The Construction of the New Kalocsa-Paks Danube Bridge

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Abstract The Kalocsa-Paks Danube Bridge is a significant infrastructural project in Hungary, designed to enhance regional connectivity and economic development. Spanning 946 meters across the Danube, this bridge connects the towns of Kalocsa and Paks, providing a vital link for transportation and logistics.

The bridge consists of three separate structural parts, 2 floodplain bridges – length of 506 meters - and the first extradosed Danube riverbridge in Hungary – spans 440 meters. Designed to support both vehicular and pedestrian traffic, the bridge features a main span of 200 meters and a width of 22.5 meters, accommodating multiple lanes and walkways.

The construction incorporates high-strength steel and reinforced concrete, ensuring structural integrity and longevity. The height of the river bridge's pylons is only 21.8 meters, which took part in the load bearing during the cantilever assembly with 80 extradosed cables. At the same time, the incremental longitudinal launching of the flood plain bridges took place.

The bridge design emphasizes sustainability, with measures to minimize environmental disruption during and after construction.

Upon completion, the Kalocsa-Paks Danube Bridge will significantly reduce travel times, enhance the connectivity of central Hungary, supporting both local industries and cross-regional commerce. The technical handover has been completed, the ceremonial inauguration and opening to traffic of the first extradosed bridge on the Hungarian section of the Danube took place on June 6, 2024.

1 Introduction

1.1 The project participants

As a result of the public procurement procedure conducted by NIF National Infrastructure Development Private Company Limited (NIF Zrt.), the construction of a new Danube bridge and the related roads 512 and 5124, connecting to the surrounding settlements and the M6 motorway, was carried out by Duna Aszfalt Zrt. as the Main Contractor. The Construction Contracts came into effect on January 5, 2021, with the final completion date for the construction works set for May 31, 2024.

The project is being implemented as a state investment, with the Ministry of Construction and

Transport exercising the client rights and technical supervision. The detailed design of the bridge was prepared by CÉH zRt. and Pont-TERV Zrt., while the road designs were created by UTIBER Kft., commissioned by Duna Aszfalt Zrt.

1.2 Basic data of the bridges

The new bridge crosses the Danube River at the 1520.446 river kilometer marker. The bridge is 946.2 meters long and is divided into three sections: left floodplain bridge (220.1 m), main river bridge (440 m), right floodplain bridge (286.1 m).

The superstructures of the floodplain bridges are designed as steel box girders, while the superstructure of the main river bridge has a composite cross-section and is of the extradosed type, where the box-shaped structure is composed of steel girders, as well as lower and upper reinforced concrete slabs (flanges). The maximum width of the bridge cross-section is 19.26 m for the floodplain bridges and 23.26 m for the main river bridge. The structure stands on 10 supports, including 2 abutments, 4 floodplain piers, 2 common piers, and 2 river piers. The foundation of the bridge was implemented using pile foundations with drilled shaft support technology. Both the floodplain bridges and the main river bridge are supported by reinforced concrete piles with a diameter of 1.5 m, providing the necessary load-bearing capacity over a total length of 2230 m. The reinforced concrete piers of the substructures have pointed arches at both the front and rear, with their axes approximately parallel to the regulatory line of the Danube. Their structural height varies between 10.3 and 17.6 m. The elliptical reinforced concrete pylon reaches a height of 21.8 m above the deck level, and 10 extradosed cables are anchored on each side, totaling 80 inclined cables supporting the load-bearing of the stiffening girder over a length of approximately 4730 m.

Figure 1: Aerial view of the worksite, foto: Mihaly Erdei magyarepitok.hu

1.3 Effective design of organisation

The majority of the structure is located within the floodplain, an area of significant importance due to its Natura 2000 nature conservation designation. This designation played a crucial role during the planning phase in designing the construction technology, optimizing the size of the temporarily used areas for construction, and thereby preserving the surrounding natural assets.

Figure 2: Application of augmented reality

By utilizing augmented reality, it became possible to efficiently calculate and evaluate the assembly technologies from both technical and economic perspectives already in the bidding phase of the project. This approach significantly contributed to the detailed planning of both on-site and global organization, particularly concerning the transportation of large quantities of materials and the delivery of steel bridge elements manufactured in Duna Group's production facilities.

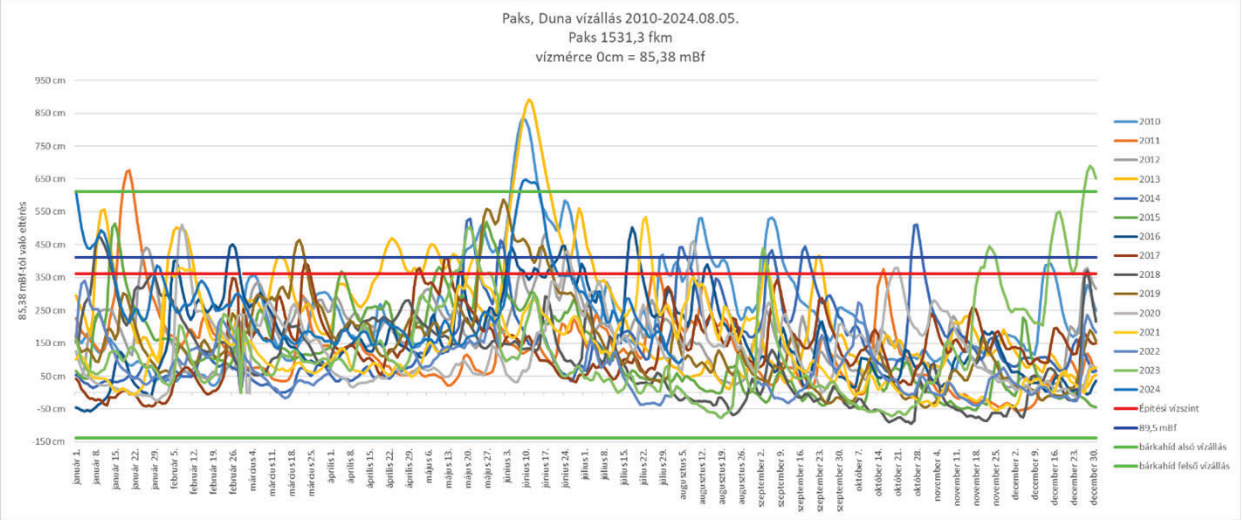

Figure 3: Analysis of the Danube's water levels over the past 10 years

In order to determine the elevation of the service roads, we analyzed more than 10 years of water level data (Figure 3), and to demonstrate feasibility from the perspective of flood management, we conducted a 2D numerical hydraulic analysis for the relevant section of the Danube, as required by the Authorities.

2 Construction of Floodplain bridges

2.1 Description of the structures

The left bank floodplain bridge (on the Kalocsa side) begins from abutment No. 1, which is to be constructed on the floodplain side of the existing flood protection embankment, extending towards Paks. The bridge is 220.1 meters long and 19.26 meters wide. The abutment, two floodplain piers, and one river pier serve as the substructure for the superstructure, with the spans of the bridge uniformly measuring 73 meters.

The structure of the right bank floodplain bridge (on the Paks side) is similar to that of the left bank floodplain bridge. It begins from abutment No. 10 and extends towards Kalocsa up to pier No. 7. The abutment is located on the floodplain side of the existing flood protection embankment. The bridge structure is 286.1 meters long and 19.26 meters wide. The substructure consists of 1 abutment, 2 floodplain piers, and 1 river pier, with the spans of the bridge uniformly measuring 95 meters.

The superstructure of both floodplain bridge sections is similarly designed: an orthotropic deck plate, parallel-flange, multi-span, continuous, inclined-web, steel box girder bridge. The primary load-bearing elements of the structure are made of S355 and S460 grade steel, with a total weight of approximately 3600 tons.

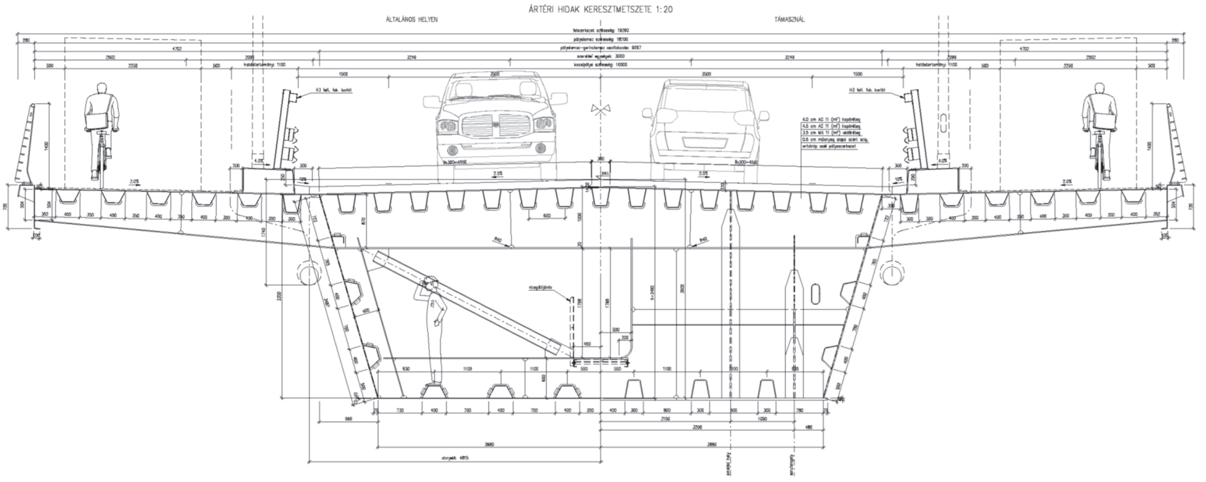

Figure 4: Cross-section of the floodplain bridges

The width of the superstructures is 19.26 meters, and the structural height—considering the deck surfacing system—is constant at 3625 mm. The lower surface of the box girder follows the longitudinal profile due to the constant web height. The distance between the inclined web plates at the plane of the steel deck plate is 9300 mm, and at the lower flange line, it is 7360 mm. The orthotropic steel deck plate is supported by trapezoidal cross-section longitudinal ribs, 300 mm high and spaced at 0.6 meters, and crossbeams, 1000 mm high, spaced at 3.65 meters. The web plates and bottom plate of the stiffening girder are reinforced by elements oriented longitudinally and perpendicularly. The two main girders are connected by truss diaphragms every 7.30 meters, i.e., at every second crossbeam. Over the supports, solid diaphragms allow the structure to be lifted, facilitating bearing replacement during construction and operation. The cantilever attached to both sides of the box girder carries the load of the bicycle path and the raised curb. The ends of the cantilevers are closed off by a 720 mm high steel curb longitudinal beam.

2.2 Manufacturing and assembly technology

The steel structures for the new bridges were primarily fabricated at the Duna Group's production plant. The scale of the work is well illustrated by the fact that over the course of more than two and a half years, we successfully delivered 5,000 tonnes of welded steel structures. With such a large quantity of raw material, maximizing material yield during cutting is crucial from an economic perspective. To achieve this, and in line with the continuously developed and tested process, we ordered the required materials in custom, project-specific dimensions, which approach enhanced material efficiency by 5-6%, resulting in hundreds of tonnes less waste for the project.

The right bank bridge divided into 13 bridge elements and the left bank bridge into 16 bridge elements, each further broken down into 8 to 10 components per cross-section. The bridge elements, treated with corrosion protection under factory conditions, were transported by road to the assembly areas established at the abutments of the respective banks.
After on-site receipt, the elements were assembled in a specially designed spatial assembly jig. The longitudinal joints were completed in three phases, moving one bridge element length forward parallel to the bridge axis in each phase. After each push phase, new bridge elements could be received in the vacated assembly jig, ensuring the continuity of construction. Once the longitudinal joints (welds) were completed, the cross-sections were joined, and in the fourth phase, the fully welded bridge section was transferred to the paint booth, where the entire structure received a corrosion protection coating and a uniform topcoat in accordance with standard requirements.
The main girders of the left floodplain bridge, weighing 1600 tons, and the right floodplain bridge, weighing 2000 tons, were moved into their planned positions using an incremental launching technique towards the Danube.

The forward movement of the continuously constructed bridge structure from the assembly area occurred on temporary trestle structures and piers built on the floodplain, using hydraulic push pads installed on them. The movement was executed by hydraulic cylinders installed in the push pads, utilizing push shoes that formed a continuous chain on top of the push pads. The bridge structures were pushed in 15 phases, 1.8 meters above the final deck level to facilitate assembly and, after moving into their final positions, to allow the removal of the push pads and lowering onto the bearings.

Figure 5: Left floodplain bridge during longitudinal launching (foto: Tamas Dernovics, magyarepitok.hu)

3 Construction of the extradosed riverbridge

3.1 Description of the structure

The superstructure of the river bridge is a three-span, extradosed type bridge with a composite cross-section, featuring a two-cell box girder that is parabolically tapered over the river piers. The main girder of the bridge is a two-cell box girder, with sloped sidewalls and a central wall made of steel trapezoidal plate girders, a bottom of reinforced concrete slab, and a top section of cantilevered reinforced concrete deck on both sides. The superstructure is constructed with a prestressed concrete deck slab, prestressed concrete bottom slab with bonded tendons along the longitudinal direction to accommodate construction and permanent loads, and internally guided unbonded tendons within the box girders to manage live load effects, according to the extradosed system. Up to 32.5 meters from the river piers No. 5 and No. 6 (up to the extradosed cable anchorage points), the height of the box girder varies, being 6.5 meters above the river piers, and 3.5 meters in the constant height sections measured along the roadway axis. The flanges are welded to the upper and lower planes of the trapezoidal plate girders. The girders are connected to the reinforced concrete deck and bottom slabs by headed studs welded onto the flanges. The cross-sectional transverse stiffness of the trapezoidal plate girder is ensured by steel crossbeams integrated with the web plates, installed every 5 meters, which correspond to the so-called construction bulk length. The upper and lower flanges of the crossbeams are also connected to the reinforced concrete deck and bottom slabs with welded headed studs.

To increase the moment-carrying capacity of the superstructure, 10 extradosed cables were installed on each side of the pylons, anchored at 5-meter intervals. Both the deck slab and the bottom slab are longitudinally prestressed. In accordance with the cantilever construction method, bonded

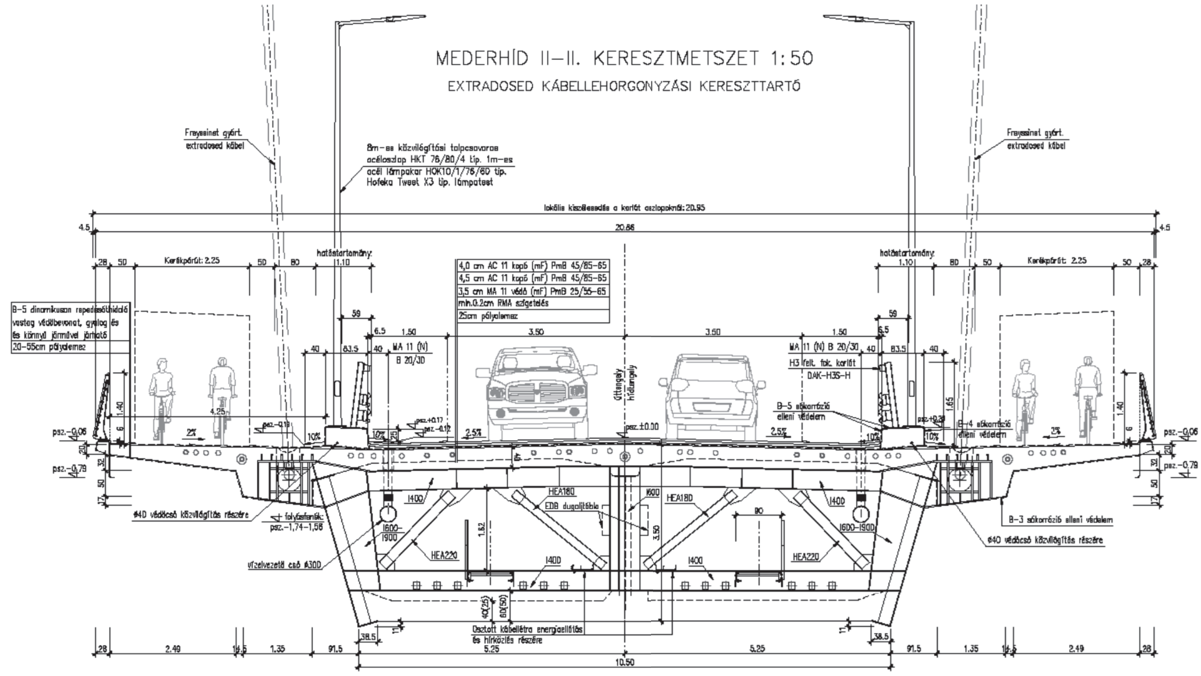

Figure 6: Cross-section of the riverbridge

tendons are placed in the upper deck slab. In the bottom slab, both bonded tendons and unbonded sliding tendons, which are guided directly above the bonded ones, are also utilized.

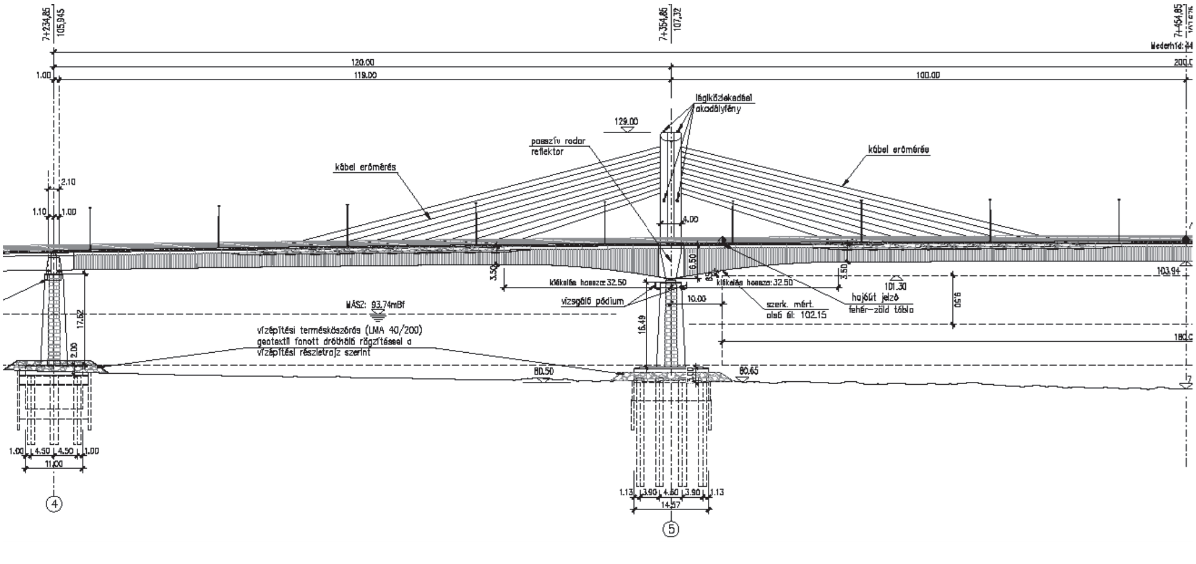

Figure 7: Sideview of the riverbridge

3.2 Manufacturing and assembly technology

The superstructure of the river bridge is divided into a total of 89 segments. The steel stiffening girders share the common characteristic of having a width of approximately 12 meters at the deck level and a trapezoidal web with a variable height ranging from 6 to 3 meters. The bending of

the trapezoidal cross-section web panels was carried out at the SSAB Poland factory in Oborniki. Using a press brake with a bending length of 12,200 mm and a bending force of 2,000 tonnes, it was possible to bend the entire web plate with a thickness of up to 20 mm in a single operation.The pre-assembly of the steel structure for these segments was carried out in Csepel, and the 5-meter-long steel stiffening girders were then transported to the site via barges.
After the completion of river piers No. 5 and No. 6, the construction of the superstructure proceeded in parallel phases using the free cantilever method, starting from the piers. Each subsequent segment was added to the initial segment using form travelers, and once the C45/55 concrete reached the early required strength, the adjoining segments were post-tensioned together using internal sliding tendons.

Figure 8: Cantilever construction of the river bridge (photo: Mihaly Erdei, magyarepitok.hu)

By cyclically repeating the described work phases, the superstructure reached the mid-span closure and the common piers numbered 4 to 7 near the riverbanks. A single free cantilever construction cycle comprises more than 150 work processes, including the necessary inspections and the fulfillment of assembly phase criteria. To manage these processes effectively, real-time tracking of 52 milestones is required every day, around the clock. This ensures that the cyclically repeating processes and capacity management are carried out with the highest level of efficiency.

The traditional free concrete casting method is supplemented with the cable connection of the segments to the pylons due to the extradosed nature of the bridge. In the pylons, passive anchoring was applied using an embedded steel structure, while the lower, active anchoring (and tensioning) of the cables with 37, 43, and 55 strands, chosen according to the required loads, was carried out at reinforced concrete anchoring blocks located beneath the deck slab cantilevers within the steel

Figure 9: Cantilever construction of the river bridge (photo: Tamas Dernovics magyarepitok.hu)

stiffening girder.

To optimize the pylon anchorages and the number of strands in the inclined cables, we used custom-manufactured steel link elements instead of saddle supports. These elements allowed for the asymmetric connection of cables, thus optimizing the force distribution.

Due to the installation tolerance of the inclined cable system, the placement of the steel stiffening girder and the passive anchoring steel structure in the pylon was a critical task, with a final plate alignment tolerance of just 10 milliradians. Therefore, the dimensional tolerance check required special solutions throughout the manufacturing, pre-assembly, and on-site assembly processes.

Among the elements to be manufactured, the most complex were the steel stiffening girders with integrated anchorage heads. The manufacturing required exceptional precision, as it was necessary to butt-weld a 40 mm thick anchorage steel tube to a 30 mm thick crossbeam web with an angular tolerance of 0.1149°, ensuring that the tube was positioned at an angle to both the horizontal and vertical planes. Additionally, a support plate with a thickness of 80 mm was welded onto the tube. During the production of the anchorage points for the inclined cables, numerous butt welds were made with plate thicknesses ranging from 40 mm to 80 mm; it was crucial to properly determine and validate the welding sequence. Given the complex geometry, this validation was performed under workshop conditions, using methods such as static scanning and surface model comparison

The elements were trial-assembled prior to delivery, as the large amount of welding and the complex geometry provided little opportunity for adjustments or potential repairs on-site.

During on-site assembly, the final designed shape of the bridge was achieved through iterative

Figure 10: Worksite in the floodplain (photo: Mihaly Erdei, magyarepitok.hu)

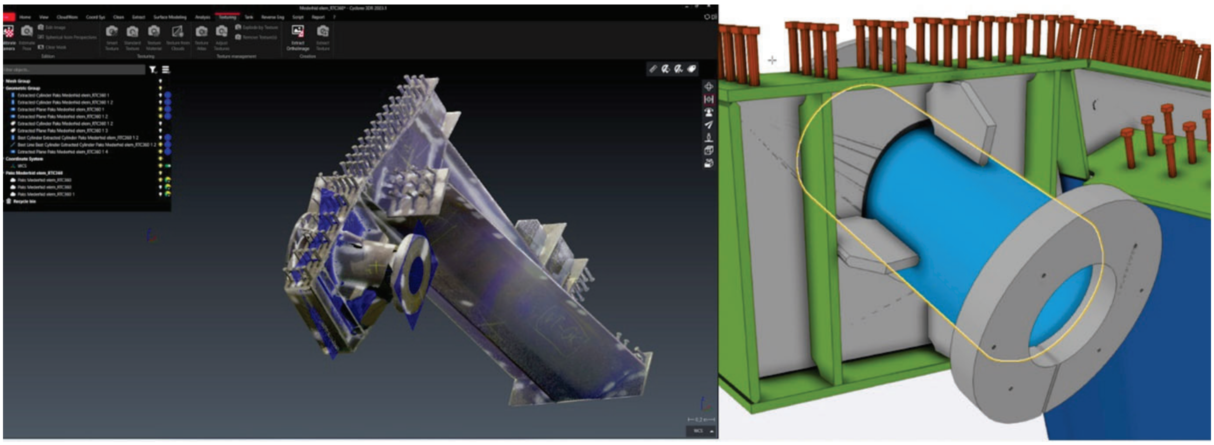

Figure 11: Comparison of static scanning of the subcomponent of the stiffener with a 3D model

adjustments across 89 segments. In each free cantilever cycle, the current shape of the bridge was evaluated, and as a result, the absolute and relative alignment coordinates for the subsequent elements were determined. The longitudinal extent of the bridge and the narrow area available for construction (limiting the viewing angle) significantly constrained our geodetic orientation possibilities. This challenge was addressed by establishing "daily" control points and using auxiliary structures outfitted with reflective foils that projected reference planes.

Figure 12: Setting passive anchoring link elements on top of the pylon

4 Conclusion

Following the barrel rolling in March, the test loading of the bridges was completed in the first days of May 2024, and the technical handover was successfully concluded in the same month. The Tomori Pál Danube Bridge, the twentieth bridge on the Hungarian section of the Danube, was officially inaugurated and opened to traffic on June 6, 2024.

Figure 13: The Tomori Pál Danube bridge (photo: Mihaly Erdei, magyarepitok.hu)