INNOVATIVE SOLUTION FOR A BRIDGE OVER VISTULA RIVER IN TORUŃ

K. Wąchalski

PONT-PROJEKT Sp. z o.o., Gdańsk, Poland.

e-mail: wachalski@pontprojekt.pl,

SUMMARY

During the realization of the bridge a few innovative solutions were applied. The solution of foundation laying on prefabricated piles transferring a huge horizontal arch thrust is an unique and individual application for the bridge of such a large scale. In the field of technology a novel PTFE material is a challenge, increasing durability of pot bearings. Another innovation worthy of mentioning is a new analytical approach to the problem of mastic asphalt surface design. An interesting approach to the structural inspection issue is a geometrical and strain gauge monitoring concept.

Keywords: *Steel arch bridge, new PTFE in pot bearing, prefabricated piles, geometry control, mastic asphalt.*

1. INTRODUCTION

Construction of the arched bridge in Toruń has recently become one of the greatest engineering events. In December 2013 the city of Toruń saw the biggest arched bridge in Poland, named after General Elżbieta Zawacka.

Fig. 1. *View over the bridge in Toruń.*

The bridge of two spans, each one 270 m long, is an element of the bridge crossing over the Vistula river of an entire length of 3 km of bridge structures. A new arch bridge was designed as a steel structure, each of its spans including parabolic box girders and an orthotropic deck suspended by means of tubular hangers. The arch is modelled by a hingeless system without a tie, transferring the entire arch thrust into supports.

A Toruń Commune was an investor of the bridge building, represented by the Municipal management Board of Roads in Toruń. The bridge was designed by the Gdańsk design studio PONT-PROJEKT, the STRABAG company was a general contractor.

2. DESIGN ASSUMPTIONS

The object consists of two arched spans, each one 270 m long. The arrow of the arches equals 50m. The arch cross section is a steel hexagonal box 3.5 m deep and 2.7 m wide. The arch planes are inclined by a 10 ° angle (Fig. 2).

Six keystone beams were applied in every span between the arches for the bracing. The plate is attached by tubular suspender to the arches. The Ø 219 and Ø 244 diameter suspenders made it possible to achieve the desired architectural and economic effect.

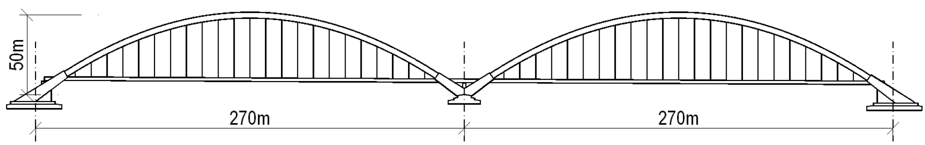

Fig. 2. *Side view.*

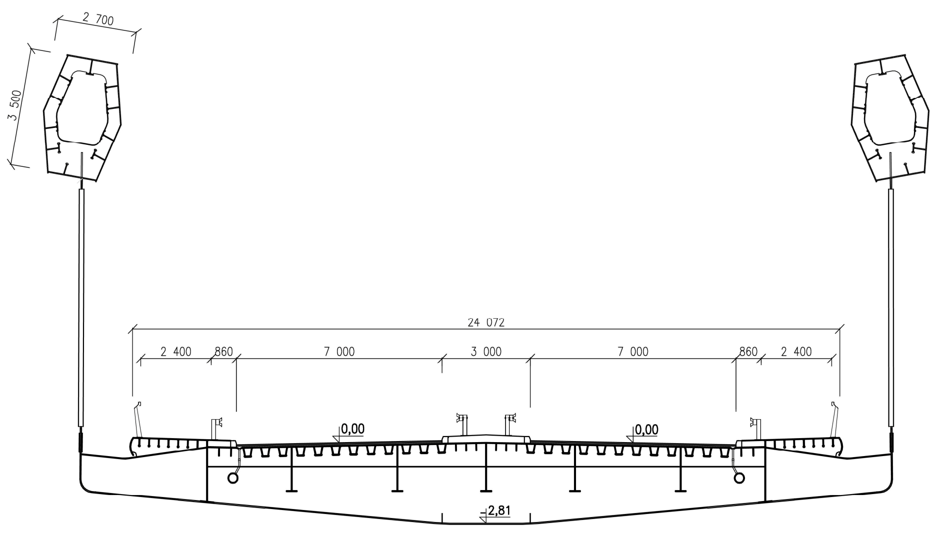

Fig. 3. *Cross section.*

The deck was designed as a steel grate structure with an orthotropic roadway plate. The width of the deck is 24 m (Fig. 3). The bridge supports are massive reinforced concrete structures build on reinforced concrete prefabricated piles 40x40 m. The middle support is additionally located on an artificial island, situated in the centre of the river channel. Steel arches are anchored in reinforced concrete headboards by means of steel bolts. The designed supports are transferring vertical loads and a huge horizontal arch outward thrust.

3. FOUNDATIONS WORKS

A unique and innovative structural solution, applied in the project, is foundation of the bridge supports, transferring a huge outward arch thrust to the subsoil by means of a multitude of concrete prefabricated piles. This was a necessity due to specific grade conditions. On the other hand, a hingeless structural model allowed for an optimal design of slender girders of a high appearance. A detailed study on this innovative method to conduct foundation works is included in a separate article submitted to the conference.

The middle support, common for both bridge spans of bridge, was designed as a spindle-shaped artificial island 130 m long. This solution raised the safety of supports, mostly emerged from difficult hydrological conditions of the Vistula River.

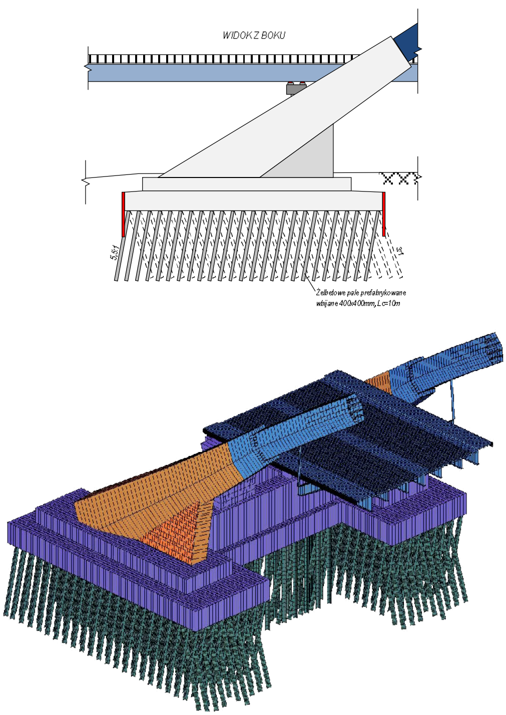

Fig. 4. *Model of support.*

4. MONITORING OF THE ASSEMBLY PROCESS

A new approach to inspection procedures of the assembly was applied during the construction works. It covered an active system to control the assembly geometry and an assembly strain gauge monitoring. The experience in geometric control of building cable-stayed bridges was applied in the field of arch bridge construction. Attention was focused on merging the assembly sections of the arch girders and the control of the loaded arch performance. A well-designed network of benchmarks on every bridge part and its synchronic work in the bridge structure domain made it possible to fabricate and precisely join hexagonal box sections (Fig. 5).

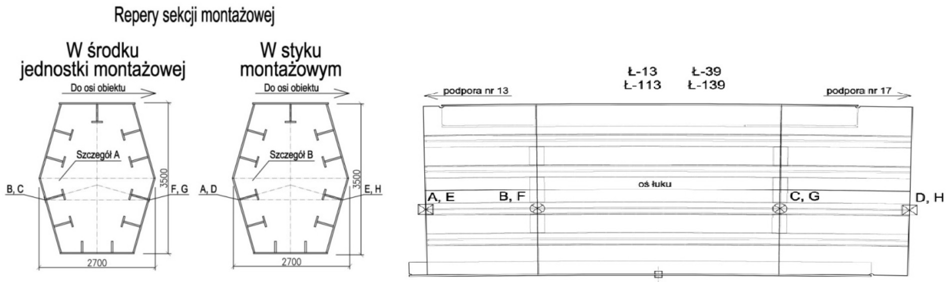

Fig. 5. Benchmarks system.

The control system also allowed for the production of independent arch steel sections by three manufacturing companies not conducting the test assembly.

Moreover, the project assumed the monitoring of the stress control of the key elements of the bridge structure - steel and concrete connections in the headboards of the arch. The control procedure was based on strain gauge measurements, compared with the computational results conducted on advanced FEM models. Measurements were also used to assess the temporary support structural behaviour and to guide the arch during the erection (Fig. 7).

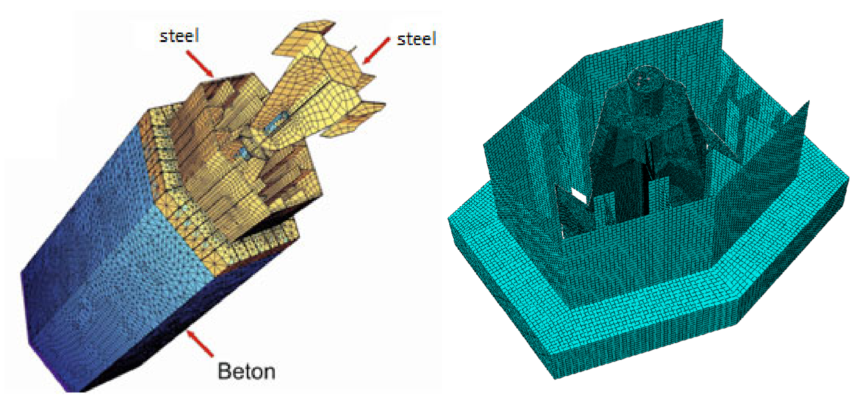

***Fig. 6.** FEM models for tensometric control (left [3], right [5]).*

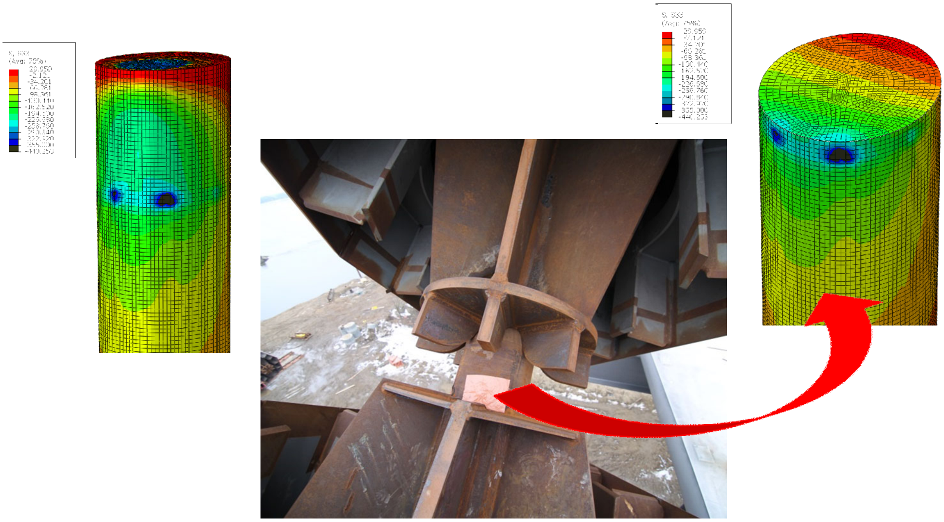

Fig. 7. Results of tensometric control ([5]).

5. POT BEARINGS

The innonative solution of material technology was the introduction of pot bearing of a five times longer durability compared to typical solutions. The modern sliding PTFE material, known as "grey Teflon", with much better parameters due to abrasion was applied for bearings. The new PTFE solutions have been recently applied in spherical river bearings, not to be implemented in pot bearings up till now. The bearing manufacturer along with the designer have worked out an individual documentation based on tests performed in the laboratory in Ispra near Milan (Italy). The use of a hundred new pot bearings for the bridge and approach flyovers is the first worldwide application of this kind.

6. PAVEMENT – MASTIC ASPHALT

During raising the bridge, a long-lasting long-lived surface was designed of poured asphalt and MMA insulations. There were demanded the modern attempt at the surface on the difficult ground - for steel orthotropic plate in the project. Rules were implemented to developing recipes and making the surface of cast asphalt based on the best experiences in the world and applications on the biggest bridges in the world (Great Belt, Queensferry Crossing Bridge). In this respect, a computational attempt assuming the full cooperation and an anastomosis of the surface with the structure of the pier was innovative Non-linear calculations of FEM were used to the evaluation (Figs. 8) and other principles of receipt examination based on the new mechanical approach (Figs. 9).

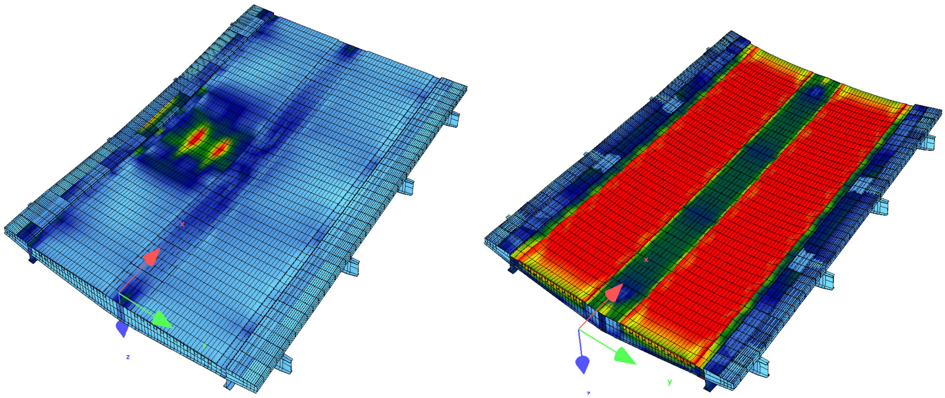

Fig. 8. *FEM analysis.*

Expectations, which a good surface should rival on the bridge are:

- airtightness, full filling with bituminous binder,
- resistance to wheel-rut, the appropriate hardness as the proper of soften temperature and the static penetration MA,
- resistance to cracks at the great ground susceptibility and low temperatures, the great resilience as a resilient return MA,
- the resistance to changeable loads and endurance cracks as the due dynamic search,
- coarseness being responsible for a safety of vehicles on the road.

The best solution is a modern surface of mastic asphalt (MA) hasing permanence of over 50 years (Fig. 9).

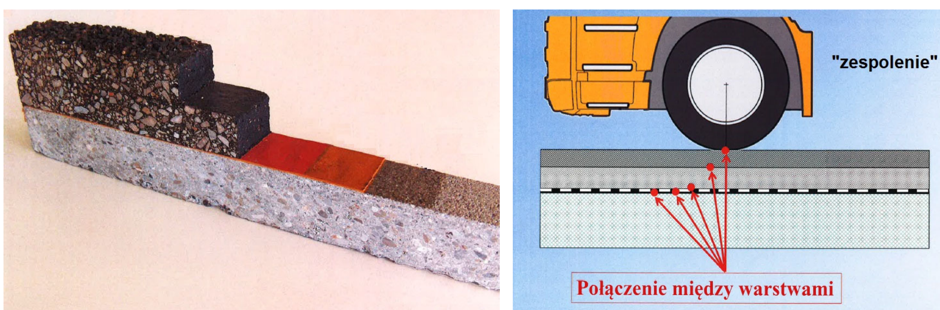

Fig. 9. *Pavement layer connection.*

7. CONCLUSION

Construction of the bridge in Toruń was a great opportunity to implement new innovative technologies and solutions. The associated experience will take its advantage with a development perspective during next construction tasks. The suggested solutions of foundation works on prefabricated piles for such a big object are unique in the world scale. They exhibit the action of transferring huge reactions of bridge supports to the ground based on moderately compacted sands. The design proposed author's own concepts of geometrical and tension active control during the assembly. From the material point of view solutions are implemented to improve durability of bridge elements, as the road surface of poured asphalt and pot bearings with a novel sliding PTFE material. These solutions make up a novelty in the field both in domestic and international scale.

Fig. 10. *Application of MA.*

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