VTT Expert Services Oy
PL 1001 (Kemistintie 3)
02044 VTT
Tel.: + 358 20 722 4911
Fax: +358 20 722 7003

VTT EXPERT SERVICES OY

Authorized and notified according to article 10 of the Council Directive 89/106/EEC of 21 December 1988 on the approximation of laws, regulations and administrative provisions of Member States related to Construction Products

MEMBER OF EOTA
MITGLIED DER EOTA

European Technical Approval ETA-13/0603
Europäische Technische Zulassung

German translation of the cover page prepared by VTT Expert Services Ltd. Original ETA in English with cover page in Finnish and English

Trade name Handelsbezeichnung:	**HPKM 16, HPKM 20, HPKM 24, HPKM 30, HPKM 39 column shoes**
Holder of approval: Zulassungsinhaber:	**Peikko Group Oy** **PL 104** **FIN-15101 Lahti**
Generic type and use of construction product: Zulassungsgegenstand und Verwendungszweck	**Column shoe for connecting columns to concrete structures** Stützenschuh zum Anschluss von Stahlbeton-Fertigteilstützen an Betonkonstruktionen
Validity from/to: Geltungsdauer vom/bis:	**from 12.06.2013 to 12.06.2018** vom 12. Juni 2013 bis 12. Juni 2018
Manufacturing plants: Herstellwerke	**Plants 1, 3 and 4** Werke 1, 3 und 4
This European Technical Approval contains Diese europäische technische Zulassung umfasst	22 pages including 2 annexes comprising 10 pages 22 Seiten einschliesslich 2 Anhänge mit 10 Seiten

EOTA

European Organisation for Technical Approvals
Europäische Organisation für Technische Zulassungen

.

I LEGAL BASES AND GENERAL CONDITIONS

1. This European Technical Approval is issued by the VTT Expert Services Oy 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 the Council Directive 93/68/EEC of 22 July 1993 [2] and regulation (EC) No 1882/2003 of the European Parliament and of the Council [3];
   - Laki rakennustuotteiden hyväksynnästä (230/2003) luvut 3 ja 10, Ympäristöministeriön asetus rakennustuotteiden hyväksynnästä 3 § sekä Ympäristöministeriön 18.12.2009 antama valtuutuspäätös (19/629/2009).
   - Common Procedural Rules for Requesting, Preparing and the Granting of European Technical Approvals set out in the Annex of Commission Decision 94/23/EC [4];
   - Commonly agreed assessment procedure, September 2010.

2. The VTT Expert Services Ltd is authorised 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 with 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 manufacturer 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 the VTT Expert Services Ltd pursuant to Article 5 (1) of the 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 the VTT Expert Services Ltd. 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 VTT Expert Services Ltd in English. This version corresponds to the version circulated within EOTA. Translations into other languages have to be designated as such.

---

1 Official Journal of the European Communities Nº L 40, 11.2.1989, p. 12
2 Official Journal of the European Communities Nº L 220, 30.8.1993, p. 1
3 Official Journal of the European Communities Nº L 284, 31.10.2003, p. 25
4 Official Journal of European Communities Nº L 17, 20.1.1994, p. 34

II SPECIFIC CONDITIONS OF THE EUROPEAN TECHNICAL APPROVAL

1 Definition of product and intended use

1.1 Definition of product

The column shoes, illustrated in Annex 1, are connectors made of steel plates and reinforcing steel bars: The components of a column shoe are connected to each other by welding. The steel material is specified in Annex 2.

The column shoes consist of a base plate, bent side plate, main anchorage bars and a rear anchorage bar. There may also be thin, non-structural steel plates which serve as moulds when concreting the column.

The exact geometry and weight of the column shoes, the minimum size of the column cross-section and the anchor bolts to be used with the columns shoes are specified in detail in Appendix 2.

1.2 Intended use

The column shoes serve as connectors between a concrete column and concrete foundation or other concrete structure. They are inserted inside hoop reinforcement at the lower end of a column before concreting. After hardening of the concrete, the column is installed in its final position. The column shoes are fixed with nuts and washers to anchor bolts which have previously been concreted to the supporting lower structure. The space between the end of the column and the supporting structure as well as the recesses for the nuts are grouted with non-shrink mortar or concrete.

The following limitations apply

- The grade of the concrete used for the column shall be in the range C30/37 to C70/85 in accordance with *EN206: Concrete. Performance, production, placing and compacting criteria*
- The bolts which the column shoes are connected to, shall both have a European Technical Approval and be approved by the manufacturer of the column shoes for this purpose
- The connection is subjected to external atmospheric exposure or exposure in internal conditions including permanently damp conditions. Particularly aggressive conditions, e.g. marine or chemical pollution are excluded
- The connection is subjected to static or quasi-static loading only
- The column shoe connections are only used where the column is horizontally supported by foundation, floor or a set of beams (sway frames included) but not in the span of a column

- The lowest temperature of use is -20°C.

1.3 Assumed working life of the construction product

The provisions and the verification and assessment methods included or referred to in this ETA have been written based upon the assumed working life of the column shoe for the intended use of 50 or 100 years, when installed in the works, depending on the ambient conditions and on the working life of the column it is inserted to, provided that the column shoe is subject to appropriate installation, use and maintenance (see 4.4). In no occasion is the working life of the column shoe longer than that of the column. These provisions are based upon the current state of the art and the available knowledge and experience.

"Assumed working life" means that, when an assessment following the CUAP provisions is made, and when this working life has elapsed, the real working life may be, in normal use conditions, considerably longer without major degradation affecting the Essential Requirements.[5]

The indications given as to the working life of the construction product cannot be interpreted as a guarantee given by the product manufacturer or his representative or the approval body issuing the ETA, but are regarded only as a means for choosing the appropriate products in relation to the expected economically reasonable working life

1.4 Terminology

1.4.1 Common terms relating to the Construction Products Directive

For the meaning of these terms see EOTA document "Common terms used in Guidelines for European Technical Approval" published on the EOTA website.

1.4.2 Specific terms used in this CUAP

Annex 1 illustrates the specific terms.

1.4.2.1 Base plate
Thick, horizontal steel plate provided with a vertical hole; fixed to a threaded anchor bolt by two nuts and two washers

1.4.2.2 Side plate
Vertical, bent steel plate welded to the bottom plate

1.4.2.3 Anchor bar
Vertical reinforcing bar welded to side plate

[5] The real working life of a product incorporated in a specific works depends on the environmental conditions to which that works is subject and the particular conditions of the design, execution, use and maintenance of that works may be outside this ETA. Therefore, it cannot be excluded that in these cases the real working life of the product may also be shorter than the assumed working life.

1.4.2.4 Rear bar
Partly vertical reinforcing bar, lower end bent, welded to side plate

1.4.2.5 Top plate (optional)
A thin, non-structural steel plate parallel to the base plate but above it, serves as a mould when the column is concreted.

2 Characteristics of product and methods of verification

2.1 Characteristics of product

The column shoes covered by this European Technical Approval are HPKM 16, HPKM 20, HPKM 24, HPKM 30 and HPKM 39. They correspond to the drawings and provisions given in Annex 1. The characteristic material values, dimension and tolerances of the column shoes not indicated in Annex 1 shall correspond to the respective values laid down in the technical documentations[6] of this European Technical Approval. The product characteristics and methods of verification and assessment are listed in Table 1.

Table 1 - Product characteristics and methods of verification and assessment.

Nr	Product characteristic *(where relevant with footnote*) (where relevant indicate respective ID clause)*	Option "No Performance Determined"	Method of verification and assessment	Expression of product performance *(value, class, NPD, criterion, etc)*
(1)	(2)	(3)	(4)	(5)
Essential Requirement 1: Mechanical resistance and stability				
1	Tolerances on size	No	Control plan	List of values
2	Material properties	No	Annex 1	Class
3	Resistance against normal force, bending moment and shear force	No	2.2.2, 2.2.3	Criterion
4	Bending stiffness	No	2.2.3	Stiffness class
Essential Requirement 2: Safety in case of fire				
5	Resistance fo fire	No	2.2.4	Temperature for determining the resistance class without shielding
General aspects relating to fitness for use *				
6	Resistance to corrosion	No	2.2.5	Exposure classes for which concrete cover or coating is required
*) Aspects of durability and economy of the works (see CPD Annex 1, sentence 1 and 2) which are not dealt with under Essential Requirements 1 to 6. Such aspects are also referred to as "serviceability".				

[6] The technical documentation of this European Technical Approval is deposited at the VTT Expert Services Ltd 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.

The mechanical resistance of the connections comprising HPKM column shoes and HPM anchor bolts is calculated according to the design rules given in Annex 2.

Regarding the requirements concerning safety in case of fire it is assumed that the column shoe connection meets the requirements of A1 in relation to the reaction to fire in accordance with the stipulations in the Commission decision 96/603/EC, amended in 2000/605/EC.

The temperature development for determining the fire resistance of the connections comprising HPKM column shoes and HPM anchor bolts is given in Section 2.2.3.2.

Each column shoe is marked by the manufacturer's name Peikko, factory code, type code (e.g. HPKM 16) and identification number for tracing the data about materials, production etc.

2.2 Mechanical resistance

2.2.1 General

The assessment of fitness of the column shoe for the intended use in relation to the requirements for mechanical resistance and stability and safety in use in the sense of the Essential Requirements 1 and 4 has been made in accordance with the commonly agreed assessment procedure.

2.2.2 Verification by calculations

The resistance of a column shoe in tension and compression is η_d times of the resistance of the anchor bolts designated to the column shoe where $\eta_d \leq 0{,}90$. The value of η_d has been verified experimentally, see 2.2.3. It is required that

1. the nominal resistance of the anchor bars is ≥ the nominal resistance of the anchor bolt
2. the nominal resistance of the welds connecting the anchor bars to the side plate is at least twice the nominal resistance of the anchor bolt
3. The nominal resistance of the welds between the side plate and base plate is at least twice the nominal resistance of the anchor bolt
4. The nominal resistance of the side plate is at least twice the nominal resistance of the anchor bolt.

According to the calculations, all of these requirements are met.

2.2.3 Verification by mechanical testing

Pursuant to CUAP, two stiffness tests, five bending tests and two shear tests have been carried out. The stiffness tests verified that stiffness class BS0, see Annex 2, can be applied. The bending and shear tests verified the design method for mechanical resistance presented in Annex 2.

2.3 Resistance to fire

2.3.1 General

The resistance to fire is determined by the degree of utilization of the anchor bolts and by the temperature development of the steel, see Table 2. The degree of utilization depends on the loads, structural design etc. and it has to be determined by the structural engineer in each specific case. It should be noted that, the design rules for normal temperature limit the highest degree of utilization for the yield stress of the anchor bolts to 90%.

2.3.2 Verification by fire tests and numerical simulations

Finite element models for connections with all considered column shoe types have been created in accordance with the commonly agreed assessment procedure. Using these models, the temperature fields vs. time in the connections have been solved when the connection is exposed to standard fire. The average temperature in the hottest section of the anchor bolt proved to be critical in fire resistance.

To calibrate the numerical results, a fire test on three connections, one with HPKM 16, one with HPKM 24 and one with HPKM 39 column shoes, each with

minimum column cross-section, has been carried out. The resulting average temperature in the critical zone of the connection, i.e. in the hottest section of the anchor bolt, has been determined using the measured temperatures for the tested connections. The temperature development in connections with HPKM 20 and HPKM 30 column shoes has been taken from numerical results which have been calibrated to test results. The whole process is explained in more detail in report [2]. The resulting temperatures to be used in fire design in accordance with the relevant Eurocodes are given in Table 2.

Table 2 - Average temperature T [ºC] in critical section of anchor bolt. Time means the time from the beginning of standard fire exposure.

Time [min]	HPKM 16	HPKM 20	HPKM 24	HPKM 30	HPKM 39
60	500	500	450	430	390
90	670	610	630	630	570
120	800	780	740	730	700

2.4 Resistance to corrosion

The concrete cover for the reinforcing bars of the column is designed according to Eurocode 2. The same concrete cover is also applied to the anchor bars of the column shoes in all exposure classes and to the plate-like components of the column shoes in the exposure classes for which the concrete cover is required according to Table 3. When these requirements are

met, the resistance of the column shoes against corrosion is supposed to be the same as that of the column.

Table 3 - Concrete cover for plate-like components of column shoes in different exposure classes.

Exposure class	Concrete cover
X0	Not needed
XC1, XC2, XC3	Either concrete cover or coating
XC4, XD1, XD2, XD3	Required
XS1, XS2, XS3	Required
XF1, … ,XF4	Required
XA1, XA2, XA3	Required

2.5 Other issues

There may be other requirements applicable to the products falling with 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 compiled with, when and where they apply.

3 Evaluation of Conformity and CE marking

3.1 Attestation of conformity system

According to the communication of the European Commission[7] the system(s) of attestation of conformity laid down in the decision 2000/606/EC of the European Commission[8] for pile joints and rock shoes (and given in Table 3 *)* shall also be applied to column shoes. This system of attestation of conformity, referred to as system 2+, according to Council Directive 89/106/EEC Annex III laid down by the European Commission provides:

Certification of the conformity of the product by a Notified Certification Body on the basis of:

(a) Tasks for the manufacturer:
  (1) initial type-testing of the product;
  (2) factory production control;
  (3) testing of samples taken at the factory in accordance with a prescribed test plan;

(b) Tasks for the notified body:
  (4) certification of factory product control on the basis of:
    - initial inspection of factory and of factory production control;

[7] Letter of the European Commission of 22.07.02 to EOTA
[8] Official Journal of the European Communities L 258/40 of 12.10.2000

- continuos surveillance, assesment and approval of factory production control

(5) initial inspection of factory and of factory production control;

(6) continuous surveillance, assessment and approval of factory production control.

3.2 Responsibilities

3.2.1. Tasks of the manufacturer

3.2.2.1. Initial type-testing of the product

For initial type-testing the results of the tests performed as part of the assessment for the European Technical Approval are used unless there are changes in the production line or plant. In such cases the necessary initial type-testing has to be agreed between the VTT Expert Services Oy and the approved bodies involved.

3.2.1.1 Factory production control

The manufacturer has a factory production control system in the plant and exercises permanent internal control of production. All the elements, requirements and provisions adopted by the manufacturer are documented in a systematic manner in the form of written policies and procedures. This production control system ensures that the product is in conformity with the European Technical Approval.

The manufacturer shall only use raw materials supplied with the relevant inspection documents as laid down in the control plan[6].

The factory production control shall be in accordance with the control plan of June 2013 which is the 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 at VTT Expert Services Ltd[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 of the manufacturer

The manufacturer shall, on the basis of contract, involve a body which is approved (notified) for the tasks referred to in section 3.1 in the field of column shoes in order to undertake the actions laid down in sections 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.

[9] The control plan is a confidential part of the documentation of the European technical approval, and not published together with the ETA, and is only handed over to approved body involved in the conformity attestation procedure.

3.2.2. Tasks of approved bodies

3.2.2.2. Initial inspection of factory and of factory production control

The approved body shall ascertain that, in accordance with the control plan, the factory and the factory production control are suitable to ensure continuous and orderly manufacturing of the anchor according to the specifications mentioned in 2.1. as well as in the Annexes to the European Technical Approval, in accordance with the control plan.

3.2.2.3. Continuous surveillance

The approved body shall visit the factory at least once a year for regular inspection. It has to be verified that the system of factory production control and the manufacturing process are maintained taking account of the control plan.

Continuous surveillance and assessment of factory production control have to be performed according to the control plan.

The results of product certification and continuous surveillance shall be made available on demand by the certification body or inspection body, respectively, to the VTT Expert Services Ltd.

In cases where the provisions of the European Technical Approval and the prescribed test plan are no longer fulfilled the conformity certificate shall be withdrawn.

3.3 CE-Marking

The CE marking shall be affixed on the product itself, on a label attached to it or on the packages of the products and on the accompanying documents.

anchors.

The letters “CE” shall be followed by the identification number of the notified certification body, and be accompanied by the following additional information:

- the name and address of the ETA holder (legal entity responsible for the manufacture) and identification number of the manufacturing plant
- the last two digits of the year in which the CE-marking was affixed;
- the number of the EC-certificate of factory production control
- the trade name of the product
- the number of the European Technical Approval

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

4.1 Manufacturing

The column shoe is manufactured in accordance with the provisions of the European Technical Approval using the manufacturing process as identified during the inspection of the plant by the VTT Expert Services Ltd and the approved body and laid down in the technical documentation.

All welds for steel-steel connections shall meet the requirements for class C presented in EN ISO 5817/AC:2006-04. All welds for steel-rebar or rebar-rebar connections shall meet the requirements presented in EN ISO 17660-1:2006-09.

4.2 Packaging, transport, storage of the product

- The data about specific conditions concerning the column shoe are provided by the manufacturer to those who are concerned
- Instructions for installation, use and maintenance are made available with all deliveries. Graphic illustrations are recommended
- All column shoes are painted with a color indicating the type of the product and provided with manufacturer's label including at least
  - designation of the product
  - code of the manufacturing plant
  - production batch identification

4.3 Installation of the product in the works

It is assumed that the instructions of the manufacturer are followed when

- choosing column shoes and bolts
- dimensioning the column
- reinforcing the column
- fixing the column shoes to the casting mould
- casting the column
- installing the anchorage bolts
- installing the columns
- applying the torque to the nuts of the column shoe - bolt connection pursuant to Table 3
- grouting the joints and recesses.

Table 4. Minimun torque Tmin [Nm].

	HPKM 16	HPKM 20	HPKM 24	HPKM 30	HPKM 39
T_{min} [Nm]	120	150	200	250	350

4.4 Use, maintenance, repair

- The product shall be installed and used as described in this ETA.
- The concrete cover or coating, when it is required, is properly maintained and repaired to prevent corrosion of the column shoes and to keep the fire resistance unchanged.

4.5 Further assumptions

It is also assumed that

- the resistance of the column is verified separately according to EN 1992-1-1 and EN 1992-1-2 applying manufacturer's instructions for the details like the shear reinforcement around the column shoes
- the resistance of the bolts is verified separately according to the relevant European Technical Approval (ETA)
- in ordinary cases the minimum number of column shoes is four per column connection but it is also possible to have only two column shoes per connection provided that the column is laterally supported until the mortar in the connection has hardened.

On behalf of VTT Expert Services Oy

Espoo 18.06.2013

Liisa Rautiainen

Assessment Manager

Matti Pajari

Leading Expert

ANNEXES

1 Characteristics of column shoes
2 Design in normal temperature

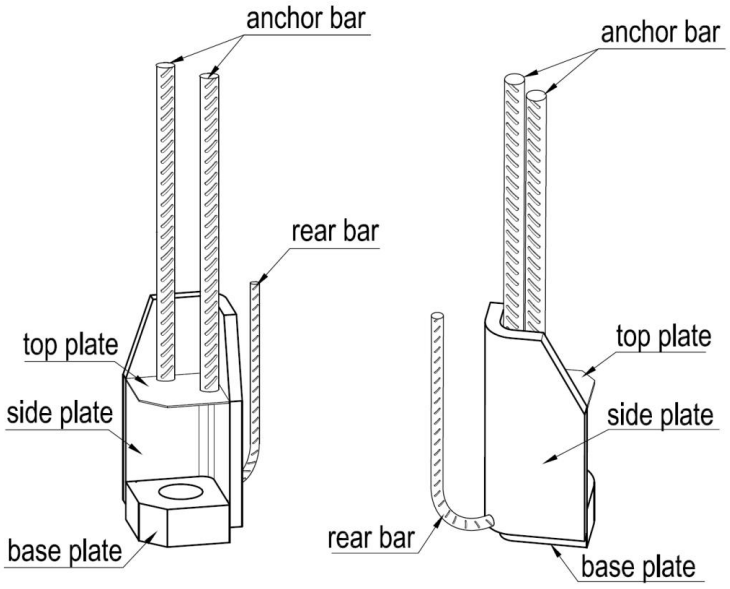

Fig. 1. Illustration of HPKM column shoe

Table 1. Materials. The steel plates and the the fillet material shall meet the requirements of EN 10025.

Component	Steel
Base plate	S355J2+N
Side plates	S355J2+N
Top plate (optional)	S235JR
Main anchor bars	See Table 2
Rear bar	See Table 2

Table 2. Requirements for reinforcing steel

General	All requirements set in EN 10080 and EN 1992-1-1, Annex C for the reinforcing steel of Class B, strength class 500 MPa
Additional	- The steel shall be weldable

Table 3. Anchor bolt and minimum concrete section for HPKM column shoes.

Column shoe	Anchor bolt[1)]	Minimum section mmxmm
HPKM 16	HPM 16	230x230
HPKM 20	HPM 20	240x240
HPKM 24	HPM 24	250x250
HPKM 30	HPM 30	280x280
HPKM 39	HPM 39	360x360

[1)] ETA -02/0006

Peikko HPKM Column shoe **Characteristics of column shoes**	**Annex 1** of European Technical Approval **ETA-13/0603**

The geometry and tolerances of HPKM column shoes are specified in Annex 1 of the Control Plan.

Peikko HPKM Column shoe **Characteristics of column shoes**	**Annex 1** of European Technical Approval **ETA-13/0603**

List of Symbols

$A_{anc,i}$ nominal cross-sectional area of anchor bar *i*
A_{bolt} tensile stress area of anchor bolt
$A_{plate,i}$ nominal cross-sectional area of side plate *i*
L_{lap} lap length
M_{Ed} design value of bending moment (action effect)
M_i bending moment in the middle of subzone *i* in numerical comparison
M_t theoretical yielding moment of column shoe connection
N_{anc} sum of nominal axial resistances of straight anchor bars
$N_{anc,weld}$ sum of calculated nominal resistances of welds between straight anchor bars and bond plate(s) in the direction of anchor bolt
$N_{bolt,nom}$ nominal axial resistance of anchor bolt
$N_{side,weld}$ sum of calculated nominal resistances of welds between the side plate(s) and base plate in the direction of the anchor bolt
N_{Ed} axial load on connection
N_{Ed}^1 axial load on a single bolt or column shoe
N_{plate} sum of nominal axial resistances of side plates
N_{Rd} design value of axial resistance of column shoe
P point load
V shear force
V_{Ed} shear load on a connection
V_{Ed}^1 shear load on a single bolt or column shoe
V_{Rd} shear resistance of a connection
a_b coefficient calculated as in EN 1993-1-8, table 3.4
d_b diameter of nominal stress area in thread of anchor bolt
$f_{anc,y,i}$ yield strength of anchor bar *i*
$f_{base,u}$ ultimate strength of base plate
$f_{bolt,u}$ ultimate strength of anchor bolt
$f_{bolt,y}$ yield strength of anchor bolt
$f_{plate,y,i}$ nominal yield strength of side plate *i*
$f_{bolt,yd}$ design yield strength of anchor bolt, used for design of column shoe connection
h_{nut} thickness of nut below base plate
k_i flexibility factor in 5.8.3.2 of EC2, *i* = 1 or 2
k_1 coefficient calculated as in EN 1993-1-8, table 3.4
m number of straight anchor bars
n number of active column shoes

t_r equivalent span of anchor bolt
t_{grout} thickness of grout
t_{base} thickness of base plate
x longitudinal coordinate
α_b coefficient calculated from $f_{bolt,y}$
γ_{M2} safety factor for ultimate strength of anchor bolt, used for design of anchor bolt
γ_{bolt} safety factor for yield strength of anchor bolt, used for design of column shoe
η_d experimental reduction factor = 0,90
μ friction coefficient between base plate and grout

1 GENERAL

There is no one-to-one correspondence between the mechanical resistance of a *column shoe as delivered* and the mechanical resistance of a *column shoe connection*. A connection is subjected to various action effects like axial force, shear force and bending moment in different combinations, and the stiffness of the connection also has an impact on the design of the column. It is impossible to determine the mechanical resistance or stiffness of a column shoe connection as a set of values determined according to some standards. Therefore, these properties are declared as a set of design rules for the *connection or column or works* in which the column shoes are intended to be used. These design rules are incorporated in the ETA.
A distinction is made between

- the design of the column shoe as delivered (Stage 0)
- the design of the column shoe connection before grouting (Stage I)
- the design of the column shoe connection after the grout has hardened (Stage II)
- the design of the anchor bolts

The design of the column shoes as delivered has been considered as a part of the initial type testing.

The design rules for the column shoe connection are given in Chapter 2.

The design of the anchor bolts shall be carried out according to their ETA.

Some design rules for the column shoe connections only reflect the properties of the anchor bolt. This is explained by the fact that, *in order to facilitate the design of the connection and column*, *the manufacturer claims, that the column shoe is strong enough to carry a certain share of the loads which the related anchor bolt is able to carry*.

The tensile resistance of the anchor bolt given in ETA cannot always be 100% exploited because the tension in the column shoe is eccentric with respect to the centroidal axis of the bolt. This is reflected in the design rules which are based on the yield strength of the anchor bolt instead of the ultimate strength.

2 DESIGN RULES FOR MECHANICAL RESISTANCE AND BENDING STIFFNESS OF CONNECTION

2.1 Position of column shoes and design of connected concrete structures

In ordinary cases the column shoes are placed in the corners of a column as shown in Fig. 1.a and 1.b. Intermediate columns shoes, see Fig. 1.d, are used if the resistance of those in the corners is not high enough or when the tensile forces cannot be properly transferred through the corners of the concrete element only (Fig. 1.b). In some cases two columns shoes per column may be enough (Fig. 1.c). The connections with two column shoes belong to stiffness class BS0, see Table 1.

The distance between adjacent column shoes is determined not only by their resistance but also by the transfer of the forces from the anchor bars to the concrete element and from the anchor bolt to the foundation. In all cases shall the concrete structures be designed to carry the concentrated loads due to the column shoes and anchor bolts.

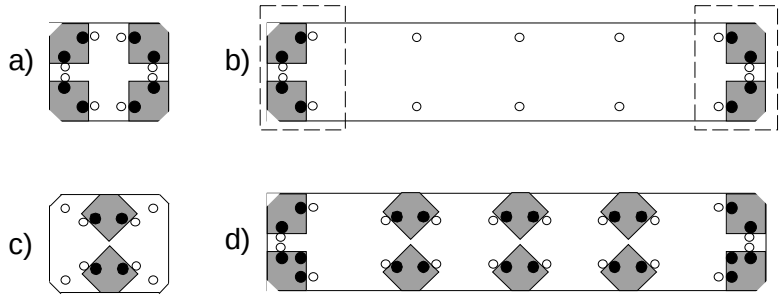

Fig. 1. Examples of column shoe configurations.

2.2 Mechanical resistance of column shoes in Stage I

2.2.1 Action effects

Before grouting the connection, the normal force N_{Ed}^{1} for a single column shoe is calculated from the total normal force N_{Ed} and bending moment M_{Ed} acting at the connection, assuming that the column shoes act as an infinitely stiff plate fixed rigidly to the end of the column. This is also assumed when calculating the normal force and bending moment which the anchor bolts are subjected to.

The design shear force for a column shoe is calculated by dividing the total shear force to those column shoes only which are compressed transversely against the end of the column when the column is subjected to a shear force, see Fig. 2.

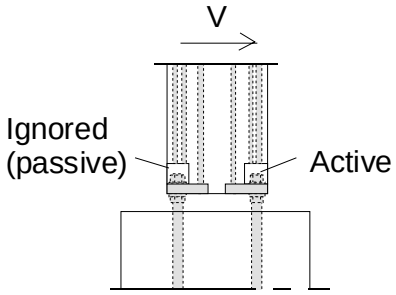

Fig. 2. Only the column shoes on the right hand side are considered active against shear.

2.2.2 Resistance

The resistance of a column shoe subjected to axial force and shear shall satisfy

$$\frac{16\left|V_{Ed}^{1}\right|t_R}{\pi d_b^3}+\frac{4\left|N_{Ed}^{1}\right|}{\pi d_b^2}\le min\left\{\eta_d\frac{f_{bolt,y}}{\gamma_{M2}};\frac{f_{bolt,u}}{\gamma_{bolt}}\right\} \qquad (1)$$

where, see Fig. 3,

V^1_{Ed} is shear load on a bolt (action effect),
N^1_{Ed} axial load on a bolt (action effect), calculated from the total axial force N_{Ed} and bending moment M_{Ed}
d_b diameter of nominal stress area in thread of anchor bolt,
t_R $= t_{grout} – h_{nut}+d_b/2,$
η_d reduction factor ≤ 0,90, the value is determined in initial type testing,
$f_{bolt,y}$ yield strength of bolt steel
$f_{bolt,u}$ ultimate strength of bolt steel
γ_{M2} material safety factor for the bolt according to EN 1993-1-1, 6.1.
γ_{bolt} material safety factor for the bolt according to the relevant European Technical Approval

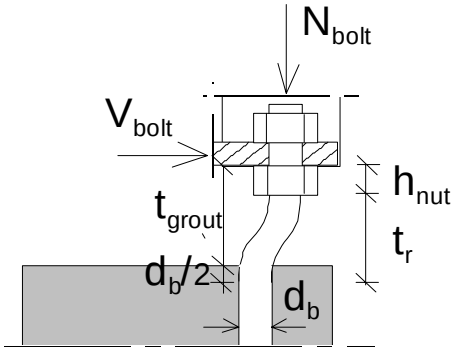

Fig 3. Loads and parameters characterising the column shoe connection in Stage I.

2.3 Mechanical resistance of column shoes in Stage II

2.3.1 General

When calculating the action effects of a column, the rigidity of the end connections has to be estimated. It is assumed (and verified in the initial type testing) that the rectangular cross-sections with at least four column shoes behave rigidly in bending or they are at least as stiff as continuously reinforced cast-in-situ columns, whereas a connection with two columns shoes has to be regarded as as a hinge.

Table 1. Bending stiffness of connection. Classification and design assumptions.

Stiffness class	
BS0	- ≥ 4 column shoes/connection, one in each corner of a rectangular cross-section - column designed assuming rigid*) column shoe connection
BS2	- cases other than BS0 - column designed assuming hinged column shoe connection

*) as rigid as in a continuously reinforced cast-in-situ connection

When calculating the resistance of the connection, four different cases are considered:
1. Resistance of the grouted connection subjected to axial load and bending
2. Shear resistance of individual column shoes subjected to compression
3. Shear resistance of individual column shoes subjected to tension
4. Resistance of the column end

2.3.2 Design criterion for grouted section subjected to axial force and bending

The resistance of the grouted section above the foundation and below the column shoes is calculated according to EN 1992-1-1 assuming that the section behaves as a concrete section reinforced with the anchor bolts. For the bolts, the bilinear stress-strain assumption with a horizontal top branch (EN 1992-1-1, 3.2.7 b) is applied assuming that the design strength of the anchor bolt is

$$f_{bolt,yd} = \min\{\eta_d f_{bolt,y}/\gamma_{M2}\,;\, f_{bolt,u}/\gamma_{bolt}\} \qquad (2)$$

where

η_d is reduction factor = 0,90
$f_{bolt,y}$ yield strength of steel in the anchor bolt,
$f_{bolt,u}$ ultimate strength of steel in the anchor bolt,
γ_{M2} material safety factor according to EN 1993-1-8, Table 2.1,
γ_{bolt} material safety factor according to ETA-02/0006 (anchor bolt ETA)

2.3.3 Resistance of column end

The resistance of the column end subjected to axial load, shear and bending is calculated according to EN 1992-1-1. Particularly, the main reinforcement shall be extended down to the column shoe level and
the lap length, see Fig. 4, shall meet the requirements given in EN 1992-1-1, 8.7.

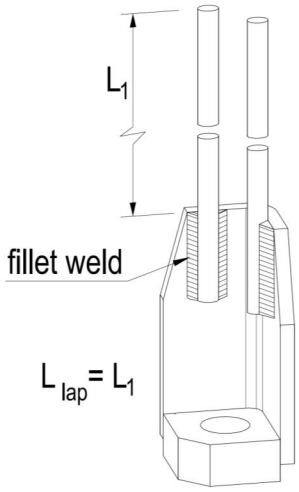

Fig. 4. Determining lap length L_{lap}. The fillet welds and the side plate next to the anchor bar reduce the bond effectively.

2.3.4 Interaction of axial force, bending moment and shear force

2.3.4.1 General

Interaction of axial force, bending moment and shear force is taken into account by considering each individual column shoe separately. Since the bending and axial loading result in tensile or compressive forces in the individual column shoe - anchor bolt combinations, the interaction problem is simplified to interaction of normal force and shear force.

2.3.4.2 Action effects

The action effects at the connection are first divided to the individual column shoes.

The axial force N_{Ed}^{1} for a single anchor bolt or column shoe is calculated from the total axial force N_{Ed} and bending moment M_{Ed} acting at the connection, assuming that the column shoes act as an infinitely stiff plate, fixed rigidly to the end of the column, and the grouted connection behaves as a concrete section reinforced with the anchor bolts.

The design value of the shear force for a single column shoe on the active side, see Fig. 2, is calculated from

$$V_{Ed}^{1} = \frac{V_{Ed} - \mu N_{Ed}}{n} \qquad (3)$$

where

V_{Ed} is the design value of the total shear force,

μ friction coefficient between base plate and grout (= 0,20 for sand-cement mortar according to EN 1993-1-8, Chapter 6.2.2),

N_{Ed} the design value of the total axial force,

n the number of the individual column shoes which are transversely compressed against the end of the column due to the shear force. The column shoes at the opposite side of the connection are ignored when calculating the shear resistance, see Fig. 2.

2.3.4.3 Resistance of column shoe in axial loading

The resistance of a column shoe in tension and compression is calculated from

$$N_{Rd} = min\left\{\eta_d \frac{f_{bolt,y}}{\gamma_{M2}}; \frac{f_{bolt,u}}{\gamma_{bolt}}\right\} A_{bolt} \quad (4)$$

where

$f_{bolt,y}$ is the yield strength of the steel in the anchor bolt,
$f_{bolt,u}$ is the ultimate strength of the steel in the anchor bolt,
A_{bolt} stress area in thread of anchor bolt,
γ_{M2} material safety factor for the bolt according to EN 1993-1-1, 6.1,
γ_{bolt} material safety factor for the bolt in the ETA,
η_d reduction factor (= 0,90).

2.3.4.4 Shear resistance of column shoe

The shear resistance of a column shoe is calculated according to EN 1993-1-8, 6.2.2, from

$$V_{Rd} = min\left\{F_{1,vb,Rd}; F_{2,vb,Rd}\right\} \quad (5)$$

where $F_{1,vb,Rd}$ and $F_{2,vb,Rd}$ are obtained from

$$F_{1,vb,Rd} = \frac{k_1 a_b f_{base,u} d_b t_{base}}{\gamma_{M2}} \quad (6)$$

$$F_{2,vb,Rd} = \frac{\alpha_b f_{bolt,u} A_{bolt}}{\gamma_{M2}} \quad (7)$$

$$\alpha_b = 0{,}44 - (0{,}0003 MPa^{-1}) f_{bolt,y} \quad (8)$$

In these expressions

k_1, and a_b are coefficients calculated as in EN 1993-1-8, Table 3.4,
$f_{base,u}$ is the ultimate strength of the base plate,
d_b diameter of nominal stress area in thread of anchor bolt,
t_{base} thickness of the base plate,
γ_{M2} material safety factor according to EN 1993-1-8, Table 2.1,
$f_{bolt,u}$ ultimate strength of steel of the anchor bolt,
A_{bolt} tensile stress area of the anchor bolt.

2.3.4.5 Design criterion for column shoe subjected to shear and axial load

The shear resistance of a column shoe subjected to shear and compression shall meet the requirement

$$V_{Ed}^1 \le V_{Rd} \qquad (9)$$

where V_{Ed}^1 and V_{Rd} are calculated from Eqs (4) and (6), respectively.

The simultaneous tensile force N_{Ed}^1 and shear force V_{Ed}^1 in each column shoe shall satisfy the conditions

$$\frac{\left|N_{Ed}^1\right|}{1{,}4N_{Rd}} + \frac{\left|V_{Ed}^1\right|}{V_{Rd}} \le 1 \qquad (10)$$

$$\frac{N_{Ed}^1}{N_{Rd}} \le 1 \qquad (11)$$

where N_{Rd} and V_{Rd} are calculated from Eqs (5) and (6), respectively.