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No. 09 – Brno – arch bridge over Hybešova street

railway truss arch bridge	
South Moravian Region, Brno district	
cad. territories Brno-City, Staré Brno	
buffer zone*	
TÚ 2001, DÚ J1, evd. km 143,143	49°11'19.8"N 16°36'35.7"E

CTU
CZECH TECHNICAL UNIVERSITY IN PRAGUE

*the bridge is in the administrative process of the declaration of a cultural monument, buffer zone of the urban conservation area of the city of Brno, buffer zone of Villa Tugendhat (WHL UNESCO)

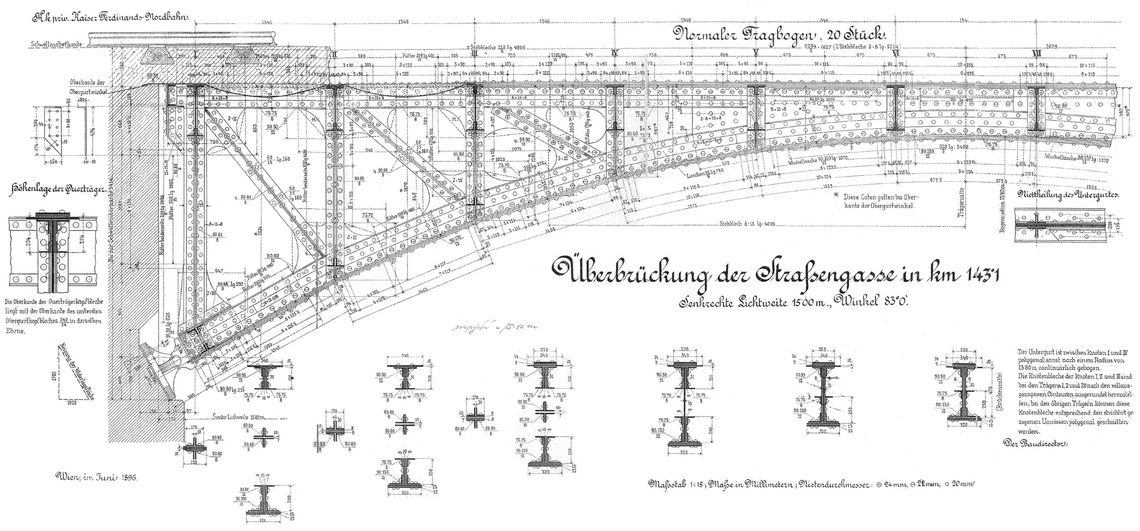
History

The original steel truss bridge from 1897 carries the tracks of the Brno main railway station over Hybešova/Úzká Street. During 2018–2020, the bridge was reconstructed.

It is an arched, riveted, truss bridge consisting of an upper bridge deck with buckle plates, located at km 143,143 of the Emperor Ferdinand Northern Railway. The bridge consists of a single span and is made up of four supporting structures. The span of the bridge is 22.10 m long, 56.20 m wide and 6 m high. The total length of the bridge is 92.23 m with a crossing angle of 83°. The lower structure consists of two abutments (stone in the lower part, concrete with plaster in the upper part). The steel structures are supported by the abutments on transverse movable bearings.

The bridge is particularly interesting because of the use of the so-called "buckle plates" ("puklovka" in Czech). The buckle plates are rectangular (also square or trapezoidal) plates, which are bent and bulged to resemble the shape of an inverted arch. The size of the buckle plates used to vary from 1 to 4 m^2 with a plate thickness of 8–10 mm. They were attached to the steel structures in the frames between the transoms and stringers. A drainage hole was then located at the deepest point of the purlin.

The steel structure of the bridge was supplied by Pražská akciová strojírna, formerly Ruston & Co. It was approved on the 17th of November 1897 and the 14th of July 1898. The bridge is a listed heritage structure. The process of the declaration of the bridge as a cultural monument has been initiated. In 2018–2020 it underwent a complete reconstruction costing more than 255 million CZK.



Original drawings: Standard beam and material distribution (SŽ archive)

Experimental and numerical analysis

In-situ tests were carried out as part of the reconstruction, focusing mainly on the historic member of the bridge deck, the so-called "buckle plate". The aim of the analysis was to determine the real condition of the historic buckle plates and their subsequent service life. The survey included both destructive and non-destructive tests, as well as static and dynamic laboratory testing of the historic and new buckle plates formed according to current procedures.

Furthermore, tensile tests, chemical composition and metallographic analysis of the material were carried out. These tests showed high quality steel, with a yield strength of min. R_{eH} = 282 MPa. The steel has different, better properties than is common for mild or wrought steel. This is a consequence of the forging and hot forming of the buckle plate.

After these tests, static and dynamic loading tests were carried out. A test set-up was created for the load test. The test assembly consisted of a steel frame, into which the plates of the existing historic buckle plates were riveted and then filled with gravel. A sleeper was placed on top of the gravel, through which the load was imposed. The loading was carried out under conditions corresponding to the actual loading of the buckle plate in the bridge. During the loading, the stresses and the vertical and horizontal deformation of the plate were measured.

Original drawings: Standard beam and material distribution (SŽ archive)

Experimental and numerical analysis results

In addition to the experiment, numerical analysis was used to determine the behaviour of the buckle plates. A detailed and comprehensive numerical model was created from spatial, plate-wall and solid elements, including contact surfaces. The resulting loading effects were compared with the measurement results from the laboratory test and the model was further validated in this way to best represent the actual behaviour of the buckle plate.

Subsequently, experimental and numerical analyses were also performed on new plates produced by cold-forming and welding. The results of the experimental and numerical analyses showed differences in the behaviour of the conventional numerical model and the real structure. The differences are due to the load distribution and the interaction of the track bed.

In contrast to the original assumption of the reconstruction project, which considered the replacement of the vast majority of the purlins, it was, for the most part, possible to retain the original purlins. Experimental analysis of the new buckle plates showed very little difference when compared with the behaviour of the historic buckle plates. The fatigue strength at the plate welds of the new truss was also checked. Based on the results of the experimental and numerical work, the minimum allowable thickness of the ductile iron plate was set at 6.35 mm.

Test assembly with gravel bed and sleeper

The bridge deck and coating of the end cross beam

Assessment of the bridge condition

The bridge is well maintained; a complete repair carried out in 2018 included the replacement of some bridge plates and the restoration of corrosion protection. After this repair, the bridge is in good condition. The future use of the bridge will be decided by the Brno city administration in conjunction with the renovation of the main railway station.