From the fabrication to the maintenance – a report of the history of the Mur River Wooden Bridge in Styria/Austria

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ABSTRACT: This article describes the history of the Mur River Wooden Bridge, which was built in 1993 in Styria/Austria as a three-hinged arch bridge with supported carriageway. It covers the fabrication and assembly of the wooden bridge and a description of the supporting system, as well as the results of the accomplished bridge inspection in the year 2003, and the consequential ordered measures of rehabilitation. Furthermore, there are given the incurred costs and the determined annual maintenance percentage of the bridge.

1 MUR RIVER WOODEN BRIDGE – PROJECT DESCRIPTION

1.1 General

The Mur River Wooden Bridge (Wenner-Bridge) in the municipalities St. Georgen and St. Lorenzen/Murau was designed in 1993 as a three-hinged arch bridge with supported carriageway and longitudinal girders. The parabolic three-hinged arches form the main structure and design element of the bridge. The arch itself spans 45.00 m and has a rise of the arch of 12.50 m. The bridge length of 85.00 m defines the length of the four longitudinal girders, which consist of four parts for transportation and assembly-technical reasons.

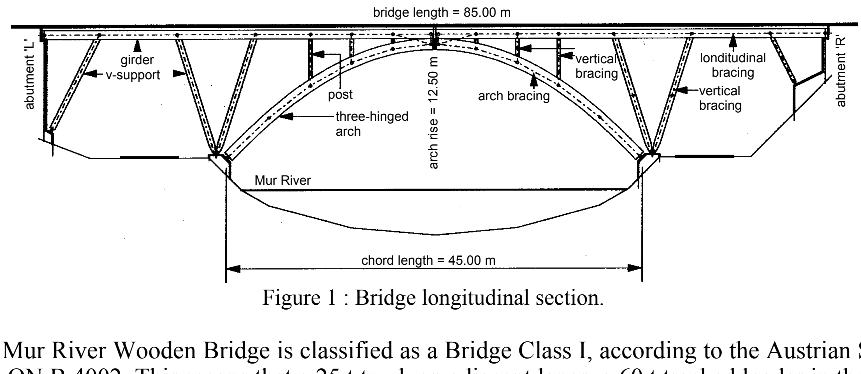

Figure 1 : Bridge longitudinal section.

The Mur River Wooden Bridge is classified as a Bridge Class I, according to the Austrian Standard ON B 4002. This means that a 25 t truck on adjacent lanes, a 60 t tracked loader in the single-handed attempt respectively and a uniformly distributed load of 5 kN/m² on the remaining area has to be considered for each traffic direction.

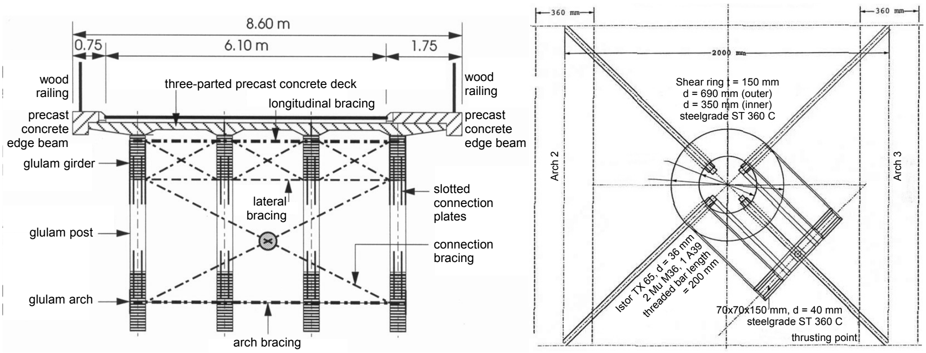

Figure 2 : Bridge cross section (left); Connection detail for diagonal connection bracing (right).

The total width of the bridge is 8.60 m. The decision in favour of a longitudinal prestressed carriageway slab consisting of tapered, precast concrete parts of quality B400 was made regarding to statical-constructive requirements, efficient constructional wood preservation and a smooth assembly process.

1.2 Design and Construction

1.2.1 Main support structure

The main support structure, i.e. the three-hinged arches (b/h = 360/1200 mm), the V-supports (b/h = 360/600 mm), the posts (b/h = 360/360 mm) and the girders (b/h = 360/1000 mm), is fabricated from block-glued larch glued laminated timber (approximately 300 m^3).

The vertical loads are carried by the girders into the V-support. In the crown, loads are directly applied into the arch because of the bending resistant connection of girder and three-hinged arch via slotted steel plates.

Loads perpendicular to the longitudinal axis of the bridge, like wind and lateral loads, are carried off by a bracing system which consists of transverse and longitudinal bracings as well as connection bracings (use of steel grades ST 360 C, ST 510 C and Tenax TX 65). The connection bracing consists of crossed tension members (d = 20-36 mm; steel grade ST 510 C or Tenax TX 65) as well as compression steel posts (hollow sections, d = 100-133 mm, wall thickness = 6.3-20 mm) and top and bottom chords, formed by the wooden main structure. The load between the tension members is transferred in the crossing point of the diagonals on particularly designed shear rings, see Fig. 2.


Figure 3 : Main support structure (left); Bearing points of: girders (middle), Arch and V-support (right).

1.2.2 Bearing and Connections

Anchored and reinforced elastomeric bearings are used at the abutment and the pier, which are able to resist tensile forces. All remaining bearing points of the structural system act as pinned support with pin diameters of d = 60-100 mm, depending on the statical requirements.

All connections are implemented as steel-to-timber connections with two slotted steel plates and steel dowels. The fasteners and steel elements have the steel grades St 360 C and St 510 C.

1.2.3 Carriageway

The carriageway slab (h = 160-280 mm) consists of longitudinal prestressed (type VT 04-100), tapered precast concrete elements of quality B400 (approximately 180 m^3). The shear connection of the concrete slabs with the wooden girder consists of bonded threaded steel rods, d = 30 mm, counterplate and screw joints. In addition to the two dilation systems on abutment and pier, a dilation system in the center of the bridge was necessary, see Fig. 4, middle. Precast concrete elements were arranged as edge beams.

1.2.4 Railing

The basic structural components of the railing construction are made of larch glued laminated timber, the planking from larch boards. The joint of handrail and waist rail in the center of the bridge is designed as a dilation system in form of a slotted, longitudinal moveable steel connection pin, d = 30 mm.

Figure 4 : Prestressed concrete slabs (left); Dilation in bridge center (middle); Dilation system of the waist rail (right).

1.2.5 Constructural wood preservation

During the planning process and especially during the detail design, considerable attention was drawn to provide sufficient constructional wood preservation with additional chemical surface protection.

A substantial portion of the wood structure is protected by the carriageway deck. The top sides of the three-hinged arches are covered by steel sheets, just as the bearing points of the V-supporting and struts. Furthermore all end grain surfaces of the main carrying structure are protected against influences of the weather by a complete sealing.

A special protection system has been applied on 48 exposed joints. At these points the slots between the connecting plates and the notched wood surfaces were completely sealed. First, the drill holes have been impregnated with an injection of approximately one bar pressure. After a defined setting time, a synthetic resin with three to four bar pressure was injected, eliminating exposure to weathering conditions. As complemented preventive measure, the entire timber construction was protected by a full surface coating of paint against the influences of the weather. Further chemical treatments for wood preservation were not applied.

1.3 Bridge fabrication

The fabrication of the structural bridge elements took place in three phases. The entire steel elements were manufactured in December 1992 and January 1993, whereas all steel elements and fasteners were hot-dip galvanised after completion (total weight of steel elements: 69 t). Lamination of the wood members was begun in March 1993. Great care was required during the fabrication of the glued laminated timber elements. Not only the gluing of the 25 mm thick single laminations to a single cross section had to take place, but also the gluing of two single glulam elements was necessary due to the statically required width of the structural elements. An equilibrium moisture content of 14 % was aimed during the manufacture of the glulam members. After fabrication of the straight members, such as posts, girders and struts, the arch elements were produced. The subassembly of the wooden and steel elements began simultaneously. It was possible to do the accurate drillings and slots of the wooden members by the use of templates.

1.4 Assembly

To prepare for the assembly, it was necessary to provide a sufficient joining and assembling area on both river banks. The delivered wood elements were assembled on-site to form half of the arched truss. After securing the arch truss with mounting walls (weight of the entire truss element with all steel elements was 20 t), the lifting of the arch truss members was begun. Two cranes, a 160 t auto crane and a 130 t undercarriage crane were used.

After three of the four arch planes were assembled and secured, the threading of the horizontal connecting rods was begun. This very delicate assembly took two days for the arch bracing. Afterwards the fourth arch truss plane could be shear-connected with the bracing. The next steps were joining and coupling the arch truss members with the king post truss members at the girder joint, whereas a 35 t auto crane was available.

The first phase of on-site assembly was completed with the placement of the lateral connecting rods, which required an assembly time of six weeks. After completion of the wooden main support structure the assembling of the precast concrete slabs with mounting the shear connection (steel rods) with the girders and prestressing of the slaps was begun. Finally, the dilation systems, the edge beams and the wooden handrails could be assembled.

Figure 5 : Assembling of the main structure (left, middle); Threading of the connection brace (right).

2 INSPECTION, MAINTAINANCE AND REHABILITATION

Three bridge inspections were accomplished (1994, 1998 and 2003) since the construction of the Mur River Wooden Bridge, whereas persons of the structural design and the realisation as well as municipal representatives were present. The entire bridge construction could be checked with an auto crane and a lifting gear respectively. In the year 2003 the bridge inspection was done with an inspection manual, which especially had been developed for timber bridges by the Institute of Timber Engineering and Wood Technology/Graz Technical University. After completion of the bridge inspection in 2003, a local company was instructed to take necessary rehabilitation measures, which were accomplished in the years 2004 and 2005.

A cost-saving and more practical alternative for the (expensive) auto crane could be found for the extensive work on the main support structure (specially the three-hinged arches). Steel members were fastened to the three-hinged arches by threaded rods, which served as anchorage for a scaffold platform for two of the four arches. The finished platform substantially facilitated the work for the necessary measures.

Figure 6 : Platform for the work at the main structure (left, middle); Joints: control of the firm fit (right).

The following sections describe the results of the bridge inspection in the year 2003 and the accomplished rehabilitation measures, whereas the following areas were inspected in 2003:

- Microclimate
- Substructure – abutment, drainage, dilation system
- Main supporting structure – wooden three-hinged arch, V-support, girder, posts, struts
- Main supporting structure – bracing system, fasteners
- Carriageway deck
- Wooden hand railing

Due to the limited length of this article not all areas shown above can be discussed in the following sections.

2.1 Microclimate

2.1.1 Inspection

The bearing points of the arches and V-supports were negatively influenced due to the adjacent vegetation. This means that the wooden surfaces were in the shade on the one hand (this has pros and cons) and permanently influenced by moisture on the other hand.

2.1.2 Rehabilitation measures

The vegetation close to the bearing points was eliminated in the course of the repair measures.

2.2 Main supporting structure, bracing system, fasteners

2.2.1 Inspection

The surface coating of paint of the inside arranged girders, three-hinged arches and V-supports was in a good condition. The bearing points (steel plates, dowels, pins) showed a clean and dry condition because of the weather-protected situation.

The surfaces and bearing points of the outside arranged three-hinged arches, V-supports and struts in contrast, already showed substantial weathering with partial strong discolorations (washing). More or less deep, mostly locally limited cracks were noticed. Supplementing wood moisture measurements delivered a moisture content of 12 % to 16 % at the bearing points of the three-hinged arches and the V-supports. Only one arch bearing point, arranged on the outside, showed a higher wood moisture content of approximately 20 %.

All flexible seals required repair or were lacking. The surface coating of the steel elements was already partly flaked off, which caused commencing corrosion of the surfaces.

The connection bracing system showed first signs of corrosion; the load bearing capacity was not affected.

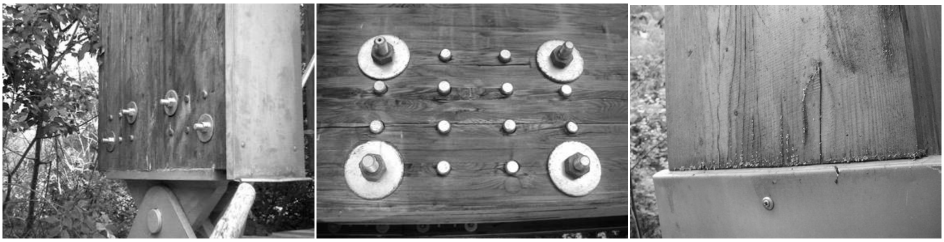

Figure 7 : Substantial weathering with discoloration and locally limited cracks; Lacking flexible seals.

2.2.2 Rehabilitation measures

The supporting structure was cleaned using compressed air prior to the first steps of reconstruction. The cracks caused by the influence of weathering were force-locked filled with epoxy resin. The entire wooden structure was impregnated, primed and coated with a wood preservation paint. Furthermore a renewal of the flexible seals and of the corrosion protecting coat of all steel sheets and elements took place. All joints (screws, bolts) were examined for their firm fit and retightened if necessary. As an additional measure, three sides of an arch bearing point (the wood moisture content was approximately at 20 % at the time of bridge inspection) were completely encased with larch three-layer boards. A measuring device might be arranged for a continuous gauging of the moisture content at the bearing point of the arch.

Figure 8 : Finished coating of the left bridge side (left); Renewed flexible seals (middle); Additional measure: encased arch bearing point (right).

2.2.3 Future measures

To ensure the permanency of the protecting surface finish, the coating should be renewed every 8-10 years (inside lying parts), and every 5-6 years for exposed parts. Since the outside lying surfaces of the three-hinged arches are extremely exposed to strong weathering, a complete cover should be considered. This could be done with vertical planking or with replaceable board elements in order to achieve the demanded service life of the structural elements. The periodical cleaning with compressed air of the bearing areas of the main support structure is important in order to provide the efficient drain of water.

2.3 Carriageway deck

2.3.1 Inspection

Some points with water drain were noticed between carriageway slab and edge beam (mainly in the area of the cross joints of the edge beams). Those areas showed discolorations and efflo-resce, but the wooden construction was not yet effected. The bottom view of the concrete fore-land-bridge also showed dark areas (water spots?), whereas the operability of the sealing could not be completely ensured. The surface coating of the edge beams was chipped off in a large area.

2.3.2 Rehabilitation measures

After cleaning (sandblast and high pressure cleaner), the damaged coating of the edge beams could be repaired with an epoxy resin bonding agent and treated with a PU-based sealing afterwards.

2.4 Wood railing

2.4.1 Inspection

The railing and particularly the hand rail were generally in a bad condition at the time of the bridge inspection. The hand rail, implemented as a flatwise glulam beam, showed very strong indicates of weathering combined with distinct cracking. In some areas wood crumbling already took place. In areas of bordering vegetation, the railing (hand rail, posts) showed moss and lichen infestation.

2.4.2 Rehabilitation measures

The entire railing construction was cleaned in the course of the rehabilitation works. The mostly intact zones of the hand rail were mortised; strongly damaged zones were completely replaced. The wood repair material, which was brought in in the course of an earlier measure of rehabilitation, was removed and new properly matching fillings were bonded. All end grain surfaces were protected with a sealant. After these rehabilitation measures the coating of the surfaces took place with a wood preservation paint.

An additional cover measure was taken to extend the durability of the hand rail, whereas two different systems were used. The coming years will show the success of these two systems regarding a perfect constructional wood preservation. A bituminous coating and a self-adhesive bitumen foil, covered with larch boards, was applied to one hand rail. The other hand rail was protected by a rear ventilated metal sheeting, see Fig. 9 (middle, right).

Figure 9 : Condition of the handrail in 2003 (left); Additional cover measures (middle, right).

3 SUMMARY

An important indicator for the economic efficiency of a bridge is the annual maintenance percentage p, which is indicated in [%] of the construction costs. In Austria this characteristic value is specified for road bridges of wood with 2.0 % by the authorities, whereas this value is based on a theoretical service life of only 40 years. This low characteristic value implies a lower competitive position compared to other building materials such as concrete, reinforced concrete and steel.

After the considerable rehabilitation works, a cost listing was accomplished and the annual maintenance percentage could be determined, see Table 1.

Table 1 : Cost listing of the Mur River Wooden Bridge

	Date of realisation EUR	2006*. EUR
Construction cost (without design)	1.823.967	2.963.946
Wooden structure + carriageway	1.101.949	1.790.667
Bridge inspections	12.954	17.692
Rehabilitation measures	179.161	199.425

*Costs of the realised workings are index adjusted, relating to 2006

The annual maintenance percentage could be determined as 0.93 %, based on 13 years.

The cost listing of the Mur River Wooden Bridge as well as different investigations in Austria, Switzerland and Germany show that the officially specified characteristic values in Austria do not correlate with the values determined in practice. In this regard an important step was done in Germany with the DGfH-project in the year 2005, which documents a realistic recommendation for the annual maintenance percentage and the service life of timber bridges by collected data from field investigations, Gerold (2005).

The Mur River Wooden Bridge is in a good condition after the considerable rehabilitation works. Due to the reconstruction of the surface coating and filling of local cracks (epoxy resin gluing), the wooden main structure is on the best way to achieve or even exceed the theoretical service life. A continuous inspection of the bridge building has to be carried out, whereas an interval of two years is regarded as ideal. Some bridge areas surely require further maintenance measures. First of all, the periodical coating of the wooden main support and the wooden railing has to be ensured. Furthermore, the complete covering of the extremely exposed outside surfaces of the three-hinged arch should be considered during the next few years to avoid heavy weathering influences.

Although the constructional wood preservation had a great importance in the planning process, some bridge areas prove as susceptible beyond a certain period of use (observation period). If this period does not last for a too long time, effective measures can also be taken later to ensure the good state of preservation of the building component.

The next major bridge inspection will take place in the year 2008 and will show the general state of the bridge. It will also be seen, if the arranged wood preservation measures will prove. After the results of that bridge inspection, the required work should be accomplished until to the year 2010.

Figure 10 : Mur River Wooden Bridge (Wenner-Bridge), December 2006, ski-region St. Georgen/St. Lorenzen (Styria, Austria).

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