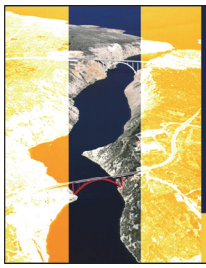

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LARGE SPAN ARCH BRIDGES IN POLAND

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Abstract: *In recent years several large arch bridges with span of more than 100 m were built in Poland. Two large arch bridges have been designed: the bridge in Toruń is under construction and erection of the bridge in Warsaw has been put on hold due to the economic crisis. The following selected arch structures are described in the paper in the order of increasing span:*

- *The bridge over the Kameszniczanka Creek valley in Milówka (completed in 2007) with spans of 103.8 m;*
- *Footbridge over the Vistula River in Cracow (2011) with span of 148.0 m;*
- *The bridge over the San River (under construction) with span of 150.0 m;*
- *The bridge over the Dziwna River in Wolin (2003) with span of 165.0 m;*
- *The Kotlarski Bridge over the Vistula River in Cracow (2001) with span of 166.0 m;*
- *The bridge over the Vistula River in Puławy (2008) with span of 212.0 m;*
- *The bridge over the Vistula River in Toruń (under construction) with spans of 270.0 m;*
- *The Krasińskiego Bridge in Warsaw (planned) with span of 277.1 m.*

Design solutions and construction technology of the bridges are presented.

1 INTRODUCTION

For the last ten years several arch bridges with span greater than 100 m have been built in Poland. Most of them are structures crossing major rivers. The paper presents selected examples of recently built large span arch bridges of different types, mostly steel structures. The largest arch bridge in Poland (over the Vistula River in Toruń) is at the moment under construction and even longer structure is planned to be erected in Warsaw.

2 BRIDGE IN MILÓWKA OVER THE KAMESZNICZANKA CREEK VALLEY

The bridge in Milówka is a part of the S69 expressway, which has been planned as a road connecting city of Bielsko-Biała (and the S1 expressway) with Slovakia (border crossing in Zwardoń / Skalité). It is the most spectacular structure along the route, situated in attractive mountainous region. Concrete bridge with a total length of 662.5 m consists of nine beam spans with a minimum length of 32.0 m (side spans), typical length of 41.0 m and three true arches with spans of 103.84 m (Figure 1). Maximum height of piers is 27 m and the deck width is 12.9 m.

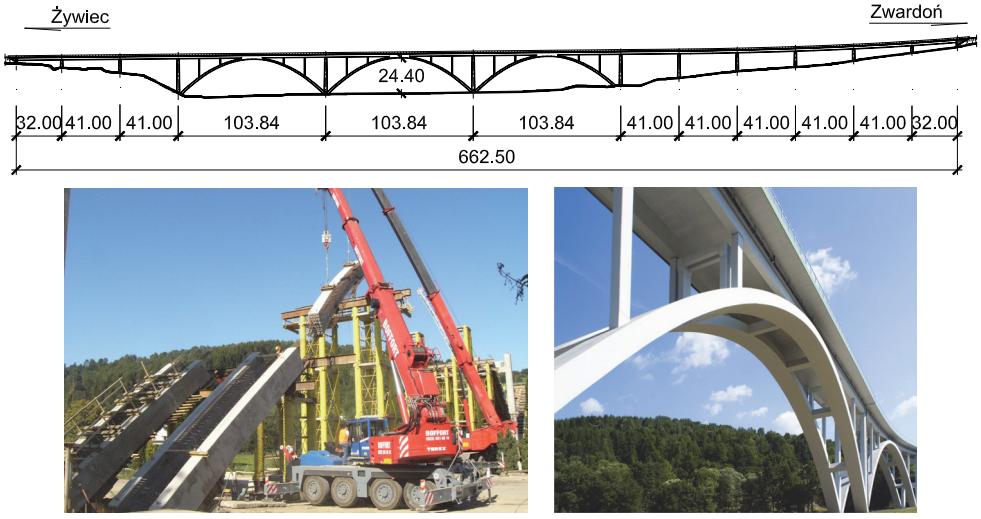

Figure 1: Bridge in Milówka: side view, assembly of arch segments [1] and view of completed structure (photo: GDDKiA Katowice)

Beam spans and the deck supported by arches (with the same cross-section) were constructed using movable scaffolding, which was convenient due to the inaccessibility of the sloped terrain under the bridge. The main arch spans (two girders in the cross-section, spacing of 6.80 m) were erected using large size prefabricated elements [1] with a cross-section of 0.60 × 1.00÷1.40 m, supported during construction stage on steel auxiliary supports (Figure 1). The following assumptions were made:

- precast elements formed side parts of each arch girder to which the formwork of the middle, cast in-situ part of the section was installed;

- due to the large weight (up to 36 tons) precast elements were fabricated on site;
- monolithic connections of precast elements were made in the base nodes of concrete columns supporting the upper deck.

Each arch span consists of $2 \times 2 \times 7 = 28$ prefabricated elements. Their assembly was conducted in the direction from the supports to the crown of the arch, using two cranes.
The bridge in Milówka, designed by Stähler+Knoppik Ing. and completed in 2007 is at the moment the largest Polish concrete arch bridge.

3 KAZIMIERZ-PODGÓRZE FOOTBRIDGE IN CRACOW

Design of Kazimierz-Podgórze Footbridge over the Vistula River is a result of architectural competition. The winner proposed a steel bowstring arch with a span of 148 m [2]. The main girder has a circular cross-section formed by two steel tubes: an outer with a diameter of 2.02 m and an internal with a diameter of 1.62 m. Space between the tubes is filled with concrete. Rise of the arch fixed in concrete abutments is 15.3 m. The footbridge has two steel decks, each 3.0 m wide, suspended by net arranged hangers (Figure 2). The orthotropic decks, covered with exotic wood pavement, are connected by transverse tubes with a diameter of 0.51 m, spaced every 5.0 m. Under the decks, acting as a tie-beam, external tendons have been additionally installed. The footbridge was assembled on the river bank. Then the whole structure weighing about 700 tons was placed on barges, rotated and fixed to the abutments.
The footbridge was designed by Autorska Pracownia P-P A. Getter (architectural design) and Promost Consulting, Research & Design Office Mosty-Wrocław, Konsultacyjne Biuro Projektowe Żółtowski (detailed design). It was completed in 2010.

Figure 2: Kazimierz-Podgórze Footbridge (photos: Ł. Chamów)

4 NETWORK ARCH BRIDGES

The road bridge on the bypass of Wolin (part of the S3 expressway) connects Wolin Island with mainland [3]. It consists of three multi-span steel-concrete composite and prestressed concrete flyovers and a tied network arch main bridge over the Dziwna River with a span of 165.0 m (Figure 3). Total length of the bridge is 1096 m. Arch girders inclined to the road axis, with a constant rectangular cross-section of 1.00 × 1.80 m, are braced by seven tubular struts with a diameter of 1.22 m. The deck consists of three longitudinal beams composite with a concrete slab, connected by crossbeams to which intersecting diagonal hangers are anchored. Active anchorages are located inside the arches. Longitudinal beams are prestressed by six cables, anchored in concrete bases of the arches. Construction technology

included assembling the girders using auxiliary supports situated in the river and successive suspension of deck segments. The bridge, designed by Transprojekt Gdański, was opened in 2003 and at that time was the largest arch bridge in Poland.
The bridge over the San River is under construction along the A4 motorway section Radymno-Korczowa (near Polish-Ukrainian border) [4]. It consists of two separate structures - one for each carriageway of the highway. It is a single-span bowstring arch bridge with a span of 150.0 m. The deck is a steel grid of longitudinal beams and crossbeams composite with reinforced concrete deck slab, suspended to two vertical arch girders by a net of diagonal hangers. Side concrete crossbeams are joined monolithically with massive bases of the arch girders. Tension in the deck is compensated by prestressing it by 27L15.7 mm tendons. The arches were assembled using auxiliary supports placed on the previously launched deck, supported by temporary piers. The bridge has been designed by Arcadis.

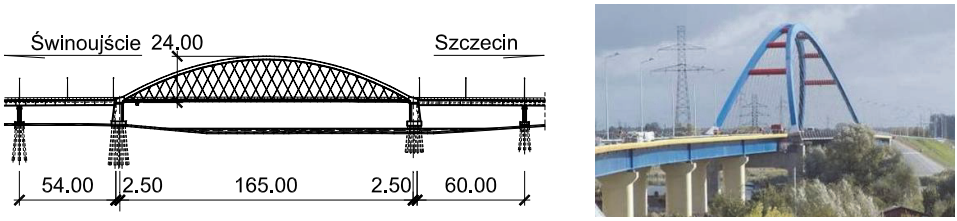

Figure 3: Side view and photo of the bridge over the Dziwna River

5 KOTLARSKI BRIDGE IN CRACOW

The concept of the Kotlarski Bridge over the Vistula River in Cracow was the result of an architectural competition. A design of a bridge of untypical configuration and a span of 166.0 m was selected as the winner. It is a simply supported spatial structure, formed by four (two internal and two external) "lens" shaped arch girders and orthotropic deck [5]. The girders consist of parabolic upper arches and circular lower arches of various rise (Figure 4). The bridge carries a double-track tram line, two road carriageways and routes for pedestrians and cyclists.

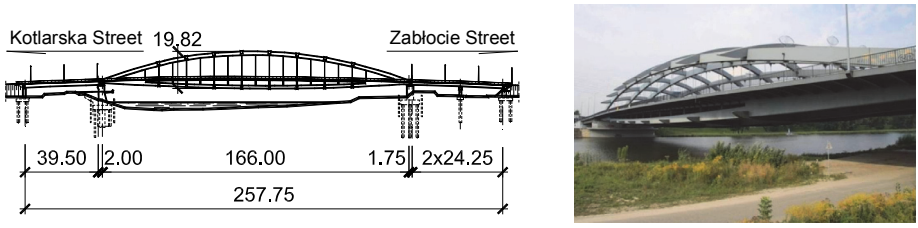

Figure 4: Side view and overall view of the Kotlarski Bridge in Cracow

The bridge deck is a steel orthotropic plate, made of closed ribs, transversal I-shaped floorbeams and longitudinal main tie beams, located in the planes of arch girders. Main beams are suspended to the upper arches by hangers (Maccaloy 460 tension bars) and supported on lower arches by I-shaped columns. The arch girders have a box cross-section

with dimensions of 0.95 × 2.00 m (upper inner arches) and 0.95 × 1.60 m (upper outer arches and lower arches). The arches are braced transversally by curved box struts. Concrete solid supports are founded on piles (right river bank) and cavity walls (left riverside).
Construction of the superstructure was conducted in two main stages:

- incremental launching of preassembled bridge deck and lower arches, using temporary supports situated in the river;
- assembly of upper arches, struts and installation of hangers from the deck level.

The bridge, designed by Transprojekt Kraków, was opened to traffic in December 2001 and has been considered a bridge landmark of Cracow.

6 BRIDGE OVER THE VISTULA RIVER IN PUŁAWY

John Paul II Bridge over the Vistula River on the ring road of Puławy is a part of the S12 expressway, section Radom - Lublin. The total length of the bridge is 1038 m and its 212.0 m long main span is at the moment the largest arch in Poland. It is a continuous 14-span structure with spans of 44.0 + 3 × 56.0 + 6 × 64.0 + 80.0 + 212.0 + 80.0 + 44.0. The main tied through arch span (Fig. 5) is suspended by 28 units of hanger bars [6]. The rise of the arch over the roadway is 24.0 m. Supports of the main span are founded on bored piles with a diameter of 1.50 m.

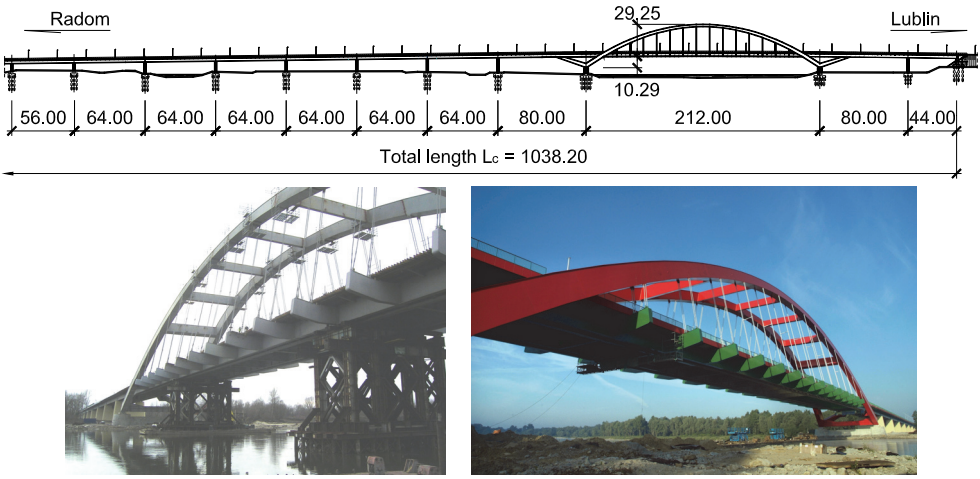

Figure 5: Bridge in Puławy: side view, view during construction and completed structure

The deck is a steel-concrete composite structure. Tie beam consists of four plate girders of constant height of 3.00 m grouped in two tandems (two plate girders spaced at 2.5 m in each tandem) with spacing of 12.5 m. The girders are braced by crossbeams with regular spacing of 4.0 m. The reinforced concrete deck slab has an average thickness of 0.27 m.
Two arch girders, inclined to the bridge axis, have a rhomboidal box cross-section, varying from 2.50 × 3.00 m at the supports to 2.50 × 2.00 m at the crown. The arches are braced by box struts. Each hanger consists of four tension bars with a diameter of 81 mm anchored in

the crossbeam and in the webs of the arch with use of fork connectors. Spacing of the hangers is 12.0 m and their length varies from 3.5 to 24.0 m.
Steel deck of the main span was constructed using two auxiliary supports situated in the river (Figure 5). Segments of the arches (each of them was divided into three assembly units) were assembled on the riverside. Each segment was then launched along the tie girders into the final position, lifted, supported by assembly towers and joined by welding. After installation of hangers the reinforced concrete deck slab was cast.
Due to the complexity of the structure a monitoring system has been installed on the bridge. It consists of three subsystems: structure monitoring, video monitoring system and a weather station.
The bridge in Puławy, designed by Pomost Warszawa, was opened to traffic in July 2008.

7 BRIDGE OVER THE VISTULA RIVER IN TORUŃ

The new bridge over the Vistula River in Toruń is under construction along the newly designed section of the national road DK1. It consists of substructures:

- right riverside flyovers with lengths of 221.7 m + 279.5 m;
- arch bridge with a length of 540.0 m (Figure 6);
- left riverside flyovers with lengths of 435.3 m + 394.9 m.

The main bridge is a half-through fixed arch structure with spans of 2 × 270.0 m [7]. Central support is situated on an artificial island in the middle of the river. The bridge, apart from concrete bases of the arches, is a steel structure. Arch girders, designed as hexagonal box sections with dimensions of 2.50 × 3.00 m, are inclined to the axis of the bridge and braced by four struts. The deck with a height of 3.00 m is a steel orthotropic plate, made of closed ribs under the road pavement, open ribs under the sidewalks, longitudinal beams and transversal crossbeams suspended to the arches. Total width of the deck, carrying two carriageways (2 × 7.0 m) and sidewalks, is 24 m. The bridge is founded on prefabricated RC piles 0.40 × 0.40 m.

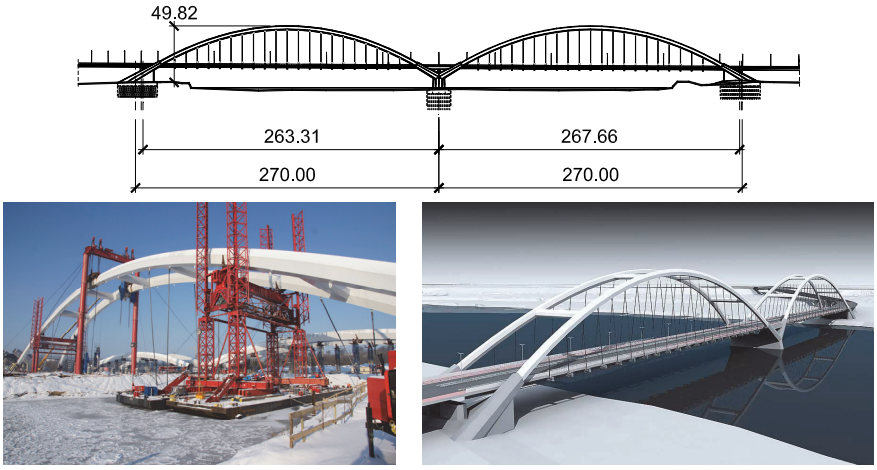

Figure 6: Side view, assembly of the arches (photo: K. Jędrzejewski – Strabag) and computer image of the bridge in Toruń [7]

The arch spans will be constructed in the following steps:

- construction of foundations, including central support, located on the artificial island;
- erection of concrete arch bases,
- assembly of arch segments on a construction site located on the river bank;
- water transport of assembled arches (approx. weight of each is 3000 tons);
- fixing the arches to the concrete bases of supports;
- assembly of 30 m long deck segments in the direction from the supports towards the center of the span.

The designer of the bridge in Toruń is Pont-Projekt. It is expected to be completed till the end of 2013.

8 KRASIŃSKIEGO BRIDGE IN WARSAW

The Krasińskiego Bridge has been designed on the route that was already planned in the thirties of the last century. The main span is formed by two steel arches inclined to the bridge axis, to which a steel-concrete composite deck is suspended [8].

The bridge crossing the Vistula River will have no supports in the stream (Figure 7). The main span is a bowstring arch with a length of 277.09 m and rise of 34.0 m. The deck width is 42.0 m. The steel box girder with curved bottom flange interacts with a 0.22 m thick reinforced concrete deck slab. The arch consists of two steel box girders with trapezoidal cross-section. Their width varies from 2.75 m to 3.25 m at the deck level. Both arches merge into one box section in the middle of the span. The depth of the arches varies from 3.00 m (at the crown) to 4.00 m. The deck is suspended by 28 pairs of radially arranged hangers. Spacing of anchorages is constant in the arch (8.94 m) and variable in the deck (8.00 m to 9.50 m).

Detailed design of the bridge was prepared by IBDiM and Systra. Its construction has been put on hold due to the economic crisis.

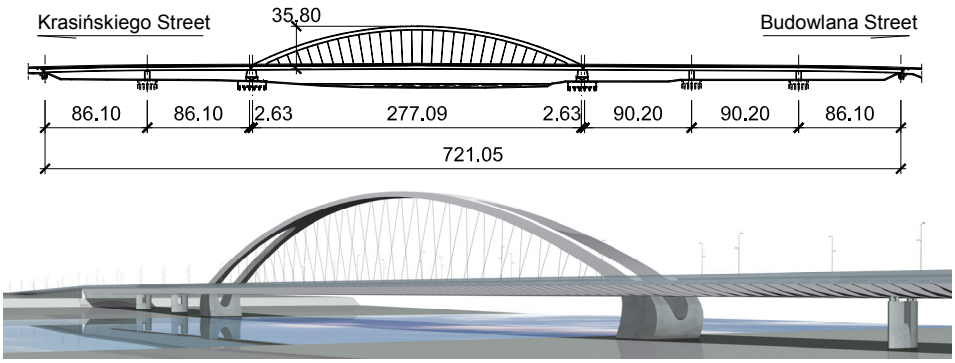

Figure 7: Krasińskiego Bridge - side view and computer image [8]

9 CONCLUSIONS

Characteristics of largest Polish arch bridges are summarized in Table 1. Examples given in the paper show that the most common type is a tied arch bridge with steel arch and steel-concrete composite deck. There are very few new concrete arch bridges, usually with shorter spans. Also true arch bridges, usually built over mountain valleys, are rare, as Poland is generally a lowland country.

Name	Span [m]	Material: Arch / Deck	Completed	Location
Krasińskiego Bridge over the Vistula River	277.1	steel / composite	Planned	Warsaw
Bridge over the Vistula River	270.0	steel / steel	Under construction	Toruń
John Paul II Bridge over the Vistula River	212.0	steel / composite	2008	Puławy
Kotlarski Bridge over the Vistula River	166.0	steel / steel	2001	Cracow
Bridge over the Dziwna River	165.0	steel / composite	2003	Wolin
Bridge over the San River	150.0	steel / composite	Under construction	A4 motorway
Kazimierz – Podgórze Footbridge over the Vistula River	148.0	steel / steel	2011	Cracow
Bridge over the Skawa River	123.4	steel / composite	2012	Sucha Beskidzka
Bridge over the Kameszniczanka Creek	103.8	concrete / concrete	2007	Milówka

Table 1: List of selected largest arch bridges in Poland

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