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FOOTBRIDGE ACROSS LITAVKA RIVER, BEROUN. DESIGN BASED ON VIBRATION EIGENFREQUENCIES AND EIGENMODES

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Introduction

The proposed structure is supposed to bridge Litavka river near Beroun city center, allowing the city to expand its parks and leisure time areas to the river's so far inaccessible right bank. A 37 m single-span structure from architectural bureau HABE was chosen. It combines two usual building materials – glulam timber and steel into unique structure. This design respects existence of another nearby footbridge, massive glulam arch structure, being more subtle while crossing longer span. This subtlety brought lack of stiffness indeed, resulting in very low first eigenfrequencies and critical load. The structure required to be redesigned, in terms of structural engineering, but also keep its original visual appearance.

Description of original structure

The main load bearing elements of the original design are two 37 meters long arch-shaped trusses positioned on both sides of the footbridge. The truss girders are curved both in different radii and are made of glulam timber, rectangular cross section. The diagonals are round steel pipes. The wooden slab walkway is situated in the level of bottom girders' top surface, following their curvature. The superstructure was originally intended to be lodged directly on the concrete substructure.

All the features mentioned above turned out to be problematic: the subtle superstructure being too vulnerable to vibration yet the walkway too rigid and stiff and lodged without any bearings directly to the substructure. The first eigenfrequency was about 2.2 Hz, right in the step frequency interval (1.6 ÷ 2.4 Hz) with eigenmode representing lateral vibration with cross section deformation. The critical loading ratio for characteristic load combination was only about 4, which meant the structure is vulnerable to stability loss.

Modification of the original design

First of all, the superstructure supports were changed to elastomere bridge bearings promising better static function and longer serviceability of the structure. Then original wooden

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walkway was replaced by steel one, yet plated with wooden sheets to maintain its visual appearance for users. It was possible to place the walkway in between the bottom girders not disturbing the side view of the footbridge anymore.

The biggest changes were made to the superstructure itself. Original design allowed the main trusses to tilt freely around horizontal axis due to lack of any cross section stiffening. Many variants of cross section stiffening were judged and finally multiple U-shaped frames were chosen. Every in-plane truss diagonal works as out-of-plane stiffener strut, supporting the top girder in lateral direction. The bottom tie beam of the stiffener is also a part of horizontal stiffener and as non-visible member is made of an I-beam.

Finally, the joint of the horizontal and vertical member of the cross section stiffeners had to be designed. It had to be stiff enough to act as frame cornet and also not violating the walkway profile. The complicated design resulted from its three dimensional function, joining six members in three different planes: wooden main truss bottom girder, steel diagonals of horizontal stiffener and tie beam and two struts of cross section stiffener, altogether with technological demand of being welding free since wooden elements were connected to this joint.

Eigenmode based design

For every variant a calculation of eigenmodes has been done on 3D FEM model in FEAT 3.0 software. The frame cornet stiffness was taken into account by calculating its torsional stiffness using shell model of symmetric half of one pair of stiffening frames with common tie beam. This calculated stiffness was introduced to the global FEM model and eigenmodes were calculated.

Conclusions

The original design was revised in terms of structural engineering. The excessive vibration under pedestrian loading was probably avoided and general increase in structure serviceability and reliability was reached. Visual appearance of the structure was not affected by the undergone structural changes, furthermore, is valued as more appealing by the author of the original design.

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