TECHNICAL FEATURES OF DELTABEAMS

By Vaclav Vimmr

1. INTRODUCTION

Deltabeams are gaining popularity in many European countries. Quite a few articles in previous issues of Peikko News were devoted to interesting applications of Deltabeams. We can be sure that even more interesting writings are in progress. But not too much attention has been paid to the technical features of the product.

Let us look at the structural principles of the Deltabeam composite system, basic design principles including simplified preliminary design, and a tool for the choice of Deltabeam cross sections. Finally the main technical advantages of Deltabeams are briefly discussed.

2. STRUCTURAL PRINCIPLES

The hollow steel cross-section is ideally suited for composite performance when filled with concrete and provided by transversal reinforcement protruding through steel beams. The bottom side ledges can support various floor slabs ranging from cast-in-situ concrete, composite or fully prefabricated slabs of various cross sections.

For reconstructions, trapezoidal deck profiles as permanent formwork filled by cast-in-situ concrete can be used. When the concrete has hardened, effective composite behaviour of steel box together with cast-in-situ or in some cases also precast concrete is developed [Fig. 1]. The composite action increases the stiffness of a structure and can assist in reducing steel consumption.

Joints between Deltabeams can be designed as continuous or hinge. In case of hinge joints, appropriate provisions should be made in floor slabs to avoid cracking. Thanks to so called side connections, Deltabeam can provide support to another usually perpendicular Deltabeam [Fig. 2]. The possibility to produce Deltabeam as precambered enables the elimination of deflection due to self-weight [Fig. 3].

The range of applications of the Deltabeam from a structural point of view depends on the available cross-sections. A cross-section is featured by height, width, ledges, and side shuttering. The list of standard cross-sections is shown in Table 1 (next page).

Cross-sections are featured by

- height, ranging from 200 mm to 500 mm,
- width that is the bottom of a box from 200 mm to 600 mm
- ledges of the bottom flange 97,5 mm and 130 mm

Table 1 also includes a list of edge beams corresponding to the internal beams that can be associated with the side shuttering.

3. DESIGN PRINCIPLES AND STRUCTURAL CONSIDERATIONS

The traditional structural system of a composite beam is usually based on the idea that the concrete flange is in compression and the steel section is largely in tension. The forces between the two materials are transferred by shear connectors. The benefits of composite action are increased strength and stiffness, which leads to economy in the size of the beam.

Deltabeam is rather more progressive because the top plates are in compression in case of sagging (positive) moments together with infill concrete. The bottom steel flange (together with reinforcing bars when they are present) is in tension. In case of hogging (negative) moments the bottom plate together with infill concrete is in compression and the upper steel flange is in tension.

Detailed calculation and design

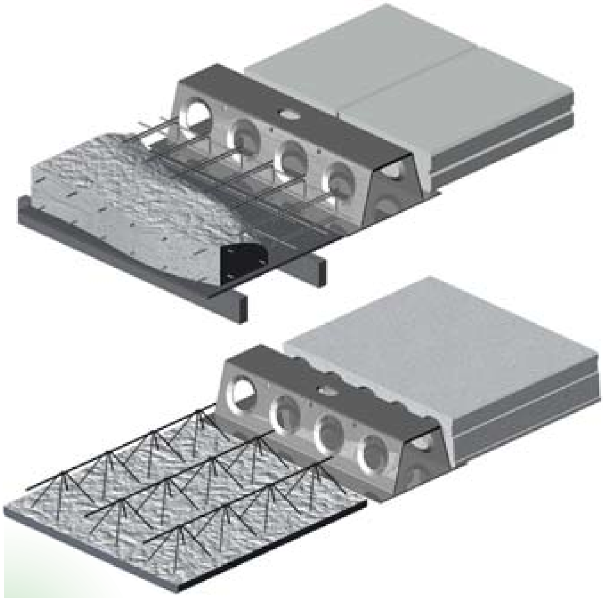


Fig. 1 *Composite Deltabeam*

Fig. 2 *Side joint of Deltabeams*

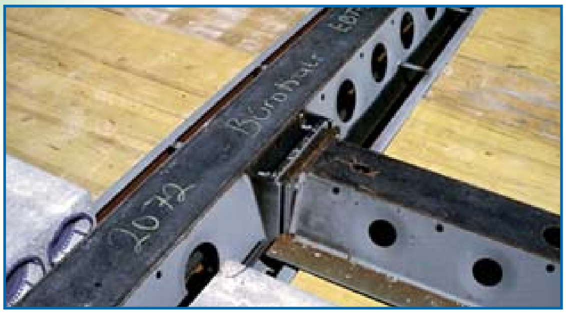
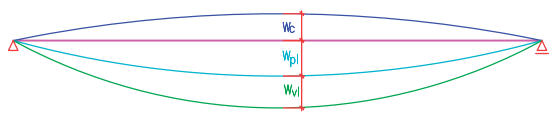


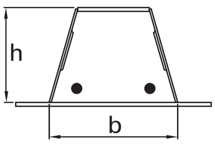
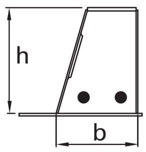
Fig. 3 *Deflection of Deltabeams*



$W_c = W_{sw}$

W_c - camber
W_{sw} - defection of steel box due to self weight
W_{pl} - long term deflection due to permanent loads
W_{vl} - deflection due to variable loads

Table 1 Overview of standard cross-sections

Internal beam		Edge beam	
			
h	b	h	b
200	200	200	215
200	300	200	245
200	400		
220	300	220	250
220	400		
250	300	250	260
250	400		
260	300	260	230, 260
260	400	260	290, 325
300	300	300	270
300	400		
320	300	320	250, 285
320	400	320	310, 365
370	400	370	325
370	500		
400	400	400	295
400	500		
500	500	500	350
500	600		

including workshop drawings are provided by the Deltabeam producer. A proposal of geometry and a list of actions must be provided by a responsible structural engineer in the project.

For preliminary design and estimation of the appropriate Deltabeam cross-section, it is possible to adopt the following simplified assumption.

The concrete can be fully neglected and thus the steel, both top and bottom flanges, takes the bending moments while shear is transferred by webs.

$$M_a \leq A_{st} \cdot f_y \cdot z \,,$$

where

A_{st} – area of top flange (usually decisive)
f_y – yield strength of steel
z – lever arm (distance between centres of gravity of top and bottom plates)

The allowable load-bearing capacities for single span simply supported composite beams taken from [3] are illustrated by diagrams in Fig. 4 for internal beams and on Fig. 5 for edge beams. Capacity curves were created under the following assumptions:

- Material of steel beam S355J2+N
- Concrete class C25/30
- 30% of live load is static
- Temporary surface loading during construction is 0,5 kN/m^2
- Nonstructural concrete screed 50 mm is calculated in the weight
- Composite action of hollow core units is neglected

For the preliminary design consideration, it is possible to check the expected composite slabs performance from diagrams in Fig. 6 and 7.

These diagrams have been developed on the basis of the diagrams in Fig. 4 under the following assumptions

- hollow core units are used
- the total design load is 10 kN/m^2
- Fig. 6 is valid for simply supported internal beams
- Fig. 7 applies for 3 field continuous internal beams of the same span

The Deltabeam should be checked for a condition where the precast concrete units are placed first on one side of the beam (which causes out-of-balance forces), leading to combined bending and torsion on the section. In cases where the precast units are very heavy, it may be necessary to organise the installation of the units so that loads on either side of the beam are approximately balanced. Sometimes provisional propping is needed.

Due to the eccentricity between the ends of the precast units and the centroid of Deltabeam, a particular design consideration is the presence of a transverse moment in the flange plate.

4. ADVANTAGES OF COMPOSITE DELTABEAMS

• The Deltabeam concept can be classified as a slim floor approach. Deltabeam enables the creation of flat slabs employing precast concrete elements. The best results are reached when prestressed concrete hollow-core units are used. It offers a flat soffit to the floor.

• Composite Deltabeams eliminate punching problems in flat slabs.

• High stiffness of the cross-section due to composite action enables relatively large spans.

• The consequences of the low structural height of slabs are cost reduction for construction of external walls, reduced maintenance costs, and lower operational cost of buildings due to smaller areas of heat loss through external walls.

• Deltabeams provide an effective solution in case of transferring concentrated loads.

• The self-weight of the Deltabeam steel box is rather low and this can be a great advantage in cases of reconstructions. Deltabeams supporting steel trapezoidal deck profiles for composite slabs offer a convenient solution for such cases.

5. CONCLUSIONS

The Deltabeam composite system brings many new challenges to structural engineers. Composite structures extend the advantages of prefabricated structures, open new fields of applications, and increase their competitiveness.

The efficient technical support of the Peikko company makes the design and application of the composite Deltabeam system very convenient for structural engineers and construction companies.

REFERENCES

[1] EN 1993-1-1: 2005 Eurocode 3: Design of steel structures - Part 1-1: General rules for buildings

[2] EN 1994-1-1: 2004 Eurocode 4: Design of composite steel and concrete structures – Part 1-1: General rules and rules for buildings

[3] Peikko Group: Deltabeam Composite Beam. Peikko brochure 4/2007

The author, Mr. Vaclav Vimmr, Ph.D. in Structural Engineering, is the owner and leader of the engineering office STU-K, a.s. in Prague, the Czech Republic.

- Author of more than 100 technical papers
- Member of CEN technical committees and working groups TC 229 Precast Concrete Products, TC 250/SC2/ WG2 Fastening in Concrete
- Member of CIB Commission W23 Wall Structures
- Member of fib Commission 5 Structural Service Life Aspects
- Member of Scientific Committee for evaluation of Doctoral theses at the Czech Technical University Prague

Fig. 6 *Size of fields - simply supported beams*

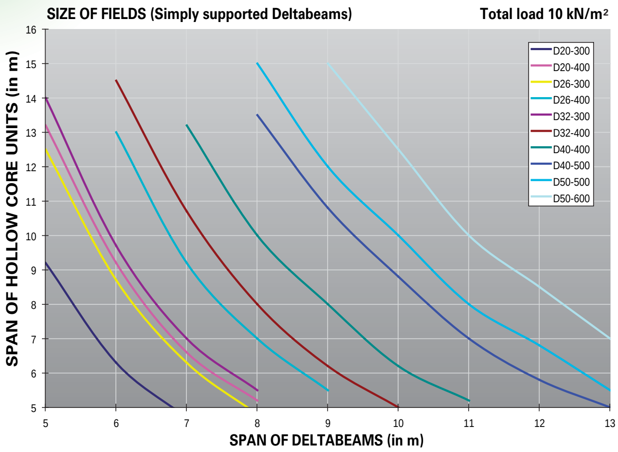
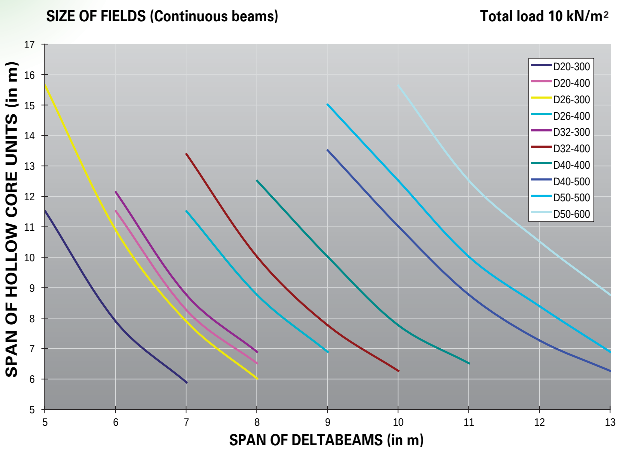


Fig. 7 *Size of fields - continuous beams*



The load bearing capacities of hollow core units in Fig. 6 & 7 must be checked according to producer's documentation.

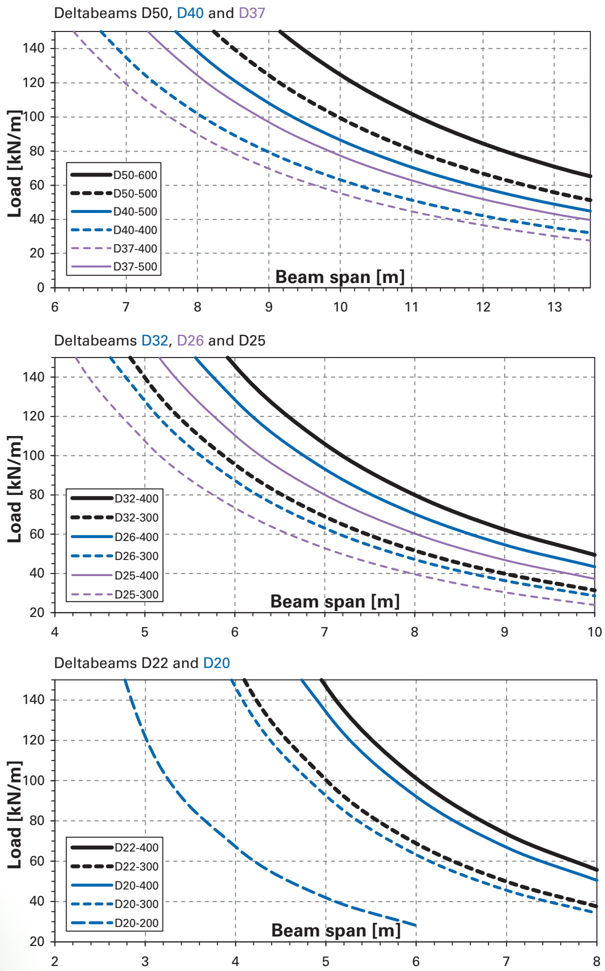


Fig. 4 *Load-bearing capacities of internal composite Deltabeams*

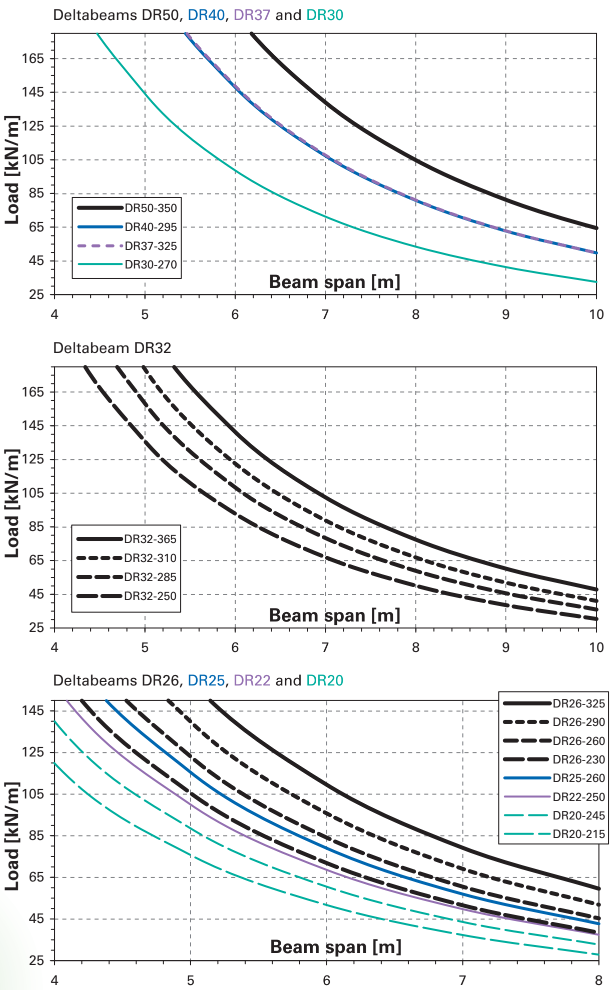


Fig. 5 *Load-bearing capacities of edge Deltabeams*