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REFURBISHMENT OF THE VORDERRHEIN-ROADBRIDGE NEAR VALENDAS IMPLEMENTING A GFRP-WOOD HYBRID SLAB

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1. INTRODUCTION

The road bridge crossing the Vorderrhein close to the railway station Valendas-Sagogn (CH) is a steel truss from 1903, which was refurbished in 2017 for an expected design working life of 70 years. A GFRP-wood hybrid slab replaced the existing bridge deck, increasing the allowed service loads from 9 t to 18 t. The refurbishment was planned by the engineering consortium thomas ekwall tragwerksplaner eth and Flückiger + Bosshard AG. The sandwich slab was produced and assembled on site by the company LeichtbauWeis AG. The project was supervised by the infrastructure department of the Raetian Railway RhB, which transferred the ownership of the bridge to the contiguous municipalities Safiental and Sagogn after completion.

This is just the second road bridge in Switzerland after the Avançon-bridge [1] which has been built using this manufacturing process. Besides dealing with horizontal loads such as stalling and impacts in statical verifications, the consequences of high temperatures caused by asphalting on the GFRP was evaluated in preliminary tests.

Fig. 1: Asphalted GFRP-Wood slab with steel guard rails.

2. PLANNING

Construction

The bridge slab is 62.07 m long with 3.30 m effective width. Considering weight and transportation boundaries, the slab was subdivided in ten elements with maximal length of 6.81 m (The expansion joints are independent from the slab). Each element has a 170 to 210 mm thick glulam spruce core GL 24h spanning transversally, enwrapped in a 6 mm thin matrix of vinyl ester synthetic resin. Glass fiber mats Saertex U-E-1751g/m^2 are integrated to the matrix (with a 55% ratio) using the vacuum infusion technique. Guard rails in steel are structurally glued to the GFRP on the lateral sides. The elements are separated to each other by 6 mm transversal joints and fixed to the steel substructure underneath using wood screws. The drainage occurs by longitudinal and transversal slopes, without perforating the slab elements.

Statics

The GFRP-Layer was not considered in the slab dimensioning. The wooden core was dimensioned for self-weight (slab 1.0 kN/m^2 + asphalt 1.6 kN/m^2) and trafic loads (surface loads 2.7 kN/m^2 + Axle 2x126 kN). Transverse compression at the supports as well as fatigue due to bending were determining for the ultimate limit state (ULS). The deformations in middle span satisfied the comfort criteria L/500 of the serviceability limit state (SLS).

The M16 wood screws (36 Pcs. in each element) transmit stalling loads up to 222 kN in the substructure by shear resistance. The guard rail transmit up to 100 kN impact loads in the slab elements, activating the shear and tensile resistance of the Sikadur 30 LP structural glue. [2]

Pavement

The sandwich elements have a surface coating Sikadur-188 Resin broadcasted with Quarz sand 0.7-1.2mm, so-called Hessensiegel. The slab joints are sealed with Dilatec stripes and Sikaflex PRO-3 mastic. Warm rolled asphalt AC TD 16 N (combined asphalt base and surface layer) of 60 mm at 160°C was applied on the slab, which was recovered preliminarily with glass fleece.

3. PRELIMINARY TESTS

Three preliminary tests were implemented to measure the temperature and estimate the behavior of the GFRP-Layer during asphalt works, thus defining the maximal allowed paving temperature and various constructive details. [3]

Test with Rolled Asphalt on a Big Sample

The purpose of the first test was to estimate the temperature in the GFRP-Layer during asphalting on a sample with the measurements L=1.40 m, B=0.80 m, H=0.14 m and 12% moisture content. Wooden core, GFRP-Layer, Guard rails and transition joints and surface coating (Hessensiegel) were constructed according to the bridge slab. Six temperature sensors NiCrNi Type K with glass silk wire were applied on the lower surface of the GFRP, next to the core. The rolled asphalt was poured on the sample and compacted manually (the weight of the combination roller wasn't simulated).

Fig. 2: Sample of the first preliminary test before asphalting.

The installation temperature of +157°C sank immediately to +141.8°C before compacting. The maximal measured Temperature in the GFRP-layer (measuring device DTH-TYPK-2K) was +112.6°C and in the structural glue +54.0°C, barely satisfying the accepted upper limits of +120°C for the GFRP (noticeable stiffening losses) and +54°C for the glue (thermolability). On site, it was therefore decided to add a layer of glass fleece to increase temperature losses.

The guard rail didn't move and the structural glue remained hard, although the glass transition temperature (+45°C) was exceeded for approximately 90 min. Although these effects are reversible, the ten slab elements were placed in an isolated containment during seven days at +35°C to increase the glass transition limit to +55°C.

The influence of high temperatures in the wooden core was not specifically analyzed, since estimated as uncritical: The massive spruce core quickly spreads the heat and the vapor pressure. Since the GFRP-layer is completely sealed and bonded to the wooden core and air pockets are chased during the vacuum infusion process, the risk of damages due to blistering and delamination can be avoided.

Table 1: Results of the preliminary tests with rolled asphalt on a big sample.

t [min]	0	10	20	30	40	90	max
Asphalt [C°]	141.8	116.0	104.4	98.8	91.1	75.2	141.8
at GFRP/wood [C°]	27.5	95.5	109.6	112.6	108.6	85.5	112.6
in structural glue [C°]	26.0	49.5	53.6	54.0	51.1	42.5	54.0

Test with Hot Grout on the Big Sample

The purpose of the second test was to measure the temperature of the GFRP-Layer due to pouring of hot grout in the transition joints located next to the slabs front face. This was effectuated on the sample of the first test, whereas one half of the front face was covered with 2 mm thick tar paper. The 80 mm thick joint was progressively filled with Risoplast 164 at +174°C. The temperature of the GFRP-Layer only increased to +90.0°C under the Hessensiegel and +80.3°C where the tar paper was added. This area is therefore uncritical.

Table 2: Results of the preliminary tests with hot grout on the big sample.

t [min]	0	10	40	75	105	max
Under seal [C°]	27.3	81.2	89.1	90.0	89.2	90.0
Under tar+seal [C°]	26.5	51.1	79.0	80.3	79.8	80.3

Test with Hot Grout on Small Samples

The purpose of the third and final test was to measure the temperature and evaluate the behavior of the GFRP-layer alone due to the heat. Two samples of 4.8 mm thick GFRP-plates were supported on two sides each, whereas the second sample also received a Hessensiegel. The +174°C hot grout was poured into a 60 mm high square frame, whereas the temperature of the upper surface (grout) and lower surface (GFRP) were measured with a laser device Bosch PTD-1.

Thanks to the Hessensiegel, the lower surface of the second sample got -13°C colder than the first sample. The GFRP-plates had a plastic deformation of approximately 5 mm, without indication of fire or liquefaction and remained waterproof. Since the GFRP-Layer will be supported by the wooden core, a temporarily low stiffness shouldn't be problematic.

Table 3: Results of the preliminary tests with hot grout on small samples.

Measurement	0	45	55	75	105	max
Grout 1st Plate [C°]	30	177	157	–	–	–
Under 1st Plate [C°]	30	103	106	–	–	106.0
Grout 2nd Plate [C°]	30	190	111	–	–	–
On 2nd Plate [C°]	30	–	115	116.0	112.1	116.0
Under 2nd Plate [C°]	30	83	93	–	–	93.0

4. ASSEMBLY

The slab elements including the guard rails were transported from Arbon to Valendas using motor truck and train carriage. Placement, calibration and assembly were effectuated with truck crane in 10 hours. The next day, the elements were fixated from underneath and sealed according to following steps: Predrilling of the GFRP with diamond bits, wood drilling, sealing of the bored hole with epoxy resin, screwing of the wood screws and sealing of the slab joints.

Fig. 3: Assembly of a sandwich slab element.

The pavement company completed the structure with draining rails, drain troughs, grouting of the expansion joints and placing the glass fleece. The rolled asphalt was placed in one stage with one small paver and one combination roller. The installation temperature of the asphalt didn't exceed 160°C, as assumed in the preliminary tests.

5. CONCLUSION

This project demonstrates that a hybrid GFRP-wood bridge slab can be realized with the conventional methods of rolled asphalting. In contrast to the Avançon-bridge, where the asphalt was tempered with adjuvants to preserve the statically activated, 22 mm thick GFRP-chords, the GFRP-envelope in Valendas was chosen only for its sealing qualities, thus reducing the layer thickness to 6 mm. Static calculations were limited to the wooden core and therefore based on established norms. These advantageous boundaries, including the short spans of 57 cm between the beams of the substructure, made the hybrid slab economically attractive compared to a steel orthotropic plate and more durable compared to a conventional wood plate. The bridge in Valendas is a reference object to observe the behavior of such a bridge slab and asphalt layer under high humidity and temperature changes.

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