- protection from flying sparks, open flames and heat exposure,
- packaging of bars prior to transport shall ensure protection against mechanical damage by forklift trucks or lifting equipment.

If the Schöck Combar is stored for more than four weeks, the following shall be observed:

- dry or covered storage,
- storage temperature shall be between -20 °C and 40 °C,
- no exposure to direct sunlight.

2.2.3 Marking

The delivery note for the construction product shall be marked by the manufacturer with the national conformity mark (*Ü-Zeichen*) in accordance with the Conformity Marking Ordinances (*Übereinstimmungszeichen-Verordnungen*) of the federal states. The following shall also be indicated on the delivery note:

- The Schöck Combar shall be stored in dry or covered conditions,
- at a temperature of between -20 °C and 40 °C away direct sunlight.

The following information shall be printed in a weather-resistant manner with a spacing of 2 m on each Schöck Combar:

- designation 'Schöck Combar'
- approval number
- manufacturing plant
- diameter as well as production date

The mark shall only be applied if the requirements given in Section 2.3 'Confirmation of conformity' are met.

2.3 Confirmation of conformity

2.3.1 General

The manufacturer shall confirm for each manufacturing plant that the Schöck Combar complies with the provisions of the national technical approval included in this decision by way of a declaration of conformity based on factory production control and a certificate of conformity issued by a certification body recognised for these purposes as well as on regular external surveillance carried out by a recognised inspection body in accordance with the following provisions:

To grant the certificate of conformity and for external surveillance including the associated product testing, the manufacturer of the construction product shall use a certification body and an inspection body recognised for these purposes.

The declaration of conformity shall be submitted by the manufacturer through marking of the construction products with the national conformity mark including statement of the intended use.

The certification body shall send a copy of the certificate of conformity issued by it to DIBt.

A copy of the initial type-testing evaluation report shall also be sent to DIBt.

2.3.2 Factory production control

A factory production control system shall be set up and implemented in each manufacturing plant. Factory production control shall be understood to be continuous surveillance of production by the manufacturer to ensure that the manufactured construction products meet the provisions of the national technical approval included in this decision.

Factory production control shall be carried out as specified in the test plan deposited with DIBt and the external surveillance body.

The results of factory production control shall be recorded and evaluated. The records shall include at least the following information:

- designation of the construction product or the starting material and the components,
- type of check or test,
- date of manufacture and testing of the construction product or the starting material or the components,
- results of the checks and tests as well as, if applicable, comparison with the requirements,
- signature of the person responsible for factory production control.

The records shall be kept for at least five years and submitted to the inspection body used for external surveillance. They shall be submitted to DIBt and the competent supreme building authority upon request.

If the test result is unsatisfactory, the manufacturer shall immediately take the necessary measures to resolve the defect. Construction products which do not meet the requirements shall be handled in such a way that they cannot be confused with compliant products. After the defect has been remedied, the relevant test shall be repeated immediately – where technically feasible and necessary to show that the defect has been eliminated.

The manufacturer shall keep the latest versions of each of the following documents available.

Documentation of the operational prerequisites demonstrating at least the following points:

- proof of qualification of deployed personnel,
- proof of regular personnel training.

General description for the executing company covering at least the following points:

- current version of the approval,
- storage, transport and installation specifications.

The executing company shall be authorised by the manufacturer.

2.3.3 External surveillance

In each manufacturing plant, factory production control shall be verified regularly, but at least twice yearly, by means of external surveillance in accordance with the test plan deposited with DIBt.

Samples for random testing shall be taken in accordance with the test plan deposited with DIBt within the scope of external surveillance.

The results of certification and external surveillance shall be kept for at least five years. They shall be presented by the certification or inspection body to DIBt and the competent supreme building authority upon request.

3 Provisions for planning, design and execution

DIN EN 1992-1-1 in conjunction with DIN EN 1992-1-1/NA shall apply to planning and design with the following amendments.

The members reinforced with the Schöck Combar rebar with a nominal diameter of 32 mm shall be supported directly in accordance with DIN EN 1992-1-1 in conjunction with DIN EN 1992-1-1/NA, NA 1.5.2.26.

3.1 Ensuring durability

DIN EN 1992-1-1 in conjunction with DIN EN 1992-1-1/NA, Clause 4.1 and 4.2 shall apply to all exposure classes XC, XD and XS in accordance with DIN EN 1992-1-1 in conjunction with DIN EN 1992-1-1/NA, Clause 4.2. The minimum concrete cover for ensuring the bond $c_{min} \geq d_f$ shall be complied with. A concrete cover c_{min} < 10 mm is not permissible.

3.2 Ultimate limit state

3.2.1 Bending with or without longitudinal force and longitudinal force alone

3.2.1.1 General

DIN EN 1992-1-1, Clause 6.1 shall apply with the following amendments:

- For the characteristic long-term tensile strength of the Schöck Combar, f_{fk} = 580 N/mm^2 shall apply. A partial safety factor of γ_f = 1.3 shall be used. For design, the assumption of linear-elastic behaviour of the Schöck Combar with a modulus of elasticity of E_f = 60,000 N/mm^2 shall be permitted. Hence the characteristic long-term tensile strength f_{fk} of the Schöck Combar replaces both the characteristic yield stress f_{yk} and the characteristic tensile strength $f_{tk,cal}$ of the reinforcing steel in accordance with DIN EN 1992-1-1, Clause 3.2.7.
- The Schöck Combar shall not be prestressed or used as a compressive reinforcement.
- The resultant forces shall be determined in accordance with DIN EN 1992-1-1, Clause 5.4 for uncracked cross sections. Calculation in accordance with DIN EN 1992-1-1, Clause 5.4 with cracked cross sections and in accordance with Clauses 5.5 to 5.7 is not permissible.

- As a substitute for the yield point of the reinforcing steel ε_{su}, the yield point values ε_{fud} given in Table 1 shall be assumed for the Schöck Combar with structurally determinate structures. With structurally indeterminate structures, the values in Table 2 for yield point $\eta_{rot}\ \varepsilon_{fud}$ shall be assumed.
- The cross-sectional area of the Schöck Combar reinforcement to be taken into consideration for bending design for a cross section shall not exceed the maximum value of 0.035 A_c.

3.2.1.2 Design long-term tensile strength values for the Schöck Combar for structurally determinate systems

For the Schöck Combar in connection with structurally determinate systems, the design values given in Table 1 for long-term tensile strength f_{fd} and yield point ε_{fud} as a function of concrete strength shall apply.

Table 1: Design values for long-term tensile strength as a function of concrete strength class for structurally determinate structures

Compressive strength class of concrete	Design value of long-term tensile strength f_{fd} for structurally determinate structures [N/mm²]	Yield points ε_{fud} [‰]
C12/15	330	5.5
C16/20	390	6.5
≥ C20/25	445	7.4

3.2.1.3 Design long-term tensile strength values for the Schöck Combar for structurally indeterminate systems

For the Schöck Combar in connection with structurally indeterminate systems, the design values given in Table 2 for long-term tensile strength and yield point as a function of concrete strength shall apply.

Table 2: Design values for long-term tensile strength as a function of concrete strength class for structurally indeterminate structures

Compressive strength class of concrete	Design value of long-term tensile strength $\eta_{rot} f_{fd}$ for structurally indeterminate structures [N/mm²]	Yield points $\eta_{rot}\ \varepsilon_{fud}$ [‰]
C12/15	274	4.6
C16/20	325	5.4
≥ C20/25	370	6.1

3.2.2 Shear force

3.2.2.1 Components not requiring design shear reinforcement

DIN EN 1992-1-1 in conjunction with DIN EN 1992-1-1/NA, Clause 6.2.2 shall apply with the following amendments:

- Equation (6.2a) shall be replaced by the following equation:

$V_{Rd,ct}$ or
$$V_{Rd,c} = \frac{0{,}138}{\gamma_C} \cdot \kappa \cdot \left(100 \cdot \rho_l \cdot \frac{E_f}{E_s} \cdot f_{ck}\right)^{1/3} \cdot b_w \cdot d$$

- Equation (6.2a) in accordance with DIN EN 1992-1-1 is not applicable to the Schöck Combar.
- Each cross section in which the design value of the shear force is $V_{Ed} \leq V_{Rd,ct}$ or $V_{Rd,c}$ as per the above equation does not require design shear reinforcement. However, for beams and one-way slabs with $w/h < 5$, a structural minimum shear reinforcement made from reinforcing steel B500B or B500 NR in accordance with DIN EN 1992-1-1 in conjunction with DIN EN 1992-1-1/NA, Clauses 9.2.2, 9.3.2 and 9.4.3 is required.

3.2.2.2 Components requiring design shear reinforcement

This application area is excluded in accordance with this decision.

3.3 Serviceability limit state

3.3.1 Limitation of concrete compressive stresses

For the limitation of the concrete compressive stresses, DIN EN 1992-1-1 in conjunction with DIN EN 1992-1-1/NA, Clause 7.2 shall apply with the following supplement:

- The Schöck Combar shall not be used as a compressive reinforcement.

3.3.2 Crack width control

Determination of the minimum reinforcement for crack width control in accordance with DIN EN 1992-1-1, Clause 7.3.2 and crack width control without direct calculation in accordance with DIN EN 1992-1-1, Clause 7.3.3 is not permissible.

The calculated crack width w_k perpendicular to the Schöck Combar shall not exceed 0.4 mm. The calculated crack width w_k parallel to the Schöck Combar shall not exceed 0.2 mm in the anchorage zone. This shall apply to all exposure classes XC, XD and XS in accordance with DIN EN 1992-1-1 in conjunction with DIN EN 1992-1-1/NA, Clause 4.2.

Determination of crack width shall be carried out in accordance with DIN EN 1992-1-1, Clause 7.3.4 with the following amendments:

- ε_{sm} shall be replaced by ε_{fm} as the mean strain of the Schöck Combar,
- E_s shall be replaced by E_f in accordance with Section 3.2.1.1 and shall be the modulus of elasticity of the Schöck Combar,
- σ_s shall be replaced by σ_f and shall be the stress of the Schöck Combar in the crack,
- equation (7.11) in accordance with DIN EN 1992-1-1 shall be replaced by:

$$s_{r,max} = \frac{d_f}{2{,}8 \cdot \text{eff } \rho_f} \leq \frac{\sigma_f \cdot d_f}{2{,}8 \cdot f_{ct,eff}}$$ for Schöck Combar rebars with nominal diameter 8 to 25 mm

$$s_{r,max} = \frac{d_f}{2{,}1 \cdot \text{eff } \rho_f} \leq \frac{\sigma_f \cdot d_f}{2{,}1 \cdot f_{ct,eff}}$$ for Schöck Combar rebars with nominal diameter 32 mm

with $$\text{eff } \rho_f = \frac{A_f}{A_{c,eff}}$$

3.3.3 Limitation of deformations

Determination of the expected deflection of one-way members may be carried out based on booklet 533 of the German Committee for Reinforced Concrete (DAfStb) if the following conditions are met:

- The member in question is mainly loaded in bending.
- Under the load combination decisive for deflection, the stress in the Schöck Combar is not greater than 300 N/mm².
- The occurring loads are represented by equivalent loads.

– The members in question are slabs or beams with rectangular cross sections.

If these conditions are not met, more precise verification using a nonlinear method is required.

The total deformation results from the deformation fractions due to loading as well as the time-dependent fractions due to creep and shrinkage of the concrete.

3.3.3.1 Deformations resulting from loading in consideration of concrete creep

The method described here is based on an idealised bending stiffness distribution separated into uncracked (condition I) and cracked (condition II) cross sections (see Figure 1). First, the entire beam is to be divided into cracked and uncracked regions (see Figure 1).

For continuous beams, division into cantilever beams and single-span beams is required (see Figure 2).

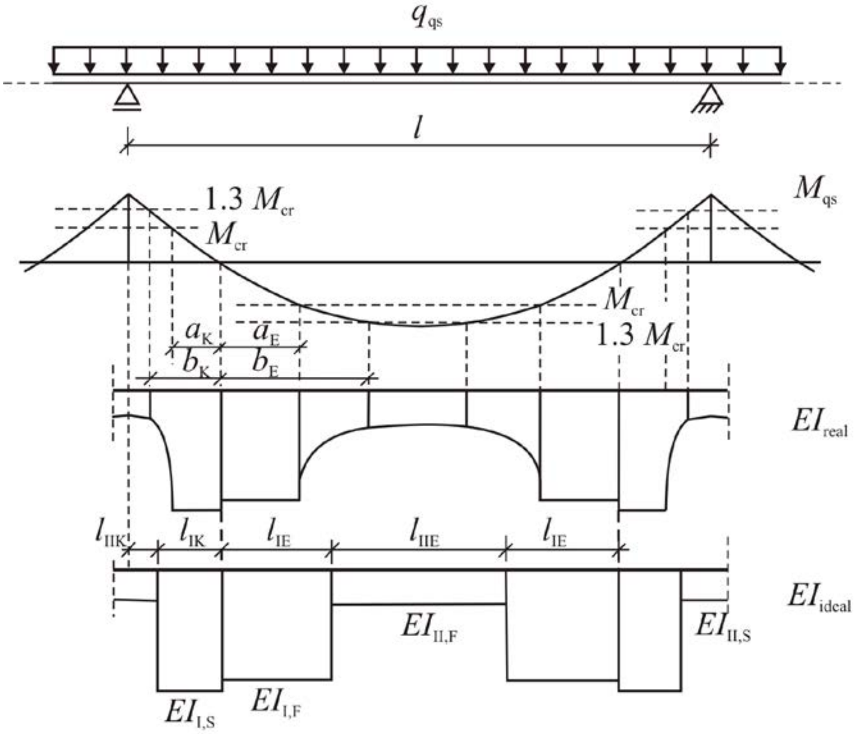


Figure 1: Comparison of real and idealised bending stiffness distribution along the inner span length in accordance with DAfStb booklet 533

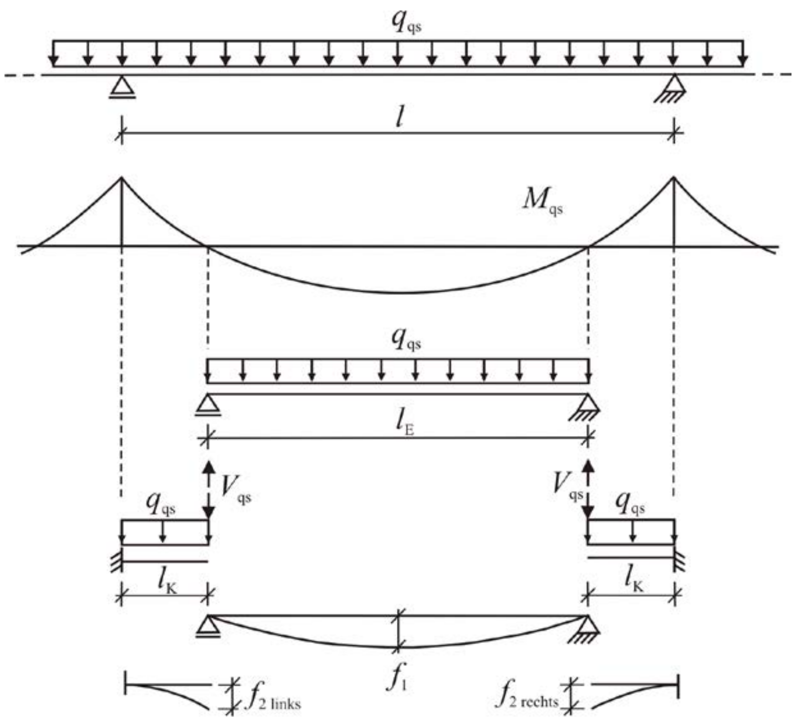


Figure 2: Structural system and moment distribution as well as individual subsystems in accordance with DAfStb booklet 533

From the relations

$$a_E = \frac{l_E}{2} - \sqrt{\left(\frac{l_E}{2}\right)^2 - \frac{2{,}0}{q_{qs}} \cdot M_{cr}} \le \frac{l_E}{2}$$ and $$b_E = \frac{l_E}{2} - \sqrt{\left(\frac{l_E}{2}\right)^2 - \frac{2{,}6}{q_{qs}} \cdot M_{cr}} \le \frac{l_E}{2},$$

the averaged length $l_{IE} = \frac{a_E + b_E}{2}$ of the uncracked region for the articulated single-span beam results, and from the relations

$$a_K = \sqrt{\left(\frac{V_{qs}}{q_{qs}}\right)^2 + \frac{2{,}0}{q_{qs}} \cdot M_{cr}} - \frac{V_{qs}}{q_{qs}} \le l_K$$ and $$b_K = \sqrt{\left(\frac{V_{qs}}{q_{qs}}\right)^2 + \frac{2{,}6}{q_{qs}} \cdot M_{cr}} - \frac{V_{qs}}{q_{qs}} \le l_K$$, the averaged length $l_{IK} = \frac{a_K + b_K}{2}$ of the uncracked region for the cantilever beam results. Where:

M_{cr} = the cracking moment,

q_{qs} = the quasi-static load,

l_E = the span length of the equivalent single-span beam (see Figure 2),

l_K = the span length of the equivalent cantilever beam (see Figure 2),

V_{qs} = the edge shear force of the equivalent single-span beam.

For determination of the cracking moment $M_{cr} = f_{ct,cal} \cdot W$, a concrete tensile strength of $f_{ct,cal} = 0.04 \cdot f_{cm}$ is used. W is the modulus of the uncracked cross section.

For further calculations, the effective bending stiffnesses and the effective modulus of elasticity of the concrete $E_{c,eff}$ are required.

$$E_{c,eff} = \frac{E_c}{1 + \varphi(\infty, t_0)}$$

The creep coefficient $\varphi(\infty, t_0)$ can be determined in accordance with DIN EN 1992-1-1, Figures 3.1a and 3.1b. The equations for determination of the moments of inertia in condition I and in condition II (I_I and I_{II}) under pure moment loading are given in Table 3. As per Figure 1, differentiation between the region of positive moments (span moment region) $I_{I,F}$ as well as $I_{II,F}$ and the region of negative moments (support moment region) $I_{I,S}$ as well as $I_{II,S}$ is also necessary. For the special case in which the reinforcement in the span moment region is equal to the reinforcement in the support moment region, the following shall apply:

$I_I = I_{I,F} = I_{I,S}$ or

$I_{II} = I_{II,F} = I_{II,S}$.

Where:

I_I is the second moment of area given in Table 3 for uncracked concrete (condition I),

I_{II} is the second moment of area given in Table 3 for cracked concrete (condition II),

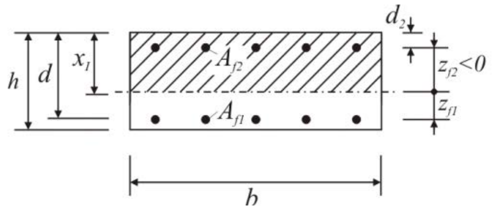
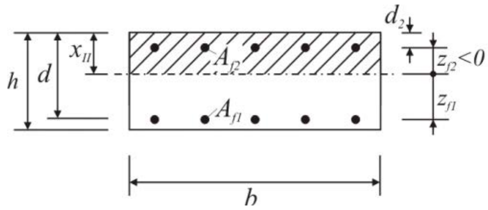
$I_{I,F}$ is the second moment of area given in Table 3 for uncracked concrete (condition I) in the span moment region,

$I_{II,F}$ is the second moment of area given in Table 3 for cracked concrete (condition II) in the span moment region,

$I_{I,S}$ is the second moment of area given in Table 3 for uncracked concrete (condition I) in the support moment region,

$I_{II,S}$ is the second moment of area given in Table 3 for cracked concrete (condition II) in the support moment region.

Table 3: Compilation of geometrical quantities x, I and S for conditions I and II in components with rectangular cross sections loaded in bending

Size	Condition I	Condition II
		
x	$x_I = k_{xI} \cdot h;\quad \rho_{II} = A_{f1}/(b \cdot h);\quad \alpha_e = \frac{E_f}{E_{c,eff}}$ $k_{xI} = (0{,}5 + A_I)/(1 + B_I)$ $A_I = \alpha_e \cdot \rho_{II} \cdot d/h \cdot (1 + A_{f2} \cdot d_2/(A_{f1} \cdot d))$ $B_I = \alpha_e \cdot \rho_{II}(1 + A_{f2}/A_{f1})$	$x_{II} = k_{xII} \cdot d;\quad \rho_{III} = A_{f1}/(b \cdot d);\quad \alpha_e = \frac{E_f}{E_{c,eff}}$ $k_{xII} = -B_{II} + \sqrt{B_{II}^2 + 2A_{II}}$ $A_{II} = \alpha_e \cdot \rho_{III} \cdot (1 + A_{f2} \cdot d_2/(A_{f1} \cdot d))$ $B_{II} = \alpha_e \cdot \rho_{III} \cdot (1 + A_{f2}/A_{f1})$
I	$I_I = k_I \cdot b \cdot h^3/12$ $k_I = 1 + 12 \cdot (0{,}5 - k_{xI})^2 + 12 \cdot \alpha_e \cdot \rho_{II} \cdot (d/h - k_{xI})^2$ $+ 12 \cdot \alpha_e \cdot \rho_{II} \cdot \frac{A_{f2}}{A_{f1}} \cdot (k_{xI} - d_2/h)^2$	$I_{II} = k_{II} \cdot b \cdot d^3/12$ $k_{II} = 4 \cdot k_{xII}^3 + 12 \cdot \alpha_e \cdot \rho_{III} \cdot (1 - k_{xII})^2$ $+ 12 \cdot \alpha_e \cdot \rho_{III} \cdot \frac{A_{f2}}{A_{f1}} \cdot (k_{xII} - d_2/d)^2$
S	$S_I = A_{f1} \cdot z_{f1} + A_{f2} \cdot z_{f2};\quad z_{f2} < 0$	$S_{II} = A_{f1} \cdot z_{f1} + A_{f2} \cdot z_{f2};\quad z_{f2} < 0$

For a span ratio of $0.8 l_1 \leq l_2 \leq 1.2 l_1$ for equal quasi-static loads, a resultant force distribution of a beam supported on both ends for the loading and the span l of the continuous beam inner span (see Figure 2 below) can be assumed. The deformation in the middle of the inner span of a continuous beam is composed of the deformation of the articulated single-span beam f_1 and the displacements of the cantilever beams $f_{2,links}$ and $f_{2,rechts}$ to the left and right of it:

$$f_1 = \frac{5}{384} \cdot l_E^4 \cdot q_{qs} \cdot \frac{1}{E_{c,eff}\ I_{II,F}} - \frac{1}{24} \cdot l_{IE}^3 \cdot q_{qs} \cdot (4 \cdot l_E - 3 \cdot l_{IE}) \cdot \left(\frac{1}{E_{c,eff}\ I_{II,F}} - \frac{1}{E_{c,eff}\ I_{I,F}} \right)$$

$$f_{2,links} = \left(\frac{1}{3} \cdot V_{qs,links} \cdot l_{K,links}^3 + \frac{1}{8} \cdot q_{qs} \cdot l_{K,links}^4 \right) \cdot \frac{1}{E_{c,eff}\ I_{II,S,links}}$$
$$- \left(\frac{1}{3} \cdot V_{qs,links} \cdot l_{IK,links}^3 + \frac{1}{8} \cdot q_{qs} \cdot l_{IK,links}^4 \right) \cdot \left(\frac{1}{E_{c,eff}\ I_{II,S,links}} - \frac{1}{E_{c,eff}\ I_{I,S,links}} \right)$$

$$f_{2,rechts} = \left(\frac{1}{3} \cdot V_{qs,rechts} \cdot l_{K,rechts}^3 + \frac{1}{8} \cdot q_{qs} \cdot l_{K,rechts}^4 \right) \cdot \frac{1}{E_{c,eff}\ I_{II,S,rechts}}$$
$$- \left(\frac{1}{3} \cdot V_{qs,rechts} \cdot l_{IK,rechts}^3 + \frac{1}{8} \cdot q_{qs} \cdot l_{IK,rechts}^4 \right) \cdot \left(\frac{1}{E_{c,eff}\ I_{II,S,rechts}} - \frac{1}{E_{c,eff}\ I_{I,S,rechts}} \right)$$

If the above-mentioned span ratio is not adhered to and/or if the quasi-static loading of the continuous beams differs greatly, the division into articulated single-span beams and cantilever beams is made in accordance with the moment distribution from the continuous beam calculation. In the equations given previously for displacements of the cantilever beam ends $f_{2,links}$ and $f_{2,rechts}$, the displacements resulting from twisting of the fixed supports on the cantilevers shall also be considered. Twisting of the fixed support of a cantilever beam may be equated with the twisting of the associated cross section from the continuous beam calculation.

The total deformation to be expected as a result of quasi-static loading in consideration of concrete creep for the inner span may be determined from the sum of the value of deformation of the articulated single-span beam and the mean deformation of the two adjacent cantilever beams:

$$f = f_1 + \frac{f_{2,\text{links}} + f_{2,\text{rechts}}}{2}$$

The deflection of an articulated single-span beam can be calculated directly; for edge spans, single-span and cantilever beams shall be combined accordingly based on the method for inner spans (see above).

3.3.3.2 Deformations as a result of shrinkage

The simplified method of calculating the deformation as a result of shrinkage is based on resultant equivalent moments for shrinkage of concrete in a reinforced cross section. The equivalent moments are determined separately for condition I and condition II:

$$M_{\text{cs,I,F}} = \varepsilon_{\text{cs}\infty} \cdot E_\text{f} \cdot S_{\text{I,F}} \qquad M_{\text{cs,II,F}} = \varepsilon_{\text{cs}\infty} \cdot E_\text{f} \cdot S_{\text{II,F}}$$ and

$$M_{\text{cs,I,S}} = \varepsilon_{\text{cs}\infty} \cdot E_\text{f} \cdot S_{\text{I,S}} \qquad M_{\text{cs,II,S}} = \varepsilon_{\text{cs}\infty} \cdot E_\text{f} \cdot S_{\text{II,S}}$$, where:

$M_{\text{cs,I,F}}$, $M_{\text{cs,I,S}}$	is the moment resulting from shrinkage in condition I for the span moment and support moment regions,
$M_{\text{cs,II,F}}$, $M_{\text{cs,II,S}}$	is the moment resulting from shrinkage in condition II for the span moment and support moment regions,
$\varepsilon_{\text{cs}\infty}$	is the shrinkage strain of concrete at time t=∞ in accordance with DIN EN 1992-1-1, Clause 3.1.4(6),
E_f	is the modulus of elasticity of the Schöck Combar,
$S_{\text{I,F}}$, $S_{\text{I,S}}$	is the first moment of area in condition I for the span moment and support moment regions (see Table 3),
$S_{\text{II,F}}$, $S_{\text{II,S}}$	is the first moment of area in condition II for the span moment and support moment regions (see Table 3).

The equations for determination of the first moment of area in condition I and in condition II under pure moment loading are given in Table 3. In the case of continuous beams, differentiation between the span moment region, $S_{\text{I,F}}$ and $S_{\text{II,F}}$, and the support moment region, $S_{\text{I,S}}$ and $S_{\text{II,S}}$, is also necessary

The cross-sectional deformations in condition I and condition II as a result of shrinkage are yielded for the span moment region from

$$\kappa_{\text{cs,I,F}} = \frac{M_{\text{cs,I,F}}}{E_{\text{c,eff}}\ I_{\text{I,F}}} \qquad \kappa_{\text{cs,II,F}} = \frac{M_{\text{cs,II,F}}}{E_{\text{c,eff}}\ I_{\text{II,F}}}.$$

and for the support moment region from

$$\kappa_{\text{cs,I,S}} = \frac{M_{\text{cs,I,S}}}{E_{\text{c,eff}}\ I_{\text{I,S}}} \qquad \kappa_{\text{cs,II,S}} = \frac{M_{\text{cs,II,S}}}{E_{\text{c,eff}}\ I_{\text{II,S}}}.$$

$E_{\text{c,eff}}$ shall be determined in accordance with Section 3.3.3.1 and the moments of inertia $I_{\text{I,F}}$ and $I_{\text{II,F}}$ and $I_{\text{I,S}}$ and $I_{\text{II,S}}$ shall be determined in accordance with the equations in Table 3.

The deflection at the span midpoint of an articulated single-span beam as a result of shrinkage is yielded from:

$$f_{1cs} = \frac{1}{2} \cdot l_{IE}^2 \cdot \kappa_{cs,I,F} + \frac{1}{8} \cdot \left(l_E^2 - 4 \cdot l_{IE}^2\right) \cdot \kappa_{cs,II,F}$$

The deflection for a cantilever beam as a result of shrinkage is yielded from:

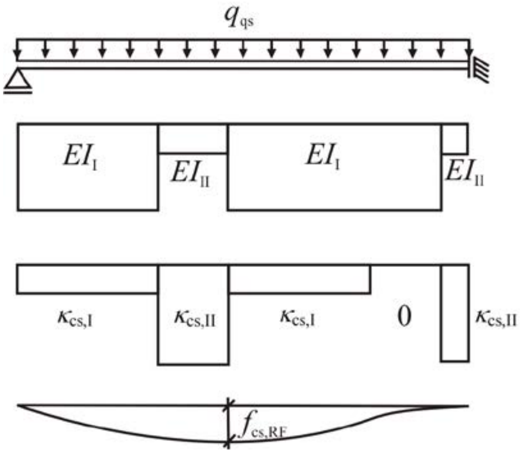
$$f_{2cs} = \frac{1}{2} \cdot l_{IK}^2 \cdot \kappa_{cs,I,S} + \frac{1}{2} \cdot \left(l_K^2 - l_{IK}^2\right) \cdot \kappa_{cs,II,S}$$

For simplification, the shrinkage in the inner spans of a continuous beam system can be neglected and the approximation below can be used for the edge spans.

The deflection $f_{cs,RF}$ can be calculated as a function of the length of the cracked regions $l_{II,RF}$ in relation to the total length of the edge span l_{RF} with the coefficients k_I and k_{II} as shown in Figure 3:

$$f_{cs,RF} = k_I \cdot \kappa_{cs,I} \cdot l_{RF}^2 + k_{II} \cdot \kappa_{cs,II} \cdot l_{RF}^2$$

If the cross-sectional values in the span moment region differ from those in the support moment region, $\kappa_{cs,I} = \max(\kappa_{cs,I,F}, \kappa_{cs,I,S})$ and $\kappa_{cs,II} = \max(\kappa_{cs,II,F}, \kappa_{cs,II,S})$ may be used. Division into cantilever and single-span beams for determination of the stiffness distribution is carried out in accordance with Section 3.3.3.1.



$\frac{\sum l_{II,RF}}{l_{RF}}$	k_I [-]	k_{II} [-]
0	0.0313	0.0000
0.05	0.0462	0.0020
0.10	0.0445	0.0205
0.25	0.0285	0.0426
0.33	0.0215	0.0503
0.50	0.0107	0.0555

Figure 3: Coefficients k_I and k_{II} for determination of $f_{cs,RF}$ in accordance with DAfStb booklet 533

3.4 General reinforcement rules

3.4.1 Schöck Combar bar spacing

DIN EN 1992-1-1, Clause 8.2 shall apply with the following amendment:

Lap joints are excluded in accordance with this decision.

3.4.2 Bending the Schöck Combar

The Schöck Combar is not intended to be bent. DIN EN 1992-1-1, Clause 8.3 shall not apply.

3.4.3 Design bond stress

For verification of anchoring under good bond conditions in accordance with DIN EN 1992-1-1, Clause 8.4.2, the characteristic and design values for bond strength given in Tables 4-1 and 4-2 shall apply. These values are based on the core diameter d_f of the Schöck Combar.

The partial safety factor is γ_c = 1.5.

Table 4-1: Characteristic and design values for bond strength as a function of concrete strength for Schöck Combar bars with nominal diameter 8 to 25 mm under good bond conditions

Compressive strength class of concrete	Characteristic concrete compressive strength f_{ck} [N/mm²]	Characteristic bond strength f_{bk} [N/mm²]	Design bond strength f_{bd} [N/mm²]
C12/15	12	2.17	1.45
C16/20	16	2.66	1.77
C20/25	20	3.05	2.03
C25/30	25	3.39	2.26
C30/37	30	3.49	2.33
C35/45	35	3.58	2.39
C40/50	40	3.68	2.45
C45/55	45	3.77	2.51
C50/60	50	3.87	2.58

Table 4-2: Characteristic and design values for bond strength as a function of concrete strength for the Schöck Combar rebar with nominal diameter 32 mm under good bond conditions

Compressive strength class of concrete	Characteristic concrete compressive strength f_{ck} [N/mm²]	Characteristic bond strength f_{bk} [N/mm²]	Design bond strength f_{bd} [N/mm²]
C12/15	12	2.67	1.11
C16/20	16	2.05	1.36
C20/25	20	2.35	1.56
C25/30	25	2.61	1.74
C30/37	30	2.68	1.79
C35/45	35	2.75	1.84
C40/50	40	2.83	1.89
C45/55	45	2.90	1.93
C50/60	50	2.98	1.98

For reasonably good bond conditions in accordance with DIN EN 1992-1-1, Clause 8.4.2, the values given in Tables 5-1 and 5-2 shall apply.

Table 5-1: Characteristic and design values for bond strength as a function of concrete strength for Schöck Combar rebars with nominal diameter 8 to 25 mm under reasonably good bond conditions

Compressive strength class of concrete	Characteristic concrete compressive strength f_{ck} [N/mm²]	Characteristic bond strength f_{bk} [N/mm²]	Design bond strength f_{bd} [N/mm²]
C12/15	12	1.64	1.09
C16/20	16	1.94	1.32
C20/25	20	2.30	1.53
C25/30	25	2.67	1.78
C30/37	30	3.01	2.01
C35/45	35	3.34	2.23
C40/50	40	3.51	2.34
C45/55	45	3.69	2.46
C50/60	50	3.87	2.58

Table 5-2: Characteristic and design values for bond strength as a function of concrete strength for the Schöck Combar rebar with nominal diameter 32 mm with reasonably good bond conditions

Compressive strength class of concrete	Characteristic concrete compressive strength f_{ck} [N/mm²]	Characteristic bond strength f_{bk} [N/mm²]	Design bond strength f_{bd} [N/mm²]
C12/15	12	1.26	0.84
C16/20	16	1.49	0.99
C20/25	20	1.77	1.18
C25/30	25	2.05	1.37
C30/37	30	2.32	1.54
C35/45	35	2.57	1.71
C40/50	40	2.70	1.80
C45/55	45	2.84	1.89
C50/60	50	2.98	1.98

For concrete covers of c < 16 mm, the transferable bond stresses f_{bk} and f_{bd} in Tables 4 and 5 shall be reduced by the factor k = 0.2+0.05•c.

3.4.4 Anchorage length

The required minimum anchorage length $l_{b,min}$ shall be determined using equation $l_{b,min} = 10 \cdot d_f \geq 160$ mm for bars with a nominal diameter 8 to 25 mm and

$l_{b,min} = 13 \cdot d_f \geq 160$ mm for the bar with nominal diameter 32 mm.

For reasonably good bond conditions, the following shall apply:

$l_{b,min}$ = 14•d_f ≥ 224 mm for bars with nominal diameter 8 to 25 mm and

$l_{b,min}$ = 18•d_f ≥ 224 mm for the bar with nominal diameter 32 mm.

3.5 Design rules

3.5.1 Minimum reinforcement and maximum reinforcement

DIN EN 1992-1-1, Clauses 9.2.1.1 and 9.2.4 shall not apply. The minimum reinforcement for ensuring ductile behaviour of the concrete member in accordance with DIN EN 1992-1-1 in conjunction with DIN EN 1992-1-1/NA, Clause 5.10.1 shall be calculated for the cracking moment with a mean concrete tensile strength f_{ctm} in accordance with DIN EN 1992-1-1, Table 3.1 and a Schöck Combar stress of $\sigma_f = 0.83 * f_{fk}$ = 445 N/mm².

The cross-sectional area of the Schöck Combar reinforcement to be taken into consideration for bending design for a cross section shall not exceed the maximum value of 0.035 A_c.

3.6 Resistance to fire

DIN 4102-4 shall not apply. Verification of the classification as fire resistance class F90 shall be carried out with a factor of 0.45 applied to the values for bond strength given in Section 3.4.3, Tables 4 and 5. The minimum concrete cover c_{min} shall be 6.5 cm.

3.7 Execution

3.7.1 General

All specifications set out in DIN 1045-3 in conjunction with DIN EN 13670 for reinforcing steel shall apply, with the following amendments:

- Reinforcement and concreting work may only be carried out by personnel who have been instructed in the correct handling and provided with the safety instructions for applying the Schöck Combar by the manufacturer and meet the requirements set out in Section 2.3.2.
- Oil or other stains shall be removed prior to installation of the Schöck Combar.
- The Schöck Combar is not intended for bending.
- In the installed condition, the Schöck Combar shall not deviate from a straight line by more than 5 mm per metre of length. For the nominal diameters 8 and 12 mm, the maximum permissible deviation is 10 mm.
- Mechanical rebar connections and lap joints are not permissible.
- The bars shall be cut to length on the construction site using hacksaws or band saws or diamond or carbide cutting discs. Coating of the cut surfaces is not necessary if the structurally required length of the Schöck Combar is increased by 1 cm at each end with a cut surface.
- The Schöck Combar shall not be cut with bolt cutters or shears.
- It is recommended that gloves are worn when working with the Schöck Combar.
- Measures shall be taken to prevent the reinforcement from rising when concrete is being cast.

3.7.2 Confirmation of conformity

The executing company shall provide a declaration of conformity in accordance with Section 16a(5) and Section 21(2) of the Model Building Code to confirm the conformity of the construction technique with the general construction technique permit. This declaration shall be handed over to the client for forwarding to the competent building authority upon request.

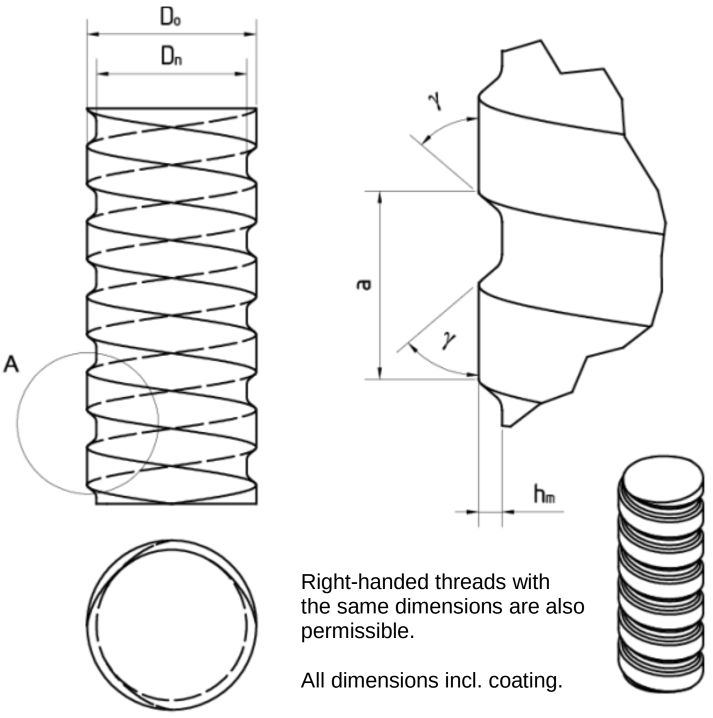
Unless otherwise specified, the following standards are referred to in the national technical approval:

DIN 1045-3:2012-03	Concrete, reinforced and prestressed concrete structures – Part 3: Execution of structures – Application rules for DIN EN 13670
DIN 1045-3 Corr.1:2013-07	Concrete, reinforced and prestressed concrete structures – Part 3: Execution of structures – Application rules for DIN EN 13670, Corrigendum to DIN 1045-3:2012-03
DIN 4102-4:1994-03	Synopsis and application of classified building materials, components and special components
DIN 4102-4/A1:2004-11	Synopsis and application of classified building materials, components and special components: Amendment 1
DIN EN 206-1:2001-07	Concrete – Part 1: Specification, performance, production and conformity
DIN EN 206-1/A1:2004-10	Concrete – Part 1: Specification, performance, production and conformity; German version EN 206-1:200/A1:2004
DIN EN 206-1/A2:2005-09	Concrete – Part 1: Specification, performance, production and conformity; German version EN 206-1:2000/A2:2005
DIN EN 1992-1-1:2011-01	Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings; German version EN 1992-1-1:2004 + AC:2010
DIN EN 1992-1-1/A1:2015-03	Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings; German version EN 1992-1-1:2004/A1:2014
DIN EN 1992-1-1/NA:2011-01	National Annex – Nationally determined parameters – Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings
DIN EN 1992-1-1/NA:2013-04	National Annex - Nationally determined parameters – Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings
DIN EN 1992-1-1/NA/A1:2015-12	National Annex – Nationally determined parameters – Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings; Amendment A1

Dr.-Ing. Lars Eckfeldt
Head of Section

Drawn up by

View (2:1) **Detail A (5:1)**



Right-handed threads with the same dimensions are also permissible.

All dimensions incl. coating.

Nominal diameter	D_n	[mm]	8	12	16	20	25	32
Outer diameter	D_0	[mm]	9	13.5	18	22	27	34
Rib lead	a	[mm]	8.5	8.5	8.5	8.5	8.5	8.5
Rib height	h_m	[mm]	0.45	0.65	0.9	0.9	0.9	0.9
Flank angle	γ	[°]	50	50	50	50	50	50
Nominal cross section	A_f	[mm²]	50	113	201	314	491	804
Weight per metre length	-	[g/m]	133	292	517	788	1210	1940

Properties of straight bars		**Unit**	**Combar®**
Char. short-term tensile strength	f_{tk0}	[N/mm²]	>1000
Char. long-term tensile strength	f_{tk}	[N/mm²]	580
Modulus of elasticity	E_f	[N/mm²]	60000
Design bond stress	f_{bd}	[N/mm²]	s. Section 3.4.3
Electromagnetic conductivity			None
Thermal conductivity	λ	W/mK	0.7 (longitudinal axis)
			0.5 (perpendicular)
Coefficient of thermal expansion	α	K^{-1}	$0.6 \cdot 10^{-5}$ (longitudinal)
			$2.2 \cdot 10^{-5}$ (perpend.)
Electrical resistivity	ρ	Ωm	$>10^{10}$
Density	ρ	[g/cm³]	2.2

Schöck Combar reinforcing bar made from glass fibre reinforced plastic,
Nominal diameters: 8, 12, 16, 20, 25 and 32 mm

Geometry and properties

Annex 1