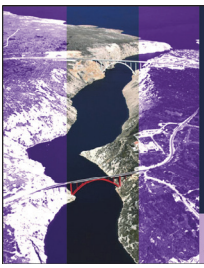

7th International Conference on Arch Bridges
ARCH'13
2 - 4 October 2013 Trogir - Split, Croatia
AESTHETICS AND HISTORY

UNUSUALLY SHAPED ARCH BRIDGES

Jan Biliszczuk[*], Wojciech Barcik[+], Jerzy Onysyk[#] & Robert Toczkiewicz[◊]

[*] Prof., Civ. Eng., Wrocław University of Technology,
Research & Design Office MOSTY-WROCŁAW, Wrocław, Poland
jan.biliszczuk@pwr.wroc.pl

[+] M.Sc., Civ. Eng., Research & Design Office MOSTY-WROCŁAW, Wrocław, Poland
wbarcik@mosty-wroclaw.com.pl

[#] PhD, Civ. Eng., Wrocław University of Technology,
Research & Design Office MOSTY-WROCŁAW, Wrocław, Poland
jerzy.onysyk@pwr.wroc.pl

[◊] PhD, Civ. Eng., Research & Design Office MOSTY-WROCŁAW, Wrocław, Poland
robert.toczkiewicz@mosty-wroclaw.com.pl

Keywords: Landmark structure, steel arch bridge, architectural design.

Abstract: *Arch bridges with untypical shape and structural configuration, built in Poland in recent years, are presented in the paper. The following footbridges, urban bridges and viaducts with steel arches and various deck types are described:*

- *Footbridge over the Odra River in Wrocław (completed in 2002): a tied arch structure with a steel deck and an arch made of intercrossing steel tubes;*
- *City viaduct in Bydgoszcz (2008): a structure with half arch girders;*
- *Viaduct in Gdańsk (2013): a structure with crossing tubular arches;*
- *Footbridge over the S11 expressway (2008): an inclined arch with curved GFRP deck;*
- *Viaduct along the ring road of Pabianice (2012): horizontally and vertically curved, skewed bridge with two inclined arch girders;*
- *Double arch viaduct over the A2 motorway (2006);*
- *Viaduct over the S3 expressway (2009) with high rise arch of a gothic shape.*

Conclusions concerning architectural value of constructing landmark bridge structures are summarized in the paper.

1 INTRODUCTION

Arch bridges are one of the oldest types of structures. Despite their long history they still give designers great opportunities to diversify their architectural and structural configuration. This includes arrangement of bridge deck, hangers and particularly type and shape of arch girders. Arch structures are often built as medium span bridges. They are constructed over dual carriageway roads (e.g. motorways), when it is not advisable to locate pier in central median. At the same time they can also be landmark structures. It is especially desirable in the case of plains, when a long ride across a monotonous landscape may result in tiredness and disorientation of a driver. Such function of bridge structures is very important in lowland countries, such as Poland [1].
Bridges of unusual shape are often built in cities, where they have a chance to become their distinctive trademark and be recognized by both city dwellers and visitors.
The paper presents selected examples of arch bridges, viaducts and footbridges of unusual shape (landmark structures), built in recent years in Poland.

2 URBAN STRUCTURES

2.1 Słodowa Footbridge over the Odra River in Wrocław

The Odra River has formed a group of islands as it flows through the centre of Wrocław. This is the oldest part of the city (called Ostrów Tumski), where Wrocław was founded in the early Middle Ages. Many buildings in this area were destroyed during the Second World War. The redevelopment plan specifies that the islands are to become recreational area. This required construction of new footbridges crossing the Odra River and allowing for easy access to the islands [2]. The designs were selected on the basis of architectural contest.

Figure 1: Views of the Słodowa Footbridge in Wrocław

The concept of Słodowa Footbridge provided a structure distinct in form and complementing the background. The main part of the footbridge is a 48 m long tied arch

consisting of two high rise interpenetrating parabolic steel tubes with a 0.51 m diameter (Figure 1). Both arch girders are connected by transverse tubes and fixed in the support crossbeams at the ends of the tie-deck. The deck is a steel multi-cell box girder suspended by 20 inclined hangers.
During construction the steel structure of the footbridge was divided into nine elements: four arch segments, two side crossbeams and three deck segments. All of them were transported along the river to the site. The arch segments were welded together in horizontal position on a barge anchored to the riverbank. Temporary bracing and tie were applied. Assembled arch with a weight of approx. 25 t was rotated to the vertical position, lifted by movable cranes and placed on the supports. Then the deck was suspended by temporary ropes and welded to the side crossbeams. In the last stage temporary tie bars were removed and ropes were replaced by inclined hangers.
The Słodowa Footbridge was designed by Research & Design Office Mosty-Wrocław and built in 2002.

2.2 "Shark's fin" viaduct over a railway line in Bydgoszcz

The viaduct in Bydgoszcz, located along the Gdańska Street over a railway line, is a steel structure with a very untypical shape of main girders. They are formed as two half-arched frames with a box-section, braced by struts and top lateral bracing (Figure 2). An orthotropic steel deck is suspended on the half-arches. It consists of two main longitudinal beams, located in planes of the main girders and transversal crossbeams supporting longitudinal ribs and deck plate. The viaduct, which has been named a "shark's fin" because of its unusual shape, has a length of 49.1 m and width of 17.4 m. As an urban landmark structure it has been additionally exposed at night by an illumination system.
The viaduct was designed by Jan Siuda and constructed in 2008.

Figure 2: Views of the "shark's fin" viaduct in Bydgoszcz (photos: K. Janikowska)

2.3 Viaduct along the Słowackiego Route in Gdańsk

The viaduct was built in Gdańsk along the Słowackiego Route, in the direct vicinity of the Euro 2012 PGE Arena stadium [3]. The longest span of a four-span flyover, crossing railroad tracks, is a tied arch with a length of 120 m (Figure 3). The tie of the span is a concrete box girder, longitudinally and transversally prestressed, with overhangs supported by steel tubular struts. The box girder is suspended along its center web axis to an arch made of steel tubes. It consists of two identical tubular girders, shifted 4.0 m along the axis of the bridge. The tubes are crossing so that at the deck level they are located above each other, while in the mid-span alongside each other (Fig. 3). Both girders are braced transversally by tubes with a smaller diameter, forming a spatial structure.
The arch was assembled of three large-size sections, lifted by movable cranes located on the bridge deck supported by auxiliary towers. The segments were supported by temporary towers and welded. Then side sections were fixed to the concrete bases formed in the tie girder over the supports.
Construction of the viaduct, designed by Top Projekt and GTI, was completed in 2012.

Figure 3: Views of the viaduct in Gdańsk under construction (photos: K. Topolewicz)

3 LANDMARK VIADUCTS AND FOOTBRIDGES OVER MOTORWAYS

3.1 Footbridge over the S11 expressway near Kórnik

The footbridge over the S11 expressway is a structure combining unusual shape with a modern composite deck structure [4]. The main span over the road is a fixed steel arch, supporting a horizontally curved deck (Figure 4).
In the original design it was assumed that the main elements of the arch span were to be made of tubular sections. Because of difficulties in producing proposed shapes of steel tubes the designers used welded box sections instead. The arch with a box section has been formed as a sector of a circle with a span of 40 m, deflected from the vertical by 17°. It is fixed in concrete pedestals of complex shape. The main element of the deck is a curved trapezoidal steel box girder with a height of 0.60 m. Its location varies along the span – it approaches edge (hangers' side) in the middle of the span. On both sides of the main girder radially arranged cantilevers supporting deck panels are welded. In every second inner cantilever inclined Macalloy bar hangers are anchored. Deck of the main span is filled with GFRP composite polymer panels [4]. Other spans are steel beams composite with

reinforced concrete slab. Access ramps leading to the footbridge are reinforced concrete plate structures.
All steel surfaces of the footbridge are painted white. Concrete elements (piers, concrete spans, stairs) have been left in natural color.
The footbridge was designed by Transprojekt Warszawa. Construction was completed in 2008.

Figure 4: Views of the footbridge near Kórnik (photos: K. Janikowska)

3.2 Viaduct over the ring road of Pabianice

Unusual, "crooked" viaduct, designed by Mosty Katowice, was built in 2012 along the ring road of Pabianice, which is a part of the S14 expressway (west bypass of Łódź). Designing an arch structure in that place was a challenge, due to the vertical and horizontal curvature of the road and large skew angle of the structure. It resulted in an untypical structure with a span of 80 m, formed by asymmetric curvatures (Figure 5). The viaduct is curved in horizontal and vertical planes and the hangers have variable angle of inclination. Inclined

arch girders are shifted along each other, which in combination with road curvature, variable inclination of hangers and large skew angle of struts bracing the arches makes the viaduct seem unstable. During construction period people living in the neighborhood were even calling the construction office and alarming that the viaduct would collapse.
The structure distinguishes in very flashy colors. Steel arches are painted purple and the bridge deck is in yellow and orange colors. When traveling it is for sure not so easy to overlook this bridge, though very high noise barriers interfere with its view. Strong interest in the design made the owner organize a competition for the name of the viaduct, which has been officially called "the labyrinth".

Figure 5: Views of the “crooked” viaduct near Pabianice (photos: www.gotowski.pl)

3.3 “Rainbow” viaduct over the A2 motorway

The structure consists of two pairs of concrete filled steel tube arches of different geometry. Static scheme is composed of two arches: a hinged outer girder, supported on foundations and a tied arch fixed at both ends of the deck (Figure 6). The deck is a concrete beam-slab structure, consisting of two side girders, transverse crossbeams and a reinforced concrete slab, min. 0.27 m thick. Longitudinal tie beams are prestressed by tendons. Additionally in

side parts of the span an extra prestressing is applied to the slab between the bearings and the first hangers. The total length of the viaduct is 76.30 m and the width is 14.08 m.
Apart from unusual structural configuration, the viaduct distinguishes in a very aggressive mixed color scheme. No wonder that it has been named by the drivers a "rainbow" viaduct. As a landmark structure the viaduct has been additionally exposed by an illumination system, which allows the travelers for its easy identification at night.
The viaduct was designed by Transprojekt Gdański and built in 2006.

Figure 6: The “rainbow” viaduct over the A2 motorway (photos: K. Janikowska)

3.4 Viaduct over the Klucz interchange junction on the S3 expressway

Figure 7: View of the viaduct in the Klucz interchange

The viaduct, situated in the Klucz interchange of the S3 expressway and the A6 motorway near Szczecin, has been designed as a landmark structure. Steel-concrete composite span with a total length of 61.50 m and width of 8.80 m is suspended to an arched pylon. The 26 m high steel pylon with a box cross-section has a shape of a high gothic arch with pointed apex (Figure 7). Four hangers are anchored at the top of the pylon and at the edges of the deck crossbeams. The viaduct has been designed as a distinctive and visible from

afar gate, greeting travelers entering the city via the S3 expressway. It is painted in the "local" green and blue colors of Szczecin, according with the strategy of promoting the city. The structure was designed by Transprojekt Gdańsk and erected in 2009.

4 CONCLUSIONS

For the last ten years more than 2000 bridges, including several dozen of landmark structures, have been built in Poland. The paper presents few examples of unusually shaped arch bridges. In their design a unique architectural form has been emphasized. Final results vary. Some structures are interesting, the others may seem bizarre. Their aesthetic evaluation is a very individual issue. Landmark bridges may arouse either extreme admiration or total negation.

Cost of structures presented in the paper is about 20 ÷ 30 % higher than of typical arch bridges and approximately 30 ÷ 50 % higher than of beam bridges. This increase is mostly an effect of higher costs of construction.

REFERENCES

[1] Biliszczuk, J., Onysyk, J., Barcik, W., Hildebrand, M., Sułkowski, M. 2005. Bridge structure as landmark along Polish motorways. Proc. of fib Symposium *Keep Concrete Attractive*, Budapest, 23-25 May 2005.

[2] Biliszczuk, J., Barcik, W., Boniecki, T., Rudze, J., Stempin, P., Styrylska, J. 2005. Footbridges on the river Odra's Island in Wrocław. Proc. of Second International Conference *Footbridge 2005*, Venice, 6-8 December 2005.

[3] Topolewicz, K., Galewski, T. 2013. Construction of the WD-1 viaduct along the Słowackiego Route – section III in Gdańsk (in Polish). *Mosty* 1/2013: 39-43.

[4] Mossakowski, P., Wróbel, M., Zobel, H., Żółtowski, P. 2005. Pedestrian steel arch bridge with composite polymer deck. Proc. of IV International Conference on Current and future trends in bridge design, construction and maintenance, Kuala Lumpur, 10-11 October 2005.