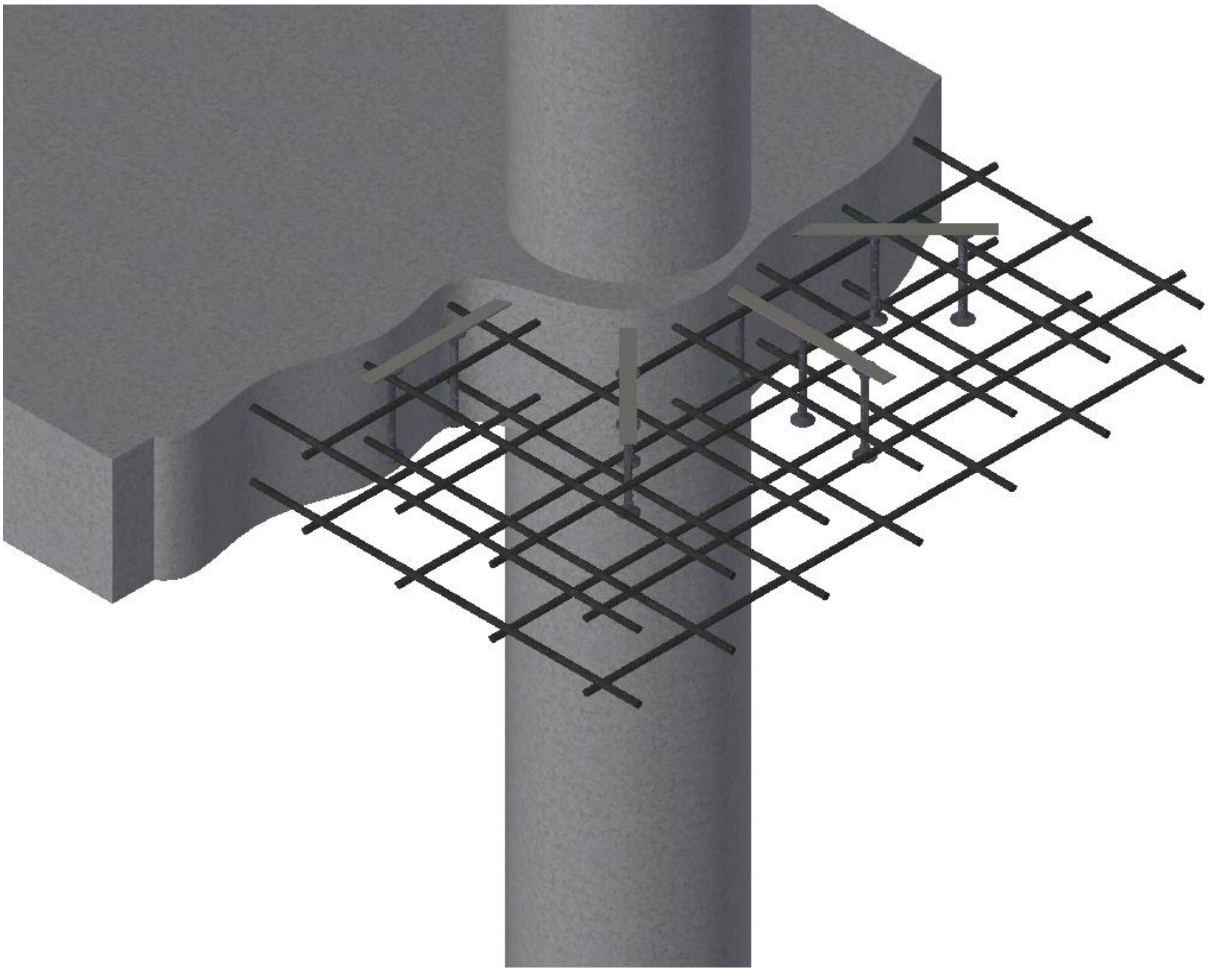
TECHNICAL DOCUMENTATION

REINFORCEMENT SYSTEMS | PUNCHING AND SHEAR REINFORCEMENT SYSTEM



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INTRODUCTION

The TSR punching shear reinforcements are used in flat slabs or ground slabs and provide additional reinforcement around columns and wall ends.

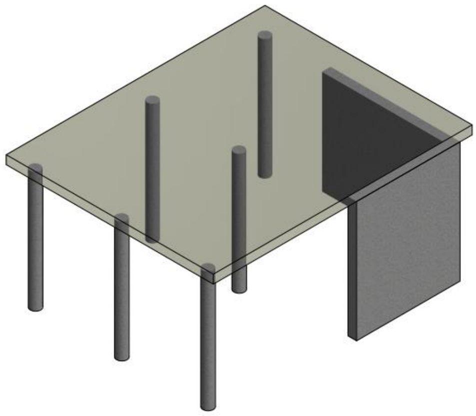
SYSTEM ADVANTAGES

TSR – shear reinforcement ensures:

- Higher punching resistance than conventional stirrup reinforcement
- Simple and efficient installation
- Low formwork costs
- Optimum use of space – a large distance between supporting columns
- Easy installation from above and below.
- Easier installation of building utilities under slabs, such as pipes or ducts.

TSR consists of double headed studs connected by an assembly profile – a strip of flat steel. The products designed and manufactured by Terwa ensure a much simpler installation of the product than other traditional reinforcement elements (stirrups). This applies in both cases – when TSR is used in cast-in situ or in precast elements.
Being a fully integrated system in prefabricated elements, it is therefore, an ideal system for thin monolithic structures or flat concrete slabs.

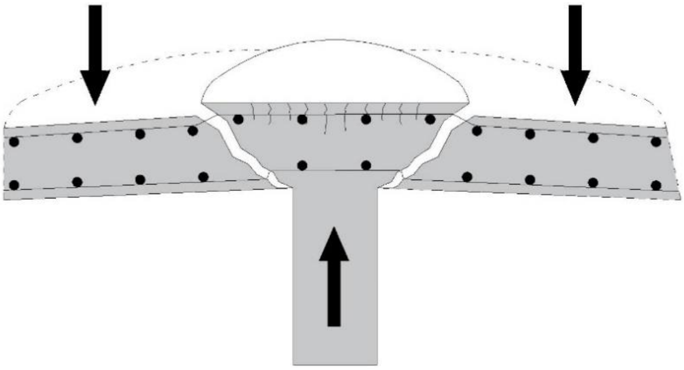
PRODUCT PROPERTIES



Flat slab supported on columns without enlarged heads and walls.

Reinforced concrete flat slabs are currently one of the most popular structural systems in residential, administrative, industrial buildings and many other types of buildings. This type of construction made from concrete slabs without beams or enlarged column heads allows an optimal and flexible use of space. Due to the thinner, lighter and simpler concrete slabs, the construction cost can be substantially reduced. Also, the floor height can be reduced by using TSR shear reinforcement.

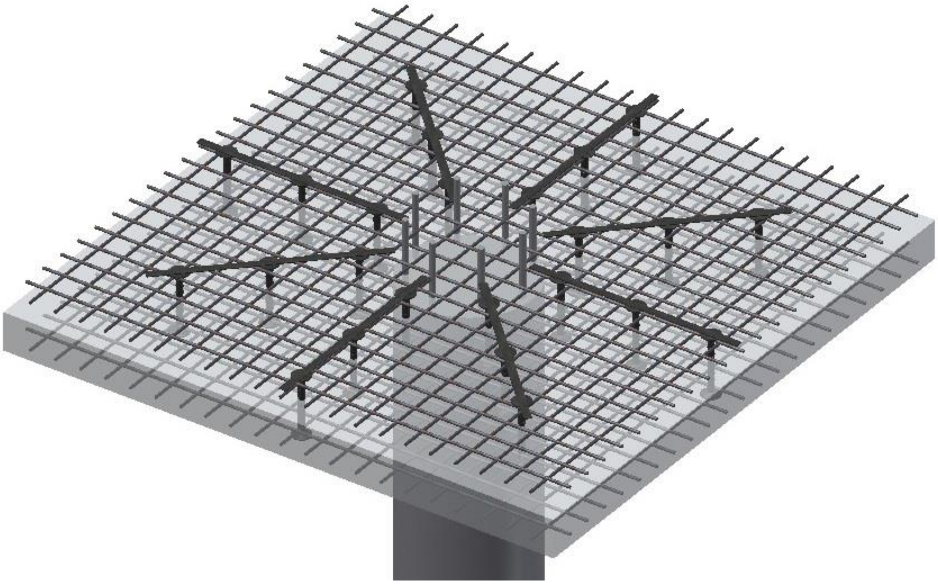
In the support area, around the column head, the bending moments are combined with transverse loads – reaction from supports. These load concentration leads to increased stresses and then to failure of the slab by punching.
Previously, slab with increased thickness or columns with enlarged heads where used to prevent punching shear failure. Stirrup cages used as punching shear reinforcements implies a complicated installation with higher costs. Compared to stirrup cages, the TSR system is more suitable for higher loads around column heads.



Failure of a slab by punching.

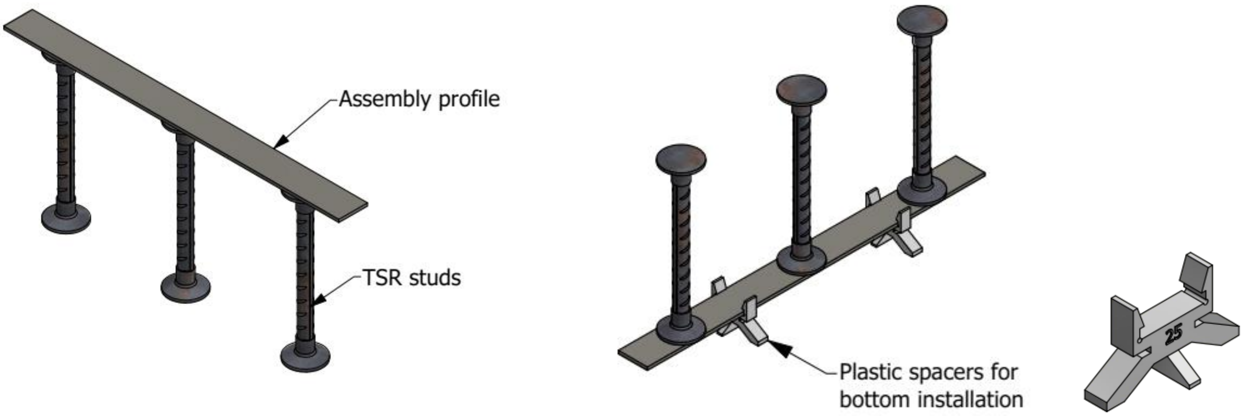
EN – Original Instructions

To prevent shear failure, TSR is also used in ground slabs in a similar manner as in flat slabs. Other applications (TSR used as shear reinforcement in beams or support wall ends) are possible as well.



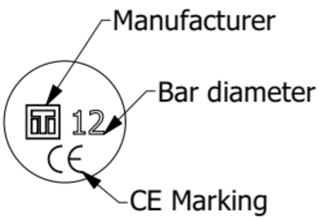
Flat slab reinforced with TSR

TSR elements consists of double forged heads studs made of rebar steel welded to an assembly profile. The heads are hot forged at a diameter equal to 3 x diameter of the rebar. The rebar used has a characteristic yield strength of 500 MPa. The assembly profile has no load bearing function; it only ensures the correct alignment, spacing and positioning of the studs during their installation into concrete slabs.
Material used: - assembly profile, 30x4 mm strips made of S235JR EN 10025-2: 2004 and TSR studs made of rebar B500B EN 10080. The spacers used for bottom installation of TSR elements are made of plastic material.



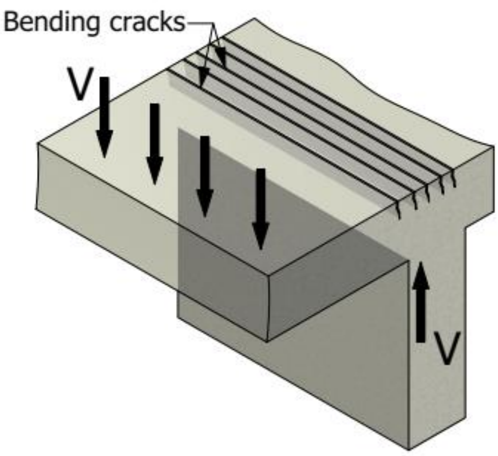
Available types of TSR elements

Each TSR stud is clearly marked with rebar dimension and the manufacturer logo.

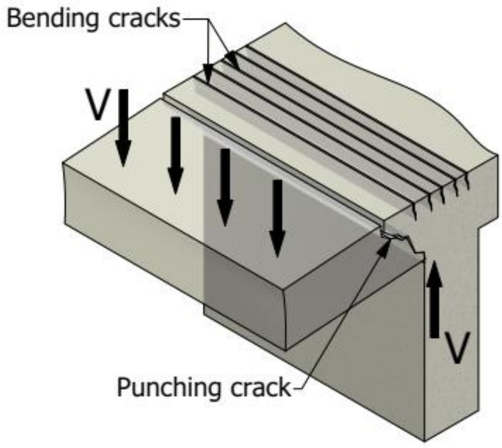


STRUCTURAL BEHAVIOUR

The weight of a slab supported on a column determines shear stresses in the slab which could result in the column punching through the slab when additional reinforcement has not been provided.

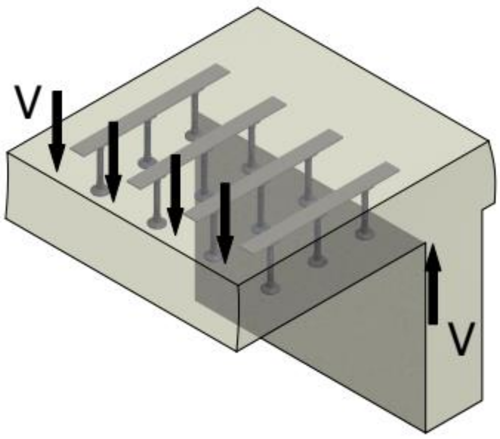


Forces in slabs without shear reinforcement before failure



Forces in slabs without shear reinforcement before failure

TSR studs are designed to prevent the occurrence and expansion of inclined punching cracks. The TSR studs act as vertical tensile components.



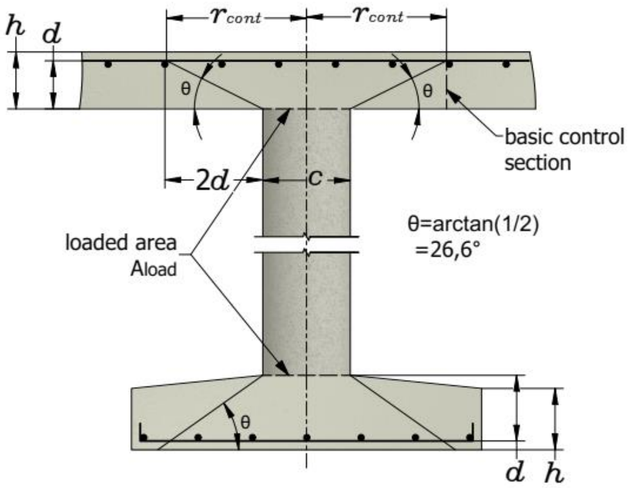
Forces in slab with TSR reinforcement.

The excellent anchorage properties of TSR studs enable the slab reinforced with TSR studs to develop resistances that are significantly higher than the resistances of slabs reinforced with conventional reinforcement (stirrups).

TECHNICAL INFORMATION

PUNCHING

The verification model for punching shear at the ultimate limit state is illustrated below.

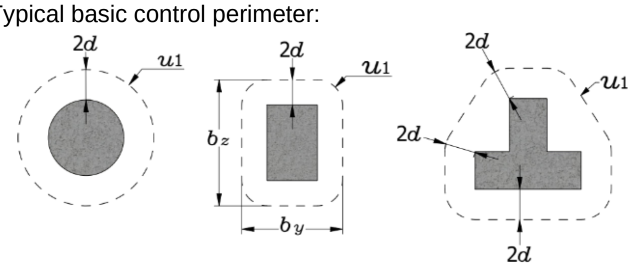


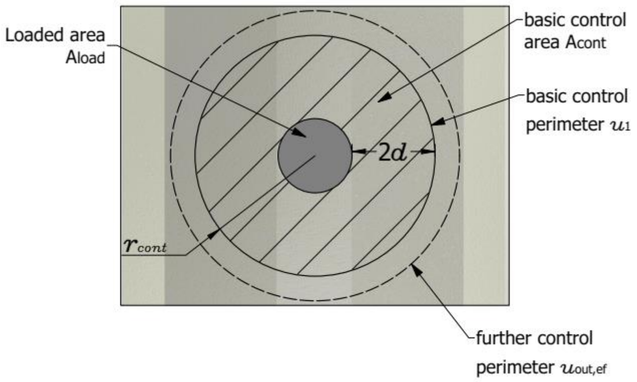
Punching shear can result from a concentrated load or reaction acting on the loaded area A_{load} of a slab or a foundation.

The shear resistance should be checked at the face of the column and the basic control perimeter $\boldsymbol{u_1}$
Further perimeter $\boldsymbol{u_{out,ef}}$ is the perimeter where shear reinforcements are no longer required.

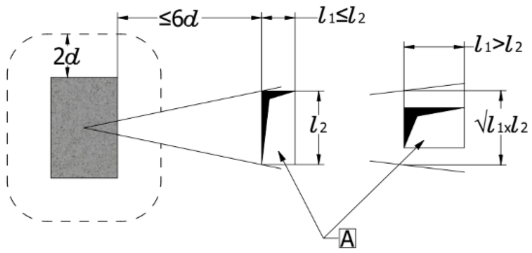
The control section is perpendicular to the middle plane of the slab for slabs of constant depth.
For slabs or footings of variable depth other than step footing, the effective depth may be assumed to be the depth at the perimeter of the loaded area.

Typical basic control perimeter:

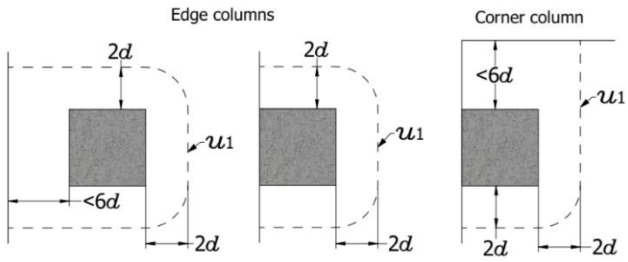


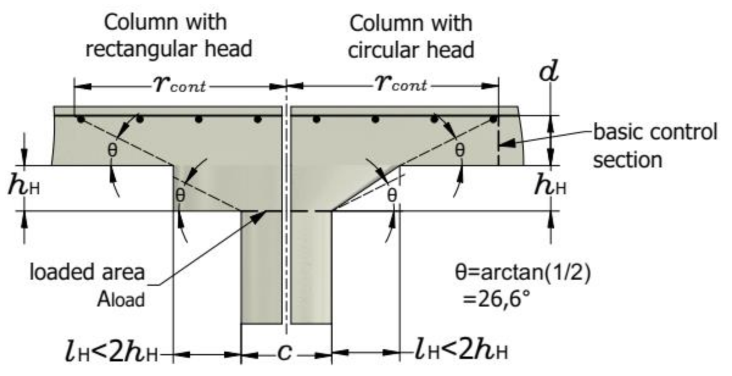


Control perimeter near an opening A:



Basic control perimeter for loaded areas close to or at edge or corner:





For slabs with a column head for which $\boldsymbol{l_H < 2h_H}$ punching shear stresses is only required to be checked on the control section outside the column head.

For a circular column:

$$r_{cont} = 2d + l_H + 0.5c$$

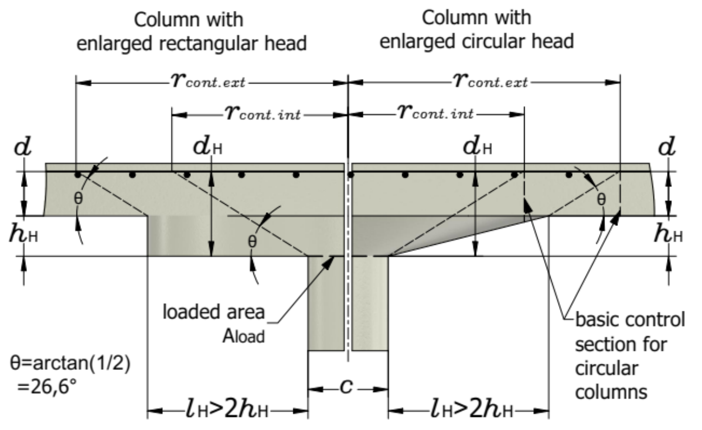
Where:

l_H – distance from the column face to the edge of the column head.

c – diameter of a circular column

For a rectangular column, the value r_{cont} may be taken as the lesser of:

$r_{cont} = 2d + 0.56\sqrt{l_1 l_2}$ and $r_{cont} = 2d + 0.69 l_1$



For slabs with a column head for which $\boldsymbol{l_H < 2h_H}$ punching shear stresses is required to be checked on the control section.

For a circular column:

$$r_{cont,ext} = 2d + l_H + 0.5c$$

$$r_{cont,int} = 2(d + h_H) + 0.5c$$

PUNCHING SHEAR CALCULATION

The design stresses along the control section are:

- $v_{Rd,c}$ – design value of the punching shear resistance of a slab without punching shear reinforcement along the control section considered
- $v_{Rd,cs}$ – design value of the punching shear resistance of a slab without punching shear reinforcement along the control section considered
- $v_{Rd,max}$ – design value of the maximum punching shear resistance along the control section considered

The following checks should be done:

a) At the column perimeter, or the perimeter of the loaded area, the design value of the applied force stress should be:

$$v_{Ed} \leq v_{Rd,max}$$

b) Punching shear reinforcement is not necessary if:

$$v_{Ed} \leq v_{Rd,c}$$

c) If $v_{Ed} > v_{Rd,c}$ for the control section considered punching shear reinforcement must be provided according:

$$v_{Rd,cs} = 0.75 v_{Rd,c} + 1.5 \left({}^{d}/_{S_r}\right) A_{sw} f_{ywd,ef} \left({}^{1}/_{(u_1 d)}\right) \sin\alpha$$

EN – Original Instructions

Where the support reaction is eccentric with regard to the control perimeter, the maximum shear stress should be:

$$v_{Ed} = \beta \frac{V_{Ed}}{u_i d}$$

Where:

d - effective depth of the slab, which may be $d = {(d_y + d_z)}/{2}$, d_x, d_y is the effective depth in the y and z- directions of the control section.
u_i – is the length of the control perimeter being considered
β – is given by:

$$\beta = 1 + k \frac{M_{Ed}}{V_{Ed}} . \frac{u_1}{W_1}$$

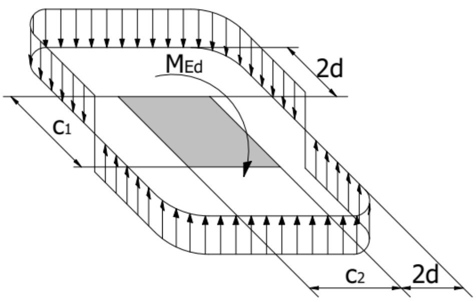
Where:
u_1- the length of the basis control perimeter
k – coefficient dependent on the ratio between the column dimension c_1 and c_2
W_1 – corresponds to a distribution of shear as is illustrated below, and is a function of the basic control perimeter u_1

$$W_i = \int_0^{u_i} |e| dl$$

dl – a length increment of the perimeter
e – the distance of dl from the axis around which the moment M_{Ed} acts.

${c_1}/{c_2}$	≤ 0.5	1.0	2.0	≥ 3.0
k	0.45	0.60	0.70	0.80

Shear distribution due to an unbalanced moment at an internal slab column connection



- For a rectangular column:

$$W_1 = \frac{c_1^2}{2} + c_1 c_2 + 4c_2 d + 16d^2 + 2\pi d c_1$$

Where:
c_1 – is the column dimension parallel to the eccentricity of the load
c_2 – is the column dimension perpendicular to the eccentricity of the load

- For internal circular columns:

$$\beta = 1 + 0{,}6\pi \frac{e}{D + 4d}$$

D – is diameter of the circular column
e – is the eccentricity of the applied load $e = {M_{Ed}}/{V_{Ed}}$

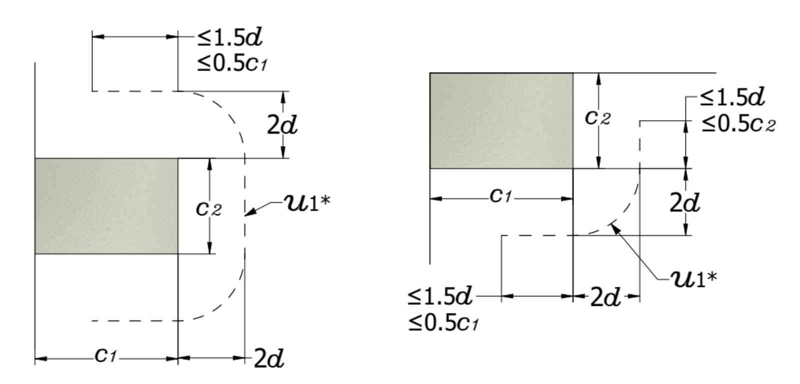
- For an internal rectangular column where the loading is eccentric to both axes:

$$\beta = 1 + 1.8\sqrt{\left(\frac{e_y}{b_z}\right)^2 + \left(\frac{e_z}{b_z}\right)^2}$$

e_y and e_z - the eccentricities M_{Ed}/V_{ed} along y and z-axes respectively, e_y – result from a moment about the z axis and e_z – from a moment around the y-axis
b_y and b_z – the dimensions of the control perimeter

- For edge column connections, where the eccentricity perpendicular to the slab edge is toward the interior and there is no eccentricity parallel to the edge, the punching force may be considered to be uniformly distributed along the control perimeter u_{1*} as shown below:

u_{1*} - Reduced basic perimeter



Edge column	Corner column

For eccentricities in both orthogonal directions:

$$\beta = \frac{u_1}{u_{1*}} + k\frac{u_1}{W_1}e_{par}$$

Where:
- u_1 is the basic control perimeter
- u_{1*} is the reduced basic control perimeter
- e_{par} is the eccentricity parallel to the slab edge resulting from a moment around an axis perpendicular to the slab edge.
- k – may be determined from table above with c_1/c_2 replaced by $c_1/2c_2$.
- W_1 – is calculated for the basic control perimeter u_1

For a rectangular edge column:

$$W_1 = \frac{c_2^2}{4} + c_1c_2 + 4c_1d + 8d^2 + \pi dc_2$$

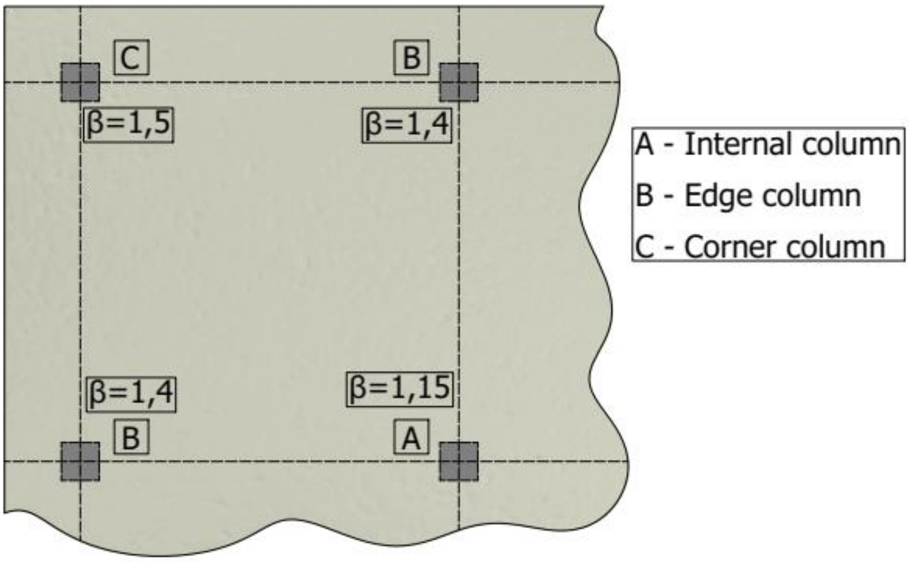
For a corner column where the eccentricity is toward the interior of the slab, it is assumed that the punching force is uniformly distributed along the reduced control perimeter u_{1*}. In this case, the value for β may be considered as:

$$\beta = \frac{u_1}{u_{1*}}$$

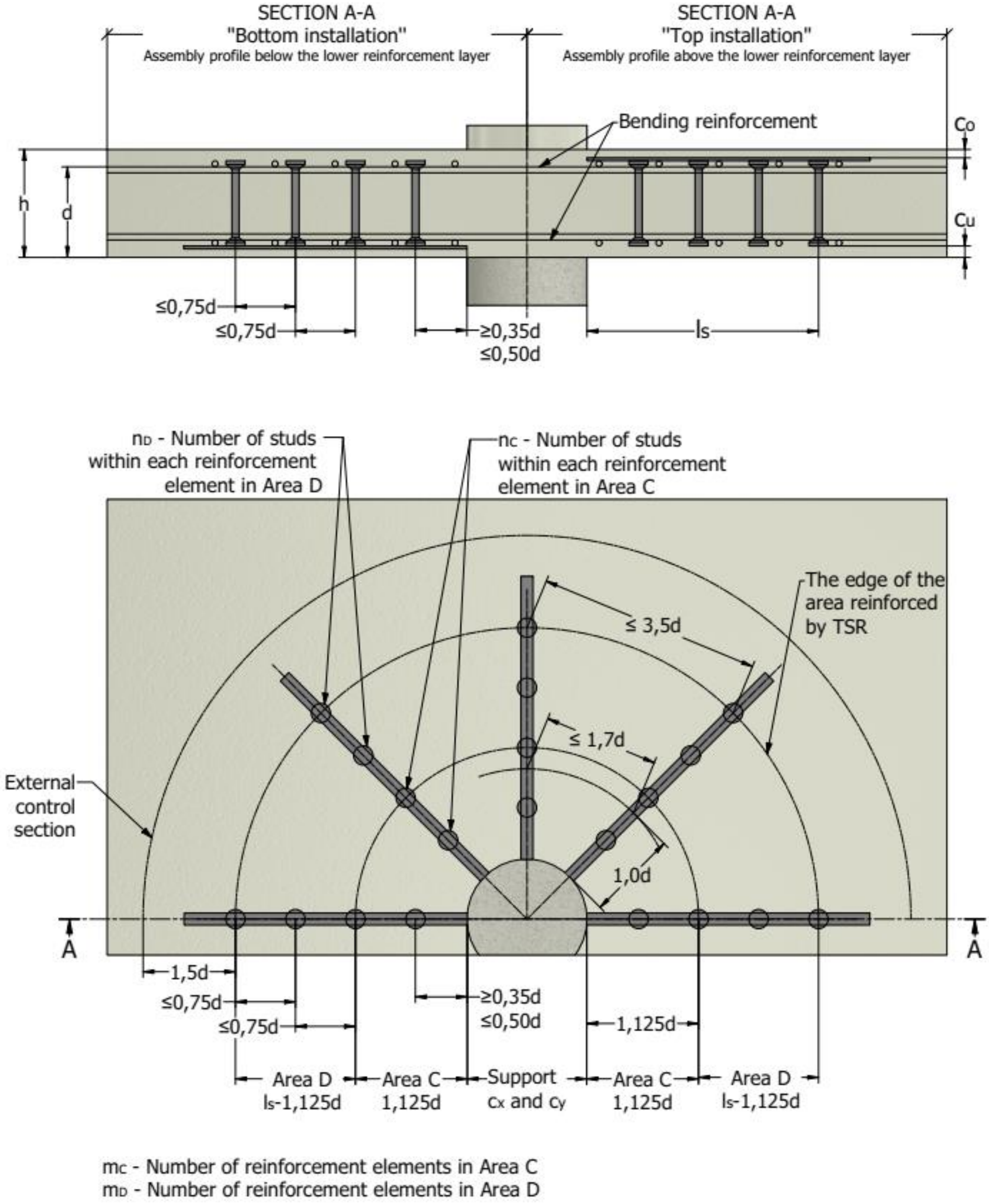
In both cases, edge column and corner column, if the eccentricity is the exterior β is: $\beta = 1 + k\frac{M_{Ed}}{V_{Ed}}.\frac{u_1}{W_1}$

For structures where the lateral stability does not depend on frame action between the slab and the columns, and where the adjacent spans do not differ in length by more than 25%, approximate values for β may be used.

Recommended values are given in figure below:

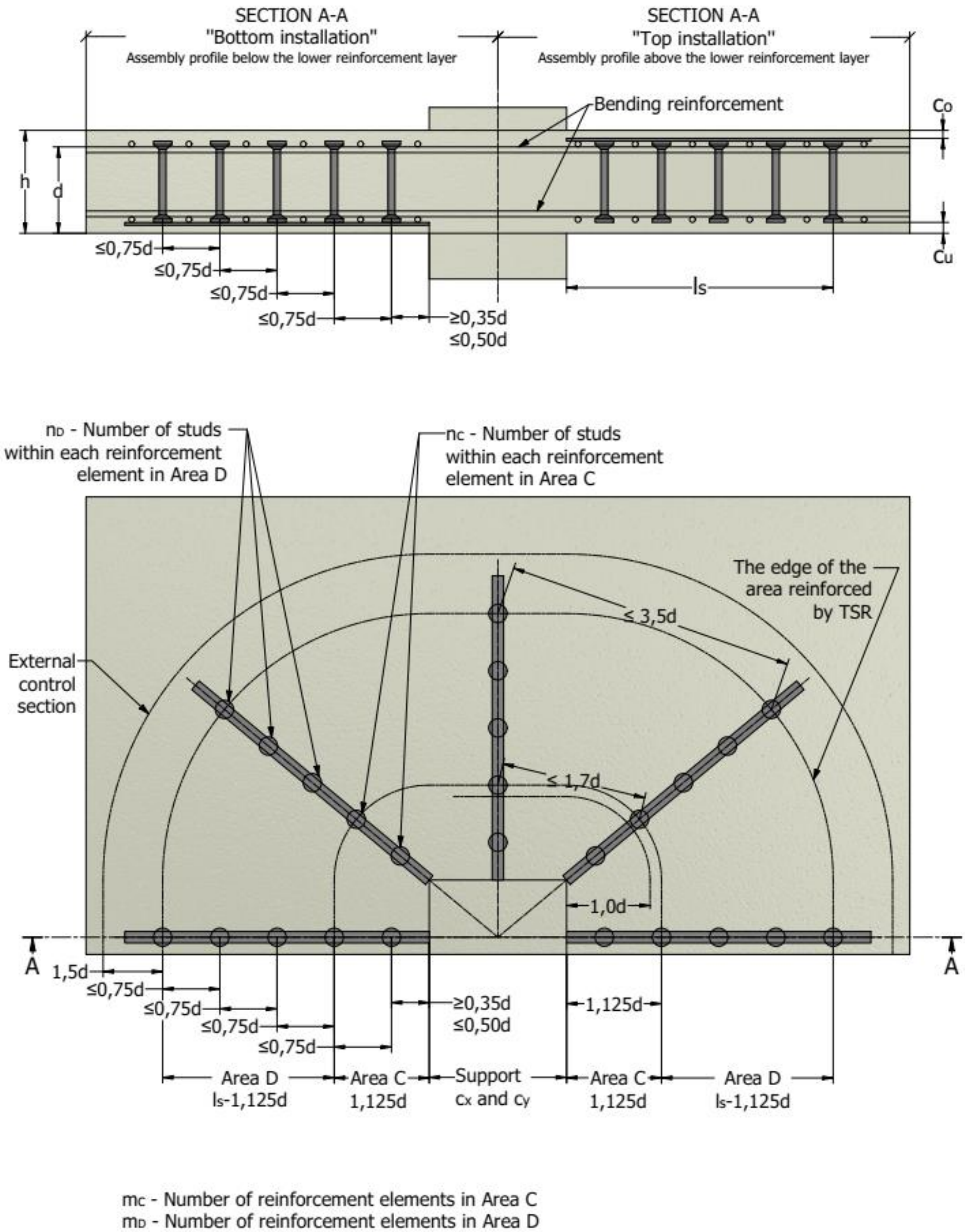


The section and top view of slabs and ground floor reinforced with TSR in accordance with recommendations of EN 1992-1-1, 6.4.2 are shown on figures below. Typically, TSR elements are organised radially around the column. Alternative arrangements of TSR elements are possible, provided that requirements for the maximum spacing of TSR studs are fulfilled.



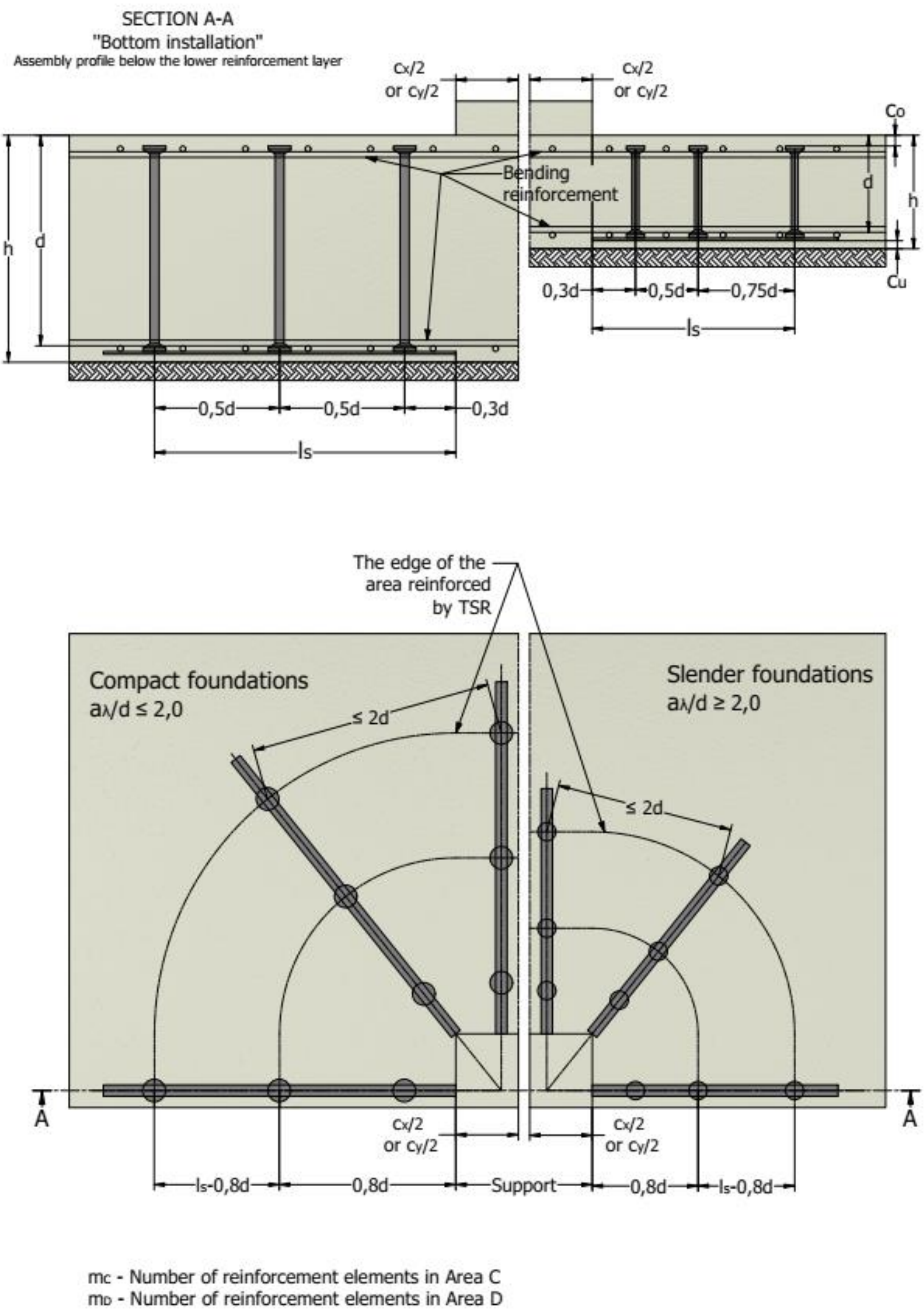
Arrangement of standard elements section and top view

Section and top view of flat slab with circular column



Arrangement of standard elements section and top view

Section and top view of flat slab with rectangular column



Arrangement in ground slabs and footings

Section and top view of a ground slab or footing reinforced by TSR studs

Punching shear resistance of slabs and column bases without shear reinforcement

1) The punching shear resistance of a slab and column bases without shear reinforcement for the basic control section is determined according to Eq. (6.47) of EN 1992-1-1, as:

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

Where:

f_{ck} – is in MPa

$k = 1 + \sqrt{\frac{200}{d}} \leq 2.0$ d in mm

$\rho_l = \sqrt{\rho_{ly}.\rho_{lz}} \leq 0.02.$

ρ_{ly}, ρ_{lz} relate to the bonded tension steel in y and x-direction respectively. The values ρ_{ly} and ρ_{lz} should be calculated as mean values into account a slab width equal to the column width plus 3d each side.

$\sigma_{cp} = (\sigma_{cy} + \sigma_{cz})/2.$

Where:

σ_{cy}, σ_{cz} are the normal concrete stresses in the critical section in y and z-directions (MPa, positive if compression)

$\sigma_{cy} = \frac{N_{Ed,y}}{A_{cy}}$ and $\sigma_{cz} = \frac{N_{Ed,z}}{A_{cz}}$

$N_{Ed,y}$, $N_{Ed,z}$ are the longitudinal forces across the full bay for internal columns and the longitudinal force across the control section for edge column. The force may be from a load or prestressing action

A_c is the area of concrete according to the definition of N_{Ed}

The values $C_{Rd,c}$, v_{min} and k_1 for use in a country may be found in its National Annex. The recommended value for

$C_{Rd,c} = 0.18/\gamma_c$, $v_{min} = 0.035k^{3/2}f_{ck}^{1/2}$ and $k_1 = 0.1$

2) The punching resistance of column bases should be verified at control perimeters within 2d from the periphery of the column.

For concentric loading, the net applied force is $V_{Ed,red} = V_{Ed} - \Delta V_{Ed}$

Where:

V_{Ed} is the applied shear force

ΔV_{Ed} is the net upward force within the control perimeter considered – upward pressure from the soil minus self-weight of base.

$$v_{Ed} = V_{Ed,red}/ud$$

$$v_{Rd} = C_{Rd,c}k(100\rho_l f_{ck})^{1/3} x\, 2d/a \geq v_{min} x\, 2d/a$$

Where:

a is the distance from the periphery of the column to the considered control perimeter.

The values $C_{Rd,c}$, v_{min} and k_1 for use in a country may be found in its National Annex. The recommended value for

$C_{Rd,c} = 0.18/\gamma_c$, $v_{min} = 0.035k^{3/2}f_{ck}^{1/2}$ and $k = 1 + \sqrt{\frac{200}{d}} \leq 2.0$

For eccentric loading:

$v_{Ed} = \frac{V_{Ed,red}}{ud}[1 + k\frac{M_{Ed}u}{V_{Ed,red}W}]$, where k is from below table.

c_1/c_2	≤ 0.5	1.0	2.0	≥ 3.0
k	0.45	0.60	0.70	0.80

Punching shear resistance of slabs and column bases without shear reinforcement

1) Where shear reinforcement is required, it should be calculated in accordance with:

$$v_{Rd,cs} = 0.75 v_{Rd,c} + 1.5 \left({}^{d}/_{S_r} \right) A_{sw} f_{ywd,ef} \left({}^{1}/_{(u_1 d)} \right) \sin\alpha$$

Where:

A_{sw} is the area of one perimeter of shear reinforcement around the column [mm²]
s_r is the radial spacing of perimeters of shear reinforcement [mm]
$f_{ywd,ef}$ is the effective design strength of the punching shear reinforcement, according to

$f_{ywd,ef} = 250 + 0.25d \leq f_{ywd}$ [MPa]

d is the mean of the effective depth in the orthogonal directions [mm]
α is the angle between the shear reinforcement and the plane of the slab

If a single line of bent-down bars is provided, then the ratio ${}^{d}/_{s_r}$ may be given the value 0,67.

2) Adjacent to the column the punching shear resistance is limited to a maximum of:

$$v_{Ed} = \frac{\beta V_{Ed}}{u_0 d} \leq v_{Rd,max}$$

Where:
u_0 for an interior column $u_0 = enclosing\ minimum\ periphery$ [mm]
for an edge column $u_0 = c_2 + 3d \leq c_2 + 2c_1$ [mm]
for a corner column $u_0 = 3d \leq c_1 + c_2$ [mm]
c_1, c_2 are the rectangular column dimensions
β see above formulas
The value of $v_{Rd,max}$ for use in a country may be found in its National Annex. The recommended value is $0.5 v f_{cd}$.
Where:
$v = 0.6[1 - \frac{f_{ck}}{250}]$ (f_{ck} in MPa).

3) The control perimeter at which shear reinforcement is not required $u_{out,ef}$ should be calculated:

$$u_{out,ef} = \frac{\beta V_{Ed}}{v_{Rd,c} d}$$

The outermost perimeter of shear reinforcement should be placed at a distance not greater than kd within u_{out} or $u_{out,ef}$, see pictures below. The value of k for use in a country may be found in its National Annex. The recommended value is $k = 1.5$

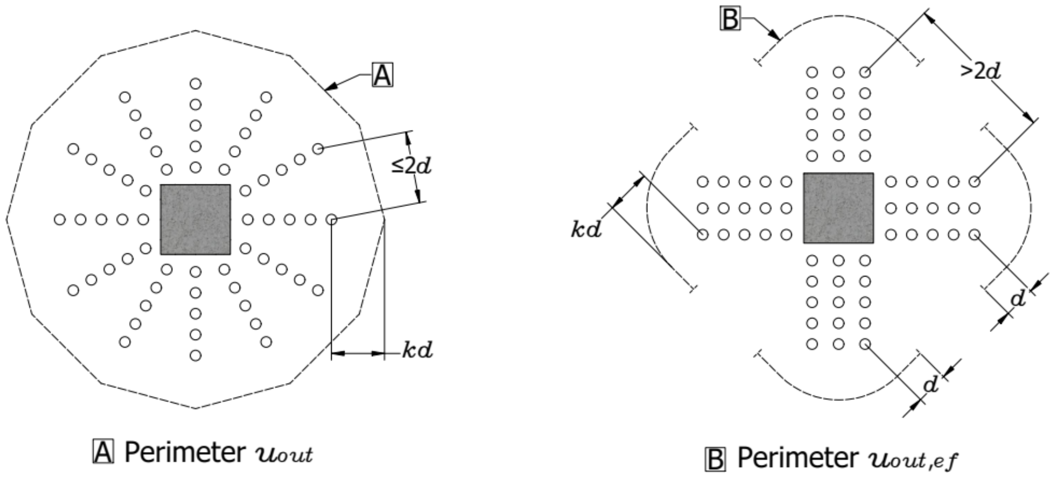
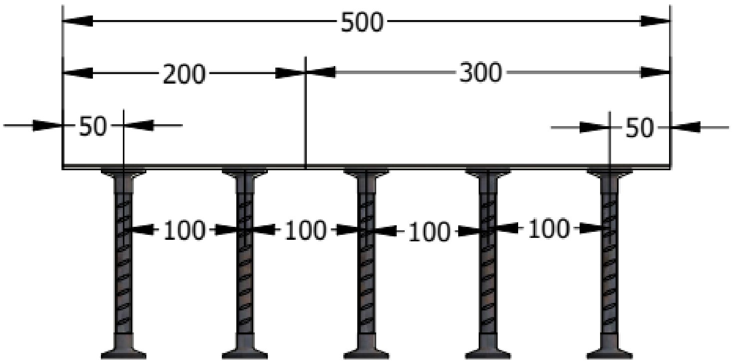


Figure 9. Control perimeter at internal columns

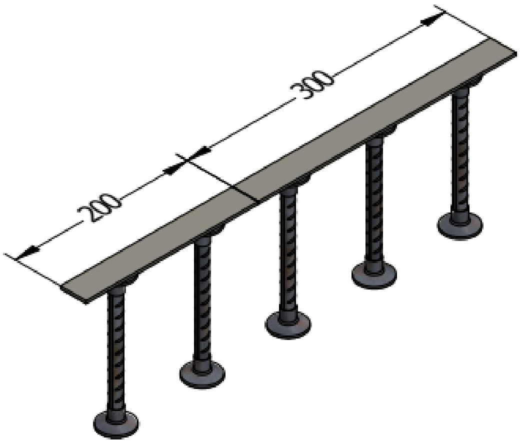
APPLICATION

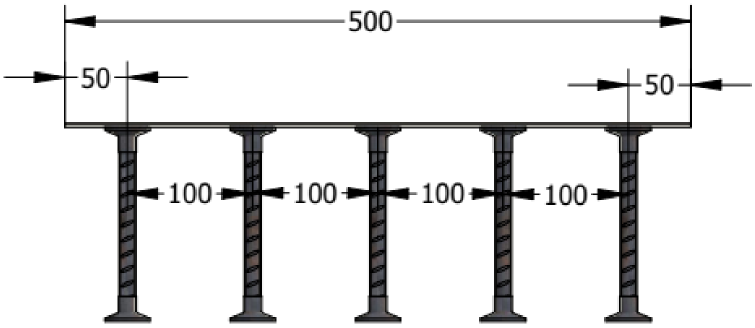
The minimum depth of a slabs reinforced with TSR is 180 mm.

The reinforcement of flat slabs with TSR may be provided as a combination of 2 or 3 studs elements or by complete elements where all studs are welded to one assembly profile. In thick slabs, foundation slabs and where high ratios of reinforcement steel are used, it is recommended to install the TSR complete elements first, using the bottom-up method.

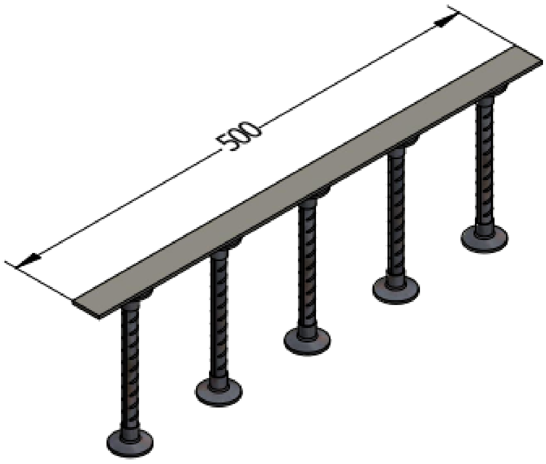


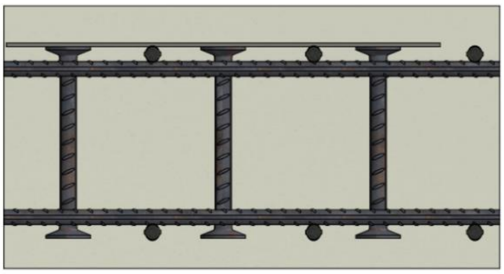
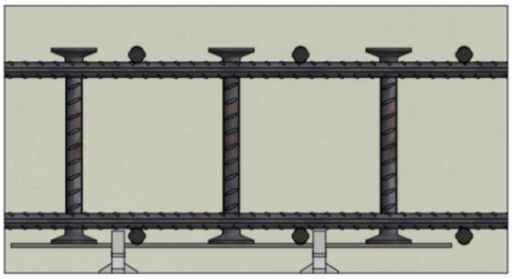
TSR-12/155-2/200 (50/100/50)
TSR-12/155-3/500 (50/2 x 100/50)



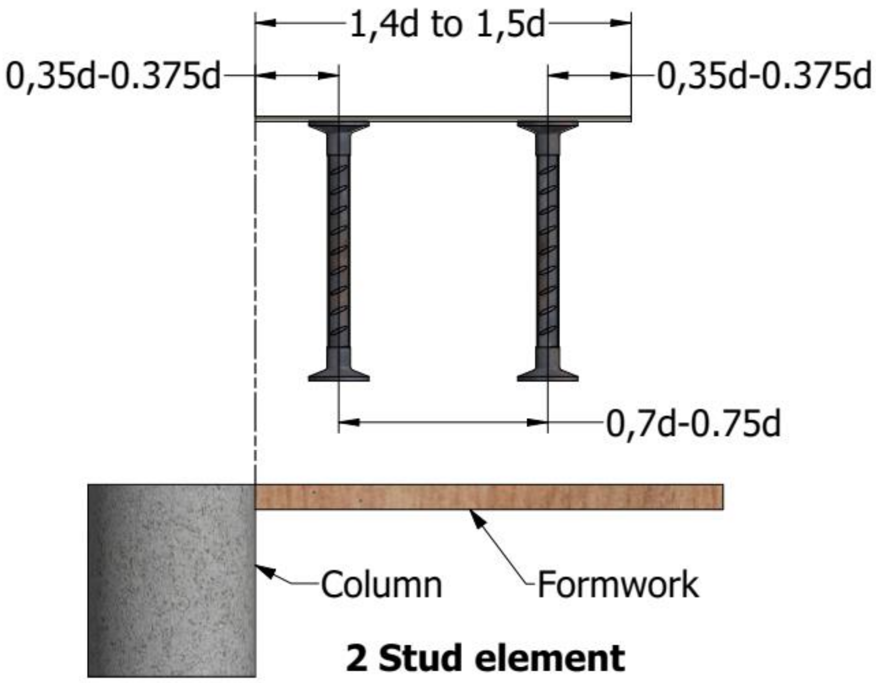


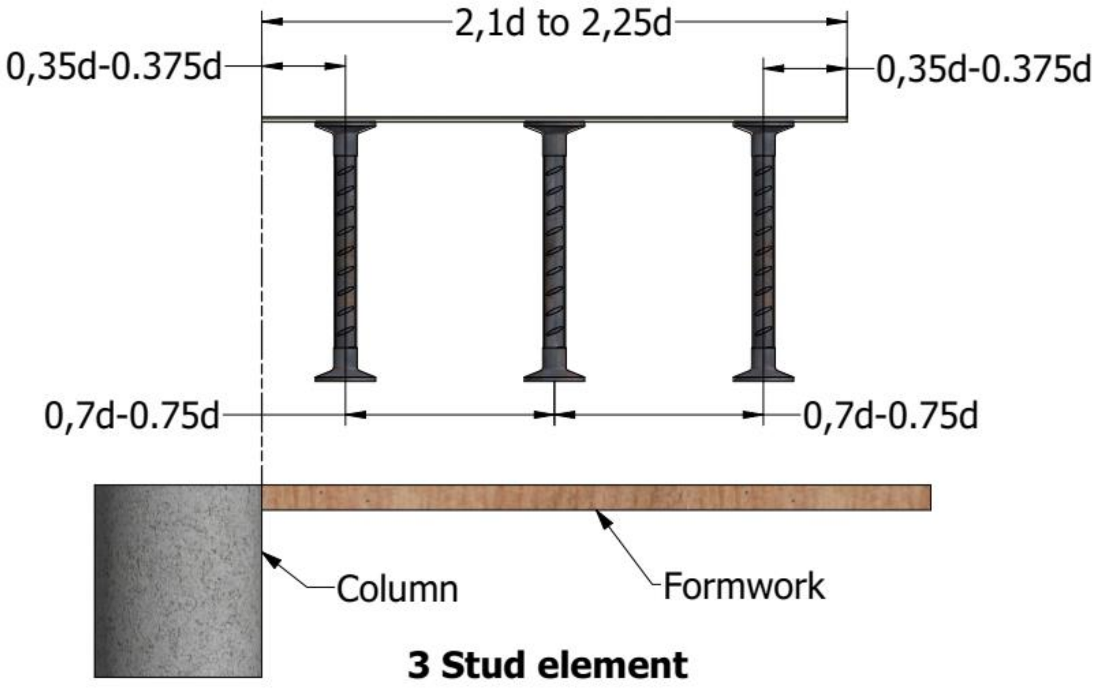
TSR-12/155-5/500 (50/4 x 100/50)



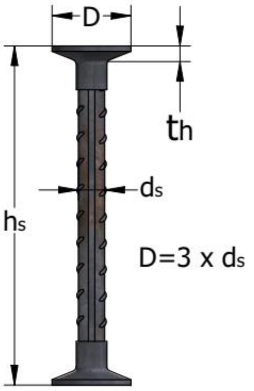
Symmetrical TSR elements are preferably installed from above	TSR complete elements are preferably installed from below before placing the main reinforcement
	

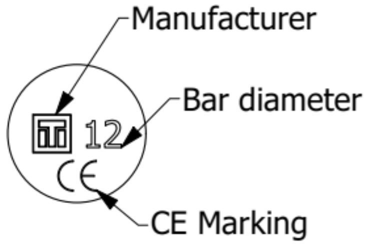
STANDARD SHEAR REINFORCEMENT DESCRIPTION





TSR stud anchor dimensions and markings



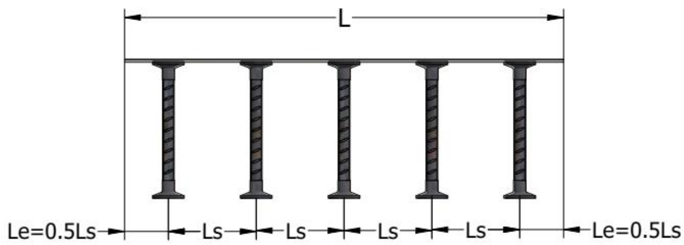


Diameter of the stud d_s [mm]	Diameter of the head D [mm]	Head thickness t_h [mm]	Cross section area of the stud A_s [mm]	Characteristic value of yield strength f_{yk} [MPa]	Characteristic resistance of the stud $F_k = Af_{yk}$ [kN]
10	30	6	79	500	39.5
12	36	7	113		56.5
14	42	8	154		77.0
16	48	8.5	201		100.5
20	60	10	314		157.0
25	75	14	491		245.5

Order description

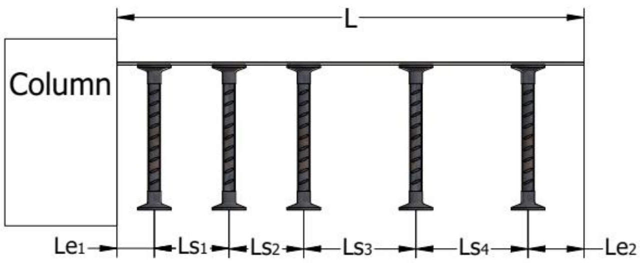
1) Standard type

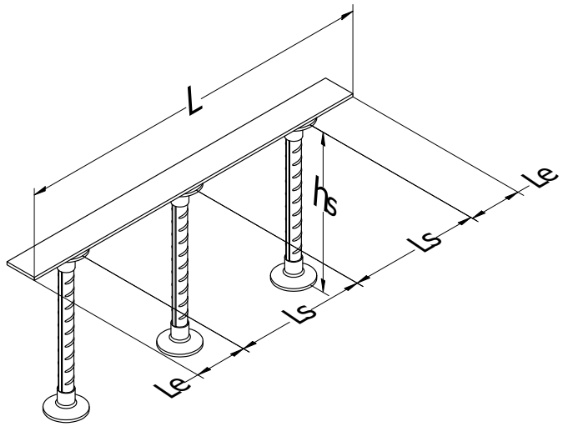
Type		Stud dimensions d_s/h_s				Number of studs		Element length L
TSR	**-**	**12**	**/**	**155**	**-**	**5**	**/**	**500**



2) Complete element

Type		Stud dimensions d_s/h_s				Number of studs		Element length L	End spacing Le_1		Stud spacings ($Ls_1/Ls_2/Ls_3/\ldots.Ls_n$)						End spacing Le_2
TSR	**-**	**12**	**/**	**155**	**-**	**5**	**/**	**500**	**(40**	**/**	**80**	**/**	**80**	**/**	**120**	**/**	**120 / 60)**





Standard available types

d_s	Ø10		Ø12		Ø14		Ø16		Ø20		Ø25		
Anchor qty	2	3	2	3	2	3	2	3	2	3	2	3	
Anchor height h_s [mm]	Element length		Element length		Element length		Element length		Element length		Element length		Anchor distance Ls [mm]
105													80
115													80
125													100
135			200	300									100
145			200	300									100
155			220	330									110
165			240	360									120
175			240	360									120
180			250	350									125
185			280	420			280	420					140
190			300	450									150
195			280	420			280	420					140
205	280		280	420			280	420					140
215			300	450			300	450	300	450			150
225			320	480			320	480	320	480			160
235			340	510			340	510	340	510	340	510	170
245			360	540			360	540	360	540	360	540	180
255							360	540	360	540	360	540	180
265							380	580	380	580	380	580	200
275							400	600	400	600	400	600	200
285							420	630	420	630	420	630	210
295							440	660	440	660	440	660	220
305													
315													
325													
335													
345													
350													
355													
365													
375													
395													
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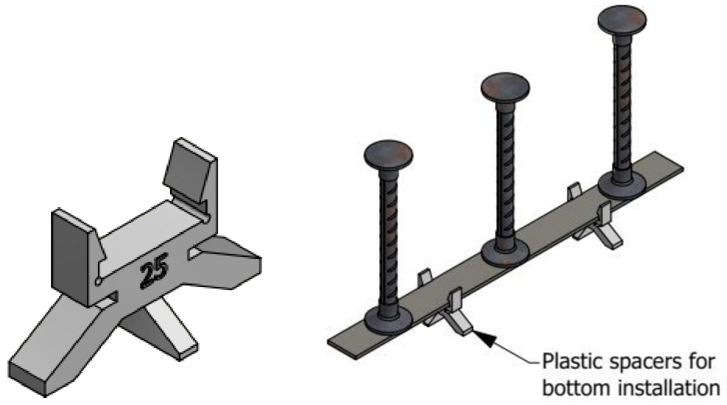
455													

Installation accessory dimensions

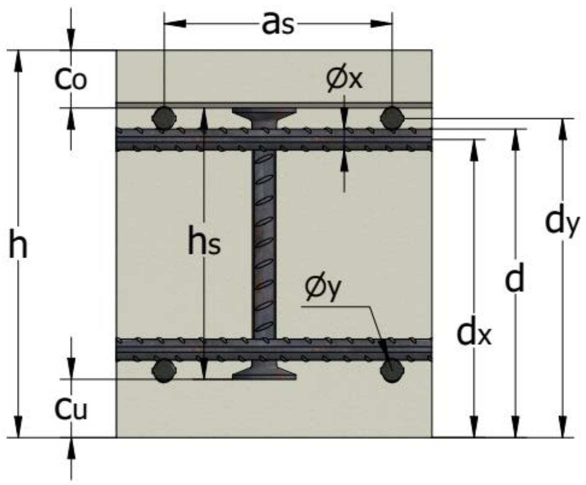
For bottom installation, we recommended the plastic spacer.



Spacer type	Article number	Concrete cover dimension c_u [mm]
TPS 20	65598	20
TPS 25	65599	25
TPS 30	65600	30
TPS 35	65601	35

CALCULATION EXAMPLE

INTERNAL COLUMN



Column dimensions	$c_x = 350mm$
	$c_y = 350mm$
Concrete grade	C 30/37
Height of slab	$h = 300\ mm$
Concrete cover dimension	$c_o = 30\ mm$
Concrete cover bottom	$c_u = 25\ mm$
Diameter of bending reinforcement	$\emptyset_x = 16\ mm$
	$\emptyset_y = 16\ mm$
Dimension $a_{s,x}$ and $a_{s,y}$	$a_{s,x} = 120\ mm$
	$a_{s,y} = 120\ mm$
Applied load	$V_{Ed} = 950\ kN$

Effective depth and bending reinforcement ratio.

1) Effective depth

$$d_y = h - c_0 - {}^{\emptyset_y}/_2 = 262\ mm$$

$$d_x = h - c_0 - \emptyset_y - {}^{\emptyset_y}/_2 = 246\ mm$$

$$d = \frac{d_x + d_y}{2} = 254\ mm$$

2) Bending reinforcement ratio

- Area of one reinforcement bar in x direction:

$$A_{s,x} = \frac{\pi \emptyset_x^2}{4} = 201.062\ mm^2$$

- Area of one reinforcement bar in y direction:

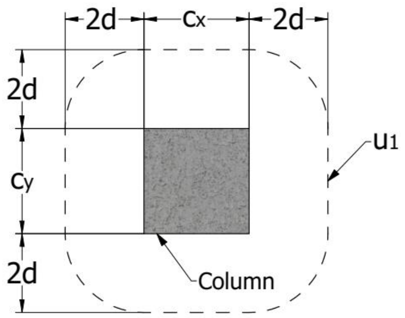
$$A_{s,y} = \frac{\pi \emptyset_y^2}{4} = 201.062\ mm^2$$

$$\rho_x = \frac{A_{s,x}}{a_{s,x} \cdot d_x} \cdot 100 = 0.68\%$$

$$\rho_y = \frac{A_{s,y}}{a_{s,y} \cdot d_y} \cdot 100 = 0.64\%$$

$$\rho_l = \sqrt{\rho_x \cdot \rho_y} = 0.66\%$$

Basic control perimeter (u_1) and perimeter of column (u_0)



$$u_1 = 2\pi \cdot 2 \cdot d + 2 \cdot c_x + 2 \cdot c_y = 4591.85\ mm$$

$$u_0 = 2 \cdot (c_x + c_y) = 1400\ mm$$

Load increase factor $\beta = 1.15$ for internal column.

Punching shear resistance of slabs without shear reinforcement

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

$\sigma_{cp} = 0$ – without prestressing force

$$C_{Rd,c} = {}^{0.18}/_{\gamma_c} = 0.12$$

$$k = 1 + \sqrt{\frac{200}{d}} = 1.89 \leq 2.0$$

$$v_{min} = 0{,}035 k^{3/2} f_{ck}^{1/2}$$

$$v_{Rd.c} = C_{Rd,c} k (100 \rho_l f_{ck})^{1/3} = 0.12 \cdot 1.89 \cdot (100 - 0.0066 \cdot\ 30)^{1/3} = 0.613\ MPa$$

$v_{min} = 0{,}035k^{3/2}f_{ck}^{1/2} = 0.035 \cdot 1.89^{3/2} \cdot 30^{1/2} = 0.498\ MPa$

Shear stress calculated along the critical perimeter:

$$v_{Ed} = \beta\frac{V_{Ed}}{u_i d} = 1.15\frac{950000}{4591.85 \cdot 254} = 0.937\ MPa$$

Maximum resistance of slab with punching reinforcement:

$v_{Rd,max} = 0.5 v f_{cd} = 0.5 - 0.528 \cdot 20 = 5.28\ MPa$

$$v = 0.6\left[1 - \frac{f_{ck}}{250}\right] = 0.528$$

Load bearing capacity of the slab:

$v_{Rd,c} < v_{Ed} < v_{Rd,max}$

$0.613 < 0.937 < 5.28$

TSR shear reinforcement can be used.

If $v_{Rd,c} \geq v_{Ed}$ no TSR reinforcement is needed.

If $v_{Ed} > v_{Rd,max}$ maximum resistance of slab exceeded.

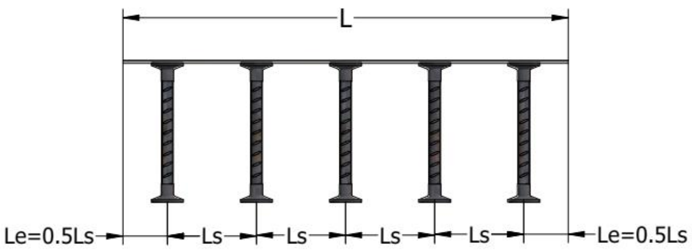
Dimension of TSR studs is:

$h_s = h - c_u - c_0 = 300 - 25 - 30 = 245\ mm$

Spacing between TSR elements:

L_{s1} =180 mm $\quad {L_{s1}}/{d} = 0.709 < 0.75$

$L_e = 90\ mm \quad {L_e}/{d} = 0.354 < 0.5; < 0.35$



Number of studs and length of reinforcement elements:

$$u_{out,req} = \frac{\beta \cdot V_{Ed}}{v_{Rd,c,out} d} = \frac{1.15 \cdot 950000}{0.613 \cdot 254} = 7016.6\ mm$$

Required length of outer perimeter:

$$l_{s,req} = \frac{u_{out,req} - 2 \cdot (c_x + c_y)}{\pi \cdot 2} - 1.5 \cdot d = \frac{7016.6 - 2 \cdot (350 + 350)}{\pi \cdot 2} - 1.5 \cdot 254 = 513\ mm$$

Minimum number of TSR reinforcement in one element:

$$n_{req} = \frac{l_{s,req} - L_e}{L_s} + 1 = \frac{513 - 90}{180} + 1 = 3.35 \rightarrow n_{prov} = 4$$

Provided length of one element:

$$l_{s,prov} = L_e + \left(n_{prov} - 1\right) \cdot L_s = 90 + (4 - 1) \cdot 180 = 630\, mm.$$

Provided control perimeter:

$$u_{out,prov} = 2 \cdot \pi \cdot \left(l_{s,prov} + 1.5 \cdot\ d\right) + 2 \cdot c_x + 2 \cdot c_y = 2 \cdot \pi \cdot (630 - +1.5 \cdot 254) + 2 \cdot 350 + 2 \cdot 350 = 7752.3\, mm$$

Outer control perimeter checking:

$$u_{out,req} \leq u_{out,prov} \rightarrow 7016.6 \leq 7752.3$$

$$l_{s,req} \leq l_{s,prov} \rightarrow 513 \leq 630$$

Resistance of the slab in the outer perimeter.

$$v_{Ed,out} = \beta \frac{V_{Ed}}{u_{out,prov} d} = 1.15 \frac{950000}{7752.3 \cdot\ 254} = 0.554\, MPa$$

Checking:

$$v_{Rd,c} \geq v_{Ed,out}$$

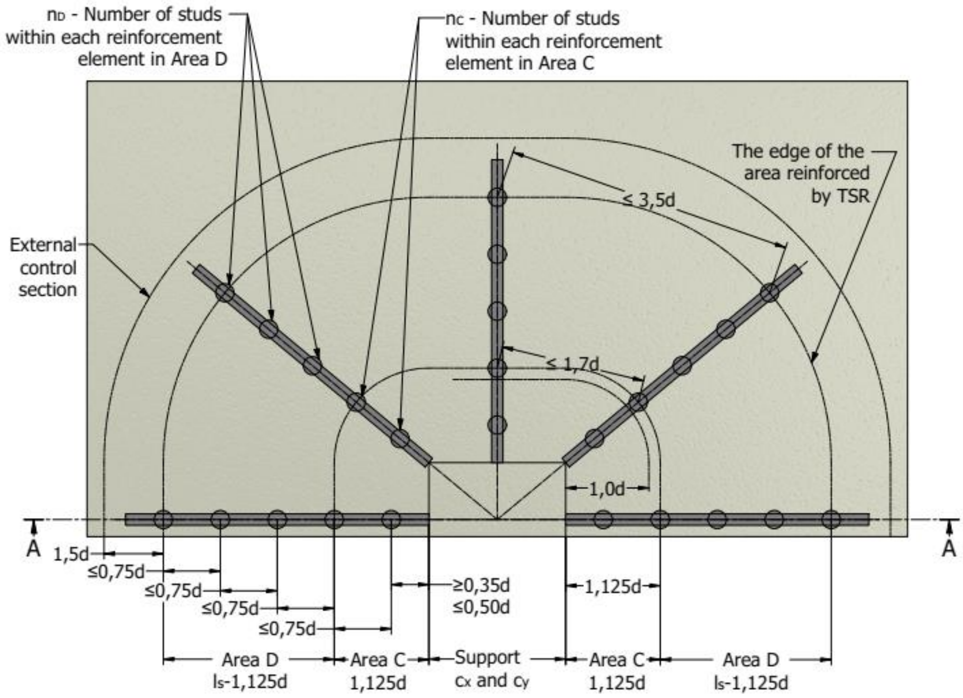
$$0.613 \geq 0.554$$

Number of reinforcement elements

Strength condition:

$$\beta \cdot V_{Ed} \leq m_{c,req} \cdot n_c \cdot \frac{F_k}{\gamma_s \cdot \eta} \rightarrow m_{c,req} \geq \frac{\beta \cdot V_{ed} \cdot \gamma_s \cdot \eta}{n_c \cdot F_k}$$

Where:
F_k – characteristic value of tensile strength of the stud
m_c – number of elements (rows) in the area C
n_c – number studs of elements (rows) in the area C, $n_c = 2$
γ_s – partial safety factor for steel ($\gamma_s = 1.15$)
· η – factor to take account the effective depth, $\eta = 1.0\ for\ d \leq 200\ mm;\ \eta = 1.6\ for\ d \geq 800\ mm$; for other values, use linear interpolation.



mc - Number of reinforcement elements in Area C
mD - Number of reinforcement elements in Area D

Diameter of studs	10	12	14	16	20	25
F_k [kN]	39.5	56.5	77.0	100.5	157.0	245.5
$m_{c,req}$	20	14	10	8	5	3
$m_{c,spac}$	8	8	8	8	8	8
$m_{c,prov}$ =, $\max\{m_{c,req}; m_{c,spac}\}$	20	14	10	8	8	8
$V_{Rd,s}$ [kN]	1081.8	1083.2	1054.4	**1101**	**1719.9**	**2689.5**
$\beta \cdot V_{Ed}$ [kN]	1092.5	1092.5	1092.5	**1092.5**	**1092.5**	**1092.5**

Total resistance of TSR:

$$V_{Rd,si} = m_{c,prov} \cdot n_c \cdot \frac{F_k}{\gamma_s \cdot \eta}$$

Checking:

$$\beta \cdot V_{Ed} \leq V_{Rd,si}$$

TSR – 16/245-2/360 (90/180/90) + TSR-16/245-2/360 (90/180/90)

Or

TSR-16/245-4/720 (90/3*180/90)

CONTACT

TERWA is the global supplier for precast and construction solutions with multiple offices around the world. With all our staff, partners and agents, we are happy to provide all construction and precast companies who work in the building industry with full service and 100% support.

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