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Authorised and notified according to Article 10 of the Council Directive of 21 December 1988 on the approximation of laws, regulations and administrative provisions of Member States relating to construction products (89/106/EEC)

DIBt

Mitglied der EOTA
Member of EOTA

European Technical Approval ETA-03/0041

English translation prepared by DIBt - Original version in German language

Handelsbezeichnung *Trade name*	Nelson-Kopfbolzen *Nelson Headed Studs*
Zulassungsinhaber *Holder of approval*	Nelson Bolzenschweiß-Technik GmbH & Co. KG Flurstraße 7-19 58285 Gevelsberg
Zulassungsgegenstand und Verwendungszweck *Generic type and use of construction product*	Stahlplatte mit einbetonierten Nelson-Kopfbolzen aus Stahl und aus nichtrostendem Stahl *Steel plate with cast-in Nelson-headed studs made of steel and of stainless steel*
Geltungsdauer: *Validity:*	vom *from* 18 November 2008 bis *to* 18 November 2013
Herstellwerke *Manufacturing plants*	Herstellwerk 1 Herstellwerk 2

Diese Zulassung umfasst *This Approval contains*	30 Seiten einschließlich 7 Anhänge *30 pages including 7 annexes*
Diese Zulassung ersetzt *This Approval replaces*	ETA-03/0041 mit Geltungsdauer vom 13.11.2003 bis 13.11.2008 *ETA-03/0041 with validity from 13.11.2003 to 13.11.2008*

I LEGAL BASES AND GENERAL CONDITIONS

1 This European technical approval is issued by Deutsches Institut für Bautechnik in accordance with:

- Council Directive 89/106/EEC of 21 December 1988 on the approximation of laws, regulations and administrative provisions of Member States relating to construction products[1], modified by Council Directive 93/68/EEC[2] and Regulation (EC) N° 1882/2003 of the European Parliament and of the Council[3];
- Gesetz über das In-Verkehr-Bringen von und den freien Warenverkehr mit Bauprodukten zur Umsetzung der Richtlinie 89/106/EWG des Rates vom 21. Dezember 1988 zur Angleichung der Rechts- und Verwaltungsvorschriften der Mitgliedstaaten über Bauprodukte und anderer Rechtsakte der Europäischen Gemeinschaften (Bauproduktengesetz - BauPG) vom 28. April 1998[4], zuletzt geändert durch Gesetz vom 06.01.2004[5];
- Common Procedural Rules for Requesting, Preparing and the Granting of European technical approvals set out in the Annex to Commission Decision 94/23/EC[6].

2 Deutsches Institut für Bautechnik is authorized to check whether the provisions of this European technical approval are met. Checking may take place in the manufacturing plant. Nevertheless, the responsibility for the conformity of the products to the European technical approval and for their fitness for the intended use remains with the holder of the European technical approval.

3 This European technical approval is not to be transferred to manufacturers or agents of manufacturers other than those indicated on page 1, or manufacturing plants other than those indicated on page 1 of this European technical approval.

4 This European technical approval may be withdrawn by Deutsches Institut für Bautechnik, in particular pursuant to information by the Commission according to Article 5(1) of Council Directive 89/106/EEC.

5 Reproduction of this European technical approval including transmission by electronic means shall be in full. However, partial reproduction can be made with the written consent of Deutsches Institut für Bautechnik. In this case partial reproduction has to be designated as such. Texts and drawings of advertising brochures shall not contradict or misuse the European technical approval.

6 The European technical approval is issued by the approval body in its official language. This version corresponds fully to the version circulated within EOTA. Translations into other languages have to be designated as such.

1 Official Journal of the European Communities L 40, 11.02.1989, p. 12
2 Official Journal of the European Communities L 220, 30.08.1993, p. 1
3 Official Journal of the European Union L 284, 31.10.2003, p. 25
4 Bundesgesetzblatt I, p. 812
5 Bundesgesetzblatt I, p.2, 15
6 Official Journal of the European Communities L 17, 20.01.1994, p. 34

II SPECIFIC CONDITIONS OF THE EUROPEAN TECHNICAL APPROVAL

1 Definition of product and intended use

1.1 Definition of product

The steel plate with cast-in Nelson-headed studs consists of one or more headed studs which are welded-on to a steel plate. The headed studs and the plate consist of steel or stainless steel. The headed studs have a diameter of the shaft of 10, 13, 16, 19, 22 and 25 mm. At the one end a head is formed by upsetting. The other end is prepared for drawn arc stud welding with ceramic ferrule or shielding gas (method 783 according to EN ISO 4063:2002-02).

The product is surface-flush anchored in the concrete.

For the installed product see figure given in Annex 1.

1.2 Intended use

The steel plate with welded-on headed studs is intended for uses where requirements concerning mechanical resistance and stability as well as safety in use in the sense of the Essential Requirements ER1 and ER4 of the Directive 89/106/EEC shall be satisfied and where failure of the anchorage may cause risk to human life and health and/or lead to considerable economic consequences.

Regarding the requirements concerning safety in case of fire (ER 2) it is assumed that the construction product meets the requirements of class A1 in relation to reaction to fire in accordance with the stipulations of the Commission decision 96/603/EC, amended by 200/605/EC.

If the fire resistance is relevant then the fire resistance of the concrete member in which the construction product is anchored is to be tested according to test method provided in order to be classified according to EN 13501-2.

The steel plate with welded-on headed studs is to be used for the anchorage under static or quasi static actions as well as under not predominantly static actions (fatigue actions) in reinforced normal concrete of the minimum strength class C 20/25 according to EN 206-1:2000-07. The construction product may be anchored in cracked and non-cracked concrete. The anchorage is admissible with single studs or groups of studs, which consist of two up to nine headed studs. The construction product can be stressed by a tensile load, shear load or a combination of tensile and shear loads.

The steel plate with the welded-on headed studs is anchored in the concrete surface-flush. Other steel components may be welded-on to the steel plate.

The steel plate made of steel according to EN 10025 with welded-on headed studs made of steel S235J2+C450 according to EN 10025 may only be used in concrete subject to dry internal conditions.

The steel plate made of stainless steel (1.4571; 1.4401) with welded-on headed studs made of stainless steel (1.4301; 1.4303) may be used in concrete components subject to dry internal conditions and in concrete components subject to external atmospheric exposure (including industrial and marine environment) or exposure in permanently damp internal conditions, if no particular aggressive conditions exist. Such particular aggressive conditions are, e.g. permanent, alternating immersion in seawater or the splash zone of seawater, chloride atmosphere of indoor swimming pools or atmosphere with extreme chemical pollution (e.g. in desulphurization plants or road tunnels where de-icing material is used).

The provisions made in this European technical approval are based on an assumed intended working life of the product of 50 years. The indications given on the working life cannot be interpreted as a guarantee given by the producer, but are to be regarded only as a means for choosing the right products in relation to the expected economically reasonable working life of the works.

2 Characteristics of the product and method of verification

2.1 Characteristics of the product

2.1.1 General

The characteristic material values, dimensions and tolerances of the product not indicated in the Annexes shall correspond to respective values laid down in the technical documentation[7] of this European technical approval.

The characteristic values for the design calculation of the anchorage are given in Annexes 4 to 6.

2.1.2 Headed stud

The headed studs made from steel according to EN ISO 13918:2008 "Studs and ceramic ferrules for arc stud welding" shall correspond to the materials, mechanical properties and dimensions given in Table 1, 2 and 3, Annex 3.

It is also permissible to use two headed studs welded one on top of the other by arc stud welding (see Annex 2). A padded ring is to be placed under the head of the first stud. The padded ring is to be secured in its position to make a permanent compression of ≥ 5 mm possible. The padded ring can be made, for example, of technical felt or cellular rubber. The external diameter of the padded ring shall exceed the head diameter and the inside diameter shall be less than the shaft diameter. The padded ring shall prevent a contact of the lower head at the concrete and a transmission of loads by the lower stud head.

2.1.3 Steel plate

The steel plates, on which headed studs of steel S235J2+C450 according to Table 2, Annex 3 will be welded, shall consist of the materials S235JR, S235JO, S235J2, S355JO or S355J2 according to Table 2, Annex 3.

The steel plates, on which headed studs of stainless steel (1.4301; 1.4303) according to Table 3, Annex 3 will be welded, shall consist of the stainless steel 1.4571 or 1.4401 according to Table 3, Annex 3.

Because of the stress of the steel plate in the direction of the thickness a possibly not homogeneous structure of the steel plate in this direction shall be taken into account. At the same time the risk of lamellar tearing as well as lamellar imperfections in the steel plate shall be paid attention to.

For not predominantly static loads ultrasonic tested steel plates shall be used.

2.1.4 Welded joint

The headed studs shall be welded to the steel plate by means of drawn arc stud welding with ceramic ferrules or shielding gas in accordance with EN ISO 14555:2006. Welding of the headed studs via arc stud welding may be performed in the manufacturing plant or on the construction site

For the safeguarding of the quality assurance of the welded connection the provisions of EN ISO 14555:2006 "Welding – Arc stud welding of metallic materials" and EN ISO 3834:2005 "Quality requirements for fusion welding of metallic materials" shall apply for the executing company.

2.1.5 Marking

Each headed stud is marked with the identifying mark of the producer and the material according to Annex 3.

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7 The technical documentation for this European technical approval is deposited at Deutsches Institut für Bautechnik and, as far as relevant for the tasks of the approved bodies involved in the attestation of conformity procedure, is handed over to the approved bodies.

2.2 Methods of verification

2.2.1 General

The assessment of the fitness of the product for the intended use with regard to the requirements of mechanical resistance and stability as well as safety in use in the sense of the Essential Requirements 1 and 4 was performed based on the ETAG 001 "Guideline for European technical approval of Metal Anchors for Use in Concrete" and the tests carried out.

2.2.2 Tests carried out

The following tests were carried out for determination the characteristic resistance of the headed stud under different conditions:

1. Tests for determination of the steel resistance under tension load,
2. Concrete cone failure, centric tension tests with single fastening without influence of spacing and edge distance,
3. Blow-out failure, centric tension tests with single fastening; member edge c_1 = 60 mm.

2.2.3 Calculated verifications

2.2.3.1 Basic values for the characteristic resistance under tension load

(1) Steel failure

The characteristic resistance $N_{Rk,s}$ for the cross section of the shaft is determined according to Annex C, clause 5.2.2.2 of ETAG 001 and proved by the test series 1, clause 2.2.2. The characteristic resistance in case of steel failure is given in Table 5, Annex 5.

(2) Pull-out failure

The characteristic resistance $N_{Rk,p}$ in case of failure by pull-out is given in Table 5, Annex 5.

(3) Concrete cone failure

The test values (mean values) resulting from test series 2 of clause 2.2.2 prove the calculation values with reference to ETAG 001. The characteristic resistance $N_{Rk,c}$ in case of concrete cone failure is determined according to Annex 7, clause 3.3.

(4) Blow out failure

The test values (mean values) resulting from test series 3 of clause 2.2.2 prove the calculation values with reference to ETAG 001. The characteristic resistance $N_{Rk,cb}$ in case of blow out failure is determined according to Annex 7, clause 3.4.

(5) Splitting failure due to loading

The required cross section of the minimum reinforcement shall be determined according to Annex 7, clause 3.5.

(6) Characteristic resistance of hanger reinforcement under tension load

The characteristic resistance $N_{Rk,h}$ of a bar of the hanger reinforcement depending on the nominal length of the headed stud (h_n) and the anchorage length ($l_{V,R}$) of the hanger reinforcement is given in Table 6, Annex 5.

2.2.3.2 Basic values for the characteristic resistance under shear load

(1) Steel failure without lever arm

The characteristic resistance $V_{Rk,s}$ for the cross section of the shaft was determined with reference to Annex C of ETAG 001. The α-value is 0.6.
The characteristic resistance in case of steel failure is given in Table 8, Annex 6.

(2) Pry-out failure

The characteristic resistance $V_{Rk,cp}$ shall be determined with reference to Annex C clause 5.2.3.3 of ETAG 001 and according to Annex 7, clause 4.2.

(3) Concrete edge failure

The characteristic resistance $V_{Rk,c}$ in case of concrete edge failure under shear load is determined with reference to Annex C clause 5.2.3.4 of ETAG 001 and according to Annex 7, clause 4.3.

(4) Characteristic resistance of hanger reinforcement under shear load

The characteristic resistance $V_{Rk,h}$ of a bar of the hanger reinforcement with the corresponding anchorage length $l_{V,R}$ is given in Table 9, Annex 6.

3 Attestation of conformity of the product and CE marking

3.1 System of attestation of conformity

According to the Decision 96/582/EEC of the European Commission[8] system 2(i) (referred to as System 1) of the attestation of conformity applies.

This system of attestation of conformity is defined as follows:

System 1: Certification of the conformity of the product by an approved certification body on the basis of:

(a) Tasks for the manufacturer:
  (1) factory production control;
  (2) further testing of samples taken at the factory by the manufacturer in accordance with a prescribed test plan;

(b) Tasks for the approved body:
  (3) initial type–testing of the product;
  (4) initial inspection of factory and of factory production control;
  (5) continuous surveillance, assessment and approval of factory production control.

Note: Approved bodies are also referred to as "notified bodies".

3.2 Responsibility

3.2.1 Tasks for the manufacturer

3.2.1.1 Factory production control

The manufacturer shall exercise permanent internal control of production. All the elements, requirements and provisions adopted by the manufacturer shall be documented in a systematic manner in the form of written policies and procedures, including records of results performed. This production control system shall insure that the product is in conformity with this European technical approval.

The manufacturer may only use initial/raw/constituent materials stated in the technical documentation of this European technical approval.

The factory production control shall be in accordance with the control plan of November 2008 relating to this European technical approval which is part of the technical documentation of this European technical approval. The control plan is laid down in the context of the factory production control system operated by the manufacturer and deposited with Deutsches Institut für Bautechnik.[9]

The results of factory production control shall be recorded and evaluated in accordance with the provisions of the control plan.

3.2.1.2 Other tasks for the manufacturer

The manufacturer shall, on the basis of a contract, involve a body which is approved for the tasks referred to in section 3.1 in the field of anchors in order to undertake the actions laid

8 Official Journal of the European Communities L 254 of 08.10.1996.

9 The "control plan" is a confidential part of the European technical approval and only handed over to the approved body involved in the procedure of attestation of conformity. See section 3.2.2.

down in section 3.2.2 For this purpose, the control plan referred to in sections 3.2.1.1 and 3.2.2 shall be handed over by the manufacturer to the approved body involved.

The manufacturer shall make a declaration of conformity, stating that the construction product is in conformity with the provisions of this European technical approval.

3.2.2 Tasks for the approved bodies

The approved body shall perform the

- initial type-testing of the product,
- initial inspection of factory and of factory production control,
- continuous surveillance, assessment and approval of factory production control

in accordance with the provisions laid down in the control plan.

The approved body shall retain the essential points of its actions referred to above and state the results obtained and conclusions drawn in a written report.

The approved certification body involved by the manufacturer shall issue an EC certificate of conformity of the product stating the conformity with the provisions of this European technical approval.

In cases where the provisions of the European technical approval and its control plan are no longer fulfilled the certification body shall withdraw the certificate of conformity and inform Deutsches Institut für Bautechnik without delay.

3.3 CE marking

The CE marking shall be affixed on the packaging. The letters "CE" shall be followed by the identification number of the approved certification body, where relevant, and be accompanied by the following additional information:

- the name and address of the producer (legal entity responsible for the manufacture),
- the last two digits of the year in which the CE marking was affixed,
- number of the EC certificate of conformity for the product,
- number of the European technical approval,
- name of the product.

4 Assumptions under which the fitness of the product for the intended use was favourably assessed

4.1 Manufacturing

The European technical approval is issued for the product on the basis of agreed data/information, deposited with Deutsches Institut für Bautechnik, which identifies the product that has been assessed and judged. Changes to the product or production process, which could result in this deposited data/information being incorrect, should be notified to Deutsches Institut für Bautechnik before the changes are introduced. Deutsches Institut für Bautechnik will decide whether or not such changes affect the approval and consequently the validity of the CE marking on the basis of the approval and if so whether further assessment or alterations to the approval shall be necessary.

4.2 Installation

4.2.1 Design of anchorages

The fitness of the construction product for the intended use is given under the following conditions:

The design of the anchorage is based on the design method in Annex 7 under the responsibility of an engineer experienced in anchorages and concrete building.

Verifiable calculation notes and drawings are prepared taking account of the loads to be anchored. The transfer of the loads to be anchored in the concrete member is verified.

Single studs or groups of studs consisting of two to nine headed studs according to Annex 4 are used. Headed studs of the same diameter and length are used only in a group of headed studs.

Non-cracked concrete may be assumed in special cases if in each case it is proved that under service conditions the anchor with its entire anchorage depth is located in non-cracked concrete. For the structural analysis stresses in the concrete shall be taken into account which are induced by external loads, including anchors loads, and due to restraint of instrinsic (e.g. shrinkage of concrete) or extrinsic imposed deformations (e.g. due to displacement of support or temperature variations).

The position of the product is indicated on the design drawings (e.g. position of the headed studs towards the reinforcement or the supports).

Because of the stress of the steel plate in the direction of the thickness a possibly not homogeneous structure of the steel plate in this direction shall be taken into account. At the same time the risk of lamellar tearing as well as lamellar imperfections in the steel plate shall be paid attention to.

For not predominantly static loads ultrasonic tested steel plates shall be used.

On the anchorage of not predominantly static action the following characteristic range of steel stresses may not be exceeded:

- tensile load $\Delta\sigma$ = 100 N/mm²
- shear load $\Delta\tau$ = 35 N/mm²
- hanger reinforcement $\Delta\sigma$ = 60 N/mm²

The partial safety factor for fatigue strength may be taken with γ_{Mf} = 1.35.

4.2.2 Installation

The fitness for use of the anchor can only be assumed if the anchor is installed as follows:

- Installation carried out by appropriately qualified personnel and under the supervision of the person responsible for technical matters on site.
- Use of the product only as supplied by the manufacturer without exchanging the components.
- Installation in accordance with the manufacturer's specifications and the design drawings with exact position, dimensions of the steel plate and size and length of the headed studs.
- The anchorage shall be fixed to the formwork or auxiliary constructions in a way that no movement of the product will occur during placing of reinforcement or during placing and compacting of the concrete.
- The concrete under the head of the headed stud shall be properly compacted (no cavities). For large fixtures (steel plate $>$ 400 mm x 400 mm) vent openings shall be provided. These shall be specified in the installation instructions.
- Observation of the prescribed values of installations.

Welding-on of the intended and designed steel components to the cast-in construction product may only be performed by companies meeting the corresponding quality requirements for welding according to EN ISO 3834 "Quality requirements for fusion welding of metallic materials ".

4.2.3 Responsibility of the manufacturer

It is in the responsibility of the manufacturer to ensure that the information on the specific conditions according to 1 and 2 including Annexes referred to and 4.2.1 and 4.2.2 is given to those who are concerned. This information may be made by reproduction of the respective parts of the European technical approval. In addition all installation data shall be shown clearly on the package and/or on an enclosed instruction sheet, preferably using illustration(s).

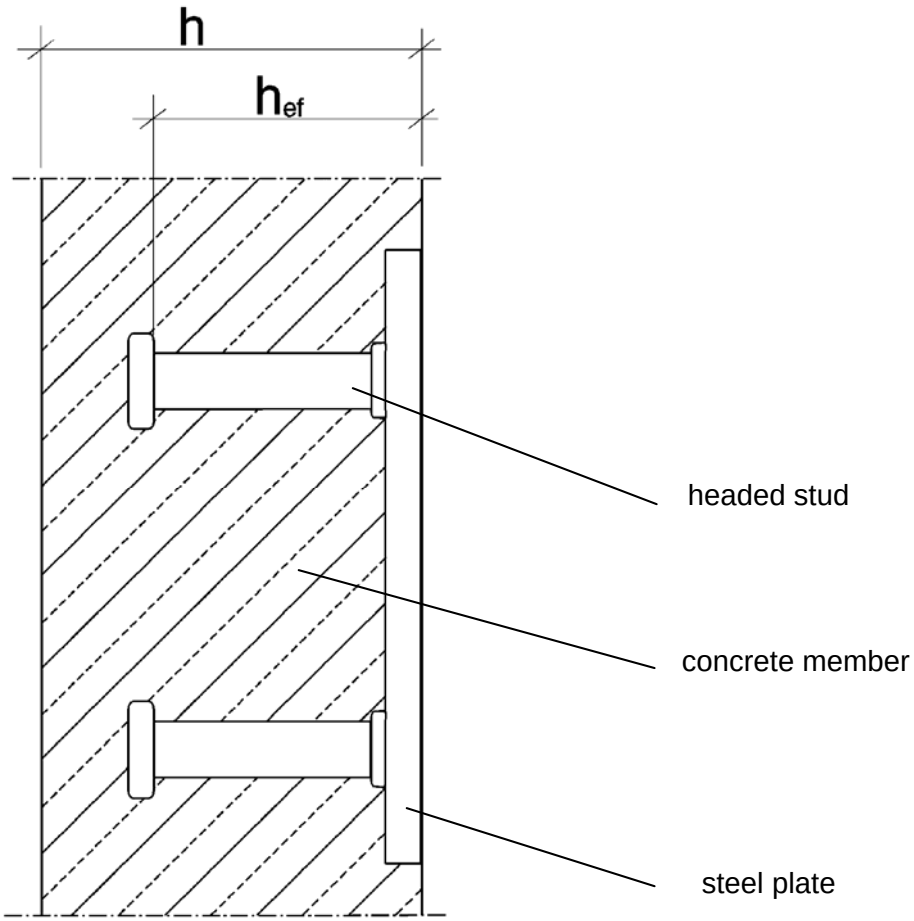
The minimum data required are:

- Dimensions of the steel plate,
- diameter of the headed studs,
- length of the headed studs,
- number of the headed studs,
- material of the steel plate,
- material of the headed studs and
- details on the installation of procedure, preferably by using illustrations.

All data shall be presented in a clear and explicit form.

Dipl.-Ing. E. Jasch
President of Deutsches Institut für Bautechnik
Berlin, 18 November 2008

beglaubigt:
Müller

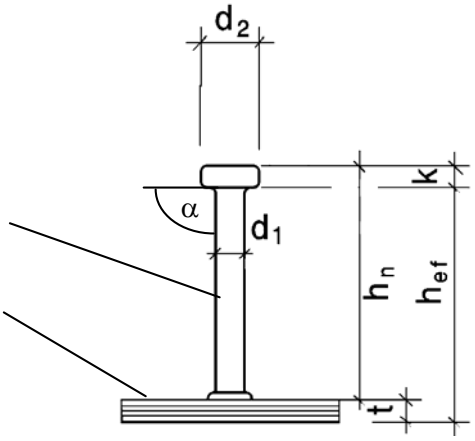


h_{ef} = effective anchorage depth
h = thickness of concrete member

Steel plate with cast-in Nelson headed studs made of steel and stainless steel	**Annex 1** of the European Technical Approval **ETA-03/0041**
Product and intended use	

1 headed stud

2 steel plate

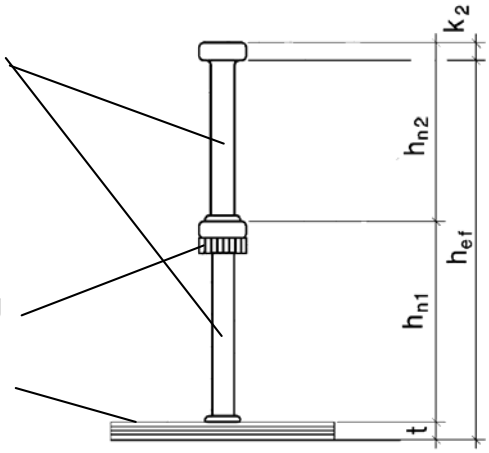


$h_{ef} = h_n - k + t$

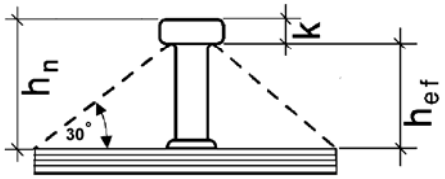
1 headed studs

padded ring

2 steel plate



$h_{ef} = h_{n1} + h_{n2} - k_2 + t$

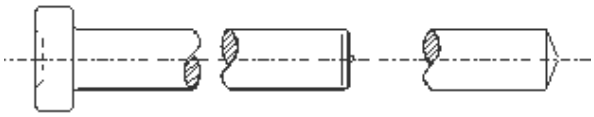


$h_{ef} = h_n - k$
(if the theoretic cone meets the steel plate at angle of ~ 30°)

d_1 = diameter of shaft
d_2 = diameter of head
h_{ef} = effective anchorage depth
h_n = nominal length of the headed stud (after welding)
k = thickness of the head
t = thickness of the steel plate
α = 90°

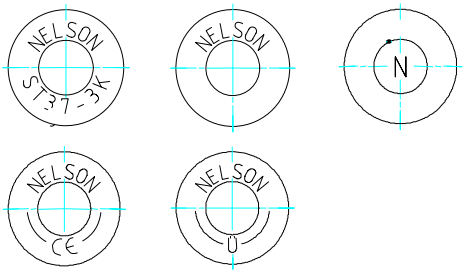
Steel plate with cast-in Nelson headed studs made of steel and stainless steel	**Annex 2** of the European Technical Approval **ETA-03/0041**
Details of the construction product	

Marking



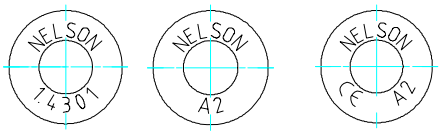
Form A Form B

Steel



Marking:
Manufacturer = Nelson or N
Steel S235J2 = St37-3K
alternatively: steel = without

Stainless steel



Marking:
Manufacturer = Nelson
Stainless steel = 1.4301/1.4303
or A2

Table 1: Dimensions

Headed stud type	Shaft ∅ $d_{1-0,4}$ mm	Head ∅ d_2 mm	Nominal length		thickness of the head k mm
			min h_n mm	max h_n mm	
10	10	19	50	200	7.1
13	13	25	50	400	8
16	16	32	50	525	8
19	19	32	75	525	10
22	22	35	75	525	10
25[1)]	25	40	75	525	12

[1)] Headed stud type 25 only steel S235J2

Steel plate with cast-in Nelson headed studs made of steel and stainless steel	**Annex 3** of the European Technical Approval **ETA-03/0041**
Dimensions, Materials	

Table 2: Materials steel

Part	Denomination	Material	Mechanical properties
1	Headed stud according to EN ISO 13918:2008, Type: SD1	S235J2+C450 EN10025:2005 Conforms to material group 1 ISO/TR 15608 within the limits: C ≤ 0,2% AL≥ 0,02%	$f_{uk} \geq 450$ N/mm², $f_{yk} \geq 350$ N/mm²
2	Steel plate	Steel S235JR; S235JO; S235J2 according to EN 10025:2005	f_{uk} = 340-470 N/mm², f_{yk} = 225 N/mm²
		S355JO; S355J2 according to EN 10025:2005	f_{uk} = 510-680 N/mm², f_{yk} = 345 N/mm²

Table 3: Materials stainless steel

1	Headed stud according to EN ISO 13918:2008, Type:SD3	Stainless steel 1.4301; 1.4303 according to EN 10088:2005	$f_{uk} \geq 540$-780 N/mm², $f_{yk} \geq 350$ N/mm²
2	Steel plate	Stainless steel 1.4571; 1.4401 according to EN 10088:2005	f_{uk} = 530-680 N/mm², f_{yk} = 220 N/mm²

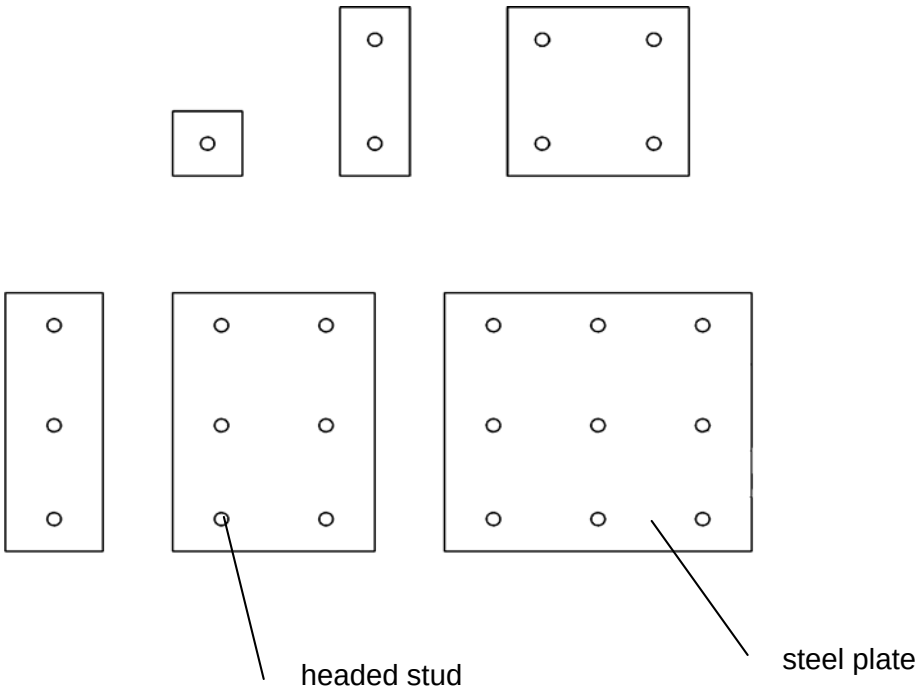
Table 4: Installation indices for headed studs made of steel and stainless steel

Nominal size (mm)		10	13	16	19	22	25[1)]
anchorage depth	min h_{ef}[mm]	50	50	50	75	75	75
minimum spacing	s_{min} [mm]	50	70	80	100	100	100
minimum edge distance	c_{min} [mm]	50	50	50	70	70	100
characteristic spacing	s_{cr} [mm]	3 h_{ef}					
characteristic edge distance	c_{cr} [mm]	1.5 h_{ef}					
minimum thickness of concrete member	h_{min} [mm]	h_{ef} + k + c_{nom}[2)]					

[1)] Headed stud type 25 only steel S235J2

[2)] c_{nom} = required concrete cover according to national regulations

Arrangement of the headed studs



Steel plate with cast-in Nelson headed studs made of steel and stainless steel	**Annex 4** of the European Technical Approval **ETA-03/0041**
Installation, Arrangement of the headed studs	

Table 5: Characteristic values of resistance to tensile load for the design according to Annex 7

Headed stud – nominal size		**10**	**13**	**16**	**19**	**22**	**25**[1)]
Steel failure for headed studs made of steel S235 J2							
Characteristic resistance	$N_{Rk,s}$ [kN]	32	56	86	122	164	213
Partial safety factor	γ_{Ms} [x)]	1.54					
Steel failure for headed studs made of stainless steel							
Characteristic resistance	$N_{Rk,s}$ [kN]	39	67	103	146	197	--
Partial safety factor	γ_{Ms} [x)]	1.85					
[1)] Headed stud type 25 only steel S235J2							
Pull-out failure							
Characteristic resistance	$N_{Rk,p}$ [kN]	30	50	90	75	85	115
Increasing factors ψ for the characteristic resistance	C25/30	1.10					
	C30/37	1.22					
	C35/45	1.34					
	C40/50	1.41					
	C45/55	1.48					
	C50/60	1.55					
Partial safety factor	γ_{Mp} [x)]	1.5					
Concrete cone failure							
Effective anchorage depth	h_{ef} [mm]	$h_n - k + t$					
Characteristic spacing	$s_{cr,N}$ [mm]	$3h_{ef}$					
Characteristic edge distance	$c_{cr,N}$ [mm]	$1.5h_{ef}$					
Partial safety factor	γ_{Mc} [x)]	1.5					
Blow-out failure							
Partial safety factor	γ_{Mcb} [x)]	1.5					

[x)] In absence of other national regulations.

Steel plate with cast-in Nelson headed studs made of steel and stainless steel	**Annex 5** of the European Technical Approval **ETA-03/0041**
Characteristic values of resistance to tensile load	

Table 6: Characteristic resistance of a hanger reinforcement bar to tensile load and anchorage length of the hanger reinforcement

Hanger reinforcement concrete reinforcing steel B 500B			∅ 12	∅ 14	∅ 16
Characteristic resistance of a hanger reinforcement bar	$N_{Rk,h}$ [kN]	h_n [1] ≥ 150 mm	27	36	45
		h_n [1] ≥ 200 mm	31	40	50
		h_n [1] ≥ 300 mm	35	44	55
		h_n [1] ≥ 350 mm	37	47	59
Anchorage length of the hanger reinforcement	l_{VR} [mm]		660	770	880
Partial safety factor	γ_{Mh} [x]	1.5			

[1] h_n = Nominal length of the headed stud

[x] In absence of other national regulations.

Table 7: Displacement under tensile load

Headed stud – nominal size	**10**	**13**	**16**	**19**	**22**	**25**[2]
Displacements[1] to 0.7 mm under following loads in [kN]	14	20	25	30	35	45

[1] The indicated displacements are valid for short term loading, the displacements can be increased under long term loading to 1.8 mm.

[2] Headed stud type 25 only steel S235J2

Table 8: Characteristic values of resistance to shear load for the design according to Annex 7

Headed stud – nominal size		**10**	**13**	**16**	**19**	**22**	**25**[1]
Steel failure for headed studs made of steel S235J2							
Characteristic resistance	$V_{Rk,s}$ [kN]	19	33	51	73	99	128
Partial safety factor	γ_{Ms} x)	1.28					
Steel failure for headed studs made of stainless steel							
Characteristic resistance	$V_{Rk,s}$ [kN]	23	40	62	88	118	--
Partial safety factor	γ_{Ms} x)	1.54					
1) Headed stud type 25 only steel S235J2							
Concrete pry-out failure							
Factor in equation (5.6) to Annex C section 5.2.3.3 of ETAG 001, $N_{Rk,c}$ according to Annex 7, section 3.3	k	2.0					
Partial safety factor	γ_{Mcp} x)	1.5					
Concrete edge failure							
Effective length of the headed stud	$l_f = h_{ef}$ [mm]	$h_n - k + t$					
Effective outside diameter	$d_{nom} = d_1$ [mm]	10	13	16	19	22	25
Partial safety factor	γ_{Mc} x)	1.5					

x) In absence of other national regulations.

Steel plate with cast-in Nelson headed studs made of steel and stainless steel	**Annex 6** of the European Technical Approval **ETA-03/0041**
Characteristic values of resistance to shear load	

Table 9: Characteristic resistance of a hanger reinforcement bar at shear load and anchorage length of the hanger reinforcement

Hanger reinforcement concrete reinforcing steel B 500B	∅ 8	∅ 10	∅ 12	∅ 14	∅ 16
Characteristic resistance of a hanger reinforcement bar $V_{Rk,h}$ [kN]	12	19	28	38	50
Anchorage length of the hanger reinforcement l_{VR} [mm]	440	550	660	770	880
Partial safety factor γ_{Mh} x)	1.15				

x) In absence of other national regulations.

Table 10: Displacements under shear load

Headed stud – nominal size	**10**	**13**	**16**	**19**	**22**	**25**[2]
Displacements[1] to 1.5 mm under following loads in [kN]	15	20	30	45	60	75

1) The indicated displacements are valid for short term loading, the displacements can be increased under long term loading to 2.0 mm.

2) Headed stud type 25 only steel S235J2

Design of anchorage of the headed studs in concrete

Table of contents

Design

1 General

The design method is used for the design of the anchorage of headed studs in concrete. It is based on the assumption that sufficient experiences are available from tests with headed bolts and metal anchors, since the design method for metal anchors (Annex C of ETAG 001) has also been derived from these tests.

The proposed design for headed studs shall be considered as transitional solution until the design method being prepared in CEN/TC250/SC2/WG2 will be available.

The design of the headed stud is based on Annex C of ETAG 001.

Anchorage is admissible only by using single headed studs or several headed studs (groups), see Annex 4. Other arrangements e.g. in a triangular or circular pattern are also allowed; however, the provisions of this design method should be applied with engineering judgement.

The anchorage may be designed as a group only, if the acting loads are transmitted via the sufficiently stiff steel plate into the individual headed studs of the group. It is only allowed to use the same diameter and length in a group.

The action-effects of the headed studs on the concrete surface shall be calculated from the forces and moments acting at the steel plate according to the theory of elasticity with the following assumptions:

- The steel plate remains plane under the action-effects.
- The stiffness of all headed studs is identical. It corresponds to the stiffness of the steel cross-section.
- The module of elasticity of the concrete shall be taken with E_c = 30.000 N/mm^2.

For anchorages at the member edge subjected to shear loading only the headed studs near the edge may be used for bearing the load.

The concrete member shall be of normal weight concrete of at least strength class C20/25.

Terminology and symbols for actions, resistances and indices shall be applied according to clause 2 of Annex C of ETAG 001.

2 Required verifications

The design of the headed studs shall be based on the safety concept with partial safety factors according to Annex C, ETAG 001.
The required verifications of the resistances are shown in Table 2.1 and 2.2.

Table 2.1: Required verifications for resistance to tension loading

Failure mode		Single anchorage	Groups
Steel failure (head stud)		$N_{Sd} \le N_{Rk,s} / \gamma_{Ms}$	$N_{Sd}^{h} \le N_{Rk,s} / \gamma_{Ms}$
Pull-out failure		$N_{Sd} \le N_{Rk,p} / \gamma_{Mc}$	$N_{Sd}^{h} \le N_{Rk,p} / \gamma_{Mc}$
Concrete cone failure without hanger reinforcement		$N_{Sd} \le N_{Rk,c} / \gamma_{Mc}$	$N_{Sd}^{g} \le N_{Rk,c} / \gamma_{Mc}$
Blow-out failure		$N_{Sd} \le N_{Rk,cb} / \gamma_{Mc}$	$N_{Sd}^{g} \le N_{Rk,cb} / \gamma_{Mc}$
Concrete cone failure with hanger reinforcement	Hanger reinforcement	$N_{Sd} \le N_{Rk,h} / \gamma_{Mh}$	$N_{Sd}^{h} \le N_{Rk,h} / \gamma_{Mh}$
	Concrete cone	$N_{Sk} \le N_{Rk,c} / 1.3$	$N_{Sk}^{g} \le N_{Rk,c} / 1.3$
Splitting failure		Minimum reinforcement acc. to 3.5	

Table 2.2: Required verifications for resistance to shear loading

Failure mode	Single anchorage	Groups
Steel failure (head stud)	$V_{Sd} \le V_{Rk,s} / \gamma_{Ms}$	$V_{Sd}^{h} \le V_{Rk,s} / \gamma_{Ms}$
Concrete pry-out failure	$V_{Sd} \le V_{Rk,cp} / \gamma_{Mc}$	$V_{Sd}^{g} \le V_{Rk,cp} / \gamma_{Mc}$
Concrete edge failure [1)]	$V_{Sd} \le V_{Rk,c} / \gamma_{Mc}$	$V_{Sd}^{g} \le V_{Rk,c} / \gamma_{Mc}$
Resistance of hanger reinforcement with anchorages near the edge	$V_{Sd} \le V_{Rk,h} / \gamma_{Mh}$	$V_{Sd}^{h} \le V_{Rk,h} / \gamma_{Mh}$

1) This verification is not required, if there is a hanger reinforcement (see section 4.4).

h maximum loaded headed stud of a group
g total load of a group

In the case of a combined tension and shear loading the following Equation shall be observed:

$$(N_{Sd}/N_{Rd})^{\alpha} + (V_{Sd}/V_{Rd})^{\alpha} \le 1 \qquad (1)$$

The ratios N_{Sd}/N_{Rd} and V_{Sd}/V_{Rd} shall each be given the maximum value from the individual failure modes.
For the anchorages without hanger reinforcement or for anchorages with hanger reinforcement for tension load and shear load the α-value in Equation (1) shall be taken with 1.5. Where either a hanger reinforcement for tension load (section 3.6) or a hanger reinforcement for shear loading at the edge (section 4.4) is taken into account for the design, the α-value shall be taken with 2/3.

3 Characteristic resistance under tension load

3.1 Steel failure

The characteristic resistance $N_{Rk,s}$ of a headed stud made of steel and of stainless steel is determined in Table 5, Annex 5.

3.2 Pull-out failure

The characteristic resistance $N_{Rk,p}$ of a headed stud made of steel and of stainless steel is determined in Table 5, Annex 5.

3.3 Concrete cone failure

With reference to Annex C of ETAG 001 the characteristic resistance to tension load of a headed stud or a group of headed studs in case of concrete cone failure shall be determined as follows:

$$N_{Rk,c} = N^{o}_{Rk,c} \cdot \frac{A_{c,N}}{A^{o}_{c,N}} \cdot \Psi_{s,N} \cdot \Psi_{re,N} \cdot \Psi_{ec,N} \Psi_{ucr,N} \text{ [N]} \qquad (2)$$

The different factors of equation (2) are given below:

a) The initial value of the characteristic resistance of a headed stud in concrete is obtained by:

$$N^{o}_{Rk,c} = 8.0 \sqrt{f_{ck,cube}} \cdot h_{ef}^{1.5} \text{ [N]} \qquad (2a)$$

with
- $f_{ck,cube}$ [N/mm²]; with $f_{ck,cube}$ maximum 60 N/mm².
- h_{ef} [mm] is given in Table 5 according to Annex 5.

b) The geometric effect of spacing and the edge distances on the characteristic resistance is taken into account by the ratio $A_{c,N} / A^{o}_{c,N}$.
with:

$A^{o}_{c,N}$ = area of concrete cone of a single headed stud with large spacing and edge distance at the concrete surface, idealized the concrete cone as a pyramid with a height equal to h_{ef} and a basic length equal to $3h_{ef}$ (see Figure 1).

$A_{c,N}$ = actual area of concrete cone of the anchorage at the concrete surface. It is limited by overlapping concrete cones of adjoining anchors ($s \leq 3h_{ef}$) as well as by the concrete member ($c \leq 1.5h_{ef}$).
Example for the calculation of $A_{c,N}$ see Figure 2.

The influencing factors ($\Psi_{s,N}$, $\Psi_{re,N}$, $\Psi_{ec,N,}$ $\Psi_{ucr,N}$) shall be determined according to sub-sections c), d), e) and f) of Annex C section 5.2.2.4 and 4.1 ETAG 001. $s_{cr,N}$ shall be taken with $3h_{ef}$, and $c_{cr,N}$ with $1.5h_{ef}$.

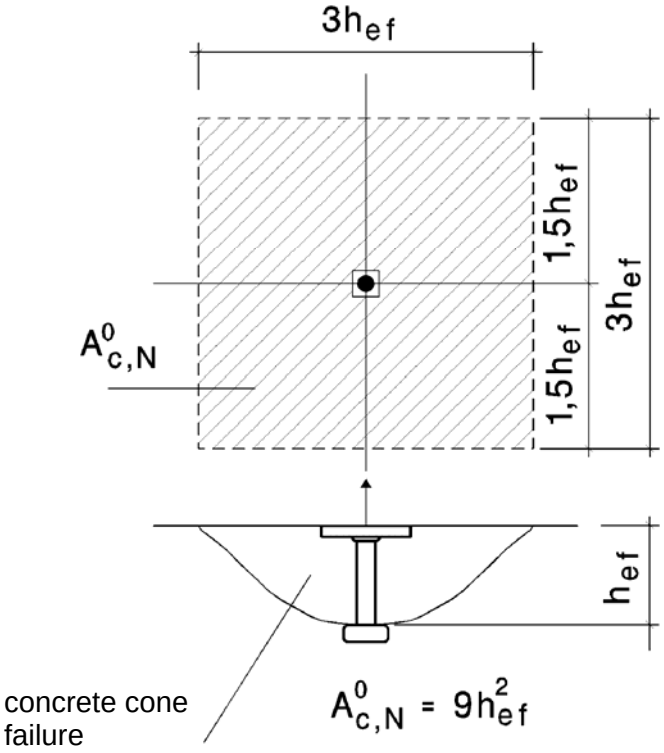
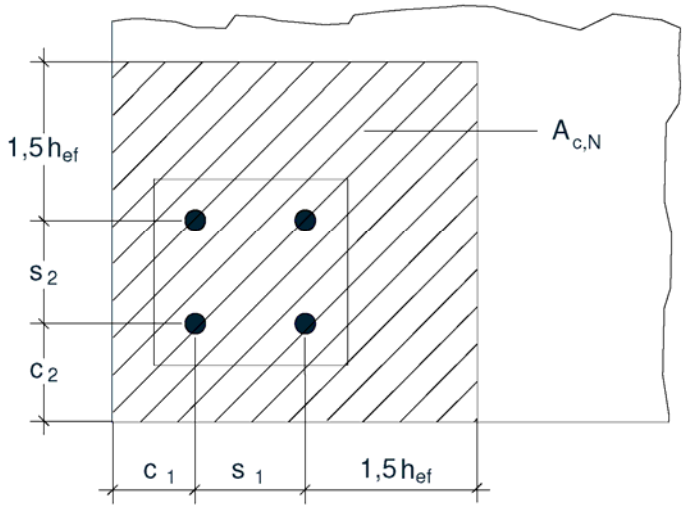


Figure 1: Idealized concrete cone failure and area $A^0_{c,N}$ of concrete cone



$A_{c,N} = (c_1+s_1+1.5h_{ef})(c_2+s_2+1.5h_{ef})$
if : $c_1 ; c_2 \leq 1.5h_{ef}$
$s_1 ; s_2 \leq 3h_{ef}$

Figure 2: Example of actual areas $A_{c,N}$ of the idealized concrete cones of headed stud in the case of axial tension load

3.4 Blow-out failure

The characteristic resistance $N_{Rk,cb}$ of a headed stud in case of local concrete blow-out failure at the edge shall be determined with reference to Annex C, ETAG 001 as follows:

$$N_{Rk,cb} = N^0_{Rk,cb} \cdot \frac{A_{c,Nb}}{A^0_{c,Nb}} \cdot \psi_{s,Nb} \cdot \psi_{ec,N} \quad [N] \qquad (3)$$

The verification against local concrete blow out failure at the member edge shall be made always, where the edge distance is $c \leq 0.5\ h_{ef}$ in one direction.
In the following the individual factors of equation (3) are given:

a) The initial value of the characteristic resistance of a headed stud is

$$N^0_{Rk,cb} = 8.5 \cdot c_1 \cdot d_1 \cdot \sqrt{f_{ck,cube}} \quad [N] \qquad (3a)$$

for $f_{ck,cube}$ = 60 N/mm² as maximum.

$f_{ck,cube}$	= characteristic concrete compression strength	[N/mm²]
c_1	= edge distance	[mm]
d_1	= shank diameter	[mm]

b) The influence of spacing and edge distances on the characteristic resistance is taken into account by the ratio $A_{c,Nb}$ / $A^o_{c,Nb}$:

$A^o_{c,Nb}$ = 36 c_1^2; projected area of an individual headed stud (on the lateral surface of the concrete), assuming the concrete cone as a pyramid with the peak in the middle of the head, with a height equal to c_1 and a base length equal to 6 c_1 (see Figure 3).

$A_{c,Nb}$ = existing projected area (on the lateral surface of the concrete).
For the calculation the concrete cone shall be idealized as above and the overlapping of the projected areas of adjoining headed studs shall be noted. An example for the calculation of the projected area is shown in Figure 4.

c) The influence factor $\Psi_{s,Nb}$ takes account of the disturbance of stress in the concrete at the corner of the concrete member.

$$\Psi_{s,Nb} = 0.7 + 0.3 \cdot \frac{c_2}{3c_1} \leq 1 \qquad (3b)$$

For securing the member corner it is necessary to provide a corner reinforcement.

d) The factor $\Psi_{ec,Nb}$ takes account of an eccentric tension loading of the row of headed studs.

$$\Psi_{ec,Nb} = \frac{1}{1 + 2e / (6c_1)} \leq 1 \qquad (3c)$$

e = "internal" eccentricity of the tensioned headed stud

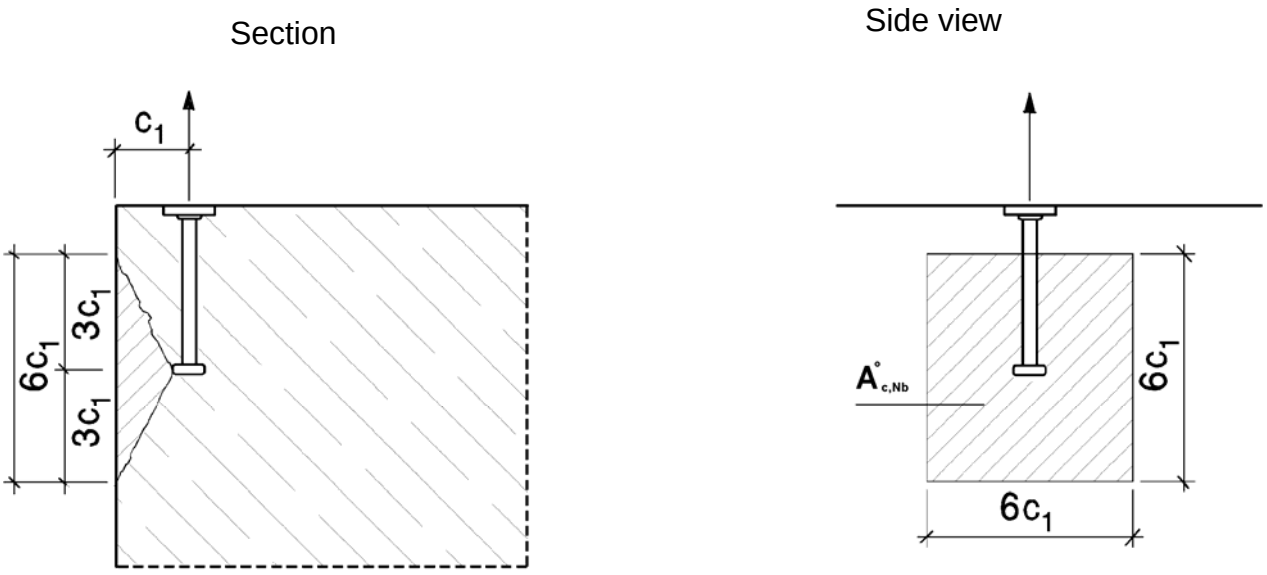
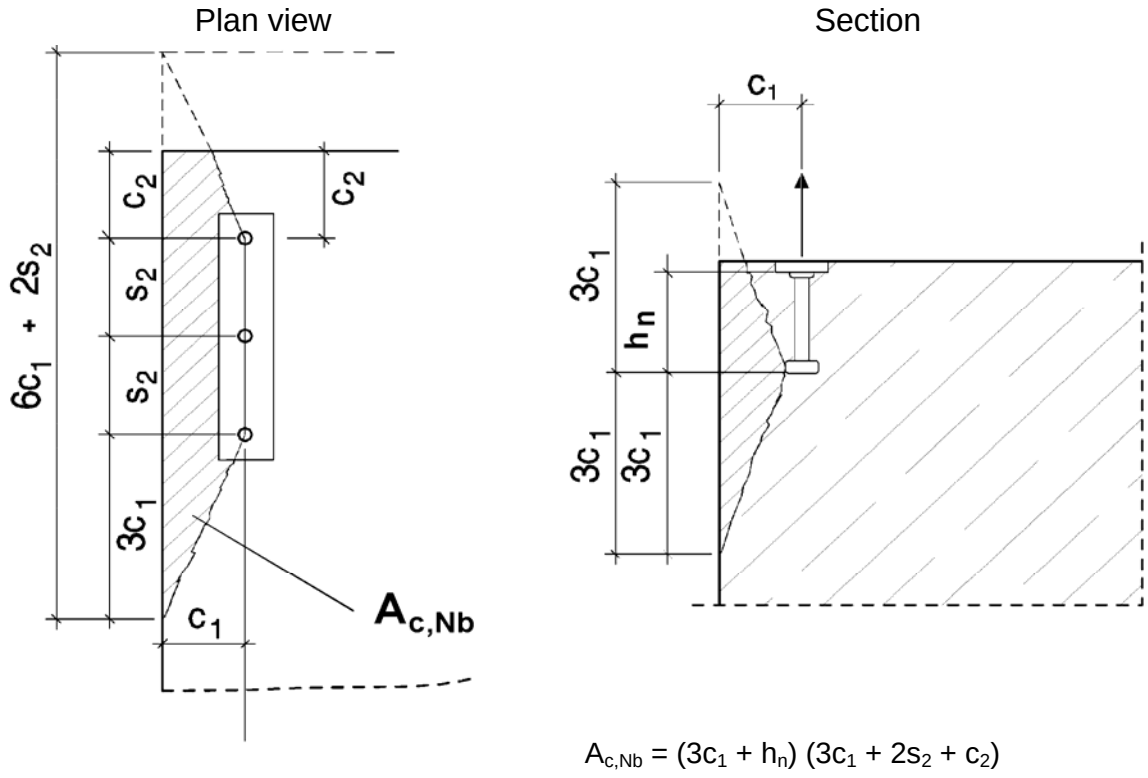


Figure 3 : Idealized concrete cone of the headed stud in the case of local concrete blow-out failure at the edge of an individual headed stud



$A_{c,Nb} = (3c_1 + h_n)\ (3c_1 + 2s_2 + c_2)$

Figure 4 : Idealized concrete cone of the headed stud in the case of local concrete blow-out failure at the edge

Steel plate with cast-in Nelson headed studs made of steel and stainless steel	**Annex 7.6** of the European Technical Approval **ETA-03/0041**
Design of anchorage of the headed studs in concrete	

3.5 Splitting failure

A minimum reinforcement with the following section A_S shall exist in order to prevent a splitting of the concrete member:

$$A_{S\,erf} = 0.5 \bullet \frac{\sum N_{Sd}}{f_{yk} / \gamma_{Mh}} \quad [mm^2] \qquad (4)$$

$\sum N_{Sd}$ = Sum of the tensile forces of the headed studs in tension under the design value of the actions [N]

f_{yk} = Yield strength of reinforcement [N/mm²]

γ_{Mh} = Partial safety factor for the reinforcement according to national rules; in the absence of such rules, the partial safety factor can be taken with 1.15 from EC 2.

This minimum reinforcement can be omitted, if there is at least one cross-wise reinforcement (B 500 B) ∅ 8/15 in the zone of the headed studs.
For slab- and plate-like members the reinforcement against splitting must be provided in both directions, i.e. in the case of members subjected mainly to tension the reinforcement shall be provided on both cross-sectional surfaces and in the case of members subjected mainly to bending on the side exposed to tension. It shall consist of at least three bars with a bar distance ≤ 150 mm and shall be anchored, outside the anchorage, with an anchorage depth according to national rules.

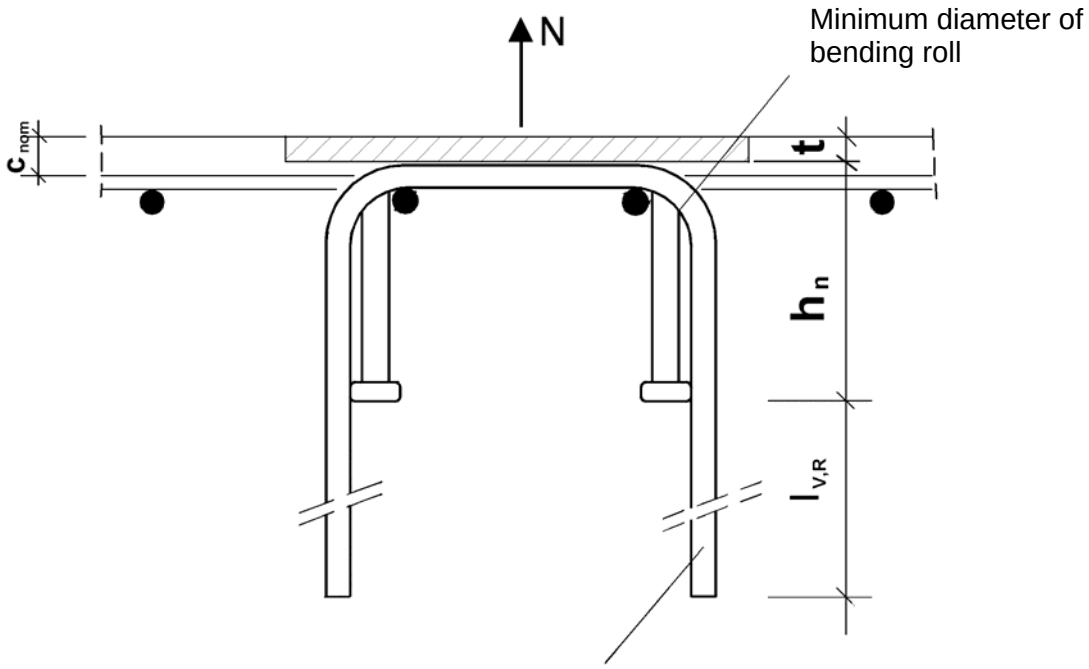
For linear structures the splitting reinforcement needs to be provided in one direction only. In the case of anchorages near the edge of members this reinforcement must be also provided as edge reinforcement with corresponding hanger reinforcement.

3.6 Characteristic resistance of a hanger reinforcement under tension load

An additional hanger reinforcement may be taken into account for resistance to the tension load, if the length of the headed stud in the concrete is at least 150 mm and the edge distance is $c \geq 1.5\ h_{ef}$.
The reinforcement shall consist of reinforcing steel B 500 B with a diameter of ≤ 16 mm.
The characteristic resistance $N_{Rk,h}$ of a bar of the hanger reinforcement is given in Table 6, Annex 5.1 depending on the nominal length of the headed stud (h_n) in concrete and the length of the anchorage ($l_{V,R}$) of the hanger reinforcement.
Where a hanger reinforcement is provided at the headed stud according to Figure 5, Annex 7.8 verification against concrete cone failure needs to be performed only for the limit state of serviceability with $\gamma_G = \gamma_Q = 1.0$ and $\gamma_{Mc} = 1.3$. The edge distance is $c \geq 1.5\ h_{ef}$.

The hanger reinforcement shall be anchored at the side opposite to the load direction in the concrete.

For eccentric tension loading all headed studs shall be provided with the reinforcement determined for the maximum loaded headed stud.



c_{nom} = required concrete cover
h_n = nominal length of the headed stud (after welding)
$l_{V,R}$ = anchorage length of the hanger reinforcement
t = thickness of the steel plate

For the hanger reinforcement only ties or loops may be used, which rest directly on the headed stud.

Figure 5: Hanger reinforcement under tension load

Steel plate with cast-in Nelson headed studs made of steel and stainless steel	**Annex 7.8** of the European Technical Approval **ETA-03/0041**
Design of anchorage of the headed studs in concrete	

4 Characteristic resistance under shear load

4.1 Steel failure

The characteristic resistance $V_{Rk,s}$ is given in Table 8, Annex 6.

4.2 Pry-out failure

The characteristic resistance $V_{Rk,cp}$ shall be determined with reference to Annex C section 5.2.3.3 of ETAG 001.
The k-value is given in Table 8, Annex 6.
$N_{Rk,c}$ shall be determined according to equation (2), Annex 7.3 for the headed studs stressed by shear loads.

4.3 Concrete edge failure

For the verification and determination of the characteristic resistance $V_{Rk,c}$ in case of concrete edge failure the specifications given in Annex C section 5.2.3.4 of ETAG 001 shall apply. In equation (5.7a) of ETAG 001 for $d_{nom} = d_1$ and for $l_f = h_{ef}$ shall be used.

4.4 Characteristic resistance of a hanger reinforcement under shear load

The characteristic resistance $V_{Rk,h}$ of the hanger reinforcement to take up the shear load and the necessary anchorage length l_{VR} of the hanger reinforcement is given in Table 9, Annex 6.1.
The verification against concrete edge failure according to section 4.3 can be omitted, if a hanger reinforcement is provided according to Figures 6 and 6a of Annex 7.10.
The hanger reinforcement shall be anchored on the side not exposed to the loading with an anchorage length $l_{V,R}$ which is given in Table 9, Annex 6.1.
For eccentric shear loading the reinforcement determined for the maximum loaded headed stud shall be used for all headed studs.
For the hanger reinforcement only ties or loops may be used, which rest directly on the headed studs.

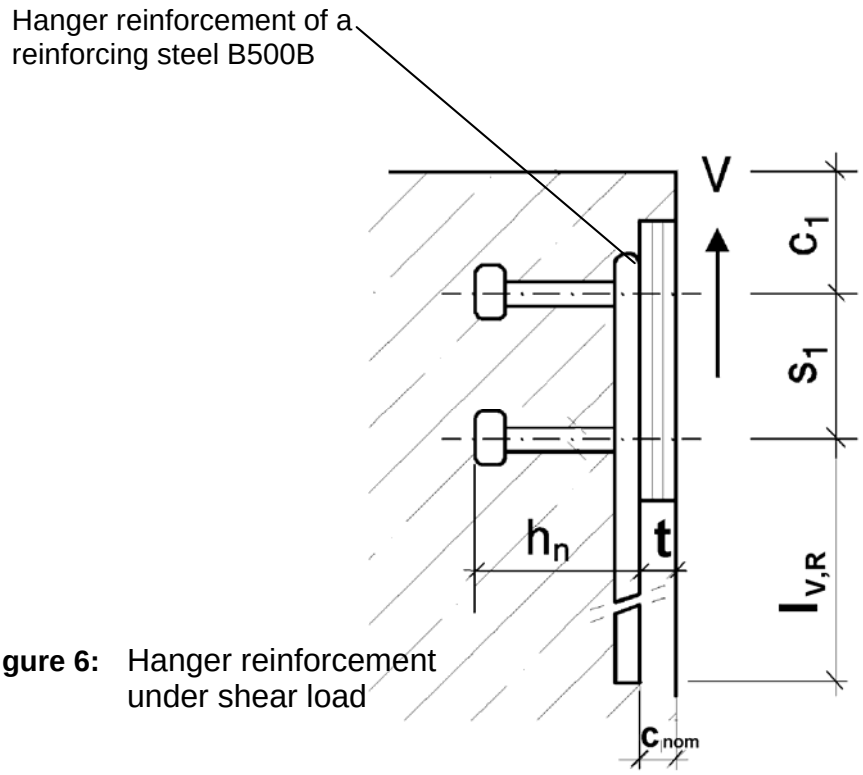


Figure 6: Hanger reinforcement under shear load

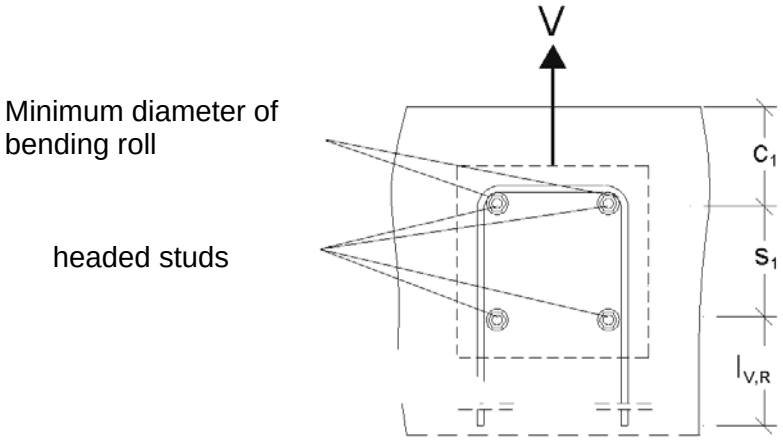


Figure 6a : Example of a hanger reinforcement under shear load

c_{nom} **=** required concrete cover ($c_{nom} \geq t$)
$l_{V,R}$ **=** anchorage length of the hanger reinforcement

Steel plate with cast-in Nelson headed studs made of steel and stainless steel	**Annex 7.10** of the European Technical Approval **ETA-03/0041**
Design of anchorage of the headed studs in concrete	

5 Resistance of concrete member

The shear resistance of the concrete member shall be verified according to section 7.2 of Annex C, ETAG 001 with the following modifications:

- The distance < h_{ef} given in section 7.2 c) of the hanger reinforcement from the outermost anchors of a group shall be 0.5 $h_{ef} \leq 50$ mm for headed studs.

- The checks required in Table 7.1 for ensuring the shear resistance of the concrete member are modified for headed studs as follows:

Calculated value of shear force of the concrete member under due consideration of the headed studs	Spacing between single headed studs and groups of headed studs [mm]	N_{sk} [kN]	Proof of calculated shear force resulting from headed studs loads
$V_{Sd} \leq 0{,}8 \bullet V_{Rd,ct}$	$a \geq 3\ h_{ef}$	≤ 60	not required
$0{,}8 \bullet V_{Rd,ct} \leq V_{Sd} \leq 1{,}0 \bullet V_{Rd,ct}$	$a \geq 3\ h_{ef}$ und $a \geq 200 \bullet \sqrt{N_{sk}}$	≤ 30	not required
	$a \geq 3\ h_{ef}$	≤ 60	required: $V_{Sd,a} \leq 0.4\ V_{Rd,ct}$ or hanger reinforcement
		> 60	not required , but hanger reinforcement