Teglværks Bridge—Copenhagen

Kjeld Thomsen, MSc; Christian Riis Petersen, MSc; ISC Consulting Engineers A/S, Copenhagen, Denmark. Contact: kbt@isc.dk

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Abstract

The missing link has finally been completed between two newly developed residential areas located in the small islands of Teglhølmen and Slaugholm in Copenhagen Harbour. For the past 10 years several relatively large residential areas have been developed on the connected islands of Teglhølmen and Slaugholm and it has been a fundamental request from the residents and the Copenhagen Municipality to provide the areas with a connection in the form of a bridge in order to divert the traffic from the residential areas directly to the main traffic roads of Copenhagen. A bridge was therefore built between Teglhølmen and Slaugholm with a new outstanding concept of hydraulically operated bascule bridge. The new bridge is an important contribution towards improving the infrastructure of the area. The structure is 100 m long and was designed with five spans in total of which the centre span is a bascule bridge and the two adjacent spans on each side are post-tensioned concrete. The purpose for designing the bascule span was that when the inner harbour is blocked with ship traffic a navigational opening 15 m wide can be established.

Keywords: bascule bridge; box girder bridge; orthotropic steel plate; Copenhagen harbor; concrete.

Introduction

A new bridge connection between the islands Teglhølmen and Slaugholm in Copenhagen Harbour was advertised for prequalification in the summer of 2006 and six consulting firms were selected for participation in the design competition for the bridge link. The Municipality of Copenhagen (client), chose the proposal submitted by the authors’ company due to its economic reasonability and outstanding design. The bridge is 100 m long between the abutments on the quays of the two islands (Fig. 1). The 19.6 m centre span consists of a bascule span. The span length was chosen to provide a free navigational clearance 15 m wide. The total width of the bridge is 18.5 m and includes two vehicular traffic lanes, two bicycle lanes and two pedestrian lane.

The two side spans on each side of the bascule span are 19.1 and 19.6 m, respectively, and consist of post-tensioned concrete slab bridges (Fig. 2).

The bascule span is unique, due to the fact that the mechanical system provided by the hydraulic anchor stays is integrated in the structural system. The bascule span is designed as a box girder bridge with an orthotropic steel plate deck. The box girder is provided with triangular supports 6 m high. Those triangular structures are connected with the back stays consisting of hydraulic cylinders in turn connected at the top of the triangle and anchored in the next support, approximately 17 m from the bascule rotation link.

The concrete spans are supported at the quay-side abutments and on two sets of columns placed respectively 19.1 and 38.7 meters from the quay side. These columns supports are circular steel tubes filled with reinforced concrete. The concrete filled steel tubes are drilled down into the limestone.

The geometry of the triangular structures is balanced accurately to ensure the stability of the system and the hydraulic cylinders are retracted fully and the bridge floor is in the vertical position exposed to full wind load.

The control tower for the bridge is located dedicated away from the bascule span outside the intermediate support for the side spans. It is connected with a small pedestrian bridge to give access to the operative personnel. The opening of the bridge is operated from the top floor in the control tower.

Design Basis

As the European standards for bridge design have not yet been introduced and certified for application in Denmark, Danish standards have been the basis for the design of the bridge. These standards cover safety classification, material quality control as well as loads on structures and foundations. However, the European standards from the preliminary editions have been applied as a supplement in cases where the Danish standards do not cover the issue. The general loading conditions are combined with the special loading conditions issued by the Danish Road Directorate for bridges. The same applies for the mechanical and hydraulic components which have been based on Danish standards with anchorage point in the concrete deck will be active only during the lift operation of the bascule span. In the closed state of the bridge, the bridge deck will be simply supported at both cantilevered concrete slabs.

For horizontal loads, the concrete spans are restrained at the column supports. Ship impact on the bridge floor is limited to 100 t—reflecting the fact that ships are only able to navigate at moderate speed. The bascule span also has been designed for a horizontal load of 100 t from ship impact and the rotation bearings are able to withstand this load at the rotation points. In the opposite end of the bascule span, a horizontal bearing is provided to resist the ship impact.

Concrete Spans

The cross-section of the concrete spans (Fig. 4) has a total width of 23.1 m at the centre. The top of the concrete slab follows the geometry of the road surface, and the centre portion has a horizontal underside, curved towards the roadway to 330 mm. The depth of bridge slab in the centre is 800 mm. The concrete slab is post-tensioned in the longitudinal direction with a total of 23 tendons with passive anchorages near the intermediate support and with the
Fabrication and Transportation

The bascule span was fabricated in a steel workshop in Bialystok in Poland. The sections were then transported by road to the quay side in Gdansk, where the bridge floor sections and the stiffening triangle were welded together. The entire welded structure was then transported on a barge to the bridge site and lifted in place by two cranes mounted on the concrete side spans. The total weight of the bascule span is 150 t. After positioning on bearings and mounting of the rotation bearing (Fig. 7), the hydraulic members were connected to the top of the triangular structure and to the anchorage of the concrete side spans (Fig. 8).

Control Tower

The control tower is located on the southern side of the bridge and to the west. The distance from the centre line of the support for the control tower to the edge of the bridge is 7.7 m. The location of the control tower was chosen to minimize the hydraulic piping connection to the two hydraulic support cylinders integrated in the triangular support and lifting system (Fig. 9). The control tower is designed as a three storey structure with the lower storey reaching into the water. The entrance level and the top level with the control panel, allow a view towards both traffic and ships navigating through the canal.

The two top storeys are designed as a lightweight structure with a steel skeleton covered with insulated, corrosion-resistant steel walls. The watertight concrete caisson supported on the monopiles contains the mechanical, electrical and hydraulic installations. Furthermore, this concrete structure has room for an oil spill tank in case of oil leakage from the hydraulic system. The pile support is drilled into the limestone and fixed into the limestone in a manner similar to the bridge columns. The control tower is connected to the pedestrian area of the bridge through another short bridge providing access to the employees.

Foundations and Abutments

To avoid any transfer of vertical load to the almost 100 year old existing quay construction, a new sheet pile wall was driven approximately 1.5 m in front of the old quay. The space between the old quay and the new sheet pile wall was filled with non-reinforced low-strength concrete. A concrete block was cast on top of the sheet pile and connected to the old concrete wall to support the bridge as

Post-tensioning carried out from the slab ends. The bridge slab is moreover reinforced with ribbed bars in the longitudinal direction as well as in the transverse direction. Spray-type membrane insulation of the concrete surface was carried out according to the rules of the Danish Road Directorate and a 90 mm asphalt wearing surface was placed on top of the membrane.

Bascule Spans

Steel Bridge Deck

The outer dimensions of the steel bridge cross section, designed as a hollow box section, are identical to those of the cross section of the concrete spans (Fig. 5). The wearing surface on the steel bridge deck consists of an epoxy layer and therefore the height of the box section is increased and adapted to the total height of the concrete spans cross-section, inclusive of the asphalt layer. As a result, the maximum height of the box section is 900 mm at the centre of the span.

The bridge deck is designed as an orthotropic steel type with longitudinal trapezoidal stiffeners spanning 3.6 m between the transverse diaphragms. The stiffening of the bottom plate is carried out with bulb sections, provided in order to attain the necessary buckling resistance of the bottom flange.

The bascule section, as a whole, has been designed for a fatigue life of 100 years. The corrosion resistance of the interior of the box section is secured by a dehumidification system.

Lift Structure

The monopole triangular support structures, with a mutual distance of 8 m, consist of welded hollow sections. The hydraulic members are pin-connected at the top of the triangular structures; and at the anchorage in the adjacent concrete spans.

The hydraulic members are sensitive to auto-vibrations from wind load. To prevent oscillation, a hydraulic damping system has been installed close to the connection to the concrete anchorages. Joints at the top and at the anchorage are built with spherical pin bearings. The same applies for the rotation bearings at the bridge deck joints at the rotation end. Reinforced elastomer bearings have been installed at the far end of the steel structure in the support lines. A horizontal bearing in the centre line transfers the transverse horizontal loads to the foundations.

Mechanical System

The hydraulically operated member activated during the opening of the bascule span, in the open position carries compression forces as well as tensile forces to resist wind loads. The hydraulic system is designed to resist a maximum characteristic wind load of 15 m/s, an average of 10 m at 10 m above sea level. For discussions on similar hydraulically operated bascule and swing bridges, see Refs.[1–3].

Operation

The operation of the bascule spans commences with activating navigation signals as well as barriers for preventing the traffic on the bridge and in the pedestrian and bicycle areas. Thereafter, the hydraulic system is activated and opening starts (Fig. 6). The entire operation is controlled by a computer system and managed from the control tower. The total opening time from the start of activating the signalling is 150 s or 2.5 min. The opening time for the bascule span proper is 2 min.

Fig. 5: Cross section of bascule span (Units: mm)

Fig. 6: Bridge open

Fig. 7: Detail of rotation bearing (Units: mm)

Fig. 8: Detail of hydraulic member connection (Units: mm)
well as the roadway approach slab. The sheet piles were anchored with Ø 63.5 bar anchors in the subsoil at an angle of 45° with the horizontal. The anchors have a length of 13.5 m. Corrosion resistance for the sheet piles is provided with cathode protection. The sheet piles were driven approximately 4 m down into the limestone.

The columns are constructed in two sections. First a Ø 1500 diameter tube was drilled approximately 1.5 m into the limestone layer, located approximately 1 to 1.5 m below the seabed (Figs 10 and 11).

Inside this tube, the limestone was drilled to a depth of approximately 9 m, a reinforcing cage was inserted and the column was filled with concrete up to a level of 4 m below the water surface. A Ø 813 mm corrosion-resistant steel tube was inserted in the outer tube and the space between the upper tube and the lower tube was filled with reinforced concrete. This ensured that the columns were fixed in the limestone layer as well as into the concrete bridge floor with adequate reinforcement provided at the connection between the column and the bridge deck. The columns adjacent to the navigation opening also provide support for the fender railing to absorb impact from passing ships.

The monopile support for the control tower is constructed in a similar manner; and, the tube drilled into the limestone is fixed directly into the bottom slab of the concrete chamber in the control tower.

**Environmental Considerations**

In order to abide by the strict requirements for environmental protection from any pollution above as well as below the water surface, all surface water runoff from the bridge passes through coal filters located behind the bridge abutments. Any oil spill leakage from the hydraulic system is led directly to an oil spill tank, located in the basement of the control tower.

**Conclusion**

The tender for the bridge was advertised in July 2009 and five contractors were pre-qualified to submit bids for the entire construction. The bids were received in August 2009. After evaluation, the Municipality of Copenhagen handed over the contract for building the bridge to the Danish Constructors. Excavation began on 22 January, 2010. The steel structure was delivered on site on 16 August, 2010 and the bascule span and the road surface layer were completed in October 2010. The bridge was handed over to the client and inaugurated on 22 January, 2011, 1 month ahead of schedule, and opened for traffic on the same day.

**References**


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