New Bridge over the Sava River on the Location of Old Sava Bridge in Belgrade – Bridge Superstructure

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DOI: https://doi.org/10.14459/icbdb24.40

Abstract This paper describes the design of the New Sava bridge, that is planned to be built on the place of the Old Sava bridge in Belgrade city center. Focus is on the Building permit design phase of the bridge superstructure, including the future development of the design, related to the bridge construction. The New Sava bridge shall be 420m long, with 166m main span over Sava River navigation profile. The superstructure of the bridge is designed as aesthetic, innovative continuous composite girder, supported with two asymmetric arches in the main span. The influence of the input parameters on the bridge design, structural detailing and calculation modelling in relation with the adopted methodology of execution are also presented.

Keywords: New Sava Bridge, Old Sava Bridge, bowstring arch, composite structures, steel structures

1 Introduction

New Sava Bridge Project started in 2020 as a Design-Build contract between the Republic of Serbia and the Chinese company PowerChina International, for the building of the new, modern bridge with the higher capacity at the same location of the Old Sava Bridge. The New Sava Bridge is intended to increase road traffic capacity between two city parts over the Sava River and provide better communication for the new part of Belgrade on the right bank-Belgrade Waterfront, defined by the Special purpose area spatial plan (see Figure 1 and Figure 2). For the design works in this contract, a joint venture is formed consisting of: Millennium Team Belgrade, Mostogradnja Ing Belgrade, Faculty of Technical Science Novi Sad and IO Design Enterprise Belgrade. The scope of the design works involves the Building permit and Execution design phase for the following major parts: 1. Demolition design; 2. Design of the New Bridge; 3. Design of the Approach Structures and 4. Design for the working plateau. The superstructure represents the most complex part of the New Bridge design, impacting design and execution works in the most significant way.

Figure 1: Panorama of the new city quarter with the New Sava bridge (courtesy of Belgrade Waterfront Serbia)

The Project is based on the competition design solution and Preliminary design done by the Institute of Transportation CIP Belgrade [1] and the Employers Requirements [2] issued by the Investor-Belgrade Land Development Public Agency.
At the current state of the Project, the Building Permit design phase [3] is finished and approved for all major parts, design for Execution is currently in progress, and preparatory execution works started at the temporary working plateau at the left riverbank (see Figure 3). Design is developing following the Contractor's methodology of execution, where all construction phases are considered throughout the structural design and the graphical documentation is in line with the assembly parts that are to be shipped from China. The entire Project is based on European standardization for design and execution.

1.1 Old Sava Bridge

Old Sava Bridge (see Figure 5) is the war bridge, built in 1942, by the German Reich, purposed to maintain the connection over the Sava River in Belgrade, when it was interrupted by the demolition

Figure 2: Night view of the new bridge in the new city quarter (courtesy of Belgrade Waterfront Serbia)

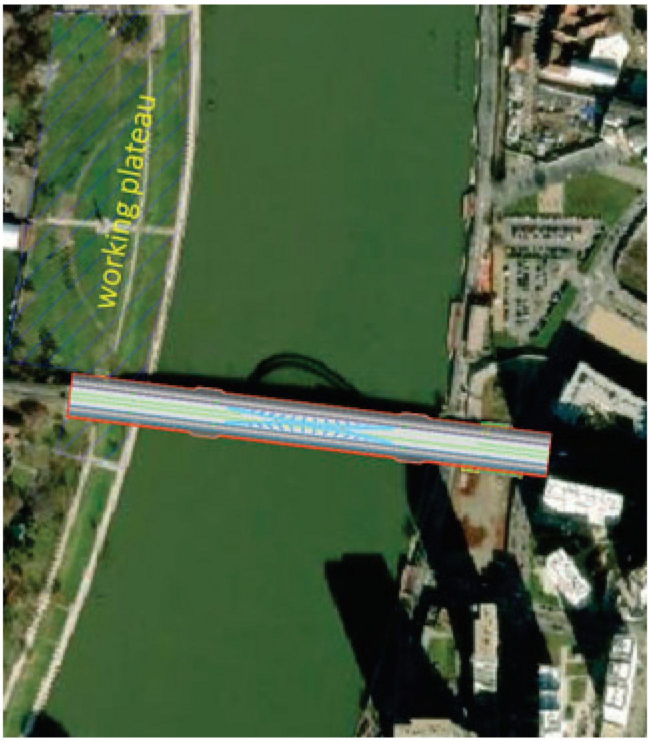

Figure 3: Bridge location and the arrangement of the working plateau

of King Alexander Bridge. The bridge has been built as a temporary structure for military transport. The structural system of the old bridge consists of a steel continuous beam with riveted connections. The Old Sava Bridge has seven spans with the arrangement: 41.3+53.1+53.1+106.2+53.1+53.1+41.3 = 401.2m, where the main span is designed as bowstring arch with vertical hangers. The bridge has been repaired and/or reconstructed on multiple occasions (1954,1966,1972,1983 and 2007) due to the consequences of the bombardment, intensive traffic and the adoption of tram traffic on the bridge. Everyday traffic over the bridge causes unacceptable noise and vibrations, accompanied by additional problems related to the functionality of the existing light steel bridge deck, thus there is an imminent need for mitigation of these effects. Considering the current state of the steel structure, piers and foundations, adequacy for the new demands regarding river navigational profile, old steel material, and capabilities of further repairs and reconstructions of the carriageway structure, total demolition of the old bridge has been decided.

Figure 4: Old Sava Bridge at present

1.2 New Bridge Disposition

The total length of the New Bridge (axial distance of the piers and abutments) is to be L=420,0 m, with the arrangement of the spans L=54,0+73,0+166,0+73,0+54,0=420,0 m. The main span of the bridge is designed as the twin bowstring network arches in an asymmetric arrangement (see Figure 5). The total width of the bridge is to be B=38,1m (at the expanded parts of the bridge deck B=43,4m, see Figure 6). The bridge traffic profile consists of two 6.5m wide road traffic lines, two tram tracks in the middle of the deck and two 3.6m wide pedestrian and bicycle lanes that are expanding for additional 2,5 meters at the location of the observation decks. The bridge shall carry significant city installations including high-voltage cable.

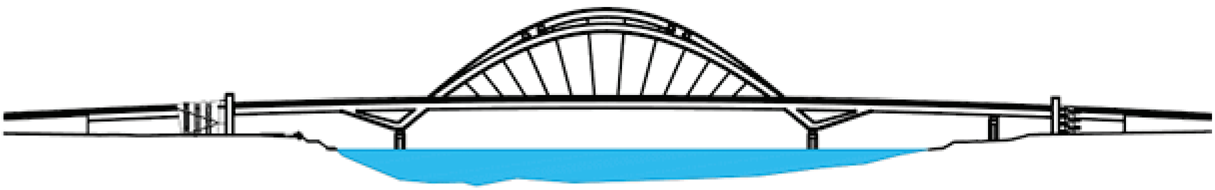

Figure 5: Appearance of the bridge

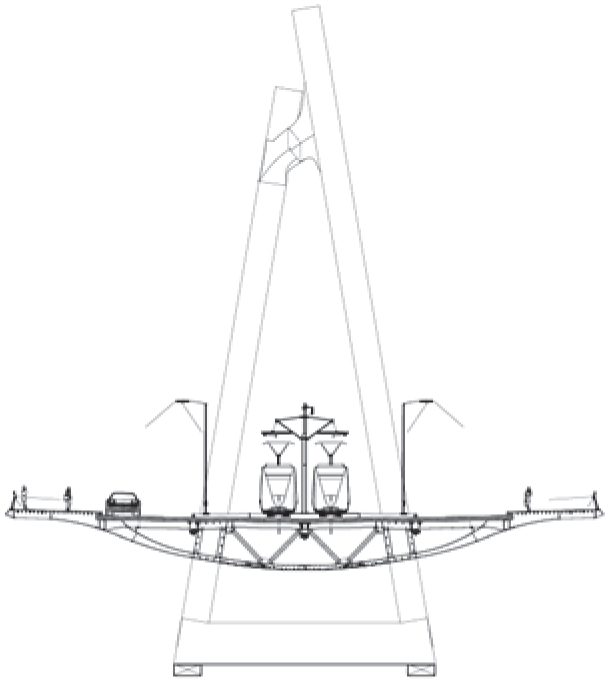

Figure 6: Cross section of the bridge

2 Bridge Superstructure Elements

The bridge superstructure consists of continuous carriageway structure spanning all over the length of the bridge with constant depth and the tandem of arches, hangers and struts that support the main span. Road and tram traffic are carried by the 250mm thick concrete slab, while the deck of the pedestrian part is adopted as steel orthotropic plate. An embedded rail system in the floating slab over the bridge slab is adopted for the tram track. Between two slabs, a sound and vibration isolation layer will be installed. Concrete slabs are designed as cast in situ, in two phases: first, where the portions outside the shear connectors zones are executed and the second, where the connection with the steel structure is established. Cross girders are arranged at a 6m distance. The carriageway structure transfers loads in the perpendicular direction to the bridge Main beams/Ties which are parts of the main structural system together with the arches, struts and hangers (see Figure 7). The bridge shall have 24 hangers, 12 per arch, located in its plane, with converging arrangement. Hangers are designed as parallel strand system (PSS) with pin connection anchors.

Main beams/Ties are continuous box shape girders, suspended on hangers in the main span at a 9 meters spacing, while on the other spans supported on the bridge piers. Arches are rectangular box sections h/b=3/2m, (see Figure 9) spanning 166m in asymmetric configuration, connected at span thirds with the unique joint elements in order to increase rigidity of the system. Entire Superstructure is modelled and graphically developed in software package Autodesk Advance Steel.

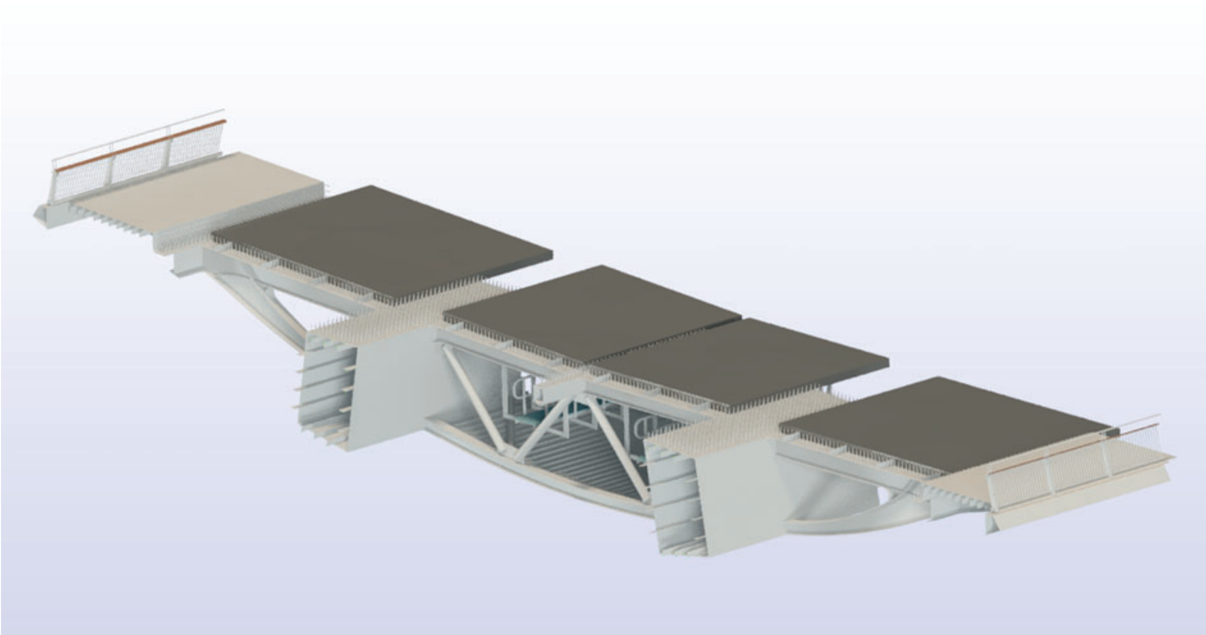

Figure 7: Carriageway structure segment

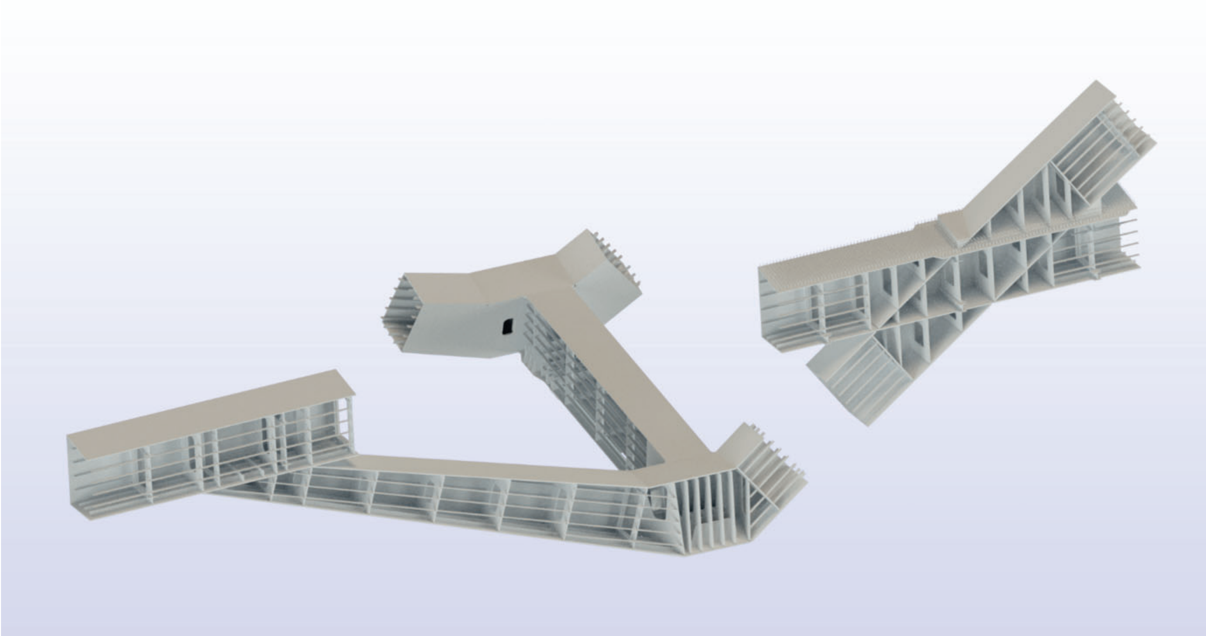

Figure 8: Complex intersection of main elements of the structure at the location of the main support

3 Calculation Modeling

For the purpose of the calculation, sets of global and local models are developed to fully obtain results of the complex behavior of the structure, covering geometry specifics, non-linear staging, time-depending effects, types of loading, local stressing factors etc. As previously mentioned, special attention is given to the methodology of execution, hence there is a significant portion of

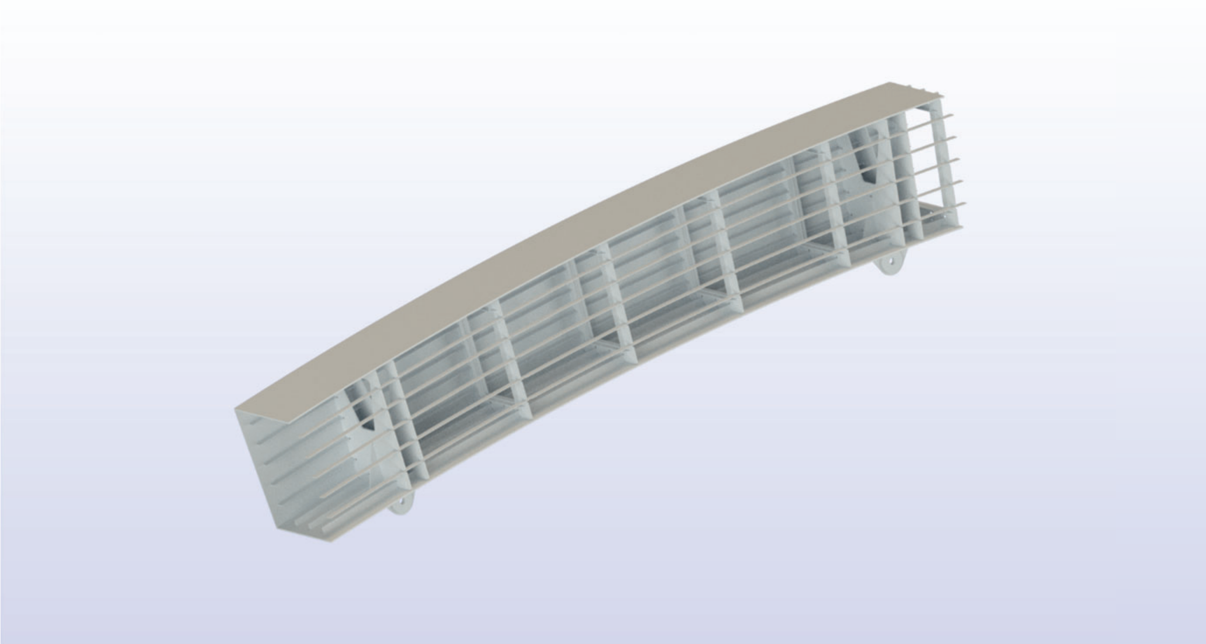

Figure 9: Assembly part of the arches

stressing that comes from the permanent loads, thus history of loading as well (see Figure 10 and Figure 11). Nonlinear staged calculation is conducted in software package CSI Bridge considering temporary supporting of the structure during assembly, phases of the hanger pretension and other effects of the execution.

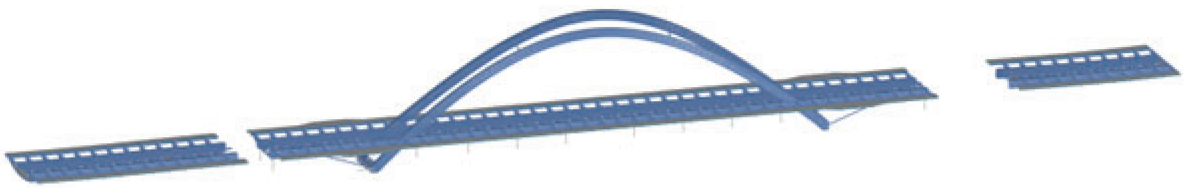

Figure 10: Global calculation model for the one phase of the execution

4 Execution Methods

To achieve the desired aesthetic appearance and to mitigate the effects of the shrinkage and the concrete slab interactions in the tensioned portions of the carriageway structure, non-standard design solutions have been adopted for the superstructure. To achieve two-step concreting of the concrete slab, a special methodology has been developed that accommodates all benefits of the solution. A moving scaffolding will be mounted on multiple locations of the carriageway structure to complete the first phase of concreting to minimize execution time (see Figure 13).

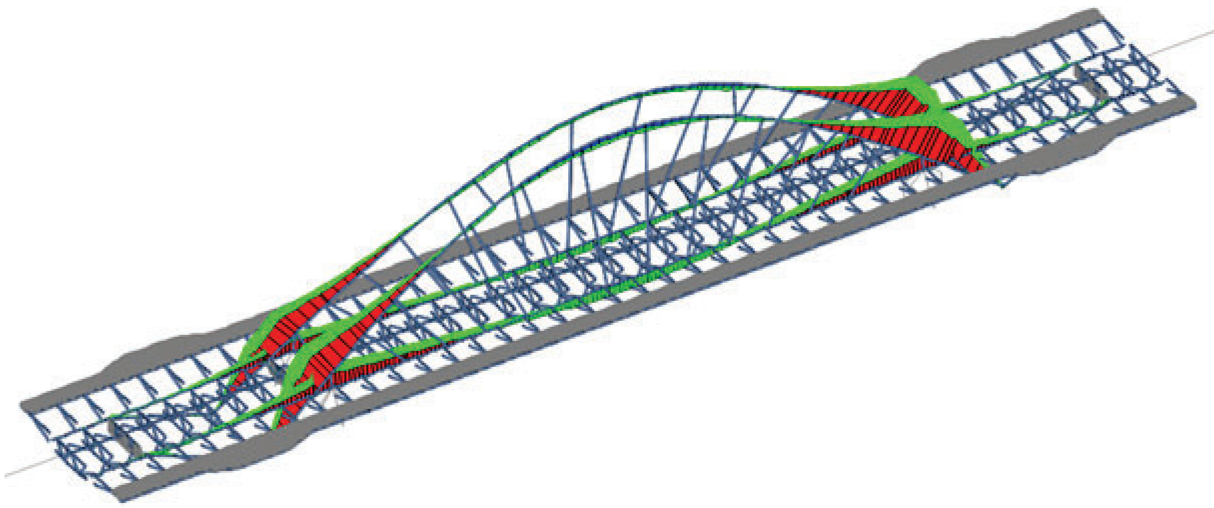

Figure 11: Global calculation model for the phase of transport of the mains span with barges

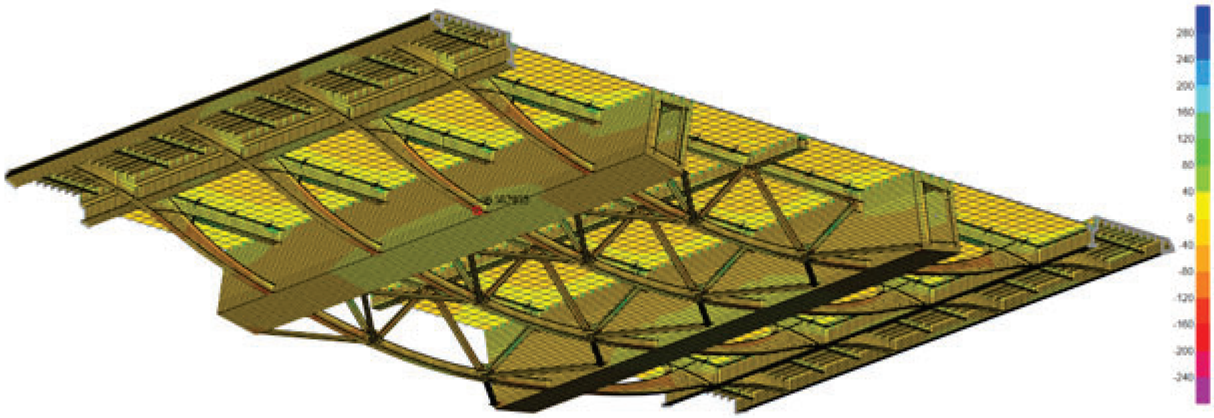

Figure 12: Local model of the carriageway structure

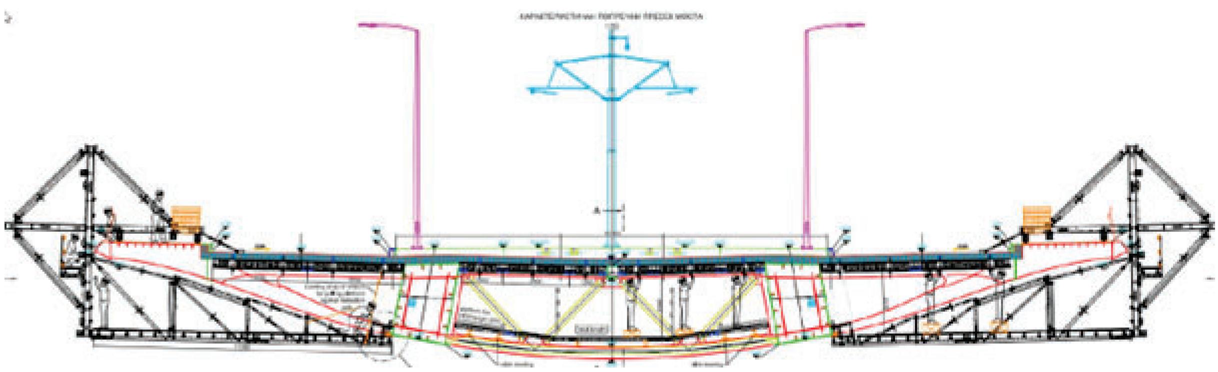

Figure 13: Scaffolding for the execution of the bridge slab

Design of the temporary support structures on the working plateau is in progress as well (see Figure 14), providing input data for the working plateau design and defining assembly parts for the Superstructure. Technical measures are provided to maintain the geometry of the Superstructure main span during the assembly process, thus eliminating the influence of uneven settlements.

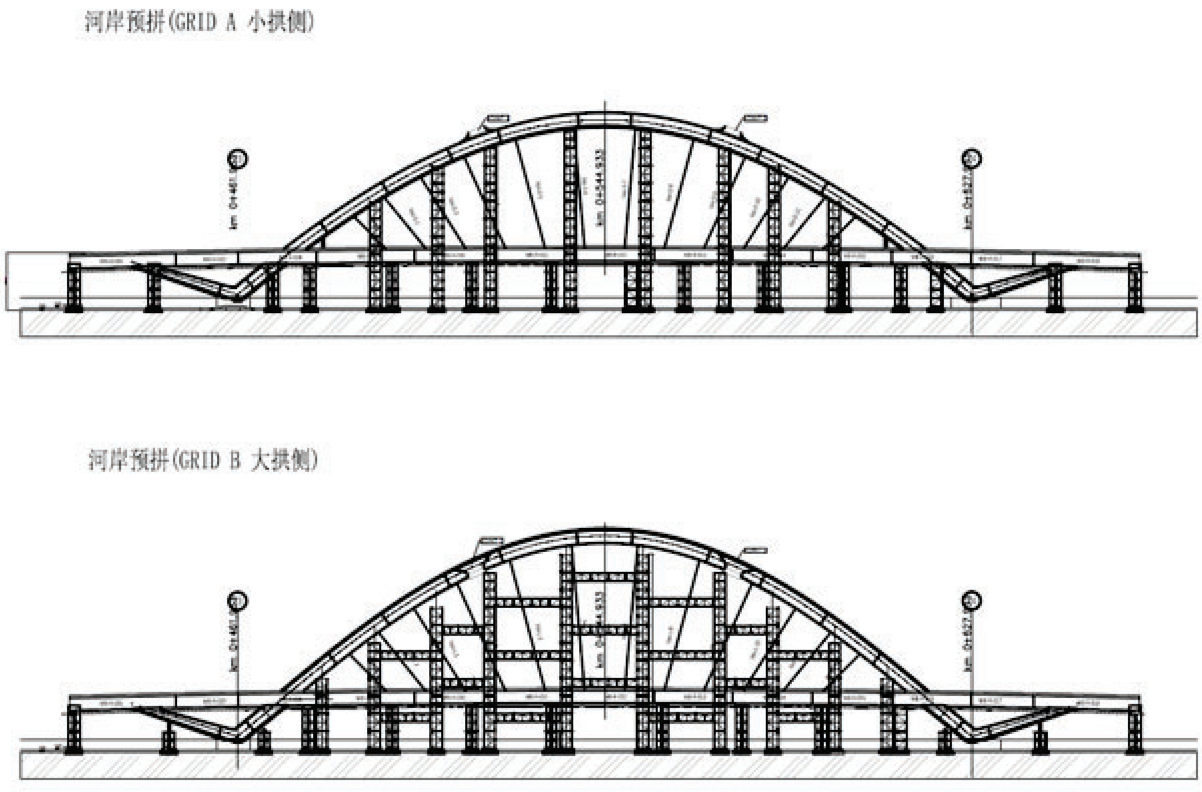

Figure 14: Arrangement of the temporary supports at the working plateau

5 Conclusion

The New Sava Bridge Project is one of the most important projects that is currently developing in Sebia and shall represent significant landmark of Belgrade city center after the completion. The Main Contractor PowerChina International with its partners has carried out all the activities related to the preparation for the execution, including additional investigation works (geotechnical, unexploded ordinance, seismic and wind effects etc.), comprehensive methodology of execution, Building Permit design phase, solving the challenges related to building a high capacity bridge on such a demanding location, approval of the Technical control and companies of public interest and finally opened temporary building site on the left Sava bank. In the following period, intensive construction works are expected, after the approval of the Design for Execution, the completion of the working plateau, and the demolition of the old bridge.

6 References

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