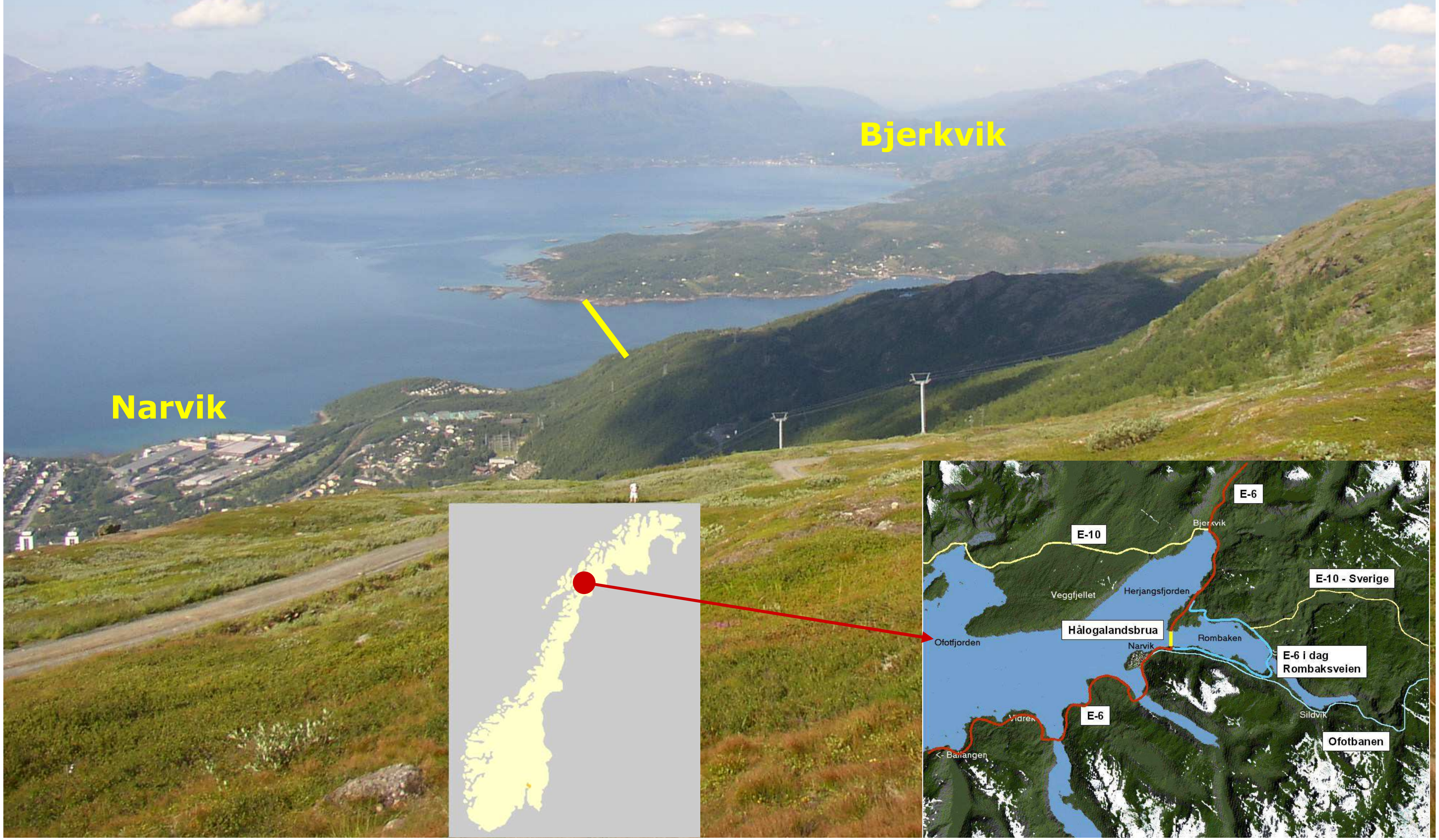
Hålogaland Suspension Bridge, Narvik, Norway

IABSE Denmark Mini-seminar 2013

Lars Jensen COWI A/S



Introduction

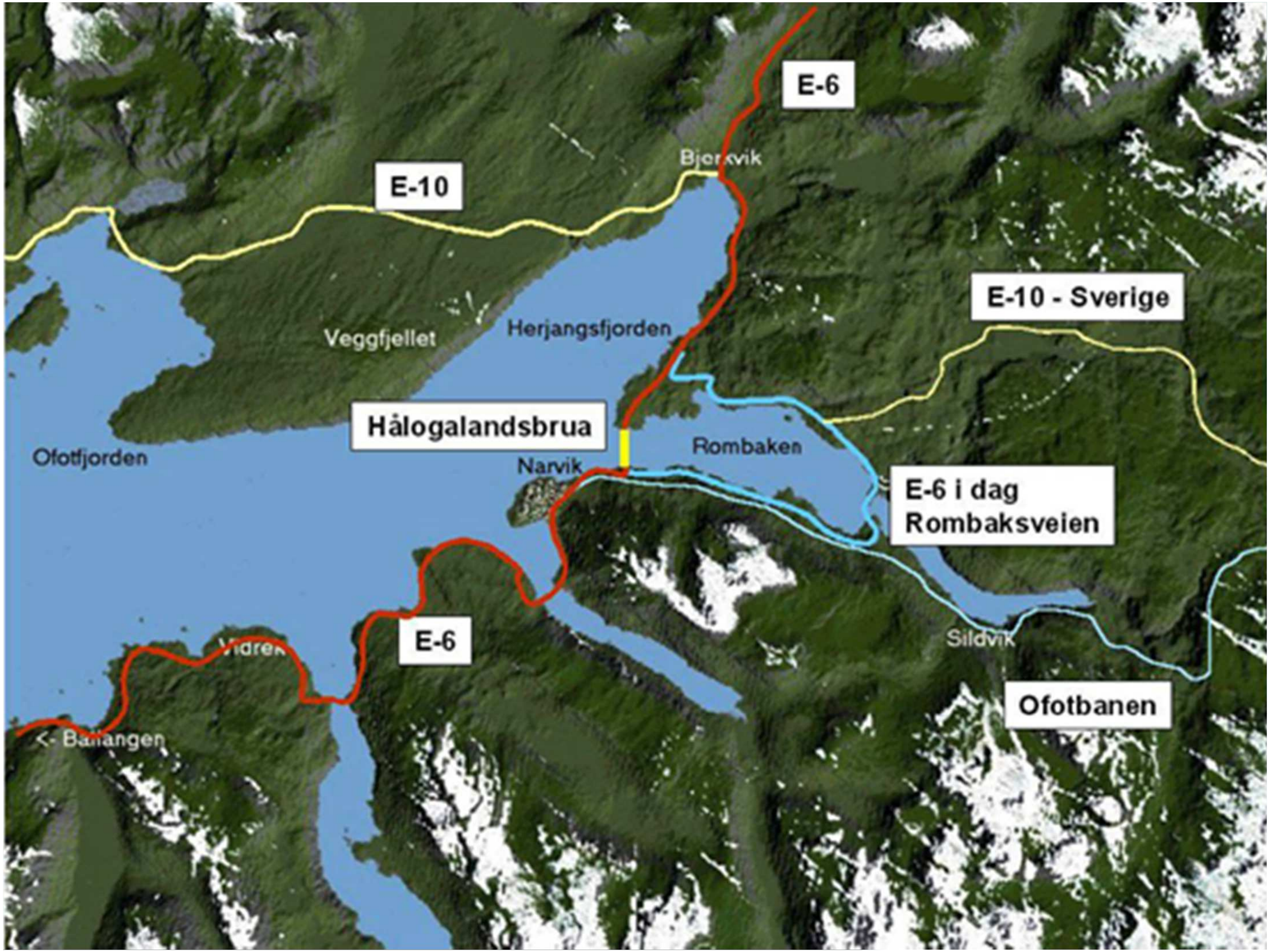
Scope of Work:

- Basic design for 2 suspension bridge solutions incl. construction cost estimates
- Detailed design for 1 suspension bridge solution

COWI Team:

• COWI	Project management, global and aerodynamic analyses, cable structures, steel box girder, cable anchorages, approach viaducts
• Dissing+Weitling	Architect
• Johs Holt	Pylons incl. foundations
• NGI	Expert rock cable anchorages and foundations

Client: Norwegian Public Roads Administration, Region North


E-6
Bjerkvik
E-10
E-10 - Sverige
Veggfjellet
Herjangsfjorden
Hålogalandsbrua
Ofotfjorden
Narvik
Rombaken
E-6 i dag
Rombaksveien
E-6
Sildvik
Ofotbanen

Hålogaland Bridge

2007-2008:	Basic Design and construction cost estimates
2009-2010:	Tender Project (Detailed Design)
2012:	Financing finally approved by Stortinget
2012:	Tender documents finalised
2012 (Oct):	Road and rock works tendered
2013 (Feb):	Concrete works tendered – contract in June
2013 (Apr):	Steel and cable works tendered – contract in August
2017:	Bridge to be completed

Bridge layout

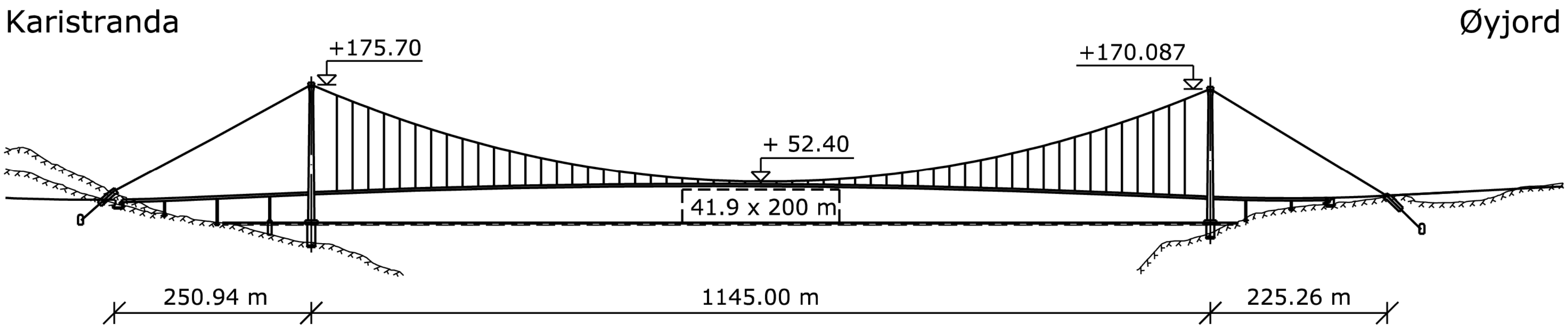
Challenges:

- Aerodynamic issues
- Inclined cable system
- Pylon foundations at level -30 m
- Transition from Clients standard rules to Eurocode during the project period
- Eurocode – Hålogaland Bridge is the first suspension bridge in Norway designed in accordance with Eurocode
- International contractors and suppliers?
  - Text on all drawings is in Norwegian as well as English
  - Particular specifications prepared in Norwegian as well as English

Bridge layout

Characteristics:

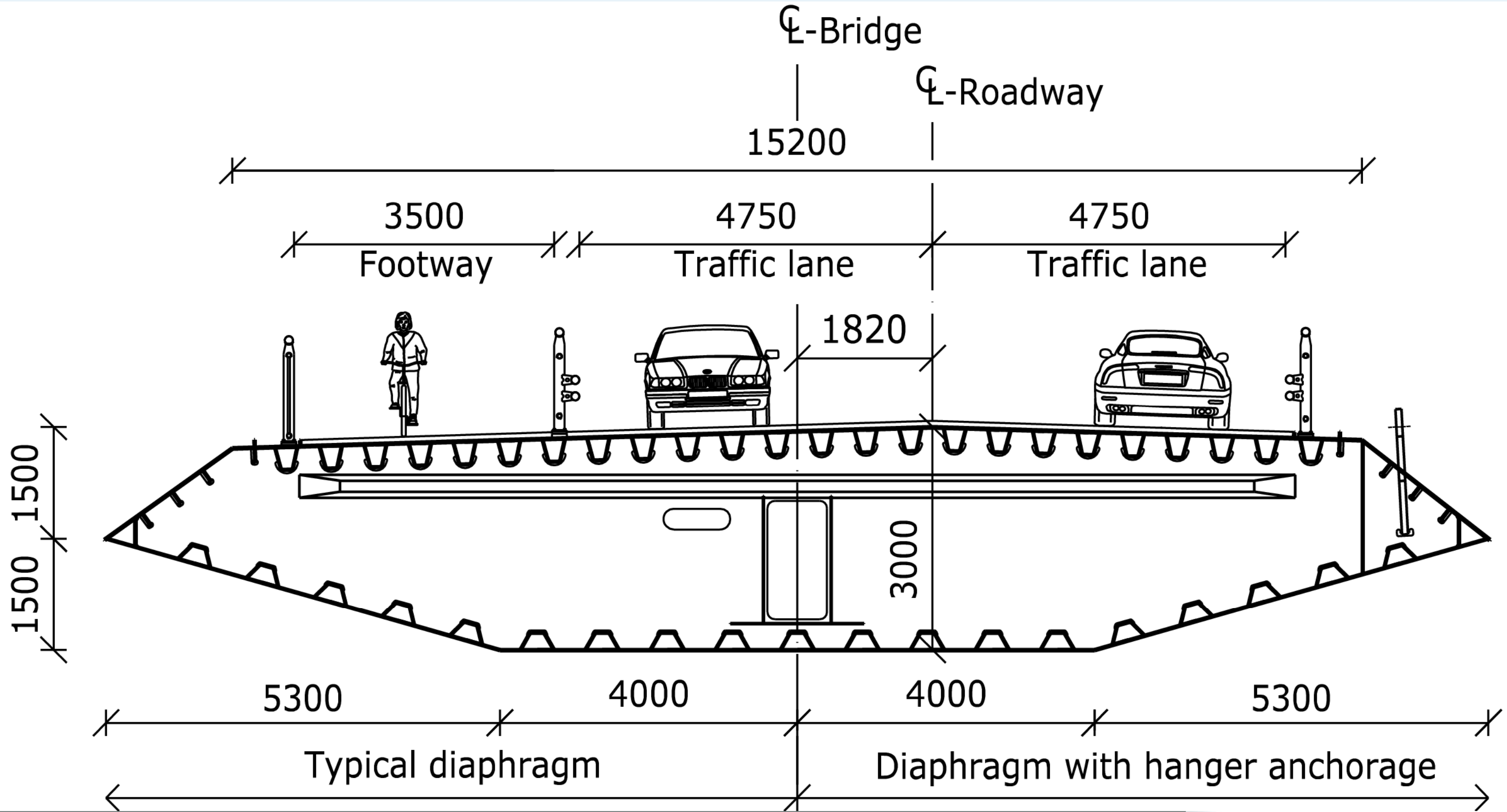
- Single span suspension bridge
- Second longest main span in Norway, 1145 m
- Span to sag ratio is 9.5
- Cables anchored directly to the rock
- Vertical navigation clearance 40 m above high water



Bridge deck

Cross section:

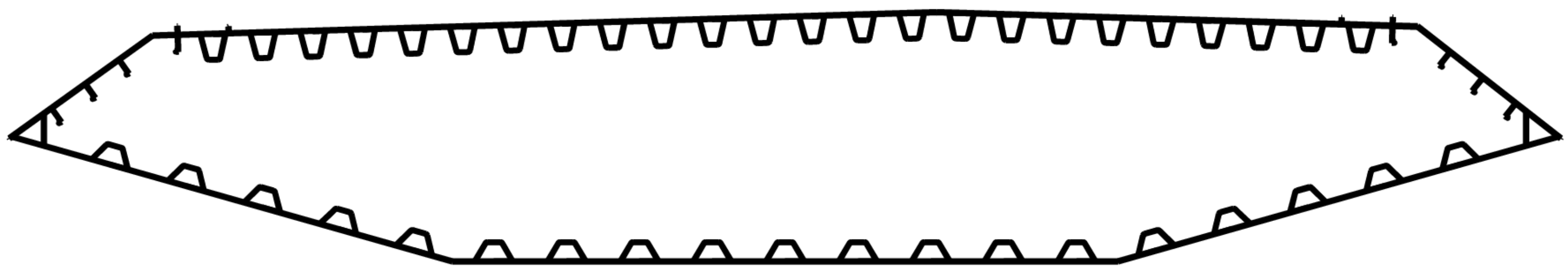
- Closed steel box girder
- Total width of bridge deck 18.6 m



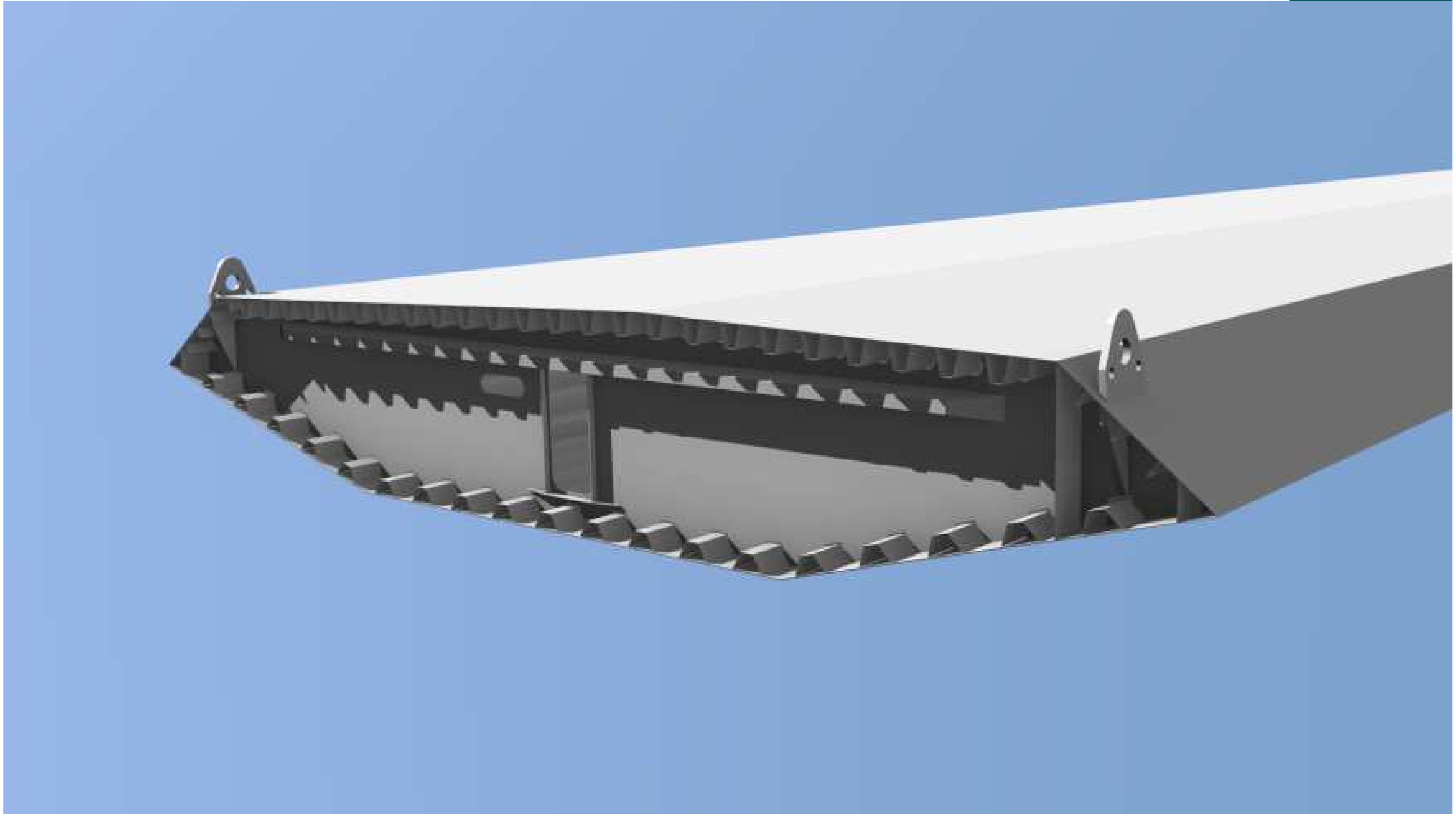
Bridge deck

General arrangement:

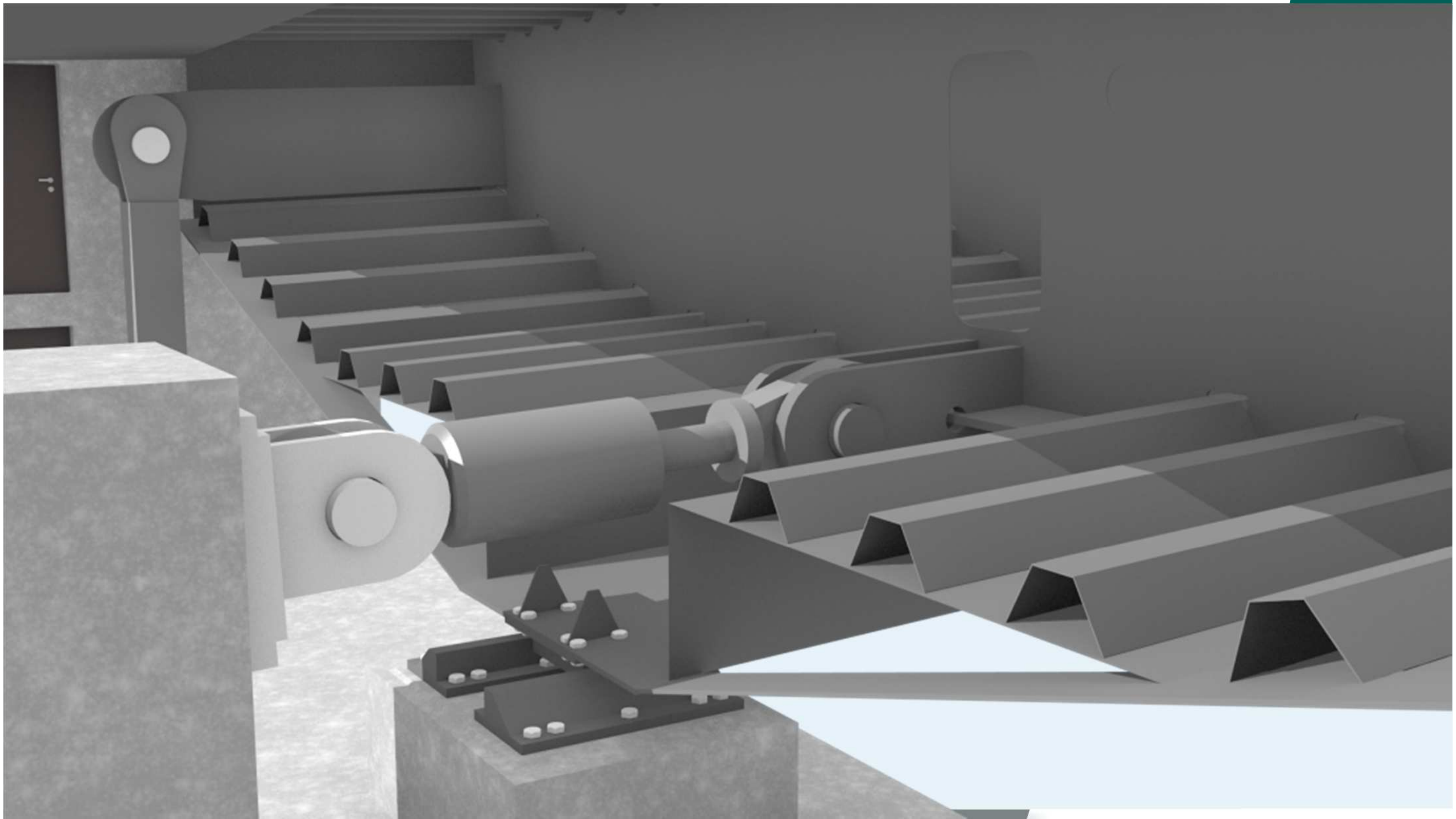
- Deck panel: 14 mm deck plate, 6 mm trough stiffeners
- Bottom panel: 8 mm bottom plate, 6 mm trough stiffeners
- Diaphragms each 4.0 m
- Steel grade: NS EN 10025 S355N or M
- Steel quantity 7100 t – equivalent to 480 kg/m^2



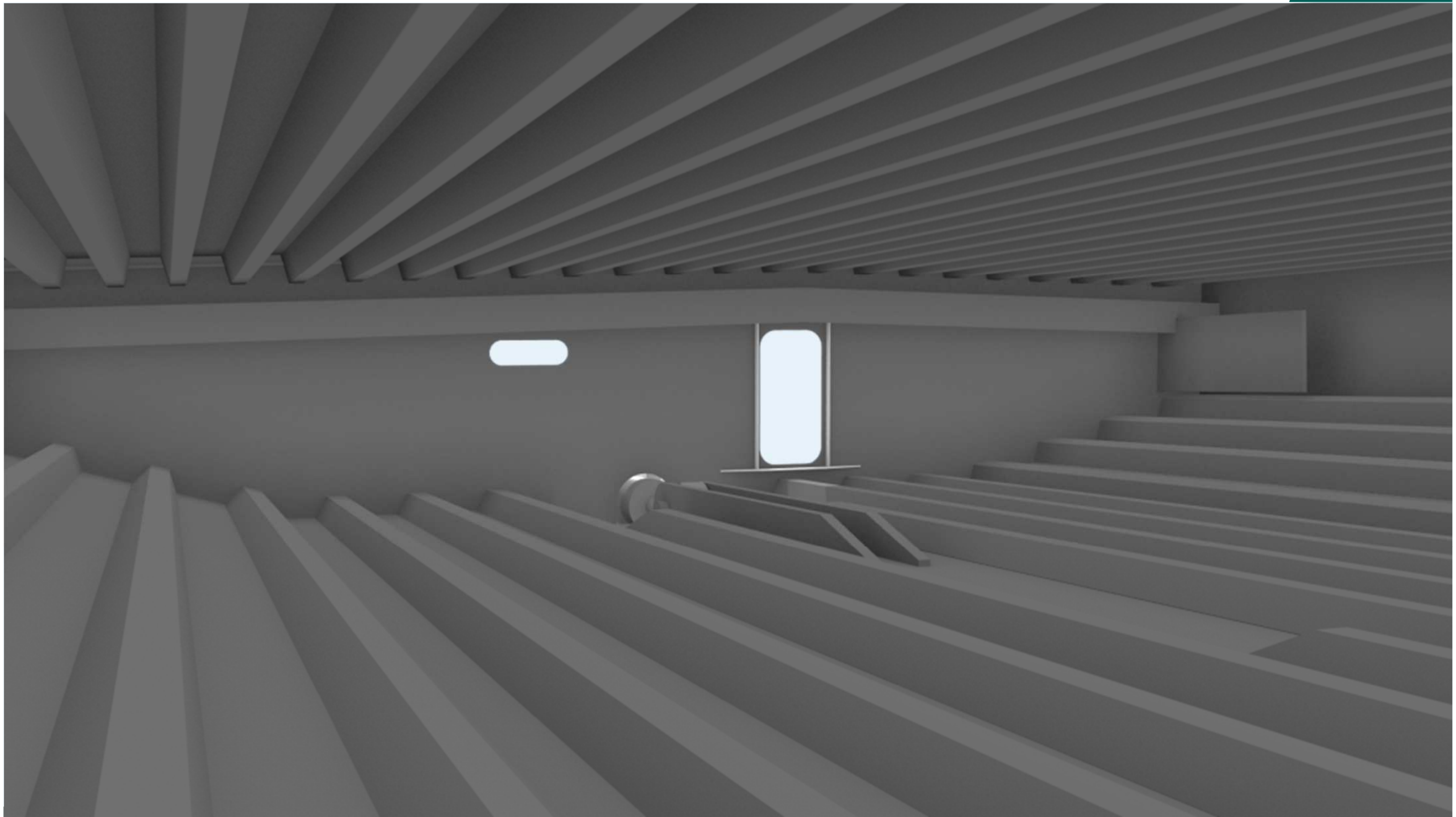
Bridge deck



Bridge deck



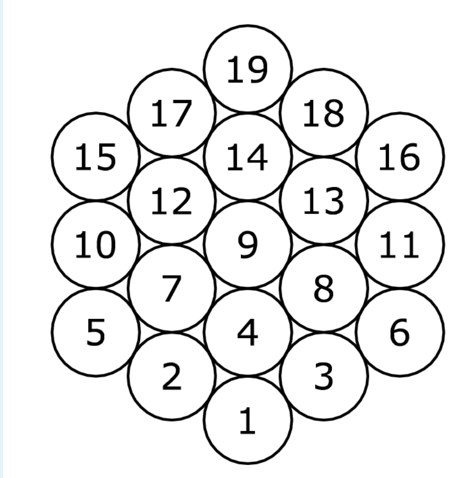
Bridge deck

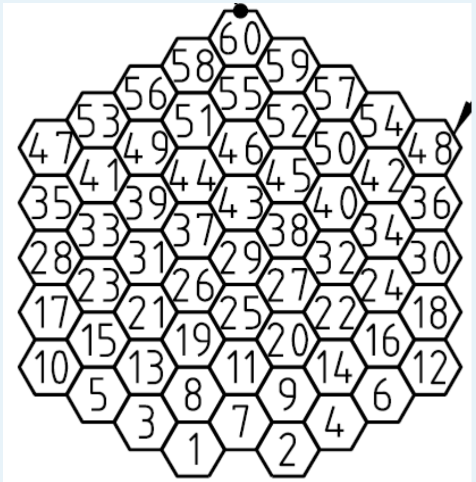


Main cables

General arrangement:

- 5.38 mm wires – breaking strength 1770 MPa
- Design is based on air spinning as construction method – similar to Hardanger Bridge
- 19 strands in main span – each having 328 wires
- 6232 wires in total - area 0.142 m^2
- Cable diameter after compaction 0.478 m
- Additional strands in side spans due to local site constraints
- Tender is also open for PPWS as construction method – 60 strands in main span each having 91 wires of 5.75 mm diameter
- Steel quantity approx 4000 t





Main cables

Distribution of unfactored tension for 1770 MPa cables

Dead load, cables	16%
Dead load, steel deck	40%
Dead load, pavement	18%
Dead load, equipment	4%
Dead load, total	**78%**
Traffic	16%
Wind and temperature	6%

Main cables
Application of high strength steel

Cable wires – breaking strength:

- 1570 MPa – Storebælt, Denmark (opened 1998)
- 1770 MPa – Akashi-Kaikyo, Japan (opened 1998)
- 1860 MPa – Yi Sun-Sin, Korea (opened 2012)
- 1960 MPa – 3 bridges under construction, Korea (planned 2014-2018)

General data for main cables	Unit	1570 MPa	1770 MPa	1860 MPa
Cable area	m^2	0.165	**0.142**	0.133
Cable, diameter	mm	515	**478**	464
Cable steel quantity	t	4675	**4020**	3780

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Main cables
Application of high strength steel

Cable wire strength	Area	Δ-quantity	Deflection	Cable diameter
1570 MPa	116%	+ 655 t	89%	0.52 m
1770 MPa	**100%**	**-**	**100%**	**0.48 m**
1860 MPa	94%	- 240 t	105%	0.46 m

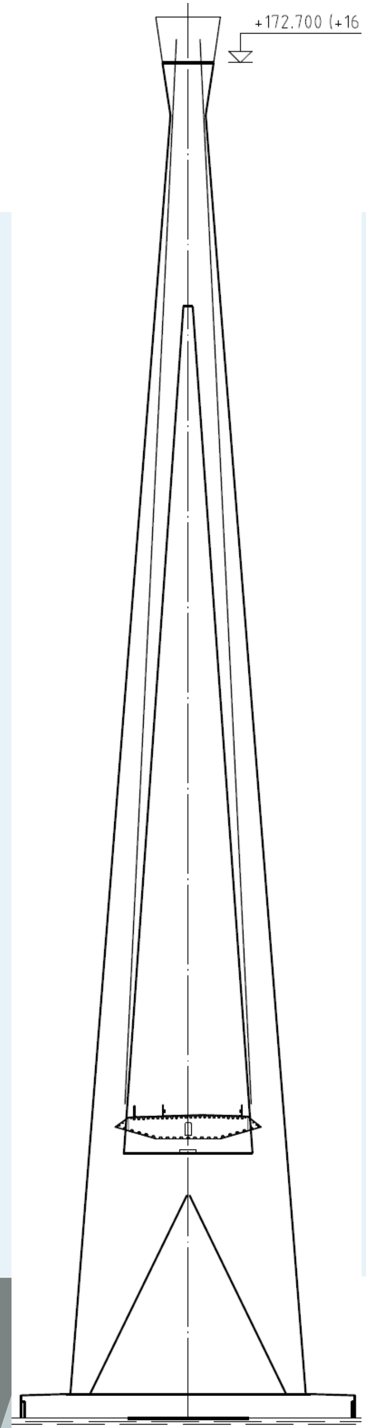
Conclusions:

- Cable forces due to dead load and cable quantities are reduced by adopting the highest possible cable wire strength
- Thereby significant cost savings are obtained in cables and anchorages
- Related savings are obtained in pylons, foundations and construction time
- Smaller wind load due to smaller cable diameter
- Slightly increased deflections

Pylons

General arrangement:

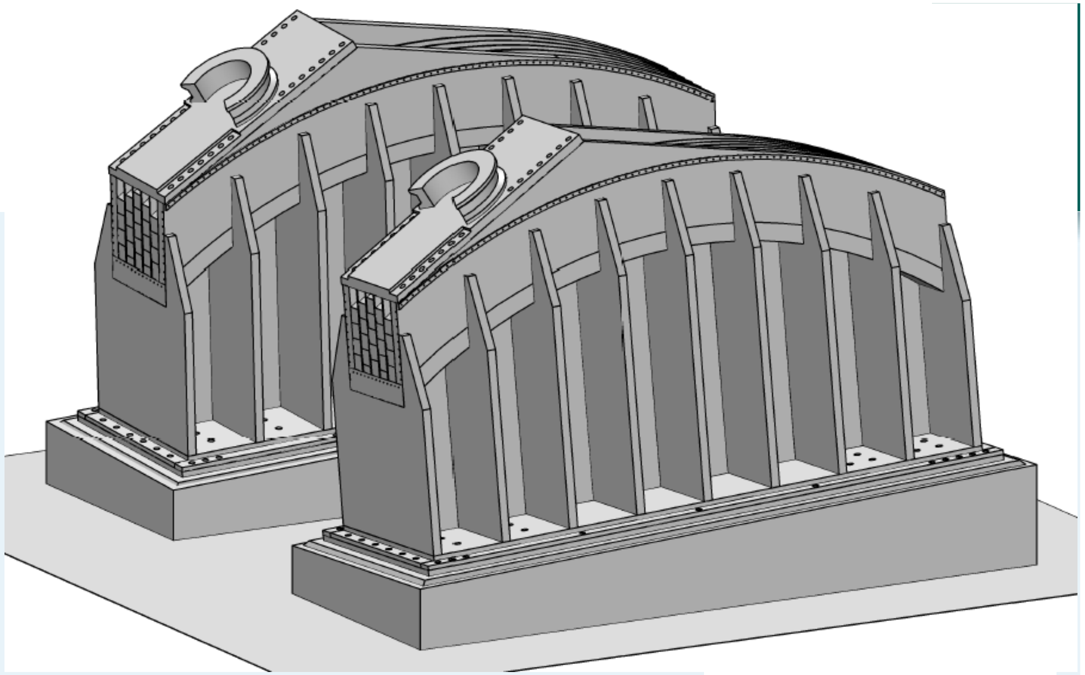
- Slender
- A-shaped, concrete, inclined cable planes
- Simple geometrical shape
- Light appearance due to tapering downwards
- Landmark for the region

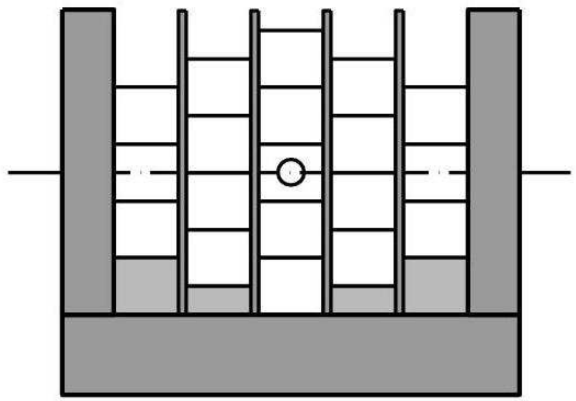


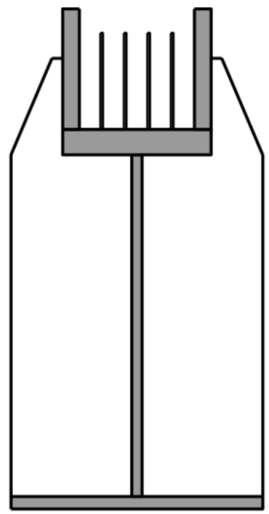
Cable structures
Saddles

Tower saddles:

- Welded steel structures
- Steel grade:
  NS EN 10025 S460N eller M
- Ribs: 50-60 mm
- Troughs: 80-120 mm
- Quantity approx 50 t
- "Open" structures – easy to inspect and maintain



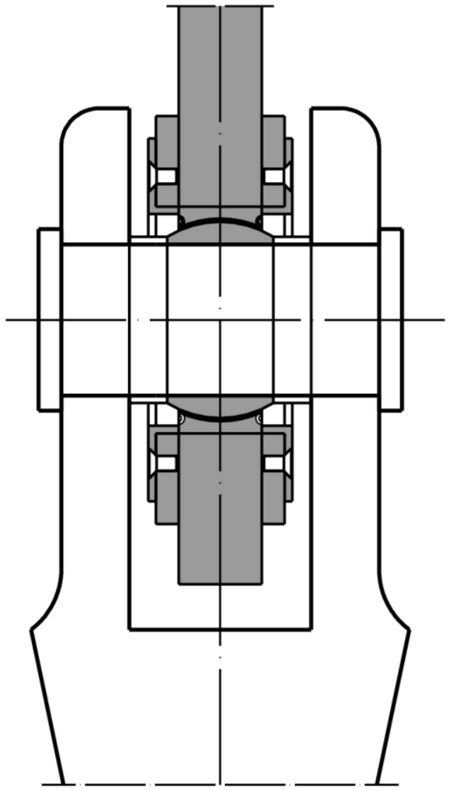


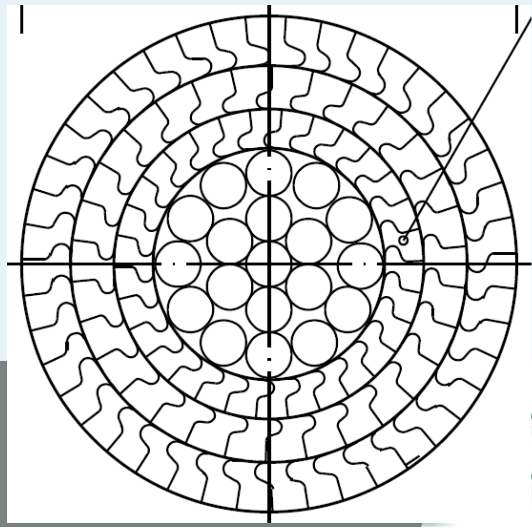


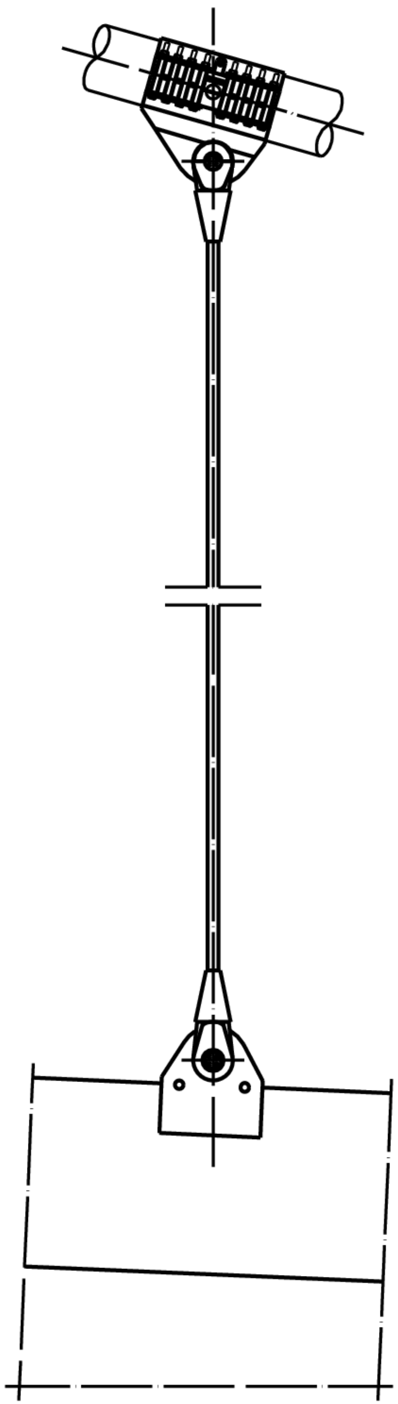
Cable structures
Hangers

General arrangement:

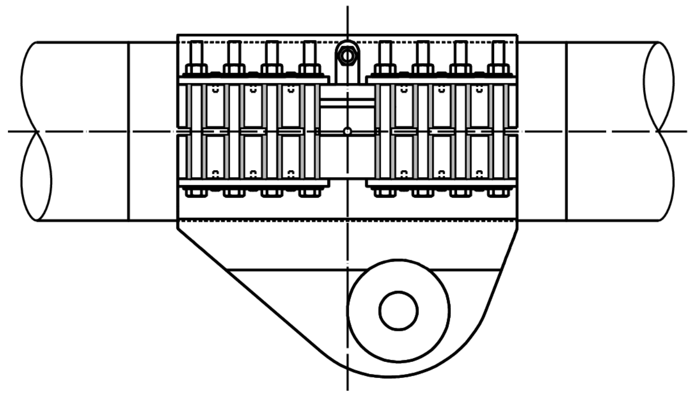
- Locked coil cables – 130 t
- EN 12385-10 – 1570 MPa
- Min breaking load 4.89 MN
- Diameter 70 mm
- Painted

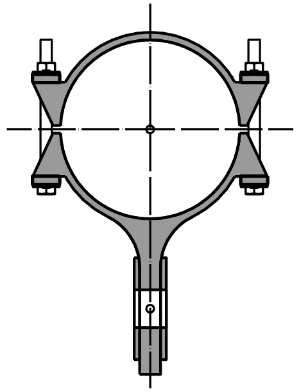






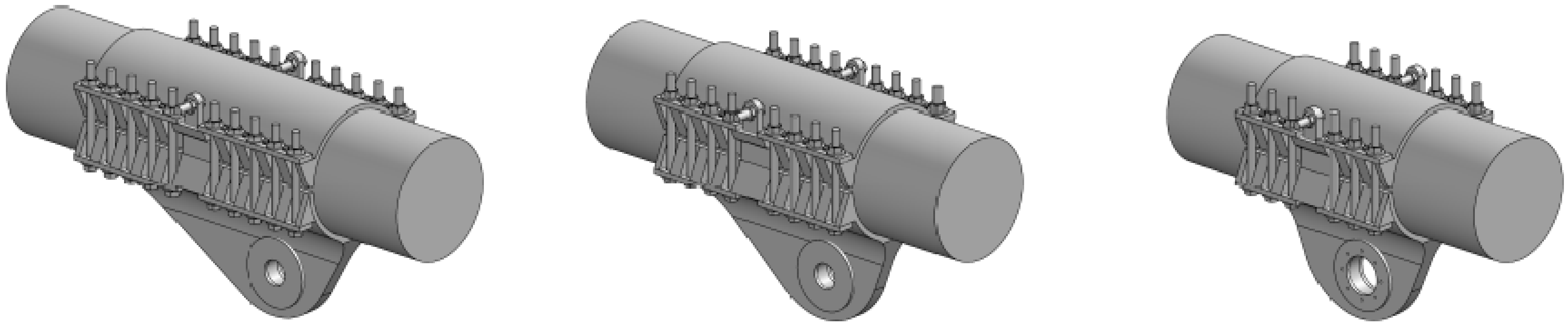
Cable structures
Cable clamps





General arrangement:

- Cast steel or welded steel structures – 50 t
- Membrane: 20 mm
- Eye plate: 55 mm, 15 mm cheek plates
- Stål grade: Cast steel NS EN 10293 G20MN5+QT eller NS EN 10025 S355NL
- Bolts easy to inspect and replace



Aerodynamic issues

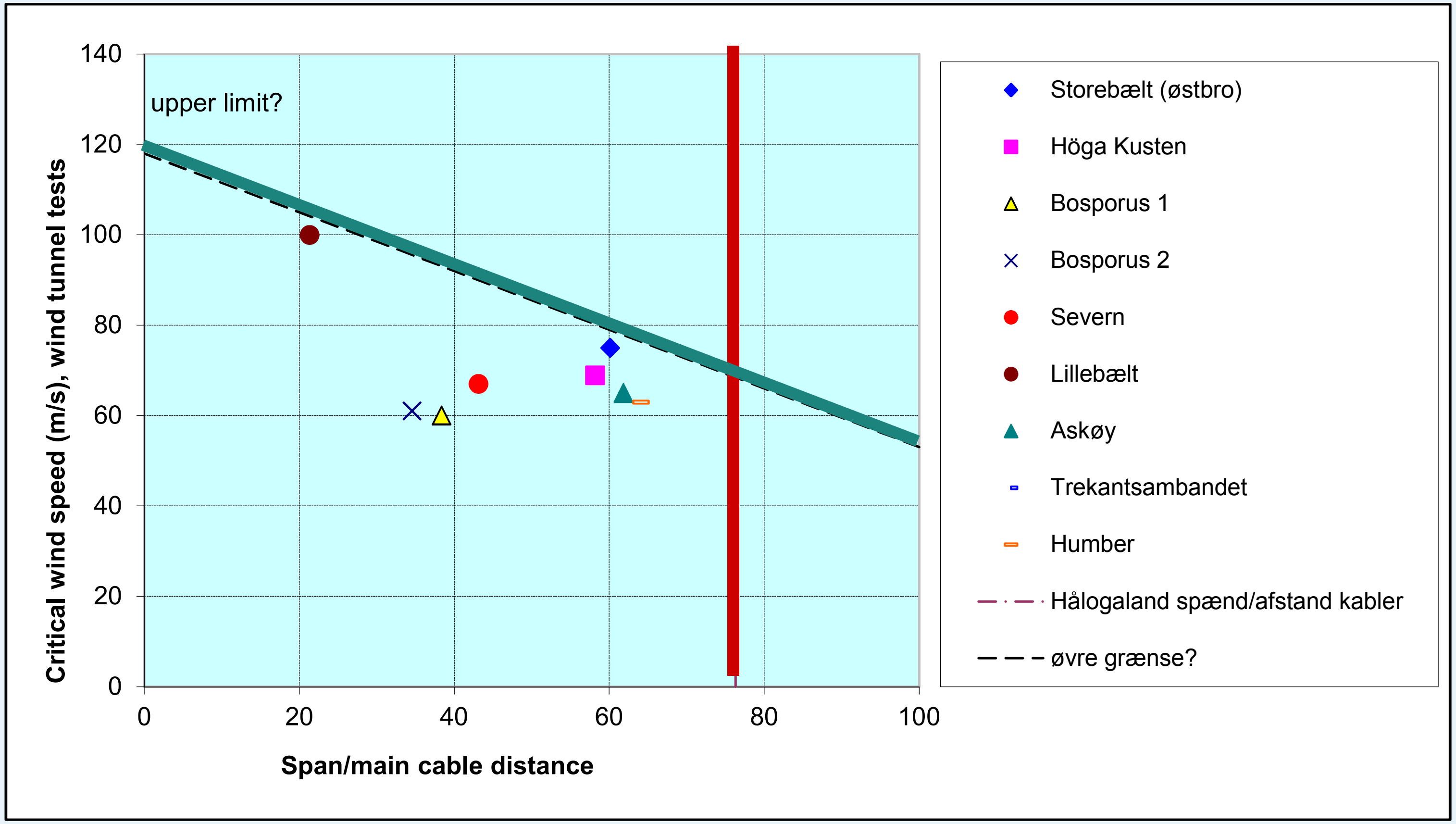
Challenges:

- Document sufficient critical wind speed
- Avoid vortex shedding excitation of the steel box girder

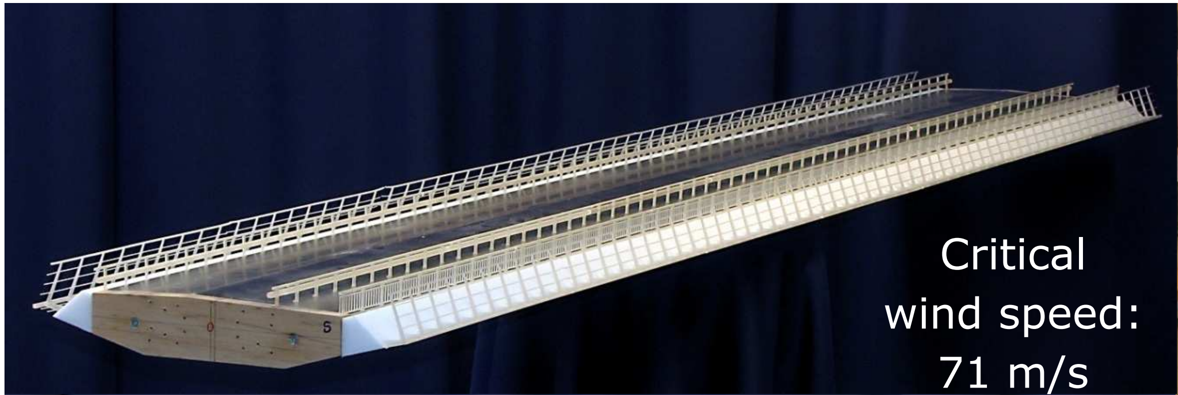
Critical wind speed
Background

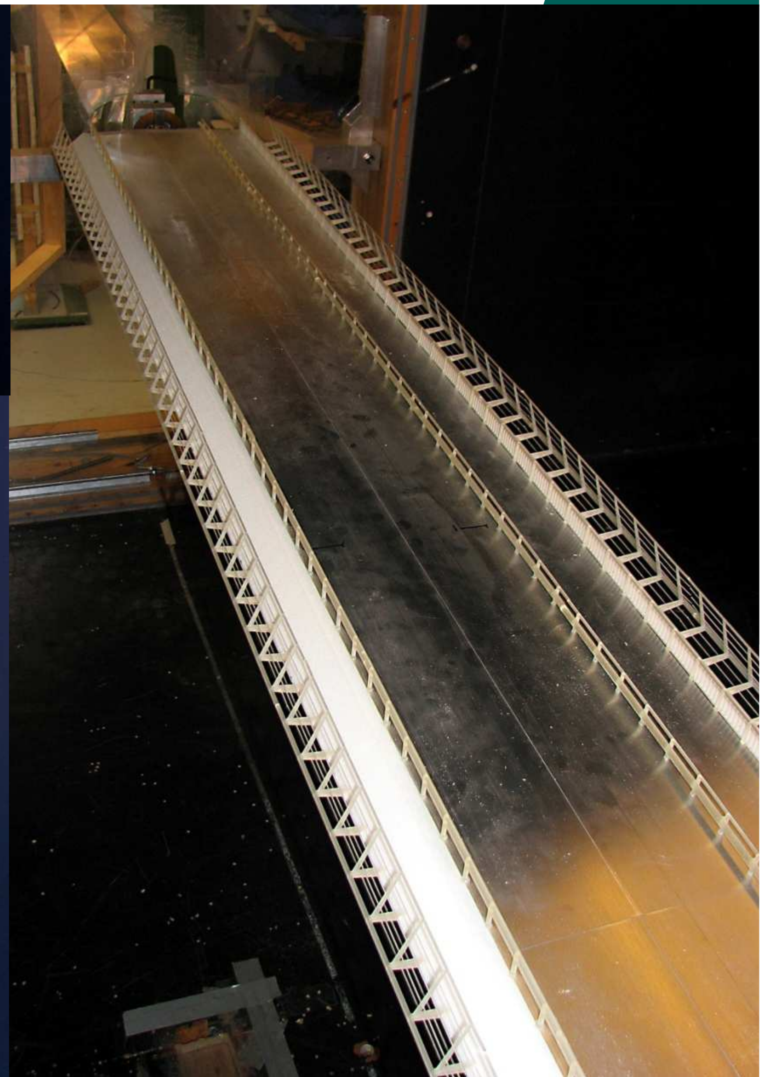
Requirement for Hålogaland bridge is 63.1 m/s

Documented critical wind speed for box girder suspension bridges



Critical wind speed
Wind tunnel tests





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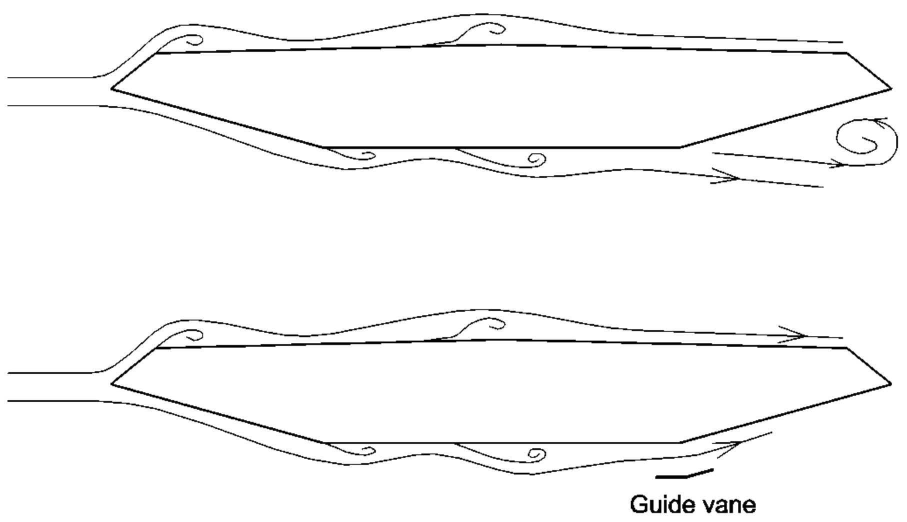
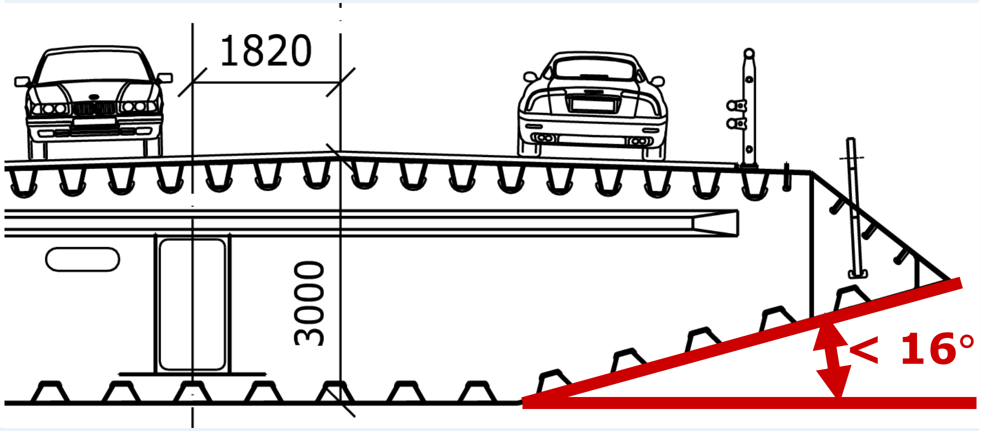
Vortex shedding excitation

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



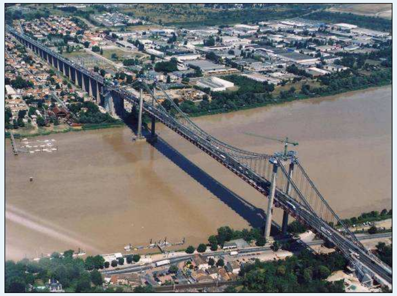


Thereby the sensitivity to vortex shedding excitation is reduced and it is not required to install guide vanes

Corrosion Protection Systems for Cables

New system:

- Dehumidification by dry air flow through the cables in addition to galvanizing of the cable wires
- Effectiveness is proven on suspension bridges in Denmark, Sweden, France and Japan



Background for new system:

- Nowadays design lifetime up to 200 years is required (Messina Bridge)
- Life Cycle Costs for bridges shall be minised
- System is developed based on experience gained from application of dehumidification systems in closed steel box girders

Corrosion Protection Systems for Cables

Features of dehumidification system:

- Complete corrosion protection of the cables
- Cables enclosed in an atmosphere with relative humidity below 60% - thereby corrosion cannot occur
- System provides overpressure in the cables - thereby water/moisture cannot enter the cables through any leaks

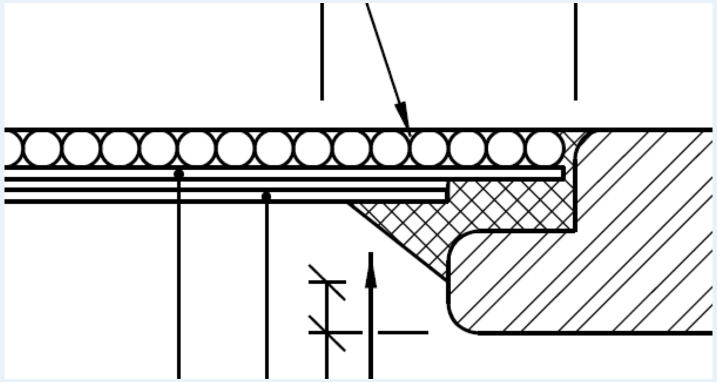
Dehumidification system comprises 3 major components:

- Sealing system for the cables
- Dehumidification system producing and blowing dry air through the cables
- Control and monitoring system for system functionality, relative humidity, temperature, flow and pressure

Corrosion Protection Systems for Cables

Component 1: sealing system:

- Elastomeric wrap for cable sections between cable bands
- Applied under tension with a 50% overlap
- Special details developed for cable bands etc. using combinations of sealer strips and adhesive caulk



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Corrosion Protection Systems for Cables

Component 2: dehumidification system:

- Produces dry air and blows it through the cables – max 40% relative humidity at injection points
- Overpressure inside the sealed cables - at injection points max. 2.5 kPa
- Components: dehumidification plants, injection points and exhaust points

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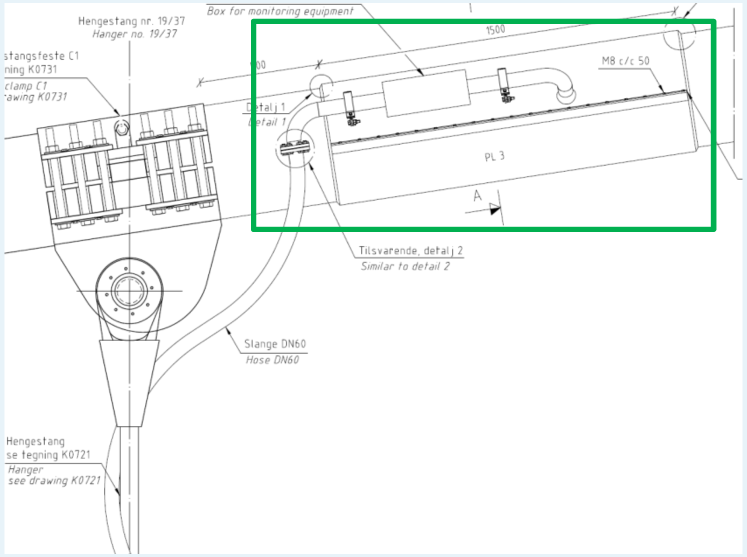
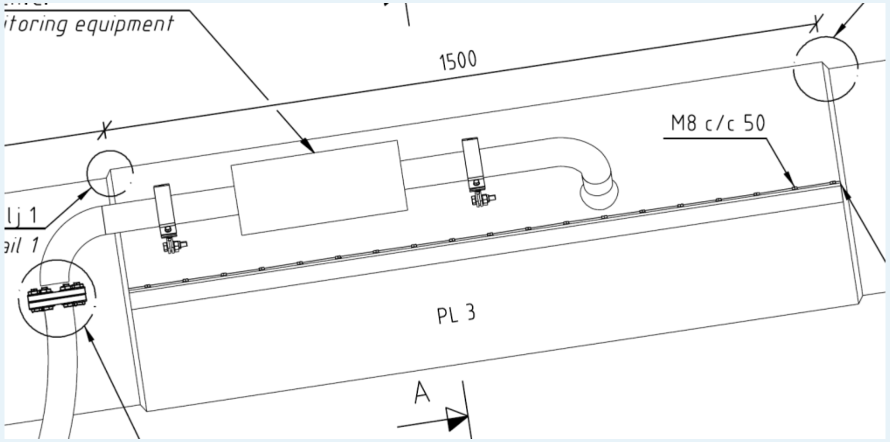
Corrosion Protection Systems for Cables

Component 3: control and monitoring system:

- Temperature, relative humidity, flow and pressure are measured at all injection and exhaust sleeves for permanent monitoring of system operation and documentation of corrosion protection





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Corrosion Protection Systems for Cables

Hålogaland Bridge:

- Handbook 185 requires dehumidification of main cables