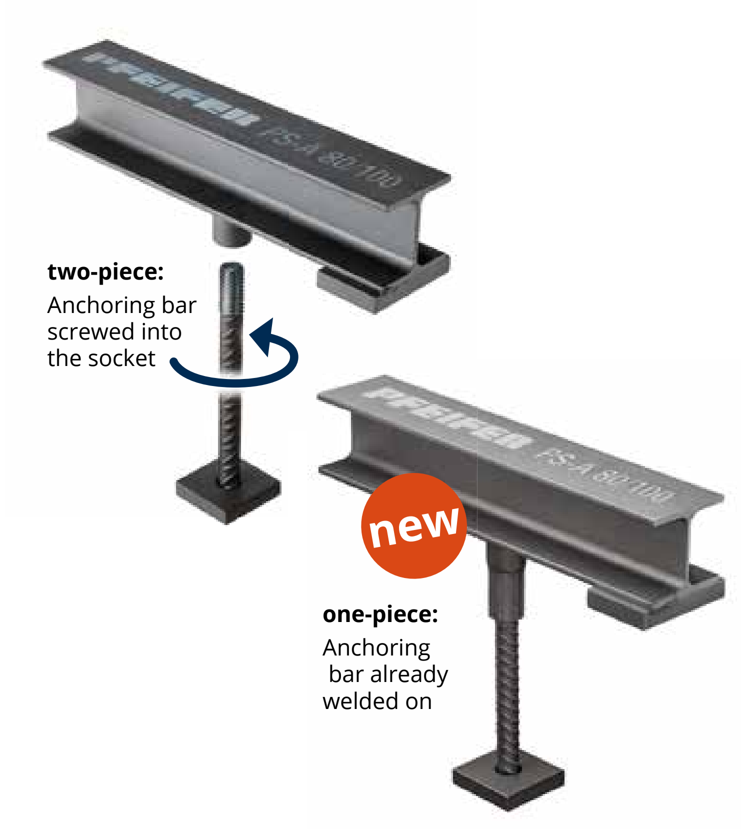
Steel Bearing

Dimensioning notes

PFEIFER

Steel bearing

for supporting ribbed ceilings and joists



PFEIFER Steel Bearings absorb the dead weight loads during the installation of elements. Together with the inserted reinforcement and the in-situ concrete layer, live loads are safely diverted into the ceiling joists. The entire support structure can be planned, dimensioned, manufactured and installed more easily without bearing ledge supporting joists. The lower installation heights and the even surface of the ceilings are further advantages.

π plates

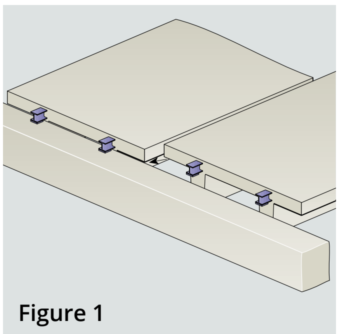


Figure 1

Trough plates

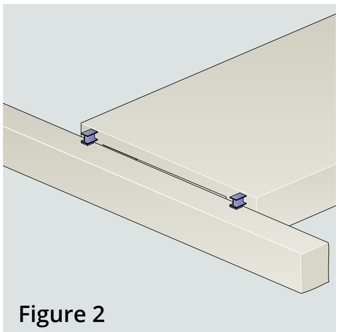


Figure 2

Joists / secondary beams

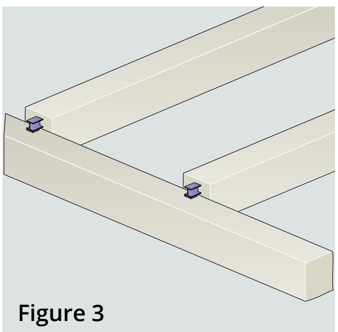


Figure 3

Application notes

PFEIFER steel bearings were developed for the cost-effective support of π plates, trough plates and joists (figs. 1-3). The large eccentricities that usually occur in both the installation and end states due to conventional constructions with bearing ledges can be avoided by using steel bearings. Time and costs can be saved as a result. Cost-intensive supports using scaffolding towers or the like can also be dispensed with. The PFEIFER steel bearings are designed to absorb the entire bearing support force during installation, which results from the dead weight of the precast element, the topping layer and the live load when concreting. In the final state the steel bearings work together with the mortised concrete support.

You can find the approval, dimensioning software, pre-dimensioning tables and more here:

www.pfeifer.info/steel-bearing

Design resistances

In principle, distinction is made between the installation state and the end state when dimensioning the PFEIFER PS-A steel bearings. These states must be considered separately.

Installation state

The installation state is the period in which the topping layer cross-section of the slab is not yet effective. When determining the stresses, the dead weight of the precast elements, the topping layer, a man load and influences that may occur during installation must be taken into account.

The applicable design resistances for the installation state can be taken from Table 1. These depend in particular on the height of the web. The minimum concrete quality of the precast element is C35/45.

End state

In the end state the PS-A steel bearing and the in-situ concrete bracket work in combination. Therefore, the relevant design resistances are different to those that apply during the install-ation state. The relevant influences are the dead weights of the precast element, topping layer and covering as well as imposed loads.

The relevant design resistance decisive for the end state can be simply read off from dimensioning tables, depending on a few boun-dary conditions. These are to be taken from the current building authority approval. For a fundamental description of the dimensioning procedure, the three necessary steps are briefly described below:

Step 1:

-In order to cover as many possible installation situations as possible, two basic modules (figs. 4 and 5) were adopted into the approval. These are distinguished by the geometry of the web. These basic modules are assigned in the resistance dimensioning table. In principle, when defining the module to be employed, it must be determined which module can be fitted into the existing web geometry. The type of precast element – π plate, trough plate, secondary beams or ceiling joist – is thereby irrelevant (figs. 6-8).

Step 2:

Next, the dimensioning table is selected with the bearing required for the installation state and the matching basic module (see step 1). After that the necessary design resistance can be read off according to the influences, depending on the web height, plate thickness and the quality of the top layer concrete.

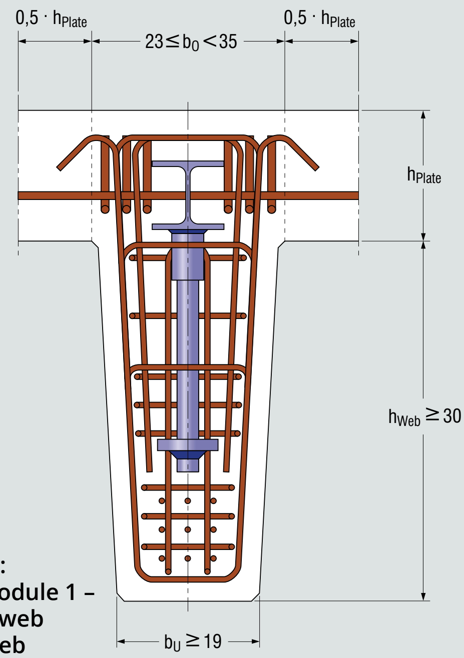


Figure 4: Basic module 1 – narrow web Plate, web

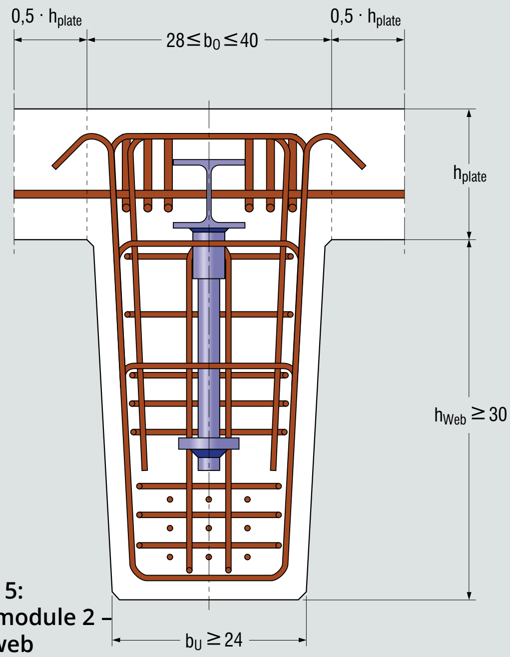


Figure 5: Basic module 2 – wide web

Table 1: Load capacity of the steel bearing in the mounting state, depending on the web height

Web height h [cm]	Working load limit $V_{Rd,mounting}$ in the mounting state [kN]											
	PS-A 65			PS-A 80/100			PS-A 130			PS-A 160		
30 ≤ h < 40	65	65	65	80	80	80						
40 ≤ h < 50	65	65	65	100	100	100						
50 ≤ h < 60	65	65	65	100	100	100	130	130	130			
60 ≤ h < 70	65	65	65	100	100	100	130	130	130	160	160	160
h ≥ 70	65	65	65	100	100	100	130	130	130	160	160	160

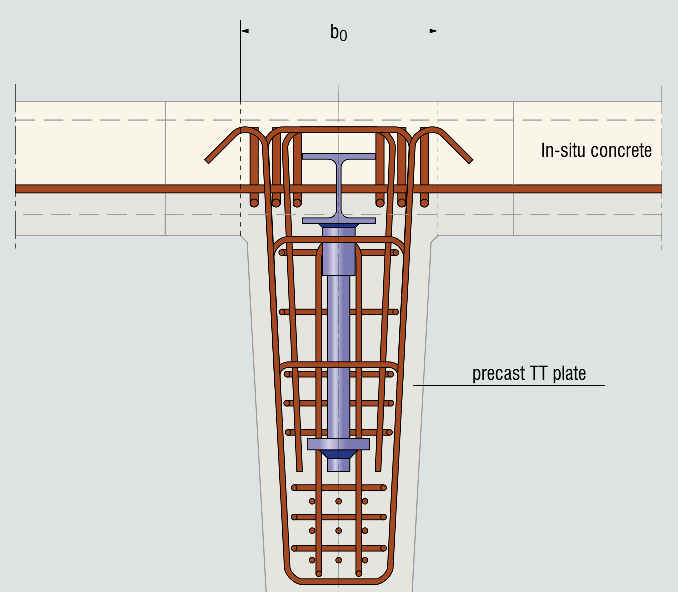
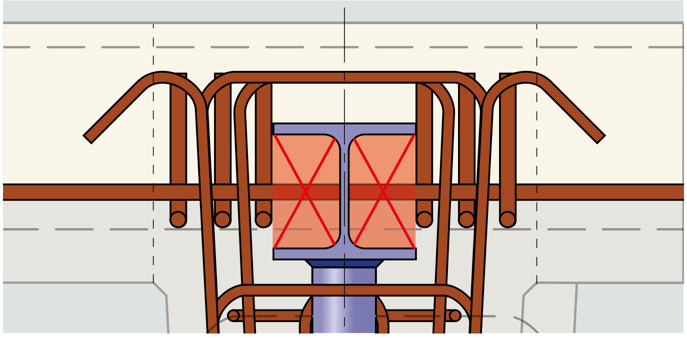


Figure 6:
π plate with basic module



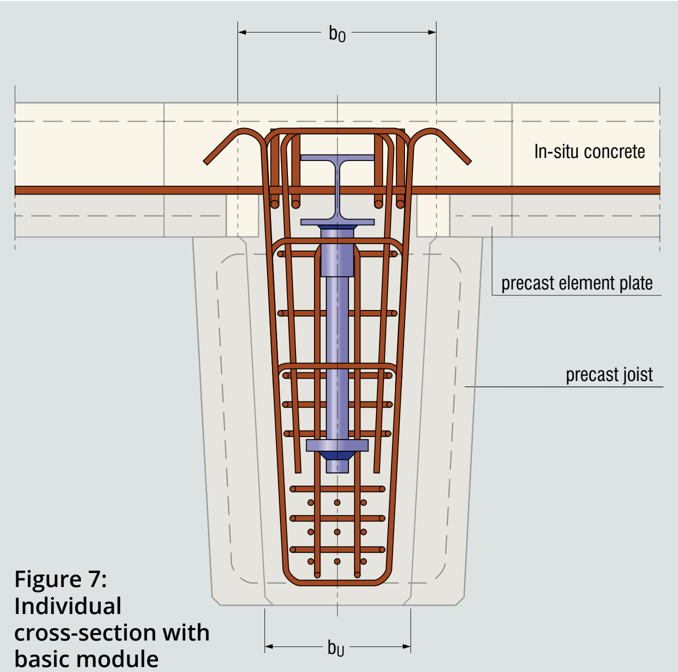


Figure 7:
Individual cross-section with basic module

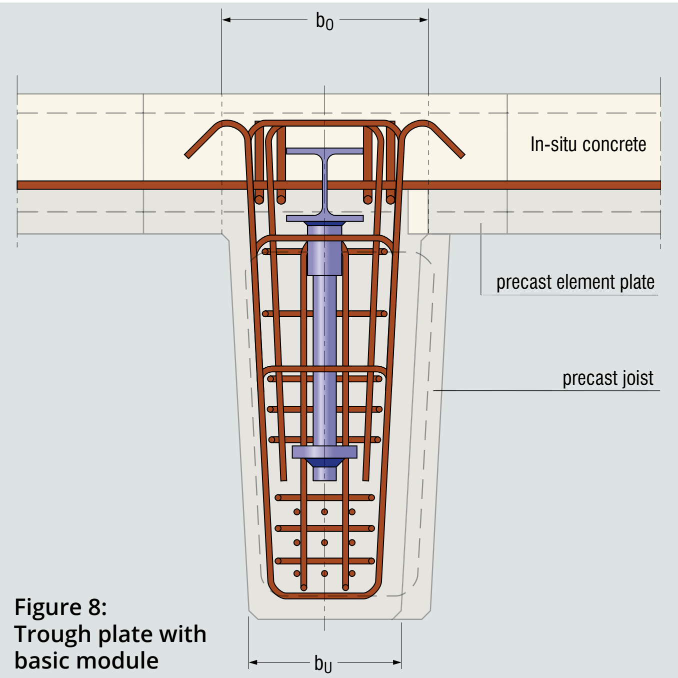


Figure 8:
Trough plate with basic module

Notice: The additional horizontal reinforcement bars must ideally always be outside the steel bearing cross-section.

Step 3:
With the design resistance that has now been assigned, the necessary reinforcement can be read off from the table and the bearing point can be elaborated in accordance with the “general technical application criteria” from the building authority approval.

Remark regarding building site operations:

From a minimum strength of the topping layer of $0.4 \cdot f_{ck}$ a maximum live load of $q_{ck} = 1$ kN/m² can be applied without exact proof.

In case of higher loads these are to be verified by means of an exact calculation.

Construction principles

Concrete qualities

The precast concrete elements must be at least of the quality C35/45 and the load transferring elements (e.g. ceiling joists) at least of C25/30. The quality of the top layer concrete must be selected according to the dimensioning tables.

Embedment depth of the anchor plate in the web.

In order to ensure sufficient anchorage in the precast element, the anchoring bar of the steel bearing must be of the following minimum length (fig. 9).

$l \geq 0{,}55 \cdot h_{Web} \geq 210$ mm
[ordering size / anchoring bar length: $H \geq l + 15$ mm]

Minimum anchoring bar lengths:

PS-A 65 :	H ≥225 mm, $Ü_{plt}$ 35 mm
PS-A 80/100:	H ≥ 225 mm, $Ü_{plt}$ 45 mm
PS-A 130:	H ≥ 300 mm, $Ü_{plt}$ 48 mm
PS-A 160:	H ≥ 350 mm, $Ü_{plt}$ 48 mm

Reinforcement

The reinforcement required in the bearing area is illustrated qualitatively in fig. 10. The necessary calculated verifications of, for example, anchoring and overlap lengths as well as all other reinforcement determinations are to be taken from the appendices to the national technical approval (fig. 10).

Cutouts

Cutouts in the level surface are permissible only if they are at least half the ceiling thickness away from the web (fig. 10). Reinforcements must be replaced here if necessary.

Exposure class

With regard to reinforcement corrosion, the exposure classes XC1-XC3 according to DIN EN 1992-1-1, table 4.1 were taken as the basis for the dimensioning of the PS-A steel bearing. More severe requirements to the exposure class must be considered and verified separately. In particular, the underside of the steel bearing may have to be provided with an additional layer of anti-corrosion coating. In this case the planned concrete coverage is 15 mm thick.

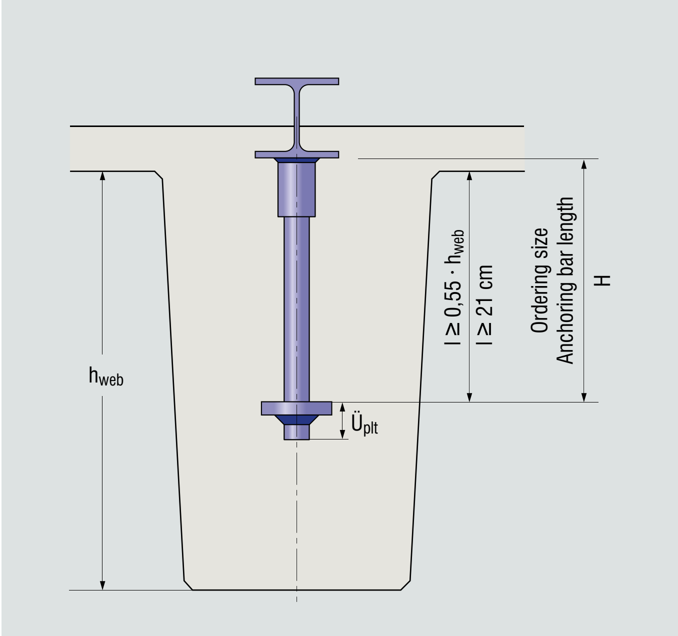


Figure 9: Embedment depth

Fire resistance

When using the PFEIFER PS-A Steel Bearing to support reinforced concrete constructions on which fire resistance demands are placed, section 3.2 according to the building authority approval is to be taken into account. In general, a categorisation into "Fire retardant", "Fire resistant" and "Fire resistance 120 min" is possible according to the building authority approval.

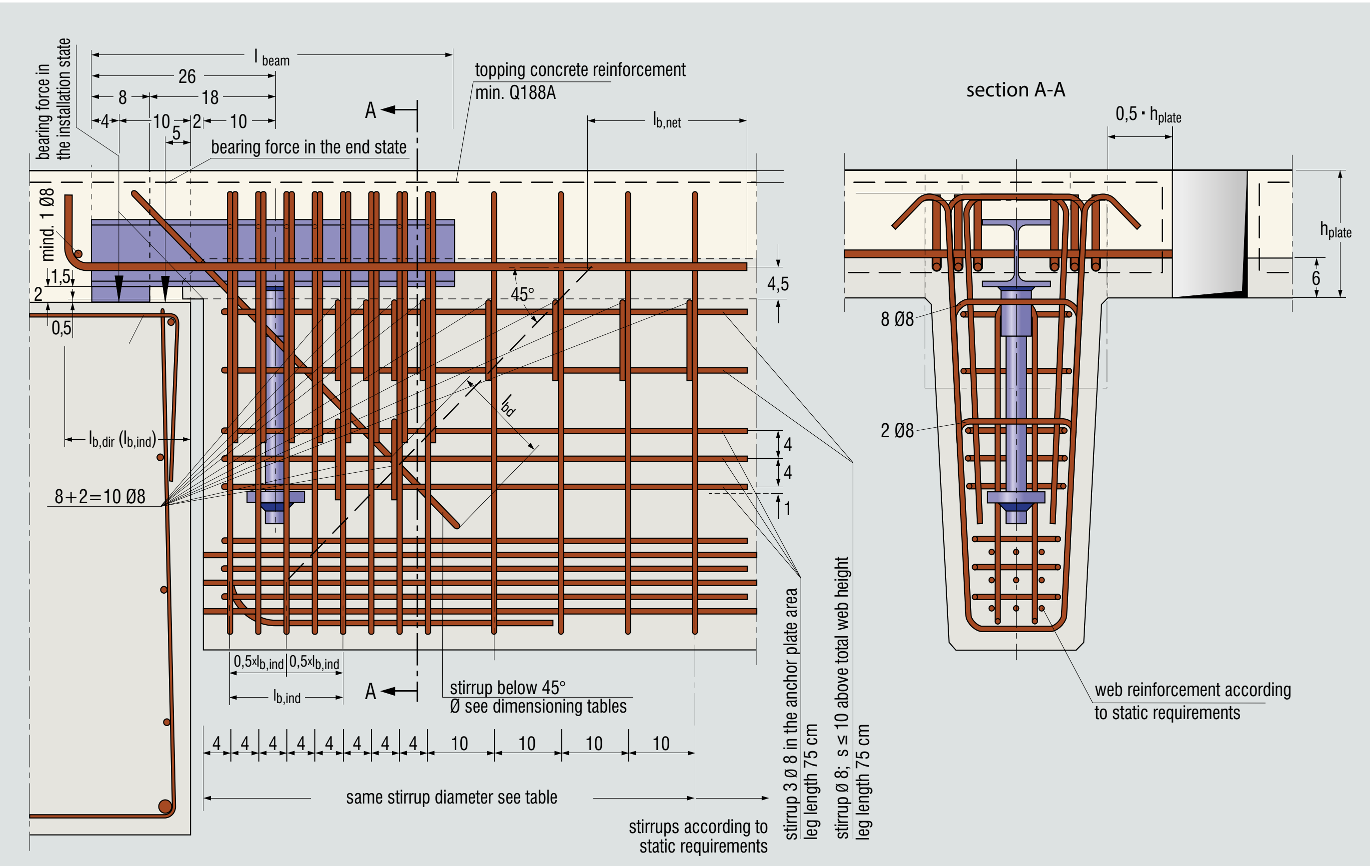


Figure 10

Dimensioning example according to Eurocode 2

Preliminary remarks:

This calculation and dimensioning example for the PFEIFER PS-A Steel Bearing shows the typical calculation procedure and the verification steps the planning engineer has to carry out.

The dimensioning tables and data from the currently valid general building authority approval Z-15.6-287 are used.

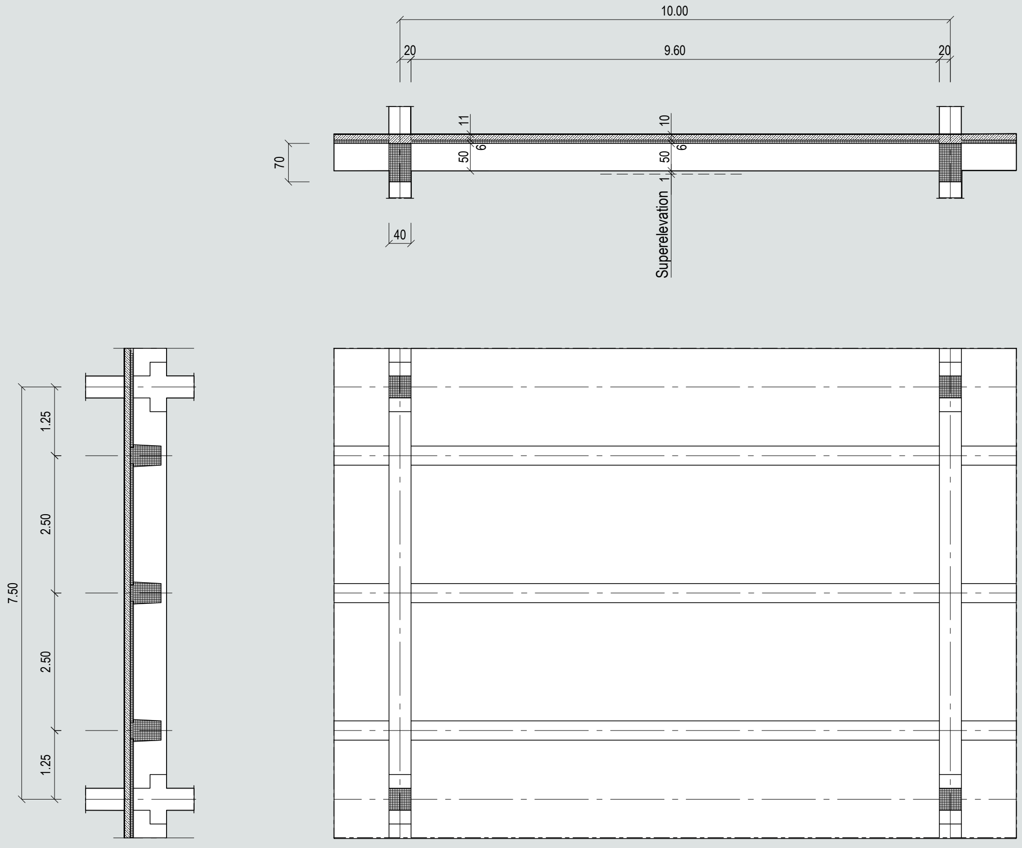
Further measures are necessary to derive the horizontal forces.

Depending on the assembly and concreting process, additional measures must be taken to secure the precast elements against tipping over or twisting in the installation state, especially in the case of secondary and primary joists, as the steel bearing cannot dissipate torsional moments (proofs/specifications by user).

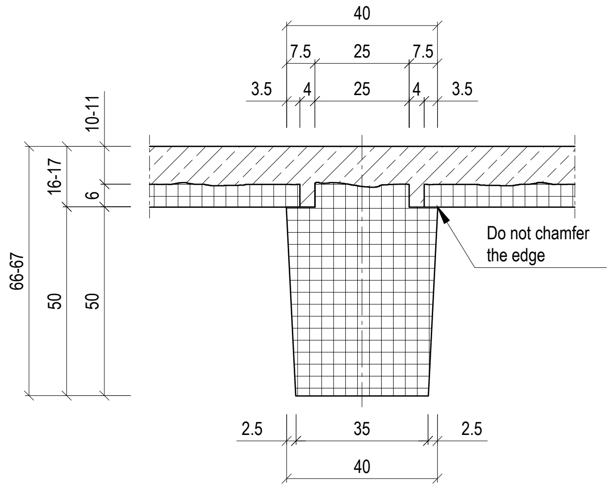
In the right-hand column on the following pages you can find additional cross-references and references.

1. System, component dimensions, materials, concrete cover:

Supporting structure, ceiling construction:

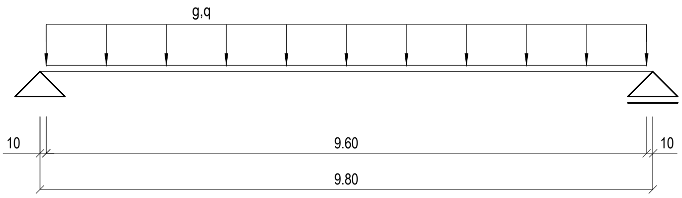


Secondary joist considered in cross-section:



Taking into account a superelevation of 1 cm in the centre of the field

Static system of the secondary joist:



Materials:

Concrete quality of topping layer: C25/30
Concrete quality of precast element: C35/45
Reinforcing steel: B500B

Exposure class:

Reinforcement corrosion triggered by carbonation: XC3 (assumption)

Concrete corrosion as a result of alkali-silicic acid reaction: W0

Minimum concrete cover according to EN 1992-1-1/NA, 4.4.1.2:

Topping layer:

$$c_{min} = \max. \begin{cases} c_{min,\,b} \\ c_{min,\,dur} + \Delta c_{dur,\gamma} - \Delta c_{dur,st} - \Delta c_{dur,add} \\ 10\text{ mm} \end{cases}$$

$$= \max. \begin{cases} 12\text{ mm (max. bar diameterr)} \\ 20\text{ mm} \\ 10\text{ mm} \end{cases}$$

$$= 20\text{ mm}$$

Size allowance according to EN 1992-1-1/NA, 4.4.1.3:

$\Delta c_{dev} = 15\text{ mm}$

$\rightarrow c_{nom} = c_{min} + \Delta c_{dev} = 20 + 15 = 35\text{ mm}$

Precast element:

$$c_{min} = \max. \begin{cases} 12\text{ mm (assumed max. bar diameter)} \\ 20\text{ mm} \\ 10\text{ mm} \end{cases}$$

$$= 20\text{ mm}$$

Size allowance according to EN 1992-1-1/NA, 4.4.1.3:

$\Delta c_{dev} = 15\text{ mm}$

Since the technical approval requires a minimum concrete strength class of C35/45 (> C30/37), the value of the minimum concrete cover $c_{min,dur}$ according to EN 1992-1-1/NA, Table 4.3DE may be reduced by 5 mm.

According to EN 1992-1-1/NA, 4.4.1.3 (3), the size allowance in the precast element may be reduced by 5 mm.

$\rightarrow c_{nom} = c_{min} + \Delta c_{dev} = 20 - 5 + 15 - 5 = 25\text{ mm}$

2. Cut-outs:

In this example there are no cut-outs in the area of the bearing.

Minimum spacing of cut-outs in the level surface of the web outer edge: Z-15.6-287, Annex 2, point 19

3. Actions:

(characteristic values)

3.1 Permanent actions

Precast element:

$$g_{1,k} = (0{,}50 \cdot \frac{0{,}35 + 0{,}40}{2} + 2{,}5 \cdot 0{,}06) \cdot 25 \quad = \quad 8{,}44\,\frac{kN}{m}$$

Top layer:

$$g_{2,k} = 2{,}5 \cdot \frac{0{,}10 + 0{,}11}{2} \cdot 25 \quad = \quad 6{,}56\,\frac{kN}{m}$$

Superstructure loads (concrete + installation):

$g_{3,k} = 1,20 \frac{kN}{m^2}$

$\rightarrow g_{3,k} = 2,5 \cdot 1,20 \quad = \quad 3,00 \frac{kN}{m}$

3.2 Changeable actions:

Imposed load: $q_k = 5,00 \frac{kN}{m^2}$

$\rightarrow q_k = 2,5 \cdot 5,00 \quad = \quad 12,50 \frac{kN}{m}$

Man load: $Q_{M,k} \quad = \quad 1,00\ kN$ — Z-15.6-287, Annex 2, point 16

4. Dimensioning value of the bearing force per steel bearing:

Partial safety factors in the limitation states of the load capacity:

Caution: The reduction of γ_G and γ_Q in the installation state is not permissible (Z-15.6-287, section 3.3.3 or Annex 2, point 16).

Permanent actions: $\gamma_G = 1,35$

Changeable actions: $\gamma_Q = 1,50$

4.1 Installation state:

Precast element: $G_{1,d} = \gamma_G \cdot \frac{1}{2} \cdot g_{1,k} \cdot l = 1,35 \cdot \frac{1}{2} \cdot 8,44 \cdot 9,60 \quad = \quad 54,69\ kN$

Topping layer: $G_{2,d} = \gamma_G \cdot \frac{1}{2} \cdot g_{2,k} \cdot l = 1,35 \cdot \frac{1}{2} \cdot 6,56 \cdot 9,60 \quad = \quad 42,51\ kN$

Man load: $Q_{M,d} = \gamma_Q \cdot Q_{M,k} = 1,50 \cdot 1,00 \quad = \quad 1,50\ kN$

Bearing support force during erection: $V_{Ed,\ mounting} \quad = \quad 98,70\ kN$

4.2 Final state:

Precast element: $G_{1,d} \quad = \quad 54,69\ kN$

Topping layer: $G_{2,d} \quad = \quad 42,51\ kN$

Superstructure loads: $G_{3,d} = \gamma_G \cdot \frac{1}{2} \cdot g_{3,k} \cdot l = 1,35 \cdot \frac{1}{2} \cdot 3,00 \cdot 9,60 \quad = \quad 19,44\ kN$

Live load: $Q_d = \gamma_Q \cdot \frac{1}{2} \cdot q_k \cdot l = 1,50 \cdot \frac{1}{2} \cdot 12,5 \cdot 9,60 \quad = \quad 90,00\ kN$

Bearing support force in the final state: $V_{Ed,\ total} \quad = \quad 206,64\ kN$

5. Plate thickness on bearing:

Plate thickness in bearing area in final state with topping layer:

h_{plate} = 16 cm + 1 cm (Superelevation) = 17 cm

6. Dimensioning:

selected:
Pfeifer Steel Bearing PS-A 80/100

Z-15.6-287, Annex 1, Page 2, Table 1.4

Embedment depth of the anchor plate in the web:

$l = 0,55 \cdot h_{Web}$ = 210 mm — Z-15.6-287, Annex 2, point 1

$l = 0,55 \cdot 500$ = 275 mm

H = l + 15 mm = 275 + 15 mm = 290 mm

Length starting from 225 mm with 25 mm graduation (steps stocked as standard)

selected: H = 300 mm

6.1 Installation state

Proof of the transversal shear force carrying capacity in the mounting state

According to Z-15.6-287, Annex 1, Table 1.4 for web height 50 cm:

$V_{Rd,\,mounting} = 100\ kN$

$$\frac{V_{Ed,\,mounting}}{V_{Rd,\,mounting}} = \frac{98{,}7}{100} = 0{,}99 < 1{,}0$$

Z-15.6-287, Annex 1, Table 1.4

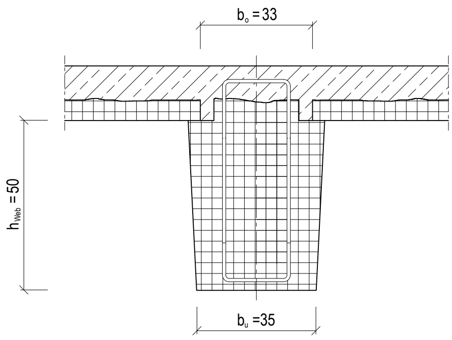
Note: Appropriate measures are to be taken to prevent the secondary joist tipping over or twisting in the mounting state (e.g. fixing brackets bolted to anchor channels).

Proof:

6.2 Final state

Base module assignment

Z-15.6-287, Annex 2, pages 1 u. 3



Geometric boundary conditions:

1. Web height:	h_{web}	= 50 cm	> 30 cm
2. Web width, bottom:	b_u	= 35 cm	> 24 cm
3. Web width, top:	b_o	= 33 cm	≥ 28 cm

→ All 3 minimum dimensions are complied with for the base module 2.

→ Assignment of the cross section to base module 2 is thus justified.

Remark about the base module assignment

If the geometric boundary conditions of base module 2 are complied with, the assignment of base module 1 would generally also be permissible. However, this would produce less favourable values, therefore the assignment of base module 2 should be aimed for if this is justified by the existing cross section dimensions.

Proof of the transversal shear force carrying capacity in the final state: selected bearing reinforcement

– Horizontal additional concrete steel reinforcement: 4 ∅12 ∅ 4, 52 cm^2 (Reinforcement position 5)

– Suspension reinforcement (stirrup/each two legged):

Stirrups and stirrup caps:	∅ 8	Reinforcement position 1/2
Bent-up loop:	∅10	Reinforcement position 6
Stirrup below 45°:	∅10	Reinforcement position 7

– Values taken from the dimensioning table

Transversal shear force carrying capacity in the final state:	$V_{Rd,total}$	=	234,15 kN
Use of the stirrup caps:	$A_{s,reg}/A_{s,actual}$	=	1,00
Ratio value (to Z-15.6-287, Annex 2.7, point 7):	ζ	=	1,00
Actual anchorage length of the lower web reinforcement:	$l_{b,ind,actual}$	=	12,3 cm

Z-15.6-287, Annex 3 (pages 12 of 22), line 10

PS-A 80/100
Base module 2
Web height 50 cm
Plate thickness 17 cm
Topping layer C25/30
Horizontal additional concrete steel reinforcement: 4 ∅ 12

Proof:

$$\frac{V_{Ed,\,total}}{V_{Rd,\,total}} = \frac{206{,}64}{234{,}15} = 0{,}88 < 1{,}0$$

7. Load of the in-situ topping in building site operation:

7.1 Permissible changeable actions after installation of the in-situ topping without exact proof:

Per unit area: $q_{m,k} = 1{,}00 \frac{kN}{m^2}$

$q_{m,d} = \gamma_Q \cdot q_{m,k} = 1{,}50 \cdot 1{,}00 = 1{,}50 \frac{kN}{m^2}$

Requirement: Minimum early aged concrete strength 40% of f_{CK} of the topping layer (Z-15.6-287, section 4.3).

7.2 Permissible changeable actions with more exact proof:

Per bearing:

$$Q_{M,d,zul} = V_{Rd,Mon} - V_{Ed,Mon} + 0{,}4 \cdot (V_{Rd,total} - V_{Rd,Mon})$$

$$Q_{M,d,zul} = 100{,}00 - 98{,}70 + 0{,}4 \cdot (234{,}15 - 100{,}00) = 54{,}96\,kN$$

$$Q_{M,k,zul} = \frac{Q_{M,d}}{\gamma_Q} = \frac{54{,}96}{1{,}50} = 36{,}64\,kN$$

Per unit area:

$$q_{m,k,zul} = \frac{\text{number of steel bearings} \cdot Q_{M,k,zul}}{A} = \frac{2 \cdot 36{,}64}{2{,}5 \cdot 9{,}60} = 3{,}05 \frac{kN}{m^2}$$

Residual load capacity of steel girder + concrete portion at a strength of the early aged concrete of 40 % of f_{CK} of the topping layer

8. Reinforcement layout:

8.1 Anchoring of the additional concrete steel reinforcement

Reinforcement position 5

8.1.1 Anchoring above the joist

End bearing, direct bearing, angle hook, good bond, B500B, C25/30:

Z-15.6-287, Annex 2, point 4

$$l_{b,dir,req} = \frac{2}{3} \cdot \alpha \cdot \frac{\varnothing}{4} \cdot \frac{f_{yd}}{f_{bd}} \cdot \frac{A_{s,req}}{A_{s,actual}} \begin{cases} \geq 6 \cdot d_s \\ \geq 16\,cm \end{cases}$$

$$\alpha_a = 0{,}7$$

$$f_{yd} = \frac{f_{yk}}{\gamma_s} = \frac{500}{1{,}15} = 434{,}78 \frac{N}{mm^2}$$

$$f_{bd} = 2{,}7 \frac{N}{mm^2}$$

$$l_{b,red} = \frac{\varnothing}{4} \cdot \frac{f_{yd}}{f_{bd}} = \frac{1{,}2}{4} \cdot \frac{434{,}78}{2{,}7} = 48{,}31\ cm$$

Calculation of $A_{s,req}$ by linear interpolation (values from the dimensioning table):

Z-15.6-287, Annex 3, page 12, lines 9 a. 10

$$A_{s,req} = 2{,}26 + \frac{206{,}64 - 160{,}65}{234{,}15 - 160{,}65} \cdot (4{,}48 - 2{,}26) = 3{,}65\ cm^2$$

Anchoring

$$l_{b,dir,req} = \frac{2}{3} \cdot 0{,}7 \cdot 48{,}31 \cdot \frac{3{,}65}{4{,}52} = 18{,}2\,cm \begin{cases} \geq 6 \cdot 1{,}2 = 7{,}2\,cm \\ \geq 16\,cm \end{cases}$$

Transverse reinforcement in the anchoring area:

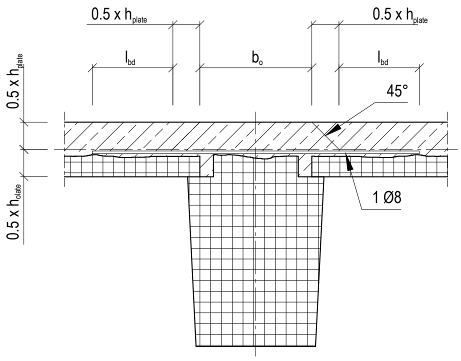
selected: 1 ∅ 8

Z-15.6-287, Annex 2, point 8
Reinforcement position 101

Bend rectangular if in web area of steel girder.

Length of the transverse reinforcement:

The required length is determined as follows:



$$l_{erf} = b_o + 2 \cdot 0,5 \cdot h_{plate} + 2 \cdot l_{bd} = b_o + h_{plate} + 2 \cdot l_{bd}$$

mit $l_{bd} = l_{b,eq} = \alpha_1 \cdot l_{b,\,rqd}$ — DIN EN 1992-1-1/NA, 8.4.4 (2)

Straight bar ends, good bond, B500B, C25/30:

$$\alpha_1 = 1,0$$

$$f_{yd} = \frac{f_{yk}}{\gamma_s} = \frac{500}{1,15} = 434,78 \frac{N}{mm^2}$$

$$f_{bd} = 2,7 \frac{N}{mm^2}$$

$$l_{b,rqd} = \frac{\varnothing}{4} \cdot \frac{\sigma_{sd}}{f_{bd}} = \frac{0,8}{4} \cdot \frac{434,78}{2,7} = 32,21 \text{ cm}$$

with $\sigma_{sd} = f_{yd}$

required actual: $\frac{A_{s,req}}{A_{s,actual}} = 1,0$

$$l_b = l_{b,eq} = 1,0 \cdot 32,21 \cdot 1,0 = 32,21 \text{cm} > l_{b,min}$$

$$\rightarrow l_{req} = 33,0 + 17,0 + 2 \cdot 32,21 = 114,4 \text{ cm}$$

selected: L = 115 cm

8.1.2 Anchoring in the precast element

moderate bond, B500B, C35/45

$$l_{bd} = \alpha_1 \cdot \frac{\varnothing}{4} \cdot \frac{f_{yd}}{f_{bd}} \cdot \frac{A_{s,req}}{A_{s,actual}} \quad 10d_s$$

Z-15.6-287, Annex 2, point 5

$$\alpha_1 = 1,0$$

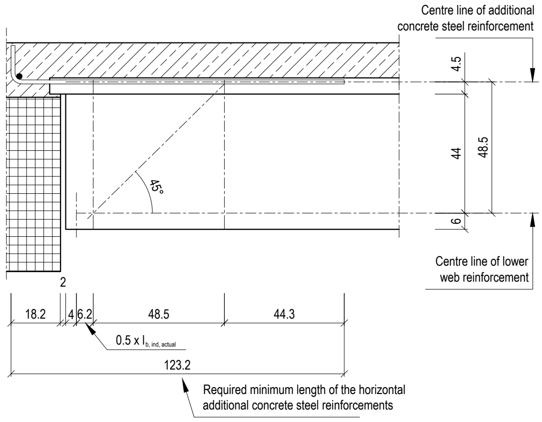
$$f_{bd} = 3,4 \frac{N}{mm^2} \cdot 0,7 = 2,38 \frac{N}{mm^2}$$

$$l_{b,rqd} = \frac{\varnothing}{4} \cdot \frac{\sigma_{sd}}{f_{bd}} = \frac{1,2}{4} \cdot \frac{434,78}{2,38} = 54,80 \text{ cm}$$

with $\sigma_{sd} = f_{yd}$

Anchoring

$$l_{bd} = 1,0 \cdot 54,80 \cdot \frac{3,65}{4,52} = 44,3 \text{cm} > 10 \cdot 1,2 = 12 \text{ cm}$$



$l_{b,ind,actual}$ see Z-15.6-287, Annex 3

8.2 Anchoring of the lower web reinforcement (prestressing steel or untensioned reinforcement)

Z-15.6-287, Annex 2, point 7

The lower web reinforcement is anchored with stirrups.

Required stirrup cross section: $A_{s,req} = \frac{V_{Ed,total} \cdot \zeta}{f_{yd}} = \frac{206,64 \cdot 1,00}{43,48} = 4,75\,cm^2$

according to dimensioning table PS-A80/100

Note:
According to Z-15.6-287, Annex 2, point 7, the cross section of the bent-up loop ∅ 10 (two legged) may be applied for $A_{s,actual}$. In addition, the existing lower longitudinal web reinforcement (prestressing steel and untensioned reinforcement) can be considered if the existing development length is at least $10 \times d_s$. As this is not the case here, you are generally on the safe side.

Bent-up loop Ø 10 (two legged): $A_{s,actual} = 1,57\,cm^2$

$\Delta A_{s,req} = 4,75 - 1,57 = 3,18\,cm^2$

selected: B500B 4 stirrups ∅10 (two legged)

Reinforcement position 10/11

$\Delta A_{s,actual} = 4 \cdot 2 \cdot 0,785 = 6,28\,cm^2 > \Delta A_{s,req} = 3,18\,cm^2$

Anchorage length $l_{b,ind,req}$ of the stirrup

Indirect bearing, loops, good bond, B500B, C35/45

$$l_{b,ind,req} = \alpha_1 \cdot \frac{\varnothing}{4} \cdot \frac{f_{yd}}{f_{bd}} \cdot \frac{A_{s,req}}{A_{s,actual}} \begin{cases} \geq 10 \cdot d_s \\ \geq 12\,cm \end{cases}$$

Z-15.6-287, Annex 2, point 7

$$\alpha_1 = 0,7$$

$$f_{bd} = 3,4\,\frac{N}{mm^2}$$

$$l_{b,rqd} = \frac{\varnothing}{4} \cdot \frac{\sigma_{sd}}{f_{bd}} = \frac{1,0}{4} \cdot \frac{434,78}{3,4} = 31,97cm$$

with $\sigma_{sd} = f_{yd}$

Anchoring

$$l_{b,ind,req} = 0,7 \cdot 31,97 \cdot \frac{3,18}{6,28} = 11,3\,cm \begin{cases} < l_{b,ind,actual} = 12,3\ cm \\ > 12\ cm \\ > 10 \times\ d_s = 10\ cm \end{cases}$$

Required leg length of the stirrups

$l_{total} = l_{b,ind,actual} + l_o \geq l_{bd}$ of the lower web reinforcement starting from point A
(EN 1992-1-1/NA is to be observed)

See next page for sketch

Good bond, straight bar ends, full joint:

$l_{b,rqd} = 31{,}97$ cm

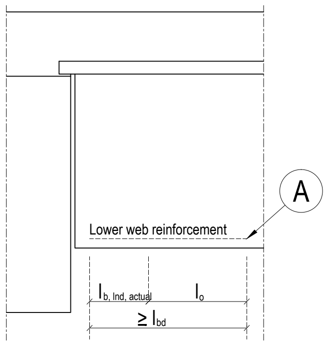
$$l_o = \alpha_1 \cdot \alpha_3 \cdot \alpha_5 \cdot \alpha_6 \cdot l_{b,rqd} \begin{cases} \geq 0{,}3 \cdot \alpha_1 \cdot \alpha_6 \cdot l_{b,rqd} \\ \geq 15 \cdot \varnothing \\ \geq 20\,\text{cm} \end{cases}$$

$$l_s = 1{,}0 \cdot 1{,}0 \cdot 1{,}0 \cdot 1{,}4 \cdot 31{,}97 \cdot \frac{3{,}18}{6{,}28} = 22{,}7\text{ cm} \begin{cases} \geq 0{,}3 \cdot 1{,}0 \cdot 1{,}4 \cdot 31{,}97 = 13{,}43\text{ cm} \\ \geq 15 \cdot \varnothing = 15 \cdot 1{,}0 = 15\,\text{cm} \\ \geq 20\,\text{cm} \end{cases}$$

Leg length of the stirrups

$l_{total} = 12{,}3 + 22{,}7 = 35$ cm

Structurally, the same leg length (l = 75 cm) is selected as for reinforcement positions 8 and 9.



8.3 Transverse shear reinforcement and splitting tensile reinforcement

selected:	8 ∅ 8	Reinforcement position 4/12
	2 ∅ 8	Reinforcement position 13

According to approval Z-15.6-287, Annex 2, fig. 17 ("General technical application criteria")

Z-15.6-287, Annex 2, fig. 17

Note:
On account of the reinforcement of the recess for the element slabs, 8 + 2 = 10 ∅ 8 are actually arranged from pos. 4 and 12 (see reinforcement drawing).

8.4 Overlap length of the stirrup caps with the continuous main stirrups

Reinforcement position 1/2

Good bond, B500B, C25/30

Z-15.6-287, Annex 2, Pkt. 2

$$l_o = 1{,}40 \cdot \frac{A_{s,req}}{A_{s,actual}} \cdot \frac{\varnothing}{4} \cdot \frac{f_{yd}}{f_{bd}} \quad 20\text{ cm}$$

$$f_{bd} = 2{,}7\,\frac{N}{mm^2}$$

$$l_o = 1{,}4 \cdot 1{,}0 \cdot \frac{0{,}8}{4} \cdot \frac{434{,}78}{2{,}7} = 45{,}1\text{ cm}$$

Note:
This required overlap length results in accordance with Z-15.6-287 if the joint of the rebars is located in the precast element and in the topping layer. In this case, to be on the safe side, the lower absorbable bonding stresses of the topping layer are applied over the entire length.

$\frac{A_{s,req}}{As_{,actual}}$ according to the dimensioning table PS · A 80/100

In the present example, however, the overlapping joint is arranged entirely within the precast element. The absorbable bonding stresses of the precast element concrete are thus relevant.

Reinforcement position 1/2

Required overlap length in case of joint overlap in the precast element:

$$l_{o,Precast\ element} = \frac{f_{bd\ top.\ layer}}{f_{bd\ Precast\ element}} \cdot l_o \geq 20\,cm$$

└ joint overlap determined according to Z-15.6-287

Z-15.6-287

$$l_{o,\ Precast\ element} = \frac{2,7}{3,4} \cdot 45,1 = 35,8\,cm$$

This makes it possible to install stirrups pos. 1 and 4 as well as 2 and 3 in one plane (see reinforcement drawing) without them intersecting. This is advantageous with regard to the required space.

For design notes, refer also to section 11.

Other shapes such as closed stirrups can also be executed. The "General technical application criteria" (Z-15.6-287) must be fulfilled.

8.5 Anchoring of the stirrup under 45° inclination in the precast web

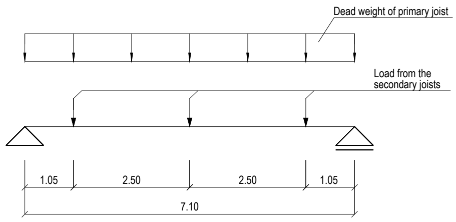
Reinforcement position 7

$$h_{Web} = 50\,cm \rightarrow l_{b,net} \geq 20\,cm$$

Z-15.6-287, Annex 2, point 9

9. Load application primary joist, eccentricities, bearing:

Static system of primary joist



Mounting the primary joist on the column bracket with elastomer bearings.

Bearing dimensions: $b \times d \times t = 300 \times 150 \times 10$ mm

Assumption: $\sigma_{perm} = 15 \frac{N}{mm^2}$ (→ permissible compressive stress of the elastomer bearing)

Reference: DIN 4141, Part 3, Bearings in the construction industry

9.1 Proof of the edge tensile force $F_{t,d}$ in the primary joist

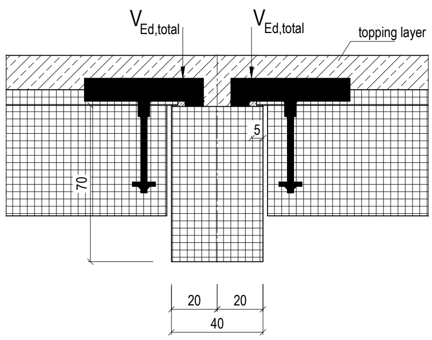
The final state of the transversal shear force carrying capacity $V_{Ed,total}$ with double-sided changeable load is applied here, as this is the decisive case for the ultimate limit state of the looad capacity.

Z-15.6-287, Annex 2, point 13

$$F_{t,d} = V_{Ed,total} \cdot \left(\frac{e}{d} - \frac{1}{6}\right) \geq 0$$

DAfStb. book 240, section 5.3, eq. (5.4)

Point of application of the bearing forces



Point of application of the loads in the final state: Z-15.6-287, Annex 2, point 15

$$V_{Ed,total} = 206,64\ kN$$

$$e = 0,20 - 0,05 = 0,15\,m$$

$$d = 0,40\,m$$

$$F_{t,d} = 206,64 \cdot \left(\frac{0,15}{0,40} - \frac{1}{6}\right) = 43,05\ kN$$

Required edge tensile reinforcement in the primary joist

$$A_{s,req} = \frac{F_{t,d}}{f_{yd}} = \frac{43,05}{43,48} = 0,99\ cm^2$$

selected: B500A 4 ∅ 6 (1-legged)

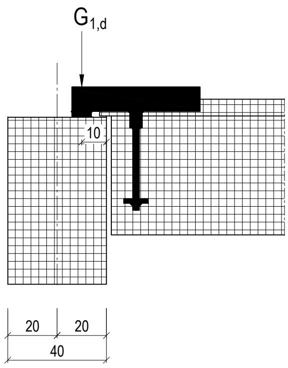
Use a thin bar diameter.
Reinforcement position 14

$$A_{s,actual} = 1,13\,cm^2 > A_{s,actual} = 0,99\ cm^2$$

Notice:
The proof of the bearing pressure of the PFEIFER Steel Bearing is part of the type-static calculation and no longer has to be explicitly provided by the user!

9.2 Eccentricity and bearing pressure of the main joist in the installed state in case of single-sided element slab positioning without topping layer

Point of application of the installation bearing force:



Point of application of the load in the installation state: Z-15.6-287, Annex 2, point 14

Note:
Secure secondary beams against twisting or tipping over in the installed state!

Characteristic stresses

Precast secondary joist and element slabs without topping layer:

$$G_{1,k} = \frac{G_{1,d}}{\gamma_{G,sup}} = \frac{54,69}{1,35} = 40,51\ kN$$

see paragraph 4.1

Dead weight of primary joist:

$$g_{HU,k} = 0,40 \cdot 0,70 \cdot 25 = 7,00\,\frac{kN}{m}$$

„Primary joist“

Characteristic bearing reaction

From secondary joists and element slabs:

$$A_{D,k} = B_{D,k} = \frac{1}{2} \cdot 3 \cdot 40,51 = 60,77\ kN$$

„Slab“

From dead weight of primary joist:

$$A_{HU,k} = B_{HU,k} = \frac{1}{2} \cdot 7,00 \cdot 7,10 = 24,85\ kN$$

Maximum eccentricity on bearing

$$M_{A,d} = \left(\frac{b}{2} - 0,10\right) \cdot A_{D,k} \cdot \gamma_{sup} = \left(\frac{0,40}{2} - 0,10\right) \cdot 60,77 \cdot 1,05 = 6,38\ kNm$$

„Eccentricity“

Reference: EN 1990
Proof of the positional security

$$A_{A,d} = A_{D,k} \cdot \gamma_{sup} + A_{HU,k} \cdot \gamma_{inf} = 60,77 \cdot 1,05 + 24,85 \cdot 0,95 = 87,42\ kN$$

gaping joint at joist bearing

$$e = \frac{M_{A,d}}{A_{A,d}} = \frac{6,38}{87,42} \cdot 100 = 7,3\,cm < \frac{30,0}{3} = 10,0\ cm$$

Maximum bearing pressure

$$M_P = \left(\frac{b}{2} - 0{,}10\right) \cdot A_{D,k} = \left(\frac{0{,}40}{2} - 0{,}10\right) \cdot 60{,}77 = 6{,}08\,kNm$$

"Pressure"

Reference DIN 4141, Part 3, Bearings in the construction industry

$$A_P = A_{D,k} + A_{HU,k} = 60{,}77 + 24{,}85 = 85{,}62\,kNm$$

$$e = \frac{M_P}{A_P} = \frac{6{,}08}{85{,}62} \cdot 100 = 7{,}1\,cm \begin{cases} \geq \frac{30{,}0}{6} = 5{,}0\,cm \\ < \frac{30{,}0}{3} = 10{,}0\,cm \end{cases}$$

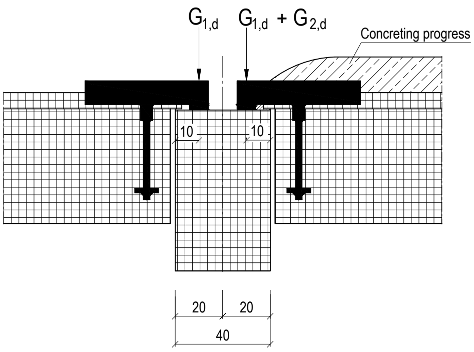
$$c = \frac{30{,}0}{2} - 7{,}1 = 7{,}9\,cm$$

$$\sigma_{actual} = \frac{2 \cdot A_P}{3 \cdot b \cdot c} = \frac{2 \cdot 85{,}62}{3 \cdot 15{,}0 \cdot 7{,}9} \cdot 10 = 4{,}82\,\frac{N}{mm^2} < \sigma_{perm} = 15\,\frac{N}{mm^2}$$

Elastomer bearing pressure under joist

9.3 Eccentricity and bearing pressure of the joist in the mounting state with double-sided element slab positioning and single-sided topping layer

Point of application of the installation bearing force:



Point of application of the load in the mounting state: Z-15.6-287, Annex 2, point 14

Note:

Secure secondary beams against twisting or tipping over in the mounting state.

Characteristic actions

Precast secondary joist and element slabs without topping layer:

$$G_{1,k} = 40{,}51\,kN$$

see paragraph 9.2

Topping layer:

$$G_{2,k} = \frac{G_{2,d}}{\gamma_{G,sup}} = \frac{42{,}51}{1{,}35} = 31{,}49\,kN$$

see paragraph 4.1

Dead weight of primary joist:

$$g_{HU,k} = 7{,}00\,\frac{kN}{m}$$

Characteristic bearing reactions

From secondary joist and element slabs:

$$A_{D,k} = B_{D,k} = 60{,}77\,kN$$

see paragraph 9.2

From topping layer:

$$A_{Auf,k} = B_{Auf,k} = \frac{1}{2} \cdot 3 \cdot 31{,}49 = 47{,}24\,kN$$

From dead weight of primary joist:

$$A_{HU,k} = B_{HU,k} = 24{,}85\,kN$$

see paragraph 9.2

Maximum eccentricity on bearing

$$M_{A,d} = \left(\frac{b}{2} - 0{,}10\right) \cdot \left(A_{Auf,k} \cdot \gamma_{sup} + A_{D,k} \cdot \left(\gamma_{sup} - \gamma_{inf}\right)\right) =$$

$$= \left(\frac{0{,}40}{2} - 0{,}10\right) \cdot \left(47{,}24 \cdot 1{,}05 + 60{,}77 \cdot \left(1{,}05 - 0{,}95\right)\right) = 5{,}57\,kNm$$

Reference: EN 1990 Proof of the position stability

$$A_{A,d} = A_{D,k} \cdot (\gamma_{sup} + \gamma_{inf}) + A_{Auf,k} \cdot \gamma_{sup} + A_{HU,k} \cdot \gamma_{inf} =$$
$$= 60,77 \cdot (1,05 + 0,95) + 47,24 \cdot 1,05 + 24,85 \cdot 0,95 = 194,75\,kN$$

$$e = \frac{M_{A,d}}{A_{A,d}} = \frac{5,57}{194,75} \cdot 100 = 2,9\,cm < \frac{30,0}{6} = 5,0\,cm$$

no gaping joint

Maximum bearing pressure

$$M_P = \left(\frac{b}{2} - 0,10\right) \cdot A_{Auf,k} = \left(\frac{0,40}{2} - 0,10\right) \cdot 47,24 = 4,72\,kNm$$

$$A_P = 2 \cdot A_{D,k} + A_{Auf,k} + A_{HU,k} = 2 \cdot 60,77 + 47,24 + 24,85 = 193,63\,kN$$

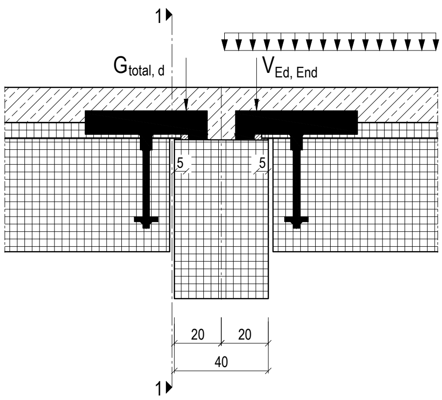
$$e = \frac{M_P}{A_P} = \frac{4,72}{193,63} \cdot 100 = 2,4\,cm < \frac{30,0}{6} = 5,0\,cm$$

$$\sigma_{actual} = \frac{A_P}{b \cdot d} \cdot \left(1 + \frac{6 \cdot e}{d}\right) = \frac{193,63}{15,0 \cdot 30,0} \cdot \left(1 + \frac{6 \cdot 2,4}{30,0}\right) \cdot 10 = 6,4\,\frac{N}{mm^2} < \sigma_{perm} = 15\,\frac{N}{mm^2}$$

Elastomer bearing pressure under joist

9.4 Eccentricity and bearing pressure of the joist in the final state with single-sided changeable stress

Point of application of the bearing forces:



Point of application of the loads in the end state: Z-15.6-287, Annex 2, point 15

Characteristic actions

Precast secondary joist and element slabs with topping layer:

$$G_{1,k} + G_{2,k} = 40,51 + 31,49 = 72,00\,kN$$

see paragraph 9.2/9.3

Superstructure loads:

$$G_{3,k} = \frac{G_{3,d}}{\gamma_{G,sup}} = \frac{19,44}{1,35} = 14,40\,kN$$

see paragraph 4.2

Imposed load:

$$Q_k = \frac{1}{2} \cdot q_k \cdot A_{total} = \frac{1}{2} \cdot 5,0 \cdot 2,5 \cdot 10,0 = 62,5\,kN$$

Dead weight of primary joist:

$$g_{HU,k} = 0,40 \cdot 0,87 \cdot 25 = 8,70\,\frac{kN}{m}$$

Characteristic bearing reactions

From secondary joists and element slabs:

$$A_{D,k} = B_{D,k} = \frac{1}{2} \cdot 3 \cdot (2 \cdot (72,00 + 14,40) + 62,5) = 352,95\,kN$$

From dead weight of primary joist:

$$A_{HU,k} = B_{HU,k} = \frac{1}{2} \cdot 8,70 \cdot 7,10 = 30,89\,kN$$

$$A_{total,k} = B_{total,k} = 383,84\,kN$$

Bending dimensioning of the slab in section 1 – 1

$M_{Ed} = 1{,}50 \cdot 62{,}5 \cdot (0{,}20 - 0{,}05) = 14{,}06$ kNm

$h = 17$ cm

$d = 13$ cm

$b = 1{,}00$ m

$f_{cd} = 14{,}2 \frac{MN}{m^2}$

$\frac{f_{yd}}{f_{cd}} = 30{,}7$

$\mu = \frac{14{,}06}{1{,}0 \cdot 13^2 \cdot 1{,}42} = 0{,}059$

$\rightarrow \omega_1 = 0{,}0610$

$\rightarrow A_{s_1} = \omega_1 \cdot \frac{b \cdot d}{\frac{f_{yd}}{f_{cd}}} = 0{,}0610 \cdot \frac{100 \cdot 13}{30{,}7} = 2{,}58 \frac{cm^2}{m}$

Dimensioning is done in the cross section 1 – 1. For simplification and to be on the safe side, however, the bending moment above the centre of the joist is used for this.

For the arrangement and execution of the reinforcement, refer also to DAfStb. Book 220, Section 2.5 and F. Leonhardt "Vorlesungen über Massivbau [Lectures on structural concrete]", 3rd Part (Published March 1977), Section 9.4

Bearing pressure

$\sigma_{actual} = \frac{A_{total}}{b \cdot d} = \frac{383{,}84}{15{,}0 \cdot 30{,}0} \cdot 10 = 8{,}53 \frac{N}{mm^2} < \sigma_{perm} = 15 \frac{N}{mm^2}$

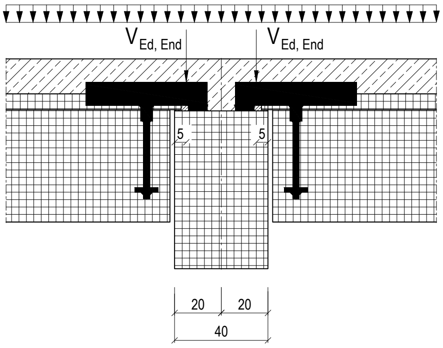
Reference: DIN 4141, Part 3, Bearings in the construction industry

Elastomer bearing pressure under joist

No eccentricity occurs for the bearing in the final state as the eccentricity of the live load is dissipated as a bending moment in the slab.

9.5 Eccentricity and bearing pressure of the joist in the final state with double-sided changeable stress

Point of application of the bearing forces:



Point of application of the loads in the final state, Annex 2, point 15

Characteristic actions

Precast secondary joist and element slabs with topping layer:

$G_{1,k} + G_{2,k} = 72{,}00$ kN

see paragraph 9.4

Superstructure loads:

$G_{3,k} = 14{,}40$ kN

Imposed load:

$Q_k = 62{,}50$ kN

Dead weight of primary joist:

$g_{HU,k} = 8{,}70 \frac{kN}{m}$

Characteristic bearing reactions

From secondary joists and element slabs:

$A_{D,k} = B_{D,k} = \frac{6}{2} \cdot (72{,}00 + 14{,}40 + 62{,}5) = 446{,}7$ kN

From dead weight of primary joist:

$A_{HU,k} = B_{Hu,k} = \frac{1}{2} \cdot 8{,}70 \cdot 7{,}10 = 30{,}89$ kN

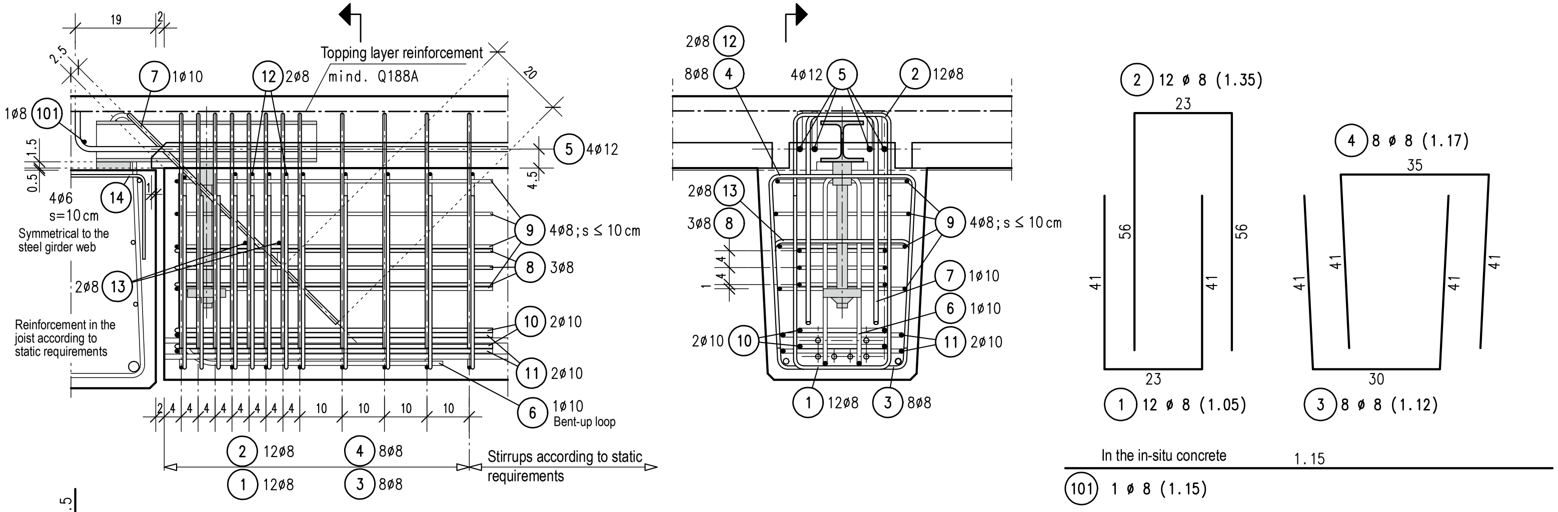
$A_{total,k} = B_{total,k} = 477{,}59$ kN

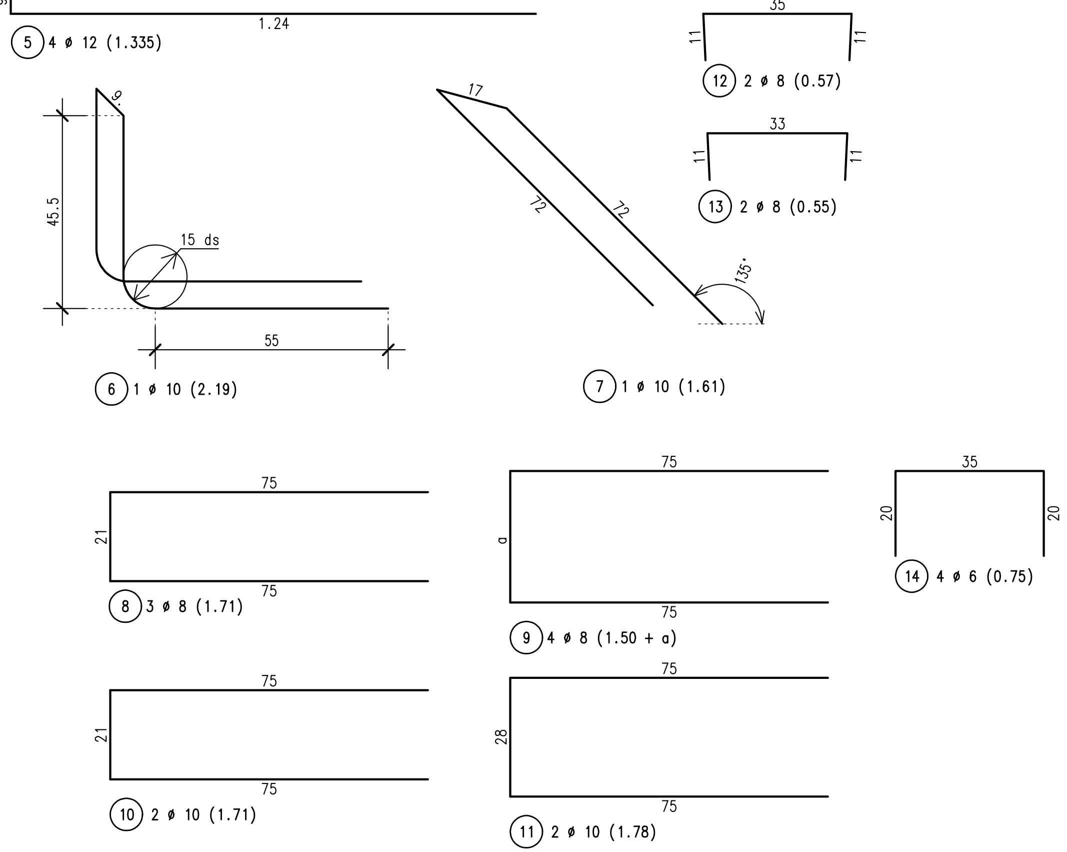
Bearing pressure

$\sigma_{actual} = \frac{A_{total}}{b \cdot d} = \frac{477{,}59}{30 \cdot 15} \cdot 10 = 10{,}6 \frac{N}{mm^2} < \sigma_{perm} = 15 \frac{N}{mm^2}$

Reference: DIN 4141, Part 3, Bearings in the construction industry

10 Reinforcement plan:





For bending points without specification of the mandrel diameter, its minimum value applies $4d_s$ (d_s < 20 mm) res. $7d_s$ (d_s ≥ 20 mm).

Quality control measures according to EN 1992-1-1/NA,4.4.1.3(3) are agreed for the installation of the reinforcement.

Load of the in-situ topping in building site operation:

Prerequisite: Minimum young concrete strength 40% of f of the topping layer (acc. to Z-15.6-287, par. 4.3). Refer to Section 7 for maximum live load in building site operation.

The precast secondary supporting beam must be protected against rotating/tipping over when installed!

The stirrups shown are easy-to-assemble bending suggestions. Other shapes, such as closed stirrups, are also possible. The "General technical application criteria" (Z-15.6-287, Annex 2) has to be fulfilled.

Example: PFEIFER PS-A Steel bearing

Exposure classes:	XC3/W0
Materials:	
Concrete:	
– Top layer:	C25/30
– Precast element:	C35/45
Reinforcing steel:	B 500 B
Concrete cover:	
– Top layer:	c_{nom} = 35 mm
– Precast element:	c_{nom} = 25 mm

11. Design notes:

As a supplement to the regulations and specifications of the German building authority approval Z-15.6-287 (Annex 2), this section contains further notes on the structural design of the PFEIFER PS-A Steel Bearing.

11.1 TT-plates

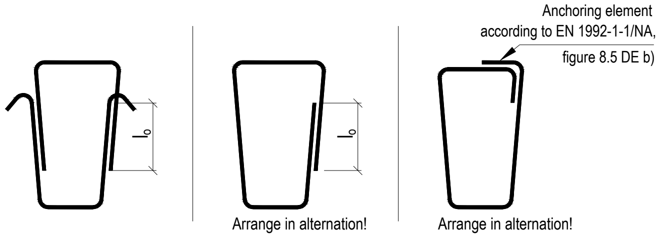
See following reference schematic to 1, 2,…

1 Do not arrange any horizontal concrete steel reinforcements near the steel profile (reinforcement drawing, pos. 5).

2 Observe the required rebar spacings according to EN 1992-1-1/NA, 8.2..

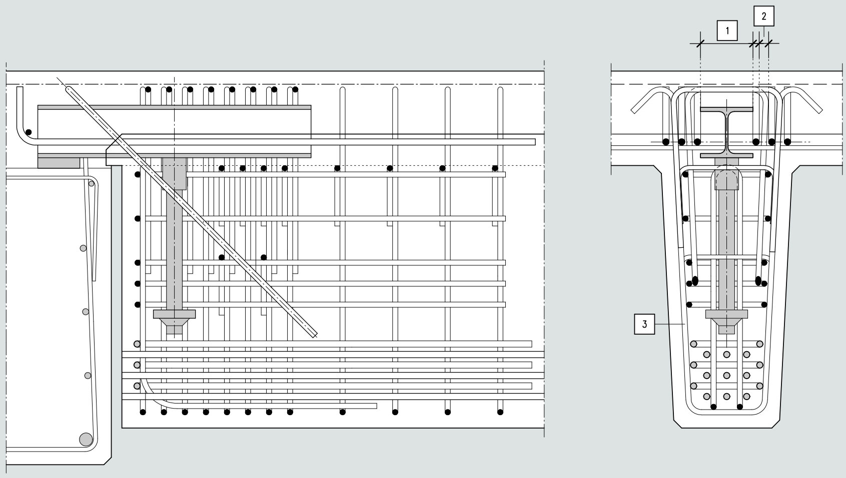
EN 1992-1-1/NA, 8.2

3 Possible stirrup shapes of the vertical suspension reinforcement:



The stirrups are to be executed in a way that the reinforcement concentration is as low as possible in the stirrup lock area and that the rebar spacing requirements according to EN 1992-1-1/NA, 8.2 are met.

EN 1992-1-1/NA, 8.2



11.2 Precast joists (with recesses on both sides for element slabs)

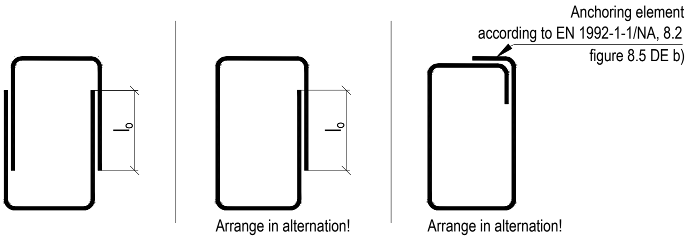
See following reinforcement schematic to 1, 2,…

1 Do not arrange any horizontal concrete steel reinforcement near the steel profile (reinforcement drawing, pos. 5)..

2 Observe the required rebar spacings according to EN 1992-1-1/NA, 8.2.

EN 1992-1-1/NA, 8.2

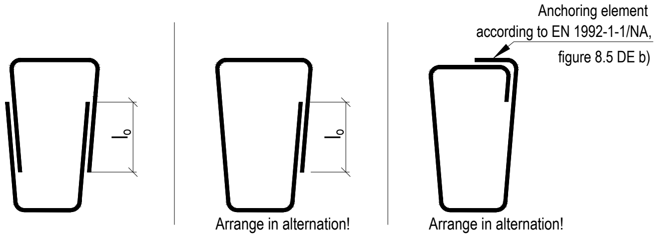
3 Possible stirrup shapes of the vertical suspension reinforcement:



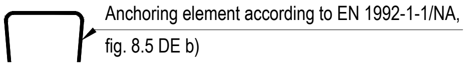
The stirrups are to be executed in such a way that the reinforcement concentration is as low as possible in the stirrup lock area and that the rebar spacing requirements according to EN 1992-1-1/NA, 8.2 are met (see Section 8.4 Note about the execution of reinforcement positions 1 – 4).

EN 1992-1-1/NA, 8.2

4 Possible shapes of the additional stirrups for the reinforcement of the recesses for the element slabs (cross section and quantity according to main statics at least 8 ∅8).



5 Lay out stirrups ∅ 8 over the entire cross section width.



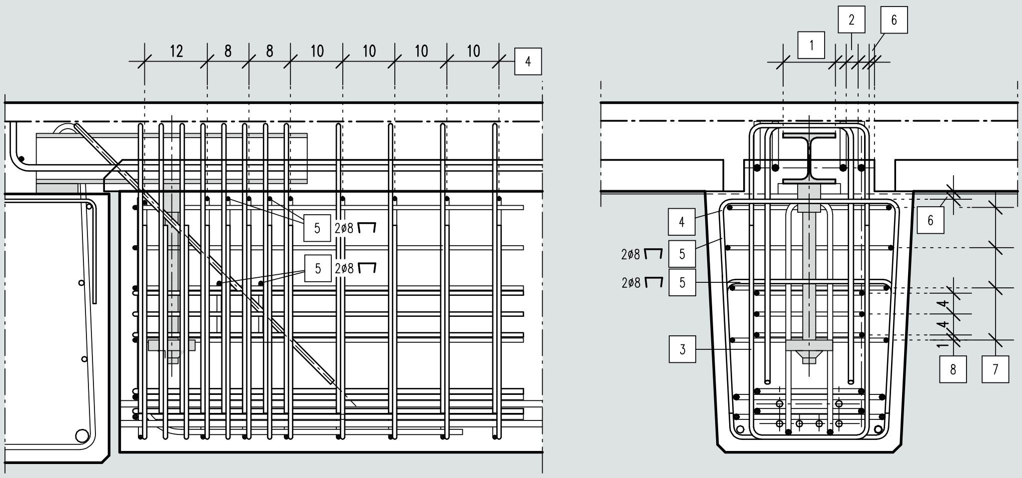
6 Minimum concrete cover in the recess area $c_{nom} = c_{min} \geq d_s \geq 10$ mm.

Z-15.6-287, Annex 2, fig. 13

7 Lay out horizontal stirrups (∅ 8; s ≤ 10 cm; leg length 75 cm) over the total cross section width and insert to the entire web height (from top edge of anchor plate to bottom edge of slab).

8 Arrange concentrated horizontal stirrups (3 ∅ 8; s = 4 cm; leg length 75 cm) within the vertical suspension reinforcement (see reinforcement drawing, pos. 8).

9 The precast secondary joist is to be secured against twisting/tipping over in the mounting state (proof/specifications by user depending on the assembly and concreting procedure). For example, protection against tipping over may possibly be achieved with fixing brackets bolted to anchor channels cast into the secondary and primary joist.



11.3 Trough plates (with single-sided recess for element slabs)

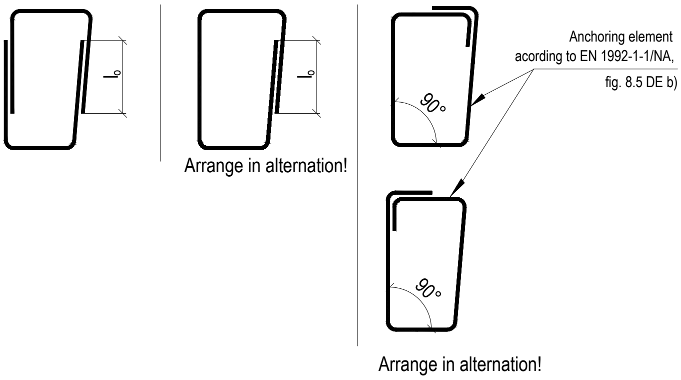
See following reinforcement schematic to 1, 2 ...

1 Do not arrange any horizontal concrete steel reinforcement near the steel profile (reinforcement drawing, pos. 5) (refer also to point 9).

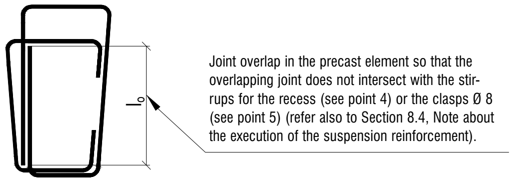
2 Observe the required rebar spacings according to EN 1992-1-1/NA, 8.2 (refer also to point 9).

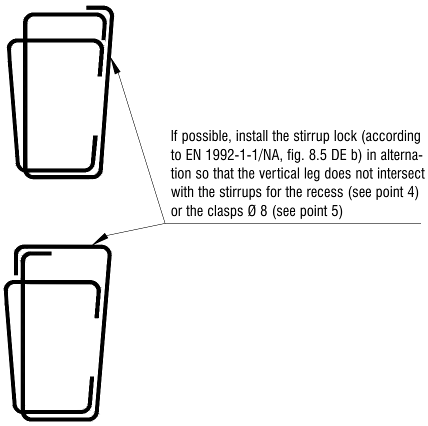
EN 1992-1-1/NA, 8.2

3 Possible stirrup shapes of the vertical suspension reinforcement:

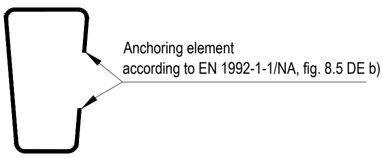


The stirrups are to be executed in such a way that the reinforcement concentration is as low as possible in the stirrup lock area and that the rebar spacing requirements according to EN 1992-1-1/NA, 8.23 are met.
The following executions, for example, are advantageous with regard to space requirements:

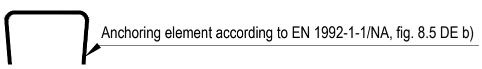




4 Recommended bending shape of the additional stirrups for the reinforcement of the recess for the element slabs (cross section and quantity according to main statics at least 8 ∅ 8).



5 Lay out clasps ∅ 8 over the entire cross section width.



Z-15.6, 287, Annex 2, fig. 13

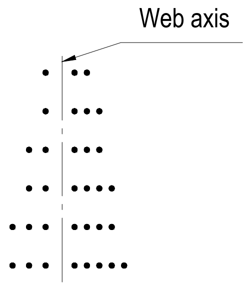
6 Minimum concrete cover in the recess area $c_{nom} = c_{min} \geq d_s \geq 10$ mm

7 Lay out horizontal stirrups (∅ 8; s ≤ 10 cm; leg length 75 cm) over the total cross section width and insert to the entire web height (from top edge of anchor plate to bottom edge of slab).

8 Arrange concentrated horizontal stirrups (3 ∅ 8; s = 4 cm; leg length 75 cm) within the vertical suspension reinforcement.

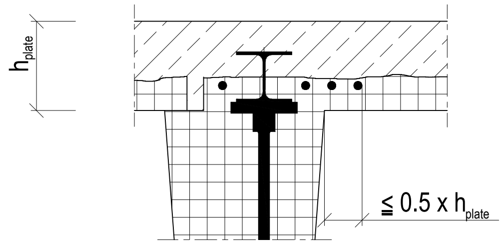
9 If necessary, the horizontal additional concrete steel reinforcement can also be arranged asymmetrically to the web axis, provided the following conditions are met:

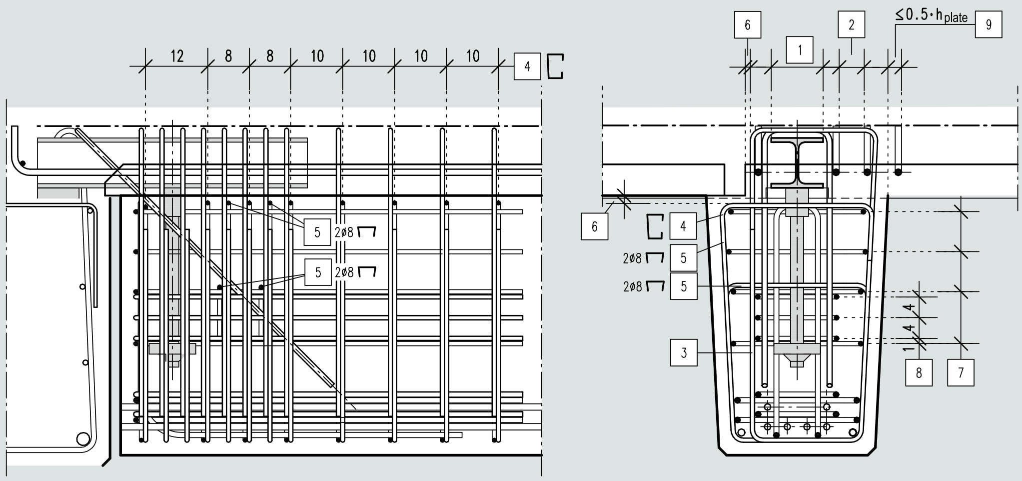
1.) The number of horizontal additional concrete steel reinforcement (reinforcement drawing, pos. 5) on both sides differs by 2 pieces at the most, which means that the following (asymmetric) arrangements are possible:



and:

2.) The maximum permissible distance from the outer edge of the web is $0.5 \times h_{plate}$





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