Deutsches Institut für Bautechnik

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Approval body for construction products and types of construction

Bautechnisches Prüfamt

An institution established by the Federal and Laender Governments

Designated according to Article 29 of Regulation (EU) No 305/2011 and member of EOTA (European Organisation for Technical Assessment)

European Technical Assessment ETA-17/0738 of 18 February 2022

English translation prepared by DIBt - Original version in German language

General Part

Technical Assessment Body issuing the European Technical Assessment:	Deutsches Institut für Bautechnik
Trade name of the construction product	TransMIT punching shear reinforcement
Product family to which the construction product belongs	Punching shear reinforcement with L- or Z-shaped metal sheets
Manufacturer	TransMIT Gesellschaft für Technologietransfer mbH Kerkrader Straße 3 35394 Gießen DEUTSCHLAND
Manufacturing plant	Werk 1
This European Technical Assessment contains	30 pages including 26 annexes which form an integral part of this assessment
This European Technical Assessment is issued in accordance with Regulation (EU) No 305/2011, on the basis of	EAD 160057-00-0301, Edition: 11/2020
This version replaces	ETA-17/0738 issued on 1 September 2020

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Specific Part

1 Technical description of the product

The TransMIT punching shear reinforcement system with metal sheets consists of cut, punched and bent steel sheets according to EN 10025-2:2004, with or without additional stirrups made of reinforcing steel B500A or B500B.

A distinction is made between the punching shear reinforcement system with L-sheets and the punching shear reinforcement system with Z-sheets. The punching shear reinforcement system with L-sheets is two-parted consisting of metal sheets with either one or two specially bent reinforcing steel stirrups, which are suspended in the metal sheets (two-part system). The L-sheets are manufactured in the horizontal slot type (letter "H" in the type designation) and diagonal slot type (letter "S" in the type designation). The punching shear reinforcement system with Z-sheets consists of single-part metal sheets without stirrups made of reinforcing steel (one-part metal sheets).

The detailed product description is given in Annex A.

2 Specification of the intended use in accordance with the applicable European Assessment Document

The performances given in Section 3 are only valid if the product is used in compliance with the specifications and conditions given in Annex B.

The verifications and assessment methods on which this European Technical Assessment is based lead to the assumption of a working life of the product of at least 50 years. The indications given on the working life cannot be interpreted as a guarantee given by the producer, but are to be regarded only as a means for choosing the right products in relation to the expected economically reasonable working life of the works.

3 Performance of the product and references to the methods used for its assessment

3.1 Mechanical resistance and stability (BWR 1)

Essential characteristic	Performance
Increasing factor for punching shear resistance	$k_{pu,sl}$ = 2,05 for L-shaped metal sheets $k_{pu,sl}$ = 1,71 for Z-shaped metal sheets $k_{pu,fo}$ = 1,40
Increasing factor for maximum interface shear resistance	$k_{max,i}$ = 0,5

3.2 Safety in case of fire (BWR 2)

Essential characteristic	Performance
Reaction to fire	class A1

4 Assessment and verification of constancy of performance (AVCP) system applied, with reference to its legal base

In accordance with EAD No. 160057-00-0301 the applicable European legal act is: [97/597/EC(EU)].

The system(s) to be applied is (are): [1+]

5 Technical details necessary for the implementation of the AVCP system, as provided for in the applicable EAD

Technical details necessary for the implementation of the AVCP system are laid down in the control plan deposited with Deutsches Institut für Bautechnik.

Reference Documents

EN 10025-2: 2019-10	Hot rolled products of structural steels - Part 2: Technical delivery conditions for non-alloy structural steels
EN 206:2013 + A1:2016	Concrete - Specification, performance, production and conformity
EN 1992-1-1:2004 + AC:2010	Design of concrete - Part 1 -1: General rules and rules for buildings

Dipl.-Ing. Beatrix Wittstock
Head of Section

beglaubigt:
Schüler

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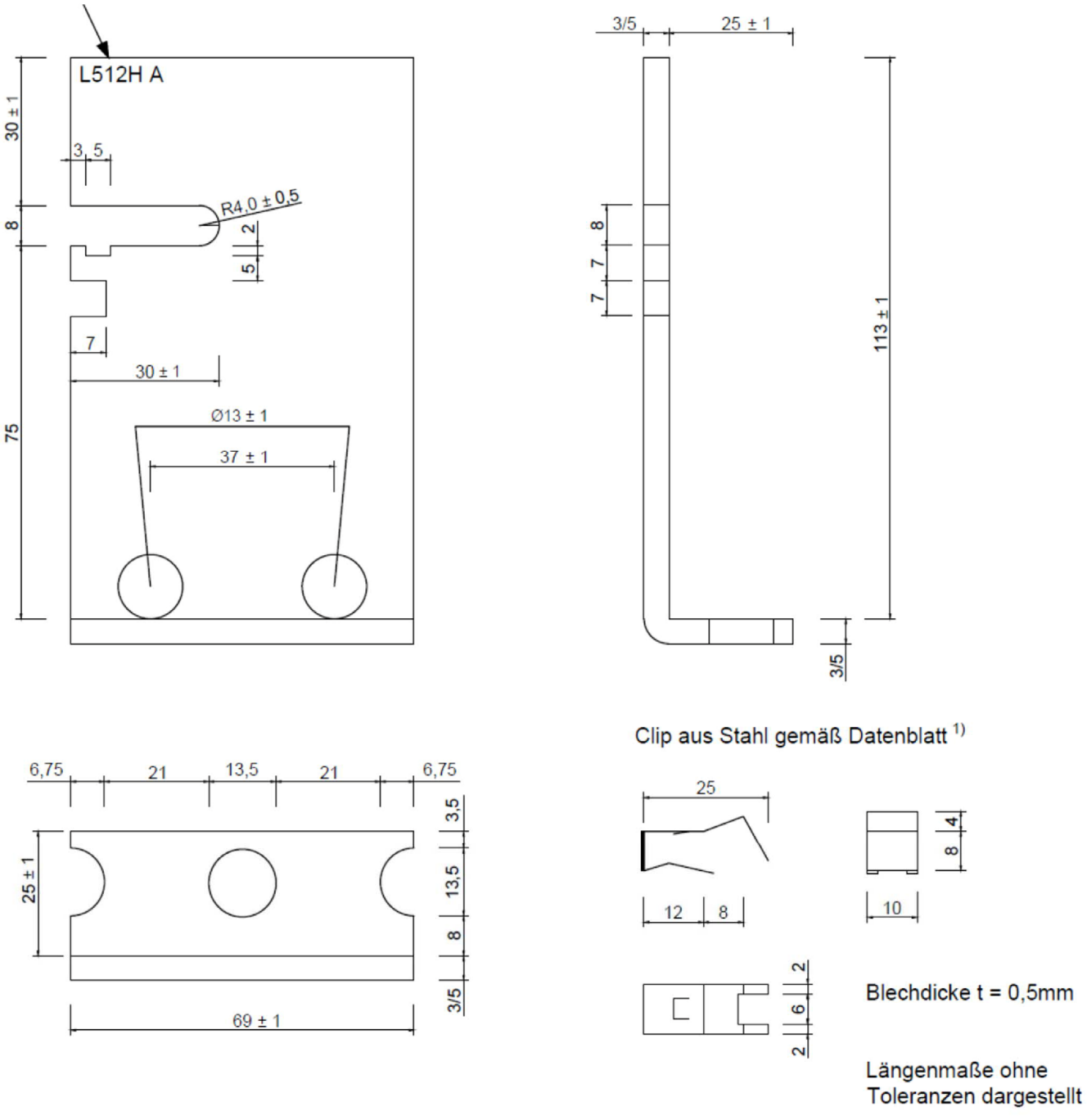
L-SHEETS WITH HORIZONTAL SLOTTED HOLE IN STEEL ACCORDING TO DATA SHEET [1)]

Dimensions, bracket

Marking:

(sheet type - sheet thickness - Ø reinforcement - hole type - abbreviation of manufacturer's works)



1) The data sheet is deposited with Deutsches Institut für Bautechnik and the third-party inspection bodies.

TransMIT punching shear reinforcement	Annex A1
L-sheets with horizontal slotted hole made of steel	

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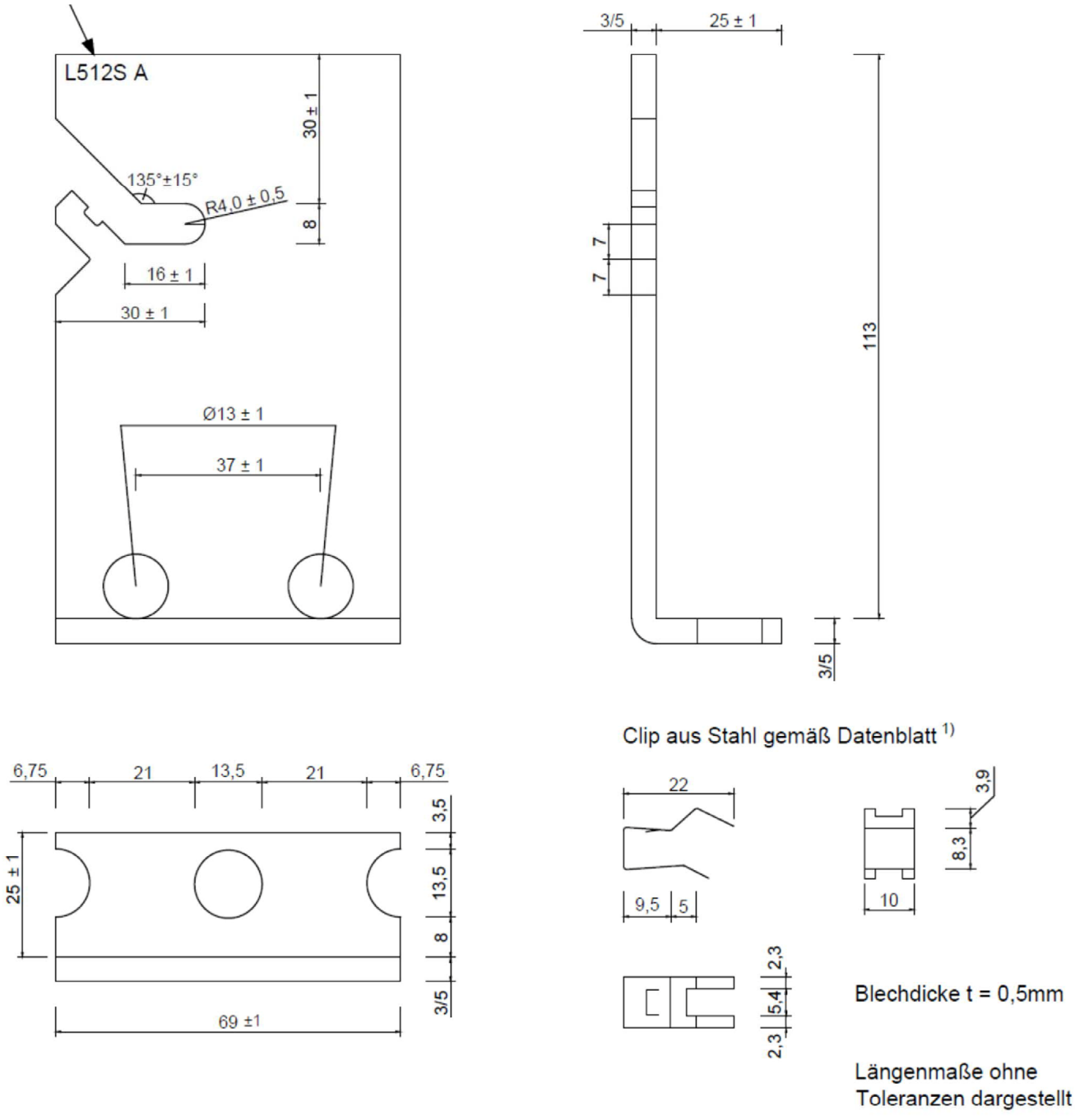
L-SHEES WITH OBLIQUE SLOTTED HOLE MADE OF STEEL ACCORDING TO DATA SHEET [1)]
Dimensions, bracket

Marking:

(sheet type - sheet thickness - Ø reinforcement - hole type - abbreviation manufacturer's plant).



1) The data sheet is deposited with Deutsches Institut für Bautechnik and the third-party inspection bodies.

TransMIT punching shear reinforcement	Annex A2
L-sheets with horizontal slotted hole made of steel	

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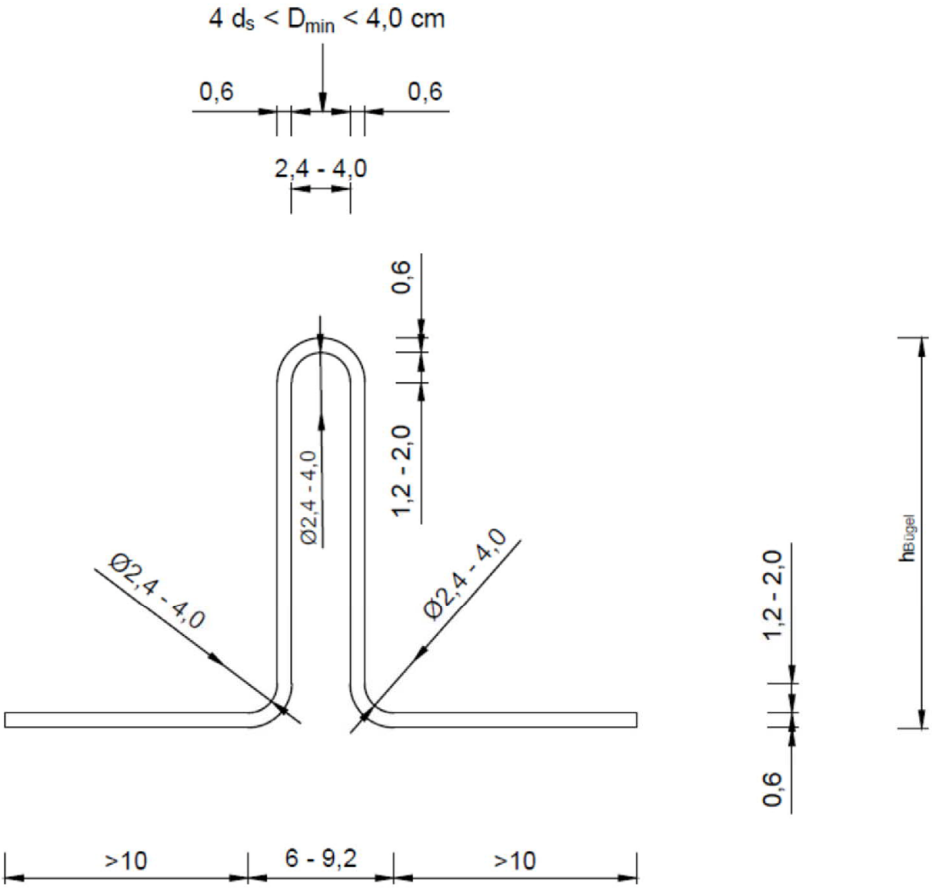
CLIP Ø 6 MM TOP OPEN
B500 A / B500 B / B500 A NR / B500 B NR

Abmessungen



Alle Maße in [cm]

$h_{bracket}$ as a function of the slab height h and the concrete cover of the plate at the bottom (c_{bottom}) and the top layer of the flexural reinforcement at the top (c_{top}). For c_{bottom} and c_{top} see also Annex B2, B3.
Slab height h < 24 cm: $h_{top} = (h - c_{top} - c_{bottom} - 7.5) \cdot 1.06$
Ceiling height h ≥ 24 cm: $h_{bracket} = h - c_{top} - c_{bottom} - 6.5$

h and c in [cm]

TransMIT punching shear reinforcement	Annex A3
clip Ø 6 mm top open	

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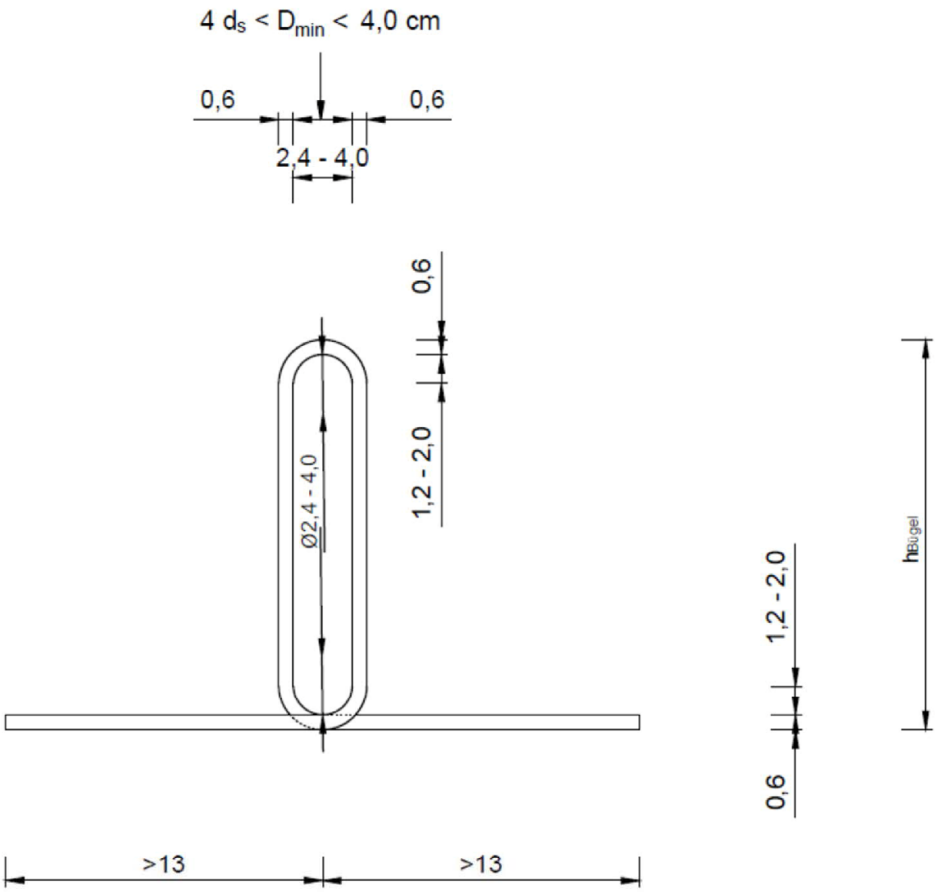
CLIP Ø 6 MM TOP CLOSED
B500 A / B500 B / B500 A NR / B500 B NR

Abmessungen



Alle Maße in [cm]

$h_{bracket}$ as a function of the slab height h and the concrete cover of the plate at the bottom (c_{bottom}) and the top layer of the flexural reinforcement at the top (c_{top}). For c_{bottom} and c_{top} see also Annex B2, B3.
Slab height h < 24 cm: $h_{top} = (h - c_{top} - c_{bottom} - 7.5) \cdot 1.06$
Ceiling height h ≥ 24 cm: $h_{bracket} = h - c_{top} - c_{bottom} - 6.5$

h and c in [cm]

TransMIT punching shear reinforcement	Annex A4
clip Ø 6 mm top closed	

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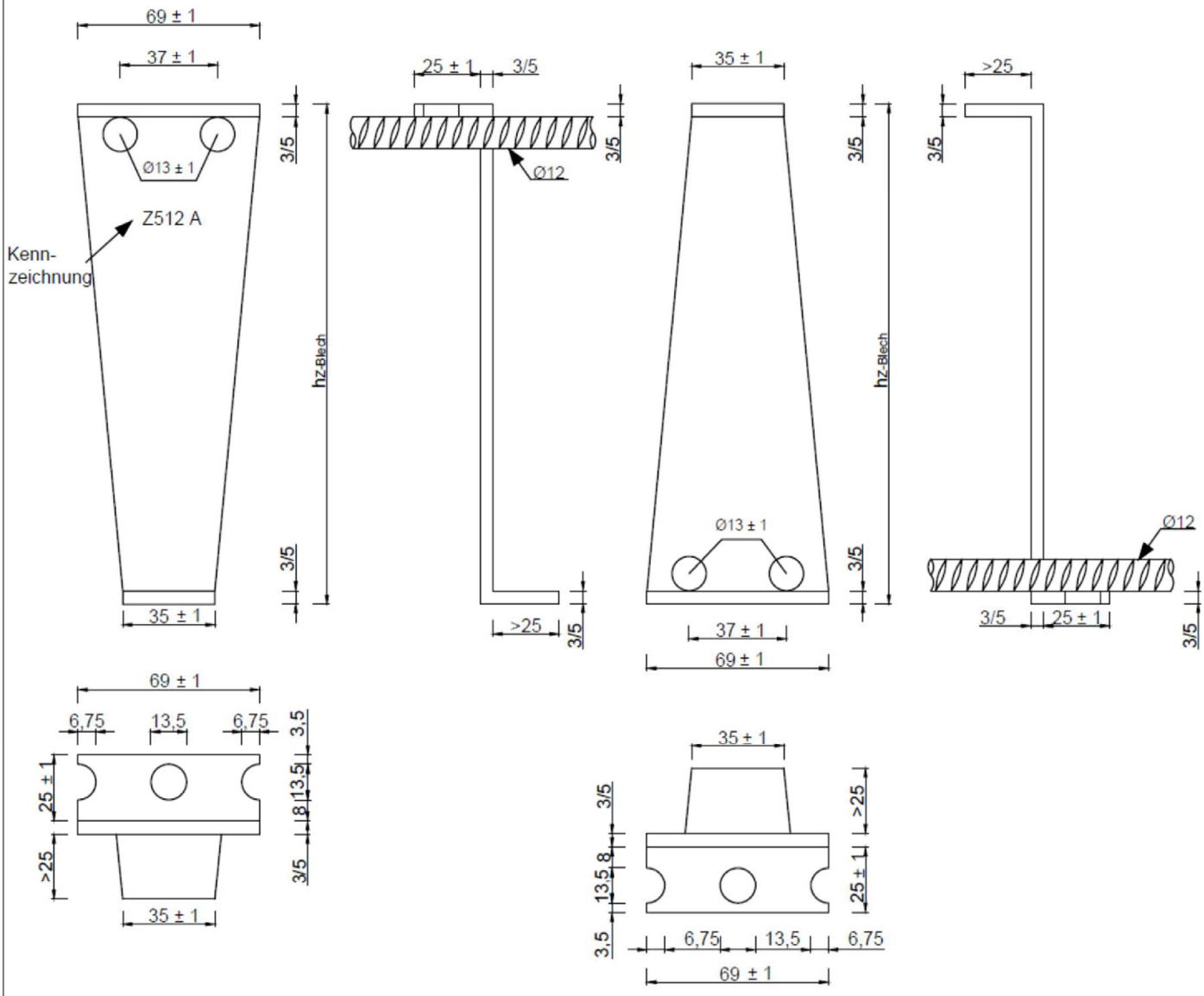
STEEL Z-SHEETS ACCORDING TO DATA SHEET [1)]

Measurements, installation



Installation from above

Installation from below

$h_{Z\ sheet}$ depending on panel height

1) The data sheet is deposited with Deutsches Institut für Bautechnik and the third-party inspection bodies.

TransMIT punching shear reinforcement	Annex A5
Steel Z-sheets	

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SPECIFICATION OF THE PURPOSE OF USE

General

- Use to increase the punching shear resistance of floor slabs, foundations and floor slabs under static and quasi-static loads.

- Design according to EN 1992-1-1:2004/A1:2014, clause 6.4 and Annexes C.1 and C.2

- The reinforcement required above the column for bending shall comply with EN 1992-1-1, 9.3.1.

- Free edges shall be framed in accordance with EN 1992-1-1, 9.3.1.4.

- Floor slabs or foundations and floor slabs consisting of reinforced normal weight concrete of strength classes C20/25 to C50/60 according to EN 206:2013+A1:2016.

- Floor slabs or foundations and floor slabs with a thickness h of

L-shaped sheets with one specially bent stirrup 18 cm ≤ h ≤ 40 cm

L-shaped sheets with two specially bent stirrups 18 cm ≤ h ≤ 110 cm

Z-shaped sheets 18 cm ≤ h ≤ 110 cm

- To ensure anchorage and to secure the position of the sheets during installation, reinforcing steel bars with a diameter of 12 mm and the following specifications are passed through holes provided for this purpose in the sheets:

Yield strength: fyk ≥ 500 MPa

Ratio of tensile strength to yield strength: (ft/fy)k ≥ 1.05

Elongation: uk ≥ 2.5 %.

- The supplementary reinforcement extends at least 20 cm beyond the sheet or covers the adjacent reinforcing bars of the flexural tensile reinforcement.

- The reinforcement elements are arranged uniformly (circularly or orthogonally) in the punching shear area of the column or the highly concentrated load.

- Steel sheets of the same type, dimensions and number of stirrups are arranged in the punching shear area - if line elements are used in precast elements, sheets with a smaller thickness and one stirrup are also used at a distance > 2.0 d.

- The Z-shaped sheets and the two-part L-shaped sheets with suspended stirrups enclose or extend to the outermost upper and the outermost lower reinforcement layer.

- The reinforcement elements are positioned so that the concrete cover complies with the provisions of EN 1992-1-1.

- The reinforcement elements are positioned in the area of the support or highly concentrated load in such a way that the minimum and maximum distances between the sheets comply with the provisions of Annex B5.

TransMIT punching shear reinforcement	Annex B1 Sheet 1/2
Specification of the purpose of use - general	

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Arrangement and spacing of the punching shear reinforcement elements

- The reinforcement elements are distributed evenly (circularly or orthogonally) within the punching shear area.
- The distances of the elements in the direction of radii a (radial direction) extending from the loaded surface (column) do not exceed the following values:

  The distance of a reinforcement element to the previous or next circular section must not exceed 0.75 d.

  The distance of the first row of reinforcement elements from the column gate shall be about 0.375 d and shall not exceed 0.5 d.
- The respective circular section can be assigned the reinforcement elements at a distance of 0.375 d to the inside and to the outside.
- The distances at of the reinforcement elements next to each other in the direction of the course of the circular sections (tangential direction) must not exceed the following values:

  $a_t \leq \max(140\ mm; 0{,}6 \cdot d \cdot i);\ i = 1$

  $a_t \leq 0{,}6 \cdot d \cdot i;\ i \geq 2$

  with i = number of the circular section

  Alternatively, up to a maximum load capacity of vRd,max = 1.46 · vRd,c, a star-shaped distribution with a mean angle of 60° (6-pointed star for internal supports) can be arranged.
- If the required punching shear reinforcement elements cannot be arranged next to each other on a circular section, they shall be installed at equal distances within the area between the circular section under consideration and the nearest circular section to the column, considering the spacing rules.

TransMIT punching shear reinforcement	Annex B1 Sheet 2/2
Specification of the purpose of use – arrangement of the elements	

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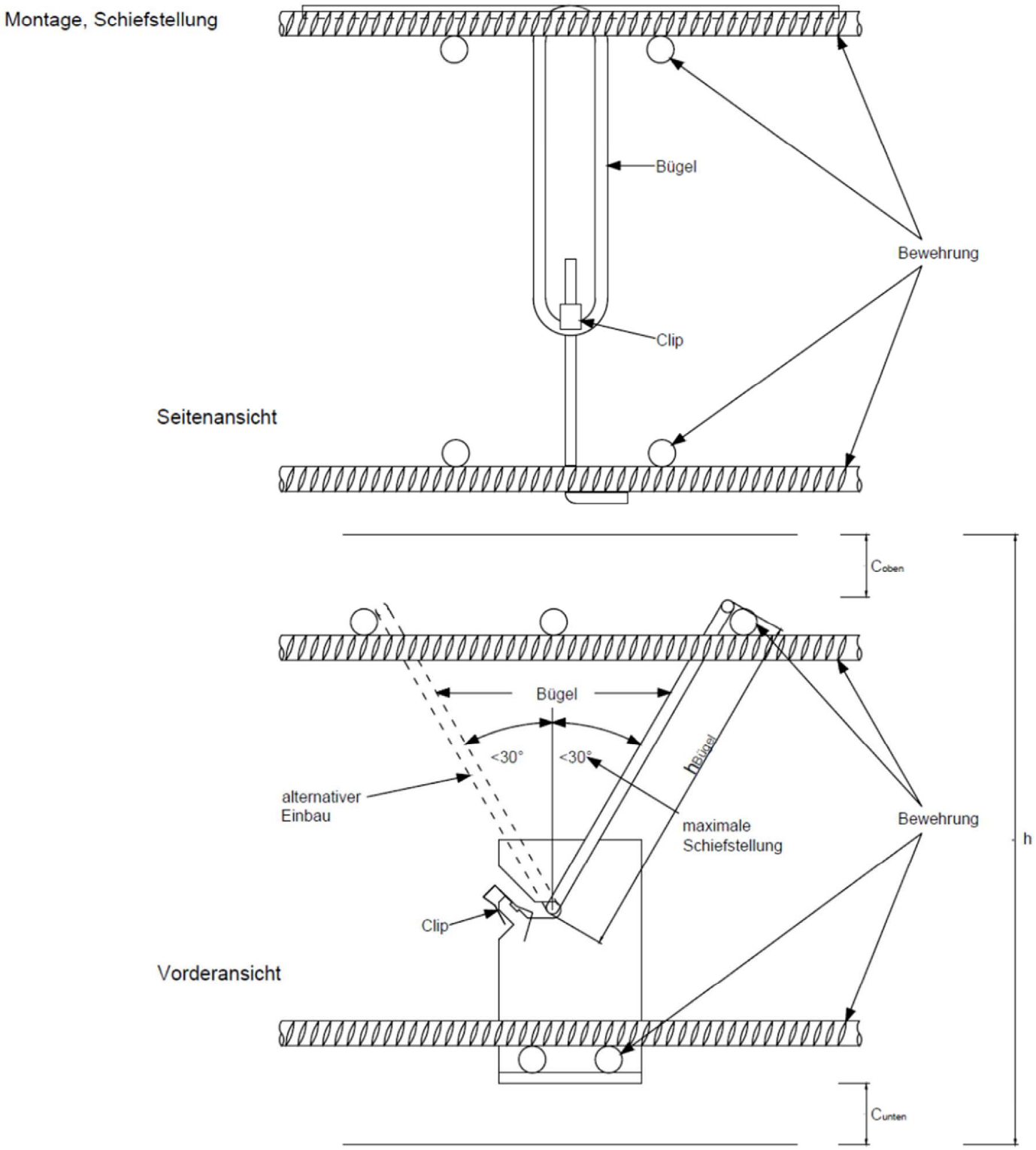
L-SHEETS WITH OBLIQUE SLOTTED HOLE, WITH ONE CLOSED BRACKET

with parallel arrangement of the stirrup legs to the uppermost layer of the upper reinforcement



$H_{bracket}$ as a function of slab height and concrete cover see Annex A3/A4.

TransMIT punching shear reinforcement	Annex B2
L-sheets with oblique slotted hole, with one closed bracket	

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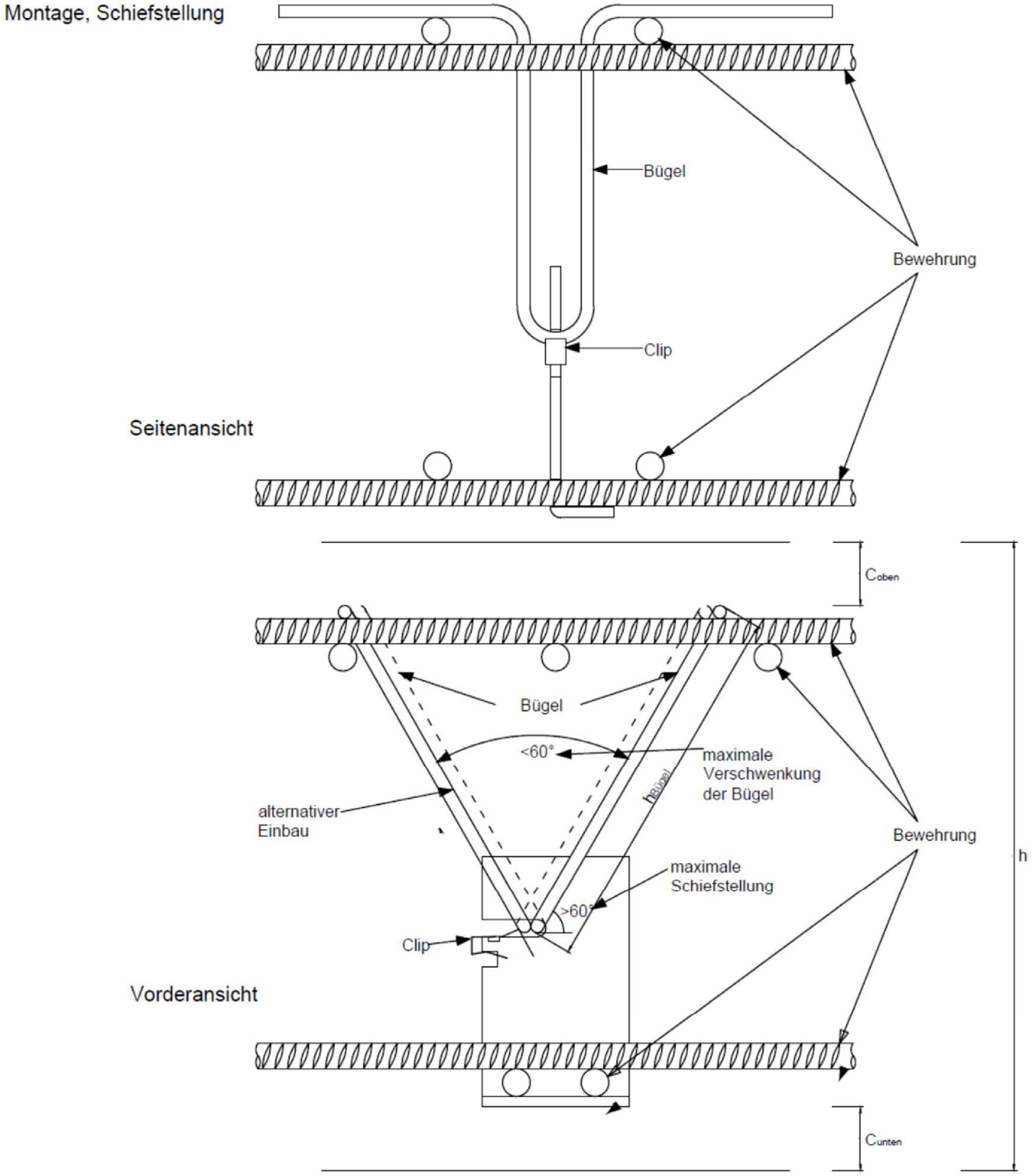
L-SHEETS WITH HORIZONTAL SLOTTED HOLE, WITH TWO OPEN TOP BRACKETS

with the stirrup legs perpendicular to the top layer of the upper reinforcement



$h_{bracket}$ depending on the slab height and the concrete cover, see Annex A3/A4.

TransMIT punching shear reinforcement	Annex B3
L-sheets with horizontal slotted hole, with two brackets open at the top	

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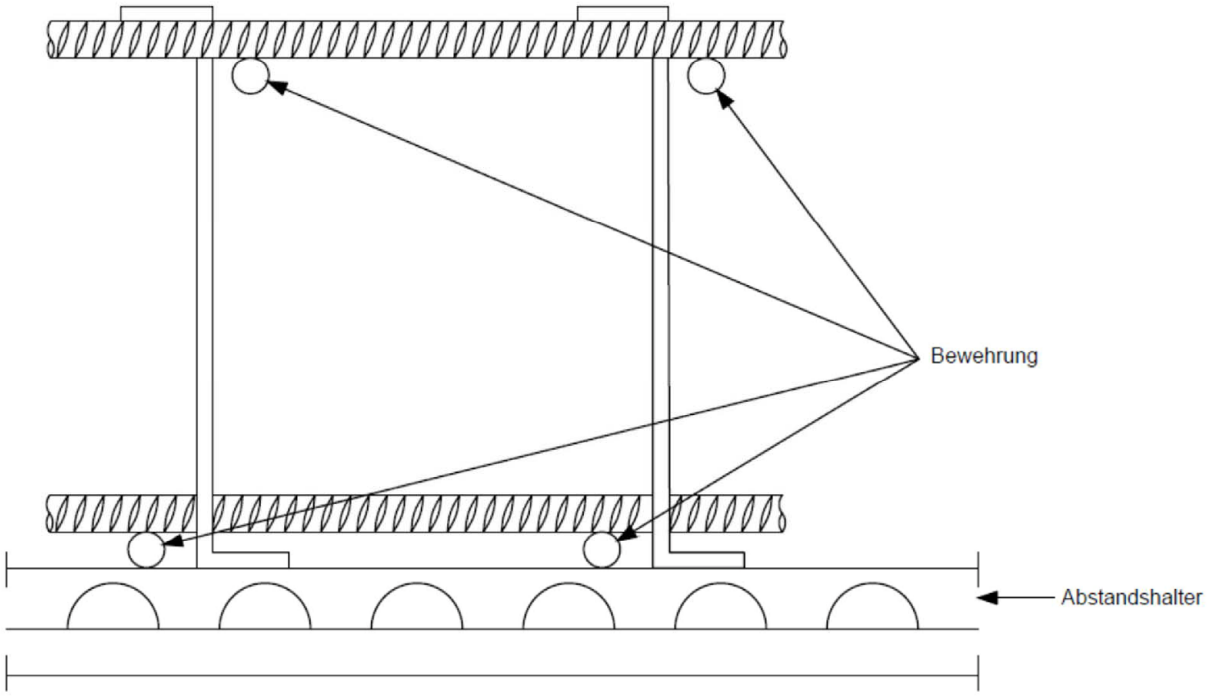
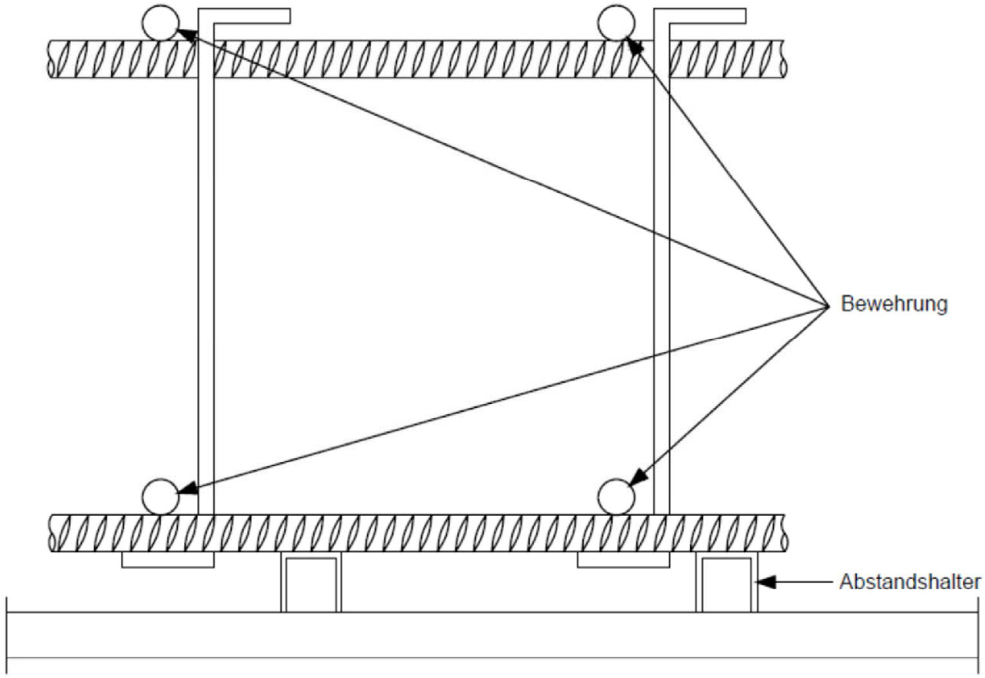
Z-SHEETS - INSTALLATION



Einbau von oben



Einbau von unten

TransMIT punching shear reinforcement	Annex B4
Z-sheets - installation	

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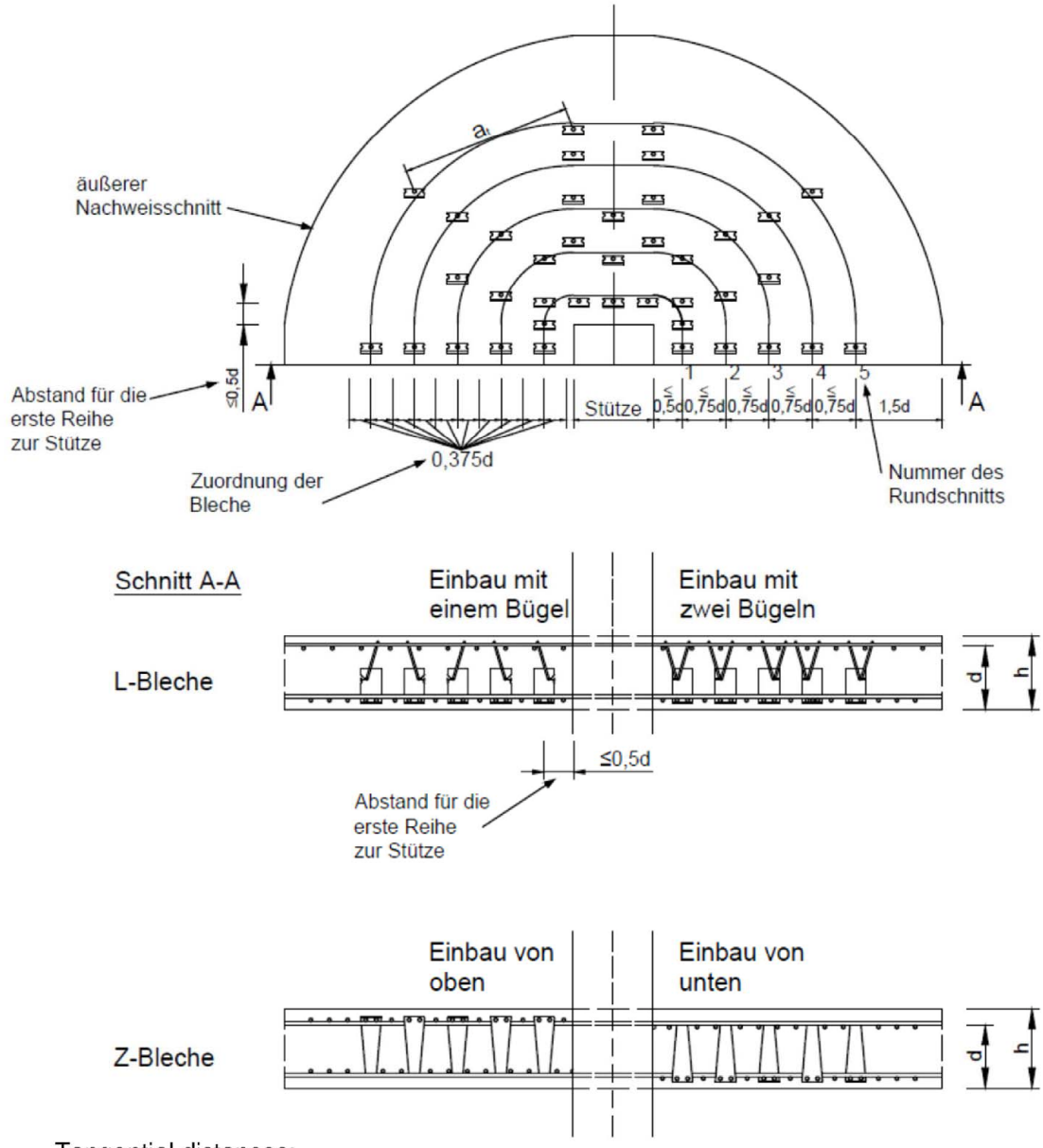
PRINCIPLE ARRANGEMENT OF PUNCHING SHEAR REINFORCEMENT WITH L- OR Z-SHEETS



Tangential distances:
at ≤ max(140 mm; 0,6·d·i); i = 1
at ≤ 0,6·d·i; i ≥ 2 i = number of the circular section
Alternatively, up to a maximum load capacity of vRd,max = 1.46 · vRd,c, a star-shaped distribution with a mean angle of 60° (star of 6 for internal supports) can be arranged.

Assignment of the sheets:
The respective circular section can be assigned the plates at a distance of 0.375 d to the inside and 0.375 d to the outside.

TransMIT punching shear reinforcement	Annex B5
Principle arrangement of punching shear reinforcement with L- or Z-sheets	

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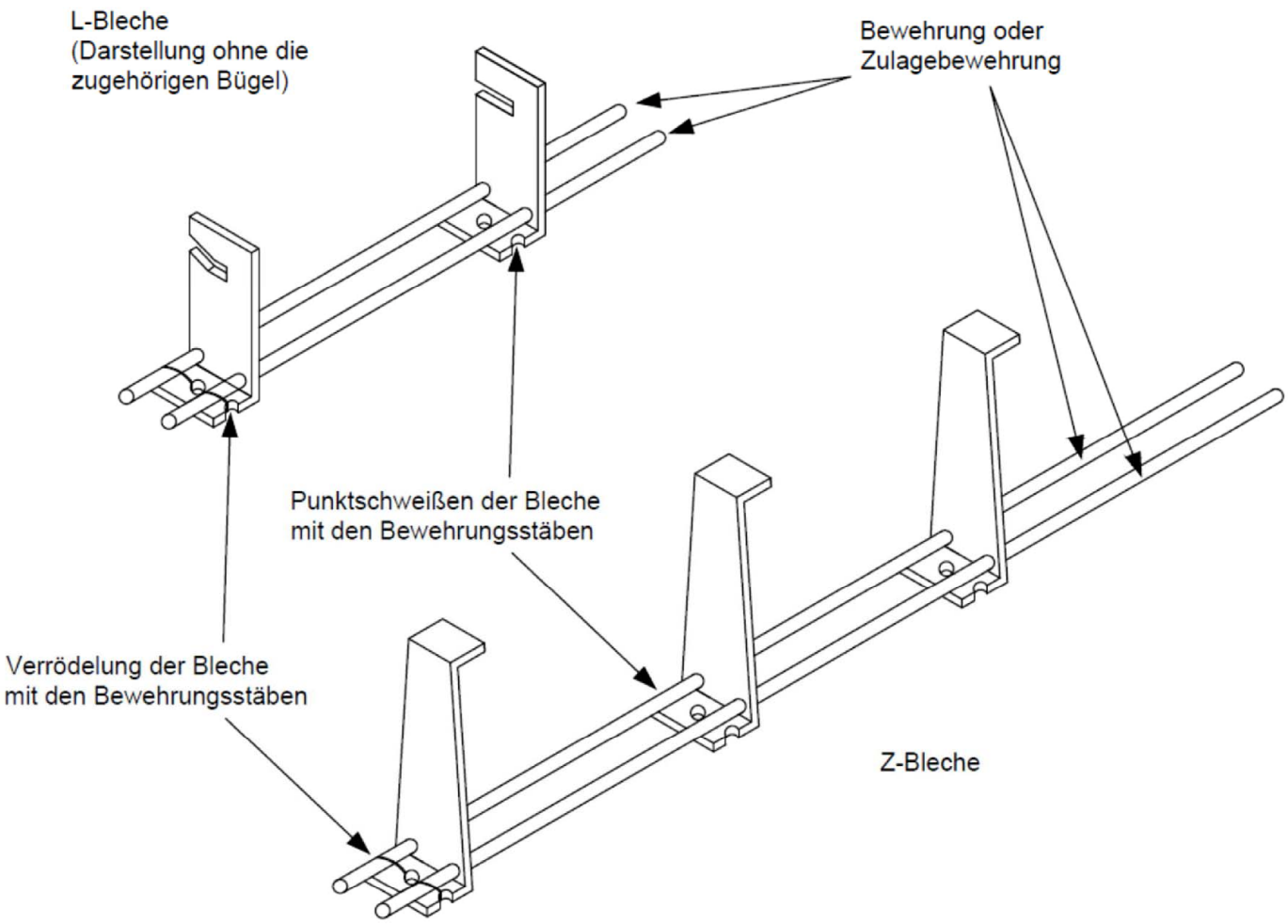
LINE ELEMENTS



TransMIT punching shear reinforcement	Annex B6
Line elements	

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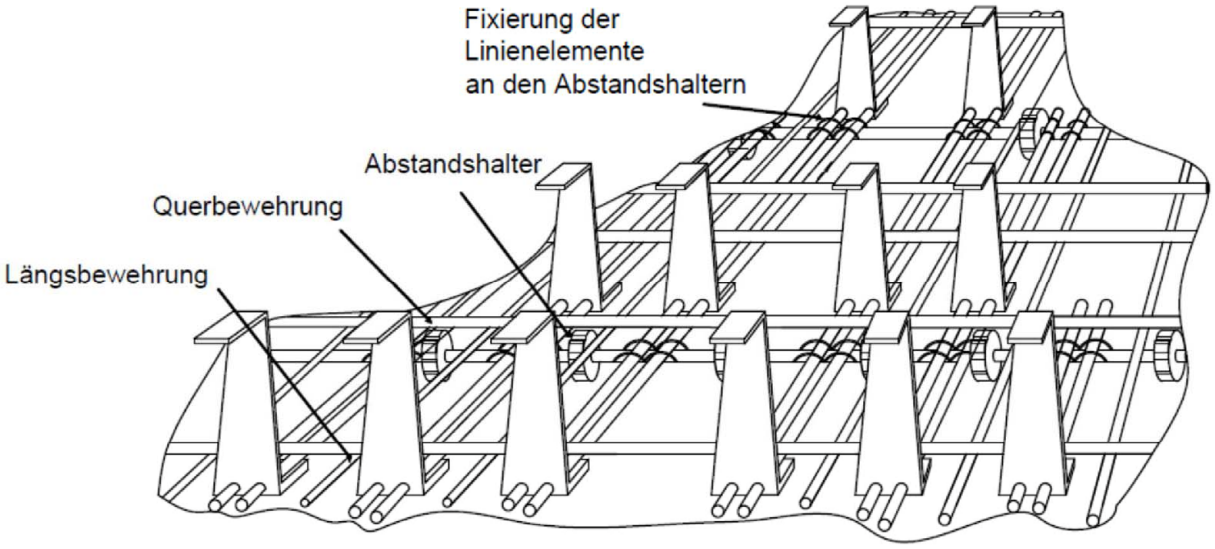
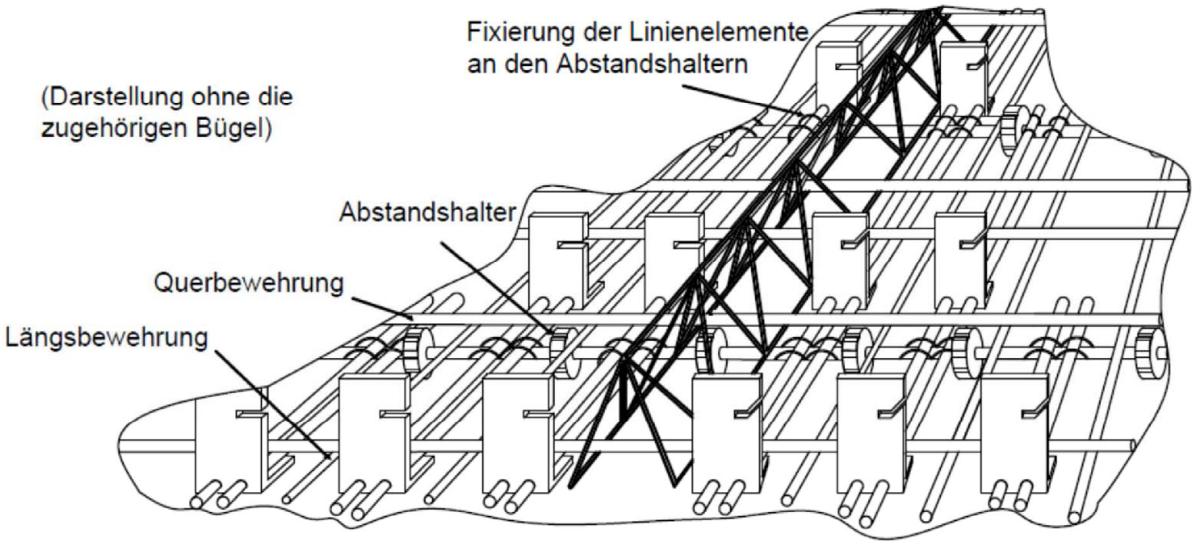
ASSEMBLY OF THE LINE ELEMENTS WITH Z-SHEETS
Example in-situ concrete ceiling



ASSEMBLY OF THE LINE ELEMENTS WITH L-SHEETS
Example prefabricated ceiling



TransMIT punching shear reinforcement	Annex B7
Assembly of the line elements	

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INSTALLATION INSTRUCTIONS

Installation of the punching shear reinforcement system for semi-prefabricated ceilings

The Z-shaped steel sheets and the split L-shaped steel sheets with suspended stirrups can be used in in-situ concrete as well as in precast elements. They enclose or extend to the outermost upper and outermost lower reinforcement layer. The stirrup legs can be installed parallel or perpendicular to the top layer of the upper reinforcement.

The element arrangement given by the design is divided into individual positions, so-called line elements, parallel to the reinforcement direction. By threading the sheets onto the two reinforcement bars at the specified distances, the line elements are produced on site.

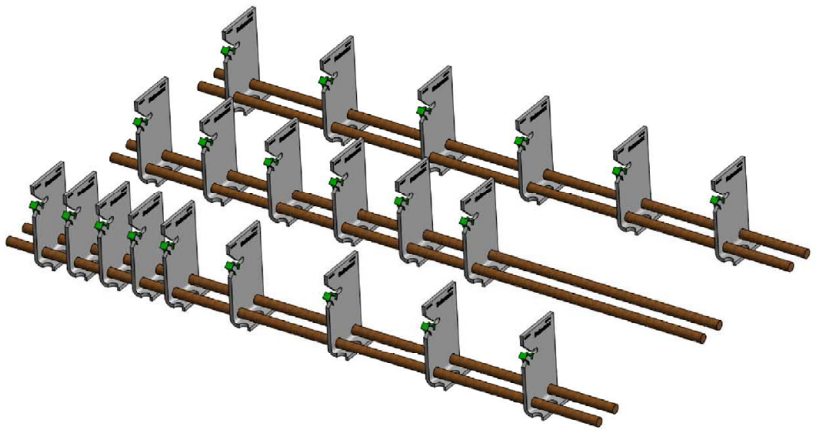
When reinforcing the floor slabs, the line elements are placed on the lower spacers in the direction of the reinforcement like additional beams.

The concreted-in L-sheet does not protrude beyond the lattice girders in the case of semi-prefabricated slabs and the slabs can be stacked without additional spacers.

After the upper reinforcement layer has been placed on site, the stirrups are clipped into the slotted hole of the L-sheets from above and placed over the upper reinforcement layer. The stirrups do not have to be tied and may have a maximum inclination of 30°.

1. Production of the line elements

The Z or L sheets with pre-assembled clip are delivered in packaging units.
The production of the line elements is carried out according to the specifications from the static calculation. The sheets delivered to the consumer are fixed to the longitudinal bars ds = 12 mm by crimping or tacking.



Optionally, ready-made line elements can be installed.

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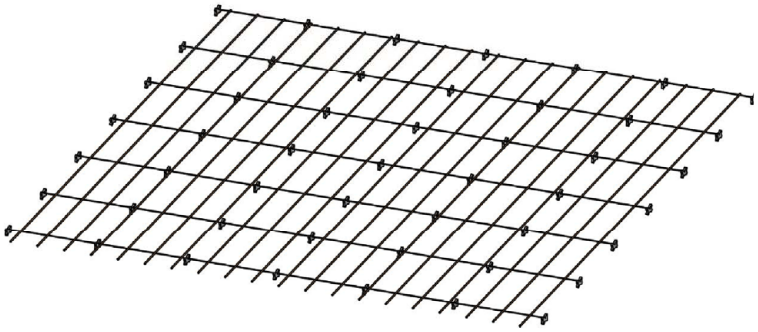
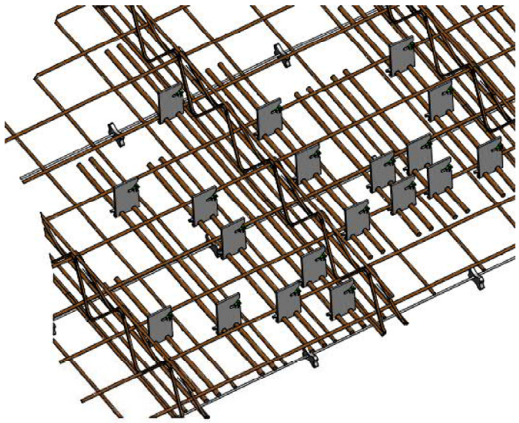
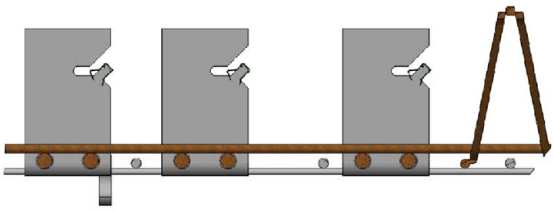
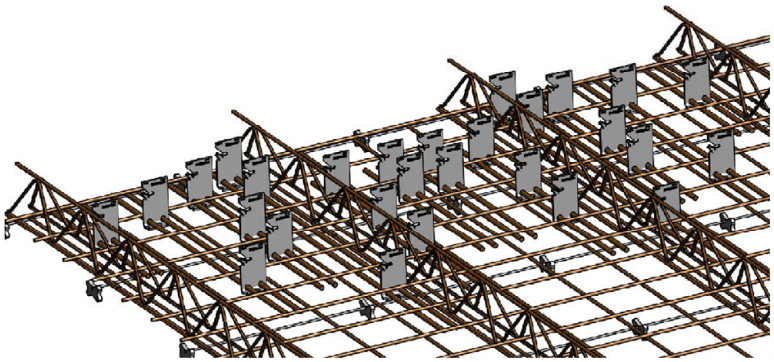
2. Laying the lower cross reinforcement with appropriate spacers on the shuttering table



3. Assembly of the line elements by simply placing them parallel to the reinforcement direction and the lattice girders







The position can be secured by spring clips or binding wire.

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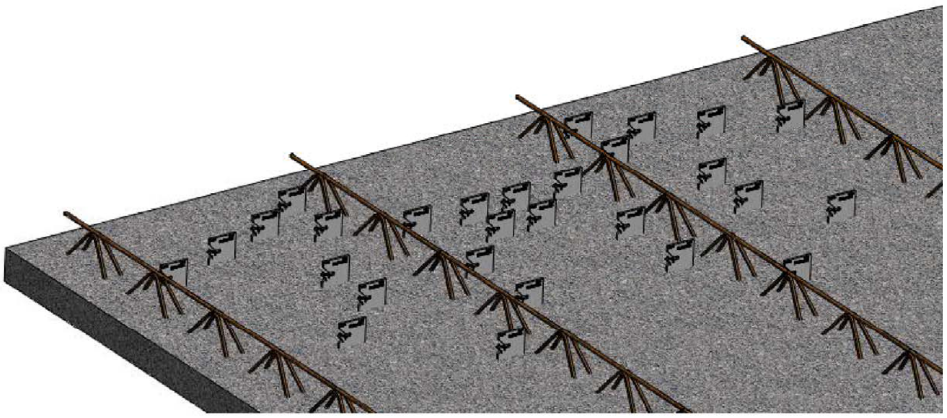
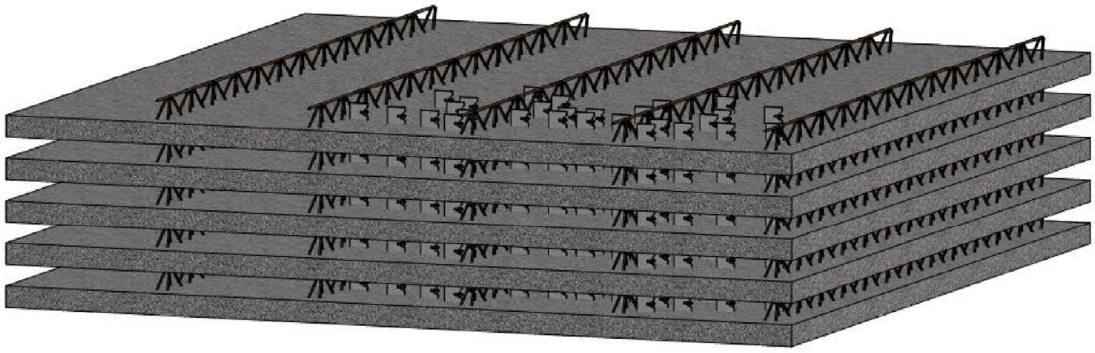
4. Concreting of the respective ceiling element



5. Lifting the slab elements from the formwork and stacking them



TransMIT punching shear reinforcement	Annex B8 Sheet 3/5
Intallation instructions	

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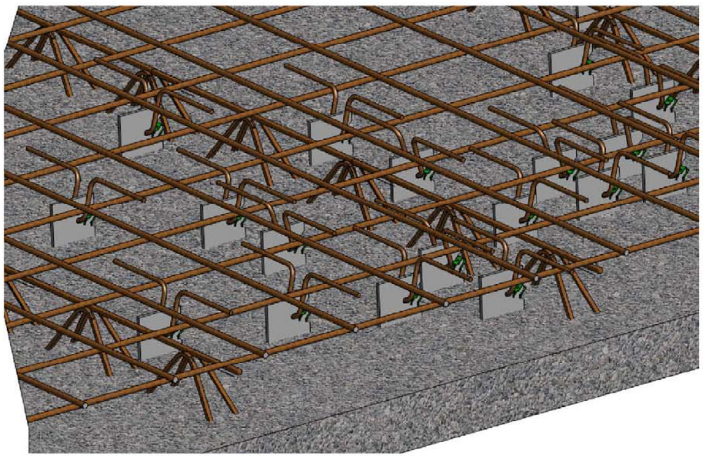
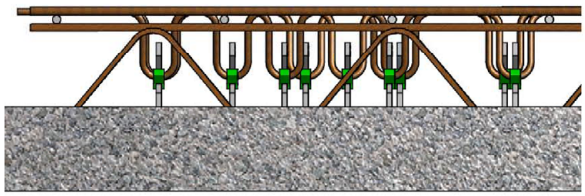
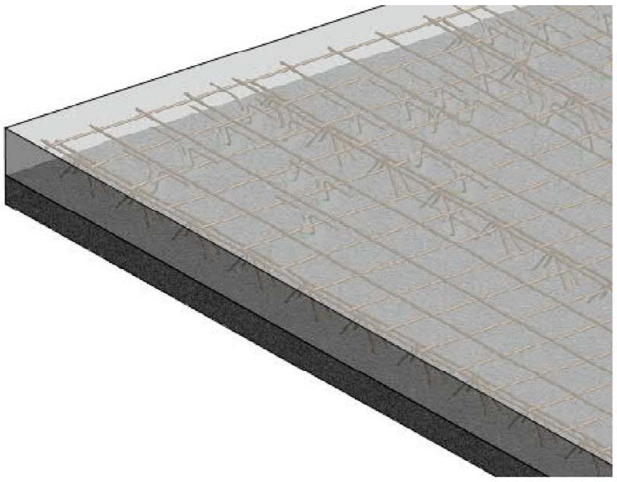
6. Completion of the punched-through elements by clipping in the associated brackets





The brackets can be manufactured on site according to the specifications from the structural calculations or delivered to the construction site by the reinforcing steel dealer.
Optionally, the stirrups can be purchased from the sheet metal supplier or from the precast plant in the required quantity.

7. Concreting the required top concrete on the construction site



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Further provisions for the execution

When using TransMIT punching shear reinforcement systems with steel plates in element slabs, the butt joints must be at least 4 cm wide in the punching shear area - if element joints cannot be avoided - for safe transmission of the compressive forces and must be filled with in-situ concrete. The distance between the edge of the element slab and the column edge must be in the range of -1 cm to +4 cm, assuming that the upper edge of the construction joint of the column is below the underside of the element slab. The distance between the element panel and the edge of the support may be waived for linear element panels if the element panel edge is fully supported.

In the case of an excessively high reinforced concrete column or correspondingly stiff steel load introduction plates for steel or composite columns that penetrate the slab, the punching shear check should be re-checked with the static useful height $d_{red} \leq d - x$ (x is the dimension for the indentation of the column into the slab) measured above the column. The maximum distance of the first row to the column should also be designed with the reduced static effective height. For the other radial and tangential distances, the static useful height d is decisive.

The following must be observed for installation on site:

- The grouting of the joint in the compression zone between the panel and the outer surface of the column must be carried out with suitable grouting concrete of the same strength as that of the in-situ concrete.
- If the element slabs are placed on the column, the joint between the slab and the column must be grouted over the entire surface to ensure the transmission of loads from the upper storeys through the node area.
- The concrete structure of the element slab must not be impaired by subsequent caulking work (adjustment to construction tolerances).
- The concrete must be well compacted in the area of the node.

TransMIT punching shear reinforcement	Annex B8 Sheet 5/5
Intallation instructions	

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DETERMINATION OF THE PUNCHING SHEAR RESISTANCE

The verification of safety against punching shear in the ultimate limit state shall be carried out as follows:

The punching shear resistance in the ultimate limit state shall be verified in the critical circular section. The slab is to be dimensioned in such a way that a minimum moment can be absorbed in accordance with the national regulations. Outside the circular section, the verification in the ultimate limit state is to be carried out for bending and shear force.

To determine the punching shear resistance, an inner critical circular section u1, at a distance of 2.0 d from the edge of the column (d = effective static effective height), and an outer circular section uout, at a distance of 1.5 d from the outermost reinforcement row of the punching shear reinforcement, is assumed to run around the column perpendicular to the slab plane. For foundations, the distance to the critical circular section must be determined iteratively.

For circular columns with a circumference u0 smaller than 12 d and for columns whose ratio of the long column side to the short column side does not exceed 2.0, the critical circular section may be determined as described above. If these conditions are not met, the shear force must be concentrated on the column corners and the critical round section reduced.

For unevenly shaped column cross-sections, the shortest length around the load application area is to be assumed for the round section u0. The critical round section u1 is to be determined according to EN 1992-1-1, 6.4.2.

First, the design value of the acting shear force v_{Ed} along the critical round section u_1 is to be calculated:

$$v_{Ed} = \frac{\beta \cdot V_{Ed}}{u_1 \cdot d} \qquad \text{(A1)}$$

v_{Ed}	acting shear force per unit area along the critical circular section
β	Coefficient for taking into account the influences of load eccentricities
V_{Ed}	Design value of the acting shear force
u_1	Circumference of the critical circular section at a distance of 2.0 d from the column surface (load application surface)

For structures whose stability against lateral deflection is independent of the frame action between slab and column and where the spans of the adjacent bays do not differ by more than 25 %, approximate values for β may be used:

Inner support β = 1.10
Edge support β = 1.40
Corner support β = 1.50 (A2)
Wall corner β = 1,20
Wall end β = 1,35

Alternatively, the value β may be calculated according to the more accurate method according to EN 1992-1-1. However, the procedure with the reduced critical circular section is not permitted.

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Punching shear reinforcement in slabs is required if the acting shear force per unit area along the critical circular section is greater than the design value of the punching shear resistance without shear reinforcement according to equation (A3):

$$v_{Rd,c} = C_{Rd,c} \cdot k \cdot (100 \cdot \rho_l \cdot f_{ck})^{1/3} + k_1 \cdot \sigma_{cp} \geq (v_{min} + k_1 \cdot \sigma_{cp}) \qquad (A3)$$

CRd,c empirical factor. The recommended value is CRd,c = 0.18/γC.
γC Partial safety factor for concrete (γC = 1.5).
k Factor to account for the dimensional scale effect, d in [mm].

$$k = 1 + \sqrt{\frac{200}{d}} \leq 2{,}0$$

ρ_l averaged degree of reinforcement in y- and z-direction.

$$\rho_l = \sqrt{\rho_{lz} \cdot \rho_{ly}} \leq \begin{cases} 2{,}0 \\ 0{,}5 \cdot f_{cd} / f_{yd} \end{cases}$$

f_{cd} Design value of the cylindrical compressive strength of the concrete
f_{yd} Design value of the yield strength of the reinforcing steel
k_1 empirical factor, the recommended value is $k_1 = 0{,}1$
σ_{cp} Concrete normal stresses in the critical cross-section (pressure positive)
v_{min} $(0{,}0525/\gamma_C) \cdot k^{3/2} \cdot f_{ck}^{1/2}$ for d ≤ 600 mm
$(0{,}0375/\gamma_C) \cdot k^{3/2} \cdot f_{ck}^{1/2}$ for d > 800 mm, intermediate values may be linearly interpolated.

For small ratios of column circumference to static effective height (u0/d), the punching shear resistance for internal columns in flat slabs must be reduced.

$$u_0/d < 4{,}0: \qquad C_{Rd,c} = \frac{0{,}18}{\gamma_C}\left(0{,}1\,\frac{u_0}{d} + 0{,}6\right) \geq \frac{0{,}15}{\gamma_C}$$

If punching shear reinforcement is required, a sufficient quantity of punching shear reinforcement elements must be installed in the slab. The length of the circular section uout, where punching shear reinforcement is no longer required, shall be determined according to the following equation:

$$u_{out} = \frac{\beta_{red} \cdot V_{Ed}}{v_{Rd,c} \cdot d} \qquad (A4)$$

β_{red} reduced factor to take into account the influences from eccentricities along the circular section u_{out}
$v_{Rd,c}$ design value of the punching shear resistance without punching shear reinforcement according to equation (A3),
$C_{Rd,c}$ may be assumed as for components without shear force reinforcement required by calculation

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To determine the punching shear resistance along the outer circular section uout of edge and corner columns, a reduced factor β_{red} may be used in conjunction with equation (A4)

$$\beta_{red} = \kappa_\beta \cdot \beta \geq 1{,}10 \qquad \text{(A5)}$$

Edge columns $\kappa_\beta = \dfrac{1}{1{,}2 + \beta/20 \cdot l_s/d}$

Corner columns $\kappa_\beta = \dfrac{1}{1{,}2 + \beta/15 \cdot l_s/d}$

Wall corners $\kappa_\beta = 1{,}0$

Wall end $\kappa_\beta = 1{,}0$

l_s Distance between the column surface and the outermost punching shear reinforcement element.

The design value of the punching shear resistance vRd,c for foundations and floor slabs shall be determined according to the following equation:

$$v_{Rd,c} = \frac{C_{Rk,c}}{\gamma_C} \cdot k \cdot (100 \cdot \rho_l \cdot f_{ck})^{1/3} \cdot \frac{2 \cdot d}{a} \qquad \text{(A6)}$$

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DIMENSIONING FOR PUNCHING AND BONDING

General

The verification of safety against punching through of the slab is carried out according to EN 1992 1 1, unless otherwise specified in the following.
The increase of the punching shear resistance by inclined tendons may be considered according to EN 1992 1 1. In the punching shear check, the vertical component may only be considered of those tendons that run within a distance of 0.5 d from the column. For the determination of the maximum load-bearing capacity, the favourably acting normal stress σcp must not be taken into account.
A planned or unplanned skewing of the stirrups when using the L-sheets must not be taken into account in the design.

Verification of safety against punching for ceiling tiles

Maximum load-bearing capacity

The maximum load capacity in the critical circular section u1 at a distance of 2.0 d from the edge of the column is limited to:

$$v_{Rd,max} = k_{pu,sl} \cdot v_{Rd,c} \qquad \text{(A7)}$$

$k_{pu,sl}$ = 2,05 for L-sheets (see section 3.1 of the ETA)

$k_{pu,sl}$ = 1,90 for L-sheets with a bracket diameter 8 mm..
(Version: bracket according to Annex A3 or A4, sheets according to annexes A1 or A2 with 2 mm widened slot and a thickness of 5 mm))

$k_{pu,sl}$ = 1,71 for Z-sheets (see section 3.1 of the ETA)

$v_{Rd,c}$ Design value of the punching shear resistance according to equation (A3) with $C_{Rd,c} = 0{,}18/\gamma_C$

To be verified:

$$\frac{\beta \cdot V_{Ed}}{u_1 \cdot d} \le v_{Rd,max} \qquad \text{(A8)}$$

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Design of punching shear reinforcement with L-sheets

In addition to the load-bearing capacity of the L-sheets, a concrete load-bearing component is taken into account. The concrete load-bearing component is calculated in the circular section u1 at a distance of 2.0 d from the edge of the column. The required reinforcement cross-section is to be installed in each of the first three rows up to a distance of 2 d from the column.

The number of punching shear reinforcement elements shall be determined so that the following inequality for the design value including the factor β is fulfilled:

$$\beta \cdot V_{Ed} \leq V_{Rd,cs,L\text{-}sheets}$$

β	cf. annex C1
$V_{Rd,cs,L\text{-}sheets}$	Punching shear resistance of L-sheets

$$V_{Rd,cs,L\text{-}sheets} = k_1 \cdot v_{Rd,c} \cdot u_1 \cdot d + k_{2,L} \cdot n_{bracket} \cdot 2\, A_{s,bracket} \cdot f_{ywd,ef} \cdot n_{sheets} \cdot 1{,}5\, d/s_r \qquad (A9)$$

$v_{Rd,c}$	according to equation (A3)
k_1	= 0,85
u_1	circular section at a distance of 2.0 d from the edge of the column
$n_{Bügel}$	number of brackets per L-sheet (1 or 2) (1 oder 2)
$k_{2,L}$	= 0,55 coefficient of action for the bonding
$A_{s,bracket}$	cross-sectional area of a vracket leg
$f_{ywd,ef}$	= 250 + 0,25 d ≤ f_{yd} effective design value of yield strength of the stirrup, d [mm]
f_{yd}	design value of the yield strength of the reinforcing steel, f_{yd} = 435 N/mm²
n_{sheets}	number of L-sheets in circular section
s_r	radial spacing of the punching shear reinforcement (cf Annex B5)

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Design of punching shear reinforcement with Z-sheets

In addition to the load-bearing capacity of the Z-sheets, a concrete load-bearing component is taken into account. The concrete load-bearing component is calculated in the circular section u1 at a distance of 2.0 d from the edge of the column. The required reinforcement cross-section is to be installed in each of the first three rows up to a distance of 2 d from the column.

The number of punching shear reinforcement elements shall be determined so that the following inequality for the design value including the factor β is fulfilled:

$$\beta \cdot V_{Ed} \leq V_{Rd,cs,Zsheets}$$

β	cf. annex C1
$V_{Rd,cs,Z\text{-}Bleche}$	Punching shear resistance of Z-sheets

$$V_{Rd,cs,Z\text{-}sheet} = k_1 \cdot v_{Rd,c} \cdot u_1 \cdot d + (k_{2,Z} \cdot b_{sheet} \cdot t_{sheet} \cdot f_{y,d} \cdot n_{sheet} \cdot 1{,}5\ d/s_r) / k_3 \qquad (A10)$$

$v_{Rd,c}$	according to equation (A3)
k_1	= 0,85
u_1	circular section at a distance of 2.0 d from the edge of the column
$k_{2,Z}$	= 0,50 coefficient of action for the bonding
n_{sheets}	number of Z-sheets in the circular section
b_{sheet}	smallest width of the web of the Z-sheet
t_{sheet}	thickness of the Z-sheet
$f_{y,d}$	= 235 / γ_S Design value of the yield strength of the Z-sheet
s_r	radial spacing of the punching shear reinforcement (see Annex B5)
k_3 (h ≥ 60 cm)	factor for adjusting the load-bearing capacity for larger component thicknesses
	$k_3 = 1 + 0{,}2 \cdot (h - 60) / 60 \geq 1{,}0$ h [cm]

Design of punching shear reinforcement in the outer rows

From a distance of the punching shear reinforcement (L- or Z-sheets) of 2 d to the edge of the column or from the fourth row of reinforcement, the effective coefficients for the bond may be increased to $k_{2,L}$ = 1.0 or $k_{2,Z}$ = 1.0.

TransMIT punching shear reinforcement	Annex C2 Sheet 3/5
Dimensioning for punching and bonding	

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Verification of safety against punching for foundations and floor slabs

Maximum load-bearing capacity

The lower limit value of the maximum punching shear resistance vRd,max in the critical circular section is defined as a multiple of the punching shear resistance of the foundation or floor slab without punching shear reinforcement:

$$v_{Rd,max} = k_{pu,fo} \cdot v_{Rd,c} \qquad \text{(A11)}$$

$k_{pu,fo}$ = 1.4 (cf section 3.1 of the ETA)

$v_{Rd,c}$ Design value of the punching shear resistance according to equation (A6)

The required number of punching shear reinforcements in foundations and floor slabs shall be determined according to the following equation:

$$\beta \cdot V_{Ed} \le V_{Rd,s} = \frac{f_{yd} \cdot A_{sw,0,8d}}{1 - A_{crit} / A} \qquad \text{(A12)}$$

f_{yd} ≤ 435 N/mm² for brackets when using L-sheets

f_{yd} ≤ 214 N/mm² or the design value of the yield strength when using Z-sheets

$A_{sw,0,8d}$ cross-sectional area of punching shear reinforcement in the rows close to the column (first row at a distance of 0,3 d from the edge of the column, up to a distance of 0,8 d at least a second row is to be provided)

A_{crit} Area within the critical circular section at the distance to be determined iteratively a_{crit}

A Plan area of the individual foundation (for floor slabs, the area within the zero line of the radial slab bending moments).

In the case of floor slabs or very large and slender individual foundations, additional rows of punching shear reinforcement may be necessary to comply with the punching shear check outside 0.8 d. The additional reinforcement required in these additional rows must be calculated in the same way as in the case of slab foundations. The reinforcement cross-section required in these additional rows can be determined in a simplified way by "hanging up" 33 % of the acting shear force. The soil pressure within the considered reinforcement row may be completely deducted from the acting shear force.

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Verification of shear force transmission in the joint

The verification of the shear force transmission in the joint is to be carried out according to EN 1992-1-1 for each circular section.

The design value of the shear force that can be absorbed is made up of the three load-bearing components (adhesion, friction and reinforcement) and may be determined according to the following equation:

$$v_{Rdi} = c \cdot f_{ctd} + \mu \cdot \sigma_n + \rho \cdot f_{yd} \cdot (1{,}2 \cdot \mu \cdot \sin\alpha + \cos\alpha) \leq k_{max,i} \cdot \nu \cdot f_{cd} \qquad \text{(A13)}$$

$k_{max,i}$ = 0,5 (cf. annex 3.1 of the ETA)

Where c and μ are coefficients depending on the roughness of the joint, f_{ctd} is the design value of the concrete tensile strength, σn are compressive stresses (negative tension) perpendicular to the joint and ρ is the reinforcement ratio of the reinforcement crossing the joint.

The values dependent on the joint roughness can be taken from the following table.

Surface finish	c	μ	ν
Serrated	0,50	0,90	0,75
Rough	0,40	0,70	0,50
Smooth	0,20	0,60	0,20
Very smooth	0,00	0,50	0,00

The larger reinforcement quantity determined from the joint design and punching shear design is to be arranged. When using L-sheets, the cross-section of the installed stirrups and when using Z-sheets, the smallest sheet cross-section of the Z-sheet may be counted as bond reinforcement.

The stirrups of the punching shear reinforcement with L-sheets may be used with an inclination of 90° to the slab plane.

The simultaneous use of sheets and lattice girders is possible.