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Development of bridge precast beams from high performance concrete in EUROVIA CS

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Abstract. The paper presents a summary of the development of bridge precast beams in EUROVIA CS company in the last years. Several types of beams are described. The first beam that has already been applied in real construction is an Omega beam which consists of shell outside envelope enabling construction of a bridge without intermediate supports in midspan. The second one is an inverted T beam for railway and road bridges. At present, the development of UHPC beams for footbridges is going on. The plan is to create a set of shapes and solutions usable for various configurations with spans up to 15 m, fully exploiting the UHPC advantages. Another element for bridge construction developed by Eurovia and its partners is the lost formwork panel used for bridge superstructures built from both concrete and steel beams.

1. Introduction

The development of precast beams from high performance concrete since 2016 is described in this paper. Participants in the development are consultants Pontex s.r.o., precast plant PrefaPro, a.s. and Stachema. The aim was to develop precast beams for small and medium span bridges and footbridges and panels for lost formwork.

The basic idea was using high performance concrete to obtain lightweight products. The weight of the precast members is often the limiting factor in construction of bridges in complicated approach conditions on site and in the cases when the internal span has to be installed with crane standing behind the abutment. The reduced weight of members can have favorable effect on the economy, reducing both transport and assembly costs in the order of tens of percentage points.

We have decided to use UHPC for the elements of bridges and footbridges in combination with prestressing. The lost formwork elements are designed from UHPC only.

2. Omega beam

The first type of such beams was the "OMEGA" beam. Its development started in 2016 (for more details, please refer to [1, 2]) and it was used on site for the first time in 2017 on the bridge in the quarry Třebnůška (Fig. 4). The beam voided shape is based on a typical "T" beam shape normally used in the PrefaPro production site in Brandýs nad Labem.

The "OMEGA" beam consists of shell outside envelope with the shape of inverted letter Ω. The thickness of the shell is 70 – 100 mm, the height of the beam is 550 – 950 mm, depending on the span. Concrete SCC C60/75-XF2 with consistency F7 was used together with prestressing by strands Y1860

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S7. The key requirement was that the beam withstands the construction loads without intermediate support in midspan. The prestressing tendons with preinstalled anchors are placed in the casting yard (Fig. 1). The tendons are later prestressed on site after the composite reinforced concrete deck was cast.

The inner form for this beam had to be designed taking into account the uplift forces from the concrete mixture. The company Česká DOKA was involved in the design of the form and the demolding elements (Fig. 2).

Figure 1. Complete Ω beam

Figure 2. The form of the void

As a part of the development, several tests were carried out.:

1. The pull-out test of the wave transport anchor
2. Test of bond between core and shell
3. Load test (Fig. 3)

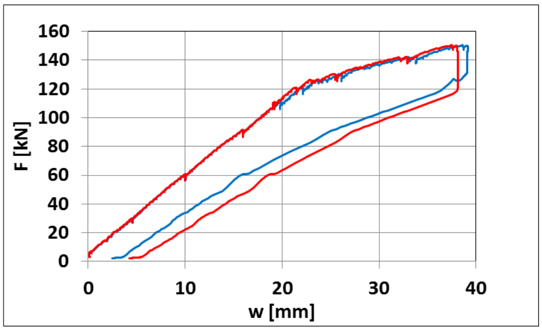


Figure 3a. Force-deflection diagram from the load test

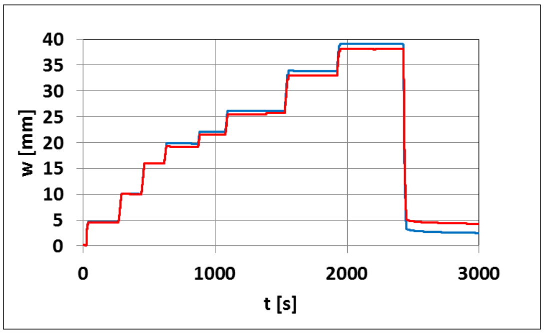


Figure 3b. Measured deflections during test

An economic comparison of assembly costs was performed comparing the typical "T" prestressed beams and the OMEGA beams (Table 1).

Table 1. Economic comparison

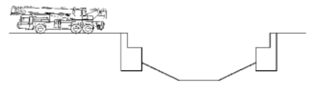
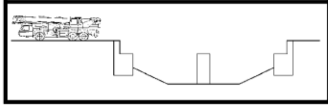
Single span	Ω15	T15	Ω21	T21	Ω24	T24
	LTM 1055	LTM 1200	LTM 1100	LTM 1200	LTM 1200	LTM 1300
	810 EUR	3890 EUR	1670 EUR	3890 EUR	3890 EUR	5470 EUR
2 span	2 x Ω21	2 x T21	2 x Ω27	2 x T27		
	LTM 1200	LTM 1500	LTM 1500	LTM 1500*	* Including 2 assembly positions	
	5520 EUR	7470 EUR	9260 EUR	11260 EUR		

Figure 4a. Beams assembly and the completed bridge

Figure 4b. Beams assembly and the completed bridge

A bid for construction of 3-span bridges was prepared in 2018, where, due to the terrain and approach limitations, the beams assembly will have to be done by crane standing behind the abutment. Again, the classical "T" beams and OMEGA beams were compared. The overall cost savings were above 10 %.

3. Inverted T beams

In 2017, a beam from UHPC for railway and road bridges was developed. The aim was to create a UHPC beam with the potential of replacing the steel "I" or "HEB" beams in these bridge structures. In the case of railway bridges, the beams are embedded in concrete deck. In road bridges, beams are supporting a composite reinforced concrete deck (Fig. 5).

The beam cross section is an inverted "T". For the length of 8.6 m (as used in the trial structure in Chrtníky bridge) the depth of beams is 350 mm (Fig. 6).

In the case of railway bridges, the transversal forces have to be carried. In the case of embedded rigid beams these are covered by transverse reinforcement running through the holes in the webs of steel beams. In the case of concrete beams with web thickness of 100 mm, the void is hard to be filled properly with the concrete of the deck which is necessary for proper functioning of the reinforcement and corrosion protection. This problem was easily solved by using transverse prestressing with MONOSTRAND strands (Fig. 7).

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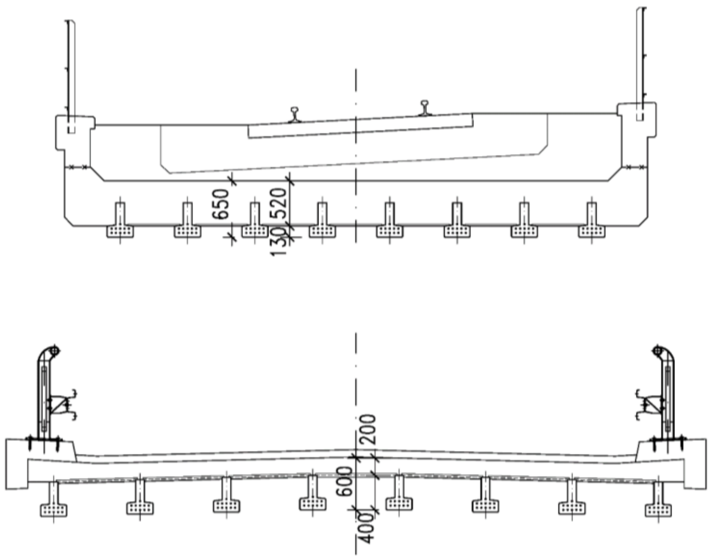

Figure 5. Bridges cross sections

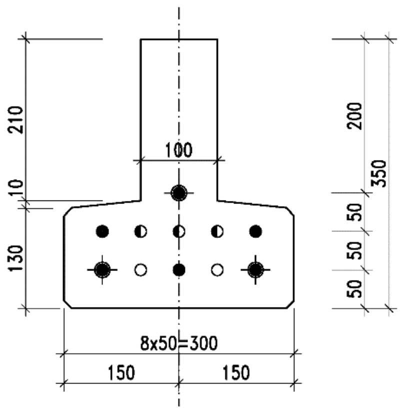

Figure 6. Beam cross section

Figure 7. Transverse prestressing

The new beams were used for the first time on the bridge in Chrtníky quarry (fig. 9) near the town of Přelouč. Due to the requirement of testing the more complicated layout designed mainly for the railway bridges and to confirm the results of the structural analysis, the alternative with embedded beams was used here for testing purposes. Plates CETRIS were used as the lost formwork. For a bigger distance between the beams, it is necessary to use lost formwork panels from UHPC to span this gap without any supports.

As a part of the development of this beam, a load test was carried out. It confirmed the results of the structural analysis. At load level of 2x242 kN the deflection of beams was 60 mm with no visible cracks. The test was finished at load level of 2x376 kN, still without a visible destruction of the specimen (Fig. 8).

More measurements are done during the long-term inspection of the bridge using built-in strain gauges and recording devices in service. These measurements were commenced in April 2018, repeated in March 2019.

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Figure 8. Deflected beam during load test

Figure 9. Assembled beams on site

After the bridge construction, a full scale load test was carried out by an accredited testing laboratory using a truck Tatra Jamal with the weight of 33.5 t (Fig. 10). Measured deflections were smaller than those calculated. The load test confirmed appropriate functioning of the structure.

Figure 10. Load test of the bridge

4. UHPC Beams for Footbridges

At present, the development of UHPC beams for footbridges is going on. The plan is to create a set of shapes and solutions usable for various configurations with spans up to 15 m, fully exploiting the UHPC advantages, durability, resistance to environmental effects etc. These beams are planned to be assembled in precast yard completely, i.e. including railing (Fig. 11).

For this project, a form is being prepared currently. Testing casts are planned for June 2019 followed by a load test in August 2019.

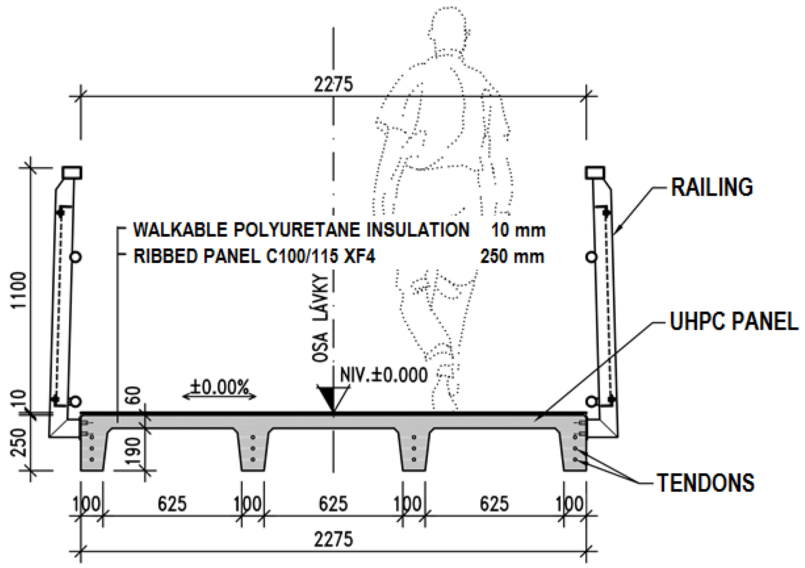

Figure 11. Footbridge precast UHPC beam

5. Lost formwork panels

Another element for bridge construction, developed by Eurovia and its partners, is the lost formwork used for bridge superstructures built from both concrete and steel beams.

The development of these elements is based on economic reasons, when the classical formwork from CETRIS plates is economically feasible up to spans 500 mm with technical limit of 800 mm.

In order to cover larger spans, decks from UHPC are being developed. For smaller spans, plain plates are used. For longer spans, decks with edge ribs are used. (fig. 12).

Figure 12. Ribbed deck of lost formwork

A load test of ribbed decks of lost formwork was done at the Klokner Institute in Prague on 1st April 2019, leading to 2 sets of rather different results (Fig. 13). The load was applied by gradual increase of the loading weight.

Due to the found differences, further investigation of the sources of differences will be done. The potential reasons are different cement used and age of tested elements.

The tested elements will be inspected in detail on the fracture areas. Some additional tests are planned to be done on each of the remaining parts of specimen to confirm the trends of previous tests on these elements. Also, the residual strength will be measured.

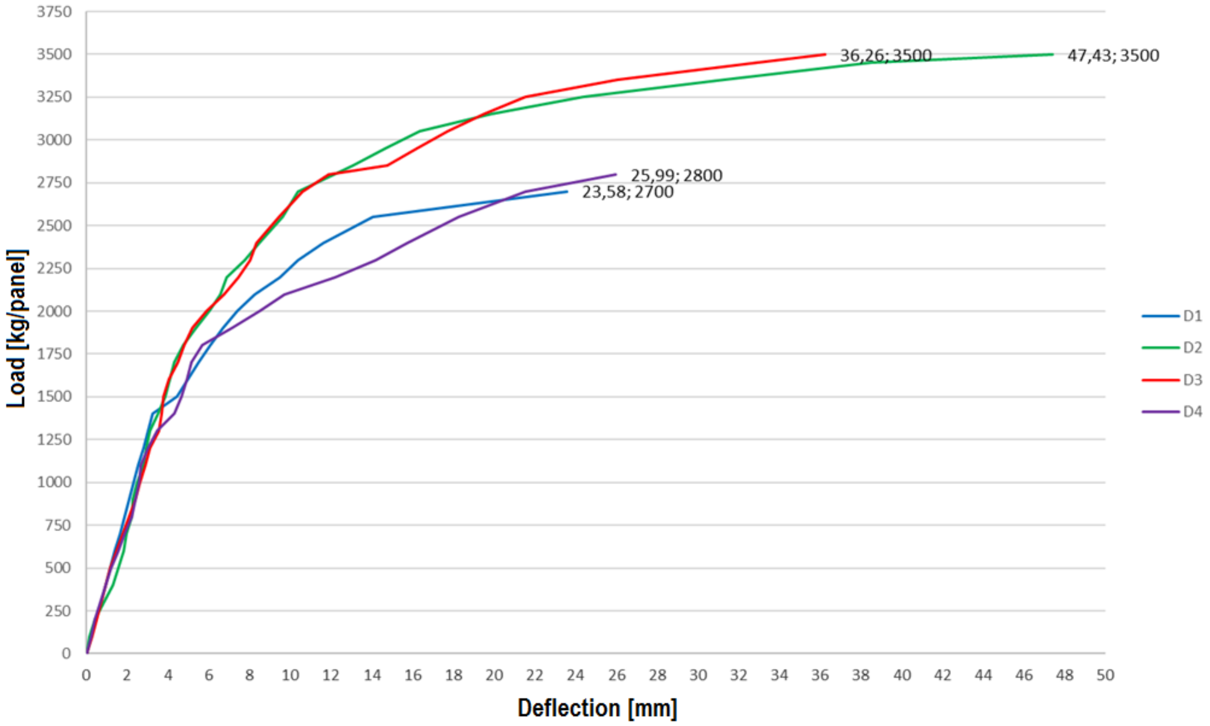

Figure 13. Load test diagrams – lost formwork elements (20 mm slabs + 50 m ribs)

6. Conclusions

The outcome of the nearly 4 year development is a set of structural members for bridge construction using high performance concrete with advantages not only in quality and durability but also in economics of the construction.

Acknowledgements

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References

[1] Bílý P, Kohoutková A and Jedlinský P 2017 FEM simulation of static loading test of the Omega beam *IOP Conference Series: Materials Science and Engineering (MSE)* **236**(1), paper no. 012066.

[2] Sýkora M, Jedlinský P and Komanec J 2017 Lightweight HPC beam OMEGA *IOP Conference Series: Materials Science and Engineering (MSE)* **236**(1), paper no. 012055.