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February 2022

European Assessment Document for

Wire loop system for the connection of precast and in-situ concrete elements

This European Assessment Document (EAD) has been developed taking into account up-to-date technical and scientific knowledge at the time of issue and is published in accordance with the relevant provisions of Regulation (EU) No 305/2011 as a basis for the preparation and issuing of European Technical Assessments (ETA).

Contents

1 SCOPE OF THE EAD

1.1 Description of the construction product

The wire loop system for the connection of precast and in-situ concrete elements (in the following referred to as "wire loop system") is a load transferring cast-in element, consisting of a box and two wire rope loops, for connecting a prefabricated concrete element to an in-situ concrete component or for connecting two in-situ concrete components or for connecting two prefabricated concrete elements.

The box (according to figure 1.1.1/ 3 and figure 1.1.2/ 3) is made of steel sheet, in which two flexible wire loops made of high-strength wire ropes are placed. None of the materials contain more than 1,0 % by weight or volume (whichever is the more onerous) of homogeneously distributed organic material.

The ends of the wire ropes (according to figure 1.1.1/ 1 and figure 1.1.2/ 1) are connected to each other by means of pressing clamps (according to figure 1.1.1/ 2 and figure 1.1.2/ 2). The pressed wire loop ends penetrating the bottom of the box and protruding from the back. The wire loops are securely fixed in the box, wherein the loop heads are folded in the initial state (position A according to figure 1.1.1 and figure 1.1.2). Before concreting of the connection component, the bent wire loops are folded out into their final position and fixed (position B according to figure 1.1.1 and figure 1.1.2).

The surface of the box is equipped with a profiled surface to ensure sufficient bonding with the surrounding concrete.

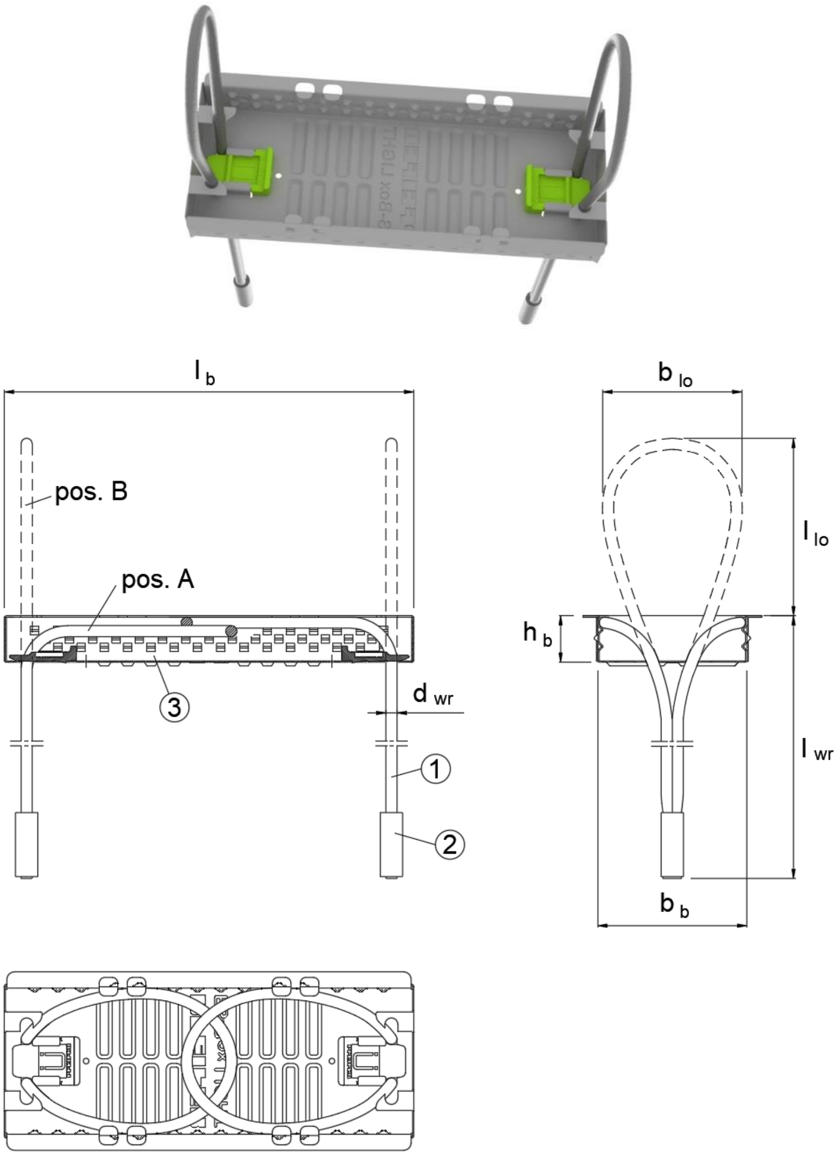


Figure 1.1.1 Wire loop system: type and geometry

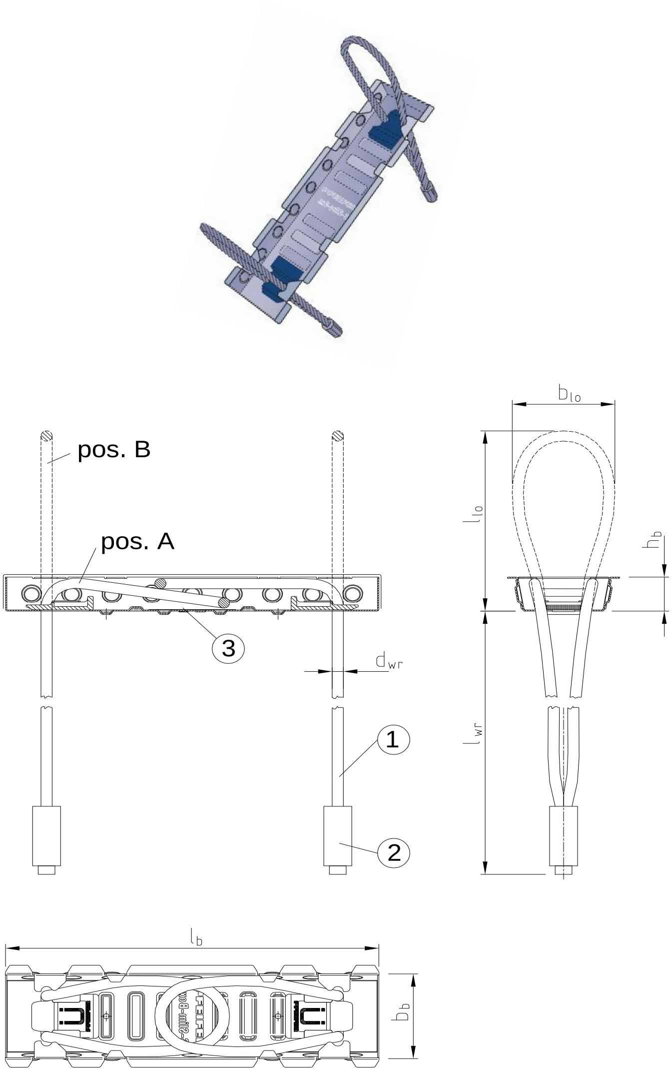


Figure 1.1.2 Wire loop system: type and geometry

The minimum and/or maximum dimensions given in Table 1.1.1, Table 1.1.2 and clause 1.2.1 are based on relevance in practice. All assessment methods are developed / adjusted according to these dimensions based on experiences and tests. Other dimensions could cause other failure modes, other stiffnesses and other mechanical models which are not assessed according to this EAD.

Concerning product packaging, transport, storage, maintenance, replacement and repair it is the responsibility of the manufacturer to undertake the appropriate measures and to advise his clients on the transport, storage, maintenance, replacement and repair of the product as he considers necessary.

It is assumed that the product will be installed according to the manufacturer's instructions or (in absence of such instructions) according to the usual practice of the building professionals.

Relevant manufacturer's stipulations, e.g., with regard to the intended end use conditions, having influence on the performance of the product covered by this European Assessment Document shall be considered for the determination of the performance and detailed in the ETA as long as the details of the assessment methods as laid down in this EAD are respected.

Box profile

The box profile consists of non-alloy steel. The box profile dimensions are given in Table 1.1.1.

Table 1.1.1: Minimum dimensions covered by this EAD

Box height h_b	≥ 20 mm
Box width b_b	≥ 40 mm
Box length l_b	≥ 150 mm

Wire loop

The wire loop consists of non-alloy steel. The wire loop dimensions are given in Table 1.1.2.

Table 1.1.2: Minimum dimensions covered by this EAD

Wire rope diameter d_{wr}	≥ 6 mm
Wire rope length l_{wr}	≥ 80 mm
Wire loop width b_{lo}	$\leq h_{min} - 2 \cdot c_{nom}$
Wire loop length l_{lo}	≥ 100 mm

Materials

The wire loop system is produced of steel according to EN 10025-1[1] [1] (box) and steel according to EN 12385-4 [6] (wire loop).

The product is not covered by a harmonised European standard (hEN).

The product is not fully covered by EAD 332589-00-0601 [8]. The product according to EAD 332589-00-0601 is intended to be used for connections of precast and in-situ concrete elements without additional mortar. The product according to EAD 332589-01-0601 is intended to be used also for the connection of precast concrete elements by using an additional mortar and overlapping of the wire loops in the joint.

For this additional intended use (connections of precast concrete elements), assessment of performance in accordance with additional essential characteristics ($v_{Rk,x}$ *or* $v_{Rk,c,u,x,5\%}$; $v_{Rk,c,u,x,min}$; $v_{Rk,c,x,crack}$) and corresponding assessment methods are added in Clause 2.2.3..

Joint casting grout - Control of consistency

The assessment methods as given in this EAD are based on the assumption that the product is installed taking into account the following conditions.:

The consistency of the grout is determined by the end user as follows. Thus, the following text shall be given in the intended use of the ETA:

"Immediately before filling the joint, the consistency of the joint casting grout shall be controlled".

A cylindrical pipe (plastic pipe ø70 mm, height 100 mm) coated inside with release agent is placed on a previously moistened glass plate or a previously moistened table and quickly filled with the mixed casting grout. Any protruding grout shall be removed with a suitable steel rule. Immediately after filling, the cylindrical pipe shall be pulled slowly and vertically upwards. The consistency is determined by the slump/spreading of the grout in two directions (axes perpendicular to each other). The slump/spreading is the average of both diameters in [mm]."

The reference spreading dimension (which shall be given in the ETA) as basis for the control of consistency shall be determined and established within the component tests described in A.2.1.6.

1.2 Information on the intended use of the construction product

1.2.1 Intended use

1.2.1.1 Intended use – wire loop system

The wire loop system is intended to be used for connecting concrete components realized by embedding the different sides of wire loops in concrete at different times (connection with in-situ concrete elements). The wire loop system is also intended to be used for connecting prefabricated components made of concrete (connection of two precast concrete elements).

The wire loop systems are intended to be installed in concrete precast elements or in components made of in-situ concrete. The intended use includes and the assessment methods are based on the following conditions:

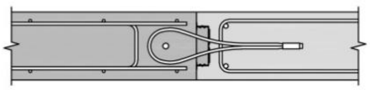
1 All undated references to standards in this EAD are to be understood as references to the dated versions listed in chapter 4.

- Boxes are securely fastened to the formwork in the area of a planned component joint before concreting. After casting of the component, the boxes act as permanent formwork in combination with the surrounding concrete.
- Connections with in-situ concrete elements: Before concreting of the connection component, the wire loops, which are initially folded into the steel-sheet-box, are folded out into their final position and fixed. A frictional connection between the two components is created by concreting the wire loops in the concrete connection component.
- Connections of two precast concrete elements: After removing the covering tapes of the boxes, the bent wire loops are folded out into their final position and fixed. This allows the precast concrete elements to be assembled and aligned. After that the joint between the elements shall be filled with joint casting grout (see also 1.2.1.2). With this a load transmission of shear forces parallel and perpendicular to the joint and tensile forces orthogonal to the joint is permitted.

The assessment methods in this EAD apply under the following conditions regarding the concrete elements:

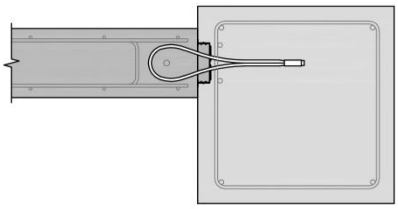
The wire loop system for connection with in-situ concrete elements is intended to be used in compacted reinforced normal weight concrete without fibres with strength classes in the range C25/30 to C50/60 all in accordance with EN 206 [3]. The minimum reinforcement is: two longitudinal bars ∅10 mm at the corners and stirrup reinforcement ∅6/150 mm in precast elements, a longitudinal bar ∅12 mm through the loops and reinforcement 1,88 cm²/m in both directions for in-situ elements.

The wire loop system for connection of two precast elements is intended to be used in compacted reinforced normal weight concrete without fibres with strength classes of minimum C30/37 in accordance with EN 206 [3]. The minimum reinforcement is: surface reinforcement 1,88 cm²/m in longitudinal and lateral direction and reinforcement bar ø12 mm through the overlapping wire loops in the area of the casted joint.

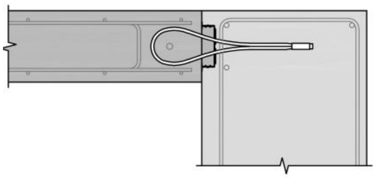


Reinforcement

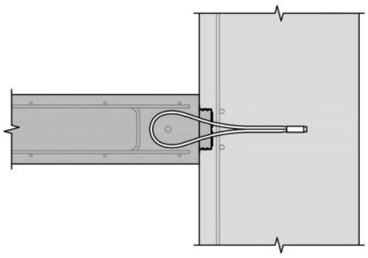
Wall to wall connection (standard detail, exemplary description of reinforcement due to wire loop system)



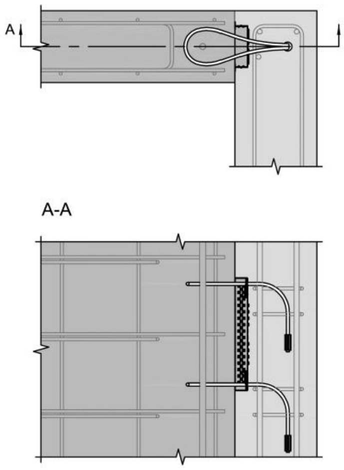
Wall to column connection



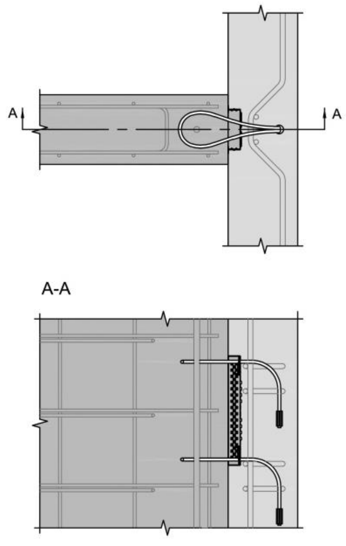
Wall to wall corner-connection



Wall to wall T-connection

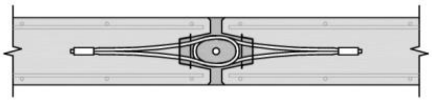


Corner-connection

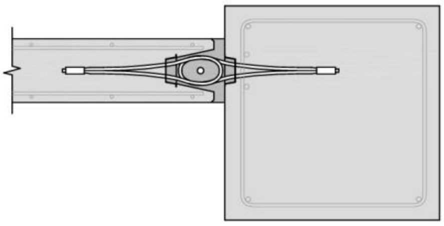


T-Connection with angled loops

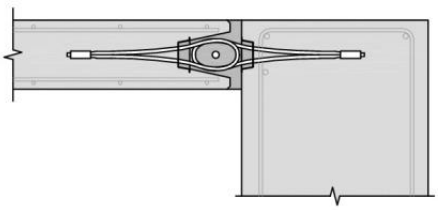
Figure 1.2.1.1.1: Example of a wire loop system embedded in two concrete members at different times (connections with in-situ concrete elements)



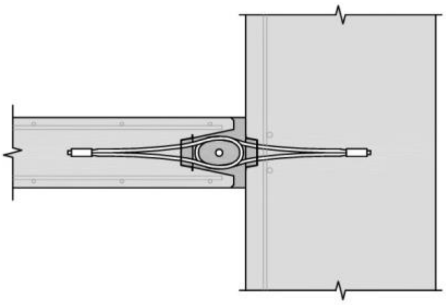
Wall to wall connection



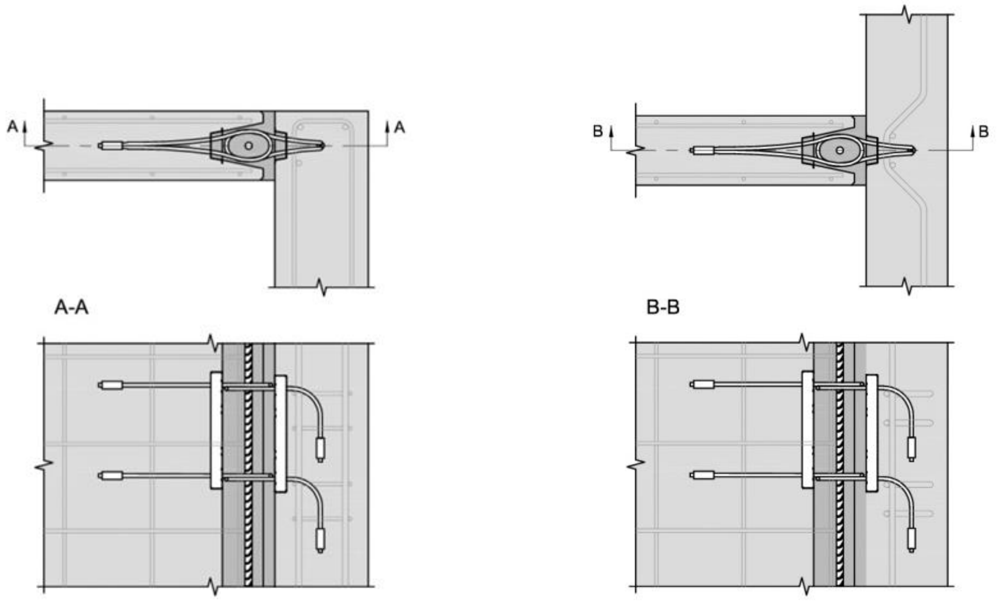
Wall to column connection



Wall to wall corner-connection



Wall to wall T-Connection



Corner connection with angled loops T-Connection with angled loops

Figure 1.2.1.1.2: Example of a wire loop system embedded in two concrete members (connection of two precast concrete elements)

The minimum edge distances $c_{1,min}$ and $c_{2,min}$ and the minimum spacing s_{min} are given by the manufacturer (see Figures 1.2.1.1.3 and 1.2.1.1.4). If the manufacturer does not specify these distances following minimum dimensions apply:

$c_{1,min} \geq 100\ mm$

$c_{2,min} \geq 25\ mm$

$s_{min} \geq 50\ mm$

$h_{1,min} = b_{lo} + 2 \cdot c_{2,min}$ *or* $h_{1,min} = b_b + 2 \cdot c_{2,min}$

$h_{2,min} = l_{wr} + c_{nom}$

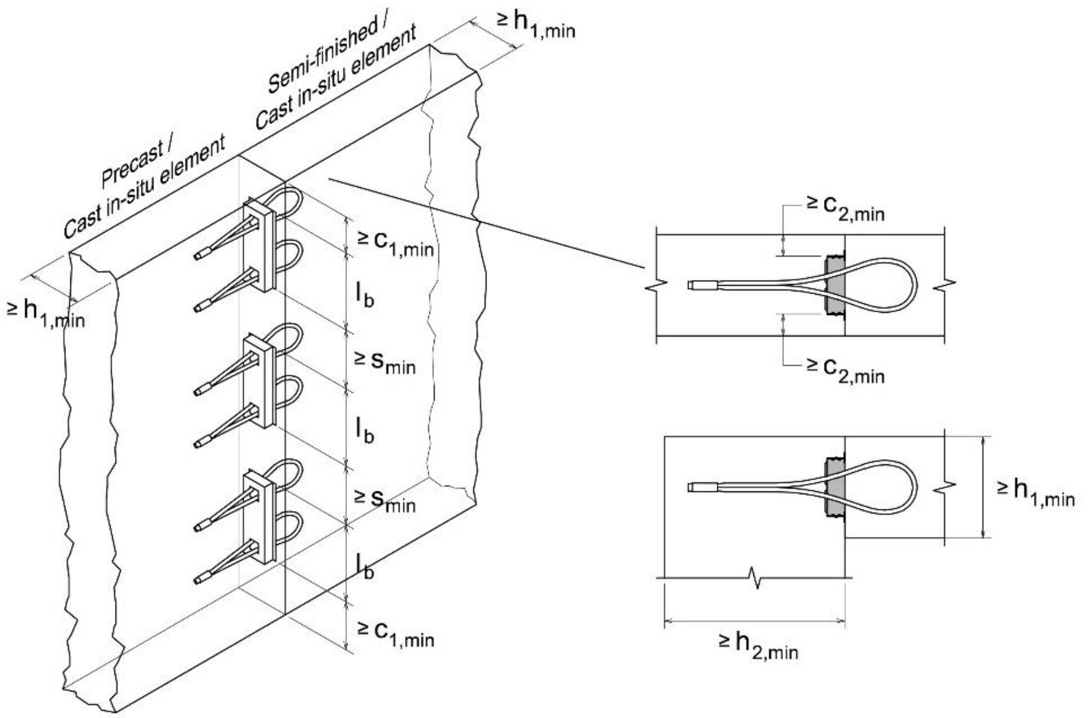


Figure 1.2.1.1.3: Minimum thickness of the two connected concrete components and minimum spacing and edge distances of the box profiles

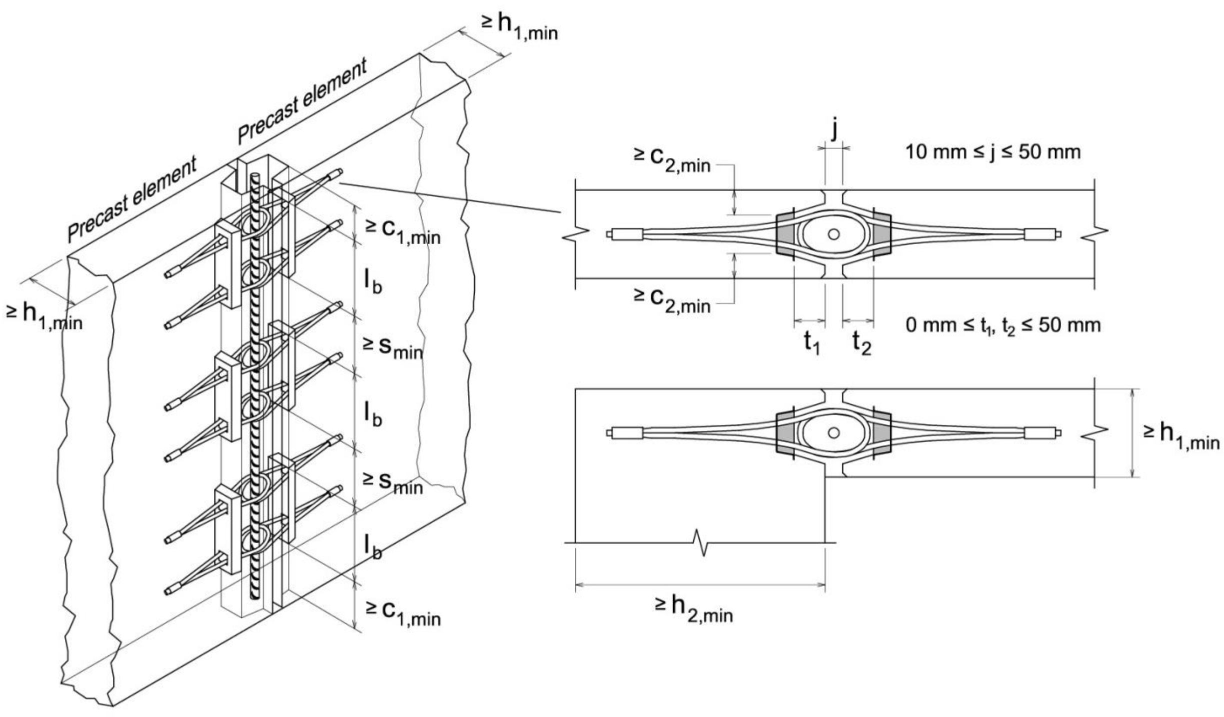
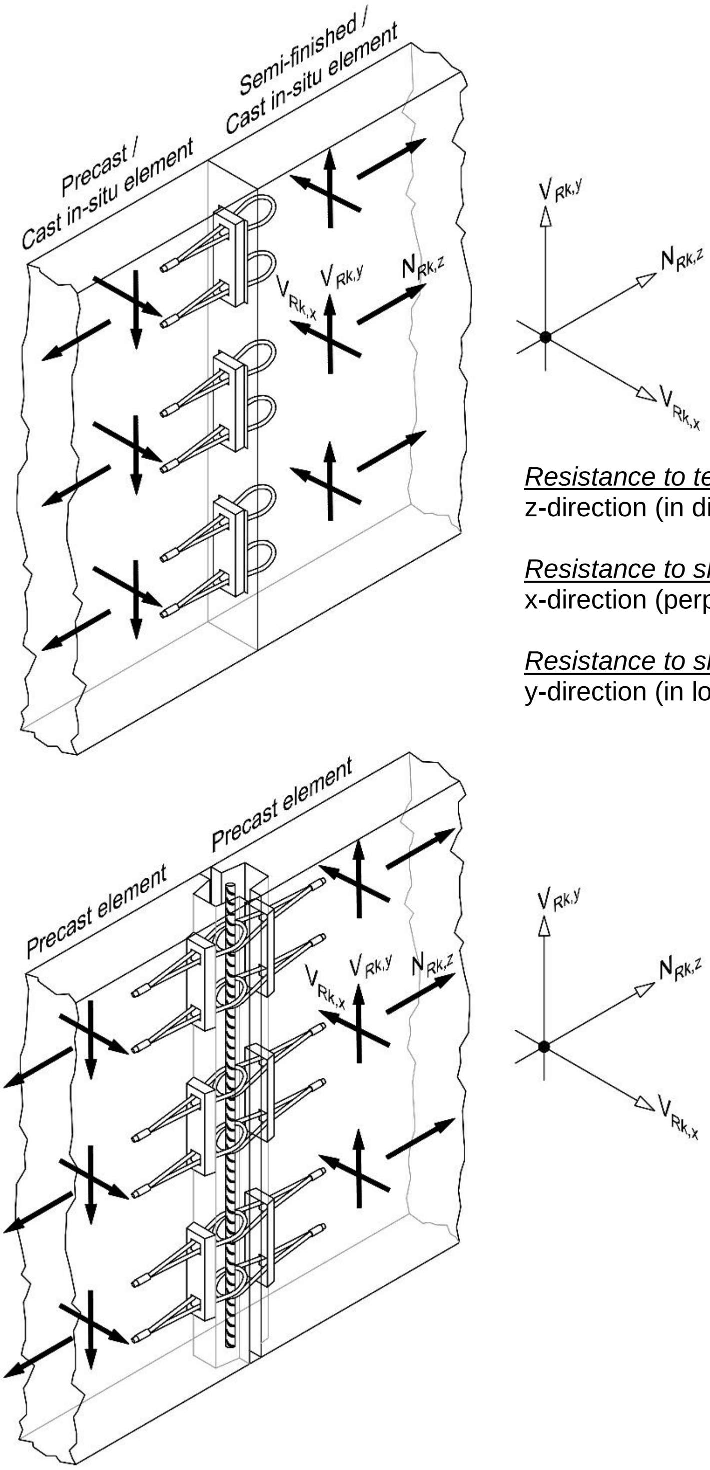


Figure 1.2.1.1.4: Minimum thickness of the two connected concrete components and minimum spacing and edge distances

The wire loop system is intended to be used under static or quasi-static loads. The system can be used to transmit tension loads, shear loads perpendicular to the longitudinal axis of the joint, shear loads acting in direction of the longitudinal axis of the joint or any combination of these loads in accordance with Figure 1.2.1.1.5 into the concrete.



Resistance to tension load
z-direction (in direction of wire loop)

Resistance to shear load
x-direction (perpendicular to longitudinal axis of box/joint)

Resistance to shear load
y-direction (in longitudinal axis of box/joint)

Figure 1.2.1.1.5: Resistances to tension load, shear load and any combinations of these

Note: In this EAD the assessment is made to determine performance of the wire loop system which can be used for design according to Technical Report TR 074 [5].

1.2.1.2 Joint casting grout

The wire loop system is intended to be used in conjunctions with the following types of joint casting grouts:

- prefabricated dry mixture (as a bagged product) which is mixed directly on site with water before installation, or
- the grout is mixed in a concrete plant on the basis of defined properties and delivered to the installation site as finished product.

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

If a prefabricated dry mixture is used, the manufacturer and the exact trade name of the bagged product shall be stated in the ETA. With dry mixtures, a distinction is made between flowable grout variants and variants with thixotropic-plastic consistency. Both variants can be used for casting the connection joints.

If the grout is produced in a concrete plant, the wire loop system is intended to be used only with a concrete according to EN 206 [3] with defined properties. In the ETA at least, the following properties of the concrete used for the assessment shall be specified. Corresponding joint casting grouts have a flowable consistency.

The assessment methods in this EAD apply under the following conditions regarding the joint casting grout:

Definition of the properties of the joint casting grout:

- maximum grain size: ≤ 8 mm
- consistency of a flowable grout

  consistency class according to EN 206 [3], Table 5 or 6: ≥ F5 or ≥ SF1
  or: slump-flow according to EN 13395-2 [13]: ≥ 550 mm

  consistency of a thixotropic-plastic grout
  slump-diameter according to EN 13395-1 [12]: ≥ 130 mm
- expansion after 24 hours according to EN 445 [10]: ≥ +0,1 Vol-%
- shrinkage after 91 days according to EN 12390-16 [11]: average value: $\varepsilon_{m,91}$ ≤ 1,5 ‰

  For grouts with a maximum grain size ≤ 4 mm, prisms with the dimensions 40 x 40 x 160 mm3 shall be used to carry out the analysis. For grouts with 4 mm < maximum grain size ≤ 8 mm, the analysis shall be carried out on cylinders with a diameter of 150 mm and a height of 300 mm.

  The casting grout to be analysed shall be compacted by poking or tapping. The initial measurement (zero measurement) shall be carried out directly after removing the formwork at the age of 24 hours. The test specimens are then stored at (20 ± 2) °C and (65 ± 5) % relative humidity. The behaviour of shrinking is determined after 91 days.

  or: according to EN 12617-4 [14] single value: $\varepsilon_{i,91}$ ≤ 2,0 ‰
- cube compressive strength after 28 days according to EN 206 [3]: $f_{ck,cube,g}$ ≥ 40 N/mm²

  or: prism compressive strength according to EN 196-1 [15]

Regarding the intended use the alternative methods referred to above are equivalent.

1.2.2 Working life/Durability

The assessment methods included or referred to in this EAD have been written based on the manufacturer's request to take into account a working life of the wire loop system for the intended use of 50 years when installed in the works (provided that the wire loop system is subject to appropriate installation (see 1.1)). These provisions are based upon the current state of the art and the available knowledge and experience.

When assessing the product, the intended use as foreseen by the manufacturer shall be taken into account. The real working life may be, in normal use conditions, considerably longer without major degradation affecting the basic requirements for works[2].

The indications given as to the working life of the construction product cannot be interpreted as a guarantee neither given by the product manufacturer or his representative nor by EOTA when drafting this EAD nor by the Technical Assessment Body issuing an ETA based on this EAD, but are regarded only as a means for expressing the expected economically reasonable working life of the product.

1.3 Specific terms used in this EAD

1.3.1 Abbreviations

MPII	=	manufacturer's product installation instructions
Sls	=	serviceability limit state
uls	=	ultimate limit state

1.3.2 Notation

x	=	direction perpendicular to longitudinal axis of the box/joint
y	=	direction in the longitudinal axis of the box/joint
z	=	direction of wire loop
b_b	=	box width [mm]
h_b	=	box height [mm]
l_b	=	box length [mm]
l_{wr}	=	wire rope length [mm]
d_{wr}	=	wire rope diameter [mm]
l_{lo}	=	wire loop length [mm]
b_{lo}	=	wire loop width [mm]
c_{min}	=	minimum edge distance in general [mm]
$c_{1/2,min}$	=	minimum edge distance [mm]
$c_{1/2}$	=	edge distance [mm]
s_{min}	=	minimum spacing in general [mm]
h_{min}	=	minimum thickness of concrete member in general [mm]
$h_{1/2,min}$	=	minimum thickness of concrete member [mm]
u,w	=	displacement [mm]
h_{fl}	=	height of the flank in the area of the joint [mm]
h_{g1}	=	height of the casted joint at box opening [mm]
h_{g2}	=	height of the casted joint at flanks edges [mm]
f_{cm}	=	mean concrete compressive strength measured on cylinders [N/mm²]
f_{ck}	=	nominal characteristic concrete compressive strength measured on cylinders [N/mm²]
$f_{ck,cube}$	=	nominal characteristic concrete compressive strength measured on cubes [N/mm²]

2 The real working life of a product incorporated in a specific works depends on the environmental conditions to which that works is subject, as well as on the particular conditions of the design, execution, use and maintenance of that works. Therefore, it cannot be excluded that in certain cases the real working life of the product may also be shorter than referred to above.

$f_{ck,test}$	=	nominal characteristic concrete compressive strength measured on cylinders referring to a series of tests [N/mm²]
$f_{cm,cube}$	=	concrete compressive strength measured on cubes [N/mm²]
$f_{cm,core}$	=	concrete compressive strength measured on cores [N/mm²]
$f_{ctk,0.05}$	=	nominal characteristic concrete tension strength [N/mm²]
$f_{cm,test}$	=	concrete compressive strength measured on cylinders referring to a series of tests [N/mm²]
$f_{cm,cube,test}$	=	concrete compressive strength measured on cubes referring to a series of tests [N/mm²]
$f_{ck,cube,g}$	=	nominal characteristic compressive strength of the joint casting grout measured on cubes [N/mm²]
$f_{ck,prism,g}$	=	nominal characteristic compressive strength of the joint casting grout measured on prisms [N/mm²]
$f_{ctk,0.05,g}$	=	nominal characteristic tension strength of the joint casting grout [N/mm²]
$f_{cm,cube,test,g}$	=	compressive strength of the joint casting grout measured on cubes referring to a series of tests [N/mm²]
$f_{cm,prism,test,g}$	=	compressive strength of the joint casting grout measured on prisms referring to a series of tests [N/mm²]
k_n	=	statistical factor [-]
cv_F	=	coefficient of variation [-]
K	=	empiric factor of minimum breaking load for a strength class of rope [-]
n_r	=	number of loops in one wire loop system [-]
R_r	=	strength class of rope [N/mm²]
t	=	time of test in progress [s]
F	=	loading in general [kN]
F_u	=	failure load in general [kN]
F_{test}	=	testing load in general [kN]
$F_{u,test}$	=	(ultimate) failure load of a test [kN]
F_Z	=	applied tension load in direction z [kN]
$F_{x/y}$	=	applied shear load in direction x/y [kN]
$F_{cyc,min}$	=	minimum value of cyclic testing load [kN]
$F_{cyc,max}$	=	maximum value of cyclic testing load [kN]
$F_{cyc,min,N}$	=	minimum value of cyclic tension testing load [kN]
$F_{cyc,max,N}$	=	maximum value of cyclic tension testing load [kN]
$F_{cyc,min,Vx/y}$	=	minimum value of cyclic shear testing load in direction x/y [kN]
$F_{cyc,max,Vx/y}$	=	maximum value of cyclic shear testing load in direction x/y [kN]
F_{min}	=	minimum breaking load of wire rope [kN]
F_{crack}	=	corresponding load to joint expansion [kN]
$F_{crack,5\%}$	=	5%-fractile of the corresponding load to joint expansion [kN]
$F_{crack,y,5\%}$	=	5%-fractile of the corresponding load to joint expansion in direction y [kN]
$F_{u,5\%}$	=	5%-fractile of failure loads [kN]
$F_{u,x/y,5\%}$	=	5%-fractile of failure loads in direction x/y [kN]
$F_{u,min}$	=	minimum failure load [kN]
$F_{u,x/y,min}$	=	minimum failure load in direction x/y [kN]

$F_{u,c}$	=	converted concrete failure load (nominal to actual compressive strength of concrete) [kN]
$F_{u,c,m}$	=	converted mean concrete failure load (nominal to actual compressive strength of concrete) [kN]
N_{cd}	=	estimated load level for tension tests [kN]
N_u	=	failure load of tension test [kN]
N_{Rk}	=	Characteristic resistance under tension load [kN]
$N_{Rk,s}$	=	Characteristic resistance to steel failure under tension load [kN]
$N_{Rk,c}$	=	Characteristic resistance to concrete failure under tension load [kN]
$N_{Rk,c,u,5\%}$	=	Characteristic resistance to concrete failure under tension load based of the 5%-fractile of the failure loads [kN]
$N_{Rk,c,u,min}$	=	Characteristic resistance to concrete failure under tension load based on the minimum failure load [kN]
$N_{Rk,c,crack}$	=	Resistance to concrete failure under tension load based on the corresponding loads to joint expansion [kN]
$V_{cd,x}$	=	estimated load level for shear tests in direction x [kN]
$V_{u,x}$	=	failure load of shear test in direction x [kN]
$V_{R,x,test}$	=	Decisive resistance to concrete failure under shear load in direction x determined on the basis of tests [kN]
$V_{Rk,x}$	=	Characteristic resistance under shear load in direction x [kN]
$V_{Rk,c,x}$	=	Characteristic resistance to concrete failure under shear load in direction x [kN]
$V_{Rk,c,x,lim}$	=	Characteristic limiting resistance to concrete failure under shear load in direction x, formed by the in-situ component in the wire loop system [kN]
$V_{Rk,c,u,x,5\%}$	=	Characteristic resistance to concrete failure under shear load in direction x on the basis of the 5%-fractile of the failure loads [kN]
$V_{Rk,c,u,x,min}$	=	Characteristic resistance to concrete failure under shear load in direction x on the basis of the minimum failure load [kN]
$V_{Rk,c,x,crack}$	=	Characteristic resistance to concrete failure under shear load in direction x on the basis of the corresponding loads to joint expansion [kN]
$v_{Rk,x}$	=	characteristic resistance under shear load in direction x [kN/m]
$v_{Rk,c,x}$	=	characteristic resistance to concrete failure under shear load in direction x [kN/m]
$v_{Rk,c,x,lim}$	=	limiting characteristic resistance to concrete failure under shear load in direction x formed by the in-situ component in the wire loop system [kN/m]
$v_{Rk,c,u,x,5\%}$	=	characteristic resistance to concrete failure under shear load in direction x on the basis of the 5%-fractile of the failure loads [kN/m]
$v_{Rk,c,u,x,min}$	=	characteristic resistance to concrete failure under shear load in direction x on the basis of the minimum failure load [kN/m]
$v_{Rk,c,x,crack}$	=	characteristic resistance to concrete failure under shear load in direction x on the basis of the corresponding loads to joint expansion [kN/m]
$V_{cd,y}$	=	estimated load level for shear tests in direction y [kN]
$V_{u,y}$	=	failure load of shear test in direction y [kN]
$V_{Rk,y}$	=	resistance under shear load in direction y [kN]
$V_{Rk,c,y}$	=	characteristic resistance to concrete failure under shear load in direction y [kN]
$V_{Rk,c,u,y,5\%}$	=	characteristic resistance to concrete failure under shear load in direction y on the basis of the 5%-fractile of the failure loads [kN]
$V_{Rk,c,u,y,min}$	=	characteristic resistance to concrete failure under shear load in direction y on the basis of the minimum failure load [kN]
$V_{Rk,c,y,crack}$	=	characteristic resistance to concrete failure under shear load in direction y on the basis of the corresponding loads to joint expansion [kN]

2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

2.1 Essential characteristics of the product

Table 2.1.1 shows how the performance of the wire loop system for the connection of precast and in-situ concrete elements is assessed in relation to the essential characteristics.

Table 2.1.1 Essential characteristics of the product and methods and criteria for assessing the performance of the product in relation to those essential characteristics

No	Essential characteristic	Assessment method	Type of expression of product performance
Basic Works Requirement 1: Mechanical resistance and stability			
1	Characteristic resistance to steel failure under tension loading	2.2.1	Level $N_{Rk,s}$ [kN]
2	Characteristic resistance to concrete failure under tension loading	2.2.2	Level $N_{Rk,c,u,5\%}$ [kN]; $N_{Rk,c,u,min}$ [kN]; $N_{Rk,c,crack}$ [kN]
3	Characteristic resistance under shear load 90° (perpendicular to longitudinal axis of joint)	2.2.3	Level For connections with in-situ concrete elements: $V_{Rk,x}$ [kN] *or* $V_{Rk,c,u,x,5\%}$ [kN]; $V_{Rk,c,u,x,min}$ [kN]; $V_{Rk,c,x,crack}$ [kN] For connections of precast concrete elements: $v_{Rk,x}$ [kN/m]*or* $v_{Rk,c,u,x,5\%}$ [kN/m]; $v_{Rk,c,u,x,min}$ [kN/m]; $v_{Rk,c,x,crack}$ [kN/m]
4	Characteristic resistance under shear load 0° (in longitudinal axis of joint)	2.2.4	Level $V_{Rk,c,u,y,5\%}$ [kN]; $V_{Rk,c,u,y,min}$ [kN]; $V_{Rk,c,y,crack}$ [kN]
Basic Works Requirement 2: Safety in case of fire			
5	Reaction to fire	2.2.5	Class

2.2 Methods and criteria for assessing the performance in relation to the essential characteristics

This chapter is intended to provide instructions for TABs. Therefore, the use of wordings such as “shall be stated in the ETA” or “it has to be given in the ETA” shall be understood only as such instructions for TABs on how results of assessments shall be presented in the ETA. Such wordings do not impose any obligations for the manufacturer and the TAB shall not carry out the assessment of the performance in relation to a given essential characteristic when the manufacturer does not wish to declare this performance in the Declaration of Performance.

If for any components covered by harmonised standards or European Technical Assessments the manufacturer of the component has included the performance regarding the relevant essential characteristic in the Declaration of Performance, retesting of that component for issuing the ETA under the current EAD is not required.

The characteristics of the casting grout (the grain size, consistency, expansion, compressive strength and the shrinking behaviour) have a severe impact on the performance of the wire loop system. Therefore, those details about the grout used for the assessment shall be indicated in the ETA. The results of the assessment based on this EAD are only valid when the grain size, consistency, expansion, compressive strength and the shrinking behaviour of the casting grout are given as specified in the ETA.

The consistency shall be determined as follows:

Immediately before filling the joint, the consistency of the joint casting grout shall be controlled.

A cylindrical pipe (plastic pipe ø70 mm, height 100 mm) coated inside with release agent shall be placed on a previously moistened glass plate or a previously moistened table and quickly filled with the mixed casting grout. Any protruding grout shall be removed with a suitable steel rule. Immediately after filling, the cylindrical pipe shall be pulled slowly and vertically upwards. The consistency shall be determined by the slump/spreading of the grout in two directions (axes perpendicular to each other). The slump/spreading is the average of both diameters in [mm].

The reference spreading dimension as basis for the control of consistency shall be determined and established within the component tests described in Annex A and shall be given in the ETA.

2.2.1 Characteristic resistance to steel failure under tension loading

<u>Purpose of assessment</u>

Determination of the characteristic resistance to steel failure under tension loading

<u>Assessment method</u>

The characteristic resistance $N_{Rk,s}$ of the wire loop system to steel failure under tension loading shall be determined as follows:

$$N_{Rk,s} = n_r \cdot 2 \cdot F_{min} / 1{,}5 \qquad (2.2.1.1)$$

$$F_{min} = K \cdot d_{wr}^2 \cdot R_r / 1000 \qquad (2.2.1.2)$$

$K; R_r$ according to EN 12385-4 [6], Annex A

d_{wr} nominal wire rope diameter according to EN 12385-4 [6], Table 5

$n_r = 2$ wire loop system with 2 loops

<u>Expression of results:</u> $N_{Rk,s}$ [kN]

2.2.2 Characteristic resistance to concrete failure under tension loading

<u>Purpose of assessment</u>

Determination of the characteristic resistance to concrete failure under tension loading

<u>Assessment method</u>

The characteristic resistance of the wire loop system to concrete failure under tension loading is based on tests.

According to Table A.1.1 at least 3 cyclic tension tests shall be carried out. The description of the tests is given in A.4.

For the evaluation of the tension test results the following values shall be considered and recorded during the test series:

- sls: cycle load value $F_{cyc,min}$ of minimum load and $F_{cyc,max}$ of maximum load → pre-set parameter,
- sls: load values F_{crack} at joint expansion Δu = 0,3 mm (at the joint) → measured values,
- uls: failure loads F_u → measured values.

The resistances shall be determined as follows:

- uls: 5%-fractile $F_{u,5\%}$ of all failure load values

  The test results (failure load values) shall be converted in relation to the nominal characteristic concrete compressive strength (see A.7.3). The 5%-fractile $F_{u,5\%}$ of the failure load values shall be calculated according to statistical procedures for a confidence level of 75 % (see A.7.4).

  $$N_{Rk,c,u,5\%} = 0{,}9 \cdot F_{u,5\%} \quad (2.2.2.1)$$

- uls: minimum test value $F_{u,min}$ of all failure load values

  The test results (failure load values) shall be converted in relation to the nominal characteristic concrete compressive strength (see A.7.3).

  $$N_{Rk,c,u,min} = F_{u,min} \quad (2.2.2.2)$$

- sls: 5%-fractile $F_{crack,5\%}$ of all load values at joint expansion Δu = 0,3 mm

  The 5%-fractiles $F_{crack,5\%}$ of the load values shall be calculated according to statistical procedures for a confidence level of 75 % (see A.7.4).

  $$N_{Rk,c,crack} = 1{,}425 \cdot 0{,}9 \cdot F_{crack,5\%} \quad (2.2.2.3)$$

  If the load-deformation behaviour of the wire loop system has been almost linear (no progressive deformation at all) during the tests $N_{Rk,c,crack}$ shall be calculated with the maximum load level $F_{cyc,max}$ of the cyclic tension tests.

  $$N_{Rk,c,crack} = 1{,}425 \cdot F_{cyc,max}/1{,}2 \quad (2.2.2.4)$$

Expression of results: $N_{Rk,c,u,5\%}$; $N_{Rk,c,u,min}$; $N_{Rk,c,crack}$ [kN]

2.2.3 Characteristic resistance under shear load 90° (perpendicular to the longitudinal axis of the joint)

Purpose of assessment

Determination of the characteristic resistance to concrete failure under shear load 90° (perpendicular to the longitudinal axis of joint)

Assessment method

The resistance $V_{Rk,x}$ of the wire loop system under shear loading perpendicular to the longitudinal axis of the joint is based on calculation which is verified by a series of tests with representative size.

According to Table A.1.1 at least 3 cyclic shear tests shall be carried out. The description of the tests is given in A.5.

Assessment by calculation for connections with in-situ concrete elements:

The resistance $V_{Rk,x}$ is the result of the following calculations (minimum value is decisive):

- The resistance $V_{Rk,c,x}$ results from the resistance of the concrete edge/flank of the precast concrete component beside the wire loop system:

  $$V_{Rk,c,x} = 16{,}7 \cdot \sqrt{f_{ck}} \cdot c_2^{1,5} \quad (2.2.3.1)$$

$c_2 \geq c_{2,min}$ $c_{2,min}$ according to clause 1.2.1

- The resistance is limited by the shear resistance $V_{Rk,c,x,lim}$ of the concrete console formed by the in-situ concrete component in the wire loop system:

$$V_{Rk,c,x,lim} = \frac{2}{3} \cdot b_b \cdot l_b \cdot f_{ctk;0,05} \quad (2.2.3.2)$$

b_b ; l_b dimension of a specimen as defined in Figure 1.1.2

$f_{ctk;0,05}$ = 1,8 N/mm² (for C25/30) according to EN 1992-1-1 [16]

$$V_{Rk,x} = min\ (V_{Rk,c,x}\ ;\ V_{Rk,c,x,lim}) \quad (2.2.3.3)$$

Assessment by calculation for connections of two precast concrete elements:

The characteristic resistance $v_{Rk,x}$ is the result of the following calculations (minimum value is decisive):

- The resistance $v_{Rk,c,x}$ results from the resistance of the concrete edge/flank of the precast concrete component beside the wire loop system:

$$v_{Rk,c,x} = 0{,}1035 \cdot f_{ck,cube}^{0,66} \cdot \left(\frac{h_1}{10}\right)^{0,33} \cdot \left(\frac{h_{fl}}{10}\right)^{1,11} \quad (2.2.3.4)$$

$$h_{fl} = 0{,}5 \cdot (h_1 - b_b)$$

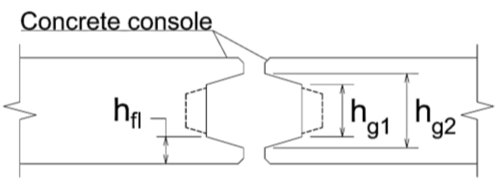
- The resistance is limited by the shear resistance $v_{Rk,c,x,lim}$ of the concrete console formed by the in-situ concrete component in the wire loop system:

$$v_{Rk,c,x,lim} = 0{,}75 \cdot \frac{2}{3} \cdot h_g \cdot f_{ctk,g} \quad (2.2.3.5)$$

$$h_g = (h_{g1} + h_{g2})/2$$

$f_{ctk,g} = 0{,}85 \cdot f_{ctk,0.05,g}$ *with:* $f_{ctk,0.05,g} \leq 2{,}7 N/mm^2$

$$v_{Rk,x} = min\ (v_{Rk,c,x}\ ;\ v_{Rk,c,x,lim}) \quad (2.2.3.6)$$



Assessment by tests for connections with in-situ concrete elements:

For the evaluation of the shear test results the following values shall be considered and recorded during the test series:

- sls: cycle load value $F_{cyc,min}$ of minimum load and $F_{cyc,max}$ of maximum load → pre-set parameters
- uls: failure loads F_u → measured values

The shear resistance is the result of the following evaluations:

- uls: 5%-fractile $F_{u,x,5\%}$ of all failure load values

  The test results (failure load values) shall be converted in relation to the nominal characteristic concrete compressive strength (see A.7.3). The 5%-fractile $F_{u,x,5\%}$ of the failure load values shall be calculated according to statistical procedures for a confidence level of 75 % (see A.7.4).

$$V_{Rk,c,u,x,5\%} = 0{,}9 \cdot F_{u,x,5\%} \quad (2.2.3.7)$$

- uls: minimum test value $F_{u,x,min}$ of all failure load values

  The test results (failure load values) shall be converted in relation to the nominal characteristic concrete compressive strength (see A.7.3).

  $$V_{Rk,c,u,x,min} = F_{u,x,min} \quad (2.2.3.8)$$

- sls: maximum load level $F_{cyc,max}$ of the cyclic shear tests

  $V_{Rk,c,x,crack}$ shall be calculated with the maximum load level $F_{cyc,max}$ of the cyclic shear tests if the load-deformation behaviour of the wire loop system has been stable during the tests.

  $$V_{Rk,c,x,crack} = 1{,}425 \cdot F_{cyc,max} / 1{,}2 \quad (2.2.3.9)$$

$$V_{R,x,test} = min\ ((V_{Rk,c,u,x,5\%} / 1{,}5)\ ;\ (V_{Rk,c,u,x,min} / 2{,}0);\ V_{Rk,c,x,crack}) \quad (2.2.3.10)$$

If $V_{R,x,test} \geq V_{Rk,x}\ /1{,}5$ then $V_{Rk,x}$ shall be given in the ETA (Case A).

If $V_{R,x,test} < V_{Rk,x}\ /1{,}5$ all sizes shall be tested and $V_{Rk,c,u,x,5\%}$; $V_{Rk,c,u,x,min}$; $V_{Rk,c,x,crack}$ shall be given in the ETA (Case B).

<u>Assessment by tests for connections of two precast concrete elements:</u>

For the evaluation of the shear test results the following values shall be considered and recorded during the test series:

- sls: cycle load value $F_{cyc,min}$ of minimum load and $F_{cyc,max}$ of maximum load → pre-set parameters
- uls: failure loads F_u → measured values

The characteristic resistances shall be determined as follows:

- uls: 5%-fractile $F_{u,x,5\%}$ of all failure load values

  The test results (failure load values) shall be converted in relation to the nominal characteristic compressive strength of the concrete and the joint casting grout (see A.7.3). The 5%-fractile $F_{u,x,5\%}$ of the failure load values shall be calculated according to statistical procedures for a confidence level of 75 % (see A.7.4).

  $$v_{Rk,c,u,x,5\%} = 0{,}9 \cdot F_{u,x,5\%} \quad (2.2.3.11)$$

- uls: minimum test value $F_{u,x,min}$ of all failure load values

  The test results (failure load values) shall be converted in relation to the nominal characteristic compressive strength of the concrete and the joint casting grout (see A.7.3).

  $$v_{Rk,c,u,x,min} = F_{u,x,min} \quad (2.2.3.12)$$

- sls: maximum load level $F_{cyc,max}$ of the cyclic shear tests

  $v_{Rd,c,x,crack}$ shall be calculated with the maximum load level $F_{cyc,max}$ of the cyclic shear tests if the load-deformation behaviour of the wire loop system has been stable during the tests.

  $$v_{Rk,c,x,crack} = 1{,}425 \cdot F_{cyc,max} / 1{,}2 \quad (2.2.3.13)$$

$$v_{R,x,test} = min\ (v_{Rk,c,u,x,5\%} / 1{,}5\ ;\ v_{Rk,c,u,x,min} / 2{,}0\ ;\ v_{Rk,c,x,crack}) \quad (2.2.3.14)$$

If $v_{R,x,test} \geq v_{Rk,x}\ /1{,}5$ then $v_{Rk,x}$ shall be given in the ETA (Case A).

If $v_{R,x,test} < V_{Rk,x}\ /1{,}5$ all sizes shall be tested and $v_{Rk,c,u,x,5\%}$; $v_{Rk,c,u,x,min}$; $v_{Rk,c,x,crack}$ shall be given in the ETA (Case B).

Expression of results:

For connections with in-situ concrete elements:

Case A: $V_{Rk,x}$ [kN] or Case B: $V_{Rk,c,u,x,5\%}$; $V_{Rk,c,u,x,min}$; $V_{Rk,c,x,crack}$ [kN]

For connections of precast concrete elements

Case A: $v_{Rk,x}$ [kN/m] or Case B: $v_{Rk,c,u,x,5\%}$; $v_{Rk,c,u,x,min}$; $v_{Rk,c,x,crack}$ [kN/m]

2.2.4 Characteristic resistance under shear load 0° (in longitudinal axis of the joint)

Purpose of assessment

Determination of the characteristic resistance to concrete failure under shear load 0° (in longitudinal axis of the joint)

Assessment method

The characteristic resistance of the wire loop system under shear loading in the longitudinal axis of the joint is based on tests.

According to table A.1.1 at least 3 cyclic shear tests shall be carried out. The description of the tests is given in A.6.

For the evaluation of the shear test results the following values shall be considered and recorded during the test series:

- sls: cycle load value $F_{cyc,min}$ of minimum load and $F_{cyc,max}$ of maximum load → pre-set parameters
- sls: load values F_{crack} at joint expansion Δu = 0,3 mm (at the joint) → measured values
- uls: failure loads F_u → measured values

The resistances shall be determined as follows:

- uls: 5%-fractile $F_{u,y,5\%}$ of all failure load values

  For connections with in-situ concrete elements the test results (failure load values) shall be converted in relation to the nominal characteristic concrete compressive strength (see A.7.3).
  For connections of precast concrete elements, the test results (failure load values) shall be converted in relation to the nominal characteristic compressive strength of the concrete and the joint casting grout (see A.7.3).
  The 5%-fractile $F_{u,y,5\%}$ of the failure load values shall be calculated according to statistical procedures for a confidence level of 75 % (see A.7.4).

  $$V_{Rk,c,u,y,5\%} = 0{,}9 \cdot F_{u,y,5\%} \quad (2.2.4.1)$$

- uls: minimum test value $F_{u,y,min}$ of all failure load values

  For connections with in-situ concrete elements, the test results (failure load values) shall be converted in relation to the nominal characteristic concrete compressive strength (see A.7.3).
  For connections of precast concrete elements, the test results (failure load values) shall be converted in relation to the nominal characteristic compressive strength of the concrete and the joint casting grout (see A.7.3).

  $$V_{Rk,c,u,y,min} = F_{u,y,min} \quad (2.2.4.2)$$

- sls: 5%-fractile $F_{crack,y,5\%}$ of all load values at joint expansion Δu = 0,3 mm

  The 5%-fractiles $F_{crack,y,5\%}$ of the load values shall be calculated according to statistical procedures for a confidence level of 75 % (see A.7.4).

  $$V_{Rk,c,y,crack} = 1{,}425 \cdot 0{,}9 \cdot F_{crack,y,5\%} \quad (2.2.4.3)$$

  Alternatively, $V_{Rk,c,y,crack}$ can be calculated with the maximum load level $F_{cyc,max}$ of the cyclic shear tests if the load-deformation behaviour of the wire loop system has been stable during the tests.

$$V_{Rk,c,y,crack} = 1{,}425 \cdot F_{cyc,max} / 1{,}2 \tag{2.2.4.4}$$

Both methods are equivalent.

Expression of results: $V_{Rk,c,u,y,5\%}$; $V_{Rk,c,u,y,min}$; $V_{Rk,c,y,crack}$ [kN]

2.2.5 Reaction to fire

The wire loop system made of steel as defined in clause 1.1 is considered to satisfy the requirements for performance class A1 of the characteristic reaction to fire in accordance with the Commission Decision 96/603/EC, as amended by Commission Decisions 2000/605/EC and 2003/424/EC, without the need for testing on the basis of it fulfilling the conditions set out in that Decision and its intended use being covered by that Decision.

Therefore, when the conditions referred to above are fulfilled, the performance of the product is class A1 which shall be stated in the ETA.

3 ASSESSMENT AND VERIFICATION OF CONSTANCY OF PERFORMANCE

3.1 System(s) of assessment and verification of constancy of performance to be applied

For the product covered by this EAD the applicable European legal act is Commission Decision 96/582/EC.

The system is 1.

3.2 Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of the wire loop system for the connection of precast concrete walls in the procedure of assessment and verification of constancy of performance are laid down in Table 3.2.1.

Table 3.2.1 Control plan for the manufacturer; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Factory production control (FPC) [including testing of samples taken at the factory in accordance with a prescribed test plan]					
1	Wire rope, ferrule Characteristics of raw material	Inspection certificate 3.1 according to EN 10204	Laid down in control plan	1	every batch/delivery of material
2	Wire rope Dimensions and construction	Measuring by caliper and optical control	Laid down in control plan	1	every batch/delivery of material
3	Ferrule Dimensions	Measuring by caliper	Laid down in control plan	1	every batch/delivery of material
4	Wire loop, box Dimensions	Measuring by caliper and optical control	Laid down in control plan	1	1^{st} per 1.000 produced boxes
5	Wire loop Minimum breaking load	Tensile test, see clause 3.4	Laid down in control plan	1	1^{st} per 4.000 produced boxes

3.3 Tasks of the notified body

The cornerstones of the actions to be undertaken by the notified body in the procedure of assessment and verification of constancy of performance for the wire loop system for the connection of precast concrete walls are laid down in Table 3.3.1.

Table 3.3.1 Control plan for the notified body; cornerstones

No	Subject/type of control	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Initial inspection of the manufacturing plant and of factory production control					
1	Notified Body will ascertain that the factory production control with the staff and equipment are suitable to ensure a continuous and orderly manufacturing of the wire loop system.	Verification of the complete FPC as described in the control plan agreed between the TAB and the manufacturer	According to Control plan	According to Control plan	When starting the production or a new line
Continuous surveillance, assessment and evaluation of factory production control					
2	The Notified Body will ascertain that the system of factory production control and the specified manufacturing process are maintained taking account of the control plan.	Verification of the controls carried out by the manufacturer as described in the control plan agreed between the TAB and the manufacturer with reference to the raw materials, to the process and to the product as indicated in Table 3.2.1	According to Control plan	According to Control plan	1/year

3.4 Special methods of control and testing used for the assessment and verification of constancy of performance

Minimum breaking load of the wire loop by tensile test according to Figure 3.4.1.

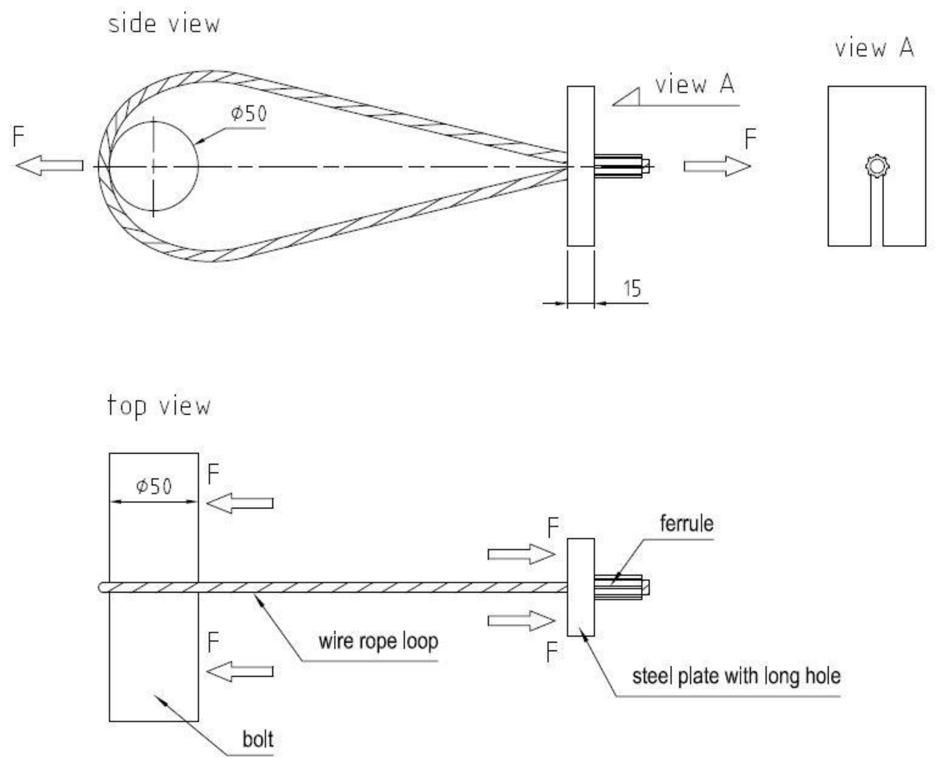


Figure 3.4.1 Tensile test (displacement-controlled loading (20-50 mm/min))

4 REFERENCE DOCUMENTS

[1] EN 10025-1:2004
Hot rolled products of structural steels - Part 1: General technical delivery conditions

[2] EN 13791:2019
Assessment of in-situ compressive strength in structures and precast concrete components

[3] EN 206:2013+A2:2021
Concrete - Specification, performance, production and conformity

[4] EN 1990:2023
Eurocode- Basis of structural and geotechnical design

[5] Technical Report TR 074:2022-04
Design of wire loop system for the connection of precast and in-situ concrete elements

[6] EN 12385-4:2002+A1:2008
Steel wire ropes – Safety – Part 4: Stranded ropes for general lifting applications

[7] EN 10204:2004
Metallic products - Types of inspection documents

[8] EAD 332589-00-0601
Wire loop system for the connection of precast and in-situ concrete elements

[9] EN 197-1:2011
Cement – Part 1: Composition, specifications and conformity criteria for common cements

[10] EN 445:2007
Grout for prestressing tendons - Test methods

[11] EN 12390-16:2019
Testing hardened concrete - Part 16: Determination of the shrinkage of concrete

[12] EN 13395-1:2002
Products and systems for the protection and repair of concrete structures - Test methods; Determination of workability - Part 1: Test for flow of thixotropic mortars

[13] EN 13395-2:2002
Products and systems for the protection and repair of concrete structures - Test methods; Determination of workability - Part 2: Test for flow of grout or mortar

[14] EN 12617-4:2002:
Products and systems for the protection and repair of concrete structures - Test methods - Part 4: Determination of shrinkage and expansion

[15] EN 196-1:2016
Methods of testing cement - Part 1: Determination of strength

[16] EN 1992-1-1:2023
Eurocode 2 — Design of concrete structures, Part 1-1: General rules and rules for buildings, bridges and civil engineering structures

ANNEX A DETAILS OF TESTS AND GENERAL ASSESSMENT OF TEST RESULTS

A.1 Test programme

Table A.1.1 Test programme

No	Test	Concrete strength	Number of tests	Section
1	Cyclic tension tests + initial static tests	C25/30	≥ 3 + 3	Annex A 4
2	Cyclic shear tests 90° + initial static tests (perpendicular to longitudinal axis of the joint)	C25/30	≥ 3 + 3	Annex A 5
3	Cyclic shear tests 0° + initial static tests (in longitudinal axis of the joint)	C25/30	≥ 3 + 3	Annex A 6

A.2 Test members and test equipment

A.2.1 Test members

A.2.1.1 General

For the concrete test members for connections with in-situ concrete elements, compacted normal weight concrete without fibres with strength class of C25/30 according to EN 206 [3] shall be used.

For the concrete test members for connections of two precast concrete elements, compacted normal weight concrete without fibres with strength class of C30/37 according to EN 206 [3] shall be used.

The test members shall be designed with minimum thickness $h_{1,min}$, the wire loop system should be situated with minimum distances between the boxes and minimum edge distances.

The reinforcement of the test members depends on the intended use of the product specified by the manufacturer as given in the MPII. If the manufacturer does not specify the reinforcement in the intended use the minimum reinforcement according to 1.2.1 applies.

A.2.1.2 Aggregates

Aggregates shall be of natural occurrence (i.e., non-artificial) and with a grading curve falling within the boundaries given in figure A.2.2.2.1. The maximum aggregate size shall be 16 mm. The aggregate density shall be between 2,0 and 3,0 t/m³ (see EN 206 [3]).

The boundaries reported in figure A.2.2.2.1 are valid for aggregates with a maximum size of 16 mm. For different values of maximum aggregate sizes, different boundaries may be adopted, if previously agreed with the responsible TAB.

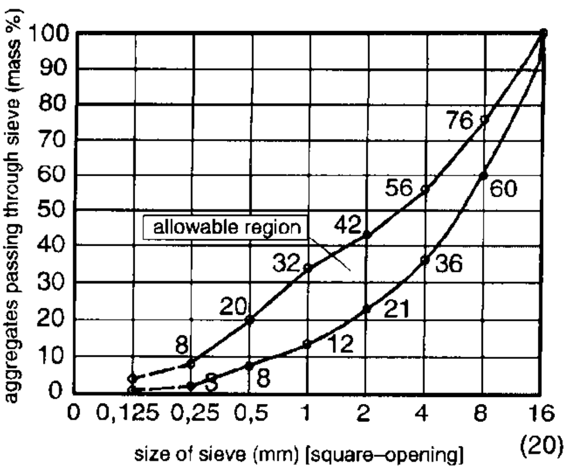


Figure A.2.2.2.1: Admissible region for the grading curve

A.2.1.3 Cement

The concrete shall be produced using Portland cement Type CEM I or Portland-Composite cement Type CEM II/A-LL, CEM II/B-LL (see EN 197-1 [9])

A.2.1.4 Water/cement ratio and cement content

The water/cement ratio shall not exceed 0,75 and the cement content shall be at least 240 kg/m^3.

No additives likely to change the concrete properties (e.g., fly ash, or silica fume or other powders) shall be included in the mixture.

A.2.1.5 Concrete strength

The tests according to Table A.1.1 for connections with in-situ concrete elements shall be carried out in standard concrete (strength class C25/30 according to EN 206 [3]). The following mean compressive strengths at the time of testing shall be reached:

C25/30	f_{cm}	=	25 - 35 MPa (cylinder: diameter 150 mm, height 300 mm)
	$f_{cm,cube}$	=	30 - 40 MPa (cube:150 x 150 x 150 mm)

The tests according to Table A.1.1 for connections of two precast concrete elements shall be carried out in standard concrete (strength class C30/37 according to EN 206 [3]). The following mean compressive strengths at the time of testing shall be reached:

C30/37	f_{cm}	=	24 - 38 MPa (cylinder: diameter 150 mm, height 300 mm)
	$f_{cm,cube}$	=	30 - 47 MPa (cube: 150 x 150 x 150 mm)

The concrete compressive strength shall be measured either on cylinders with a diameter of 150 mm and height of 300 mm, or on cubes of 150 mm. Both methods are equivalent under consideration of the following conversion.

The following conversion factors for concrete compressive strength from cube to cylinder shall be used for connections with in-situ concrete elements:

C25/30

$$f_{cm} = \frac{1}{1{,}20} \cdot f_{cm,cube} \qquad \text{(A.2.2.5.1)}$$

The following conversion factors for concrete compressive strength from cube to cylinder shall be used for connections of two precast concrete elements:

C30/37

$$f_{cm} = \frac{1}{1{,}23} \cdot f_{cm,cube} \qquad \text{(A.2.2.5.2)}$$

For other dimensions, the concrete compressive strength shall be converted as follows:

$$f_{cm,cube100} = \frac{1}{0{,}95} \cdot f_{cm,cube} \qquad \text{(A.2.2.5.3)}$$

$$f_{cm,cube} = \frac{1}{0{,}95} \cdot f_{cm,cube200} \qquad \text{(A.2.2.5.4)}$$

$$f_{cm,cube} = f_{cm,core100} \quad \text{(according to EN 13791 [2], clause 7.1)} \qquad \text{(A.2.2.5.5)}$$

For every concreting operation, specimens (cylinder, cube) shall be prepared having the dimensions conventionally employed in the member country. The specimens shall be made, cured and conditioned in the same way as the test members.

Generally, the concrete control specimens shall be tested on the same day as the wire loop system to which they relate. If a test series takes a number of days, the specimens shall be tested at a time giving the best representation of the concrete strength at the time of the wire loop system tests, e.g., at the beginning and at the end of the tests. In this case the concrete strength at the time of testing shall be determined by interpolation.

The concrete strength at a certain age shall be measured on at least 3 specimens. The mean value of the measurements governs.

A.2.1.6 Joint casting grout

As the characteristics of the casting grout (the grain size, consistency, expansion, compressive strength and the shrinking behaviour) have a severe impact on the performance of the wire loop system, those details about the grout used for the assessment shall be indicated in the ETA. The results of the assessment based on this EAD are only valid when the grain size, consistency, expansion, compressive strength and the shrinking behaviour of the casting grout are given as specified in the ETA.

The reference spreading dimension (which shall be given in the ETA) for the control of consistency on site shall be determined and established within the component tests. The procedure, therefore, is as follows:

A cylindrical pipe (plastic pipe ø70 mm, height 100 mm) coated inside with release agent is placed on a previously moistened glass plate or a previously moistened table and quickly filled with the mixed casting grout. Any protruding grout shall be removed with a suitable steel rule. Immediately after filling, the cylindrical pipe shall be pulled slowly and vertically upwards. The consistency is determined by the slump/spreading of the grout in two directions (axes perpendicular to each other). The slump/spreading is the average of both diameters in [mm].

A.2.2 Test equipment

Tests shall be carried out using measuring equipment having a documented calibration according to international standards. The load application equipment shall be designed to avoid sudden increase in load especially at the beginning of the test. The measurement bias of the measuring chain of the load shall not exceed 2% of the measured quantity value.

The test members shall be situated in the testing machine as the following:

- centric load initiation, outside the anchoring zone of the rope wires,
- restrained perpendicular to the direction of the test force, avoiding centring and constraint forces,
- the testing system shall allow asymmetric expansion of the joint and asymmetric displacements of both test member halves.

A.3 Test procedure – general aspects

The wire loop systems shall be installed according to the MPII, except where special conditions are specified in the following test series.

In absence of such instruction MPII the wire loop system shall be installed according to the usual practice of the building professionals, except where special conditions are specified in the following test series.

The conditions as specified in the following test series shall be taken into account. Additionally, and only for aspects not covered by these conditions, the MPII or, where such instructions are not available, the usual practice of the building professionals shall be taken into account.

During the tests the following values shall at least be measured and recorded:

- displacement (u) and force (F_{test}) of the tension testing machine,
- displacements perpendicular of the component joint sides (joint expansion),
- relative displacements of the component joint sides (parallel/perpendicular shift of the joint),
- forces of spreading bars in case of parallel shear force tests with intended joint expansion in z-direction,
- local displacements by inductive displacement sensors.

Table A.3.1 Displacement sensors

type of test	abbreviation	measuring point on test member	definition of measuring	direction of measuring	measuring element
Tension tests according to Table A.1.1, No 1	$u_{1,z}$	joint, front side, upper position	joint expansion perpendicular to joint	z-direction	e.g., displacement sensor
	$u_{2,z}$	joint, front side, lower position			
	$u_{3,z}$	joint, back side, upper position			
	$u_{4,z}$	joint, back side, lower position			
Shear tests 90° (perpendicular to longitudinal axis of the joint) according to Table A.1.1, No 2	$u_{1,z}$	joint, front end face, upper position	joint expansion perpendicular to joint	z-direction	e.g., displacement sensor
	$u_{2,z}$	joint, front end face, lower position			
	$u_{3,z}$	joint, back end face, upper position			
	$u_{4,z}$	joint, back end face, lower position			
	$w_{1,x}$	joint, front end face, central position	displacement of test specimens against each other perpendicular to joint	x-direction	
	$w_{2,x}$	joint, back end face, central position			
Shear tests 0° (in longitudinal axis of the joint) according to Table A.1.1, No 3	$u_{1,z}$	joint, front side, upper position	joint expansion perpendicular to joint	z-direction	e.g., displacement sensor
	$u_{2,z}$	joint, front side, lower position			
	$u_{3,z}$	joint, back side, upper position			
	$u_{4,z}$	joint, back side, lower position			
	$w_{1,y}$	joint, front side, central position	displacement of test specimens against each other parallel to joint	y-direction	
	$w_{2,y}$	joint, back side, central position			

The following occurrences shall be at least recorded (protocol and photos):

- manufacturing and concreting of the test members,
- test member before/during/after the test,
- recording of occurring displacements, cracking and spalling of concrete,
- test member behaviour during loading, load alternation (load cycling), at maximum load,
- examination of the joint by uncovering the wire loop system after the test.

A.4 Cyclic tension test

A.4.1 General

To be observed:

- Thickness of test member,
- Axial position of wire loop system,
- Axial load application referring to the loops (without affecting the area of anchoring of loops).

A.4.2 Test setup

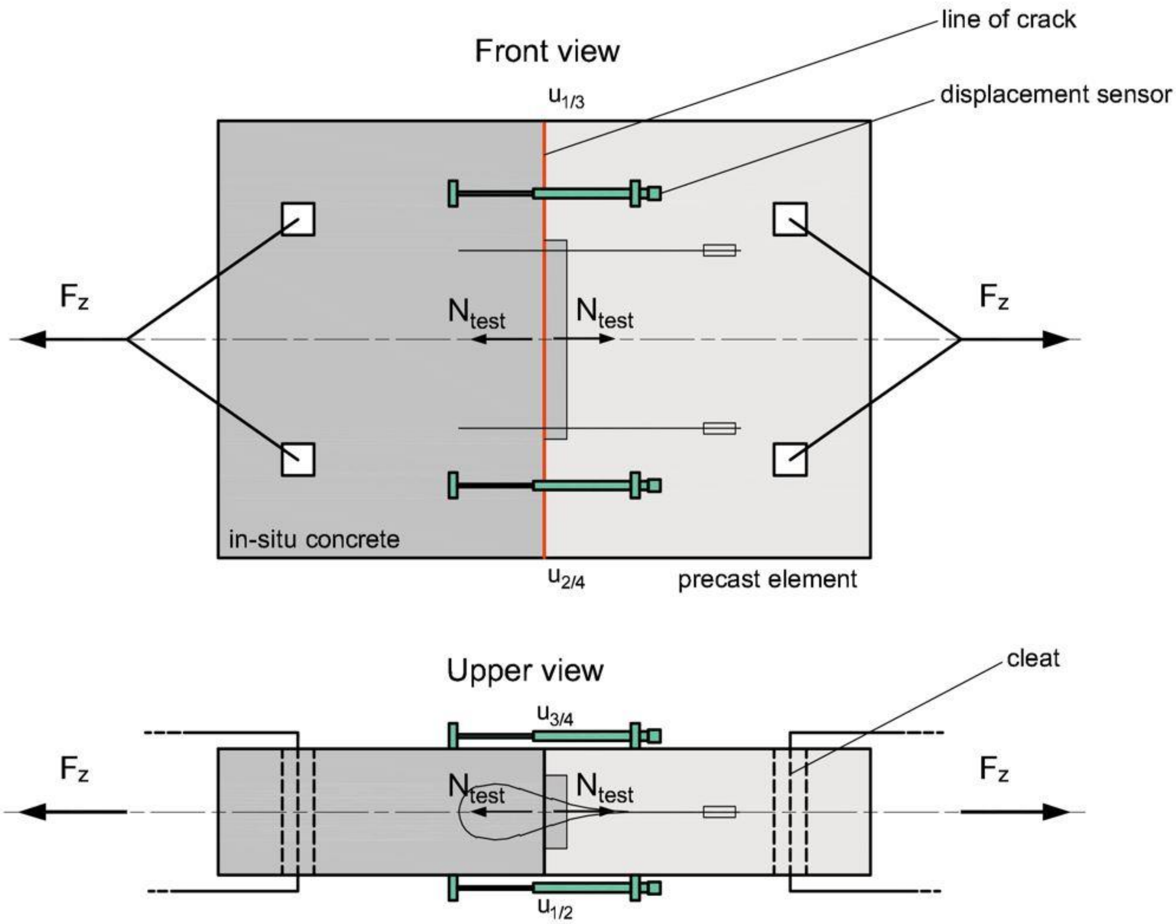


Figure A.4.2.1: Test setup for connections with in-situ concrete elements

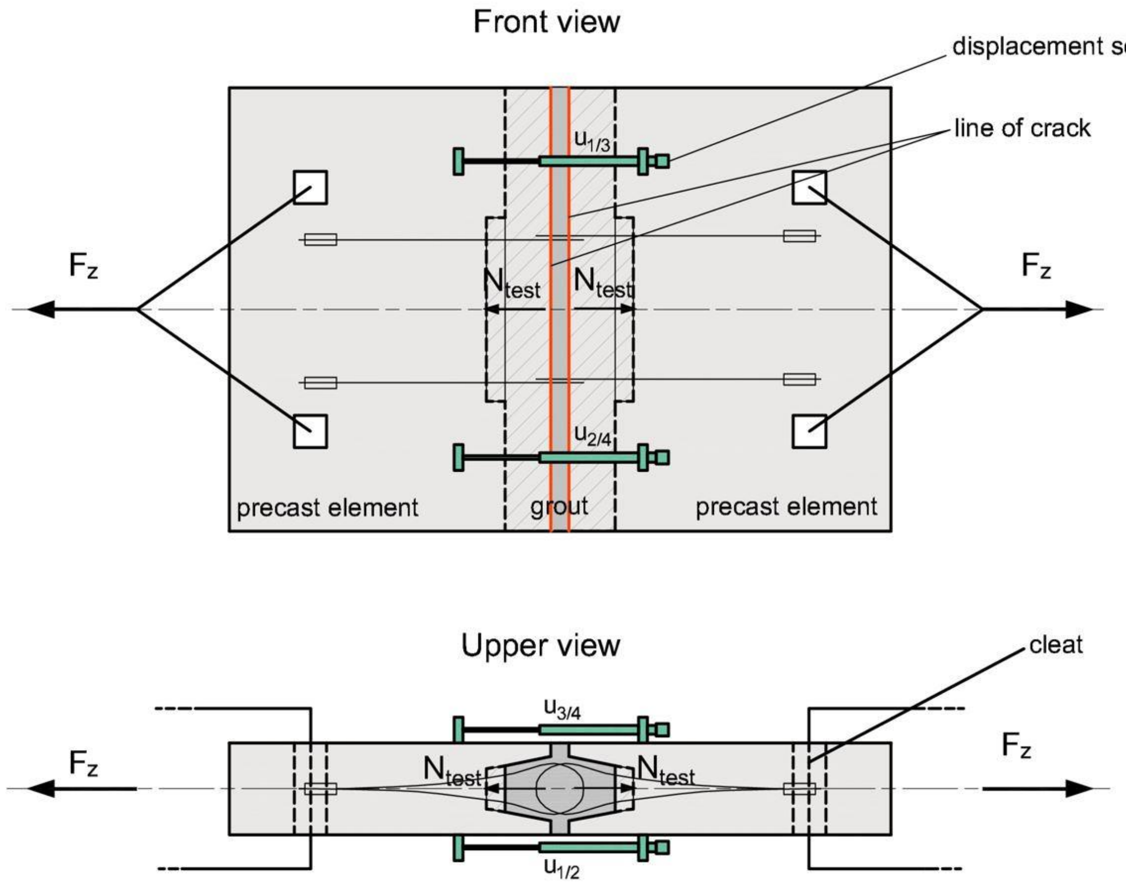


Figure A.4.2.2: Test setup for connections of two precast concrete elements

A.4.3 Determination of load levels for cyclic loading

Before carrying out the tests, the load level of cyclic loading ($F_{cyc,min,N}$; $F_{cyc,max,N}$) shall be determined.

Load levels of cyclic loading:

$$F_{cyc,min,N} = 0{,}15 \cdot N_{cd} \qquad \text{(A.4.3.1)}$$

$$F_{cyc,max,N} = 1{,}20 \cdot N_{cd} \qquad \text{(A.4.3.2)}$$

The load level shall be derived on the basis of the maximum failure loads N_u of at least 3 initial static tests.
The initial tests shall be performed with the test setup according to A 4.2. The test procedure contains tension tests until failure of test member or until immediate or steady load decline.

$$N_{cd} = \frac{N_u}{2{,}8} \qquad \text{(A.4.3.3)}$$

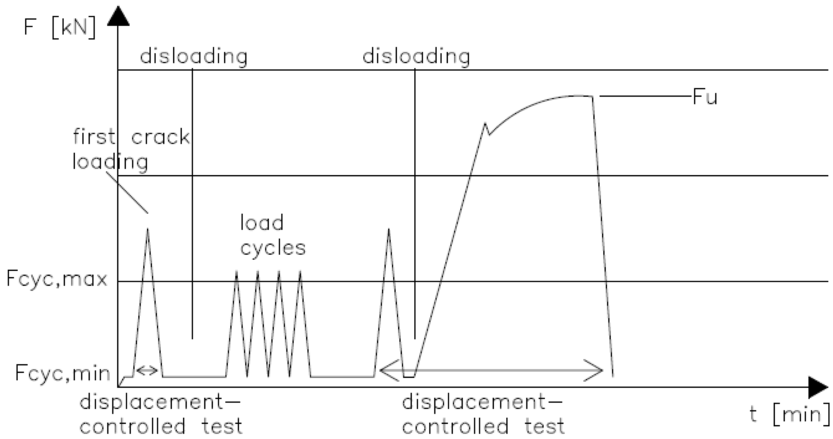
If pre-tests are performed and the intended characteristic resistance value N_{Rk} is known, the load level shall be determined as follows (without additional initial static tests).

$$N_{cd} = \frac{N_{Rk}}{2{,}1} \qquad \text{(A.4.3.4)}$$

A.4.4 Test procedure

1. starting test by applying initial load: $F_{cyc,min,N}$
2. reset of measuring equipment
3. displacement-controlled increase of load (loading) until first crack in joint occurs
4. unloading to minimum load: $F_{cyc,min,N}$ (time for unloading 10 sec. ±10%)
5. 25 load-cycles (2 cycles/min, sinusoidal or triangular load application)
(minimum load level: $F_{cyc,min,N}$ / maximum load level: $F_{cyc,max,N}$)
6. unloading to minimum load: $F_{cyc,min,N}$ (time for unloading 10 sec. ±10%)
7. displacement-controlled loading (1 mm/min) until stabilization of load (constant load by increasing displacement) or joint expansion $\Delta u_{1/2/3/4,z}$ = 2 mm
8. unloading to minimum load: $F_{cyc,min,N}$ (time for unloading 10 sec. ±10%)
9. displacement-controlled reloading (3 mm/min) until:
failure of test member / immediate or steady load decline / maximum displacement of test machine cylinder / displacement of $\Delta u_{1/2/3/4,z}$ = 40 mm

<u>Load history</u>



A.5 Cyclic shear test 90° (perpendicular to the longitudinal axis of joint)

A.5.1 General

The test setup for investigating the resistance $V_{Rk,x}$ under shear load 90° (perpendicular to the longitudinal axis of the joint) is shown in an abstract form in clause A.5.2. The tests shall be carried out on specimens positioned horizontally.

The tests for connections with in-situ concrete elements are focused on the resisting force that can be transmitted in the contact joint between the precast element (shown in light grey) and the attached concrete element (shown in dark grey).

The tests for connections of two precast concrete elements are focused on the resisting force that can be transmitted by the joint construction (wire loops in combination with joint casting grout).

To perform the loading tests, the specimens consisting of the two connected parts shall be placed in the testing facility. The specimens shall be subjected to the test forces in opposite directions in order to generate a force F_x acting in the contact joint.

For the tests an appropriate setup was chosen that allows the joint to be subjected to a pure shear load resulting of the test force. The test force is applied as a compressive force via a load beam supported on steel rollers placed on the test specimen.

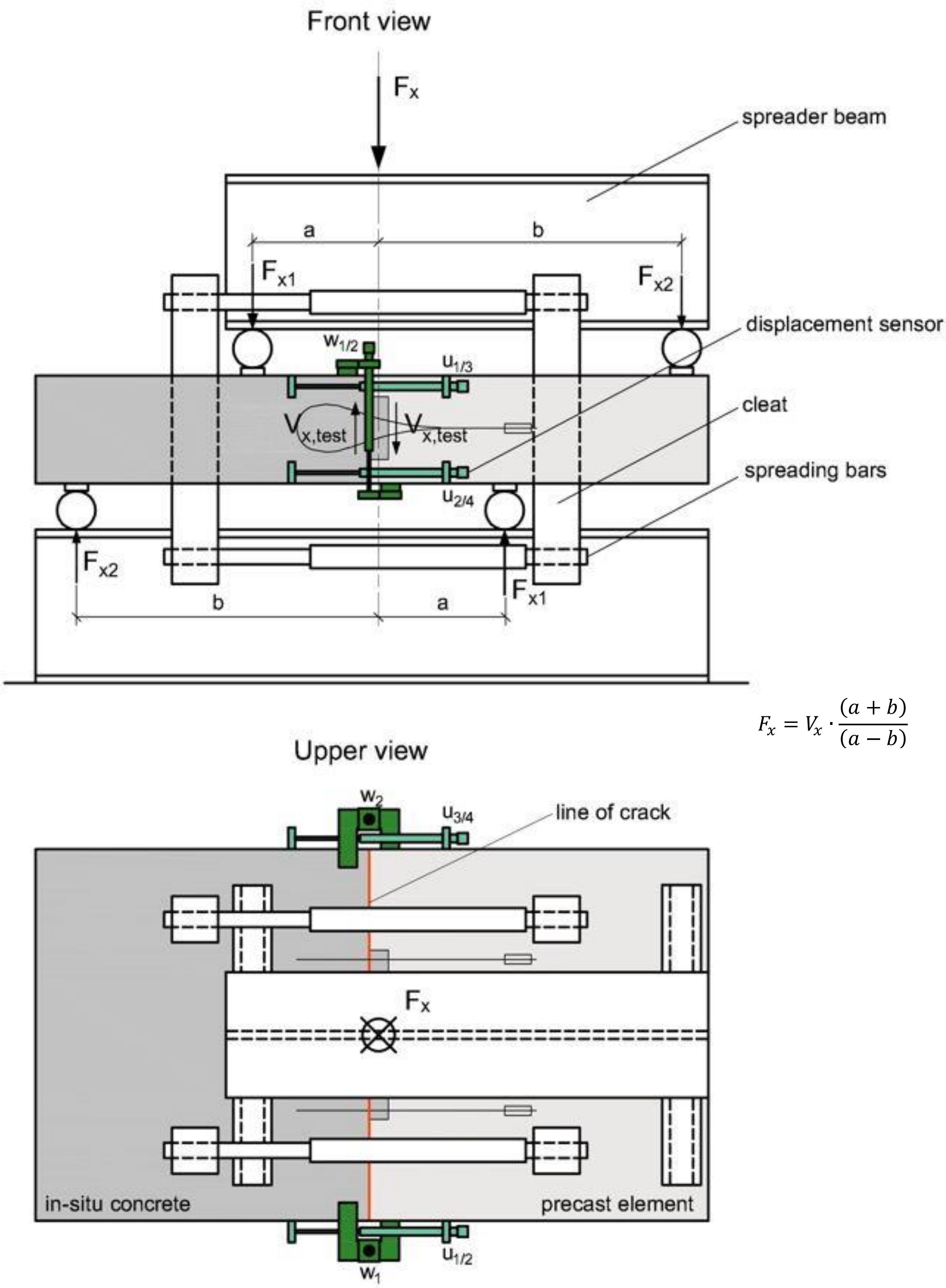
In order to ensure an even, linear distribution of the load onto the test specimen, steel strips with felt strips shall be located between the steel rollers and the concrete surface. This way this slight unevenness can be compensated.

The cracks in the contact joint shall be generated by means of steel cleats which shall be pushed through recesses in the test specimens. Two adjustable spreading bars (threaded rods) shall be placed on each side between the ends of the opposite cleats.

The exact positioning of the steel cleats depends on the dimensions of the respective test specimen and the position of the load application. The position shall be determined taking into account the following paragraph. By determining the exact position of the cleats, it shall be ensured that only shear forces act in the joint (a bending moment shall be avoided).

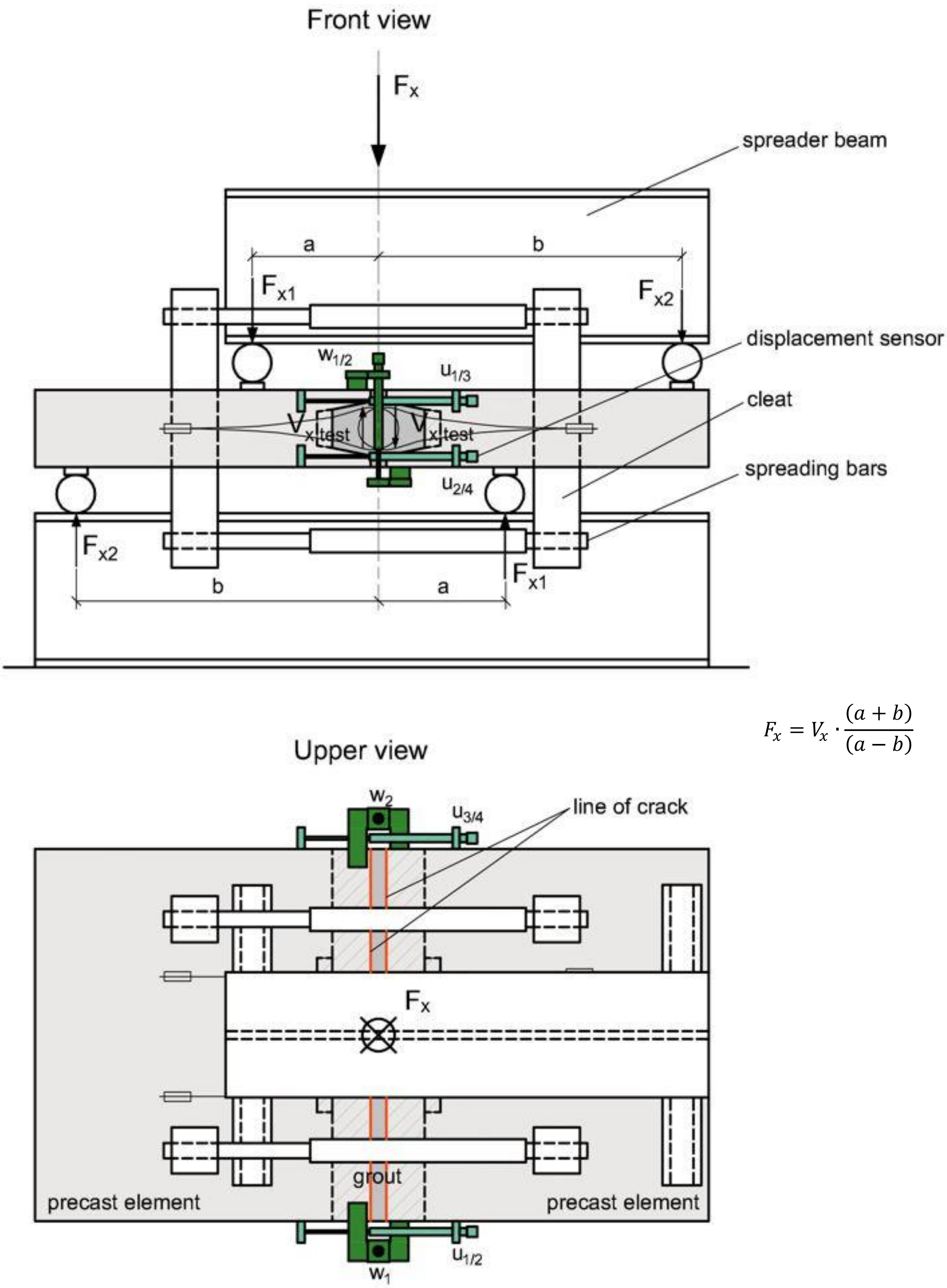
Due to the arrangement of the support- and load introduction points, the joint is subjected to a torque-free shear force by the test force. With this the concrete flank of the precast element and the mortar tooth of the concrete element are loaded systematically as load-bearing elements.

A.5.2 Test setup



$$F_x = V_x \cdot \frac{(a+b)}{(a-b)}$$

Figure A.5.2.1: Test setup for connections with in-situ concrete elements



$$F_x = V_x \cdot \frac{(a+b)}{(a-b)}$$

Figure A.5.2.2: Test setup for connections of two precast concrete elements

A.5.3 Determination of load levels for cyclic loading

Before carrying out the tests, the load level of cyclic loading ($F_{cyc,min,Vx}$; $F_{cyc,max,Vx}$) shall be determined.

Load levels of cyclic loading per box:

$$F_{cyc,min,Vx} = 0{,}15 \cdot V_{cd,x} \cdot \frac{(a+b)}{(a-b)} \qquad \text{(A.5.3.1)}$$

$$F_{cyc,max,Vx} = 1{,}20 \cdot V_{cd,x} \cdot \frac{(a+b)}{(a-b)} \qquad \text{(A.5.3.2)}$$

The load level can be derived on the basis of the maximum failure loads $V_{u,x}$ of at least 3 initial static tests. The initial tests shall be performed with the test setup according to A.5.2. The test procedure contains shear tests until failure of test member or until immediate or steady load decline.

$$V_{cd,x} = \frac{V_{u,x}}{2{,}8} \qquad \text{(A.5.3.3)}$$

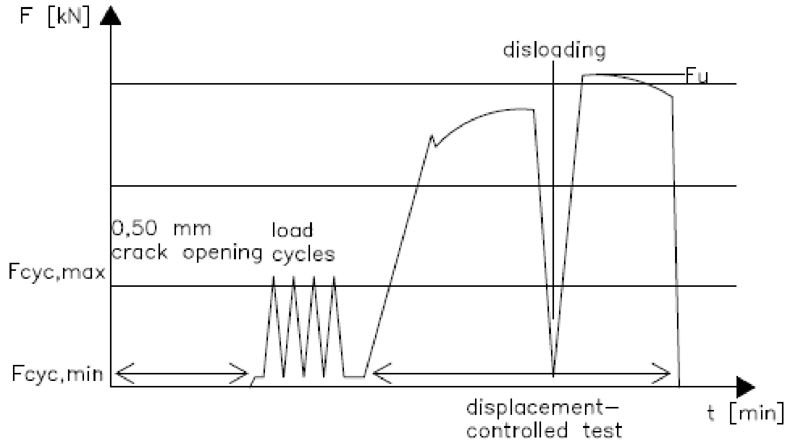
If pre-tests are performed and the intended characteristic resistance value $V_{Rk,x}$ is known, (in case of connections with two precast concrete elements $V_{Rd,x}$ determined by $v_{Rd,x}$ [kN/m] taking into account the width of the test member), the load level shall be determined as follows (without additional initial static tests).

$$V_{cd,x} = \frac{V_{Rk,x}}{2{,}1} \qquad \text{(A.5.3.4)}$$

A.5.4 Test procedure

1. starting test by applying initial load: $F_{cyc,min,Vx}$
2. reset of measuring equipment
3. setting joint expansion $\Delta u_{1/2/3/4,z}$ = 0,50 mm by tightening spreading bars (initiating crack in joint)
4. 25 load-cycles (2 cycles/min, sinusoidal or triangular load application)
   (minimum load level: $F_{cyc,min,Vx}$ / maximum load level: $F_{cyc,max,Vx}$)
5. unloading to minimum load: $F_{cyc,min,Vx}$ (time for unloading 10 sec. ±10%)
6. displacement-controlled loading (0,7 mm/min) until $\Delta w_{1/2,x}$ = 0,3 mm
7. unloading to minimum load: $F_{cyc,min,Vx}$ (time for unloading 10 sec. ±10%)
8. remove joint expansion by opening spreading bars
9. remove measuring equipment (displacement sensors u)
10. displacement-controlled reloading (1 mm/min) until:
    failure of test member / immediate or steady load decline / maximum displacement of test machine cylinder / displacement of $\Delta w_{1/2,x}$ = 40 mm

Load history



A.6 Cyclic shear test 0° (in longitudinal axis of joint)

A.6.1 General

The test setup for investigating the resistance $V_{Rk,y}$ under shear load 0° (in the longitudinal axis of the joint) is shown in an abstract form in clause A.6.2. Depending on the test setup available, the tests can be carried out on specimens positioned either vertically or horizontally. The positioning of the test specimens has no influence on the final test results.

The tests for connections with in-situ concrete elements are focused on the resisting force that can be transmitted in the contact joint between the precast element (shown in light grey) and the attached concrete element (shown in dark grey).

The tests for connections of two precast concrete elements are focused on the resisting force that can be transmitted by the joint construction (wire loops in combination with joint casting grout).

To perform the loading tests, the specimens consisting of the two connected parts shall be placed in the testing facility. The specimens shall be subjected to the test forces in opposite directions in order to generate a force F_y acting in the contact joint.

The test specimens shall be fixed in the test facility by means of two test frames made of steel in which they shall be fixed in a force-fitted and secure position. It shall be ensured that compressive forces acting perpendicular to the contact joint (resulting of eccentric force application) shall be avoided.

The cracks in the contact joint shall be generated by means of steel cleats which shall be pushed through recesses in the test specimens. Two adjustable spreading bars (threaded rods) shall be placed on each side between the ends of the opposite cleats.

A.6.2 Test setup

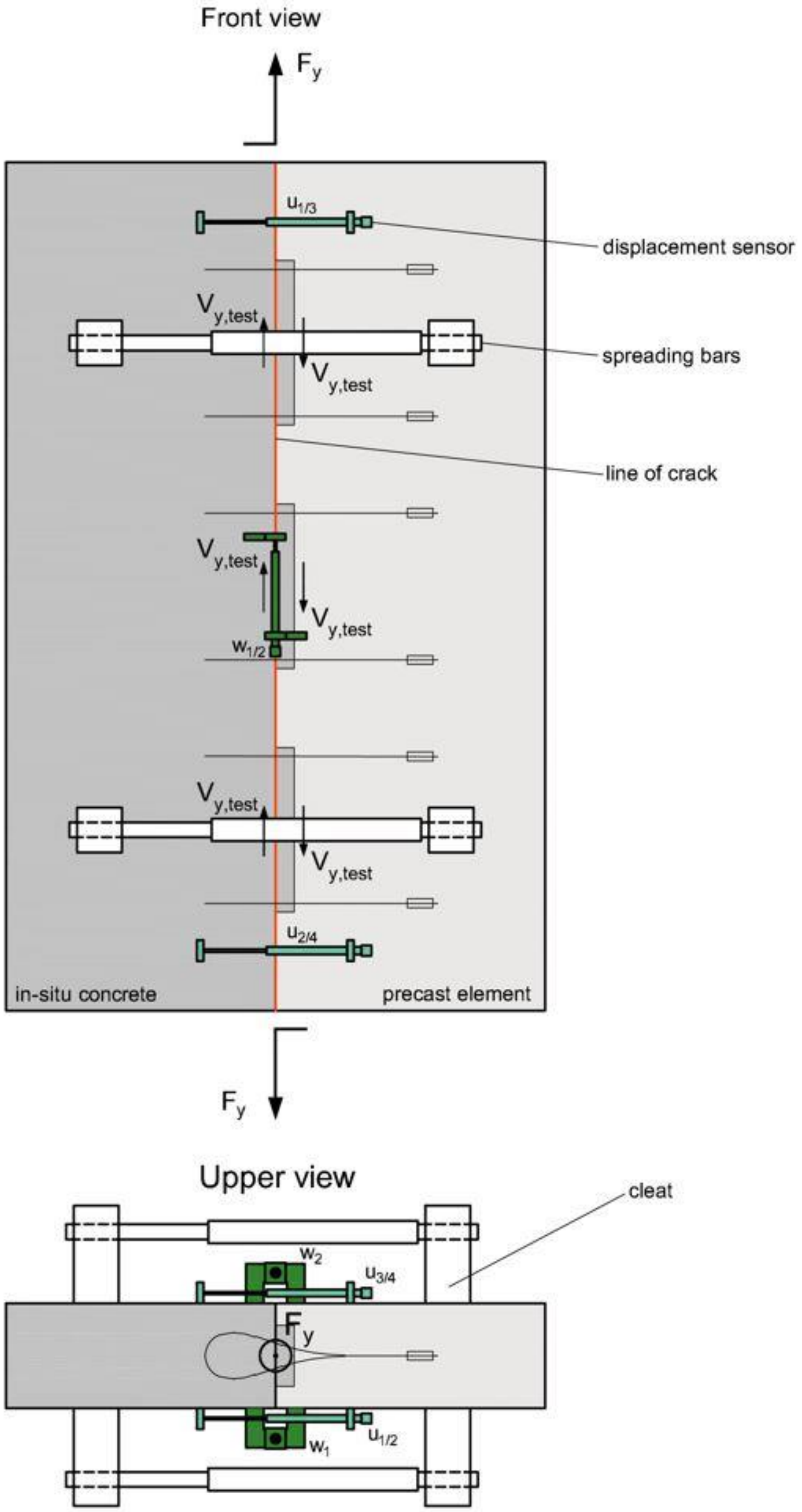


Figure A.6.2.1: Test setup for connections with in-situ concrete elements

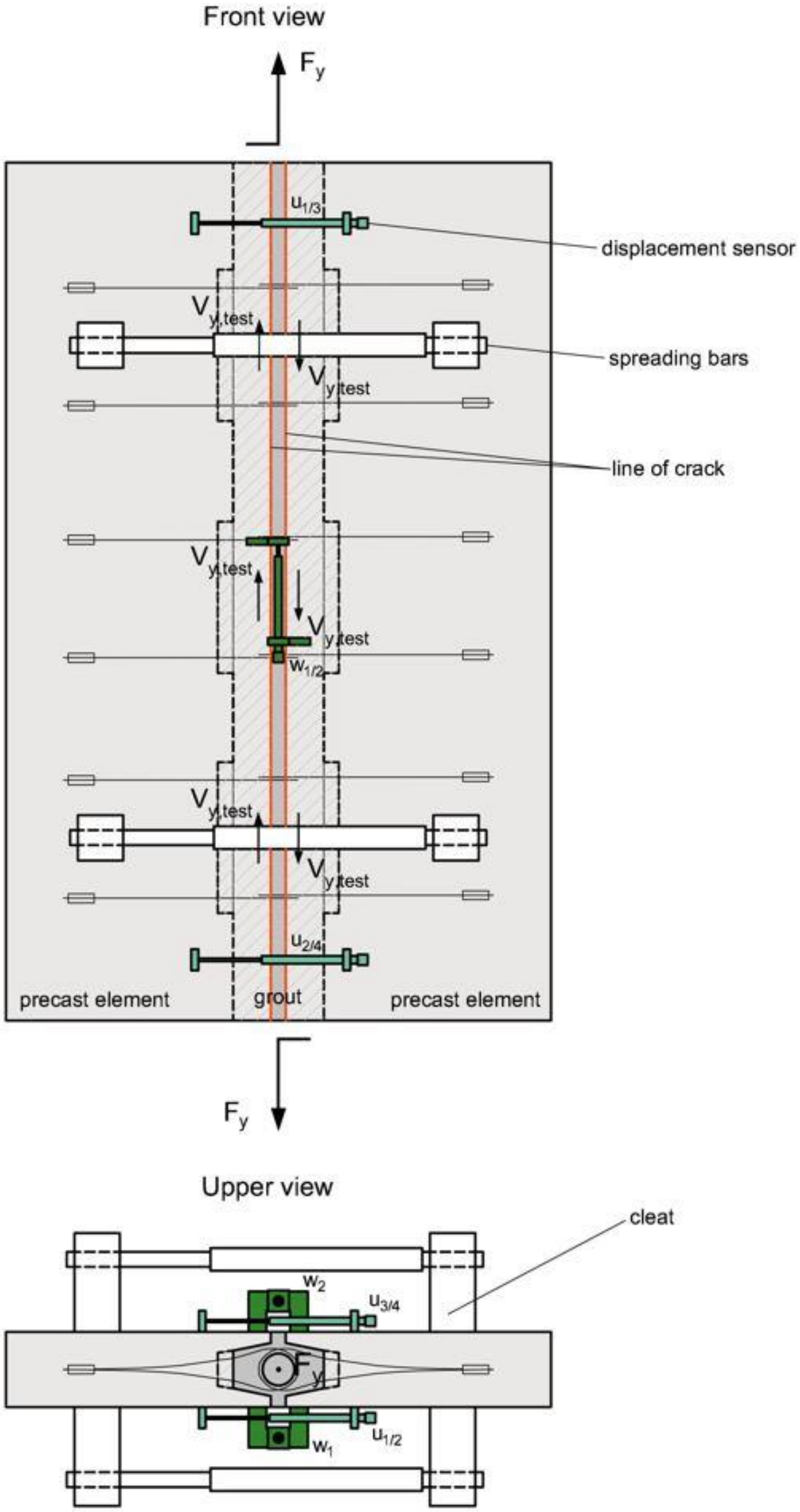


Figure A.6.2.2: Test setup for connections of two precast concrete elements

A.6.3 Determination of load levels for cyclic loading

Before carrying out the tests, the load level of cyclic loading ($F_{cyc,min,Vy}$; $F_{cyc,max,Vy}$) shall be determined.

Load levels of cyclic loading per box:

$$F_{cyc,min,Vy} = 0{,}15 \cdot V_{cd,y} \quad \text{(A.6.3.1)}$$

$$F_{cyc,max,Vy} = 1{,}20 \cdot V_{cd,y} \quad \text{(A.6.3.2)}$$

The load level shall be derived on the basis of the maximum failure loads $V_{u,y}$ of at least 3 initial static tests.
The initial tests shall be performed with the test setup according to A.6.2. The test procedure contains shear tests until failure of test member or until immediate or steady load decline.

$$V_{cd,y} = \frac{V_{u,y}}{2{,}8} \quad \text{(A.6.3.3)}$$

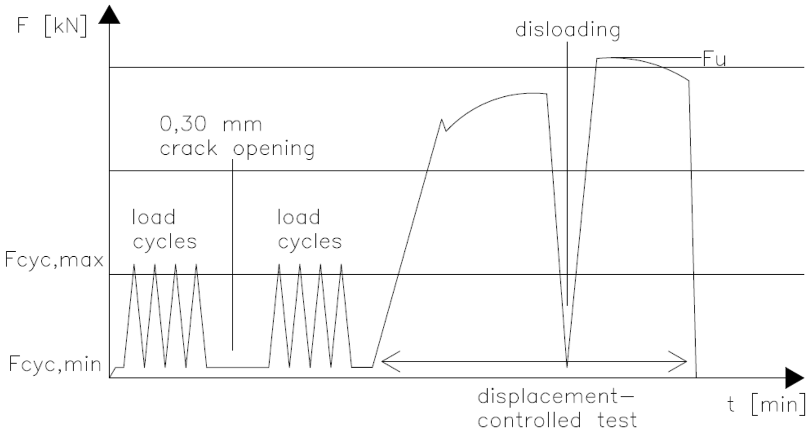
If pre-tests are performed and the intended characteristic resistance value $V_{Rk,y}$ is known, the load level can be determined as follows (without additional initial static tests).

$$V_{cd} = \frac{V_{Rk,y}}{2{,}1} \quad \text{(A.6.3.4)}$$

A.6.4 Test procedure

1. starting test by applying initial load: $F_{cyc,min,Vy}$
2. reset of measuring equipment
3. 25 load-cycles (2 cycles/min, sinusoidal or triangular load application):
(minimum load level: $F_{cyc,min,Vy}$ / maximum load level: $F_{cyc,max,Vy}$)
4. unloading to minimum load: $F_{cyc,min,Vy}$ (time for unloading 10 sec. ±10%)
5. setting joint expansion $\Delta u_{1/2/3/4,z}$ = 0,30 mm by tightening spreading bars (initiating crack in joint)
6. 25 load-cycles (2 cycles/min, sinusoidal or triangular load application):
(minimum load level: $F_{cyc,min,Vy}$ / maximum load level: $F_{cyc,max,Vy}$)
7. unloading to minimum load: $F_{cyc,min,Vy}$ (time for unloading 10 sec. ±10%)
8. displacement-controlled loading (1 mm/min) until stabilization of load (constant load by increasing displacement) or joint expansion $\Delta u_{1/2/3/4,z}$ = 2 mm
9. unloading to minimum load: $F_{cyc,min,Vy}$ (time for unloading 10 sec. ±10%)
10. remove joint expansion by opening spreading bars
11. remove measuring equipment (displacement sensors u)
12. displacement-controlled reloading (3 mm/min) until:
failure of test member / immediate or steady load decline / maximum displacement of test machine cylinder / displacement of $\Delta w_{1/2,y}$ = 40 mm

<u>Load history</u>



A.7 General assessment of test results

A.7.1 Test records

The test records shall include at least the following items:

- description and sketch of the wire loop system,
- description and sketch of the test members based on Figures given in clauses A.4.2, A.5.2, A.6.2 including dimensions, materials and the arrangement of the boxes and the reinforcement,
- description and sketch of the test equipment, test machine properties, arrangement of the test member and the measuring elements based on Figures given in clauses A.4.2, A.5.2, A.6.2,
- concrete properties (mixture, strength and stiffness),
- joint casting grout properties according to clause 1.2.1.2,
- description of the manufacturing, concreting of the test member,
- test member behaviour during loading, load alternation, at maximum load,
- documentation of the load history, displacements, occurrences of cracks, local and global failures.

A.7.2 Evaluation of the test results

For the evaluation of the test results the following measure values shall be recorded:

- tension test
  load values at joint expansion $\Delta u_{1/2/3/4,z}$ = 0,1/0,2/0,3/0,4 mm
- shear test 0° (in longitudinal axis of joint)
  load values at joint expansion $\Delta u_{1/2/3/4,z}$ = 0,1/0,2/0,3/0,4 mm
  load values at joint expansion $\Delta u_{1/2/3/4,z}$ = 0,4/0,5/0,6/0,7 mm in case of u_0 = 0,3 mm initial joint expansion
  load values at displacement $\Delta w_{1/2,x/y}$ = 1,0/1,5/2,0 mm
- shear test 90° (perpendicular to the longitudinal axis of joint)
  load values at joint expansion $\Delta u_{1/2/3/4,z}$ = 0,1/0,2/0,3/0,4 mm
  load values at joint expansion $\Delta u_{1/2/3/4,z}$ = 0,6/0,7/0,8/0,9 mm in case of u_0 = 0,5 mm initial joint expansion
  load values at displacement $\Delta w_{1/2,x/y}$ = 1,0/1,5/2,0 mm

A.7.3 Conversion of failure loads

The conversion of failure loads in case of concrete failure for connections with in-situ concrete elements is done according to equation A.7.3.1:

$$F_{u,c} = F_{u,test} \cdot \sqrt{\frac{f_{ck}}{f_{cm,test}}} \qquad \text{with } 0{,}8 \leq \frac{f_{ck}}{f_{cm,test}} \leq 1{,}25 \qquad \text{(A.7.3.1)}$$

The conversion of failure loads in case of concrete failure for connections of two precast concrete elements (precast element, joint casting grout) is done according to equation A.7.3.2:

$$F_{u,c} = F_{u,test} \cdot min.(\sqrt{\frac{f_{ck}}{f_{cm,test}}} \; or \; \sqrt{\frac{f_{ck,cube}}{f_{cm,cube,test}}} \; ; \; \sqrt{\frac{f_{ck,cube,g}}{f_{cm,cube,test,g}}} \; or \; \sqrt{\frac{f_{ck,prism,g}}{f_{cm,prism,test,g}}}) \qquad \text{(A.7.3.2)}$$

$$with\text{:} \;\; 0{,}8 \leq \frac{f_{ck}}{f_{cm,test}} \; ; \; \frac{f_{ck,cube}}{f_{cm,cube,test}} \; ; \; \frac{f_{ck,cube,g}}{f_{cm,cube,test,g}} \; ; \; \frac{f_{ck,prism,g}}{f_{cm,prism,test,g}} \leq 1{,}25$$

A.7.4 5%-fractiles

The 5 %-fractile of the ultimate loads measured in a test series shall be calculated according to statistical procedures for a confidence level of 75 %:

$$F_{u,5\%} = F_{u,c,m} \cdot (1 - k_n \cdot cv_F) \qquad \text{(A.7.4.1)}$$

$$with\ cv_F \geq 10\%$$

Note: The statistical factors k_n are defined in EN 1990 [4], Table D.1, for an unknown coefficient of variation