



Figure 2: Composite beam supported by PCs Corbels

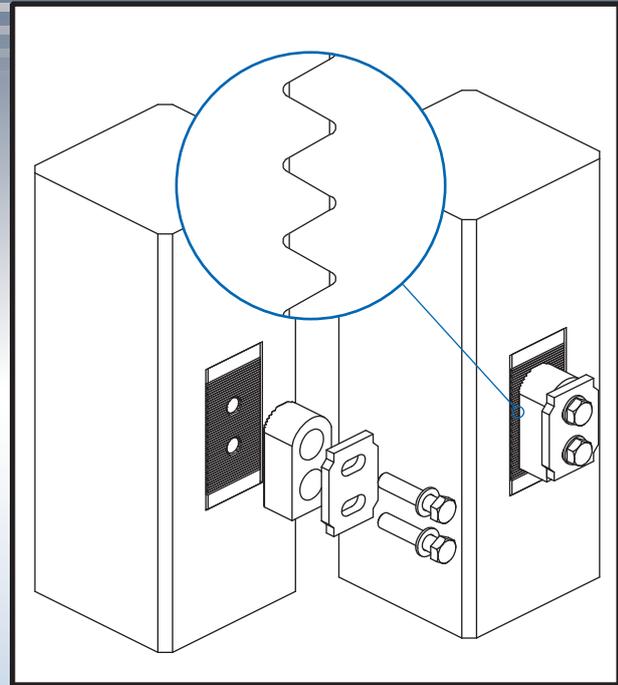


Figure 3: PCs Corbel

# Peikko PCs vs. concrete corbels

## 1. INTRODUCTION

According to the Penguin Dictionary of Building<sup>[1]</sup> „corbel is brick, masonry, or concrete projecting from a wall face, usually as a support for a beam or roof truss“. However, Peikko delivers a product that makes it necessary to correct the above definition. Peikko’s PCs Corbel is made of steel and can be used for walls and columns as well.

The traditional solution of corbels in concrete structures is based on reinforced concrete. Nonlinear distribution of stress in so called short corbels involves special provisions for reinforcement arrangements that can be found in national standards for the design of concrete structures. Unfortunately, the projecting of a concrete corbel from a supporting structural element causes some disadvantages:

- requires perforation of a standard smooth formwork
- difficulties in production process particularly when corbels are projecting upward
- concrete corbels are sensitive to damages during handling and transport

Thus standardized Peikko PCs Corbels bring an interesting solution of corbels in concrete structures.

## 2. THE DESIGN OF CORBELS

Eurocode 2<sup>[2]</sup> covers the design of concrete corbels particularly in the informative Annex J Examples of regions with discontinuity in geometry or action. Short corbels when  $a_c < z_0$  (see Fig. 1), may be designed on the basis of strut-and-tie models. The inclination of the strut is limited by  $1.0 \leq \tan \theta \leq 2.5$ .

If  $a_c < 0.5 h_c$  closed or inclined links should be provided, steel area of individual link  $A_{s,link}$  should satisfy  $A_{s,link} \geq k_1 A_{s,main}$ , where  $k_1$  is NDP, recommended value  $0.25 A_{s,main}$  is the area for the main tension corbel reinforcement.

Links are provided in addition to the main tension reinforcement. The main tension reinforcement should be anchored at both ends. It should be anchored in the supporting element (column, wall) on the far face and in the corbel as well. Anchorage lengths are more precisely specified by Eurocode<sup>[2]</sup>.

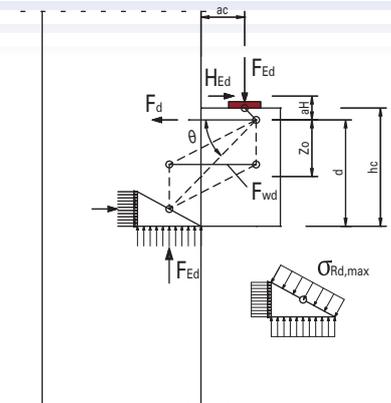


Figure 1: Corbel strut-and-tie model according to [2]

## 3. PCs CORBEL

### 3.1 General

The Peikko PCs Corbel system is an efficient tool for supporting steel, composite, or reinforced concrete beams to reinforced concrete columns or walls. The projecting parts of the corbels can be installed any time after casting and demoulding. The PCs Corbel is so small that it can be easily hidden inside a beam cross section, thus there are no projecting parts creating obstacles below the beams (Fig. 2).



Figure 4: RC beam equipped by PC end plate

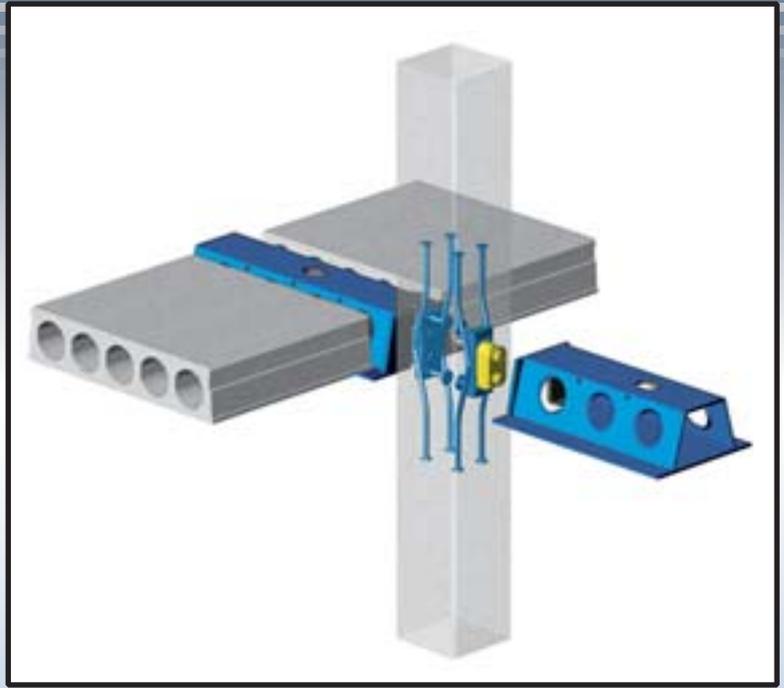


Figure 5: Deltabeams supported by PCs Corbels

### 3.2 System description

PCs Corbel is a system consisting of

- column parts
- corbel parts
- beam parts

#### a) Column part

The column part (see Fig. 3 left) is cast in a concrete column. It does not project from the surface of the concrete element.

#### b) Corbel parts

The body of a corbel and corbel plate are fastened with bolts (and washers) to the column part (see Fig. 3 right). An optional LOCK can be delivered for special loading cases (upward force in support).

#### c) Beam parts

The beam part consists of a vertical end plate plus fixing to a beam (Fig. 4). In case of Deltabeams, they are simply end and bottom plates of a special shape that fit to a projecting corbel part (see Fig. 5).

### 3.3 Additional reinforcement

When installing column parts of corbels, it is necessary to place additional stirrups according to the producer's manual recommendation. No doubt this additional reinforcement contributes to the load bearing capacities of corbels. An example of additional reinforcement arrangement is provided in Fig. 6.

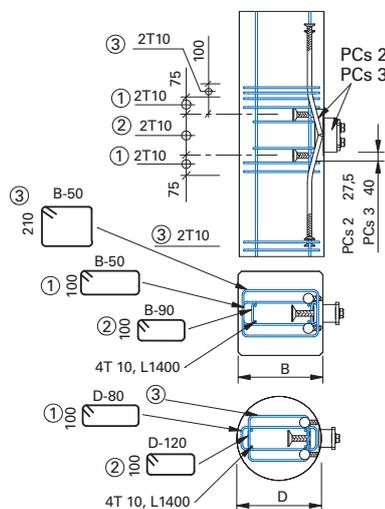


Figure 6: Additional column reinforcement

## 4. APPLICATION OF PCs CORBELS

### 4.1 General

A typical application of PCs Corbels can be seen in multi-storey columns. Especially in cases where space arrangement of corbels is required, PCs Corbels are an attractive solution. The mounting of beams can be done later, if required. If torsional moments exist, the stability of the beam must be considered. Corresponding recommendations can be found in Peikko PCs Corbel manual<sup>[3]</sup>.

### 4.2 Design

The design of PCs Corbels is very simple. The structural engineer just makes a choice of the appropriate size of PCs Corbel with regard to acting forces (design value of the applied shear force  $V_{Ed}$ , design value of the applied torsional moment  $T_{Ed}$ , design value of the applied horizontal force  $H_{Ed}$ ). The acting forces are compared with the tabulated capacities. The interaction curves of shear force on torsion capacity are provided. The capacities correspond to concrete



Photograph demonstrating the physical differences between concrete and PC corbels

of strength class C30/37. However, correction factors are given for lower strength concrete classes C25/30 and C20/25.

## 5. THE BEHAVIOUR OF PCs CORBELS

The behaviour of PCs corbels has been studied in load tests performed by the Tampere University of Technology. The tests proved the necessity of additional reinforcement. Additional reinforcement contributes not only to capacities, but also to ductile behaviour.

Two modes of failure were observed:

- concrete cone failure associated with the upper anchor
- extensive deformation of base plate

The first mode of failure – concrete cone – is fragile in nature, but thanks to additional reinforcement, concrete cone failure can be controlled. Linear elastic deformation has been observed within the range of declared capacity. The second mode of failure appeared when column width  $B$  satisfied condition  $B = 2.7 L_3$  where  $L_3$  is the depth of corbel anchors.

## 6. COMPARISON OF CORBELS - CONCLUSIONS

### 6.1 Costs

The most frequently asked question by precasters concerns the cost of products. A direct comparison of PCs Corbels' cost plus additional reinforcement to concrete corbels and its reinforcement is rather misleading. A more complex view should be applied, taking into account damages to standard formwork due to perforation needed for concrete corbels, additional concrete formwork, productivity of labour, and other aspects.

### 6.2 Productivity of labour

PCs Corbels can be placed together with ordinary column (wall) reinforcement to formwork. No special formwork for corbels is

needed. The savings in labour are higher when 3 or even 4 corbels are required.

### 6.3 Advantages of PCs Corbels

- Very simple and safe for the designer, no calculations necessary, AUTOCAD blocks and 3D symbols are available for Tekla structures, for example.

- Differences of Corbels for different loads, special PCs Corbels for location on the top of columns.

- Installation of PCs Corbels is very easy. It can be done either in the plant or on site, whichever is more convenient.

- The PCs Corbel concept enables adjustment of the location in both vertical and horizontal directions and can accommodate length tolerances of beams as well.

- The small size of PCs Corbels fits in low beams and slabs. Architectural demands for flat ceilings can be met.

- Corbels can be invisible in the finished structure.

- Easy HVAC installations below the floor slab

- Easy layout modifications

### 6.4 Conclusions

PCs Corbels represent a very competitive alternative to traditional concrete corbels. They fit very well to columns of various cross section shapes, and also to walls. PCs Corbels can be successfully employed in both precast as well as cast-in-situ concrete structures.



At the end of 2007, Peikko expanded its PCs product range with the introduction of LOCK (above) and PCs 15 (right) models.

## REFERENCES

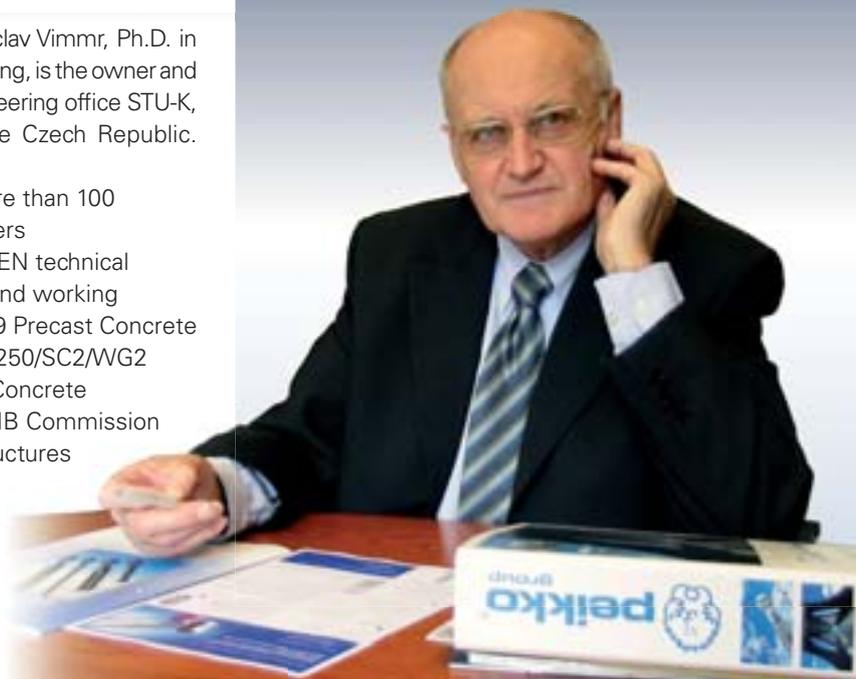
<sup>[1]</sup> Scott, J.S. Dictionary of Building. Penguin, Third edition, London 1984

<sup>[2]</sup> EN 1992-1-1:2004 Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings

<sup>[3]</sup> PCs Corbels: Peikko user manual, pre 2008

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- Author of more than 100 technical papers
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- Member of CIB Commission W23 Wall Structures



# 3D Software provider Tekla and Peikko Group intensify cooperation



## TEKLA Structures

Peikko and Tekla, the leader in 3D software solutions for the precast industry, have agreed to intensify cooperation both in technical development as well as marketing.

Peikko's products for the precast industry can be used directly by the structural designers as 3D objects in Tekla Structures software. The next update of these 3D objects with improved features will be ready to download from Peikko's www-site by April 2008. The technical suitability of the objects has also been tested with the new, coming version 14.0, scheduled to be released in 2Q 2008.

The marketing cooperation between the two companies will include joint technical seminars for designers in various countries. Peikko also intends to use the Tekla Structures software to demonstrate to customers the technical solutions designed to meet their particular requirements.

–We are very happy to deepen our cooperation with an industry leader such as Tekla. 3D design is certainly the long-term tool to improve efficiency and minimize errors at precasters. Providing standardized Peikko products in this tool is useful for all users. We also think that “3D seeing is believing,” when talking about our solutions with customers. There are definite advantages in this commencing cooperation for both Tekla and Peikko, says **Markku Koponen**, Sales Director of Peikko Group.

