EOTA®

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DOWELS FOR STRUCTURAL JOINTS UNDER STATIC AND QUASI-STATIC LOADING

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).

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1 SCOPE OF THE EAD

1.1 Description of the construction product

This EAD covers dowels for structural joints between structural concrete elements. The dowels consist of two main components:

- One or two bar(s) of rectangular, circular or elongated (elliptical -shaped) cross section
- One or two sleeve(s) of rectangular, circular or elongated (elliptical -shaped) cross section into which the bar(s) is (are) inserted

Dowels covered by this EAD meet the conditions for dowel type and dowel size as specified in 1.3.

Furthermore, depending on the dowel family, additional anchor elements and/or ancillary reinforcement are foreseen.

Fire protective products (insulation slabs, intumescent products, sealants, etc.) used for improving fire resistance could be components of the dowel or not, depending on the manufacturer's decision.

The dowels are distinguished in the following families:

(i) Dowels with a single bar and a sleeve without anchor plate and ancillary reinforcement (see figure 1.1a and 1.1b)

(ii) Dowels with a single bar and a sleeve with anchor plate and ancillary reinforcement (see figure 1.2a and 1.2b)

(iii) Dowels with a single bar and a sleeve with an anchor body (see figure 1.3)

(iv) Dowels with two bars and sleeves with an anchor body (see figure 1.4)

Within a family the following material types of bars and sleeves are possible:

- Bars and sleeves made of stainless steel or galvanized steel according to table 1.1
- Bars made of stainless steel or galvanized steel according to table 1.1 and sleeves made of plastic

Within a family the following degrees of freedom of movement are possible:

- Dowels which are able to allow axial movement only (see figure 1.1a and 1.2a)
- Dowels which are able to allow axial and lateral transverse movement (see figure 1.1b and 1.2b)

Table 1.1 Steel grades and material number

Steel grade	Material number
Galvanized steel	acc. to EN 1993-1-1[1], table 3.1 or EN ISO 683-1
Stainless steel	acc. to EN 1993-1-4, table 2.1

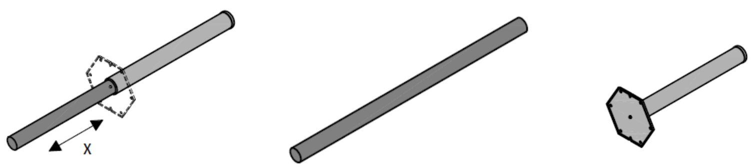

Figure 1.1a: Example for a dowel with a single bar and a sleeve without anchor plate and ancillary reinforcement and allowing axial movement only

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

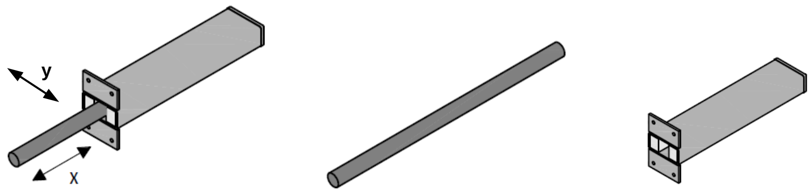

Figure 1.1b: Example for a dowel with a single bar and a sleeve without anchor plate and ancillary reinforcement and allowing axial and lateral transverse movement

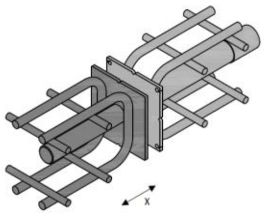

Figure 1.2a: Examples for a dowel with a single bar and a sleeve with anchor plate and ancillary reinforcement and allowing axial movement only

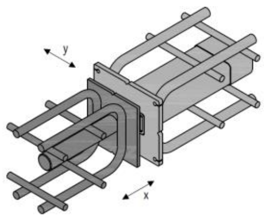

Figure 1.2b: Example for a dowel with a single bar and a sleeve with anchor plate and ancillary reinforcement and allowing axial and lateral transverse movement

Figure 1.3: Examples for a dowel with a single bar and a sleeve with an anchor body and allowing axial movement only

Figure 1.4: Example for a dowel with two bars and sleeves and allowing axial movement only

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

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 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.

1.2 Information on the intended use of the construction product

1.2.1 Intended use

This EAD covers the following specifications of the intended use:

- Dowels that transmit shear loads across an expansion joint between structural concrete elements made of reinforced normal weight concrete of strength class C20/25 to C50/60 according to EN 206
- Concrete elements with a minimum slab thickness of h = max (6 d_{bar}; 150 mm). For rectangular or elongated shaped bars the greater measure in direction of the load shall be taken as $d_{bar.}$
- Concrete elements that are subjected to static and quasi-static actions
- Concrete elements that are subjected to fire exposure
- Concrete elements that are designed according to EN 1992-1-1 or EN 1992-1-2 and EOTA TR 065
- Dowels with bars made of galvanized steel and sleeves made of galvanized steel or plastic that are subjected to dry internal environment (category C1 acc. to EN ISO 12944-2, table 1) only
- Dowels with bars made of stainless steel and sleeves made of stainless steel or plastic are subjected to environmental conditions acc. to EN 1993-1-4, table A.1 dependent on the corrosion resistant class (CRC - depending on the on the material number, see EN 1993-1-4, table A.3)

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 product for the intended use of 50 years when installed in the works (provided that the product 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.

Note: working life of fire protective products is often less than the foreseen working life of the dowel (50 years). Therefore, the working life of the dowel could be revised when fire protective products are used.

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2 The real working life of a product incorporated in a specific works depends on the environmental conditions to which that works is subjected, 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.

1.3 Specific terms used in this EAD (if necessary, in addition to the definitions in CPR, Art 2)

1.3.1 Terminology

Dowel

Structural element which consists of one or several bar(s) and one or several sleeve(s). The bar(s) and sleeve(s) form a pair and (depending on the dowel family) can be supplemented by additional anchor elements and/or ancillary reinforcement.

Bar

A steel rod or tube or hollow cross section rod (rectangular, circular or elongated (elliptical -shaped) cross section) serving to transmit shear forces over a joint between connected structural elements made of concrete.

Sleeve

Hollow element made of steel or plastic with a rectangular, circular or elongated (elliptical -shaped) cross section housing the bar on the side of the joint allowing axial movement only or axial and lateral transverse movement.

Dowel family

"Family" means a group of dowels in which the following characteristics stay the same:

- the number of bars
- the existence of an anchor plate with integrated ancillary reinforcement
- the existence of an anchor body

Dowel type

“Type” means that the dowel is basically characterised by

- the dowel family,
- the type and
- the degrees of freedom of movement.

This means that within one dowel type the dowel family, the type and the degrees of freedom of movement stay the same. Furthermore, the following characteristics stay in principle the same:

- the shape and proportion of the cross section of the bar(s) and the sleeve(s),
- the shape and proportion of the anchor plate,
- the shape and proportion of the anchor body and
- the shape and proportion of the ancillary reinforcement.

Dowel size

"Size" means that within one dowel type the following characteristics are scalable:

- the cross section of the bar(s) and the sleeve(s)
- the length of the bar(s) and the sleeve(s)
- the cross section of the anchor plate,
- the cross section of the anchor body and
- the cross section of the ancillary reinforcement.

Ancillary reinforcement

Reinforcing bars added to the dowel at the time of its fabrication in factory and mechanically connected to it (for example, by welding).

Supplementary reinforcement

Reinforcement placed in the elements to be connected at the time of dowel installation.

Slab edge reinforcement

Reinforcement (stirrups or U-bars) running along the edge of a slab to distribute the local stresses from the dowel into the slab.

Point of restraint;

Distance from the surface of the slab to the theoretical point of restraint of the dowel located inside the slab and along the dowel. This distance is used in the calculations of the resistance to steel failure of the dowel.

$X_{1,1}$;

Specific product factor not influenced by lateral movements used to calculate the force transmitted into the concrete by the stirrups arranged to the left and the right of the dowel, taking into account the part which can be allocated to the hook (bent pin at the top and bottom faces of the slab). This factor is obtained from the tests and is specific for each product.

$X_{1,2}$;

Specific product factor influenced by lateral movements used to calculate the force transmitted into the concrete by the stirrups arranged to the left and the right of the dowel, taking into account the part which can be allocated to the hook (bent pin at the top and bottom faces of the slab). This factor is obtained from the tests and is specific for each product.

X_2;

Specific product factor used to calculate the characteristic resistance to concrete edge failure of the slab at SLS. This factor is obtained from the tests and is specific for each product

X_3;

Specific product factor used to calculate the characteristic resistance to steel failure at SLS influenced by lateral movements. This factor is obtained from the tests and is specific for each product.

k_1;

Factor that taking into account the influence of concrete strength.

B_{spec};

Horizontal distance between starting points of the cracks taken from the test. It is assigned as the width of the theoretical concrete cone.

H_{spec};

Height of the starting points of the cracks taken from the tests. It is assigned as the height of the theoretical concrete cone.

2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

2.1 Essential characteristics of the product

Table 2.1 shows how the performance of the product is assessed in relation to the essential characteristics.

Table 2.1 essential characteristic 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	Resistance to steel failure at ULS	2.2.2	e [mm]
2	Resistance to concrete edge failure at ULS <u>not</u> influenced by lateral movements of the dowel	2.2.3	$X_{1,1}$ [-] $B_{spec,1}$ [mm] $H_{spec,1}$ [mm] $k_{1,1}$ [-]
3	Resistance to concrete edge failure at ULS influenced by lateral movements of the dowel	2.2.4	$X_{1,2}$ [-] $B_{spec,2}$ [mm] $H_{spec,2}$ [mm] $k_{1,2}$ [-]
4	Resistance to concrete edge failure at SLS	2.2.5	X_2 [-]
5	Resistance to steel failure at SLS	.2.2.6	X_3 [-]
Basic Works Requirement 2: Safety in case of fire			
6	Reaction to fire	2.2.7	Class
7	Resistance to fire	2.2.8	Class

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

2.2.1 General

Chapter 2.2 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.

2.2.2 Resistance to steel failure at ULS

For verification of steel failure at ULS according to EOTA TR 065 the point of restraint e [mm] is needed.
The point of restraint may be taken as $e = 0,5\ d_{bar}$ behind the concrete surface without testing.
Factors e of $0 \leq e < 0,5\ d_{bar}$ shall be assessed acc. to table 2.2.

Table 2.2 Resistance to steel failure at ULS

No	Characteristic	Number of samples	Test method and evaluation	Expression of performance
1	Resistance to steel failure	1 smallest size 1 intermediate size 1 largest size	Annex A.2	e [mm]

2.2.3 Resistance to concrete edge failure at ULS <u>not</u> influenced by lateral movements of the dowel

For verification of concrete edge failure at ULS <u>not</u> influenced by lateral movements according to EOTA TR 065 the values $X_{1,1}$ [-], $k_{1,1}$ [-], $B_{spec,1}$ [mm] and $H_{spec,1}$ [mm] are needed.

These values shall be assessed acc. to table 2.3.

Table 2.3 Resistance to concrete edge failure at ULS <u>not</u> influenced by lateral movements of the dowel

No	Characteristic	Number of samples [1)]	Test method and evaluation	Expression of performance
1	Resistance at minimum concrete strength class [2)]	3 smallest size 3 intermediate size 3 largest size	Annex A.3	$X_{1,1}$ [-] $B_{spec,1}$ [mm] $H_{spec,1}$ [mm]
2	Increasing factor for concrete strength classes higher than the minimum concrete strength class	1 smallest size 1 intermediate size 1 largest size	Annex A.3	$0 \leq k_{1,1} \leq 0,5$ [3)]

1) The number of samples is valid for one dowel type only

2) Minimum concrete strength class according to the manufacturer's technical file in the range of C20/25 to C50/60. If this information is not included, the minimum concrete strength class is C20/25.

3) For $k_{1,1} = 0$ no tests are necessary

2.2.4 Resistance to concrete edge failure at ULS influenced by lateral movements of the dowel

For verification of concrete edge failure at ULS influenced by lateral movements according to EOTA TR 065 the factors $X_{1,2}$ [-], $k_{1,2}$ [-], $B_{spec,2}$ [mm] and $H_{spec,2}$ [mm] are needed.

These factors shall be assessed acc. to table 2.4.

Table 2.4 Resistance to concrete edge failure at ULS influenced by lateral movements of the dowel

No	Characteristic	Number of samples [1)]	Test method and evaluation	Expression of performance
1	Resistance at minimum concrete strength class [2)]	3 smallest size 3 intermediate size 3 largest size	Annex A.3	$X_{1,2}$ [-] $B_{spec,2}$ [mm] $H_{spec,2}$ [mm]
2	Increasing factor for concrete strength classes higher than the minimum concrete strength class	1 smallest size 1 intermediate size 1 largest size	Annex A.3	$0 \leq k_{1,2} \leq 0,5$ [3)]

1) The number of samples is valid for one dowel type only

2) Minimum concrete strength class according to the manufacturer's technical file in the range of C20/25 to C50/60. If this information is not included, the minimum concrete strength class is C20/25.

3) For $k_{1,2} = 0$ no tests are necessary

2.2.5 Resistance to concrete edge failure at SLS

For verification of concrete edge failure at SLS according to EOTA TR 065 the factor X_2 [-] is needed.
This factor shall be assessed acc. to table 2.5.

Table 2.5 Resistance to concrete edge failure at SLS

No	Characteristic	Number of samples	Test method and evaluation	Expression of performance
1	Resistance to concrete edge failure at SLS	- 1)	Annex A.4	X_2 [-]

1) No tests are required; the factor X_2 must be determined from the tests according to 2.2.2 and 2.2.3.

2.2.6 Resistance to steel failure at SLS

For verification of steel failure at SLS according to EOTA TR 065 the factor X_3 [-] is needed.
This factor shall be assessed acc. to table 2.6.

Table 2.6 Resistance to steel failure at SLS

No	Characteristic	Number of samples	Test method and evaluation	Expression of performance
1	Resistance to steel failure at SLS	- 1)	Annex A.5	X_3 [-]

1) No tests are required; the factor X_3 must be determined from the tests according to 2.2.3.

2.2.7 Reaction to fire

Dowels with bars and sleeves made of steel are considered to satisfy the requirements for performance class A1 of the characteristic reaction to fire in accordance with the EC Decision 96/603/EC without the need for testing on the basis of fulfilling the conditions set out in that Decision and its intended use being covered by that Decision.

Therefore, the performance of such dowels is class A1.

For dowels with sleeves made of plastic it is considered that contribution to fire of the sleeve is negligible and need not to be tested. This is due to the fact that the sleeves are almost complete embedded in material of class A1 (concrete) and have only a small visible area on the surface of the concrete element in the field of joints.

Therefore, the ETA shall state that the performance of such dowels is class A1 and shall refer to the fact that the contribution of plastic sleeves to a fire is negligible.

2.2.8 Resistance to fire

The part of the works or assembled system in which the dowel is intended to be incorporated, installed or applied shall be tested, using the test method relevant for the corresponding fire resistance class, in order to be classified according to EN 13501-2.

These tests have to be performed with the most unfavourable joint width, which mainly depends on the fire protective product used, the unprotected dowel length, etc. The behaviour to high temperatures of the dowel material (stainless or galvanized steel) and of the sleeve material (plastic or steel) has to be taken into account when defining the worst case for testing.

The specification of the fire protective product used (insulation slabs, intumescent products, sealants, etc.) shall be given in the ETA by means of, e.g. trade name, main features related to the given performance, etc.

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 products covered by this EAD the applicable European legal act is Commission Decision 2003/639/EC(EU).

The system is 2+ for any use except for uses subject to regulations on reaction to fire performance.

Due to the specific provisions given in clause 2.2.7 only system 4 is relevant with regard to reaction to fire for products covered by this EAD.

3.2 Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of the product in the procedure of assessment and verification of constancy of performance are laid down in Table 3.1.

Table 3.1 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	raw material – mechanical characteristics	3.4.1	[1]	3 (all types)	each batch
2	Dowel - geometrical characteristics	3.4.2	[1]	3 each size	per 1000 dowels [2]

1) criteria are laid down in the manufacturer's technical file

2) if the production lot is < 1000 pcs, tests shall be performed at least once per production week or per production batch

3.3 Tasks of the notified body

The intervention of the notified body for reaction to fire is not necessary.

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 product are laid down in Table 3.2.

Table 3.2 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	Ascertain that the factory production control with the staff and equipment are suitable to ensure a continuous and orderly manufacturing of the product	3.4.3	3.4.3	[1)]	When starting the production or a new production line
Continuous surveillance, assessment and evaluation of factory production control					
2	Ascertain that the factory production control and the specified manufacturing process are maintained	3.4.4	3.4.4	[1)]	1 per year

[1)] not applicable

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

3.4.1 Control of raw materials by manufacturer

The raw materials shall be subject to control by the manufacturer before acceptance. Check of raw materials shall include control of the inspection documents presented by the supplies of the initial materials (comparison with nominal values).

The manufacturer may only use raw materials with the following verifications:

Bars:	material properties to be proven by an inspection certificate 3.1 according to EN 10204 - Yield strength, Tensile strength, Elongation at break A_5
Sleeves made of steel:	material properties to be proven by an inspection certificate 3.1 according to EN 10204 - Yield strength, Tensile strength, Elongation at break A_5
Sleeves made of plastic:	material properties to be proven by an inspection certificate 3.1 according to EN 10204
Anchor plates:	material properties to be proven by an inspection certificate 3.1 according to EN 10204 - Yield strength, Tensile strength, Elongation at break A_5
Ancillary reinforcement:	material properties to be proven by an inspection certificate 3.1 according to EN 10204 - Yield strength, Tensile strength, Elongation at break A_{gt}

3.4.2 Control of the dowel by manufacturer

Measuring the following dimensions:

Bar	• Diameter • Length • Width • Height
Sleeve	• Diameter • Length • Width • Height • Wall thickness
Anchor body	• Length • Width • Height • Wall thickness
Anchor plate	• Length • Width • Thickness
Welding seams	• Length • Width
All parts	• Visual appearance to ensure freedom from surface breaking defects

Depending on the system, additional dimensions could be relevant and should be checked.

3.4.3 Control in the context of initial inspection by notified body

Check of the measures taken by the manufacturer with regard to personnel, equipment and documentation system in the area of incoming goods and production.

The quality of the personnel, equipment and documentation system shall be appropriate for the controls as indicated in Table 3.1.

In particular the following items shall be appropriately considered

- presence of suitable test equipment
- presence of trained personnel
- the suitability of the factory production control established by the manufacturer
- full implementation of the control plan

3.4.4 Control in the context of continuous surveillance by notified body

Check of the quality of the personnel, equipment and documentation system and of the controls carried out by the manufacturer as indicated in Table 3.1 as well as of the documented results of the controls.

The quality of the personnel, equipment and documentation system shall maintain and the controls carried out by the manufacturer shall follow the control plan as indicated in Table 3.1. Documented results of the controls shall be in line with the criteria laid down in the manufacturer's technical file.

In particular the following items shall be appropriately considered:

– Inspection of factory, of the production of the product and of the facilities for factory production control
– Evaluation of the documents concerning factory production control
– Issuing a report of surveillance

4 REFERENCE DOCUMENTS

EN 1990:2002 + A1:2005 + A1:2005/AC:2010	Eurocode: Basis of structural design
EN 1992-1-1:2004 + AC:2010	Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings
EN 1992-1-2:2004 + AC:2008	Eurocode 2: Design of concrete structures - Part 1-2: General rules – Structural fire design
EN 1993-1-1:2005 + AC:2009	Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings
EN 1993-1-4:2006 + A1:2015	Eurocode 3: Design of steel structures - Part 1-4: General rules - Supplementary rules for stainless steels
EN 206:2013+A1:2016	Concrete - Specification, performance, production and conformity
EN 197-1:2011	Cement - Part 1: Composition, specifications and conformity criteria for common cements
EN 10204:2004	Metallic products - Types of inspection documents
EN 13501-2:2016	Fire classification of construction products and building elements - Part 2: Classification using data from fire resistance tests, excluding ventilation services
EN ISO 683-1:2018	Heat-treatable steels, alloy steels and free-cutting steels – Part 1: Non-alloy steels for quenching and tempering
EN ISO 12944-2:2017	Paints and varnishes - Corrosion protection of steel structures by protective paint systems - Part 2: Classification of environments (ISO 12944-2:2017)
EOTA TR 065: 2019-10-31	Design of Structural Joints with Shear Dowels

ANNEX A TEST METHODS AND ASSESSSMENT OF THE TEST RESULTS FOR RESISTANCE TO CONCRETE EDGE FAILURE AND STEEL FAILURE

A.1 General

Mechanical and geometrical characteristics as well as tolerances of the dowels according to the manufacturer's technical file shall be considered during assessing.

A.2 Steel failure at ULS

A.2.1 Purpose

The aim of the tests with steel failure is to find out the point of restraint expressed as factor e [mm].

A.2.2 Test methods

One test with the smallest, one test with the intermediate and one test with the largest dowel size shall be performed according to Annex B.

All 3 tests shall be performed with the maximum joint width.

The test specimens shall be designed to create steel failure.

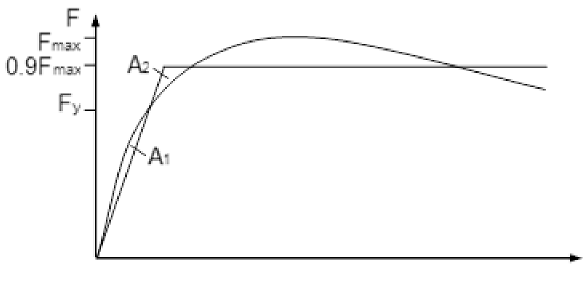
A.2.3 Assessment

The specific product factor e for the point of restraint is determined according to equation A.1 as maximum value of the individual factors e_i.

$$e = \max.\ e_i \qquad (A.1)$$

The individual factors e_i are obtained by comparing the load at point of yielding $F_{y,i}$ determined from tests according to figure A.1 with the theoretical load-bearing capacity $V_{Rk,s,i}$ according to equation A.3. The factor e_i corresponds to the value used to calculate the theoretical load-bearing capacity $V_{Rk,s,i}$ so that the equation A.2 is fulfilled.

$$F_{y,i} / V_{Rk,s,i} \geq 1{,}0 \qquad (A.2)$$



1. Draw a line parallel to the x-axis 10% below the point of maximum load F_{max}.
2. Draw a line from the origin such that the area between this line and the curve A1 and the area between this line, the line parallel to the x-axis and the curve A2 is balanced.
3. The point of yielding is determined by the intersection of the line from the origin and the curve.

Figure A.1 a): Determination of the load at point of yielding $F_{y,i}$

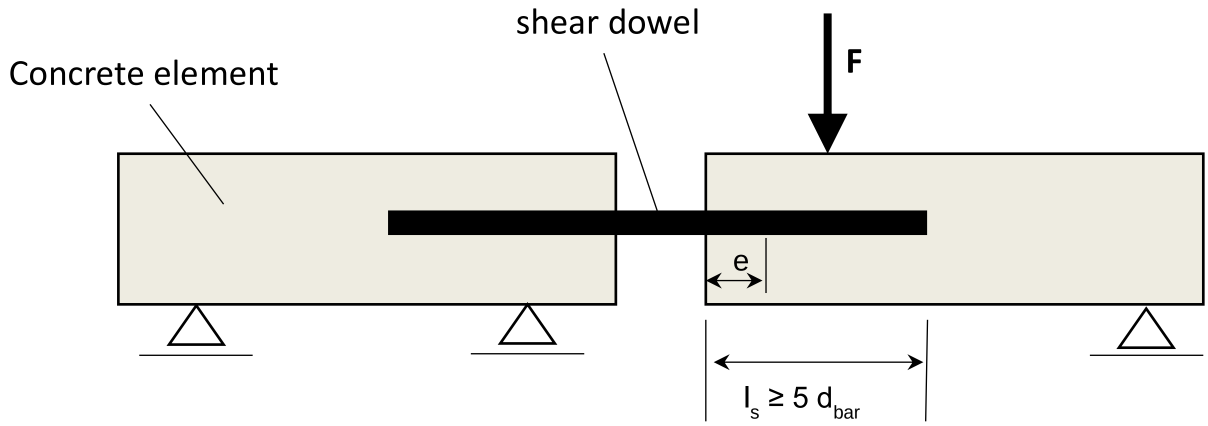


Figure A.1 b): Position of the point of restraint “e”

$$V_{Rk,s,i} = \frac{f_{yk,bar}}{\sqrt{\frac{(t+2e_i)^2}{(4 \cdot W_{pl,bar}^2)} + \frac{3}{A_{s,bar}^2}}} \tag{A.3}$$

with:

$f_{yk,bar}$	=	actual yield strength of the bar used in the test [N/mm²]
t	=	joint width in the test [mm]
e_i	=	factor for the point of restraint adjusted in such way that for the individual test member "i" equation A.2 is fulfilled [mm]
$W_{pl,bar}$	=	plastic section modulus of the bar used in the test [mm³]
$A_{s,bar}$	=	cross-sectional area of the bar used in the test [mm²]

A.3 Concrete edge failure at ULS

A.3.1 Purpose

The aim of the tests with concrete edge failure is to find the location of the starting point(s) of the cracks at failure load. In general, this starting point(s) can be located anywhere between the dowel axis and the outmost point of the anchor body. In Figure A.2 different starting points of the cracks indicated with red dots and the development of the cracks to the concrete edge (dashed lines) are shown. The inclination of the cracks is stipulated to 1:1,5 (≈ 34°). Depending on the starting point of the cracks, different amounts of reinforcement (stirrups) will be activated and are considered in the evaluation according to equations (A.5) and (A.6).

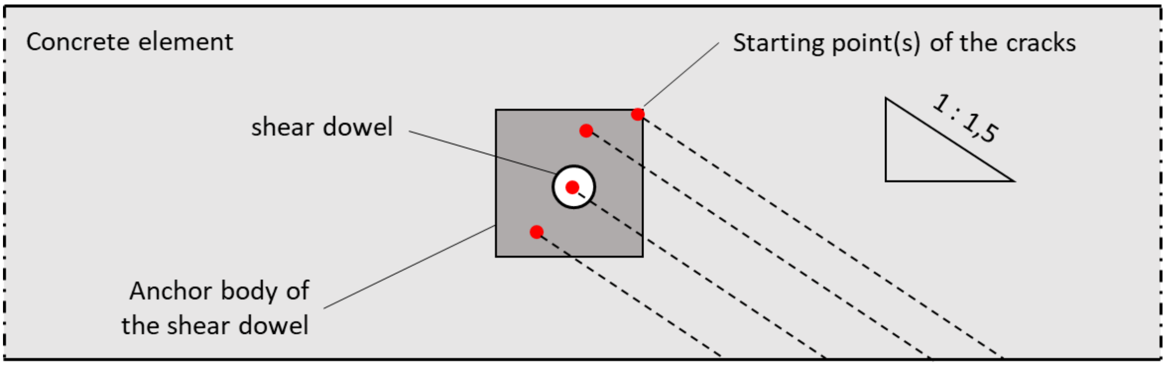


Figure A.2: Example for different starting points of the crack

A.3.2 Test methods

A.3.2.1. General

The tests may be carried out in slabs with shear reinforcement to prevent any premature failure under loading. This shear reinforcement should be placed outside of the predicted area of the concrete cone to avoid any influence on the load bearing capacity.

These tests shall be designed in order to create an edge failure.

At any step of the assessment, the special properties of the stainless steel such as lower Young modulus and hence lower stiffness shall be taken into account (see Annex B).

The test setup and the concrete strength of the test member at time of testing shall comply with the provisions given in Annex B. All tests shall be performed with the minimum slab thickness (depending on the bar diameter d_{bar}).

The joint width could affect the load bearing capacity. Therefore, the tests shall be performed with different joint widths. Within the total number of tests according to section A.3.2.2 or A.3.2.3 at least 2 different joint widths shall be tested (this means that the overall number of tests according to section A.3.2.2 and A.3.2.3 must not be increased). Preferable the minimum and maximum joint width according to the manufacturer's technical file shall be tested. If this information is not included, the minimum joint width is 10 mm and the maximum joint width is 60 mm.

A.3.2.2. Resistance to concrete edge failure at ULS not influenced by lateral movements of the dowel – specific product factor $X_{1,1}$ and $B_{spec,1}$ and $H_{spec,1}$

Per dowel type: 3 tests with the smallest, 3 tests with intermediate and 3 tests with largest dowel size shall be performed.

The tests shall be performed with the minimum concrete strength class according to the manufacturer's technical file in the range of C20/25 to C50/60. If this information is not included, the minimum concrete strength class is C20/25.

Before loading to failure 10 vertical load cycles with an upper limit of $0.50 \cdot V_{Rk,ce,ULS}$ (working load) and a lower limit of $0.10 \cdot 0.5 \cdot V_{Rk,ce,ULS}$ shall be performed. The loading rate shall not exceed 10 % of the working load per minute.

A.3.2.3. Resistance to concrete edge failure at ULS influenced by lateral movements of the dowel – specific product factor $X_{1,2}$ and $B_{spec,2}$ and $H_{spec,2}$

Per dowel type 3 tests with the smallest, 3 tests with the intermediate and 3 tests with the largest dowel size shall be performed.

The tests shall be performed with the minimum concrete strength class according to the manufacturer's technical file in the range of C20/25 to C50/60. If this information is not included, the minimum concrete strength class is C20/25.

Before loading to failure prior lateral transvers movements of 1000 cycles with a displacement equal to 80 % of the total possible movement according to the manufacturer's technical file shall be performed. If this information is not included, the total possible movement is equal to the width of the sleeve (see Figure 1.1.b dimension of the sleeve opening in direction of “y” axis).

The cycling frequency of the side movements should not be higher than 0.5 Hz.

During the cycles the dowels shall be loaded with a vertical sustained load $V_{sust,i}$ according to the manufacturer's technical file. If this information is not included, the vertical sustained load $V_{sust,i}$ is equal to $V_{Rk,s,20,i}$ according to section A.5.3. The vertical sustained load shall be kept constant within a range of +/-10%.

If the concrete members (crack width >0,3mm) or the dowel damaged or failed (yielding of the dowel, sleeve or dowel worn out) during the cycles the test shall be repeated with a reduced vertical sustained load $V_{sust,i}$.

The following parameters shall be documented during the test:

- Horizontal and vertical load
- Horizontal and vertical displacement between both concrete members

The horizontal displacement of the loaded slab must be checked close to the joint and on the opposite edge of the slab to ensure that the rotation of the slab is under control while transverse loading is applied. The following criteria shall be met:

- Joint displacement: No tolerance
- Opposite edge: +/-10% of the horizontal displacement to be applied between both concrete members

After application of the lateral transverse movements the test members shall be loaded to failure. Before loading to failure 10 vertical load cycles with an upper limit of $0.50 \cdot V_{Rk,ce,ULS}$ (working load) and a lower limit of $0.10 \cdot 0.5 \cdot V_{Rk,ce,ULS}$ shall be performed. The loading rate shall not exceed 10 % of the working load per minute.

If the assessment of the specific product factors according to A.3.3 is to be done by a common evaluation of all test results from A.3.2.2 and A.3.2.3, the number of tests may be reduced to 1 test with the smallest, 1 test with the intermediate and 1 test with the largest dowel size. This predicts that the dowel type is the same and only the shape of the sleeve is different. The overall number of tests reduces than to 9 tests according to A.3.2.2 plus 3 tests according to A.3.2.3 that is 12 tests. The specific product factors according to A.3.3 are then valid for both situations.

A.3.2.4. Influence of the concrete compressive strength– specific product factor $k_{1,1}$ and $k_{1,2}$

Per dowel type: 1 test with the smallest, 1 test with the intermediate and 1 test with the largest dowel size shall be performed.

The tests shall be performed with the maximum concrete strength class according to the manufacturer's technical file in the range of C20/25 to C50/60. If this information is not included, the maximum concrete strength class is C50/60.

If $k_{1,1(2)} = 0$ is accepted, no tests are necessary

The test setup and the concrete members shall be equal to test setup and the concrete members used for the tests according to A.3.2.2 or A.3.2.3 respectively.

A.3.3 Assessment

A.3.3.1. Specific product factor $X_{1,1(2)}$

The specific product factor X_1 is determined as follows:

$$X_{1,1(2)} = ((V_{u,test,i} - V_{u,cal,i,2})/V_{u,cal,i,1})_{5\%\text{-Fractile}} \quad \text{(A.4)}$$

with

$V_{u,test,i}$ = failure load obtained from the tests according to section A.3.2.2 or A.3.2.3 for the individual test member "i" used in the test

$V_{u,cal,i,1}$ = failure load calculated according to equation A.5 for the test member "i" used in the respective test

$V_{u,cal,i,2}$ = failure load calculated according to equation A.6 for the test member "i" used in the respective test

$$V_{u,cal,i,1} = \sum \psi_i\, A_s\, f_{yk}\, (f_{cm,test,i}/f_{ck,nom})^{0,5} \quad \text{(A.5)}$$

$$V_{u,cal,i,2} = \pi \cdot d_s \cdot \sum l'_{1,i} \cdot 2{,}25 \cdot 0{,}3 \cdot (f_{cm,test,i} - 8\text{ MPa})^{2/3} \quad \text{(A.6)}$$

with

ψ_i = $1 - 0{,}2 \cdot (l_{c,i} / c_1)$

$l_{c,i}$ and c_1 according to Fig. A.3

Note: Factor ψ_i is taking into account the lateral distance of the stirrups from the dowel

A_s = cross section area of the stirrup

f_{yk} = characteristic yield strength of the stirrup

$l'_{1,i}$ = $l_{1,i} - l_{1,min}$

$l_{1,i}$ acc. to Fig. A.3

$l_{1,min} = d_s + 0{,}5\, d_b \geq 4d_s$

$f_{cm,test,i}$ = mean concrete compressive strength of the test member "i" used in the test

$f_{ck,nom}$ = characteristic concrete compressive strength according to the minimum concrete strength class according to the manufacturer's technical file in the range of C20/25 to C50/60. If this information is not included, the minimum concrete strength class is C20/25.

$((V_{u,test,i} - V_{u,cal,i,2})/V_{u,cal,i})_{5\%\text{-Fractile}}$ = 5%-fractile of the ratio $(V_{u,test,i} - V_{u,cal,i,2})/V_{u,cal,i}$ for a confidence level of 75 %. For determination of the 5%-fractile a normal or log-normal distribution and a known standard deviation of the population shall be assumed:

$$((V_{u,test,i} - V_{u,cal,i,2})/V_{u,cal,i,1})_{5\%\text{-Fractile}} = (V_{u,test,i} - V_{u,cal,i,2})/V_{u,cal,i,1})_m\, (1 - k_n \cdot COV) \quad \text{(A.7)}$$

with

COV = coefficient of variation taken from the tests, COV ≥ 10%

k_n = fractile factor according to table A.1 or according to EN 1990, Table D.1 (Note: EN1990 Table D.1 allows also to use a log-normal distribution)

Table A.1 Values k_n for characteristic values (5%-fractile)

n	1	2	3	4	5	6	8	10	20	30	∞
COV known	2,31	2,01	1,89	1,83	1,80	1,77	1,74	1,72	1,68	1,67	1,64

A.3.3.2. Specific product factors $B_{spec,1(2)}$ and $H_{spec,1(2)}$

The specific product factors $B_{spec,1(2)}$ and $H_{spec,1(2)}$ shall be taken from the tests according to section A.3.2.2 or A.3.2.3 by evaluation of the cracking process (see figure A.3).

A.3.3.3. Specific product factor $k_{1,1(2)}$ considering influence of concrete strength

For each individual test member the value $k_{1,1(2),i}$ shall be determined by using the following equation:

$$k_{1,1(2),i} = \frac{\ln \dfrac{V_{u,test,i,fck,max} - V_{u,cal,i,2}}{\sum \psi_i \cdot A_s \cdot f_{yk}}}{\ln \dfrac{f_{cm,test,i,fck,max}}{f_{ck,nom}}} \qquad \text{(A.8)}$$

$V_{u,test,i,fck,max}$ = failure load obtained from the tests according to section A.3.2.2 or A.3.2.3 for the individual concrete slab "i" with a concrete compressive strength according to the maximum concrete strength class according to the manufacturer's technical file in the range of C20/25 to C50/60. If this information is not included, the maximum concrete strength class is C50/60.

$V_{u,cal,i,2}$ = failure load calculated according to equation A.6 with $f_{cm,test,i,fck,max}$ of the test member "i" used in the test

$f_{cm,test,i,fck,max}$ = mean concrete compressive strength of the test member "i" used in the test

$f_{ck,nom}$ = characteristic concrete compressive strength according to the minimum concrete strength class according to the manufacturer's technical file in the range of C20/25 to C50/60. If this information is not included, the minimum concrete strength class is C20/25.

The specific product factor $k_{1,1(2)}$ is determined as mean value of the individual values $k_{1,1(2),i}$:

$$k_{1,1(2)} = \text{mean}\,(k_{1,1(2),i};\ k_{1,1(2),i};\ k_{1,1(2),i}) \leq 0{,}5 \qquad \text{(A.9)}$$

A.4 Concrete edge failure at SLS

A.4.1 Purpose

The aim is to determine the load at which starting of crack appears.

A.4.2 Test methods

No tests are required. The factor X_2 will be determined from the tests according to A.3.2.2 and A.3.2.3.

A.4.3 Assessment

The specific product factor X_2 is determined as follow:

$$X_2 = (V_{s,test,i}/V_{u,test,i})_{5\%\text{-Fractile}} \quad (A.10)$$

with

$V_{s,test,i}$ = mean load at which the crack width is > 0,3 mm obtained from the tests according to section A.3.2 for the individual test member "i" used in the test

$V_{u,test,i}$ = failure load obtained from the tests according to section A.3.2 for the individual test member "i" used in the test

$(V_{s,test,i}/V_{u,test,i})_{5\%\text{-Fractile}}$ = 5%-fractile of the ratio $V_{s,test,i}/V_{u,test,i}$ for a confidence level of 75 %. For determination of the 5%-fractile a normal or log-normal distribution and a known standard deviation of the population shall be assumed:

$$(V_{s,test,i}/V_{u,test,i})_{5\%\text{-Fractile}} = (V_{s,test,i}/V_{u,test,i})_m \, (1 - k_n \cdot COV) \quad (A.11)$$

with

COV = coefficient of variation taken from the tests, COV ≥ 10%

k_n = fractile factor according to table A.1 or according to EN 1990, Table D.1 (Note: EN1990 Table D.1 allows also to use a log-normal distribution)

A.5 Steel failure at SLS

A.5.1 Purpose

The aim is to determine the load at which no damage of the dowel or concrete occurs during lateral movements of the dowel.

A.5.2 Test methods

No tests are required. The factor X_3 will be determined from the tests according to A.3.2.3.

A.5.3 Assessment

The specific product factor X_3 is determined as follow:

$$X_3 = \min (V_{sust,i}/V_{Rk,s,20,i}) \quad (A.12)$$

with

$V_{sust,i}$ = vertical sustained load $V_{sust,i}$ applied in the tests according to A.3.2.3 where no damage or failure of the concrete member or the dowel occur for the individual test member "i" used in the test

$V_{Rk,s,20,i}$ = characteristic resistance to steel failure of the dowel according to equation A.3 with 20 mm joint width (t = 20 mm) for the individual test member "i" used in the test

min $(V_{sust,i}/V_{Rk,s,20,i})$ = minimum value of the individual ratios of $V_{sust,i}/V_{Rk,s,20,i}$.

A.6 Abbreviations

In this annex the following abbreviations are used. For further definitions see also figure A.3.

$V_{cal,1}$ = force transmitted into the concrete by the stirrups arranged to the left and right of the dowel, only taking into account the part which can be allocated to the hook (bent pin at the top and bottom faces of the slab)

$V_{cal,2}$ = bonding action along the straight part of the stirrup between top and bottom faces of the slab

$A_{s,bar}$ = cross section area of the bar

A_s = cross section area of the stirrup

$f_{yk,bar}$ = characteristic yield strength of the bar

f_{yk} = characteristic yield strength of the stirrup

$f_{cm,test,i}$ = mean concrete compressive strength of the individual test member i

$f_{ck,nom}$ characteristic concrete compressive strength according to the minimum concrete strength class according to the manufacturer's technical file in the range of C20/25 to C50/60. If this information is not included, the minimum concrete strength class is C20/25.

ψ_i = factor taking account the distance $l_{c,i}$ of the considered stirrup to the dowel

$l_{c,i}$ = distance of the considered stirrup to the dowel

c_1 = distance between bar and faces of the slab in load direction, see Fig. A2 (for dowels with multiple bars the smallest value of the individual distances between bar and faces of the slab in load direction is decisive)

k_1 = influence of the concrete strength

$l'_{1,i}$ = effective anchorage length of the considered stirrup

$l_{1,i}$ = anchorage length of the considered stirrup

$l_{1,min}$ = $(0{,}5 \cdot d_b + d_s)$

d_b = mandrel diameter of the stirrup

d_s = diameter of the stirrup

b_{cone} = $B_{spec,1(2)} + 2 \text{ x}(H_{spec,1(2)} / \tan \alpha)$ with $1/\tan \alpha = 1{,}5$

$B_{spec,1(2)}$ = distance between starting points of the cracks taken from test

$H_{spec,1(2)}$ = height of the starting point of the crack taken from test (height of the concrete cone)

d_{bar} = diameter of the dowel. For rectangular or elongated shaped bars the greater measure in direction of the load shall be taken as d_{bar}.

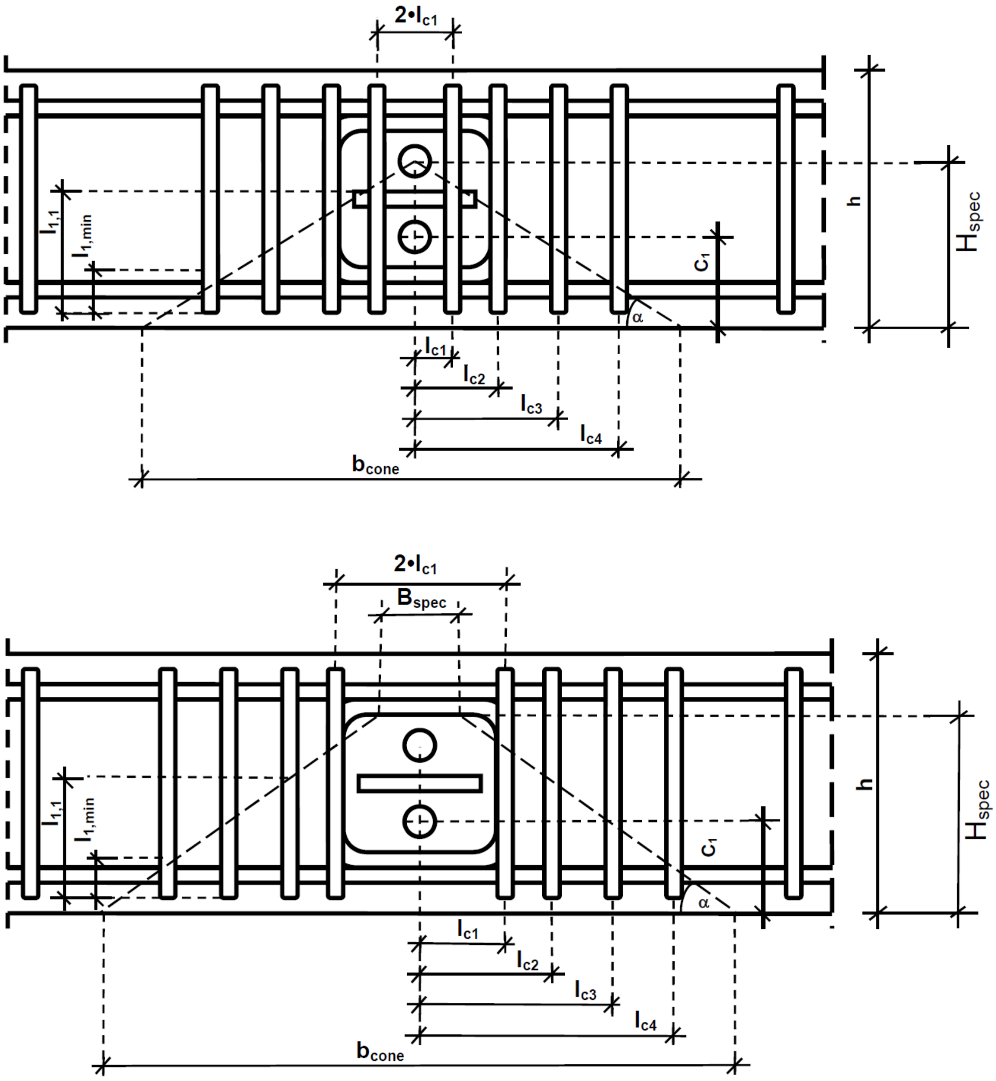


Figure A.3 Definition of the relevant parameters

ANNEX B DETAILS OF TESTS

B.1 General

For the materials use in the tests the following information shall be provided:

- material strength of galvanized steel in accordance with EN 1993-1-1, Table 3.1 or EN ISO 683-1 (i.e. stress-strain curve, materials strain at yielding and failure),
- material strength of stainless steel in accordance with EN 1993-1-4, Table 2.1 (i.e. stress-strain curve, materials strain at yielding and failure),
- concrete in accordance with EN 206:2015 and Annex B.4

B.2 Testing arrangement

The tests are to be performed on concrete members with a minimum thickness of max (6 d_{bar}, 150 mm). The overall dimensions should follow Figure B1.

The reinforced concrete members should consist of two separate reinforced concrete slabs linked by the dowel.

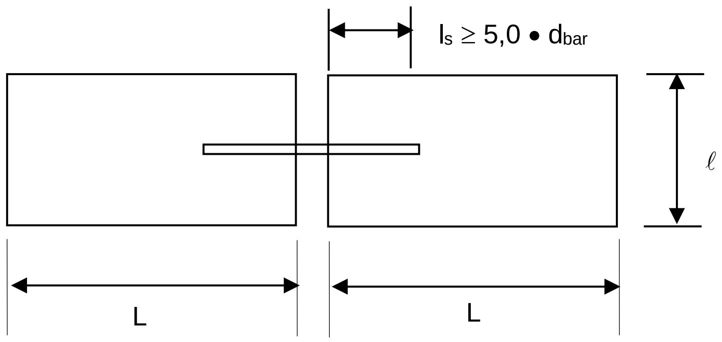
Note: For improvement of the economy of the tests it could be an option to prescribe a different reinforcement in each slab, so the concrete edge failure appears only in the weakest slab (to be called, for instance, the supported slab), whilst the other slab would not be affected (to be called, for instance, the supporting slab). Alternatively, the tested slab could be supported in a strong enough concrete wall by means of the dowel connector.

The parameters to be taken into account are as follows:

- the type of dowel
- the width of the joint crossed by the dowel,
- the test value of the compression strength of the concrete,
- the slab thickness,
- the type of local concrete reinforcement around the dowel area.

The tests shall be performed with an amount of stirrup reinforcement which allows a mean load-bearing capacity related to concrete edge failure. The first both stirrups shall be located as shown in figure B.3

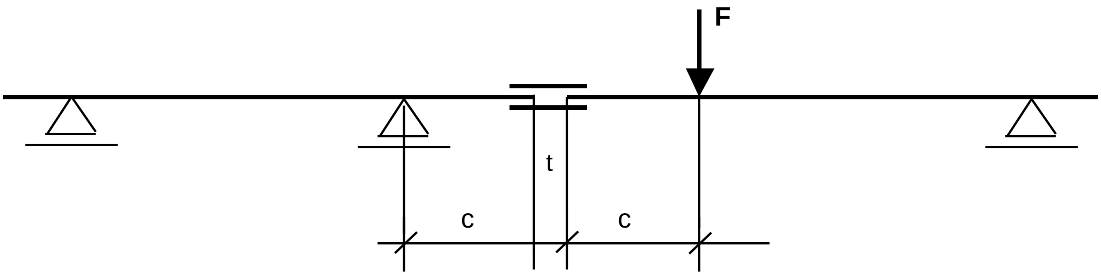
The tests are performed by loading the dowel in shear.



$L \geq 4\ l_s \geq 26\ d_{bar}$ where d_{bar} is the diameter (or the transverse dimension) of the dowel in the direction of shear force

$\ell \geq 70$ cm (or width of the predicted cone)

Figure B.1: Principle scheme of the test setup - plan view of the test slabs



c ≥ 35 cm (or half of the predicted cone width)

Figure B.2: Principle scheme of the test setup - side view of the test slabs

The reinforcement of the test slab shall consist of an edge strengthened beam comprising longitudinal and transverse reinforcement.

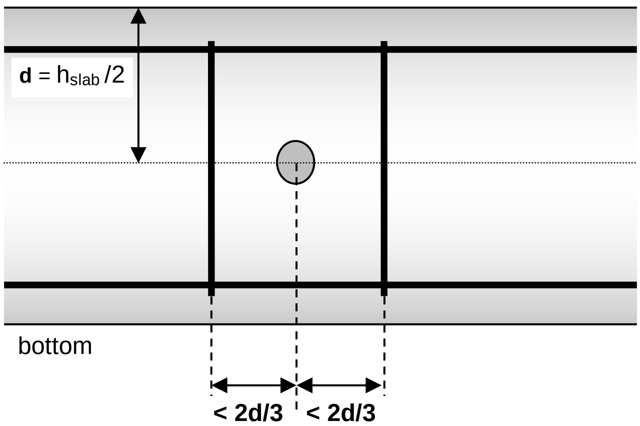


Figure B.3: View of stirrup reinforcement framing the dowel axis

B.3 Measuring equipment

The measurements recorded during the test at each increment of load are as follows:

- The vertical deflection of the slabs on either side of the joint can be measured by a linear displacement sensor placed on both sides of the slab to avoid measuring the displacement in the cone area once the slab is cracked. The deflection is calculated by the mean value of them,
- The vertical load F_v applied on the slab,
- The horizontal load F_h applied on the slab,
- Possible settlement of the fixed support,
- The load at which the first crack appears on the top or bottom face of the tested slab, and the growing of the crack. This is obtained by placing a displacement sensor on the upper edge of the test slab above the dowel. Whenever critical cracks appear on the edge of the tested slab, the width, length and the place of the cracks have to be documented,
- The maximum load applied during the test to reach a crack width equal to 0,3mm on the top or bottom face of the tested slab, and the growing of the crack from the beginning of the test. This is obtained by placing a displacement sensor on the upper edge of the test slab above the dowel. Whenever critical cracks appear on the edge of the tested slab, the width, length and the place of the cracks have to be documented.

B.4 Concrete members used for the tests

The concrete members shall be made of compacted normal weight concrete with strength classes C20/25 – C50/60 in accordance with EN 206. The concrete strength class used for the test members must be given in the ETA. The concrete members have to meet the following requirements:

- cement type shall be CEM I, CEM II/A-LL, CEM II/B-LL (according to EN 197-1),
- the water-cement ratio shall not exceed 0,75. The cement content shall be at least 240 kg/m³,
- no fibre content

The concrete compression strength of test members at the day of testing shall meet the following specification:

f_{cm} = f_{ck} + 5 N/mm² with a tolerance of ±5 N/mm²

f_{cm} = mean concrete compression strength of the test member measured either on cylinders or cubes

f_{ck} = characteristic concrete compressive strength according to the concrete strength class

The concrete compressive strength shall be measured either on at least 3 cylinders with a diameter of 150 mm and height of 300 mm, or on at least 3 cubes of 150 mm.

The following conversion factors for concrete compressive strength from cube to cylinder or vice versa shall be used:

C20/25 to C45/55 $f_{cyl} = \frac{1}{1{,}25} f_{cube150}$

C50/60 $f_{cyl} = \frac{1}{1{,}20} f_{cube150}$