Design Challenges for Hålogaland Bridge, Norway

Allan LARSEN
Mechanical Engineer, Ph.D
COWI A/S
Copenhagen, Denmark
aln@cowi.dk

Allan Larsen, born 1953, has worked in bridge aerodynamics for 20 years. Among his long span bridge references are Great Belt Bridge, Denmark, Pont de Normandie, France, High Coast Bridge, Sweden, Stonecutters Bridge, Hong Kong and Messina Bridge tender design, Italy.

Lars JENSEN
Senior Project Manager
COWI A/S
Copenhagen, Denmark
lsj@cowi.dk

Lars Jensen, born 1962, has worked in the field of design of cable-supported bridges during the past 15 years. Among his suspension bridge references are the High Coast Bridge in Sweden (tender and detailed design) and the Messina Strait Bridge in Italy (tender design).

Bernt JAKOBSEN
Business Development Manager, Dr. ing.
COWI AS
Oslo, Norway
bjak@cowi.no

Bernt Jakobsen, born 1944, has worked in the field of structural engineering for 40 years. His experience relates primarily to bridges and marine structures and in particular to offshore concrete structures.

Summary

The COWI Team prepared in 2007 Basic Design and construction cost estimates for Hålogaland Bridge. The bridge is arranged as a single span suspension bridge with A-shaped concrete pylons, inclined cable planes and a closed steel box girder as bridge deck. The combination of a slender bridge and 2.2m high safety railings to prevent would-be-suicides jumping on impulse from the bridge poses a severe design challenge to fulfil the aerodynamic stability requirement of 56m/s at bridge deck level. The issue of vortex induced vibrations for closed steel box bridge decks poses another design challenge. The box section is arranged in such a way that the slope of the lower inclined side plates is at 15.8 degrees in relation to the horizontal bottom plate. Wind tunnel tests carried out in smooth flow have proved that vortex induced vibrations will not occur, thus saving the costs of installation and maintenance of mitigation measures.

Keywords: Suspension bridge; safety railing; aerodynamic stability; vortex shedding excitation.

1. Introduction

The Hålogaland Bridge is located at Narvik in northern Norway, crossing "Rombaksfjorden" with water depths up to 350 m. The bridge is part of a new alignment of the E6 highway between Narvik and Bjerkvik which will shorten the existing E6 by 17 km. It will carry a two lane highway and a footway/bicycle path.

The COWI Team prepared in 2007 the design for a suspension bridge alternative on behalf of the Norwegian Public Roads Administration, Region North. The COWI Team consists of COWI, Dissing+Weitling, Johs. Holt and the Norwegian Geotechnical Institute.

The bridge is arranged with the pylons founded on shore directly on rock resulting in a 1,345 m main span, see Fig. 1.

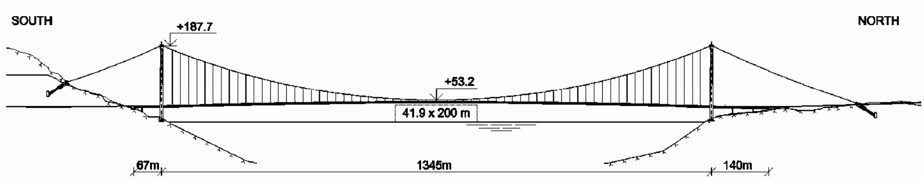

Fig. 1: Layout of the suspension bridge alternative

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2. Design Challenges

The many design challenges faced by the bridge designer vary from the choice of bridge type that will meet the requirements to load carrying capacity. At the same time the chosen bridge concept shall be the most economical in terms of construction, durability and future maintenance costs and the aesthetics shall be considered in a satisfactory way. For Hålogaland Bridge, the 350 m water depth and 1.3 km width of the Rombaksfjord at the bridge site pointed to a cable supported bridge as the only realistic solution. A single span suspension bridge appeared to be the most economical alternative because good quality rock is readily available for anchoring of the cables, although a hybrid cantilever beam/cable-stay /suspension bridge structure was explored by a competing design team.

The important design challenges are described below:

- The ratio of main span length to main cable distance is 90 whereas the typical ratio for suspension bridges lies within the range of 55-60. Moreover, it is required that in addition to ordinary parapets, the bridge is also to be equipped with 2.2m high safety railings to prevent would-be suicides jumping on impulse from the bridge. The combination of a slender bridge and high railings poses a severe design challenge to fulfil the aerodynamic stability requirement of a wind speed of 56m/s at bridge deck level. The aerodynamic stability has been verified through numerical analyses and wind tunnel tests where a critical wind speed of 61m/s was obtained.
- It was a challenge to develop a box girder that does not respond to vortex shedding excitation as is known from the Great Belt East and Osterøy Bridges. Series of wind tunnel tests conducted for the design of the High Coast Suspension Bridge in Sweden and the two span suspension bridge connecting the main land of Chile to the island of Chiloé together with the fact that classical airfoils display increasing lift with increasing inflow angle till about 16 deg. where upon they stall rendered valuable help in this respect. The slope angels of the lower inclined side plate for the High Coast Bridge and the Chiloé Bridge were all less than $\theta = 16$ deg. Revisiting the Great Belt East and Osterøy box girders yielded lower inclined side plate slope angles $\theta = 26.6$ deg. and $\theta = 29.5$ deg., thus in retrospect, the observed vortex shedding oscillations for these bridges in full scale as well as in wind tunnel tests was not a surprise. Based on the experience from vortex shedding tests with various box cross section geometries and the stall angle for airfoils, the lower side panel angle of the Hålogaland Bridge was set at $\theta = 15.8$ deg. Wind tunnel tests were commissioned and a section model at scale 1:50 was constructed for verification that vortex induced oscillations were indeed mitigated also in presence of the external safety railings. The wind tunnel tests demonstrated that vortex induced oscillations were absent supporting that the flow along the bottom plate will stay mainly attached if θ is less than approx. 16 deg.

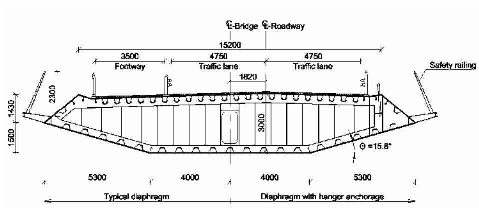

Fig. 2: Steel bridge deck in main span with safety railings

Fig. 3: Rendering of Hålogaland Bridge (prepared by Dissing+Weitling)