LARGE SPAN BRIDGES IN POLAND

J. Biliszczuk¹, J. Onysyk², W. Barcik³, R. Toczkiewicz⁴ and A. Tukendorf ³

ABSTRACT

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The following arch bridges are described:
- The bridge over the Vistula River in Puławy: continuous multi-span steel-concrete beam, main span is a steel tied through arch with a length of 212 m;
- The bridge over the Vistula River in Toruń: entirely steel structure, two fixed arches with a span of 270 m each.

The following cable-stayed and extradosed bridges are presented:
- The Solidarności Bridge over the Vistula River in Płock: a cable-stayed bridge with a span of 375 m (the longest span in Poland), steel deck is suspended by a single plane of cables to two I-shaped steel pylons fixed in deck;
- The Rędziński Bridge over the Odra River in Wrocław: 612 m long concrete structure with two main spans of 256 m, two separate prestressed concrete decks are suspended to a single 122 m high H-shaped pylon;
- The bridge over the Vistula River in Kwidzyn: the main 808 m long bridge is a six-span extradosed prestressed concrete beam, length of the main spans is 204 m.

The paper describes construction technology and selected design solutions of the aforementioned bridges.

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Large span bridges in Poland

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Introduction

For the last years several arch bridges and cable-stayed bridges with a span greater than 200 m have been built in Poland. Most of the new large-span structures are crossing major rivers (the Vistula River and the Odra River). They are also often built in cities, where they have a chance to become their distinctive trademark and be recognized both by city dwellers and visitors.

The paper presents selected examples of recently built large-span arch bridges and cable-stayed bridges. It describes construction technology and design concepts of the bridges which at the moment can be considered the greatest achievements of Polish civil engineering.

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Arch bridges

Bridge over the Vistula River in Puławy (2008)

John Paul II Bridge over the Vistula River is situated along the ring road of Puławy – a part of the S12 expressway, section Radom – Lublin [1]. The total length of the bridge is 1038 m. It is a continuous 14-span structure with spans of $44.0 + 3 \times 56.0 + 6 \times 64.0 + 80.0 + 212.0 + 80.0 + 44.0$ m (Fig. 1). The deck of the main tied through arch span crossing the riverbed is suspended by 28 units of hanger bars. Rise of the arch over the roadway is 24.0 m. Supports of the main span are founded on bored piles.

The deck is a steel-concrete composite structure. Tie beam consists of four plate girders of a 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 [1]. The girders are braced by crossbeams with regular spacing of 4.0 m. The reinforced concrete deck slab has a thickness of 0.27 m.

Two inclined to the bridge axis arch girders have a rhomboidal box cross-section, varying from $2.50 \times 3.00$ m over the support to $2.50 \times 2.00$ m in 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 using fork connectors. Spacing of the hangers is 12.0 m, their length varies from 3.5 to 24.0 m.

Figure 1. Side view of the bridge over the Vistula River in Puławy.

Figure 2. Assembly of arch segments [2].

Steel deck of the main span was constructed using two auxiliary supports situated in the river (Fig. 2). Segments of the arches (each of them was divided into three units) were assembled on the riverside. Each segment was then launched on trolleys along the tie beam into the final position, lifted, supported by assembly towers and joined by welding [2]. The reinforced concrete deck slab was cast after installation of hangers.

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 was designed by Pomost Warszawa.
Bridge over the Vistula River in Toruń (2013)

The bridge in Toruń is situated along the newly built section of the national road DK1. It consists of the following structures:

- right riverside flyovers with a length of 221.7 m + 279.5 m;
- arch bridge with a length of 540.0 m (Fig. 4);
- left riverside flyovers with a length of 435.3 m + 394.9 m.

The main bridge is a half-through fixed arch structure with two spans of 270.0 m. Central support is situated on an artificial island in the middle of the riverbed (Fig. 4). The bridge, apart from concrete bases of the arches, is a steel structure. Arch girders, designed as hexagonal box section with dimension of 2.50 × 3.00 m, are inclined to the axis of the bridge and braced by six struts. The deck with a height of 3.00 m is a steel orthotropic plate consisting 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 and sidewalks is 24 m. The bridge is founded on prefabricated reinforced concrete piles 0.40 × 0.40 m.
The arch spans were constructed in the following stages [3]:
- construction of foundations including central support located on the artificial island;
- erection of concrete arch bases;
- assembly of arch segments on the construction site located on the river bank;
- water transport of assembled arches of approx. weight of 3000 tons each (Fig. 5);
- placing the arches on the concrete bases of supports (Fig. 6) and welding the joints (the arches are fixed in the supports);
- assembly of 30 m long deck segments in the direction from the supports towards the center of the span.

The bridge in Toruń was designed by Pont-Projekt, Gdańsk.

Figure 5. Assembly of steel arches using floating temporary supports (photo: K. Jędrzejewski – Strabag).

Figure 6. Details of the structure: support of steel arches (left photo K. Jędrzejewski – Strabag) and fork anchorage of hanger.

Cable-stayed bridges

Solidarity Bridge over the Vistula River in Plock (2005)

The Solidarity Bridge was built as an alternative to the only existing rail-road bridge, connecting districts of Plock situated on both sides of the river, built before the Second World War.

The total length of the new bridge is 1200 m. It consists of two structures:
- main bridge over the Vistula River with a length of 615 m – it is a cable-stayed structure suspended by a single plane of stays (along the axis of the bridge) to two pylons, with a main span of 375 m and four back spans (Fig. 7);
- access flyover with a length of 585 m crossing left riverside flood plains – it consists of two continuous five-span beams with spans of 58.50 m.

![Bridge Diagram]

Figure 7. Solidarity Bridge in Płock – basic dimensions.

The girder of the main bridge is a three-cell box section with a constant height of 3.56 m and a width of 27.25 m (Fig. 7). Outer webs are inclined. Internal vertical webs form a central cell where the steel pylons are fixed and the anchor blocks are located. The deck is an orthotropic plate with closed longitudinal ribs under the roadway and open ribs under the sidewalks. Transverse bracing bars and sidewalk cantilevers are spaced every 3.75 m. Diaphragm plates are located above supports and in sections where the stays are anchored. All connections are welded.

![Bridge Construction]

Figure 8. Construction of bridge in Płock.
Steel pylons with a height of 63.7 meters above the deck level are fixed in the deck axis. They have a rectangular cross-section varying from $3.75 \times 2.25$ m at the base to $3.12 \times 2.25$ m at the top. Anchorages are spaced every 6.25 m in the pylon and 22.5 m in the deck. The main span is suspended to each pylon by seven pairs of harp-arranged cables. The number of backstays is the same. The length of the cables varies from 39 to 187 m. Each cable consists of a bundle of 47 to 84 parallel high strength steel strands with a diameter of 15.7 mm.

Superstructure of the main span was cantilevered at the same time from both sides of the river (Fig. 8). Preassembled segments with a length of 22.5 m and a weight of about 240 tons were transported on barges, lifted and welded to the previously erected structure. Joined segments were consecutively suspended to the pylons. Connection of both cantilevers was the last stage of construction.

The Solidarity Bridge in Płock (Fig. 9) is so far the structure with the longest span in Poland. It is also the first structure that has been equipped with a complex structural monitoring system [4]. The bridge was designed by Budoplan Płock.

![Figure 9. View of completed bridge (photo: M. Hildebrand).](image)

**Rędziński Bridge over the Odra River in Wrocław (2011)**

The largest bridge structure along the motorway ring road of Wrocław is the Rędziński Bridge crossing the Odra River [5]. The bridge consists of three structures:

- E1 south flyover: 610 m long, 11 span continuous beam (box girder), made of prestressed concrete, span lengths $40 + 2 \times 52 + 56 + 6 \times 60 + 50$ m;
- M2 cable-stayed main bridge: 612 m long, span lengths $50 + 2 \times 256 + 50$ m, with two separate superstructures suspended to a single 122 m high pylon (Fig. 10);
- E3 north flyover: 520 m long, nine-span continuous beam (box girder), made of prestressed concrete, span lengths $50 + 7 \times 60 + 50$ m.

The superstructure of the main bridge consists of two separate prestressed concrete box girders suspended to an H-shaped concrete pylon (Fig. 10). The foundation of the pylon is a concrete massive slab with base dimensions of $67.4 \times 28.0$ m and thickness variable from 2.5 to 6.5 m, placed on 160 reinforced concrete piles.

The pylon is a hybrid structure: its legs and the lower parts of the arms are made of reinforced concrete, the upper part of the arms (above the deck level) is a hollow composite structure. The lower crossbeam is a post-tensioned concrete element, the upper crossbeam is a post-tensioned steel-concrete box structure. Inside the pylon, a steel core was placed [5].

![Figure 10. View of pylon (photo: M. Hildebrand).](image)
formed the inner formwork during erection of the pylon and it interacts with the reinforced concrete shell, transferring vertical forces and bending moments. In the cable anchorage zone the core carries horizontal forces transmitted to the walls of the pylon by cable stays. The steel core and the reinforced concrete shell act as a composite section due to shear studs welded to the core’s side plates. An important load carrying element of the pylon is the upper crossbeam (compressed and torsioned). It was vertically and longitudinally post-tensioned.

![Diagram of the bridge](image)

**Figure 10.** Rędziński Bridge over the Odra River – basic dimensions.

The superstructure of the main bridge was longitudinally launched on steel column temporary supports and large truss supporting structures over the channel locks (Fig. 11). Fabrication of the segments was carried out in stages including placing side precast elements, casting the bottom slab and webs (Fig. 11), casting the deck slab, tensioning centric cables and launching the segment.

![Construction photos](image)

**Figure 11.** Construction of the Rędziński Bridge: fabrication of deck segments (left photo) and longitudinal launching of the deck.
The decks are suspended by 160 stay cables. Passive anchorages are located in the pylon, active anchorages are situated in edge beams of each deck. Views of completed bridge are presented in Fig. 12.

The Rędziński Bridge was designed by Research & Design Office Mosty-Wrocław.

Figure 12. Views of completed Rędziński Bridge.

**Bridge over the Vistula River in Kwidzyn (2013)**

The bridge in Kwidzyn has a total length of 1867 m and consists of five structures. The main 808 m long bridge is a six-span extradosed beam. The span lengths are 70.0 + 130.0 + 2 × 204.0 + 130.0 + 70.0 m (Fig. 13). It is one of the largest structures of this type in the world.

Figure 13. Bridge in Kwidzyn - side view and cross-section near the pylon.

The superstructure is a 3.50 m high box girder with inclined webs (Fig. 13). Post-tensioning system consists of internal cables installed inside the box girder and of 108 external tendons, each consisting of 75 high strength steel strands, conducted through the low
pylons. The stays are deflected in saddles and anchored in cross-beams on both sides of the girder. Height of the pylons above the deck level is only 17.2 m (~1/12th of the span). The superstructure and the pylons were made of high strength concrete class C70/80 [6].

The main part of the bridge (over the riverbed) was constructed section-by-section using underslung movable scaffolding system (Fig. 14). The superstructure was divided into 12 sections, each 50 m long [6]. For this purpose it was necessary to build 13 temporary concrete supports, six of which were located in the river current. The scaffolding consisted of two box girders supporting the formwork.

Each section was erected in stages. The bottom plate and the webs were cast in the first stage and the deck plate of the box girder was concreted in the second stage. In the first phase of construction the segments were post-tensioned only by internal cables. The remaining parts of the spans (crossbeams, diaphragms, edge beams and anchoring zones) were concreted using movable scaffolding trolleys after completion of the main part of the girder. Construction time of one section of the superstructure was three weeks [6].

The bridge in Kwidzyn (Fig. 14) was designed by Transprojekt Gdańsk, Gdańsk.

![Figure 14. Bridge in Kwidzyn: span-by-span construction of the superstructure (left photo: P. Zawiła) and view of completed structure (photo: Budimex).](image)

**Conclusions**

Characteristics of the largest Polish arch and cable-stayed bridges are summarized in Table 1.

The most common type of a large-span arch bridge is a tied arch with steel main girders and steel-concrete composite deck [7]. There are few new concrete arch bridges, usually with shorter spans. Also upper deck structures, usually built over mountain valleys, are rare, as Poland is generally a lowland country.

Among the large-span cable-stayed bridges the most common type is a structure with a steel-concrete composite deck suspended to a concrete pylon. The largest cable stayed bridge is an entirely steel structure. Quite uncommon is the configuration of the largest concrete cable-stayed bridge. Its most distinguishing characteristic is suspension of two separate concrete decks to a single pylon and hence four planes of stays. Also the concrete bridge in Kwidzyn should be noticed, as it is one of the largest extradosed bridges in the world.
Table 1. List of selected largest arch and cable-stayed bridges in Poland.

<table>
<thead>
<tr>
<th>Type</th>
<th>Name</th>
<th>Span [m]</th>
<th>Material Arch (Pylon) / Deck</th>
<th>Completed</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arch bridge</td>
<td>Bridge over the Vistula River</td>
<td>270.0</td>
<td>steel / steel</td>
<td>2013</td>
<td>Toruń</td>
</tr>
<tr>
<td></td>
<td>John Paul II Bridge over the Vistula River</td>
<td>212.0</td>
<td>steel / composite</td>
<td>2008</td>
<td>Puławy</td>
</tr>
<tr>
<td></td>
<td>Kotłarski Bridge over the Vistula River</td>
<td>166.0</td>
<td>steel / steel</td>
<td>2001</td>
<td>Cracow</td>
</tr>
<tr>
<td></td>
<td>Bridge over the Dziwna River</td>
<td>165.0</td>
<td>steel / composite</td>
<td>2003</td>
<td>Wolin</td>
</tr>
<tr>
<td></td>
<td>Bridge over the San River</td>
<td>150.0</td>
<td>steel / composite</td>
<td>2014</td>
<td>A4 motorway</td>
</tr>
<tr>
<td></td>
<td>Bernatka Footbridge over the Vistula River</td>
<td>148.0</td>
<td>steel / steel</td>
<td>2011</td>
<td>Cracow</td>
</tr>
<tr>
<td>Cable-stayed bridge</td>
<td>Solidarity Bridge over the Vistula River</td>
<td>375.0</td>
<td>steel / steel</td>
<td>2005</td>
<td>Płock</td>
</tr>
<tr>
<td></td>
<td>Rędziński Bridge over the Odra River</td>
<td>256.0</td>
<td>concrete / concrete</td>
<td>2011</td>
<td>Wrocław</td>
</tr>
<tr>
<td></td>
<td>Siekierkowski Bridge over the Vistula River</td>
<td>250.0</td>
<td>concrete / composite</td>
<td>2008</td>
<td>Warsaw</td>
</tr>
<tr>
<td></td>
<td>3rd Millenium Bridge over the Vistula River</td>
<td>230.0</td>
<td>concrete / composite</td>
<td>2001</td>
<td>Gdańsk</td>
</tr>
<tr>
<td></td>
<td>Bridge over the Vistula River</td>
<td>204.0</td>
<td>concrete / concrete</td>
<td>2013</td>
<td>Kwidzyn</td>
</tr>
<tr>
<td></td>
<td>Świętokrzyski Bridge over the Vistula River</td>
<td>180.0</td>
<td>concrete / composite</td>
<td>2000</td>
<td>Warsaw</td>
</tr>
</tbody>
</table>

References

4. Hildebrand M. Seven years of structural monitoring of a large steel cable stayed bridge. Proc. of *Workshop on Civil Structural Health Monitoring (CSHM-4) “SHM systems supporting extension of the structures’ service life”*; Berlin, 6-8 November 2012.