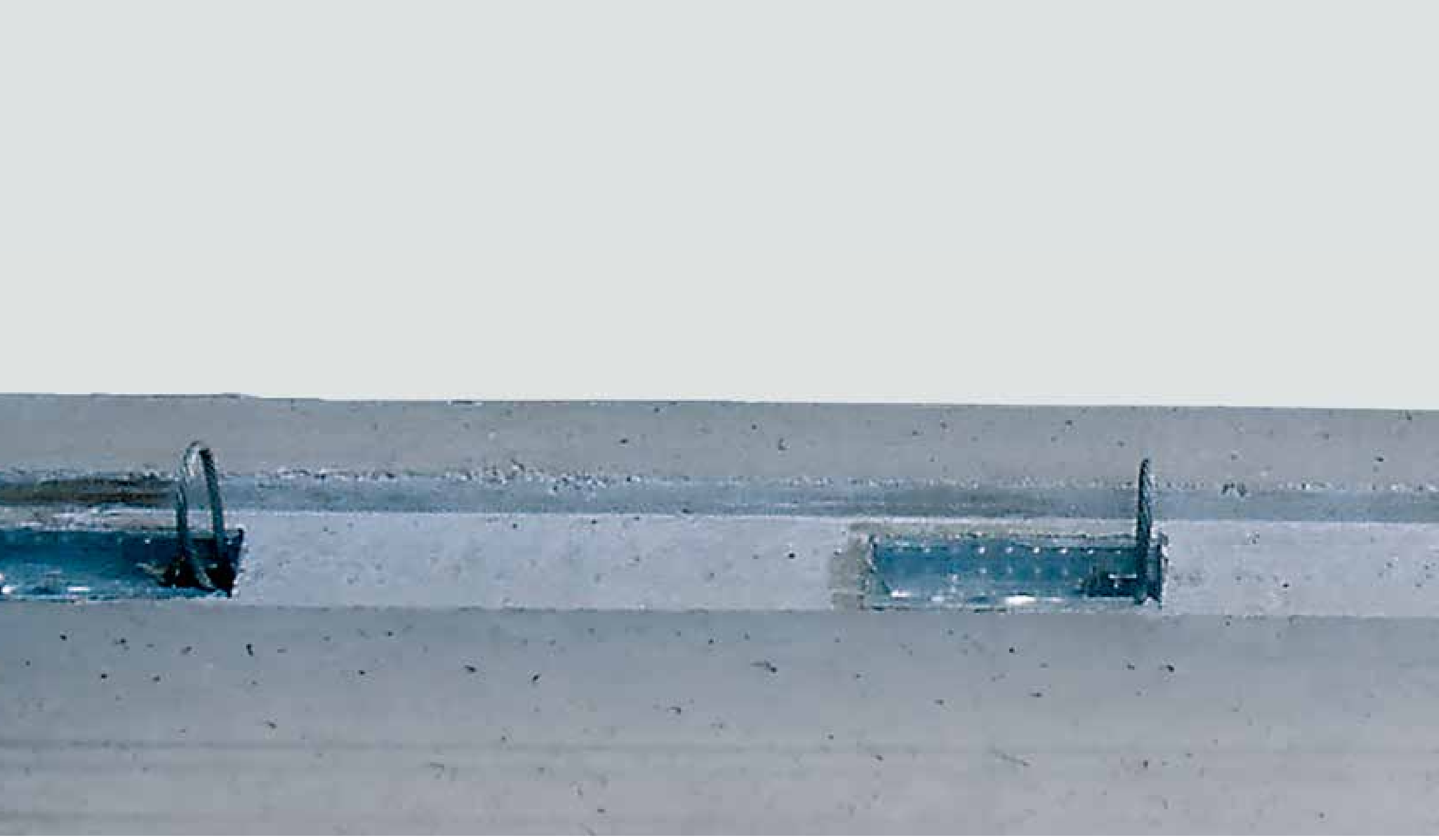
PFEIFER

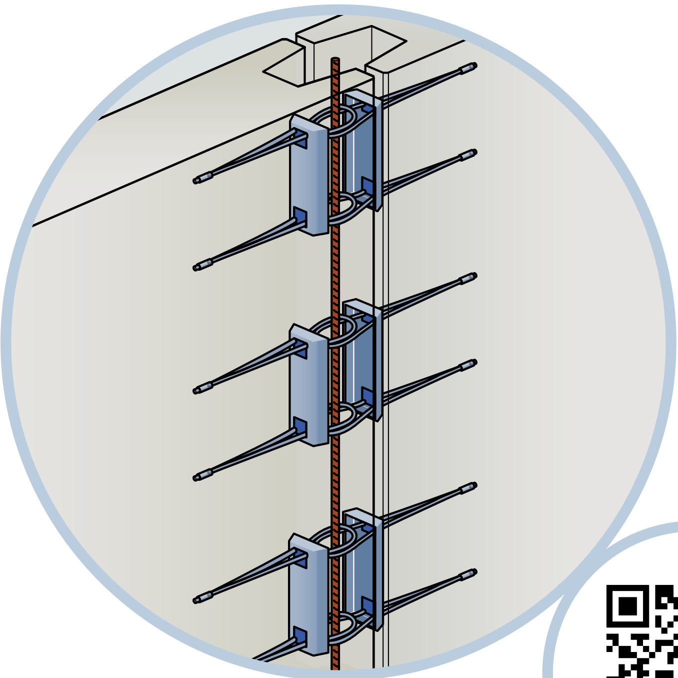
# PFEIFER VS® connecting loops

## Technical Manual



## PFEIFER VS® connecting loops

The PFEIFER VS®-Boxes are designed for economical connections of wall-type pre-cast concrete elements and for the connection of columns and walls.
With the PFEIFER VS®-Boxes, wall joints can be produced inexpensively, easily and safely.
The products consist of a sturdy sheet steel box in which one or two fold-out, flexible wire rope connection loops are located. The coloured clip within the boxes identifies the respective length of the integrated wire rope loops resp. the type of box. Only boxes with clips of the same colour can be combined.



### Your advantages

- Efficient, for use with thinnest walls
- Flexible adaptation to static requirements – Individual determination of load-bearing capacities based on component and grout properties and through case-related positioning of boxes
- Loading in all three load directions and interaction of loads
- Joint filling with grouted concrete according to EN 206 possible
- Only surface reinforcement required – No additional reinforcement required (no additional edge stirrups and longitudinal edge reinforcement)
- Low mortar consumption
- Colour-coded sealing slides for easy assignment

The contact details of our locations and sales partners can be found at

**www.pfeifer.info/contacts-cls**

We look forward to hearing from you!

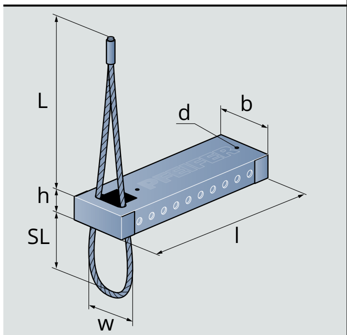
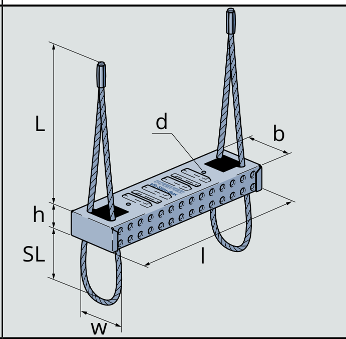
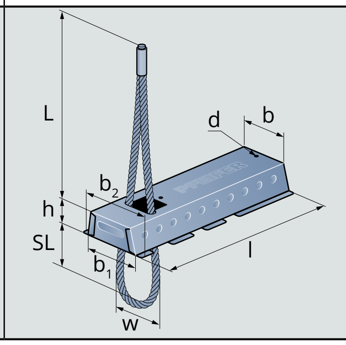
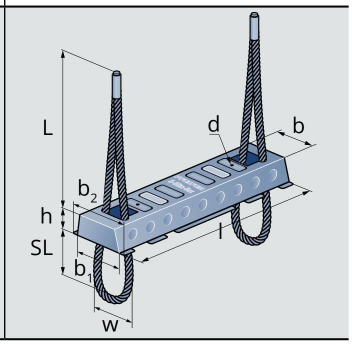
## Content

# 1. Product description

## 1.1 Types

Box types with single or double loop

## 1.2 Product dimensions

| VS®-Box CLASSIC | VS®-Slim-Box CLASSIC | VS®-Box EASYFILL | VS®-Slim-Box EASYFILL |
|---|---|---|---|
|  |  |  |  |

| Type | Ref. no. | Dimensions | | | | | | | | | Colour clip | Packing unit | Weight approx. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | b [mm] | $b_1$ [mm] | $b_2$ [mm] | l [mm] | h [mm] | L [mm] | SL [mm] | w [mm] | d [mm] | | [pieces] | [kg/pcs] |
| VS®-Box CLASSIC | 389146 | 50 | – | – | 160 | 20 | 192 | 80 | 60 | 3 | black | 110 | 0,21 |
| VS®-Slim-Box CLASSIC | 410244 | 50 | – | – | 180 | 20 | 192 | 80 | 60 | 3 | black | 80 | 0,40 |
| VS®-Box EASYFILL | 325523 | 45 | 50 | 60 | 160 | 20 | 180 | 80 | 55 | 3 | black | 800 | 0,21 |
| VS®-Slim-Box EASYFILL | 309578 | 45 | 50 | 60 | 200 | 20 | 204 | 80 | 55 | 3 | blue | 400 | 0,36 |

Ø-Rope: 6,0 mm

## 1.3 Product properties

**Table 1**

| | VS®-Box CLASSIC | VS®-Slim-Box CLASSIC | VS®-Box EASYFILL | VS®-Slim-Box EASYFILL |
|---|---|---|---|---|
| Box material | Steel sheet, galvanized | | | |
| Rope material | Round strand rope, galvanized | | | |
| Rope diameter | 6 mm | | | |

# 2. Application condition

## 2.1 Intended use

The VS®-Boxes may be used to connect precast concrete walls to each other and to precast concrete columns.

**Table 2**

| VS®-Box CLASSIC | VS®-Slim-Box CLASSIC | VS®-Box EASYFILL | VS®-Slim-Box EASYFILL |
|---|---|---|---|
|  |  |  |  |
| Flowable grout ✓ | | Flowable grout ✓ | |
| Thixotropic-plastic mortar ✗ | | Thixotropic-plastic mortar ✓ | |

## 2.2 Application range

The boxes are installed „recessed", which means that both opposite retaining boxes are installed set back from the external edges of the precast element.

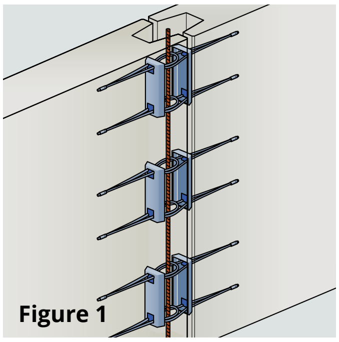


**Figure 1**

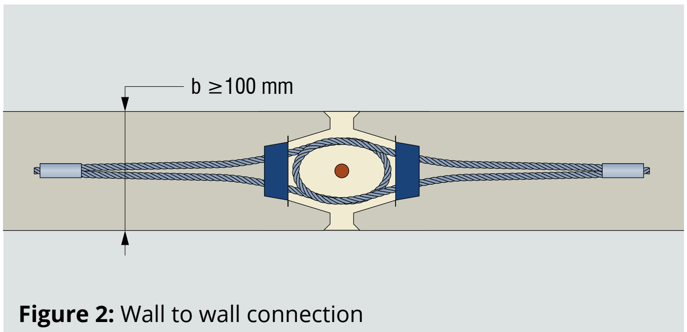


**Figure 2:** Wall to wall connection

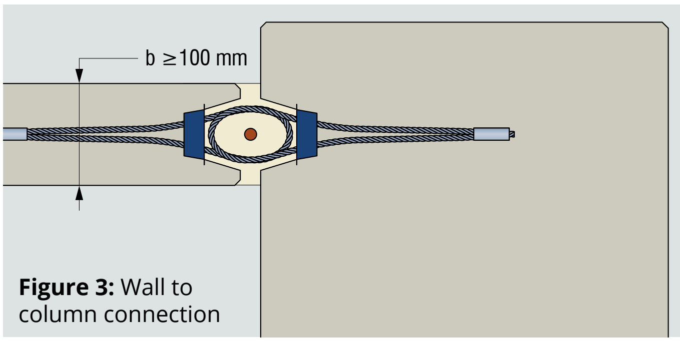


**Figure 3:** Wall to column connection

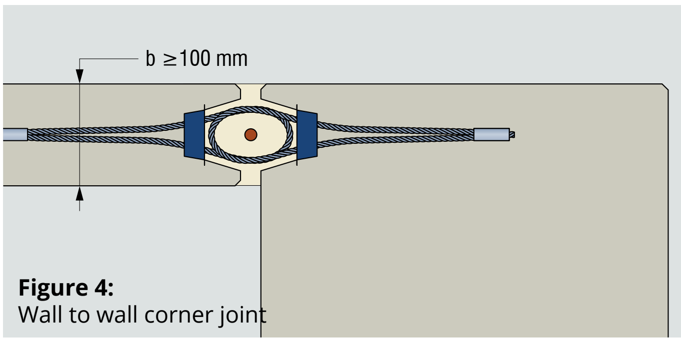


**Figure 4:** Wall to wall corner joint

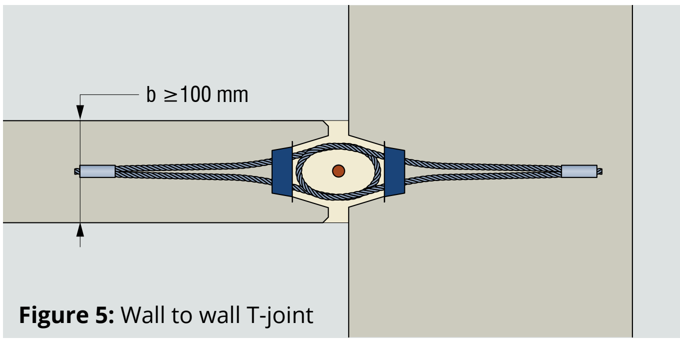


**Figure 5:** Wall to wall T-joint

## 2.3 Load transmission possibilities

The system can transmit tensile forces, parallel shear forces and perpendicular shear forces, both individually and in combination. The load directions are illustrated taking the double-loop boxes as an example.

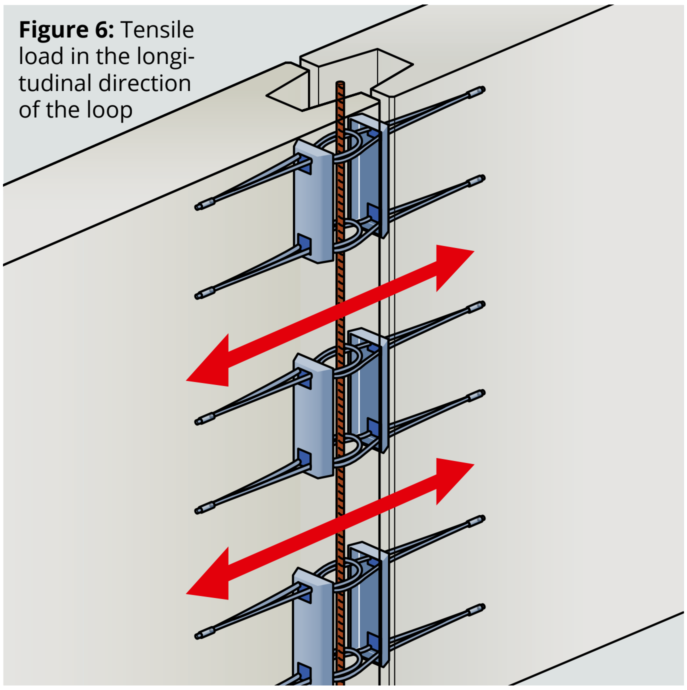


**Figure 6:** Tensile load in the longitudinal direction of the loop

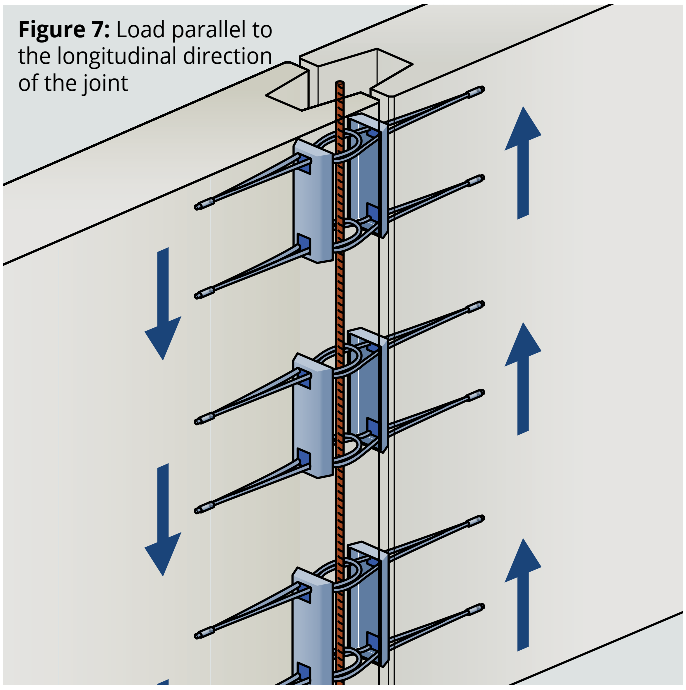


**Figure 7:** Load parallel to the longitudinal direction of the joint

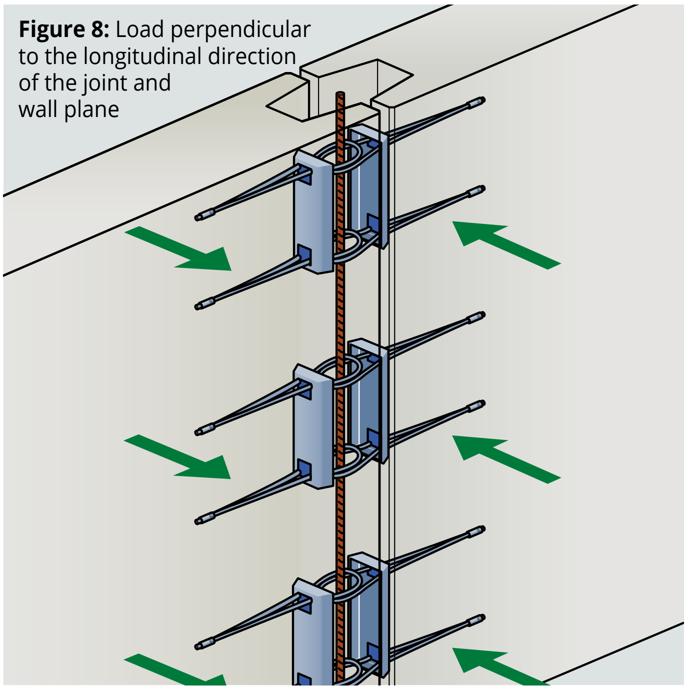


**Figure 8:** Load perpendicular to the longitudinal direction of the joint and wall plane

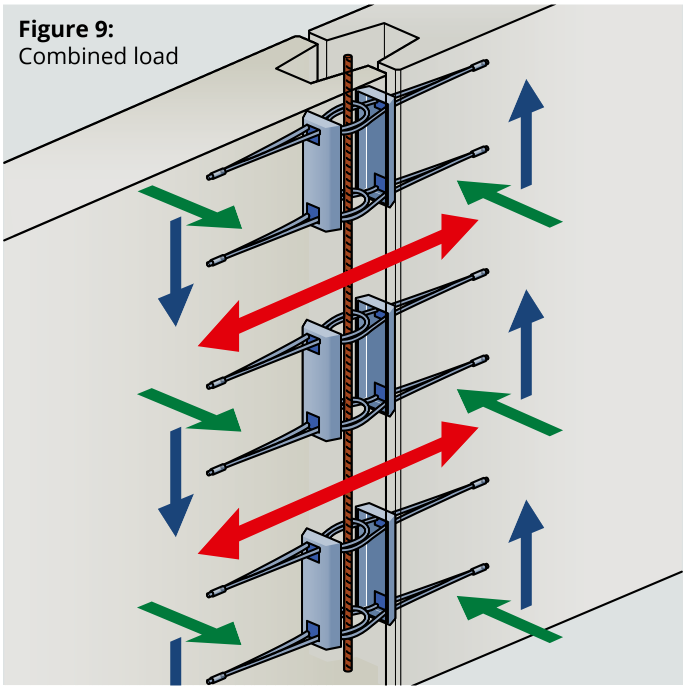
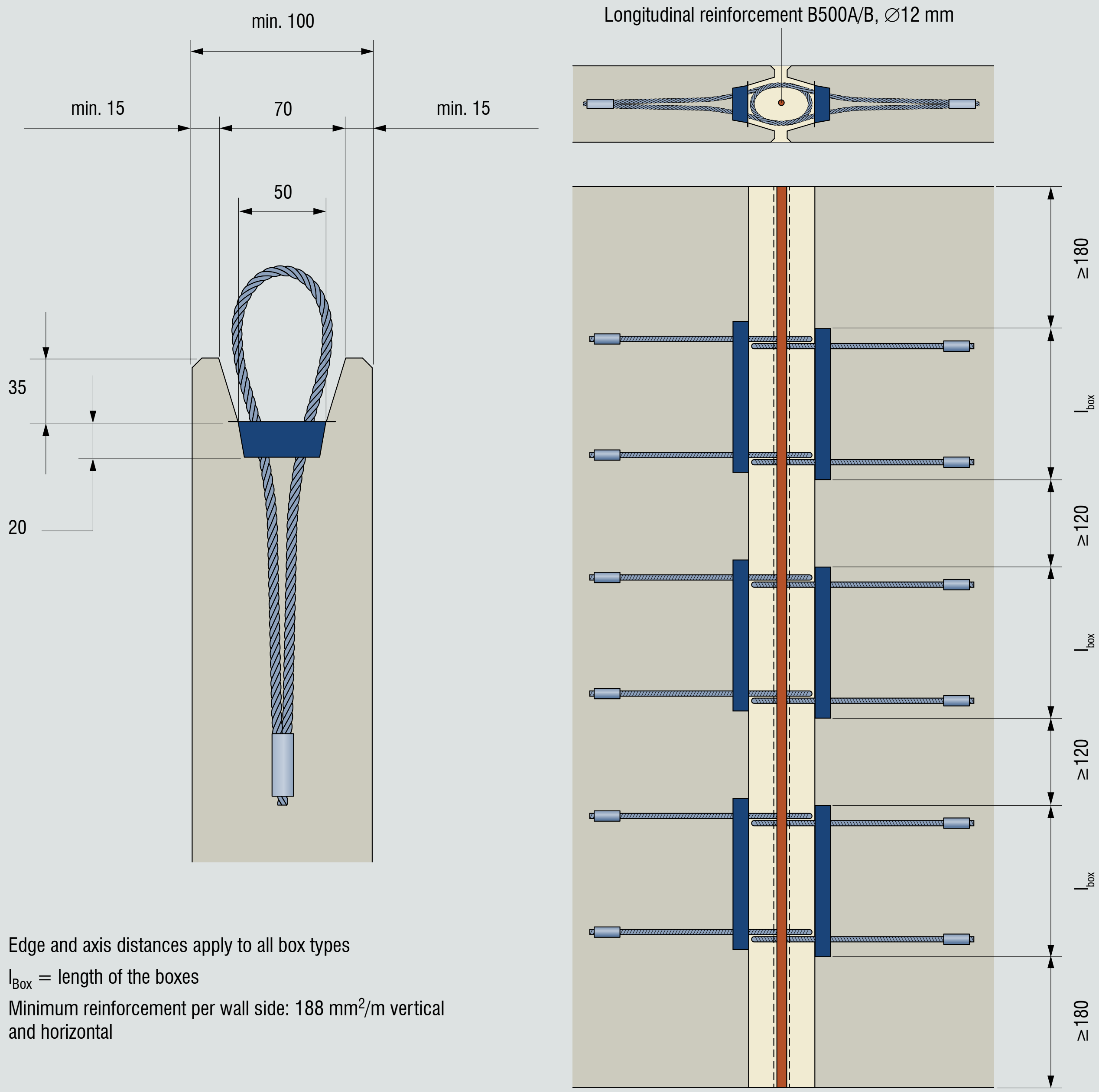


**Figure 9:** Combined load

# 3. Structural element properties

## 3.1 Dimensions and reinforcement



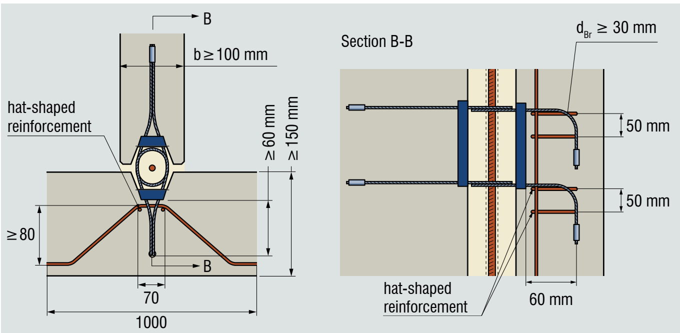

Edge and axis distances apply to all box types

$l_{Box}$ = length of the boxes

Minimum reinforcement per wall side: 188 mm²/m vertical and horizontal

**Figure 10:** Geometry of the deepened joint and reinforcement

## 3.2 Additional notes




Wall to wall T-joint – detail with bent wire rope loops

VS®-Boxes are to be installed with an appropriate concrete cover. Proof of the required concrete cover is to be provided in accordance with EN 1992-1-1, section 4. The required exposure class is to be selected according to the environmental requirements.

**Note about bending anchoring loops:**

When the elements have small dimensions, the anchoring loop of the VS rope loop box can be bent. With T-joints, the thickness of the abutted wall can therefore be reduced to 150 mm. The working load limits (Tables 6 to 10) of the bent rope loop box are to be limited according to the specification of ETA-22/0224. Test series have shown that an additional „hat-shaped“ reinforcement is necessary for anchoring the regular loads.

# 4. Structural element connection

## 4.1 Joint geometry

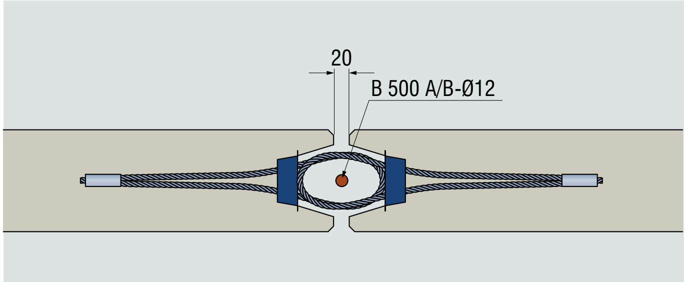



**Figure 11:** Standard joint

## 4.2 Joint filling mortar

### 4.2.1 Notes and advantages

The joint casting grout consists of cement, mineral aggregate and water and, if necessary, concrete additives and/or concrete admixtures.

Production:
- Delivered to the installation site as prefabricated dry mixture (bagged product) and mixed directly on site with water (before installation)
- Delivered to the installation site as finished product, after being mixed in a concrete plant on the basis of defined properties

**Table 3**

| Characteristics | |
|---|---|
| **Flowable grout** | **Thixotropic-plastic mortar** |
| **Usable with** | |
|     |   |
| **Workability** | |
| High | Medium-high |
| **Consistence** | |
| Fluid | Viscous |
| **Joint filling** | |
| Optimal | Extra care: avoid empty spaces |
| **Filling tools** | |
| Standard | Extra tools i. e.: nozzle |
| **Joint closing** | |
| Closure of the joint on both sides, e.g.: shuttering board | On one side for short joint lengths i. e.: strong duct tape |
| **Workers' skills** | |
| Standard | Instructed personnel only (induction is necessary in machine and grouting technology, mortar systems, etc.) |

### 4.2.2 Requirements

Definition of the properties of the joint casting grout:

**Table 4**

| **Properties** | | **Flowable grout** | **Thixotropic-plastic mortar** |
|---|---|---|---|
| Maximum grain size | | ≤ 8 mm | |
| Consistency | | EN 206, Table 5 ≥ F5<br>EN 206, Table 6 ≥ SF1<br>slump-flow – EN 13395-2 ≥ 550 mm | slump-diameter – EN 13395-1<br>≥ 130 mm |
| Expansion after 24 hours according to EN 445 | | ≥ +0,1 Vol-% | |
| Shrinkage value after 91 days | EN 12390-16 | average value: $\varepsilon_{m,91} \leq 1,5$ ‰ | |
| | EN 12617-4 | single value: $\varepsilon_{i,91} \leq 2,0$ ‰ | |
| Compressive strength after 28 days | EN 206, cube | $f_{c,cube,g} \geq 40$ N/mm² | |
| | EN 196-1, prism | $f_{c,prism,g} \geq f_{c,cube,g} / 0,85$ | |

# 5. Installation instructions

## 5.1 Manufacture of the structural elements

Most wall elements are concreted on formwork tables. The following work steps are necessary (see figures 15 and 16):

- Fastening of a trapezoidal-shaped recess strip at the front-sided vertical end of the wall element
- Straight threading of the rope end into the reinforcement and fixing 90° to the joint
- Nailing or gluing of the boxes to the formwork

**Note:**

It must be ensured that the boxes are always located at the same height (offset ≤ 20 mm).

### Tolerances

The VS® Slim Box connection acts as an overlapping joint. For that reason, the loops must each lie above one another within certain vertical and horizontal tolerances.

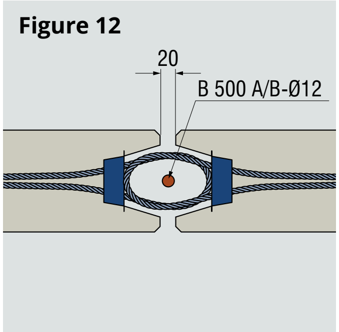



**Figure 12**

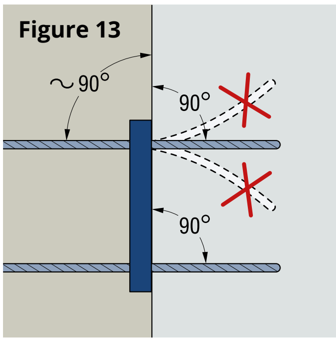



**Figure 13**

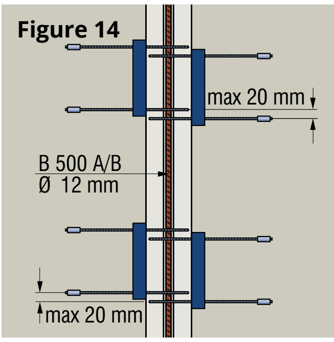



**Figure 14**

### Installation

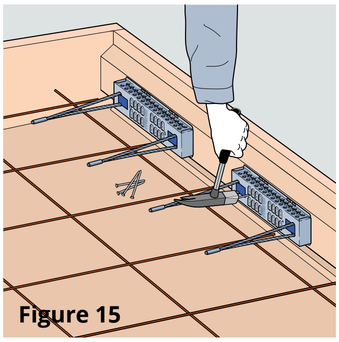


**Figure 15**

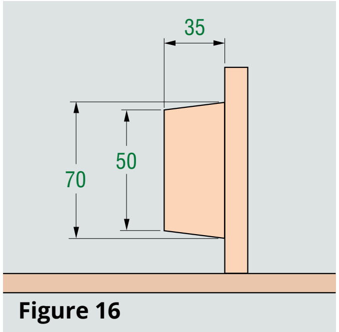



**Figure 16**

## 5.2 Connection of the structural elements

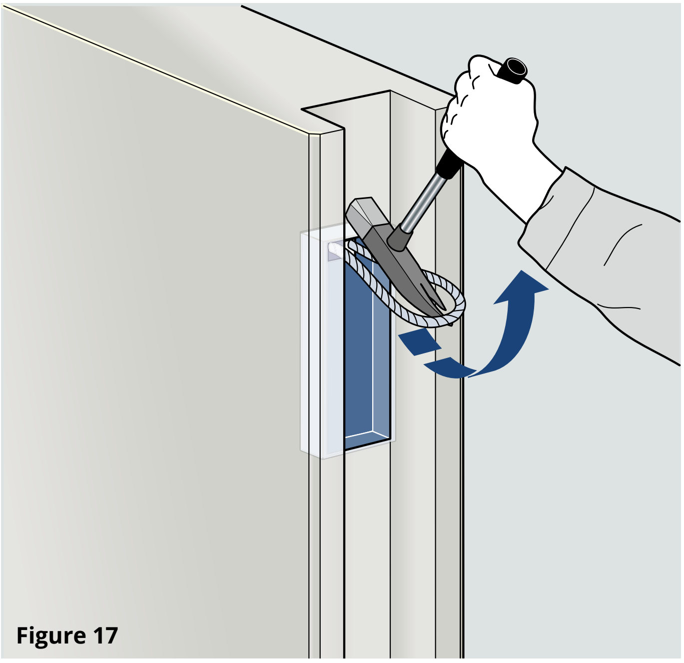


Figure 17

**Before connecting the precast elements:**
- Remove the covering adhesive tape
- Release the wire rope loop from the fixing
- Fold out to the intended position (90° to the joint)
- Remove dirt or grease from the joint
- Check the position of the wire rope loop
- Thread in longitudinal reinforcement B500A/B, Ø 12 mm

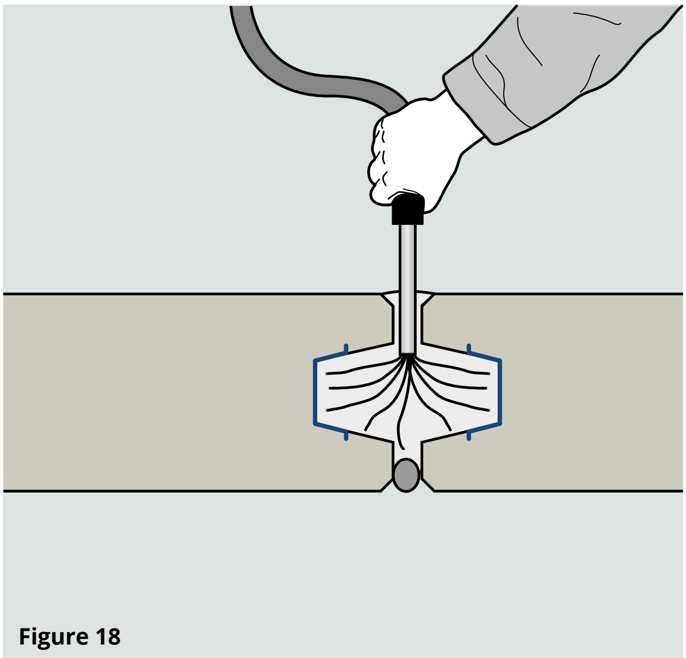


Figure 18

**Connection of the precast elements:**
- Complete closure of one side of the joint (foam, rubber hose, shuttering board)
- Fill the open joint side evenly and continuously from bottom to top

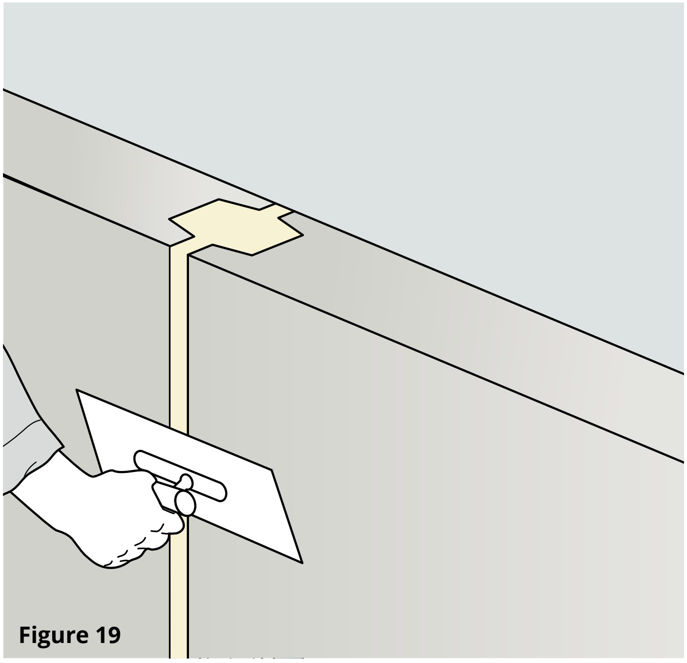


Figure 19

**After joining the precast elements:**
- Smooth the joint with a trowel

## Nozzle making

The user can make the filling nozzle from commercially available 22 mm ($^3/_4$") copper heating pipe and attach it to the pump hose with the aid of a solder fitting (Figures 20 and 21).

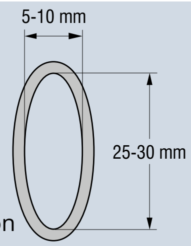



**Figure 20:** Cross-section of the filling nozzle ("flat pressed" $^3/_4$" tube)

Figure 21

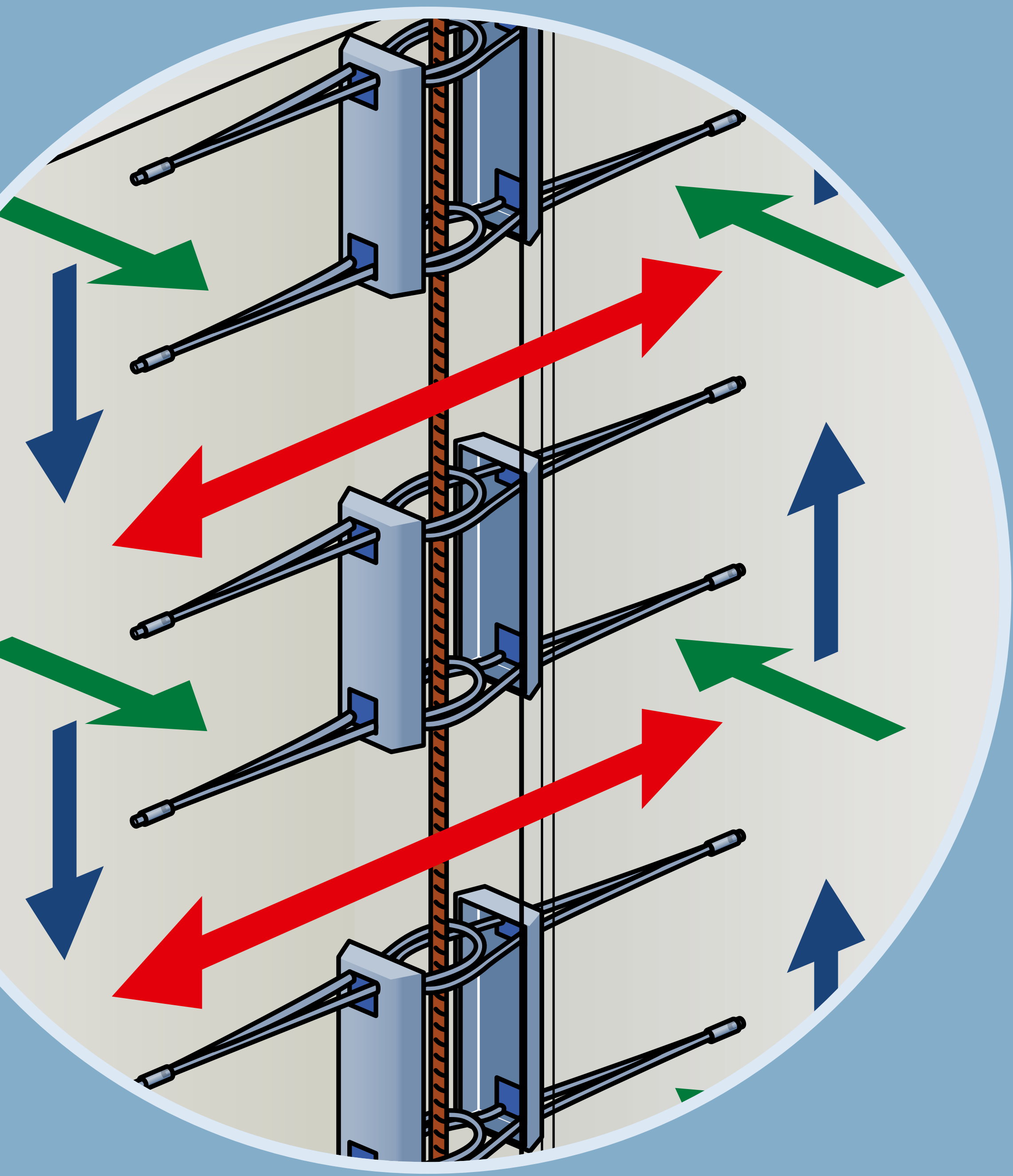
**Note:**

this information only concerns the introduction of the thixotropic/plastic material into the joint!

**Caution:**

**Do not constrict the filling space.** If pre-compressed strips are to be pressed into the side joints without affecting the casting space, the effective lateral concrete cover of the rail and the wire rope loop is reduced. This must also be taken into account by the planners in the dimensioning.

# Dimensioning



# 6. Dimensioning and planning

The precast concrete elements being connected must be construed by a responsible planner in a minimum concrete grade of C25/30 in accordance with EN 1992-1-1. The connection made with the PFEIFER-VS® rope loop boxes is considered to be a reinforced joint with design resistances for tensile and transverse shear forces. The corresponding design resistances are based on a detailed dimensioning concept and are listed in the tables in chapter 6.4. The dimensioning concept was created on the basis of an external expert's report and the design resistances confirmed by an independent expert opinion.

## 6.1 Dimensioning concept

The tensile and shear resistances of the PFEIFER-VS® rope loop boxes are determined by calculation on the basis of a dimensioning concept. This concept is based on different load-bearing models that map the working load limits of the various elements and components of a wire rope loop connection with grouting box (e.g. anchoring in concrete as well as shear models and strut and tie models). The resistances of the individual components are determined and overlaid, resulting in the working load limit of the complete system. The calculated working load limits are calibrated and verified on the basis of structural element tests.

### Load case: assembly

No loads can be borne by the PFEIFER-VS® rope loop boxes during the assembly of the precast concrete elements and without filled element joints. The stability of the structural elements must be ensured, for example, by temporary props (e. g. PFEIFER MoFi fastener for push-pull props).

### Load case: final condition

The PFEIFER-VS® rope loop boxes are fully load-bearing after the target strength of the joint mortar is reached. The loads according to chapter 6.4 can thus be borne by the rope loop boxes.

Crack widths as a result of constraining forces must be limited through planning to 0.3 mm.

## 6.2 Additional information on the tables

The design resistances in chapter 6.4 are to be selected in relation to the box type, the compressive strength of the structural element, the compressive strength of the joint mortar and the thickness of the structural element. Both the strength grades and the correlating cube and prism compressive strengths according to EN 206:2013, section 8.2.1.3.2 are specified. Selection can be made according to the manufacturer's specifications.

When dimensioning the connection, the evidence for each load direction must be kept individually. When overlaying tensile and transversal shear loads, note that the tensile forces arising from the shear forces must be taken into account with an externally acting tensile force (see interaction condition, chapter 6.5).

## 6.3 Safety factors

The dimensioning values in the ultimate limit state listed in chapter 6.4 were determined taking into account the following safety factors:

**Table 5:** Safety factors for ULS dimensioning

| | | |
|---|---|---|
| Partial safety factor for concrete in general: | $\gamma_c$ | = 1,50 |
| Partial safety factor for concrete cone failure: | $\gamma_c$ | = 1,50 |
| Partial safety factor for pull-out: | $\gamma_c$ | = 1,50 |
| Partial safety factor for pry-out: | $\gamma_c$ | = 1,50 |
| Partial safety factor for concrete with transversal shear load perpendicular to the joint: | $\gamma_c$ | = 1,50 |
| | | |
| Factor for taking into account long-term influences on the concrete compressive strength: | $\alpha_{cc}$ | = 0,85 |
| Factor for taking into account long-term influences on the concrete tensile strength: | $\alpha_{ct}$ | = 0,85 |
| | | |
| Partial safety factor for round strand rope: | $\gamma_{s,Rope}$ | = 1,50 |
| Partial safety factor for reinforcing steel: | $\gamma_{s,B}$ | = 1,20 |
| | | |
| System reduction factor for EASYFILL *single rope* with load $N_{Rd}/V_{II,Rd}$: | $\eta_{E1}$ | = 0,85 |
| System reduction factor for EASYFILL *double rope* with load $N_{Rd}/V_{II,Rd}$: | $\eta_{E2}$ | = 0,95 |
| System reduction factor for CLASSIC *single rope* with load $N_{Rd}/V_{II,Rd}$: | $\eta_{C1}$ | = 0,85 |
| System reduction factor for CLASSIC *double rope* with load $N_{Rd}/V_{II,Rd}$: | $\eta_{C2}$ | = 0,95 |
| | | |
| System reduction factor for $N_{Rd}/V_{II,Rd}$: when using free-flowing grouts | $\eta_V$ | = 1,00 |
| System reduction factor for $N_{Rd}/V_{II,Rd}$: when using plastic (thixotropic) joint mortars | $\eta_P$ | = 0,90 |

The system reduction factors are used to map influences from scaling effects, variances, imperfections, eccentricities or environmental influences.

## 6.4 Dimensioning Tables

**Table 6:** VS®-Box EASYFILL 1-Rope – Design resistance per pair of boxes

| Grout | | | Precast concrete | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Average prism compressive strength | Average cube compressive strength | Compressive strength class | C25/30 | | C30/37 | | C35/45 | | C40/50 | |
| $f_{c,m,prism,28d}$ [N/mm²] | $f_{c,m,cube,28d}$ [N/mm²] | – [–] | $N_{Rd}$ [kN] | $V_{Rd,II}$ [kN] | $N_{Rd}$ [kN] | $V_{Rd,II}$ [kN] | $N_{Rd}$ [kN] | $V_{Rd,II}$ [kN] | $N_{Rd}$ [kN] | $V_{Rd,II}$ [kN] |
| **Wall thickness h = 100 mm** | | | | | | | | | | |
| ≥ 49 | ≥ 42 | C30/37 | 7,3 | 11,4 | 7,3 | 11,4 | 7,3 | 11,4 | 7,3 | 11,4 |
| ≥ 65 | ≥ 55 | C40/50 | 8,7 | 12,7 | 9,5 | 13,8 | 9,8 | 14,7 | 9,8 | 15,0 |
| ≥ 76 | ≥ 65 | C50/60 | | 13,1 | | 14,1 | 10,3 | 15,0 | 11,0 | 15,9 |
| **Wall thickness h ≥ 120 mm** | | | | | | | | | | |
| ≥ 49 | ≥ 42 | C30/37 | 7,3 | 11,4 | 7,3 | 11,4 | 7,3 | 11,4 | 7,3 | 11,4 |
| ≥ 65 | ≥ 55 | C40/50 | 8,9 | 12,9 | 9,8 | 15,0 | 9,8 | 15,0 | 9,8 | 15,0 |
| ≥ 76 | ≥ 65 | C50/60 | | 13,3 | 10,6 | 15,5 | 12,2 | 17,6 | 12,2 | 18,4 |

**Table 7:** VS®-Slim-Box EASYFILL 2-Ropes – Design resistance per pair of boxes

| Grout | | | Precast concrete | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Average prism compressive strength | Average cube compressive strength | Compressive strength class | C25/30 | | C30/37 | | C35/45 | | C40/50 | |
| $f_{c,m,prism,28d}$ [N/mm²] | $f_{c,m,cube,28d}$ [N/mm²] | – [–] | $N_{Rd}$ [kN] | $V_{Rd,II}$ [kN] | $N_{Rd}$ [kN] | $V_{Rd,II}$ [kN] | $N_{Rd}$ [kN] | $V_{Rd,II}$ [kN] | $N_{Rd}$ [kN] | $V_{Rd,II}$ [kN] |
| **Wall thickness h = 100 mm** | | | | | | | | | | |
| ≥ 49 | ≥ 42 | C30/37 | | 25,3 | | 25,3 | | 25,3 | | 25,3 |
| ≥ 65 | ≥ 55 | C40/50 | 12,5 | 26,9 | 13,7 | 29,2 | 14,8 | 31,1 | 15,8 | 32,8 |
| ≥ 76 | ≥ 65 | C50/60 | | | | 29,5 | | 31,8 | | 33,8 |
| **Wall thickness h = 120 mm** | | | | | | | | | | |
| ≥ 49 | ≥ 42 | C30/37 | | 25,3 | | 25,3 | 16,4 | 25,3 | 16,4 | 25,3 |
| ≥ 65 | ≥ 55 | C40/50 | 15,0 | 27,4 | 16,4 | 31,9 | 17,8 | 33,6 | 19,0 | 33,6 |
| ≥ 76 | ≥ 65 | C50/60 | | | | 32,9 | | 37,2 | | 39,5 |
| **Wandstärke h = 150 mm** | | | | | | | | | | |
| ≥ 49 | ≥ 42 | C30/37 | 16,4 | 25,3 | 16,4 | 25,3 | 16,4 | 25,3 | 16,4 | 25,3 |
| ≥ 65 | ≥ 55 | C40/50 | 18,8 | 27,4 | 20,5 | 31,9 | 21,9 | 33,6 | 21,9 | 33,6 |
| ≥ 76 | ≥ 65 | C50/60 | | | | 32,9 | 22,2 | 37,2 | 23,7 | 41,1 |
| **Wall thickness h = 180 mm** | | | | | | | | | | |
| ≥ 49 | ≥ 42 | C30/37 | 16,4 | 25,3 | 16,4 | 25,3 | 16,4 | 25,3 | 16,4 | 25,3 |
| ≥ 65 | ≥ 55 | C40/50 | 19,8 | 27,4 | 21,9 | 31,9 | 21,9 | 33,6 | 21,9 | 33,6 |
| ≥ 76 | ≥ 65 | C50/60 | | | 23,8 | 32,9 | 26,6 | 37,2 | 27,4 | 41,1 |
| **Wall thickness h ≥ 200 mm** | | | | | | | | | | |
| ≥ 49 | ≥ 42 | C30/37 | 16,4 | 25,3 | 16,4 | 25,3 | 16,4 | 25,3 | 16,4 | 25,3 |
| ≥ 65 | ≥ 55 | C40/50 | 19,8 | 27,4 | 21,9 | 31,9 | 21,9 | 33,6 | 21,9 | 33,6 |
| ≥ 76 | ≥ 65 | C50/60 | | | 23,8 | 32,9 | 26,6 | 37,2 | 27,4 | 41,1 |

The resistances apply when using free-flowing grout. No plastic (thixotropic) joint filling mortars may be used with the box types VS®-Box CLASSIC and VS®-Slim-Box CLASSIC.

**Table 8:** VS®-Box CLASSIC 1-Rope – Design resistance per pair of boxes

| Grout | | | Precast concrete | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Average prism compressive strength | Average cube compressive strength | Compressive strength class | C25/30 | | C30/37 | | C35/45 | | C40/50 | |
| $f_{c,m,prism,28d}$ [N/mm²] | $f_{c,m,cube,28d}$ [N/mm²] | – [–] | $N_{Rd}$ [kN] | $V_{Rd,II}$ [kN] | $N_{Rd}$ [kN] | $V_{Rd,II}$ [kN] | $N_{Rd}$ [kN] | $V_{Rd,II}$ [kN] | $N_{Rd}$ [kN] | $V_{Rd,II}$ [kN] |
| **Wall thickness h = 100 mm** | | | | | | | | | | |
| ≥ 49 | ≥ 42 | C30/37 | 7,3 | 11,4 | 7,3 | 11,4 | 7,3 | 11,4 | 7,3 | 11,4 |
| ≥ 65 | ≥ 55 | C40/50 | 9,8 | 15,0 | 9,8 | 15,0 | 9,8 | 15,0 | 9,8 | 15,0 |
| ≥ 76 | ≥ 65 | C50/60 | 9,8 | 15,4 | 10,7 | 16,6 | 11,6 | 17,6 | 12,2 | 18,4 |
| **Wall thickness h ≥ 120 mm** | | | | | | | | | | |
| ≥ 49 | ≥ 42 | C30/37 | 7,3 | 11,4 | 7,3 | 11,4 | 7,3 | 11,4 | 7,3 | 11,4 |
| ≥ 65 | ≥ 55 | C40/50 | 9,8 | 15,0 | 9,8 | 15,0 | 9,8 | 15,0 | 9,8 | 15,0 |
| ≥ 76 | ≥ 65 | C50/60 | 10,1 | 15,8 | 12,1 | 18,3 | 12,2 | 18,4 | 12,2 | 18,4 |

**Table 9:** VS®-Slim-Box CLASSIC 2-Ropes – Design resistance per pair of boxes

| Grout | | | Precast concrete | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Average prism compressive strength | Average cube compressive strength | Compressive strength class | C25/30 | | C30/37 | | C35/45 | | C40/50 | |
| $f_{c,m,prism,28d}$ [N/mm²] | $f_{c,m,cube,28d}$ [N/mm²] | – [–] | $N_{Rd}$ [kN] | $V_{Rd,II}$ [kN] | $N_{Rd}$ [kN] | $V_{Rd,II}$ [kN] | $N_{Rd}$ [kN] | $V_{Rd,II}$ [kN] | $N_{Rd}$ [kN] | $V_{Rd,II}$ [kN] |
| **Wall thickness h = 100 mm** | | | | | | | | | | |
| ≥ 49 | ≥ 42 | C30/37 | | 25,3 | | 25,3 | | 25,3 | | 25,3 |
| ≥ 65 | ≥ 55 | C40/50 | 12,5 | 32,9 | 13,7 | 33,6 | 14,8 | 33,6 | 15,8 | 33,6 |
| ≥ 76 | ≥ 65 | C50/60 | | 32,9 | | 34,0 | | 35,1 | | 36,1 |
| **Wall thickness h = 120 mm** | | | | | | | | | | |
| ≥ 49 | ≥ 42 | C30/37 | | 25,3 | | 25,3 | 16,4 | 25,3 | 16,4 | 25,3 |
| ≥ 65 | ≥ 55 | C40/50 | 15,0 | 33,6 | 16,4 | 33,6 | 17,8 | 33,6 | 19,0 | 33,6 |
| ≥ 76 | ≥ 65 | C50/60 | | 34,6 | | 36,0 | | 37,2 | | 38,5 |
| **Wall thickness h = 150 mm** | | | | | | | | | | |
| ≥ 49 | ≥ 42 | C30/37 | 16,4 | 25,3 | 16,4 | 25,3 | 16,4 | 25,3 | 16,4 | 25,3 |
| ≥ 65 | ≥ 55 | C40/50 | 18,8 | 33,6 | 20,5 | 33,6 | 21,9 | 33,6 | 21,9 | 33,6 |
| ≥ 76 | ≥ 65 | C50/60 | | 34,6 | | 38,9 | 22,2 | 40,5 | 23,7 | 41,1 |
| **Wall thickness h = 180 mm** | | | | | | | | | | |
| ≥ 49 | ≥ 42 | C30/37 | 16,4 | 25,3 | 16,4 | 25,3 | 16,4 | 25,3 | 16,4 | 25,3 |
| ≥ 65 | ≥ 55 | C40/50 | 21,9 | 33,6 | 21,9 | 33,6 | 21,9 | 33,6 | 21,9 | 33,6 |
| ≥ 76 | ≥ 65 | C50/60 | 22,5 | 34,6 | 24,7 | 40,7 | 26,6 | 41,1 | 27,4 | 41,1 |
| **Wall thickness h ≥ 200 mm** | | | | | | | | | | |
| ≥ 49 | ≥ 42 | C30/37 | 16,4 | 25,3 | 16,4 | 25,3 | 16,4 | 25,3 | 16,4 | 25,3 |
| ≥ 65 | ≥ 55 | C40/50 | 21,9 | 33,6 | 21,9 | 33,6 | 21,9 | 33,6 | 21,9 | 33,6 |
| ≥ 76 | ≥ 65 | C50/60 | 22,5 | 34,6 | 27,0 | 40,7 | 27,4 | 41,1 | 27,4 | 41,1 |

The resistances apply when using free-flowing grout. Plastic (thixotropic) joint filling mortars may also be used with the box types VS®-Box EASYFILL and VS®-Slim-Box EASYFILL. In this case, the resistances specified above must be reduced by the factor 0.9.

**Table 10:** Vertical transverse force $v_{Rd,\perp}$ – Design resistance for all four box types per running meter

| Grout: Average prism compressive strength | Grout: Average cube compressive strength | Grout: Compressive strength class | Precast concrete: $v_{Rd,\perp}$ [kN/m] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $f_{c,m,prism,28d}$ [N/mm²] | $f_{c,m,cube,28d}$ [N/mm²] | – [–] | C25/30 | C30/37 | C35/45 | C40/50 | C25/30 | C30/37 | C35/45 | C40/50 | C25/30 | C30/37 | C35/45 | C40/50 |
| | | | Wall thickness h = 100 mm | | | | Wall thickness h = 120 mm | | | | Wall thickness h = 140 mm | | | |
| ≥ 49 | ≥ 42 | C30/37 | 3,9 | 4,5 | 5,2 | 5,5 | 6,1 | 7,0 | 8,0 | 8,5 | 8,4 | 9,7 | 11,1 | 11,9 |
| ≥ 65 | ≥ 55 | C40/50 | | | | | | | | | | | | |
| ≥ 76 | ≥ 65 | C50/60 | | | | | | | | | | | | |
| | | | Wall thickness h = 150 mm | | | | Wall thickness h = 160 mm | | | | Wall thickness h = 180 mm | | | |
| ≥ 49 | ≥ 42 | C30/37 | 9,7 | 11,2 | 12,7 | 13,7 | 11,0 | 12,7 | 14,4 | 15,5 | 13,8 | 15,9 | 18,1 | 19,4 |
| ≥ 65 | ≥ 55 | C40/50 | | | | | | | | | | | | |
| ≥ 76 | ≥ 65 | C50/60 | | | | | | | | | | | | |
| | | | Wall thickness h = 200 mm | | | | Wall thickness h = 250 mm | | | | Wall thickness h = 300 mm | | | |
| ≥ 49 | ≥ 42 | C30/37 | 16,7 | 19,3 | 21,9 | 23,5 | 24,8 | 28,5 | 28,7 | 28,7 | 28,7 | 28,7 | 28,7 | 28,7 |
| ≥ 65 | ≥ 55 | C40/50 | | | | | | | 32,5 | 34,8 | 33,8 | 34,8 | 34,8 | 34,8 |
| ≥ 76 | ≥ 65 | C50/60 | | | | | | | | | | 38,3 | 38,3 | 38,3 |

**Note:** At least two Pfeifer VS® boxes are to be installed per joint. The transversal shear force carrying capacity perpendicular to the joint may only be applied from a joint length of at least 1.00 m with structural elements with a thickness of less than 0.14 m.

## 6.5 Proof of concept

### Shear force parallel to the joint

For a shear force parallel to the joint reinforced with the VS® Box, a corresponding design resistance (shear force parallel $V_{Rd,II}$) may be applied in the ultimate limit state according to the table above.

### Shear force perpendicular to the joint

For a shear force perpendicular to the joint reinforced with the VS® Box, a corresponding design resistance (shear force perpendicular $v_{Rd,\perp}$) may be applied in the ultimate limit state according to Table 10, depending on the element thickness and the concrete strength class.

Expansion forces (tensile) result from stresses perpendicular to the joint. These tensile forces are absorbed by the wire rope loop.

### Shear forces parallel and perpendicular to the joint combined

When shear forces perpendicular and parallel to the joint act simultaneously, the interaction of the shear forces is to be verified by means of the interaction relationship shown in Table 11.

### Tensile forces across the VS® loops

The different loading directions result in individual tensile force components that act in the direction of the wire rope loop. The sum of these individual components and any acting "outer" tensile force (total tensile force) is verified on the basis of the tensile force resistance $N_{Rd}$ of the boxes according to the above table.

### Verification of tensile force

**Table 11:** Verification of tensile force

| Stress from | Parallel shear force $V_{Ed,II}$ | Perpendicular shear force $v_{Ed,\perp}$ | "Outer tensile force" |
|---|---|---|---|
| Tensile force component | $n_{Ed,VII} = 0,75 \cdot v_{Ed,II}$ | $n_{Ed,V\perp} = 0,25 \cdot v_{Ed,\perp}$ | $n_{Ed,N}$ |

Verification of the total tensile force:

$$\frac{n_{Ed,VII} + n_{Ed,V\perp} + n_{Ed,N}}{n \cdot N_{Rd}} \leq 1,0$$

- $n$ [Box/m] : Number of VS®-Boxes per metre of joint
- $N_{Rd}$ [kN/Box] : Design resistance – tensile force per VS® Box
- $n_{Ed,N}$ [kN/m] : Acting "outer" tensile force per metre of joint
- $n_{Ed,VII}$ [kN/m] : Expansion force from shear force parallel per metre of joint
- $n_{Ed,V\perp}$ [kN/m] : Expansion force from shear force perpendicular per metre of joint

### Verification of shear force

$$\frac{V_{Ed,II}}{V_{Rd,II}} \leq 1,0$$

$V_{Ed,II}$ [kN/Box]: Acting shear force parallel per box
$V_{Rd,II}$ [kN/Box]: Design resistance of the shear force resistance parallel per box

$$\frac{v_{Ed,\perp}}{v_{Rd,\perp}} \leq 1,0$$

$v_{Ed,\perp}$ [kN/m]: Acting shear force perpendicular per metre of joint length
$v_{Rd,\perp}$ [kN/m]: Design resistance of shear force perpendicular of the joint per metre

$v_{Ed,II} = n \cdot V_{Ed,II}$

$V_{Ed,II}$ [kN/Box] : acting shear force parallel per box
$v_{Ed,II}$ [kN/m] : acting shear force parallel per metre of joint

## 6.6 Fire Resistance

According to EN 1992-1-2, section 5.2, the critical temperature for strands and wire ropes is 350 °C. If VS-Boxes are used in load-bearing walls, the design requirements according to 1992-1-2, section 5.4 must be taken into account.

According to EN 1992-1-2, sec. 2.1.2 (6) the use of VS-Boxes in fire walls is not permitted if conditions against impact stress (criterion M) must be fulfilled.

# 7. VS®-Box selection aid

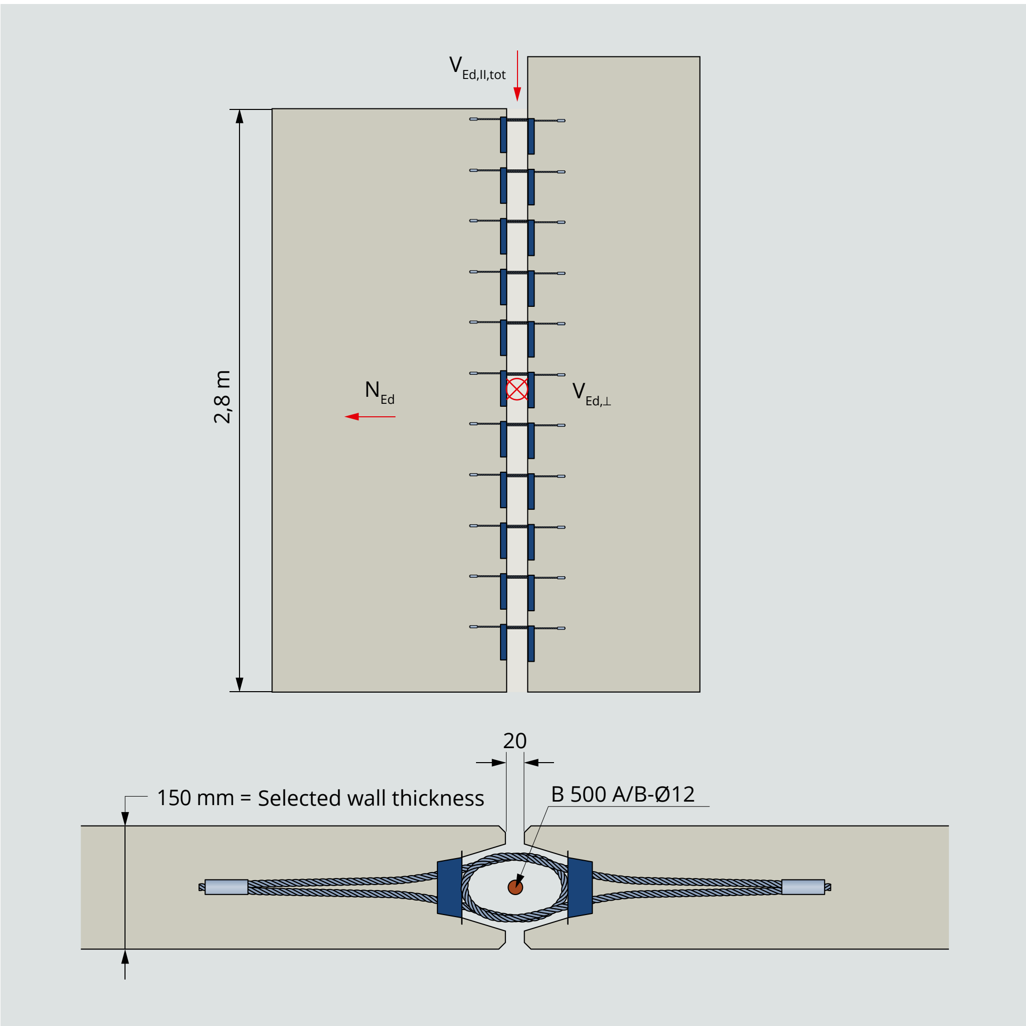
Required input values for selecting the appropriate VS® Box:

- Consistency of the joint filling mortar (free flowing/plastic)
- Joint filling mortar quality
- Structural element concrete quality
- Structural element geometry
- Real load

### Selection example

1. Selection of the appropriate box (criteria: single or double-rope box, mortar free flowing or plastic, etc.)
2. Determination of the maximum possible number of boxes
3. Table input – dimensioning values
4. Proof check
5. Possible optimisation of the number of boxes with low utilisation

| | |
|---|---|
| **Joint filling mortar consistency** | Thixotropic/plastic |
| **Choice of box** | VS®-Box EASYFILL (single-rope box) |
| **Joint filling mortar quality** | C30/37 |
| **Structural element concrete quality** | C30/37 |
| **Structural element geometry** | Wall thickness: d = 150 mm |
| | Wall length: l = 2800 mm |
| **Real loads** | Tensile force: $N_{Ed}$ = 10 kN or $n_{Ed,N}$ = 10kN / 2,8 m = 3,6 KN/m |
| | Parallel shear force: $V_{Ed,II,tot}$ = 50 kN |
| | Perpendicular shear force: $V_{Ed,\perp}$ = 22,4 kN or $v_{Ed,\perp}$ = 22,4 kN / 2,8 m = 8,0 kN/m |




**Geometric boundary conditions**

**Wall length** [mm]:
$l_{Wall}$ = 2800

**Box length** [mm]:
$l_{Box}$ = 160

**Min. distance** [mm]:
$s_{Box}$ = 120

**Min. edge distance** [mm]:
$c_{Box}$ = 180

**Number of boxes** [Box]:
$n_{Box} \leq (l_{Wall} - 2 \cdot c_{Box} + s_{Box}) / (l_{Box} + s_{Box})$
$= (2800 - 2 \cdot 180 + 120) / (160 + 120) = 9{,}14$

$n_{Box}$ = 9

**Number of boxes per metre of joint** [Box/m]:
$n = n_{Box} / l_{Wall} = 9 / 2{,}8 = 3{,}2$

## Static proofs

**Extract from Table 8 with resistances $N_{Rd}$ and $V_{Rd,II}$ for VS® Box EASYFILL**

| Grout | Precast concrete | | | |
|---|---|---|---|---|
| Compressive strength class | C25/30 | | C30/37 | |
| – [–] | $N_{Rd}$ [kN] | $V_{Rd,II}$ [kN] | $N_{Rd}$ [kN] | $V_{Rd,II}$ [kN] |
| **Wall thickness h = 100 mm** | | | | |
| C30/37 | 7.3 | 11.4 | 7.3 | 11.4 |
| C40/50 | 9.8 | 15.0 | 9.8 | 15.0 |
| C50/60 | 9.8 | 15.4 | 10.7 | 16.6 |
| **Wall thickness h ≥ 120 mm** | | | | |
| C30/37 | 7.3 | 11.4 | ③ 7.3 | ① 11.4 |
| C40/50 | 9.8 | 15.0 | 9.8 | 15.0 |
| C50/60 | 10.1 | 15.8 | 12.1 | 18.3 |

**Extract from Table 10 with resistance $v_{Rd,\perp}$ for VS®-Boxes**

| Precast concrete | | | |
|---|---|---|---|
| $v_{Rd,\perp}$ | | | |
| C25/30 [kN/m] | C30/37 [kN/m] | C35/45 [kN/m] | C40/50 [kN/m] |
| **Wall thickness h = 100 mm** | | | |
| 3,9 | 4,5 | 5,2 | 5,5 |
| **Wall thickness h = 150 mm** | | | |
| 9,7 | ② 11,2 | 12,7 | 13,7 |

| Proof | Parallel shear force $V_{II}$ | Perpendicular shear force $V_{\perp}$ | Tensile force N | |
|---|---|---|---|---|
| Stress total or per box: | $V_{Ed,II,tot} = 50{,}0$ kN<br>bzw.<br>$V_{Ed,II} = \frac{V_{Ed,II,tot}}{n_{Box}} = \frac{50\ \text{kN}}{9\ \text{Box}} = 5{,}6\ \frac{\text{kN}}{\text{Box}}$ | $V_{Ed,\perp} = 22{,}4$ kN<br>: 2,8 m | $N_{Ed} = 10{,}0$ kN<br>: 2,8 m | Stress |
| Stress per metre of joint: | $v_{Ed,II} = n \cdot V_{Ed,II} = 3{,}2\ \frac{\text{Box}}{\text{m}} \cdot 5{,}6\ \frac{\text{kN}}{\text{Box}}$<br>$= 17{,}9\ \frac{\text{kN}}{\text{m}}$ | $v_{Ed,\perp} = 8{,}0\ \frac{\text{kN}}{\text{m}}$ | $n_{Ed,N} = 3{,}6\ \frac{\text{kN}}{\text{m}}$ | Stress |
| Resistance per box or per metre of joint: | ① $V_{Rd,II} = 0{,}9 \cdot 11{,}4\ \frac{\text{kN}}{\text{Box}}$ *)<br>$= 10{,}3\ \frac{\text{kN}}{\text{Box}}$ | ② $v_{Rd,\perp} = 11{,}2\ \frac{\text{kN}}{\text{m}}$ **) | ③ $N_{Rd} = 0{,}9 \cdot 7{,}3\ \frac{\text{kN}}{\text{Box}}$ *)<br>$= 6{,}6\ \frac{\text{kN}}{\text{Box}}$ | Resistance |
| Proofs: | $\frac{V_{Ed,II}}{V_{Rd,II}} = \frac{5{,}6\ \frac{\text{kN}}{\text{Box}}}{10{,}3\ \frac{\text{kN}}{\text{Box}}} = 0{,}54 \leq 1{,}0$ ✓ | $\frac{v_{Ed,\perp}}{v_{Rd,\perp}} = \frac{8{,}0\ \frac{\text{kN}}{\text{m}}}{11{,}2\ \frac{\text{kN}}{\text{m}}} = 0{,}71 \leq 1{,}0$ ✓ | $\frac{0{,}75 \cdot v_{Ed,II} + 0{,}25 \cdot v_{Ed,\perp} + n_{Ed,N}}{n \cdot N_{Rd}} = \leq 1{,}0$<br>$\frac{0{,}75 \cdot 17{,}9 + 0{,}25 \cdot 8{,}0 + 3{,}6}{3{,}2 \cdot 6{,}6} = 0{,}9 \leq 1{,}0$ ✓ | Proof |

*) Reduction of resistance by 10 % due to use of plastic mortar
**) No reduction of the resistance necessary with vertical shear force

The proofs in this example are fulfilled with the type VS-Box EASYFILL (single-rope box) selected at the start. If the proofs are not fulfilled, the proof procedure can be repeated with the working load limits of a double-rope box.

**Caution:**

The boxes approved for the respective mortar properties (free flowing or thixotropic plastic) must be taken into account when selecting. These are shown on page 5.

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