EUROPEAN ASSESSMENT DOCUMENT

EAD 160003-00-0301

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DOUBLE HEADED STUDS FOR THE INCREASE OF PUNCHING SHEAR RESISTANCE OF FLAT SLABS OR FOOTINGS AND GROUND SLABS

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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

This EAD covers the punching shear reinforcement elements with double headed studs made of ribbed or smooth shafts and a head at both ends. The reinforcement elements comprise at least two double headed studs with the same diameter and shape (ripped or smooth) and the following specifications:

- double headed studs with shaft diameter d_A of 10 mm ≤ d_A ≤ 25 mm
- double headed studs with a head diameter $d_K \geq 3 \cdot d_A$
- double headed studs with shafts made of weldable ribbed reinforcement bars or weldable structural steel with the following characteristics:

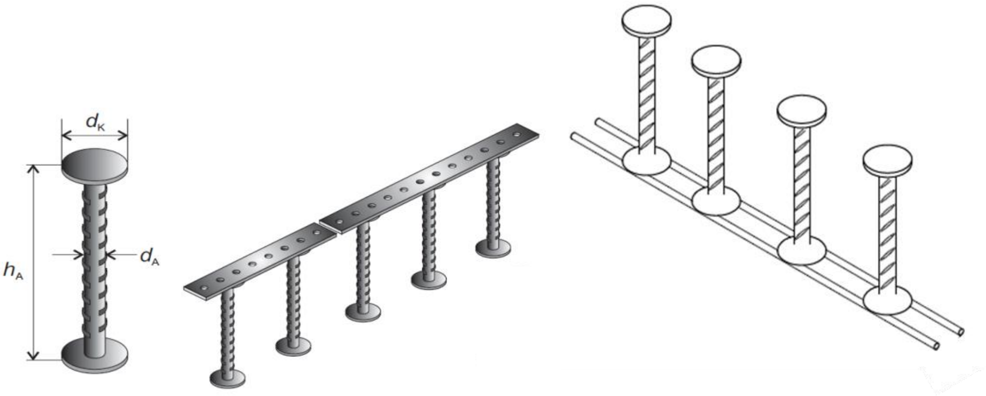
yield strength:	$f_{yk} \geq 500$ MPa
ratio of tensile strength over yield strength:	$(f_t/f_y)_k \geq 1{,}05$
elongation:	$\varepsilon_{uk} \geq 2{,}5\%$

The double headed studs are connected in one of the following examples:

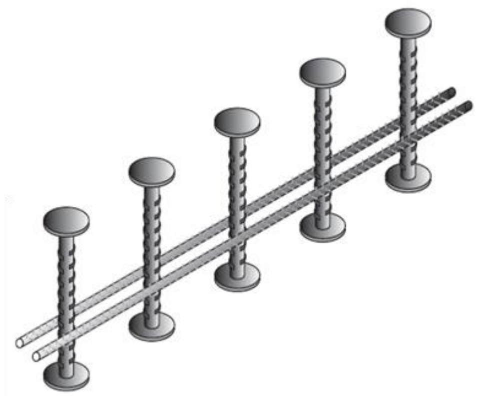
a) by a rail, studs are tack welded or clamped at one end to a rail made of non-structural steel or reinforcing bars or (see Figure 1.1 a))

b) by reinforcing bars welded to the shaft, non-structural ribbed reinforcing bars are spot welded to the shaft (see Figure 1.1 b))

c) clamped with plastic locks to a steel or plastic rail (see Figure 1.1 c))



a)



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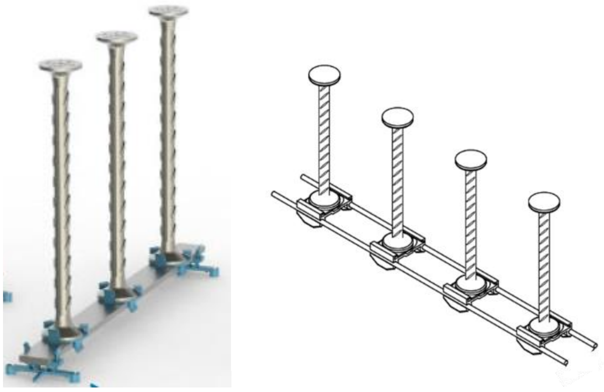


c)

Figure 1.1: Examples of connections of double headed studs

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

The reinforcement elements with double headed studs are intended to be used for the increase of the punching shear resistance of flat slabs or footings and ground slabs under static, quasi-static and fatigue loading.

The reinforcement elements with double headed studs are located adjacent to columns or high concentrated loads.

This EAD covers the following specifications of the intended use:

- flat slabs or footings and ground slabs made of reinforced normal weight concrete of strength class C20/25 to C50/60 according to EN 206-1:2000
- flat slabs or footings and ground slabs designed according to EN 1992-1-1
- increase of punching shear resistance of flat slabs or footings and ground slabs calculated and designed according to eota TR 060
- flat slabs or footings and ground slabs with a minimum thickness of h = 180 mm
- flat slabs or footings and ground slabs with a maximum effective depth of d = 300 mm (only for double headed studs with smooth shafts)
- reinforcement elements with double headed studs of the same diameter and type (ripped or smooth) in the punching area around a column or high concentrated load
- reinforcement elements with double headed studs installed in an upright (rail at the bottom of the slab) or hanging position
- reinforcement elements with double headed studs positioned such that the double headed studs are perpendicular to the surface of the slabs or footings and ground slabs
- reinforcement elements with double headed studs directed radially towards the column or high concentrated load and distributed evenly in the critical punching area

- reinforcement elements with double headed studs positioned such that the upper heads of the studs reach at least to the outside of the uppermost layer of the flexural reinforcement
- reinforcement elements with double headed studs positioned such that the lower heads of the studs reach at least to the outside of the lowest layer of the flexural reinforcement
- reinforcement elements with double headed studs positioned such that the concrete cover complies with the provisions according to EN 1992-1-1
- reinforcement elements with double headed studs positioned such that the minimum and maximum distances between the double headed studs on an element and between the elements as arranged around a column or area of high concentrated load complies with the provisions according to Annex A

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[1].

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 (if necessary in addition to the definitions in CPR, Art 2)

1.3.1 Abbreviations

Indices

A	anchor
R	resistance
V	shear force
c	concrete
fo	footing or ground slab
k	characteristic value
max	maximum
min	minimum
pu	punching shear
re	reinforcement
s	steel
sl	flat slab
y	yield

[1] 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.

Mechanical characteristics

$v_{Rd,c}$	punching shear resistance without shear reinforcement
f_{ck}	design compressive cylinder strength (150 mm diameter by 300 mm cylinder)
f_{yk}:	characteristic value of yield stress of the stud

Concrete, reinforcement and double headed studs

a	distance from column face to control perimeter
u_0	column perimeter
m_C:	number of elements (rows) in the area C
n_C:	number of studs of each element (row) in the area C
d_A:	shaft diameter of the double headed stud
s_w	radial distance between different rows of double headed studs
β	coefficient taking into account the effects of load eccentricity
β_{red}	reduced coefficient taking into account the effects of load eccentricity
d	effective depth
u_1	perimeter of the critical section at a distance of 2,0·d from the column face
l_s	distance between column face and outermost row of stud
h	member thickness of the slab or footings and ground slabs
d	effective depth as defined in EN 1992-1-1

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 double headed studs 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	Increasing factor for punching shear resistance of monolithic slabs	2.2.1	$k_{pu,sl}$ [-] $k_{pu,fo}$ [-]
2	Characteristics resistance to fatigue loading	2.2.2	$\Delta\sigma_{Rsk,n=2\cdot10^6}$ [MPa]
Basic Works Requirement 2: Safety in case of fire			
3	Reaction to fire	2.2.3	class

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

2.2.1 Increasing factor for punching shear resistance

The characteristic increasing factors according to Table 2.2 are determined by means of testing. Possible tolerances as specified by the manufacturer shall be considered. The tests shall be performed and evaluated according to the method given in Table 2.2.

These factors are applicable for calculation of the punching shear resistance of flat slabs according to TR 060 Equation (2.17) or for footings and ground slabs according to TR 060 Equation (2.19).

Table 2.2 Characteristic increasing factor for punching resistance

No	characteristic	number of samples	test method and evaluation	expression of performance
1	characteristic increasing factor for punching shear resistance of flat slabs	≥ 6 large scale tests [1)]	Annex B.1.2	$k_{pu,sl}$ [-]
2	characteristic increasing factor for punching resistance of footings and ground slabs	≥ 3 large scale tests [1) 2)]	Annex B.1.3	$k_{pu,fo}$ [-]

1) concrete members with double headed studs

2) no test are required if for footings and ground slabs a characteristic increasing factor for punching resistance $k_{pu,fo}$ = 1,5 is accepted

2.2.2 Characteristic resistance to fatigue loading for $N = 2 \cdot 10^6$ load cycles

The characteristic fatigue strength according to Table 2.3 shall be determined by means of testing. Possible tolerances as specified by the manufacturer shall be considered. The tests shall be performed according to the method given in Table 2.3.

Table 2.3 Characteristic fatigue resistance to fatigue loading

No	characteristic	number of samples	test method and evaluation	expression of performance
1	characteristic fatigue strength for $N = 2 \cdot 10^6$ load cycles	≥ 6 small stud size ≥ 6 medium stud size ≥ 3 largest stud size	Annex B.2	$\Delta\sigma_{Rsk,n=2 \cdot 10^6}$ [N/mm²]

2.2.3 Reaction to fire

The product is 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 it fulfilling the conditions set out in that Decision and its intended use being covered by that Decision.

Therefore the performance of the product is class A1.

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: Decision [97/597/EC(EU)]
The system is: [1^+]

3.2 Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of the double headed studs 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)					
1	raw material – mechanical characteristics	Annex D.1	1)	all	each delivery
2	double headed studs – geometrical characteristics	Annex D.2	1)	3 each size 2)	2000 manufactured meters of stud rails or per 10.000 studs or once per production week 3)
3	double headed studs – mechanical characteristics	Annex D.3	1)		

1) according to the manufacturer technical file

2) each type of material

3) whichever criterion is the more rigorous

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 double headed studs 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 punching shear reinforcement	Verification of the complete FPC, to be implemented by the manufacturer	-	-	When starting the production or a new production line
Continuous surveillance, assessment and evaluation of factory production control					
2	Ascertain that the system of factory production control and the specified automated manufacturing process are maintained	Verification of the controls carried out by the manufacturer on the raw materials, on the process and on the product as indicated in Table 3.1	-	-	1 per year
Audit-testing of samples taken by the notified product certification body at the manufacturing plant or at the manufacturer's storage facilities					
3.	double headed studs – geometrical characteristics	Annex D.2	1)	3 per small and 3 per large size 2)	1 per year
4	double headed studs – mechanical characteristics	Annex D.3	1)		
5	double headed studs – fatigue strength	Annex D.4	1)	3 per size	1 size per year and all sizes in 5 year

1) according to the manufacturer technical file

2) each type of material

4 REFERENCE DOCUMENTS

As far as no edition date is given in the list of standards thereafter, the standard in its current version at the time of issuing the European Technical Assessment, is of relevance.

EN 1990	Eurocode - Basis of structural design
EN 1992-1-1	Design of concrete structures – Part 1-1: General rules and rules for buildings
EN 206	Concrete - Specification, performance, production and conformity
ISO 12491	Statistical method for quality control of building materials and components
EN 10204	Metallic products - Types of inspection documents
EN ISO 6892-1	Metallic materials - Tensile testing - Part 1: Method of test at room temperature
EOTA TR 060	Increase of punching shear resistance of flat slabs or footings and ground slabs - Calculation methods

ANNEX A SPECIFICATION ON THE INTENDED USE

A.1 Positioning of the reinforcement elements and the double headed studs

A.1.1 Specifications for Flat slabs

The studs of the first row are placed at a radial distance from the column face between 0,35d and 0,5d.

The studs of the second row are placed at a radial distance from the column face of ≤ 1,125d.

The radial spacing of the studs is ≤ 0,75d.

The tangential spacing of the studs is ≤ 1,7d at a radial distance from the column face of ≤ 1,0d.

The tangential spacing of the studs is ≤ 3,5d at a radial distance from the column face of > 1,0d.

The area with a radial distance from the face of the column of ≤ 1,125d is called area C.

The area with a radial distance from the face of the column of > 1,125d is called area D.

If the number of reinforcement elements in the area D is larger compared to the area C, the additional reinforcement elements in the area D are placed radially to the column and at even tangential spacing.

For thick slabs where reinforcement elements with three or more headed studs are used in area C, the radial distance is reduced according to the following equation:

$$s_{w,area\,D} = \frac{3 \cdot d \cdot m_D}{2 \cdot n_c \cdot m_C} \leq 0{,}75 \cdot d$$

m_C: number of elements (rows) in the area C

m_D: number of elements (rows) in the area D

n_C: number of studs of each element (row) in area C

For double headed studs placed next to free slab edges and recesses, a transverse reinforcement is provided to control the transverse tensile forces.

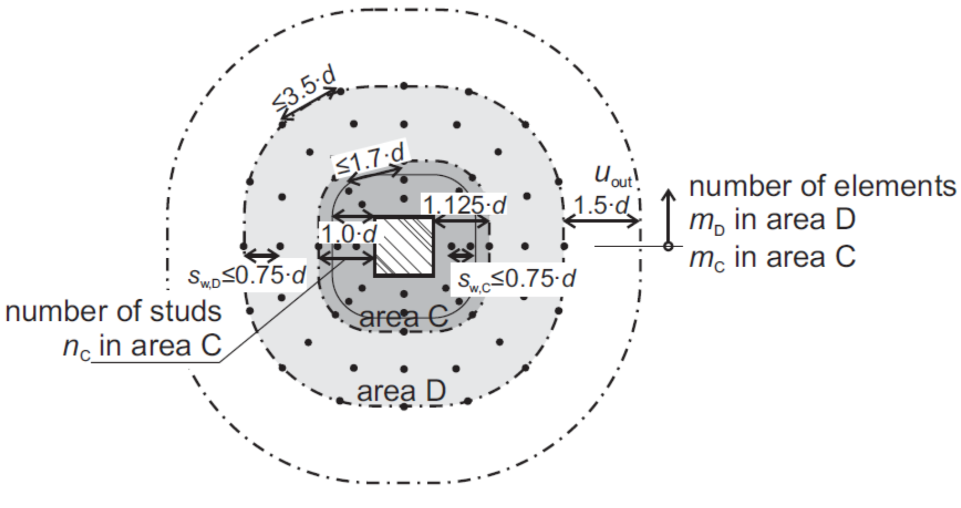


Figure A1: maximum spacing of studs in area C and D of flat slabs

A.1.2 **Footings and ground slabs:**

The studs of the first row are placed at a radial distance from the column face of 0,3d.
The studs of the second row are placed at a radial distance from the column face of ≤ 0,8d.
The radial spacing of the studs is ≤ 0,5d.
The tangential spacing of the studs is ≤ 1,5d at a radial distance from the column face of ≤ 0,8d.
The tangential spacing of the studs is ≤ 2,0d at a radial distance from the column face of > 0,8d.
The double headed studs are evenly distributed along the circular sections.
The area with a radial distance from the face of the column of ≤ 0,8d is called area C.
The area with a radial distance from the face of the column of > 0,8d is called area D.
For slender footings with a_λ/d > 2,0 (see Figure A2) the radial distance in the area D is ≤ 0,75d.

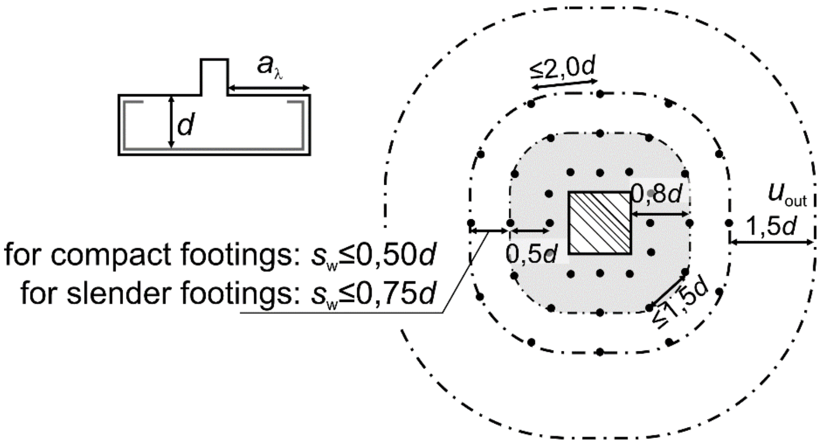


Figure A2: maximum spacing of studs in slender and compact footings

ANNEX B DETAILS OF TESTS AND EVALUATION OF THE TEST RESULTS

B.1 Punching resistance

B.1.1 General

The test set up and the test procedure shall comply with the requirements according to Annex C.

The increasing factors determined according to section B.1.2 and B.1.3 are valid for flexural reinforcement with a yield strength $f_{yk} \leq f_{yk,test}$. In general flexural reinforcement with a yield strength of f_{yk} = 500 MPa will be used in the tests. The increasing factors then are only valid for slabs or footings and ground slabs with flexural reinforcement with yield strength of $f_{yk} \leq 500$ MPa.

According to EN 1992-1-1 section 3.2.2 (3) the rules for design and detailing in EN 1992-1-1 are valid for reinforcing steel with yield strength of 400 MPa $\leq f_{yk} \leq$ 600 MPa. In order not to limit the scope of EN 1992-1-1 at least one test with yield strength of the flexural reinforcement with 500 < $f_{yk,test} \leq$ 600 MPa should be conducted in addition to the test series acc. to section B.1.2.

The arrangement of the reinforcement elements in the concrete specimen shall comply with the provision according to Annex A.

The tests shall be performed with the maximum spacing of the double headed studs according to Annex A.

The punching tests shall be performed with different effective depths, with different concrete strengths, different column diameters and different reinforcement ratios.

All parameters should be chosen carefully so as to allow extrapolating the influence of these parameters where necessary, especially in such cases where direct test results cannot be obtained due to technical limitations (i.e. slab thickness).

The test specimens should generally represent the most unfavourable conditions according to Annex A (e.g. maximum spacing of the double headed studs).

The calculation methods described in TR 060 for determining the punching resistance comprises the scaling factor which is assumed and confirmed by EN 1992-1-1.

An evaluation of all tests shall be carried out by comparing the value determined by calculation with the value determined by testing:

$$x_i = \frac{R_{test,i}}{R_{calc,i}} \qquad \text{(B.1)}$$

with:

$R_{test,i}$ = failure load from the individual test series acc. to table B.1 or table B.2
$R_{calc,i}$ = $v_{Rd,c}$ acc. to TR 060 Equation (2.10) for flat slabs or Equation (2.16) for footings and ground slabs calculated for the test member (slab or footing) used in the respective test

Test results, where bending failure occurs, shall be not considered.

For calculation of $R_{calc,i}$ the characteristic compressive cylinder strength f_{ck} shall be determined as follows:

$f_{ck} = f_{cm} - 4$ [MPa] with f_{cm} = measured value of concrete cylinder compressive strength in the test

B.1.2 Punching resistance of flat slabs

Large scale tests shall be performed according to Table B.1.

Table B.1 - Large scale tests for flat slabs

No	failure mode	test parameters [1)]	number of tests
1	punching failure	h = min; f_{ck} = min	≥ 1
2	punching failure	h = min; f_{ck} = max	≥ 1
3	punching failure	h = max; f_{ck} = min	≥ 1
4	punching failure	h = max; f_{ck} = mean to max	≥ 1
5	punching failure	h = mean; f_{ck} = min to mean	≥ 1
6	steel failure	h = mean; f_{ck} = mean to max	≥ 1

1) h_{min} = 180 mm, h_{max} = 400 mm, $f_{ck,min}$ = 20 MPa, $f_{ck,max}$ = 50 MPa

For each test series acc. to table B.1 the factor x_i shall be determined acc. to equation (B.1).

The characteristic increasing factor for punching resistance of slabs $k_{pu,sl}$ shall be determined as 5%-fractile (acc. to B.3) of the values x_i.

B.1.3 Punching resistance of footings and ground slabs

Large scale tests shall be performed according to Table B.2.

The test specimen is loaded at least by 16 identical loads to achieve approximately a uniform pressure.

Table B.2 - Large scale tests for footings and ground slabs

No	failure mode	test parameters [1)]	number of tests
1	punching failure	d ≥ 500 mm; f_{ck} = 20 to 30 MPa	≥ 3

[1)] The shear span – depth ratio of the footings should vary between a_λ/d =1.25 and 2.00, with a_λ is the distance from the face of the column to the line of contra flexure for the bending moments in radial direction.

For each test series acc. to table B.2 the factor x_i shall be determined acc. to equation (B.1).

The characteristic increasing factor for punching resistance of slabs $k_{pu,fo}$ shall be determined as 5%-fractile (acc. to B.3) of the values x_i.

B.2 Characteristic resistance to fatigue loading for N = $2{\cdot}10^6$ load cycles

Load-cycle tests shall be performed with an upper level of $\sigma_{up} = 0{,}6\, f_{yk,nom}$, a certain stress range of $\Delta\sigma_s = k_1$ [MPa] and at least N = $2{\cdot}10^6$ load cycles.

All steel qualities/properties specified by the manufacturer shall be tested.

The value k_1 is specified by the manufacturer.

Note: For practical reasons a value k_1 = 90 MPa is recommended.

The testing frequency shall be between 0,1 Hz and 20 Hz. A low frequencies of 0,1 Hz to 5 Hz may be used for high stress ranges near the static resistance resulting in large plastic deformations.

The test should be performed on double headed studs cast in concrete (see figure B.1.) Alternatively the test setup acc. to Figure D.1 may be used.

If no failure occurs up to N = $2{\cdot}10^6$ load cycles the characteristic stress range $\Delta\sigma_{Rs,k,n=2\cdot10^6}$ shall be determined as follows:

$\Delta\sigma_{Rsk,n=2\cdot10^6} = 0{,}78 \cdot k_1$ [MPa]

If a failure occurs before reaching N = $2{\cdot}10^6$ load cycles the test series shall be repeated with a smaller value k_1 [MPa].

If in 3 further tests on a reduced stress level no failure occurs the stress range $\Delta\sigma_{Rsk,n=2\cdot10^6}$ shall be determined as shown before.

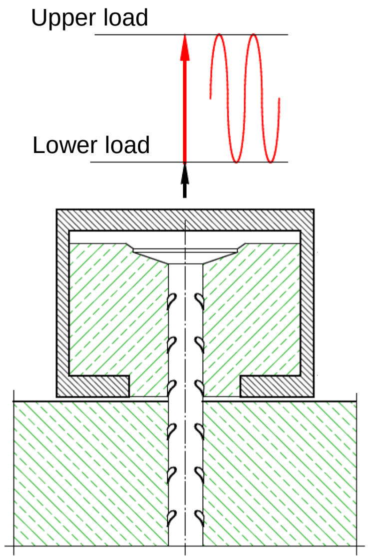


Figure B.1: test set-up for fatigue loading

B.3 Determination of the 5%-fractile

The 5 %-fractile shall be determined in accordance with annex D of EN 1990 using a known standard deviation and a confidence level of 75 %.

Instead of the k_n-values according to Table D.1 of EN 1990 the values according to ISO 12491, Table 6 (y = 0,75, p = 0,95) shall be used.

ANNEX C REQUIREMENTS FOR THE LOAD BEARING TEST ON SLABS FOR DETERMINATION OF THE INCREASING FACTOR FOR PUNCHING SHEAR RESISTANCE

C.1 General

Test specimen for the punching shear tests to determine the maximum shear strength shall be designed to exhibit punching shear failure inside the critical perimeter. (Other failure modes should not be taken into account when assessing the load bearing capacity.)

In order to simulate realistically the conditions on the construction site, test specimens shall be full scale test. Effective depth of the slab and column diameter shall be chosen appropriately to cover unfavourable effects of bending over the column head.

Concrete strength and flexural reinforcement ratio shall be chosen appropriately to allow the assessment of the full range of concrete strength classes. This may follow from an evaluation of tests where the influence of concrete strength on the load bearing capacity is evident.

The anchorages of the shear reinforcement should have normal cover. Anchorage above the level of the flexural reinforcement, or very close to the surface of the compression zone is more favourable than normal practice.

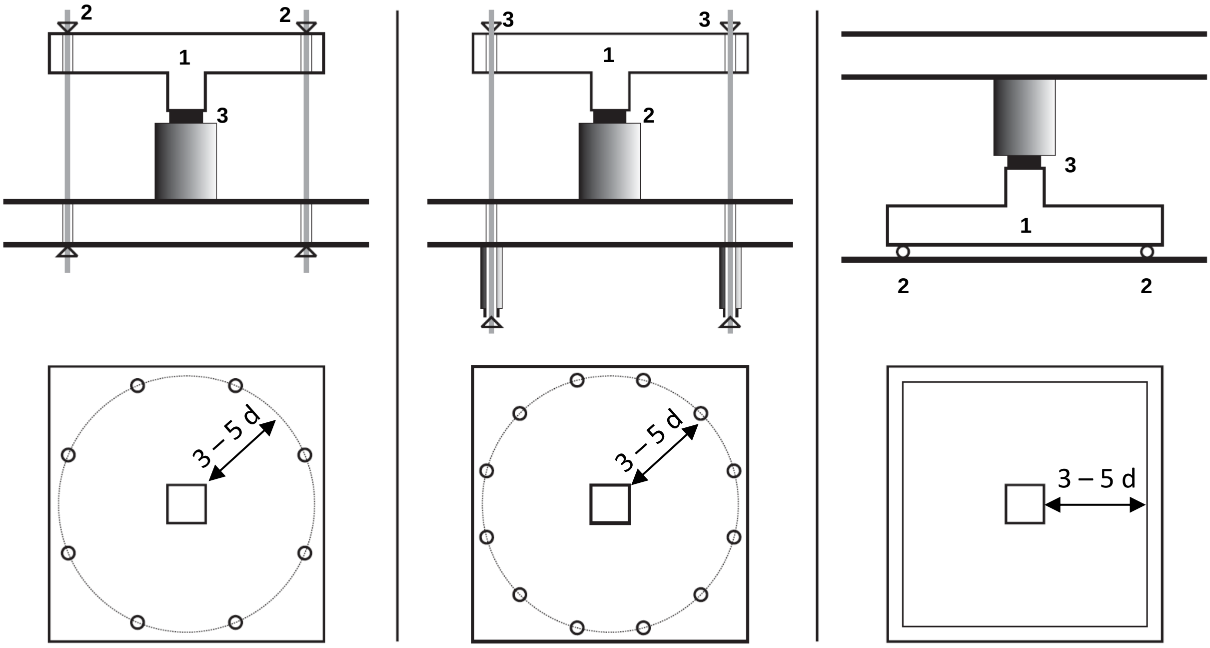
All relevant properties shall be documented by proper measuring methods, including appropriate measuring devices. These shall allow for the evaluation of the following:

- Crack development in dependence of the loading history (first crack, crack propagation, maximum crack at design load level);
- Residual load bearing capacity (if any) after failure, determined by re-loading;
- Concrete strain and splitting (if any);
- Effects of the boundary conditions (load distribution, membrane effects (if any));
- Vertical displacements of the ends of the slab should be measured allowing to define the “rotation capacity” and to assess the ductility of failure;
- Strains of the flexural reinforcement;
- Material properties of the concrete and the reinforcement steel.

C.2 Load bearing test on slabs

The types of specimens most commonly used in punching tests of flat slabs are illustrated in figure C.1. In such specimens, the clear distances between loads and supports should as long as the distance between the peak of the negative bending moment and the beginning of the positive bending moment for typical slabs. Any reduction of this distance reduces the local strains of the concrete and the flexural reinforcement near the column. Clear distances of 3·*d* to 5·*d* should be suitable for reinforced concrete slabs.

The slab should not extend significantly beyond the outer loads or reactions. Large extensions which are favourable for the development of a compressive membrane action shall be avoided.



Legend: 1 = test member (slab with column), 2 = support, 3 = load application point

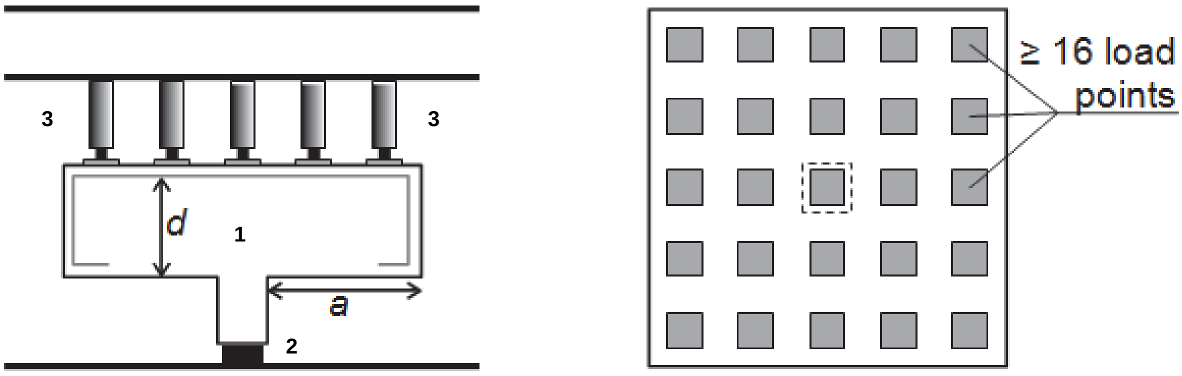
Figure C.1: different test setups for flat slabs

The bearings of load application points and/or supports near the slab edge should allow freedom of outward movement (no membrane action and no friction). The failure load is being not only increased by friction up to 15 %, but also by membrane action, increasing failure loads up to 25 %. Therefore, such tests are unsuitable for determining maximum punching load resistance in the context of this EAD.

To allow freedom of outward movement and freedom of radial and tangential movement elastomeric bearings and spherical bearings for the load application points and supports should be used. The test setup in the middle of figure C.1 ensures a uniform load distribution (due to the number of the load application points) and avoids friction and membrane forces (due to the arrangement of the load application points and the support). Therefore the test setup in the middle of figure C.1 shall be chosen to determine the maximum load bearing capacity.

C.3 Load bearing test on footings

The proposed test setup for footings is shown in figure C.2. The test specimen is loaded at least by 16 identical loads to achieve approximately a uniform pressure. To avoid a membrane action in the specimen, the load application points shall allow freedom of radial and tangential movement. Otherwise the failure loads have to be reduced by the amount of friction and membrane forces. The test members for punching tests on footings shall have at least an effective depth of $d \geq 500$ mm or the maximum thickness h which is applied for.



Legend: 1 = test member (footing with column), 2 = support, 3 = load application point

Figure C.2: test setup for footings

ANNEX D ASSESMENT OF THE VERIFICATION OF CONSTANCY OF PERFORMANCE – DETAILS FOR AVCP

D.1 Raw material

The raw materials shall be subject to control and tests 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 raw materials shall be supplied with the following documents:

Rails and Bars:	Material and material properties to be proven by a test report 2.2 according to EN 10204.
Studs:	Material and material properties to be proven by an inspection certificate 3.1 according to EN 10204.
Ancillary components:	Dimensions and material properties to be proven by a test report 2.2 according to EN 10204.

D.2 Geometrical characteristics

The geometrical characteristics according to Table D.1 shall be determined by means of measuring. Possible tolerances as specified by the manufacturer shall be considered.

Table D.1 determination of geometrical characteristics

No	characteristic	number of samples	test method and evaluation	expression of performance
1	diameter of the shaft	5 each stud size	(1)	d_A [mm]
2	diameter of the head	5 each stud size	(1)	d_K [mm]
3	head thickness	5 each stud size	(1)	h_K [mm]
4	height of the stud	5 each stud size	(1)	h_A [mm]
5	diameter of non-structural reinforcing bars	5 each element typ	(1)	d_s [mm]
6	width of the non-structural steel rail	5 each element typ	(1)	b [mm]
7	thickness of the non-structural steel rail	5 each element typ	(1)	t [mm]

(1) Measuring and comparing with manufacturer technical file

D.3 Mechanical characteristics

D.3.1 General

The mechanical characteristics according to Table D.2 shall be determined by means of testing. Possible tolerances as specified by the manufacturer shall be considered. The tests shall be performed according to the method given in Table D.2.

Table D.2 determination of mechanical characteristics for static and quasi-static loading

No	characteristic	number of samples	test method and evaluation	requirement
1	characteristic yield strength	≥ 5 each stud size	D.3.2	$f_{yk} \geq 500$ [MPa]
2	characteristic ratio tensile strength / yield strength	≥ 5 each stud size	D.3.2	$(f_t/f_y)_k \geq 1{,}05$ [-]
3	characteristic strain at maximum force	≥ 5 each stud size	D.3.2	$\varepsilon_{uk} \geq 2{,}5$ [%]

D.3.2 Test methods

Tests according to EN ISO 6892-1 shall be performed.

In the tests the stud head shall be supported by a ring with a diameter 1.5 d_A. For the test set-up, see Figure D.1.

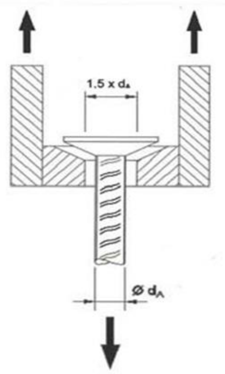


Figure D.1: test set-up for tension tests

The characteristic yield strength f_{yk} shall be determined as 5%-fractile (acc. to B.3) of the test results f_y.

The characteristic strain at maximum force ε_{uk} shall be determined as 5%-fractile (acc. to B.3) of the test results ε_u.

The characteristic ratio of tensile strength/yield strength $(f_t/f_y)_k$ shall be determined as 5%-fractile (acc. to B.3) of the ratio f_t/f_y.

D.4 Fatigue strength

Load-cycle tests with a upper level of $\sigma_{up} = 0{,}6\ f_{yk,nom}$, a stress range of $\Delta\sigma_{Rsk,n=2\cdot10^6}/0{,}78$ and at least $n = 2\cdot10^6$ load cycles shall be performed.

The constancy of performance is verified if the number of cycles exceeds $n = 2\cdot10^6$.