DOI: 10.2478/sspjce-2023-0015

Steel-Concrete Composite Bridge Diagnostics and Reconstruction

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Abstract

Many bridges in Slovakia are reaching their designed life span these days. Due to frequent errors during the construction of those bridges as well as bad maintenance, steel-concrete bridges are now in a critical state and urgent repairs of those structures are needed. In this article progressive methods of retrofitting existing concrete bridges are shown. In the presented method, the original pillars and original bridge deck will remain in their place, and on the existing deck new composite, steel-concrete bridge deck with encased steel members of progressive shape will be created. This method brings significant cost reduction for such retrofitting and enables the application of increased loads on the bridge.

Keywords: continuous shear connector, bridge repair, steel-concrete composite

1 Introduction

The technical condition of many bridges in Slovakia as well as meeting the requirements of their purpose are currently not satisfactory. Their maintenance, repair or reconstruction are limited by the limited financial sources for such purpose. For this reason, new innovative construction designs and techniques need to be considered in such processes that lower the construction time and cost.

This paper describes the steel-concrete pedestrian bridge diagnostics and reconstruction using such innovative solutions. In the new structure, continuous shear connectors will be used. There are no documented bridges with such design in Slovakia. Typically, the whole I-beam is used, such as in the Hodonín – Holič bridge [1]. To lower the cost, the existing structure will not be taken down, but rather serve as a formwork during the construction period.

Worldwide, bridges with encased steel continuous shear connectors are more widely used. In Germany, the so-called PRECObeam (Prefabricated enduring composite beams), containing clothoid-shaped continuous shear connectors, were introduced. The first such bridge was built in 2003. Several bridges based on this design were also built in Poland and France since 2009 [2]. Although typically used as short-span road bridges, in 2011 in Germany, a railway bridge

was build using the VFT-Rail type of PRECObeam cross-section. In the VFT-Rail design, the clothoid-shaped shear connectors are placed from both top and bottom edge of the bridge [3].

2 Existing Bridge

The bridge in question (see Figure 1) is situated in the village of Čečejovce, in southeastern Slovakia. It is a steel-concrete pedestrian bridge composed of two steel rails laid longitudinally at the bottom surface of concrete deck (see Figure 2). The lower structure consists of outer supports and three internal supports. The central pillar is based on slab foundations. The interior supports, as well as the end supports, are probably based on slab foundations. The overall length of the bridge is 19.1 m, with the longest span of 5.9 m. There is no available documentation for the existing bridge. The year of construction of the bridge, or any additional reconstruction, is unknown.



Figure 1: Existing pedestrian bridge

Two pipelines are lying in parallel with the bridge deck, supported by a steel structure connected to the bridge (see Figure 2).

The existing bridge no longer meets the requirements of the investor (the village of Čečejovce), whose request was the small vehicles to be able to cross the bridge.

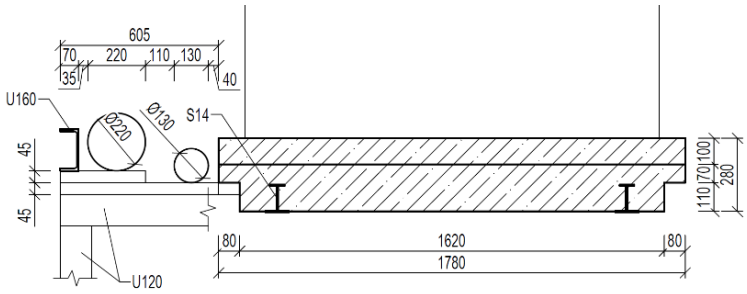


Figure 2: Cross-section of the existing bridge

3 Diagnostics

Based on the investor's requirements, a diagnosis of the existing bridge was carried out to identify its shortcomings and the potential for its expansion. It consisted of taking measurements of actual dimension of the bridges upper and lower structure, as well as of the evaluation of concrete strength and geological foundations for increased loading from vehicle line.

3.1 Assessment of Concrete

The analysis was performed on boreholes (see Figure 3a) from the middle pillar - borehole 1; bridge supports - borehole 2; and from the bridge deck - borehole 3. Based on the analysis, the following deficiencies of the existing structure were found [3]:

- Bore 1 had a total length of 190 mm. The concrete was porous - probably under-compacted.
- Bore 2 had a total length of 220 mm. Similar to the pillar and the end support, the concrete was porous.
- Bore 3 had a total length of 107 mm. It was created over a concrete-covered steel rail. The borehole was realized in order to determine the quality of the bridge deck concrete and to determine the height of the concreted steel rail.

The concrete sample specifications and concrete test results are shown in Table 1.

Table 1: Measured strength of concrete

Soil class	**Bore 1**	**Bore 2**	**Bore 3**
Height of bore (mm)	190	220	107
Weight (g)	1918.5	1846.9	1989.2
Diameter (mm)	104.80	104.50	104.30
Height of tested sample (mm)	105.00	105.20	103.10
Manner of violation	common	common	common
Reinforcement	without	without	2/6/21 and 27 mm from the bottom edge
Max grain size (mm)	30.0	32.0	23.0
Density (kg/m^3)	2118	2047	2258
Surface (mm^2)	8626	8577	8544
Force (kN)	108.6	96.7	257.2
Compressive strength in cube (MPa)	12.6	11.3	30.1

a)  b) 

Figure 3: a) Sampling from the middle pillar, b) reinforcement at the upper surface above the pillar

Based on the optical assessment of the bridge, other violations of the structure threatening its stability were found, namely insufficient coverage of the reinforcement and its corrosion, mechanical damage to the concrete, corrosion, and degradation of the concrete at the place of anchoring of the railing, and others (see Figure 3b).

3.2 Engineering-Geological Ratios

The village of Čečejovce is situated in the Košice Basin 22 km southwest of Košice at an altitude of 205 m. Due to the fact that no geological survey was carried out in this location, the information was obtained from available sources from the State Geological Institute of Dionýz Štúr, Map server - Geological map of the territory (see Figure 4) [5].

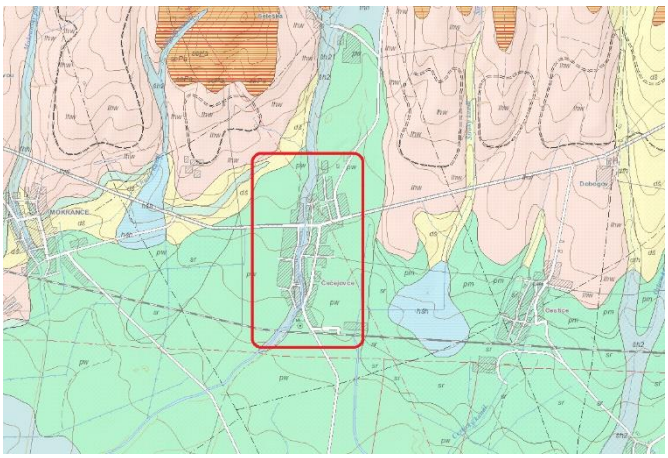


Figure 4: Geological map of the territory of the village of Čečejovce

From the point of view of the regional geomorphological division of the territory of Slovakia, the area of interest and its surroundings belong to the southern part of the Košice basin. Sediments of the Quaternary, Neogene substratum participate in the geological structure of the territory [4].

The Quaternary is represented in the surroundings by sediments, which are made up of sandy to clayey gravels. "These are sediments rising directly to the surface in floodplains, or only floodplain sections of streams. They are mostly found in the immediate vicinity of recent streams, mainly in the alluvial parts of meanders, as well as in parts of the artificially removed surface of alluvial clays and fine sandy clays of the flood facies." [5]

"Due to the influence of the laterally moving flow, during its simultaneous slight deepening, the gravels of the bot-tom accumulation were washed away and subsequently deposited. The resedimented material mostly comes from the upper gravel horizon of the bottom accumulation of the relevant stream, while the current state of the sur-face of the bottom accumulation, compared to its original surface, always represents an erosion reduction of ap-prox. 0.5 - 4 m. A characteristic feature of resedimented sandy gravels is their often alternating, but not very pronounced sorting of the positions of fine sands and gravels compared to bottom accumulation gravels. The thickness of the layers of resedimented gravel ranges from 0-2 (3) m." [5]

On the basis of this information, alternating positions of sandy silts (F3) and sandy to clayey gravels (G2 to G4) can be considered as a possible base soil in the given location under the existing load-bearing elements of the footbridge.

A detailed engineering-geological profile was not implemented in the given location, therefore, for the purpose of assessing the bearing capacity of the foundation soil, it is possible to consider only indicative values of the bearing capacity (see Table 2). For the design and assessment of sheet foundation structures in accordance with EC-7, in design situations where computational models are not available, limit states may be avoided by the use of prescribed measures. These include conventional and generally conservative design rules [6][7][8].

Table 2: Estimated bearing capacity of the soil at the construction site

Soil class	**Soil symbol**	**The name of the soil**	**Bearing capacity of the soil R_p (kPa)**
F3	MS,p	Sandy silt	275
G2	GP	Poorly grained gravel	650 (for b=1m)
G4	GM	Silty gravel	300 (for b=1m)

The proposal by adopting the prescribed measures can be used on the basis of comparable experience, i.e., documented or otherwise clearly established information relating to the foundation soil considered in the proposal (the values listed in Table 2 are according to STN 73 1001 from 1987) [6].

3.3 Results of Diagnostics

By diagnosing the footbridge in the village of Čečejovce, the dimensions of the existing footbridge were deter-mined, on the basis of which the drawing documentation was processed. Samples were taken from the bridge deck and the substructure, from which the concrete strengths of the outer supports and the intermediate pillar were determined. From the available documents on engineering-geological conditions, it follows that the foundation soil could be sandy silt or clay gravel. From the assumed values of the bearing capacity of the foundation soil and the dimensions of the foundations, the bearing capacity of the foundations under the central

pillar was determined to be 1343 kN; and the bearing capacity of the foundations under the outer supports to be 472 kN.

The expected load from the new bridge construction with one lane for road traffic and emergency vehicles is:

- End support N_{Ed} = 385 kN < 472 kN
- Middle pillar N_{Ed} = 636 kN < 1343 kN

Where N_{Ed} is the design value of the compressive normal force.

Based on these analyses, it can be concluded that the existing footbridge support structures are suitable for a new bridge with one lane for passenger traffic and pedestrians.

4 New Bridge

In order to lower the cost of construction, the deck of the new bridge was designed to be on top of the existing structure, which can serve as the concrete formwork during the construction process.

4.1 Design

During the inspection of the bridge, two pipelines were found laying on the supports of the bridge parallel to the bridge. As part of the design of the new supporting structure, it is not necessary to relocate these lines. The new supporting structure avoids them (see Figure 5).

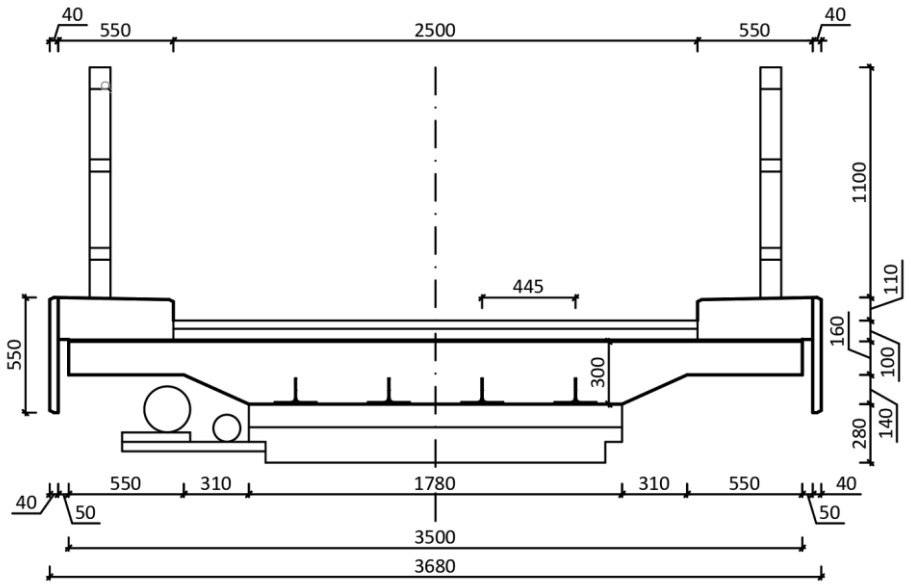


Figure 5: New cross-section

The supporting structure of the bridge is formed by four steel-concrete composite beams (see Figure 6a) created by longitudinally cutting the HE200A steel beam, creating puzzle dowels (see Figure 6b), with upper concrete consoles of dimensions 0.55 m x 0.16 m with a run-up length of

0.31 m on both sides of the cross-section of the bridge. The axial distance of the beams is 0.445 m. In the longitudinal direction, the cross-section is almost constant, the height of the middle part must be adjusted on the spot to compensate for the unevenness of the existing structure and create the proposed longitudinal slope of 0.5%. The height should not exceed 300 mm in any place, and its possible increase should be reflected in the increase of the cover layer of the bottom reinforcement. The load-bearing elements were created from rolled steel profiles of steel with strength S355, load-bearing concrete reinforcement marked B500 and concrete class C30/37 [8][9][10][11].

The specific shape of shear connectors used in the new bridge design is based on previous research of continuous shear connectors at Technical University of Košice [12][13][14]. In-between each of the dowels the concrete stud is formed, which provides high longitudinal shear resistance. The puzzle shape of the connector allows easier placement of the reinforcement cage into the con-vex parts of the puzzle cut and therefore simplifies and shortens the construction.

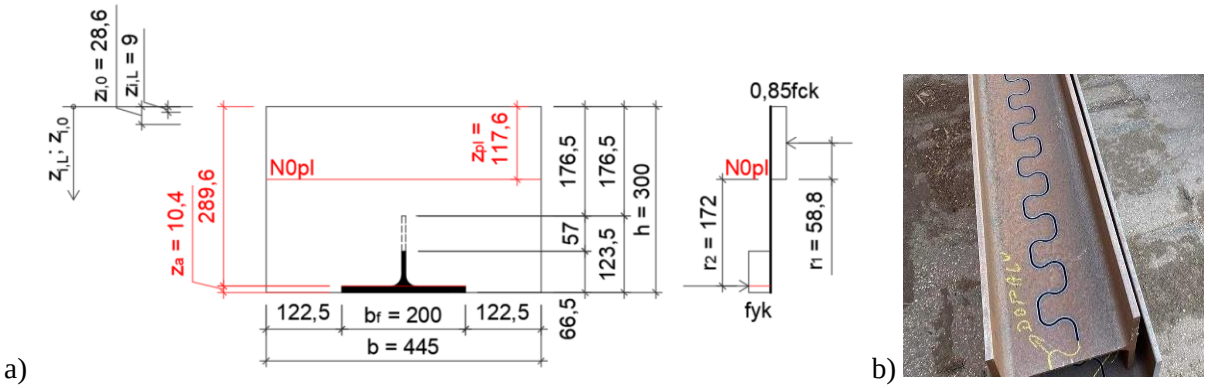


Figure 6: a) Characteristics of one composite beam, b) the H-beams with puzzle shaped cut, before separations (measurements in mm)

The railing of the bridge is designed as steel. The railing is anchored to the monolithic reinforced concrete ledge 0.2m from the outer edge. The cornice is anchored to the supporting structure by means of bow ties as stated in VL 4 (Sample sheets 4 of the Slovak Road Administration). The cornices are designed monolithically with a cornice prefab made of polymer concrete with a width of 40 mm and a visual height of 0.55 m.

The drainage of the new bridge structure is designed based on the existing condition. The bridge is designed with a longitudinal slope of 0.5% towards Kostolna Street. At the end, it is necessary to create a drainage channel and ensure the drainage of rainwater.

4.2 Construction

During the construction process it will be necessary to fully support the deck of the existing structure, which will serve as a formwork. After the construction will be finished, the original steel-concrete deck will only support its own weight. To prevent any unwanted connection between the existing deck and the new deck, it is necessary to create a hydro isolation layer in between the two decks. Also, it is necessary to leave a sufficient expansion joint filled with flexible material at the ends of the bridge to allow volume changes of the bridge.

Before the opening of the bridge, traffic signs limiting the maximum weight of the vehicle (3.5 tons) will be placed at its entrance.

5 Conclusion

This paper presented the diagnostics and reconstruction of a pedestrian bridge in the Slovak village of Čečejovce. Based on the results of diagnostics, the new bridge deck was designed. It included a continuous shear connector with puzzle dowel connection. This type of shear connector is not traditionally used in Slovak steel-concrete composite bridges.

Also, the new innovative solution for bridge structures that no longer meet the requirements for their use or are in bad technical condition was described. The solution brings advantages such as lower financial expenses as well as quicker, easier and more environmentally friendly construction process.

Unfortunately, after the problems with the construction company, in 2023 the investor decided to change not only the company, but also the design of the new bridge. The new road bridge, built in December of 2023, has an steel orthogonal deck. This type of solution is very common in Slovakia, and uses a large amount of steel, which typically increases the price of the bridge.

Acknowledgments

The paper has been supported by The projects: VEGA 1/0172/20 “Stress and deformation analysis of load-bearing components made out of steel, glass and compo-site materials“ of the Scientific Grant Agency of the Ministry of Education, science, research and sport of the Slovak Republic and the Slovak Academy of Sciences and by the project Slovak Research and Development Agency under the contract No. APVV-15-0486 “Analysis of Shear Connection Influence in Bridges with Encased Beams”.

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