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# DESIGN OF A PEDESTRIAN BRIDGE ON THE DISPLACED RIVERBED OF THE ĆEHOTINA RIVER IN PLJEVLJA, MONTENEGRO[**]

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***Abstract***

*This paper aims to review the design of a pedestrian bridge on the displaced riverbed of the Ćehotina River in city Pljevlja. The footbridge is intended for pedestrian and cyclist traffic. The design of the pedestrian bridge is part of the Main Design of Bridges on the Displaced Riverbed of the Ćehotina River. The paper describes in detail the bridge design, the choice of a static calculation software, as well as which standards were used for dimensioning the elements and adopting legally prescribed bridge dimensions.*

***Keywords:*** *bridge, pedestrian bridge, Ćehotina, riverbed, standards*

## 1 INTRODUCTION

A bridge is a construction object built to cross natural and artificial obstacles. The purpose of a bridge is to enable people and vehicles to cross them. Bridge design is a complex construction and technical undertaking, which must meet many requirements, not just the technical solution of its supporting structure [1]. Bridges are key to the development of infrastructure and often play a significant role in the economy, connecting regions and facilitating everyday life. In addition to functionality, bridges often become symbols, and some of them are also known for their aesthetic design, historical significance or engineering achievements.

Bridge construction requires precise planning, engineering, selection of materials and labor, so that the bridge is safe and long-lasting. Bridges, like all other construction projects, must meet the requirements of quality, durability, functionality, cost-effectiveness, aesthetics and ecology, that is, environmental impact. To successfully solve such requirements, one must have a wide range of knowledge, and in the case of larger and more complex projects, it is necessary to involve a larger number of experts in different specialties [2].

These requirements are often mutually contradictory and must be harmonized through compromise. Problems of designing and constructing civil engineering structures are an integral part of bridge construction. Therefore, knowledge of various disciplines

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is necessary in order to achieve reliable, durable and economical structures. When designing bridges, it is necessary to decide on the type of bridge, the choice of materials, the method of construction and maintenance [3].

## 2 LOCATION OF THE PEDESTRIAN BRIDGE

The strategy for further development of coal exploitation in the Pljevlja Basin from the Potrlica - Kalušići open-pit mine envisages the relocation of the Ćehotina riverbed across the levels of the internal landfill. After the formation of the internal landfill at the "Potrlica" open-pit mine at an elevation of 760 meters above sea level, the Ćehotina river is planned to be returned through the exploitation field of the Mine. A watertight channel to direct the Ćehotina river is planned to be constructed through the disposal area with a total length of approximately 2.9 km, from the position of the "Durutovići" dam to the bridge at the waterfall of the exit portal of the Velika Pliješ tunnel (elevation 750 meters above sea level) near the sedimentation tank, at the exit from the exploitation field of the Mine.

As part of the relocation of the Ćehotina river, a pedestrian bridge crossing (hereinafter referred to as the footbridge) is planned in Pljevlja. The footbridge is intended for pedestrian and cyclist movement. The beginning of the bridge is at km 1+530, as shown in Figure 1.

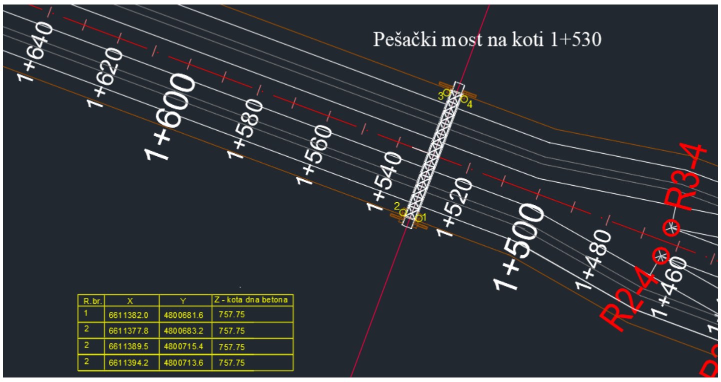


**Figure 1** *Situation plan showing the bridge on the displaced riverbed of the Ćehotina River*

## 3 DESCRIPTION OF THE PEDESTRIAN BRIDGE

The width and height of the pedestrian bridge were determined based on the condition that two rows of cyclists can easily pass one another. The footbridge is intended for pedestrians and cyclists [4]. The width and height of the footbridge were determined based on the condition that two rows of cyclists can be found on it (Figure 2). For this reason, the width and height of the bridge were adopted as 3 m, while the length was conditioned by the width of the canal that it must bridge, without the support foundation encroaching on the canal profile. The dimensions of the transverse profile of the pedestrian bridge were adopted in accordance with the Manual for Road Design in the Republic of Serbia [4]. The exact location of the bridge was defined together with the Investor. In this way, the location was defined on the ground, the microlocation (situation) and the longitudinal profile of the bridge were recorded.

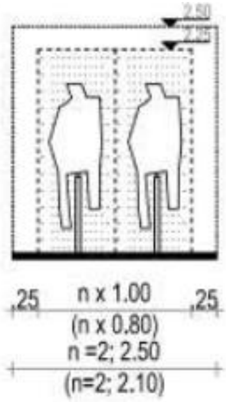


**Figure 2** *Section of the bicycle path [1]*

The bridge structure is steel, prefabricated and rests on two foundations of a movable and immovable support (Figure 3). The steel spatial lattice above the Ćehotina river channel has a span of l = 36.0 m. The structural elements are standard rolled profiles in welded construction, and prefabricatedly connected on site, so that the dimensions of the segments do not exceed 12 m. The steel structure is constructed in the intended vertical lattice segments, 4 segments 6 m long and one, central, of 12 m, which are interconnected by prefabricated extensions. The assembly is planned with a truck crane. The first and last frames of the bridge are prefabricated, made in the workshop, welded and placed on the supports. The supports are dimensioned to absorb horizontal and vertical forces [5]. A layer of waterproofing is planned over the concrete slab, and then the production of cast concrete, which has a transverse slope of more than 1%.

**Figure 3** *3D view of the pedestrian bridge on the displaced riverbed of the Ćehotina River*

Static and seismic calculations of the steel structure of the structural elements were performed in the program "TOWER 8" - a static analysis program. Static influences were calculated according to the first-order theory. Seismic influences were calculated according to EN - Equivalent static load for the VIII seismic zone with a realistic distribution of masses. The structural design shows a table of materials, sets of beams with dimensions, the position of all loads acting on the structure, M, T, N diagram for relevant combinations, stress and stability control of the main structural elements. Dynamic analysis was performed in accordance with EC recommendations [5].

Dimensioning of steel elements is performed for the most unfavorable influences - the relevant combination for bending, torsion and shear. Dimensioning is shown separately for each element of the main structural beam, for relevant load combinations according to the current standards for steel structures. For the corresponding rods, deformation control was performed, stability control for rods exposed to pressure and bending, tension and bending, stability control for lateral buckling, control of parallel stresses and permissible deflections. The calculation of connections for relevant influences was performed in the IdeaStatica program.

Foundation T1 on the left bank of the relocated Ćehotina River accepts reactions from the fixed bridge support at the level of +759.25 m, is founded in a landfill formed in the previous period and has dimensions B/L=500/400cm. The foundation elevation is at +757.75 m, and the excavation elevation is +756.50 m. The calculation model is designed so that the relevant horizontal forces (primarily the combined forces that occur due to the lateral effect of the wind) are transferred to the concrete foundation via dowels. Foundation T2 on the right bank of the displaced Ćehotina River accepts reactions from a frame that is hingedly supported on a reinforced concrete foundation at the level of +759.25 m. It is founded in a landfill formed in the previous period and has dimensions B/L=500/210 cm. The foundation elevation is at +757.75 m, and the excavation elevation is +756.50 m. The calculation model is designed so that the relevant horizontal forces are transferred to the foundation by friction between the bearing plate and the dowel and via the anchors.

Soil replacement to a depth of 1 m is planned under the foundation. At the excavation bottom elevation of +756.50 m, the subsoil is compacted to Ms=20 MPa and the existing soil is further replaced with crushed stone in layers of 20 cm with compaction, so that the compressibility modulus at the foundation elevation of +757.75 m is 50 MPa. After excavation and compaction, a geogrid is placed in the foundation pit to strengthen the soil and prevent uneven settlement, and a 15 cm protective layer of gravel is placed over it, followed by a 10 cm layer of lean concrete. It is mandatory to install markers on the bridge piers immediately after concreting in order to monitor soil settlement and deformation of the structure.

## 4 CONCLUSION

This paper presents the design of the pedestrian bridge on a displaced riverbed of the Ćehotina River. The design process itself was a complex construction and technical undertaking that required numerous requirements to be met. First of all, the dimensioning of the steel elements was carried out for the most adverse impacts in order to ensure their reliability.

The use of the static calculation software, the calculation of connections, as well as the drawing and modeling software significantly facilitated the design process. All standards were met during the design, both in terms of bridge dimensions and static requirements and anti-corrosion protection. On the other hand, the aesthetic aspect of the bridge was also met, which in the near future may become a symbol of the location.

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