EUROPEAN ASSESSMENT DOCUMENT

EAD 160057-00-0301

May 2018

L- OR Z-SHAPED METAL SHEETS 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 L- or Z-shaped metal sheets for the increase of punching shear resistance of flat slabs or footings and ground slabs (in the following referred to as L- or Z-shaped metal sheets). The L-shaped metal sheets additionally consist of one or two specially bent stirrups made of reinforcing steel. The L- or Z-shaped metal sheets and the specially bent stirrups have the following specifications:

- L- or Z-shaped metal sheets made of structural steel according to EN 10025-2[1] with thickness of ≥ 3 mm
- specially bent stirrups (for the L-shaped metal sheets) made of ribbed reinforcement bars according to EN 1992-1-1, Annex C and with diameter ≥ 6 mm.

Note: The above specifications are based on the current experiences regarding the applicability of the assessment methods and criteria as well as of the actions to be undertaken by the manufacturer and notified body in the procedure of AVCP.

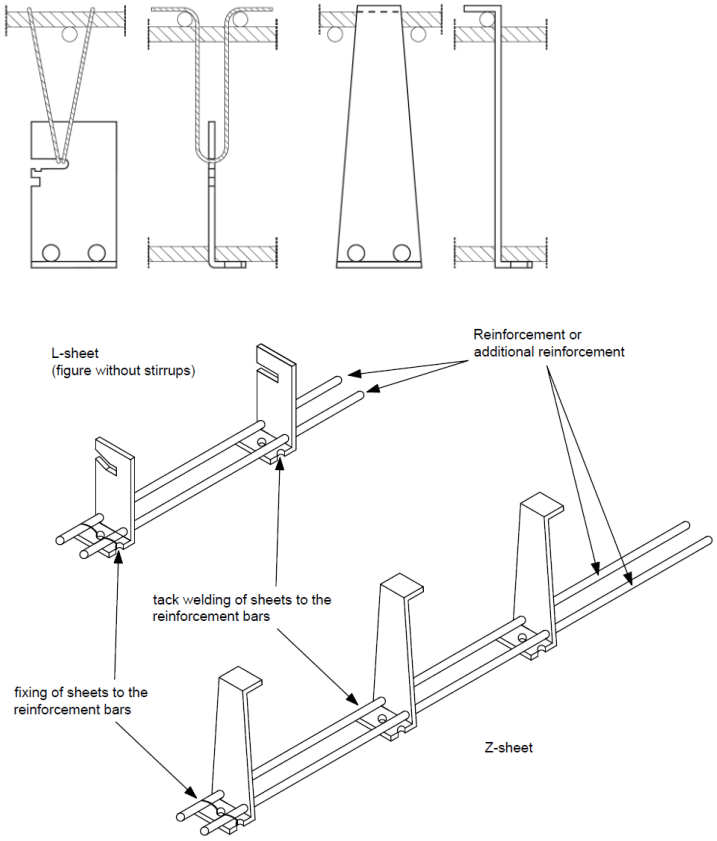


Figure 1: L- or Z-shaped metal sheets

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.

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.

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 L- or Z-shaped metal sheets and the specially bent stirrups are intended to be used as reinforcement elements for the increase of the punching shear resistance of flat slabs or footings and ground slabs under static and quasi-static loading.

The L- or Z-shaped metal sheets and the specially bent stirrups are also intended to be used as interface reinforcement in composite flat slabs.

The reinforcement elements 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 1992-1-1
- flat slabs or footings and ground slabs designed according to EN 1992-1-1
- flat slabs or footings and ground slabs with a height h of

L-shaped metal sheets with one specially bent stirrup	18 cm ≤ h ≤ 40 cm
L-shaped metal sheets with two specially bent stirrups	18 cm ≤ h ≤ 110 cm
Z-shaped metal sheets	18 cm ≤ h ≤ 110 cm

- to ensure anchoring and to secure the metal sheets while concreting, reinforcing steel bars according to EN 1992-1-1, Annex C with diameter 12 mm are guided through holes provided in the metal sheets.
- the reinforcing steel bars extend at least 20 cm beyond the metal sheets or cover the adjacent reinforcing steel bars of the flexural tensile reinforcement
- reinforcement elements are distributed uniformly, circularly or orthogonally in the punching area around the column or high concentrated load
- metal sheets of the same shape, the same dimensions and the same number of stirrups are arranged in the punching area - when using linear elements in prefabricated slabs, metal sheets with a smaller thickness and one stirrup are also used at distances > 2,0 d
- the Z-shaped metal sheets and the two-part L-shaped metal sheets with mounted stirrups enclose or extend to the outermost upper and outermost lower reinforcement layer
- reinforcement elements positioned such that the concrete cover complies with the provisions according to EN 1992-1-1
- reinforcement elements positioned such that the minimum and maximum distances between the metal sheets around a column or area of high concentrated load comply with the provisions according to Annex A

Note: The above specifications are based on the current experiences regarding the applicability of the assessment methods and criteria as well as of the actions to be undertaken by the manufacturer and notified body in the procedure of AVCP.

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.

1.3 Specific terms used in this EAD

1.3.1 Abbreviations

Indices

c	concrete
fo	footing or ground slab
i	interface
k	characteristic value
max	maximum
min	minimum
pu	punching shear
re	reinforcement
s	steel
sl	flat slab
y	yield

Mechanical characteristics

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

Concrete, reinforcement and L- or Z-shaped metal sheets

a_r	radial distance between metal sheets
a_t	tangential distance between metal sheets
d	effective depth of the slab or footing according to EN 1992-1-1
h	member thickness of the slab or footings and ground slabs

[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.

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 L- or Z-shaped metal sheets is assessed in relation to the essential characteristics.

Table 2.1 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	Increasing factor for punching shear resistance of monolithic slabs	2.2.1	$k_{pu,sl}$ [-] $k_{pu,fo}$ [-]
2	Increasing factor for maximum interface shear resistance	2.2.2	$k_{max,i}$ [-]
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

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.

2.2.1 Increasing factor for punching shear resistance

The characteristic increasing factor is determined by means of testing. Possible tolerances of material properties and dimensions of the L- or Z-shaped metal sheets shall be considered. The tests shall be performed and evaluated according to the method given in Table 2.2.

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 L- or Z-shaped metal sheets – ≥ 6 (3) tests for L-shaped metal sheets and ≥ 6 (3) tests for Z-shaped metal sheets

2) no tests are required if for footings and ground slabs a characteristic increasing factor for punching resistance $k_{pu,fo}$ = 1,4 is accepted

2.2.2 Increasing factor for maximum interface shear resistance in composite slabs

The characteristic increasing factor is determined by means of testing. Possible tolerances of material properties and dimensions of the L- or Z-shaped metal sheets shall be considered. The tests shall be performed and evaluated according to the method given in Table 2.3.

Table 2.3 Characteristic increasing factor for maximum interface shear resistance

No	characteristic	number of samples	test method and evaluation	expression of performance
1	characteristic increasing factor for maximum interface shear resistance of composite flat slabs	≥ 3 full scale tests [1) 2)]	Annex B.2	$k_{max,i}$ [-]

1) concrete members with L- or Z-shaped metal sheets – ≥ 3 tests for L-shaped metal sheets and ≥ 3 tests for Z-shaped metal sheets

2) no tests are required if a characteristic increasing factor for maximum interface shear resistance in composite slabs $k_{max,i}$ = 0,5 is accepted

2.2.3 Reaction to fire

The L- or Z-shaped metal sheets are 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 fulfilling the conditions set out in that Decision and its intended use being covered by that Decision.

Therefore, the performance of such L- or Z-shaped metal sheets 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 product covered by this EAD the applicable European legal act is Commission Decision 97/597/EC. The system is: 1+

3.2 Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of the L- or Z-shaped metal sheets 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	L- or Z-shaped metal sheets – geometrical characteristics	Annex D.2	1)	3 2)	per 2.000 manufactured meters of linear elements or per 10.000 metal sheets or once per production week 3)
3	L- or Z-shaped metal sheets – mechanical characteristics	Annex D.3	1)		

1) according to the manufacturer's technical file

2) per shape, material and thickness

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 L- or Z-shaped metal sheets 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	Annex D.4	Annex D.4	[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	Annex D.5	Annex D.5	[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.	L- or Z-shaped metal sheets – geometrical characteristics	Annex D.2	[2)]	5 [3)]	1 per year
4	L- or Z-shaped metal sheets – mechanical characteristics	Annex D.3	[2)]		

[1)] not applicable

[2)] according to the manufacturer's technical file

[3)] per shape, material and thickness

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 10204:2004	Metallic products - Types of inspection documents
EN 10025-2:2019	Hot rolled products of structural steels - Part 2: Technical delivery conditions for non-alloy structural steels
EN ISO 6892-1:2019	Metallic materials - Tensile testing - Part 1: Method of test at room temperature (ISO 6892-1:2019)

ANNEX A SPECIFICATION ON THE INTENDED USE

A.1 Positioning of the reinforcement elements

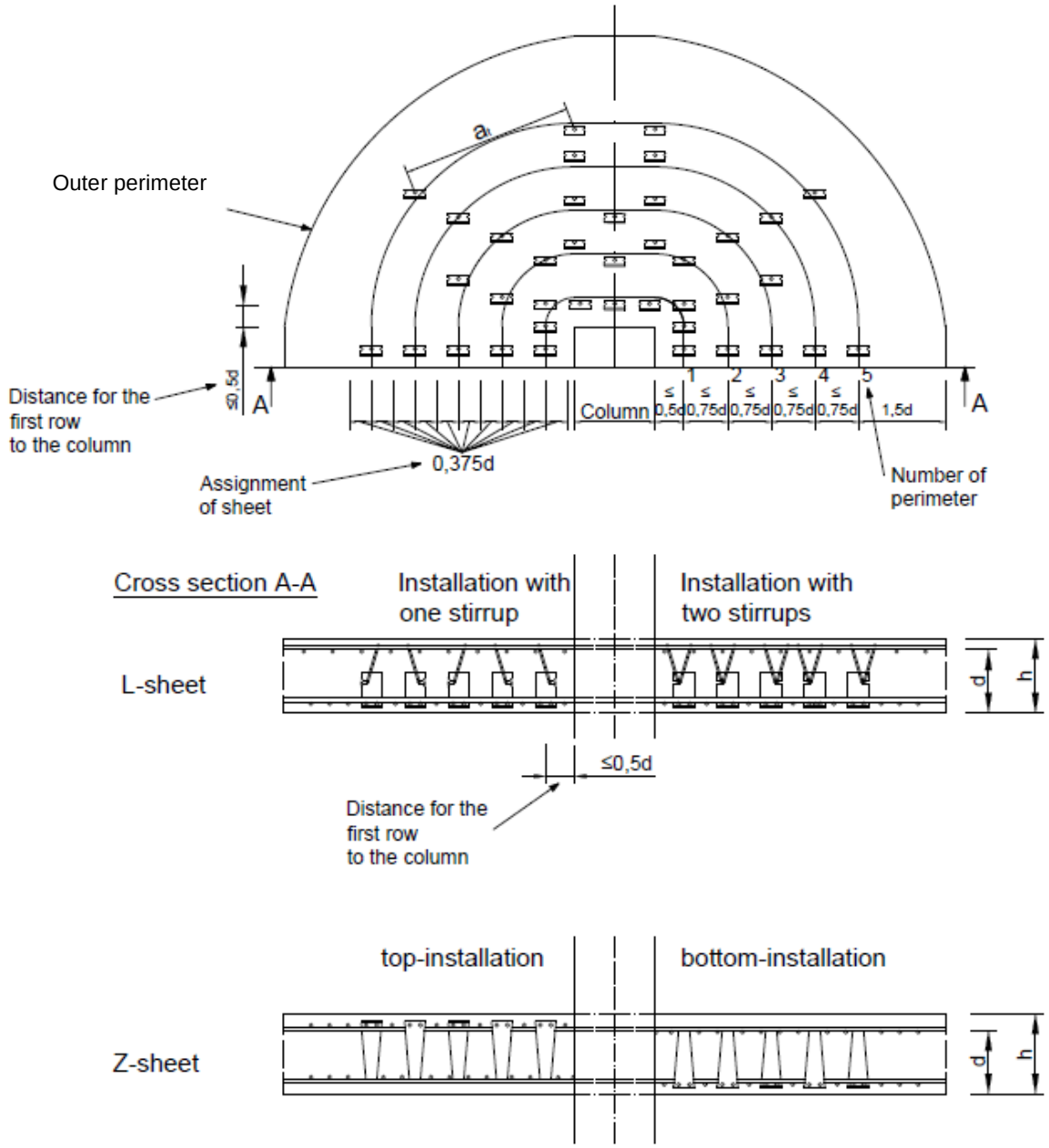
- The reinforcement elements are distributed uniformly (circular or orthogonal) within the punching area (see figure A.1)
- The distances a_r of the reinforcement elements in the direction of the radii (radial direction) from the loaded area (column) shall not exceed the following values:

  The distance of a reinforcement element to the previous or next perimeter shall not exceed 0,75 d.
  The distance of the first row of the reinforcement elements from the column surface shall be approximately 0,375 d and shall not exceed 0,5 d.
- The reinforcement elements can be assigned to the respective perimeter in the distance 0,375 d inwards and outwards.
- The distances a_t of the reinforcement elements one beside the other in the direction of the course of the perimeters (tangential direction) shall not exceed the following values:

  $a_t \leq$ max. (140 mm; 0,6·d·i); i = 1

  $a_t \leq 0{,}6 \cdot d \cdot i$; $i \geq 2$

  with i = number of perimeter
- If the required punching shear reinforcing elements cannot be arranged side by side on a perimeter, they are installed at regular intervals (under consideration of the spacing provisions) within the area between the perimeter considered and the next perimeter located to the column



tangential distance:
$a_t \leq \max(140mm; 0,6 \cdot d \cdot i)$; i = 1
$a_t \leq 0,6 \cdot d \cdot i$; i ≥ 2
i = number of perimeter

Arrangement of the sheets:
Each perimeter contains the sheets with spacing of 0,375d inside and a spacing of 0,375d outside.

Figure A.1: arrangement of the sheets

ANNEX B DETAILS OF TESTS AND EVALUATION OF THE TEST RESULTS

B.1 Punching resistance

B.1.1 General

The test setup 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 ≤ f_{yk} ≤ 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 < $f_{yk,test}$ ≤ 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 provisions according to Annex A.

The tests shall be performed with the maximum spacing of the L- or Z-shaped metal sheets 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 L- or Z-shaped metal sheets).

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

$$x_i = \frac{R_{test,i}}{R_{calc,i}} \tag{B.1}$$

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 Equation (B.1.1) for flat slabs or Equation (B.1.2) for footings and ground slabs calculated for the test member "i" (slab or footing) used in the respective test

$$v_{Rd,c} = C_{Rd,c} \cdot \kappa \cdot \sqrt[3]{100 \cdot \rho_l \cdot f_{ck}} + k_1 \cdot \sigma_{cp} \geq \left(v_{min} + k_1 \cdot \sigma_{cp}\right) \tag{B.1.1}$$

with:

$C_{Rd,c}$ empirical factor, the recommended value is $C_{Rd,c} = \frac{0{,}18}{\gamma_c}$

γ_c partial safety factor for concrete (recommended value is γ_c = 1,5)

κ coefficient to take into account size effects, *d* in [mm]

$$\kappa = 1 + \sqrt{\frac{200}{d}} \leq 2{,}0$$

ρ_l mean reinforcement ratio of y- and z-directions

$$\rho_l = \sqrt{\rho_{lx} \cdot \rho_{ly}} \leq \left\{ \begin{matrix} 2{,}0\% \\ 0{,}5 \cdot \frac{f_{cd}}{f_{yd}} \end{matrix} \right\}$$

f_{cd} design value of cylinder compressive strength
f_{yd} design value of yield strength of reinforcing steel
k_1 empirical factor, the recommended value is 0,1
σ_{cp} normal stresses in concrete in the critical section

$v_{min} = \frac{0{,}0525}{\gamma_c} \cdot \kappa^{1,5} \cdot f_{ck}^{0,5}$ for $d \leq 600$ mm

$v_{min} = \frac{0{,}0375}{\gamma_c} \cdot \kappa^{1,5} \cdot f_{ck}^{0,5}$ for $d > 800$ mm

(intermediate values are linearly interpolated)

In case of small ratios of the column perimeter to the effective depth (u_0/d), the punching resistance has to be reduced as follows:

$$u_0/d < 4{,}0: \quad C_{Rd,c} = \frac{0{,}18}{\gamma_c} \cdot \left(0{,}1 \cdot \frac{u_0}{d} + 0{,}6\right) \geq \frac{0{,}15}{\gamma_c}$$

$$v_{Rd,c} = C_{Rd,c} \cdot \kappa \cdot \sqrt[3]{100 \cdot \rho_l \cdot f_{ck}} \cdot \frac{2 \cdot d}{a} \geq v_{min} \cdot \frac{2 \cdot d}{a} \qquad \text{(B.1.2)}$$

with:

$C_{Rd,c}$: $0{,}15/\gamma_c$ for compact footings with $a_\lambda/d \leq 2{,}0$
$0{,}18/\gamma_c$ for slender footings and ground slabs

a: the distance from the column face to the control perimeter considered

The governing distance a ($\leq 2\,d$) leads to the minimum value of $v_{Rd,c}$ and can be determined iteratively.

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 = distance from the surface 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 Interface shear resistance of composite slabs

B.2.1 General

The reinforcement elements can be used as interface shear reinforcement in composite flat slabs.

The interface shear resistance shall be proved in perimeters around the column. The nearest perimeter to the column is situated in a distance of 1.5d. Additional perimeter further away from the column can be proved with reduced interface shear reinforcement.

The interface shear resistance is given by equation (B.2).

$$v_{Rdi} = c \cdot f_{ctd} + \mu \cdot \sigma_n + \rho \cdot f_{yd} \cdot (1{,}2 \cdot \mu \cdot \sin\alpha + \cos\alpha) \leq k_{max,i} \cdot \nu \cdot f_{cd} \quad \text{(B.2)}$$

$k_{max,i}$ determined acc. to section B.2.2

c,μ,ν coefficient depending on the roughness given in EN 1992-1-1

B.2.2 Determination of $k_{max,i}$

At least 3 punching shear tests with composite slabs within the range of table B.1 shall be carried out to determine the k_{maxi} according to equation (B.2). The increasing factor for maximum interface shear resistance for each single test shall be determined by equation (B.3).

$$k_{max,i,test} = \frac{v_{Edi,test}}{\nu \cdot f_{ck}} \quad \text{(B.3)}$$

$k_{max,i,test}$ increasing factor for maximum interface shear resistance for a single test

$v_{Edi,test}$ interface shear resistance reached in the test

with

$v_{Edi,test} = V_{test} / (u_{1.5d} \cdot z)$

ν factor for the roughness of the interface

for a smooth surface with a roughness R_T < 1.5 mm measured with the sand patch method a value of ν = 0.2 is recommended

for a rough surface with a roughness R_T ≥ 1.5 mm measured with the sand patch method a value of ν = 0.5 is recommended

The characteristic compressive cylinder strength f_{ck} in equation (B.3) shall be determined as $f_{ck} = f_{cm}$ - 4 [MPa] with f_{cm} = measured value of concrete cylinder compressive strength in the test (f_{cm} should be taken as the minimum of the precast and in situ strength).

The increasing factor $k_{max,i}$ in the ETA can be taken as the minimum of $k_{max,I,test}$ of at least 3 tests (≥ 3 tests for L-shaped metal sheets and ≥ 3 tests for Z-shaped metal sheets).

No tests are required if a characteristic increasing factor for maximum interface shear resistance in composite slabs $k_{max,i}$ = 0,5 is accepted.

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 %.

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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 at construction works, full scale test specimens shall be used. 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.

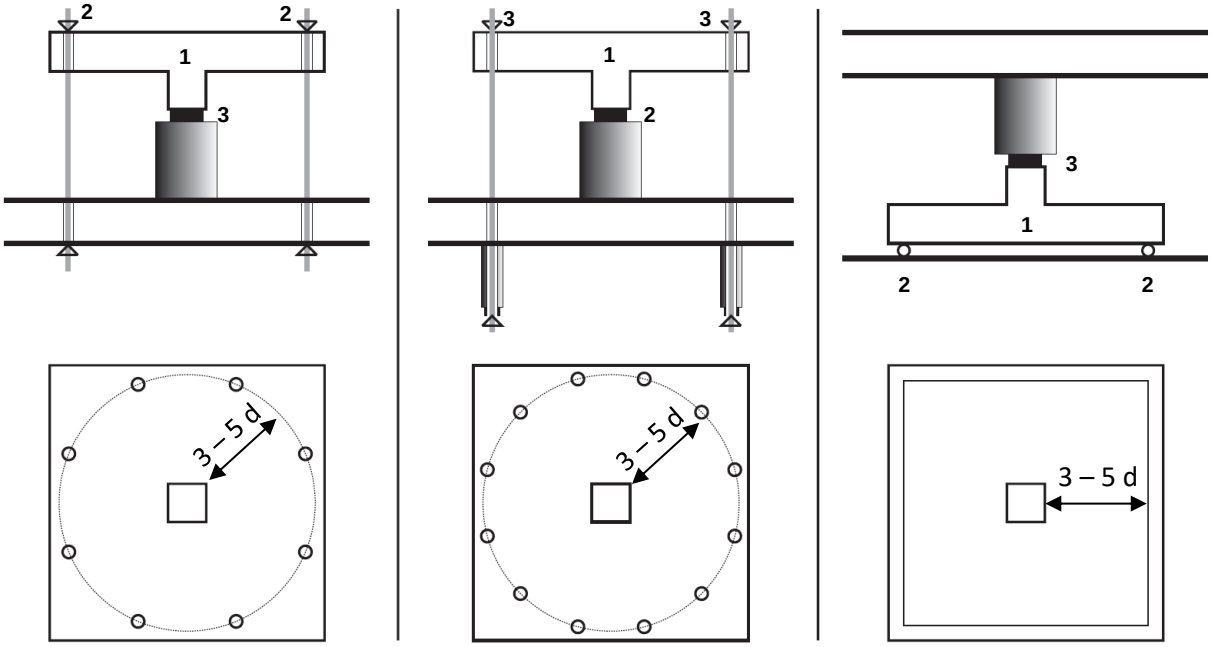
All relevant properties shall be documented by proper measuring methods, including appropriate measuring devices. These shall allow for the evaluation of the following:

- 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 be 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 $3 \cdot d$ to $5 \cdot d$ 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

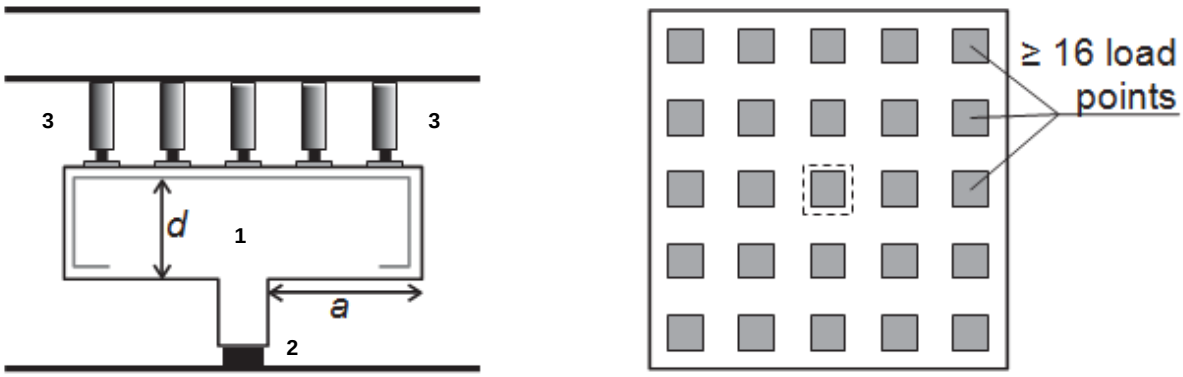
Figure C.1: different test setups for flat slabs

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 ≥ 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 ASSESSMENT OF THE VERIFICATION OF CONSTANCY OF PERFORMANCE – DETAILS FOR AVCP

D.1 Raw material

The raw materials shall be checked before acceptance. Check of raw materials shall include control of the inspection documents presented by the supplier of the initial materials. The properties of the raw material shall comply with the values according to the manufacturer's technical file.

The raw materials shall be supplied with the following documents:

Metal sheets: Material and material properties to be proven by an inspection certificate 3.1 according to EN 10204 - Yield strength, Tensile strength, Elongation at break A_5

Stirrups: Material and material properties to be proven by an inspection certificate 3.1 according to EN 10204 - Yield strength, Tensile strength, Elongation at break A_{gt}

Steel clips: Dimensions and material properties to be proven by a test report 2.2 according to EN 10204 - Yield strength, Tensile strength, Elongation at break A_5

D.2 Geometrical characteristics

The geometrical characteristics according to Table D.1 shall be determined by means of measuring. The geometrical characteristics shall comply with the values according to the manufacturer's technical file.

Table D.1 Determination of geometrical characteristics

No	characteristic	test method and evaluation	expression of performance
1	thickness	(1)	[mm]
2	shape	(1)	[mm]

(1) Measuring and comparing with manufacturer's 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. The mechanical characteristics shall comply with the values according to the manufacturer's technical file. 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	test method and evaluation	requirement
1	characteristic yield strength	D.3.2	$f_{yk} \geq 500$ [MPa]
2	characteristic ratio tensile strength / yield strength	D.3.2	$(f_t/f_y)_k \geq 1{,}05$ [-]
3	characteristic strain at maximum force	D.3.2	$\varepsilon_{uk} \geq 2{,}5$ [%]

D.3.2 **Test methods and evaluation**

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

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 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.

D.5 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.