HEAVY MOVABLE STRUCTURES, INC.
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Teglvaerks Bridge, Copenhagen - Denmark

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Summary

The missing link has finally been closed between two newly developed residential areas located on the small islands Teglholmen and Sluseholmen in Copenhagen Harbour.

For the past 10 years several relatively large residential areas have been developed on the connected islands – Teglholmen and Sluseholmen – and it has been a fundamental wish from the residents and

FIG. 1 Teglvaerks Bridge – Finished

Copenhagen Municipality to provide the area with a connection in form of a bridge in order to lead the traffic from residential areas more directly to the main traffic roads of Copenhagen.

A new bridge therefore has been built between Teglholmen and Sluseholmen with a new outstanding concept for a hydraulic operated bascule bridge. The new bridge is an important contribution to improving the infrastructure of the area.

The bridge is 100 m long and designed with five spans in total of which the centre span is a bascule bridge with two neighbour spans on each side in post-tensioned concrete. The motive for the bascule span is that the inner harbour is trafficked with ships and therefore a navigational opening of 15 m width has been established.

Introduction

The new bridge connection between the islands Teglholmen and Sluseholmen in Copenhagen Harbour was advertised for prequalification in the summer of 2008 and six consulting firms were selected for participation in the design competition for the bridge link. ISC Consulting Engineers A/S´s proposal for the link was selected as the most outstanding and economically reasonable for the client – the Municipality of Copenhagen.

The bridge is 100 m long between the abutments on the quays of the two islands. The centre span of 19.6 m consist of a bascule bridge span. The span length is chosen in order to provide a free navigational opening of 15 m width. The total width of the bridge is 18.5 m and includes two road lanes, two bicycle lanes and two pedestrian lanes.
The two side spans on each side of the bascule span are 19.1 m and 19.6 m respectively, and the structures are post-tensioned concrete slab bridges.

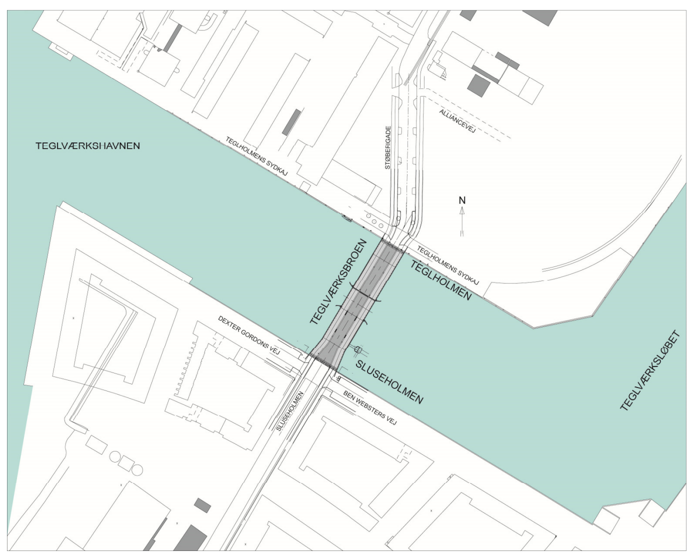

FIG. 2 General plan

The bascule span is outstanding in the way, that the mechanical system provided by 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 with a top level 6 m above the bridge deck. These triangular structures are connected with back stays in the shape of the hydraulic cylinders connected at the top of the triangle and anchored near 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 m and 38.7 m from the quayside. These column 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 very accurately to assure the stability of the system when 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 discretely apart 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

Due to the fact that the European Standards for bridge design have not yet been introduced and certified for application in Denmark – the Danish standards basically have been the basis for the design of the bridge. These standards cover standards for safety classification, material quality control as well as loads

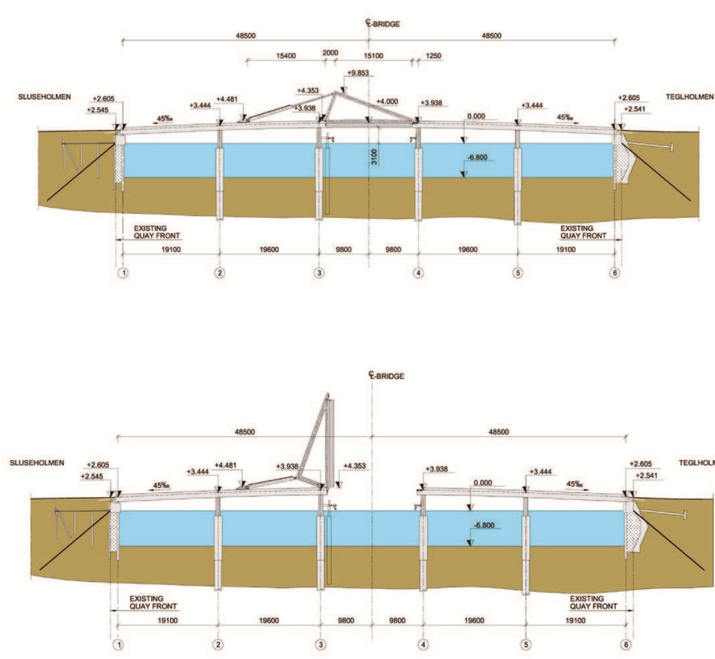

FIG. 3 Bridge closed - Bridge open

on structures and foundations. However, the European standards in 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 installations which have been based on Danish Standards and the EU Directives covering the subject.

Apart from the traffic loads, wind loads have a certain importance on the design as well as ice loads and ship impact.

The primary structure of the bascule span is designed in steel S355 applied in an appropriate quality class depending on the location in the structure. The concrete quality for the concrete spans has a characteristic strength 40 MPa.

Structural System

The bridge connection over the 97 m wide canal consists of two concrete spans on either side of the 19.6 m wide centrally located navigation opening.

The concrete spans are fixed to anchored sheet pile walls built in front of the existing quays because the old bearing capacity of these quay wall for horizontal load are inadequate partly due to deterioration.

The bascule span together with the fender system for the ships leaves 15 m horizontal navigation clearance. Two plane triangular structures are connected to the bridge deck of the bascule span, which has a total length of 17.3 m.

The hydraulic members connected to the top of the triangular structure with anchorage point in the concrete deck will only be active during the lift operation of the bascule span. In the closed condition of the bridge, the bridge deck will be simply supported at both cantilevered concrete slabs.

For horizontal loads the concrete spans will be restrained in the column supports. Ship impact on the bridge floor is limited to only 100 ton– adapted to the fact that ships are only able to navigate at moderate speed. The bascule span as well has been designed for a horizontal load of 100 ton 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.

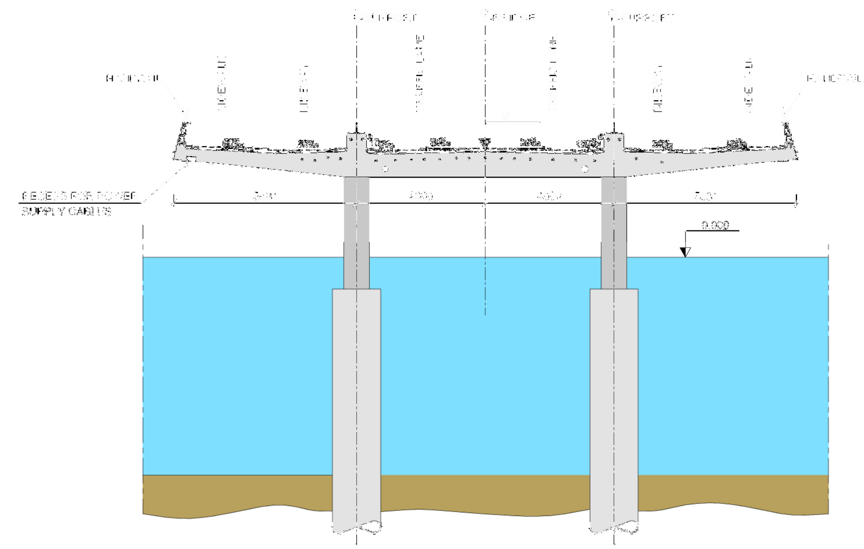

FIG. 4 Cross section of concrete spans

Concrete Spans

The cross section of the concrete spans has a total width of 23.1 m, the centre part for road traffic have a horizontal underside, and the slab is tapered towards the edges to 330 mm. The depth of bridge slab in the centre is 800 mm and the topside of the concrete is adapted to the geometry of the road surface. 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 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 of the slab. Spray type membrane insulation of the concrete surface was carried out according to the rules of the Danish Road Directorate and a 90 mm wearing asphalt was placed on top of the membrane.

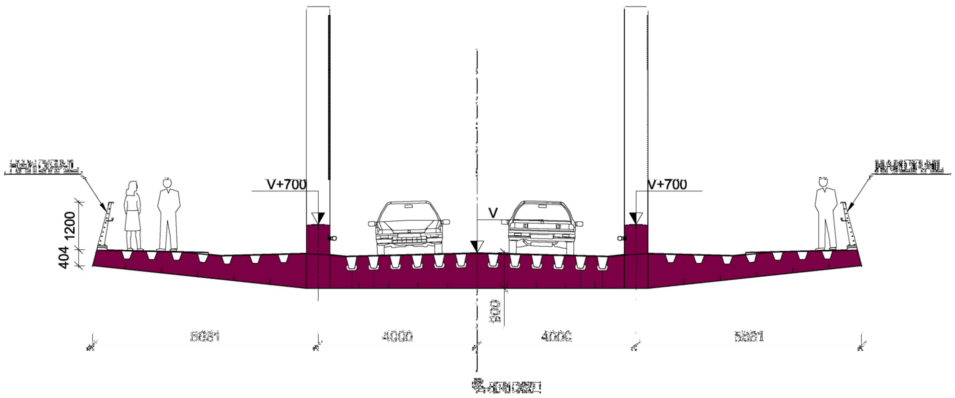

FIG. 5 Cross section

Bascule Spans

Steel Bridge Deck

The geometry of the bridge deck, designed as a hollow box section, is identical with the cross section of the concrete spans. The wearing surface on the bridge floor is carried out as a thin epoxy layer and therefore the height of the box section is increased and adapted to the total height of the concrete spans, inclusive the asphalt layer. Therefore the maximum height of the box section is 900 mm in the centre of the span.

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

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

FIG. 6 Bridge open

Lift Structure

The monoplane triangular support structures, with a mutual distance of 8 m, are carried out as welded hollow sections. At the top of the triangular structures the hydraulic members are pin-connected the same applies for 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 of the concrete anchorage.

Joints at the triangular top and at the anchorage are carried out as spherical pinbearings. 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

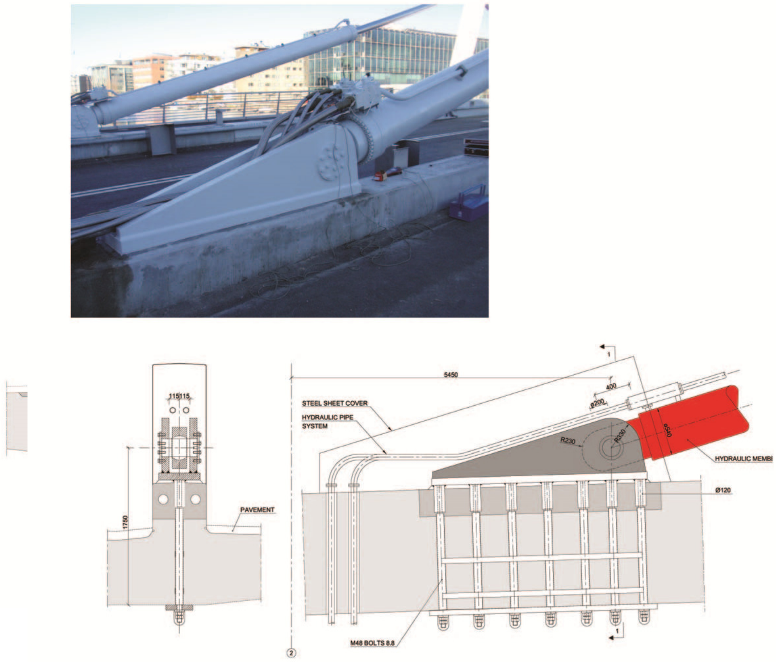

FIG. 8 Detail of hydraulic member connection

The hydraulic operated member activated for the opening of the bascule span, shall in the open position carry 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/sec, 10 min average in 10 m height above sea level. Application of comprehensive hydraulic operated bascule and swing bridges refer [1] [2] and [3]

Operation

The operation of the bascule spans commences with activating navigation signals as well as barriers activated for preventing of traffic on the bridge and on the pedestrian and bicycle areas. These barriers are closed after the bridge has been cleared for road traffic. Thereafter the hydraulic system is activated and opening starts. 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 sec or 2.5 minutes. The opening time for the bascule span proper will be 2 min.

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Fabrication and transportation

The bascule span was fabricated in a steel workshop in Bialystok in Poland. The sections were then transported on road to the quay side in Gdansk, where the bridge floor sections and the stiffening triangle were welded together. The entire welded structure is then transported on barge to the bridge site and lifted in place by 2 cranes mounted on the concrete side spans. The total weight of the bascule span is 150 ton. After positioning on bearings and mounting of the rotation bearing, the hydraulic members were connected to the top of the triangular structure and to the anchorage of the concrete side spans.

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 is a consequence of minimizing the hydraulic piping connection to the 2 hydraulic supports cylinders integrated in the triangular support and lifting system. The control tower is designed as a 3 storey structure with a lower storey reaching into the water. The entrance level as well as the top level, containing the control panel is arranged on the top with view both to traffic and to ships navigating through the canal.

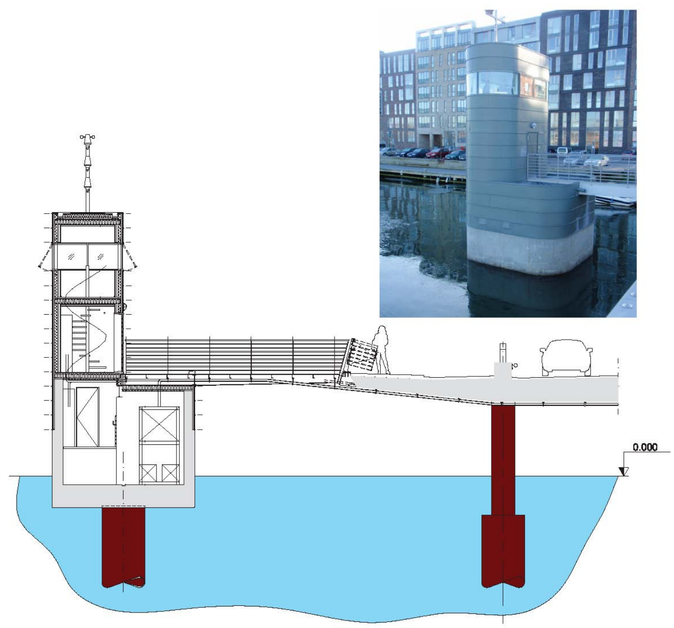

FIG. 9 Section in control tower

The 2 top storeys are designed as a light weight structure with a steel skeleton covered with insulated, plane corrosion resistant steel walls. The water-tight concrete caisson supported on a monopile contains the mechanical, the electrical and the 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 in the limestone just as the columns for the bridge.

The control tower is connected to the pedestrian area on the bridge with a short bridge to provide access for the employees.

Foundations and Abutments

To avoid any transfer of vertical load to the almost 100 year old existing quay construction the 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. On top of the sheet pile and connected to the old concrete wall a concrete block was cast to support the bridge as well as the roadway approach slab. The sheet piles are anchored with Ø 63.5 bar anchors in the subsoil at an angle of 45o with the horizontal. The anchors have a length of 13.5 m.

Corrosion protection of the sheet piles is provided with cathodic protection. The sheet piles were driven approximately 4 m down into the limestone.

The columns are constructed in 2 section. First a Ø 1500 diameter tube was drilled approximately 1.5 m into the limestone layer, located approximately 1 – 1.5 m below the seabed.

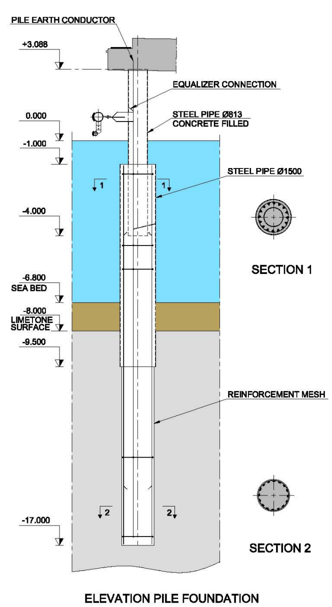

FIG. 10 Elevation pile foundation

Inside this tube the limestone was drilled out to a depth of approximately 9 m and a reinforcing cage was inserted and the column was filled with concrete up to a level of 4 m below the water surface. Hereafter 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 means that the columns will be 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 supports for fender railing to absorb impacts from the passing ships.

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

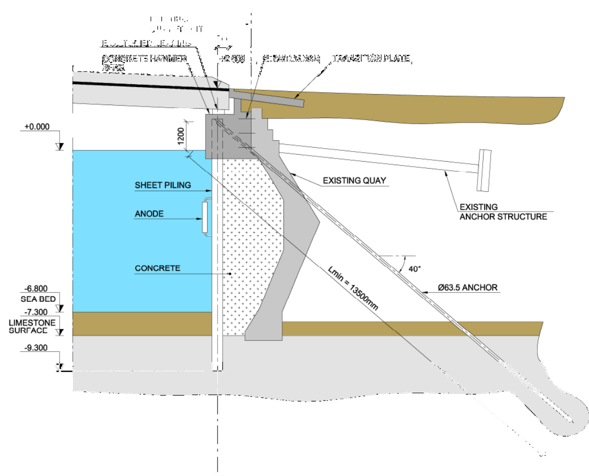

FIG. 11 Abutment

Environmental considerations

In order to abide the strict requirements for environmental protection of any pollution above as well as below the water surface, all surface water from the bridge must be lead through pipes to coalfilters located behind the bridge abutments and any oil spill from leakage from the hydraulic system is lead directly to an oil spill tank, located in the basement of the control tower.

Conclusion

The issue for tender of the bridge was placed in July 2009 and 5 contractors were pre-qualified to give bids for the entire construction.

The bids were received in August 2009. After an evaluation of these, The Municipality of Copenhagen – handed over the contract for building the bridge to the Danish Constructors CG Jensen. Excavation began 22nd January 2010.

The steel structure was delivered on site 16th August 2010 and the bascule span and the road surface layer were finally completed in October 2010. The bridge was finally handed over to the client and inaugurated January 22nd 2011 one month ahead of schedule, and opened for traffic on the same day.

Data:

Client:	Municipality of Copenhagen
Contractors:	CG Jensen A/S
Consultants:	ISC Consulting Engineers A/S
Architects/esthetical consultants:	Hvidt Architects A/S

References:

[1] SEI 3/1998 Swing Bridge across a navigation canal, Denmark.

[2] IABSE 34th IABSE Symposium, Venice, Italy, September 22-24, 2010, Odins Bridge Crossing Odense Canal.

[3] SEI, 3/2004 Opera Bridges, Copenhagen, Denmark.