Economic Composite Constructions for Bridges: Construction Methods Implementing Composite Dowel Strips

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Abstracts: Composite dowel strips find a wide application in bridges. They are easy to manufacture and the transmission of shear forces of the composite action is long lasting and robust. Beside the innovative composite action new construction methods for composite bridges are established. The article summarizes already executed bridge structures implementing composite dowel strips due to construction details and economic aspects.

1. Introduction

Eastern Europe´s infrastructure is in a stage of active building boom but also in a process of modernization and strengthening of its existing transportation network. Beside the birth of political and social challenges the fall of the Iron Curtain has changed the demands on its infrastructure. At the beginning of the 1990´s new goals for the pan-European transport to achieve have been compiled and European corridors have been defined which are passing through Poland and Romania, among others. Numbers of the new tracks are awarded through the procedure called Design & Build that gives consortiums of construction and consulting engineering firms the opportunity to realize a full section of a (railway) line under economic aspects. Based on this procedure new developed, economical construction methods are applied under economical demands even beyond the German-speaking area.

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1.1 Use of filler beam decks on bridge construction

First bridges with filler beam decks used as load-bearing elements were built at the end of 19th century for the German railway system. The concrete wasn´t charged bonded but acted as a slab element and as a constant anticorrosive. In the 1930´s new efficient systems with buckled sheets were developed before pre-stressed concrete bridges for short and middle span length were established after Second World War [1]. Only the introduction of headed studs as economical shear connecting elements, which are easy to design, and the introduction of German standard for composite constructions DIN 1078 in 1955 have provided the basis for the construction of composite bridges of short and middle span lengths in Germany. Frequently the Perfobond-strip was used for bridge constructions in non-European countries [2]. In spite of the official approval in Germany [3] the shear connector was only used in exceptional cases. But the approval was the starting point for systematic investigations regarding the load bearing behaviour of the shear connector like it was done at University of Bundeswehr in Munich (Ger) [4]. Other research projects have placed the emphasis on the fatigue behaviour of beams that will lead to a request on a national technical approval as per DIBt [5] [6]. The bearing behaviour of the composite dowel is described in [7], [8], [9] and features regarding its fabrication, bearing behaviour and during construction progress several considerable advantages:

- The cutting line is double-symmetric and can be fabricated nearly without any outcuts.
- The filler beam decks are bisect centric with the cutting line and contain the shear connector.
- The reinforcement can be prefabricated as a cage and can be placed into the open steel dowel from above
- The composite dowel exhibits high bearing capacity and robustness against fatigue failure.
- Halved filler beam decks and welded T-profiles with composite dowels are suitable as external reinforcement for new structural systems

Due to systematic research on the bearing capacity of composite dowels and the resulting development of the design concept, composite dowels are used frequently in bridge constructions at the present. By practical examples in Poland, Germany, Austria and Romania different design principles and constructive details are explicated. The economic efficiency is described through Design & Build project.

First bridges with composite dowels were built as fly-overs in Pöcking (Ger) and Vigaun (A). Recently, bridges for the Deutsche Bahn were built on the basis of the intensive research regarding fatigue behaviour of composite dowels.

1.2 Types of cross-sections of VFT®-girders with composite dowels

Composite dowels, which have been developed out of the Perfobond-strip [2], are examined over the last 15 years systematically [10]. Preparatory works on a national technical approval as per DIBt are the basis for the use of the composite dowel strips [6]. Related to headed studs, composite dowels are not only optional shear connector. Due to the different bearing behaviour and form of constructions new construction designs can be created. By placing the composite dowel in the web of the girder, the top flange can be omitted for the reason that it is only used to fix the headed studs. Figure 1 is showing the typified cross sections exemplarily.

By cutting a filler beam deck in the centre line, two equal halves including the composite dowel result. Lying next to each other they can be combined to a composite beam (Figure 1a). The composite joint is on the level of the prefabricated flange near to the neutral axis of the beam and gets it load primary due to the transfer of longitudinal shears. The gap between the two halves is filled with concrete.

Advantages of cross-section a) are:

- Robust bearing behaviour consequently to the concrete core in the case of impact loads
- Slim structure with two steel girders at the cross-section
- Good aesthetic aspect due to the outside lying web surface

Commonly used rolled sections provide girder depth up to 1,10 m. Using flange thickness from 12 to 20 cm the depth of the prefabricated beam results to a maximum of 0,60 m. For that reason the span length of Duo-WIB-bridges is limited to 20 m approximately. By installing only one external reinforcement-element in the centre of the concrete web of the prefabricated beam, the depth of the construction is independent from the depth of the girder web (Figure 1b). The essential advantages of this construction type, that is called Mono-WIB, are:

- Economical production due to the fact that standard formwork for pre-stressed beams can be used
- Efficient material input because the steel bears the tensile stress and the concrete the compressive- and shear stress
- Consequently to a variable concrete web the girder depth is independent of the steel section
- Due to haunches the superstructure can be accommodated to the line of force and frame systems are easy to realize
- Robust bearing behaviour consequently to the concrete web in the case of impact loads
- No horizontal surfaces (pollution by birds)

One disadvantage of the far located composite dowel strip to the neutral axis is that the steel dowel not only gets local shear loads but also centric tension as a result of global bending moment (cp. [6], [8]) and gets consequently higher fatigue loads due to global bending moments.

The self-weight of cross-sections a) and b) is up to double-higher compared to VFT-girders ([11], [12]). For economical mobile crane capacities and uncomplicated handling during transportation to construction site the sensible application area for the VFT-beam is limited to a length of 35 m, similar to pre-stressed beams. At larger span length, especially at frame constructions, the VFT-beam with welded steel girders is worthwhile. If composite dowels are designed to be at the web of the steel girder, the upper flange, that is normally used to fix the headed studs, can be omitted (Figure 1d). At the area of negative bending-moments und high loadings in the composite joint top flanges with composite dowels can be installed (Figure 1c and Figure 32).

The use of external reinforcement at slabs causes slim building elements. For bridges with in-situ concrete for roadways and at railway-bridges with high compacted cross-sections, like the VFT-Rail® is, slabs with external reinforcement are used (Figure 1e to 1g; [13], [14], [15]).

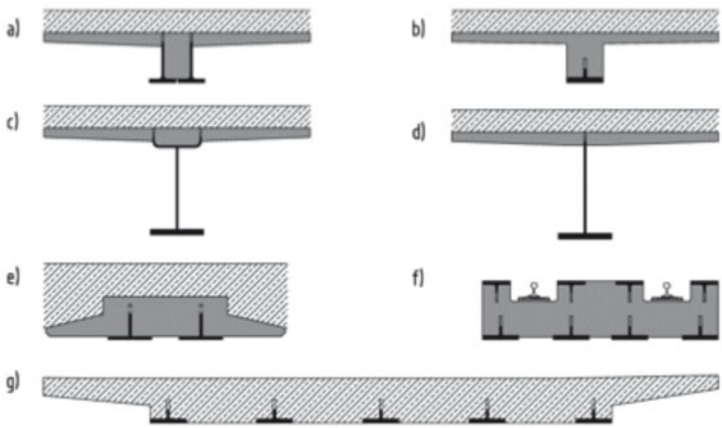

Figure 1: Typified cross-sections: VFT-WIB construction method called „duo-WIB“ (a) and „mono-WIB“(b) and using welded sections (c+d); special types VFR-Rail (f) and external reinforcement in in-situ plate cross-section

2. Bridges with multiple girders in concrete web (Multi-WIB Construction)

2.1 Roadway bridges

2.1.1 Fly-over Pöcking (Ger) as part of Hindenburgstraße

The bridge owned by the village Pöcking leads Hindenburgstraße direction Possenhofen across railroad Munich – Mittenwald. The existing bridge with filler beam decks (WIB) was needed to rebuild after more than 100 years. The new bridge was to reach higher clear width by remaining the construction type because an uplifting of the bridge gradient was difficult to realize due to the confined spaces [16].

The frame construction composed of two single spans, each with a length of 16,60 m, was completed in 2003. It contains three VFT-WIB-beams with a width of 3,20 m and a construction height of 0,55 with are complemented with a 0,25 m thick in-situ concrete slab. The VFT-WIB-girders HEM1000 of quality S460ML were halved centric with the puzzle-cut-geometry PZ 420/80. The types of cut-geometries are explained in [7]. After cutting, the two identical halves are placed next to each other, flange to flange (Figure 3). To increase the robustness, the gap between the halved girders was filled with reinforced concrete. The composite dowels with PZ-geometry link into the flange of the prefabricated element (Figure 2). To install the beams during the four-hour night closure and to avoid the construction of centered cross girders, the prefabricated beams were constructed over both fields with a full length of 32,00 m (Figure 4).

The overall project amounted to 646.000 €, while 128.000 € was used for road works and 67.000 € for the stainless steel railings.

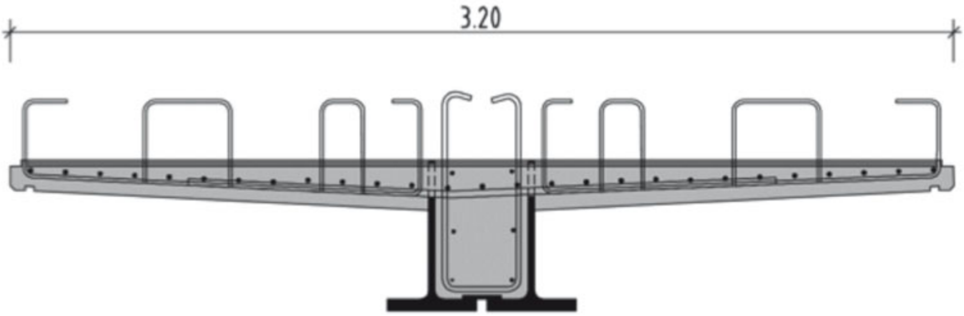

Figure 2: Cross-section of the Duo-WIB girder of the bridge located in Pöcking (Ger)

Figure 3: Cut (halved) rolled sections with PZ-geometry of the dowels and coating in the prefabrication plant

Figure 4: Bottom view with three VFT-WIB girders and spring plates at the middle support

2.1.2 Fly-over as part of road S7 (PL)

The largest projects with Duo-WIB-beams have been realized during 2009 and 2012 in Poland. The new four-lane road S7 that links Olsztynek to Nidzica and the bypass Olsztynek were advertised within a Design & Build award procedure. In this respect, 12 bridges were built in frame constructions with VFT-beams. At four roadway bridges and two wildlife-crossing-bridges with total surfaces of 3.400 m² the construction firm chose the VFT-WIB design with two filler beam decks per prefabricated element.

The roadways (MD-1 to MD-5, Figure 5) feature a separate superstructure per travel direction and are fabricated as continuous beams.

Table 1 summarizes the bridge information.

At all roadway bridges the prefabricated beams exhibit a height of 0,58 m and are complemented with an in-situ concrete slab of 0,25 m. The slenderness of the continuous beam is L/h = 22. Cross girders of concrete are located above the supports. Rolled girders of quality S355M are installed with steel profiles HEA, HEB and HEM1000, depending on applied loads.

The special fact in Poland is the prefabrication of the beams not in a factory building but on temporary installation fields next to bridge construction site. This reduces the transport costs and optimizes the lifting capacity. The beams are constructed parallel arranged on a ground-based formwork, so their position to each other is the same as in final position (Figure 6). Tolerances and inadvertent deformations are avoided consequently.

Table 1: Overview of road bridges out of VFT-WIB construction method in the course of S7 road

bridge	Span length [m]	width [m]	Crossing angle [gon]	Surface [m²]	quantity of VFT-WIB
MD 1	13,00+2x18,00+ 13,00 = 62,00	18,44 17,70	70 gon	810 / 780	6 / 6
MD 2	13,00+2x18,00+ 13,00 = 62,00	10,20	70 gon	430	4
MD 3	12,00+18,00+ 12,00 = 42,00	17,20 18,35	70 gon	720 / 770	6 / 6
MD 4	12,00+18,00+ 12,00 = 42,00	10,70	100 gon	470	4

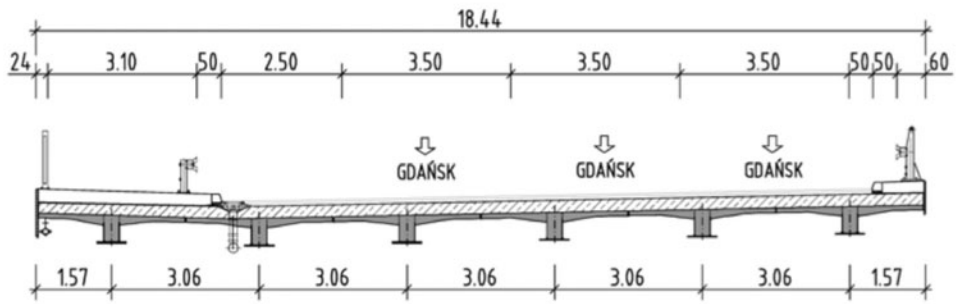

Figure 5: Carriageway to Gdansk (PL) of bridge MD-1 with 6 VFT-WIB girders in the cross-section

Figure 6: Fabrication area to cast the prefabricated elements next to the construction site

2.1.3 Roadway bridge WD-4 as part of federal road S5 crossing over rail line Chorzów Batory – Tczew (PL)

Bridge WD-4 is a special bridge. It leads federal road S5 between Stryszek and Białe Błota near Bydgoszcz with three separate superstructures across railway line 131 Chorzów Batory – Tczew and was constructed for GDDKiA, the Directorate-General for federal roads and highways, in 2009. The boundary conditions of 42 gon and slenderness of L/h = 34,66/0,85 = 42 were quite difficult. The original intension was to build a slab of in-situ concrete with internal reinforcement but due to the fluent traffic below the planned bridge this idea was hardly to realize. For that reason an alternative tender of a bridge using prefabricated elements awarded the contract.

The alternative tender contains a frame system with external reinforcement at the prefabricated elements. The bottom view of the bridge was defined as absolutely necessary by the client. Thus the prefabricated elements were designed with pulled-down flanges to meet the demands (Figure 7). The T-profiles integrate into the prefabricated element. Above the steel webs a compressed zone arises inside the concrete that bears the compressive forces resulting from self-weight of the beam and the concrete slab during construction state (Figure 8). The four prefabricated elements span only the area of railway line as they are easy and fast to install during night closure (Figure 9). The peripheral zones with haunches were casted on a formwork that was built next beside the railway line easily (Figure 10).

The construction stages are shown in Figure 11. Similar to VFT-design the whole frame corner including its haunch was casted in one step so the VFT-WIB-beams were connected to the substructure. After curing the deck slab in the field area of the bridge was casted.

The transition from the prefabricated beam to the haunch is adapted to the line of force. Therefore the external reinforcement is only installed in the sagging area of the bridge (Figure 12). The strong lower flange with a thickness of 30 mm and steel quality S355J2+N drains off (Figure 13). The web including composite dowels of MCL-geometry is embedded into the haunch and absorbs the shear force.

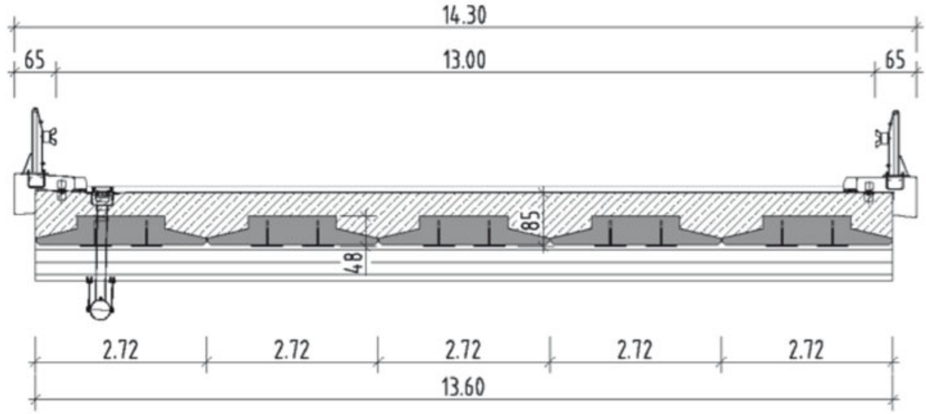

Figure 7: Cross-section of the frame bridge WD-4 with prefabricated elements

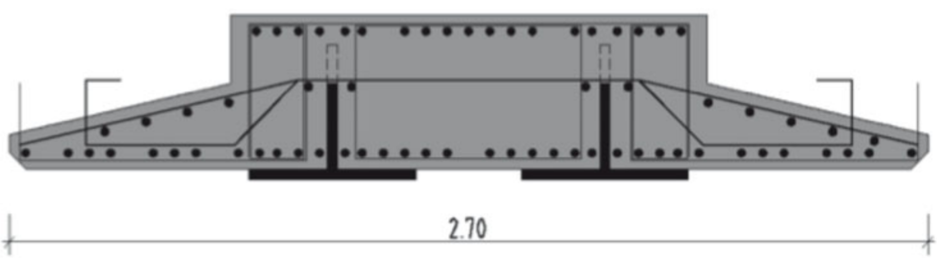

Figure 8: prefabricated element WD-4

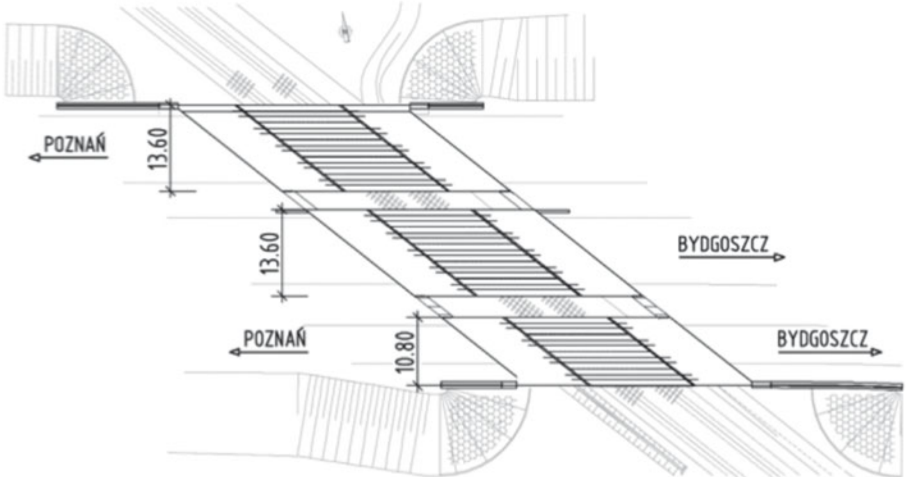

Figure 9: Bird view on the road viaduct WD-4 with an intersection angle of 42 gon

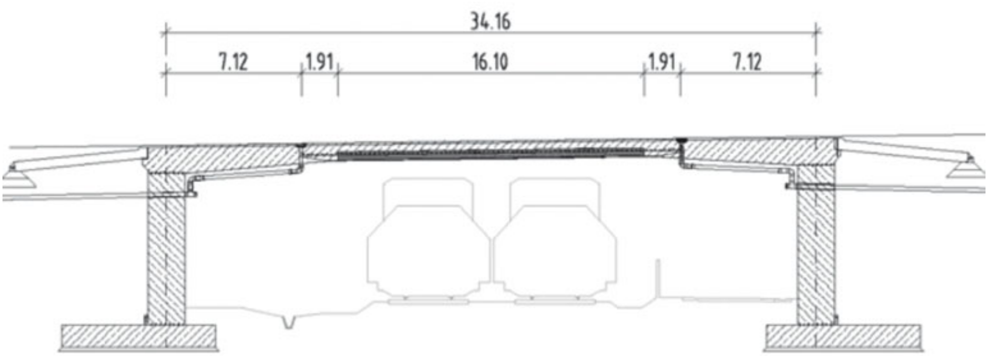

Figure 10: Longitudinal section of the road bridge WD-4 applying VFT-WIB elements in the area of the double tracked railway link

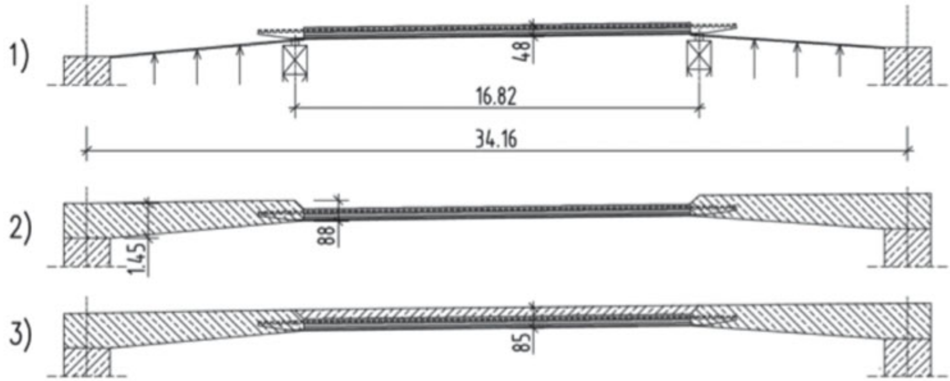

Figure 11: Construction stages of the bridge WD-4 (longitudinal section)

Figure 12: Bottom view on the external reinforcement of bridge WD-4 which adapts the force flow

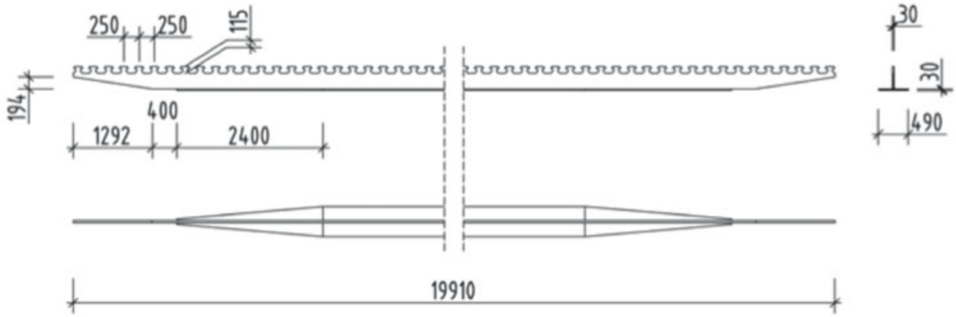

Figure 13: External reinforcement out of welded steel plates

3. Wildlife crossing bridge as part of Federal road S7 (PL)

Regarding the constructive details a more ambitious solution was applied for the wildlife crossing bridges over the federal road S7. In plan view, the wildlife crossing bridges PE-1 and PE-4 extend at their end spans from 40 m to nearly 60 m. Besides, the permanent loads at wildlife crossing bridges are much higher than permanent loads at roadway bridges that is because of the required minimum cover soil of 0,70 m.

The frame structures span over four fields with 17,00 + 2x22,00 + 17,00 = 78,00 m. The substructures are based on piles with Ø 1,00 m. Similar to the bridge in Pöcking (GER), Duo-WIB-beams are used. But haunches are hardly and inefficient to realize in the conventional method. To achieve a non-constant height of the web of the filler beam deck high expenditure is necessary. Due to the enormous slenderness and loads haunches would be advantageous under static aspects. In this case, the prefabricated beams were modified with a large pre-cambering to achieve a variable thickness of the concrete slab (Figure 14). The VFT-WIB-beams are 0,58 m high. The in-situ concrete slab varies between 0,25 m at the midspan and 0,62 m at the supports and abutments. The construction stages are shown in Figure 15 schematically. VFT-WIB-beams get installed, frame corner and cross girders reinforced and casted. Thereby, 1/3 of the end span length and 1/4 of the midspan length are connected to the in-situ concrete slab. The hardening needs 1 week and afterwards the complete deck slab gets concreted continuously. These construction stages have two advantages. The girders are loaded slightly as a result of the cross girders and frame corner concreted together with the lower part of the in-situ slab in advance. But for the following load case, that is the weight of the in-situ slab, an increased static height results. The bending moments are orientated to the supports and the midspan area gets balanced. The in-situ slab gets concreted jointless and covers the fracture pattern stemming from construction state at the supports. This reduces the fracture pattern of the deck slab thus it is comparable to the Pilgrim-step-method for composite bridges but is more material efficient due to the convenient static systems during construction state. Despite expansion of the bridge in plan view, the reinforcement is placed orthogonally. As a consequence to the variable angle of the steel girders the dowel-geometry varies to grab the orthogonal reinforcement in the recess. So the standard dowel-geometry was stretched constantly from the center to the exterior beams.

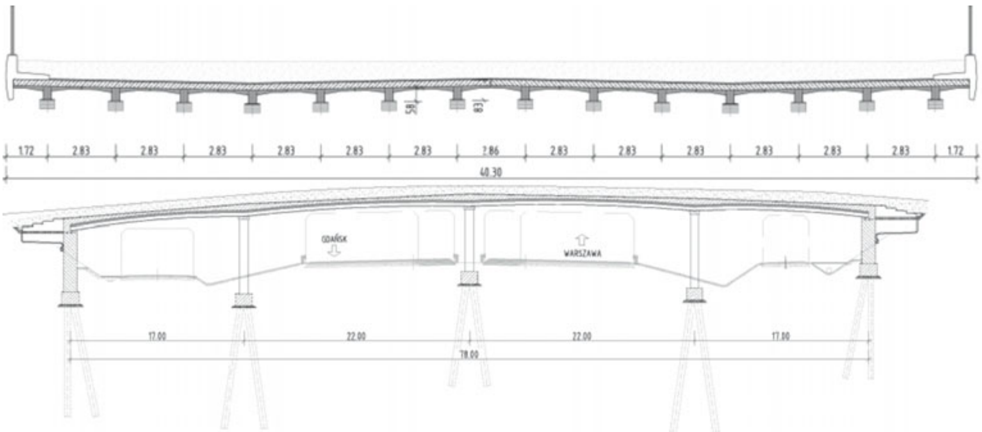

Figure 14: Midspan cross-section and longitudinal section of wildlife bridge PE-4

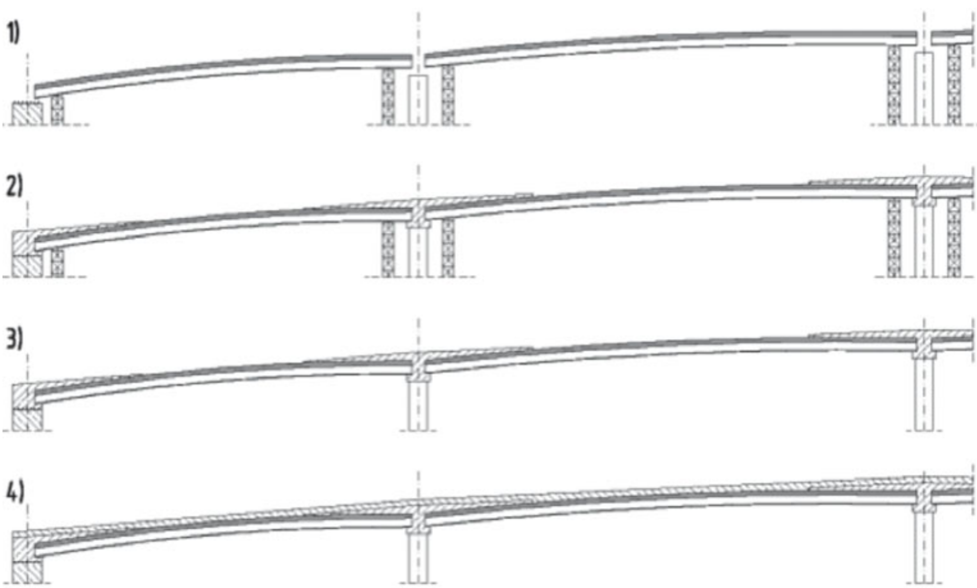

Figure 15: Schematic construction stages of the wildlife viaducts with precasted retaining walls

3.1 Railway bridges

3.1.1 Fly-over railway bridge over the Łososina River (PL)

The existing railway truss bridge at km 23,093 as part of double-track Kielce-Fosowskie over the Łososina River was refurbished to a bridge of composite prefabricated elements in the years 2009 to 2010 (Figure 16). The presented solution is a secondary concept using VTF-WIB-beams and has established itself against the conventional composite bridge. The superstructure features two single-span beams with the length of 16,50 m each. Per rail track a separate superstructure including sidewalks is foreseen. The cross-section exhibits two prefabricated composite girders having a lateral upstand acting as stop end for the in-situ concrete slab. The steel girders are defined as rolled profile HE1000x438 S460ML. They are integrated into a 0,30 **m thick ingate to heighten the construction to 1,00 m and to enable the** use of halved rolled profiles. The prefabricated elements are made of concrete C50/60, C40/50 was used for the in-situ slab.

The design-speed of the railway is 160 km/h for the classification k= +2 in accordance with Poland Directive PN-85/S-10030 [17]. The Load Class is nearly similar to the loads defined in German Standard DIN FB 101 [18] for the Load Model LM71 with classification factor α = 1,21.

For the design calculation of railway bridges the fatigue loads are playing a central role. As shear connector for the fly-over construction over the Łososina River, the modified clothoid-geometry MCL250/115 was used. The basis for the use of this geometry was developed within the European Commission's research project Preco-Beam [8] and was expanded consequently to studies of "Research Institute for Roads and Bridges" (IBDiM) ([19], [20]). Decisive for the design calculation are the structural stresses in the composite dowel because the girders are constructed without any additional welded sheet plate (Figure 17). The construction works were executed within three month.

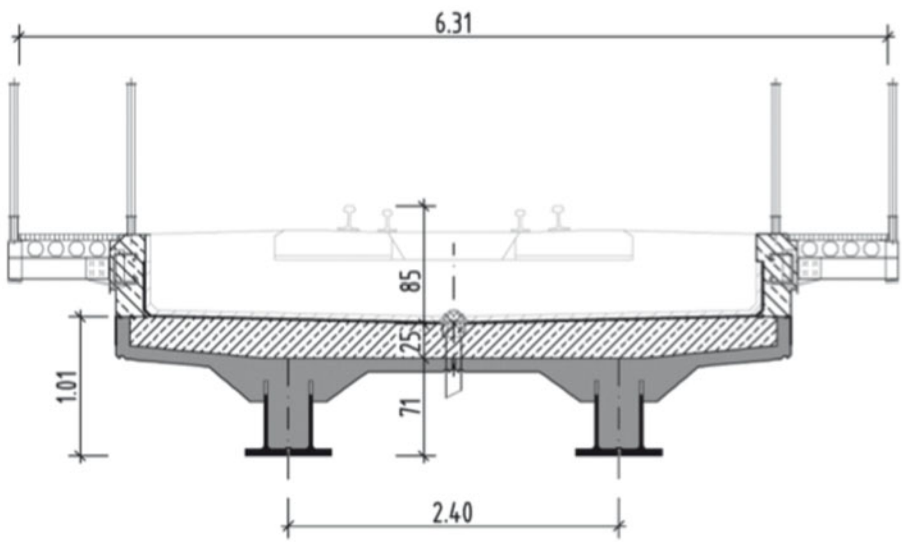

Figure 16: Cross-section of the single-track bridge over the Łososina River (PL)

Figure 17: Bottom view on the railway bridge Łososina

3.1.2 Railway bridge in Tczew (PL)

The second railway bridge in Tczew was built on the basis of earned experience from Łososina bridge as an integral construction. Due to the inner-city location a compact construction height was claimed. The frame construction leads two rail tracks over a three- lane road with span length 17,00 m + 10,50 m and full length 27,50 m and is founded on bored piles Ø 0,80 m (Figure 18). The cross-section is geometrically identic to Łososina bridge except that no rolled profiles but welded steel girders of same dimensions and quality S355K2+N were used.

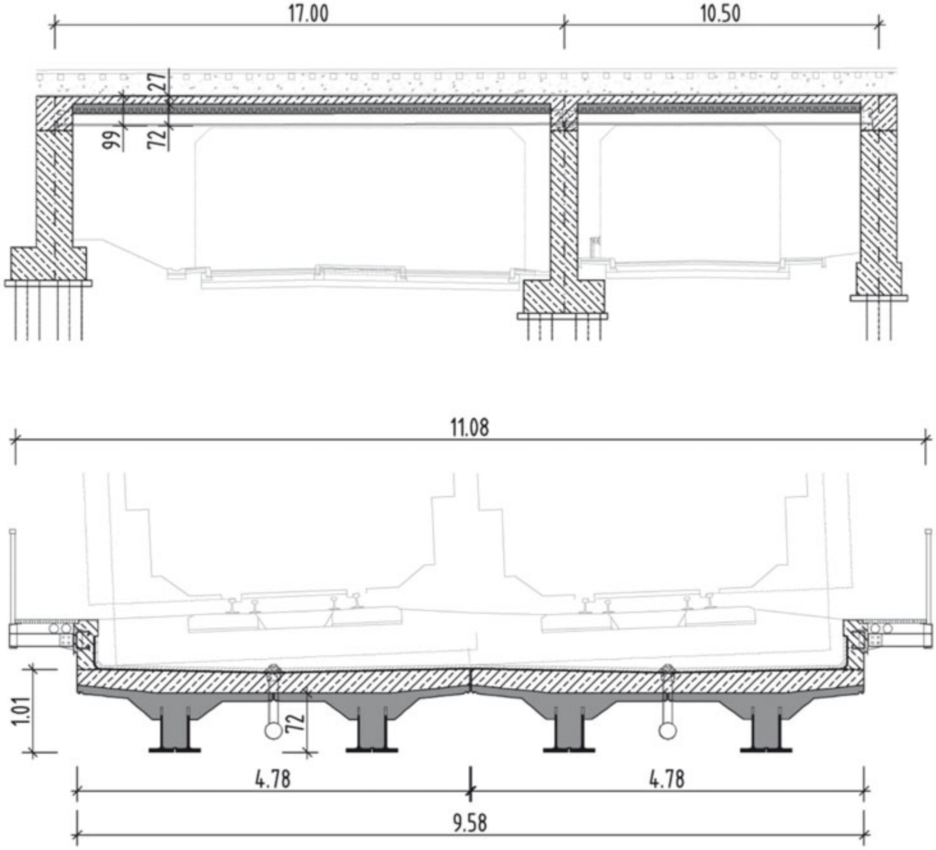

Figure 18: Longitudinal section and cross-section of the railway viaduct next to Tczew (PL) built as frame bridge implementing VFT-WIB girders

3.1.3 Railway bridge in Spergau (GER)

The railway bridge in Spergau (GER) was built for the operator InfraLeuna and exists of a frame with external reinforcement in longitudinal direction and a concrete slab with external reinforcement in transverse direction (Figure 19).

The span length of the frame is 13,00 m. The external reinforcement is located at the top and bottom side of the trough girders. The upper lamellas extend from the abutment axis to the bridge wings und cover the frame corner. The lower lamellas transmit the compression over the headed plate into the abutment. The loads acting the deck slab are lead via external reinforcement into the trough girders. The external reinforcement consists of halved rolled profiles HP305x95 quality S355 J2 and is placed every 0,50 m in transversal direction. The shear force transmission to the trough girders of these profiles is ensured by internal reinforcement and not by construction steel. The advantage of this solution is the avoidance of welding and screwing works. The trough girders were concreted under a 90° rotated position, erected after curing and the deck slab was concreted subsequently. The superstructure was lifted, connected to the substructure and shifted laterally to the end position during a weekend closure of the railway afterwards.

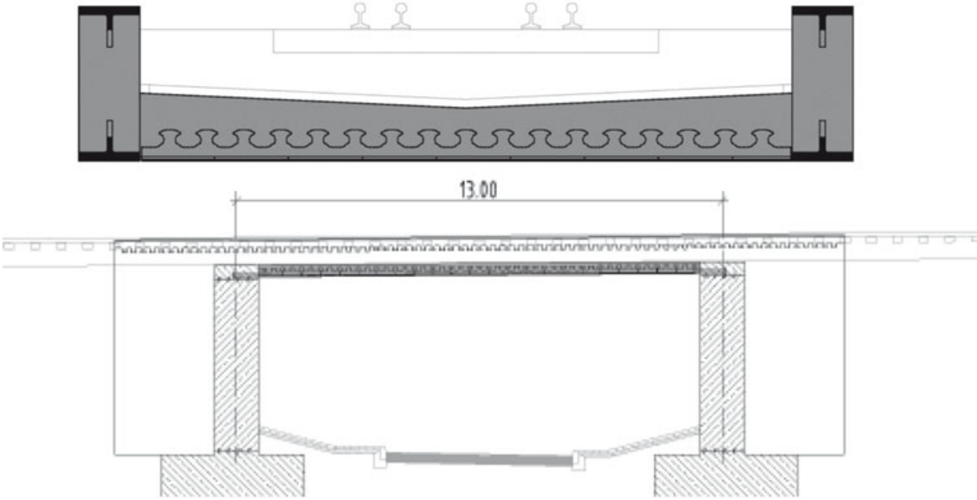

Figure 19: Cross-section and longitudinal section of the frame bridge located next to Spergau (GER) with external reinforcement applied in the trough girders and in the transversal direction of the slab

4. Bridges as Mono-WIB-Construction

The Mono-WIB-Construction is used for larger spans or frame systems requiring haunches. Besides, this construction type is the most economical option. The requirement of steel is reduced to a low level and the prefabrication in factory is easy to realize.

The range of use for frame systems with enormous slenderness has become apparent for span length from 25 to 35 m. A slim and haunched prefabricated pre-stressed girder is hard to design because the course of the pre-stress tendons have to be calculated for the huge negative bending moments in the frame system, have to provide sufficient resistance to lift it out of the formwork and have to be designed for state during construction [21]. This development will be clarified by means of the following application examples.

4.1 Road bridges over ÖBB Railway Link Salzburg – Wörgl near Vigaun and Kuchl (A)

The first Mono-WIB-bridge was built in 2008 and leads a residential road near Vigaun over the ÖBB track Salzburg – Wörgl at km 23,135. It was built as a frame over three fields with 3 x 26,15 = 78,45 m span length and a superstructure including two girders at the cross-section [22]. The consumption of 85 kg/m² construction steel, quality S460ML, was quite economical. Because of the low clear costs of 1030 € per m² bridge surface, 2010 the neighbouring bridge at Kuchel at km 23,993 was tendered in the same construction type. Contrary to Vigaun bridge, a haunched frame including four fields with full span length of 19,50 + 2 x 19,7 + 19,5 = 78,40 m and deep foundation was constructed (Figure 20). The width of the abutment´s wings are minimized through a slope protection.

The superstructure carries two lanes each 3,00 m and three VFT-WIB-beams with non-constant heights from 0,60 m at the midspans and 0,90 m at the abutments and supports. The height of the in-situ slab is 0,25 m (Figure 21). Similar to Vigaun Bridge, concrete hinges are located above the supports. The beams contain rolled profiles HD400x421 of steel quality S355ML. In the midspan area, where positive bending moments and low vertical shear and consequently low shear flow at the composite joint appear, the cross-section is designed with an offset between the concrete web and the steel flange (Figure 22 and Figure 23). At the support the concrete web reaches the steel flange so the concrete takes part in digging the axial compression as the external reinforcement is doing. Through the angular compression trajectories at the supports, the joint between concrete web and steel flange is getting over-compressed. The shear capacity of the composite dowel strip can be increased through additional stir-up reinforcement where high shear forces appear.

The cost for the bridge per m² was 1485 €. The reason for the higher costs compared to Vigaun bridge is the deep foundation, one additional column and the consideration of special load model LM3 as per ÖNORM 1991-2 including nine axes each 200 KN every 1,50 m [23].

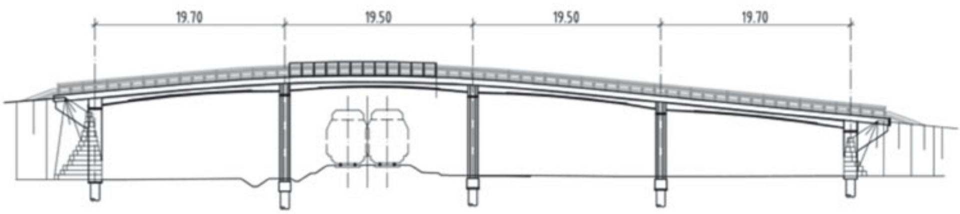

Figure 20: Road viaduct located next to Kuchl (A), general view

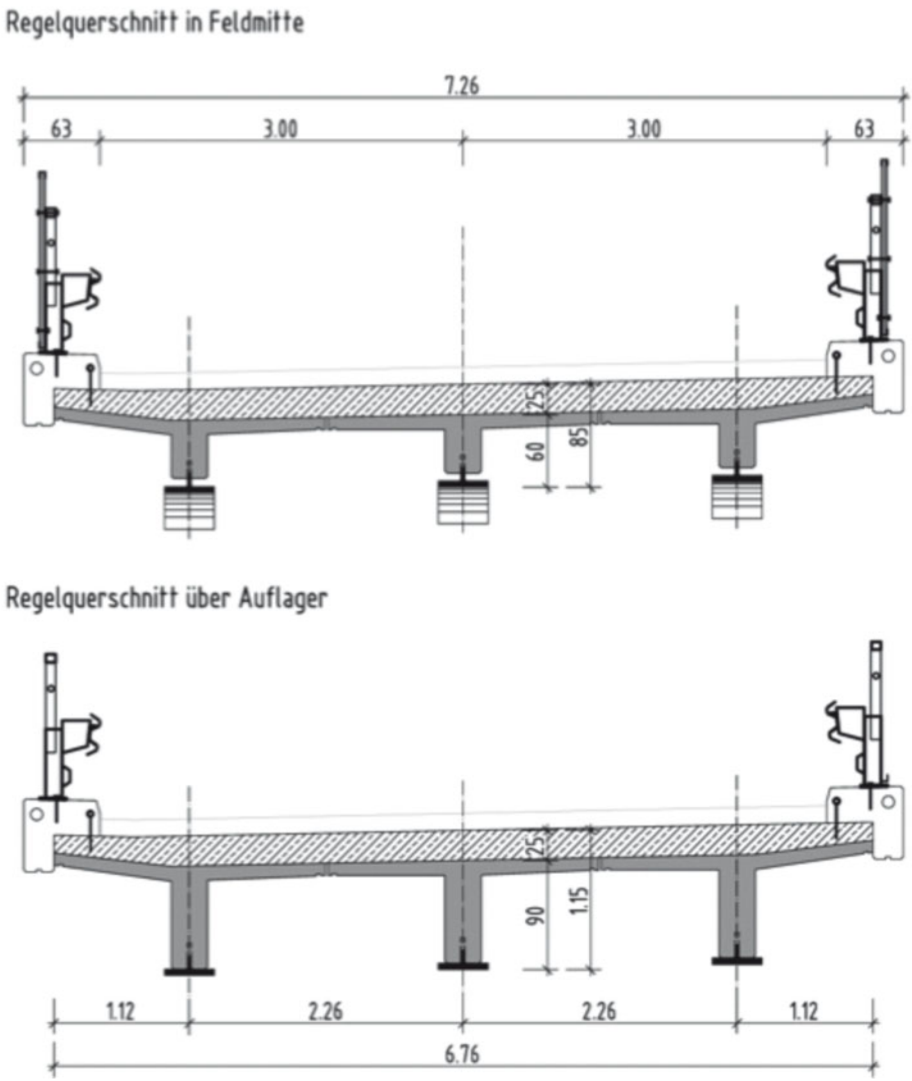

Figure 21: Cross-sections of Kuchl (A) bridge at midspan and support

Figure 22: View on Kuchl viaduct (A)

Figure 23: Bottom view on the VFT-WIB girders at Kuchl bridge (A)

4.2 Linking the ice pavilion over the Wilde Saale in Halle (GER)

The bridge over the Saale towards the ice pavilion located in Halle (GER) shows the ideal operating conditions for the VFT-WIB-construction. The span length of 23,50 m lies between 20 m and 30 m and the clearance of one sinuosity of Saale River requires a very slander construction (Figure 24and Figure 25). The slenderness of L/h = 23,50/0,85 = 27,60 at the midspans and 23,50/1,00 = 23,50 at the abutments is too ambitious to apply prefabricated pre-stressed girders. VFT-girders would be much more expensive comparatively. The bridge construction will be finalized in August 2013 and was awarded for 1570 € per m² bridge surface. The steel costs for the external reinforcement is 1200 € per metric ton. The price for a VFT-construction with welded girders would be one-and-a-half or even double higher. The self-weight of the 1,90 m wide VFT-WIB-girder is 30 metric tons and is easy to handle on site.

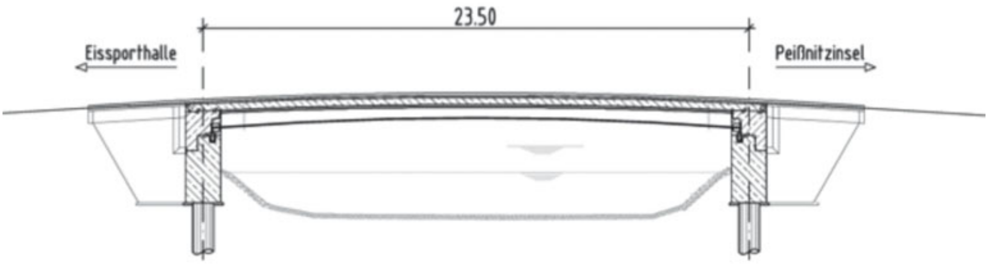

Figure 24: Longitudinal section of bridge over the Wilde Saale (Sinuosity of Saale river) located in Halle (GER)

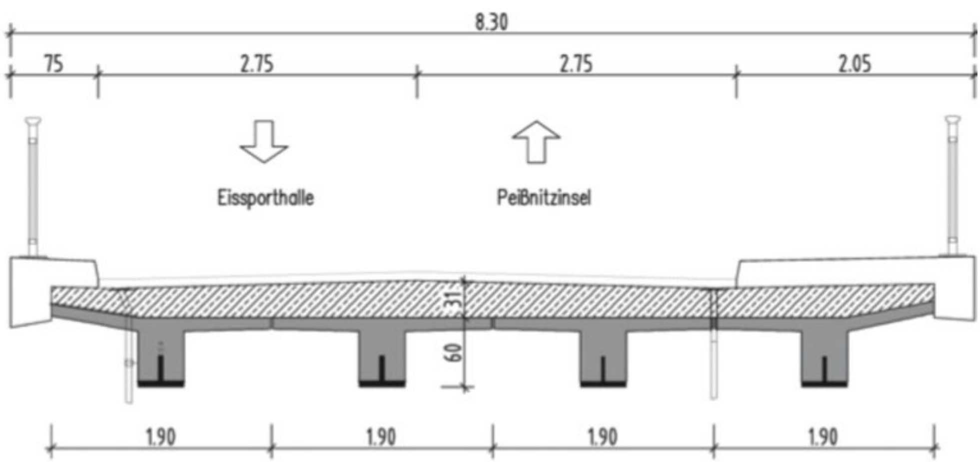

Figure 25: Cross-section at midspan of bridge in Halle with 4 VFT-WIB girders

5. VFT-bridges including composite dowel strips

5.1 VFT-bridges as frame construction

Romania is passing corridor IX, VII and IX, lots of European neighbouring countries are showing high interest in the IVth pan-European corridor that links Western Europe to the Black sea. One example for the Design & Build procedure is represented by the project "Planning and building execution of highway Orăștie-Sibiu, contract section 1" that is part of the pan-European corridor IX and passes through Romania from Nădlac to Constanţa and is separated into four contract sections each length from 16 km to 24 km. The section from Nădlac to Sibiu is located in the south of the Transylvania Basin, a quarry that lies in the northern area of the Southern Carpathians. Contract section 1 crosses Hunedoara and Alba, has a length of 24,10 km and offers 27 bridges: eight highway bridges, four of them crossing over water and four crossing over valleys, 12 railway bridges and seven additional viaducts to cross roads.

Accordingly to the tender the bridges shall be constructed for a 120-year service lifetime. All bridges within this section are designed as integral constructions. Single exception is the 240 m long highway bridge that is designed as a semi-integral construction having supports at the abutments. Over the last three years, VFT- and VFT-WIB-bridges have been applied in Romania. Generally, for bridges with length up to 35 m the use of prefabricated pre-stressed girder is the standard. For larger spans, the use of steel-composite-construction is preferred because the costs for the handling of the prefabricated elements, that means transportation and installation on site, are high relevant factors. So the decision was to build oblique bridges in prefabricated composite girders. An important simplification for the production of the steel girders is to realize the shear connection between steel girder and slab with composite dowel strips and not with headed studs. So the upper flange of the steel girder as element to fix the headed studs is not required (Figure 26).

Bridge P11 at km 0+073 leads the district road DJ 705 with a span length of 39 m to realize a clear width of 35 m in traffic direction. P11 intersects the highway in an angle of 79 gon, is based on piles **Ø 1**,20 **m and features a haunched** frame with short wings because the backfill is supported by re-anchored gabions (Figure 27 – Figure 29). The information of bridges P1 and P11 are summarized in *Table 2*.

The four T-shaped steel girders of quality S355J2G3 at the cross-section have a height of 1,20 m to 1,50 m, are getting fabricated in a factory and are complemented with a 0,15 m thick prefabricated slab of concrete C45/55. At the midspan the composite dowel strip weaves into the prefabricated element. At the end area, on a length of 6,00 m, an upper flange having two composite dowel strips at its outer edges is installed (Figure 30). The sheet plates are produced in common with the cutting of the composite dowel strip and are bent upwards in a following step.

The transition area from one to two dowels strips is shown in Figure 31. The prefabricated element acts as a compression zone and horizontal stiffening at the state of construction and as formwork for the in-situ slab. To ensure the shearing transferability, the composite dowel strip is cased with two reinforcement bars at the dowel base and two bars are going through the steel dowel (Figure 32). For both bridges, the requirement for the construction steel is around 130 kg/m². The prefabricated elements are casted on a formwork for all of the five girders on site (Figure 33) because transportation of the long girders would be complicated due to the narrow service road. The slab with a height of 0,20 m to 0,30 m is constructed with a roof pitch. The area of the slab near to the abutments is concreted with the frame corners simultaneously, the midspan area only after curing of the frame corners. Both bridges after finishing are shown in Figure 34.

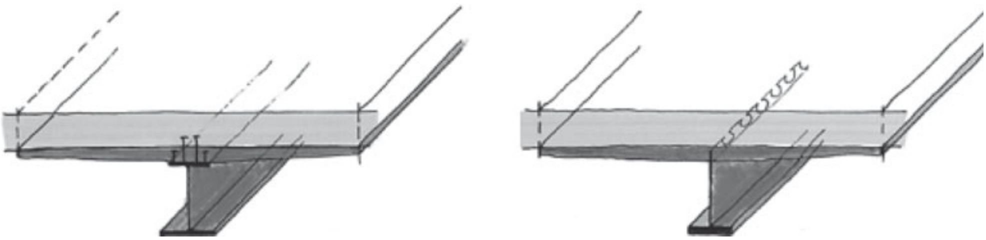

Figure 26: Conventional VFT girder using headed studs on the upper flange (left had side) and precasted composite girder implementing the composite dowels

Table 2: Information of bridges P1 and P11

Bridge	P11	P1
Span at the angle	39,04 m	38,80 m
Clear span width	35,00 m	35,00 m
Crossing angle	78 gon	87 gon
Width between railings	11,40 m	11,40 m
Construction height	1,60 – 1,90 m	1,60 – 1,90 m
Slenderness	20,5 – 24,4	20,4 – 24,2

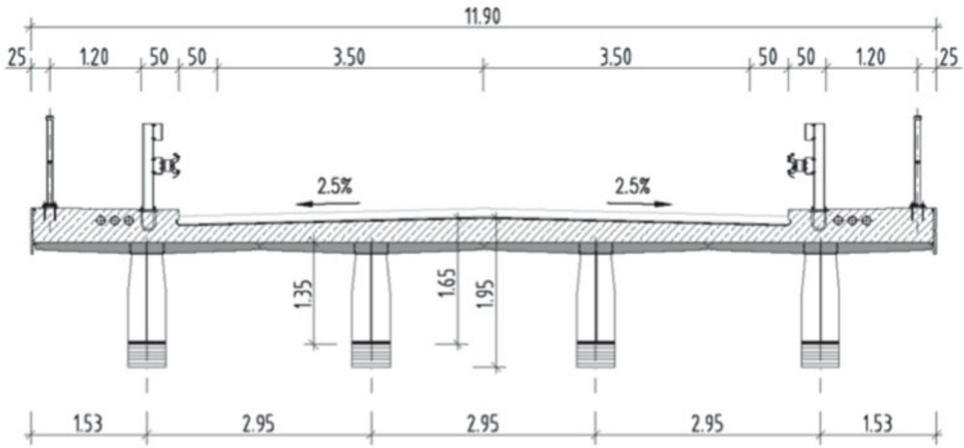

Figure 27: Figure 27: Standard cross-section P11 bridge

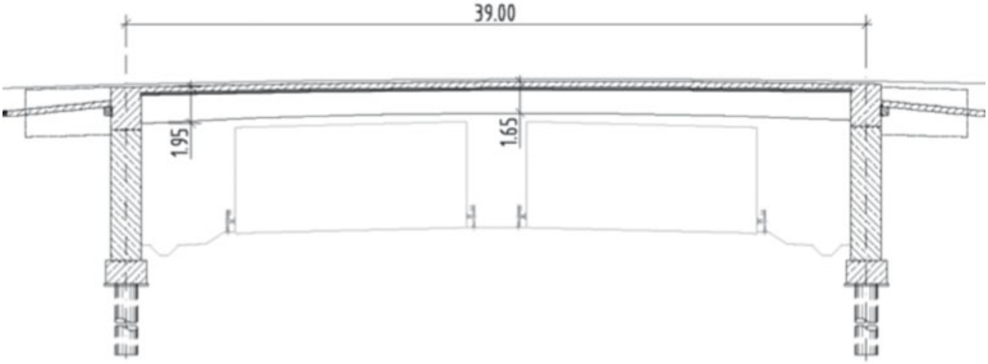

Figure 28: Figure 28: Longitudinal section of P11 bridge

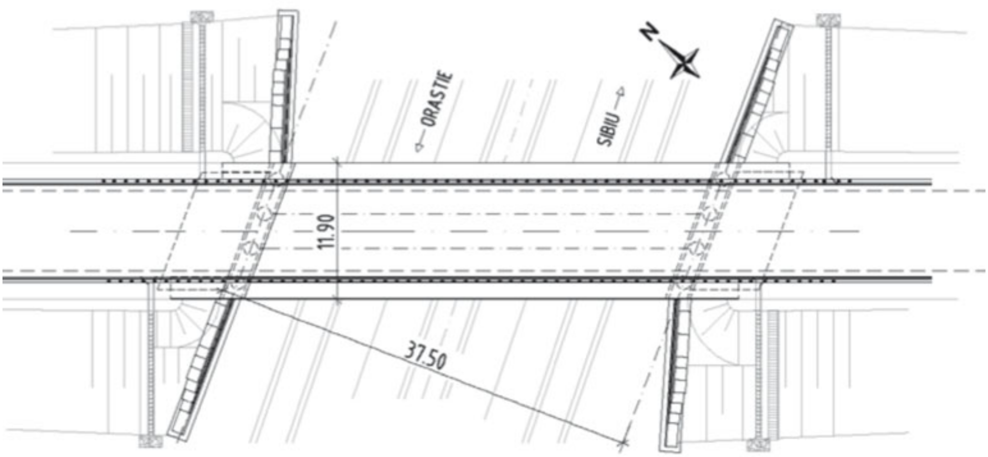

Figure 29: Figure 29: Plan view of P11 bridge

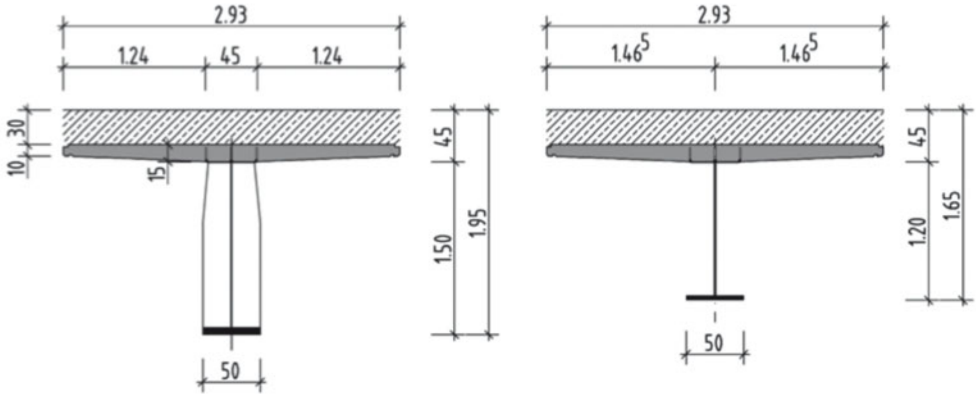

Figure 30: Figure 30: Cross-sections of VFT-girders: Cross-section at support (left-hand side) and at midspan (right-hand side)

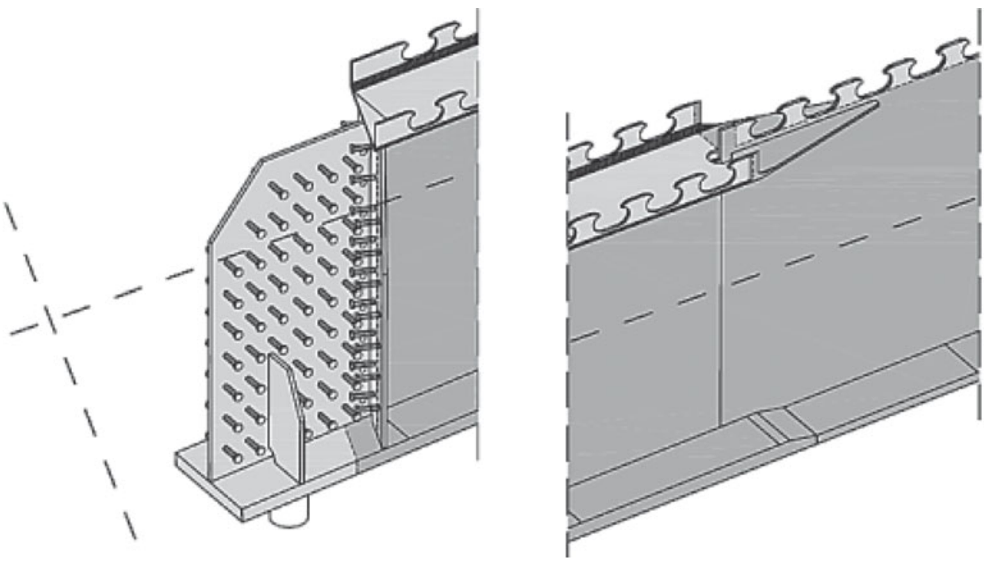

Figure 31: Figure 31: 3-d sketch of the transition area of the one composite dowel strip into two strips at the support region

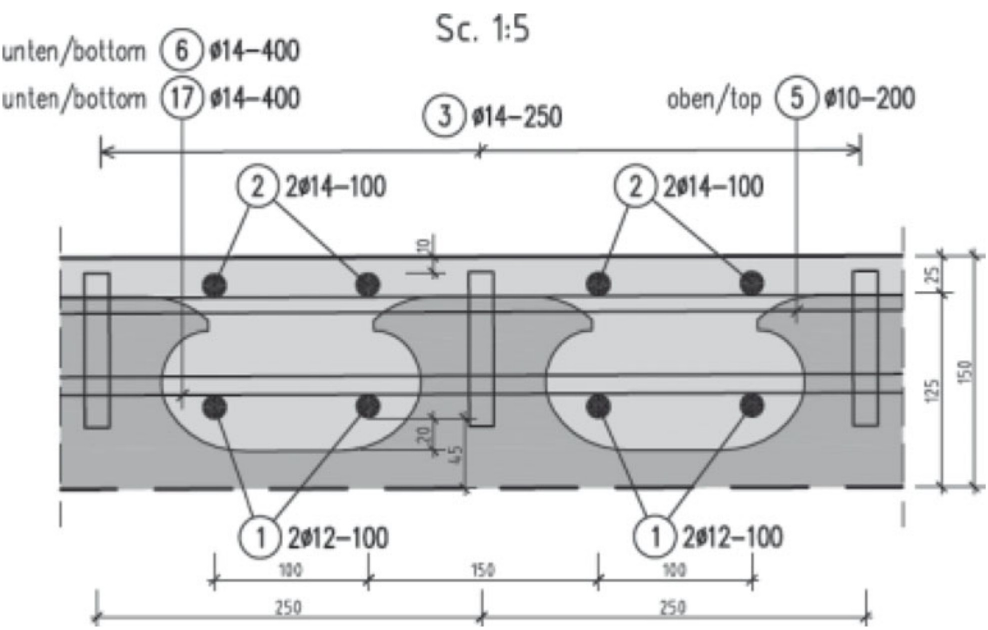

Figure 32: Figure 32: Reinforcement of composite dowel strip

Figure 33: Figure 33 Steel girders on site

← (a)

(b)
↓

Figure 34: View on structure P01 (a) and P11 (b)

5.2 Bridge over the Ursulau River in Saalfelden (A)

The bridge in Saalfelden plays a center role for composite dowel strips. The Ursulau River is highly vulnerable by flood and for that reason a clear bottom view is required by the water authority to ensure the flood discharge. The client had designed the composite slab with a steel box of slenderness 26.

The steel box has 16 cells, each 0,35 m height, and is supplemented with a 0,35 m thick in-situ slab (Figure 35). In course of the tendering the concept for the shear transferability was changed from headed studs to composite dowel strips. The webs of the steel box cells feature a composite dowel strip with MCL-geometry on their upper ends. A cover plate leads the webs into the in-situ slab. The frame is based on piles Ø 1,20 m, the span length is 18,15 m and is orientated with an angle of 78 gon (Figure 36). The steel box exists of 20 mm thick bottom and top plates, the thickness of the steel webs is 15 mm.

The steel plate was prefabricated in a factory as one element and was transported to the neighboured construction site to place it on the abutment (Figure 37). The connection between frame corners and in-situ slab was realized through a simultaneous concreting.

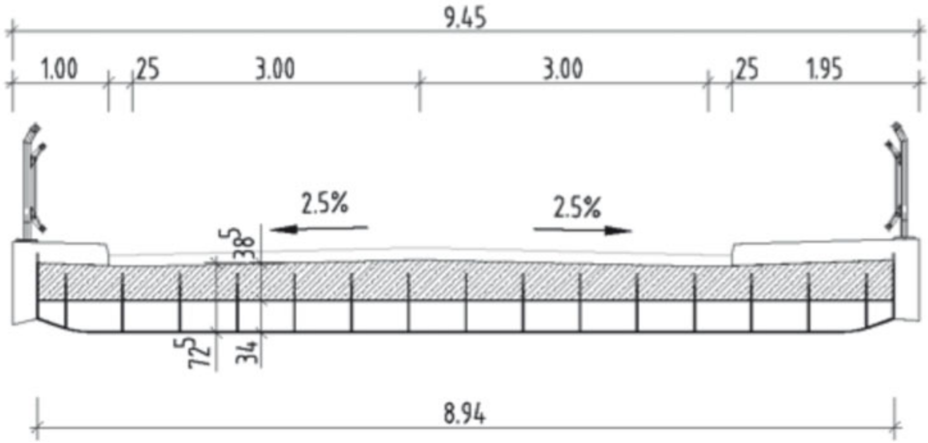

Figure 35: Cross-section of Ringlerbrücke over the river Ursulau located in Saalfelden (A)

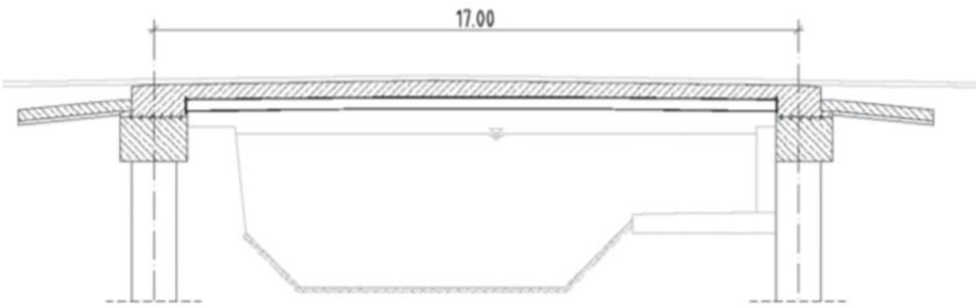

Figure 36: Longitudinal section of Ringlerbrücke Saalfelden (A)

Figure 37: Placing of the steel multi-box girder at the construction site

6. Summary

Composite dowel strips offer new types of cross-sections that are using the strengths of the current materials in an ideal way. The wide variety of use is explained by means of practical examples. Even though the bridges in different country have different signatures regarding their constructive details, the solutions for the static systems are consequent and show economic solutions that have been proved on the market.

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