R-Group Baltic OÜ

R3L Wire Rope Loop Box
Technical Manual

Design according to Eurocodes

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Contents

1. PRODUCT DESCRIPTION

R3L wire rope loop boxes manufactured by R-Group Baltic OÜ are steel parts consisting of high strength steel wires and a steel box. R3L wire rope loop boxes are installed to concrete elements before casting.

When the joint between concrete wall elements is loaded, the longitudinal shear force in the joint is divided to an angled compression component and a horizontal pull component at the indented joint. R3L wire rope loop boxes transfers the shear forces acting in the joint between concrete wall elements by the pull component of the wire rope and the compression component formed by the steel boxes and the seam.

- Easy to install through nailing or using magnet
- Tapered profile of box edged ensures secure fixing in concrete
- Since wire rope loops are flexible, they can easily be bent straight in position
- The compression sleeve transfers the load to concrete easily

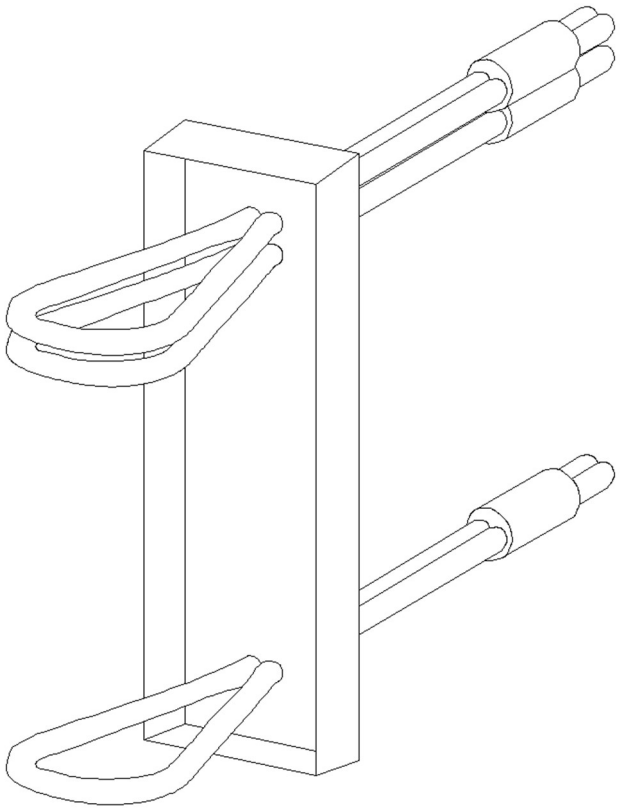


Figure 1 – R3L wire rope loop box

1.1. Dimensions

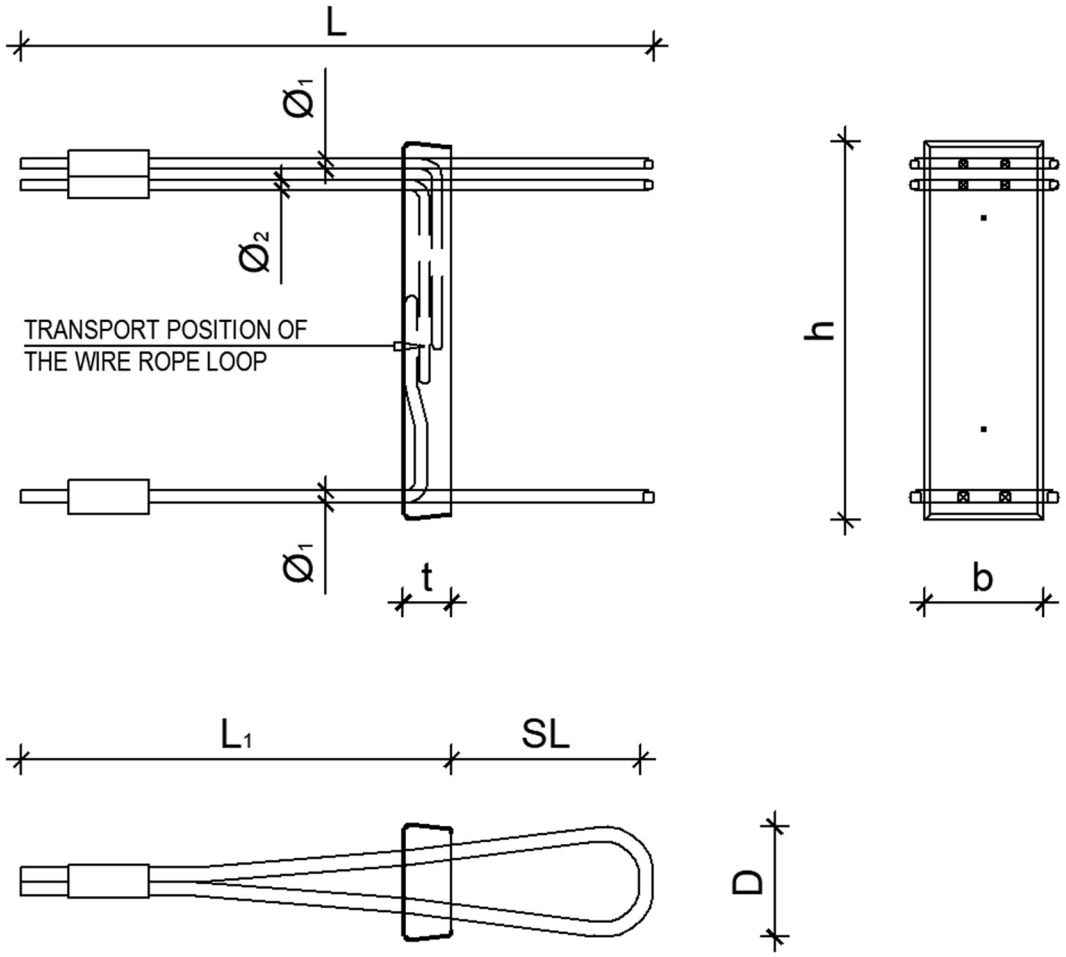


Figure 2 – Dimensions of R3L wire rope loop box

Table 2 – Dimensions and tolerances of R3L wire rope loop boxes

Wire Rope Loop Box	SL [mm]	L [mm]	L_1 [mm]	h [mm]	b [mm]	t [mm]	$Ø_1$* [mm]	$Ø_2$* [mm]	D	Weight [kg]
	±5	±10	±5	±2	±2	±2	-	-	-	-
R3L-THIN	80	296	210	180	50	20	6	5	60	xxxx
	100	316	210	180	50	20	6	5	65	xxxx
	120	336	210	180	50	20	6	5	70	xxxx
R3L-WIDE	80	301	215	220	80	25	6	5	60	xxxx
	100	321	215	220	80	25	6	5	65	xxxx
	120	341	215	220	80	25	6	5	70	xxxx

*According to EN 12385-2 or GB/T 20118-2006 or R-Wire

1.2. Material and Standards

Table 1 –R3L wire rope loop box materials and standards

Part	Material	Standard
Steel box	SGCC	JIS G3302
Wire rope	High strength steel wire rope (fu=1770MPa) 7x7 R-Wire	GB/T 20118–2006 EN 12385-2 R-Wire
Compression sleeve	Q195	GB/T 701-2008

2. MANUFACTURING

2.1. Manufacturing Method

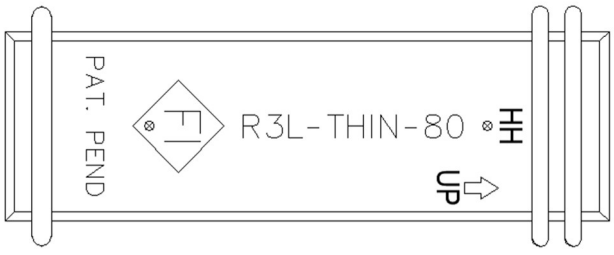
The steel is box is mechanically cut and bent to shape. The open wire rope is installed to the steel box and attached by the compression sleeve to form a loop. The wire rope is bent into the steel box and the open part of the steel box is closed by tape to protect from casting concrete.

2.2. Quality Control

Quality control of the wire rope loop box is done according to EN 1090-2 and the instructions according to quality and environment system of the R-Group Baltic OÜ (ISO9001 and ISO14001). R-Group Baltic OÜ has a quality control contract with Inspecta Sertifiointi Oy.

2.3. Markings

Marking of R3L wire rope loop boxes are engraved on the loop box itself as in the image below (as seen from inside after removing the tape – Illustrative only).



The products are delivered in Euro palettes with RSteel sticker providing information as follows:

- RSteel®'s article code
- Product name
- Quantity
- Product picture

3. RESISTANCES

3.1. Calculation principles

The shear and tensile capacities of the R3L wire rope loop boxes are calculated according to EN 1992-1-1. Capacities are calculated for static loads with the joint width presented in figure 3.

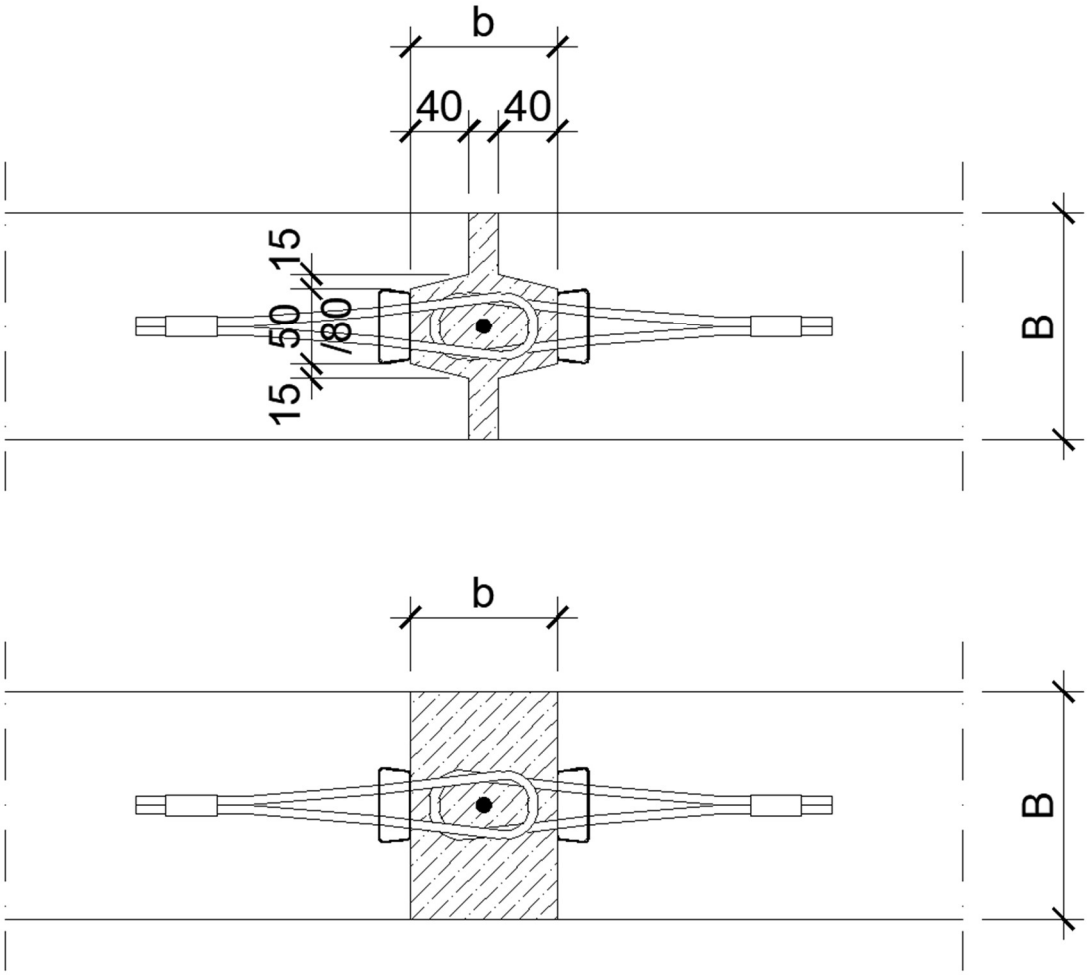


Figure 3 – Indented joint type and dimensions used in calculations of forces

For recommended seam thicknesses for R3L wire rope loop boxes, see chapter 4.1.2.

3.2. Design values of resistance for longitudinal shear force

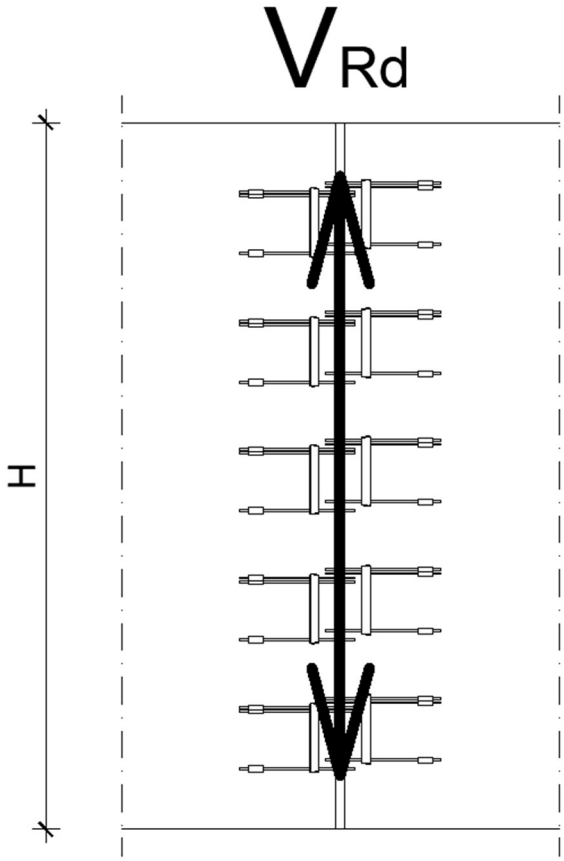


Figure 4 - Direction of longitudinal shear force in joint

Design values of resistance presented in the tables are resistances in ultimate limit state. The resistance is defined by the weakest concrete in the joint (element/joint concrete). Resistances are calculated for concrete classes C25/30, C30/37, C35/45, C40/50, C45/55, and C50/60.

Resistances are calculated for two different wall heights and for certain number of R3L wire rope loop boxes in joint. Number of wire rope loop boxes given in resistance tables is the number of wire rope loop boxes in one side of the joint. E.g. in the joint in figure 4 there is seven boxes.

Table 3 – Design value of resistances for longitudinal shear force for R3L-THIN wire rope loop boxes (80/100/120)

Number of R3L boxes [n]	Recommended Spacing [mm]	V_{Rd} [kN/m] (Wall Height H = 3m)					
		C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
14	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-
10	≤ 300	105,27	108,83	112,19	115,40	118,48	121,44
9	≤ 330	97,50	101,05	104,42	107,63	110,70	113,67
8	≤ 375	89,04	92,56	95,89	99,06	102,10	105,03
7	≤ 425	79,05	82,43	85,63	88,67	91,59	94,41
6	≤ 500	68,70	71,89	74,91	77,79	80,55	83,21
5	≤ 600	57,77	60,71	63,48	66,13	68,66	71,11
4	≤ 750	45,84	48,38	50,79	53,08	55,28	57,40

Number of R3L boxes [n]	Recommended Spacing [mm]	V_{Rd} [kN/m] (Wall Height H = 4m)					
		C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
14	285	109,16	112,71	116,08	119,29	122,36	125,33
13	≤ 305	103,33	106,88	110,25	113,46	116,53	119,50
12	≤ 330	97,50	101,05	104,42	107,63	110,70	113,67
11	≤ 360	91,50	95,05	98,40	101,60	104,67	107,63
10	≤ 400	84,08	87,54	90,80	93,92	96,90	99,78
9	≤ 440	76,50	79,84	83,00	86,01	88,89	91,67
8	≤ 500	68,70	71,89	74,91	77,79	80,55	83,21
7	≤ 570	60,58	63,58	66,43	69,14	71,74	74,25
6	≤ 665	51,97	54,73	57,34	59,83	62,22	64,52
5	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-

- If number of R3L required are 10, the capacity of joint for 3m wall = 105,27*3 = 315,81 kN
- If number of R3L required are 10, the capacity of joint for 4m wall = 85,83*4 = 343,32 kN

Table 4 – Design value of resistances for longitudinal shear force for R3L-WIDE wire rope loop boxes (80/100/120)

Number of R3L boxes [n]	Recommended Spacing [mm]	V_{Rd} [kN/m] (Wall Height H = 3m)					
		C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
14	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-
10	≤ 300	123,22	129,10	134,66	139,96	145,05	149,94
9	≤ 330	115,45	121,33	126,89	132,19	137,27	142,17
8	≤ 375	107,68	113,56	119,11	124,41	129,50	134,39
7	≤ 425	99,90	105,78	111,34	116,64	121,72	126,62
6	≤ 500	88,83	94,44	99,74	104,80	109,65	114,32
5	≤ 600	76,10	81,25	86,13	90,78	95,23	99,53
4	≤ 750	61,61	66,09	70,33	74,36	78,23	81,96

Number of R3L boxes [n]	Recommended Spacing [mm]	V_{Rd} [kN/m] (Wall Height H = 4m)					
		C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
14	285	127,11	132,99	138,55	143,85	148,93	153,83
13	≤ 305	121,28	127,16	132,72	138,02	143,10	148,00
12	≤ 330	115,45	121,33	126,89	132,19	137,27	142,17
11	≤ 360	109,62	115,50	121,06	126,36	131,44	136,34
10	≤ 400	103,79	109,67	115,23	120,53	125,61	130,51
9	≤ 440	97,70	103,56	109,10	114,38	119,45	124,33
8	≤ 500	88,83	94,44	99,74	104,80	109,65	114,32
7	≤ 570	79,41	84,69	89,69	94,45	99,02	103,42
6	≤ 665	69,15	74,00	78,59	82,97	87,16	91,21
5	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-

- If number of R3L required are 10, the capacity of joint for 3m wall = 123,22*3 = 369,66 kN
- If number of R3L required are 10, the capacity of joint for 4m wall = 103,79*4 = 415,16 kN

3.3. Design values of resistance for transverse shear force

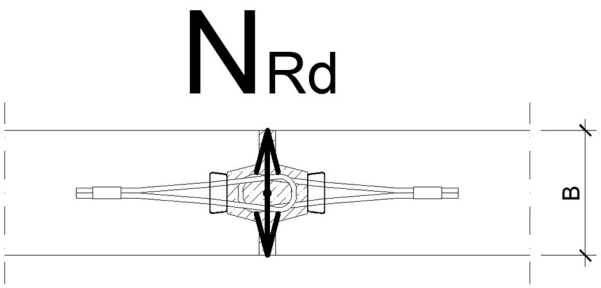


Figure 5 - Direction of transversal shear force

Design values of resistance presented in the tables are resistances in ultimate limit state. The resistance is defined by the weakest concrete in the joint (element/joint concrete).

Design values for transversal shear force apply for one pair of R3L wire rope loop boxes (one on each side of the joint). Distance between wire rope loop pairs must be according to section 4.1.1. and R3L seam dimensions according to figure 6 or 7.

3.3.1. Indented joint

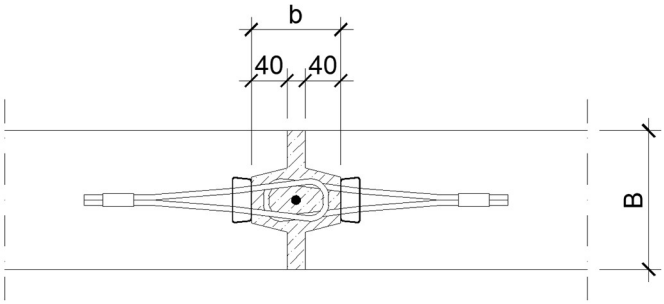


Figure 6 – Indented joint dimensions used in calculations for transversal shear force resistance in table 5

Table 5 – Design values of resistance for transversal shear for R3L wire rope loop boxes according to figure 6

R3L wire rope loop box	B [mm]	Design values for transverse shear force in one pair of wire loop box N_{Rd} [kN/m]					
		C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
R3L-THIN-80 R3L-THIN-100 R3L-THIN-120	≥ 120	14,85	16,27	17,57	18,78	19,92	21,00
R3L-WIDE-80 R3L-WIDE-100 R3L-WIDE-120	≥ 140	12,37	13,56	14,64	15,65	16,60	17,50

3.3.2. Smooth joint

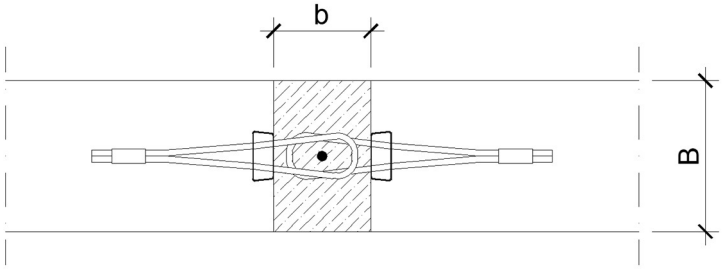


Figure 7 – Smooth joint dimensions used in calculations for transversal shear force resistance in table 5

Table 6 – Design values of resistance for transversal force for R3L wire rope loop boxes according to figure 7

R3L wire rope loop box	B [mm]	Design values for transverse shear force in one pair of wire loop box N_{Rd} [kN/m]					
		C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
R3L-THIN-80 R3L-THIN-100 R3L-THIN-120	≥ 120	3,12	3,42	3,69	3,94	4,18	4,41
R3L-WIDE-80 R3L-WIDE-100 R3L-WIDE-120	≥ 140	3,27	3,58	3,87	4,13	4,38	4,62

3.4. Design values of resistance for tensile force

Design values for transversal shear force apply for one pair of R3L wire rope loop boxes (one on each side of the joint). Distance between wire rope loop pairs must be according to section 4.1.1.

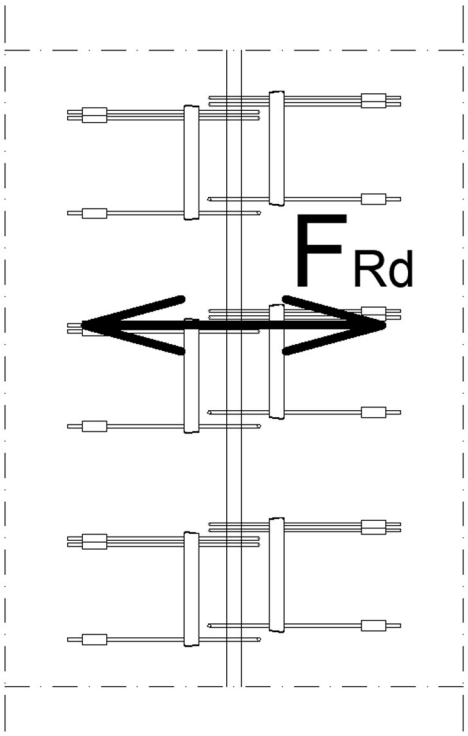


Figure 8 - Direction of tensile force

Table 7 – Design value for tensile force in one pair of wire rope loop boxes

R3L wire rope loop box	Design values for tensile force in one pair of wire loop box F_{Rd} [kN					
	C25/30	C30/37	C35/45	C40/50	C45/55	C50/60
R3L-THIN-80						
R3L-THIN-100	19,13	22,95	26,78	30,44	33,78	37,08
R3L-THIN-120						
R3L-WIDE-80						
R3L-WIDE-100	19,34	23,21	27,06	30,44	33,78	37,08
R3L-WIDE-120						

3.5. Resistance for combined forces

Resistance of R3L wire rope loop joint for combined forces may be calculated according to equation

$$\frac{V_{Ed}}{V_{Rd}} + \frac{N_{Ed}}{N_{Rd}} + \frac{F_{Ed}}{F_{Rd}} \leq 1$$

in which

V_{Ed} = design value of longitudinal shear force

V_{Rd} = design value of resistance for longitudinal shear force

N_{Ed} = design value of transversal shear force

N_{Rd} = design value of resistance for transversal shear force

F_{Ed} = design value for tensile force

F_{Rd} = design value of resistance for tensile force

3.6. Resistance for fire

Critical temperature of R3L wire rope loop boxes in fire is θcr = 350 °C. In fire design sufficient concrete cover according to EN 1992-1-2 must be designed to ensure that the critical temperature of wire rope loop boxes is not exceeded. Also, sufficient thickness of the concrete wall and the joint between walls must be designed for the required fire class.

4. APPLICATION

4.1. Limitations of application

Resistances presented in tables 2…5 are calculated for static loads. R3L wire rope loop boxes are not designed to be used for lifting or as lifting loops.

Resistance of the R3L wire rope loop boxes is defined by the weakest concrete in the joint (element/joint concrete). The resistance calculations do not take into account cracks or deformations in the joint. Resistances of the R3L wire rope loop boxes are calculated for the joint width presented in figure 2 and it is assumed that the steel boxes and the seam are fully filled with concrete.

4.1.1. Minimum edge and center distance

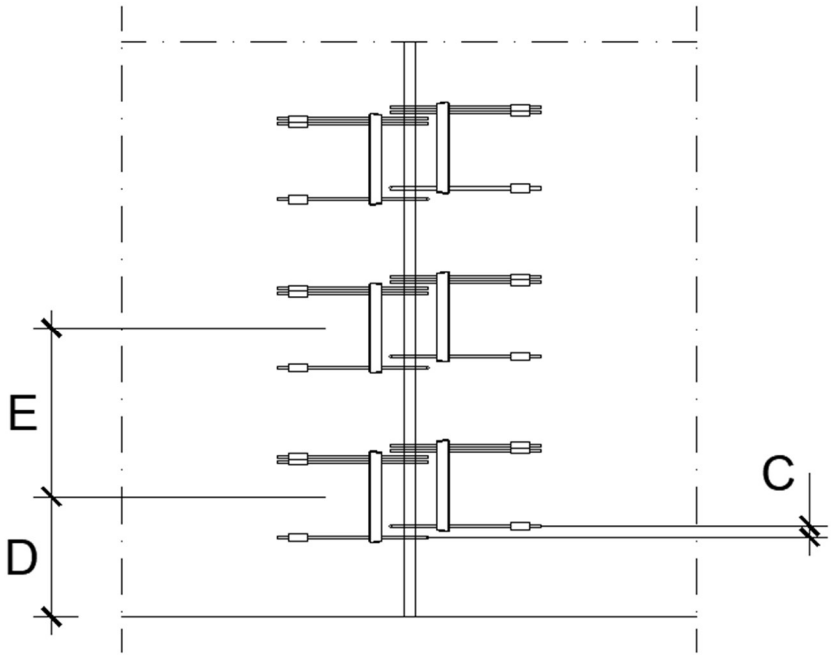


Figure 9 – Distances of R3L wire rope loop boxes

Table 8 – Minimum distances of R3L wire rope loop boxes

Wire Rope Loop Box	Center to center, E_{min} [mm]	Edge distance, D_{min} [mm]	Center to center, C_{max} [mm]	Wall width, B_{min} [mm]
R3L-THIN-80,100,120	285	250	20	120
R3L-WIDE-80,100,120	285	250	25	140

Center to center E_{min} = minimum distance between wire rope loop boxes at the same side of the joint.

Edge distance D_{min} = the minimum distance of the wire rope loop to the upper and lower edge of the concrete element.

Center to center C_{max} = minimum distance between wire rope loop boxes at opposite sides of the joint.

Wall width B_{min} = minimum total wall width.

The size of the wire rope loops must be chosen according to the thickness of the joint to enable the vertical ribbed steel bar in the joint to pass through the wire rope loop boxes on both sides of the joint.

The total wall width of the concrete wall element must be chosen taking into account the width of the indented joint (figure 2), the width of the steel box of the wire rope loop (table 1) and the required concrete cover.

4.1.2. Recommended seam thickness

Recommended and maximum seam thickness are according to table 8 and figure 7.

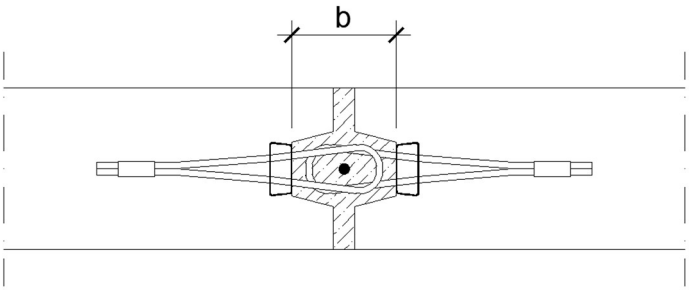


Figure 10 – Seam thickness b

Table 9 – Recommended and maximum thicknesses of the seam b

Wire Rope Loop Box	Seam thickness, b [mm]
R3L-THIN-80	100
R3L-THIN-100	120
R3L-THIN-120	140
R3L-WIDE-80	100
R3L-WIDE-100	120
R3L-WIDE-120	140

Maximum values for seam thickness b must not be exceeded when using R3L wire rope loop boxes.

4.2. Reinforcement of the concrete

4.2.1. Reinforcement of the joint

When using the R3L wire rope loop boxes, a vertical ribbed steel bar must always be installed. This ribbed steel bar is installed through the wire rope loops according to figure 8.

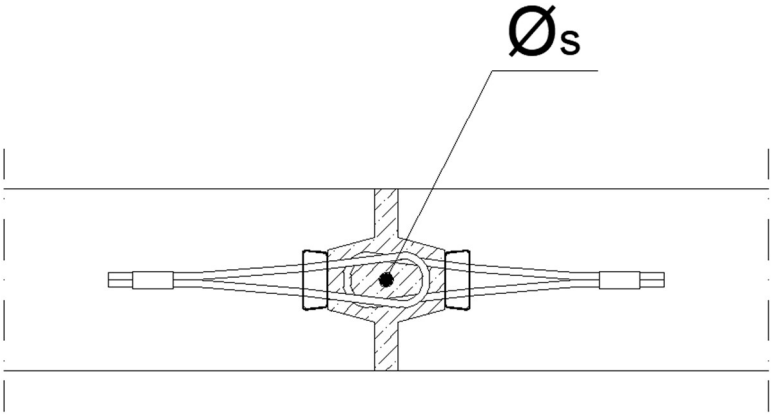


Figure 11 – Ribbed steel bar in the joint

Table 10 – Size of the ribbed steel bar in the joint, steel B500B (K500C-T)

Wire Rope Loop Box	Diameter of ribbed steel bar, $Ø_S$ [mm]
R3L-THIN-80,100,120 **R3L-WIDE-80,100,120**	14

4.2.2. Reinforcement of the concrete element

The wall elements must be reinforced according to the wall element design.

1) When R3L wire rope loop boxes are used to transfer forces

When R3L wire rope loop boxes are used to transfer forces in the joint, anchorage of the wire rope loop must be secured by overlapping the wire rope loop sufficiently with the reinforcement of the concrete element. For R3L wire rope box, the greatest design value for tensile force 37 kN. The anchorage of the wire rope loops must be designed for this force when using design values for resistances presented in tables 2…7.

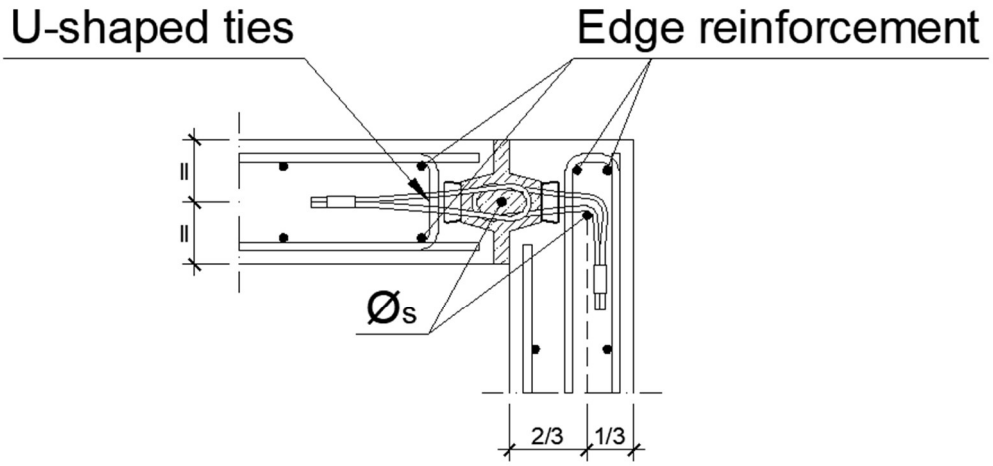


Figure 12 - Example of element edge reinforcement when transferring forces

Table 11 – Anchor reinforcement, steel B500B

Wire Rope Loop Box	Edge reinforcement [mm]	U shaped ties* [mm]
R3L-THIN-80,100,120 **R3L-WIDE-80,100,120**	Ø10	1+1 Ø8

*Quantities mentioned are per R3L box

2) When R3L wire rope loop boxes are not used to transfer forces

When R3L wire rope loop boxes are used to limit cracking of the seam or to tie elements together without defining the required force edge reinforcement of the element may be done according to principles presented in figure 9. Edge reinforcement 2-Ø10 and additional reinforcement according to figure 9 is recommended.

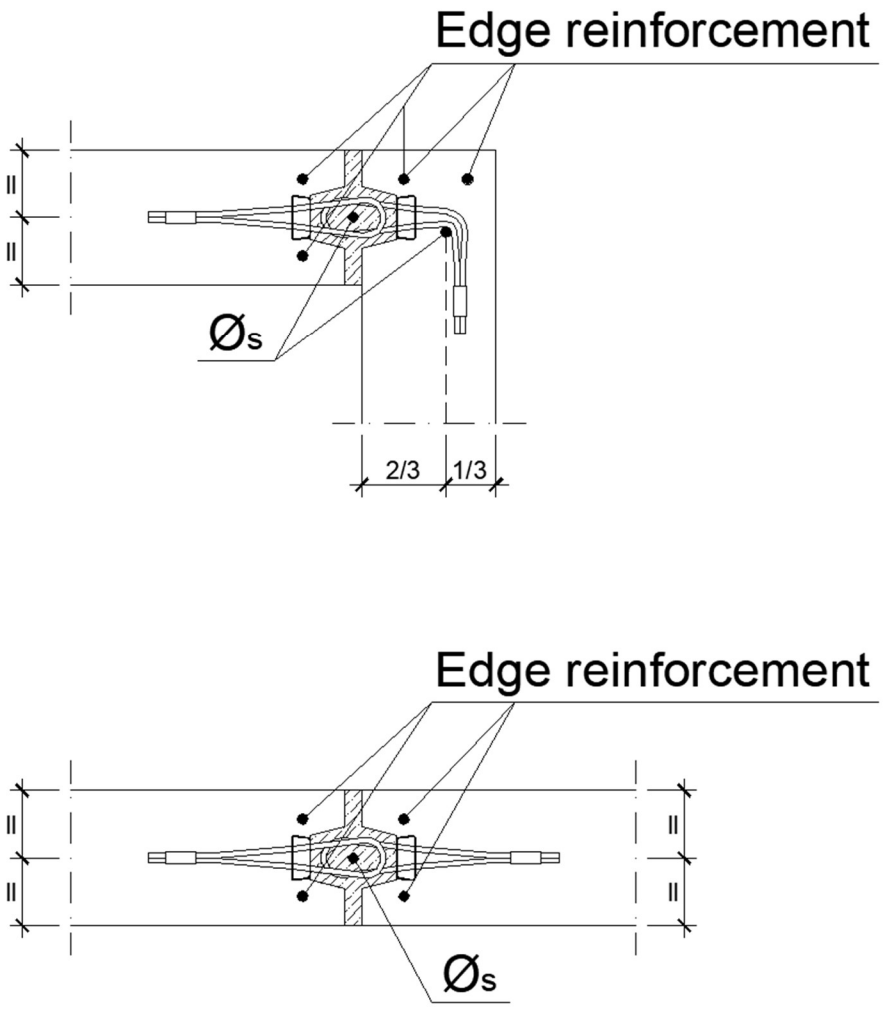


Figure 13 - Example of element edge reinforcement when not transferring forces

5. CALCULATION EXAMPLES

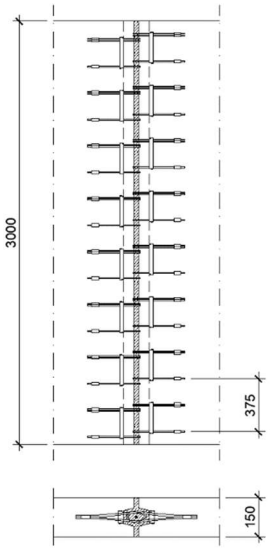
Example 1 – Wall to Wall connection with shear key (indented)

Thickness of wall, t		0,15 m
Height of wall, H		3,00 m
Grade of Concrete		C40/50
Grade of Grouting		C40/50
Longitudinal Shear Force for full height of wall		180,4 kN
Transverse Shear Force for full height of wall		21,6 kN
Using R3L-THIN-100 and a spacing of 375mm		
No. of R3Ls, nR3L = 3000/375 = 8		
Therefore, considering 8 nos. of R3L-THIN-100		
Longitudinal Shear Resistance, $V_{Rd.joint}$	= n x V_{Rd}	
	= 3 x 99,06 = 297,18 kN	
Transverse Shear Resistance, $N_{Rd.joint}$	= n x N_{Rd}	
	= 3 x 18,78 = 56,34 kN	

Verification for combined forces –

$= (V_{Ed}/V_{Rd} + N_{ed}/N_{Rd}) \leq 1$

$= (180,4/297,18) + (21.6/56,34) = 0.990 \leq 1$



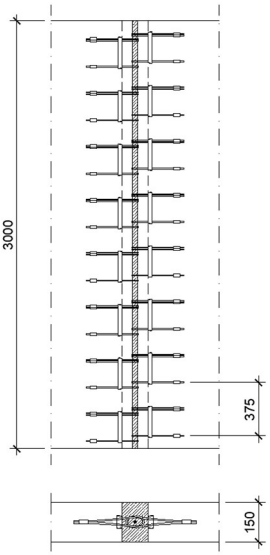
Example 2 – Wall to Wall connection with shear key (straight)

Thickness of wall, t		0,15 m
Height of wall, H		3,00 m
Grade of Concrete		C40/50
Grade of Grouting		C40/50
Longitudinal Shear Force for full height of wall		180,4 kN
Using R3L-THIN-100 and a spacing of 500mm		
No. of R3Ls, nR3L = 3000/500 = 6		
Therefore, considering 6 nos. of R3L-THIN-100		
Longitudinal Shear Resistance, $V_{Rd.joint}$	= n x V_{Rd}	
	= 3 x 79,54 = 238,62 kN	

Verification for combined forces –

$= (V_{Ed}/V_{Rd}) \leq 1$

$= (180,4/238,62) = 0.756 \leq 1$



6. INSTALLATION INSTRUCTIONS

The R3L wire rope loop boxes must be attached securely so it cannot move during casting of the concrete. At the R3L wire rope loop box the concrete must be compressed carefully. The R3L wire rope loop box cannot be vibrated.

The R3L wire rope loop boxes may be fastened to formwork with nails or by magnets. R3L wire rope loop boxes are installed according to structural designer's instructions and figures in technical manual. RWL wire rope loop boxes are tied to element reinforcement.

7. SUPERVISION OF INSTALLATION

Check list before casting:

- R3L wire rope loop box is in good condition
- R3L wire rope loop box is according to designs and in the right place
- R3L wire rope loop box is attached firmly
- The required additional reinforcement is installed

During the casting:

- R3L wire rope loop box stays in the right place
- The concrete is thoroughly vibrated around the R3L wire rope loop box

After the casting:

- The situation of the R3L wire rope loop box is according to designs
- The tape covering the steel box is removed at the factory after the concrete is hardened.