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Hjulstabron (Hjulsta bridge), Sweden

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ABSTRACT

In Sweden, the existing Hjulsta bridge that connects Norrköping to Uppsala via the Highway 55 needs to be replaced by a new bridgeas shown in *Fig. 1.* ZJA Zwarts & Jansma Architects, together with Bosch Slabbers Landscape + Urban Design (landscape architects) and Iv-Consult (engineering consultancy) formed a Dutch design and engineering team that collaborated with NRC Infrapro and the Swedish Transport Administration to formulate the specifics of the bridge. The subsequent concept design brought all requirements together, resulting in a beautiful slender steel bridge both with regards to the fixed deck as well as the moveable part.

Fig. 1. Birdeye view of the Hjulsta bridge

Keywords: Hjulsta Bridge, Movable Bridge, Bridge Design, Bascule Bridge

1 INTRODUCTION

1.1 Hjulsta bridge, Hjulsta

In Sweden, the island Märson and the land along the banks of the Mälaren Lake in which it is situated, enjoy a slightly warmer climate than the surrounding region. The hilly landscape is a patchwork of pastures, meadows and forest. The banks of the lake are curvy, with many bays and inlets sustaining a rich flora and fauna. Highway 55 runs from Norrköping to Uppsala and daily more than five thousand cars use the old Hjulsta bridge that connects the island of Märson with the north bank of the lake. The bridge, built in 1953, has a vertical clearance of six meters and has to be opened frequently for the two thousand cargo ships and eight thousand pleasure yachts that pass every year. The Swedish Transport Administration engaged in a study to find the best replacement for the old bridge (1, 2). A tunnel proved to be too expensive, a ferry inadequate and the question arose which type of bridge on exactly which location was best in technical, economic, ecological and aesthetic terms.

ZJA Zwarts & Jansma Architects, together with Bosch Slabbers Landscape + Urban Design (landscape architects) and Iv-Consult (engineering consultancy) formed a Dutch team that collaborated with NRC Infrapro and the Swedish Transport Administration to formulate the specifics of the new bridge. See *Fig. 2.* for view of the Hjulsta bridge. The Swedes tackle these kinds of questions in a different way than the Dutch. The major difference is that instead of starting with a master plan and a set of requirements, the Swedes leave the pre-requisites more open in the beginning. Architects, landscape architects, construction experts but also ecological and environmental experts take part in a process managed by the Swedish Transport Administration to investigate how the exact design of the new bridge should be formulated. Apart from building professionals, also other parties are part of this preparatory trajectory, like representatives from the shipping business, the military who will use the bridge with heavy equipment, the municipalities and residents near the bridge, cyclist organizations, farmers, the fire brigade and fishermen.

Fig. 2. A Dutch team formulated the specifics for the new bridge

2 ARCHITECTURAL DESIGN

2.1 Options

Four very different options were investigated as follows:

1. A high and not moveable bridge with considerable impact on the landscape, but friendly to all shipping

2. *A lower bridge that can be opened but high enough to let leisure boats pass without restriction*
3. *A low bridge with a moveable part that can be opened to let all shipping pass*
4. *The option to refurbish the existing bridge by replacing only the moveable part*

In all cases, different techniques to open the bridge and different trajectories were taken into account with a change in location for the bridge impacting landscape, residents and nature in varying ways. In the end, after discussing the report detailing the four options, the Swedish Transport Administration made a well-reasoned choice for option 3, a low bridge with a moveable part that can be opened to let all shipping pass.

Following considerations in regards to the typology of the moveable part of the bridge, 4 different options were examined. A preliminary design published in December 2018 presented a bascule type bridge with a counterweight above the deck level. This design considered the fact that a double leaf bridge opens more quickly and requires less energy to open than a single leaf bridge. Furthermore the arms of a double leaf bridge are typically smaller and so make less of an impact on the landscape.

2.2 Design Principle

The design of the structure is based on a gradually developing rhythm that follows the increasing height of the bridge. The higher the bridge becomes the longer the span becomes between the supports. The non-constant span-lengths affect the structural height of the deck. As a result the deck reaches its maximum cross-sectional height at the highest point of the bridge above the water, where the movable deck is. The cross-section of the deck has a tapered profile that enhances the slenderness of the structure.

Aside from the deck, the design of the supports is also reflecting the concept of gradual transformation. After various studies regarding the shape of the supports, the most preferred option was a ''Y'' shaped structure that consists of a main body at the bottom that splits in two before reaching the underside of the deck as shown in *Fig. 3a*. As the bridge gets lower and the deck becomes thinner, the main body of the column disappears in the water, keeping only the two split parts visible as shown *Fig. 3b*.

At the same time, the distance between the split parts increases. This is necessary as the underside surface of the deck increases when the tapered cross-section of the deck gets thinner. Nevertheless, the design of the columns maintains a certain degree of modularity.

a)

b)

Fig. 3. a) The "Y" shaped structure of the bridge; b) The columns of the bridge disappear in the water

2.3 Movable Part

The new Hjulsta Bridge is a bascule type bridge. This system of operable deck includes a counterweight that continuously balances the deck span, or leaf, throughout its upward swing. This bascule bridge is a double leafed bridge, with a counterweight above the deck level. As such, no underwater dry spaces need to be created in order to contain the counterweight.

The typology chosen ensures a minimal impact on the landscape due to its compactness and does not require excessive material for large structural members. Materialization is kept to a minimum, using white steel and light concrete. The bridge is made out of 2 identical operable leafs that can open and close quickly for ships to pass as shown in *Fig. 4*.

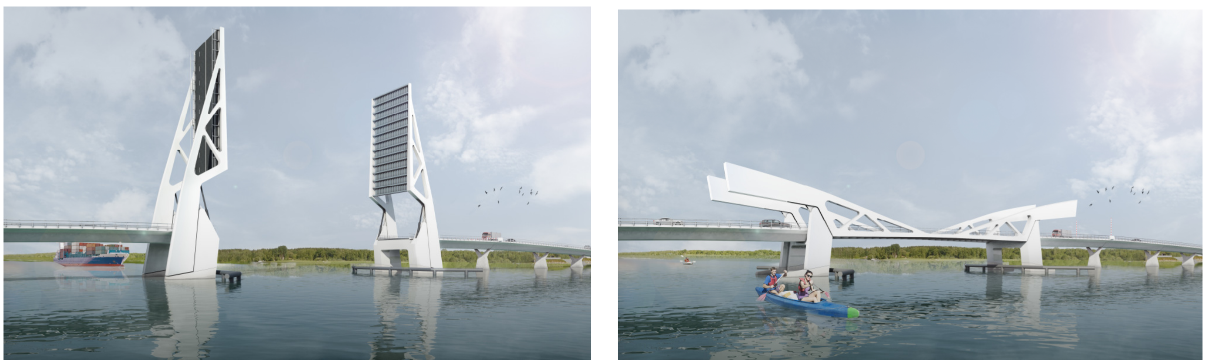

Fig. 4. The bascule bridge is a double leafed bridge

3 MATERIALIZATION

3.1 Use of steel

The design considers a minimum impact on many aspects. The vulnerable environment requires a low elevated and well-positioned bridge landing at the embankments. A higher elevation would otherwise result in larger and longer embankments that will then have considerable impact on the local infrastructure and protected oak trees in the Natura 2000 (3) area besides the road.

The clearance under the bridge at the bridge landings should be sufficient for inspection and maintenance of the bridge supports. The clearance also needs to be maximised for ship traffic. At this point the bridge span and its structural height actually determines the road alignment. The combination of a low alignment and a maximised clearance under the bridge results in a slender design. To have a proper and logical aesthetic appearance the slenderness should be kept as constant as possible.

A slenderness rate of approximately 1:20 is taken throughout the concept of the new Hjulsta bridge. Such slenderness in a bridge will result in relatively high tensile stresses, which very well suit a steel solution. A steel-concrete deck is thought to be a proper solution for the fixed deck, where steel will manage the tensile stresses and concrete will take account of the compressive part. A concrete deck is also beneficial to spread the loads toward the steel part and prevent possible local fatigue problems over the projected lifecycle of 120 years.

A further consideration for the use of steel is its sustainable character and end-of-lifecycle value, given the ability to upcycle steel. With respect to durability the nowadays high quality coatings might last up to 50 years before maintenance is necessary, resulting in a positive effect on the total life cycle cost. Steel is also relatively easy and quick to repair or rebuild in case of unforeseen damages, with a positive effect on the reliability of the bridge.

A steel solution also results in less material and mass throughout the overall design, with a positive impact on the foundation design. As shown in *Fig. 5* of the steel structure of the bridge.

Concrete is used for the bridge deck and the bridge pylons. It has more resistance against the abrasive impact due to traffic on the deck and ice and water at the splash zone of the pylons.

Fig. 5. Steel structure of the movable bridge

4 CONCLUSION

The new Hjulsta bridge has been designed in concept and is based on Dutch bridge design experience while taking many difficult and challenging local requirements into account. A concept means that the next stage of the development provides room for further optimisation of the bridge's structural elements in which the exact dimensions, cross sections, execution methodology and more can be defined.

REFERENCES

(1) More information of the Hjulsta bridge can be found at the website of the Swedish Transport Authorities: https://www.trafikverket.se/hjulstabron

(2) ZJA Zwarts and Jansma Architects: https://www.zja.nl/en/hjulstabrug-Hjulsta.

(3) More information about the European Natura 2000 network program can be found at: http://ec.europa.eu/environment/nature/natura2000/