

HPKM Column Shoe ETA-13/0603 and CE-marking

Introduction

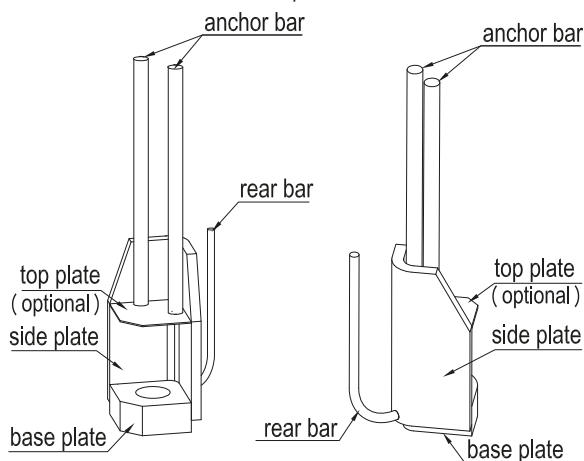
HPKM Column Shoes are fastening components (Fig. 1) used to create cost-effective stiff connections between precast concrete columns and foundations or precast columns and other columns.

The connection system consists of column shoes and anchor bolts. Column shoes are cast into precast concrete columns whereas anchor bolts are cast into foundations or other columns (Fig. 2). On construction sites, the columns are erected on the anchor bolts, adjusted to the correct level and vertical position, and fastened to the bolts by nuts. The joint between the column and the base structure is then grouted.

Making concrete columns using precast technology enables many competitive advantages to be realized, including speed of construction, accurate tolerances, high fire resistance, and high quality. Connections between precast columns are quick and easy to install, while also being economical.

Peikko Group was a pioneer of column shoes at the beginning of the 1980s. The form of the current HPKM Column Shoe was developed during the 1990s and the most recent modifications and improvements were made in 2012.

Figure 1. HPKM Column Shoe components.



Installing column shoes into the mold and erecting the precast column

The HPKM Column Shoes are placed into the reinforcement and mold of the column and fixed through their base plates to the end plate of the mold with recess boxes. Figure 3 depicts the column shoes as a part of the reinforcement and the lower end of a precast column. Supplementary reinforcement must be placed at the column base. After the column has been casted, the boxes are removed. The precast column is supported via base plates of shoes and by the lower leveling nuts (Fig. 4). Leveling nuts and washers are adjusted to the correct level. The column is erected directly on the pre-leveled washers and nuts and the upper nuts are tightened. To guarantee the desired stiffness of the connection, a minimum torque to be applied to each nut has been determined (see Table 1). The connection is completed by filling the space and recesses below the column end with non-shrink grout. Figure 5 demonstrates the connection on-site.

Table 1. Recommended minimum T_{min} and maximum T_{max} torque values of nuts [Nm].

	HPKM 16	HPKM 20	HPKM 24	HPKM 30	HPKM 39
T_{min}	120	150	200	250	350
T_{max}	170	330	570	1150	2640

Figure 2. HPKM Column Shoe connection.

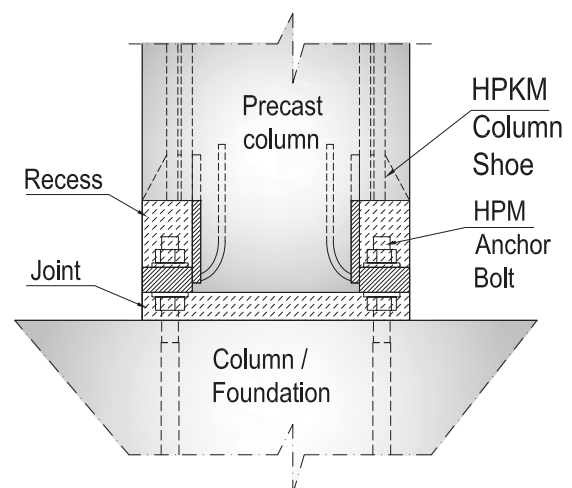


Figure 3. HPKM Column Shoes fastened to mold's plate.



Figure 4. Column erection.



Figure 5. HPKM Column Shoe connections on site.



European Technical Approval ETA-13/0603 and CE-marking

HPKM Column Shoes are unique construction products for which European Technical Approval (ETA) is granted. Based on ETA-13/0603 HPKM Column Shoes received the right to use the CE mark. ETA-13/0603 and the CE mark cover the entire column connection including all components. The CE mark means that no further approval by building authorities is required in the European Economic Area (EEA) and Switzerland.

Because column shoes are not covered by any harmonized hEN-standards, the Common Understanding of Assessment Procedure (CUAP) was followed to receive ETA-13/0603.

Design according to ETA-13/0603

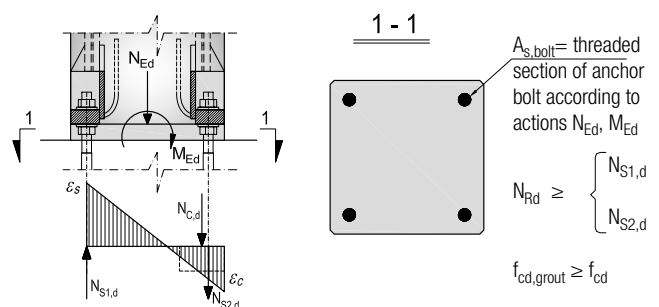
Principles

ETA-13/0603 includes pioneering design rules for column shoe connections. The rules are in accordance with EN 1992-1-1 and EN 1992-1-2 (Eurocode 2) and take into account the behavior of the completed connection and its components. The rules for mechanical behavior and fire resistance have been verified by full-scale tests. HPKM Column Shoes and column connections fulfill the ETA-13/0603 requirements for mechanical, fire, and corrosion resistance, stiffness, shear resistance, and torque of nuts. Peikko has launched design software – Peikko Designer® – to facilitate column connection design. It can be downloaded free of charge from Peikko's website www.peikko.com.

Axial and bending resistance

The joint below the bottom end of the precast column is regarded as a concrete section reinforced with anchor bolts (Fig. 6). Experimental concrete unit tests have confirmed that the stiffness of Peikko's column connection is at least as rigid as a continuously reinforced cast-in-situ column connection. The Eurocode 2 design rules for reinforced concrete structures are applied.

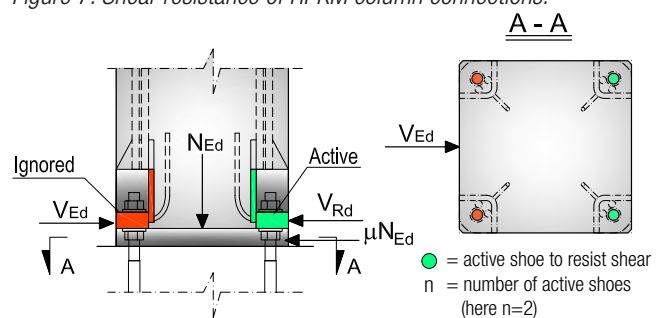
Figure 6. Axial and bending resistance of HPKM Column Connections based on Eurocode 2.



Shear resistance

It is assumed that the most severe shear action is caused by a vehicle impact. Only the bolts and column shoes on the side opposite to the impact are considered effective and active in shear design (Fig. 7). The standard EN 1993-1-8 (Eurocode 3) design rules for steel structures are applied.

Figure 7. Shear resistance of HPKM column connections.



Corrosion

In mild ambient and normal indoor conditions it is not necessary to protect the exposed steel surfaces of the column shoes. When covered with concrete, the same concrete cover for the column shoes and the column reinforcement results has the same corrosion resistance both at the connection and in the column.

Fire resistance

Temperature development and critical minimum sections of unprotected column connections with Peikko HPKM Column Shoes have been determined using both experimental fire tests and numerical FE analysis. In fire tests the Peikko column connections were exposed to standard fire according to EN 1363-1 (Fig. 8). The resulting axial force-bending moment (N-M) interaction curves can be calculated using the Peikko Designer® software.

When a concrete cover with thickness equal to the cover thickness on the column reinforcement is applied to the column shoes, the fire resistance of the column shoe connection is the same as that of the column.

Figure 8. Photos of fire test.

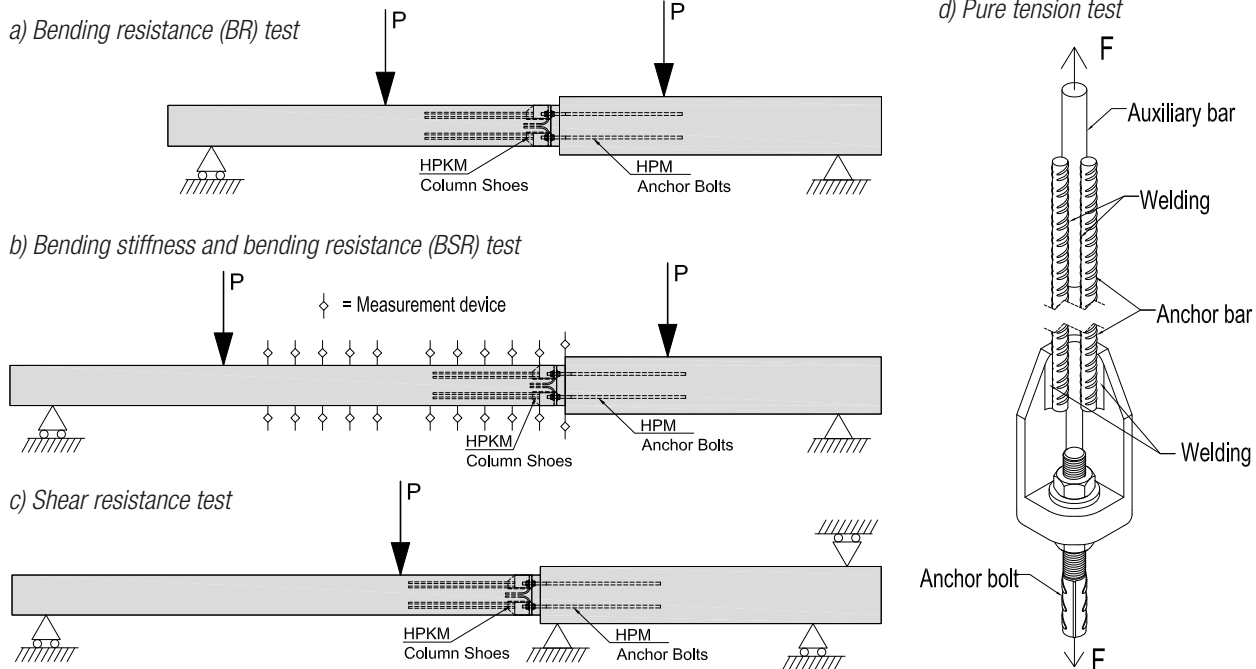


Tests for mechanical resistance and stiffness

To verify the mechanical behavior for the ETA, a large number of full-scale experimental tests on concreted connections were carried out (see Figures 9a, 9b, and 9c).

For continuous quality control, tension tests without concrete are performed regularly (see Fig. 9d).

Figure 9. Illustration of full-scale test arrangements.



These tests stressed the importance of stiffness control. When the stiffness of the column shoe zone corresponds to the stiffness of the continuously reinforced column, the existing design rules of EN 1992-1-1 for slender, continuously reinforced columns can be used. The shear tests were planned to simulate a vehicle impact in accordance with EN 1991-1-8.

Photos from mechanical resistance tests

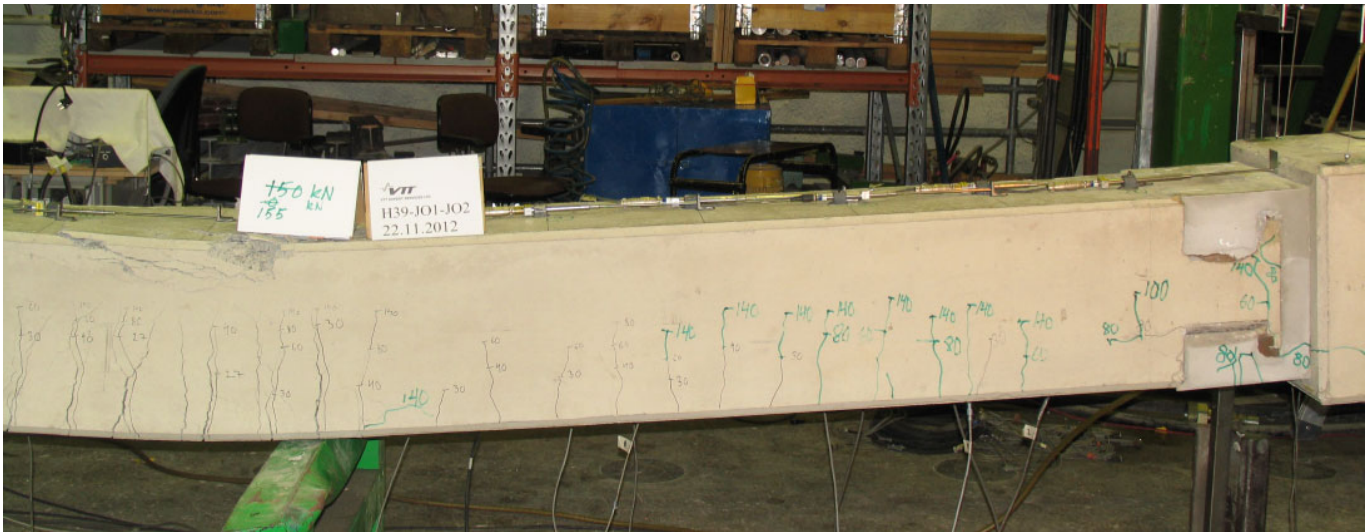
Stiffness test.



Shear test.



Stiffness test. Note failure in column.



Comparison of ETA with current local-/national approvals – approach differences

ETA-13/0603:	Local-/national approvals:
Covers the bending, compression, and shear of the entire column connection and its components.	Are issued only for single column shoes that can transfer only axial forces (tension and compression).
Required full-scale tests on concreted connections.	Do not require tests on concreted connections.
Includes technical information for fire resistance, application in different environmental circumstances, and torque for nuts.	Do not specify fire resistance, application in different environmental circumstances, or torque values.
Required the consensus of all notified European approval bodies	Do not require European-level consensus.
Takes into account two different stages: the erection stage, when the joint is not grouted, and the final stage, when the grout has hardened.	Do not consider different stages.

References:

- | | |
|----------------------------|--|
| [1] EN 1992-1-1: 2004 | Eurocode 2: Design of concrete structures. Part 1-1: General rules and rules for buildings |
| [2] EN 1992-1-2: 2005 | Eurocode 2: Design of concrete structures. Part 1-2: General rules. Structural fire design |
| [3] EN 1993-1-1: 2005 | Eurocode 3: Design of steel structures. Part 1-1: General rules and rules for buildings |
| [4] EN 1993-1-8: 2005 | Eurocode 3: Design of steel structures. Part 1-8: Design of joints |
| [5] ETAG 001, Annex C:2010 | Guideline for European Technical Approval, Design methods for anchorages |
| [6] ETA-02/0006 | European Technical Approval of short HPM L anchor bolts |
| [7] ETA-13/0603 | European Technical Approval of HPM L Column Shoe for connecting columns to concrete structures |