



COST SAVINGS IN TT FLOOR SLABS DUE TO PBH CORBEL

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1. INTRODUCTION

Prestressed double T floor slabs are very popular for long span structures thanks to their economy. They are mainly used in building structures for industrial purposes or anywhere a flat ceiling is not required. Double T floors (referred to as TT slabs herein) are usually supported by beams or girders. If TT slabs are placed on the top surface of supporting beams the structural height of the floor becomes almost unbearable. One of the possible solutions is to equip beams with flanges and create mortised ends on the TT slabs according to Fig. 1. This solution often causes concrete cracking problems due to unfavourable concentration of stresses at the re-entrant corner of the supporting area of the TT slabs. The problem of mortised ends attracted the attention of many scientists all over the world for decades [1]. The same functional effect can be reached by employing Peikko PBH corbels (see Fig. 2), while above stated problems can be effectively eliminated.

2. PBH Corbel Description and Function

PBH corbels are essentially a steel assembly allowing TT slabs to be placed on supporting girders without the necessity to create girder flanges and mortised ends on the TT slabs and at the same time minimizing the structural

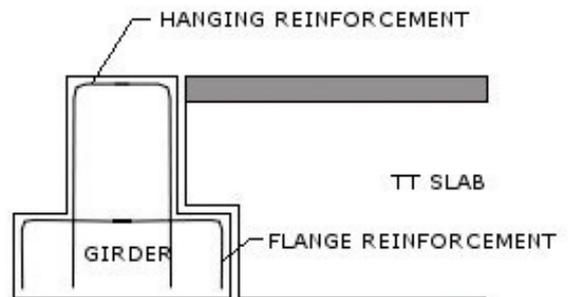


Fig. 1: Dapped ends of TT slabs

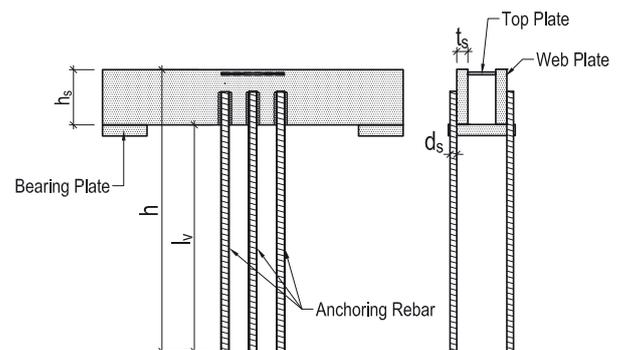


Fig. 2: PBH Corbel

height of a floor structure. The assembly mainly consists of two vertical steel plates mutually connected by bearing plates and top plates to create a horizontal steel beam of open cross section bridging the gap between the head of a TT slab and the girder. The assembly includes vertical bars as anchoring reinforcement of the assembly to a TT slab. Horizontal bearing plates are located in both ends from the assembly, and a short stabilizing plate is located on top of the steel beam in the middle. Bearing plates, 6 reinforcing anchor bars and top plate are welded to the horizontal steel beam. PBH corbels are designed to carry out both transient situations during assembly of TT slabs and the final stage when cast in-situ concrete topping is hardened.

The load bearing capacity of individual PBH corbel types during the execution phase can be seen from Table 1 while measurements are given in Table 2.

PBH corbels employ steel grade S355 and S235 according to EN 10025-2: 2004 for plates and BSt 500S according to EN 10080: 2005 for anchoring bars.

Table 1. Load bearing capacity of PBH corbels in execution phase

Type of corbel	$V_{r,d,exec}$ in KN
PBH 1	80
PBH 2	100
PBH 3	125
PBH 4	150

Note: When depth of ribs $h_w \leq 500$ mm capacities must be reduced

Table 2. Measurements of PBH corbels in mm

Type of corbel	h_s	t_s	h	l_v (*)	d_s
PBH 1	100	15	460	360	10
PBH 2	100	20	470	370	12
PBH 3	120	15	580	460	12
PBH 4	120	20	600	480	14

* l_v - length might depend on rib depth

Note: For notation see Fig. 2.

3. Structural System

Two main situations should be distinguished: the execution phase and the final stage of the floor structure.

Execution phase:

- PBH corbel acts as a simply supported beam loaded by anchoring reinforcement as illustrated by Fig 3., apart from the structural system and acting forces, it shows the distribution of b) shear forces, c) bending moments, d) bending moments due to lateral restraint and e) normal forces due to restraint
- The restraint is caused by friction between bearing plates and the concrete surface of a supporting girder in the case when neoprene bearing pads are not used.

- As far as TT slabs are concerned simplified strut and tie models according to Eurocode [2] can be used, reflecting the depth of a TT slab webs.

Both systems must carry out the following loads

- dead load of precast concrete TT slab
- dead load corresponding to structural in situ topping
- actions during execution [3]
- snow if it is relevant

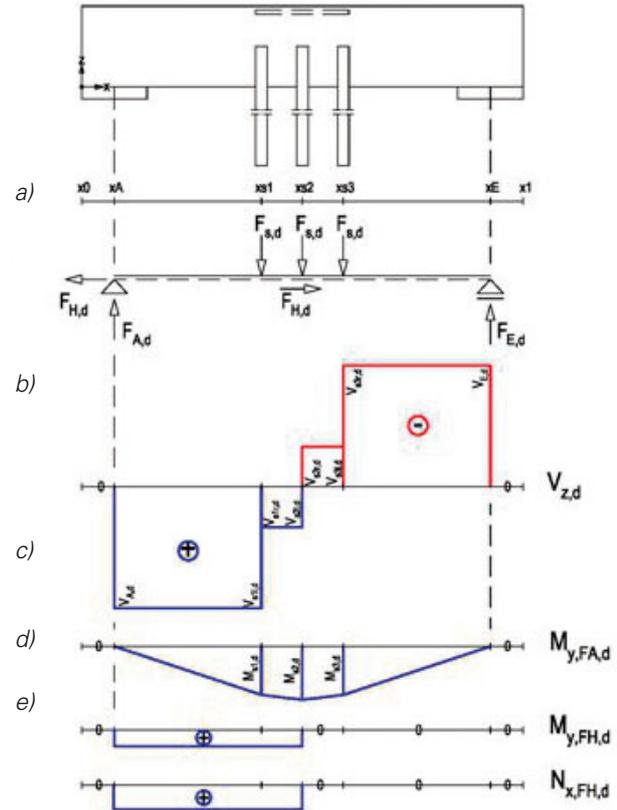


Fig. 3: Structural System of PBH Corbel in execution phase

Final stage:

When concrete topping is hardened a different structural system should be considered.

PBH corbel acts as a real corbel clamped to the precast concrete element. The structural system has changed to composite steel-concrete structure of a different shape, thus corresponding strut and tie models should be used for calculation of forces from additional loads that are:

- dead load due to flooring
- dead load caused by partitions or other relevant structures
- live loads

PBH corbel and the detailing of the ends of TT ribs must comply with Eurocodes and must be able to carry out all the forces resulting from both stages determined on principle of superposition, but taking into account applicable loads only.

4. Practical Consequences of PBH Corbels Application

The use of PBH corbels has a large number of advantages in comparison to other solutions commonly used in practice:

a) Reduction of structural height of floor (or roof) structure

Provided that the clear height of a structure is the same as the solutions shown in Fig. 4 b) and c) in comparison to Fig. 4 a) offer

- lower construction height
- smaller area of external walls and consequently lower purchase and maintenance costs
- less consumption of energy for heating during operation of a building (this is a long term effect that is interesting for the user of a building).

b) Ease of formwork, smaller amount of concrete and reinforcement

When solutions shown in Fig. 4b) and Fig. 4c) are compared then in the case of the application of PBH corbels

- Simplified formwork of girders due to rectangular cross section
- Concrete for flanges is saved
- Reinforcement of flanges is not needed
- Vertical hanging reinforcement due to change of a system from indirect support (Fig. 4b)) to direct support (Fig. 4c)) is eliminated
- Cracking problems of mortised ends are avoided
- Reduction of load eccentricity means reduction of torsional moments of girders and consequently reduction of steel for stirrups

c) Cost savings

Apart from cost reduction already discussed within paragraph 4 a) further cost reduction is resulting from paragraph 4 b) with regard to

- smaller amount of concrete
- smaller amount of girder reinforcement
- smaller amount of TT reinforcement

Fig. 4: Comparison of slabs structural heights

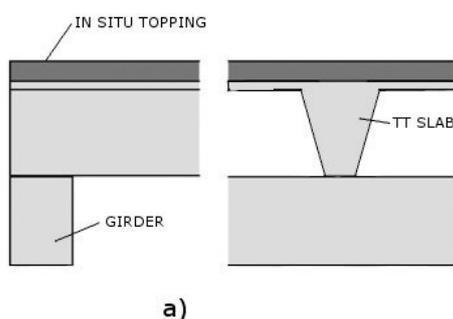


Fig. 5:

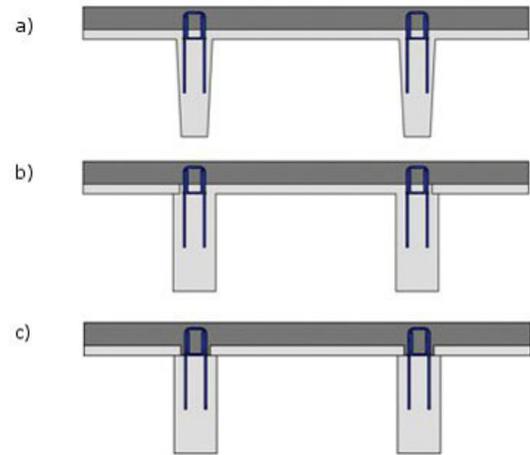


Fig. 5 STRUCTURAL ALTERNATIVES OF TT SLABS
a) classical TT slab as one precast element
b) through slab and floor plates for composite slabs
c) rectangular beams supporting floor plates for composite slabs

In addition to the above, the maintenance costs can be reduced when PBH corbels are applied because the danger of cracks in the re-entrant corners of mortised ends of TT slabs may need the application of adequate repair methods to satisfy durability requirements.

5. Examples of PBH Corbels' Application

PBH corbels have been developed particularly for TT slabs that are currently covered by European standard [4]. The most common structural alternatives of TT slabs equipped by structural topping can be seen from Fig. 5. Alternative methods shown in Fig. 5 b) and c), incorporate floor plates according to European standard [5]. PBH corbels are also used in practice for secondary composite beams (see Figs. 6 and 7).

PBH corbels have already been certified for fire resistance class F90, but when required F120 can be reached.

6. Conclusions

PBH corbels are steel assemblies that simplify floor structures, consisting of TT slabs and supporting girders. PBH corbels eliminate the need for sensitive mortised ends of TT slabs and flanges of girders. This creates favourable conditions for cost savings of materials and reduction of workload in large span floor structures based on TT prestressed concrete slabs.



Fig. 6: Beam ends equipped by PBH Corbels

7. Acknowledgement

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8. References:

[1] Mattock, A.H. and Chan, T.C.: Design and Behaviour of Dapped - End Beams. PCI Journal, V.24, No.6, November - December 1979, pp.28-45

[2] EN 1992-1-1:2004, Eurocode 2: Design of concrete structures – Part 1.1 General rules and rules for buildings

[3] EN 1991-1-6: 2003, General actions - Actions during execution

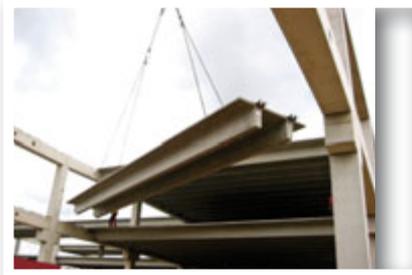


Fig. 7: Composite secondary beams placed on girders by means of PBH Corbels

[4] EN 13244: 2004 Precast concrete products - Ribbed floor elements

[5] EN 13747: 2005 Precast concrete products - Floor plates for floor systems

