SMALL BRIDGES UP TO 32,5 M SPAN IN UHPC-CONSTRUCTION – BRIDGE SYSTEMS WITH AESTHETIC REQUIREMENTS

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SUMMARY

Due to its durability and resource-conserving use, the UHPC building material is the ideal prerequisite for infrastructure construction. Due to the high degree of pre-fabrication, system bridges with spans of up to 35 m can be realized. The focus is on construction-specific design and the aesthetic shape language. In cooperation with the SDO ZT GmbH and the concrete precast elements manufacturer Franz Oberndorfer GmbH & CO KG, the bridge system construction is to be developed and implemented in three stages. The described system design attempts to make the enormous advantages of the material UHPC noticeable to the observer through material-compatible design. This development work is to contribute positively to the image of this new building material and to further applications.

1. GENERAL

Bridge systems, which are currently offered on the market by various manufacturers, are offered in the materials steel, aluminum and wood. Fig. 1 shows various bridge systems customary on the market. In addition to the material, the truss-like building block system represents the primary characteristic of these bridges.

Fig.1: On the market available bridge systems with steel and aluminium

The present paper deals with the project idea, with the specifics in the prefabrication of the components, with the examples already carried out. It deals with system bridge development with ultra-high performance concrete (UHPC) and the special properties derived from the material in terms of material efficiency and durability. The idea and approach of this type of bridge has arisen through the implementation of an interesting solution of a UHPC-shell bridge [2] in Carinthia (Austria). Starting from this implementation, which essentially corresponds to the UHPC 325 type, simplifications were made in the manufacture and assembly, and a system bridge series UHPC 125, UHPC 225 and UHPC 325 were developed, whereby the combination of numbers always had the maximum achievable span Lsp (12.5 m, 22.5 m and 32.5 m) of this bridge type (Fig. 2 and 3). As the span widens, the type of prestressing and the geometrical stiffness are changed, resulting in high-slender and elegant designs. The bridge form is always an open bridge solution with 15 ° inclination of the UHPC-walls to the outside and on the other hand has the advantage that there are small heights of the constructions, on the other hand, the construction can be experienced by the user on the bridge and thus the performance of this material becomes noticeable. This first advantage also leads to the fact that due to the low constructional heights, no ramps on the abutments are required. Furthermore, the trough shape offers the advantage that the railing construction is an integral part of the load-bearing structure and is used for design purposes. In the case of the UHPC 325, the high slenderness can only be achieved by utilizing geometric stiffnesses from the shell-bearing effect. The system design allows modular construction with almost the same formwork geometry. This provides the prerequisite for mass production and competitiveness against conventional bridge systems. The static mode of operation is based on the principle of an arch-tie-model (Fig. 3) and can be ideally implemented by flat UHPC-boards in ideal combination with prestressing cables.

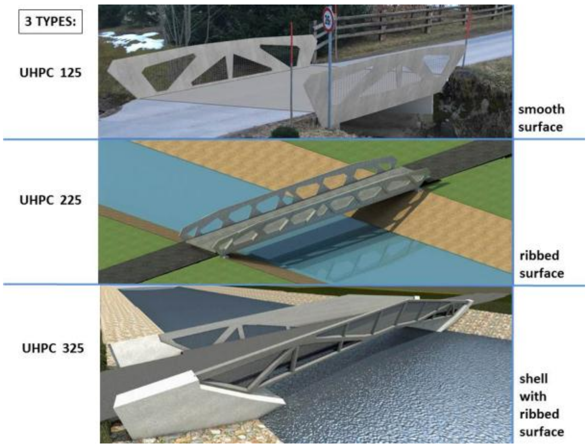

Fig.2: UHPC bridge system series open bridges (trough shaped) with variable spans

The UHPC system bridges are characterized by the fact that they are integral bridge systems without bearings and transition structures, which avoids expensive maintenance parts. The increasing span leads to static measures of the UHPC-walls, which are reflected in the different shapes and assemblies. The type UHPC 125, which is designed up to a span of 12.5 m, has a plane-parallel surface (without ribs) with a thickness of 50 mm. The low wall thicknesses are possible due to the favorable load-bearing capacity as an arch-tie-model. The openings are arranged in such a way that the printing sheet (see Fig. 3 in green) can be formed with slenderness ratio L / H = 4 to 8. Only in the case of a span of more than 12.5 m, in the UHPC 225 type, ribs with a thickness of 100 mm arranged on the outer side of the UHPC walls are required, resulting in a total thickness of 150 mm. The rib arrangement follows the strut arrangement of a truss. The slenderness ratio of the truss are for this type L/H = 7 -13. The arrangement of the bearing nose is identical to all three types on the inside of the UHPC-walls, which has a thickness of 100 mm and has a height of 300 mm for UHPC 125, and a height of 400 mm for UHPC 225 and UHPC 325. The roadway slaps (decking see subchapter 2.2 and 2.3) are placed on the inside of the bearing nose acting as support platform.

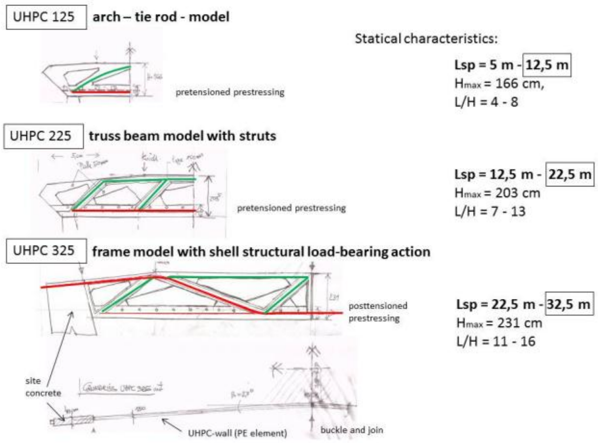

Fig. 3: Statical mode of functioning and exterior logic of the bridge system types

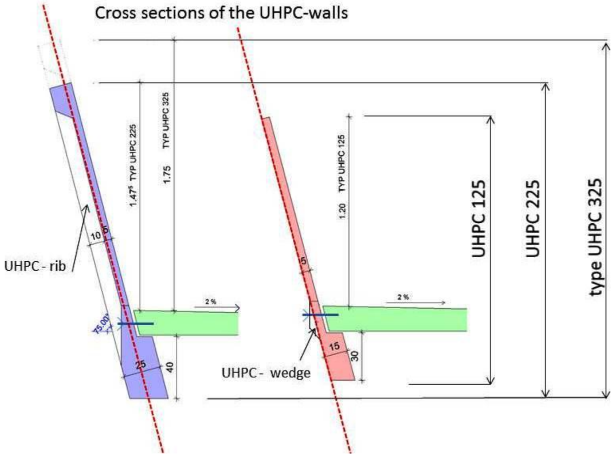

Fig. 4: Development of the cross sections per type

The ribs with a thickness of 100 mm arranged on the outside are executed with UHPC 225 and UHPC 325, the rib on the bottom flange of the UHPC-walls forming a fusion of the rib arranged on the outside and the bearing nose as base on the inside. The plane-parallel overall thickness of the bottom flange for these two types is 250 mm and is used for the accommodation of the strands in the immediate bond (UHPC 225) or for the insertion of sheaths for the post-bond (UHPC 325). In the case of UHPC 325, the arrangement of the outer-side ribs corresponds to the static requirement of a frame support. The frame leg is made of a slap with in-situ concrete (d = 40 cm, see subchapter 3.1.) with a positive pitch, which is also used as a prestressing block for the load introduction of the pretension forces during assembly. The UHPC 325 consists of two UHPC-wall elements per longitudinal side which are subsequently joined together on the construction site by pretensioning over wet joints and successfully applied at the Paulifurt bridge [2]. The buckle arranged in the plan view in the axis of symmetry with an angle of β = 2.7° leads to the positive mode of action of a space shell of the beam of frame. This ensures the buckling stability of the UHPC-walls. The slenderness ratios of the UHPC 325walls are L / H = 11-16.

2. ELEMENTS OF THE BRIDGE SYSTEMS

In the following text the individual components of the system bridges, which are essentially repeated for all three types, are described. Chapter 3 discusses some special features of the UHPC 325 type. These are due to the changed static mode of operation and the multipart as well as for the UHPC walls and for the abutment situation.

2.1 UHPC-walls

As can be seen in Fig. 4, differences in the cross section between UHPC 125, UHPC 225 and UHPC 325 result in that the two at least mentioned types have additional reinforcing ribs arranged on the outer side according to the static requirement in the longitudinal direction (see fig. 3). The cubatures per meter ([m³/lm] per profile) are for UHPC 125 i.M. 0.08 m³/lm, for UHPC 225 i.M. 0.16 m³/lm and for UHPC 325 i.M. 0.19 m³/lm. The material of the UHPC-walls is chosen for all types with C 130/155, whereby the fiber lengths should be lf = 12 or 16 mm, respectively, in order to ensure post-fracture resistance of σcf,d = 10 to 14 N/mm². The elements are only provided there with reinforcement, where tensile forces from lifting forces occur.

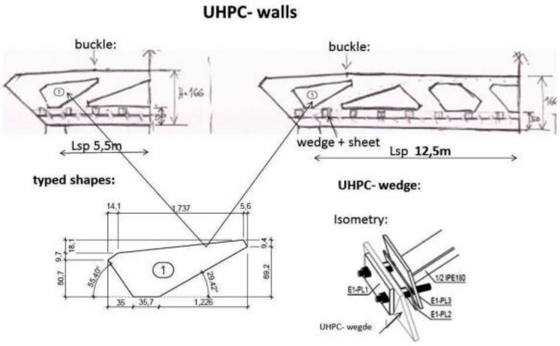

Fig. 5: UHPC-wall elements

The UHPC walls have a thickness of 50 mm outside the ribs and are provided with corresponding openings through the load flow. These opening geometries duplicate within one type, so that with a small number of typed shapes for frameworks, the opening is found and can be accommodated flexibly into the formwork geometry for different bridge lengths Lw. The UHPC-elements are concreted in the vertical position, whereby the outer and inner surfaces have a smooth structure. Plan-parallel vertical formwork edges with distances of 150 mm (UHPC 125) and 250 mm (UHPC 225 and UHPC 325) allow simple manufacture in the factory. For the UHPC 125, specially shaped UHPC wedges are required due to the 15° inclined and smooth outer surfaces in the installed state for the attachment of the roadway elements (decking). This permits a horizontal arrangement of the screw position. The total number of UHPC-wedges or the built in parts for the mounting of the roadway boards results in a road width of b = 3.5 m with n = 1.4 pcs per m² of bridge area. For UHPC 225 and UHPC 325 types, UHPC- wedges are not required due to the vertical rib geometry in the region of the screws.

2.2 Decking elements

The roadway panels (Fig. 6) are full precast element parts with system widths of b = 2.40 m and are mounted on the system depentend supporting nose of the UHPC-walls. The roadway panels are bolted to the UHPC-walls, with the screwing joint at a distance of e = 80cm. The road surface is with a roof-shaped drainage axis extending in the road axis, the plate thickness being in the roadway axis d = 12 cm and at the edges d = 16 cm. The quality of the concrete of the elements is C50/60. In order to ensure a steel connection, a ½ IPE 180 carrier is potted into the precast panel and is closed at both ends by a flange plate with welded threat nut.

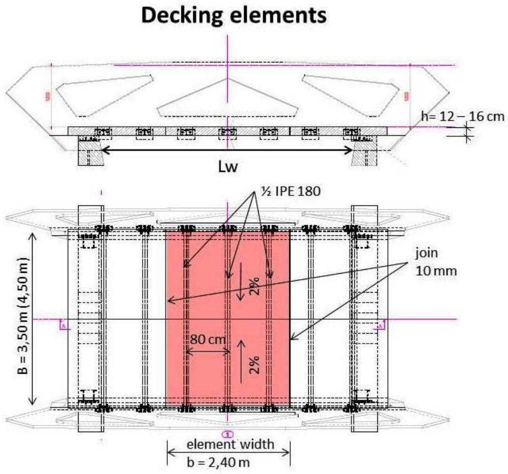

Fig. 6: Decking elements with HPC

In addition to the bridge length Lw (Fig. 6), the angle of intersection α between the abutment axis and the bridge axis can also be arbitrarily adapted. The angular adjustment is geometrically accomplished by longitudinally displacing a UHPC-wall side along the longitudinal axis of the bridge and leads to parallelogram-shaped roadway plate geometries. The axial dimension e = 80 cm of the bolted connection of the pavement panels with the UHPC-walls is maintained with an oblique-angled arrangement.

2.3 Abutment beam

The abutment beam (Fig. 7) is produced as a trapezoidal cross section with air inclination with concrete HPC 50/60. The task of the abutment beam consists, on the one hand, of establishing a rigid connection with the substructure, on the other hand, by means of specially provided built in parts, to ensure the stabilization of the UHPC-walls in the assembly process. For fixing the abutment beam with the substructure, sheaths for the grouting of steel mandrels ∅ 30 mm are provided.

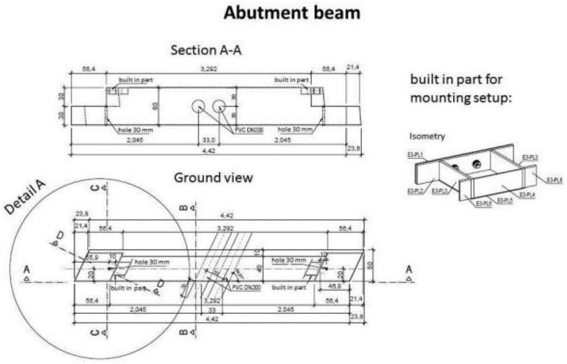

Fig. 7: Geometry of the abutment beam for a skew bridge

3. SPECIFICS ON UHPC 325 AND THE TRANSFER TO UHPC-SHELL CONSTRUCTION

3.1 Frame leg with in-situ concrete

Due to the static design of a frame construction and the two-part design of the UHPC-walls, (Fig. 8) the side abutment walls, which have a positive pitch, are made with in-situ concrete. In contrast to the other two embodiments, the prestressing is selected with a subsequent bond (posttensioned prestressing). This makes it possible to manufacture the UHPC-walls as two-part elements and to interlock them on site. The required prestressing force to absorb the frame moment is introduced into the UHPC-precast elements via the frame leg with in-situ concrete, thus enabling the controlled load introduction.

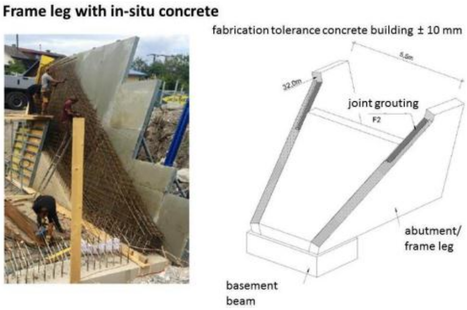

Fig. 8: Fabrication and design of the frame leg with in-situ concrete

The positive inclination of the frame leg leads tendency compared with frame constructions without a pitch to lower horizontal forces and thus to the possibility of flat foundations. The transition of the frame leg into the foundation should be articulated, but a connection with conventional reinforcement with plug-in rings is sufficiently ductile to accommodate the bearing rotations.

3.2 Joint design

A further special feature of this type is the formation of the system-depentend joints, which is to be developed from the experience of the project Paulifurt [2] as a wet joint (Fig. 9). The design of dry joints allows almost no tolerances and is more cost-intensive to manufacture. The wet joint allows the tolerance compensation, whereby a corresponding post-limit stiffness has to be taken into account.

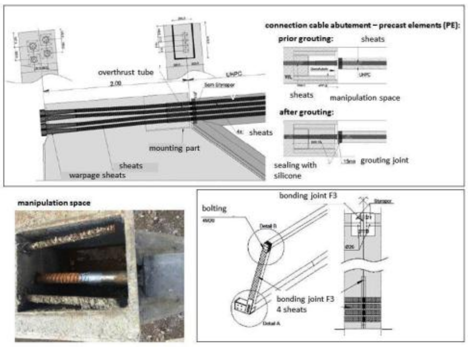

Fig. 9: Design of the wet joints and coupling joints for prestressing

A further special feature is the type of prestressing with subsequent bonding (posttensioned prestressing). This is preferable to pre-stress without bonding (pretensioned prestressing). The joints and transitions of the sheaths must be tested for leak tightness for the later grouting with the cement matrix. The project Paulifurt [2,3] (Fig. 11) has shown that expensive sealing rings can be dispensed with due to the high prestressing. A particularly neuralgic point is the transition of the sheats from the frame leg with in-situ concrete to the UHPC-precast element section, which has been solved only by a specially designed overlapping construction. The insertion of the strands into the casing should be carried out symmetrically from both sides, as is the tensioning of the litz wires so as to obtain a minimum of prestressing losses from friction.

3.3 Geometrical stiffness through shell effect

UHPC components are very thin-walled components whose high slenderness (ratio) can only be achieved by utilizing geometric stiffnesses. Thus, the buckling stability of the upper flange in the UHPC 325-walls in the field center can only be achieved by the buckle (bend) in the ground plan. This possibility of geometrical stiffness can also be achieved in the case of spatial shell elements with flat UHPC-plates. In Fig. 10, on the basis of a cantilever construction, rotationally symmetrical roof structures, such as those known e.g. can be provided for canopies. The challenge lies in the joining of the UHPC-plate elements, which can be solved from the author's point of view by means of steel elements with grouting.

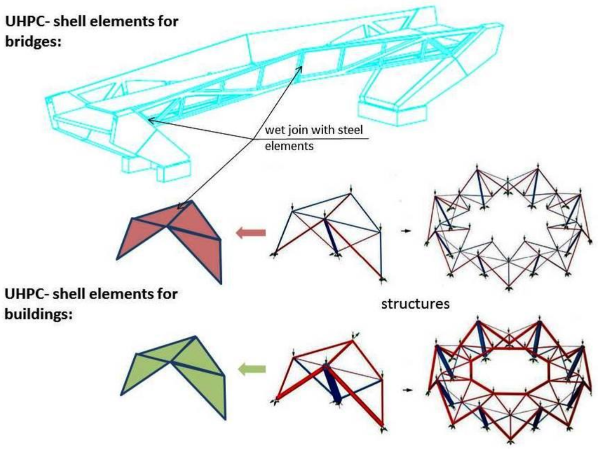

Fig. 10: Shell effect (geodesics) of the frame and other tiled slaps in buildings

4. CONCLUSIONS

Due to their characteristics bridge systems with UHPC represent a quite competitive alternative to previously implemented bridge system solutions. They offer the advantage of a resource-saving efficiency when used in a material specific correct application and also enable sustainable infrastructure projects. In the case of material specific correct application and utilization of the static advantages, beautiful shaped system bridges and buildings can be created by expressing the inner logic through the external appearance. This is perceived by the viewer as a harmonious building structure.

Fig. 11: Paulifurt bridge in Carinthia in Austria

5. REFERENCES

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[3] Olipitz, Michael (2015): „Innovationen an Beispielen einer Bogen-, Balken-, und Schalenbrücke“, article in the anniversary publication for Professor Dr. Lutz Sparowitz (75): Innovation und Ästhetik im Ingenieurbau, ISBN: 978-3-85125-431-0, December 2015, Graz.