Designing and Constructing Prestressed Bridges

Jiří Stráský and Radim Nečas
Strasky, Husty and Partners, Ltd and Brno University of Technology

a steel–concrete composite deck that is suspended on arches formed by steel boxes infilled with concrete (Figure 4.19). The arch span is 70.57 m and its rise is 12.04 m. The suspenders are formed of Macalloy bars and are arranged as a fan with the intersection situated above the arch centre. Therefore, the funicular shape of the arch is close to the shape of a fourth-degree parabola. The deck is ended by diaphragms connected to the arch footings by concrete struts. Both the arch footings and the end abutments are supported by 1.20 m diameter drilled piles arranged in a similar way as described above for other structures.

Sometimes overpasses are situated close to important sites, and can thus form a signature point at the entry into an area. The importance of the site can justify increased costs and the overpass can be designed as an interesting arch or cable-supported structure (see Figure 4.7(g)). An example is the pedestrian bridge constructed near the city of Bohumín in the Czech Republic. The bridge crosses the D1 motorway, a local road and a creek (Figure 4.20) (fib, 2014).

The total length of the bridge 115.260 m, and it is composed of two spans (lengths 54.94 + 58.29 m) that are suspended on a single V-shaped pylon located in the area between the motorway and the local highway. Due to heavy bicycle traffic in the city, it was necessary to separate the pedestrian and bicycle pathways. Therefore, the deck is formed of a central spine girder with non-symmetrical cantilevers carrying the pedestrians and bicycles. The pylon and stays are situated in the bridge axis (Figure 4.21). To balance the dead load, the shorter cantilever carrying the 2.25 m wide pedestrian pathway is solid, while the longer one carrying the 3.00 m wide bicycle pathway is formed of a slab that is unweighted by waffles.

Figure 4.20 Pedestrian bridge near Bohumín, Czech Republic

Figure 4.19 Bridge in Figure 4.18: (a) cross-section; (b) elevation

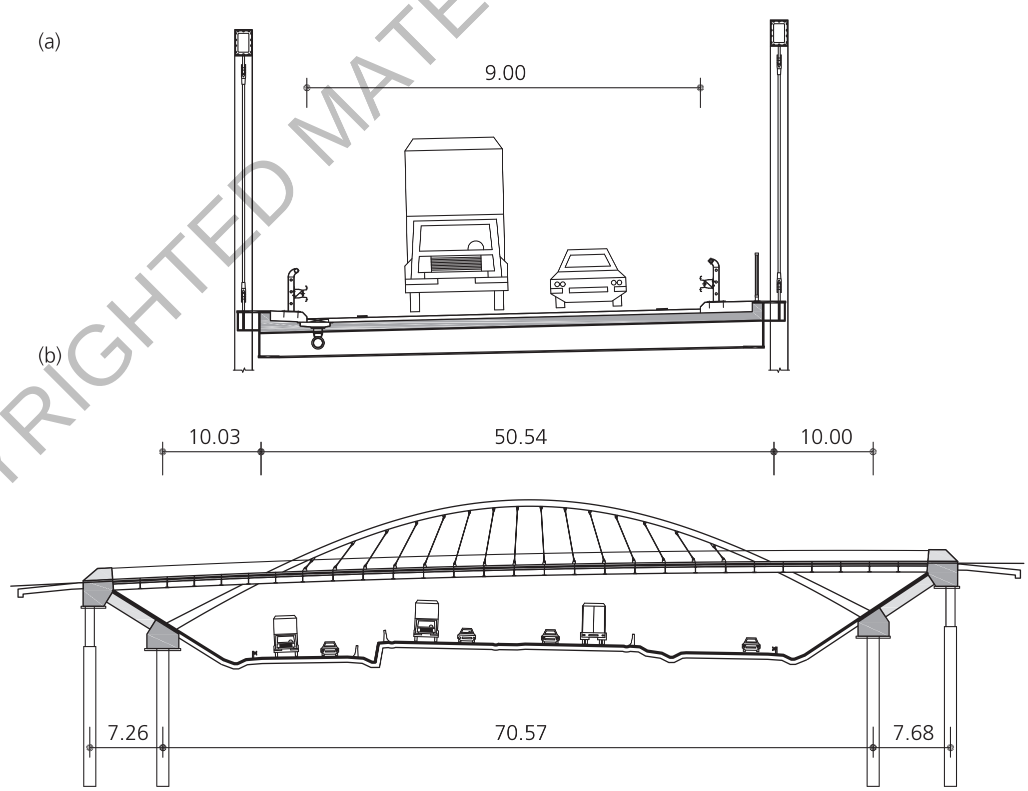

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Figure 4.78 Bridge across the Danube Canal, Vienna, Austria: (a) cross-section; (b) partial elevation; (c) elevation

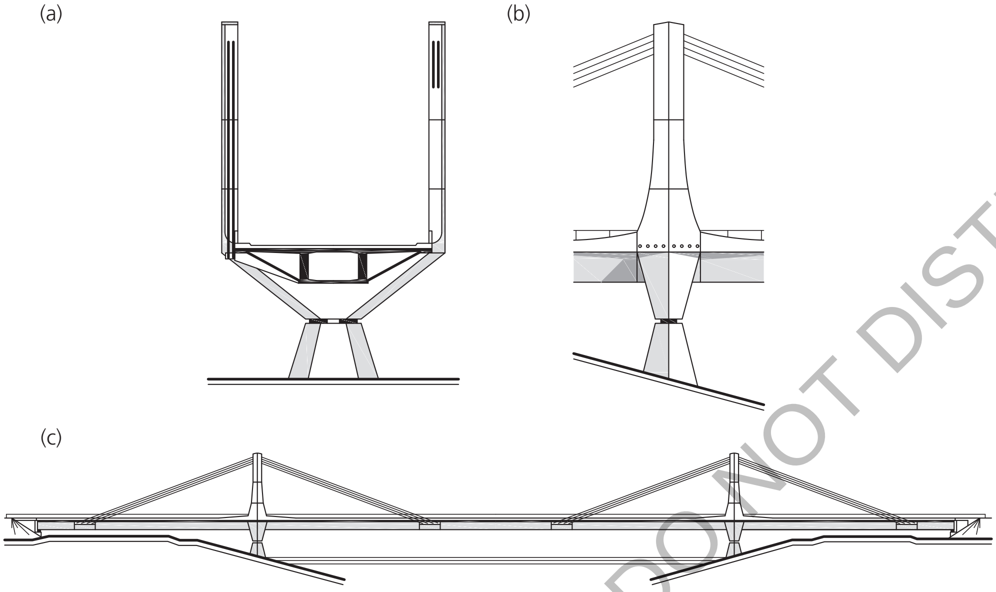

Figure 4.79 Bridge across the River Elbe, Czech Republic

Figure 4.80 Bridge in Figure 4.79: progressive deck assembly

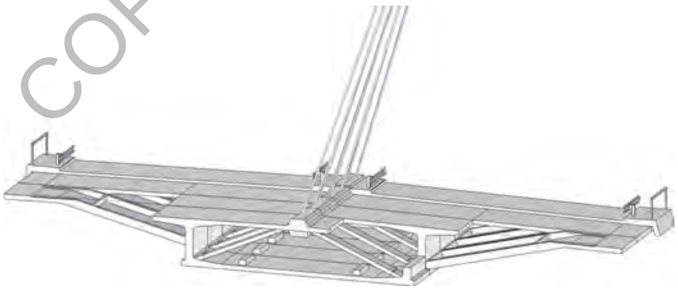

Figure 4.81 Brotonne Bridge across the River Seine, Normandy, France

The last of these arrangements is illustrated by the cable-stayed bridge across the River Odra and Antošovice Lake on the D1 motorway near Ostrava in the Czech Republic (Figure 4.83) (Stráský, 2009). The bridge is formed by a continuous structure of 14 spans, with span lengths of 21.50–105.00 m. The main span bridging the Odra River is suspended on a 46.81 m high single pylon situated in the bridge axis. As the stay cables have a symmetrical arrangement, the back-stays are anchored in two adjacent spans situated on the land between the river and the lake. The stay cables have a semi-radial arrangement; in the deck they are anchored at a distance of 6.07 m, while at the pylon they are anchored at a distance of 1.20 m.

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Figure 5.49 Bridge on the D1 motorway near Višňová, Slovakia

Figure 5.50 Bridge on the D3 motorway, Slovakia

In the construction of long railway bridges, the decks are formed of a chain of simply supported girders having a box or channel section. Launching gantries have been developed that allow the erection of girders weighing up to 600 t (Figure 5.51) (Gallo, 1990).

5.2.2 Precast segments

The bridge decks are assembled from prefabricated elements – segments of length 1.5–4.0 m. The segments usually have a single-cell box section (Figure 5.52), although multi-cell box sections, or double-T and channel sections have also been used. In the early segmental structures, the joints between the segments were formed by concrete. Modern segmental structures have epoxy joints; however, on several structures that have been built in areas with favourable climatic conditions the joints have no filler material.

Figure 5.51 Viaduct on the Rome–Florence railway, Italy

Figure 5.52 Bridge on the D5 motorway, Czech Republic

Concrete joints are now only used in the case of closure joints between individual assemblies. In epoxy joints, the epoxy resin forms only a thin layer, filling the tiny irregularities between the adjacent segments. To ensure good contact at the joints, the segments need to be manufactured in a contacting fashion. This means that the face of the already cast segment becomes the formwork for the adjacent face of the newly cast segment.

Currently, there are a number of commercially available epoxy resins. They are usually prepared from two-components: a self-adhesive and a hardener. For proper curing of the epoxy sealant, a uniform compression of 0.2–0.4 MPa is required in the joint. Although it has been verified in laboratory tests that the tensile strength of the epoxy joint is

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to the stresses originating in the deck from the global bending (${}^{G}N_X$ and ${}^{G}M_X$) (Figure 8.72).

It is for this reason that in some structures the diaphragms are not connected to the top slabs (Figure 8.66(f)). The shear flow originating in the top slab is then transferred from the top corners of the box. Half of the shear forces $T_T/2$ is transferred to the opposite corner by the transverse tensile reinforcement. The horizontal force is transferred from the upper corners to the bearings by the strut-and-tie system shown in Figure 8.71(g). The horizontal components of the forces C_P and T_P are transferred into the bearings by the compression capacity of the bottom slab.

Figure 8.74 Indirect supports of a double-T deck

The pier diaphragms of cantilever bridges have a large depth, and therefore it is necessary to carefully analyse the transfer not only of the torsional moment but also the horizontal forces originating from wind and seismic actions. Figure 8.73 shows the strut-and-tie model used by the authors in their analysis of the pier diaphragms of the cantilever bridges built in 1944 on Freeway 1 in Taiwan. The bridges, which have spans of up to 165 m, are formed of 12.20 m wide box girders that have depths ranging from 3.50 m to 8.00 m at the piers (see Figures 11.56 and 11.58).

The dimensions of the decks allowed the bridges to be modelled as 3D beam structures, which were analysed for the effects of the dead and live loads, wind and seismic actions. Significant horizontal forces H and torsional moments M_T, which originate mainly from the seismic load, are transferred from the deck via the pier diaphragms into the piers. The horizontal force H acting at the centre of gravity of the girder was proportionally distributed into the top (H_T) and bottom (H_B) slabs. The shear forces acting in the top slab T_{TS}, bottom slab T_{BS} and the webs T_W were determined from the torsional moments acting to the left and the right of the diaphragms.

As the decks of all the bridges are frame connected to piers, the forces acting in the webs and the bottom slab were transferred directly into

Figure 8.75 Indirect support: tested structure

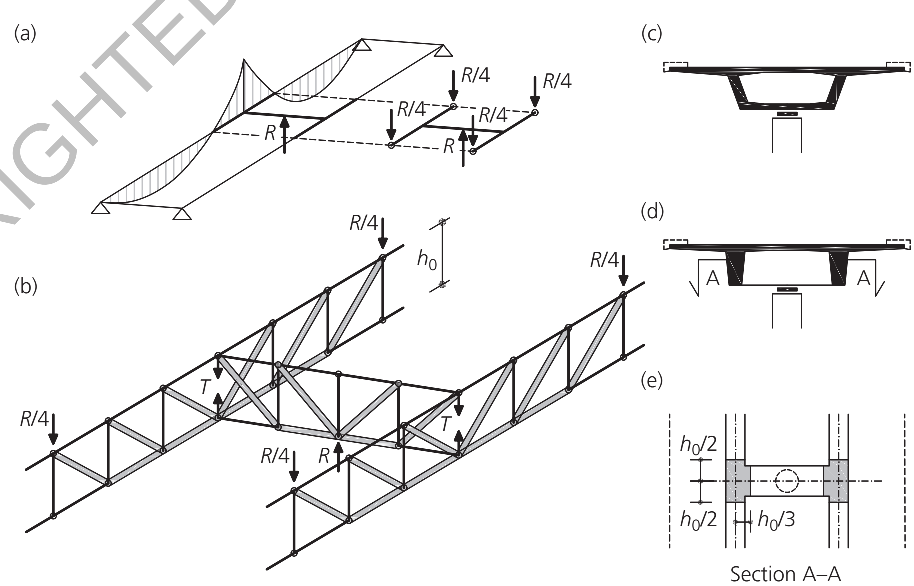

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Figure 10.23 Bridge in Figure 10.20: internal tendons

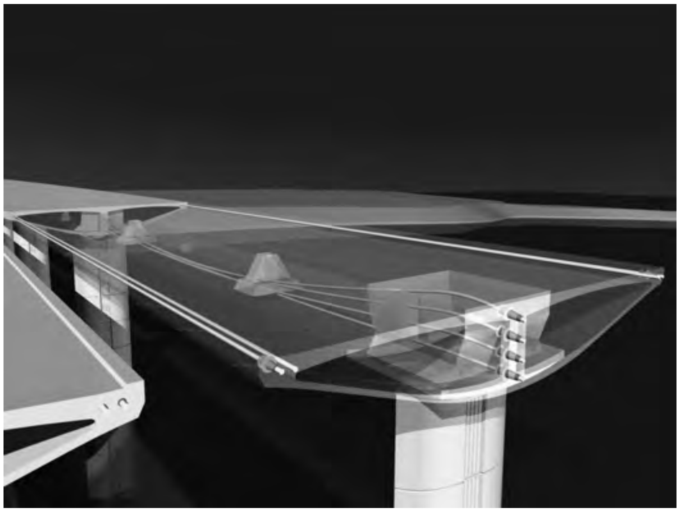
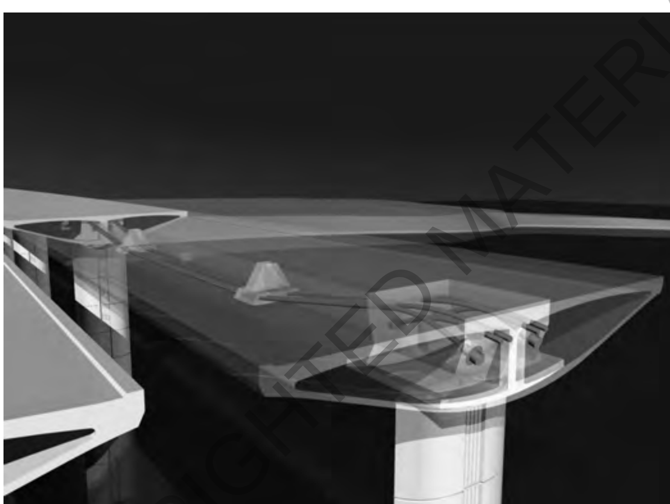


Figure 10.24 Bridge in Figure 10.20: external cables



A combination of internal tendons and external cables has also been successfully used in the construction of several bridges with progressively erected decks. The advantage of this system is demonstrated by the design of the viaduct across the Hostovsky Creek Valley built on the Expressway R1 near Nitra, Slovakia (see Chapter 4, Figures 4.60 and 4.61). The 25.66 m wide bridge deck was progressively erected in both the longitudinal and transverse directions. First, the basic box girder was cast in formwork suspended on an overhead launching gantry, and then

Figure 10.25 Motorway viaduct across Hostovsky Creek Valley, near Nitra, Slovakia: progressive construction

the precast slab struts were erected and the overhangs were cast (Figures 5.90 and 10.25).

The deck is longitudinally prestressed by internal bonded tendons situated within the basic cross-section, and by external non-bonded tendons situated inside the central box (Figure 10.26). The six bonded tendons are situated in the webs that have a constant width of 500 mm, and are coupled in each construction joint. In the 69 m long spans these tendons are supplemented by 2 × 2 tendons situated in the strengthened part of the bottom slab. Above the supports an additional 2 × 6 straight tendons are situated at the top slab. External prestressing is provided by 2 × 4 external cables. The tendons are continuous across three spans, and are anchored at the pier diaphragms. They are deviated at the pier and span deviators.

If the use of couplers is prohibited, the tendons have to be anchored at each span at two web blisters. Usually, half of the tendons are anchored at the blisters situated at the construction joints (see Figure 10.8(e)). The other half of the tendons are anchored at blisters situated symmetrically to the joint blisters. When the span is cast, the tendons anchored at the joint blisters are post-tensioned. The other half of the tendons are post-tensioned when the scaffolding is moved to the next span. As the tension originates beyond the anchors and the webs are transversely bent by eccentrically anchored tendons, the stresses at the blister areas have to be checked carefully.

For example, this arrangement was used in design of the western approach viaducts to the Kayak Bridge, which is part of the new bypass system under construction around Bratislava, Slovakia (see Chapter 5, Figures 5.83 and 5.84). The viaduct has a total length of 785 m and is formed of a continuous girder of 12 spans (lengths 53.0–67.5 m) (Figure 10.27). The bridge deck is formed of a

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