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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)

Deutsches Institut für Bautechnik

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*	Einbetonierte und an Stahlplatten angeschweißte Kopfbolzen aus Stahl und aus nichtrostendem Stahl *Headed studs cast-in and welded on steel plates made of steel and of stainless steel*
Geltungsdauer: vom *from* *Validity:* bis *to*	13 May 2013 13 May 2018
Herstellwerke *Manufacturing plants*	Herstellwerk 1 Herstellwerk 2

Diese Zulassung umfasst *This Approval contains*	31 Seiten einschließlich 23 Anhänge *31 pages including 23 annexes*
Diese Zulassung ersetzt *This Approval replaces*	ETA-03/0041 mit Geltungsdauer vom 18.11.2008 bis 18.11.2013 *ETA-03/0041 with validity from 18.11.2008 to 18.11.2013*

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], as amended by law of 31 October 2006[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 February 1989, p. 12
2 Official Journal of the European Communities L 220, 30 August 1993, p. 1
3 Official Journal of the European Union L 284, 31 October 2003, p. 25
4 *Bundesgesetzblatt Teil I 1998*, p. 812
5 *Bundesgesetzblatt Teil I 2006*, p. 2407, 2416
6 Official Journal of the European Communities L 17, 20 January 1994, p. 34

II SPECIFIC CONDITIONS OF THE EUROPEAN TECHNICAL APPROVAL

1 Definition of product and intended use

1.1 Definition of the construction product

The Nelson-headed studs welded on steel plates 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 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 steel plates with welded on headed studs are anchored surface-flush in the concrete.

An illustration of the product and intended use is given in Annex 1.

1.2 Intended use

The headed studs welded-on steel plates are 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.

The headed studs welded-on steel plates are to be used for the anchorage under static or quasi static actions as well as under fatigue actions in reinforced normal concrete of the minimum strength class C20/25 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.

Further steel components may be welded-on to the steel plate on the side which is not cast-in.

The intended use of the steel plate with welded-on headed studs concerning corrosion is given in Annex 4, Table 2 and 3 depending on the chosen material.

The provisions made in this European technical approval are based on an assumed 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.

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.

The characteristic values for the design calculation of the anchorage are given in Annexes 5 to 7.

2.1.2 Headed stud

The headed studs made of steel and stainless 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 Annex 3, Table 1 and Annex 4, Table 2 and 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 Marking

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

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 following verifications:

Verifications for tension loads for

1.	Steel failure - headed stud	$N_{Rk,s}$
2.	Concrete failure - pullout	$N_{Rk,p}$
3.	Concrete failure - concrete cone	$N_{Rk,c}$
4.	Concrete failure - splitting due to loading	$N_{Rk,sp}$
5.	Concrete failure - blow-out	$N_{Rk,cb}$
6.	Reinforcement	$N_{Rk,re}$, $N_{Rd,a}$
7.	Displacement under tension loads	δ_N

[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.

Verifications for shear loads for

1.	Steel failure without lever arm	$V_{Rk,s}$
2.	Concrete failure - pry-out	$V_{Rk,cp}$
3.	Concrete failure - concrete edge	$V_{Rk,c}$
4.	Reinforcement	$N_{Rk,re}$, $N_{Rd,a}$
5.	Displacement under shear loads	δ_V

In addition to the specific clauses relating to dangerous substances contained in this European Technical Approval, there may be other requirements applicable to the products falling within its scope (e.g. transposed European legislation and national laws, regulations and administrative provisions). In order to meet the provisions of the Construction Products Directive, these requirements need also to be complied with, when and where they apply.

3 Evaluation and attestation of conformity 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 control 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 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]

[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.

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 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 Design

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

The design of the anchorage is based on CEN/TS 1992-4:2009 "Design of fastenings for use in concrete", part 1 and 2 or on the design method in Annex 12 to 23 of this European technical approval under the responsibility of an engineer experienced in anchorages and concrete building.

The design methods must not be mixed. The characteristic values for CEN/TS 1992-4:2009 are given in Annexes 5 to 7. The characteristic values for the design method according Annex 12 to 23 are given in Annex 8 to 11.

It is generally assumed for the design method in Annex 12 to 23 that the concrete is cracked and that the occurring splitting forces are resisted by the reinforcement. The required cross section of the minimum reinforcement is determined according Annex 19.

Taking into account the loads to be anchored verifiable calculation notes and drawings are prepared.

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

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 $\gamma_{Ms,fat}$ = 1.35 shall be applied.

4.3 Installation

4.3.1 Welding of the headed studs on the steel plate

4.3.1.1 General

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. The level of quality requirements shall correspond to EN ISO 3834-2:2005 "Part 2: Comprehensive quality requirements".

4.3.1.2 Steel plates

The steel plates, on which headed studs of steel S235J2+C450 according to Annex 4, Table 2 will be welded, shall consist of the materials S235JR, S235JO, S235J2, S355JO or S355J2 according to Annex 4, Table 2.

The steel plates, on which headed studs of stainless steel (1.4301; 1.4303) according to Annex 4, Table 3 will be welded, shall consist of the stainless steel 1.4571 or 1.4401 according to Annex 4, Table 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.

The material and dimensions of the steel plate shall be according the design drawings.

4.3.1.3 Welded connection

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 welding of headed studs on the steel plate the executing company shall have a valid acceptance for arc stud welding according EN ISO 14555.

The material, the size and position of the headed studs shall be according to the design drawings.

4.3.2 Setting steel plates with headed studs in concrete

The fitness of the anchorage for the intended use can be assumed only, if the following installation conditions are kept:

- 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.
- Installation in accordance with the manufacturer's specifications and the design drawings with exact position of the steel plate.
- The anchorage is 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 is properly compacted (no significant voids). For large fixtures (steel plate > 400 mm x 400 mm) vent openings are provided. These are specified in the installation instructions.
- Compliance with the installation parameters.

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 3834:2005 "Quality requirements for fusion welding of metallic materials ". The quality level shall be according EN ISO 3834-2:2005 "Part 2: Comprehensive quality requirements".

5 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 and 4.3 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:

- diameter of the headed studs,
- length of the headed studs,
- material of the headed studs.

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

Uwe Bender
Head of Department

beglaubigt:
Müller

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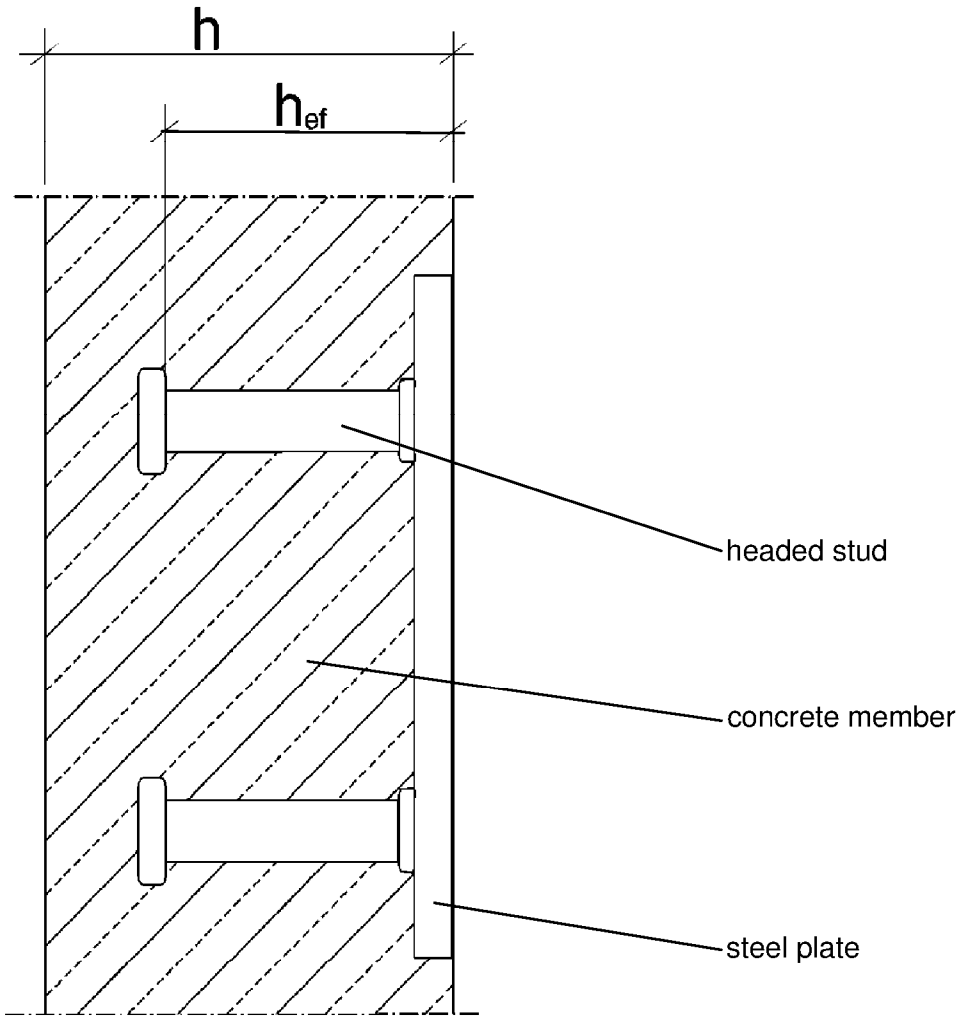


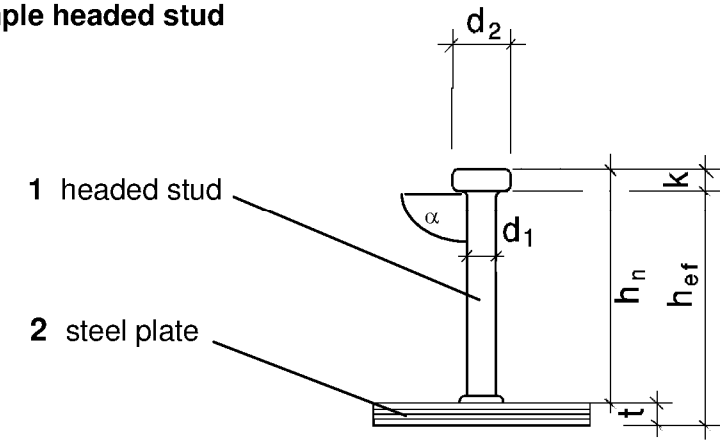
h_{ef} = effective anchorage depth

h = thickness of concrete member

Nelson headed studs	**Annex 1**
Product and intended use	

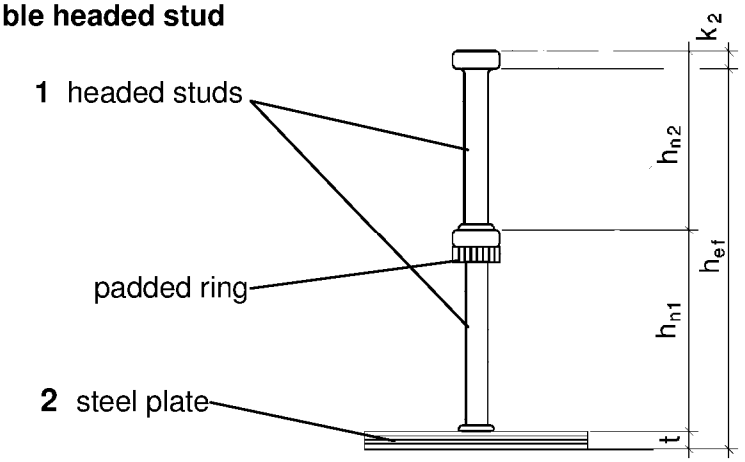
Deutsches Institut für Bautechnik DIBt

Fig. 1: Simple headed stud



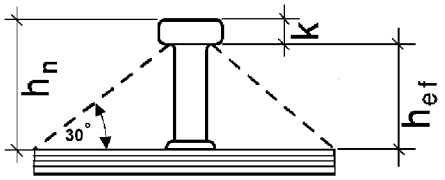
$h_{ef} = h_n - k + t$

Fig. 2: Double headed stud



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

Fig. 3: Short headed stud



$h_{ef} = h_n - k$
(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°

Nelson headed studs	**Annex 2**
Construction product	

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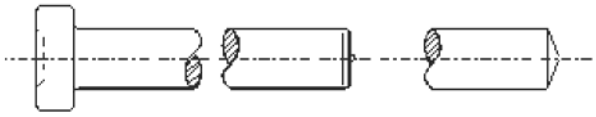
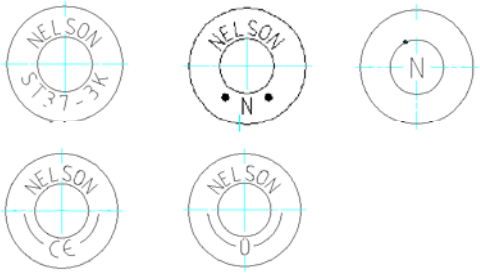
Marking



Steel



Marking: e.g.: NELSON ST37-3K
NELSON or N = Identifying mark of the producer
ST37-3K = material
or without

Stainless steel

Marking: e.g.: NELSON 1.4301
NELSON = Identifying mark of the producer
1.4301 or = material
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 or S355

Nelson headed studs	Annex 3
Marking, dimensions	

Deutsches Institut für Bautechnik DIBt

Table 2: Materials steel

Part	Denomination	Material	Mechanical properties	Intended Use
1	Headed stud according to EN ISO 13918:2008 Type: SD1	S235J2+C450 or S355 acc. 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	Steel plate with welded on headed studs may only be used in structures subject to dry internal conditions
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

Part	Denomination	Material	Mechanical properties	Intended Use
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	Steel plates with welded on headed studs may also be used in structures subject to external atmospheric exposure (including industrial and marine environment), or exposure in permanently damp internal conditions, if no particular aggressive conditions are e.g. permanent, alternating immersion in seawater or the splash zone of sea water, chloride atmosphere of indoor swimming pools or atmosphere with extreme chemical pollution (e.g. in desulphurization plant or road tunnels where de-icing materials are used).
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	

Nelson headed studs	**Annex 4**
Material, intended use	

Deutsches Institut für Bautechnik DIBt

Table 4: Installation parameters 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 or S355							
[2)] c_{nom} = required concrete cover according to national regulations							

Nelson headed studs	**Annex 5**
Installation parameters	

Deutsches Institut für Bautechnik DIBt

Table 5: Characteristic values of resistance of headed studs made of steel and stainless steel for tensile load for the design according to CEN/TS 1992-4-2:2009

Headed stud – nominal size			**10**	**13**	**16**	**19**	**22**	**25**[1]
Steel failure for headed studs made of steel								
Characteristic resistance		$N_{Rk,s}$ [kN]	35	60	90	128	171	221
Partial safety factor		γ_{Ms} [2]	1.54					
Steel failure for headed studs made of stainless steel								
Characteristic resistance		$N_{Rk,s}$ [kN]	42	72	109	153	205	--
Partial safety factor		γ_{Ms} [2]	1.85					
Pull-out failure								
Characteristic resistance		$N_{Rk,p}$ [kN]	30	50	90	75	85	115
Increasing factors ψ for the characteristic resistance		C25/30	1.20					
		C30/37	1.48					
		C35/45	1.80					
		C40/50	2.00					
		C45/55	2.20					
		C50/60	2.40					
Partial safety factor		γ_{Mp} [2]	1.5					
Concrete cone failure								
Effective anchorage depth		h_{ef} [mm]	$h_n - k + t$ [3]					
factor to take into account the influence of load transfer mechanisms	cracked concrete	k_{cr} [-]	8.5					
	uncracked concrete	k_{ucr} [-]	11.9					
Characteristic spacing		$s_{cr,N}$ [mm]	$3\ h_{ef}$					
Characteristic edge distance		$c_{cr,N}$ [mm]	$1.5\ h_{ef}$					
Partial safety factor		γ_{Mc} [2]	1.5					
Blow-out failure								
Partial safety factor		γ_{Mcb} [2]	1.5					
Splitting failure								
			Verification of splitting is not relevant [4]					

1) Headed stud type 25 only steel S235J2 or S355
2) In absence of other national regulations
3) For simple headed studs (for double headed studs resp. short studs see Fig. 2 resp. 3 in Annex 2)
4) Reinforcement to resist splitting forces see CEN/TS 1992-4-2:2009 Abs. 6.2.6.2(b)

Table 6: Displacement under tensile load

Headed stud – nominal size	**10**	**13**	**16**	**19**	**22**	**25**[2]
Displacements[1] under tensile loads 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 or S355						

Nelson headed studs	**Annex 6**
Characteristic values of resistance under tensile loads for the design according CEN/TS 1992-4-2:2009	

Deutsches Institut für Bautechnik DIBt

Table 7: Characteristic values of resistance of headed studs made of steel and stainless steel for shear load for the design according to CEN/TS 1992-4-2:2009

Headed stud – nominal size		**10**	**13**	**16**	**19**	**22**	**25**[1]
Steel failure for headed studs made of steel							
Characteristic resistance	$V_{Rk,s}$ [kN]	21	36	54	77	103	133
Partial safety factor	γ_{Ms} [2]	1.28					
Steel failure for headed studs made of stainless steel							
Characteristic resistance	$V_{Rk,s}$ [kN]	25	43	65	92	123	--
Partial safety factor	γ_{Ms} [2]	1.54					
Concrete pry-out failure							
Factor according to CEN/TS 1992-4-2:2009, section 6.3.4	k_3 [3]	2.0					
Partial safety factor	γ_{Mcp} [2]	1.5					
Concrete edge failure							
Effective length of the headed stud	$l_f = h_{ef}$ [mm]	$h_n - k + t$ [4]					
Effective outside diameter	$d_{nom} = d_1$ [mm]	10	13	16	19	22	25
Partial safety factor	γ_{Mc} [2]	1.5					

[1] Headed stud type 25 only steel S235J2 or S355

[2] In absence of other national regulations

[3] In case of supplementary reinforcement the factor k_3 shall be multiplied with 0.75

[4] For simple headed studs (for double headed studs resp. short headed studs see Fig. 2 resp. 3 in Annex 2)

Table 8: Displacements under shear load

Headed stud – nominal size	**10**	**13**	**16**	**19**	**22**	**25**[2]
Displacements[1] under shear loads 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 or S355

Table 9: Combined tension and shear load

The factor k_7 is for combined tension and shear load according to CEN/TS 1992-4-2:2009, section 6.4.1.3:	$k_7 = 2/3$

Nelson headed studs	**Annex 7**
Characteristic values of resistance under shear loads for the design according CEN/TS 1992-4-2:2009	

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Table 10: Characteristic values of resistance of headed studs made of steel and stainless steel for tensile load for the design according to Annex 12

Headed stud – nominal size		**10**	**13**	**16**	**19**	**22**	**25**[1]
Steel failure for headed studs made of steel							
Characteristic resistance	$N_{Rk,s}$ [kN]	35	60	90	128	171	221
Partial safety factor	γ_{Ms} [2]	1.54					
Steel failure for headed studs made of stainless steel							
Characteristic resistance	$N_{Rk,s}$ [kN]	42	72	109	153	205	--
Partial safety factor	γ_{Ms} [2]	1.85					
Pull-out failure							
Characteristic resistance	$N_{Rk,p}$ [kN]	30	50	90	75	85	115
Increasing factors ψ for the characteristic resistance	C25/30	1.20					
	C30/37	1.48					
	C35/45	1.80					
	C40/50	2.00					
	C45/55	2.20					
	C50/60	2.40					
Partial safety factor	γ_{Mp} [2]	1.5					
Concrete cone failure							
Effective anchorage depth	h_{ef} [mm]	$h_n - k + t$ [3]					
Characteristic spacing	$s_{cr,N}$ [mm]	3 h_{ef}					
Characteristic edge distance	$c_{cr,N}$ [mm]	1.5 h_{ef}					
Partial safety factor	γ_{Mc} [2]	1.5					
Blow-out failure							
Partial safety factor	γ_{Mcb} [2]	1.5					

1) Headed stud type 25 only steel S235J2 or S355
2) In absence of other national regulations
3) For simple headed studs (for double headed studs resp. short headed studs see Fig. 2 resp. 3 in Annex 2)

Nelson headed studs	**Annex 8**
Characteristic values of resistance under tensile loads for the design according Annex 12 to 23	

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Table 11: Characteristic resistance of a hanger reinforcement bar for 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	$l_{V,R}$ [mm]		660	770	880
Partial safety factor	γ_{Mh} [2]	1.5			

[1] h_n = Nominal length of the headed stud

[2] In absence of other national regulations

Table 12: Displacements under tensile load

Headed stud – nominal size	**10**	**13**	**16**	**19**	**22**	**25**[2]
Displacements[1] under tensile loads 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 or S355

Nelson headed studs	**Annex 9**
Characteristic values of resistance under tensile loads for the design according Annex 12 to 23 and displacements	

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Table 13: Characteristic values of resistance of headed studs made of steel and stainless steel for shear load for the design according to Annex 21

Headed stud – nominal size		**10**	**13**	**16**	**19**	**22**	**25**[1]
Steel failure for headed studs made of steel							
Characteristic resistance	$V_{Rk,s}$ [kN]	21	36	54	77	103	133
Partial safety factor	γ_{Ms} [2]	1.28					
Steel failure for headed studs made of stainless steel							
Characteristic resistance	$V_{Rk,s}$ [kN]	25	43	65	92	123	--
Partial safety factor	γ_{Ms} [2]	1.54					
Concrete pry-out failure							
Factor in equation (5.6) to Annex C section 5.2.3.3 of ETAG 001, $N_{Rk,c}$ according Annex 15, section 3.3	k	2.0					
Partial safety factor	γ_{Mcp} [2]	1.5					
Concrete edge failure							
Effective length of the headed stud	$l_f = h_{ef}$ [mm]	$h_n - k + t$ [3]					
Effective outside diameter	$d_{nom} = d_1$ [mm]	10	13	16	19	22	25
Partial safety factor	γ_{Mc} [2]	1.5					

[1] Headed stud type 25 only steel S235J2 or S355

[2] In absence of other national regulations

[3] For simple headed studs (for double headed studs resp. short headed studs see Fig. 2 resp. 3 in Annex 2)

Nelson headed studs	**Annex 10**
Characteristic values of resistance under shear loads for the design according Annex 12 to 23	

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Table 14: Characteristic resistance of a hanger reinforcement bar under 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 $l_{V,R}$ [mm]	440	550	660	770	880
Partial safety factor γ_{Mh} [1)]	1.15				

[1)] In absence of other national regulations

Table 15: Displacements under shear load

Headed stud – nominal size	**10**	**13**	**16**	**19**	**22**	**25[2]**
Displacements[1)] under shear load 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 or S355						

Nelson headed studs	**Annex 11**
Characteristic values of resistance under shear loads for the design according Annex 12 to 23 and displacements	

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Design of anchorage of the headed studs in concrete

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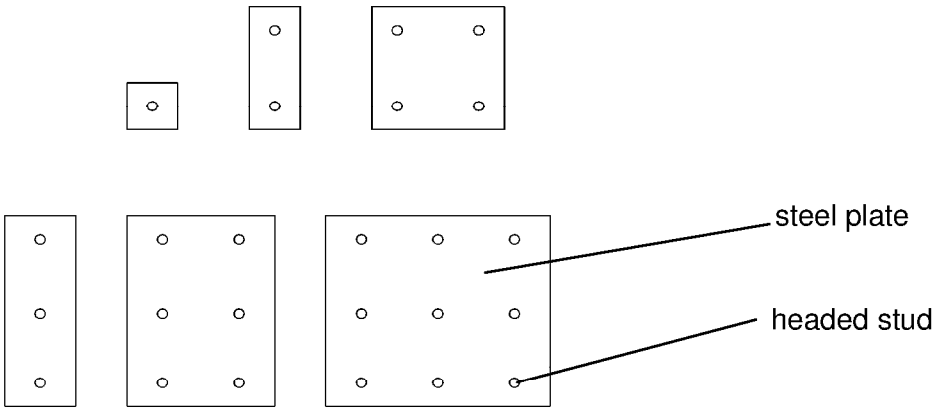
Design

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 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). Examples of typical arrangements are given in the following pictures.



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.

Nelson headed studs	Annex 13
Design of anchorage of the headed studs in concrete	

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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.

Nelson headed studs	Annex 14
Design of anchorage of the headed studs in concrete	

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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 Annex 8, Table 10.

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 Annex 8, Table 10.

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:

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

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:

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

with

- $f_{ck,cube}$ [N/mm²]; with $f_{ck,cube}$ maximum 60 N/mm².
- h_{ef} [mm] is given in Annex 8, Table 10.

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 $3h_{ef}$ (Annex 16, Fig.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 Annex 16, 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 $1.5h_{ef}$.

Nelson headed studs	**Annex 15**
Design of anchorage of the headed studs in concrete	

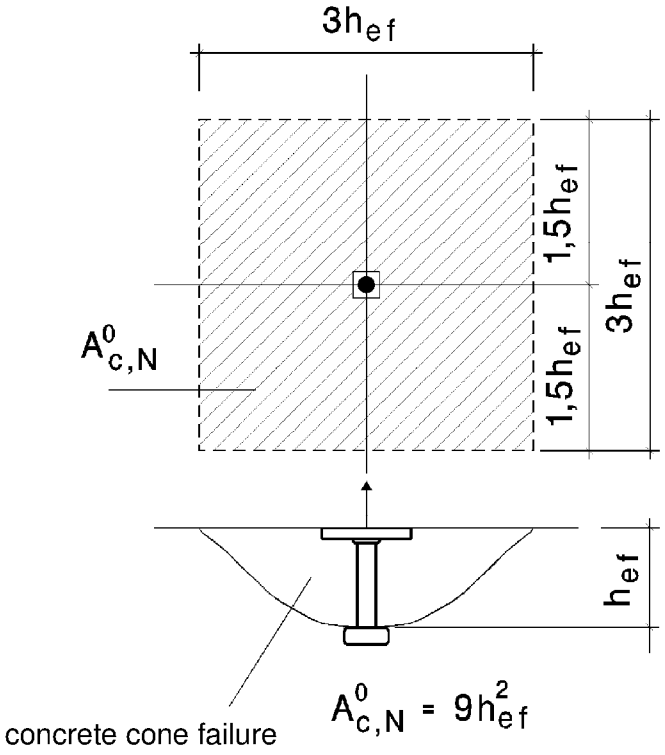
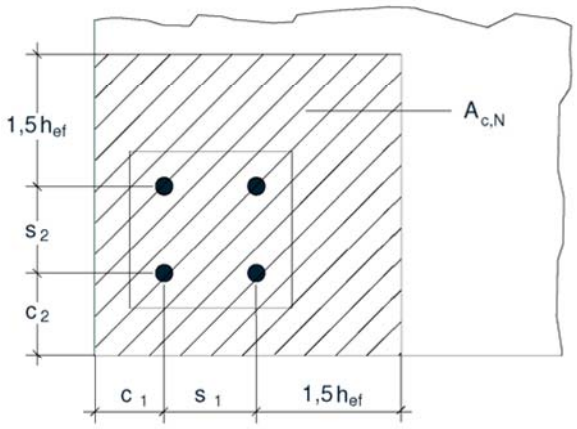


Figure 1: Idealized concrete cone failure and area $A^0_{c,N}$ of concrete cone



$$A_{c,N} = (c_1+s_1+1.5h_{ef}) \cdot (c_2+s_2+1.5h_{ef})$$

if: $c_1 ; c_2 \leq 1.5\ h_{ef}$

$s_1 ; s_2 \leq 3\ h_{ef}$

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

Nelson headed studs	**Annex 16**
Design of anchorage of the headed studs in concrete	

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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 Annex 18, 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 Annex 18, 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

Nelson headed studs	**Annex 17**
Design of anchorage of the headed studs in concrete	

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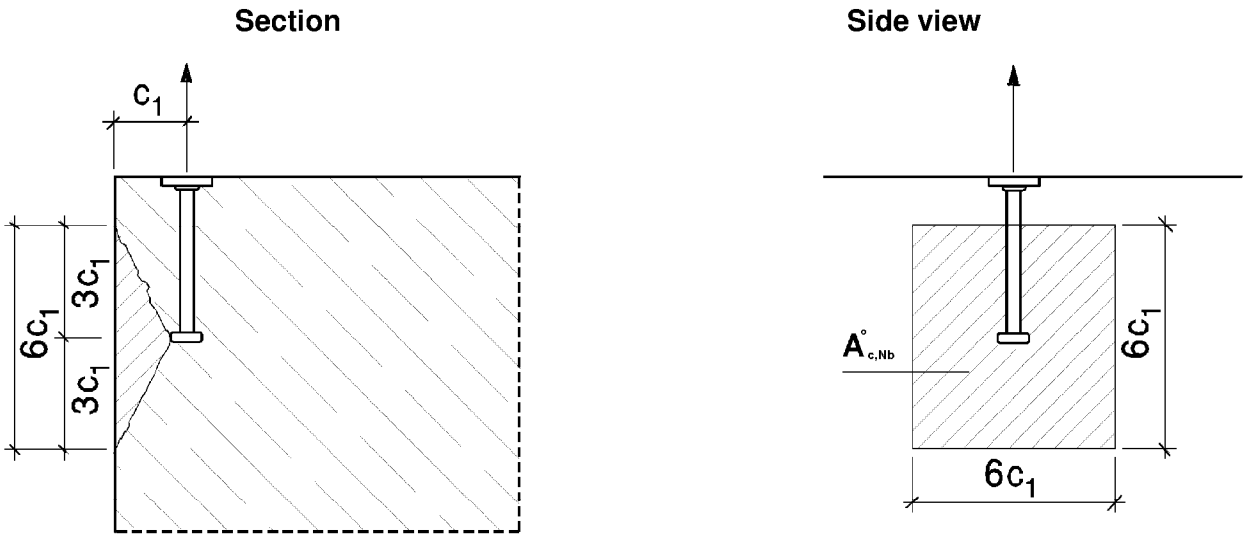
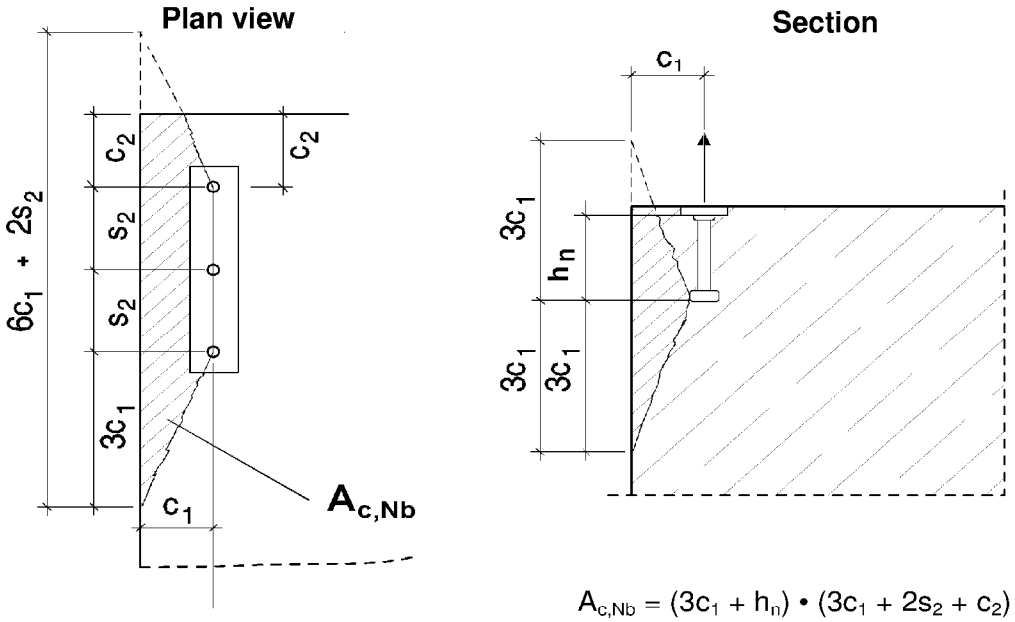


Figure 3: Idealized concrete cone of the headed stud in the case of local concrete blow-out failure at the edge of an individual headed stud



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

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

Nelson headed studs	Annex 18
Design of anchorage of the headed studs in concrete	

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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:

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

ΣN_{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 $c \geq 1.5\ h_{ef}$.

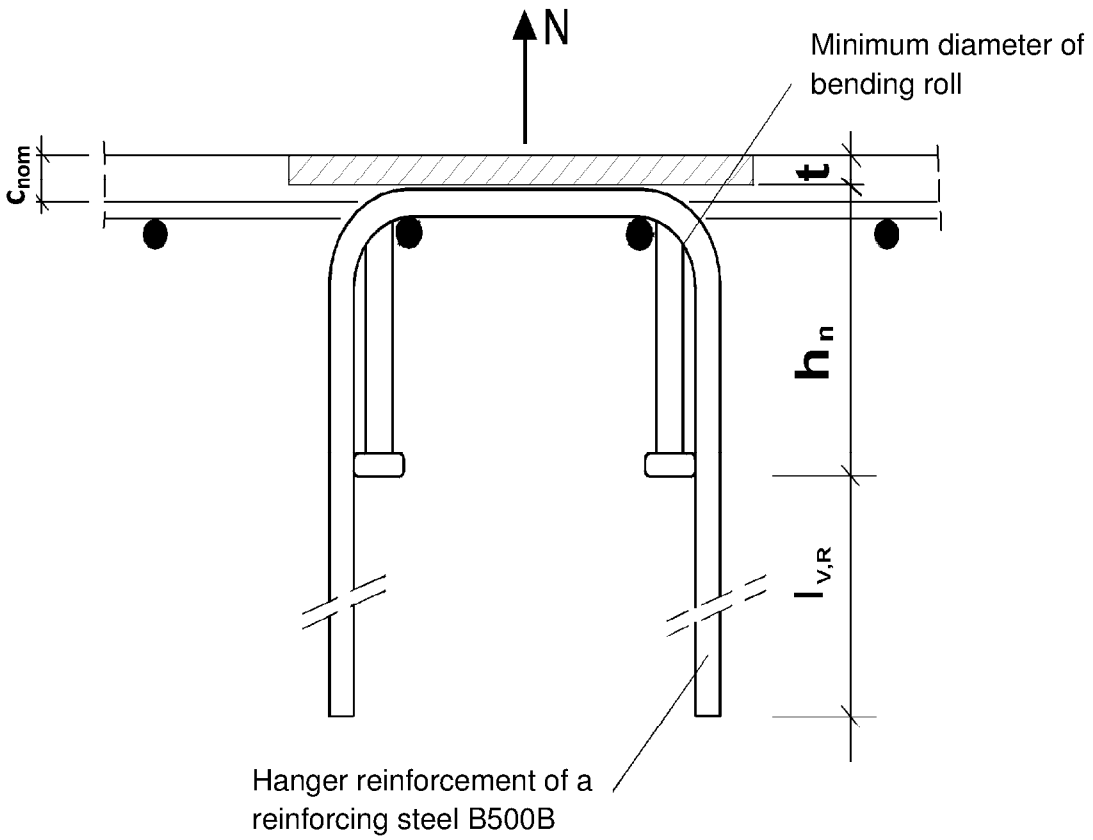
The reinforcement shall consist of reinforcing steel B 500 B with a diameter of ≤ 16 mm.
The characteristic resistance $N_{Rk,h}$ of a bar of the hanger reinforcement is given in Annex 9, Table 11 depending on the nominal length of the headed stud (h_n) in concrete and the length of the anchorage ($l_{V,R}$) of the hanger reinforcement.

Where a hanger reinforcement is provided at the headed stud according to Figure 5, Annex 20 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.

Nelson headed studs	**Annex 19**
Design of anchorage of the headed studs in concrete	



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

Nelson headed studs	**Annex 20**
Design of anchorage of the headed studs in concrete	

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4 Characteristic resistance under shear load

4.1 Steel failure

The characteristic resistance $V_{Rk,s}$ is given in Annex 10, Table 13.

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 Annex 10, Table 13.
$N_{Rk,c}$ shall be determined according to equation (2) Annex 15 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 $l_{V,R}$ of the hanger reinforcement is given in Annex 11, Table 14.

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 22.

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 Annex 11, Table 14.

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.

Nelson headed studs	**Annex 21**
Design of anchorage of the headed studs in concrete	

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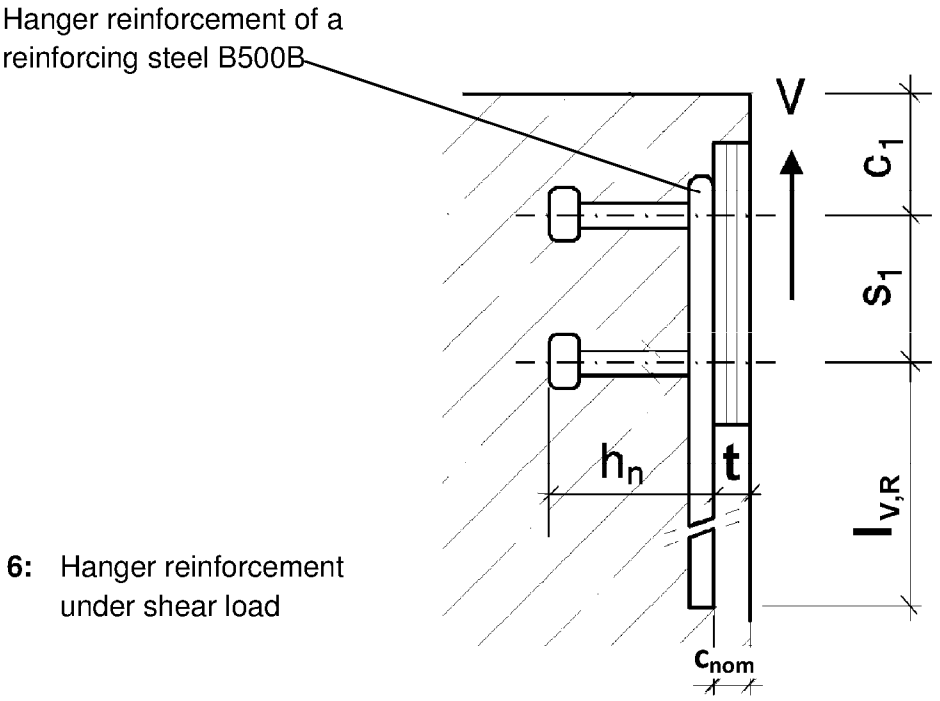

Figure 6: Hanger reinforcement under shear load

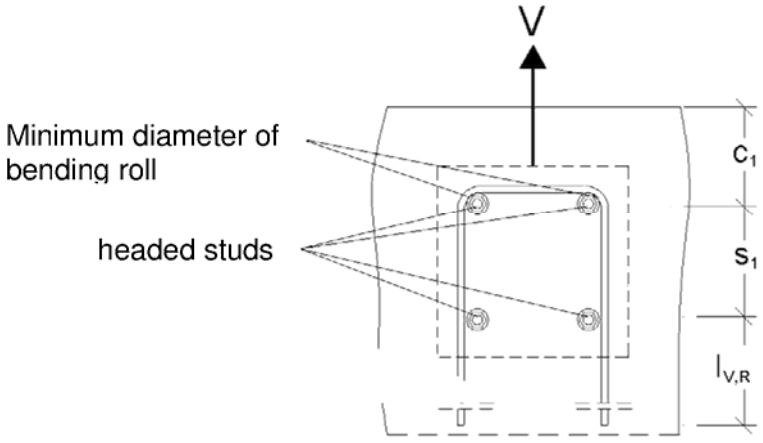

Figure 6a: Example of a hanger reinforcement under shear load

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

Nelson headed studs	Annex 22
Design of anchorage of the headed studs in concrete	

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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**
$V_{Sd} \leq 0.8 \cdot V_{Rd,ct}$	$a \geq 3\ h_{ef}$	≤ 60	not required
$0.8 \cdot V_{Rd,ct} < V_{Sd} \leq 1.0 \cdot V_{Rd,ct}$	$a \geq 3\ h_{ef}$ and $a \geq 200 \cdot \sqrt{N_{sk}}$	≤ 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

Nelson headed studs	**Annex 23**
Design of anchorage of the headed studs in concrete	