Conceptual Design of a UHPC Footbridge in the City of Villach in Southern Austria

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Abstract. *Ultra-high performance concrete (UHPC) has many advantages compared to other building materials if it is used in a proper way. To show the potential of UHPC for slender constructions, the purpose of this work was to design a UHPC-footbridge as an alternative structure to an existing bridge crossing the river Drau in the city of Villach in Southern Austria. The new bridge is a box girder bridge, constructed from fibre reinforced UHPC combined with internal and external post-tensioning. The calculation is based on the final draft of the new Austrian guideline for UHPC, the final version of which has since been published in 2023.*

Keywords. UHPC, ultra-high performance concrete, UHPFRC, ultra-high performance fibre reinforced concrete, steel fibres, prestressing, post-tensioning, footbridge, box girder

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1 Introduction

The compressive strength of Ultra-high performance concrete is 3 to 5 times higher compared to Normal Strength Concrete (NSC). Ductility and post-cracking tensile strength can be reached by the addition of steel fibres [1]. Prestressing or post-tensioning makes it possible to take full advantage of the concrete's compressive strength. The design of slender structures with a minimized self-weight can be reached with UHPC in combination with prestressing or post-tensioning and / or conventional reinforcement. This approach leads to a reduction of needed resources for associated structures, transport and storage as well. Considering the whole life cycle of UHPC, the material has the advantage of a long durability and robustness while the effort of maintenance is low.

UHPC is used as a common building material in many countries worldwide already. In Europe, France was one of the first countries implementing a national standard to regulate the usage of the material. Missing standards and regulations for UHPC in Austria lead to low usage and difficult structural application of the material. The design and calculation as well as the manufacturing and handling of UHPC are significantly different from Normal Strength Concrete (NSC). Therefore, it is important that engineers have the correct design codes and guidelines available. The first guideline for design and construction with UHPC in Austria has been published recently. This will make the application of UHPC finally easier for designers, for manufacturing companies and for contractors.

To figure out the potential of UHPC and the applicability of the new Austrian guideline for a long-span footbridge, an alternative to an existing steel bridge in the city of Villach, Southern Austria was designed. The bridge over the river Drava has to span a length of nearly 90 metres. The conceptual design is based on the valid European and Austrian design codes as well as on the final draft of the Austrian guideline for UHPC ("Österreichische Richtlinie UHPC") [1].

2 Conceptual Design

A box girder was chosen for the cross-section of the UHPC footbridge, according to the hollow box steel cross-section of the existing bridge. The chosen cross-section has also the advantageous characteristics against torsional effects, which was a fundamental requirement for the bridge. During events in the city, as for example a yearly firework, crowds of people may gather only on one side of the bridge, which results in high torsional forces in the structure. The dimensions of each part of the box girder were calculated separately and in a step by step iterative process. This resulted in a 2.75 metre high cross-section, with a bridge deck thickness of 12.5 cm, a bottom plate and box walls with the thickness of 10 cm, illustrated in Fig. 1. Compared to Normal Strength Concrete, where the dimensions would be at least between 20 and 25 centimetres according to the current regulations [2], about half as much material is needed by volume.

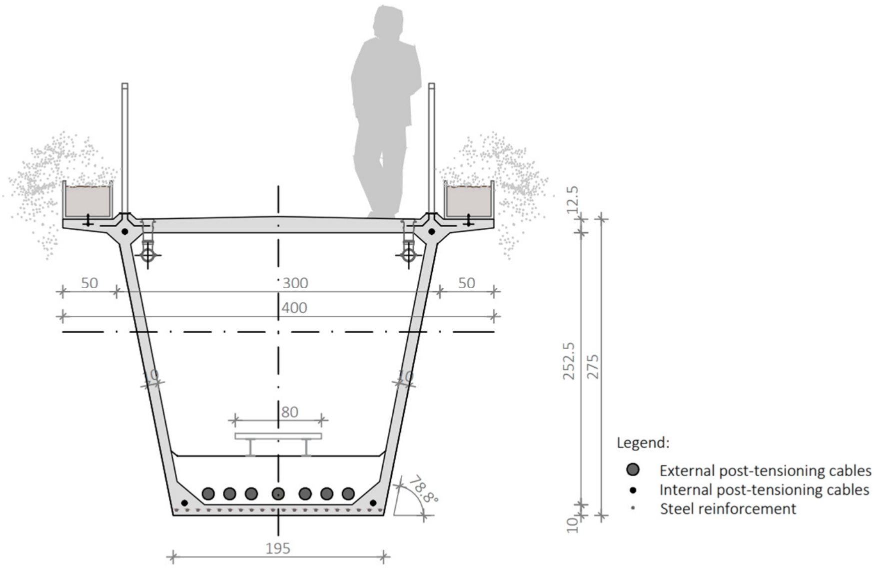

Figure 1. Cross-section of the bridge in the middle

To deal with the high positive mid-span moments of the bridge caused by the dead load and the required traffic load, post-tensioning has to be implemented into the construction. The post-tensioning is achieved on the one hand by four horizontal internal steel cables and on the other hand by seven external steel cables. One external cable is routed horizontally, while six cables are routed in a polygonal shape, following the main bending moments. The bridge can be prefabricated from several parts that can then be transported. On site, they can be connected with the internal post-tensioning cables. Afterwards, the external post-tensioning can be installed and then the whole bridge can be moved into its final position. The achieved span-to-height ratio of 31.5 is outstanding for a single-span bridge made of concrete. The bridge deck is slightly inclined in the shape of a roof, with the highest point in the middle of the deck to drain the water, which is then collected by pipes inside the hollow box girder.

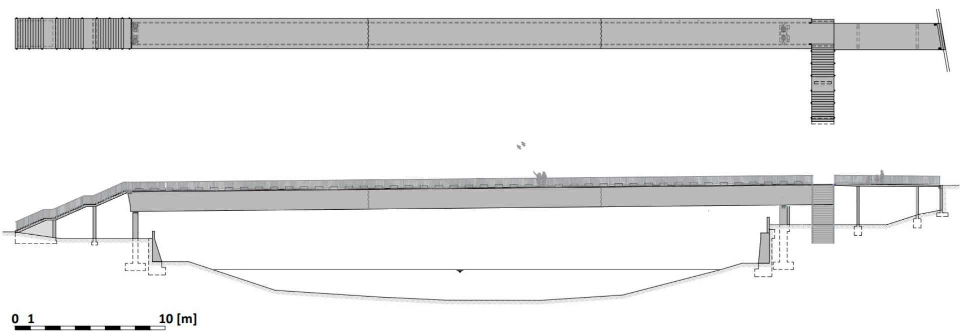

Figure 2. Top and side view of the bridge

3 Conclusion

The conceptual design of a long-span footbridge based on the new, recently published Austrian guideline for ultra-high performance concrete was successful. It has been shown that the material can be used to span large distances while keeping the dimensions of the various bridge sections such as the deck, the walls and the bottom plate of the box girder extraordinarily slender. It was also possible to reduce the height of the cross-section of the UHPC bridge compared to the mid-section of the original steel bridge by 15 %, thus achieving a span-to-height ratio of 31.5. The lower amount of material required can lead to a reduction in CO_2 emissions as well, despite the large amount of cement needed for UHPC. There is also a big difference in the dead load between both constructions. The alternative bridge is 37 % lighter than the existing steel bridge. In practice, this would in addition have a positive effect on the dimensions of the supports, which would have to bear less load.

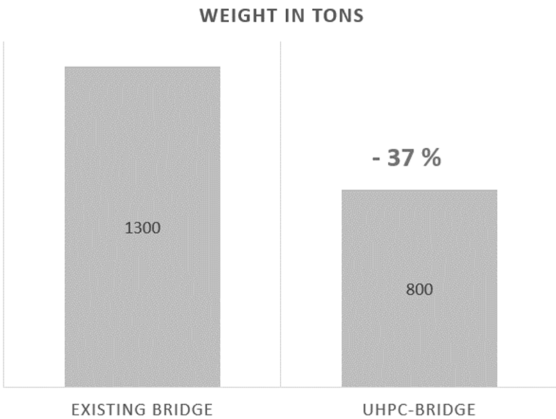

Figure 3. Comparison of the construction weight of both bridges

The work has shown that UHPC is already a promising high-strength material that can be used to design complex long-span structures based on the existing design codes. In practice, some research on certain applications is still needed, as well as companies that are prepared to work with UHPC. A first step towards was the publication of the Austrian UHPC guideline.

References

[1] *Richtlinie UHPC – Gründruck*, Österreichische Bautechnik Vereinigung (ÖBV), October 2022.

[2] *ÖNORM EN 1992-2, Eurocode 2: Design of concrete structures – Part 2: Concrete bridges – Design and detailing rules*, Austrian Standards Institute, March 2012.