Annual Bridge Conference 2010
1-2 September 2010, Oslo, Norway

Bridges in Service

Arranged by the Norwegian group of NVF Technical Committee, Bridges

Insight into today's specialist demands of management, maintenance, repair and rehabilitation of existing and new bridges

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Nordic Road Association (NVF)
The Nordic Road Association (www.nvfnorden.org) aims at developing the road and road transport sectors in Northern Europe through professional cooperation between experts from all Nordic Countries. NVF was founded 1935 and has reached well known and recognized status among professionals on its field.

Bridges Technical Committee
Bridges Technical Committee handles bridge engineering tasks under the auspices of NVF. The tasks are mostly specific to Nordic and Northern European existing and new bridge stock. Among other activities, the Committee arranges annual conferences on various technical matters. The theme of the year 2010 conference is ”Bridges in Service”.

Goal of the conference is to get insight into today's specialist demands of management, maintenance, repair and rehabilitation of existing and new bridges.

First day of the conference: Wednesday the 1st, September 2010
Venue: Bjørvika konferansesenter, Oslo Atrium, Christian Frederiks plass 6, 0051 Oslo
Home-page: www.bjorvikakonferansesenter.no

Conference banquet is arranged at Ekebergrestauranten, Oslo.
Home-page: www.ekebergrestauranten.com

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Program — Wednesday 1, September 2010

09:00	Registration	
10:00	Opening of the conference	**Jørn Arve Hasselø**, NVF
10:05	Introduction	**Risto Kiviluoma,** NVF

Part 1 Historical bridges, Chair Jørn Arve Hasselø, Norway

10:20	Protection of historical bridges in Norway	**Ingvill Hoftun** NPRA, Norway
10:50	Historical bridges in Iceland	**Guðrún Þóra Garðarsdóttir** ICERA, Iceland
11.10	Historical bridges: Gamla Årstabron	**Kurt Palmqvist** Trafikverket, Sweden
11:30	*Coffee break*	

Part 2 Bridges in service, Chair Risto Kiviluoma, Finland

12:00	Bridge management systems	**Lennart Lindblad** Trafikverket, Sweden
12:20	Probabilistic methods for materials/load resistance	**Ib Enevoldsen** Rambøll, Denmark
13:00	*Lunch*	

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14:00	Use of Probabilistic methods	**Rolf M. Larssen** Aas Jakobsen, Norway
14:20	Special inspections of bridges	**Carsten Henriksen** DRA, Denmark
14:40	Reinforcement of bridges	**Bjørn Taljsten** STO Scandinavia Sto Scandinavia/Luleå tekniska universitet, Sweden
15:00	Bridge parapets	**Otto Kleppe** NPRA, Norway
15:20	Results from field test of concrete coatings	**Eva Rodum** NPRA, Norway
15:40	*Coffee beak*	

Part 3 New bridges, Chair Morten Wright Hansen, Norway

16:10	Experiences from bridges in service used to design new bridges	**Knut Grefstad** NPRA, Norway
16:40	ETSI (Life Cycle Optimisation project) – Final report	**Matti Piispanen**, FTA, Finland **Otto Kleppe**, NPRA, Norway
17:10	Finnish life-cycle-cost design guideline	**Risto Kiviluoma** WSP, Finland
17:30	Challenges in bridge designs and maintenance for future problems	**Jens Sandager Jensen** COWI, Denmark
17:50	Conclusions and closing of seminar	**Jørn Arve Hasselø** NVF
19:30	*Conference banquet*	

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Program **Thursday 2, September 2010**

Technical tour in bridge projects on E6 motorway

08:30 Departure from hotel

E6 Kolomoen
- new bridge
- bridge parapets in Corten-steel
- new equipment (LED-lights, angled attachments of signposts

12:00 Lunch

13:00 E6 Minnesund

Minnesund bridge
- widening of carriageway from 2 to 4 lanes

Langset bridge
- rehabilitation of old bridge

Julsrud bridge
- widening of carriageway from 3 to 4 lanes

15:30 Bus transport to the airport and to the city

16:00 Bus arrival to Gardemoen Airport

Fname	Lname	company	land	Department	deltagerform
Risto	Kiviluoma	WSP Finland Ltd	Finland	Wind engineering	Speaker
Jørgen	Waag	Public Roads Administration	Norway	Eastern Region	Participant
Lennart	Lindblad	Swedish Transport Administration	Sweden	Business Area Operations	Speaker
Gudrun Thora	Gardarsdottir	ICERA	Iceland	Bridge Department	Speaker
Robert	Ronnebrant	Trafikverket	Sweden	Operations	Participant
Janar	Taal	Estonian Road Administration	Estonia	South Regional Road Administration odf ERA	Participant
Toomas	Magus	Estonian Road Administration	Estonia	West Regional Road Administration odf ERA	Participant
Tiit	Valt	Estonian Road Administration	Estonia	South Regional Road Administration of ERA	Participant
Kalmer	Helgand	Estonian Road Administration	Estonia	North Regional Road Administration of ERA	Participant
Andres	Plaat	Estonian Road Administration	Estonia	East Regional Road Administration of ERA	Participant
Kadri	Auväärt	Estonian Road Administration	Estonia	Estonian Road Administration	Participant
Vaidas	Mickevicius	UAB KELPROJEKTAS	Lithuania	Bridge	Participant
Zana	Lasiene	UAB Kelprojektas	Lithuania	bridge	Participant
Roushanak	Rouhani	Trafikkontoret Stockholm	Sweden	Anläggning	Participant
Anders	Samuelsson	Trafikkontoret Stockholm	Sweden	Anläggning	Participant
Baldvin	Einarsson	Efla	Iceland	Transportation	Participant
Maris	Duzelis	Latvian State Roads	Latvia	Bridge Department	Participant
Didzis	Zvirbulis	Latvian State Roads	Latvia	Central Region	Participant
Roberts	Noritis	Projekts3	Latvia	Bridge	Participant
Girts	Skupelis	Projekts3	Latvia	Bridge	Participant
Ugis	Riekstins	Projekts3	Latvia	Bridge	Participant
Martti	Kiisa	Estonian Road Administration	Estonia	Estonian Road Administration	Participant
Erik	Sundet	COWI	Norway	Bygg og konstruksjon	Participant
Morten Wright	Hansen	NPRA - Statens vegvesen Region øst	Norway	Bridge	Participant
Per	Arnesen	COWI AS	Norway	Bygg og konstruksjon Oslo	Participant
Jørn Arve	Hasselø	Statens vegvesen Region midt	Norway	Bru-og ferjekaiseksjonen	Participant
Heikki	Lilja	Finnish Transport Agency	Finland	Bridge Engineering	Participant
Steinar	Mo	Statens vegvesen	Norway	Samferdselsdept	Participant
Olav	Lahus	Norwegian Public Roads Administration	Norway	Bridge	Participant
Jørgen	Heuch	Statens vegvesen, Region midt	Norway	Bru- og ferjekaiseksjonen	Participant
Juha	Noeskoski	Finnish Transport Agency	Finland	Bridgedesign	Participant
Kurt	Solaas	Statens vegvesen	Norway	Region Nord	Participant
Jens Sandager	Jensen	COWI AS	Denmark	Maintenance and Rehabilitation Bridge, Tunnel and Marine Structures	Speaker
Carsten	Henriksen	Danish Road Directorate	Denmark	Maintenance and repair	Speaker
Vibeke	Wegan	Vejdirektoratet	Denmark	Vedligeholdelsesområdet	Participant
Svein Erik	Jakobsen	Aas-Jakobsen	Norway	Bru	Participant
Ulrik Sloth	Andersen	Rambøll Danmark AS	Denmark	Brovedligehold og materialeteknologi	Participant
Matti	Piispanen	Finnish Transport Agency	Finland	Bridge and Road department	Speaker

Fname	Lname	company	land	Department	deltagerform
Ove	Solheim	Statens vegvesen	Norway	Region øst	Participant
Knut	Grefstad	Norwegian Public Roads Administration	Norway	Bridge Section	Speaker
Jørn Uno	Mikkelsen	Statens vegvesen	Norway	Bru, tunnel- og elektro, Region Nord	Participant
Kurt	Palmqvist	Trafikverket	Sweden	Bridges	Speaker
Henrik Elgaard	Jensen	COWI	Denmark	Bridges	Participant
Eva	Rodum	Norwegian Public Roads Administration	Norway	Traffic Safety, Environment and Technology	Speaker
Niskanen	Olli	Finnish Transport Agency	Finland	Bridge Engineering	Participant
Trond	Østmoen	Aas-Jakobsen	Norway	Bridge department	Participant
Lars Michal	Holstad	Vik Ørsta AS	Norway	Trafikk	Participant
Rolf Magne	Larssen	Dr. Ing. A. Aas-Jakobsen AS	Norway	Bridge Division	Speaker
Otto	Kleppe	NPRA	Norway	Bridge section	Speaker
Björn	Täljsten	Sto Scandinavia AB and Luleå Universit	Sweden	Atructural Engineering	Speaker

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Bridges Technical Committee 2008-2012

Nordic Road Association

- established 1935
- model taken from PIARC's organisation and ways of working
- aims at developing the road and road transport sectors in Northern Europe through professional cooperation
- more than 800 participants in the work of its Technical Committees, Theme Groups and 6 National Boards
- participants represent 300 Member Organisations
- leading country is circulated every 4th year. At the end of the period the major conference Via Nordica is arranged

Bridges Technical Committee (TC)

- Bridge engineering (design, construction, operation, maintenance)

Chairmen and secretaries (2008-2012)

- **Risto Kiviluoma**, Olli Niskanen FINLAND (leading country* of TC)
- **Henrik Elgaard Jensen**, Vibeke Wegan DENMARK
- **Baldvin Einarsson**, Guðrún Þóra Garðarsdóttir ISLAND
- **Jørn Arve Hasselø**, Morten Wright Hansen NORWAY
- **Martin Laninge**, Anders Samuelsson SWEDEN
- **Bjarni Petersen** FAROE ISLANDS

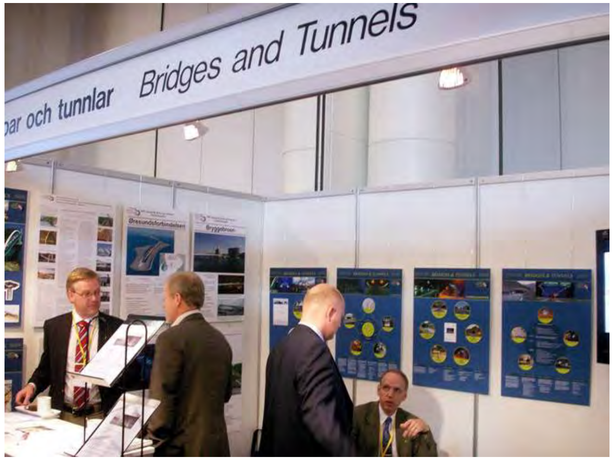
* circulated every 4th year

Methods of work

- Annual NVF Bridge Conferences
  - arranged at the first Wednesday of September
  - two days program
  - conference themes based on priorities by the organizing country

Annual NVF Bridge Conferences

- 2012 *Via Nordica, Reykjavik, Iceland*
- 2011 Copenhagen, Denmark
- **2010 Oslo, Norway**
- 2009 Gothenburg, Sweden
- *2008 Via Nordica, Helsinki, Finland*
- 2007 Reykjavik, Iceland
- 2006 Helsinki, Finland
- 2005 Copenhagen, Denmark
- *2004 Via Nordica, Copenhagen, Denmark*



- TC chairmen & secretary meetings
    - 3 physical meetings annum
    - telephone & Internet meetings when needed

- local bridge group meetings
  - 2-3 physical meetings annum in each country
  - technical tours and presentations

International co-operation and networking

- BRA, IABSE, PIARC, national professional organizations
- versatile language code in TC work:
  - TC Chairmen & Secretary meetings and correspondence: English
  - Annual NVF Bridge Conference “plenary sessions”: English
  - workgroups meetings and reports: up to workgroup leader
  - Nordic networking: Nordic languages

- technical work in Workgroups ("projects")
  - own leaders, plans and meetings
  - only experts of the specific area are involved
  - reporting options: written report downloadable on NVF web side or workshop slides on NVF web page
- workshops
  - arranged by workgroups

Workgroups (2008-2012) and their leaders

- Self compacting concrete
  - Synnøve Myren, Statens vegvesen (NO)
- Eurocodes
  - Heikki Lilja, Finnish Transport Agency (FI)
- Structural monitoring
  - Risto Kiviluoma, WSP (FI)
- Procurement methods
  - Claus Nødgaard Hansen, Danish Road Directorate (DK)
- Bridge maintenance
  - Knut Grefstad, Statens vegvesen (NO)

Nordic Bridge Prize

- awarded every 4th year in a ceremony in Via Nordica

1994

1998

For more information, presentations of previous conferences, etc. please visit

www.nvfnorden.org

Slides prepared by Risto Kiviluoma

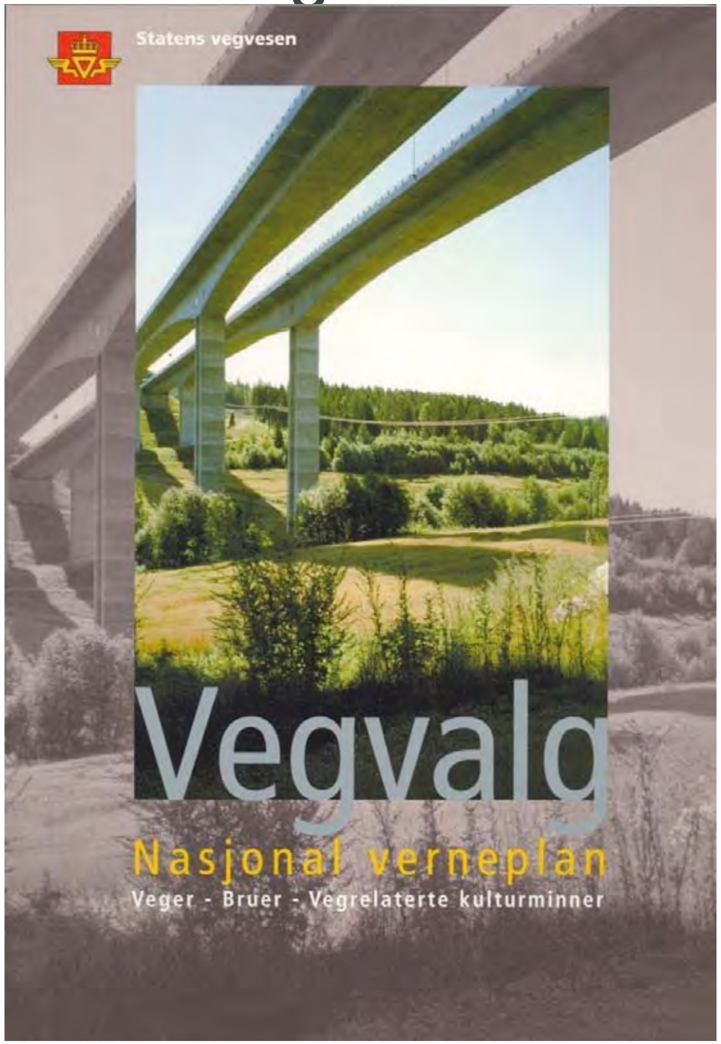
Statens vegvesen

Cultural Heritage of Bridges

Liv Marit Rui and Ingvill Hoftun
The Norwegian Public Road Administration

Foto: Colourbox

National Plan for the Protection of Roads, Bridges and Associated Cultural Relics



- A Mission from the Ministry of Transport in 1997 – The Plan was finished 2002
- The selection consists of 270 roads, bridges and buildings, along with 140 machineries
- The selection is based on sketches of road history, on a national as well as a regional level.

The National Protection Plan

- The aim of the Protection Plan has been to obtain knowledge about, and ensure for the future, a selection of historical road and bridges that are representative for the Norwegian road history from around 1537 and to the present day (1990)

Typical relics showing part of the history, has been chosen. They represent main principles of road building in Norway from The Silver Road, the first public carriageway from the silver mines from the 1620s, to the latest building of motorways of the 1990s

Bridges in the National Protecton Plan

- Bridges were chosen from the whole history of bridges and from the whole spectrum of bridge types
- 40 single bridges are protected by law (the Cultural Heritage Act)
- 6 bridges had a former legal protection

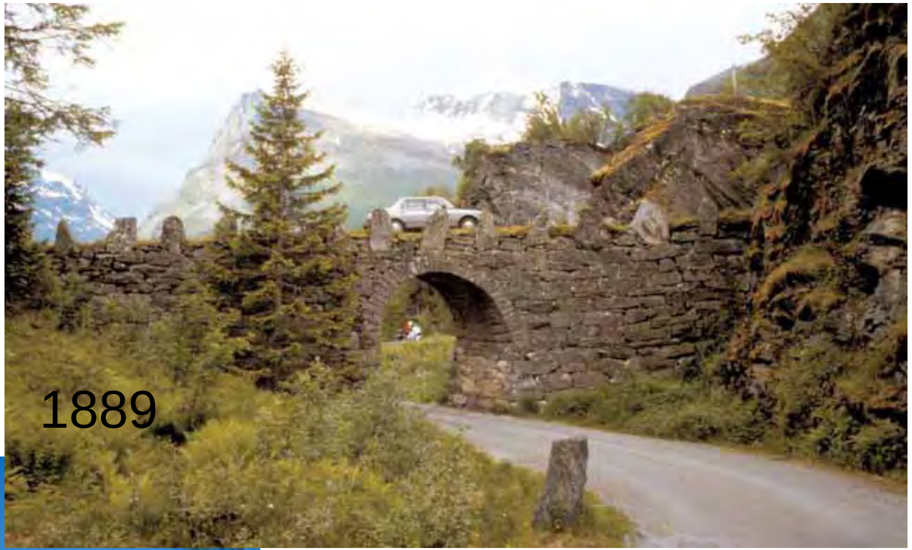
- A number of bridges are included in a historic road environment, some of them don't have a protection law

The Oldest Bridges

- Until the last part of the 1700s, bridge construction was based on experience
- Exact theories or formulas for dimensioning did not exist
- Most bridges was built in wood whish has disappeared

Early Stone Arch bridges

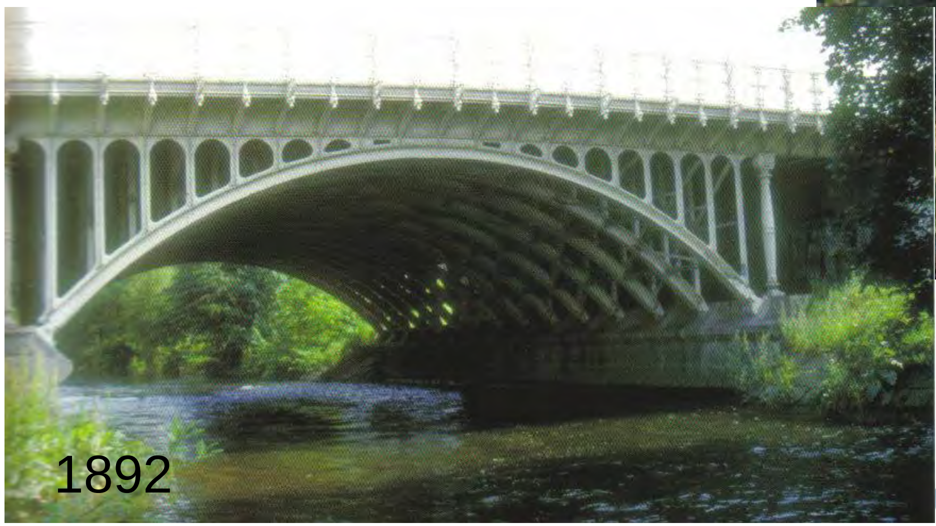
- A lot of stone arch bridges were built during 1800 century



Bridges in Iron

- During the 1800s, bridges were built in all parts of the country, using many new techniques and materials

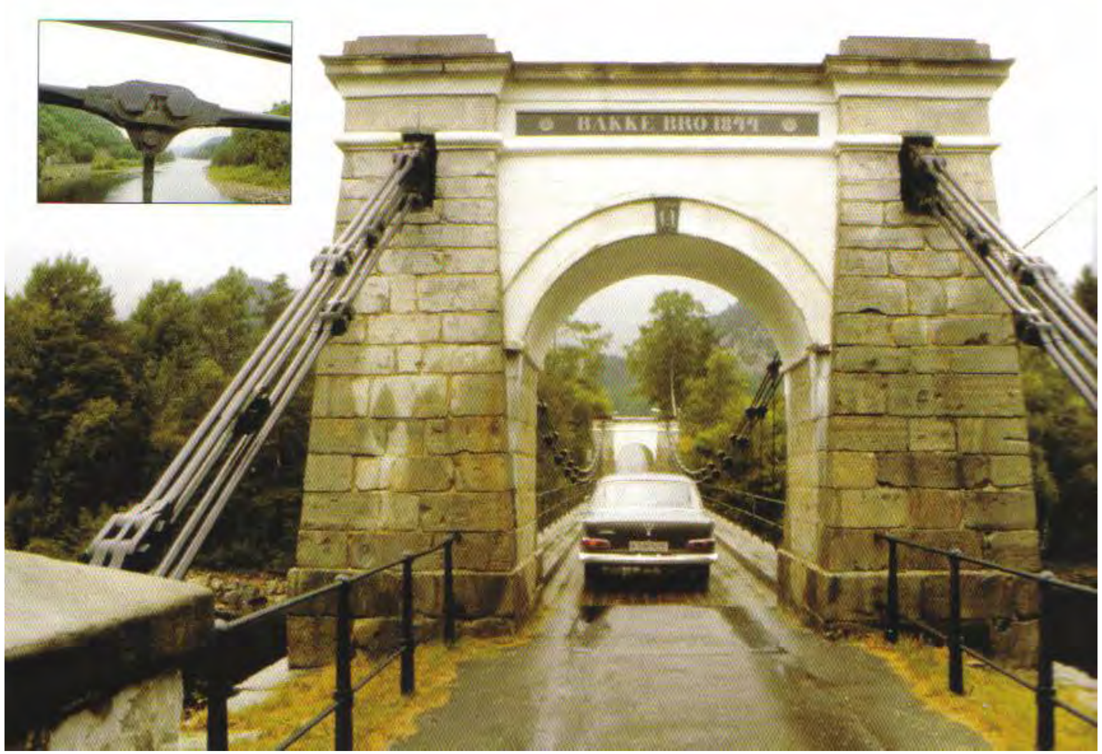
In 1837 Fosstveit bridge (Nes jernverk) was built in cast iron



Statens vegvesen

Early Suspension bridges

- The industrialism brought new materials and scientific methods for the dimensioning of constructions.
- The first Norwegian suspension bridge here in the country, Bakke bridge, was built in 1844



Development in Material Technique in early 1900

- Beyond the 1800s, it was possible to produce affordable iron and enough quantities
- During 1900s, steel cables, cement mortar, concrete and reinforced concrete were introduced

Stone Arch bridges in early 1900

- Many new arch bridges were built, constructed of cutted stones with cement fillets, allowing longer spans.

Bridges in 1950's

- Steel girders with concrete bridge deck were introduced, and a number of steel latticework bridges were constructed in this period.

1962

The production of cables gave suspension bridges a renaissance

1959

Bridges in 1960-70's

- The development of cantilevered building techniques and prestressing, made concrete a key building material.
- During the 1960s, individually formed constructions poured on-site were dominant. The Bridges connected over many wide fjord-arms

Bridges in 1980-90's

- Over time, pre-fabricated elements came into use, and standardised solutions were developed

Later in the period, more individual and on-site solutions are again used, as a result of the increased focus on adaptation to the locality and on aesthetics

Other Bridges in 1990’s

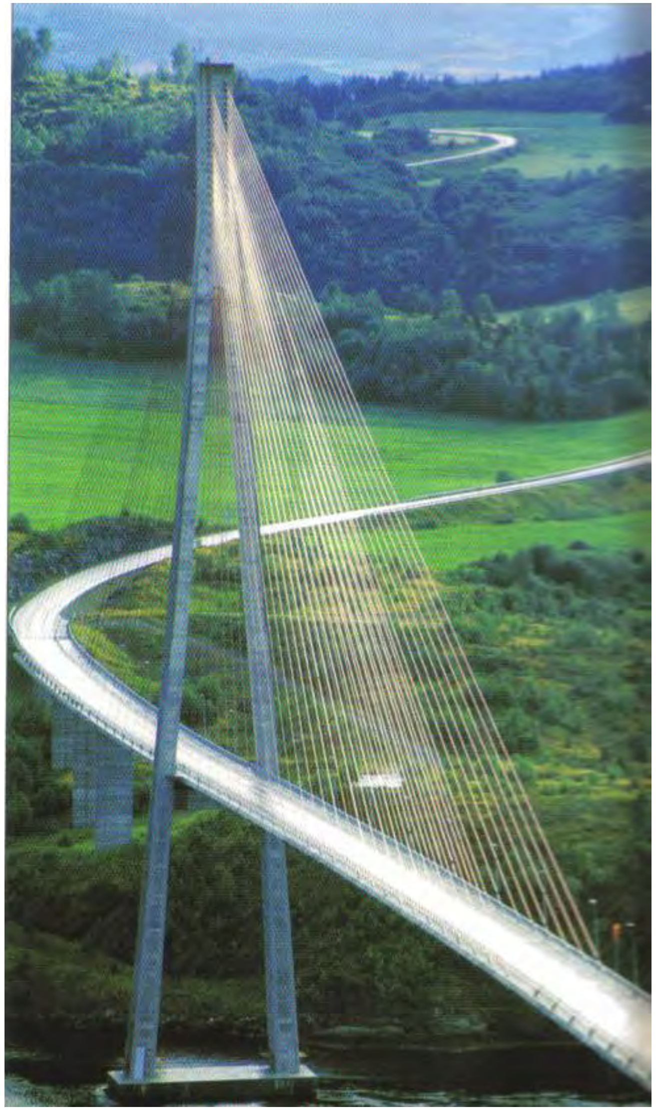
During the 1990s, wooden bridges made a comeback after the development of laminated beams.

Floating bridges represent another novel technique providing new opportunities, in particular for deep and broad straits rendering other types of bridges unsuitable.

Two such bridges have been built, the first of their kind in the world without lateral foundations, only anchored at the end point.

Consequences of the protection

- A plan of management has been made for each object, containing instructions with regard to the maintenance of the object.
- The final administration of the highway relics is to follow the normal routines.
- The challenge is to get enough money to bridges that is not in daily use
- For bridges that is in use the challenge is to maintain the original expression/view
-



Thank you!

Kalvebakken 1911
Hvelvru

Grenlandsbrua 1996

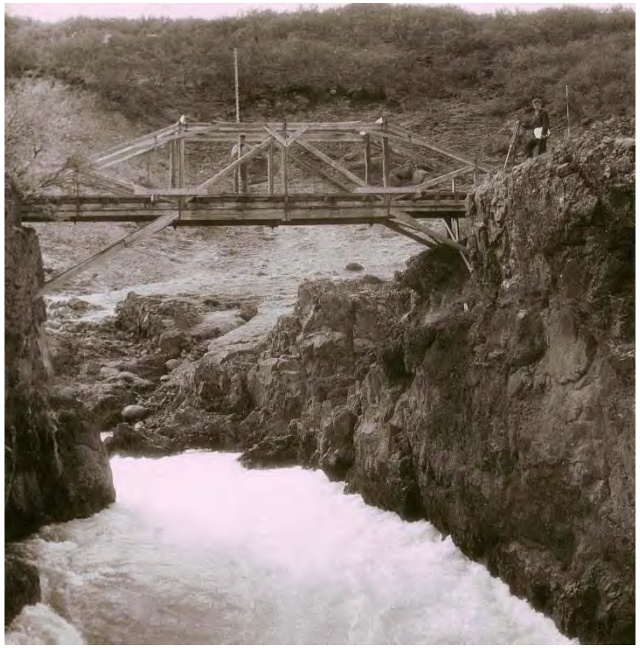
Historical bridges in Iceland

NVF - seminarium

Oslo 01. - 02. September 2010
Bridges in service.

Gudrun Thora Gardarsdottir ICERA

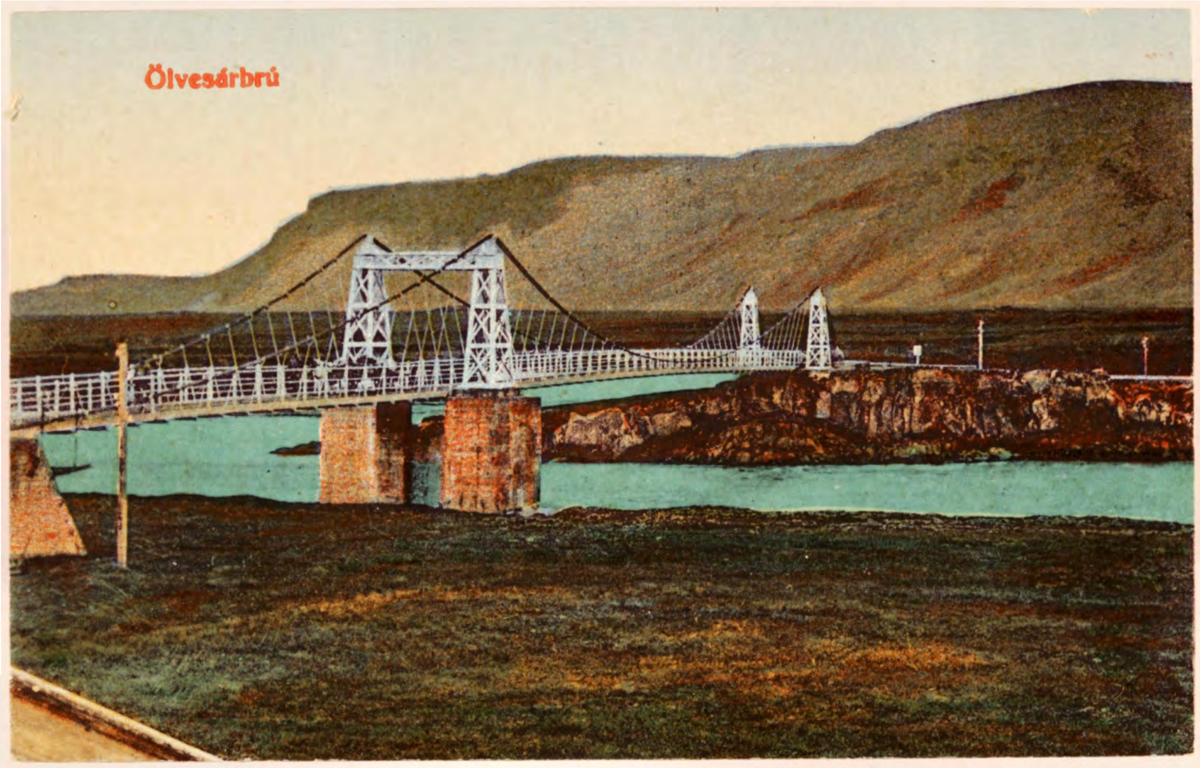
The first bridges in Iceland were timber bridges, which did not last long, none af them are left.



In Reykjavík two stone arch bridges were built one in 1845 and the other one in 1866.

In the late 19th century there was a demand for bridges which would last longer than the timber bridges – the first steel bridges were built. They were suspension bridges of steel with timber plank deck and were supposed to withstand horseback riding and pedestrian traffic.

The first one was over Ölfusá built in 1891, the longest span was 75 m. The designers were Vauchan & Dymond, Newcastle.

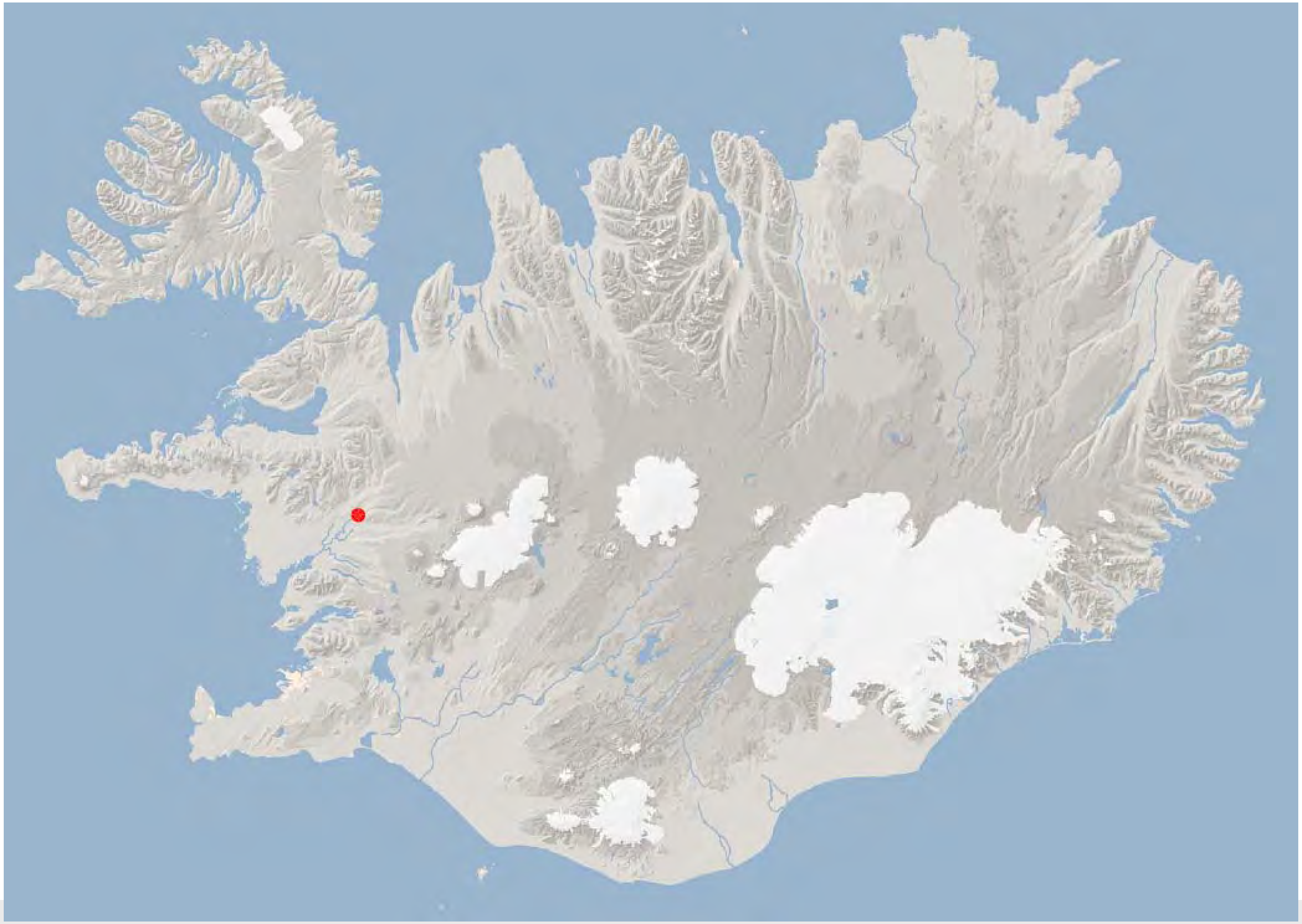


The next one was over Thjorsa, built in 1895.

It’s longest span was 78 m.

The bridges could withstand load up to 400 kg/m^2.

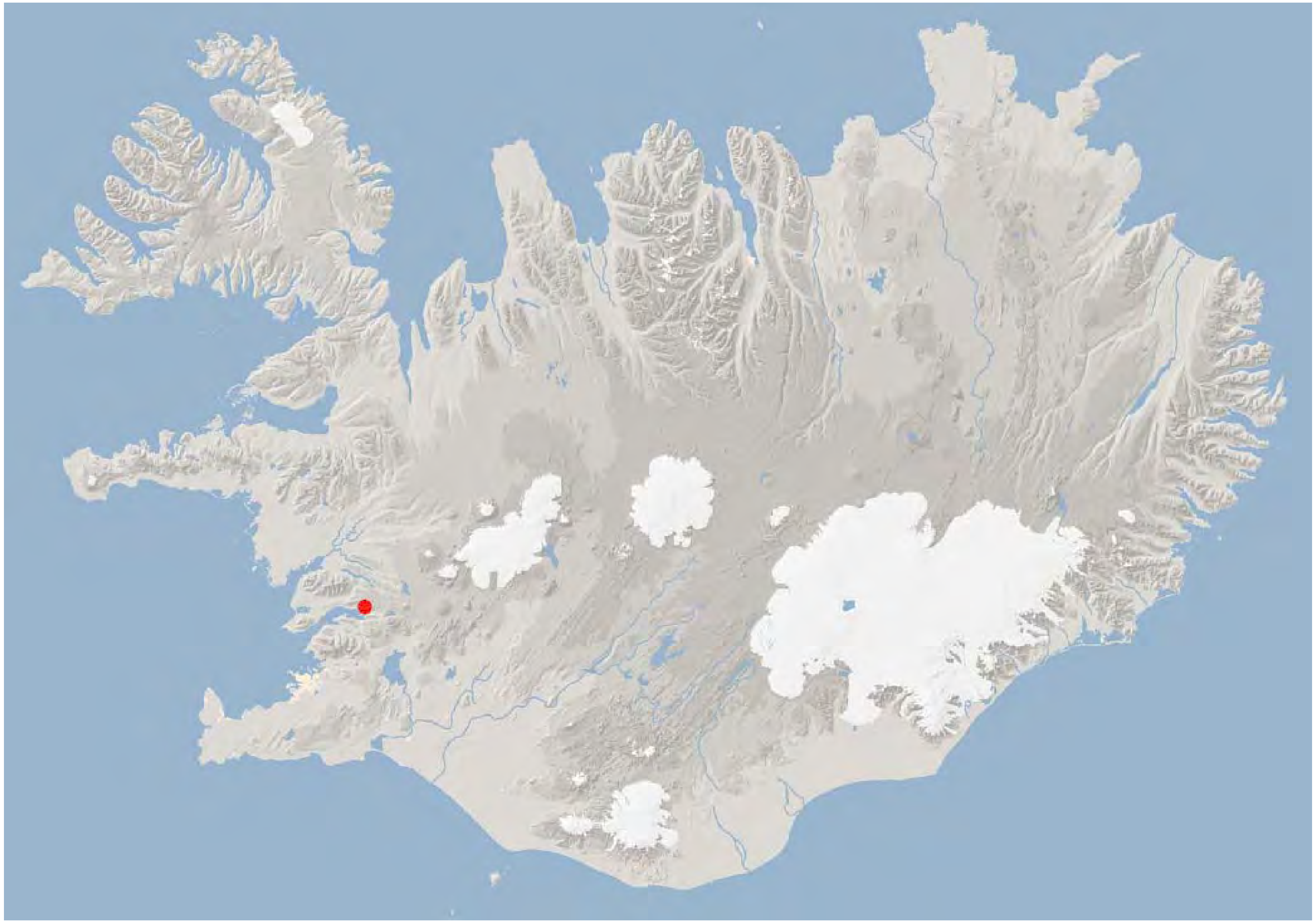
Örnólfsdalsá



The bridge over Örnólfsdalsá was built in 1899, the longest span is 33 m. The bridge is the only bridge from the 19th Century which is still in use.

The renovation of the bridge over Örnólfdalsá has already started in memory of those suspension bridges.

Bláskeggsá



The Bridge over Bláskeggsá was built in 1907.
It was the first concrete bridge outside Reykjavik.
Jón Þorláksson, State Engineer, was the designer.

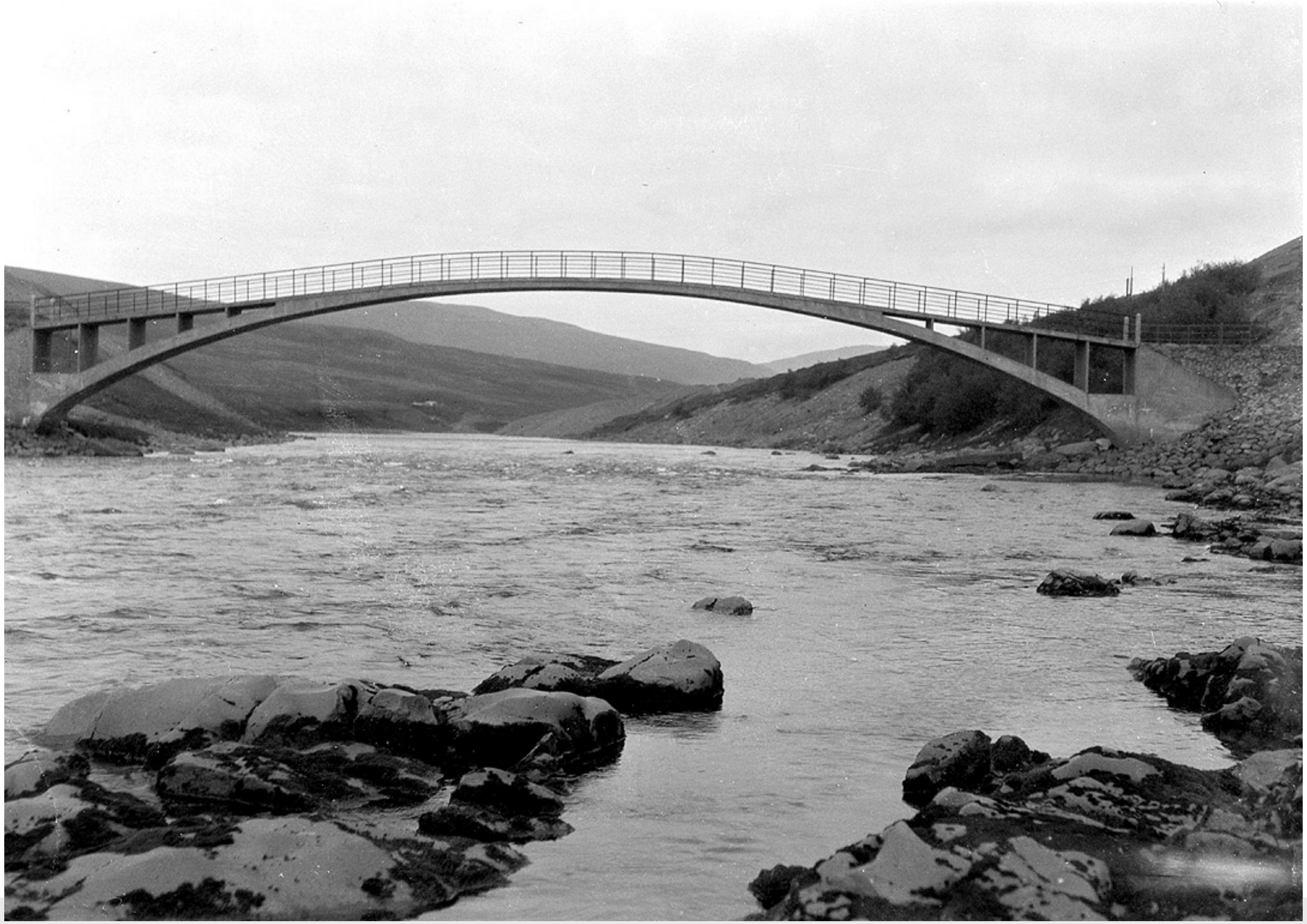
The arch is 6,9 m long and 2,8 m wide, resting on foundations built of stone.

The bridge was renovated in 2009. It is the only bridge in Iceland which has been proclaimed inviolate.

Fnjóská

The bridge across the river Fnjóská was built in 1908. It’s arch of reinforced concrete, spanning 54,8 m, was the longest in the Nordic contries

It was designed and constructed by Christiani & Nielsen of Copenhagen.



Originally intended for horsemen and horse-drawn cart, the bridge was used for all vehicular traffic until 1968, but since then for light traffic only. In 1993 the bridge was restored to its orginal form.

Jökulsá á Brú near Hákonarstaðir

The bridge over Jökulsá á Brú was constructed in 1908. It was a steel bridge 27 m long and was bought ready-made from the United States of America, where it was designed by the American Bridge Co.

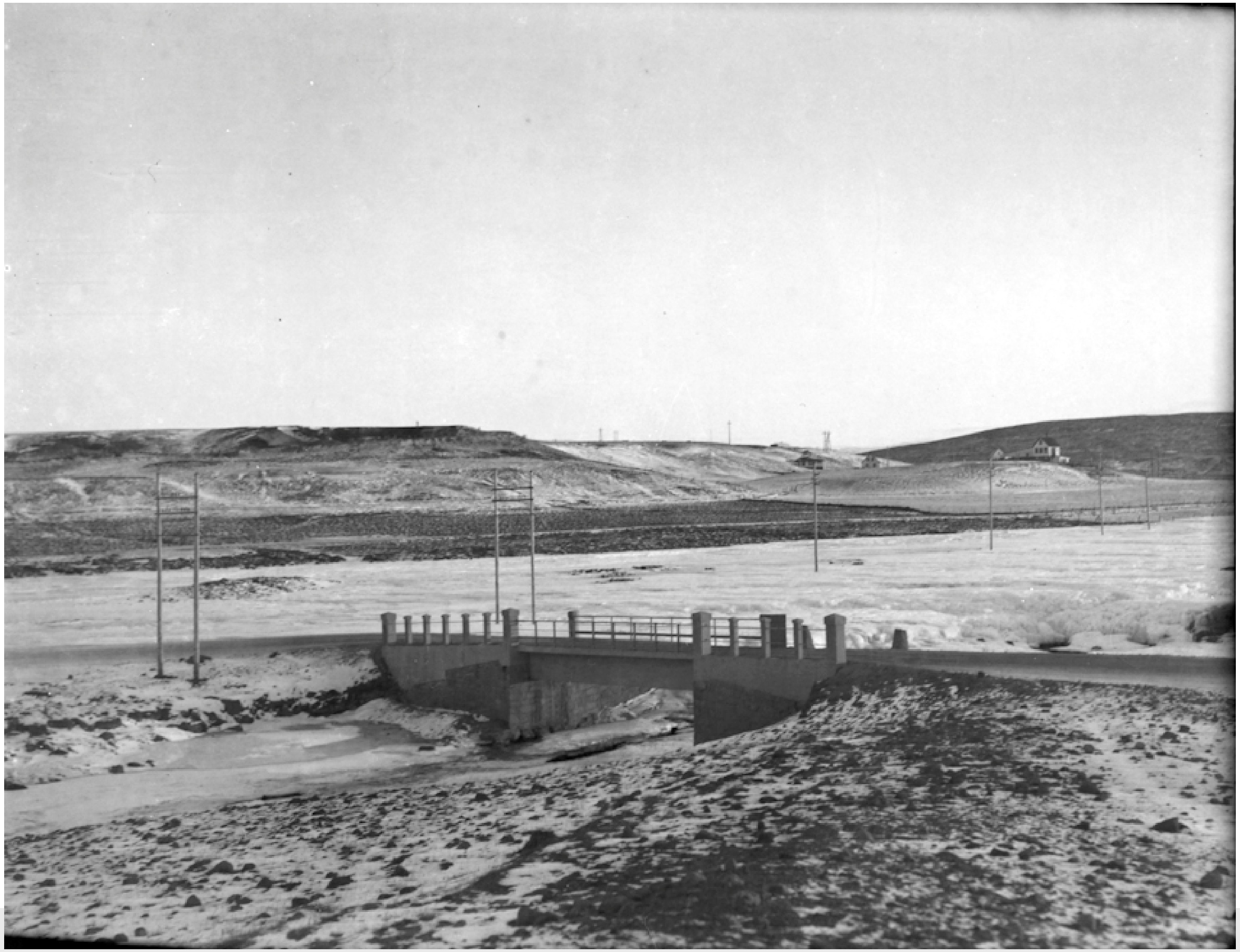
At first it was built to carry pedestrians and horses only, but later it was altered a little to withstand the traffic of motor vehicles as well. This is the oldest bridge in the country still used for automobiles.

Elliðaár

Bridges over Elliðaár

On the way east from Reykjavík are the rivers Elliðaár. The east and west river were bridged in 1883. They were timber bridges 10,7 m and 12,6 m long and rested on cut stone abutments.

In 1919 to 1920 they were rebuilt as reinforcement concrete beam bridges. The old abutments were used, but were raisen.



Those bridges are still in use today but only for a light traffic such as

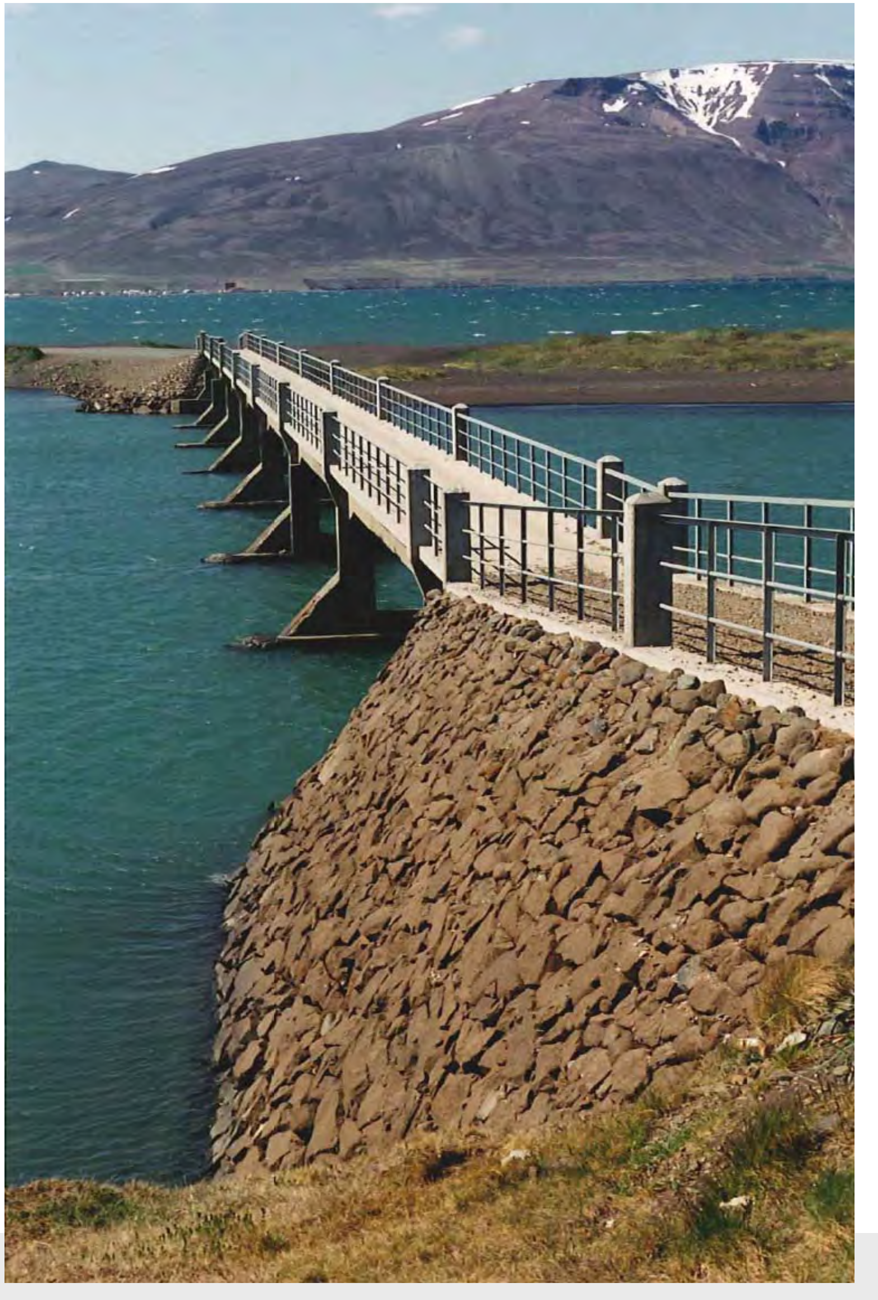
when the mayor goes fishing.

Vesturós Héraðsvatna

Bridge over Vesturós Héraðsvatna

The bridge was built in the years of 1925-1926.

Bridge over Vesturós Héraðsvatna



The bridge is a 113 m long concrete bridge in 7 spans and resting on concrete piles.

The bridge was renovated in the year 1995.

Vesturós Héraðsvatna

There used to be a ferry to come across the river before the bridge was built.

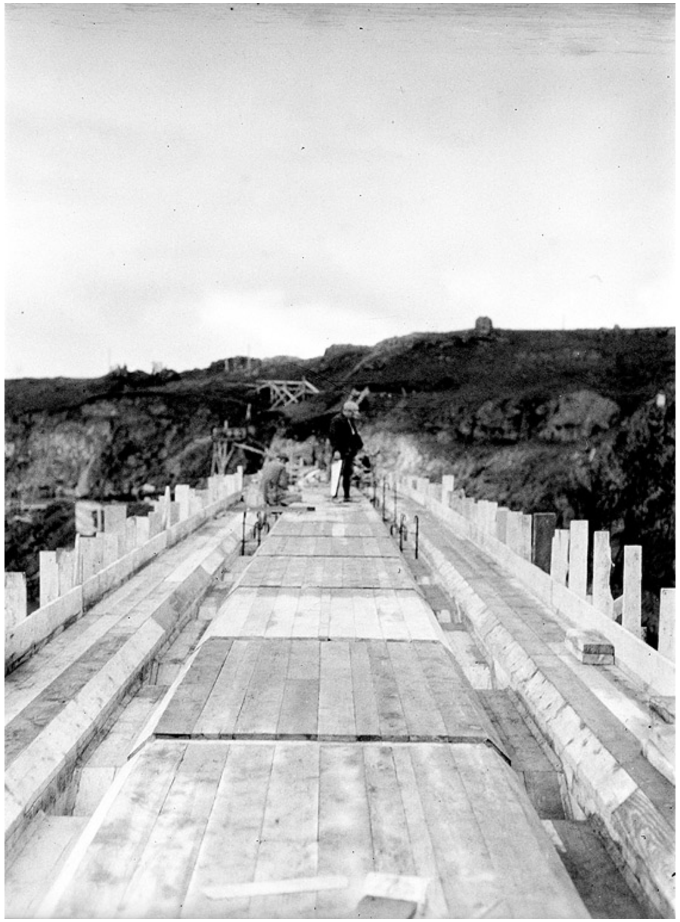
Hvítá near Ferjukoti

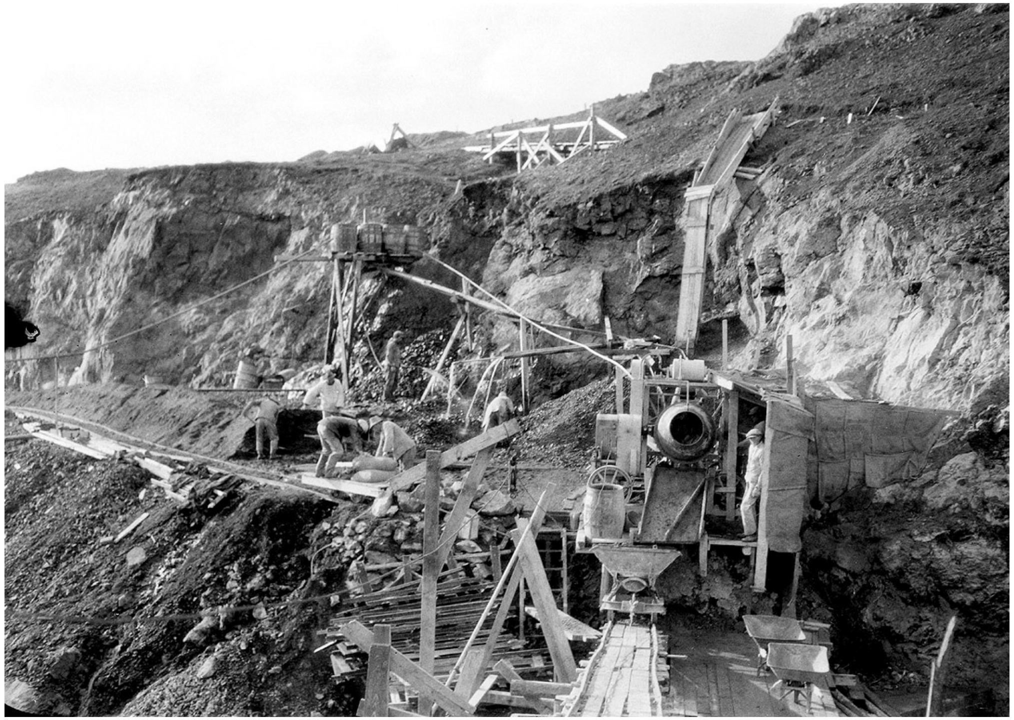
The bridge over Hvítá was built in the summer 1928. It is a concrete arch bridge in 2 spans, total length is 106 m.

There used to be a ferry over Hvítá in Borgarfjörður before the bridge was built.

The bridge in construction.

The bridge in construction.





Skjálfandafljót near Fosshóll

The bridge over Skjálfandafljót near Fosshóll

The first bridge over Skjálfandafljót near Fosshóll was a timber bridge resting on a stone foundations built in 1883.

The next bridge over Skjálfandafljót near Fosshóll was a steel bridge built in 1930. It was a steal girder bridge with timber plan deck.

The total length is 71 m, the longest span is 37 m.

The bridge over Skjálfandafljót near Fosshóll in construction.

The bridge was in full use until the year 1972. It is now used for horse and foot traffic.

Markarfljót

Markarfljót

In south Iceland the river Markarfljót spred out over a large area. Formerly a great obstacle to travellers.

To be able to bridge the glacier river it was necessary to narrow the channel. Therefore embankments were built along the riverside.

The first embankment was built in 1910 to protect the farmland in Eyjafjöll from the river.

The bridge over Markarfljot was built in 1933. It was a reinforced concrete bridge, 242 m long in 12 spans.

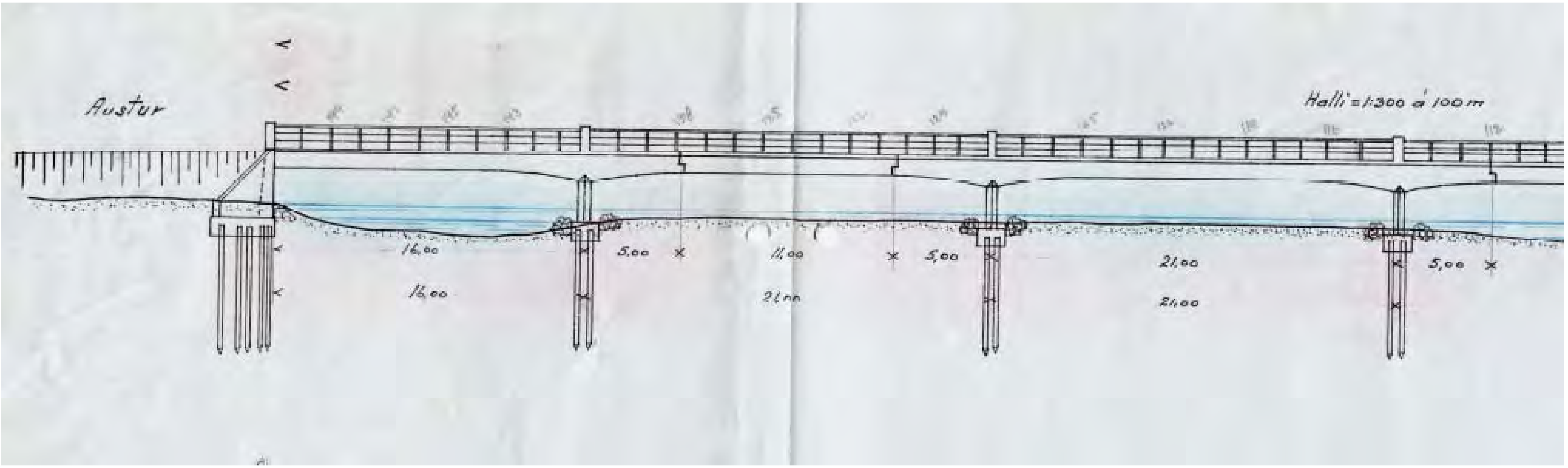
These photos are from the day of dedication in 1934.

In 1990 one of the abutment sank down about 20 cm.

FÖSTUDAGUR 3. ÁGÚST 1990 VERÐ Í LAUSASÖLU 90 KR.

Brúin yfir Markarfljót lokuð stærri bílum

BRÚNNI yfir Markarfljót var lokað fyrir umferð stærri bíla í gær eftir að grafið hafði frá brúarstólpa og hann sigið um 20 sentímetra. Samkvæmt upplýsingum Vegagerðar ríkisins átti viðgerð að hefjast um klukkan 5 í morgun, en ekki er ljóst hvenær brúin verður opnuð fyrir umferð stærri bíla á ný.
Myndina hér að ofan tók Sigurður Jónsson, fréttaritari Morgunblaðsins, af Markarfljótsbrú í gærkvöldi.



The bridge was built as a Gerber bridge so it did not collapse. A new bridge was built 5,6 km downstream from the old one.

The old bridge was just used by local farmers.

During the eruption in Eyjafjallajokull two flash floods occured in Markarfljót and National route 1 was cut at the bridge at Markarfljótsbrú.

The old bridge over Markarfljót.

The photos are not taken at the peak of the flood.

16.4.2010

News in English: Volcanic eruption under Eyjafjallajökull glacier

Repairs to the “old” bridge at Markarfljótsbrú have been made and the bridge is open to light vehicle traffic whose total weight does not exceed 12 tonnes. Traffic over the bridge will be supervised by the local emergency operations centre at Hvolsvöllur and priority will be given to vehicles transporting foodstuffs and fodder for livestock.

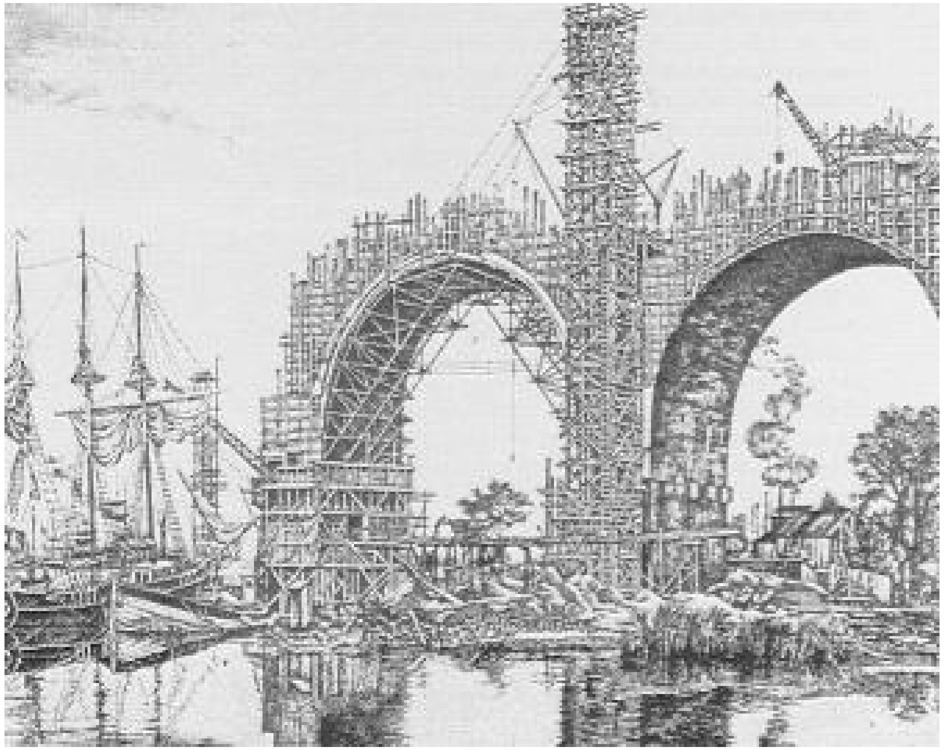
So old bridges have a second life!

Thank you

Gamla Årstabron

Repair and strengthening of the concrete arcs

Kurt Palmqvist



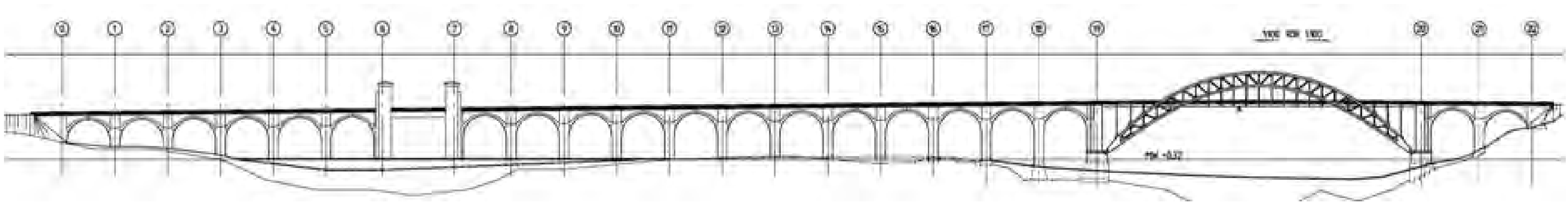
TRAFIKVERKET
SWEDISH TRANSPORT ADMINISTRATION

Gamla Årstabron

1. Background and facts
2. Repair and strengthening of concrete arcs

Gamla Årstabron
Facts

- The Bridge was built between 1925 and 1929
- The Bridge contains of 20 concrete arcs, one liftspann and one main steel arc and has a total length of 753 m
- The Bridge is a cultural monument since 1986

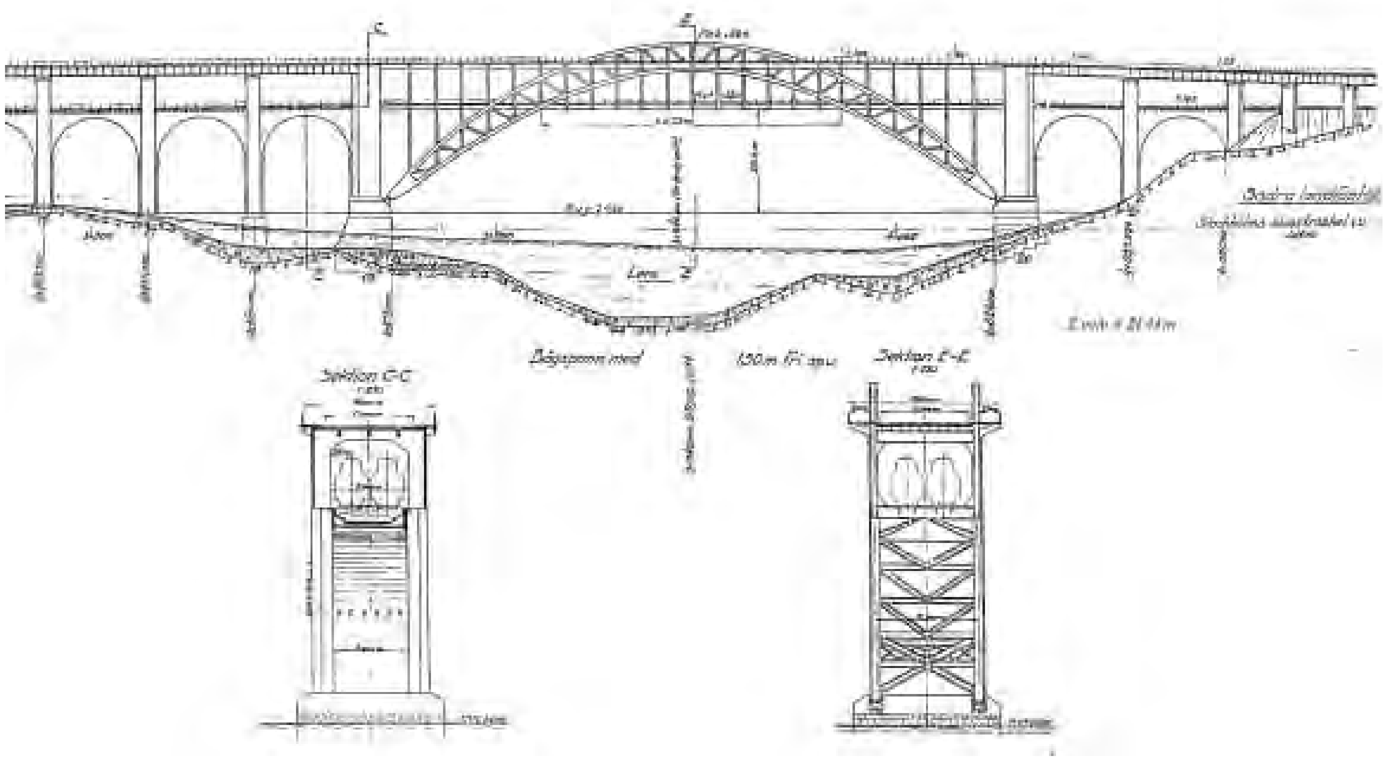


Gamla Årstabron
Orientation

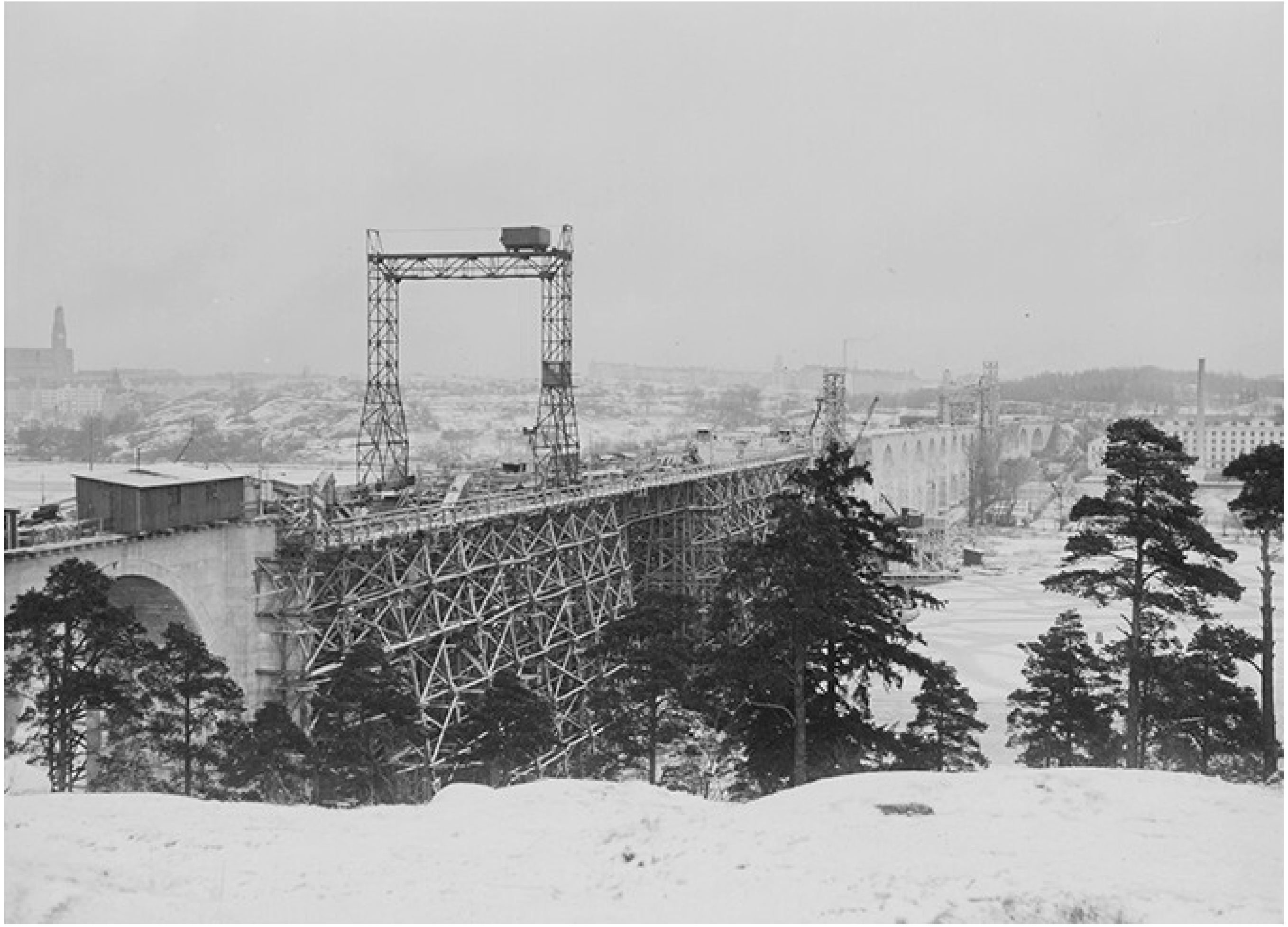
Gamla Årstabron
Overview

Gamla Årstabron
Overview

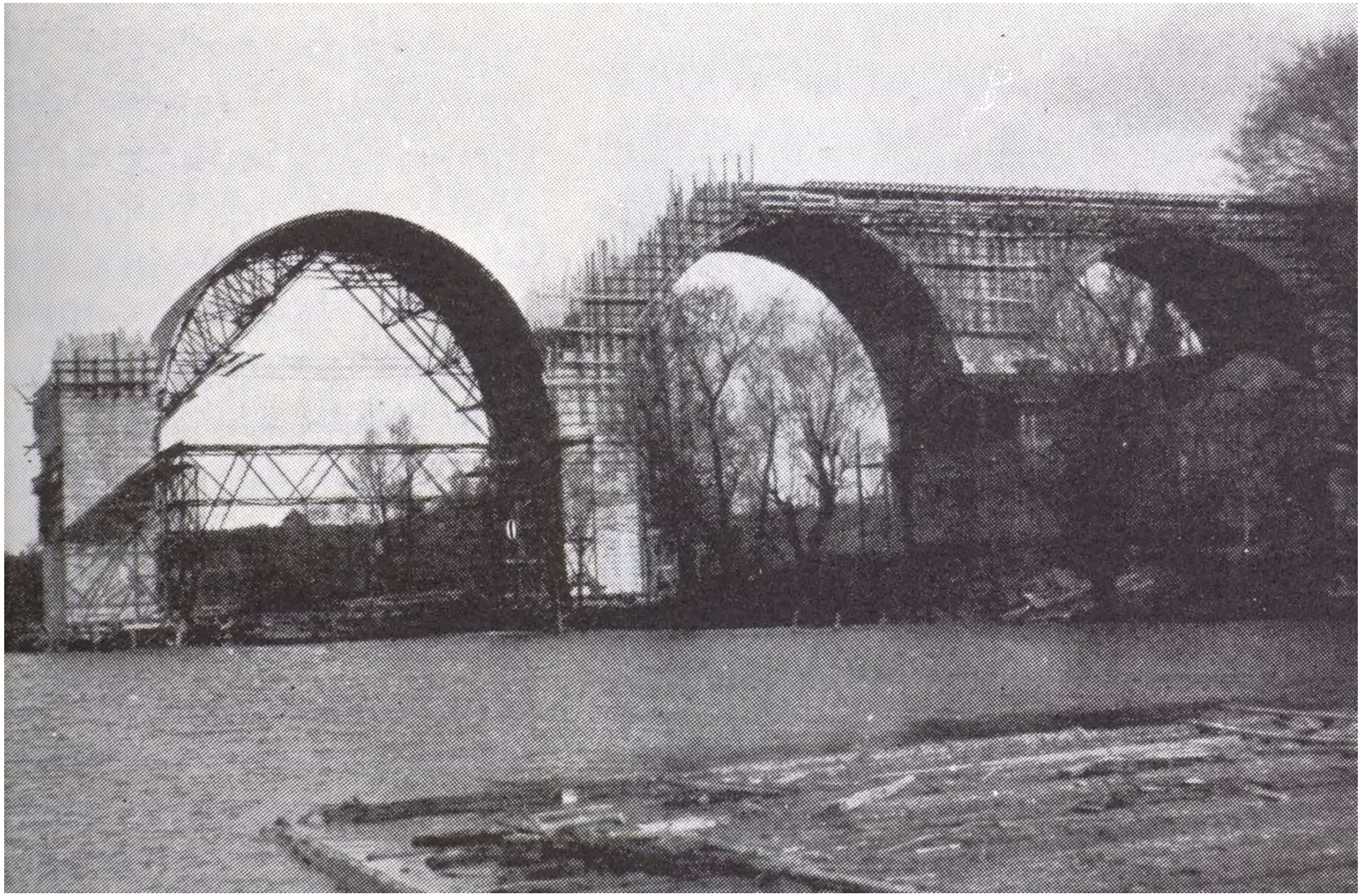
Gamla Årstabron



Gamla Årstabron



Gamla Årstabron



Gamla Årstabron
Completed bridge in 1929

Gamla Årstabron
Investigation of Bridge overall condition in the 90's

- **The concrete arcs**
  Calcium leaching, local parts of loose concrete, partial corrosion of reinforcement

- **The liftspann**
  Need for change of steel span

- **The main steel arc**
  Reinforcing of foundation for the main steel arc and repainting of the beams inside the trackzone

Gamla Årstabron
Overall plan of 2001

- Total renovation of the bridge in connection with the construction of the new railway bridge over the bay of Årsta
- The bridges will after the restoration of the old bridge act together in a four track system

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Gamla Årstabron
Connection to the Stockholm City Line

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Gamla Årstabron
Planned technical measures of 2001

Concrete arcs

- New drainage system for the superstructure
- Local repair of concrete surface

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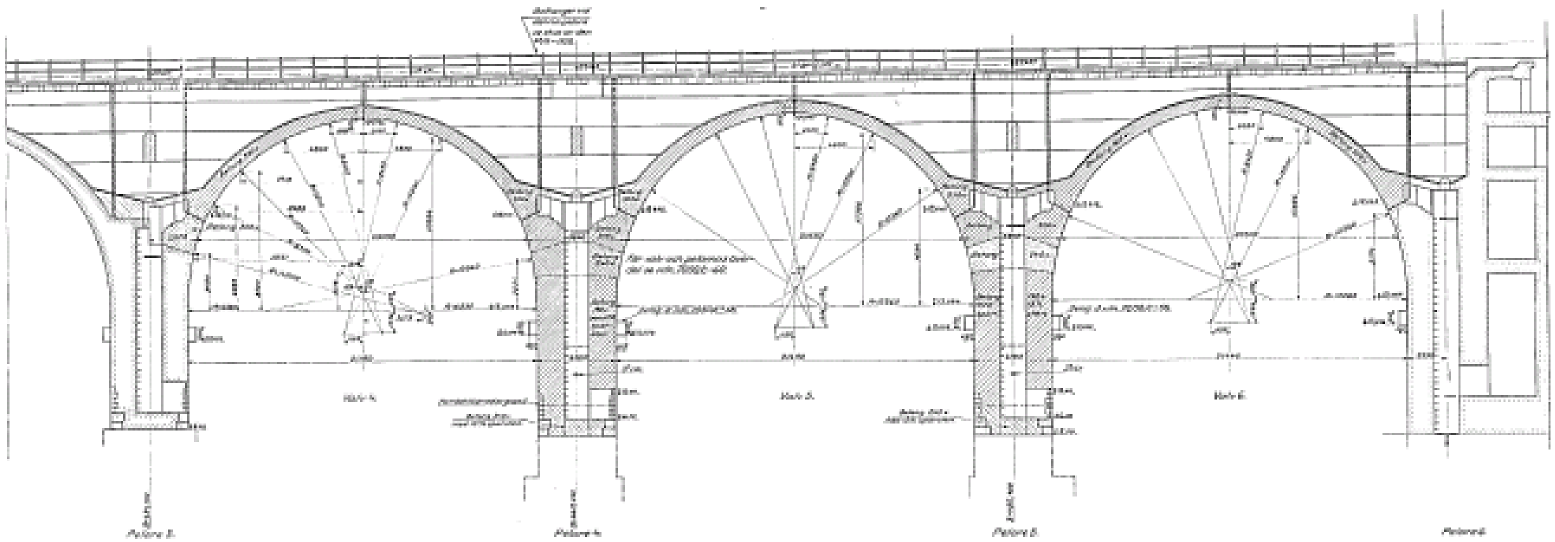
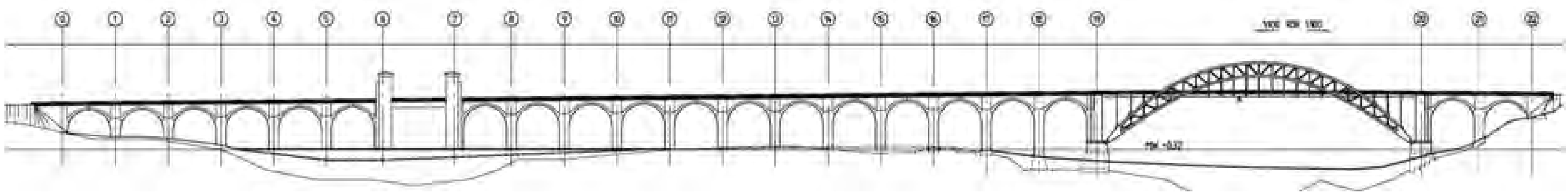
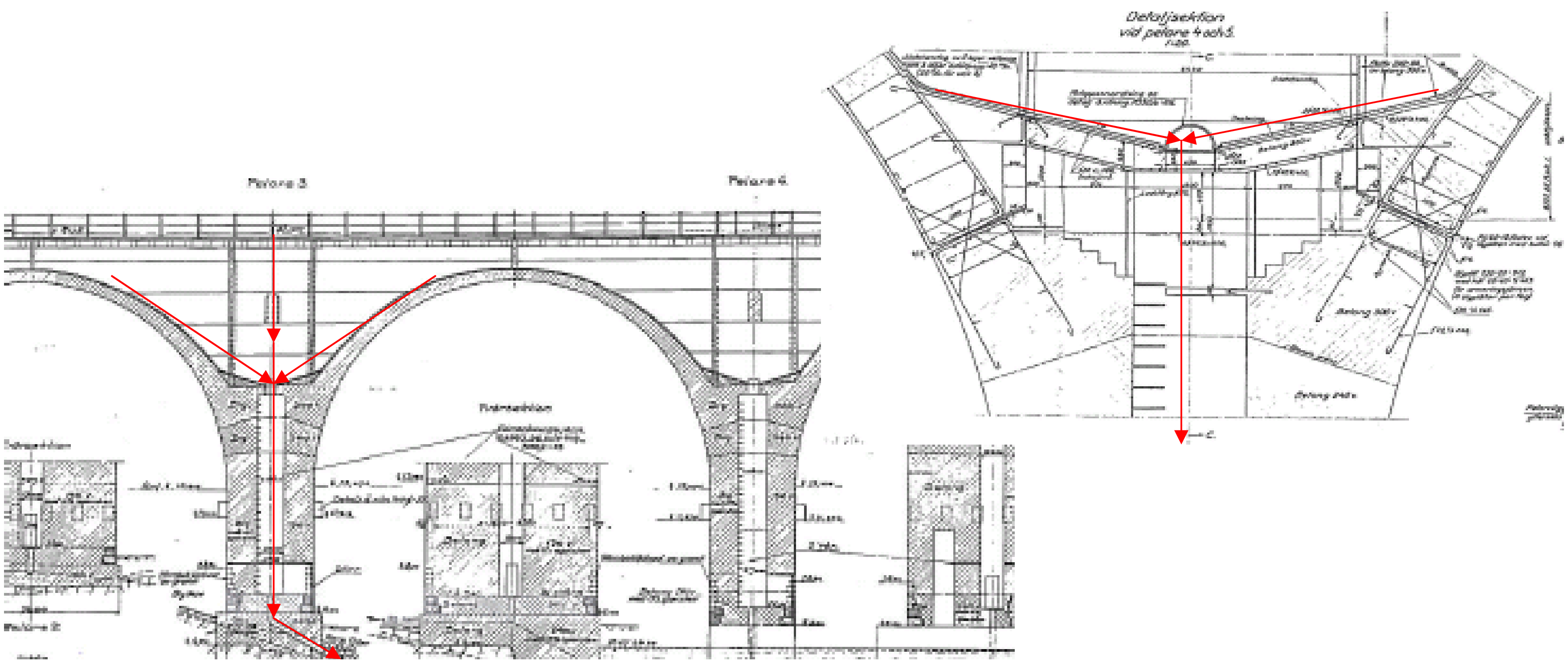
Design of the concrete arcs

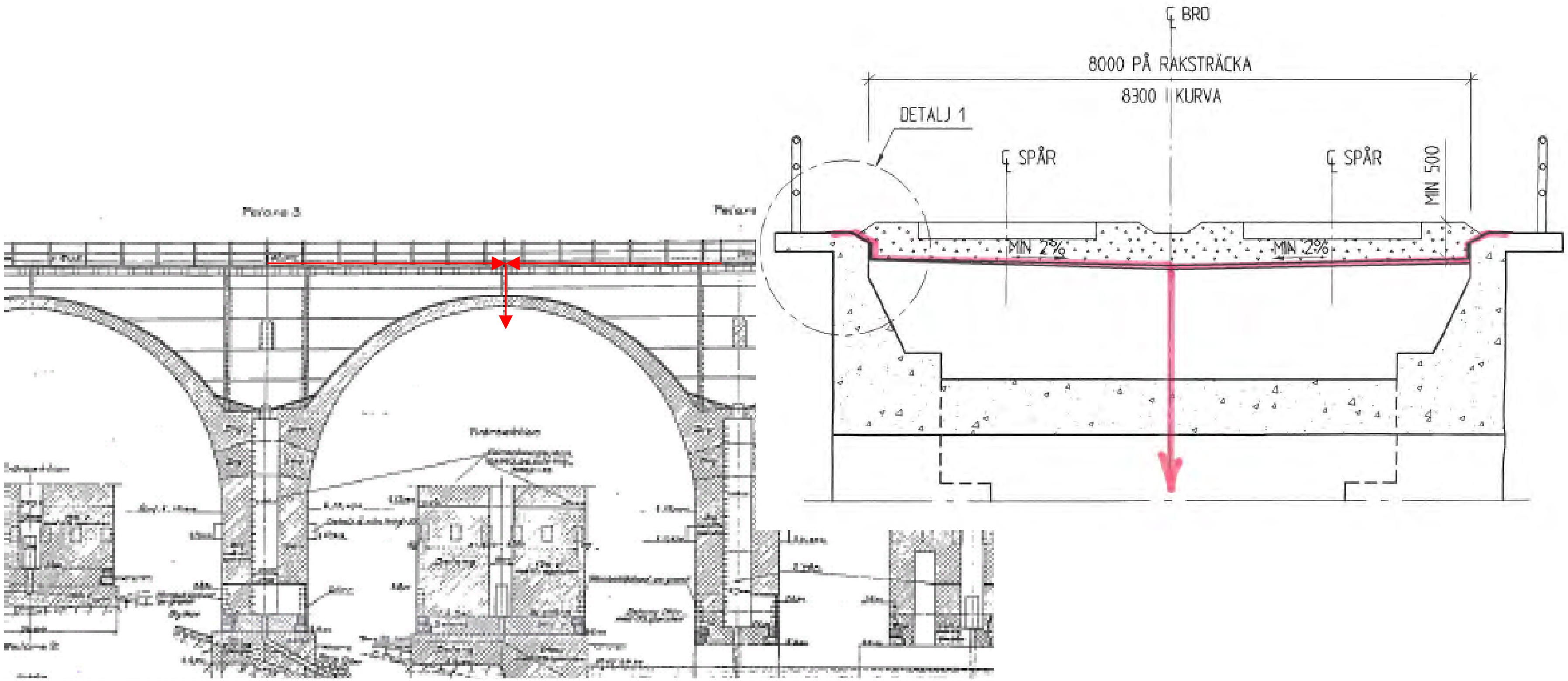




Gamla Årstabron
Original drainage system for the superstructure



Gamla Årstabron
New drainage system for the superstructure



Gamla Årstabron
Renovation works 2004 - 2006

The Bridge closed for trafik during summer – autumn 2005

- Excavation of superstructure and installation of new waterproofing
- Close inspection of the damages to use as basis for the decision of how to repair the local parts of the concrete surface
- New steel spann (the old liftspan)
- Painting of beams in track zone (main steel arc)
- Reinforcement of the foundation of the main steel arc

Gamla Årstabron
Inspection of damages of the concrete arcs

Gamla Årstabron
Inspection of damages of the concrete arcs

Gamla Årstabron
Inspection of damages of the concrete arcs

Constructi
on joints

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Questions after the inspection of damages

- Current load capacity?
- Bridge in service december 2005?
- Restrictions of the traffic? (current traffic approx. 275 trains/day)
- Heavy transports?
- Reparation HOW? WHEN? (cultural monument)
- Remaining life in service?

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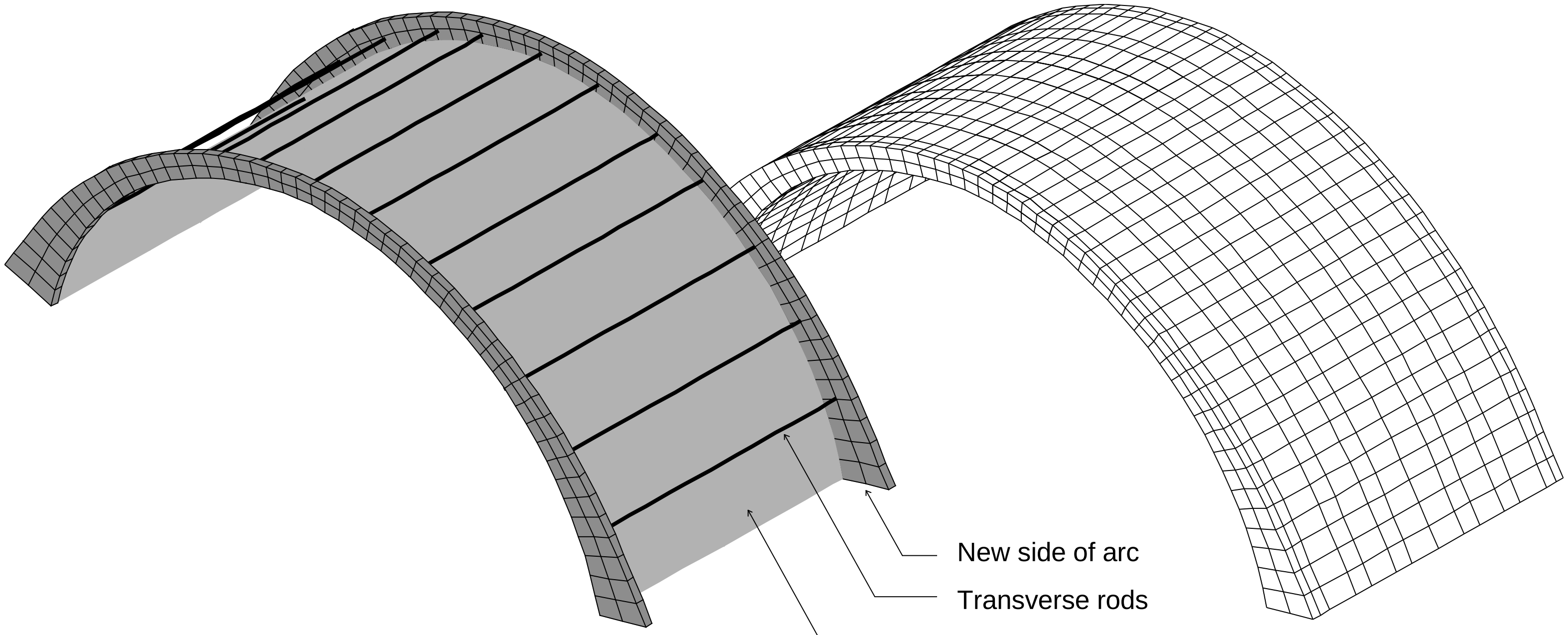
Calculations

- Required safety for traffic
- Materialproperties (weak zones, stone skeleton)
- Status of existing reinforcement (now and in fifty years)
- Linear elastic analysis
- Non-linear elastic analysis

- Calculation model calibrated against measurements

Gamla Årstabron
Strengthening of concrete arcs (F)

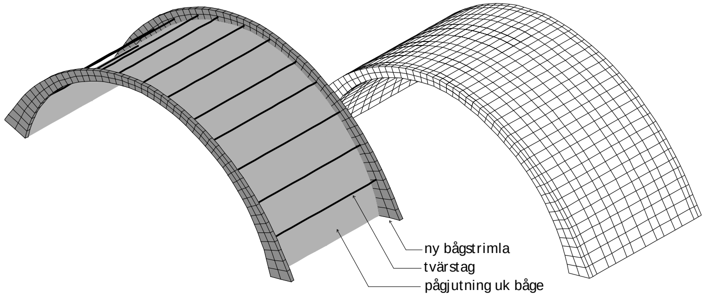


Gamla Årstabron
Strengthening of concrete arcs (F)

- New reinforced concrete cover interacting with existing arc (F)

- Concrete with strongly reduced shrinkage

- Prepack concrete



- Existing reinforcement in the construction phase / in 50 years

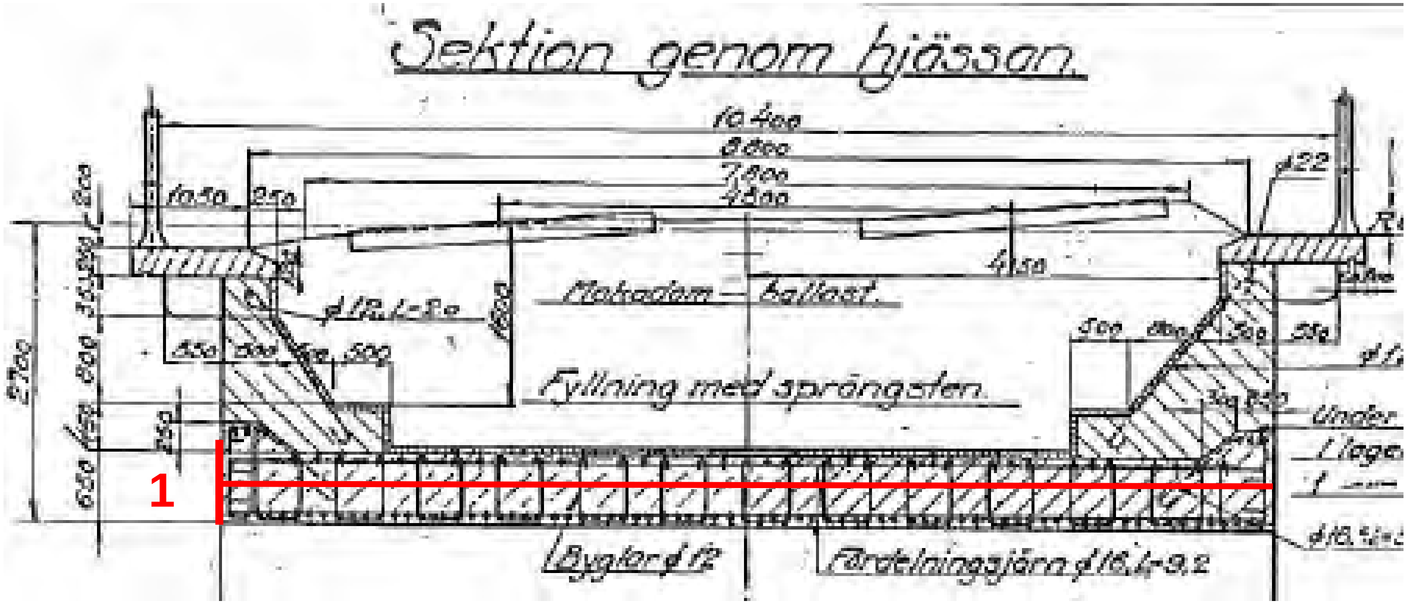
Gamla Årstabron
Strengthening of concrete arcs (F)

- Strengthening of bridge in service (ca 275 trains/day)
- Very comprehensive and detailed technical description
- The strengthening work contains very small margins and leaves no room for errors inte execution.
- Detail-driven and supervised hydrodemolition works
- Every worker at the site has got a specialized information
- The strengthening has to be done in phases

Gamla Årstabron
Phases of strengthening work (phase 1 – 3)

Phase 1

- Drilling for transversal rods
- Hydrodemolition of the first side of the arc
- Reinforcement and re-casting of the first side of the arc



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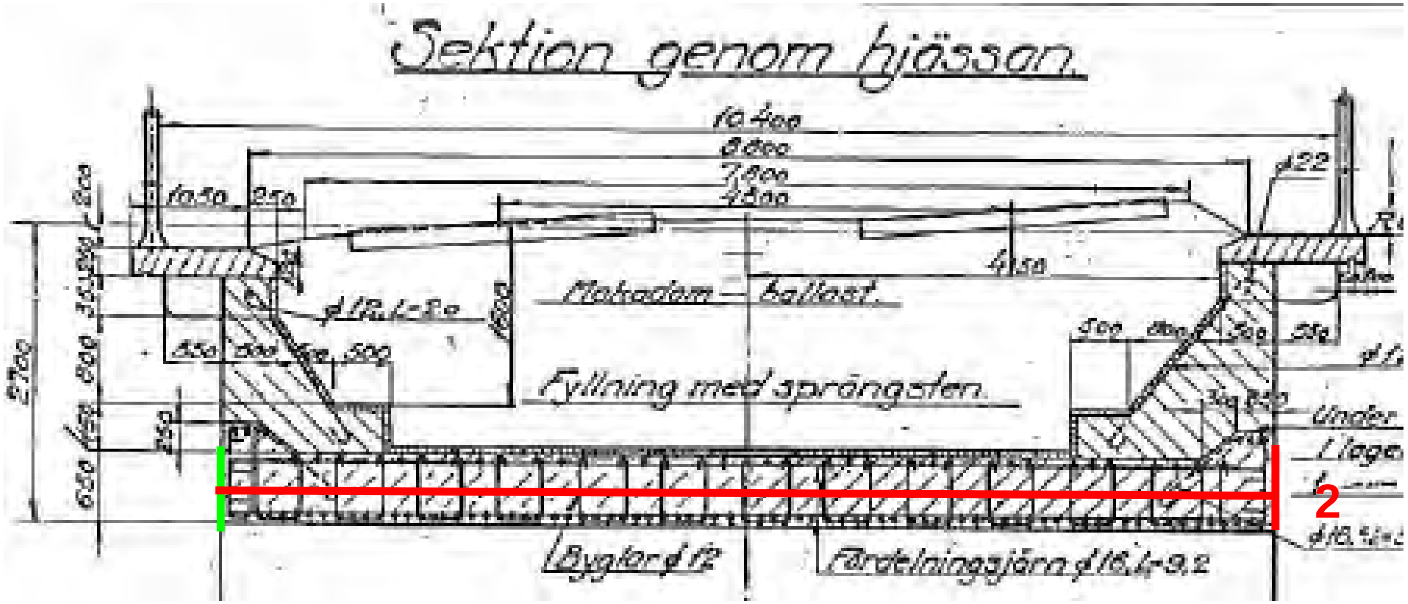
Phases of strengthening work (phase 1 – 3)

Phase 2

- Hydrodemolition of the second side of the arc
- Reinforcement and re-casting of the second side of arc
- Installation and tensioning of transverse rods



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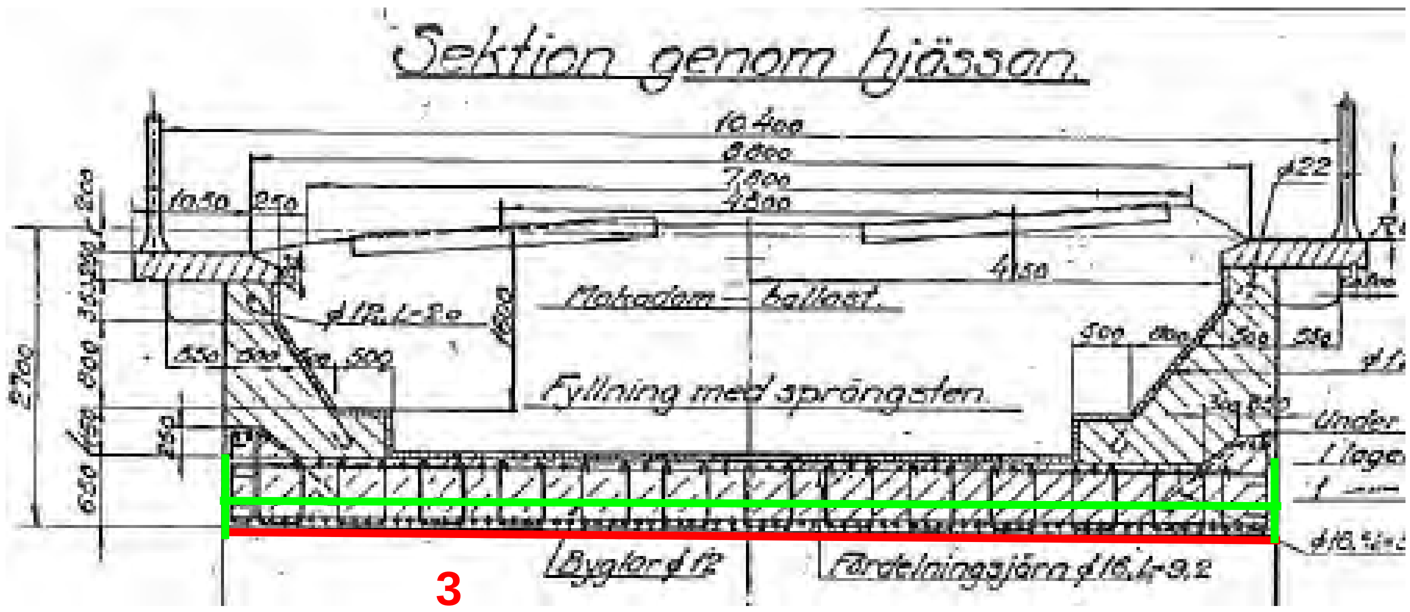
Phases of strengthening work (phase 1 – 3)

Phase 3

- Hydrodemolition of arc bottom
- Reinforcement and re-casting of arc bottom



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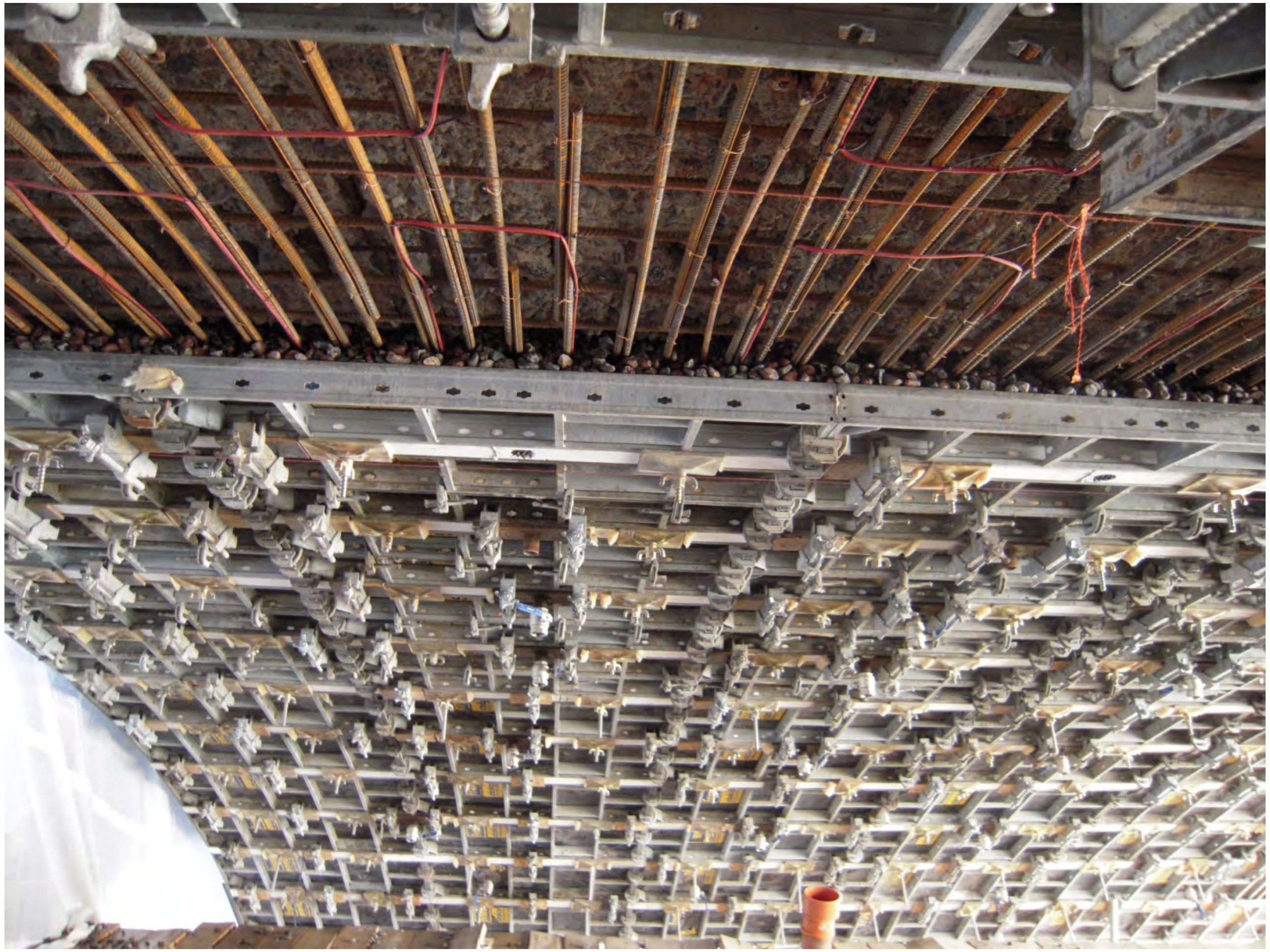
Mold, reinforcement and aggregate of phase 3



Gamla Årstabron
Mold, reinforcement and aggregate of phase 3

Gamla Årstabron
Mold, reinforcement and aggregate of phase 3

Gamla Årstabron
Thanks for your attention

NVF Annual Bridge Conference 2010

Bridge Management Systems

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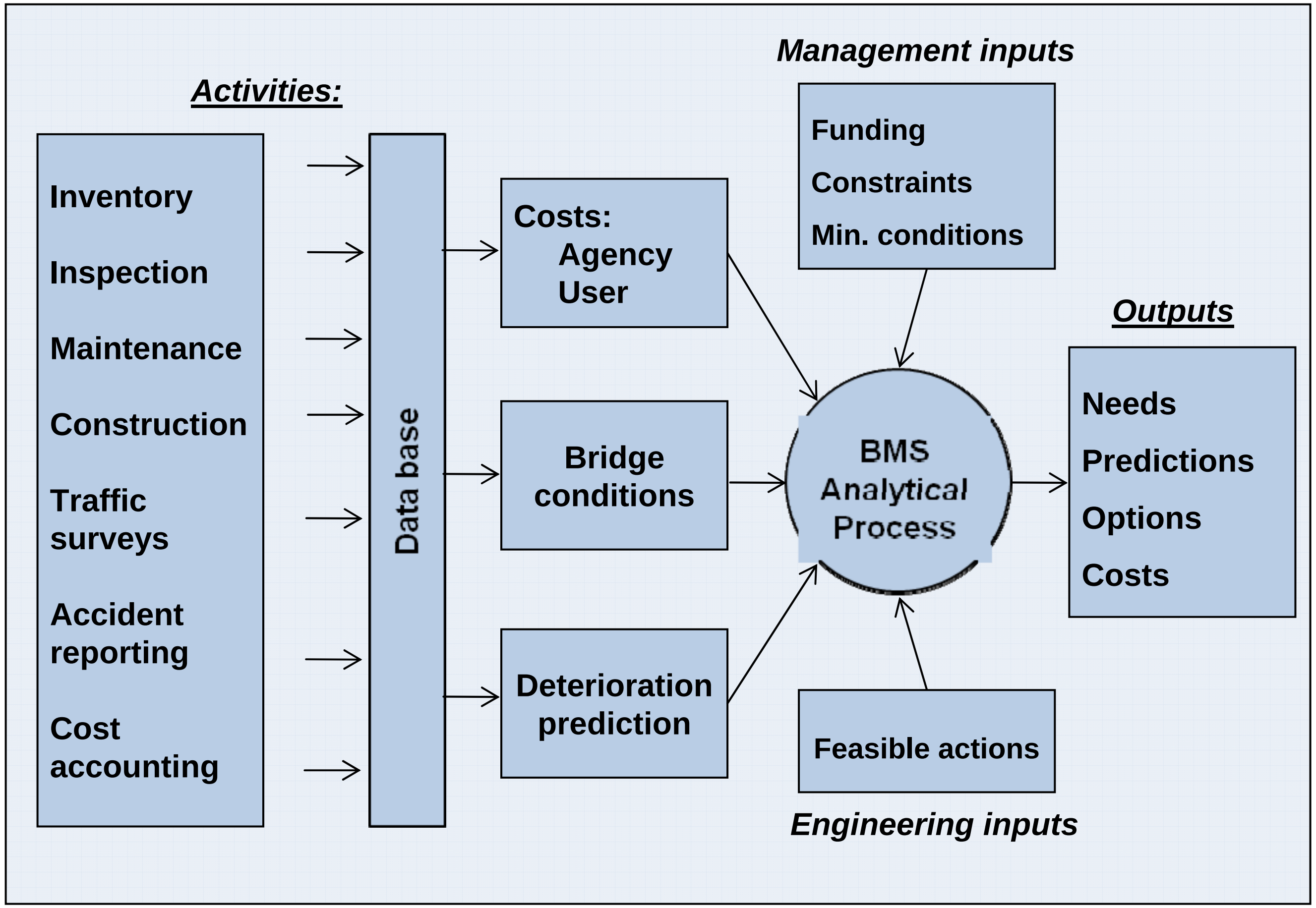
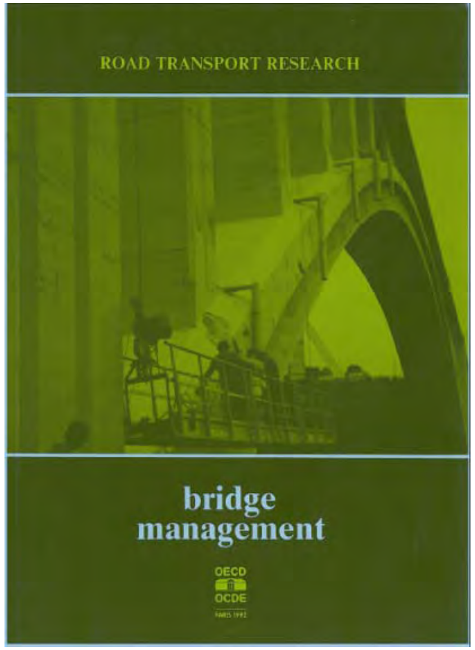
SWEDISH TRANSPORT ADMINISTRATION

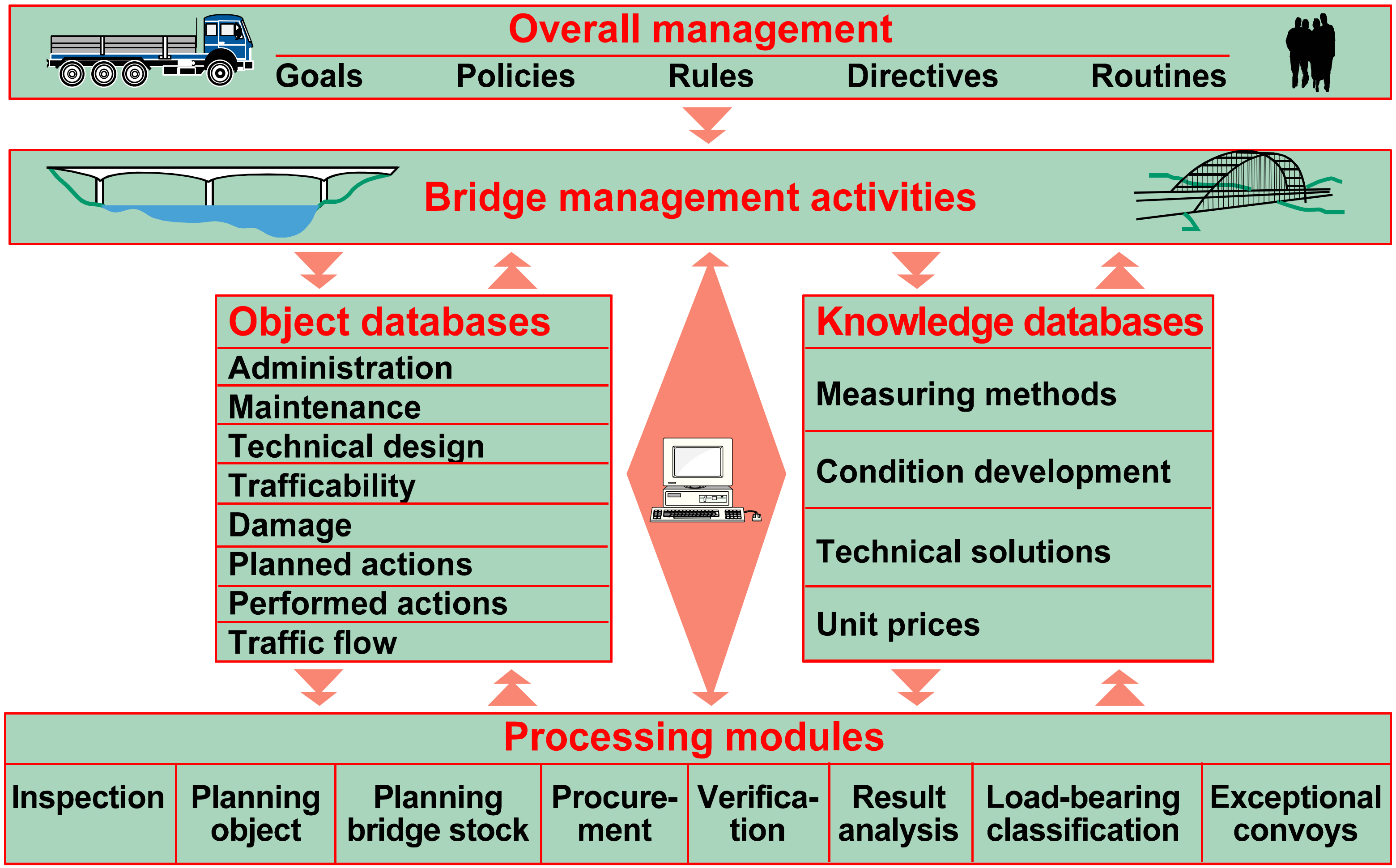
Lennart Lindblad
National Co-ordinator
Bridge Management

BMS prototype 1992 (OECD)

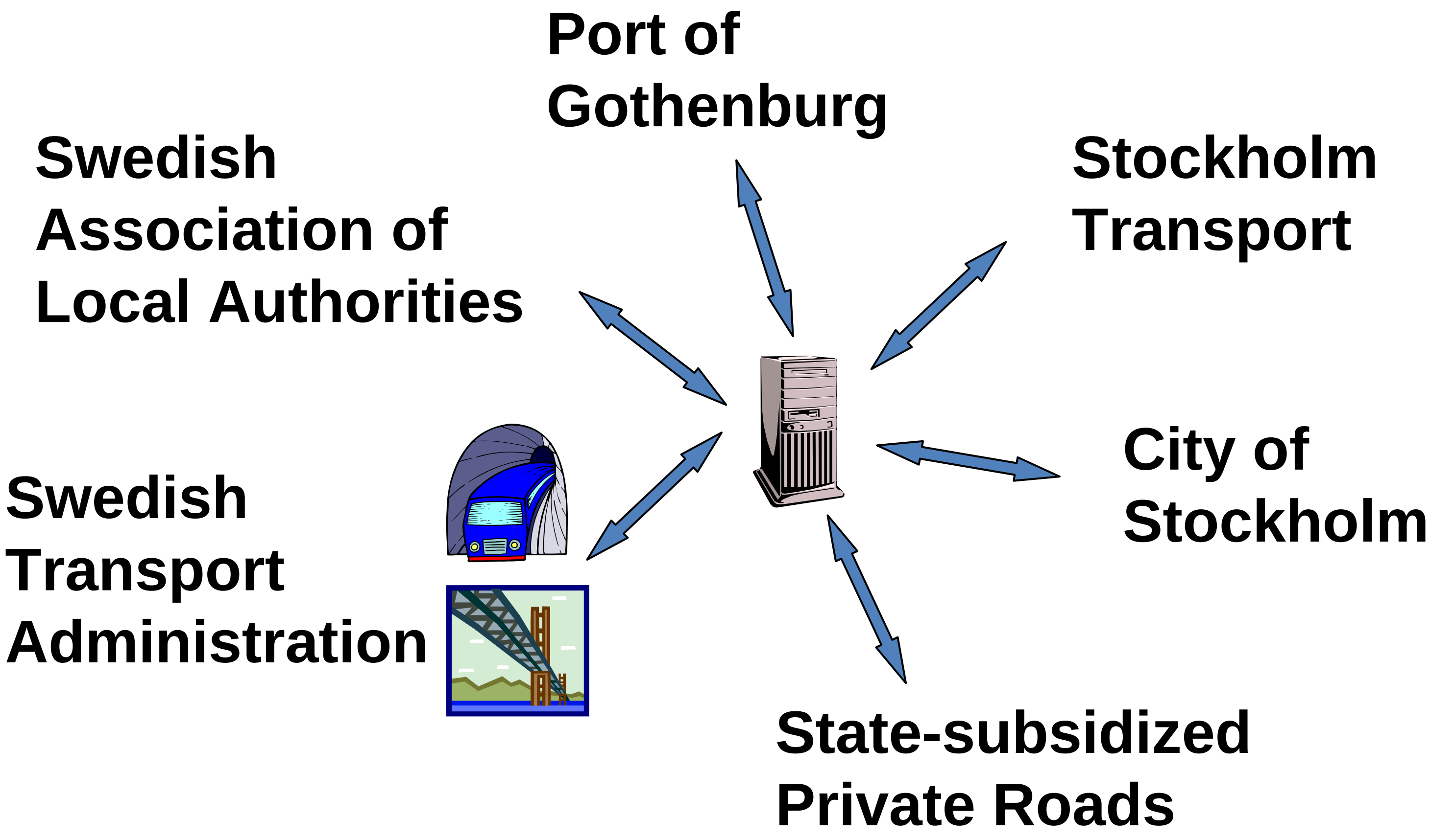




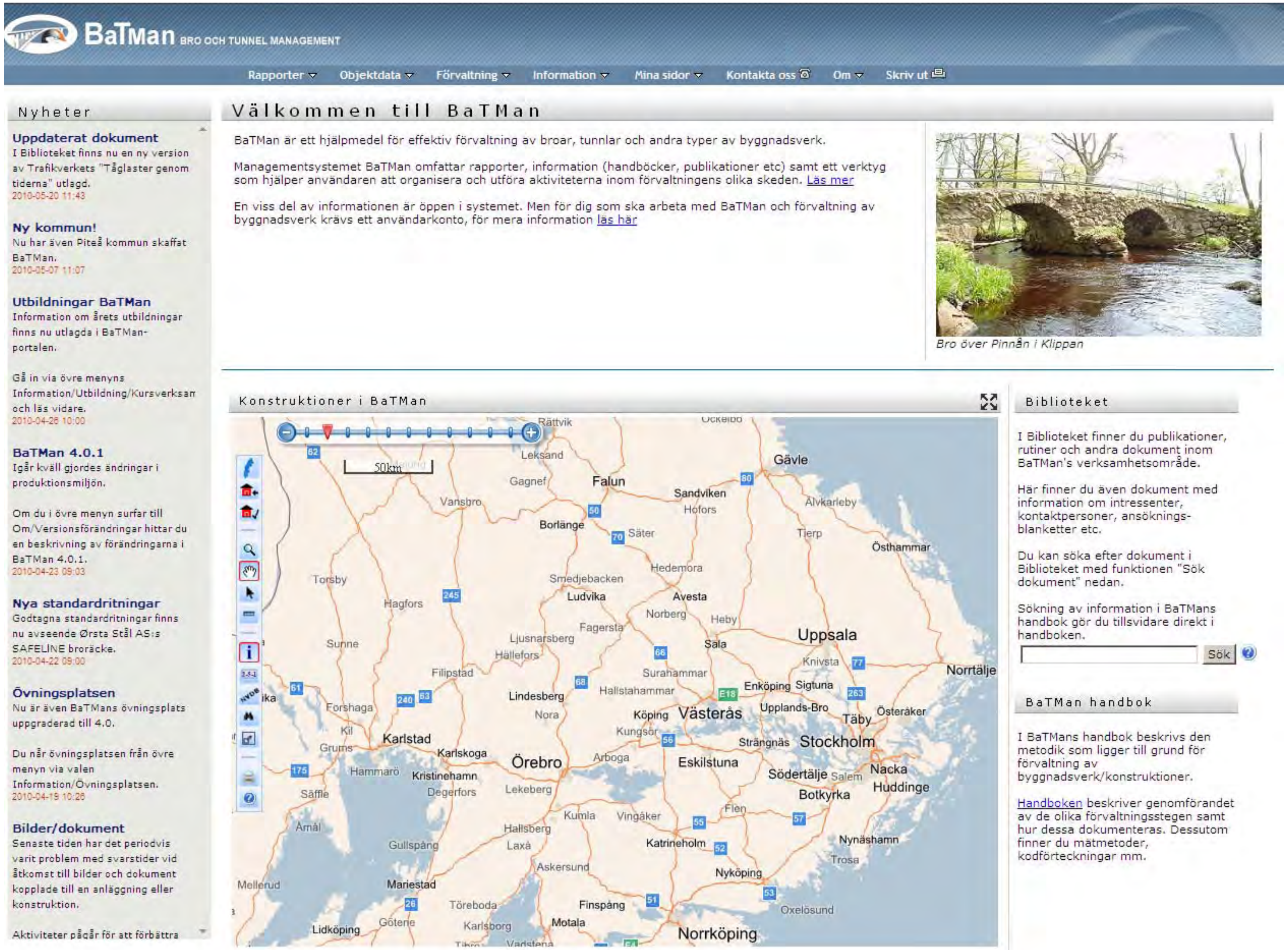
The BaTMan System



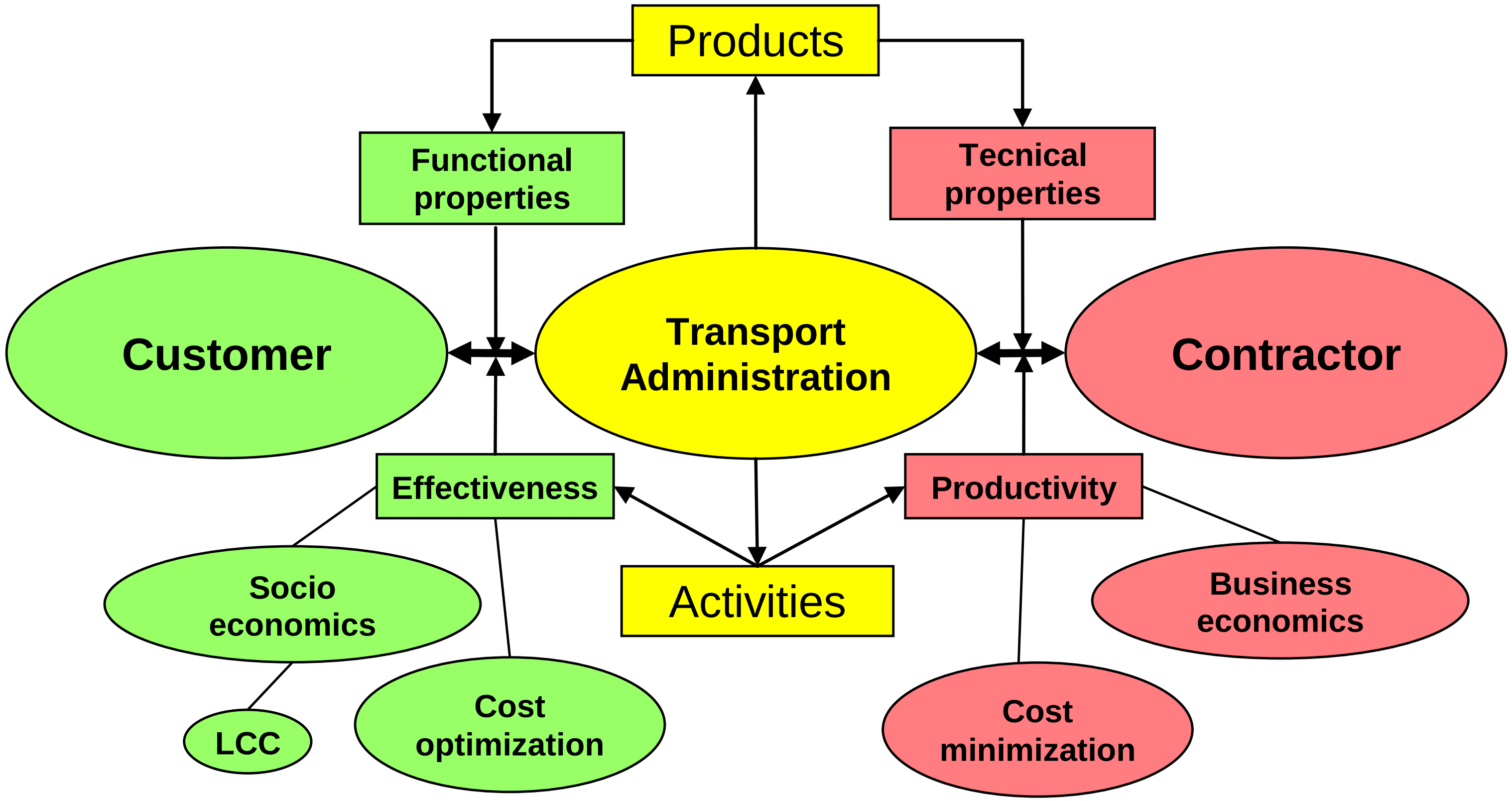
A National Internet System



The BaTMan System – https://batman.vv.se



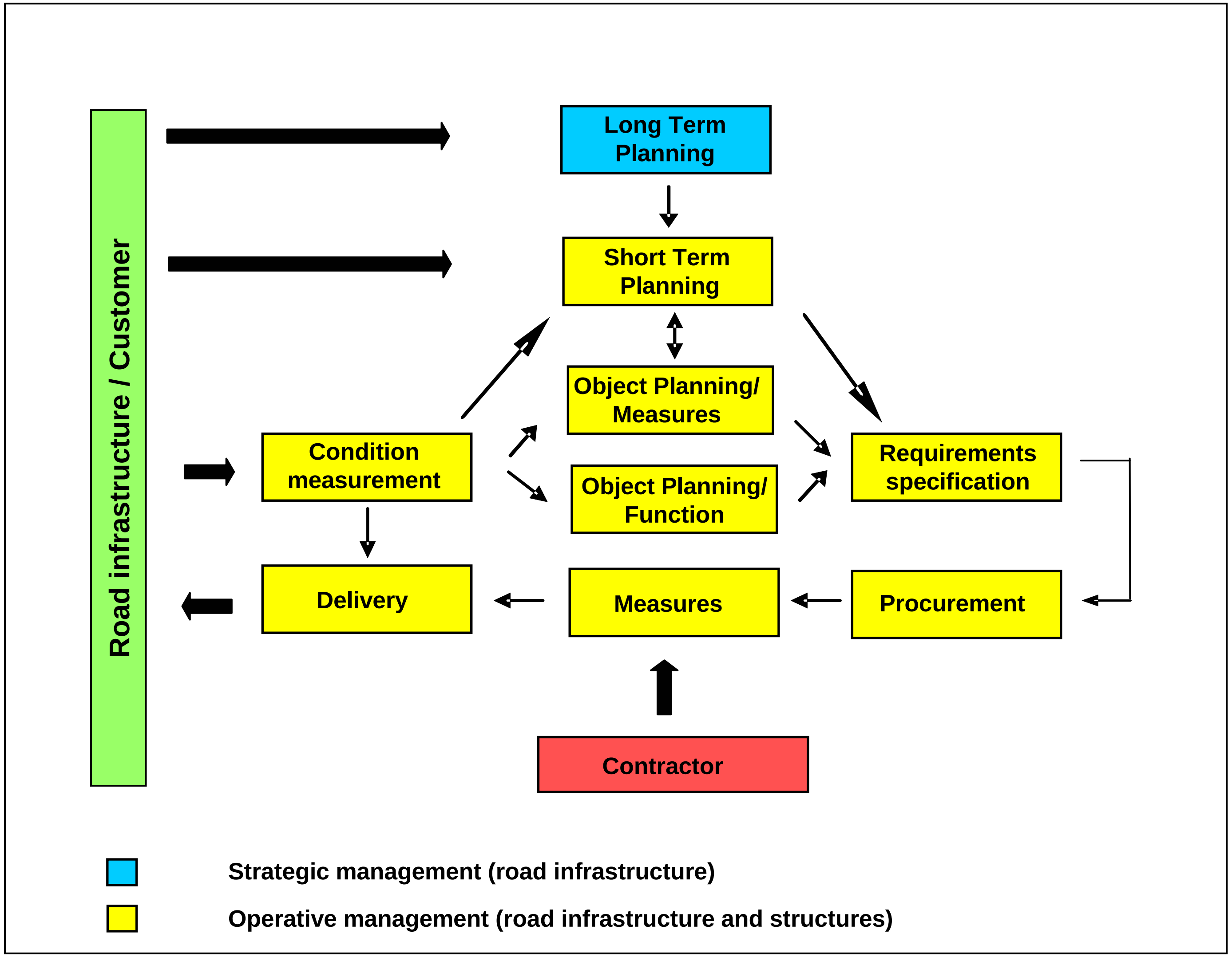
The roles of a Transport Administration



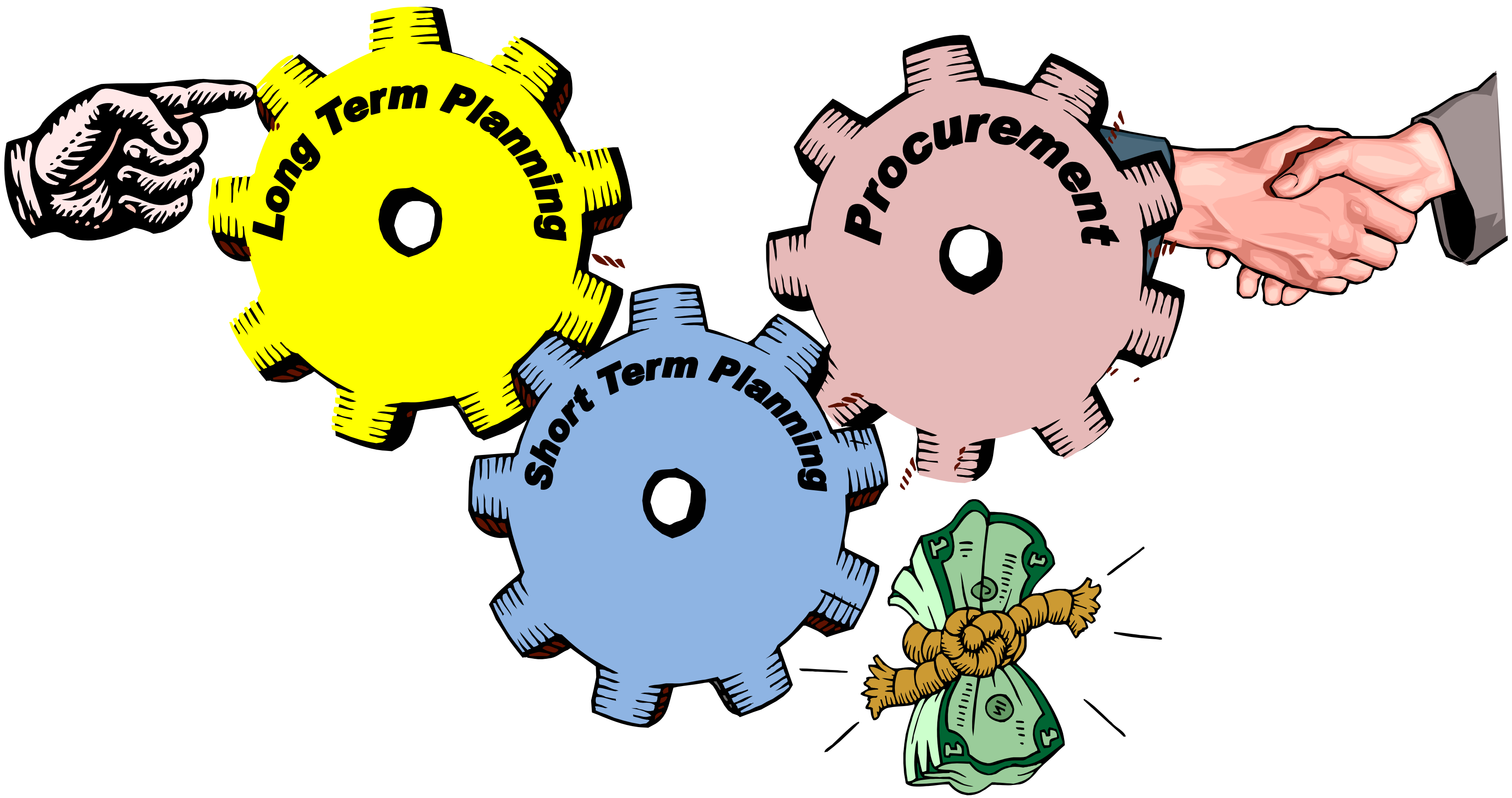
Classification of deliveries – bridge database information (examples)

Bridge over River Black in East Village Id-no. 10-4678-1	**Classification of deliveries**			
	Standard			**Condition**
Functional property	Normal	Temporary Traffic	Temporary Society	Normal
Bearing capacity	C1	D11	D21	A1
Accessibility	.....	.....	.....	.....
Robustness	.....	.....	.....	.....
Safety	.....	.....	.....	.....
Comfort	.....	.....	.....	.....
Aesthetics	.....	.....	.....	.....

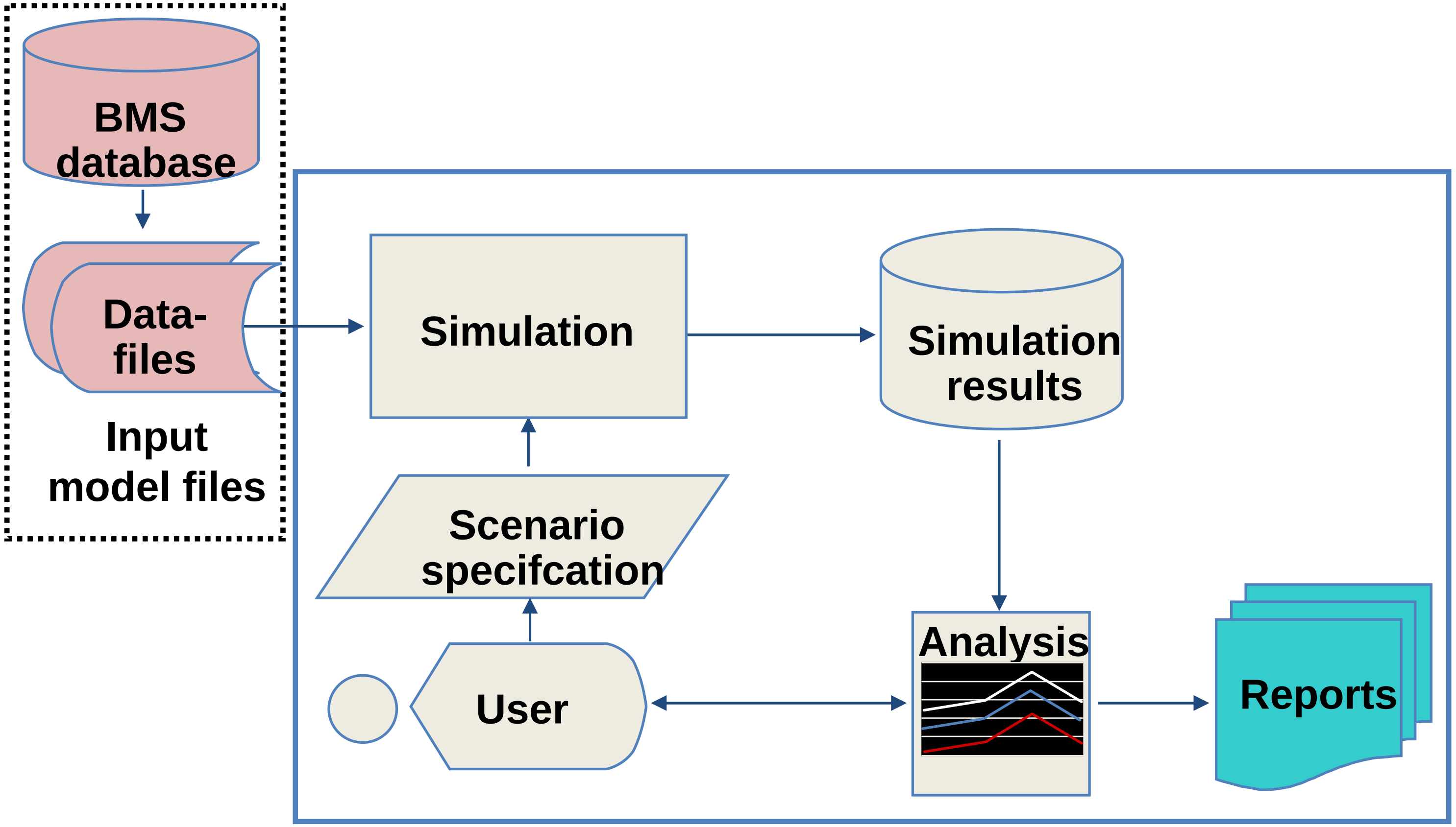
The bridge management process



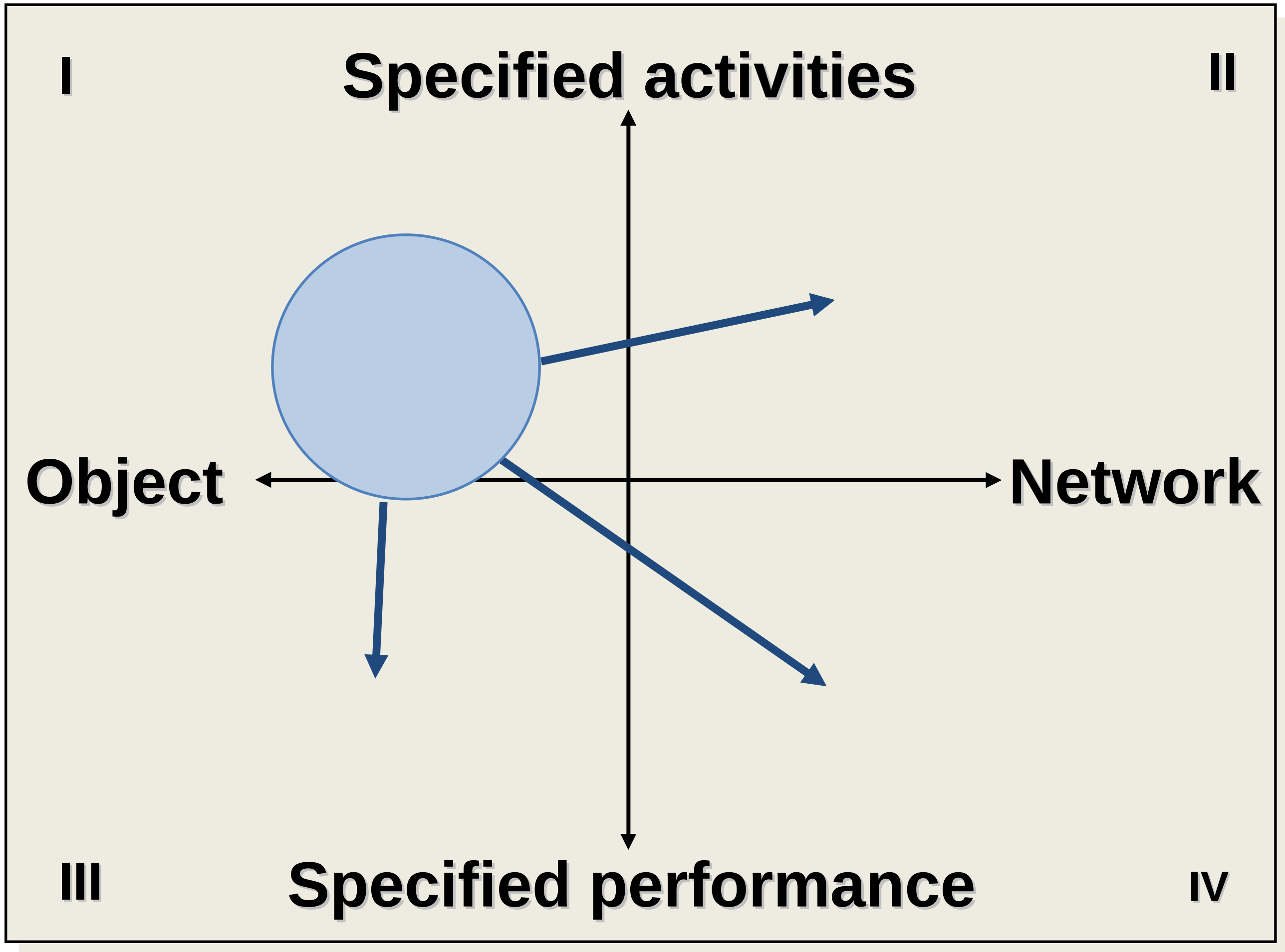
Integrated processes



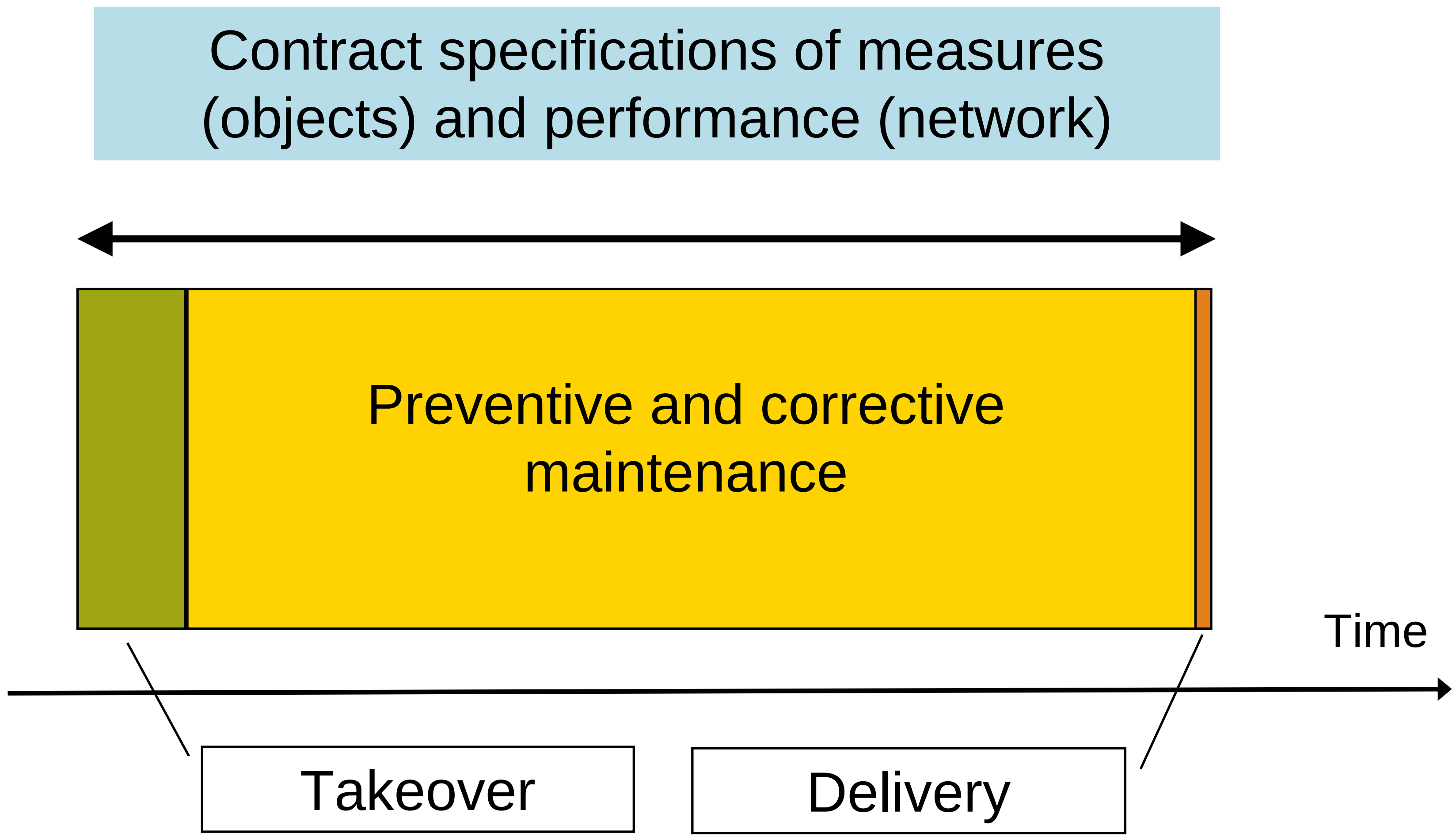
Simulation tool for long term planning



Development of forms of contracting

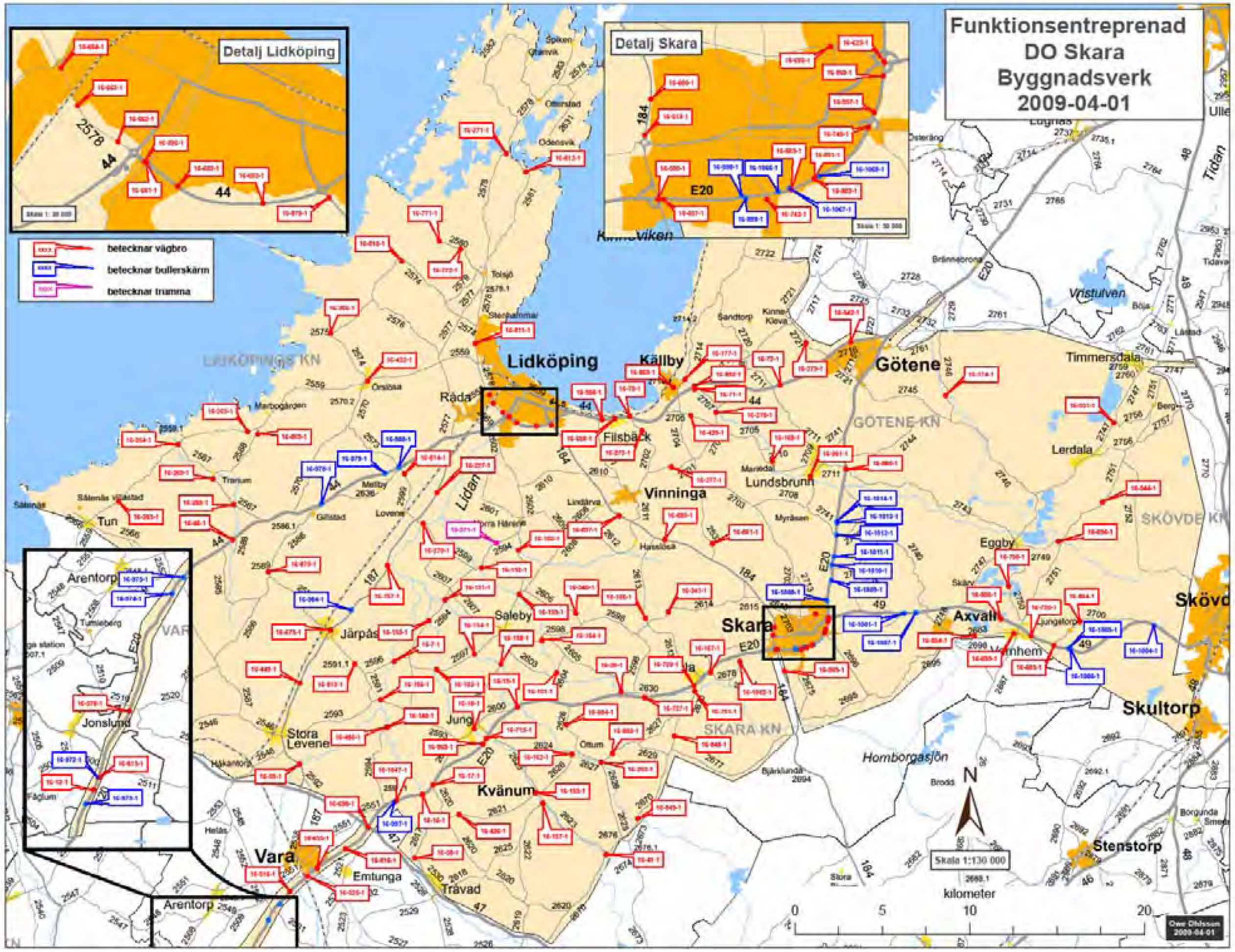


Bridge maintenance package contracts



Bridge maintenance package contracts

Ca 5 years, 100-200 mkr and 400-600 structures



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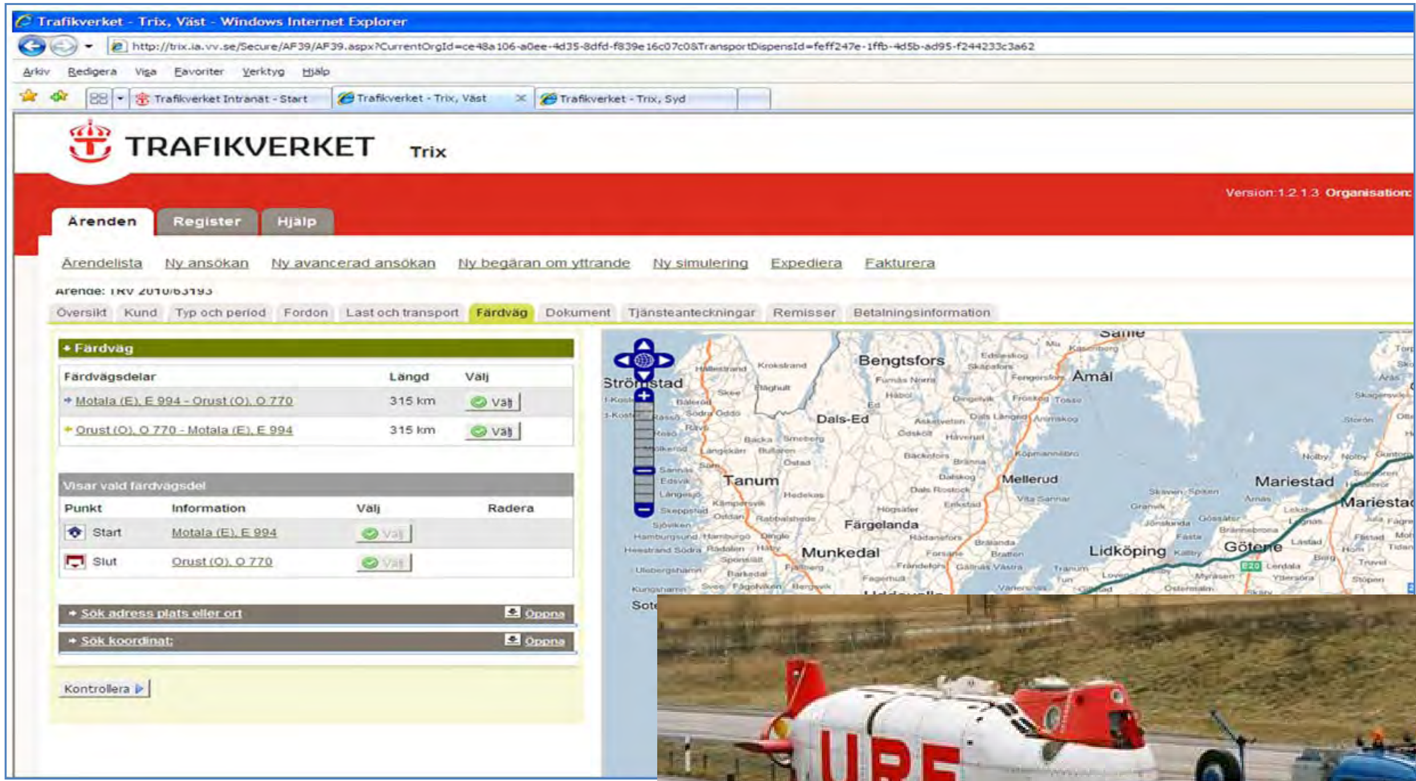
Accessibility for heavy vehicles



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BMS International overview

THE IABMAS BRIDGE MANAGEMENT COMMITTEE

OVERVIEW OF EXISTING BRIDGE MANAGEMENT SYSTEMS

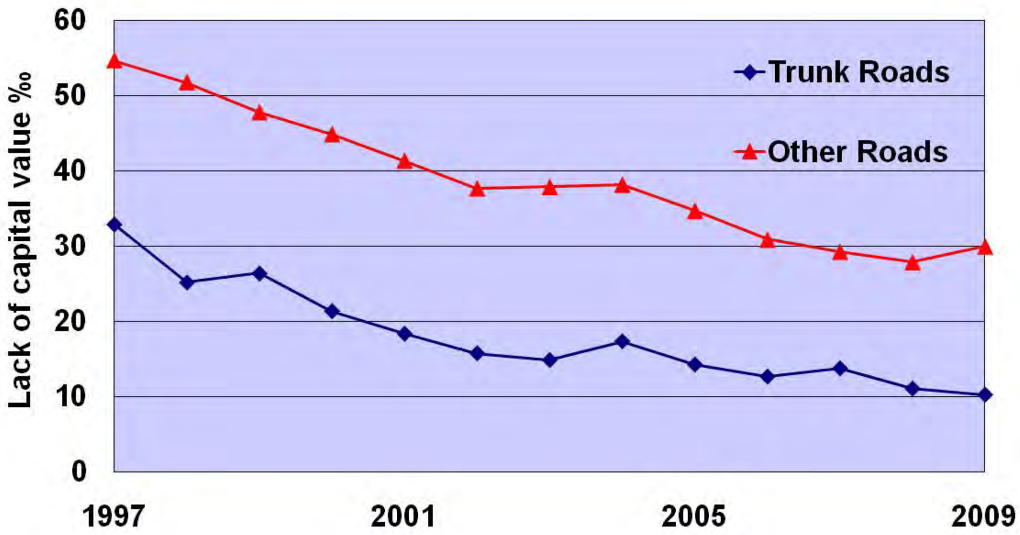
2010

BMS – Essential for a successful management

Sustainability

Effectiveness

Customer benefit



Probabilistic methods for materials and load resistance of Bridges

Ib Enevoldsen – Head of Bridges, Rambøll, Copenhagen

ibe@ramboll.dk, http://www.ramboll.dk

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STATEMENTS

- Bridges are much safer than generally documented
- Modern methods can demonstrate higher safety
- Tremendous savings can be obtained by avoiding strengthening and replacement of bridges

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- Bridge analysis is a mature field of expertise based on tradition and a large degree of conservatism
- The society of bridge engineers is more focused on standardisation than innovation
- We waste money!

Route network for special heavy permits in Denmark

- The Danish Road Directorate (DRD) is responsible for the 3500 km national road network and approximately 2100 smaller bridges and 50 special bridges and tunnels on this road network.
- The main focuses of attention for the DRD are on safety, preservation of invested capital and availability of an uninterrupted traffic flow.
- In response to these challenges the Danish Roads Directorate (DRD) have (i) established a so called Blue Road Network which comprises roads with no bridges having a class less than 100 and (ii) have produced a guideline for probability based assessment of structures on the network which fail deterministic assessment.

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Problem: Lack of load carrying capacity

- Weak bridges
- Deteriorated bridges

Low budgets for strengthening or rehabilitation

Idea: Determination of higher capacity

- Advanced analysis models

Motivation: Cost saving


Advanced analysis models in assessment of bridges

- Advanced 3D FEM analysis
- Plastic limit state analysis
- Probability-based analysis and assessment
- Fatigue analysis
- Risk analysis
- Dynamic analysis
- Safety-based maintenance management

Assessment of bridges as a decision process

BASIS:Traditional standard assessment

Principle for refinement of assessment:

The benefit of further modeling or procurement of information must be shown in advance

- Identification of significant parameters
- Documentation of the importance of the particular modeling

Experience, sensitivity analysis and parameter studies

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Probability Based Assessment of bridges

Motivation and Benefits

- **Individual bridge assessment without compromising the safety level**
- **Saving of costs for strengthening or rehabilitation projects**

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Safety approaches for assessment of existing bridges

The general approach

Based on codes for bridges

- New bridges
- Existing bridges

Generalisation

- Partial safety factor format
- Load specification
- Many types of bridges

Benefit

- Efficient and easy to use

Drawback

- Costly in case of lack of capacity

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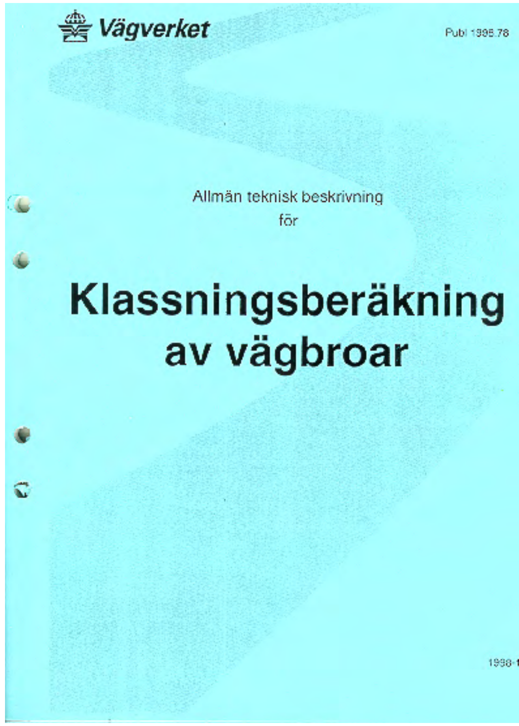
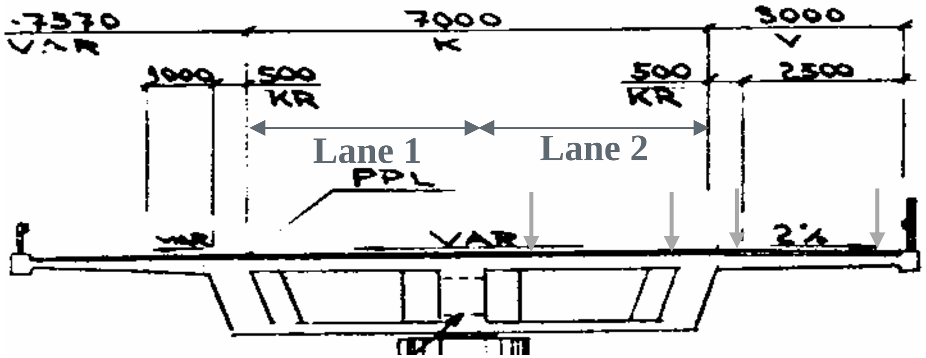
The general approach

- Banverket ”Bärighetsbestämning av järnvägsbroar” BVH 583.11
- Vägverket. ”Allmän teknisk beskrivning för Klassnings-beräkning av vägbroar”.



Conservative combination of extreme cases

- Conservative capacity models
- Conservative response models
- Conservative load magnitudes
- Conservative location of loads
- Conservative impact factors
- Conservative occurrence models



Conservative load modelling

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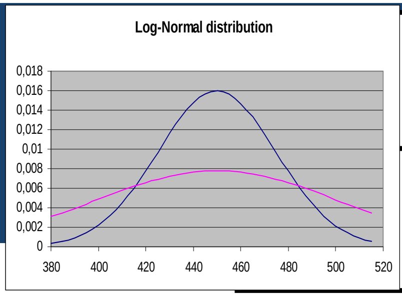

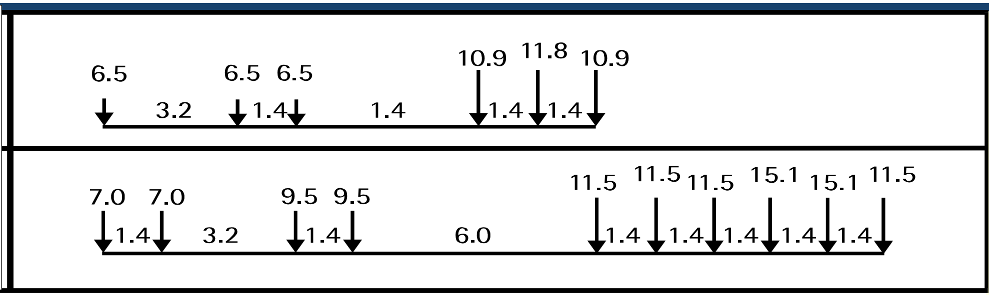

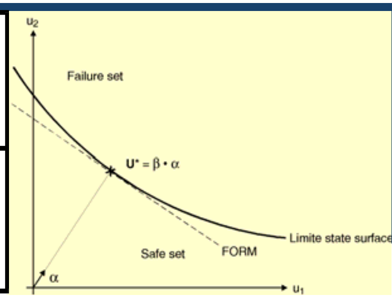

The individual approach

Concept:

- Don't necessarily have to fulfill the specific requirement of the general code
- Overall requirement for the safety level must be satisfied

Purpose:

- Cut strengthening or rehabilitation costs
- without compromising the safety level

Method:

Probabilistic-based assessment

Uncertainties of the specific conditions:

- Traffic load
- Capacities
- Models

Bridge specific "code" is obtained

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Legal justification for probabilistic-based assessment

2 :114 Säkerhetsindex

Säkerhetsindex, β, definierat enligt ISO 2394-1998, *General Principles on the reliability for Structures*, skall för en byggnadsdel vara
$\geq$ 3,7 för säkerhetsklass 1,
$\geq$ 4,3 för säkerhetsklass 2,
$\geq$ 4,8 för säkerhetsklass 3. *(BFS 1998:39)*

Vid dimensionering med hänsyn till olyckslast och risken för fortskridande ras skall säkerhetsindexet β vara minst 3,1 respektive 2,3.

Råd: Angivna β -värden avser referenstiden 1 år.

Angivna partialkoefficienter i brottgränstillstånd är beräknade med hänsyn till ovan angivna β -värden och baserade på en kalibrering enligt NKB-skrift nr 55, *Retningslinjer for last- og sikkerhedsbestemmelser for bærende konstruktioner, 1987*. *(BFS 1998:39)*

Boverkets

BKR 1999

Klassningsberäkning av vägbroar (1.1.9.3):

Klassningsberäkning med hjälp av säkerhets indexmetoden godtas efter utredning i varje enskilt fall




Nordic Background for Safety Requirements

Failure consequence (Safety class)	Failure type I, Ductile failure with remaining capacity	Failure type II, Ductile failure without remaining capacity	Failure type III, Brittle failure
Less Serious (Low safety class)	$p_f \leq 10^{-3}$ $\beta \geq 3.09$	$p_f \leq 10^{-4}$ $\beta \geq 3.71$	$p_f \leq 10^{-5}$ $\beta \geq 4.26$
Serious (Normal safety class)	$p_f \leq 10^{-4}$ $\beta \geq 3.71$	$p_f \leq 10^{-5}$ $\beta \geq 4.26$	$p_f \leq 10^{-6}$ $\beta \geq 4.75$
Very Serious (High safety class)	$p_f \leq 10^{-5}$ $\beta \geq 4.26$	$p_f \leq 10^{-6}$ $\beta \geq 4.75$	$p_f \leq 10^{-7}$ $\beta \geq 5.20$

Nordic Committee for Building Structures (NKB)
“Recommendation for Loading and Safety Regulations for Structural Design”
NKB report no. 35, 1978 & NKB report no. 55, 1987.

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Reliability-based assessment guideline

Structure of the Guideline

- The guideline itself consists of 55 pages broken into 7 chapters.

  Chapter 1 Introduction

  Chapter 2 Bridge classification by reliability analysis

  Chapter 3 Reliability requirements

  Chapter 4 Model uncertainties and computation models

  Chapter 5 Loading

  Chapter 6 Materials

  Chapter 7 Dealing with supplementary information

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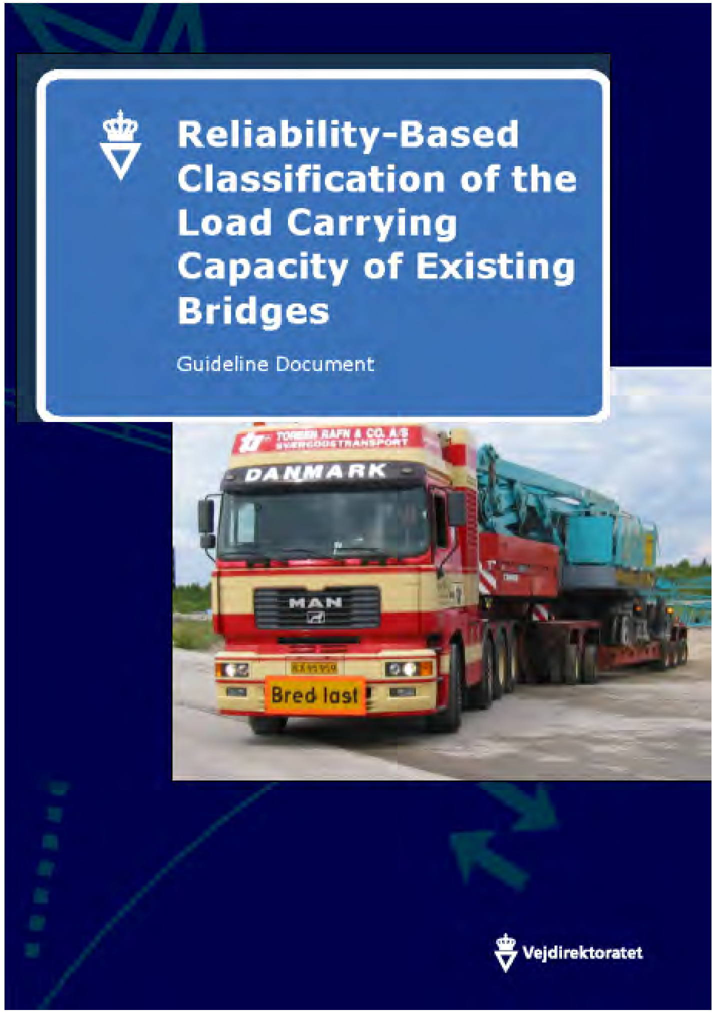

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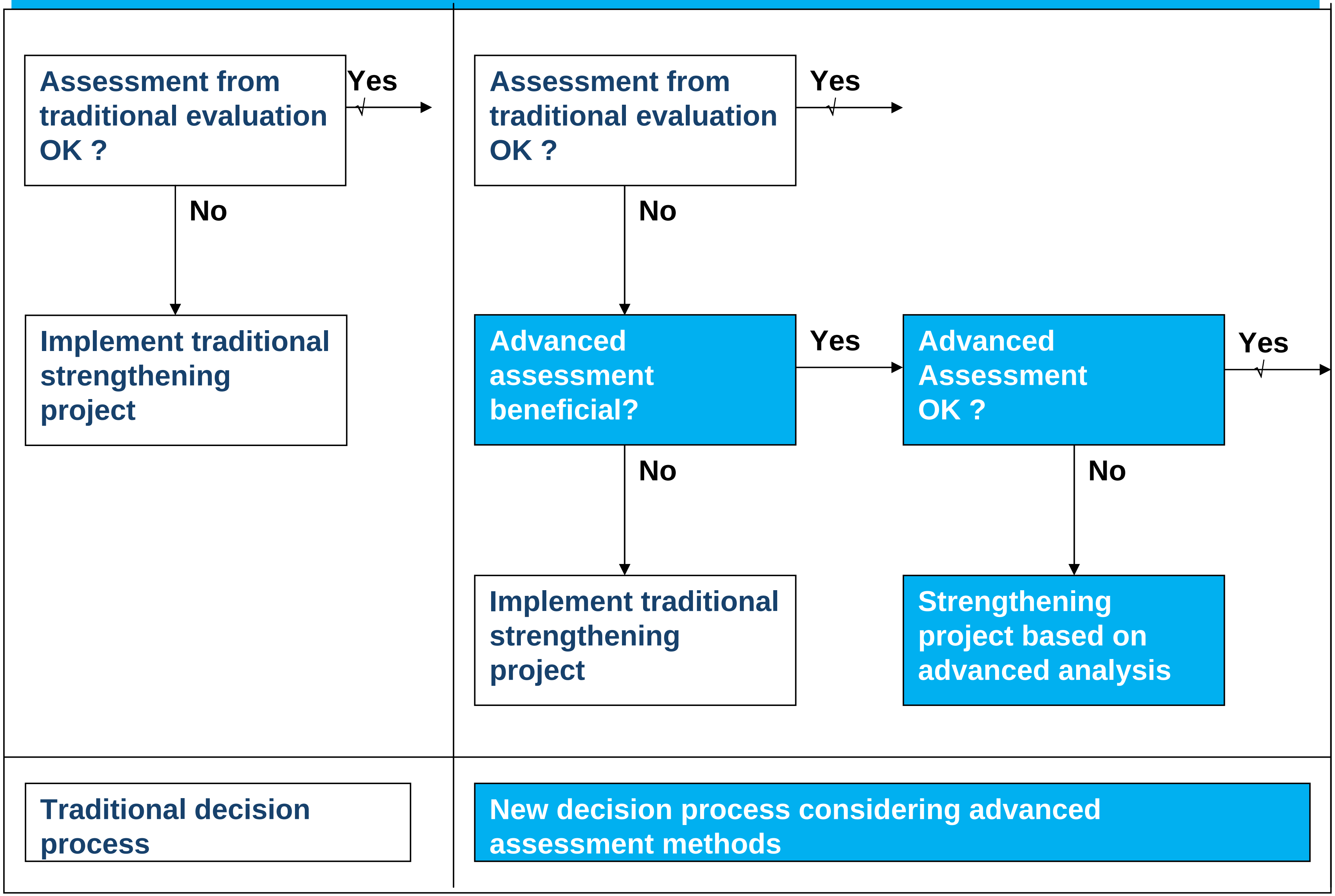
Revised Decision Process



Basis for Probabilistic Approaches

Procedure for Individual approach

1) Pre-evaluation
2) Modelling of critical limit states
3) Traffic load modelling
4) Modelling of stochastic variables
5) Calcultaion of Beta
6) Evaluation of safety level
7) Post evaluation

Modelling of Stochastic variables

Programming of limit states

→ Solver in standard reliability software

→ β Sensitivities

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Savings from Probabilistic Approaches

Practical Experience

Bridge	Result of Deterministic Analysis	Probability-based assessment	Cost Saving €
Vilsund	Max *W* = 40 t	Max *W* = 100 t	4,000,000
Skovdiget	Lifetime ~ 0 years	Lifetime > 15 years	12,500,000
Storstroem	Lifetime ~ 0 years	Lifetime > 10 years	2,500,000
Klovtofte	Max *W* = 50 t	Max *W* = 100 t	2,000,000
407-0028	Max *W* = 60 t	Max *W* = 150 t	1,500,000
30-0124	Max *W* = 45 t	Max *W* = 100 t	500,000
Norreso	Max *W* = 50 t	Max *W* = 100 t	500,000
Rødbyhavn	Max *W* = 70 t	Max *W* = 100 t	500,000
Åkalve Bro	Max *W* = 80 t	Max *W* = 100 t	1,500,000
Nystedvej Bro	Max *W* = 80 t	Max *W* = 100 t	2,000,000
Avdebo Bro	Max *W* = 80 t	Max *W* = 100 t	3,000,000
		TOTAL	30,000,000

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Practical Experience with Probability-Based Assessment of Bridges

Bridge	Deterministic analysis	Probability-based assessment
C 295	*B* = 115 kN (Max *W* = 39 t)	*B* = 240 kN (Max *W* = 81 t)
T 531	*B* = 118 kN (Max *W* = 40 t)	*B* = 226 kN (Max *W* = 76 t)
E 129	*B* = 170 kN (Max *W* = 54 t)	*B* = 215 kN (Max *W* = 71 t)

Three Swedish Road Bridge cases
with classification of load carrying capacity

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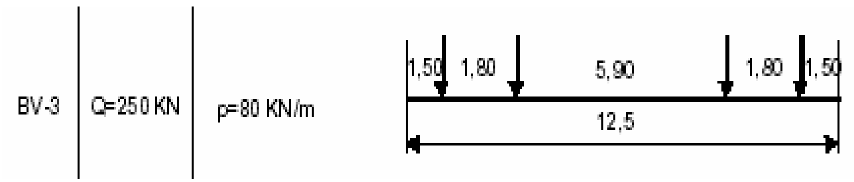
Example of Practical Application

iii. Bergeforsen Railway Bridge, Sweden

Bridge constructed in 1923
Superstructure span configuration: 42+84+42 = 168m
Side spans 22.5m + 11.6m
Total bridge length = 202.1m
Required to assess for Swedish BV-3 load model



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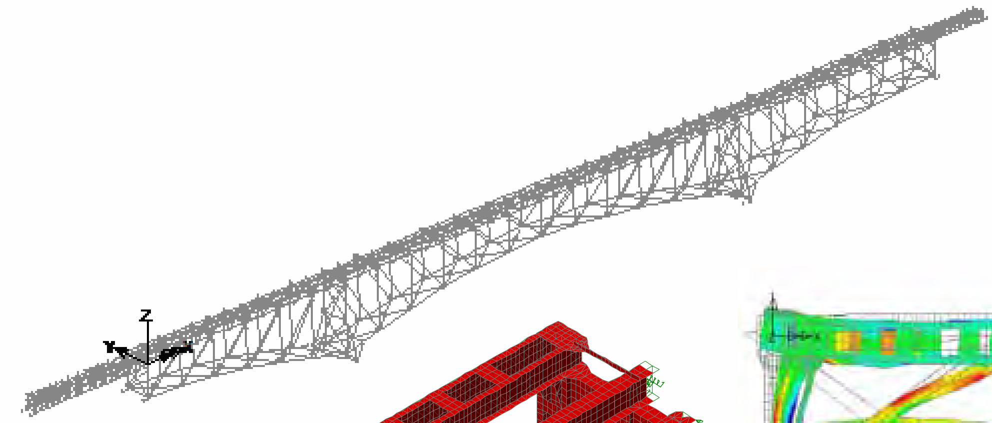
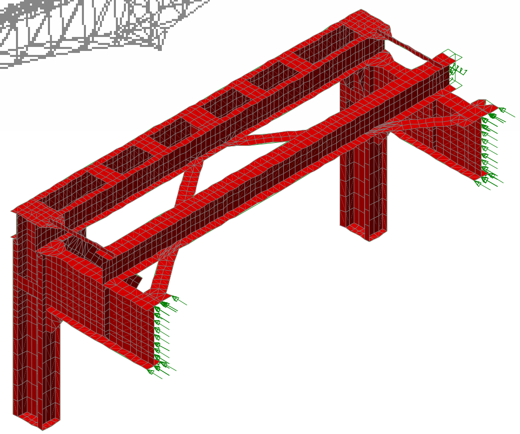
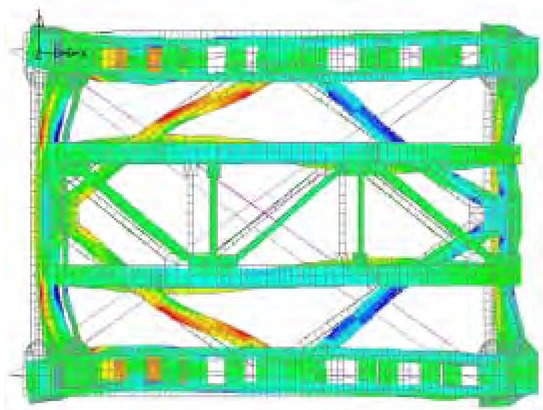
3D FEM-Modelling

Structural analysis was performed using an FE model calibrated against a shell and volume element model constructed for specific critical locations.

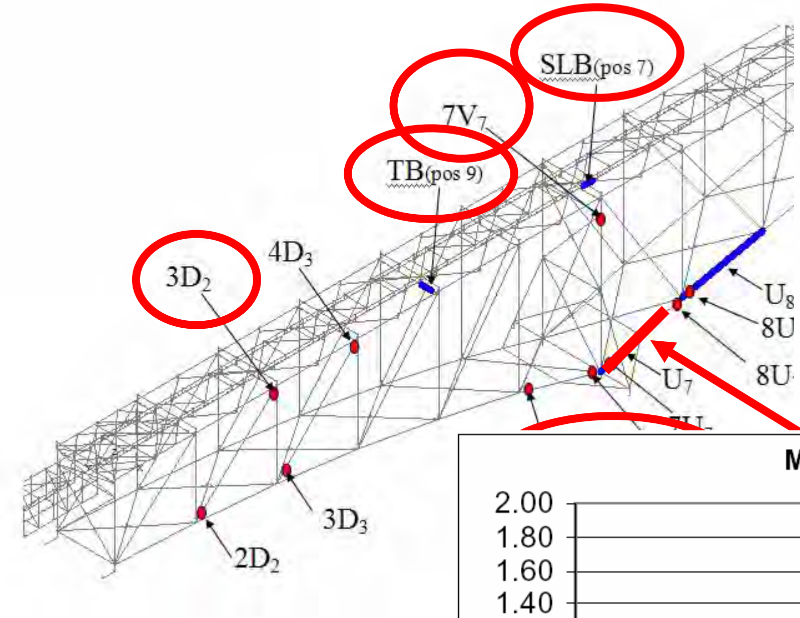


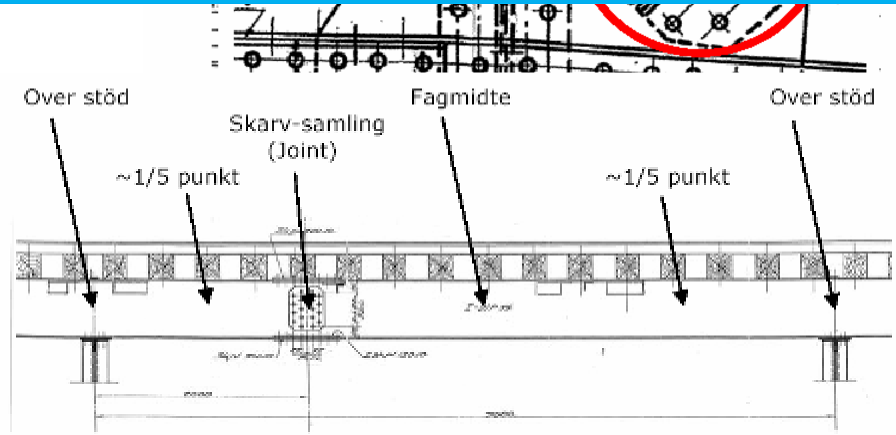




Deterministic results

Deterministic assessment - results

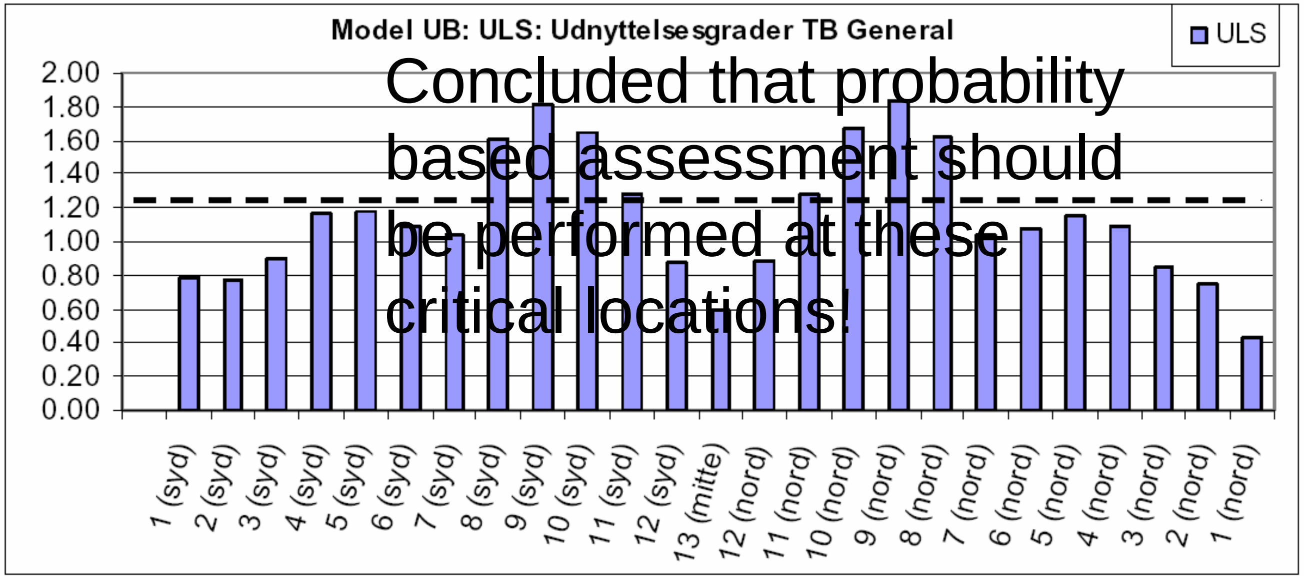




Figur 6-1 Opstalt af DIP55-profiler.

(a) Connection 2-D$_2$

- SLS capacity demo
- FLS capacity demo
- ULS capacity could joints as follows



Concluded that probability based assessment should be performed at these critical locations!

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Safety Requirements and limit states

Requirement for Safety Level

2 :114 Säkerhetsindex

Säkerhetsindex, β, definierat enligt ISO 2394-1998, *General Principles on the reliability for Structures*, skall för en byggnadsdel vara

$\geq$ 3,7 för säkerhetsklass 1,

$\geq$ 4,3 för säkerhetsklass 2,

$\geq$ 4,8 för säkerhetsklass 3.

(BFS 1998:39)

Limit State for

Elements

$g \leq 0$ where $g = f_y - |\sigma|$

σ is induced Navier Stresse due to applied loads = $\sigma_{Fx} + \sigma_{My} + \sigma_{Mz}$

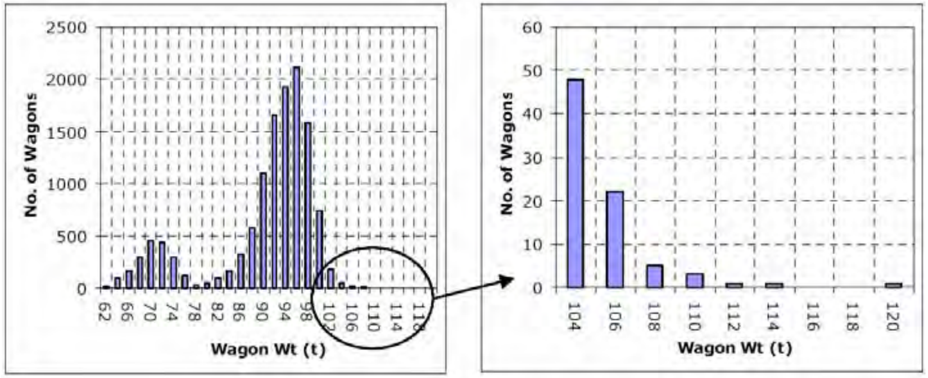
Riveted Joint Connections

$g \leq 0$ where $g = 0.85 \cdot 0.6 \cdot f_u - |\tau|$

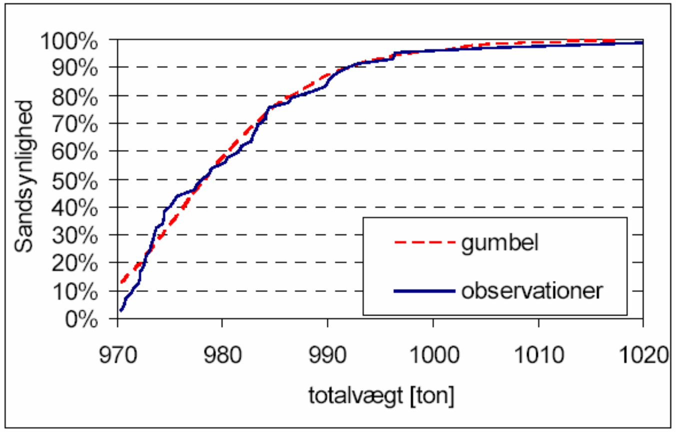
Load Modelling

Load & Load Effect Modelling - Train Load

Based on measurements it was possible to fit a standard statistical extreme distribution fit to measured data in order to determine the extreme distribution of the train load.



It was determined that the Gumbel extreme value distribution provided the best fit to the measured data.



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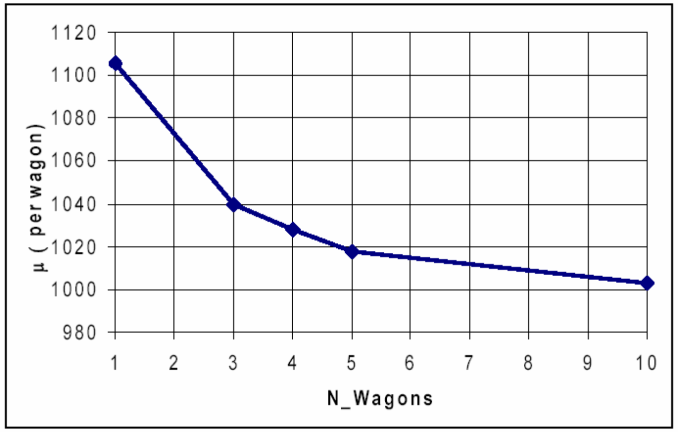
Load Modelling

Load & Load Effect Modelling - Extreme Train Load

The parameters of the Gumbel EVD were evaluated based upon the number of wagons considered.

EVD based on	μ (kN)	σ (kN)	CoV (%)
1 Wagon	1105.9	16.9	1.53
3 Wagons	3119.2 (/3=1040)	36.4	1.17
4 Wagons	4111.7 (/4=1028)	44.1	1.07
5 Wagons	5090.2 (/5=1018)	49.5	0.97
10 Wagons	10030.1 (/10=1003)	91.9	0.92

Modelling the trains in this way reduces the conservatism associated with modelling the EVD based upon 1 wagon!



Model uncertainty on wagon weight was assumed 10%, i.e. 'Small' from DRD Guideline due to extremely low CoV ranging from 1.52 – 0.92%.

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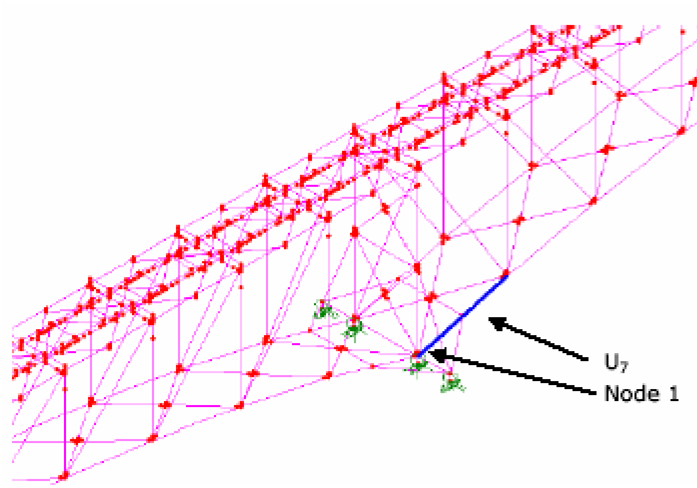
Load Effects

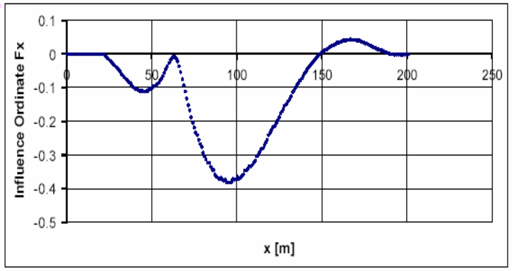
Load & Load Effect Modelling - Extreme train load

Element U_7 utilisation ratio 1.102 at Node 1.

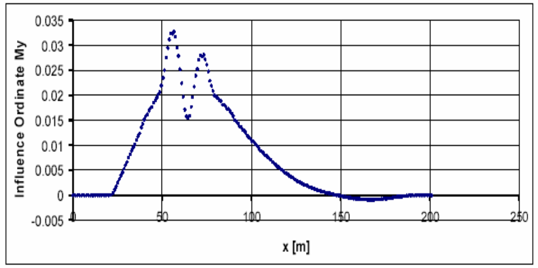
68% of this was due to F_x, with 31% due to primary bending M_y and 1% due to secondary bending M_z. Totally controlled by GLOBAL EFFECTS!

Modelling of EVD Train Load by group of 10 wagons (10x12.5=125m) appropriate

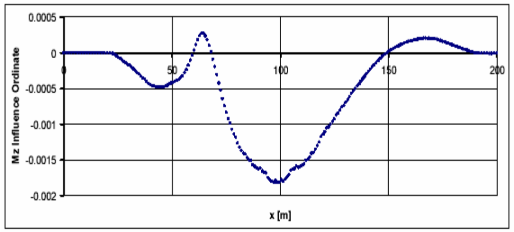




(a) F_x (68%)



(b) M_y(31%)

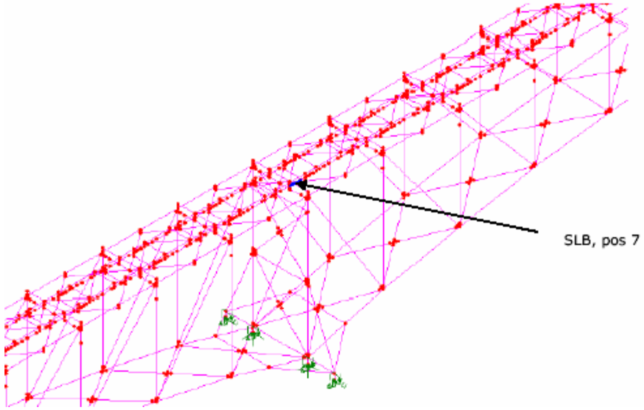


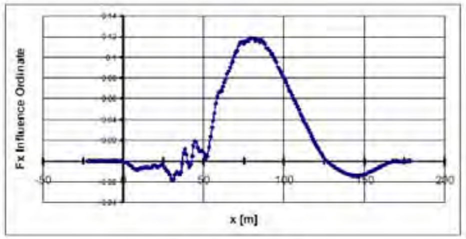
(c) M_z (1%)

Load Combination

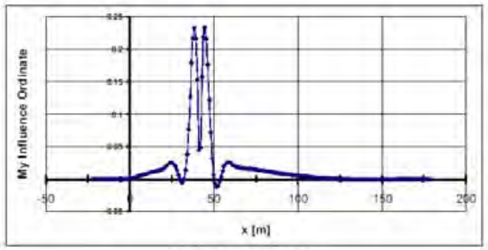
Load & Load Effect Modelling -Extreme train load + dynamic amplification of static load effect

- Element SLB, pos 7 utilisation ratio 1.635.
- 16% of this was due to F_x, with 65% due to primary bending M_y and 19% due to secondary bending M_z. Controlled by combination of Local + Global effects.
- high deterministic utilisation ratio due to requirement to model dynamic amplification based upon local effects only (resultant dynamic amplification factor = 1.53 vs. 1.06 for global effects).
- probabilistic computation of dynamic amplification considers each Navier Stress component individually applying local dynamic amplification factor to local effects and global dynamic amplification to global effects.

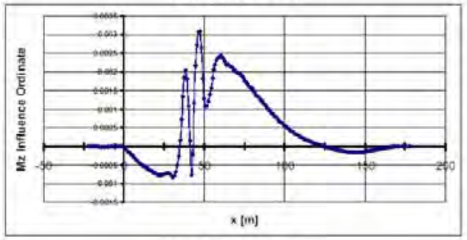




(a) F_x (16%)



(b) M_y (65%)



(c) M_z (19%)

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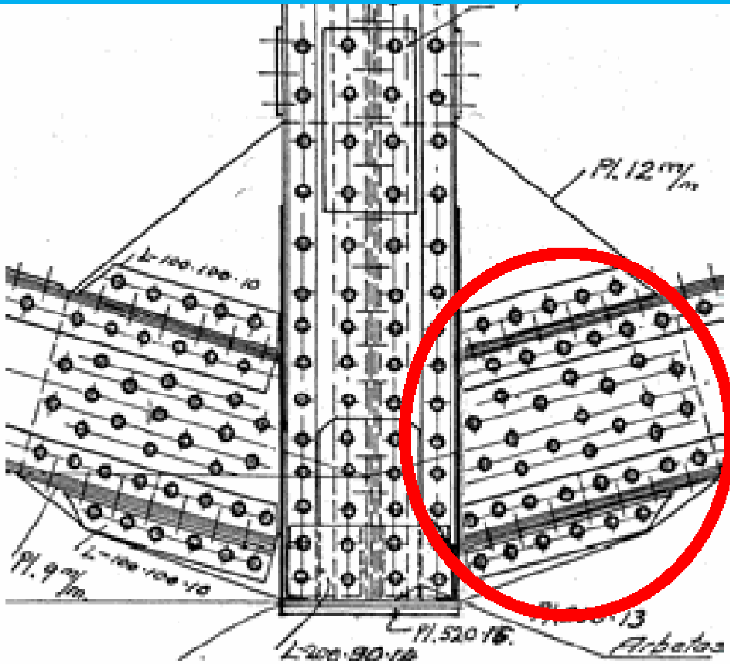
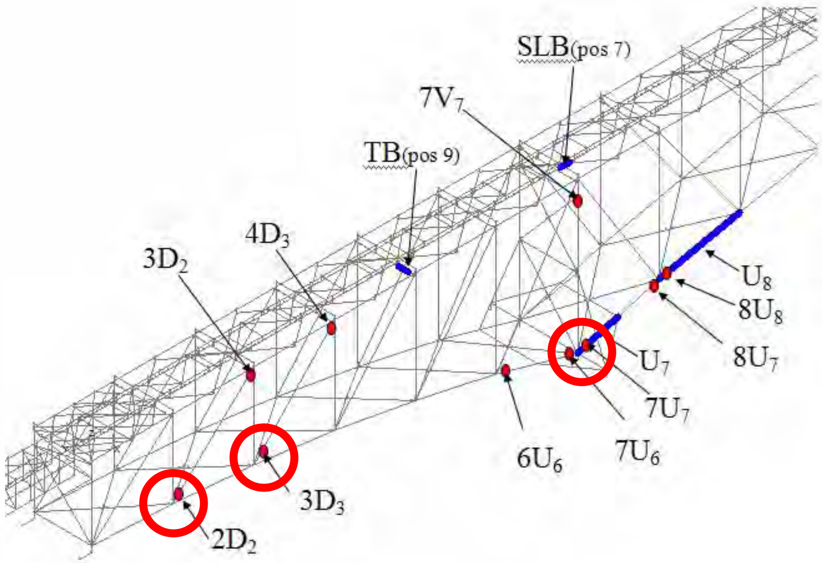
Critical locations





(a) Connection $7\text{-}U_7$

Results

β_{U_7} = 5.67 > 4.8

β_{U8} = 5.19 > 4.8

$\beta_{SLB.posn7}$ = 4.66 < 4.8 (M_z = 0, $\beta_{SLB.posn7}$ = 5.85)

$\beta_{TB,posn17}$ = 4.81 > 4.8

Joints

β_{6-U_6} = 6.38 > 4.8

β_{7-U_6} = 4.51 < 4.8 (Remedial action necessary,

Proposal A β_{7-U_6} = 6.05, Proposal B β_{7-U_6} = 7.80)

β_{7-U_7} = 4.06 < 4.8 (Remedial action necessary,

Proposal A β_{7-U_7} = 5.62, Proposal B β_{7-U_7} =7.11)

β_{8-U_7} = 6.01 > 4.8

β_{7-V_7} = 6.31 > 4.8

β_{2-D_2} = 4.42 < 4.8 (Remedial action necessary,

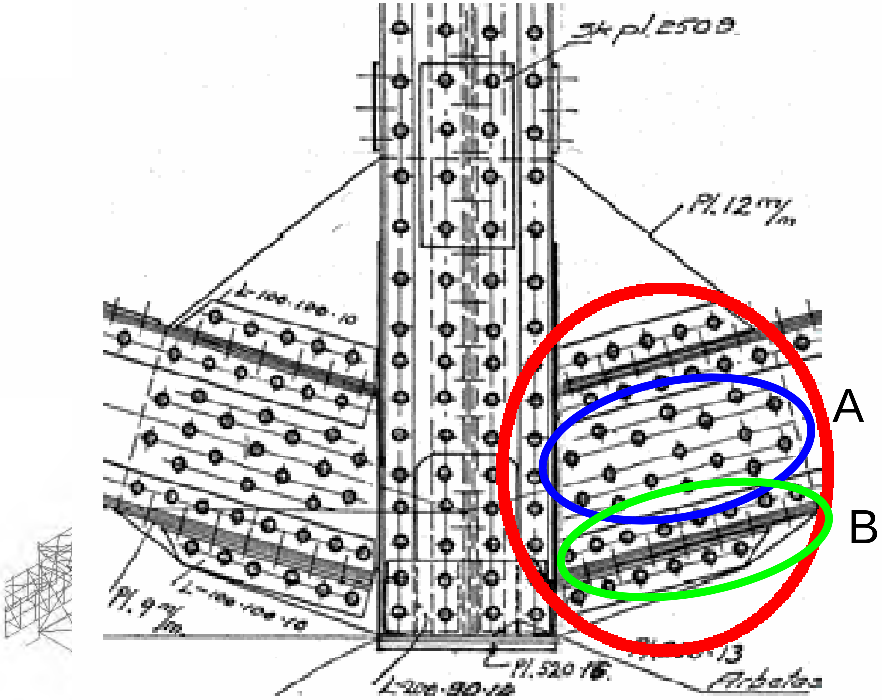
Proposal A β_{2-D_2} = 6.25)

β_{3-D_2} = 4.56 < 4.8 (Remedial action necessary,

Proposal A β_{3-D_2} > 4.8)

β_{3-D_3} = 5.18 > 4.8

β_{4-D_3} = 5.32 > 4.8



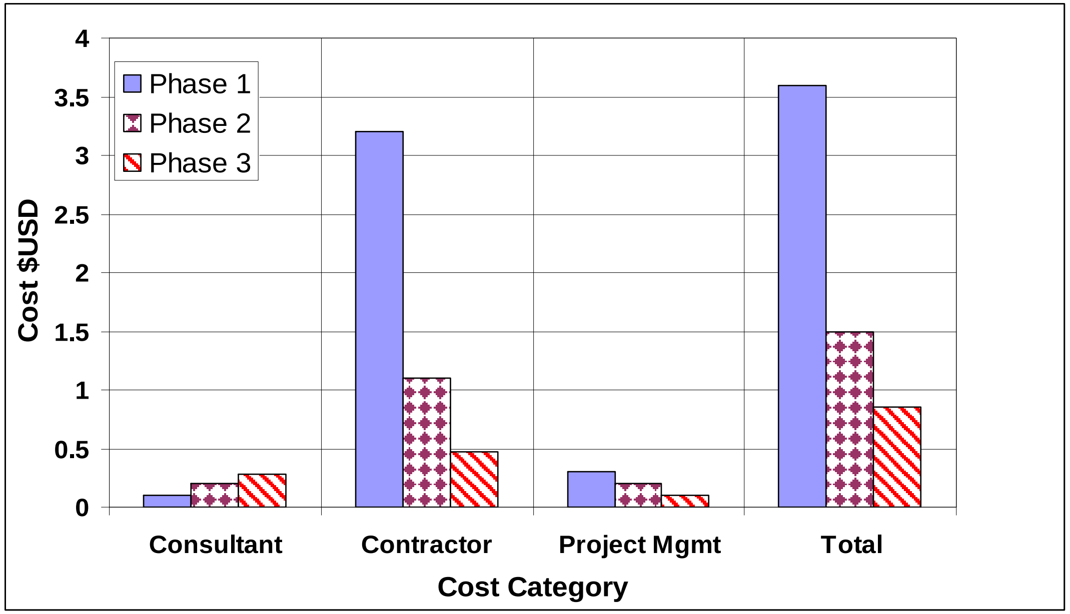
Option A = Replace rivets in zone A with 27mm dia. Bolts

Option B = Replace rivets in zone B with 27mm dia. Bolts

(a) Connection 7-U_7

Similar options considered for other joints which had failed to demonstrate sufficient capacity. Results indicated that in all cases sufficient safety could be achieved.

Beneficial investments!



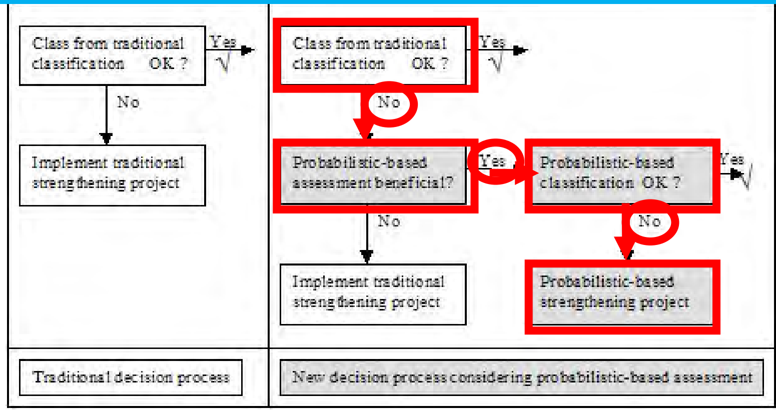


Table 7 - Results of deterministic and probabilistic assessment; O'Connor et al (2004).

	Phase 1 Deterministic Assessment ($USD)	Phase 2 Advanced Deterministic Assessment ($USD)	Phase 3 Probability Based Assessment ($USD)
Consultant Fee	$0.1ml	$0.2ml	$0.28ml
Contractor Fee	$3.2ml	$1.1ml	$0.47ml
Project Management	$0.3ml	$0.2ml	$0.1ml
Total Cost	$3.6ml	$1.5ml	$0.85ml

More Examples of Road Bridges

Six Motorway Bridges in Denmark

(a) Klovtofte Bridges

(b) Bridge at Nørresø Elevation

(c) Bridge at Rødbyhavn Elevation

(d) Åkalve Bro Elevation

(e) Nystedvej Bro Elevation

(f) Avdebo Arch Bridge

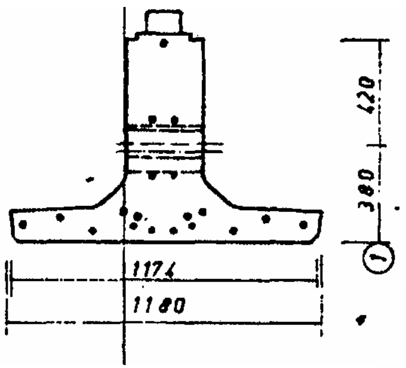
Figure 15 – Practical Examples of Probability Based Assessment of DRD Structures

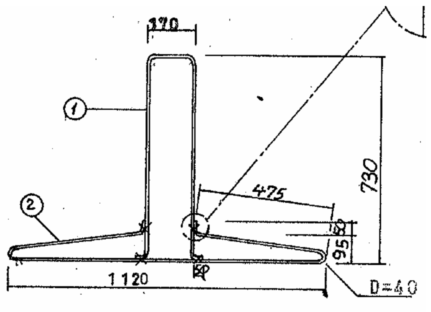
Examples of Practical Application

Description of Case Studies – 6 Motorway Bridges

(a) Beam + Slab located at Klovtofte

Built in 1970's (four continuous spans)
Precast prestressed (inverted T) beams + insitu slab
Spans are 10.7, 24.1, 24.1 and 10.7m
Width of the structure is 36.1m





Examples of Practical Application

Description of Case Studies – 6 Motorway Bridges

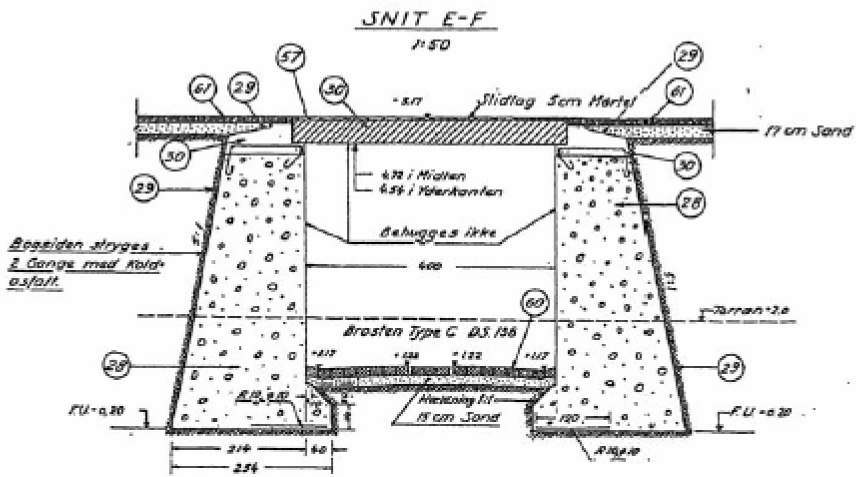
(b) Slab bridge located at Nørresø

Built in 1942 (two continuous spans).
Repaired in 1960 (additional lane on southside)
Spans are 3.56m and 5.56m (55° skew)
Width of the structure is 28.74m (post 1960).
The structural thickness of the slab varies 0.37 – 0.53m (edge to middle) .

Examples of Practical Application

Description of Case Studies – 6 Motorway Bridges

(c) Simple slab bridge located at Rødbyhavn
Built in 1942.
Repaired in 1962 (1m wide edge beam added)
Span 3.75m (58.5° skew)
Width of the structure is 24m.
The structural thickness of the slab is 0.4m.



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Examples of Practical Application

Description of Case Studies – 6 Motorway Bridges

(d) Beam & slab bridge located at Åkalve
Built in 1935 (single span).
6 parallel longitudinal beams at 1.4m centres
Width of the structure is 10m.

Examples of Practical Application

Description of Case Studies – 6 Motorway Bridges

(e) Post-tensioned slab bridge at Nystedvej

Built in 1959 (3-spans).
Spans are 6.39, 17.72 and 6.39m (63° skew)
0.5m deep longitudinally PT slab
Width of the structure is 28m.
Transversely the bridge is supported on 10 columns at 3.24m centres

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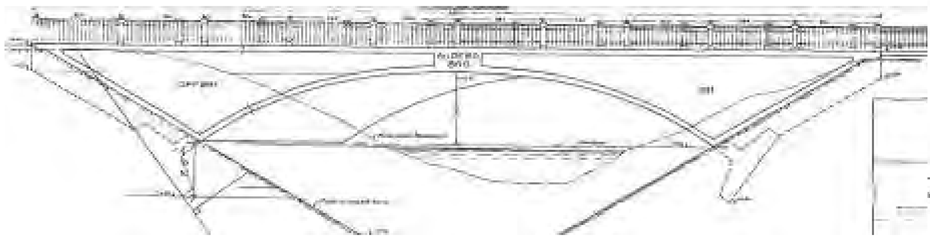
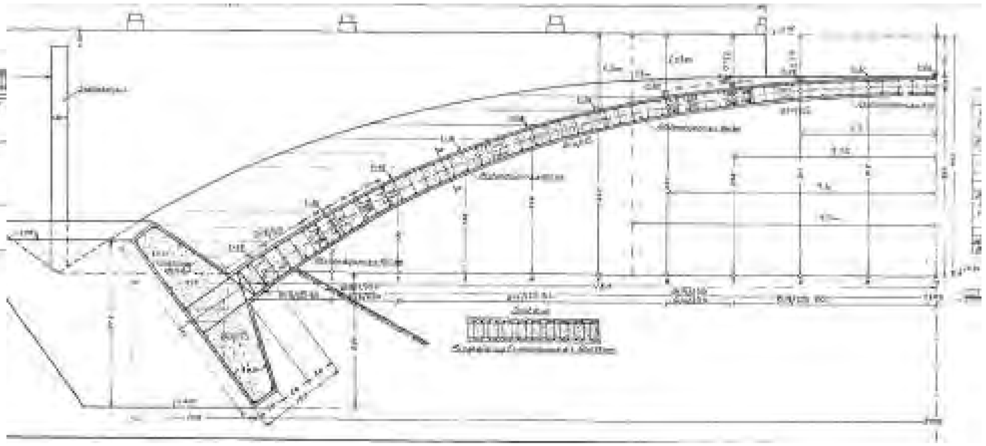
Examples of Practical Application

Description of Case Studies – 6 Motorway Bridges

(f) Concrete arch located at Avdebo

RC arch bridge built in 1932.
Skew 56.6º, clear span 23.0m, height 3.2m
Width of the structure is 9m (2 traffic lanes)
The arch thickness varies from 0.3 m at the crown to 0.6 m at the base.
Renovation in 1986 (replaced eastern edge beam)





Examples of Practical Application

Results – Load Rating

ULS beam shear capacity

ULS footing bending capacity

ULS Slab Bending Cap.

ULS hogging slab bending cap at outermost column support.

Table 1 – Deterministic Classification Results

Passage type	Normal Passage[(1)]	Restricted passage 1[(2)]	Restricted passage 2[(3)]	Restricted passage 3[(4)]
Klovtofte	50	50	60	80
Avdebo	50	50	70	75
Rødbyhavn	70	70	100	150
Nystedvej	80	150	175	200

(1) No restrictions on vehicle positions on structure, full dynamic factor applied to vehicles.
(2) Vehicles positioned in traffic lanes on structure, full dynamic factor applied to vehicles.
(3) Vehicles positioned in traffic lanes on structure, dynamic factor applied to one vehicle only.
(4) Only heavy vehicle positioned on structure in favorable position, no dynamic factor applied.

Examples of Practical Application

Results – Load Rating

ULS Slab
Bending Cap.

Passage type	Normal Passage(1)	Restricted passage 1(2)	Restricted passage 2(3)	Restricted passage 3(4)
Nørresø	50	50	80	200
Åkalve	80	80	100	200

ULS Long
Beams
Bending Cap.

Examples of Practical Application

Requirements for Safety Level

Limit State: $g \leq 0$ where $g = \tau_{cap} - \tau_{applied}$ or $g = M_{cap} - M_{applied}$

For beam and slab: $\tau_{cap} = 0.25k(1.2 + 4.0\rho_1)f_{ctd} + 0.15\sigma_{cp}$

For slabs: $M_{cap}(h, c, A_s, f_{cu}, f_y)$

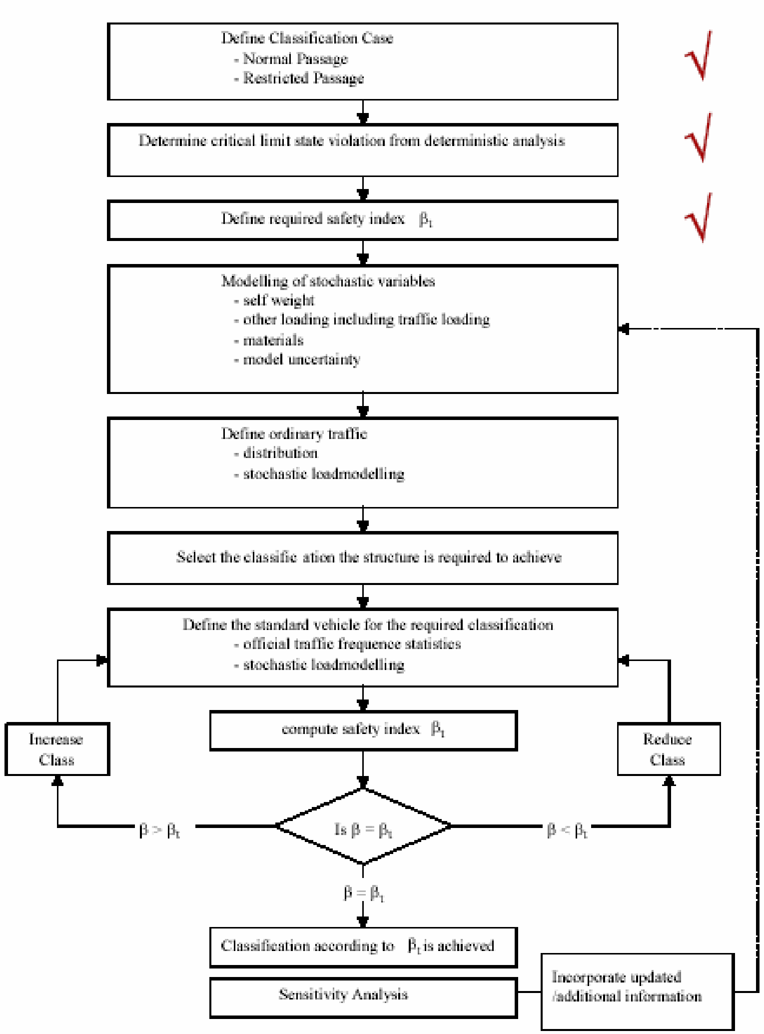
For beam and slab: $M_{cap}(h, b_f, b_w, t_f, d_x, d_y, c, A_s, f_{cu}, f_y)$

For arch footings: $M_{cap}(f_{cu}, f_y, SBC, G_S)$

For post tensioned slab: $M_{cap}(f_{cu}, f_{ps})$

where $M_{applied} = M_{DL} + M_{SDL} + M_{LL}$ (+M_{par} – PT)

Failure Consequences (Safety Class)	Failure Type I: Ductile failure *with* remaining capacity	Failure Type II: Ductile failure *without* remaining capacity	Failure Type III: Brittle failure
Very Serious: High safety class	$P_f \leq 10^{-5}$ $\beta_t \geq 4.26$	$P_f \leq 10^{-6}$ $\beta_t \geq 4.75$	$P_f \leq 10^{-7}$ $\beta_t \geq 5.20$



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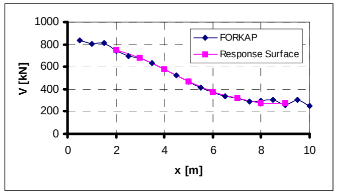
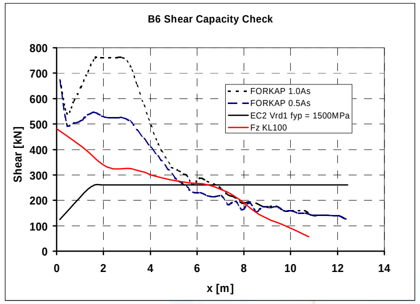
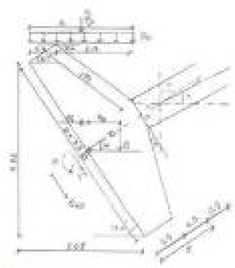
Examples of Practical Application

Response & Resistance Modelling

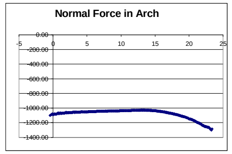
Response surface for capacity trained using, as input variables, (1) f_{cu}, (2) f_y and (3) f_{ps}

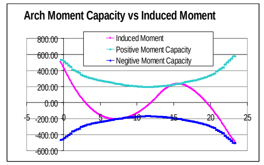






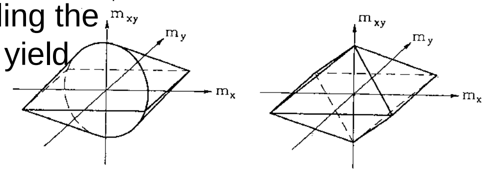
Response surface for capacity trained using, as input variables, (1) intensity of applied load, (2) f_{cu}, (3) f_y, (4) SBC, (5) γ_s





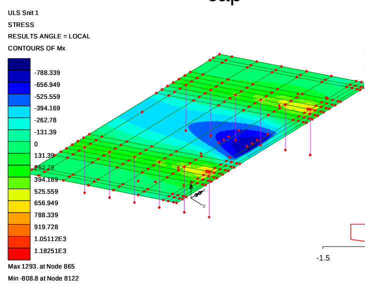
The flexural load carrying capacity of concrete slabs is calculated according to the yield criterion which is adopted in the Eurocode (Eurocode 1995).

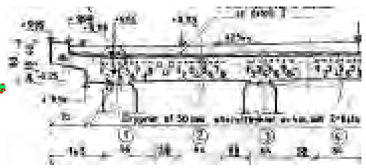
Lower bound solutions are obtained from the theory of plasticity by fulfilling the equilibrium equations and the yield criteria in the entire structure.

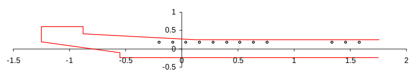


$$-(m_{Fx}^{-} - m_x)(m_{Fy}^{-} - m_y) + m_{xy}^2 \le 0$$

A response surface trained in PCROSS using f_{ps} and f_{cu} was employed to evaluate M_{cap}.







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Examples of Practical Application

Response & Resistance Modelling

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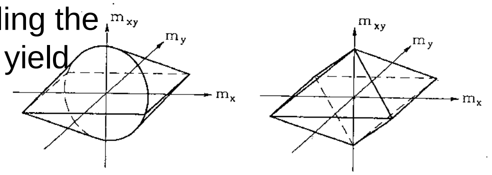
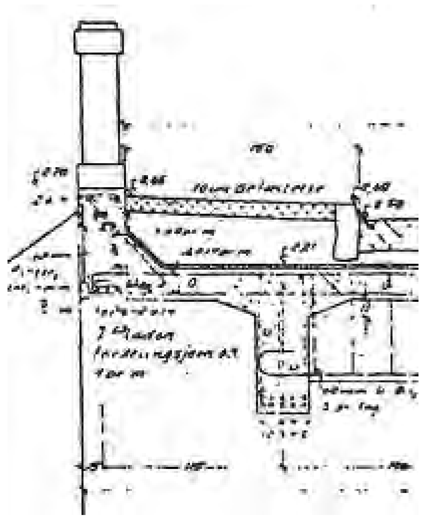


$$-(m_{Fx}^{-} - m_x)(m_{Fy}^{-} - m_y) + m_{xy}^2 \le 0$$

Bending theory was employed to evaluate M_{cap}.



Examples of Practical Application

Load Modelling

The loads to be considered as stochastic are generally the live load induced by vehicles traversing the structure, the weight of the structure itself and of superimposed loads applied to the structure. Of these the most variable are the traffic loads.

- Traffic Load Modelling considers

  Load intensity, frequency,

  dynamic amplification,

  transverse location etc.

$$
\begin{aligned}
F_{\max}(q) = & \exp(-(\nu_1 - \nu_{12})T(1 - F_1(q))) \\
& \exp(-(\nu_2 - \nu_{12})T(1 - F_2(q))) \\
& \exp(-\nu_{12}T(1 - F_{12}(q)))
\end{aligned}
$$

Examples of Practical Application

Uncertainty Modelling

The model uncertainty takes account of: (1) the accuracy of the calculation model, (2) possible deviations from the strength of material properties in the structure involved as compared with that derived from control specimens and (3) material identity.

The model uncertainty is taken into account by introducing judgement factors I_m and I_f related to the material properties and traffic loads respectively.

The judgement factor I_m, which is assumed to be log-normally distributed with mean value equal to 1.0 and coefficient of variation V_{Im}, is introduced by multiplying the basic material variables by I_m. V_{Im} , is calculated as:

$$V_{I_m} = \sqrt{V_{I_1}{}^2 + V_{I_2}{}^2 + V_{I_3}{}^2 + 2\left(\rho_1 V_{I_1} + \rho_2 V_{I_2} + \rho_3 V_{I_3}\right)V_M}$$

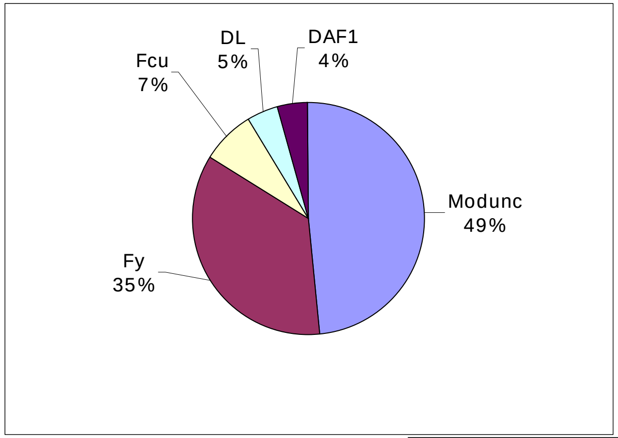
where

$$V^2 = V_M^2 + V_{I_m}^2$$

and V_m is the CoV for the basic material variable.

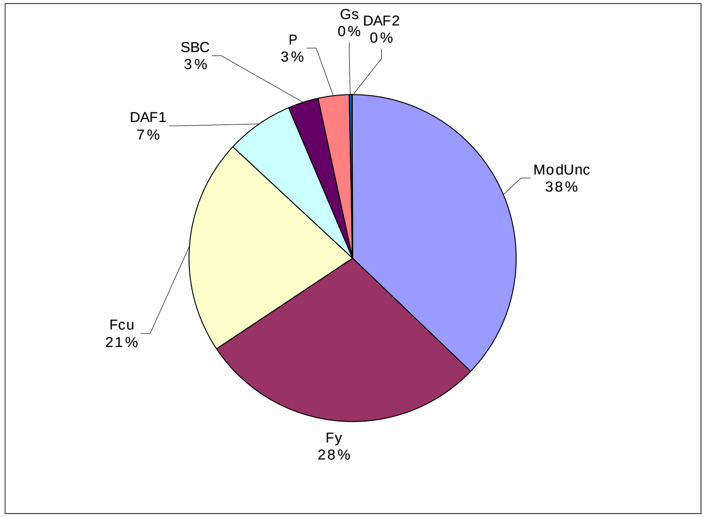
Examples of Practical Application

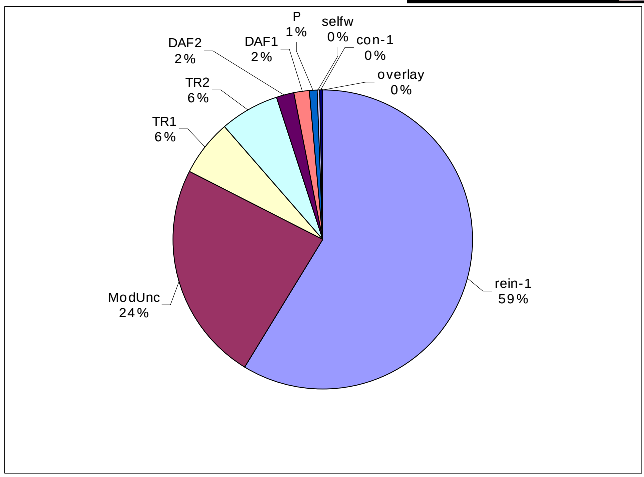
Safety Index, β & Importance Factors



β= 5.70 > 4.75

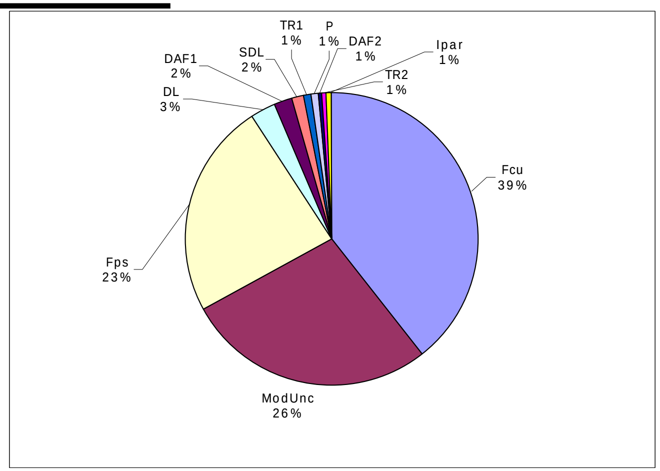
β= 5.44 > 4.75





β= 5.05 > 4.75

β= 5.06 > 4.75



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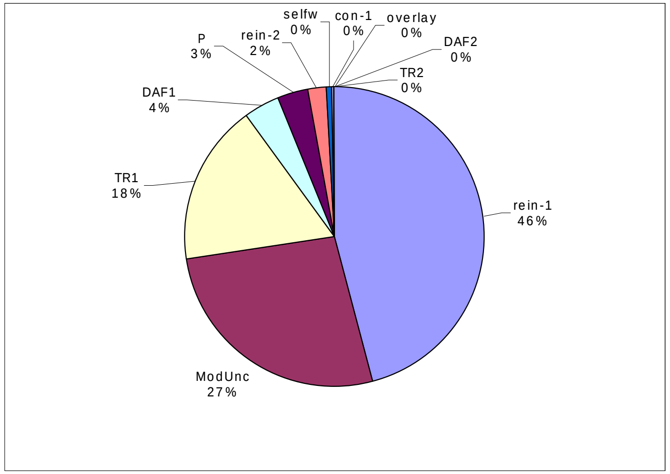
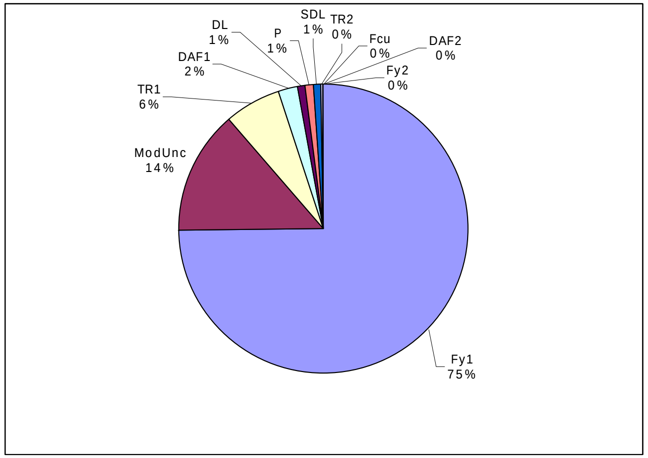
Examples of Practical Application

Safety Index, β & Importance Factors

β= 4.89 > 4.75

β= 4.96 > 4.75





Examples of Practical Application

v. Two Motorway Bridges in Sweden

(a) Bridge C295 Sävja stream, Motorway E4 Stockholm-Uppsala

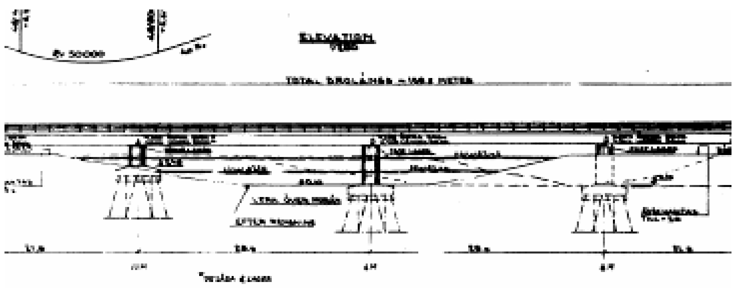
Constructed in 1971. Two traditional 4-span post-tensioned concrete motorway bridges. The total length of each of the structures is 103m. The bridges are supported at 3 centrally located circular columns and 3 supports at each abutment.

Torsion limit state in cross section close to the abutment: B_{till} = 115 kN

All other limit states: B_{till} > 240 kN

Conclusion

B_{till} should be evaluated applying probabilistic methods in the limit state of torsion in the critical cross section



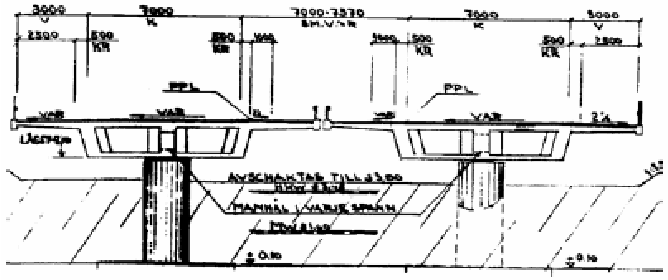


Figure 16 – C295 Bridges

Examples of Practical Application

v. Two Motorway Bridges in Sweden
(a) Bridge C295 Sävja stream, Motorway E4 Stockholm-Uppsala

Main Conclusion: $B_{till} \geq$ 240 kN

Table 9 – Partical safety factors **for** deterministic and **from** probabilistic assessment of C295

Stochastic Variable	Partial safety factors	
	Deterministic	Probability-Based
Yield stress, longitudinal reinforcement	1.32	1.07
Yield stress, transverse reinforcement	1.32	0.96
Weight, special heavy transport	1.3	1.61
Dead weight	1.0	1.00
Loss coefficient, cable force	1.0	1.05
Superimposed dead weight	1.2	1.00
Weight, ordinary transport	-	1.76

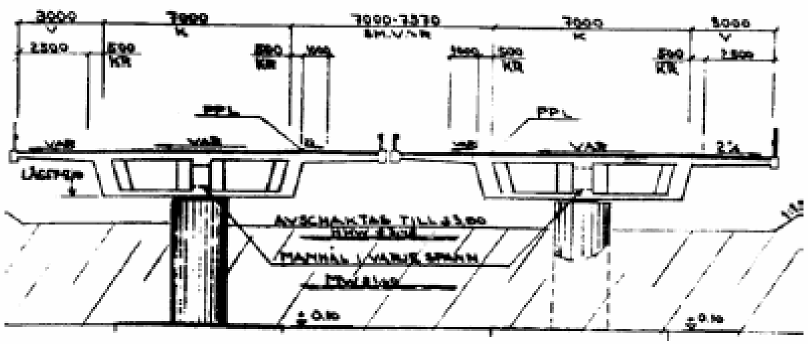


Figure 16 – C295 Bridges

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Examples of Practical Application

v. Two Motorway Bridges in Sweden

(b) Bridge E129 Motola stream

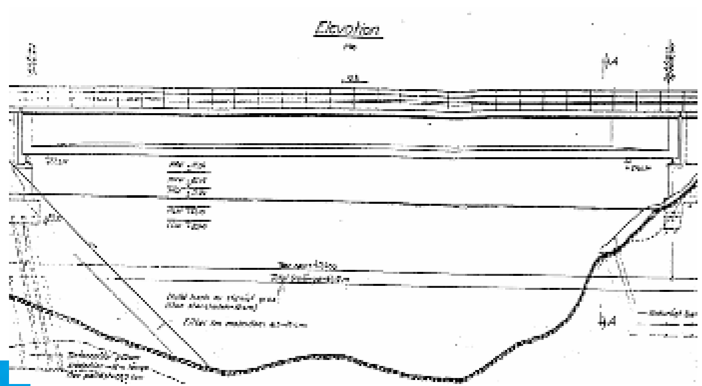
Simply supported post-tensioned concrete bridge, built in 1962m, with span length 49.4 m. The structural system is essentially two beams supporting a slab which carries a traditional two-lane main road.

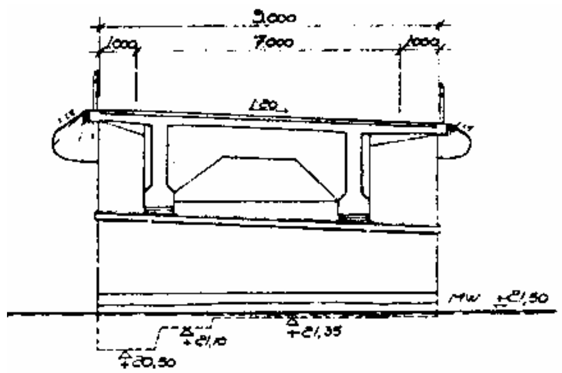
Serviceability limit state: B_{till} = 170 kN Due to a replacement of the edge beams

All other limit states: B_{till} > 215 kN

Conclusion

B_{till} should be evaluated applying probabilistic methods in the serviceability limit state





Examples of Practical Application

v. Two Motorway Bridges in Sweden

(b) Bridge E129 Motola stream

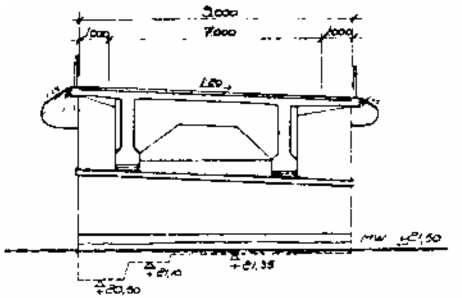
For the case of the E129 bridge the SLS is reversible. Therefore, it was concluded that the $\beta \geq 1.3$ represented a suitable requirement.

The limit state is dependent on a relatively large number of uncertain variables which were modelled stochastically e.g.:

(i) the cross sectional forces due to the cable forces, which were corrected for the influence of creep and shrinkage in the phases before and after the replacement of the edge beams.

(ii) stochastic modelling of the concrete parameters was performed according to the CEB Model Code.

Based upon this modelling ***B*max = 233 kN** was obtained for the bridge. This classification was higher than the deterministic classification obtained at the critical limit state of 170 kN and higher than the value of 215 kN corresponding to the other deterministically assessed limit states



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Conclusions

Problem:

1) Lack of load carrying capacity or exceedance of structural/performance limit state due to
   - weak bridges
   - deteriorated/(ing) bridges
   - Increasing loads

2) Low budgets for strengthening and/or rehabilitation where required

Idea:

Demonstration of higher capacity through Probabilistic safety assessments incorporating better calculation/response models

Principal Motivation:

Cost saving through Budget Optimisation

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Conclusions

- Case studies are presented to demonstrate to practical application of probability based assessment to existing bridges.
- In the cases where sufficient capacity could not be demonstrated the probabilistic methodology can be used to optimise the rehabilitation process.
- In no way has the safety of the structure been compromised rather a bridge specific code has been derived.
- The justification for the application of probability-based methods to bridges in Denmark and Sweden is provided from national codes combined with the Nordic committee recommendations (NKB 1978) and the Eurocodes.
- There are no practical or technical obstacles in applying probability-based assessment techniques.
- A clear advantage of the approach lies in its ability to incorporate bridge specific information and bridge specific safety modelling.
- Applying the probability-based approaches can result in considerable monetary savings by avoiding the need for costly strengthening and replacement of existing bridges.
- It has become the policy of the Danish Roads Directorate and Banverket that the probability-based approaches should be more frequently applied in the future.

Conclusions

An example of savings to date (>$28,000,000):

Bridge	Result of Deterministic Analysis	Probability-based assessment	Cost Saving €
Vilsund	Max W = 40 t	Max W = 100 t	4,000,000
Skovdiget	Lifetime ~ 0 years	Lifetime > 15 years	12,500,000
Storstroem	Lifetime ~ 0 years	Lifetime > 10 years	2,500,000
Klovtofte	Max W = 50 t	Max W = 100 t	2,000,000
407-0028	Max W = 60 t	Max W = 150 t	1,500,000
30-0124	Max W = 45 t	Max W = 100 t	500,000
Norreso	Max W = 50 t	Max W = 100 t	500,000
Rødbyhavn	Max W = 70 t	Max W = 100 t	500,000
Åkalve Bro	Max W = 80 t	Max W = 100 t	1,500,000
Nystedvej Bro	Max W = 80 t	Max W = 100 t	2,000,000
Avdebo Bro	Max W = 80 t	Max W = 100 t	3,000,000
		TOTAL	30,000,000

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Use of probabilistic methods

Presentation on NVF annual bridge conference 2010
1-2 September 2010, Oslo, Norway
by
Dr. Ing. Rolf Magne Larssen




Content

- Description of project/problem
- Deterministic evaluation
- Probabilistic evaluation
- Modelling of traffic loading
- Results
- Summary and conclusions

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Probabilistic methods

- Methodology for consistently handling of problems having one or more properties with random or uncertain nature
- Structural reliability calculations increasingly used for
  - **Code calibration**
  - **Maintenance management**
    - **Steel structures**
    - **Concrete structures**
  - **Service life design of concrete structures**

Use of probabilistic methods in classification

- General weakness revealed in classification calculations for cross-girders of several large suspension bridges built in the period 1956-1969
- A R&D-project initiated by NPRA
- Project aim to document larger load carrying capacity without strengthening of the physical structure

- Project was split into two phases:
  - **Part 1** **Independent more detailed deterministic classification calculations for these bridges**
  - **Part 2** **Use of probabilistic methods for classification of bridges not solved in part one**

Description of problem

- Problem in the cross-girder design revealed during classification calculations for increased traffic loading
- Three problems areas were identified in the cross-girder:
  - **Capacity of the riveted connection for the vertical and diagonal truss member**
  - **Buckling of the vertical truss member**
  - **Capacity of the upper truss member (deteriorated)**

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Description of problem

- Buckling of the vertical truss member
- Capacity of the riveted connection for the vertical and diagonal truss member
- Capacity of the upper truss member (deteriorated)

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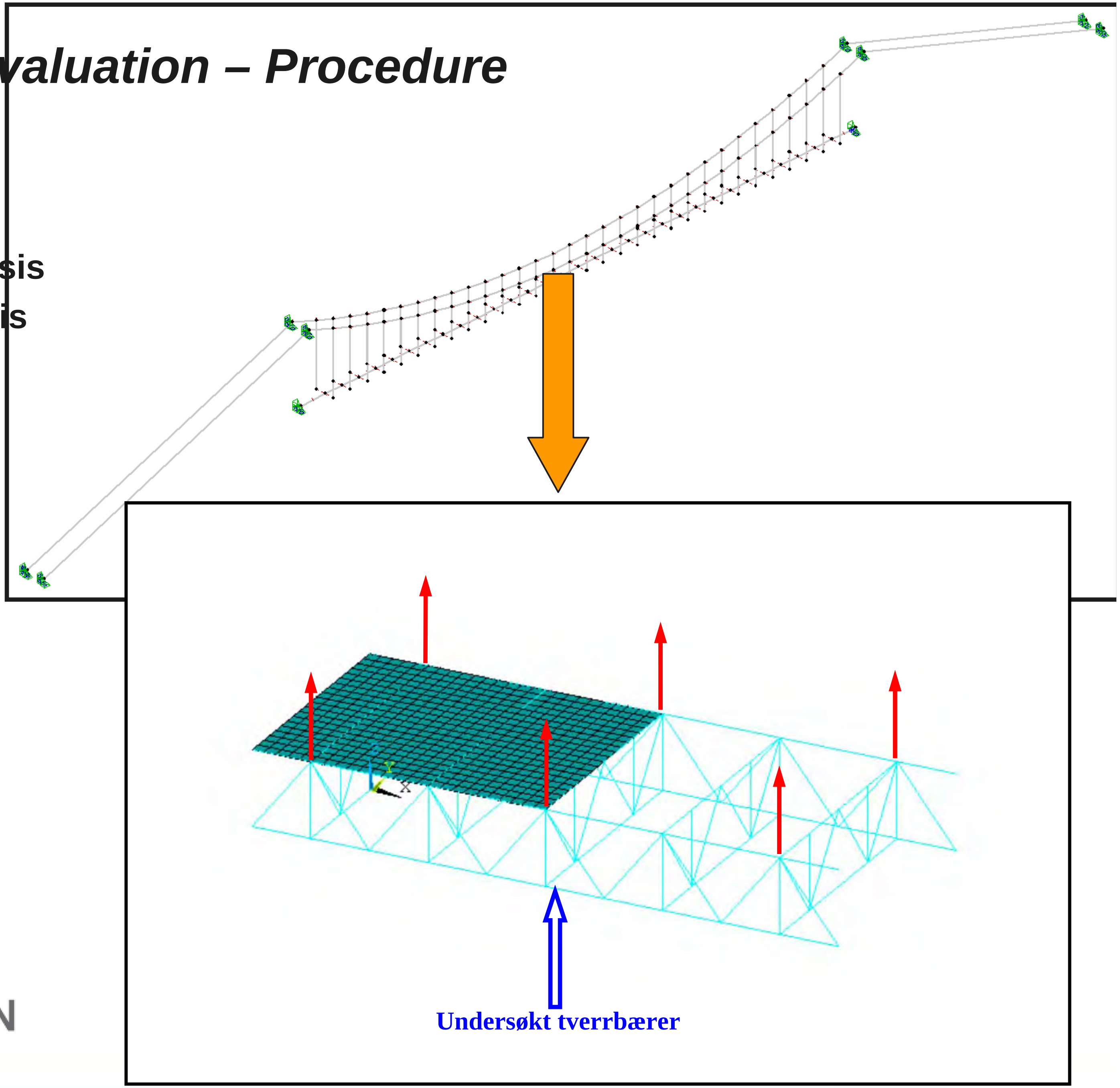
Bridges included in the investigations

- Varodd
  - **Length 618 m, Main span 337 m**
  - **Suspension bridge outside Kristiansand on E18 in West-Agder county, built 1956**
- Brevik
  - **Length 677 m, Main span 272 m**
  - **Suspension bridge near Porsgrunn in Telemark county, built 1962**
- Rombak
  - **Length 765 m, Main span 325 m**
  - **Suspension bridge near Narvik in Nordland county, built 1964**

- Other bridges on the initial list
  - **Kjerringstraumen (Length 551 m, Main span 200 m, 1969)**
  - **Tjeldsund (Length 1007 m, Main span 290 m, 1967)**
  - **Tromøy (Length 400 m, Main span 240 m, 1961)**
  - **Folda (Length 336 m, Main span 225 m, 1969)**

Deterministic evaluation – Procedure

- Load action analyses
  - **Global analysis**
  - **Local analysis**
  - **Buckling analysis**
- Code checking



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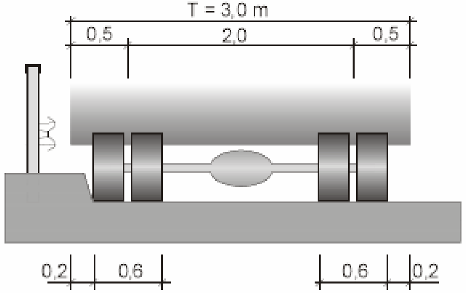
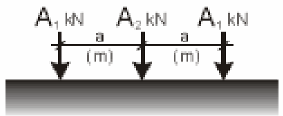
Deterministic traffic loading

- For classification calculations the deterministic traffic loading for these bridges should be based on:
  - **Bk 10 in "Bruklassifisering. Lastforskrifter for klassifisering av bruer og ferjekaier i det offentlige vegnett", 25.05.2001.**
- Loadfactors:
  - **Self weight: 1.15**
  - **Traffic loading: 1.4**
- Critical load configuration for problem areas:



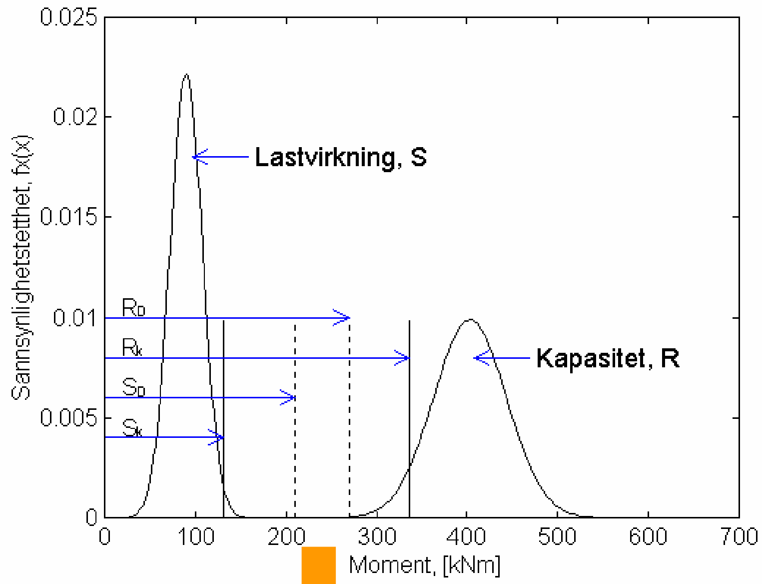
Lasttype	Lastkonfigurasjon (*) H kN	Bruksklasser				
			Bk10	BkT8	Bk8	Bk6
Trippelboggilast		A_1	70	60	50	40
		A_2	140	84	84	56
	Aksellastenes rekkefølge er vilkårlig	a	1,3	1,2	1,2	1,2

Deterministic evaluation – Summary of results

Bridge		Varoddbrua	Rombaksbrua	Brevikbrua
Span	m	337	325	272
Cross-girder spacing	m	4.86	4.95	4.92
Width girder	m	9.5	10.0	11.0
Width roadway	m	6.5	7.5	7.5
Vertical		2 L80*10	2 L90*9	2 L90*9
UR Buckling		112%	75 %	99 %
UR Rivets		157 %	110 %	116 %
Outer cross		2 L110*12	2 L100*12	2 L100*12
UR Buckling		128 %	88 %	98 %
UR Rivets		64 %	88 %	98 %
Inner cross		2 L80*10	2 L90*9	2 L90*9
UR Buckling		68 %	66 %	77 %
UR Rivets		128 %	103 %	108 %
Overgurt		DIMEL 24	DIP 20	DIMEL 24
UR stress		97 %	68 %	86 %

Probabilistic evaluation – Basis

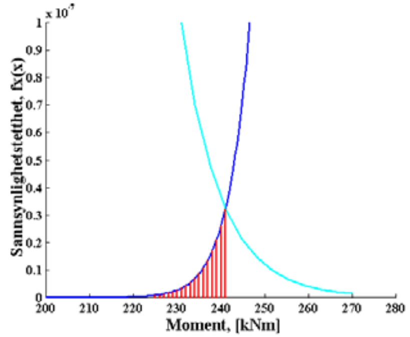
- Deterministic classification of bridges
  - **code requirements**
  - **safety by**
    - **general characteristic values**
    - **load and material factors**
- Probabilistic evaluation
  - **individual approach**
  - **individual bridge safety directly and consistently calculated**
    - **based on local traffic situation**
    - **individual strength information**
- Requirement:
  - **The overall level of safety defined by the code must be satisfied**



Probabilistic modelling:

$$M = g(R, S) = R - S = M_{kap} - M_{bel}$$

$$p_f = \int_{g(R,S)\le 0} f_{RS}(r,s)\, dr\, ds = \Phi(-\beta)$$



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Probabilistic evaluation – Procedure

- Modelling of critical limit states
  - **Buckling of the vertical truss member**
    - Load related parameters: axial force, bending moments
    - Geometrical parameters: actual length, buckling length, cross-section, imperfections
    - Material parameters: yield stress
    - Model uncertainty
  - **Rivet capacity for the truss member**
    - Load related parameters: axial force, bending moments
    - Geometrical parameters: cross- section of rivet, distance between rivets, number of rivets
    - Material parameters: yield stress
    - Model uncertainty
- Identification of uncertain parameters
- Load action evaluation
- Statistical modelling of uncertain parameters
  - **Modelling of traffic loading**
  - **Modelling of uncertain capacity parameters**
- Calculation of probability of failure or safety index for the identified limit states (by program STRUREL)
- Evaluation of safety level

Safety level – Requirements for probability of failure

Code	Target value for failure probability	
	β_T	p_{fT}
ECCS	4.2 – 4.7	$10^{-5} – 10^{-6}$
CIRIA, onshore offshore	4.2 – 4.7 3.7 – 4.7	$10^{-5} – 10^{-6}$ $10^{-4} – 10^{-6}$
NKB (Nordisk Komite for Bygg-standardisering)	4.2 – 5.2	$10^{-5} – 10^{-7}$
Norsk Standard/ Byggeforskriftene	(4.2 –) 5.2	$(10^{-5} –) 10^{-7}$
NPD	3.7 – 4.2	$10^{-4} – 10^{-5}$
NS 3490	2.3 – 3.7	$10^{-2} – 10^{-4}$

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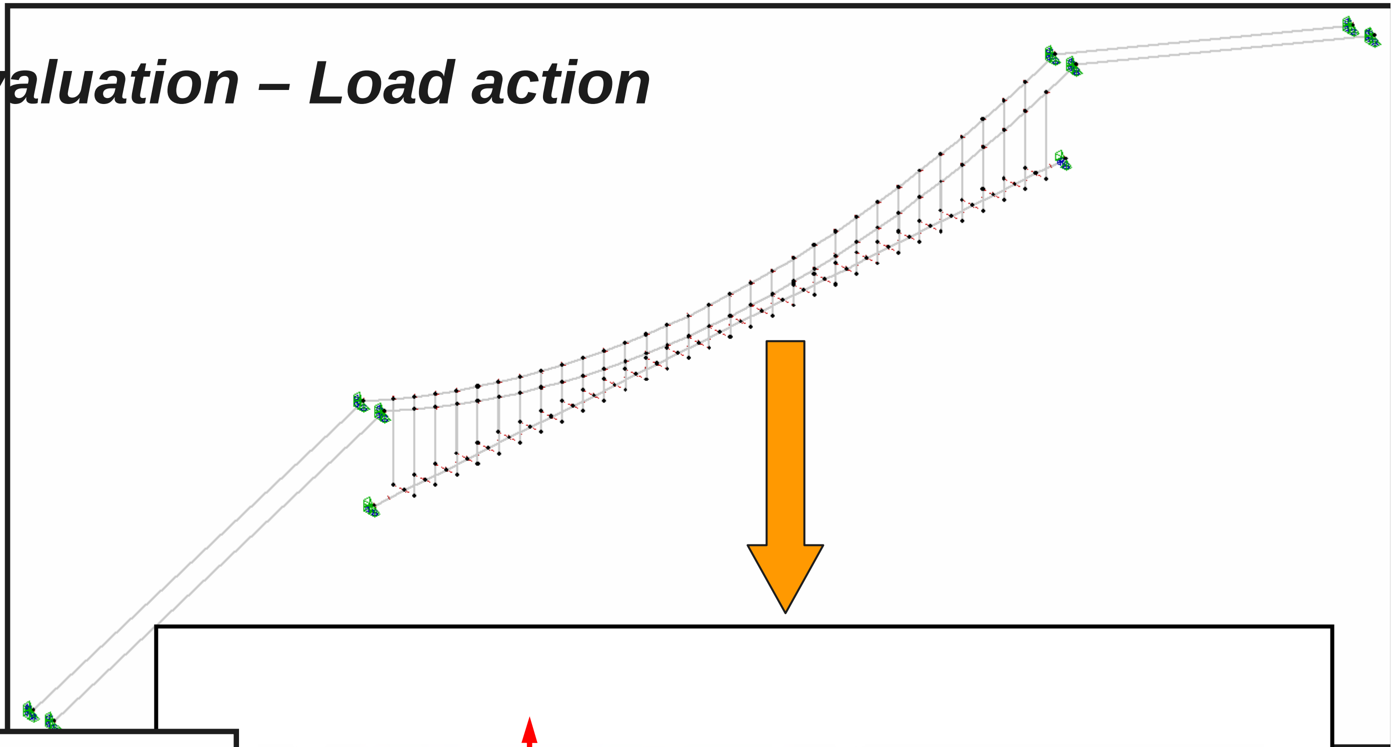
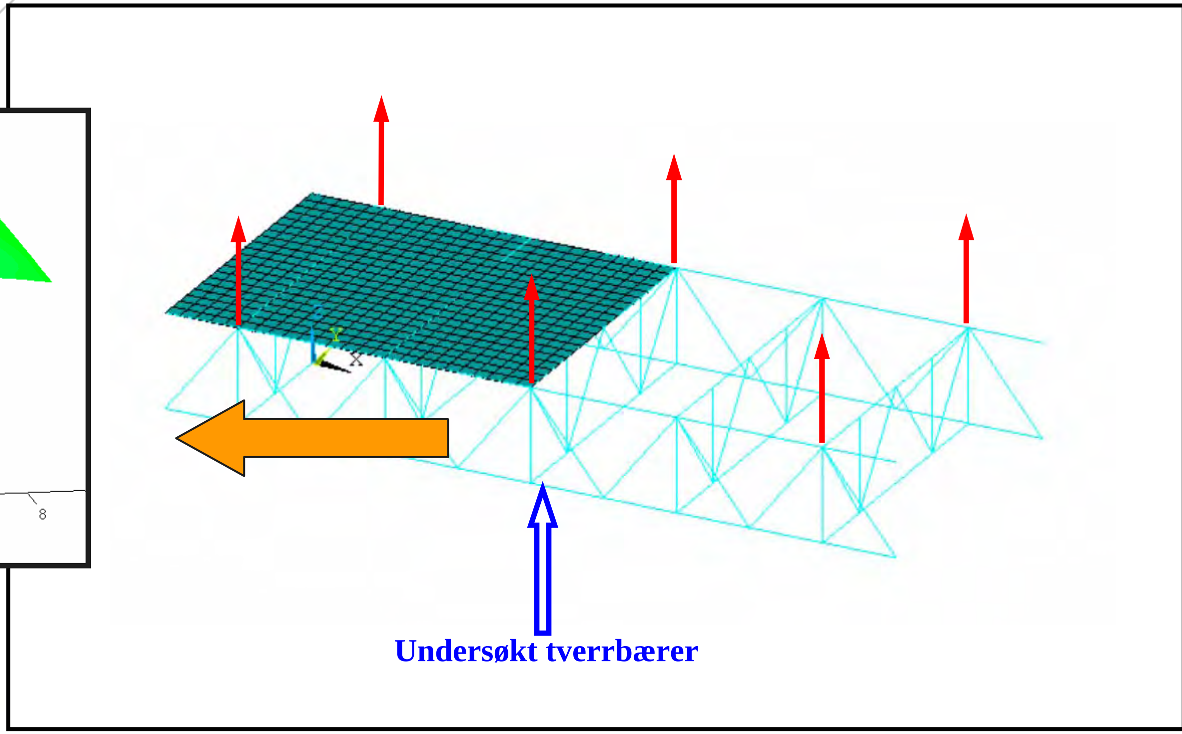
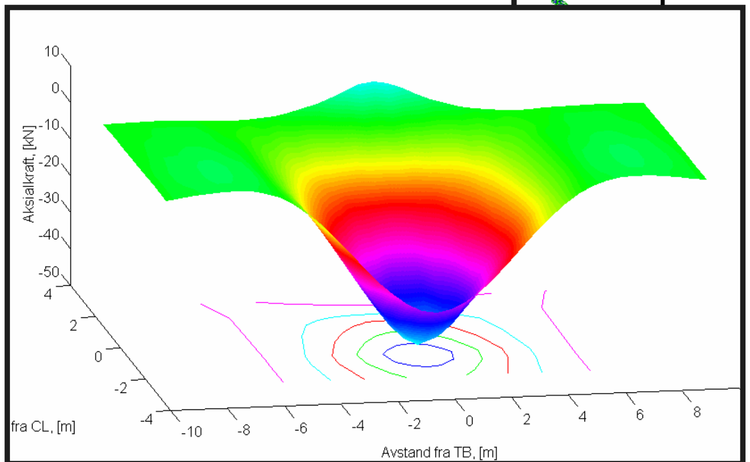
Probabilistic evaluation – Load action

- Load action analyses
  - **Global analysis**
  - **Local analysis**
  - **Influence plane for critical members**







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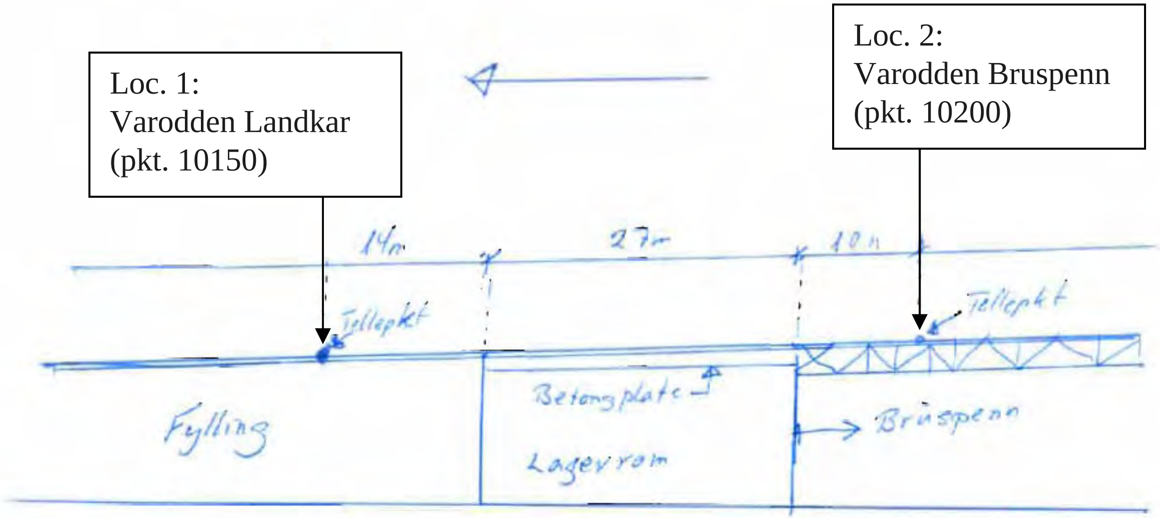
Modelling of traffic loading - Measurement

- Measurement of traffic loading at Varodd bridge
  - **18 weeks or 126 days of measurement**
  - **2 million vehicle passing**
  - **17 528 vehicle each day**
- Measurement performed at two locations
  - **One location in front of the bridge**
  - **One location on the bridge beam**



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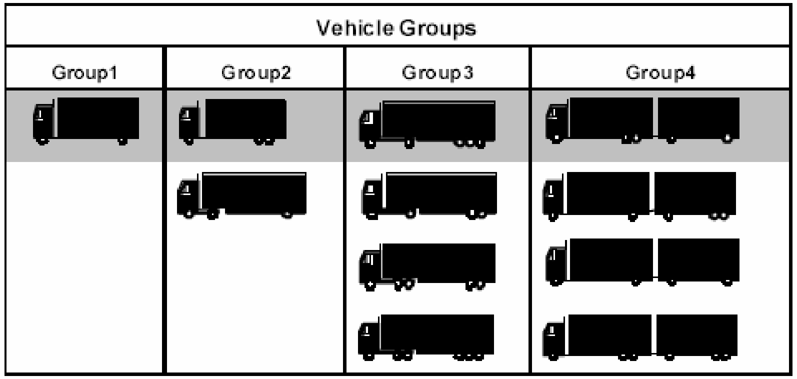
Modelling of traffic loading - Measurement

- Based further evaluation on a database for 98 159 vehicle above 10 ton
- Database contain 317 195 axel loadings
- 12.9 % of these axels have a load above 10 ton
- 0.6 % of these axels have a load above 14 ton
- 4 axels have a load above 20 ton
- Normative loading 160 kN for one axel, 140 kN for the larger in the triple-axel (including dynamic factor)

- Conclusion
  - **Very high loading**
  - **Either a large number of illegal loading**
  - **Or too high measurements**



Type	Vekt [tonn]	Akslinger [antall]	Akselvektfordeling [andel]	Akselavstand [m]
1	10 – 20	2	0.4 – 0.6	5.4
2	20 – 30	3	0.3 – 0.4 – 0.3	4.6 – 1.8
3	30 – 40	5	0.2 – 0.26 – 0.18 – 0.18 – 0.18	4.0 – 3.5 – 4.2 – 2.4
4	40 – 50	6	0.16 – 0.20 – 0.18 – 0.16 – 0.15 – 0.15	3.5 – 1.3 – 5.3 – 2.2 – 1.7
5	50 – 60	6	0.14 – 0.20 – 0.17 – 0.17 – 0.16 – 0.16	3.8 – 1.3 – 5.2 – 2.6 – 1.8
6	60 – 70	6	0.14 – 0.20 – 0.17 – 0.17 – 0.16 – 0.16	4.0 – 1.3 – 4.9 – 3.1 – 1.9
7	70 – 80	6	0.15 – 0.20 – 0.16 – 0.17 – 0.16 – 0.16	4.0 – 1.4 – 4.8 – 3.4 – 1.8
8	80 – 90	6	0.15 – 0.20 – 0.16 – 0.17 – 0.16 – 0.16	3.9 – 1.3 – 5.1 – 3.2 – 1.9
9	Over 90	8	0.13 – 0.13 – 0.14 – 0.13 – 0.13 – 0.14 – 0.13 – 0.07	3.8 – 1.4 – 4.5 – 1.5 – 3.0 – 1.7 – 1.7

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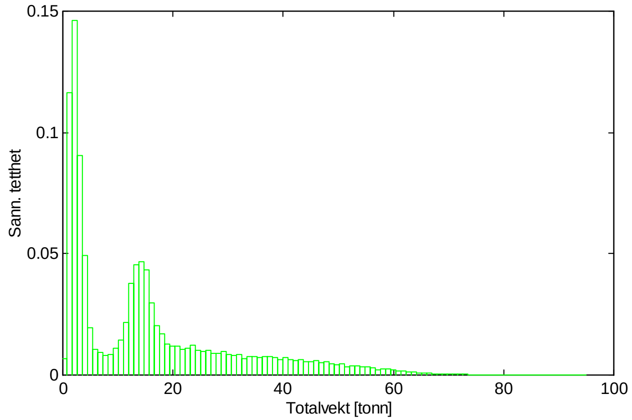
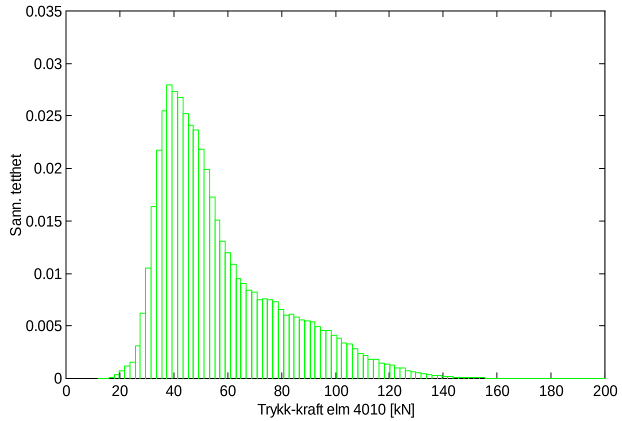
Modelling of traffic loading – Use of data

- By a combination of the
  - **Load action evaluation data**
  - **Database for heavy vehicle**

  a direct statistical description of the loading in the cross girder is achieved
- This statistical description is used as basis to find the extreme values for the load effects
- Extreme values are then described statistically and used for the probabilistic evaluation

- A model published by BRIME is adapted based on multimodal normal descriptions of the statistical information giving type I extreme distributions





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Rombak bridge - Results

- Deterministic evaluation
  - **High utilizations of rivets (110% and 103%)**
- Probabilistic evaluation
  - **Traffic description from Varodd used**
  - **Extreme values based on traffic volume for Rombak bridge**
  - **Dynamic factor added**
  - **Results**
    - $p_f = 8.2 \cdot 10^{-5}$
    - $p_f = 2.6 \cdot 10^{-5} – 3.6 \cdot 10^{-5}$
  - **Acceptable results acc. to NS 3490 – too high probability acc. to NKB**

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Brevik bridge - Results

- Deterministic evaluation
  - **High utilizations of rivets (116%)**
- Probabilistic evaluation
  - **Traffic description from Varodd used**
  - **Extreme values based on traffic volume for Brevik bridge**
  - **Dynamic factor added**
  - **Results**
    - $p_f = 7.2 \cdot 10^{-4} - 8.9 \cdot 10^{-4}$
  - **Not acceptable results**
  - **If no dynamic factor is added**
    - $p_f = 1.3 \cdot 10^{-6}$

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Varodd bridge - Results

- Initial deterministic evaluation
  - **Buckling of vertical and diagonals**
  - **High utilizations of rivets**
  - **Deterioration of upper truss**

- Refined deterministic evaluation
  - **No buckling**
  - **Acceptable utilization of rivets**
  - **Corrosion of upper truss reduce cross-section by 22%, utilization still below 60%**

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Summary and conclusions

- Probabilistic classification calculations have been performed
- Usable procedure do exist
- Usable tools for performing the calculations do exist
- Provided reliable input data results will be reliable

- In order to have reliable results:
  - **Actual data for the structure must be obtained**
  - **Traffic loading should be based on actual loading**

- Actual traffic loading on Norwegian roads is not yet determined with sufficient accuracy

- In order to have benefits of the procedure:
  - **Actual data for the structure must deviate from characteristic code values**
  - **Actual traffic loading must deviate from normative loading**

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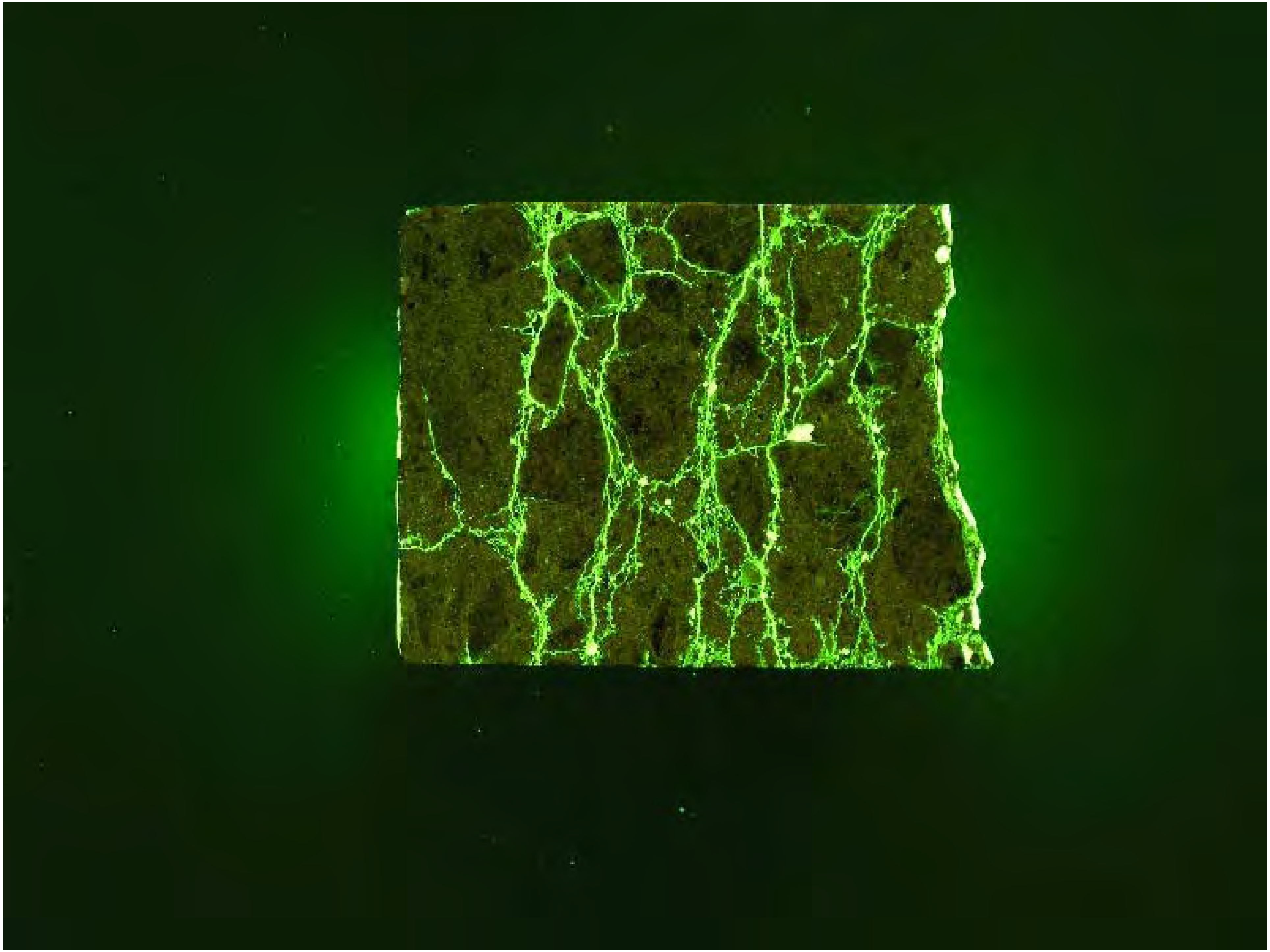
Vejdirektoratet

Special Investigation

A Strategic Tool


Typical crack formation due to ASR



Delaminated concrete due to ASR


Extensive Damage to Deck Soffit Side Due to ASR

Special Investigation; A new Approach

Purpose:

1. To assess the repair budget
2. Optimum time of execution
3. Consequences of postponing an optimum strategy 5 years

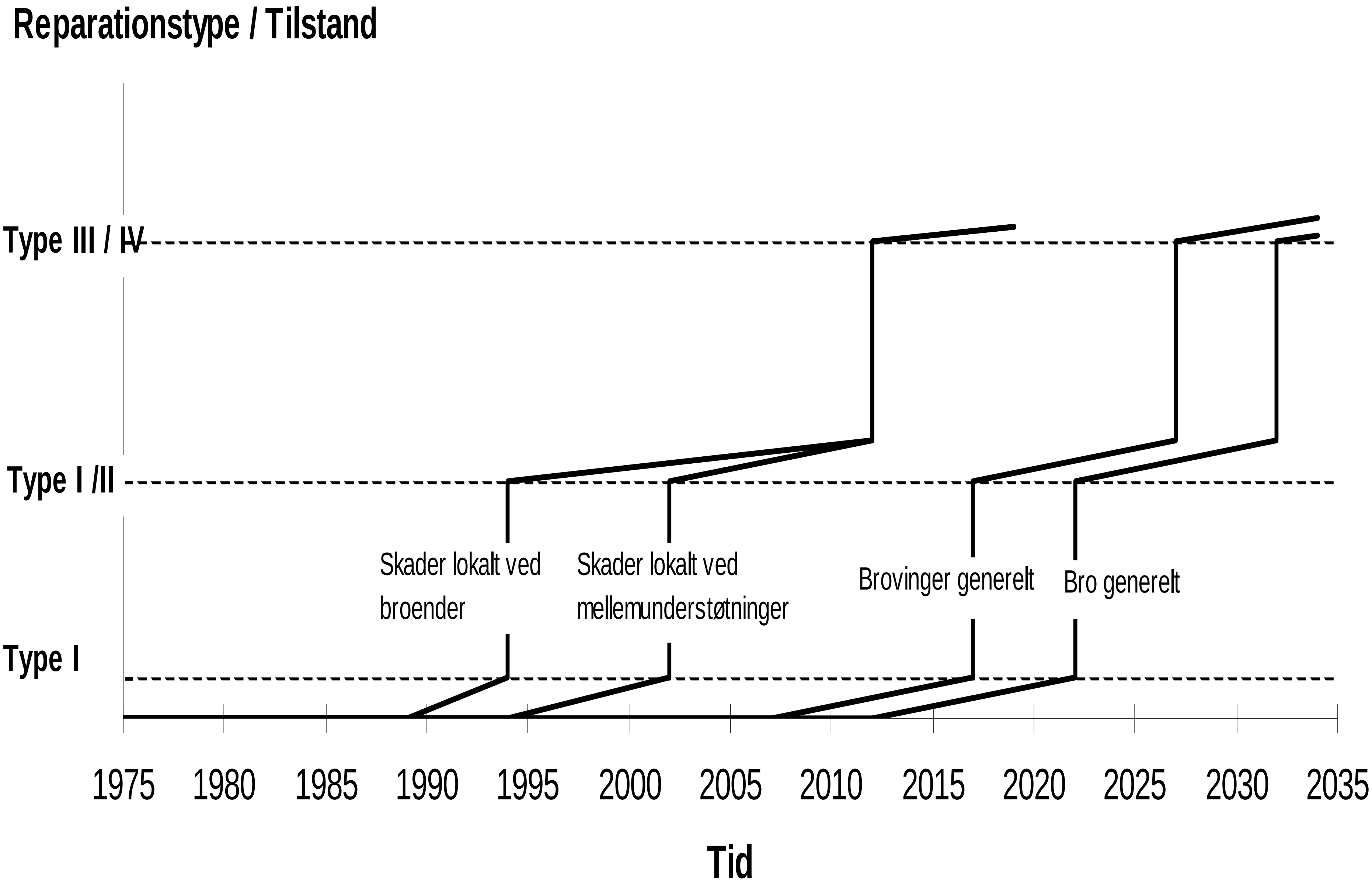
Furthermore:

1. Optimization
2. Prognosis
3. Experience

Historic Milestones

- 1980: SI – Manual
- 1986: New Concrete Specification – app. 40% new spec.
- 2002: SI – Manual revised in a DRD-version – statistic approach, service life modelling, Service life curve etc.
- 2010: Short Version SI Introduced – A New Approach

Bro 40-023



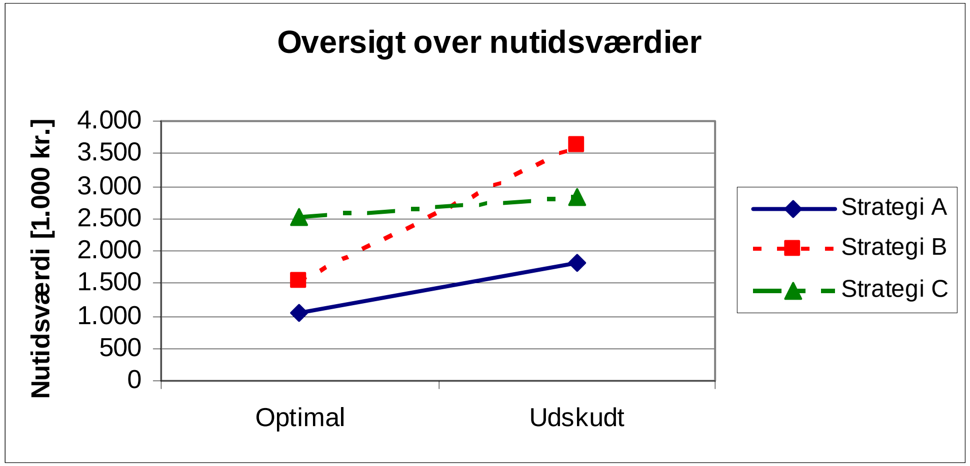
Reparationstype / Tilstand
Type III / IV
Type I /II
Type I
Skader lokalt ved broender
Skader lokalt ved mellemunderstøtninger
Brovinger generelt
Bro generelt
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
Tid

SI – Validity of Performed Test Results

The validity of the test results shall be proven to a 10 % level of significans in critical areas however 5 %.

Cost Estimate

Strategi A.		**Udgifter i 1.000 kr. ekskl. moms**			
		Optimal løsning, A0		Udskudt løsning, A5	
År		Direkte udgifter	Indirekte udgifter	Direkte udgifter	Indirekte udgifter
1	1	1.000	50		
2	2				
3	3				
4	4				
5	5				
6	6			2.000	300
7	7				
8	8				
9	9				
10	10	500	50		
11	11				
12	12				
13	13				
14	14				
15	15			500	50
16	16				
17	17				
18	18				
19	19				
20	20				


Oversigt over nutidsværdier
Nutidsværdi [1.000 kr.]
4.000
3.500
3.000
2.500
2.000
1.500
1.000
500
0
Optimal
Udskudt
Strategi A
Strategi B
Strategi C

New Approach

Old procedure:

SI of chosen elements:

Several months to prepare a few reports and only one annual optimization of repairworks

New Approach

New procedure:

SI of specific key elements – water proofing, edgebeam, crash barrier and wearing coarse:

A large number of reports within a short period and ad hoc optimization of repair works

Use of:

1. Visual inspection
2. 11 predefined strategies
3. Short report(max. 4 pages)
4. Verification during the design phase

Inddata

Broareal	800
Skade på broplade:	Ja
	Nej

Restlevetid

Element (Elementnr.)	Restlevetid (år)
Fugtisolering (8)	20
Kantbjælke (9)	10
Autoværn (10)	0
Belægning (11)	10

Strategioversigt

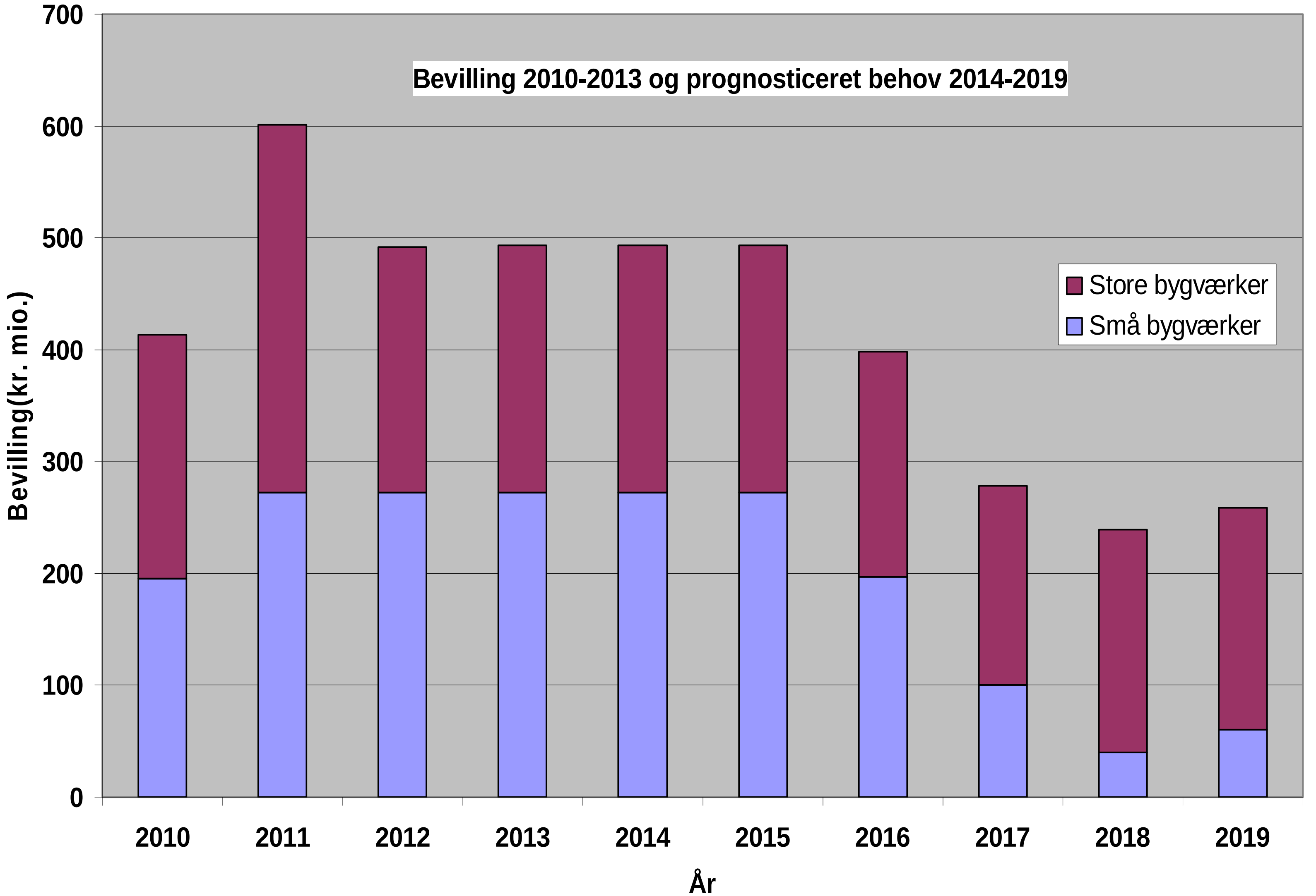
Strategi	Samlet pris	Elementkombination til udskiftning (år til udskiftning)			
E	4.949.612	8, 9, 10, 11 (10 år)	10 (0 år)		
F	4.949.612	8, 9, 10, 11 (10 år)	10 (0 år)		
A	5.023.647	8, 11 (20 år)	9, 10 (10 år)	10 (0 år)	11 (10 år)
I	5.059.918	8, 11 (20 år)	9, 10 (10 år)	10, 11 (0 år)	
C	5.666.408	8, 11 (10 år)	9, 10 (10 år)	10 (0 år)	
D	6.157.963	8, 11 (20 år)	9, 10 (0 år)	11 (10 år)	
H	6.194.234	8, 11 (20 år)	9, 10, 11 (0 år)		
B	6.800.723	8, 11 (10 år)	9, 10 (0 år)		
G	7.110.196	8, 10, 11 (0 år)	9, 10 (10 år)		
K	7.267.392	8, 9, 10, 11 (0 år)			

Experince and Prognosis

Age at time of repair:

- Rank < 2:
  - Water Proofing: 41 year
  - Edgebeam: 41 year
  - Crash Barrier: 39 year
  - Wearing Coarse: 38 year
- Rank =2:
  - Water Proofing: 17 years from first 2-rank
  - Edgebeam: 14 år years from first 2-rank
  - Crash Barrier: 16 år years from first 2-rank
  - Wearing Coarse: 16 år years from first 2-rank
- Rank > 2:
  - Within 0-5 years

Prognosis



Vejdirektoratet

Experience

Chloride Impact to Coastal Bridges:

1. Level 0:
    1. Chloride content 0-15 mm: 0,36 % of dry concrete weight
    2. Cs= 0,46 %(0,39-0,50)
    3. Diff.: 34 mm2/year(20-48)
2. Bound Chloride: 60-90 %
3. The validity of Potential mapping can be questioned
4. The validity of the 2. law of Fick can neither be proved neither be rejected

Summary

A systematic use of SI assures:

1. Repair works are initiated to the optimum time and at the lowest societal cost
2. Foreseen repair needs are proved and reported to the politicians in due time
3. Acculation of experience to continously improve methods, diagnosis and prognosis
4. Implementation of new SI-approaches to result in a more efficient administration

Innovative Strengthening Systems for Concrete Structures

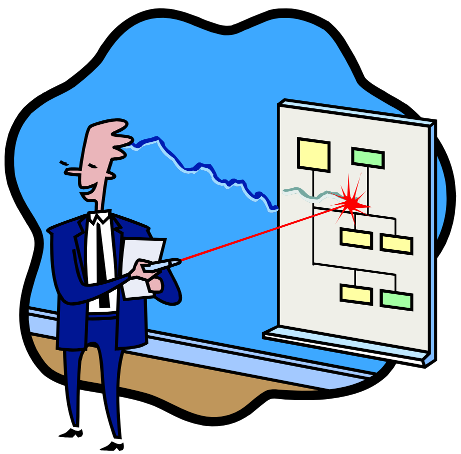
by

Professor Björn Täljsten

Sto Scandinavia AB and

Luleå University of Technology

Outline



- Introduction
- Methodology
- Strengthening
- Applications – Case Studies
- Summary and Conclusions

Introduction

Society Changes

Beginning of 1900

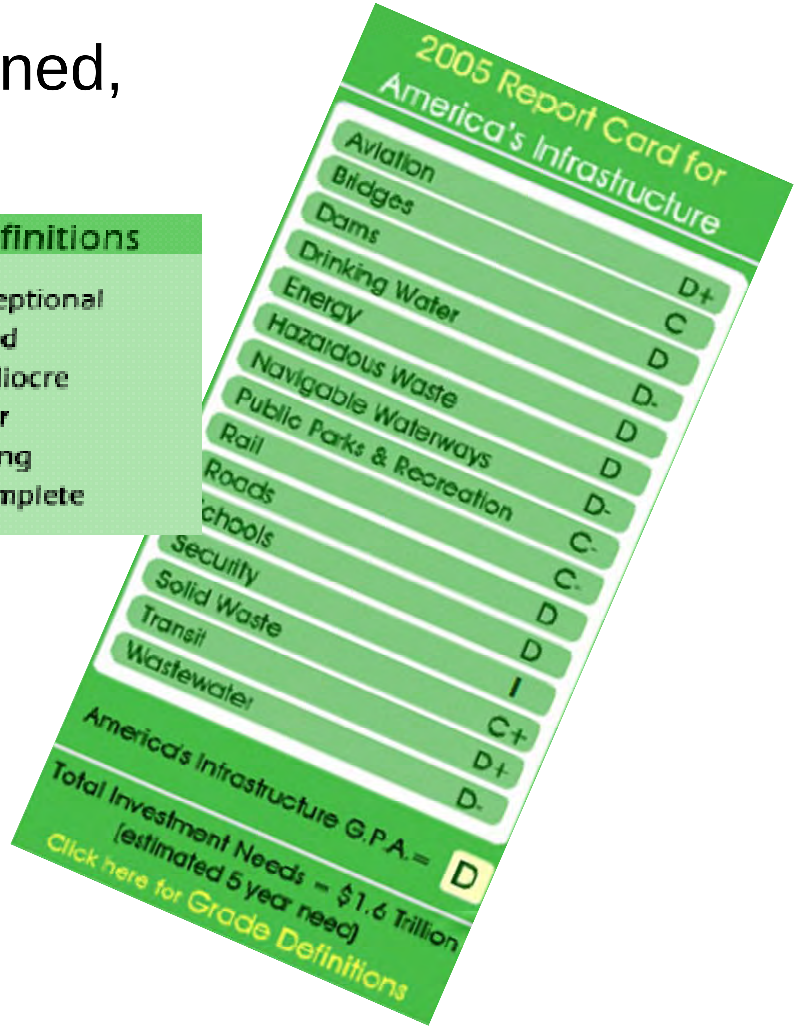
End of 1900

Introduction

Our structures needs to be maintained, repaired or/and upgraded

Grade Definitions

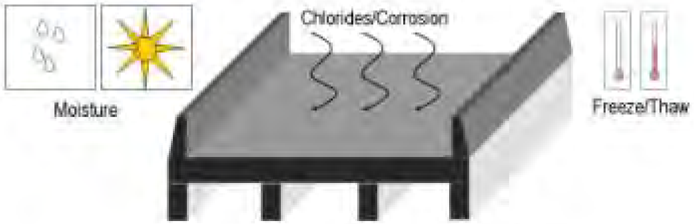
A – Exceptional
B = Good
C = Mediocre
D – Poor
F – Failing
I = Incomplete

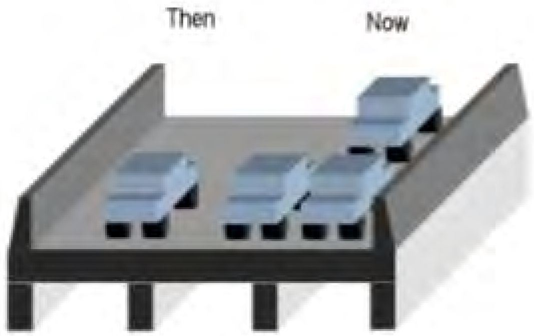


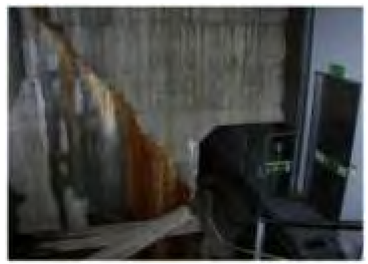
Introduction

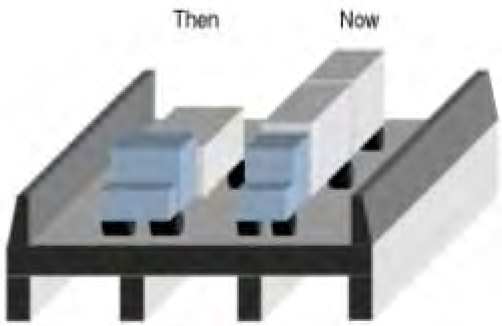
There might be many different reasons why upgrading is needed

- New demands on existing structure
- Mistakes in design or production phases
- New user demands, re-construction etc.
- Accidents
- Deterioration of existing materials, building components.









Introduction

Suggestion for assessment procedure

Step 1

Initial assessment
- Site visits
- Study of documents
- Carried out rough calculations

Step 2

Intermediate assessment
- Further inspections
- Material testing, cores etc
- More detailed calculations
- Investigations of loading etc.

Step 3

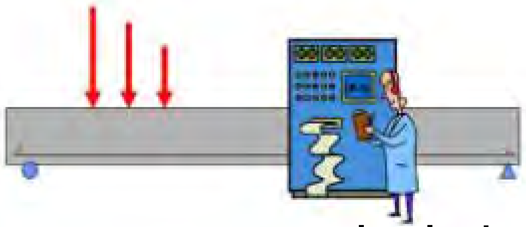
Enhanced assessment
- Laboratory investigations
- Non-destructive testing
- Investigations of Load Models
- Strengthening calculations
- Monitoring
- Decision analysis

Step 4

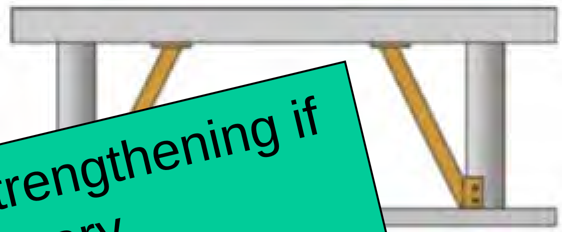
Load Testing, Destructive testing
- Design Models
- Ultimate Limit State
- Verification
- Detailed analysis

Strengthening of concrete structures

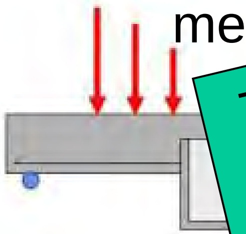
There exist many different ways to strengthen concrete structures



More accurate calculation methods

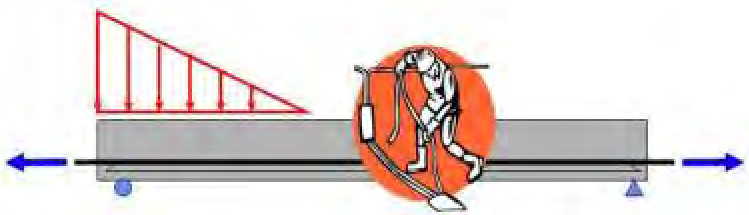


...static system



Increased ... sections

The aim should be to avoid strengthening if not absolutely necessary



External pre-stressing

Extern strengthening

Strengthening of concrete structures

External bonded reinforcement - history

1964

Steel Plates,
- South Africa

The ASSET Bridge

1975- | *1988* | *1990-* | *1993-* | *2002*

1975-
Steel Plates
- France
- UK
- Japan
- Switzerland
- USA

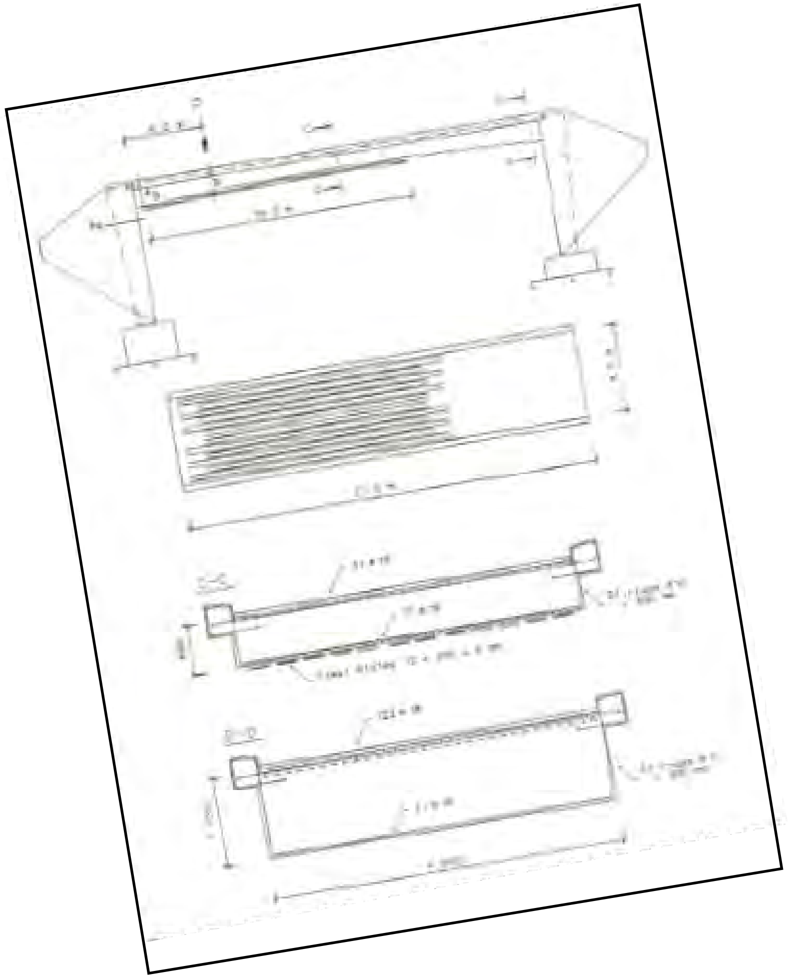
1988
Steel Plates
- Sweden

FRP
- Japan

1990-
FRP
- Switzerland
- Canada
- USA

1993-
FRP
- UK
- Sweden
- Denmark
- etc.

Strengthening of concrete structures



Field Applications– Stora Höga - 1989

- Approximately 2/3 of the bridge was strengthen with steel plates, A_s = 250 x 6 mm, weight per meter ca 12 kg.
- The bridge was loaded ca 4.0 from the left support
- Only loading after strengthening

Strengthening of concrete structures

Strengthening

Stora Höga - 1989

Strengthening of concrete structures

Stora Höga - 1989

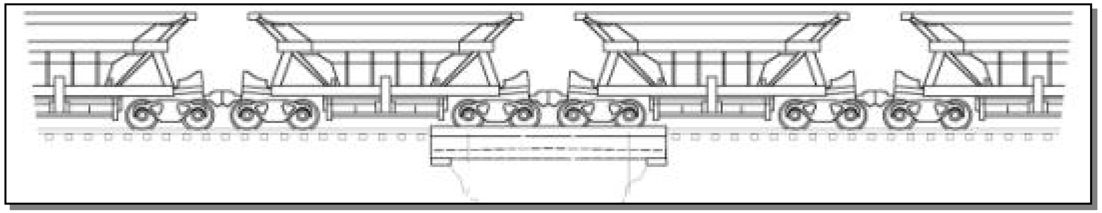
Loading - Monitoring

Steel stays anchorage
in the bedrock

Shear failure at ca 460 ton

Strengthening of concrete structures

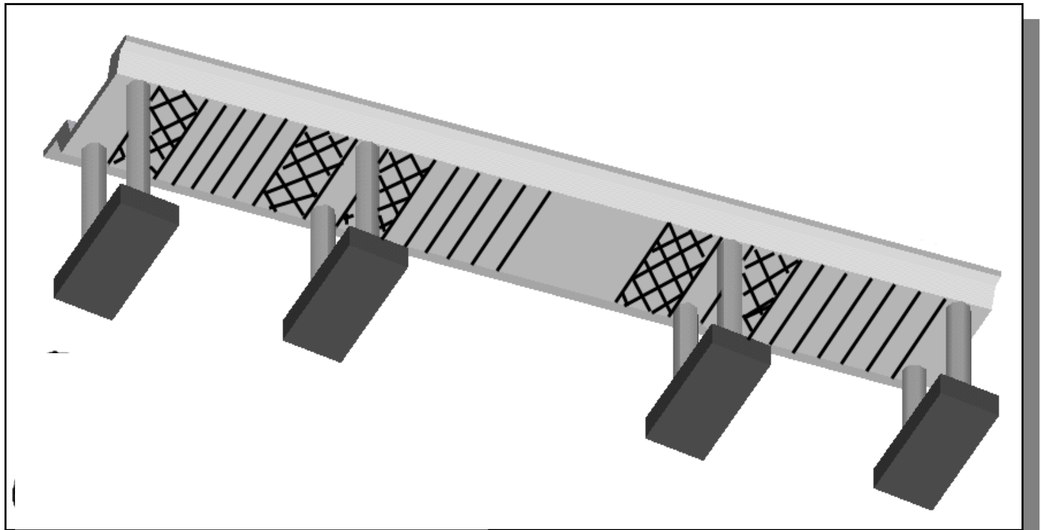
Luleå Railwaybridge- 1998



- Need of increased load bearing capacity
- Investigation of the Strengthening Method
- Full-Scale Test before and after testing

Strengthening of concrete structures

The bridge needed strengthening due to increased axle loads, from 25 to 30 tons



Strengthening for flange shear, ± 45°, 2 x 3 layers, Strengthening in cross direction, 2 layers

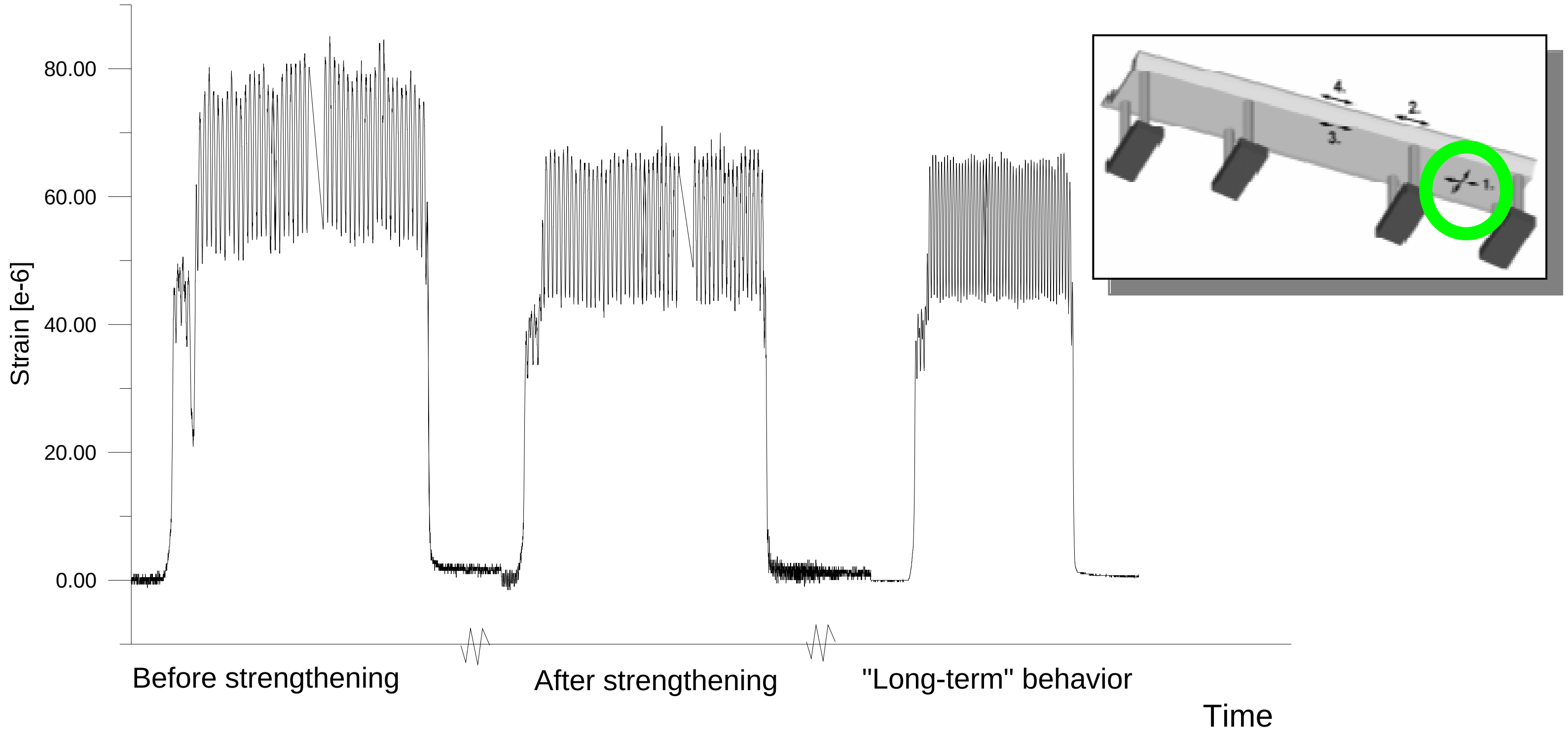
• Pre-treatment

• Strengthening

• Post-treatment

Strengthening of concrete structures

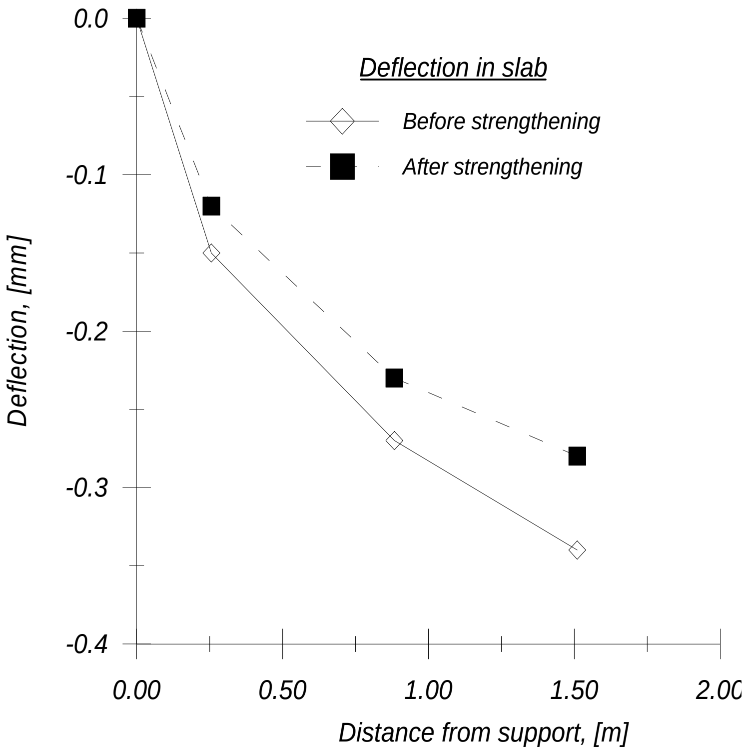
Strain measurement on steel and concrete

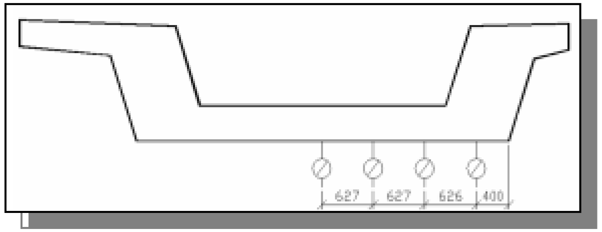


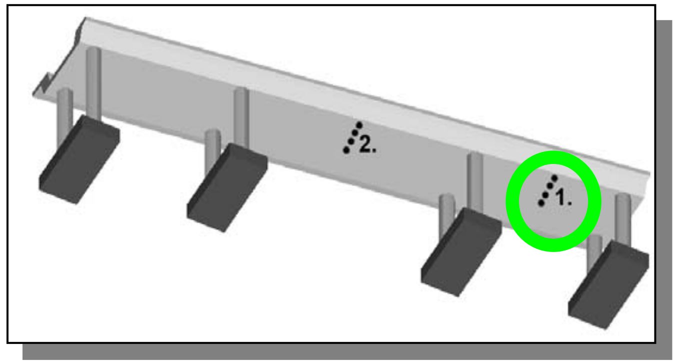
Curves are adjusted for different train weights

Strengthening of concrete structures

Measurement of deformations at two locations



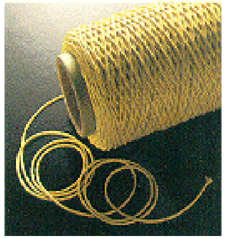




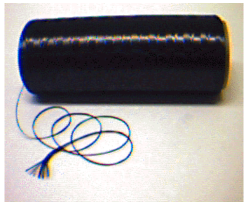
What is an FRP (Fibre Reinforced Polymers)?

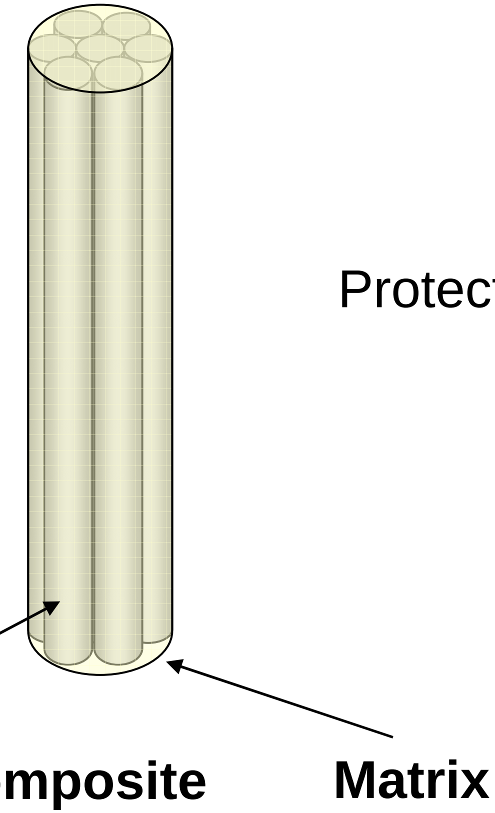
Fibres

Provide strength
and stiffness



Carbon, glass, aramid





Matrix

Protects and transfers load
between fibres

Epoxy, vinyl ester

Creates a material with attributes superior to either component alone!

Fibres **and** matrix both play critical roles in the composite material.

FRP Material for use in the construction industry

Unidirectional glass FRP bar

Carbon FRP prestressing tendon

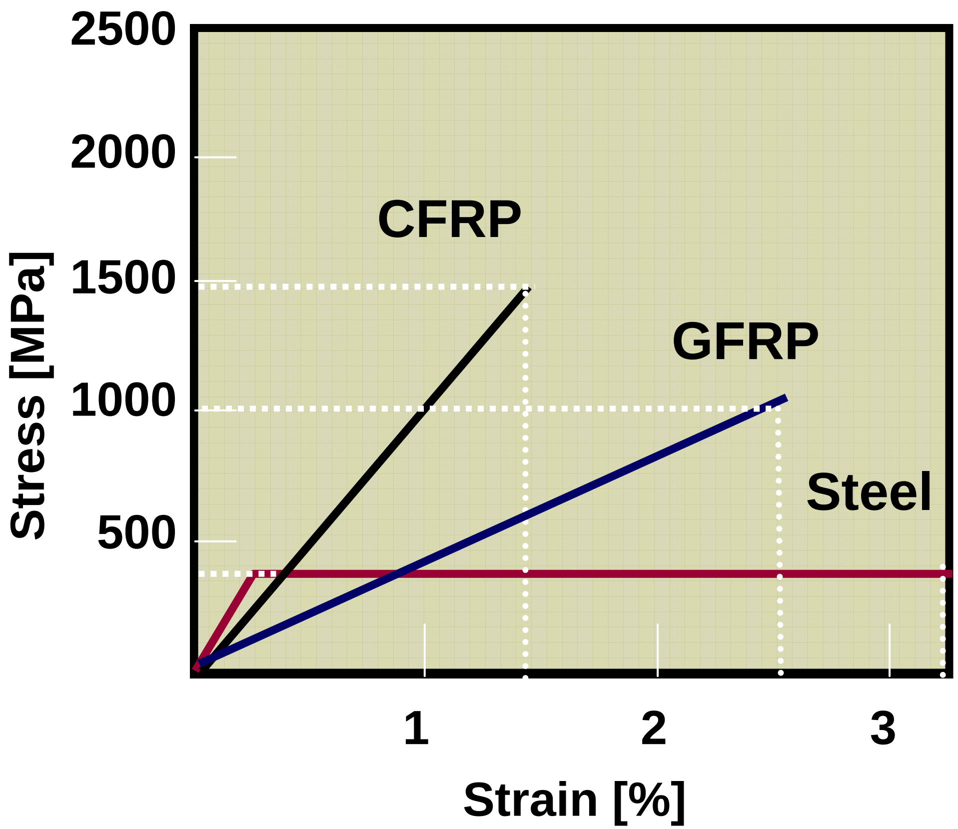
Glass FRP grid

Glass fibre roving

Carbon fibre roving

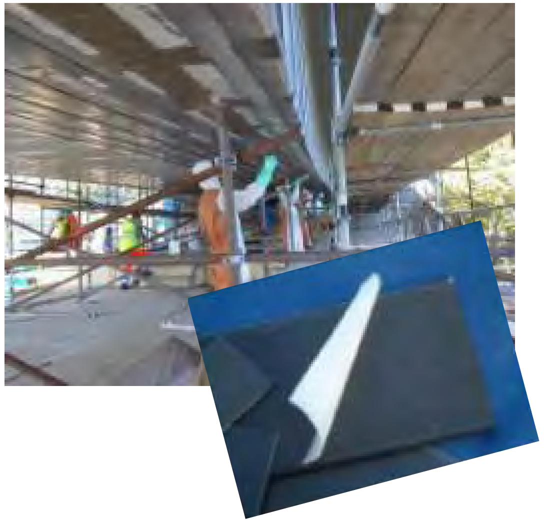
Properties of FRP in comparison with steel

- Linear elastic behaviour to failure
- No yielding
- Higher ultimate strength
- Lower strain at failure
- Comparable modulus (or higher, carbon)



External Bonded Strengthening

Laminate

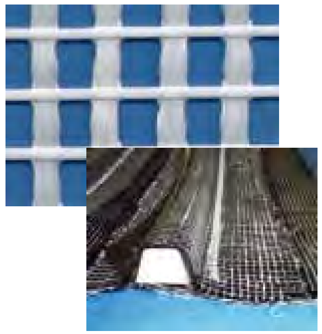


Fabrics

Rods
- Prestressed
- Non-Prestressed

Grids
MBC
Systems

Tubes



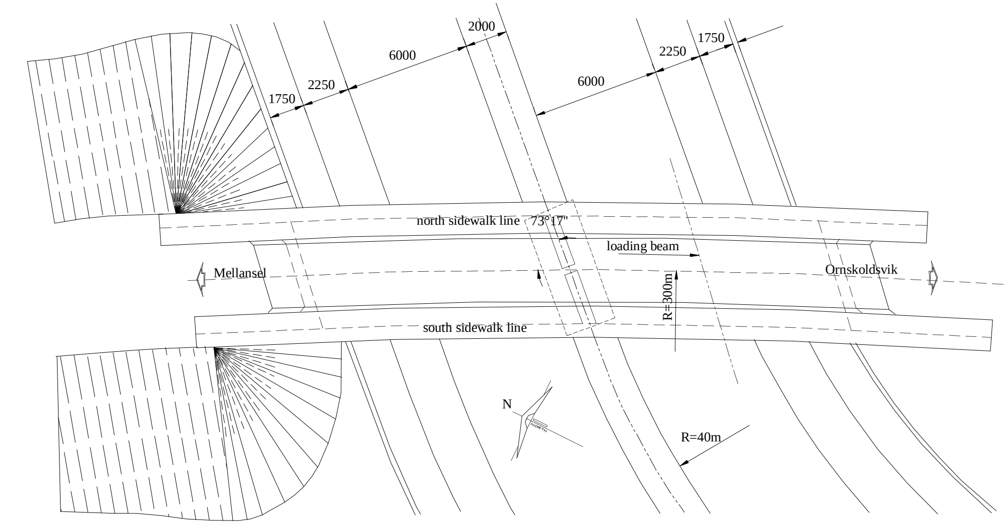
Textile
Systems

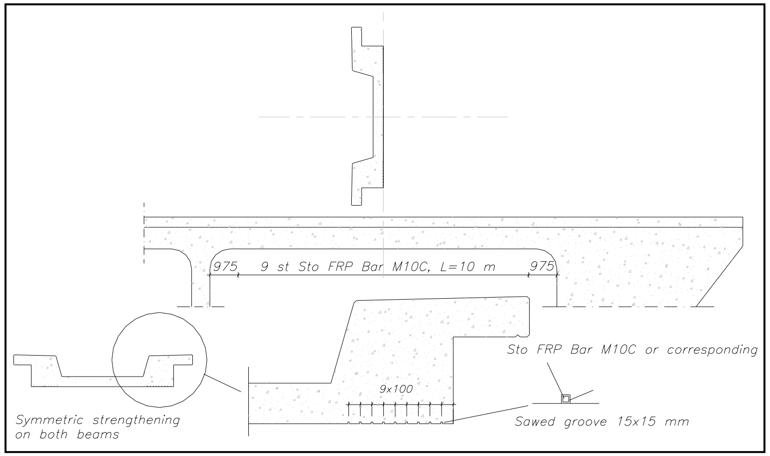
External Bonded Strengthening

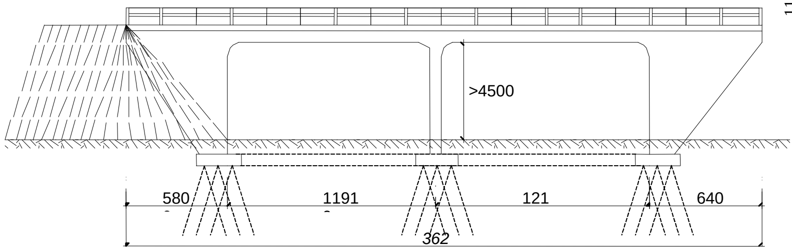
The Örnsköldsviks Bridge 2006

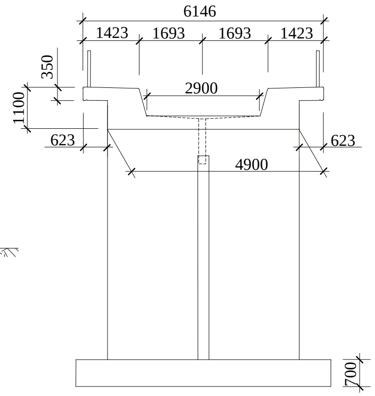
- A railway trough bridge – located in Örnsköldsvik, built in 1955
- The bridge is a traditional trough bridge built in RC
- Was demolished and removed due to the newly constructed Botnia line
- Investigation of the shear capacity
- Bending failure before shear failure – needed strengthening
- Strengthening with CFRP rods in the soffit of the beams
- Testing before and after strengthening
- Loaded with steel stays anchored in the bed-rock

The Örnsköldsviks Bridge 2006

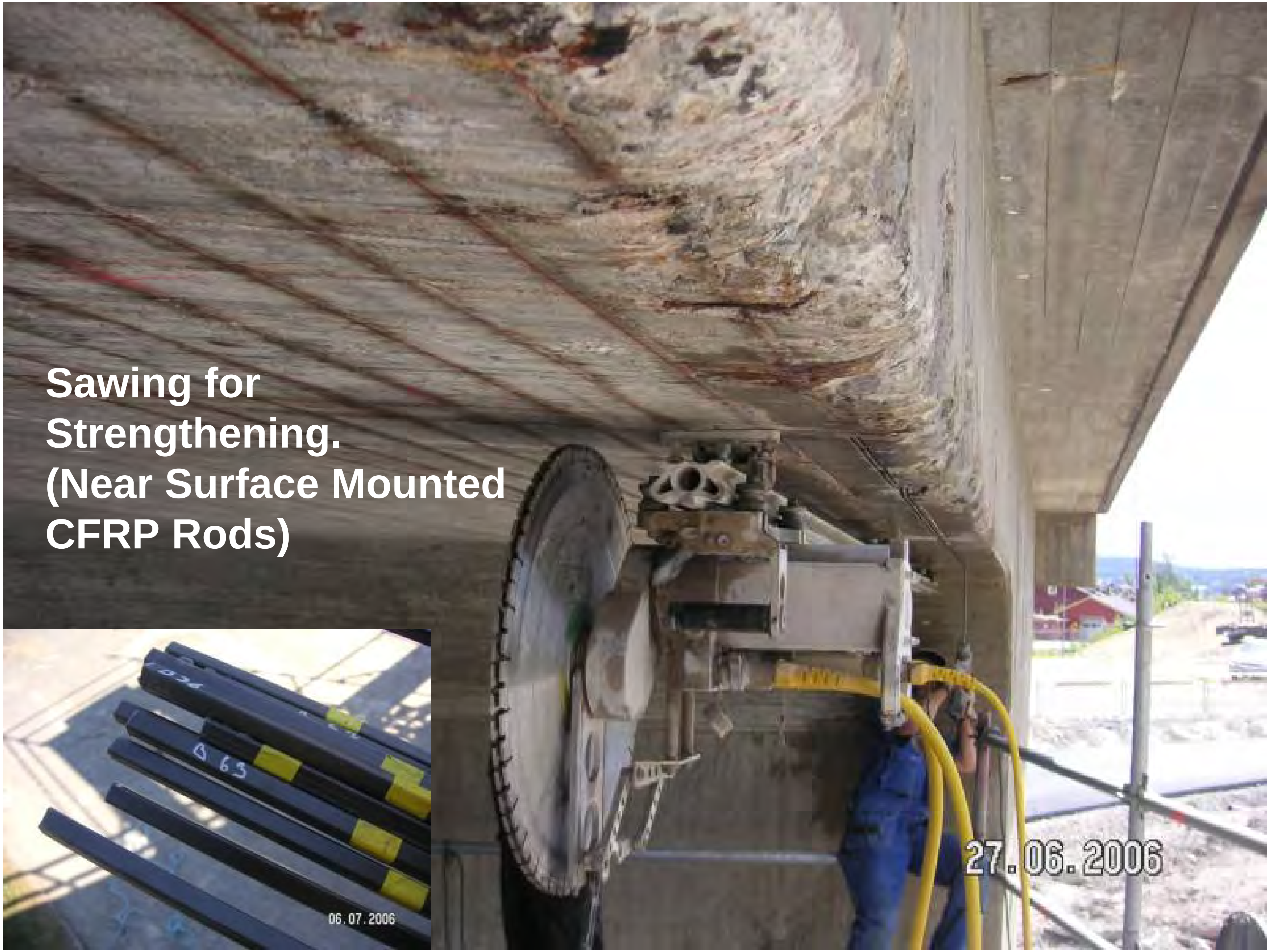








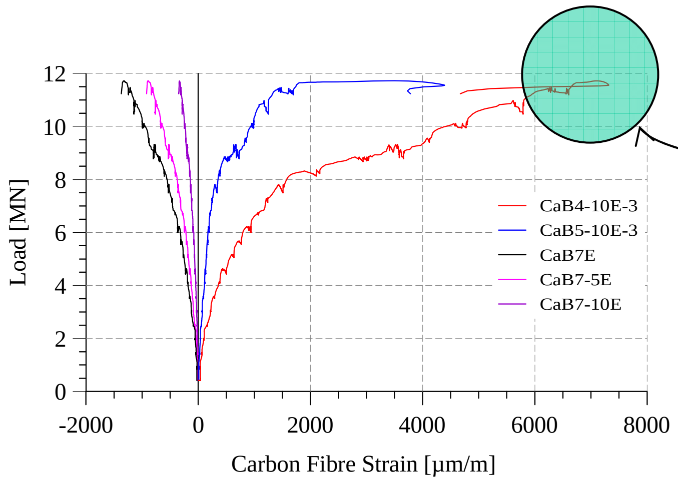
Sawing for Strengthening. (Near Surface Mounted CFRP Rods)



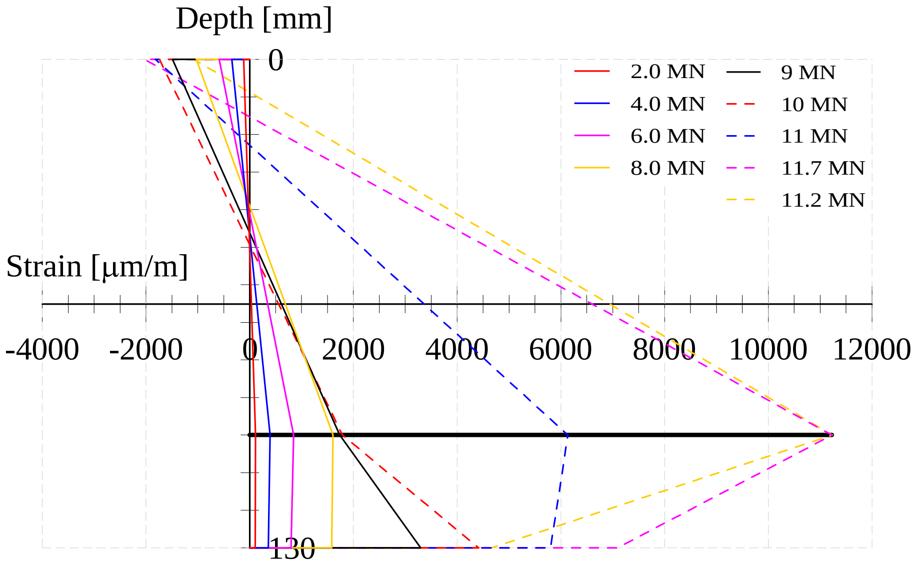



The Örnsköldsviks Bridge 2006

Monitoring



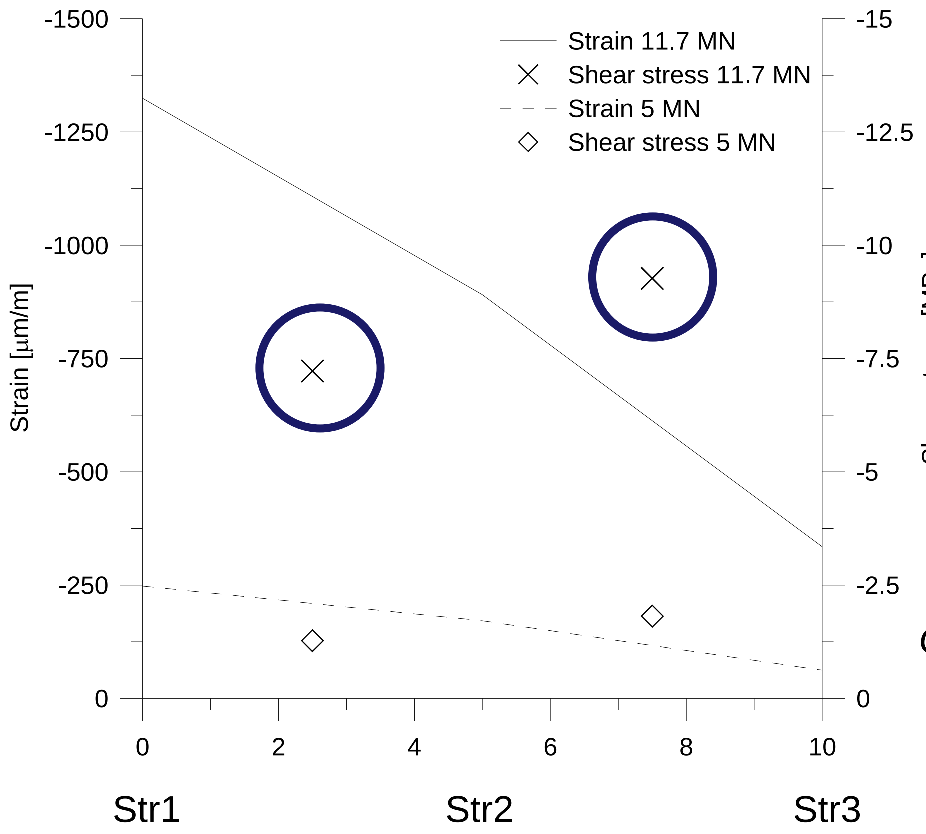
ε_{fuls} = 8000 μs

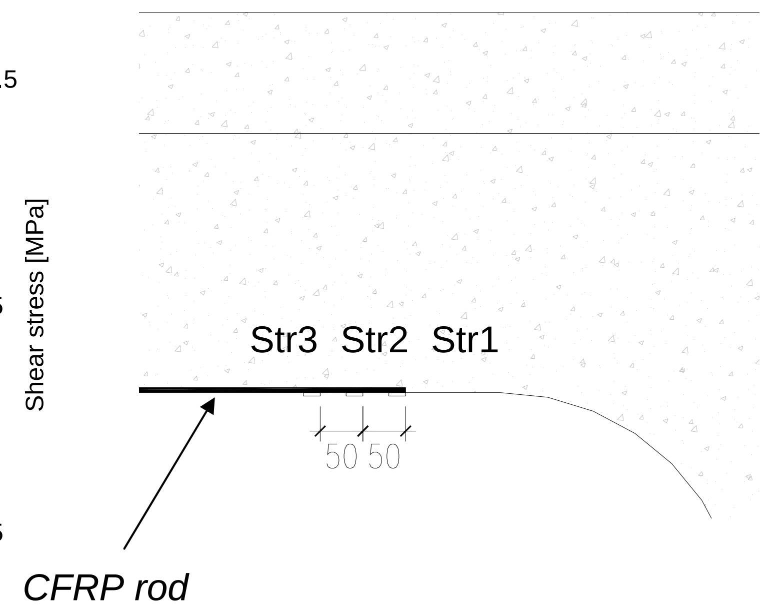



10. 07. 2006

The Örnsköldsviks Bridge 2006

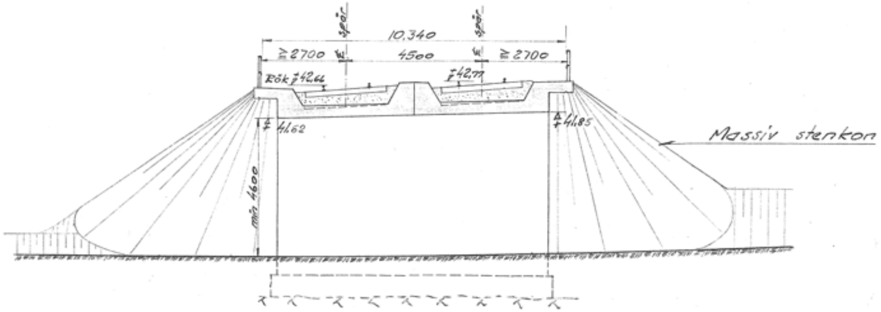
Monitoring

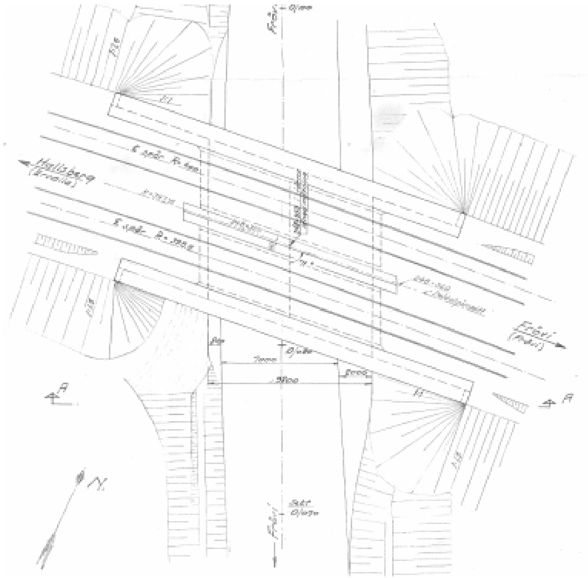




Frövifors Railway Bridge - 2007

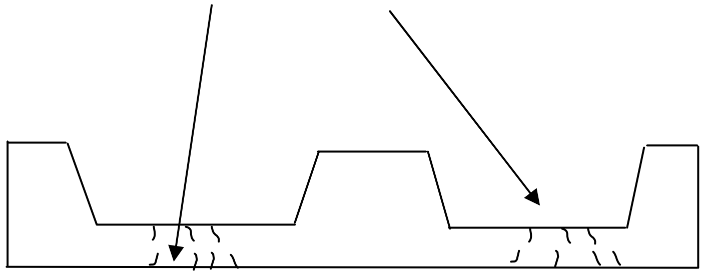
New developed strengthen technology – strengthening in the upper part of the concrete slab using CFRP tubes bonded in predrilled holes.



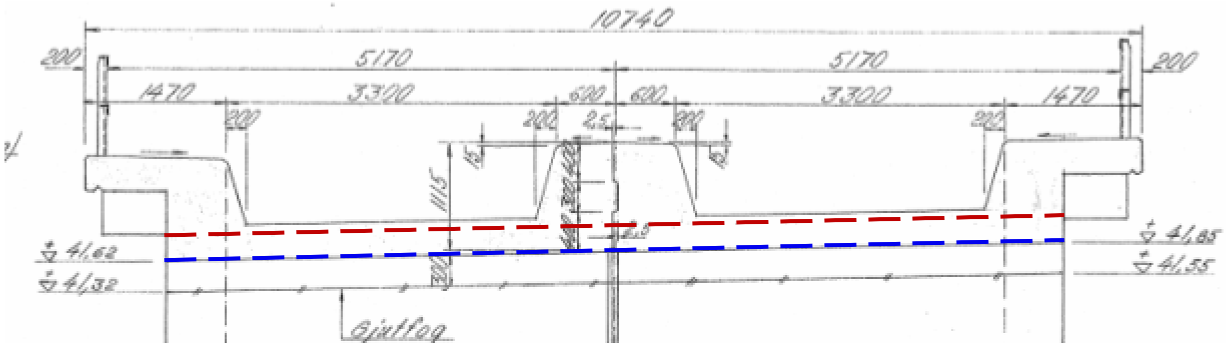


Frövifors Railway Bridge - 2007

The bridge needed to be strengthen in the cross direction in the upper and lower part of the slab.



To solve this problem, without stopping the traffic, the slab was strengthened with CFRP tubes in the upper part and NSMR rods in the lower part of the slab



Frövifors Railway Bridge - 2007

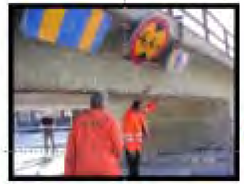
Structural Assessment

S1: Survey

Bridge owner/Consultant

S2: Condition assessment

Visual Inspections

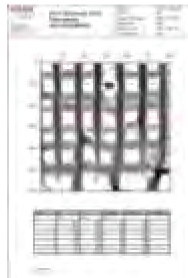


S2: Simple Calculations

Consultant

S2: Non destructive tests

Radar, ultrasonic tests etc.



S2: Material samples

Drilling of cores, pull-off etc.

S3: Laboratory testing

Concrete, Steel etc.

Frövifors Railway Bridge - 2007

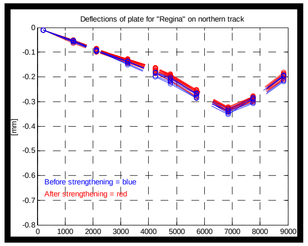
Structural Assessment

S3: Sensor installation

Specialist consultant

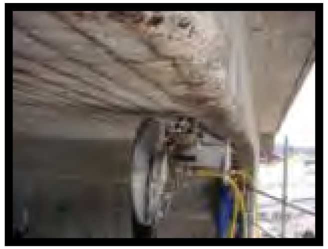
S4: Load test 1

Testing institutes



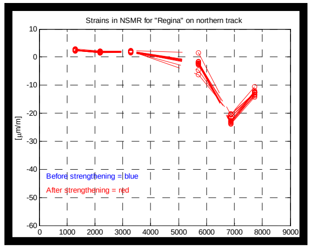
S4: Strengthening

Specialist contractors



S4: Load test 2

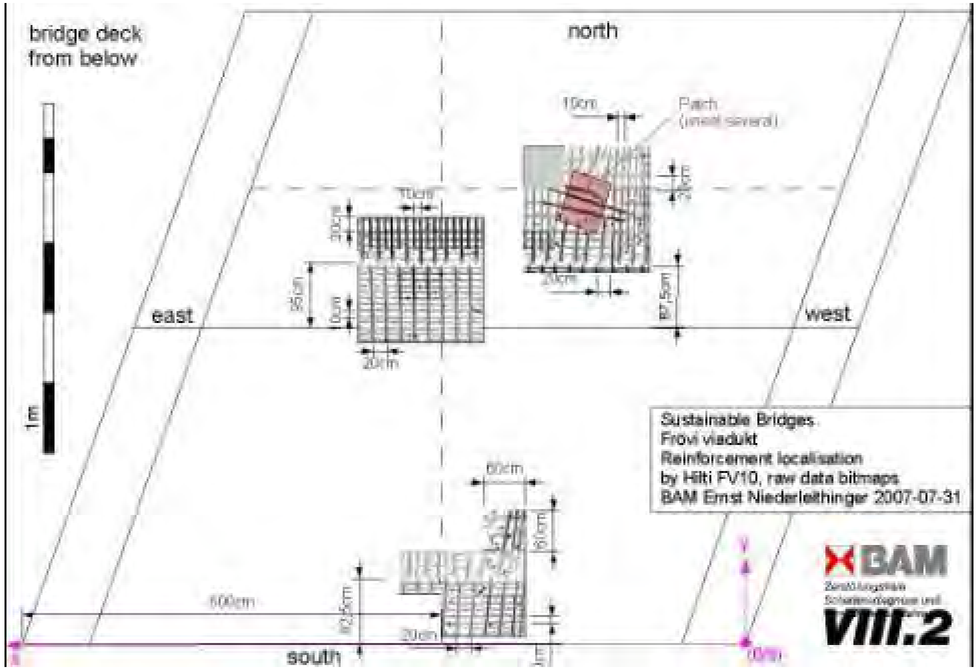
Testing institutes



S4: Detailed evaluation

Frövifors Railway Bridge - 2007

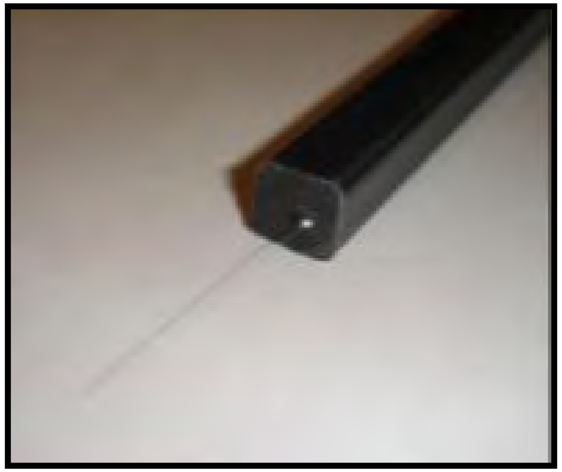
Scanning for steel reinforcement, BAM



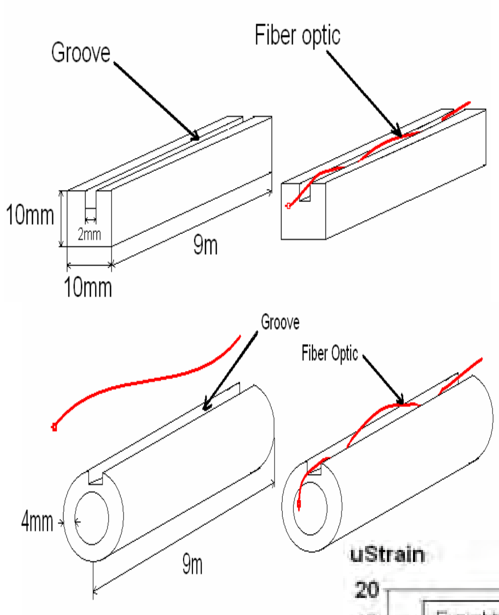
Placement of bottom steel reinforcement

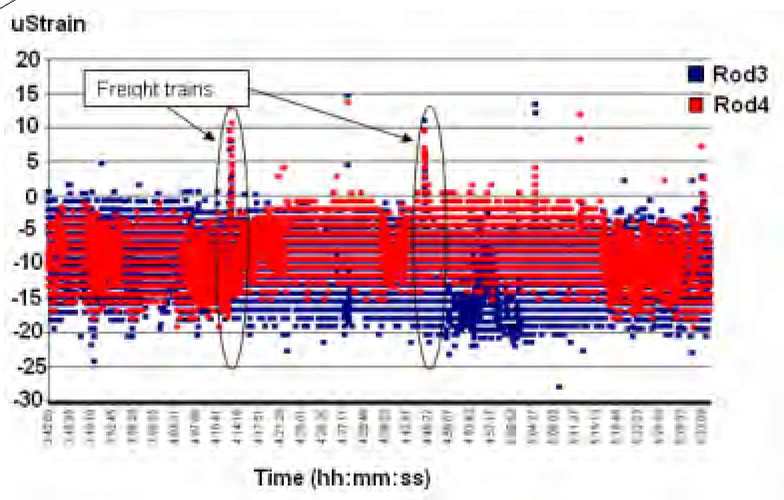
Frövifors Railway Bridge - 2007

Monitoring to assess and to verify



Smart rebar – integrated fibre optic sensors





Frövifors Railway Bridge - 2007

CFRP tubes | NSMR rods

Conclusion

- The need of maintenance, repair and upgrading is expected to increase
- Increased need to understand behaviour and performance
- Focus on technology that extend the life
- Cost effective methods, not disturbing ongoing activities
- Different methods for different applications - toolbox
- Increased focus on the service limit state

Statens vegvesen

Norwegian Public Roads Administration

Concrete Surface Protection Systems Results from Field Test Projects

Eva Rodum and Claus K. Larsen
Tunnel- and Concrete division, NPRA

NVF, Annual Bridge Conference, 2010-09-01--02, Oslo, Norway

Introduction

- NPRA owns and manages more than 17,000 bridges
- There are about 400 long concrete bridges in harsh marine climate along the Norwegian coast
- The main deterioration mechanism is chloride induced corrosion
- Bridges are designed for 100 years service-life, which assumes systematic maintenance
- Surface protection is one option which may be relevant in order to secure the designed service-life and/or reduce the maintenance/repair costs

Introduction (cont)

- Surface protection systems perform basically well in laboratory tests
- There is a need for on-site experience to reveal the “true” in-service performance and effect of the different product categories on the chloride ingress
- The objective of the field testing is two-folded:
  - Compare the chloride retarding effect of various types of products
  - Identify which parameters that may be critical for the long term effect of the products

Some of the results are published, others are preliminary

Field test projects - type of products

- Two of the three different product types ("methods") defined in EN 1504-2 are included in the tests
  - Hydrophobic impregnations (HI)
  - Coatings

i.e. silanes, siloxanes

i.e. cement based coatings

Field test projects – measurements

- Chloride ingress (main parameter)
- Depth of penetration of hydrophobic impregnations
- Bond strength of coatings

Skarnsundet bridge

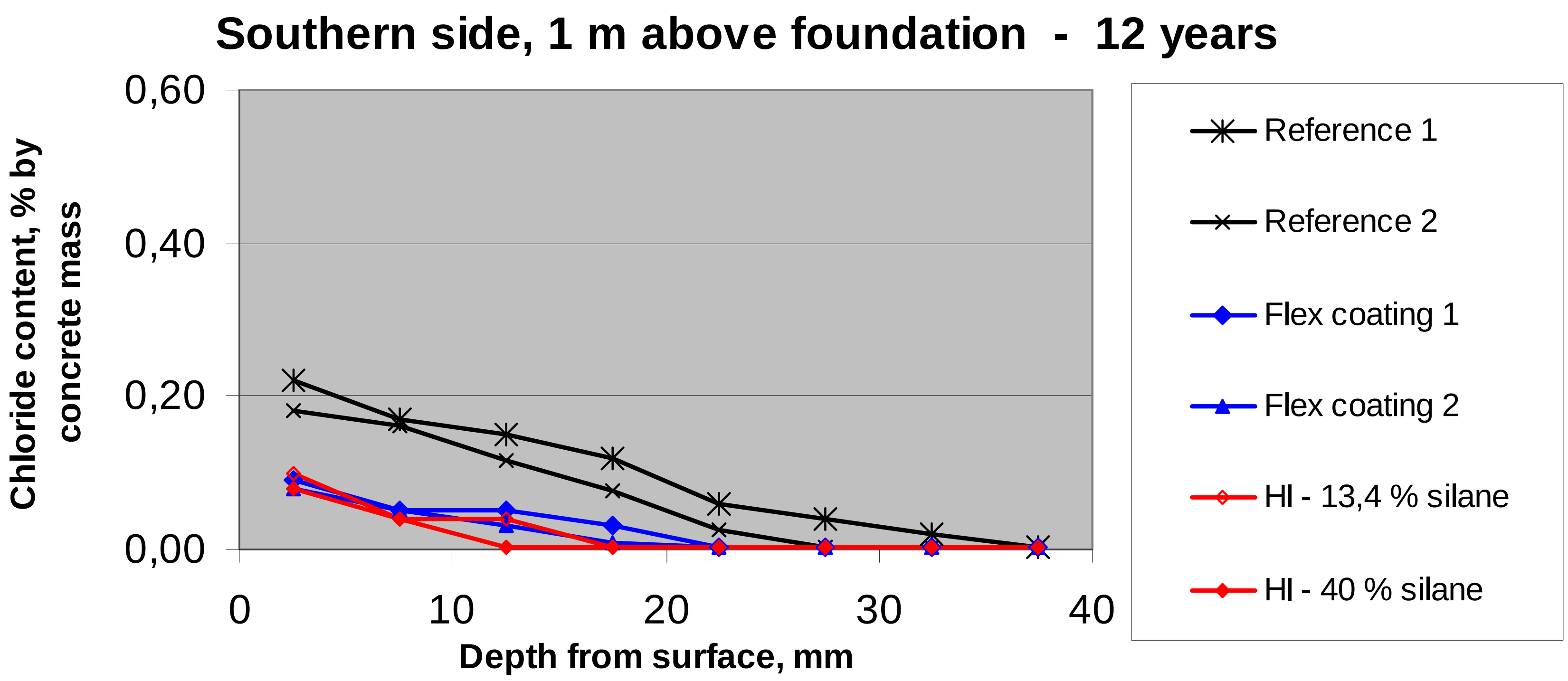
- Build: 1990
- Concrete quality: w/b ratio 0.40
- Test project started: 1993
- One tower, lower areas

Skarnsundet bridge – test project 1993

- Products
  - Two HI (13% and 40% silane in white spirit)
  - Two flexible cement based coatings
  - Several paintings and non-flexible cement based coatings

- Examined after 1-5 and 12 years

Skarnsundet bridge



- Depth of penetration not measurable

- The bond strength of all coatings is in general satisfactory after 12 years
- Local damages in the coatings (e.g. cracks) have however caused total loss of bond

Quay Sjursøya

- Build in 1960
- Repaired in 1999 due to extensive reinforcement corrosion

Quay Sjursøya*) – repaired and surface treated in 1999

- Shotcrete on the bottom side of the deck (mainly wet sprayed)
- Ordinarily concrete in beams
- w/b ratio 0.40 (theoretical!)

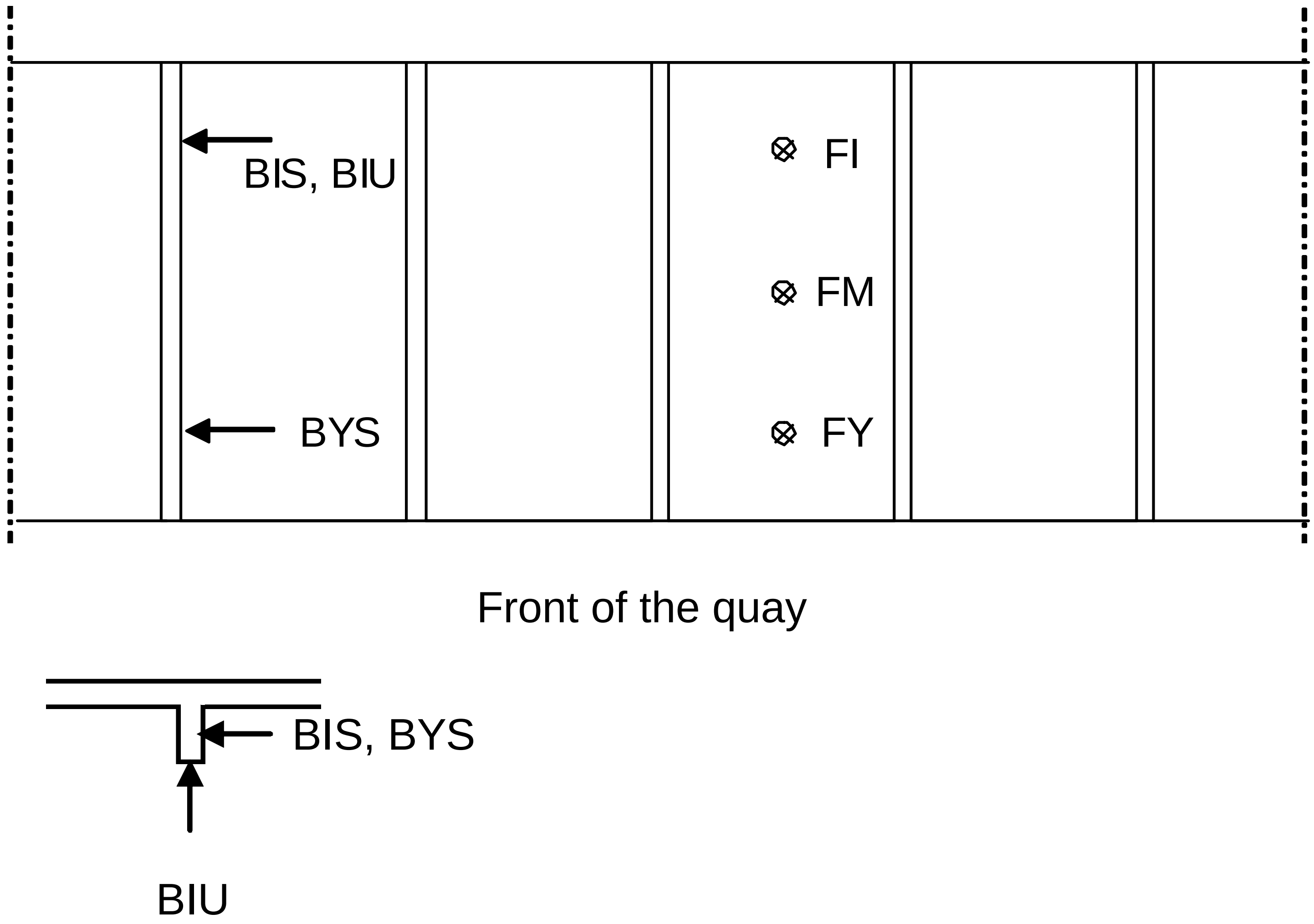
- Products
  - 4 HI 100 % silane (gel, creams and liquid)
  - 4 cement based coatings (3 flexible and 1 non-flexible)

- Products applied a few weeks after concreting
- Examined after 1, 2, 5 and 10 years

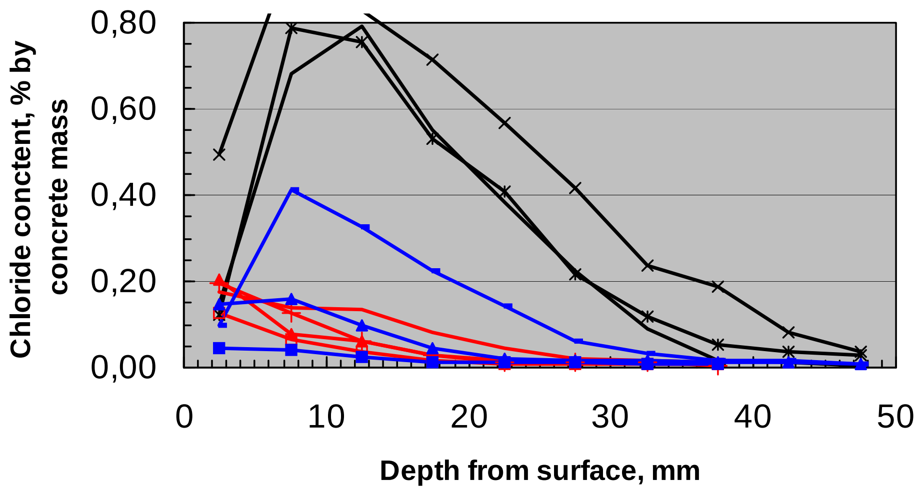
*) Project co-operation between Oslo Havnevesen, Entreprenørservice, Skanska, Stærk & Co, NPRA and NFB

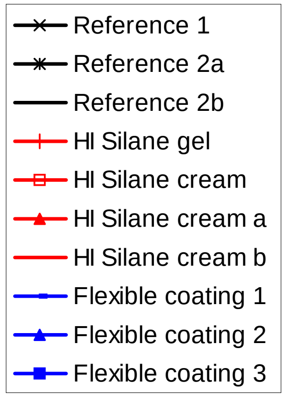
atens vegvesen
rwegian Public Roads Administration

Core locations - each test area



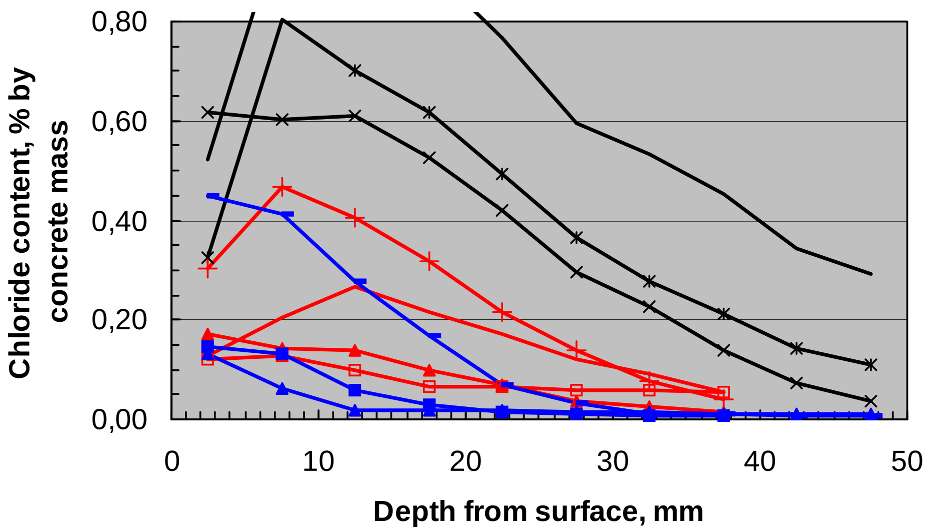
Beams (BIS) - 10 years



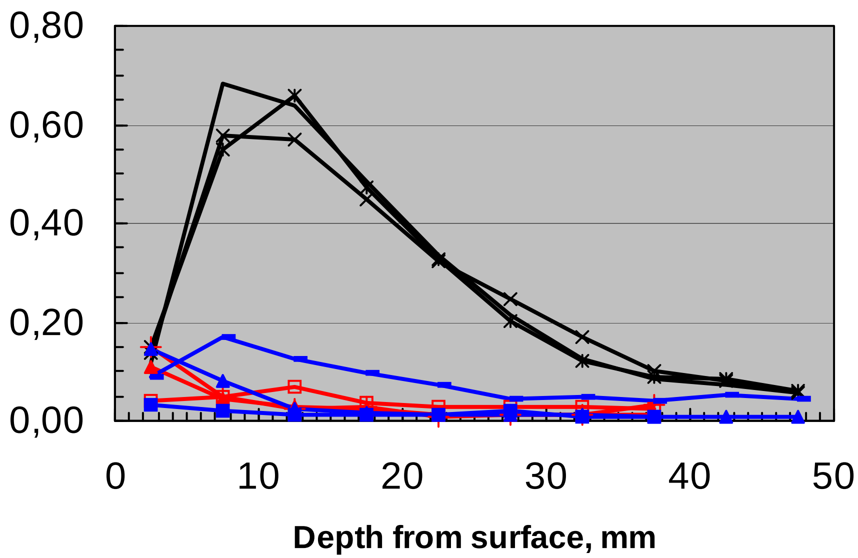


Depth of penetration: 3-6 mm

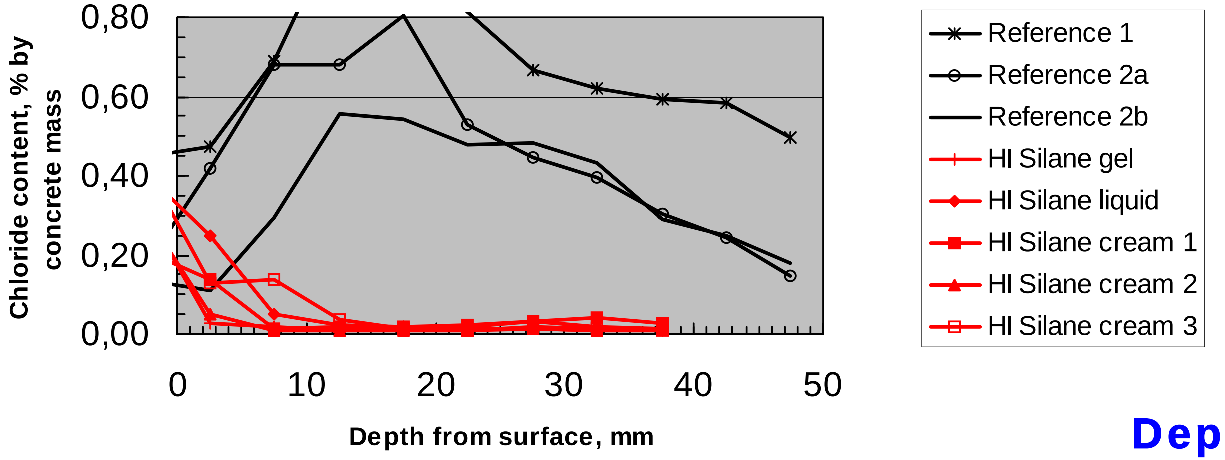
Beams (BIU) - 10 years



Beams (BYS) - 10 years

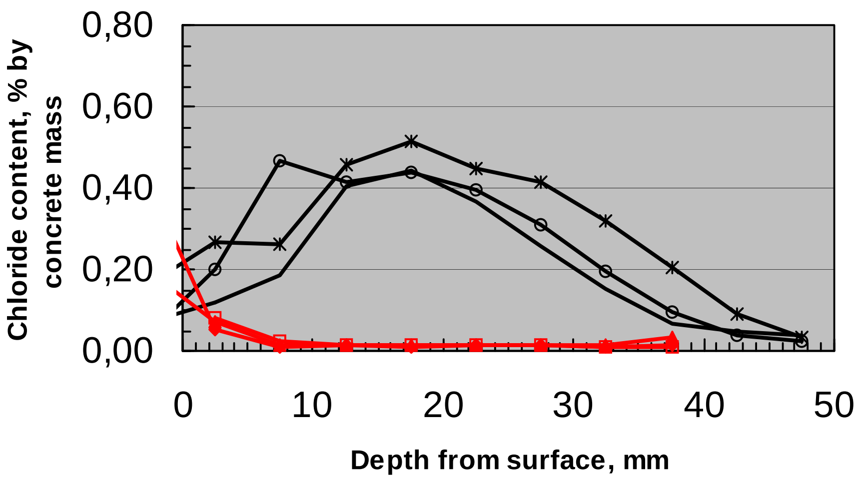


Deck (FI) - 10 years

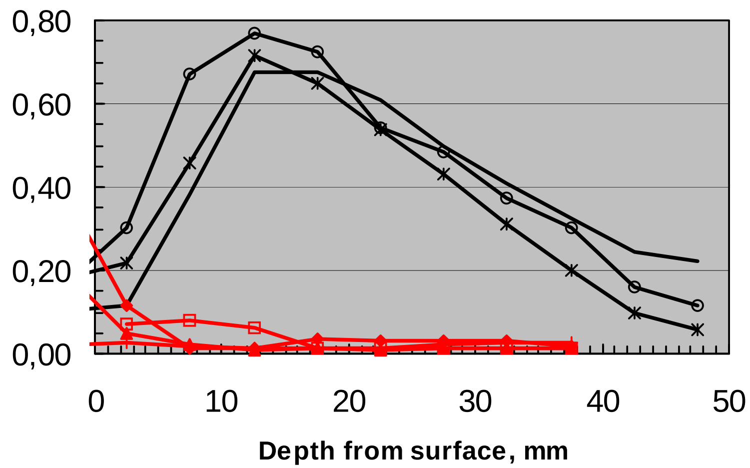


Depth of penetration: 7-15 mm

Deck (FM) - 10 years



Deck (FY) - 10 years



Gimsøystraumen bridge

Gimsøystraumen bridge (slabs - 1995)

- Concrete slabs 500x500x50 mm^3
- w/b ratio 0.40
- Cast and exposed in 1995

- Products: 9 different, among them
  - 2 HI (20 % silane/siloxane and 100 % silane)
  - 1 100 % silane +silane-acrylic topcoat
  - 1 flexible cement based coating

- 4 different surface conditions prior to application:
  - Semi-dry / Wet
  - Sand blasted / Virgin surface
- The slabs are exposed on one of the pillars on the bridge
- Chloride profiles determined after 3, 7 and 10 years

Gimsøystraumen bridge (slabs -95) - 10 years

1: HI (20 % silane/siloxane)

4: HI (100 % silane, liquid)

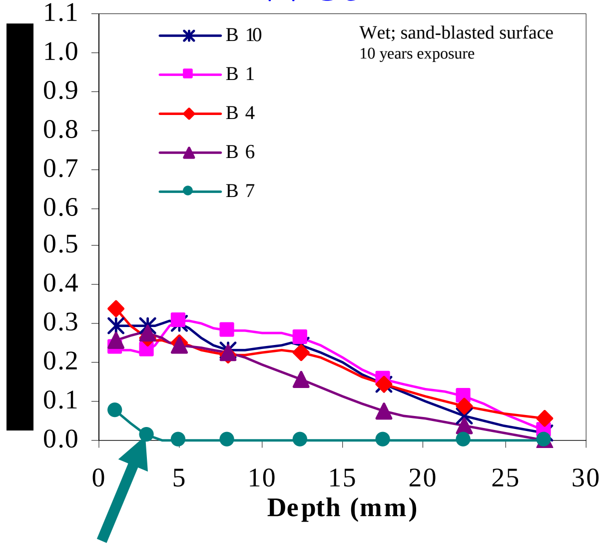
6: Same as 4 - with a silane-acrylic based top-coat

7: Flexible cement-latex-based coating

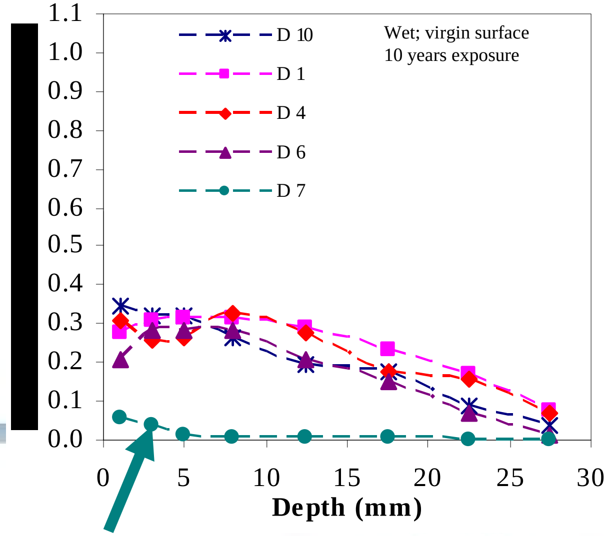
10: Untreated reference

Wet

Sand-blasted



Virgin surface



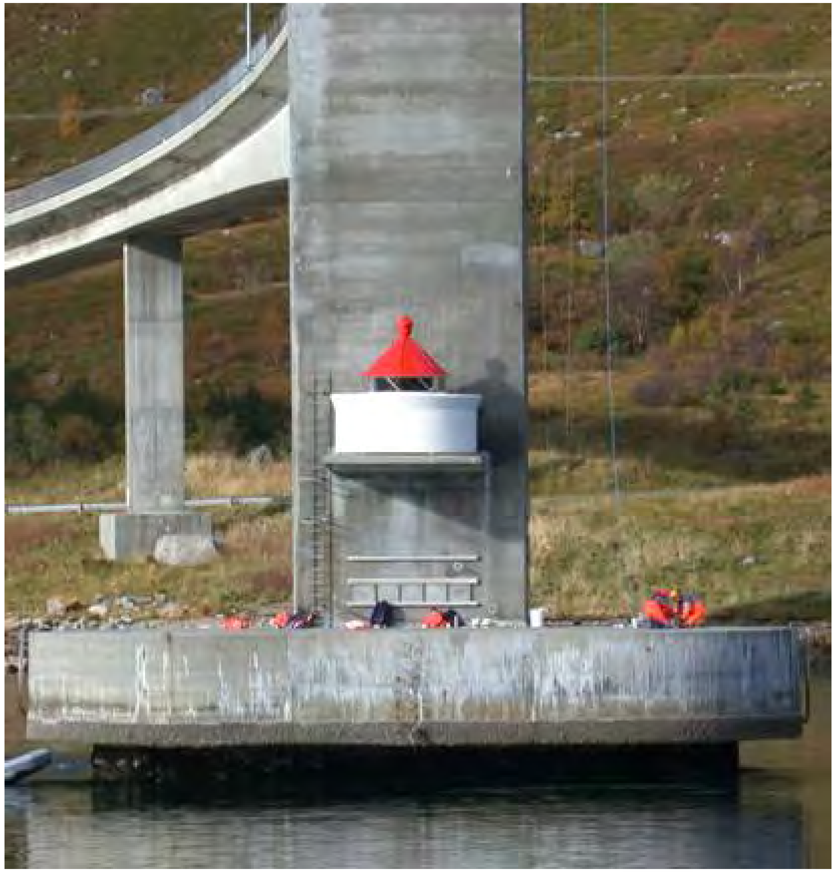
Gimsøystraumen bridge (slabs – 1998)

- Concrete slabs 500 x 500 x 50 mm^3
- w/b ratio 0.40
- Cast in 1995, exposed in 1998

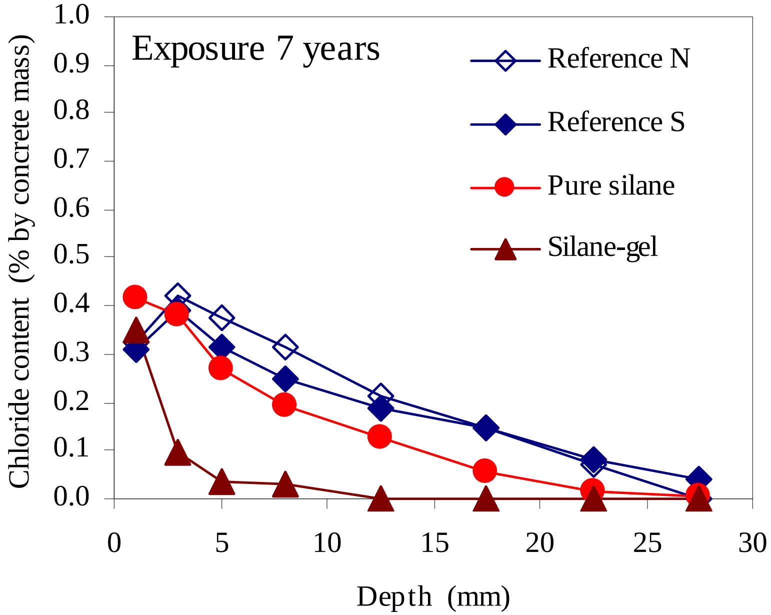
- Products
  - 2 HI (100 % silane, liquid + gel)

- 1 surface condition before treatment:
  - Dry, virgin surface

- Exposed on the same bridge pillar
- Chloride profiles after 1, 4 og 7 years



Gimsøystraumen bridge (slabs -98) - 7 years



100 % silane, liquid

Depth of penetration: 2mm

100 % silane, gel

Depth of penetration: 22mm

Lundevann bridge (edge beams and slabs - 1998)

- Edge beams repaired in 1998
- Concrete slabs 500x300x50 mm^3
- w/b ratio 0.40
- Cast and exposed in 1998

- Products:
  - 2 HI (100 % silane, liquid + gel)
  - 2 flexible cement based coatings

- 4 surface condition before treatment:
  - Virgin / Sandblasted surface
  - With / whitout curing compound

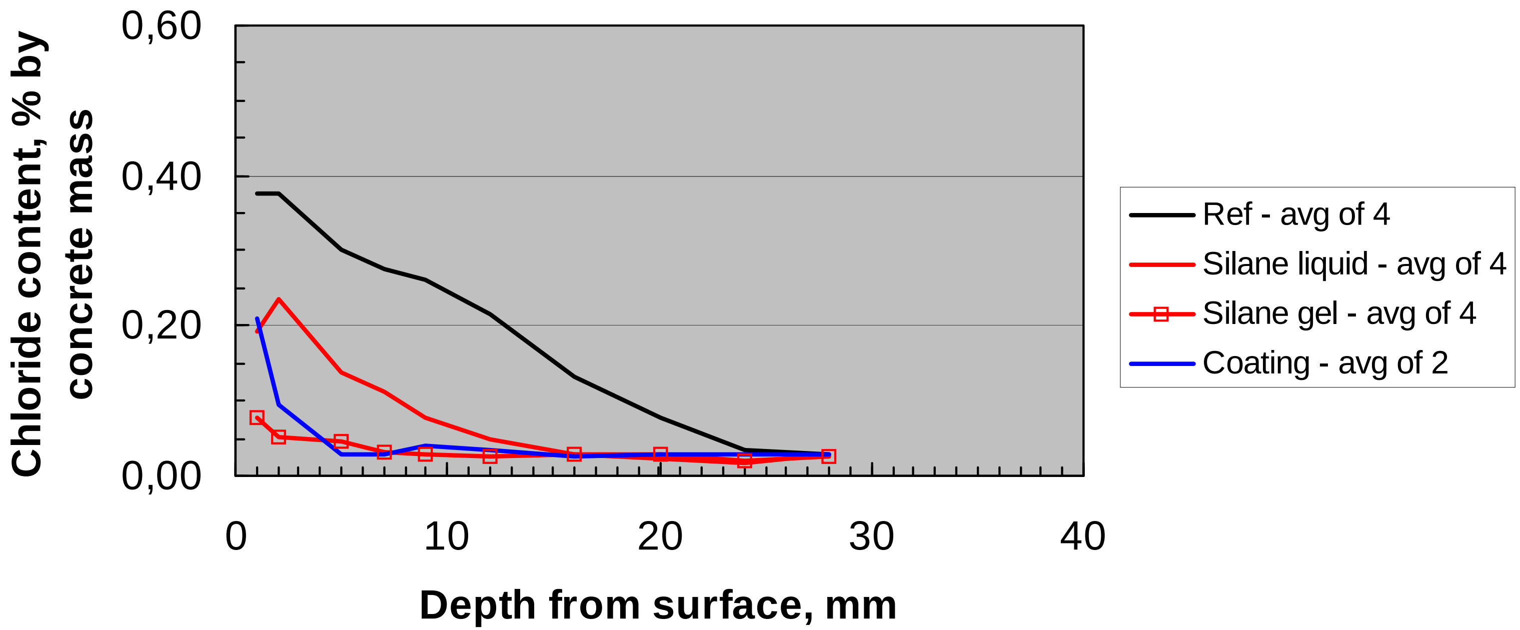
- Deicing salts

- Examinations after 1, 3 and 9 years

Lundevann bridge (beams) - 9 years

Crack-failure for the flexible coatings;
Left: initial stage with cracked coating
Middle: advanced stage with loss of bond adjacent to the crack
Right: final stage with a massive loss of bond originating from the crack

Lundevann bridge (slabs) – 9 years



100% silane, liquid

Depth of penetration: 2 mm

100% silane, gel

Depth of penetration: 9 mm

Summary I

- **Hydrophobic impregnations**
  - Show in several cases considerable reduction in chloride ingress, even after 7-12 years of exposure
  - The effect of hydrophobic impregnation is influenced by the penetration depth
  - Higher w/b ratios leads to higher penetration depths
  - The wetter the concrete substrate is before application, the smaller is the penetration depth
  - Sandblasting prior to application do not lead to increased penetration depths
  - The silane-gel show much larger penetration depths than the liquid silanes

Summary II

- **Flexible cement based coatings**
  - Perform excellent as chloride barriers as long as the coating remains intact
  - Risk of cracking
  - Cracks in the coatings can have a devastating effect on the service-life of a treatment in harsh climates with freeze-thaw actions

Statens vegvesen
Norwegian Public Roads Administration

Experiences from bridges in service used to design new bridges.

Knut A. Grefstad
Norwegian Public Roads Administration

Background information
New bridges

- Approximately 200 new constructions every year
- Bridges (Total length >= 2,5 meters)
- Pipes (Diameter >= 2,5 meters)
- Culverts (Span >= 2,5 meters)
- Constructed tunnels (cut an cover, tunnel portals, submerged tunnels etc)
- Retaining walls higher than 5 meters
- Ferry quays and landing ramps

Background information
Old bridges

- Strengthening
- Reconstruction (Widening, pedestrian lanes etc)
- Change in loads (Classification, application of membrane and asphalt etc)
- If damages that could influence the load bearing capacity are discovered

Approval process

- New constructions
- Old constructions if the construction bearing capacity is affected
- Guideline HB: 185 Bridge design regulates the approval process
- The Directorate of Public roads (the central office in NPRA) has the authority to approve nationally owned bridges
- The local Counties have the formal authority to approve bridges owned by the counties but this responsibility has been delegated to the relevant Region office in Norwegian Public Roads Administration
- The Directorate of Public roads (the central office in NPRA) usually administrate the approval process also for the bridges owned by the local Counties but does not have the authority to approve so approval is only recomended

Approval process

- Private consultants
- In house staff
- The formal approval or recommendation of approval has to be given from NPRA
- In addition, all the design drawings are checked by in house bridge maintenance personnel in order to assure access for inspection and maintenance and to reduce future maintenance costs as much as possible

Maintenance check

- Bridge level, directly affecting each bridge
- Implementation of new guidelines
- Need to improve guidelines

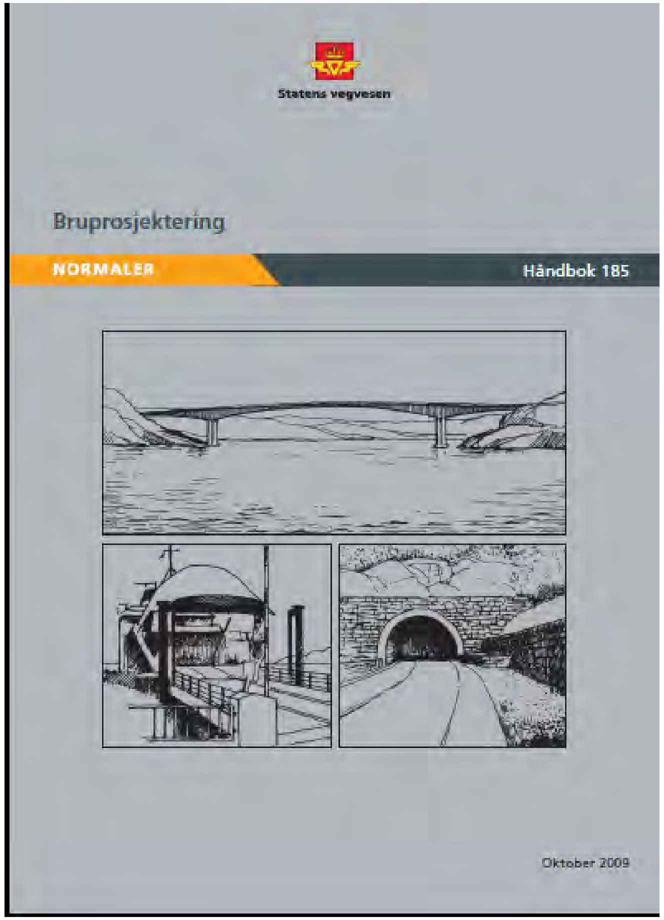
Maintenance check, important factors

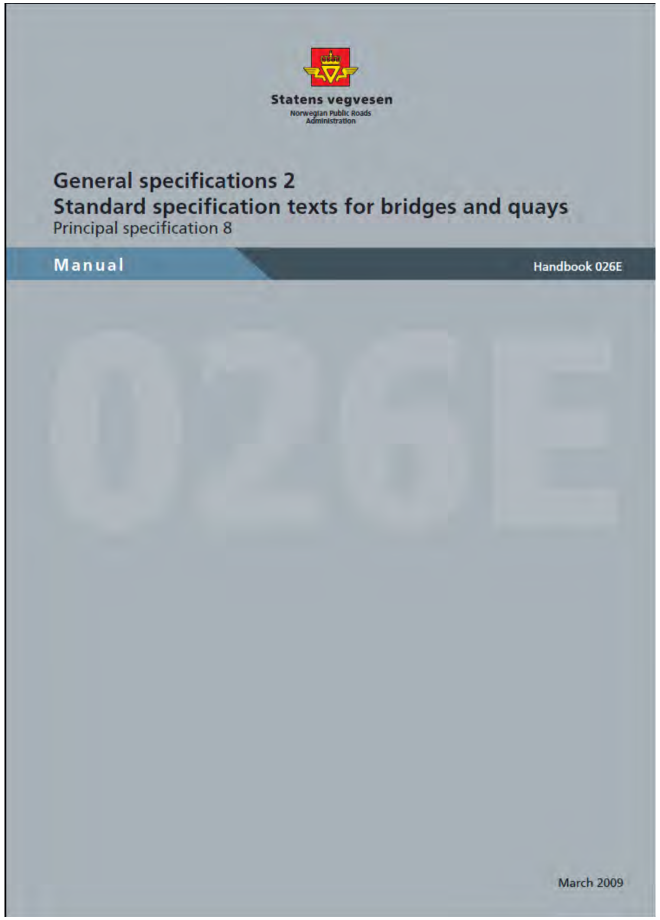
- Maintenance costs
  - Concrete members 40 %
  - Steel members 20 %
  - Wearing course and water tight membranes %
  - Bridge equipment 25 %
- Traffic regulations
- Traffic costs
- Health, Environment and Safety aspects (HMS)

Maintenance check, important elements

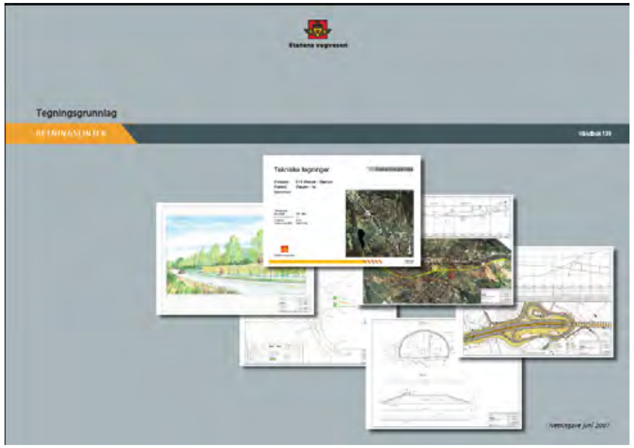
- Documentation
- Geometry, details
  - Width of the bridge deck
  - Abutments, keeping water away
  - Access
- Static system (Affecting bearings and joint constructions)
- Materials
  - Concrete cover and quality
  - Corrosion protection of steel members and partly cast-in steel
  - Waterproofing systems
- Bridge equipment
  - Construction joints, bearings, parapets, drains
- Safety aspects
  - User safety, construction safety

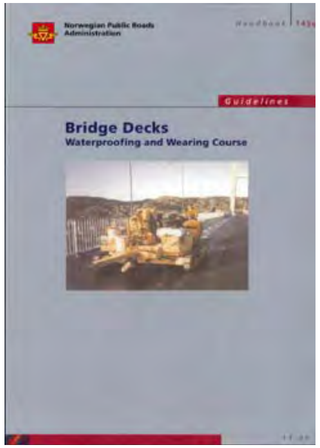
Important Guidelines



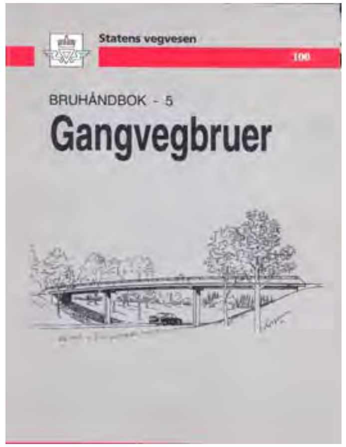


Helpful Guidelines





Guidelines, not up to date but still existing.



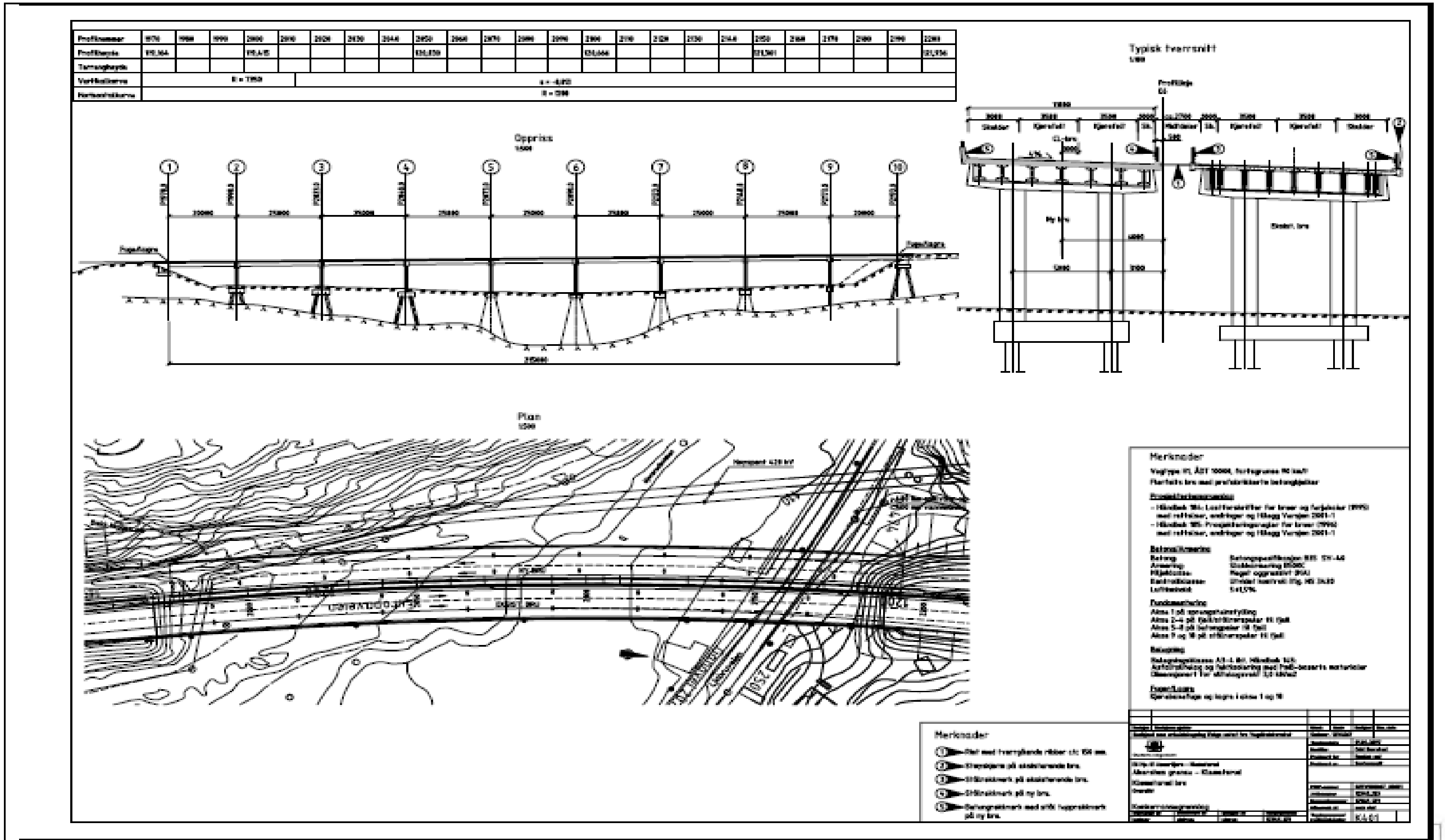
Documentation

- Handbook 185: Bridge design gives the overall regulations
  - Design aproval process
  - Design calculations
  - Design drawings (HB 139)
    - Overview drawing
    - Ground works
    - Construction elements
    - Waterproofing system
    - Supporting bearing system
    - Bridge equipment
  - Material lists
  - Inspection and maintenance plan
  - “As built” documentation

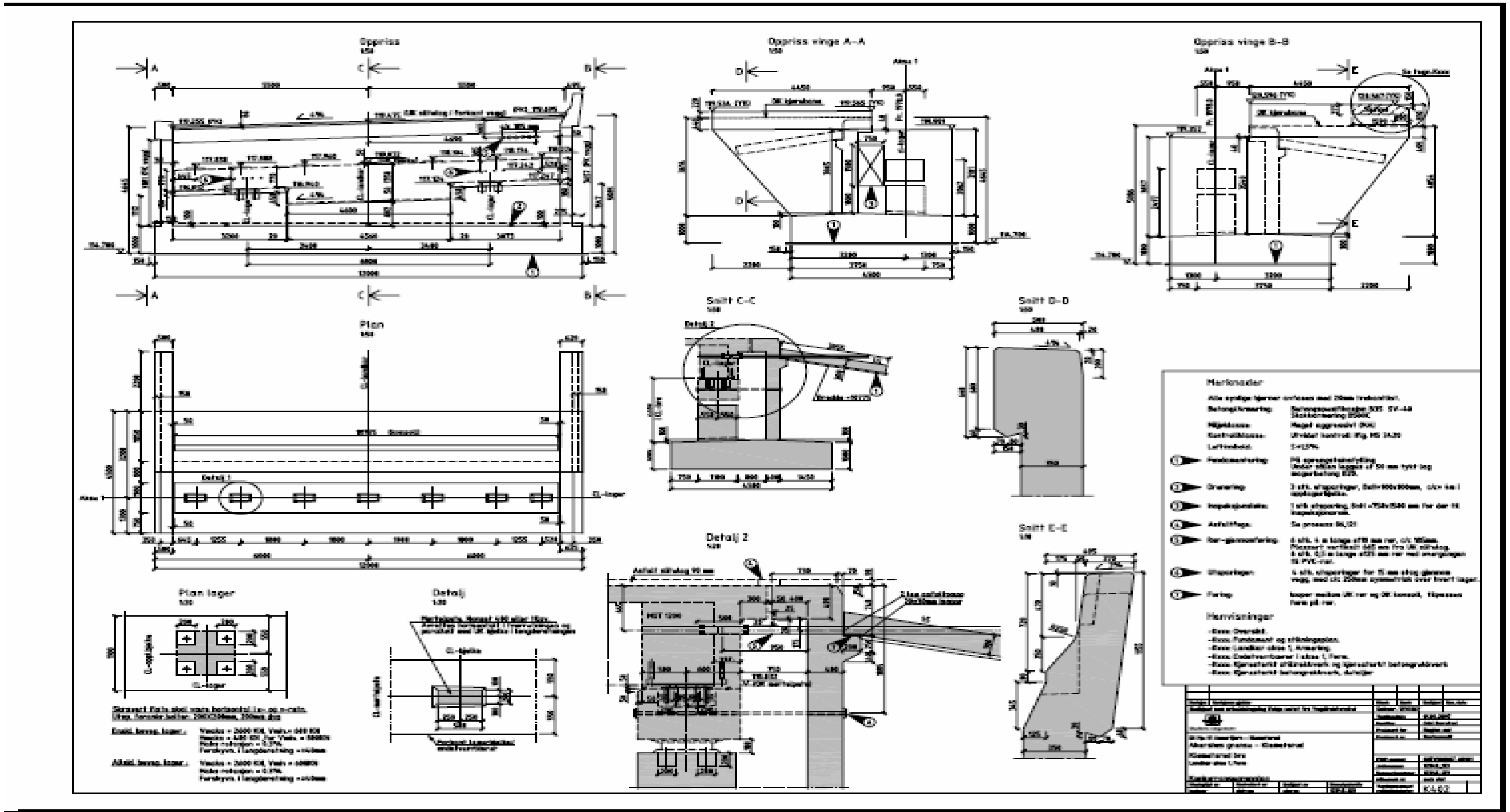
Documentation

- Detailing level
  - All the information necessary to build and operate the structure should be available from the design drawings
- Important information for the future service phase must be available from the drawings

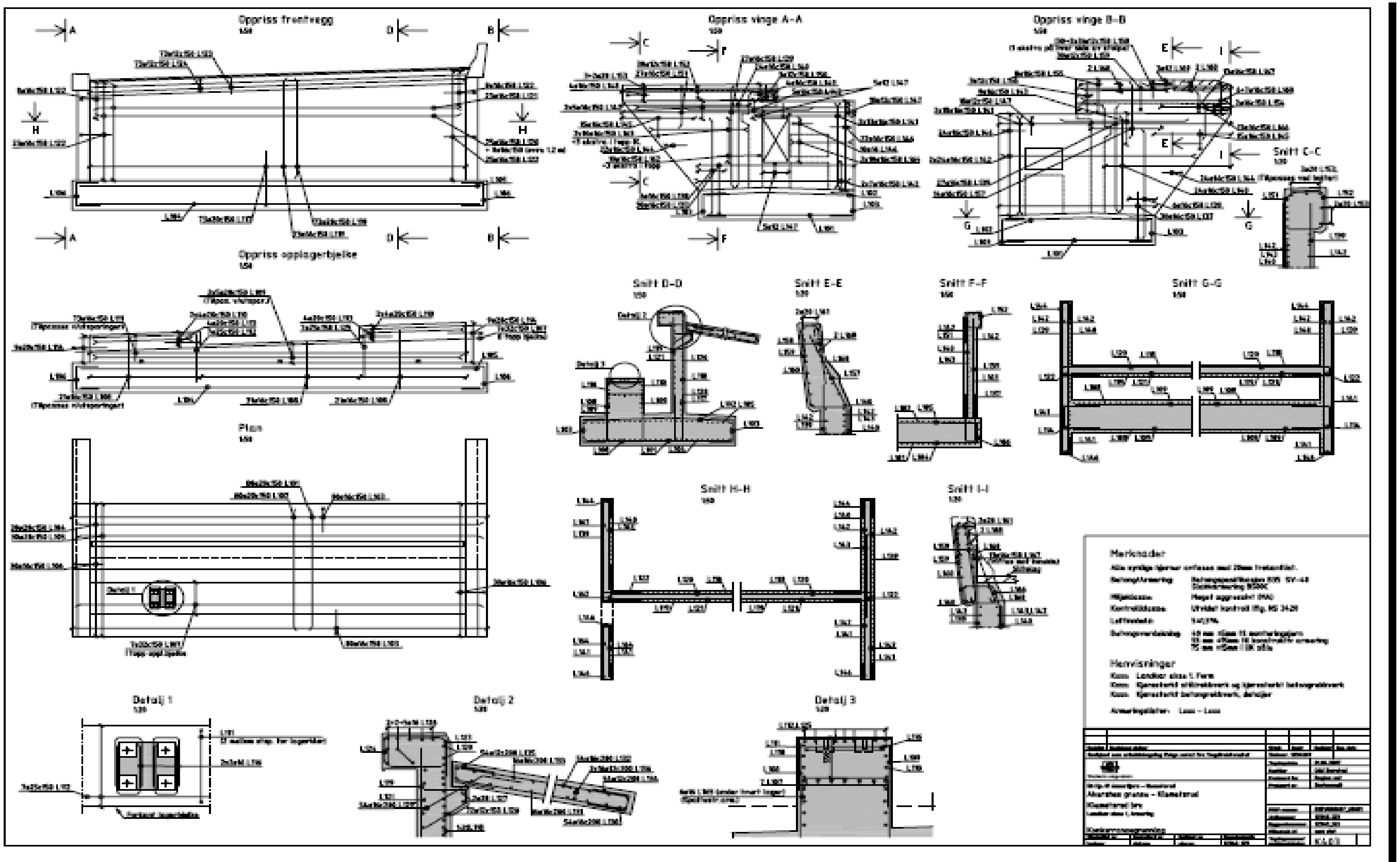
Documentation



Documentation



Documentation



Geometry

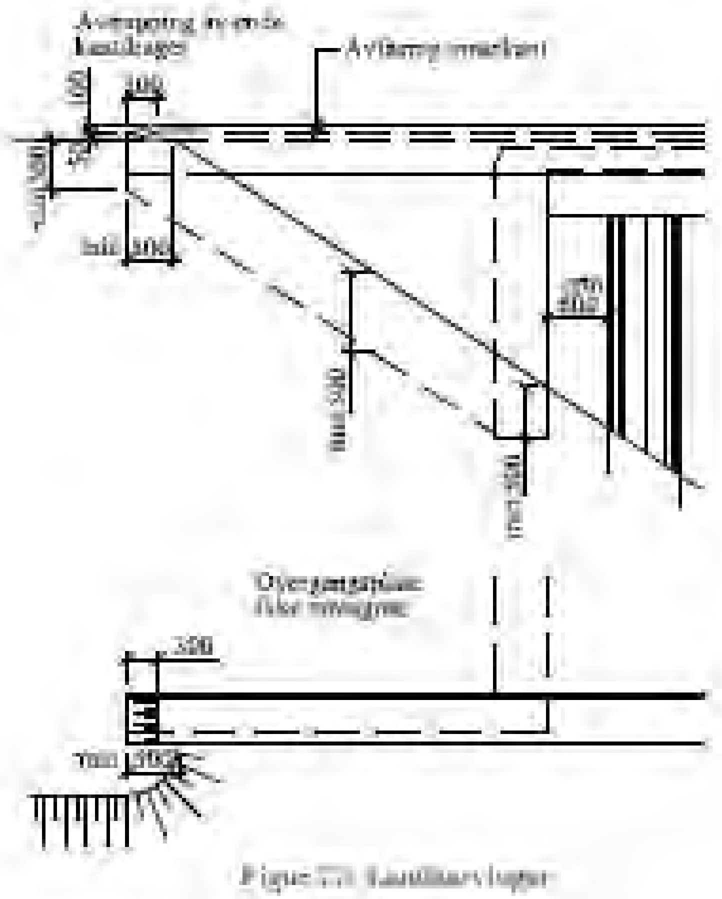
- How to inspect and maintain and satisfy the traffic demands at the same time?
- Building costs are not proportional with material quantity !!!!!!!!!!

Geometry

- Keeping water away

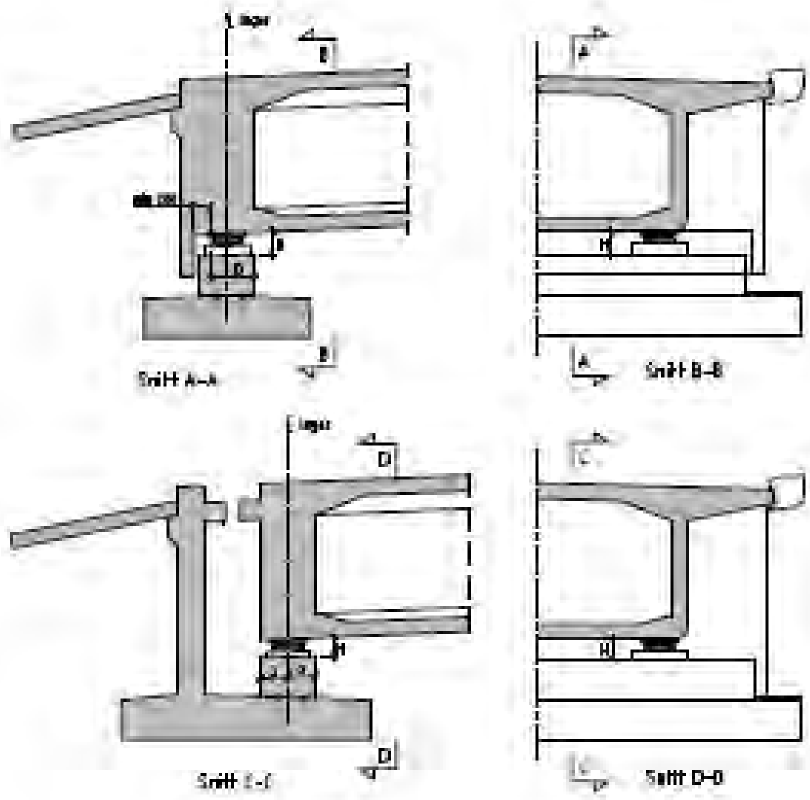
Geometry

- Jointless bridges



Geometry

- Abutments



Geometry

- Abutments

Static system

- No joint construction if possible
- If necessary, only one joint construction is generally allowed
- Demand for bearings between the superstructure and substructure if the foundation could experience vertical settlement
- As few bearings as possible both in the longitudinal and the cross direction

Materials

- Concrete

Materials

- Concrete
  - Concrete quality
  - Concrete cover
  - Fixing bars
  - Tolerances
    - +/- 5 mm for Fixing bars
    - +/- 15 mm for constructive bars

Tabell 30: Minimumsoverdekning

Eksponeringsklasse iht. NS 3473	Eksponeringsforhold, produksjonsmetode, konstruksjonstyper, osv.	Minimumsoverdekning* [mm]
XSA	Konstruksjoner – utsatt for kjemiske angrep f.eks. ved kontakt med særlig aggressive kjemikalier – i alunskifer eller sterkt sulfatholdig grunnvann	Fastsettes særskilt
XS2	Undervannsstøp (for betongstøp i vann gjelder Norsk Betongforenings publ. nr. 5, jf. pkt. 5.3.7.1.5 (s. 186))	100 (70)
XS3, XF4	I tidevannssonen og skvalpsonen (for slanke søyler kan overdekn. reduseres til 60 (40) mm dersom søylene beskyttes ekstra med membraner, tette belegg, islud, o.l.	100 (70)
XS2	Under tidevannssonen, utført som tørrstøp	60 (40)
XS1	Over tidevannssonen/skvalpsonen til en høyde av minst 6 m i lite utsatte kyststrøk, og til minst 12 m i værharde kyststrøk (høyderegelen gjelder også inn over land der eksponeringsforholdene tilsier det)	60 (40)
XF3, XF4, XD3	Oversiden av brudekker (samme krav for rustfri armering pga. behov for ev. fresing av dekket senere)	60 (60)
Uavh. av eksp.klasse	Konstruksjonsdeler der tilgjengeligheten for inspeksjon og vedlikehold er vanskelig (f.eks. i fugespalter)	60 (40)
	Etterfølgende krav knyttet til bruk av tinesalt gjelder også dersom framtidig bruk av tinesalt kan bli aktuelt:	
XF2, XF4, XD3	Pilarer nær saltet vegbane utsatt for saltsprut/-tåke (inklusive fundament og del av søyle under terreng)	60 (40)
XD1, XF2	Konstruksjonsdeler utsatt for saltsprut og fuktighet hvor avvasking fra regnvær normalt ikke finner sted (f.eks. indre del av vegger i kulverter, tunnelportaler, miljøtunneler, etc. fra 2 m over vegbanen til uk fund.)	60 (40)
XF2, XF4, XD3	Når brudekket saltes: Innerkant kantdragere/betongrekkverk. Sidekant brudekke og ytterste 2 m av uk bruplate for bruer uten kantdrager/betongrekkverk	60 (40)
XF2, XF4, XD2	Innside av vinger og frontvegger på landkar, inkl. endebjelker og vinger på landkarløse bruer, når det saltes	60 (40)
XF2, XF4, XD3	Arealer under fugekonstruksjon som vil bli utsatt for saltholdig lekkasjevann	60 (40)
XC2, XC3, XC4 XF1, XF3 XA1, XA2	Alle øvrige flater	40 (25)
XC1	Mot tørre og tilgjengelige hulrom, f.eks. i kassetverrsnitt og søyler, samt mot sparerør	30 (15)

*Overdekningsverdier i parentes gjelder for rustfri armering

Materials

- Corrosion protection of steel members
  - Duplex system:
    100 my sprayed zinc
    Three layer paint system based on Epoxy and Polyurethane
  - Hot dip galvanized steel
  - Stainless steel has to be used for partly cast-in steel for connections to parapets etc.

Materials

- Waterproofing systems

Water proofing systems

Relevant pavement types for new bridges are divided into the following classes:

A 1 Asphalt wearing course directly on the bridge deck

A 2 Asphalt wearing course with simplified bridge deck waterproofing

A 3 Asphalt wearing course with full bridge deck waterproofing

B 1 Concrete wearing course cast monolithic with the structural concrete

B 2 Concrete overlay wearing course bonded to the structural concrete

Water proofing systems

Table 1 Recommended Pavement Design Loads for Concrete and Steel Bridge Decks

AADT	Span Length Range (m)			
	l < 10	10 < l < 35	35 < l < 200	l > 200
< 2000	5.0 kN/m² (200 mm)	2.5 kN/m² (100 mm)	2.0 kN/m² (80 mm)	2.0 kN/m² (80 mm)
≥ 2000		3.0 kN/m² (120 mm)	2.5 kN/m² (100 mm)	2.0 kN/m² (80 mm)

Water proofing systems

Table 2 Selection of Pavement Classes

Wear from Studded Tires	Salting in Winter Maintenance	AADT (Design Volume)	Conventionally Reinforced Concrete Bridge Deck	Pre-stressed Bridge Deck and Steel Bridge with Concrete Deck	Steel Decks
Little Wear	No Salting	< 1000	A1 A2 B1 $\geq$ 30 mm[1] B2 $\geq$ 60 mm[1]	A2 A3 B1 $\geq$ 30 mm[1] B2 $\geq$ 60 mm[1]	A3
	Limited Salting	< 2000	A2 A3 B1 $\geq$ 30 mm[1] B2 $\geq$ 60 mm[1]	A3 B1 $\geq$ 30 mm[1]	
Extensive Wear	Heavy Salting	$\geq$ 2000	A3 B1 $\geq$ 40 mm[1,2] B2 $\geq$ 60 mm[1,2]	A3	

[1] mm indicates concrete wearing course thickness

Water proofing system

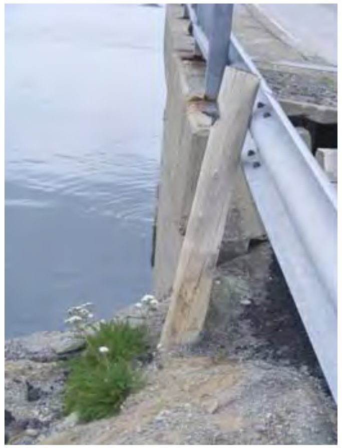
3.3.4 A3-4 Waterproofing with PmB-based Materials

The pavement is designed in the following manner (normal values):

Layer	Type	Thickness mm	Weight kg/m^2
Waterproofing	Tack Coat PmBE60, Sanded with Fine Sand 0.5-1.5 mm		0.3 - 0.5 1 - 2
	Topeka 4S	12±3	26.5±6.5
Levelling Layer (as needed)	Asphalt Concrete, Asphalt Gravel Concrete	-	-
Wearing Course	Topeka, Stone Mastic Asphalt, Asphalt Concrete	> 40	> 100
Sum		> 52	> 130

Pavement type A3-4 is equivalent to the three previously mentioned pavement types with regard to waterproofing effectiveness.

Bridge equipment



Safety aspects

- Erosion
- Vehicle hits, ship collisions
- Risk and consequences of fires
- Dangerous areas for public access
- Parapet design
  - Change-over from bridge to road, endings etc
- Risk and consequences of downfall (ice, gravel etc)

ETSI, Life Cycle Optimization for Bridges

Matti Piispanen

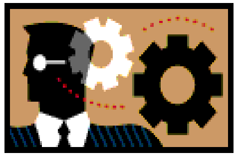
Road and Bridge Engineering

Finnish Transport Agency

NVF Annual Bridge Conference 2010
1.9.2090 Oslo

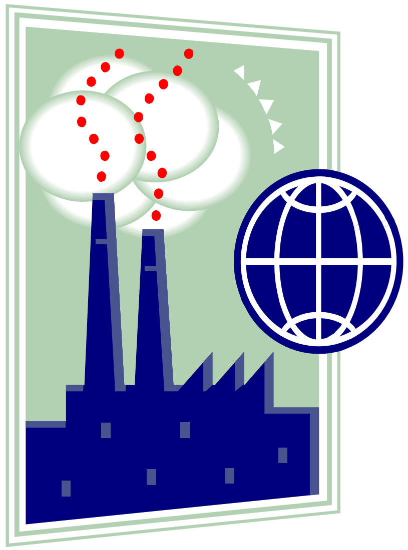
Elinkaareltaan Tarkoituksenmukainen Silta

(Bridge with optimized Life Cycle)



Compromise

LCC



LCA

"LC Culture"

ETSI -project 2004-2007-2009-2011

BRIDGE LIFE CYCLE OPTIMISATION

stage 1 2 3

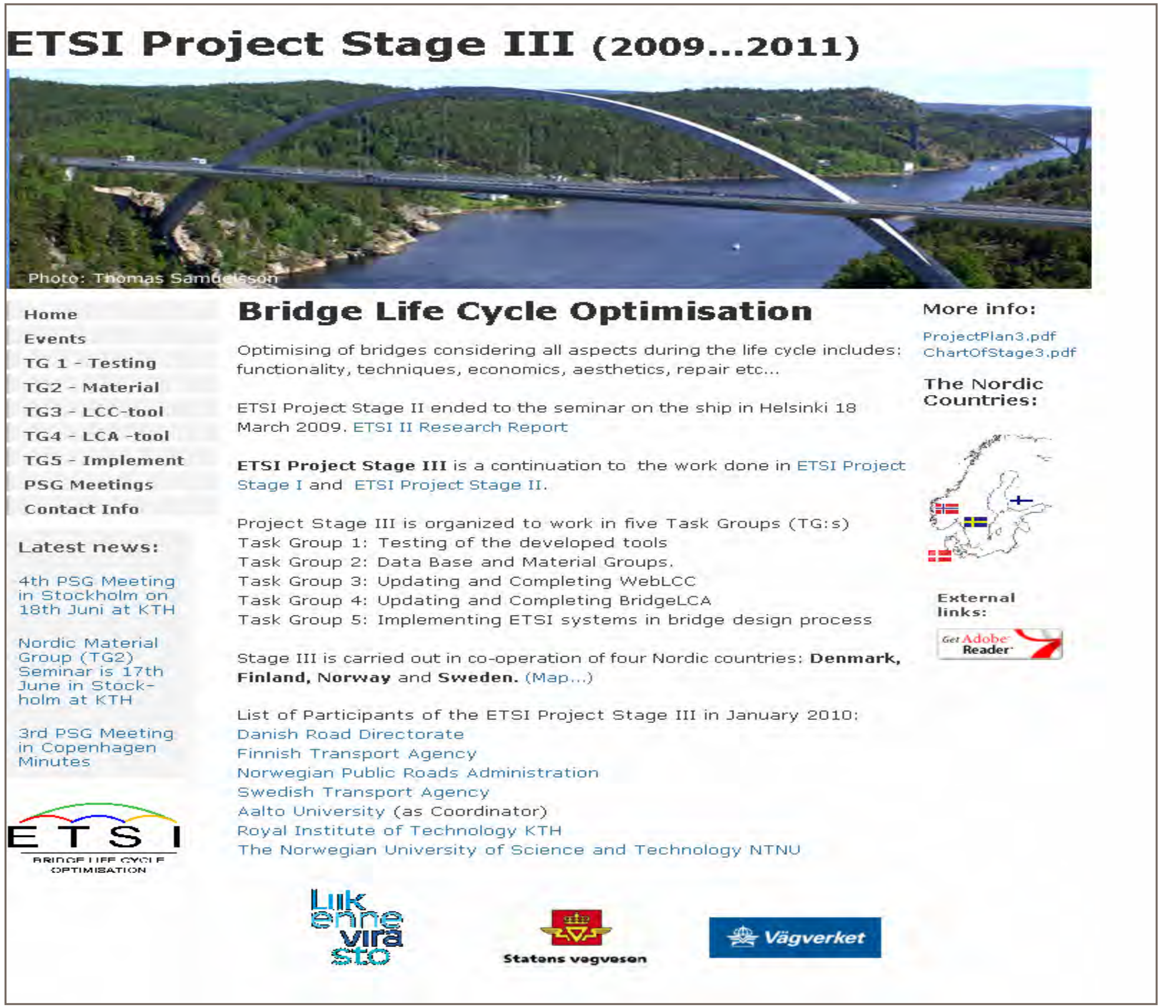
Inter Nordic project to develop methodology and tools for life cycle analysis

TRAFIKVERKET · Statens vegvesen · Liikennevirasto · Vejdirektoratet · KTH · NTNU · Aalto University · COWI

1. LCC -tool, Sweden, under development
2. LCA -tool, Norway, under development (Denmark)
3. LC culture -evaluation method, Finland, ready
4. ETSI-3, common data-base and SAAS? interface (safety?)

More Information:

http://www.tkk.fi/Yksikot/Silta/Etsiwww3/index.html



ETSI Project Stage III (2009...2011)

Photo: Thomas Samuelsson

- Home
- Events
- TG 1 - Testing
- TG2 - Material
- TG3 - LCC-tool
- TG4 - LCA -tool
- TG5 - Implement
- PSG Meetings
- Contact Info

Latest news:

4th PSG Meeting in Stockholm on 18th Juni at KTH

Nordic Material Group (TG2) Seminar is 17th June in Stock-holm at KTH

3rd PSG Meeting in Copenhagen Minutes

ETSI BRIDGE LIFE CYCLE OPTIMISATION

Bridge Life Cycle Optimisation

Optimising of bridges considering all aspects during the life cycle includes: functionality, techniques, economics, aesthetics, repair etc...

ETSI Project Stage II ended to the seminar on the ship in Helsinki 18 March 2009. ETSI II Research Report

ETSI Project Stage III is a continuation to the work done in ETSI Project Stage I and ETSI Project Stage II.

Project Stage III is organized to work in five Task Groups (TG:s)
Task Group 1: Testing of the developed tools
Task Group 2: Data Base and Material Groups.
Task Group 3: Updating and Completing WebLCC
Task Group 4: Updating and Completing BridgeLCA
Task Group 5: Implementing ETSI systems in bridge design process

Stage III is carried out in co-operation of four Nordic countries: **Denmark, Finland, Norway** and **Sweden.** (Map...)

List of Participants of the ETSI Project Stage III in January 2010:
Danish Road Directorate
Finnish Transport Agency
Norwegian Public Roads Administration
Swedish Transport Agency
Aalto University (as Coordinator)
Royal Institute of Technology KTH
The Norwegian University of Science and Technology NTNU

Liikennevirasto · Statens vegvesen · Vägverket

More info:

ProjectPlan3.pdf
ChartOfStage3.pdf

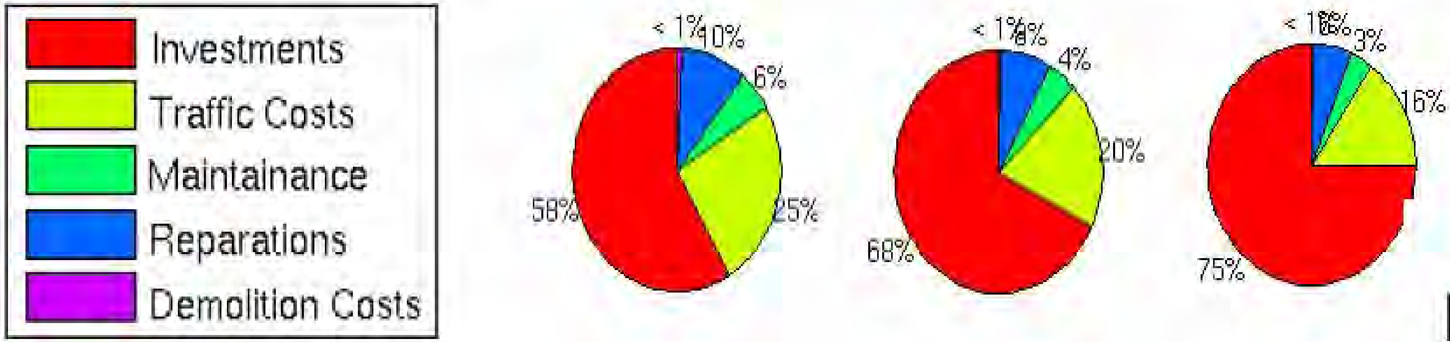
The Nordic Countries:

External links:

Get Adobe Reader

Mälkiä Canal Bridge, LCC

	Interest Rate		
	2 %	3 %	4 %
Investments Costs €	7.380.000	7.380.000	7.380.000
Maintanence Costs €	720.000	489.000	345.000
Repair Costs €	1.270.000	854.000	597.000
Traffic Costs €	3.157.000	2.133.000	1.533.000
Demolition Costs €	102.000	38.000	15.000
∑ Present Value €	12.629.000	10.895.000	9.870.000



ETSI
BRIDGE LIFE CYCLE OPTIMISATION

Mälkiä Canal Bridge, LCA

Total emissions		Mälkiä Canal Bridge	Impact per Bridge Square meter	Steel Girder Composite Bridge	Impact per Bridge Square meter
ADP	kg Sb eq	43 045,0	9,38	943,1	4,42
AP	kg SO2 eq	38 100,7	8,30	449,5	2,11
EP	kg PO4--- eq	7 931,4	1,73	77,3	0,36
GWP	kg CO2 eq	4 992 703,1	1 087,56	119 479,4	560,12
ODP	kg CFC-11 eq	0,6716	0,00	0,0144	0,00
POCP	kg C2H4	1 520,2	0,33	33,5	0,16

ETSI
BRIDGE LIFE CYCLE OPTIMISATION

LC Culture, Coefficient for Aesthetics

$$C_{rel} = k_{rel} C_{LCC}$$

$$k_{rel} = 1 - a \frac{\sum_{i=1}^{n} w_i p_i}{\sum_{i=1}^{n} w_i p_{i\max}}$$

Category	Explanation
- 2	Poor
- 1	Modest
0	Medium
+ 1	Good
+ 2	Excellent

Item	Class I		Class II		Class III	
	p_i	w_i	p_i	w_i	p_i	w_i
Integration between the bridge and the site		6		4		2
Horizontal and vertical geometry		3		2		1
Superstructure		(9)		(7)		(4)
- harmony of spans		2		2		1
- type and shape		4		3		2
- simplicity, slenderness and transparency		3		2		1
Abutments		(4)		(3)		(3)
- placement		2		1		1
- shape		1		1		1
- visible size		1		1		1
Columns, piers and pylons		(4)		(3)		(2)
- placement		1		1		1
- shape		3		2		1
Railings		2		2		1
Embellishments, surface colours and textures		2		2		1
Lighting		2		2		1
Σ		(32)		(25)		(15)

Class I	The bridge site is most demanding considering the landscape or city view.
Class II	The bridge site is demanding considering the landscape or city view.
Class III	The bridge site is conspicuous considering the landscape or city view.
Class IV	The bridge site is ordinary considering the landscape or city view.

Impact on Future Bridges

Material changes

•More LCA -friendly wood bridges?

•Impact of 100 years of maintenance into material choices and surface treatments

•Use of surface treatments and protective layers to postpone / prevent repairs

Impacts from Bridge Site

•Aesthetical and other cultural values

•Transport issues

•Traffic issues (next page)

Alas, better optimized bridges regarding life cycle costs, environmental impacts and cultural values!

Liikennevirasto

New Ideas for Bridge Sites with Dense Traffic

Should we sometimes build extra wide bridges to be able to repair railings and edge beams without traffic disturbance?

Should we choose a water isolation made of "gold" to avoid repair works among traffic?

Should we learn about fast construction methods of railway bridges even for street and road bridges?

Kuva: Megasiirto

Implementation of ETSI in Finland

Standard, comparable LCC and LCA calculation methods open remarkable innovation possibilities in for example design and build contracts. Lowest investment price isn't necessarily clients choice but the one with lowest maintenance costs and traffic disturbance.

1) Finnish Traffic Agency is going to **require LCC calculations** as part of a bridge design. The bids are evaluated according to life cycle costs.

To be completed:

- Finalizing the tool
- pricing of traffic disturbance
- a common database for life cycle values

2) Finnish Traffic Agency is going to **experiment** the use of standard **LCA** evaluation in contracts. Most likely we'll use it in future by setting limits to environmental impacts or set a price to them.

3) Finnish Traffic Agency is going to **experiment the use of cultural evaluation** in some projects. Most likely it will be applied on the most demanding bridges in the future

Finnish bridge life-cycle-cost design guideline

Dr Risto Kiviluoma

Bridges in Service - NVF Annual Bridge Conference, 1-2 September 2010, Oslo, Norway

31.8.2010

UNITED BY OUR DIFFERENCE

WSP

Index

- Introduction
- Objectives of the LCC guideline
- Methodology
- Unit data for LCC-estimate
- Format of LCC-estimate
- Summary

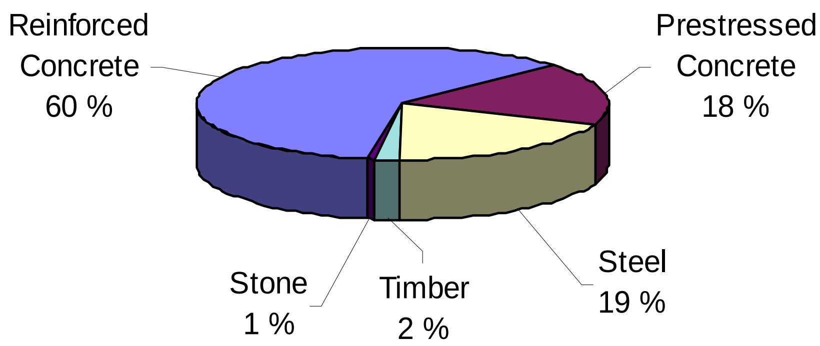
WSP

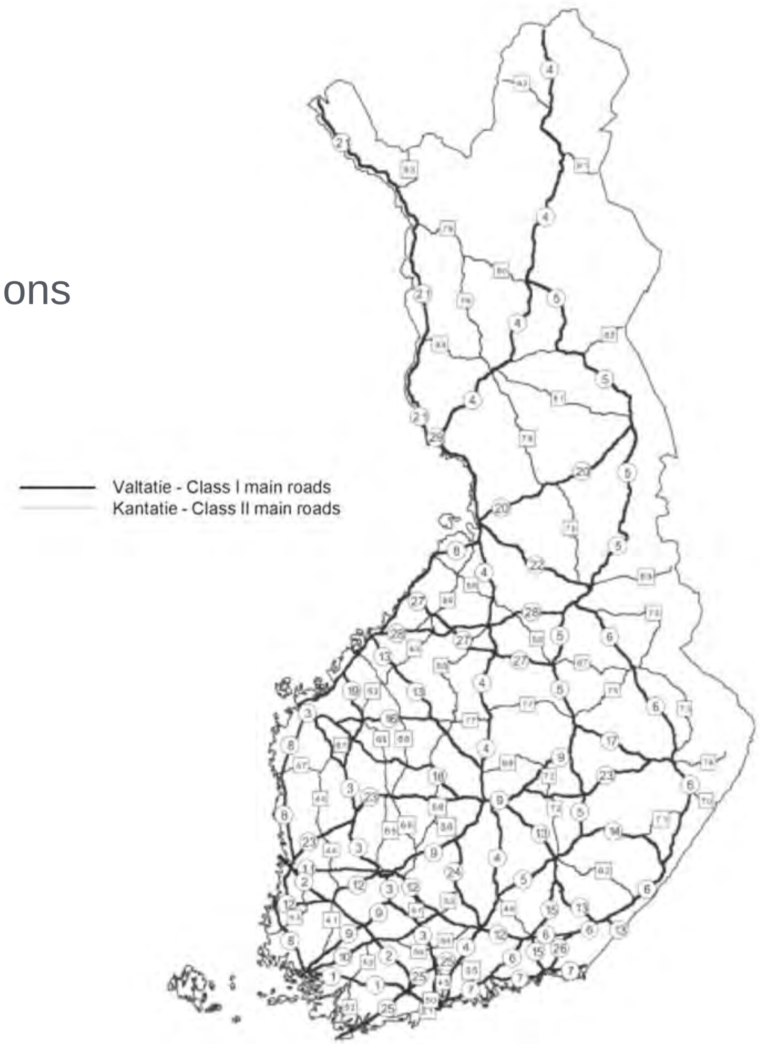
Introduction

- Bridge owners and engineers need tools to prepare life-cycle-cost (LCC) estimates at various stages of the project
- aside with the Nordic ETSI project, Finnish Transport Agency (“LiVi”) has conducted a project for developing a *design guideline* for LCC-issues of road bridges
- project team
  - LiVi: Pekka Korhonen (project manager), Jouko Lämsä, Seppo Aitta, Marja-Kaarina Söderqvist, Timo Tirkkonen, Minna Torkkeli
  - WSP: Risto Kiviluoma

Road bridges in Finland

- 14,000 bridges (span ≥ 2 m) on public roads (owned by LiVi)
- majority of bridges are small (and “ordinary”)
- LiVi is active to guide the design and constructions
- well established bridge management system (BMS). The system comprises data of 19,602 bridges, including most of the road bridges in Finland. In use for about 3 decades
- “bridges are in good care”







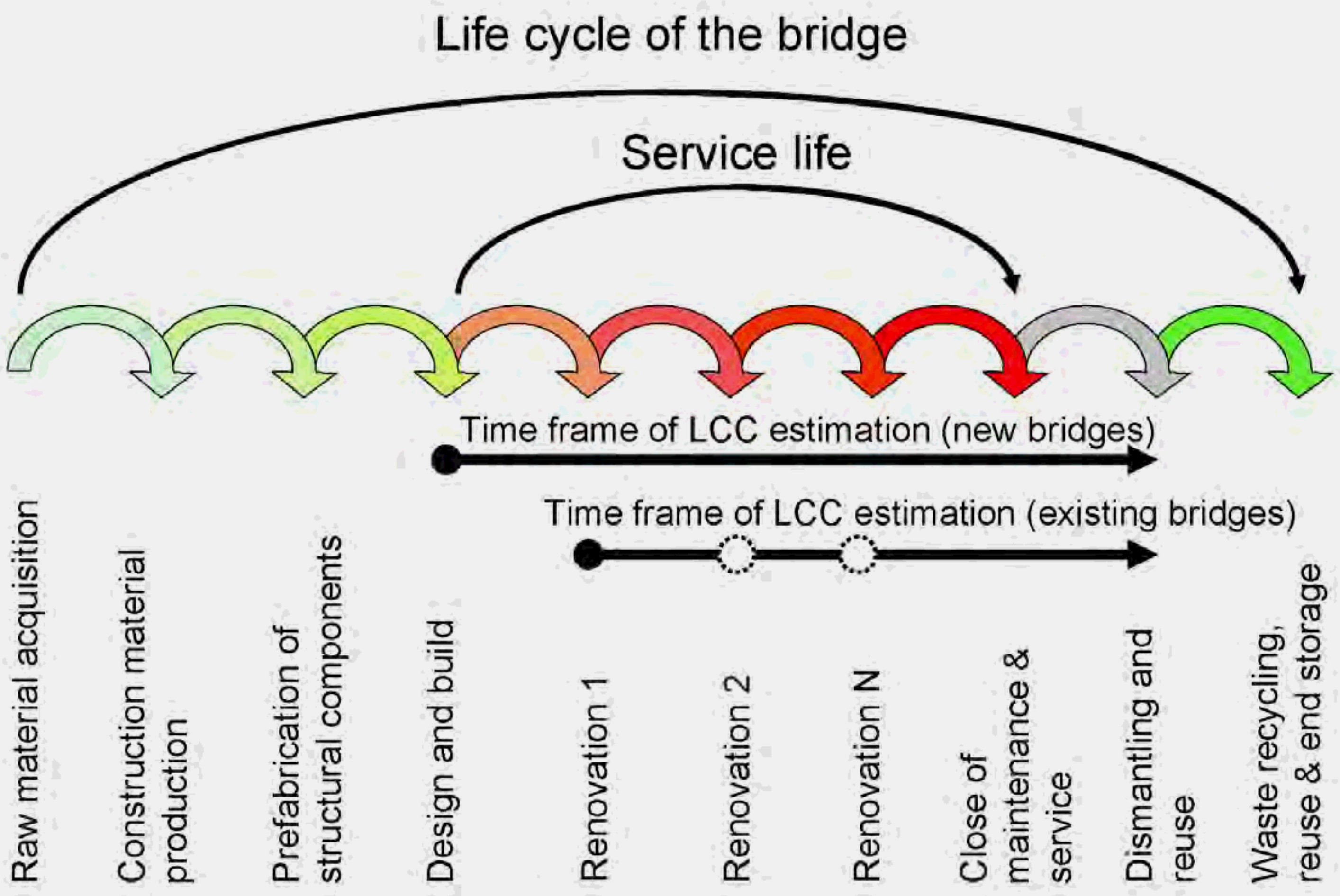






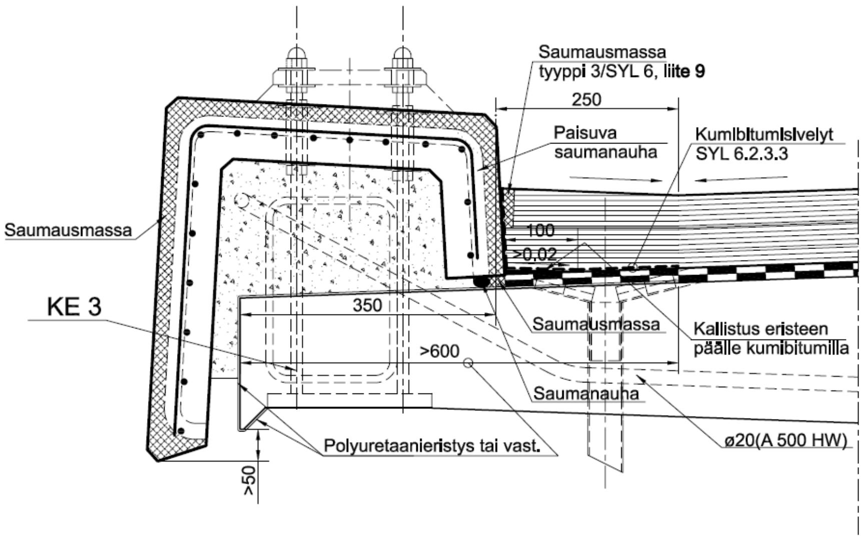

Objectives of the LCC guideline

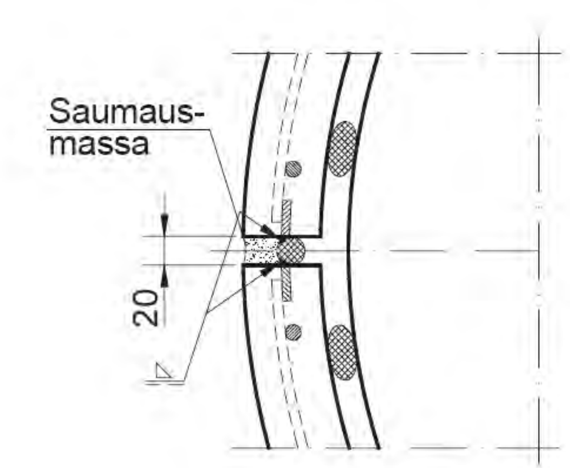
- provide instructions to estimate and allow *comparison* of costs encountered at life-cycle of a bridge
  - at design stage
  - at renovation design stage
- to cover and separate all relevant cost types; direct and indirect, of
  - bridge owning organisation
  - users
  - society
- to enhance usage of sustainable design options and repair methods



Life cycle of the bridge
Service life
Time frame of LCC estimation (new bridges)
Time frame of LCC estimation (existing bridges)
Raw material acquisition
Construction material production
Prefabrication of structural components
Design and build
Renovation 1
Renovation 2
Renovation N
Close of maintenance & service
Dismantling and reuse
Waste recycling, reuse & end storage

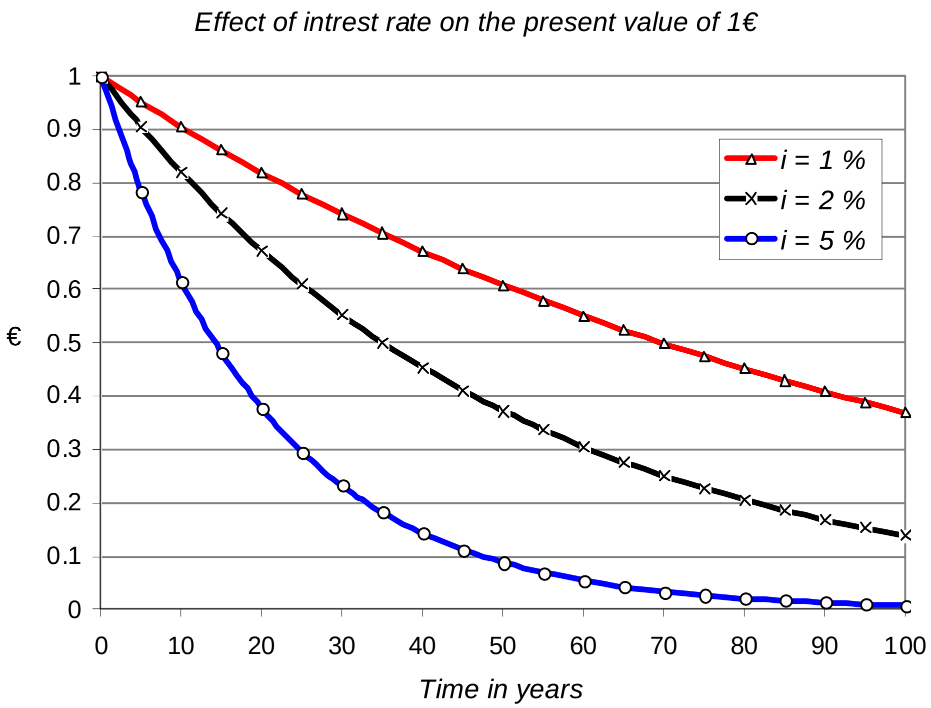
	Direct costs	Indirect costs
Agency	Construction Maintenance – curing – operating – repairing – dismantling	Risks
Users		Traffic delay costs Risks
Society		Environmental (LCA) Risks

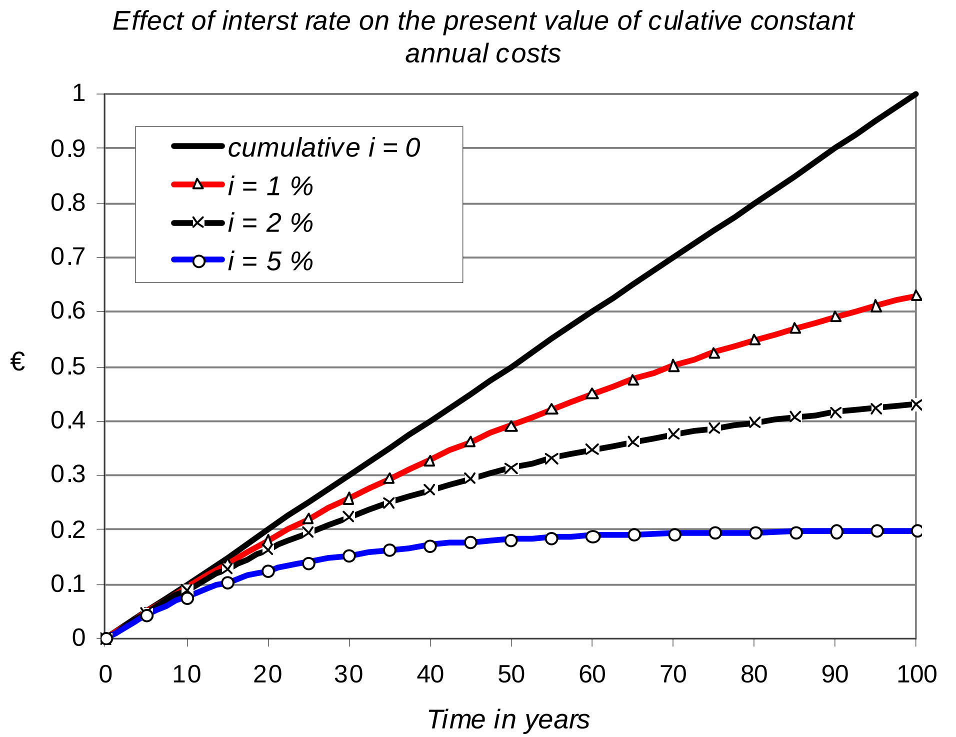

Saumausmassa
tyyppi 3/SYL 6, liite 9
250
Paisuva
saumanauha
Kumibitumisivelyt
SYL 6.2.3.3
Saumausmassa
100
>0,02
KE 3
350
Saumausmassa
Kallistus eristeen
päälle kumibitumilla
>600
Saumanauha
Polyuretaanieristys tai vast.
ø20(A 500 HW)
>50


Saumaus-
massa
20

Methodology

- extension of the methodology for standard quantity takeoff and cost estimation of a bridge:
  - cost = unit price * quantity
  - quantities as derivable from the design
- present value calculation for *all* cost types using multiple discount rates: 0%, 1%, 2% and 5%
  - using present value calculation for environmental costs reflects the improvement potential which exists in recycling, reusing, waste handling etc.
- time frame (period) for LCC-estimation is fixed, and is 100 y unless otherwise stated by the employer
  - steel pipe and timber bridges have service life less than 100 y meaning that they have to be assumed rebuilt during the period

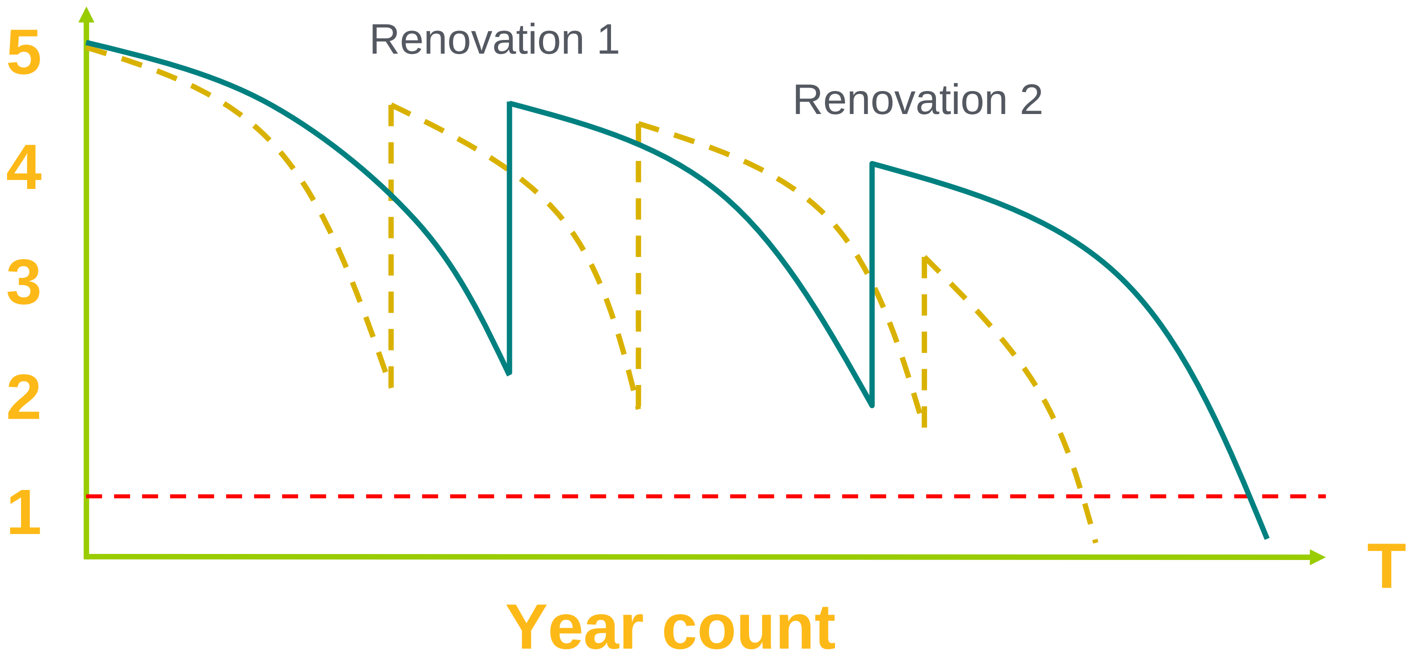

Effect of intrest rate on the present value of 1€
€
Time in years
i = 1 %
i = 2 %
i = 5 %
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
10
20
30
40
50
60
70
80
90
100


Effect of interst rate on the present value of culative constant annual costs
€
Time in years
cumulative i = 0
i = 1 %
i = 2 %
i = 5 %
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
10
20
30
40
50
60
70
80
90
100

BMS (and bridge inspections) as theoretical bases of service-life estimation

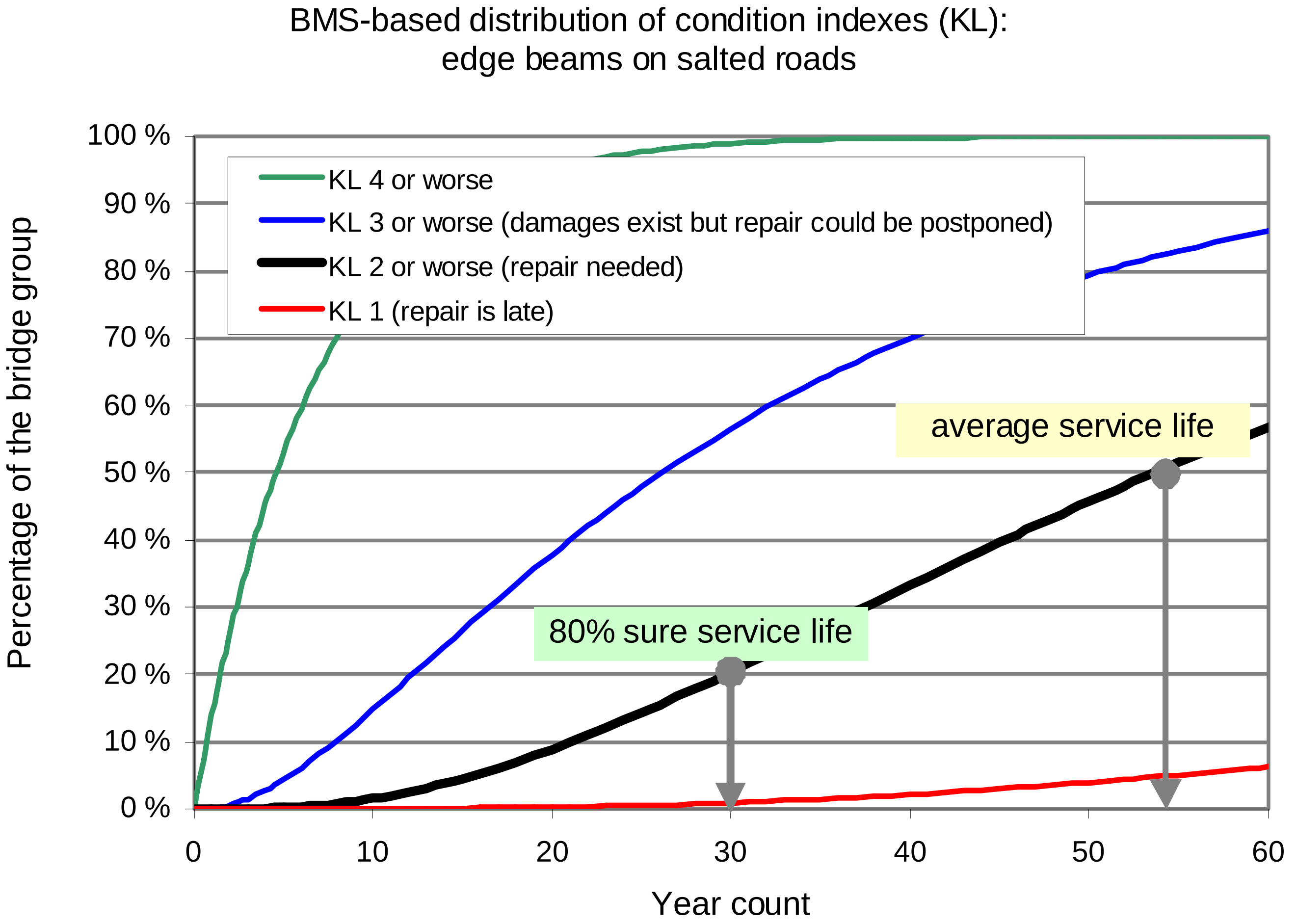
Computational condition index of a bridge

(calculated from visual bridge inspection data via BMS)



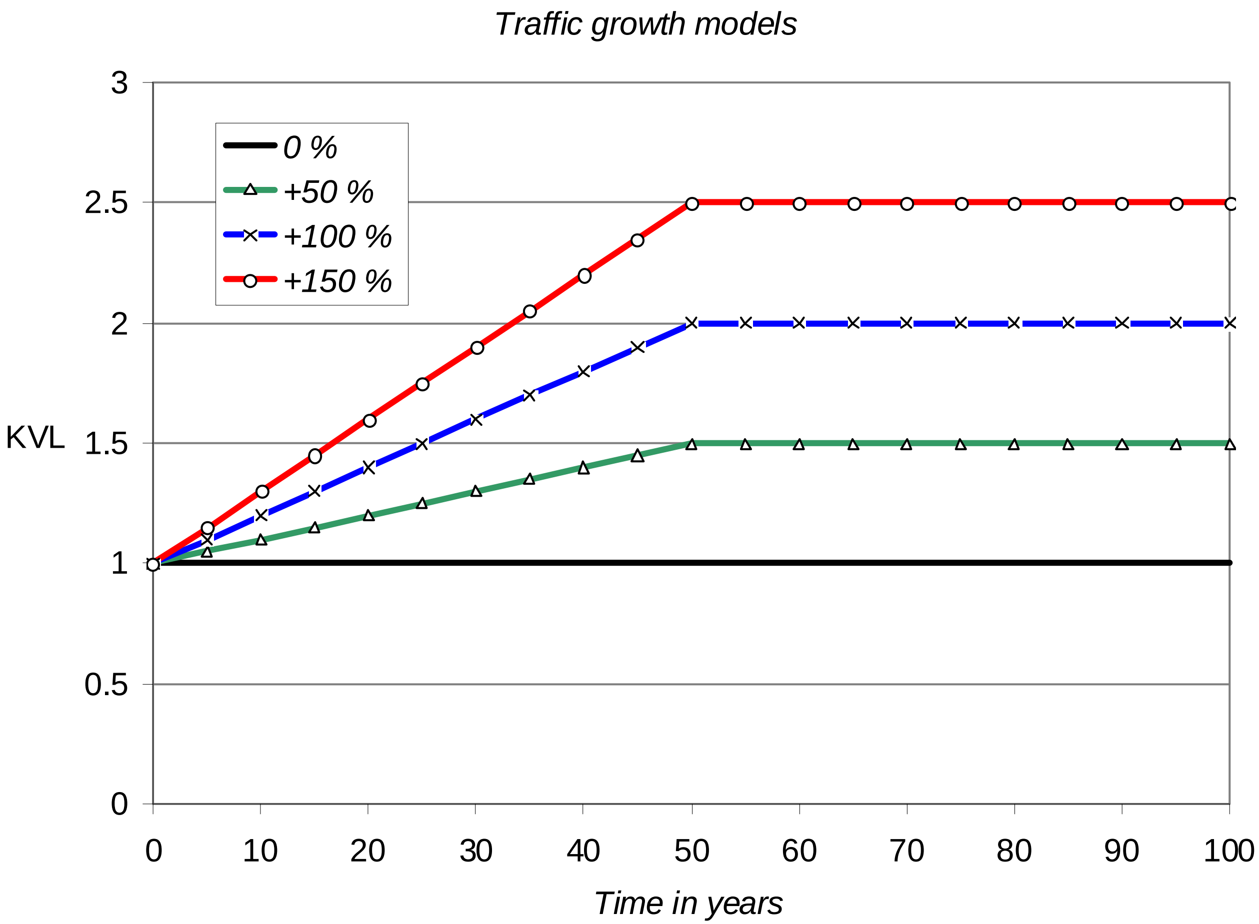
Confidence level in service-life estimation

(Finnish BMS example)



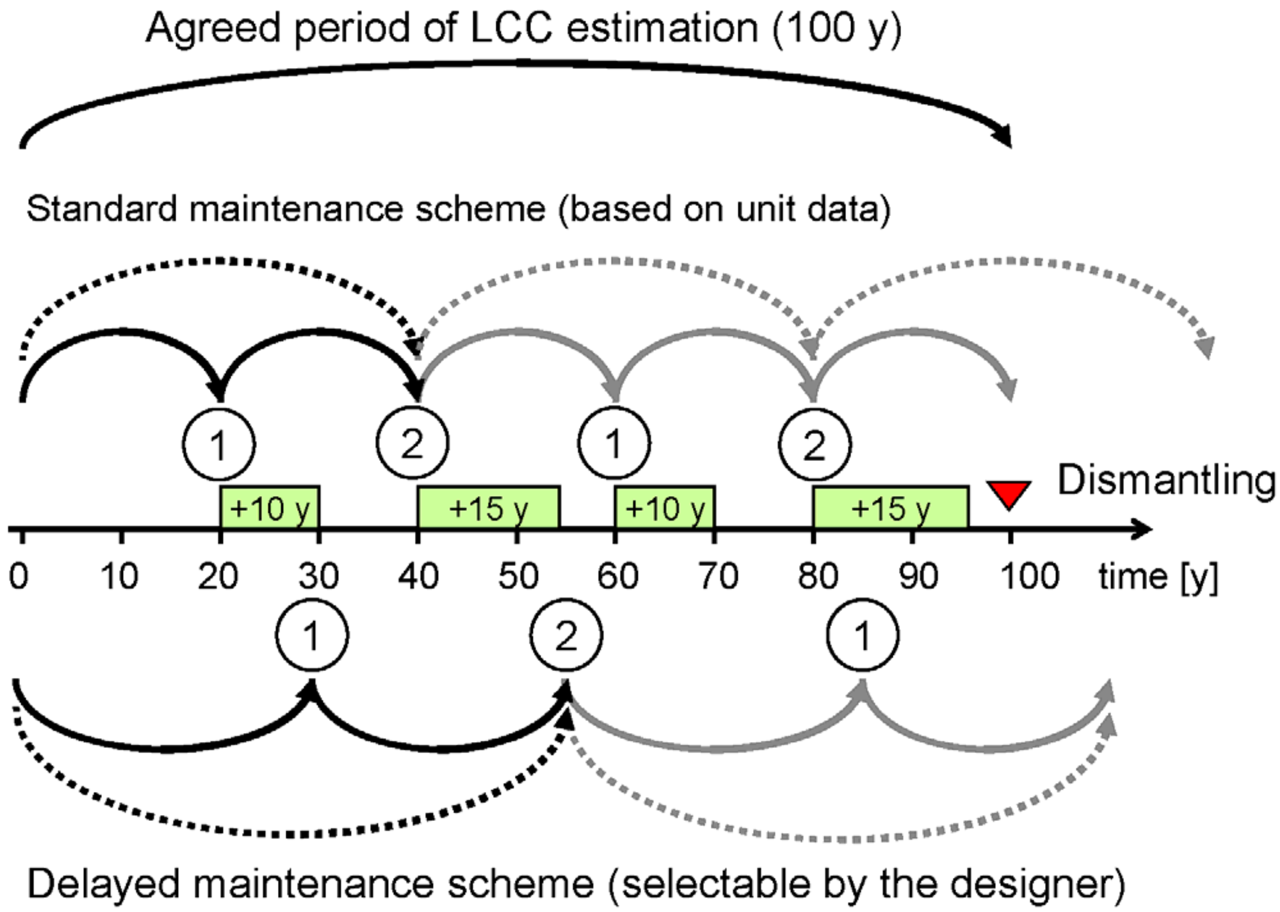
- when evaluating service life, one has to also assess related confidence (or risk) level
- LiVi's guideline produces "extended LCC-estimate" to include:
  - conventional LCC calculation
  - LCA analysis & evaluation
  - risk-analysis & evaluation
- all necessary unit data is supposed to be given in the guideline

Condition factor	Class	Description
Bridge Site (aesthetics etc.)	I II III IV	Special demanding Demanding Important Usual
Traffic volume	KVL	Average vehicles per day to be given for underpass and surpass traffic corridors
Estimate of traffic volume change in 50 y	±0% +50% +100% +150%	Quiet roads (KVL ≤ 200) Connecting roads, roads is general Main roads, highways, motorways Entrance roads of developing growing cities
Location	M1 M2 M3	Cities Densely populated areas Rural
Salt of winter road maintenance	S1 S2 S3 S4	Heavily salted (road maintenance classes 1 and 1S) Salted Salt fume No salting
Water presence	W1 W2 W3 W4 W5	Sea water: submerged structure Sea water: water and ice influence Fresh water: submerged structure Fresh water: water and ice influence No presence of permanent water
Risk of vandalism	R1 R2 R3	High Increased Normal or negligible
Condition class for steel pipe bridges	L1 L2 L3 L4	Special rating according to the guideline TIEH 210054-07


Traffic growth models
0 %
+50 %
+100 %
+150 %
KVL
3
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
70
80
90
100
Time in years

Unit (cost) data for LCC-estimate

- unit data consists on 9 tables given in Annex of the guideline (construction costs are addressed in a separate guideline by LiVi)
  1. cost of bridge design and employers costs (new bridge)
  2. durations of construction, noise, vibration and contamination (new bridge)
  3. amount of construction waste (new bridge)
  4. traffic delay costs
  5. cost of environmental impacts
  6. risks of the organisation
  7. risks of the users
  8. risks of the society (accidents etc.)
  9. costs of maintenance operations



Unit data for Maintenance

① Renovation/repair
- operation age 20 y
- delay max +10 y

② Rebuild
- operation age 40 y
- delay max +15 y

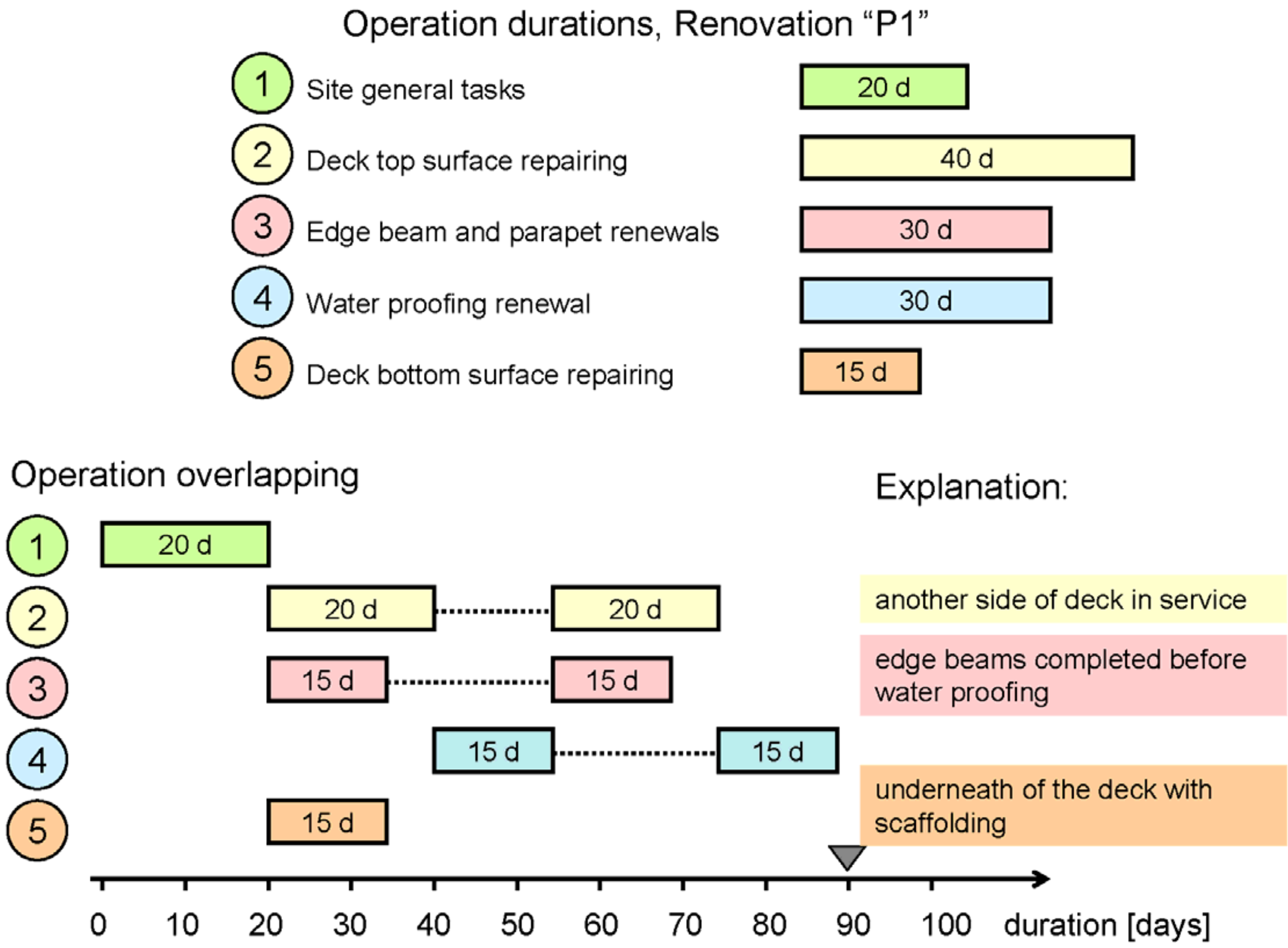
unit data for maintenance operations

Number	Title	Unit	Operat. year	Operat. delay max y	Unit costs €/yks	% const. costs	Duration d/unit	Curing €/y	Env. L_{CNE} t/unit	Noise % duration	Vibration % duration	Contamin. % duration	Waste t/unit	Remarks
1000	MAA-, POHJA- JA KALLIO-RAKENTEET													
1100	OLEVAT RAKENTEET JA RAKENNUSOSAT													
1120	POISTETTAVAT, SIIRRETTÄVÄT JA SUOJATTAVAT RAKENTEET													
1123	Poistettavat, siirrettävät ja suojattavat sillat													kierrätys ja uusiokäyttö voidaan ottaa huomioon
	- betonirakenteet	m3	-	-	-	50 %	0.01	-	-	50 %	-	50 %	0.8	
	- kivirakenteet	m3	-	-	-	50 %	0.01	-	-	50 %	-	20 %	-	
	- puurakenteet	m3	-	-	-	50 %	0.01	-	-	20 %	-	20 %	0.8	
	- teräsrakenteet	t	-	-	-	50 %	0.01	-	-	20 %	-	20 %	2.1	
	- muut rakenteet	pcs	-	-	-	50 %	0.01	-	-	20 %	-	20 %	0.1	
	* lisä kestoon kierrätyksestä						+20%							
1300	PERUSTUSRAKENTEET													
1310	MAANVARAISET PERUSTUKSET													voidaan jättää ottamatta huomioon sillan peruslaatat kts. 4207
1320	PAALUPERUSTUKSET													
1321	Lyöntipaalut													
1321.1	Betonipaalut	m												
	:1 korjaaminen	m	70	+20	-	200 %		-	-	50 %	50 %	50 %		
	* käyttöikämitoitus 100 v	*	+50											
	* ei käyttöikämitoitusta													
	* veden vaikuts W1	*	-10											
	* veden vaikuts W2	*	-20											
1321.2	Teräspaalut	m												
	:1 korjaaminen	m	70	+20	-	200 %		-	-	50 %	50 %	50 %		
	* käyttöikämitoitus 100 v	*	+50											
	* ei käyttöikämitoitusta													
	* veden vaikuts W1	*	-10											
	* veden vaikuts W2	*	-20											
	* suolauksen vaikutus S4	*	-20											
1321.3	Puupaalut	mtr												
	:1 korjaaminen	mtr	50	+20	-	100 %		-	-	50 %	50 %	50 %		
1324	Kaivettavat paalut													

- to prepare the LCC estimate, bridge engineer needs tentatively design and schedule the maintenance operations. Example:
  - edge beam service life = 25 years
  - parapet service life = 40 years
  - bridge equipment service life = 40 years
  - water proofing service life = 30 years
  - ⇒ to minimise LCC, do everything in the 1st renovation project at 30 years
- if repair is postponed, a penalty will be set to unit cost
- if new materials etc. are used that are claimed to have extended service life a penalty is set to risk value

- example of schedule for a bridge with target service life 100 years

Operation	*Abbreviation*	*Year count*
Bridge design and construction	-	0
Maintenance repair 1	Y1	15
Renovation 1	P1	30
Renovation 2	P2	60
Maintenance repair 2	Y2	80
Bridge is used till the end in intensified control	L	90
Dismantling	L	100
Curing	-	Every year
Road maintenance	T	Every year



P1 duration 90 days, overlapping save total 45 days

Format of LCC-estimate

- output as single design document: “bridge life-cycle-cost estimate”
- a spread sheet will be provided to ease the preparation
- in-detail breakdown of cost is requested
  - to allow comparison and inspection
  - to allow cost-benefit analysis of individual design solutions

- the cover page:

Liikennevirasto
Varsinais-Suomen ELY-keskus

SILLAN ELINKAARIKUSTANNUSARVIO

Suunnitelman numero	R15/12470
Kustannusindeksi i (2000=100)	139.4

RINTALAN RISTEYSSILTA, MASKU

Mt 189 rakentaminen välille Sinkkivuori-Masku

Jännitetty betoninen jatkuva ulokepalkkisilta (jBjup)
Jm (2,50) + 21,50 + 26,00 + 15,50 + (1,50) m
Hl 10,50 m
Vinous 29,1 gon
Kokonaispituus 71,80 m
Kannen pituus 67,00 m
Suunnittelukuorma LkI, Ek 1/TIEL 99

SUUNNITTELIJA	TILAAJA
Laati: 29.4.2010	Tarkastus:
Suoma Vaara	
Tarkasti: 29.4.2010	Hyväksyntä:
Kalle Kataja	

Yleiset lähtötiedot

Elinkaarikustannusarvion laadintaperusta		LiVi 2010	
Sillan suunnitelukäyttöikä		100	v
Siltapaikkaluokka		II	(vaativa)
Sillan rakennuskustannukset *	€	640 000	(i=139,4, 2000=100, ALV0)
Sillan neliöhinta *	€	849	(i=139,4, 2000=100, ALV0)
Liikennemäärä yläpuolisilla väylillä	KVL	3000	(keskim. vuorokausiliikenne)
Liikennemäärä alapuolisilla väylillä	KVL	1000	(keskim. vuorokausiliikenne)
Liikennemäärän muutosennuste		50 %	(50 v. tarastelujaksolla)
Olemassa olevan kiertotien pituus		50	km

* sillan kustannusarvion mukaan, ei sisällä suunnittelu- ja rakennuttamiskustannuksia

Sijainti- ja olosuhdekoodit

Sijainti	Sijainti-koodi	Olosuhde-koodit
Koko silta	000	Y2
Maatuki 1	100	S1, R1
Maatuki 2	200	S1, R1
Välituki 1	310	S1, R1
Välituki 2	320	V1
Päällysrakenne	400	S2, R1
Varusteet ja laitteet	600	R1
Muut siltapaikan rakennusosat	900	-

Y1=maaseutu; Y2=taajama; Y3 = kaupunki; S1=suolasumu; S2=suolattu; S3=runsas suolaus
V1=veden ja jään vaikutus, R1=pieni ilkivaltariski, R2=suuri ilkivaltariski
Teräsputkisillat: L1…L4 (olosuhdeluokka 1…4 TIEH 210054-07)

Tarkastellut kustannuslajit

Tienpitäjän kustannukset:	rakennus, kunnossapito ja riskit
Käyttäjien kustannukset:	ajokustannukset ja riskit
Yhteiskunnan kustannukset:	ympäristökustannukset ja riskit

Liitteet

A1 Käyttäjien ajokustannukset
Y1 Yhteiskunnan ympäristökustannukset
R1 Tienpitäjän riskianalyysi
R2 Käyttäjän riskianalyysi
R3 Yhteiskunnan riskianalyysi

the summary page

Kohde: Rintalan risteyssilta, Masku — ELINKAARIKUSTANNUSTEN YHTEENVETO — Sillan elinkaarikustannusarvio — pvm 29.4.2010 — sivu 2

Suunnitelman numero R15/12470 — Rahayksikkö €

	Rakenta-minen	Kunnossapito: ylläpidon kustannukset, nykyarvo				Kunnossapito: hoidon ja käytön kustannukset, nykyarvo				Elinkaarikustannusten nykyarvo			
		kust.	1 %	2 %	5 %	kust.	1 %	2 %	5 %	kust.	1 %	2 %	5 %
TIENPITÄJÄN SUORAT KUSTANNUKSET													
Kustannukset (i=100, 2000=1000)	514 000	927 000	541 700	337 900	109 900	83 250	52 472	35 879	16 550	1 524 250	1 108 172	887 779	640 450
- kustannustason indeksikorjaus	202 516	365 238	213 430	133 133	43 301	32 801	20 674	14 137	6 521	600 555	436 620	349 785	252 337
Yhteensä, pyöristettynä	717 000	1 292 000	755 000	471 000	153 000	116 000	73 000	50 000	23 000	2 125 000	1 545 000	1 238 000	893 000
(i=139,4, 2000=100, ALV0)													
% rakentamisen kustannuksista	100 %	180 %	105 %	66 %	21 %	16 %	10 %	7 %	3 %	296 %	215 %	173 %	125 %
TIENPITÄJÄN EPÄSUORAT KUSTANNUKSET													
Kustannukset (i=100, 2000=1000)													
- riskit	12 900	89 500	56 400	37 200	12 700	10 300	6 300	3 800	900	112 700	75 600	53 900	26 500
- *yhteensä*	*12 900*	*89 500*	*56 400*	*37 200*	*12 700*	*10 300*	*6 300*	*3 800*	*900*	*112 700*	*75 600*	*53 900*	*26 500*
- kustannustason indeksikorjaus	5 083	35 263	22 222	14 657	5 004	4 058	2 482	1 497	355	44 404	29 786	21 237	10 441
Yhteensä, pyöristettynä	18 000	125 000	79 000	52 000	18 000	14 000	9 000	5 000	1 000	157 000	105 000	75 000	37 000
(i=139,4, 2000=100, ALV0)													
% rakentamisen kustannuksista	3 %	17 %	11 %	7 %	3 %	2 %	1 %	1 %	0 %	22 %	15 %	10 %	5 %
KÄYTTÄJIEN KUSTANNUKSET													
Kustannukset (i=100, 2000=1000)													
- ajokustannukset	34 000	132 600	81 000	52 300	17 600	90 000	54 700	33 400	7 900	256 600	169 700	119 700	59 500
- riskit	1 000	8 000	5 500	3 800	1 400	3 200	2 300	1 700	700	12 200	8 800	6 500	3 100
- *yhteensä*	*35 000*	*140 600*	*86 500*	*56 100*	*19 000*	*93 200*	*57 000*	*35 100*	*8 600*	*268 800*	*178 500*	*126 200*	*62 600*
- kustannustason indeksikorjaus	13 790	55 396	34 081	22 103	7 486	36 721	22 458	13 829	3 388	105 907	70 329	49 723	24 664
Yhteensä, pyöristettynä	49 000	196 000	121 000	78 000	26 000	130 000	79 000	49 000	12 000	375 000	249 000	176 000	87 000
(i=139,4, 2000=100, ALV0)													
% rakentamisen kustannuksista	7 %	27 %	17 %	11 %	4 %	18 %	11 %	7 %	2 %	52 %	35 %	25 %	12 %
YHTEISKUNNAN KUSTANNUKSET													
Kustannukset (i=100, 2000=1000)													
- ympäristökustannukset	1 000	10 000	8 000	6 200	4 200	10 000	8 000	6 200	4 200	21 000	17 000	13 400	9 400
- riskit	8 800	49 100	33 200	26 100	11 700	500	400	300	200	58 400	42 400	35 200	20 700
- *yhteensä*	*9 800*	*59 100*	*41 200*	*32 300*	*15 900*	*10 500*	*8 400*	*6 500*	*4 400*	*79 400*	*59 400*	*48 600*	*30 100*
- kustannustason indeksikorjaus	3 861	23 285	16 233	12 726	6 265	4 137	3 310	2 561	1 734	31 284	23 404	19 148	11 859
Yhteensä, pyöristettynä	14 000	82 000	57 000	45 000	22 000	15 000	12 000	9 000	6 000	111 000	83 000	68 000	42 000
(i=139,4, 2000=100, ALV0)													
% rakentamisen kustannuksista	2 %	11 %	8 %	6 %	3 %	2 %	2 %	1 %	1 %	15 %	12 %	9 %	6 %
KAIKKI KUSTANNUSLAJIT YHTEENSÄ													
Tienpitäjä	735 000	1 417 000	834 000	523 000	171 000	130 000	82 000	55 000	24 000	2 282 000	1 650 000	1 313 000	930 000
Käyttäjät	49 000	196 000	121 000	78 000	26 000	130 000	79 000	49 000	12 000	375 000	249 000	176 000	87 000
Yhteiskunta	14 000	82 000	57 000	45 000	22 000	15 000	12 000	9 000	6 000	111 000	83 000	68 000	42 000
Yhteensä	798 000	1 695 000	1 012 000	646 000	219 000	275 000	173 000	113 000	42 000	2 768 000	1 982 000	1 557 000	1 059 000
(i=139,4, 2000=100, ALV0)													
% rakentamisen kustannuksista	111 %	236 %	141 %	90 %	31 %	38 %	24 %	16 %	6 %	386 %	276 %	217 %	148 %

the direct cost calculation sheet

Kohde Rintalan risteyssilta, Masku — TIENPITÄJÄN KUSTANNUKSET — Suorat kustannukset — Elinkaarikustannusarvio — pvm 29.4.2010 — sivu 4
Suunnitelman numero R15/12470 — Rahayksikkö €
Yksikkökustannukset: i=100, 2000=100, ALV0, ilman työmaan yhteiskustannuksia

Numero	Nimike	Sijainti koodi	Mitta-yks.	Määrä	Rak. yks. kust	Rak. kust.	Käyttöikä v.	Ylläpito: ajank. v.	Ylläpito: tyyppi	Ylläpito: yksik. kust.	Ylläpito: kust.	Ylläpito: nykyarvo 1 %	Ylläpito: nykyarvo 2 %	Ylläpito: nykyarvo 5 %	Hoito ja käyttö: vuosit. kust.	Hoito ja käyttö: kust.	Hoito ja käyttö: nykyarvo 1 %	Hoito ja käyttö: nykyarvo 2 %	Hoito ja käyttö: nykyarvo 5 %
1810	PENKEREET																		
1811	Maapenkereet	900	m3rtr	200	9.2	1840	20												
	- eroosiovaurioiden korjaus 1							20	Y1	20 %	368	302	248	139	-	-	-	-	-
	- eroosiovaurioiden korjaus 2							30	P1	20 %	368	273	203	85	-	-	-	-	-
	- eroosiovaurioiden korjaus 3							60	P2	20 %	368	203	112	20	-	-	-	-	-
	- eroosiovaurioiden korjaus 4							80	Y2	20 %	368	166	75	7	-	-	-	-	-
2140	PÄÄLLYSTEET JA PINTARA-KENTEET																		
2143.1	Betonikivi- ja laattapäällysteet	900	m2tr	120	36.2	4 340	20												
	- eroosiovaurioiden korjaus 1							20	Y1	20 %	868	711	584	327	-	-	-	-	-
	- eroosiovaurioiden korjaus 2							30	P1	20 %	868	644	479	201	-	-	-	-	-
	- eroosiovaurioiden korjaus 3							60	P2	20 %	868	478	265	46	-	-	-	-	-
	- eroosiovaurioiden korjaus 4							80	Y2	20 %	868	392	178	18	-	-	-	-	-
2320	NURMI- JA NIITTYVERHOUKSET																		
2321.1	Kylvönurmikot	900	m2tr	90	3.7	333	50												
	- korjaus 1							30	P1	50 %	167	124	92	39	-	-	-	-	-
	- korjaus 2							60	P2	50 %	167	92	51	9	-	-	-	-	-
4200	SILLAT																		
	Hoito ja tarkastukset																		
	* tavanomaiset siltatyypit																		
	- sillan hoito	000	kpl/v	1							-	-	-	-	500	50 000	31 514	21 549	9 924
	* siltapaikkaluokka II																		
	- sillan yleistarkastukset	000	kpl/v	0.2							-	-	-	-	40	4 000	2 521	1 724	794
	- erikoistarkastus 1	000	kpl	1				30	P1	5 000	5 000	3 710	2 760	1 157	-	-	-	-	-
	- erikoistarkastus 2	000	kpl	1				60	P2	5 000	5 000	2 752	1 524	268	-	-	-	-	-
4207	Sillan peruslaatat																		
	1: Välituki 2	320	m3tr	6.6	1 760	11 616	50												
	- betonipinnan paikkaus, vedenalainen							60	P2	50 %	5 808	3 197	1 770	311	-	-	-	-	-
	* lisä korjauksen viivästymisestä 10v							60	P2	10 %	1 162	639	354	62	-	-	-	-	-
4210	SILLAN TUKIRAKENTEET																		

- the operations duration calculation sheet

Kohde Rintalan risteyssilta, Masku KESTOT Elinkaarikustannusarvio pvm 4.8.2010 Liite K1
Suunnitelman numero R15/12470 Sivu 1

Numero	Nimike	Sijainti koodi	Mitta-yks.	Määrä	Yks. kesto vrk	Kok. kesto vrk.	Kestot ajokustannusten suhteen: Alittavat väylät %	vrk.	Ylittävät väylät %	vrk	Kestot ympäristäkustannusten suhteen: Melu %	vrk.	Tärinä %	vrk	Likaantuminen %	vrk
	RAKENTAMINEN															
	- paikalla valetut betonisillat, paaluperustut	000	kan-m2	697	0.1	70	100 %	70	-	-	25 %	17	25 %	17	100 %	70
	* lisä vesistön ylityksestä	000	kan-m2	697	10 %	7	100 %	7	-	-	25 %	2	25 %	2	100 %	7
						77		*77*				*19*		*19*		*77*
	YLLÄPITOKORJAUS 1															
1811	Maapenkereet - eroosiovaurioiden korjaus 1	900	m3rtr	200	0.01	2	-	-	-	-	-	-	-	-	-	-
2143.1	Betonikivi- ja laattapäällysteet - eroosiovarioiden korjaus	900	m2tr	120	0.01	1	-	-	-	-	-	-	-	-	-	-
4221	Betonirakenteet päällysrakenteessa - halkeamien peittäminen 1	400	m3rtr	407	0.01	4	100 %	4	-	-	-	-	-	-	-	-
4241	Liikuntasaumat - sillan saumojen tiivistäminen 1	600	mtr	160	0.01	2	-	-	-	-	-	-	-	-	-	-
4245.12	Teräskaiteet - kaiteiden oikominen 1	600	mtr	156	0.01	2	-	-	-	-	-	-	-	-	-	-
4248.51	Pintavesikouru luiskassa - uusiminen 1	900	mtr	11	0.1	1	-	-	-	-	-	-	-	-	-	-
5400	Työmaapalvelut - työmaan perustaminen ja purkaminen * korjausurakan yhteisk. 5'000... 10'000 €	000	kpl	1	2	2	100 %	2	100 %	2	-	-	-	-	100 %	2
5520	Telineet	400	m2tr	349	0.005	2	100 %	2	-	-	-	-	-	-	-	-
						15		*8*		*2*						
	PERUSKORJAUS 1															
1811	Maapenkereet - eroosiovaurioiden korjaus 2	900	m3rtr	200	0.01	2	-	-	-	-	-	-	-	-	-	-
2143.1	Betonikivi- ja laattapäällysteet - eroosiovarioiden korjaus 2	900	m2tr	120	0.01	1	-	-	-	-	-	-	-	-	-	-
2321.1	Kylvönurmikot - korjaus 1	900	m2tr	90	0.02	2	-	-	-	-	-	-	-	-	-	-

the environmental cost calculation sheet

Kohde Rintalan risteyssilta, Masku
Suunnitelman numero R15/12470

YHTEISKUNNAN YMPÄRISTÖKUSTANNUKSET
Rahayksikkö €
Yksikkökustannukset: i=100, 2000=100, ALV0

Elinkaarikustannusarvio

pvm 29.4.2010 Liite Y1
Sivu 1

Numero	Nimike	Määrätiedot			Kustannustiedot					Kustannukset, nykyarvo			
		sijainti koodi	mitta-yks.	määrä	muunto-kerroin	lask. yks.	määrä	yks. kust.	ajank. v.	kust.	1 %	2 %	5 %
4200Y1	YMPÄRISTÖKUSTANNUKSET												
4200K11	RAKENTAMINEN												
4200K112	Luonnonhaitat, materiaalisidonnaiset												
	- betonirakenteet	000	m3rtr	125	0.001	t LCNE	0.125	1 100	0	138	138	138	138
	- raudoitteet	000	kg	54000	0.00005	t LCNE	2.7	1 100	0	2 970	2 970	2 970	2 970
	- teräsrakenteet	000	t	120	0.00002	t LCNE	0.0024	1 200	0	3	3	3	3
	- pinnoitteet	000	m2rtr	120000	0.0001	t LCNE	12	1 200	0	14 400	14 400	14 400	14 400
4200K113	Luonnonhaitat, kuljetukset												
	- rakennustyöt	000	km	2000	0.001	t LCNE	2.0	1 100	0	2 200	2 200	2 200	2 200
	- jätteiden käsittely	000	km	500	0.001	t LCNE	0.5	1 100	0	550	550	550	550
4200K114	Pöly ja pienhiukkaset												
	- Y1 taajama	000	vrk	100	0.0027	asuk v	0.3	50 000	0	13 699	13 699	13 699	13 699
4200K115	Kaatopaikkajätteet												
	- muotit ja telineet	000	m2rtr	125	0.001	t LCNE	0.125	1 100	0	138	138	138	138
	- teräsbetonirakenteet	000	m3rtr	125	0.001	t LCNE	0.125	1 100	0	138	138	138	138
4200K116	Ongelmajätteet ja kemikaalit												
	- teräsbetonisillat	000	kan-m2	63	0.001	t LCNE	0.063	20 000	0	1 260	1 260	1 260	1 260
4200K117	Melu ja tärinä												
	- Y1 taajama	000	vrk	100	0.0027	asuk v	0.3	50 000	0	13 699	13 699	13 699	13 699
									yht	49 193	49 193	49 193	49 193
4200K12	YLLÄPITO												
4200K121	Luonnonhaitat, materiaalisidonnaiset												
	Peruskorjaus 1												
	- teräsbetonirakenteet	000	mrtr3	125	0.001	t LCNE	0.125	1 100	30	138	102	76	32
	- teräsrakenteet	000	kg	120000	0.00002	t LCNE	2.4	1 200	30	2 880	2 137	1 590	666
	Peruskorjaus 2												
	- teräsbetonirakenteet	000	mrtr3	125	0.001	t LCNE	0.125	1 100	30	138	102	76	32
	- teräsrakenteet	000	kg	120000	0.00002	t LCNE	2.4	1 200	30	2 880	2 137	1 590	666
4200K113	Luonnonhaitat, kuljetukset												
	- Peruskorjaus 1	000	km	2000	0.001	t LCNE	2.0	1 100	30	2 200	1 632	1 215	509
	- Peruskorjaus 2	000	km	2000	0.001	t LCNE	2.0	1 100	60	2 200	1 211	671	118

- the risk evaluation sheet

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Suunnitelman numero R15/12470

TIENPITÄJÄN RISKIANALYYSI
Rahayksikkö €
Yksikkökustannukset: i=100, 2000=100, ALV0

Elinkaarikustannusarvio

pvm 29.4.2010

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sivu 1

Numero	Riskin kuvaus	Riskin todennäköisyys			Riskin seuraukset						Riskin arvo			
		kuvaus	yksikkö	todennä-köisyys	kuvaus	yksikkö	määrä	yks. kust.	kustan-nukset	lask. toteut. vuosi	kustannukset, nykyarvo kust.	1 %	2 %	5 %
4200.T1	TIENPITÄJÄN RISKIT													
4200.T11	RAKENTAMINEN													
4200.T111	Käyttöönoton viivästymisen													
	- tavanomaiset tiesiltatyypit	tyypil.	% silloista	0.1	pieni	rak.kust.	514 000	5 %	25 700	0	2 570	2 570	2 570	2 570
4200.T12	Kustannusten ylittyminen													
	- tavanomaiset tiesiltatyypit	tyypil.	% silloista	0.1	pieni	rak.kust.	514 000	20 %	102 800	0	10 280	10 280	10 280	10 280
	* tavanomainen markkinatilanne									*yht.*	*12 850*	*12 850*	*12 850*	*12 850*
	* tavanomainen urakkamuoto													
4200.T12	YLLÄPITO													
4200.T121	Suunniteltua nopeampi peruskorjaustarve													
	Peruskorjaus 1													
	- suunnitteluratkaisut	tyypil.	% silloista	0.1	pieni	korj.kust.	280 000	10 %	28 000	30	2 800	2 077	1 546	648
	- työvirheet	tyypil.	% silloista	0.1	pieni	korj.kust.	280 000	10 %	28 000	30	2 800	2 077	1 546	648
	- materiaalit	tyypil.	% silloista	0.1	pieni	korj.kust.	280 000	10 %	28 000	30	2 800	2 077	1 546	648
	- pinnoitteet	tyypil.	% silloista	0.1	pieni	korj.kust.	280 000	10 %	28 000	30	2 800	2 077	1 546	648
	- kuormitus ja ympäristäolosuhteet	tyypil.	% silloista	0.01	pieni	korj.kust.	280 000	50 %	140 000	30	1 400	1 039	773	324
	Peruskorjaus 2													
	- suunnitteluratkaisut	tyypil.	% silloista	0.1	pieni	korj.kust.	280 000	10 %	28 000	60	2 800	1 541	853	150
	- työvirheet	tyypil.	% silloista	0.1	pieni	korj.kust.	280 000	10 %	28 000	60	2 800	1 541	853	150
	- materiaalit	tyypil.	% silloista	0.1	pieni	korj.kust.	280 000	10 %	28 000	60	2 800	1 541	853	150
	- pinnoitteet	tyypil.	% silloista	0.1	pieni	korj.kust.	280 000	10 %	28 000	60	2 800	1 541	853	150
	- kuormitus ja ympäristäolosuhteet	tyypil.	% silloista	0.01	pieni	korj.kust.	280 000	50 %	140 000	60	1 400	771	427	75
4200.T122	Peruskorjauksen laajeneminen													
	Peruskorjaus 1													
	- korjausajankohdan myöhästyminen	tyypil.	% silloista	0.1	pieni	korj.kust.	280 000	10 %	28 000	30	2 800	2 077	1 546	648
	- suunnitteluratkaisut	tyypil.	% silloista	0.1	pieni	korj.kust.	280 000	10 %	28 000	30	2 800	2 077	1 546	648
	- työvirheet	tyypil.	% silloista	0.1	pieni	korj.kust.	280 000	10 %	28 000	30	2 800	2 077	1 546	648
	- materiaalit	tyypil.	% silloista	0.1	pieni	korj.kust.	280 000	10 %	28 000	30	2 800	2 077	1 546	648
	- pinnoitteet	tyypil.	% silloista	0.1	pieni	korj.kust.	280 000	10 %	28 000	30	2 800	2 077	1 546	648
	- kuormitus ja ympäristäolosuhteet	tyypil.	% silloista	0.1	pieni	korj.kust.	280 000	50 %	140 000	30	14 000	10 387	7 729	3 239

- in the guideline, recommendations are given for utilisation of LCC-estimates
  - weighting factors for various cost items
  - discount rates
- the concept of LCC-efficiency class is introduced (to be potentially referred in bids)

Class	Savings* in LCC	Description
A	≥ 20 %	Important potential for savings. This may be due selected bridge type, material, construction methods minimizing traffic delay costs etc.
B	≥ 10 %	More efficient in LCC than average. This may be due adoption of one or more sustainable design details
C	< 10 %	LCC-estimation is done, but significant savings in LCC can not be anticipated

* compared to average of LCC of alike bridges

Conclusions

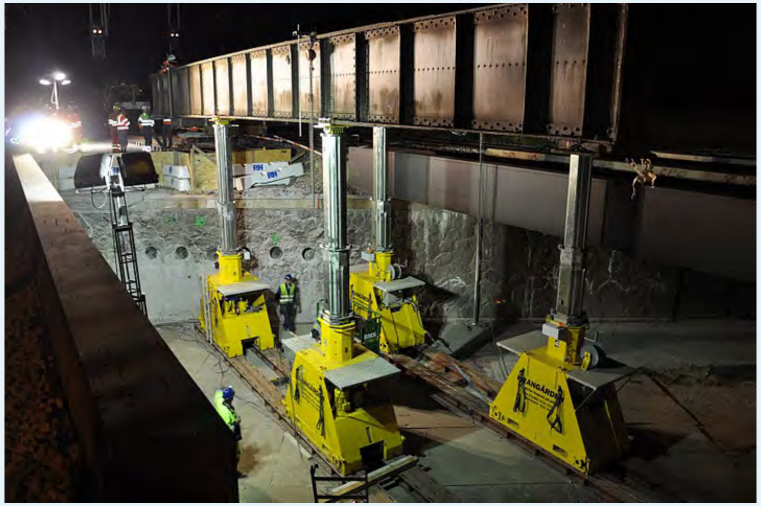
- Finnish Transport Agency has prepared a guideline for extended LCC-estimation of road bridges. The main objective is to allow comparison of cost of different designs
- the guideline requests a bridge engineer to do single additional design document “Bridge LCC-estimate”
  - the document goes in appropriate detail to comprise about 30 pp. per bridge
- guideline is planned to be published and taken in test-use at the September 2010. It contains about 30 pp. + 70 pp. as annex
- experiences obtained in the development of the guideline and its test use have been promising
  - LCC could be estimated and compared at design stage with the same methodology and mutual reliability than construction costs.

Challenges in bridge designs and maintenance for future problems

Jens Sandager Jensen

Vice President, Operation and Maintenance

COWI A/S Denmark



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Challenges in bridge designs and maintenance for future problems

Content of the presentation

- Major bridges
- Urban bridges
- Other bridges
- Design
  - Advanced repair methods
  - Design for maintenance
- Future challenges

Langeland bridge, Denmark

Major bridges
Challenges

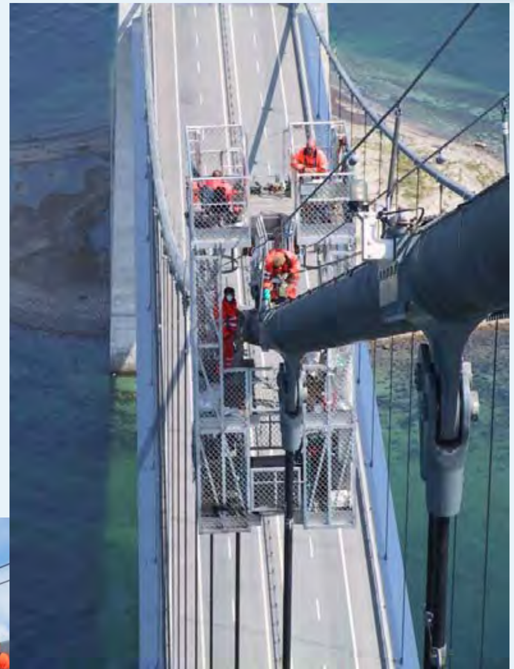
- Major bridges
  - 100 – 200 years service life
  - Increasing traffic loads and intensity
  - In service during maintenance (de-routing not possible)
  - Preventive maintenance strategies
  - Accessibility, safety and comfort

Major bridges
Inspectability

- Access for staff
  - Ancillary equipment
  - Under water
  - Inside e.g. girders
- NDT equipment and systems
  - Manual
  - Robot techniques
  - Monitoring systems

Major bridges
Maintainability

- Access for staff and equipment
- Acceptable functional reduction
- Design for maintenance/replacement of:
  - Moveable elements e.g. joints, bearings, hydraulic buffers and pendules
  - Bridge deck surfacing



Major bridges
Design

Major challenges

- Increasing lifetime requirements – up to 200 years of service life

- Increasing traffic loads and intensity

Approaches

- Design for durability
- Service life design
- Design considering Life Cycle Cost (LCC) aspects

- Ordinary traffic
- Heavy transports

Managing heavy transports in Denmark
A case story

- Consistent administration all over the country
- Reduce the number of authority to be asked
- A quick administration
- To prevent bridges from overloading
- To prevent pavement from overloading

Photo: Torben Rafn & Co.

Managing heavy transports in Denmark
A case story

Basis for the management of heavy transports in Denmark

- Bridge rating
  - Determination of the load bearing capacity in relation to standardized vehicles

→ Bridge class

- Vehicle rating
  - Comparison of the actual heavy transport with the standardized vehicles used for bridge rating (Bending moment and shear force)

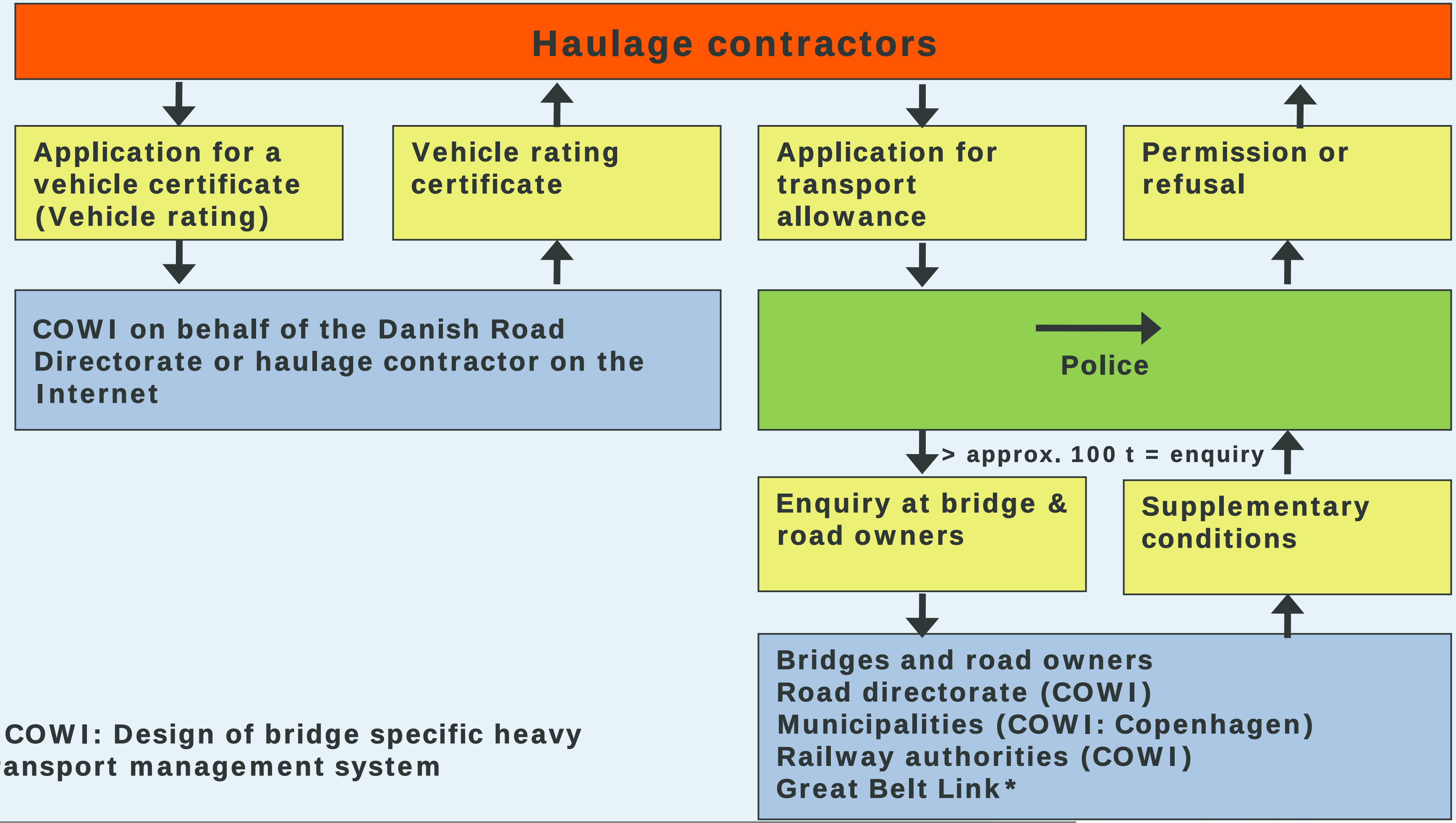
→ Vehicle class

Bridge class > Vehicle class → Permission

Heavy grid road network

Managing heavy transports in Denmark
A case story

Principles for application in Denmark



* COWI: Design of bridge specific heavy transport management system

Major bridges
Accessibility - a case story

Naini Bridge - Allahabad - India

- Flexible access facilities
- Reduced working area on bridge
- Operate on bridge between hangers
- Long radius of action

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Major bridges
Expansion joints – a case story

Little Belt Suspension Bridge - replacement

Traffic arrangements

- Closed for traffic in one side of the bridge
- Work and emergency traffic over temporary bridge

Little Belt Bridge, Denmark

Major bridges
Replacement of expansion joints

Back then, 1977-1979

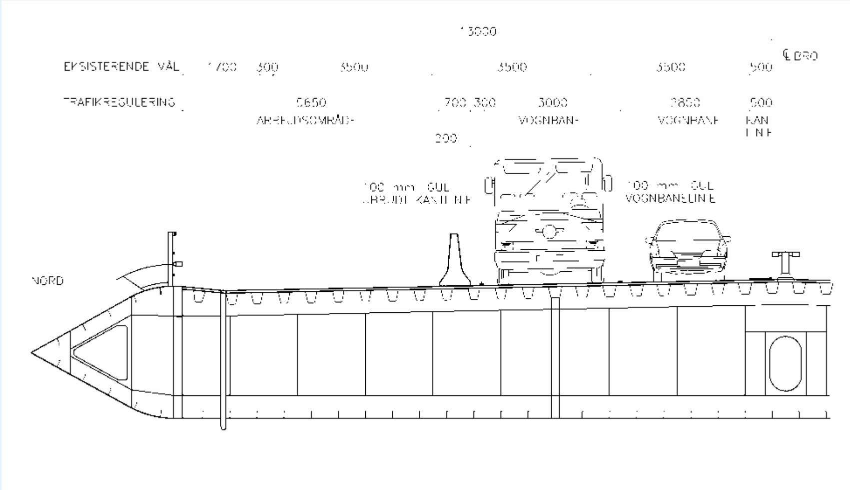
- Not much required
- Little traffic

Little Belt Bridge, Denmark

Major bridges
Replacement of expansion joints

During works

- Daily traffic approx. 52.000 vehicles
- Extensive arrangements required
- Heavy concrete barriers
- etc.



Little Belt Bridge, Denmark

Major bridges
Replacement of bearings

Replacement of bearings on Svendborg bridge, Denmark

- Hardly no space for replacement of the bearings
- The expansion joints has to be partly removed before expansion joints can be replaced
- No space for placing of hydraulic jacks
- Access facilities do not exist. At least 20 meters level height

Svendborgsund Bridge, Denmark

Cathodic protection may be the only way to durable repair

Langeland Bridge – 3 different installations for cathodic protection

- Cathodic protection, bottom plate in box girder 2010 - 2013
- Cathodic protection, top of pier shaft 2008 – 2011
- Cathodic protection, pier shaft 2009 – 2013

Langeland Bridge, Denmark

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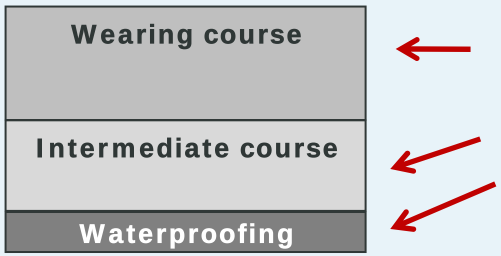
Major bridges
Bridge deck surfacing – a case story

Deterioration of bridge deck surfacing

Classic asphalt based thick surfacing (larger steel bridges)

- Service life of wearing course is limited to approx. 25 years
- After approx. 25 years wearing course is milled off (in heavy track) and replaced by new mastic asphalt or stone mastic asphalt
- Service life of the waterproofing and intermediate cover is approx. 40 – 60 years

60 mm thick asphalt based surfacing:



30 mm mastic asphalt with chippings or stone mastic asphalt, bitumen Pen 30

25 mm mastic asphalt, bitumen Pen 30

4 mm mastic (18 % bitumen, Pen 100 and 82 % limestone filler)

Major bridges
Bridge deck surfacing – a case story

Deterioration of bridge deck surfacing

Classic asphalt based thick surfacing (larger steel bridges)

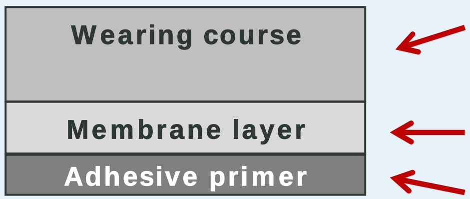
Advantages	Disadvantages
Long service life	Expensive in construction
Known technology	Heavy weight

Deterioration of bridge deck surfacing

Thin surfacing based on polymer resin (small steel bridges and movable bridges)

- Service life is limited, approx. 15 – 20 years
- After approx. 15 - 20 years surfacing is milled off and replaced by new thin surfacing renewed in the track areas in the heavy lanes
- Service life can be prolonged approx. 10 years if renewed in the track areas in the heavy lane

Thin polymer resin surfacing



6 – 8 mm wearing course including chipping (Methylene Met Acrylate (MMA), Epoxy or poly urethane modified epoxy and poly uretane)

2 mm membrane layer of pure binder

300 g/m^2 adhesive primer

Major bridges
Bridge deck surfacing – a case story

Deterioration of bridge deck surfacing

Thin surfacing based on polymer resin (small steel bridges and movable bridges)

Advantages	Disadvantages
Low weight	Lower service life than traditional mastic asphalt
Low construction cost	Large requirements to sub base regularity
Fast to apply and to repair	Large requirements to work procedures

Urban bridges

- Approx. 100 years service life
- Very high traffic intensity allow very limited time for maintenance
- No maintenance "possible" ➡ high design quality
- Alternative widening of bridge to allow for repair and maintenance

Case story: "Skæve Thorvald"

Traffic:

Average annual daily traffic: 21.173

July daily traffic: 20.159

Working day daily traffic: 24.376

2.000 – 2.500 cars in peek hour.

Capacity, normal: app. 2.000 per lane

Capacity, repair: app. 1.500- 1.800 per lane

Other bridges

- 50 – 100 years service life
- Low to medium traffic intensity
- De-routing possible ➡ bridge not in service during maintenance
- Corrective maintenance strategy is possible

Other bridges
Nordbanen – a case story

- Nordbanen is the suburban line from Copenhagen to Hillerød
- Major track renewal project in 2010:
  - Replacement of 25 km rail tracks
  - Replacement of 33 railway switches
- Total closure of suburban line for 3 months
- Simultaneously repair of 30 rail carrying bridges
  - Closure of track on bridge
    maximum 18-21 days for replacement of waterproofing
  - Closure of road under bridge
    typically 5 – 25 days for replacement of bridge
  - Closure of pedestrian / bike path under bridge
    less than 5 days for replacement of bridge / tunnel

Other bridges
Nordbanen – a case story

- Total of 29 bridges rail carrying bridges

  - 3 pedestrian tunnels replaced

  - 2 steel bridges replaced

  - 1 concrete bridge replaced
  - 1 concrete tunnel replaced

  - 11 major repairs (new waterproofing)

  - 3 tunnels changed to direct rail fastening

  - 8 minor repair works

Other bridges
Nordbanen – a case story

Requirements for new bridges:

- Adaptable to increased weight, adding additional track, etc.
- Easy maintenance without interfering with rail or road traffic
- Bridge renewal and repair must be fast (7 days a week working 3 shifts) in order not to postpone the track renewal project
- Bridge renewal done conservative by use of traditional methods (bridge owner take no major risks)
- Track cannot be closed the next 25 years (minimum)

The challenge:

- Traditional repair methods
- Shorter time schedule
- No compromise in quality and lifetime of repair works

Other bridges
Nordbanen – a case story

Vasevej

- New bridge built next to track
- Road open during construction
- Old bridge demolished
- New put into place
- Road reestablished in three weeks
- Bridge moved into place next week

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Other bridges
Nordbanen – a case story

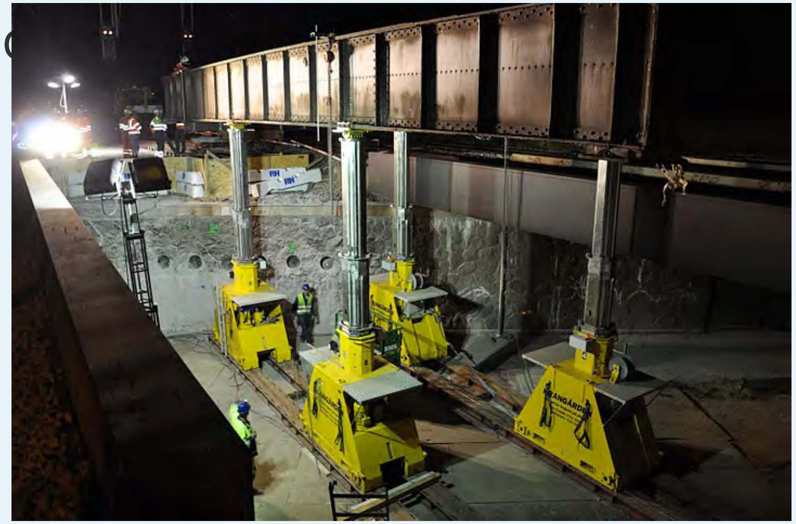
Pedestrian tunnels

- Prefabricated tunnels
  Track closed for 5 days
- Path closed to 10 days

Other bridges
Nordbanen – a case story

Hellerupvej

- Replacement of two steel bridges
  Bridges to be replaced using the track
- Geometric obstacles made it impossible to install the bridges from the road
- Road only closed for 10 days: removal of old bridge, strengthening of abutments, installment of new bridges



Design
Advanced repair methods

Chipping with water:

- Chipping with water is an integrated part of repair works (takes care of the environment)
- Robot controlled under complicated conditions

Cathodic protection

- Often the only realistic repair method on concrete in water

Design
Use of robot inside a concrete girder

- Limited space (1,4 m X 1,4 m)

Langeland Bridge, Denmark

COWI

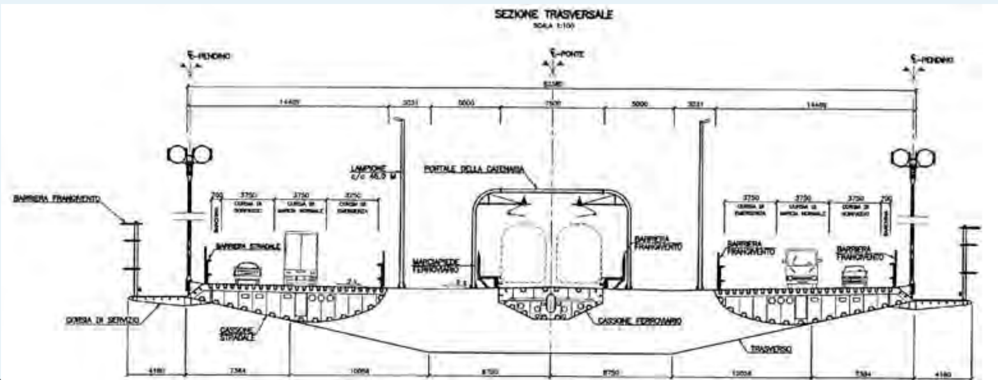
Design for maintenance

- Structures are designed to the limit. This result in lack of cross section when to be repaired
- Sometimes impossible to unload the structure during repair. This means restrictions to traffic during repair.

Svendborgsund Bridge, Denmark

COWI

Future challenges
The Messina Bridge



Girder movements at bridge end		Free system
SLS1	+/- (m)	4.9
SLS2	+/- (m)	5.9
ULS	+/- (m)	6.7
Accumulated yearly movements	m	> 100.000

Steel Construction /2009 ☐ druckfrei ☐ nach Korrektur druckfrei
Articles-No. 11

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Morten Løvseth

Datum, Unterschrift

Kolomoen bridge – a "full-rigger" on the E6 motorway

The Norwegian Public Roads Administration (NPRA) is widening the existing European Route E6 from two to four lanes over the stretch from Oslo's main airport, Gardermoen, and north to Lillehammer, the city that hosted the Winter Olympics in 1994. This is the principal road into Norway from the south and Europe, passing through Norway's capital city of Oslo and northwards to the central and northern parts of the country. The new motorway runs through unvarying, flat, spruce and pine forests, but also rich agricultural country. It includes views of spectacular mountain formations with massive boulders, and on several stretches there is a panoramic view of Norway's largest lake, Mjøsa, which it crosses twice. The road is about 150 km long, and the budget is EUR 1.4 billion.
In the middle of the stretch there is a major intersection offering a choice between Norway's two biggest valleys, Gudbrandsdalen and Østerdalen. And here, at this remote site, stands Kolomoen Bridge, deep within dense evergreen forest but visible from afar in three directions via the road corridors through the forest (Fig. 1). At the bridge, the landscape opens up into a wide clearing with the bridge as the dominant sculptural form in the centre, surrounded by the geometrical layout of the exit roads which form distinctive shapes in the terrain. In the past this intersection was so poorly marked that many vehicles heading for Østerdalen drove past without noticing that there was an exit! The bridge comes as a complete surprise to motorists, and proceeding along the wrong road is now hopefully a thing of the past (Fig. 2).

Fig. 1. Aerial photo of the intersection

Fig. 2. The bridge seen from south

1 Aesthetic guidelines for motorways

1.1 Aesthetic experiences for motorists

The project management for this stretch of road has devised strategies for providing an aesthetic experience quite different from other, similar road projects both in Norway and abroad. At intervals along the road there will be visual stimuli to make the stretch more interesting for motorists. The intention is that they will experience something approximately every three minutes. There is a psychological basis for this interval, which is about the length of most popular melodies and the intervals in classical music. Experience shows that these visual "refreshments" help to keep drivers more focused, and reduce the risk of them falling asleep at the wheel. The result will be a reduction in the number of accidents, which justifies the necessary investment in aesthetic experiences.

Other important aesthetic devices are:

– Bridges and structures are ranked in a hierarchy according to their function and significance, to offer legibility and a recognition effect to drivers. Some bridges and structures are accentuated as special highlights.
– The use and amount of road equipment and installations must be reduced to a minimum so that motorists are not bombarded with confusing instructions.
– The manner in which materials are used in essential road equipment must diminish the dominant effect of the equipment. Cor-Ten steel (weathering steel) has been selected for all road equipment in this project, e.g. guard rails, signposts, toll stations, etc.

– In Norway it is usual to have continuous full lighting along main roads with heavy traffic. In order to curb what many would call light pollution, this project has chosen a lead-in lighting system based on low-energy LED technology. The lead-in lights are placed in the central reservation and the effect can be compared to airports and landing in the dark.
– The new road is to lie level with the surrounding terrain, and not sunken, so that the horizon provides an experience for drivers.
– Focusing the panoramas from the motorway on special landscape experiences.
– Deliberate design of the side areas of the motorway without ditches and safety zones to eliminate the need for side guard rails.
– Creation of green shoulders and green central reservations for the motorway.

Fig. 3. The road with guard rails in cor-ten steel

1.2 Layout guidelines

The project was organized with a team of experts to handle and influence all planning for the project as a whole. The construction was then divided into smaller sections which were given separate "project owner" organizations.

The Norwegian Public Roads Administration (NPRA) has a central team of experts for the whole project which ensures consistent thinking and choice of solutions and equipment. In addition to technical skills of various kinds, this supervisory team also possesses landscaping and architectural expertise. There are also contracted architects who focus on selected elements such as bridges, rest areas, etc.

Work on layout guidelines to govern all further planning started early in the planning phase. They were revised and gradually refined far more than the initial version, reclassified with a higher status as a "manual" status. No deviations from this manual are accepted, e.g. for financial reasons.

2 Technological innovations for motorways

The planning of such a comprehensive road project presented challenges that resulted in a number of technical innovations for this project, for bridge structures and road planning in Norway. This was due to the vision and creative leadership of *Jørn Reinsborg*, civil engineer and original project manager, together with a highly qualified team of engineers, architects and landscape architects. This team has gradually developed into a professional think-tank for innovative road planning.

2.1 Cor-Ten steel in road equipment

Cor-Ten (weathering) steel was the material used for all road equipment such as guard rails, signposts, game fences, etc (Fig. 3). This was important visually because the dark rust colour virtually merges into the surroundings and the landscape and causes the road equipment to vanish. A not insignificant environmental and maintenance effect is also achieved when surface treatment and galvanizing are not required. As a result of the testing along this stretch of road, weathering steel has now been chosen as a standard for the entire project, and it has also inspired others to adopt it, e.g. on the E6 continuing northwards through the Gudbrandsdalen Valley.

2.2 Lead-in lighting

Lead-in lighting has been used instead of full road lighting along the motorway. This has resulted in a greater focus on both light pollution and the environmental aspect in the form of energy consumption. The outcome is a lower lighting level. This motorway has been defined as a "four-lane country road" with a lower traffic volume than, for example, motorways near the city of Oslo. With a four-lane motorway, the risk of head-on collisions is completely eliminated, and lead-in lighting is then regarded as adequate.

A concept has been developed involving low-energy LED lights which are integrated into the central reservation guard rail, with lights every 40 m (Fig. 4). The lights are always at a constant distance from the internal edge line so that the motorist can ease into a comfortable distance from this lead-in line. The road is illuminated by the car's own lights, which are also steadily improving, as exemplified by bi-xenon lights. Each lead-in light has a power of 1 W, and the saving compared with conventional road lighting is about EUR 100 000 per 10 km per year. In addition, maintenance costs for masts and lamps are many times higher for a conventional system. In view of the harsh climate in which such an LED system has to function, priority has been given to the provision of extremely robust, simple hardware.

Fig. 4. The road lighting installation with LED

2.3 Timber bridges with steel

The project team, in collaboration with architects and external engineers, have further developed the NPRA's already innovative timber bridge culture by stretching the limits for the use of timber as a construction material for bridges. The next building stages of the motorway involve a series of spectacular timber truss bridges with spans of up to 60 m in which all connectors, transitions, guard rails and other equipment are of Cor-Ten steel – for the first time on timber bridges.

3 Design of Kolomoen Bridge

3.1 Design development phase 1

The project design for this bridge and the overall aesthetic vision for the entire stretch were initiated by the original project manager, *Jørn Reinsborg*. *Reinsborg* gathered his team together with a few external architects and bridge engineers for a series of seminars at small mountain cabins and hotels over a period of several years. Endless ideas were debated for the entire stretch of road – for road profiles, the landscape, and last but not least the many bridges. A large number of more or less serious road and bridge concepts were sketched out – both at formal meetings and late into the night! One evening, purely by chance, the first sketches for Kolomoen Bridge were drawn on a table napkin. "Great", said *Reinsborg* intuitively, "this is something for us to work on!"

The chaotic tangle of cables and timber masts in this first sketch quickly resulted in the working title "the full-rigger" (Fig. 5), prompted by the many wooden masts, booms and criss-crossing ropes of great sailing ships. This rhetorical name has since provided the aesthetic guidelines for the project despite subsequent reworking in steel. The final bridge design would have been different had this working title not clung to it.

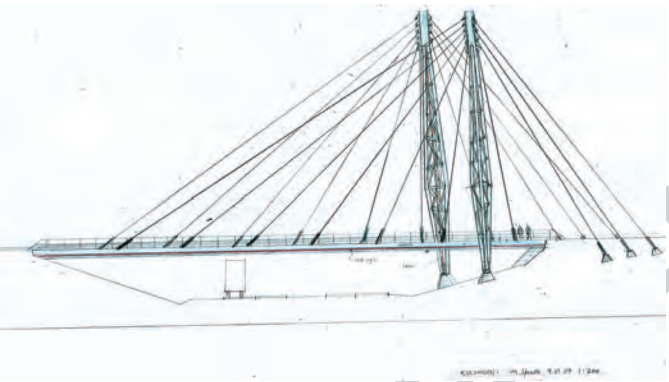


Fig. 5. The architect's last main sketch of bridge

3.2 Design development phase 2

After the joint seminars in the first round, the bridge design was developed into a conceptual project by the architect on the basis of advice on general principles from bridge constructors. It was soon discovered that the towers could not be built in timber because the forces and stresses were too great. It subsequently proved difficult to use steel in the bridge deck as this would have meant raising the roadway by a metre and rearranging the incoming slip roads in several directions, and so this option was excluded. The towers were the strongest visual elements, and a number of options were considered, as shown in (Fig. 6). The option

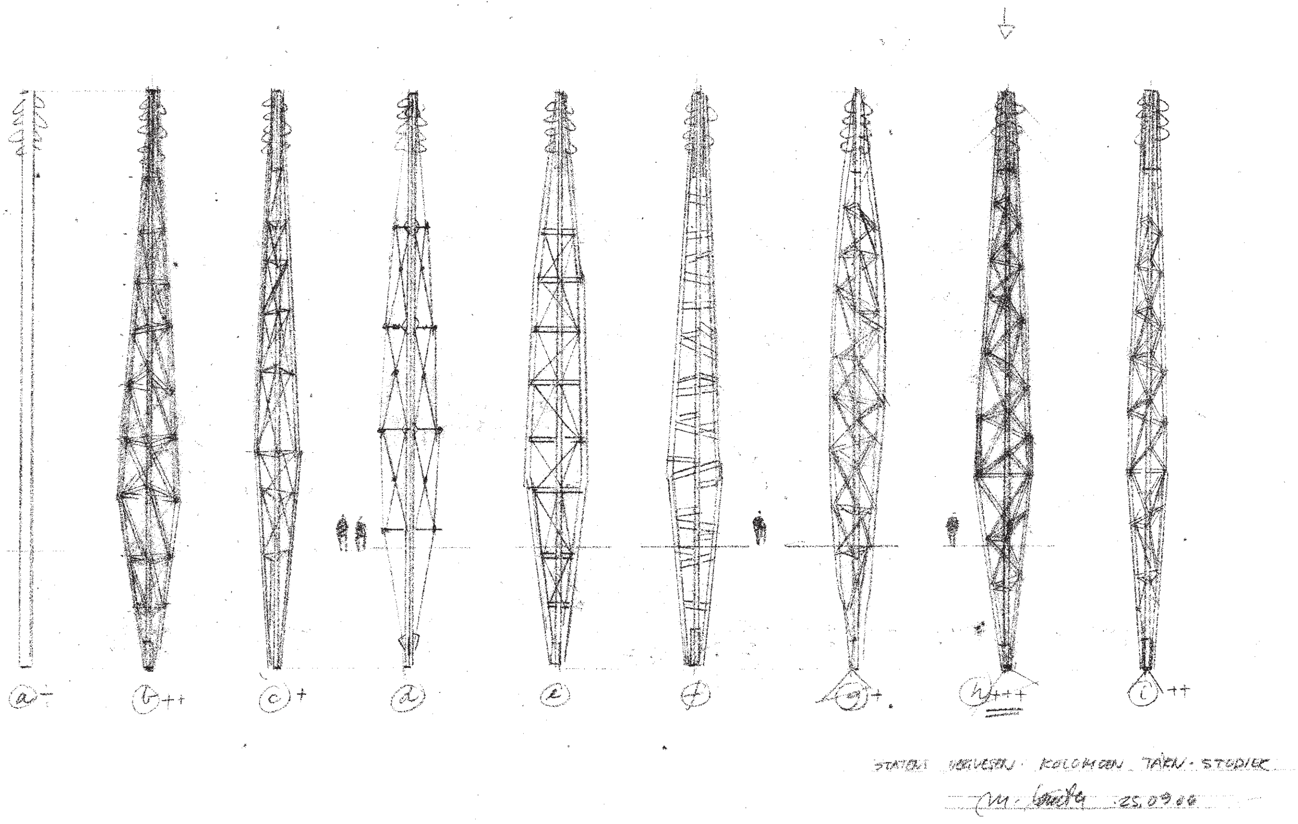


Fig. 6. The architect's studies of tower alternatives

that was selected, with trusses, yielded the desired intensity, distinctiveness and adequate dominance when viewed from a distance.

The sketches show the conceptual design that was sent out as the basis for tenders from bridge designers. As can be seen, the technical problems to be solved were highly challenging, and this was a deliberate move on the part of the project manager (Fig. 7). The special design of Kolomoen Bridge is an attempt to stretch the traditional premises for cable-stayed bridges; the towers are inclined 4° in two directions, the cables follow the curve of the main span but are fairly chaotic behind (Fig. 8). The towers are not connected at the top, and the counterweights are asymmetrical in relation to the sides of the tower (Fig. 9). Kolomoen Bridge was intended to stretch the technical limits.

3.3 Design development phase 3

Carl Hansvold, an engineer at Johs Holt AS, was nominated as chief designer. *Hansvold* immediately recognized the great challenges posed by the design and the need to make some simplifications. The cables could not be crossed as often as had been proposed and the connections at the top of the towers would have to be traditional lug-shaped plates instead of the connection anchorages as shown on the architect's sketch (Fig. 10). Apart from this, the architectural intentions were followed in all respects.

3.4 Colour

In choosing the colour of the bridge, emphasis was placed on the different seasons and how the bridge would be ex-

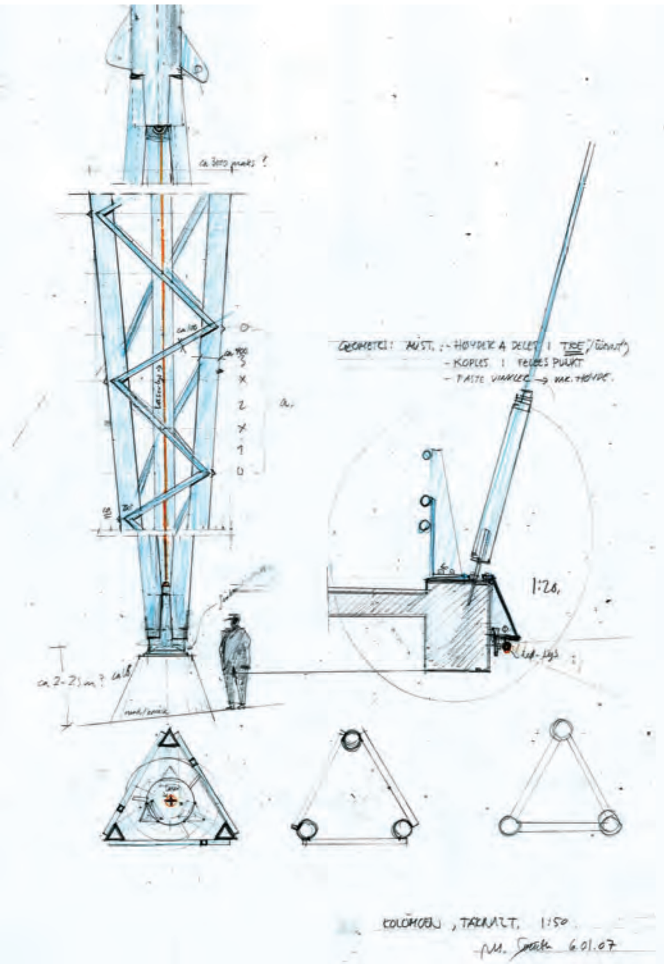


Fig. 7. The architect's sketch of tower

Fig. 9. The towers seen from a sideroad

Fig. 8. The towers seen from the bridge

Fig. 10. The towers and the cables

Fig. 11. The tower's reaching the sky

perienced in the dark. Different types of weather were also considered in relation to colour. During the Nordic winter everything is bluish white, and in summer the colours are sharply focused and green. The artificial lighting to be used at night is bluish. Certain colours also blend better with steel emotionally, as we perceive it. Grey, white and blue turned out to be good choices. The bridge would have to be light in colour so that the shadows would enhance the experience of the tubular shapes. The stays must also be visible against the bright sky (Fig. 11). After some testing, the bridge became bluish white because this resulted in the best colour in artificial lighting and in winter. This colour also functioned best in relation to the other parameters mentioned.

3.5 Parapets and guard rails

The parapets and guard rails on the bridge are of Cor-Ten steel, like similar structures on this stretch of road.

4 Challenges posed by the design of the bridge

Kolomoen Bridge is a cable-stayed bridge with a total length of 70 m and width of 13.32 m (Fig. 12). It crosses the E6 motorway and carries two lanes of traffic.

The bridge cross-section is made up of two longitudinal edge beams with a depth of 800 mm and cross-beams every 7.5 m. The top slab is 300 mm thick (Fig. 13). Lightweight aggregate (LWA) concrete with a design strength of 24 MPa and density of 18 kN/m^3 was selected in order to minimize the self-weight of the bridge superstructure. Conventional reinforcement is used, except for the cross-beams, which are post-tensioned. The wearing surface consists of a 100 mm thick layer of asphalt.

The steel towers consist of a lower tubular truss connected to a cylindrical upper part housing the stay anchorages. The steel grade is generally S355. The towers, resting on bearings that allow free rotation in all directions, are inclined 4° in both the longitudinal and trans-

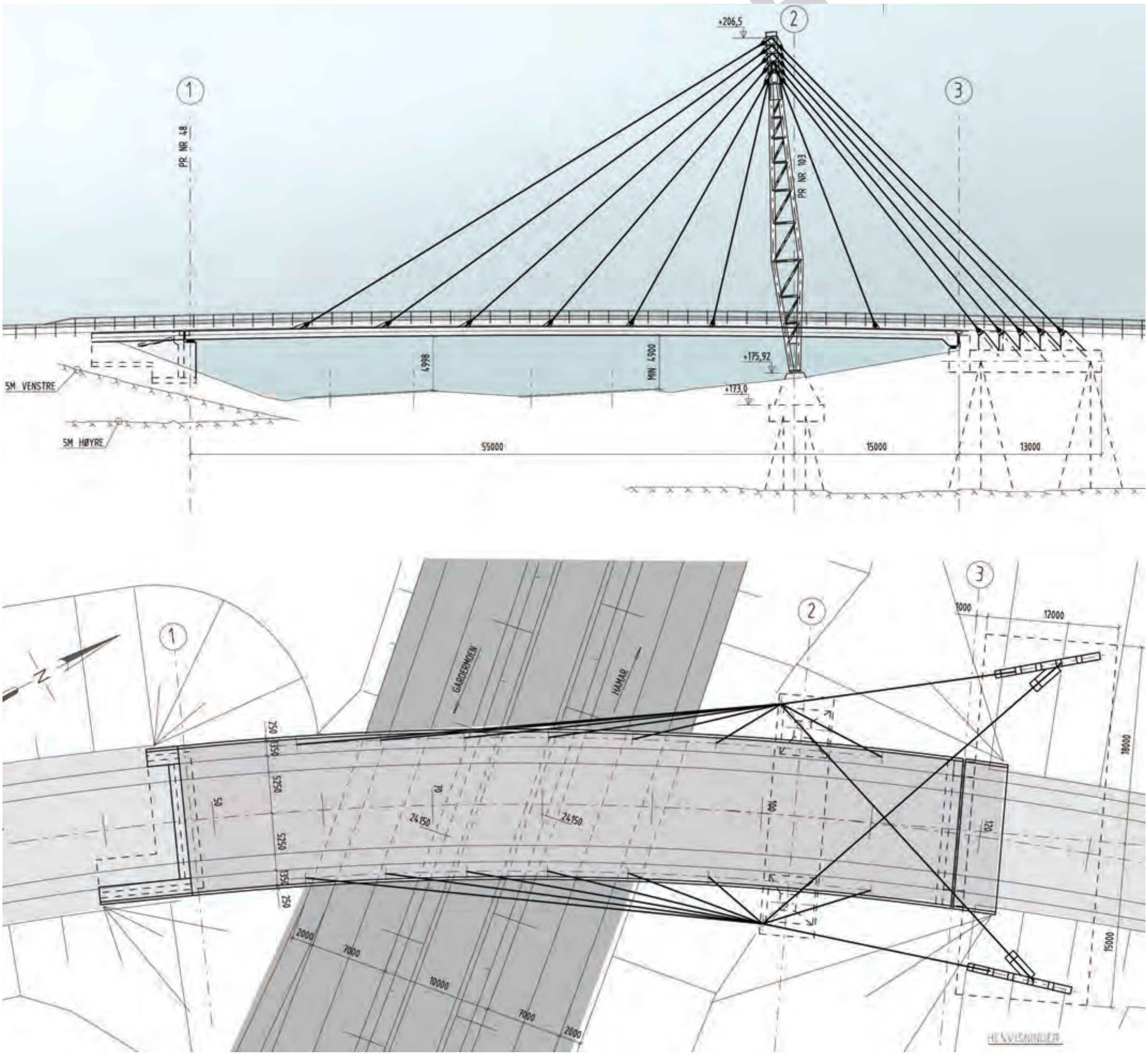


Fig. 12. The engineer's plan and elevation

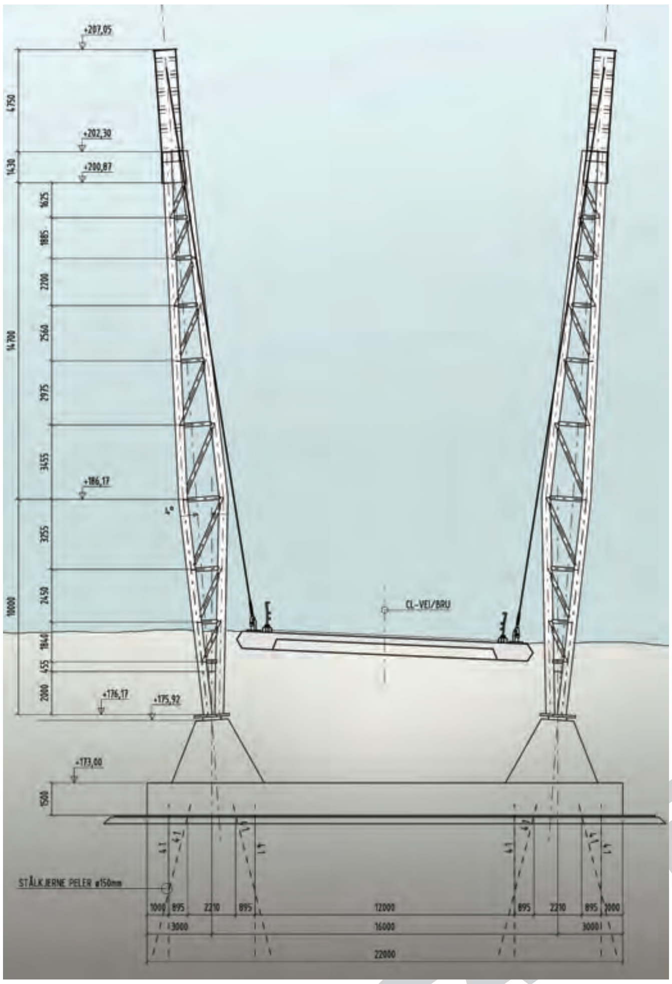


Fig. 13. The engineer's cross-section drawing

verse direction. The stability of the towers and the stay system is ensured by double cross-stays connecting the top of each tower to the counterweight anchor beam on the opposite side.

The stays consist of galvanized and painted Macalloy S520 bars varying in diameter from 75 to 100 mm. The stays were tested in accordance with the FIB Recommendations "Acceptance of stay cable systems using prestressing steels". The front stays are anchored at equidistant intervals of 7.5 m along the edge beams and the outer five back stays are anchored to a heavy concrete beam which provides the necessary balance to the bridge system. The structure has been designed to tolerate the accidental loss of any stay under full traffic load without structural instability or inelastic deformations.

The soil conditions vary considerably along the bridge axis. The abutment on grid 1 is founded on solid rock, whereas the other foundations are founded on steel core piles with a diameter of 150 mm.

5 Building the bridge

The two bridge towers are tubular trusses with a triangular configuration and cylindrical upper parts. The dimensions vary with the height as shown in Fig. 13. They weigh about 35 t each and have a height of 31 m. The width in the middle is 2.9 m. The main tubes in the trusses have dimensions of ∅ 406.4 × 25 mm, grade S355 NL. The truss diagonals are ∅168.3 × 9.52 mm, grade API 5L. The top part of each tower consists of an approx. 5 m long cylindrical plate section, grade P355NL2, with a diameter of 1000 mm, thickness of 30 mm. Stay connection plates 80 mm thick were welded to the cylinders (Fig. 14).

About 2800 hours were required for fabrication. The towers were transported over long distances from plant to plant for surface treatment, and finally by night with a police escort to the construction site. The towers were unloaded and lifted from the vehicle with two cranes. Main erection was carried out with a crane and each tower was lowered down onto its bearing. The rotation tolerance was 0.1°. The towers were stabilized with temporary backstays and positioned according to the coordinate position. The tolerance of the tower-top inner swing was 60 mm backwards and 5 mm transversely outwards. The outer swing of the tower top was 65 mm backwards and 0 mm transverse. This was particularly important for the fitting of the permanent stays (Fig. 15).

Fig. 14. The towers seen from the road guardrails

Fig. 15. Photo from the air of the bridge and the road

Special features worth mentioning are the stringent welding requirements with upgraded Welding Procedure Qualification Record (WPQR) and very tight tolerances. The tolerance for the stay connection plates at the top of each tower was 0.5°. In other respects, all work was in accordance with NPRA's "General Specifications 2 – Principal Process 8 with Extended Inspection".

Despite the fairly demanding fabrication and assembly, execution has been exemplary.

6 Tenders and costs

The bridge is part of the contract for the construction section Skaberud-Kolomoen, which is approximately 12 km long. H hre Entreprenør AS was the main contractor for this section with a contract sum of approx. EUR 60 million. Kolomoen Bridge was built at a cost of nearly EUR 4 million.

7 Procedure and design

Kolomoen Bridge is architecture with a deliberate design irrationality because the bridge is intended to challenge and be seen. The process started with the aesthetic premises instead of a structural approach as in the design development of a building's architecture, where the design is based on the aesthetic premises rather than on the obvious structural premises. Such an attitude may be unexpected in the light of bridge design traditions, but in this case has resulted in an icon for the entire stretch of the motorway and the county.

Engineering team:
Project Managers: *Jørn Reinsborg*, civil engineer (original project manager), and *Taale Stensbye*, civil engineer (current project manager), NPRA
Site Manager: *Terje Halbakken*, senior engineer, NPRA
Responsible for bridge and all other structures in the project: *Trond Arne Stensby*, senior engineer, NPRA
Bridge consultant: Johs. Holt AS, represented by *Carl Hansvold*, civil engineer
Design coordinator for whole project: *Yngve Aartun*, architect, Plan Arkitekter AS
Bridge architect: *Morten Løvseth*

Contractors:
Main contractor: Hæhre Entreprenør
Steel subcontractors: Contiga AS, Spennteknikk AS

Keywords: road bridge; cor-ten steel; cable-stayed bridge

Authors:
Trond Arne Stensby, senior engineer, NPRA, responsible for bridges and all other constructions in the project
Carl Hansvold, civil engineer, senior structural engineer, Johs. Holt AS, consulting engineers
Morten Løvseth, architect, architect for the bridge, Moe & Løvseth AS, architects


NY E6 OG KOLOMOEN BRU
STREKNING GARDERMOEN LILLEHAMMER
Foredrag:
Trond Arne Stensby
Morten Løvseth
Carl Hansvold

DEN NYE E6: EN VAKKER VEG

FORMINGSVEILEDER

Bruer og konstruksjoner er rangert i et hierarki etter funksjon og betydning for å gi lesbarhet og gjenkjennelseseffekt.

Noen bruer og konstruksjoner er fremhevd som spesielle ”highlights”, for eksempel Kolomoen bru.

VEGUTSTYR OG INSTALLASJONER

Omfang av vegutstyr og installasjoner er redusert for ikke å ”bombardere” kjørende med forstyrrende ”instrukser”.

Materialbruken i vegutstyr demper ned den dominerende virkningen av vegutstyret.

I dette prosjektet er det valgt Cor-Ten stål (rusttregt stål) i alt vegutstyr som rekkverk, skiltstolper, guardrails, bomstasjoner etc.


Cor-ten stål i utstyr

BELYSNING

For å dempe det mange vil kalle for ”lysforurensning”, er det i dette prosjektet valgt et ledelyssystem basert på lavenergikrevende LED-teknologi.

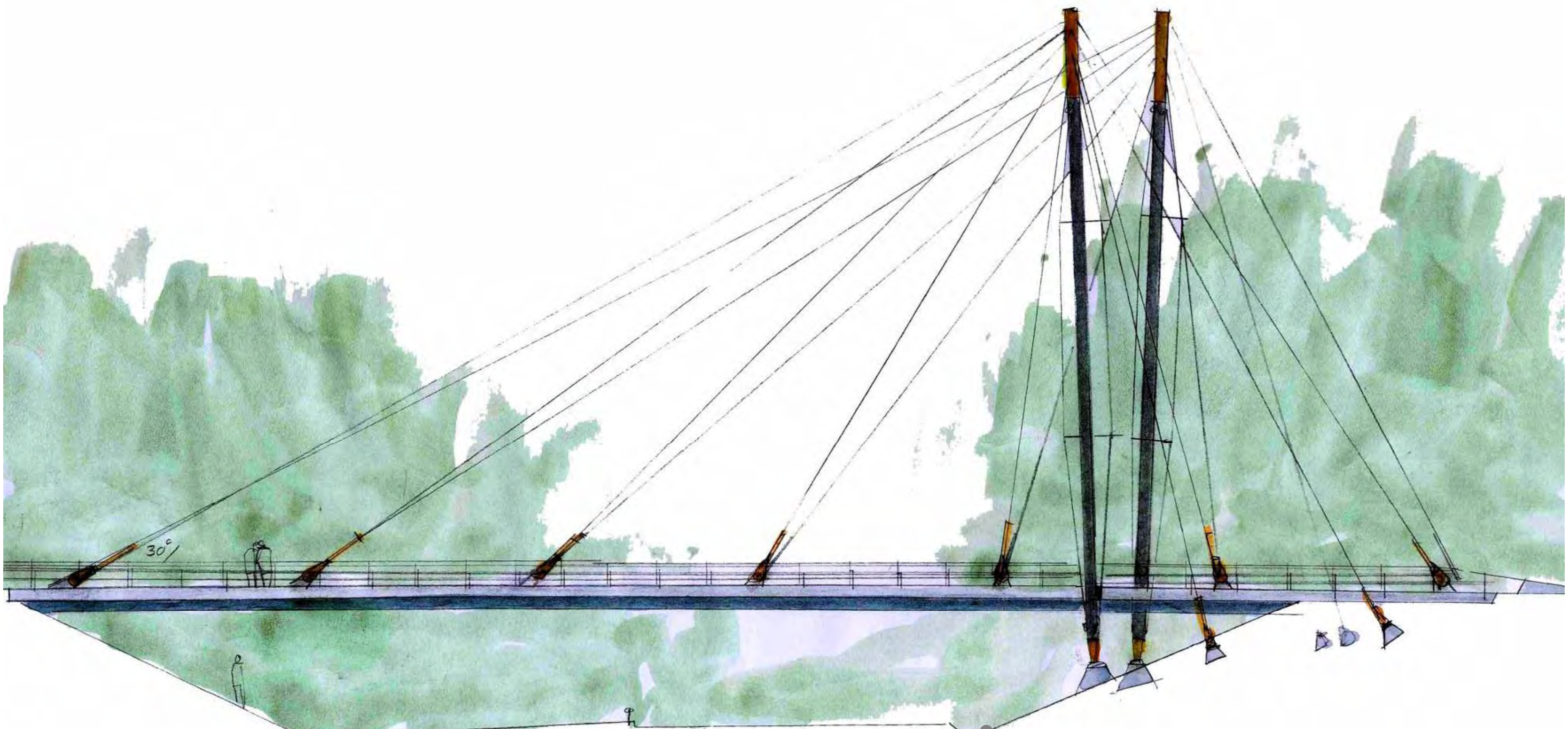
Ledelysene plasseres i midtdeleren, og effekten kan sammenlignes med flyplasser.

LED belysning


TREBRUER E6 EIDSVOLL


Kolomoenkrysset før utbygging

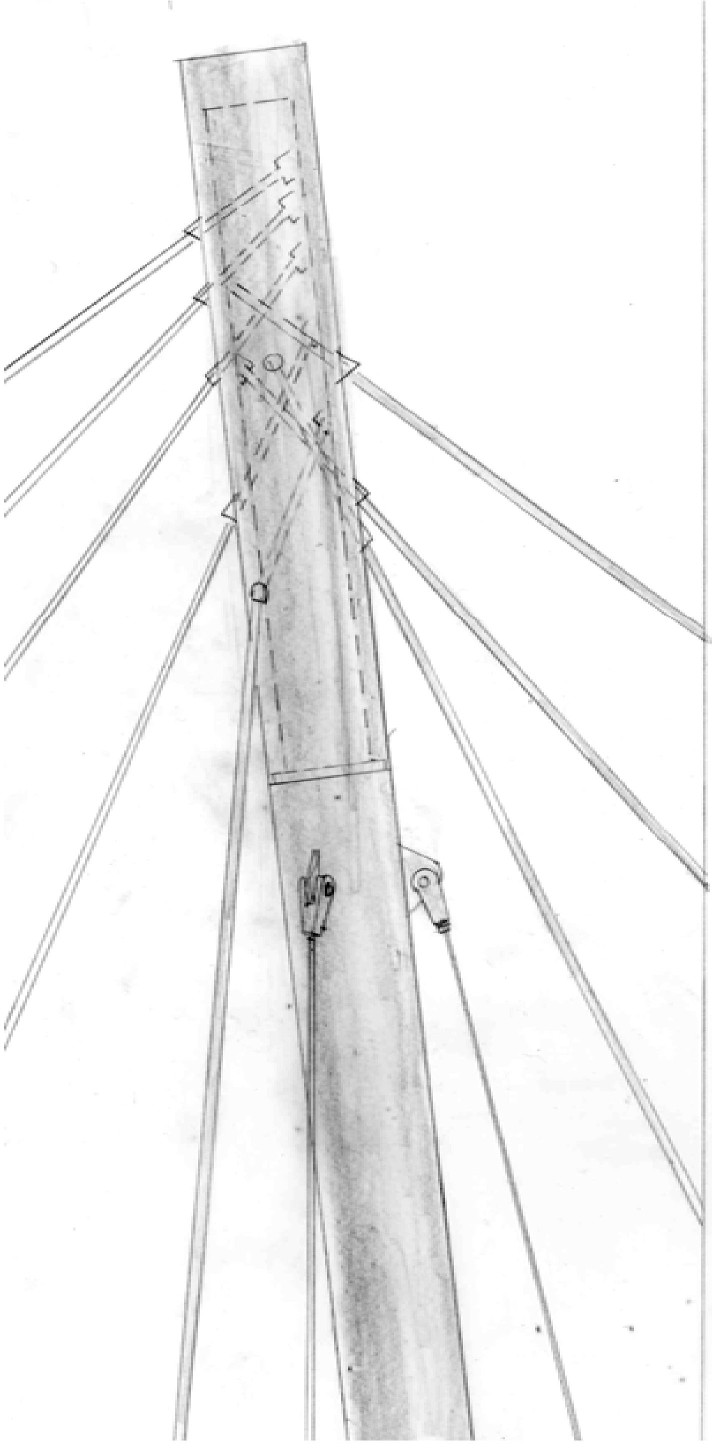

KOLOMOEN BRU - EN FULLRIGGER

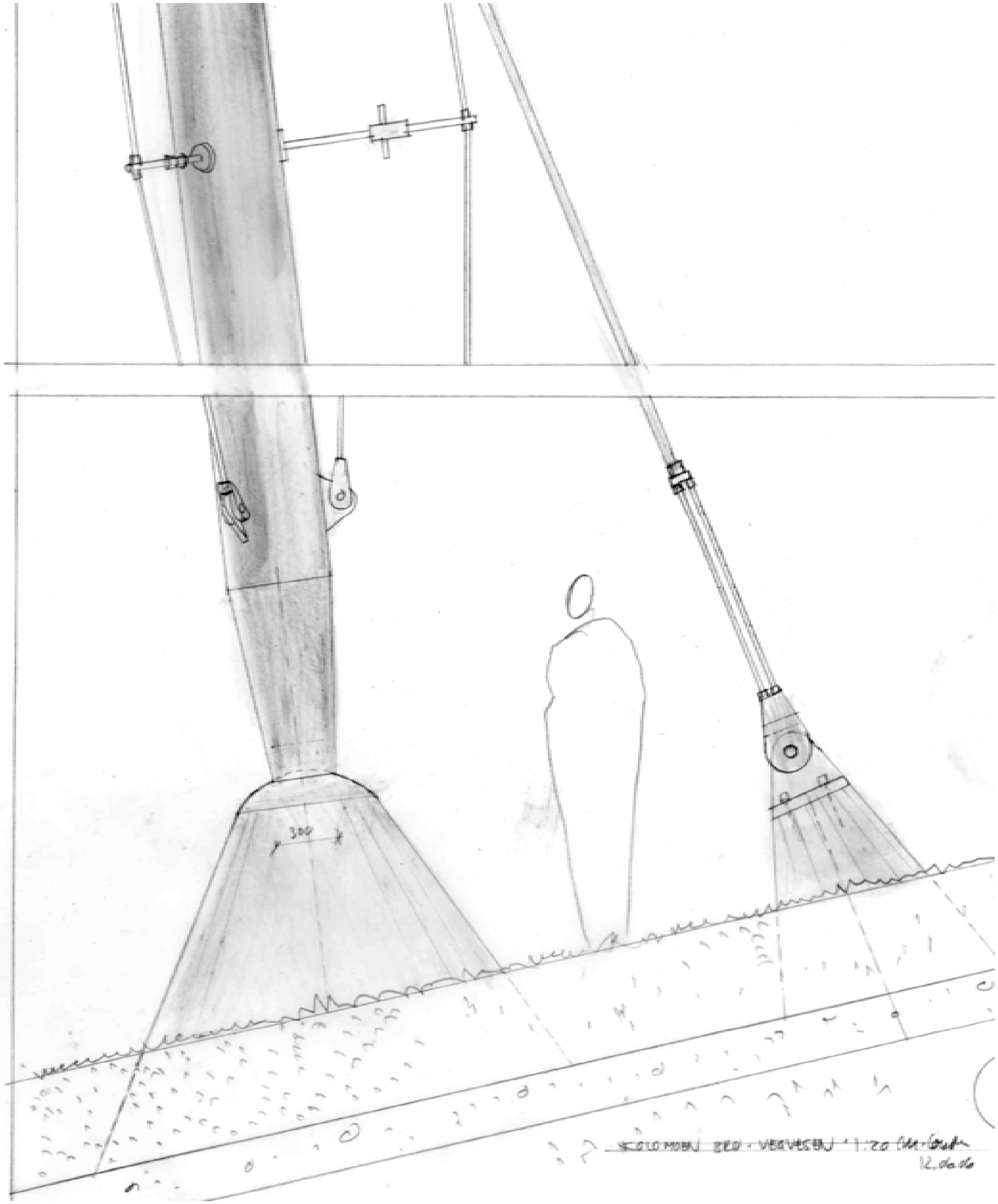


Prosess: Den første skisse og brotårn i treverk

Arbeidstittel: Fullrigger

Rådgivere konstruksjoner: Bjørn Vik og Hilde Ranem Isaksen

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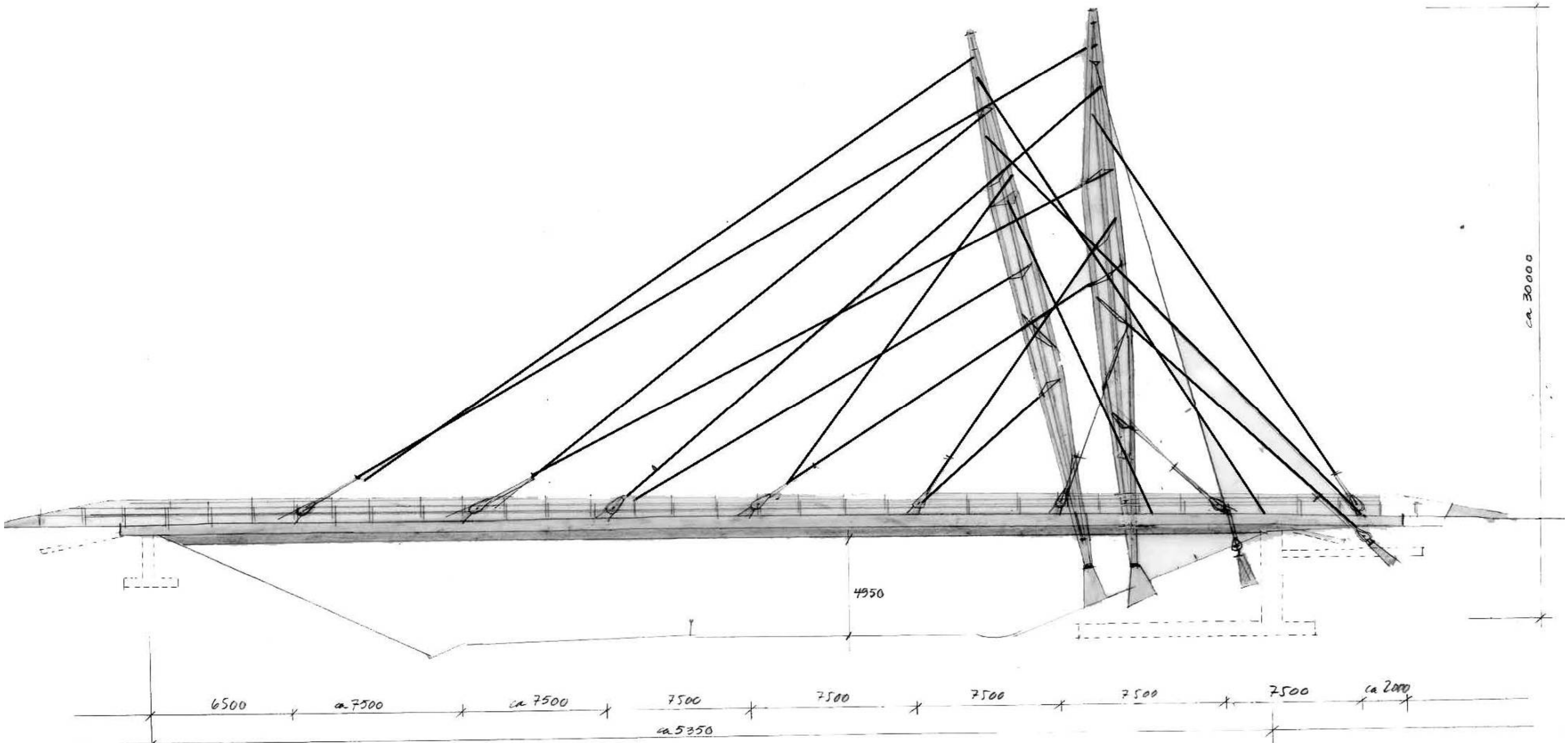

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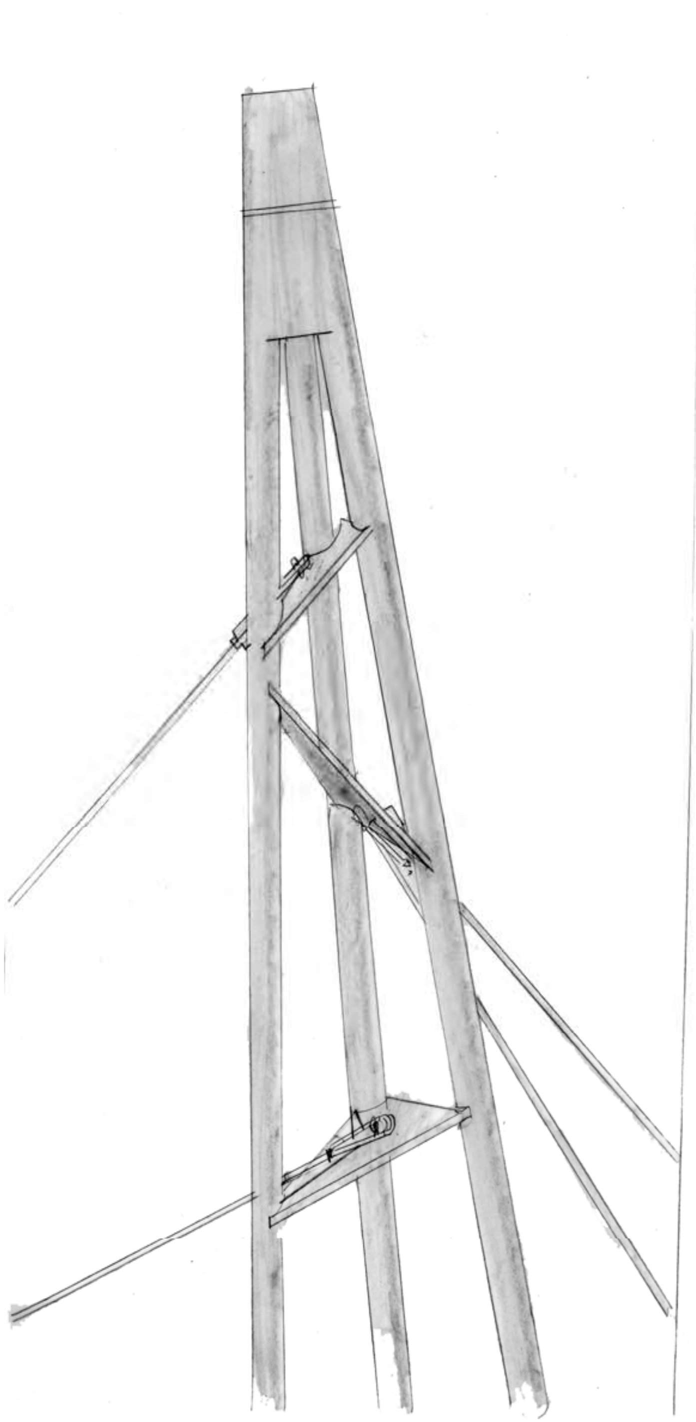

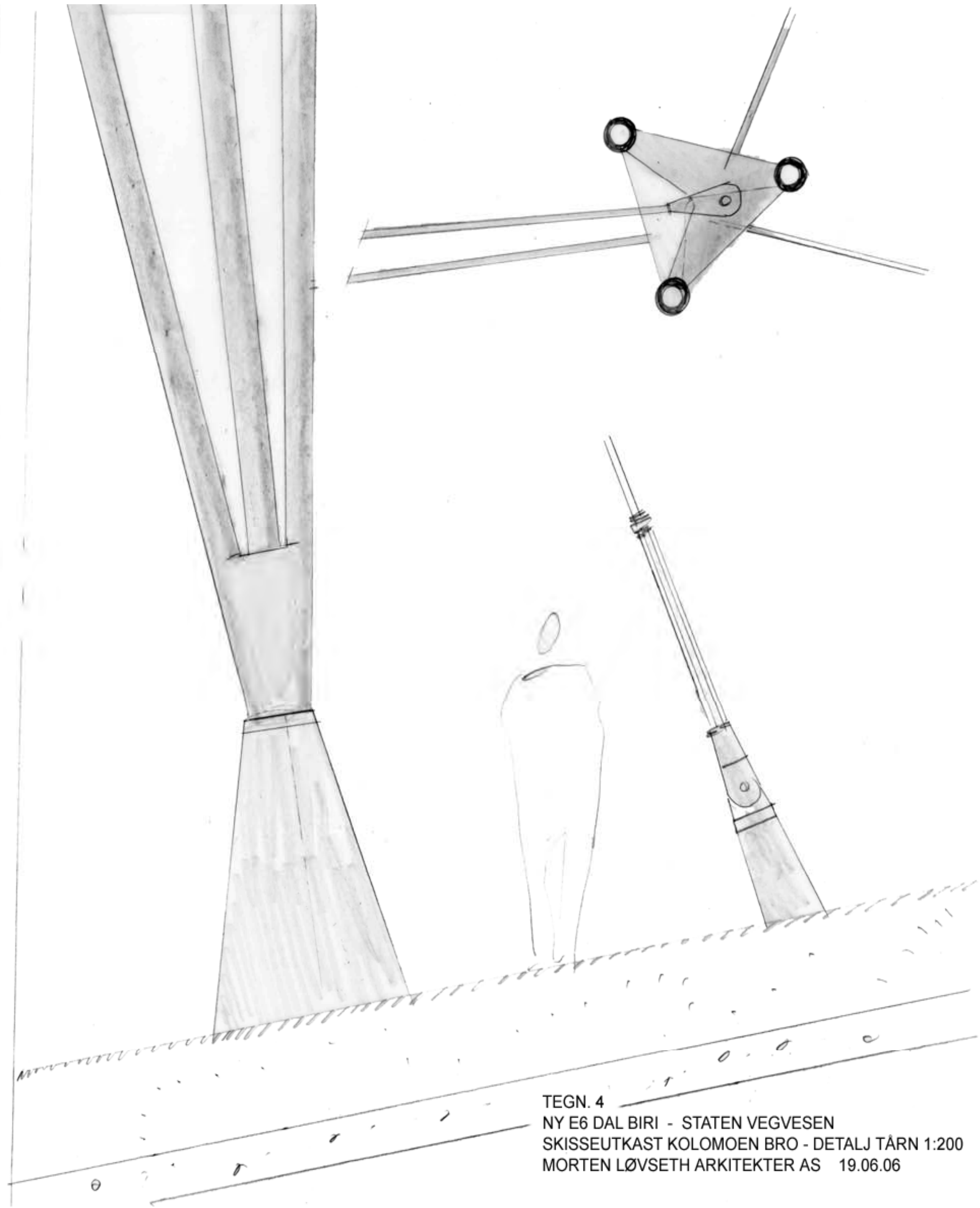

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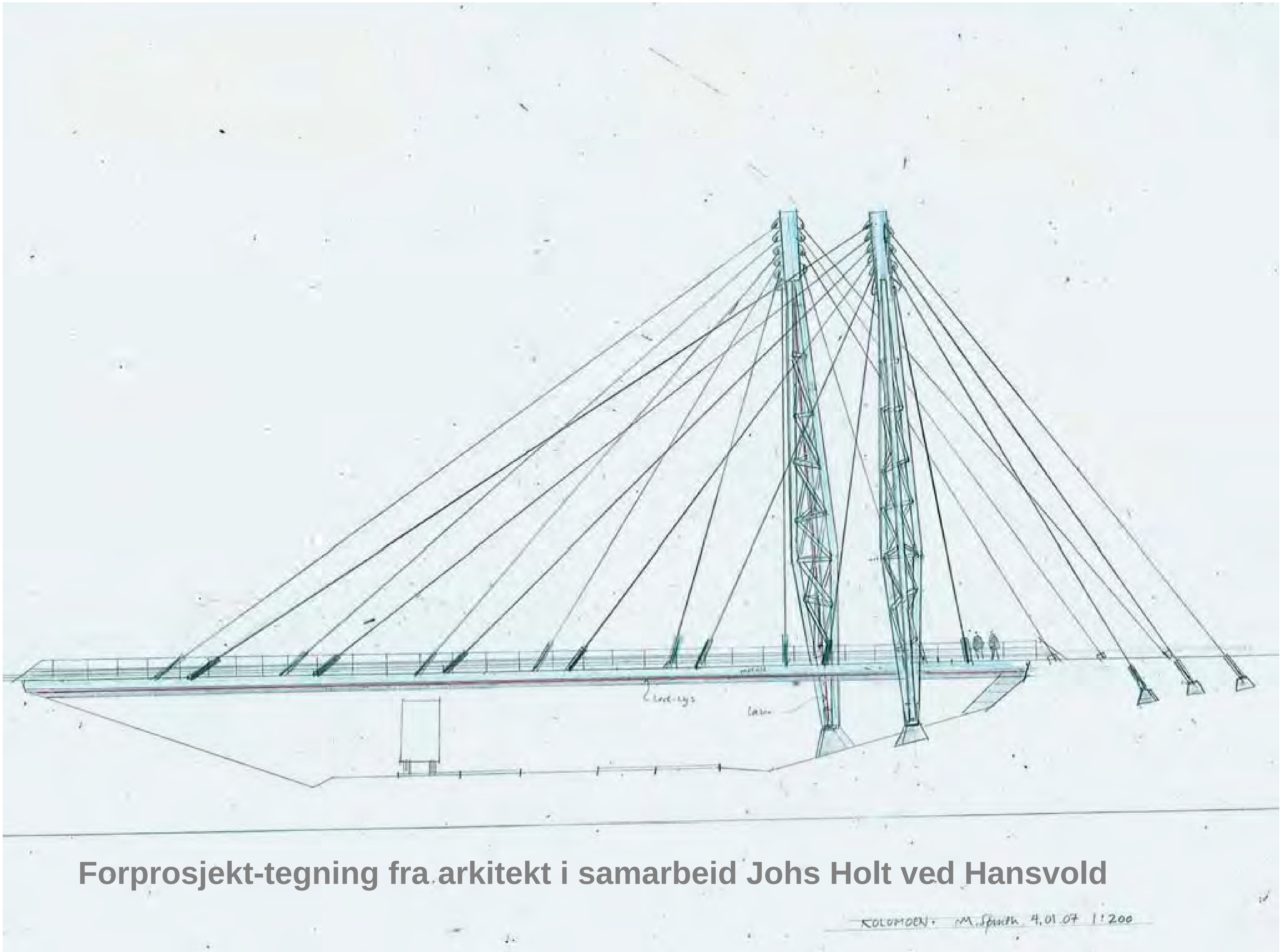
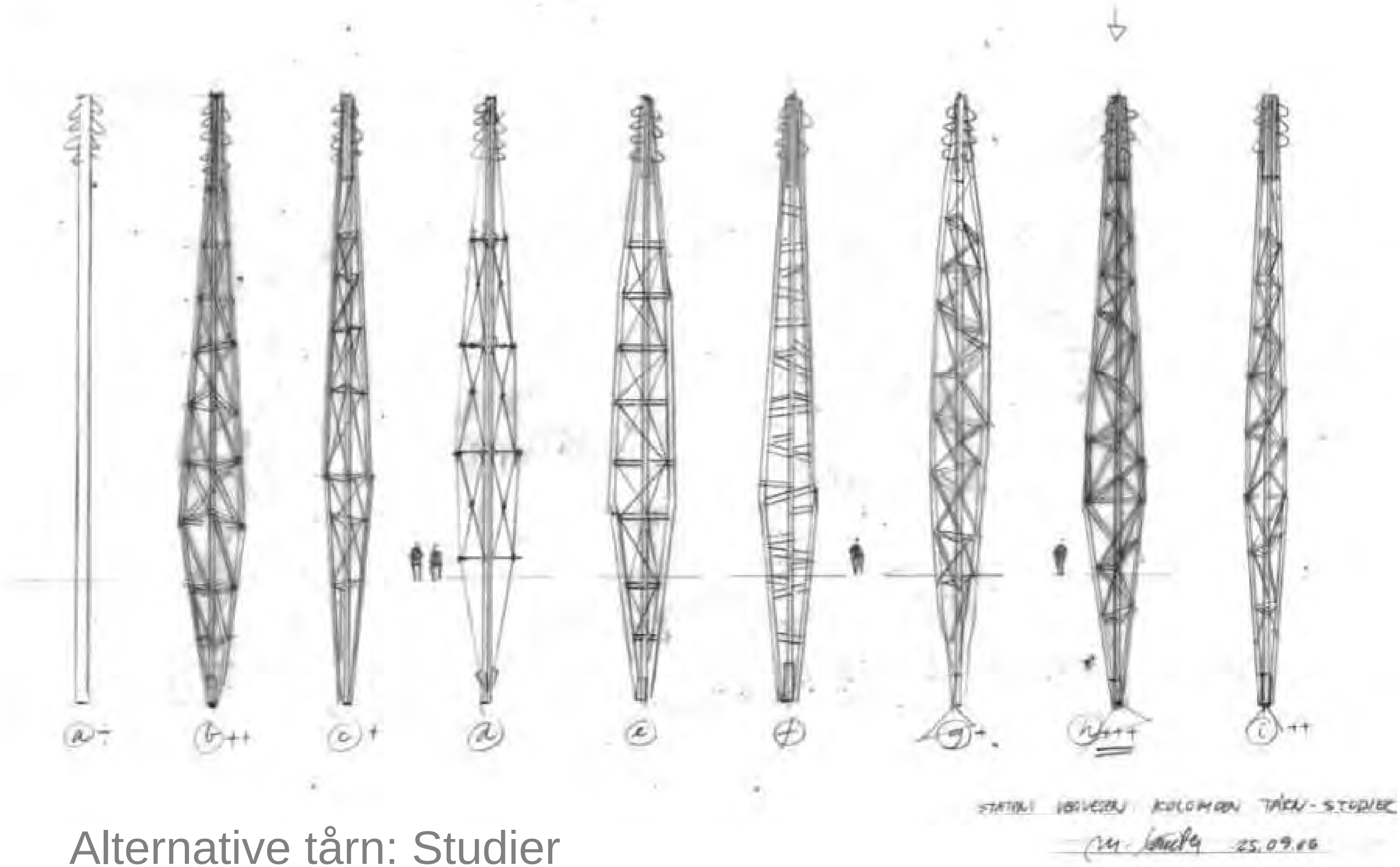
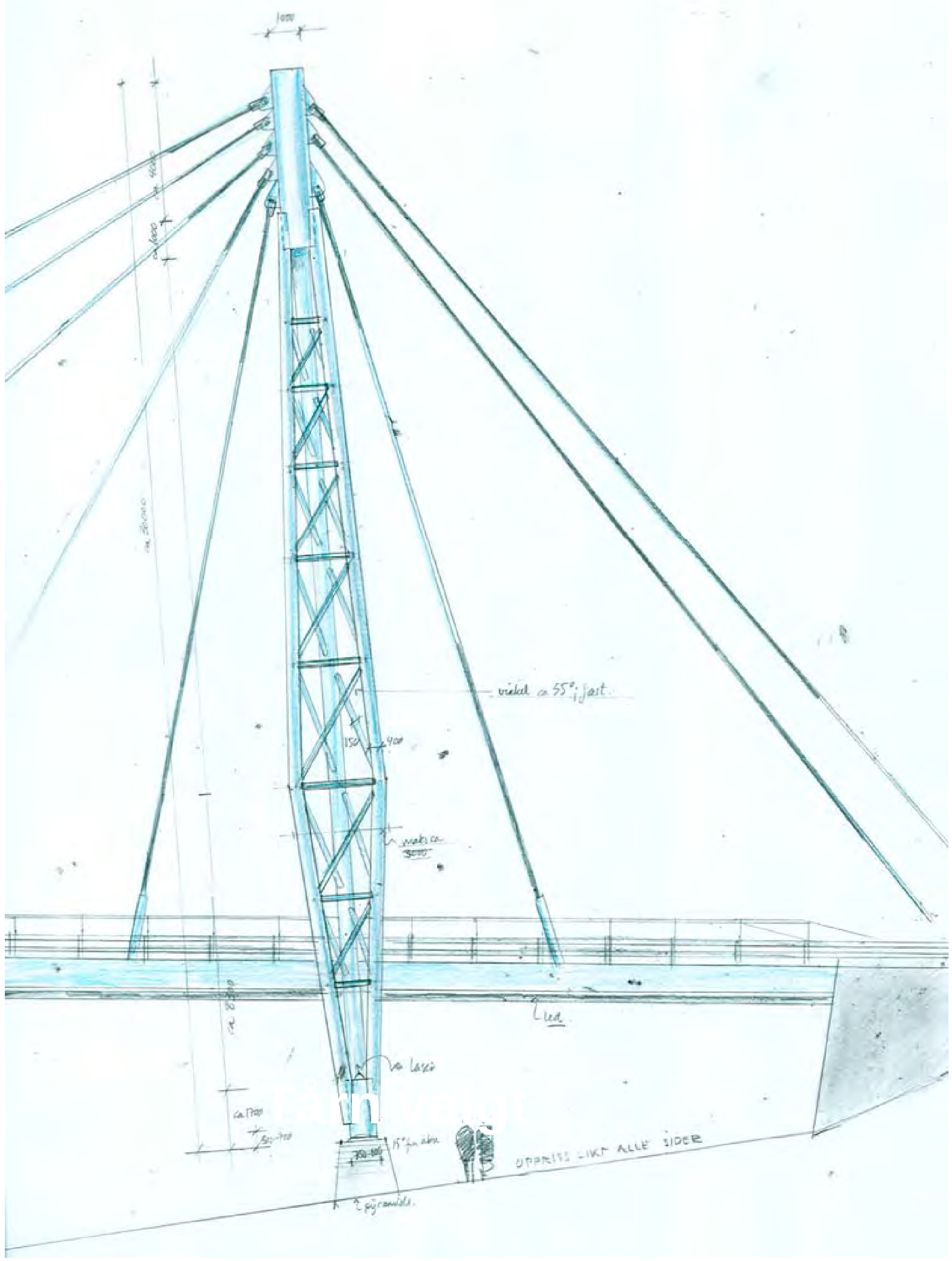


Forprosjekt-tegning fra arkitekt i samarbeid Johs Holt ved Hansvold



Alternative tårn: Studier



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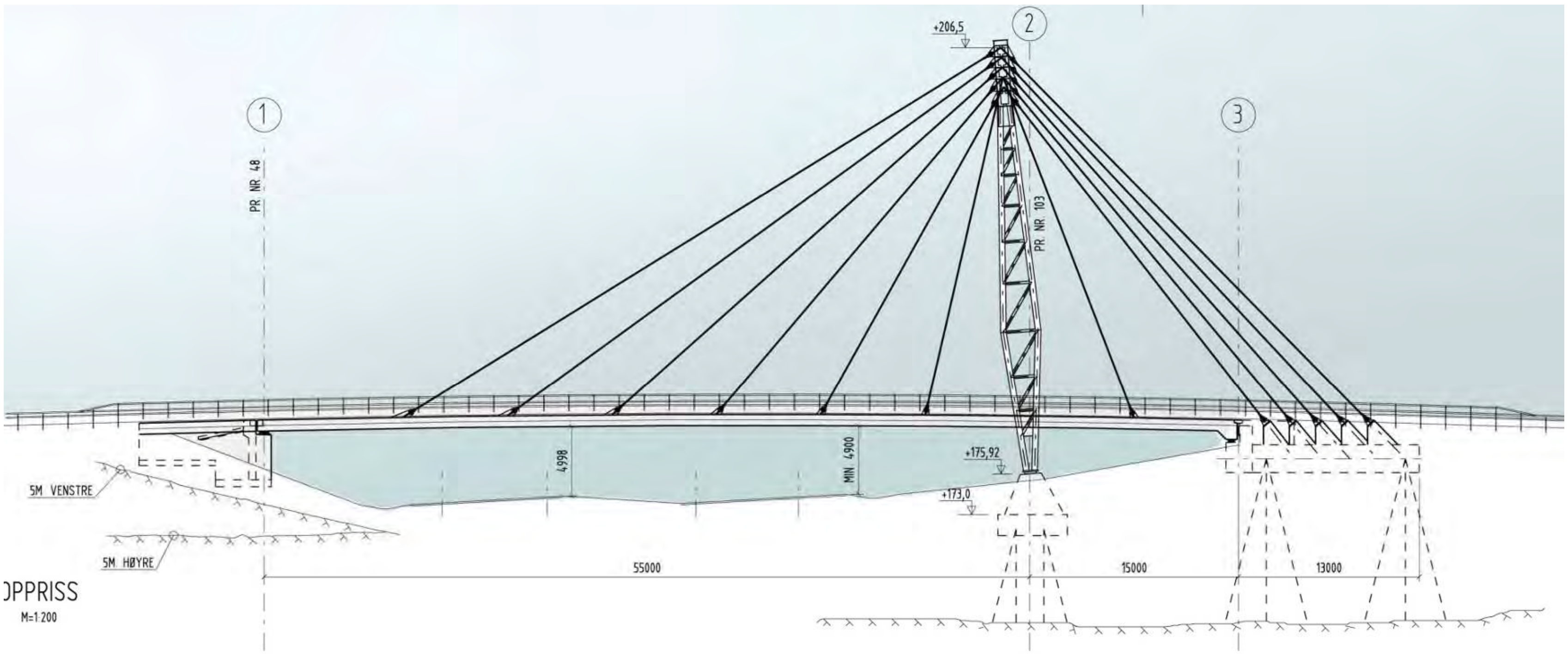

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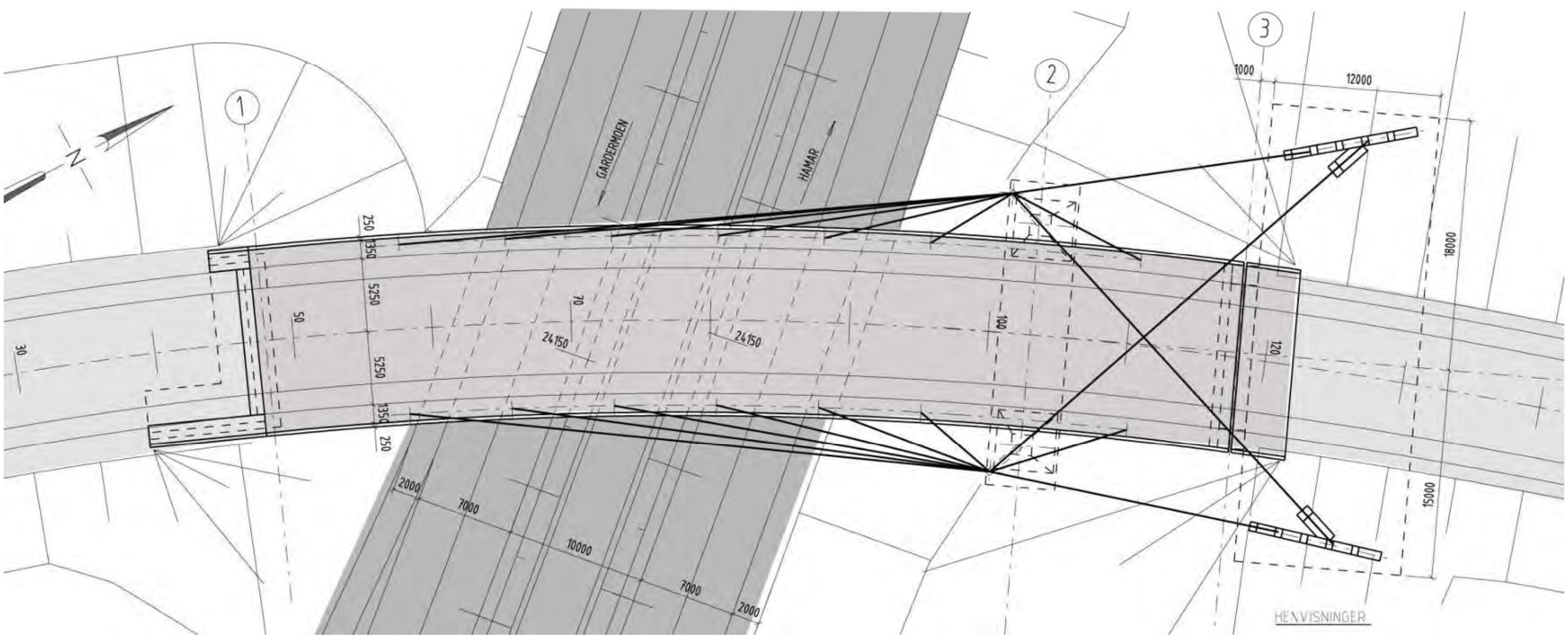

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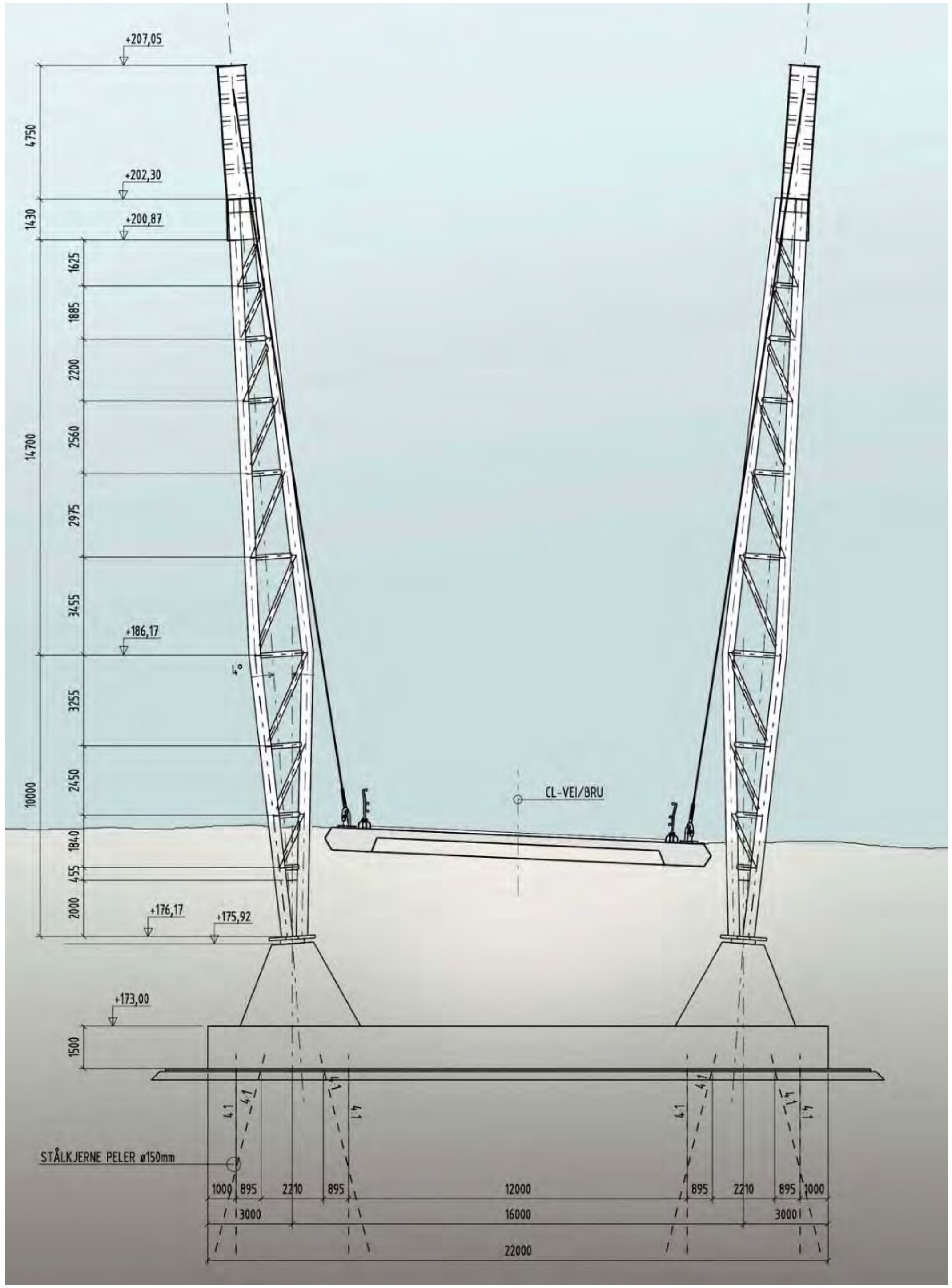

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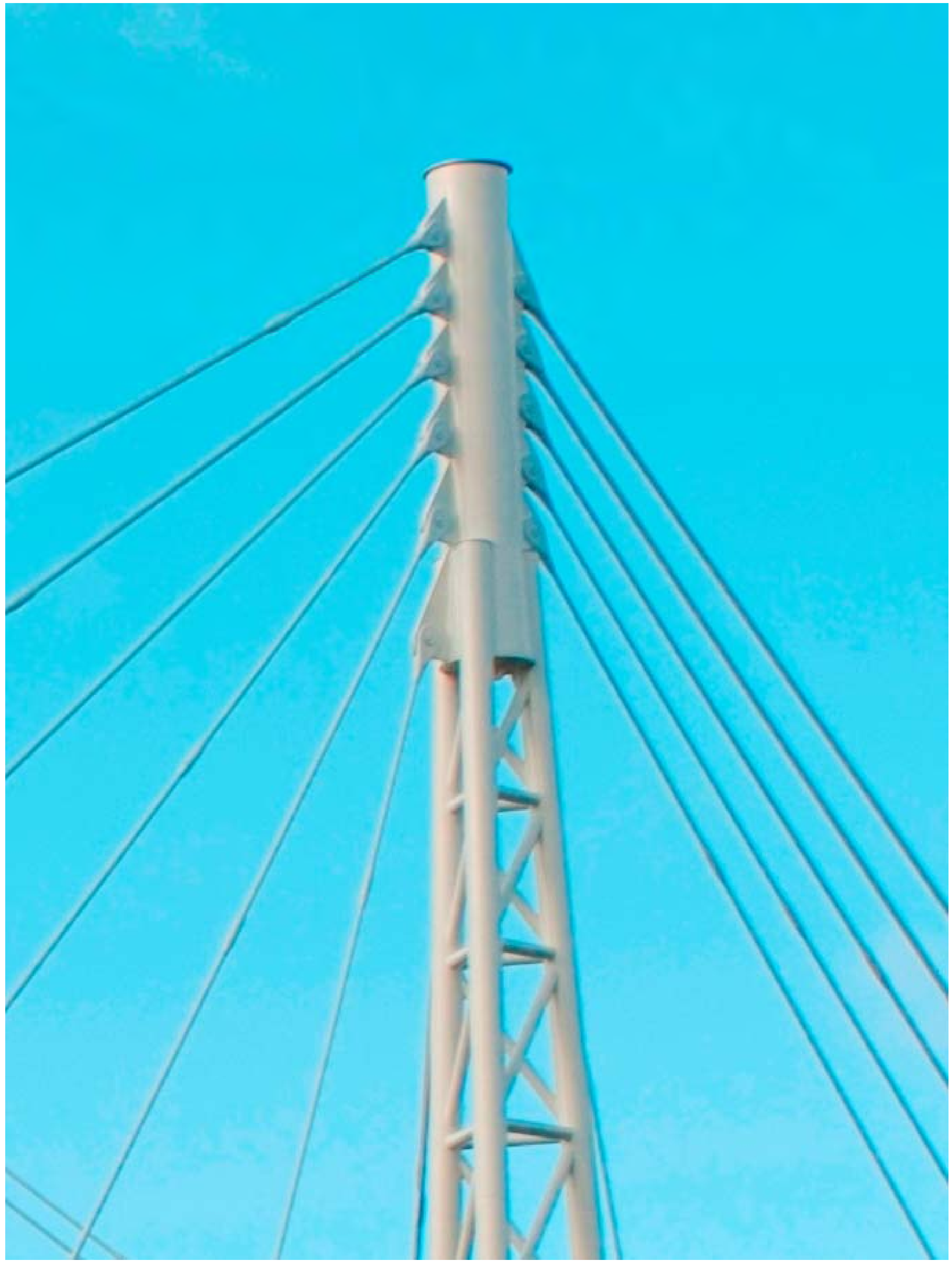
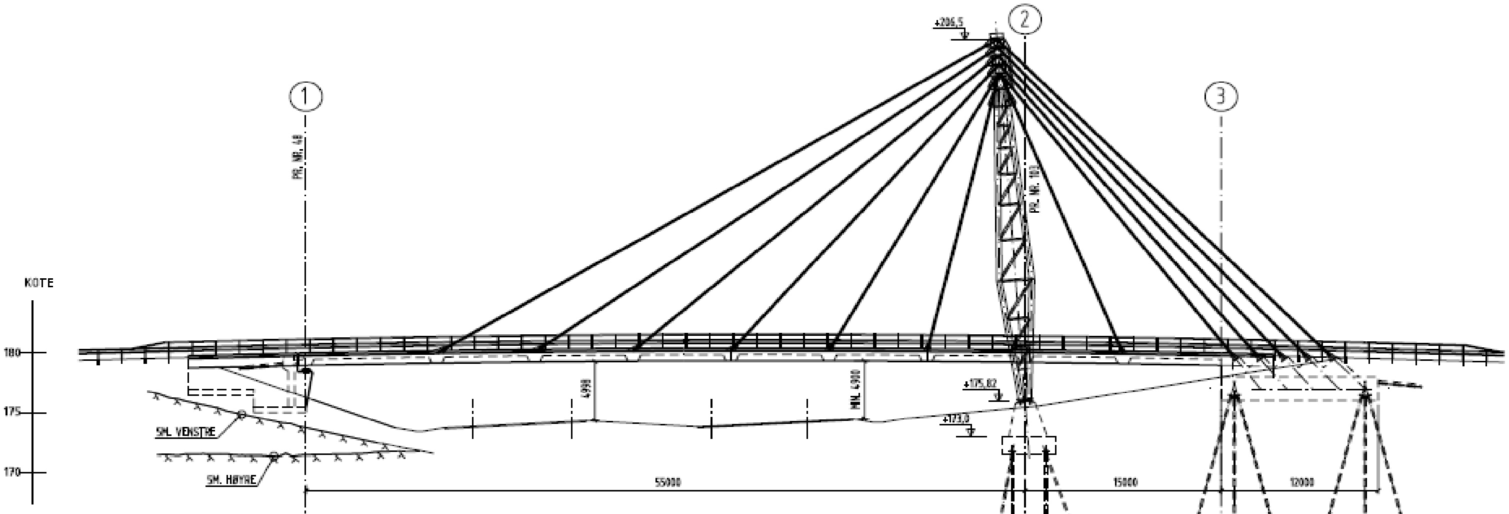


Kolomoen bru
Teknisk beskrivelse

Carl Hansvold, Johs. Holt A.S



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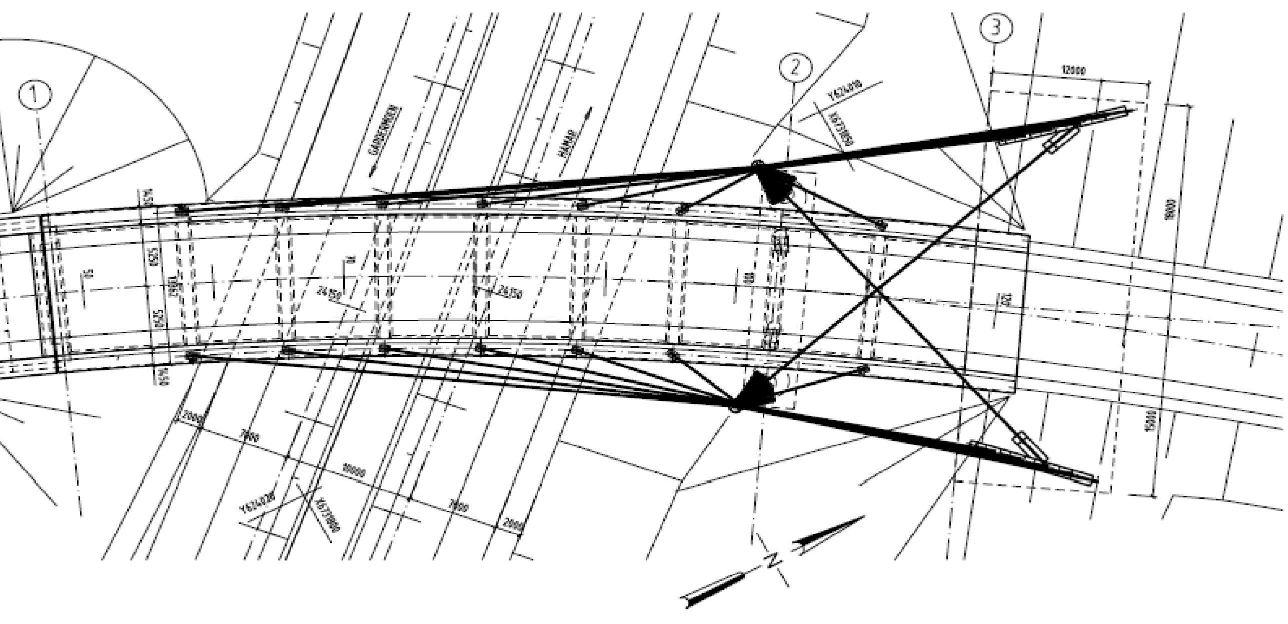

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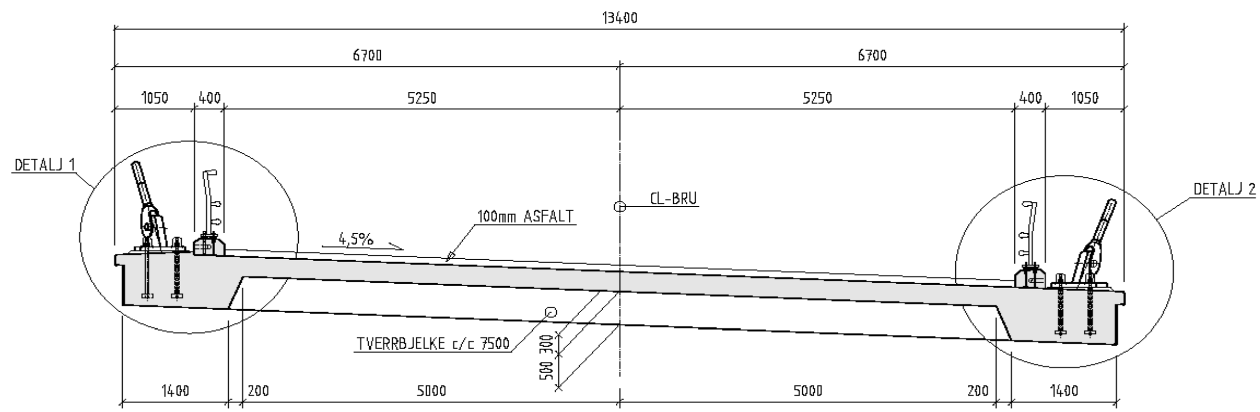

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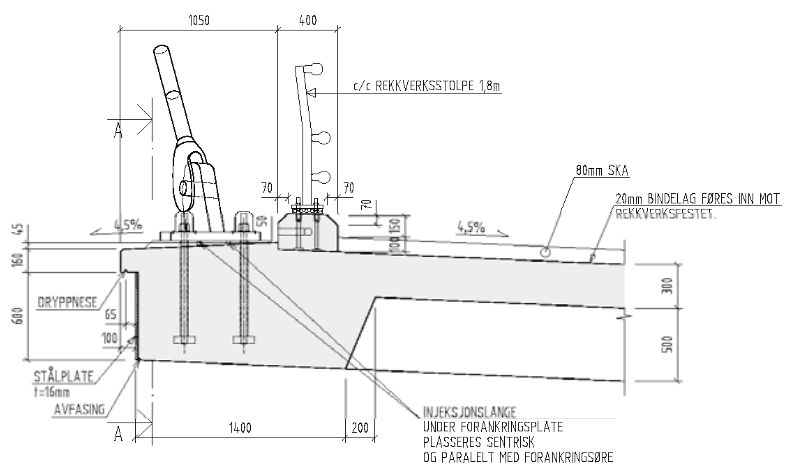

DETALJ 1
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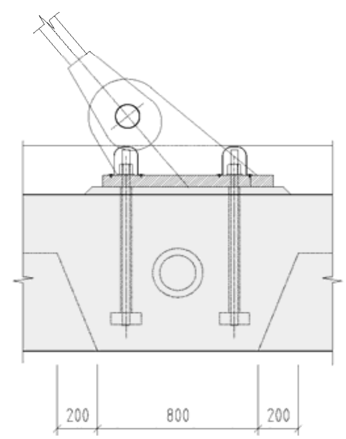
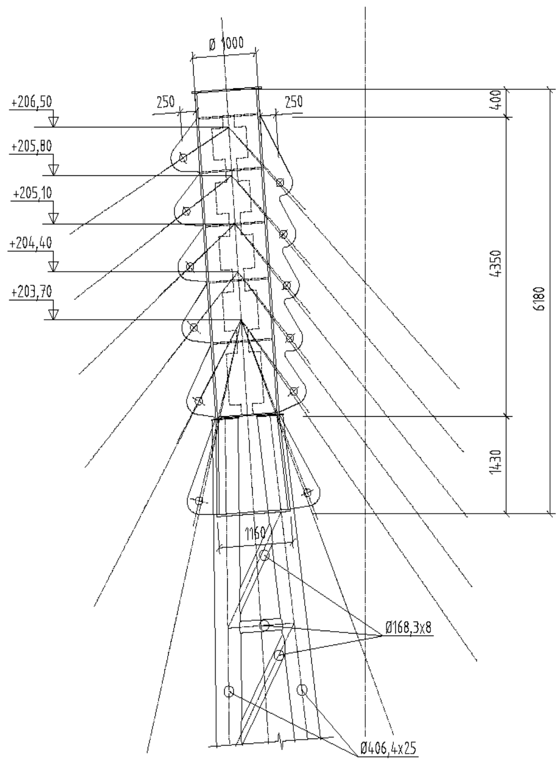
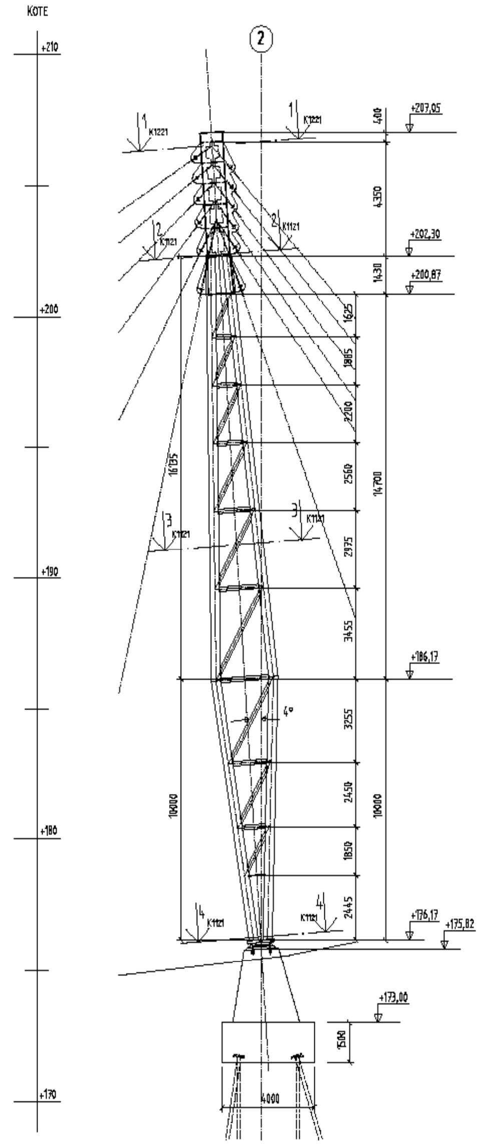


SNITT A-A
1:20

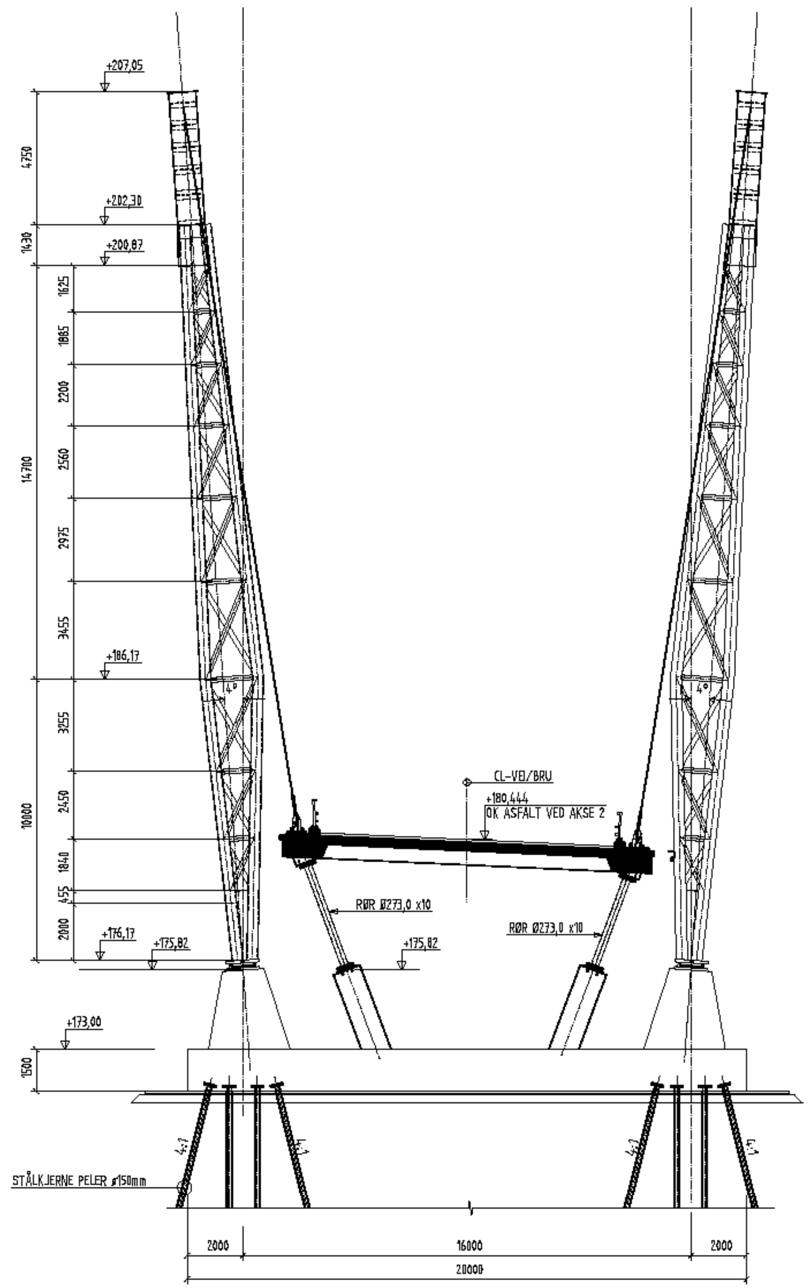
TÅRN



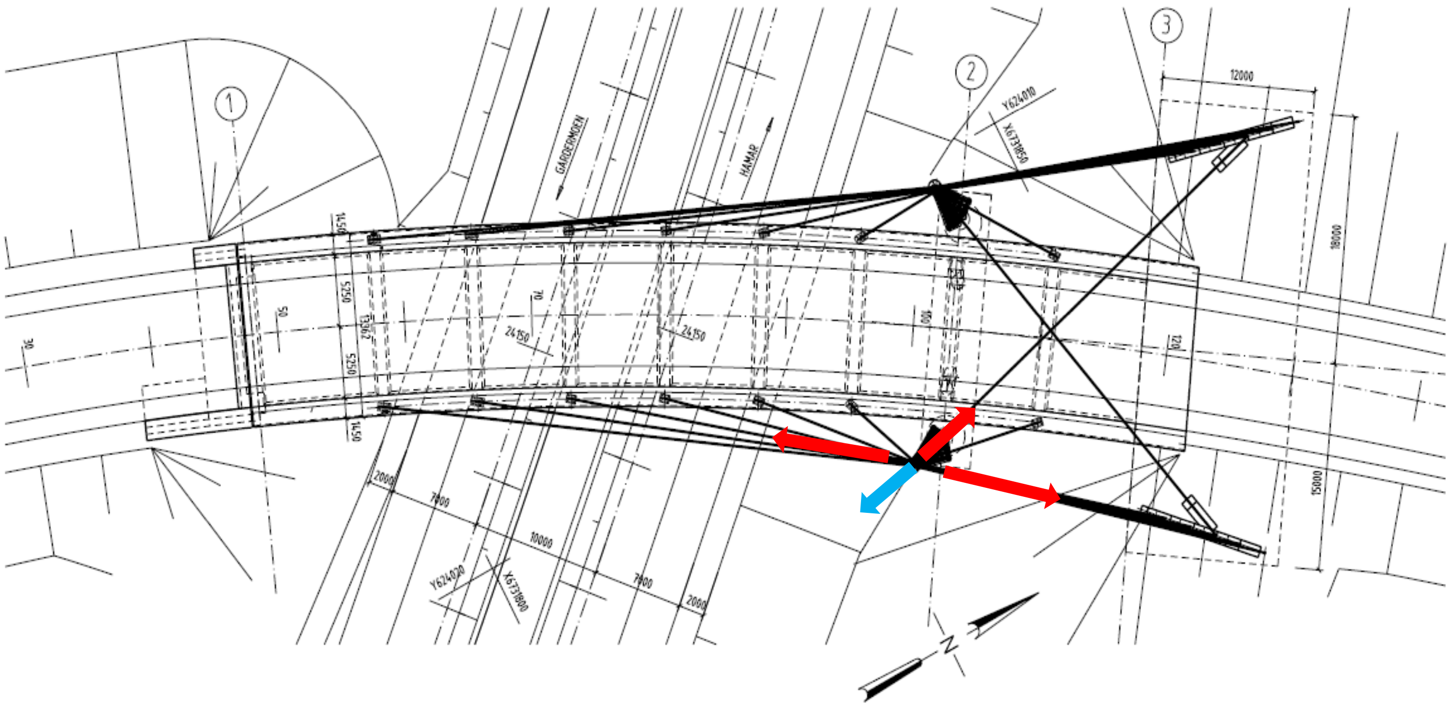
TÅRNTOPP
1:50



OPPRISS
1:100


+207,05
4750
+202,30
1430
+200,87
1625
1885
2200
2560
14700
2975
3455
+186,17
3255
2450
10000
1840
455
2000
+176,17
+175,82
4°
CL-VEI/BRU
+180,444
OK ASFALT VED AKSE 2
RØR Ø273,0 x10
+175,82
+173,00
1500
STÅLKJERNE PELER ø150mm
2000
16000
20000

LIKEVEKT TÅRNTOPP



HORISONTALKOMPONENTER:

FRA STAGKREFTER

FRA AKSIALKRAFT I TÅRN

MATERIALER

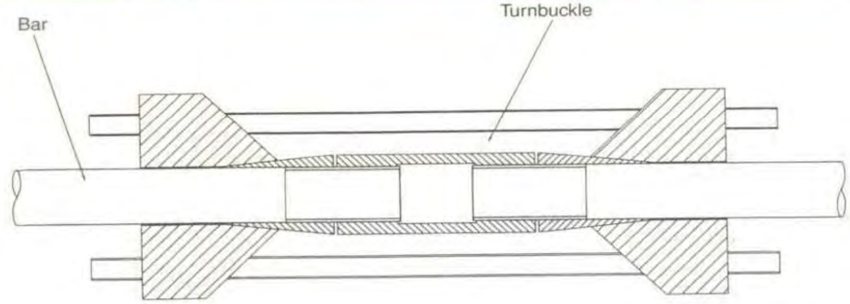
• BRUOVERBYGNING:	Lettbetong LB 45, densitet~1800kg/m3
• ØVRIG:	Betong B45 SV40
• Armering:	B500 NC
• Stål tårn:	S355 N(NL)
• Spennarmering:	CONA CMI 19 og 31 liner
• Spennstenger:	Macalloy 1030 (ø32 og ø36)
• Skråstag:	Macalloy 520 (M76-M100)

Lettbetong LB45 – Betongsammensetning

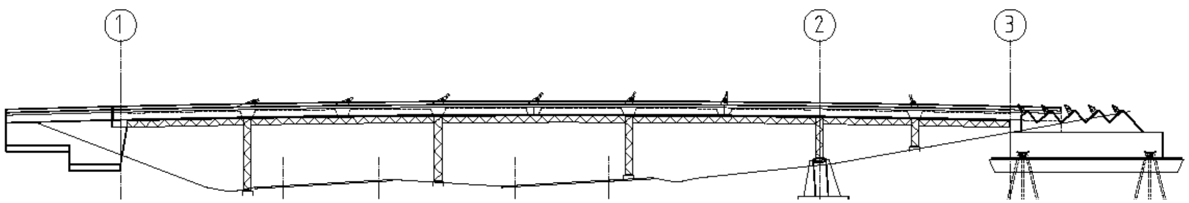
	Kg/m3	Prosent	Virkningsfaktor
Silika Fesil	36,90	8,00	2
Anleggsement	424,35	92,00	1
Vann	175,00	100,00	
Dynamon SP-N	4,68		1
Scancem VMA	4,00		1
Mapeair 25	1,85	0,40	1
0-10mm grovsand	588,72	38,00	
STALITE ½ " lettklinker	561,53	62,00	


2009/07/03 13:03

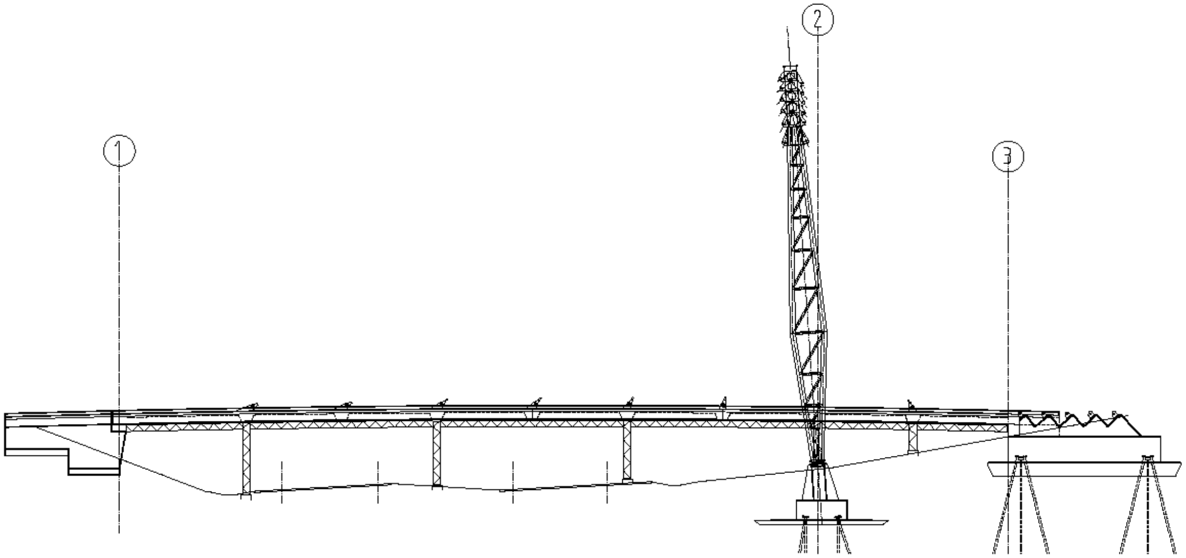
Macalloy TechnoTensioner



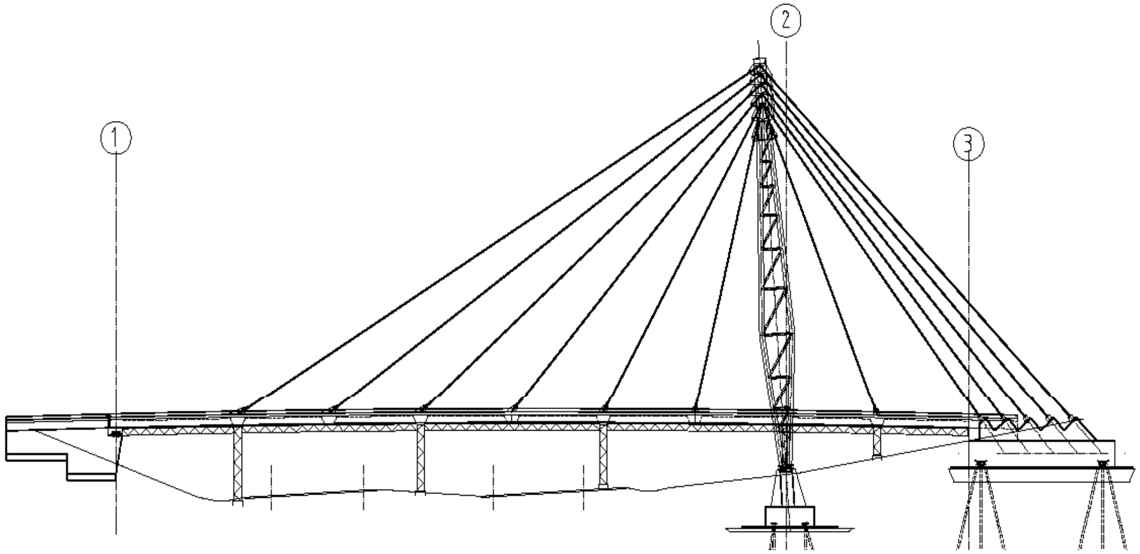

2009/07/03 12:29



<u>TRINN 1:</u>
LANDKAR AKSE 1, TÅRNFUNDAMENT, BALLASTBJELKE OG BRUOVERBYGNING BYGGES PÅ FAST STILLAS.

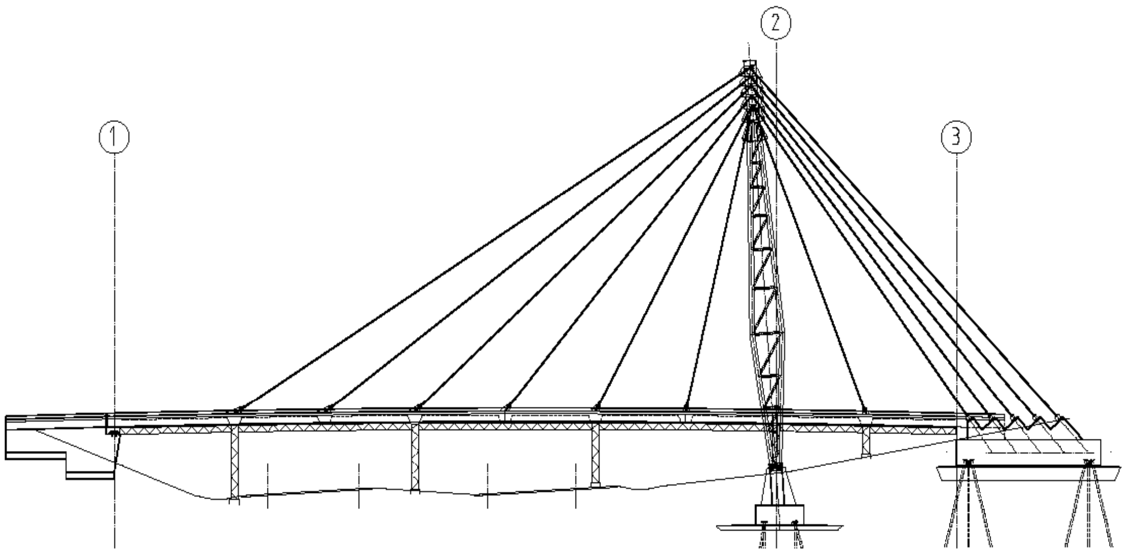


<u>TRINN 2:</u>
TÅRN MONTERES OG AVSTAGES PROVISORISK. STØRSTE TILLATTE AVVIK FRA TEORETISK TÅRNAKSE ETTER AT TÅRN ER MONTERT PÅ PERMANENTE TÅRNLAGRE: 300mm MÅLT I TÅRNTOPP.



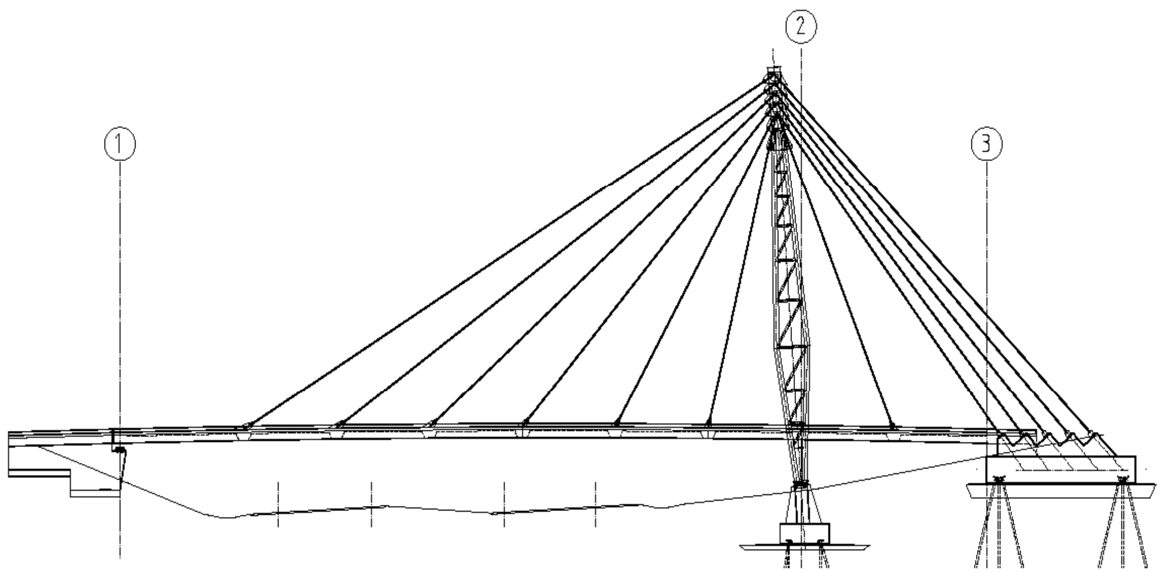
TRINN 3:

- MONTERING OG OPPSPENNING AV STAGPLAN I INNERSVING TIL S =400 kN
- MONTERING OG OPPSPENNING AV STAGPLAN I YTTERSVING TIL S =400 kN



TRINN 4:

- OPPSPENNING STAGPLAN I INNERSVING TIL TEORETISK KRAFT
- OPPSPENNING STAGPLAN I YTTERSVING TIL TEORETISK KRAFT
- RIVING AV STILLAS

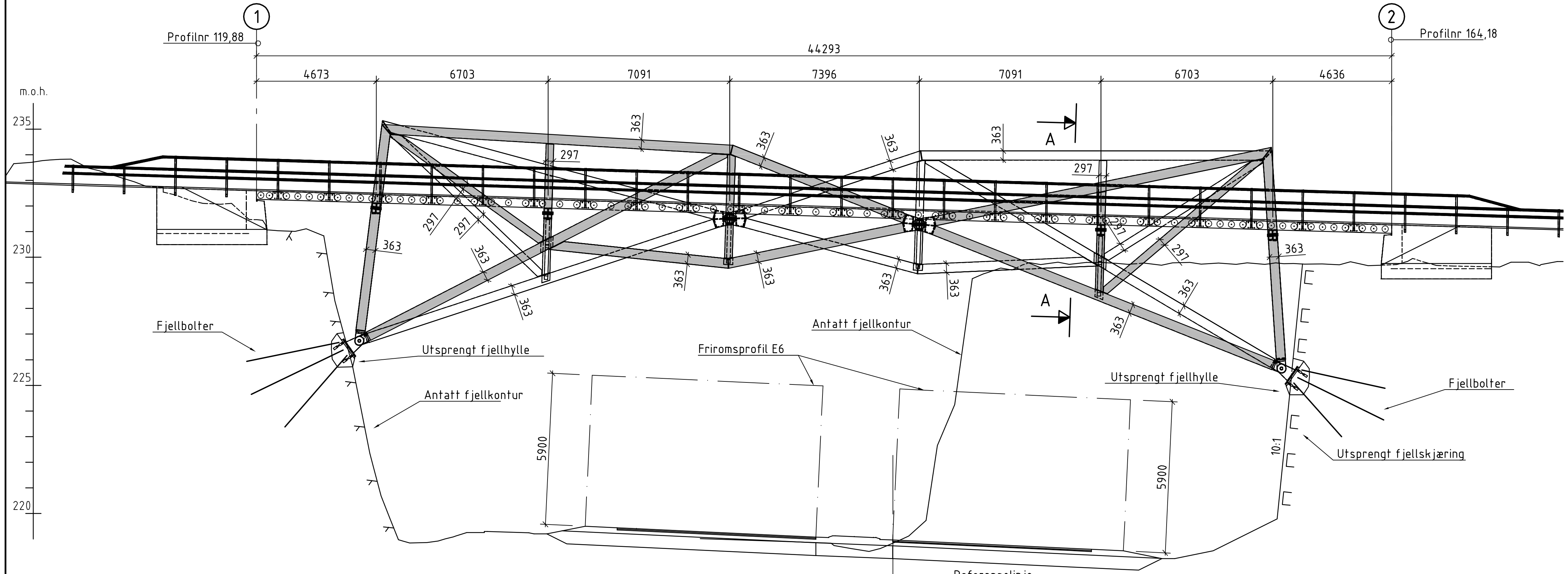


TRINN 5:

• KONTROLL OG EVT. ETTERJUSTERING INNERSVING
• KONTROLL OG EVT. ETTERJUSTERING YTTERSVING
 (KUN STIKKPRØVER UTFØRT FOR YTTERSVING)


Et innovativt vegprosjekt, en vakker veg og bruer som arkitektur

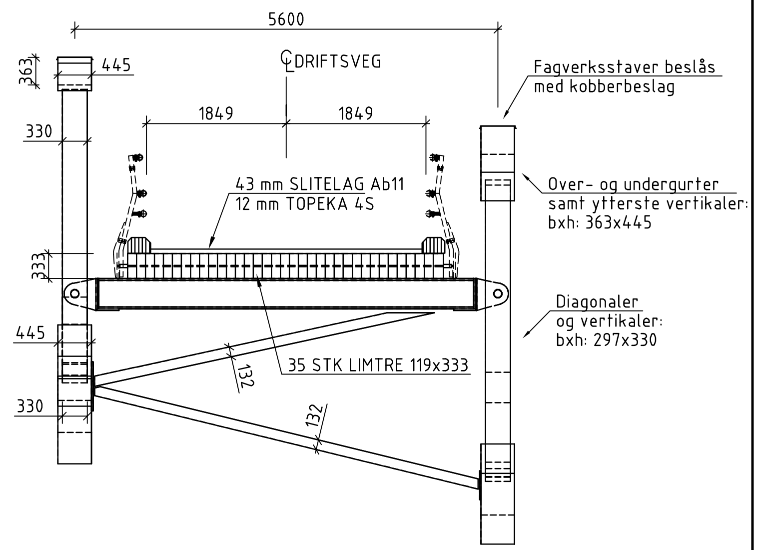
PROFILNUMMER	120	130	140	150	160
PROFILHØYDE	232,64	232,34	232,04	231,74	231,44
TERRENGHØYDE	231,74	217,96	219,00	230,00	231,00
VERTIKALKURVE			3 %		
HORISONTALKURVE			R=∞		



OPPRISS

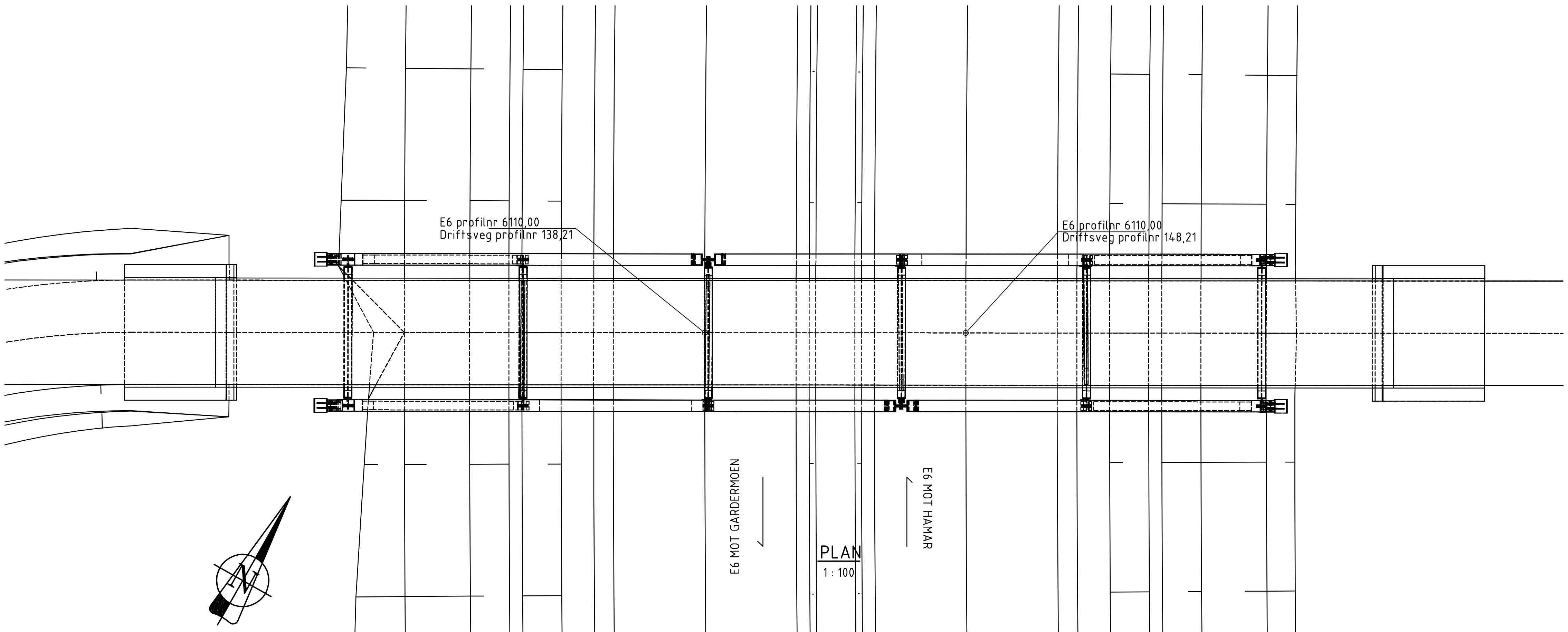
1 : 100

SØRLIG FAGVERKET ER SKRAVERT



SNITT A-A

1 : 50



HENVISNINGER:

PLAN OG PROFIL: LINJE 11000 PR 5500 - 6250	C004
PLAN OG PROFIL: LINJE 60500	D003
MÅLTEGNING	K030-02
MÅLTEGNING	K030-20
MÅLTEGNING	K030-21

ANMERKNINGER:

1. PROSJEKTERINGSGRUNNLAG:
   PROSJEKTERINGSREGLER:
   - STATENS VEGVESENS HÅNDBOK 026 PROSSESKODE 2, VERSJON NOVEMBER 2007
   - STATENS VEGVESENS HÅNDBOK 185 PROSJEKTERINGSREGLER FOR BRUER HØRINGSUTGAVE DATERT 28.05.2006

   LASTFORSKRIFTER:
   - STATENS VEGVESENS HÅNDBOK 185 PROSJEKTERINGSREGLER FOR BRUER HØRINGSUTGAVE DATERT 28.05.2006

   BELEGNING:
   - BELEGNINGSKLASSE A3 IHT HÅNDBOK 185 (HØRINGSUTGAVE 2006) ASFALTSLITELAG MED FULL FUKTISOLERING
   - DIMENSJONERENDE BELEGNINGSVEKT: 2.0 kN/m²
3. UTFØRELSE SKAL VÆRE I SAMSVAR MED PROSESSKODE 2 (2007)
4. KONTROLLKLASSE - UTVIDET KONTROLL (NS3465)
5. DRIFTSVEG, VALGT FØRINGSBREDDE 4 m.
6. ALLE MÅL I mm. ALLE KOTER OG KOORDINATER I m.
7. DIMENSJONERENDE HASTIGHET: 50 km/t
8. BETONG:
   - FUNDAMENT: B45-SV40, PROSESSKODE 2 (2007)
   - ARMERING: B 500 NC, NS3576, DEL 3
9. STÅL:
   - GENERELL STÅLKVALITET: S355 N, NS-EN 10025-3
   - GENERELL BOLTEKVALITET: 8.8
   - HVIS IKKE ANNET ER OPPGITT SKAL ALT STÅL VÆRE VARMFORSINKET
10. LIMTRE:
    - FAGVERK: GL36c (L40)
    - BRUDEKKE: GL36c (L40)

Revisjon	Revisjonen gjelder	Utarb	Kontr	Godkjent	Rev. dato

Godkjent som arbeidstegning ifølge notat fra Vedirektoratet: Saksnr. XXXXXX XX.XX.2009

Statens vegvesen

E6 HP: 13 Mogreina sør - Boksrud x181

Parsell DAL - BOKSRUD

STATSRÅDVEIEN BRU

OVERSIKT

KONKURRANSEGRUNNLAG

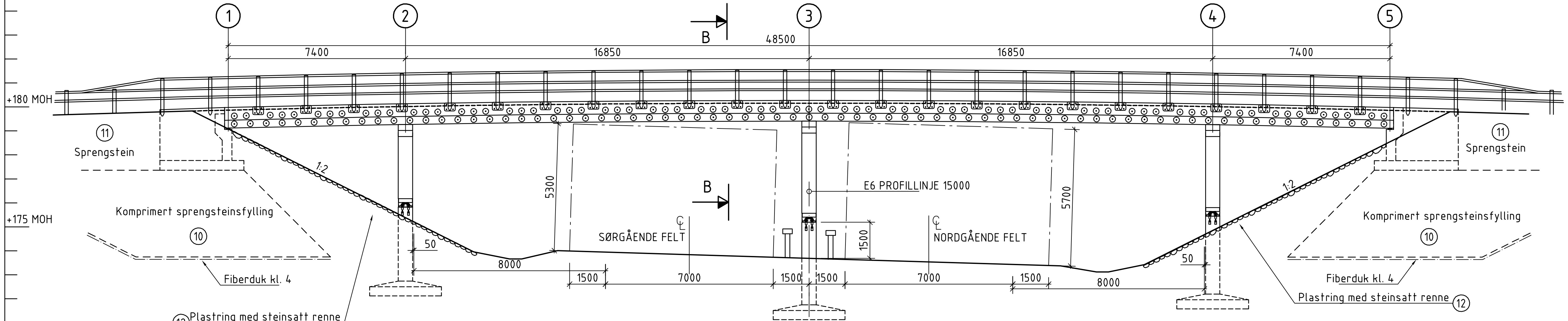
Tegningsdato	01.05.2009
Bestiller	NILS LYSBAKKEN
Produsert for	REGION ØST
Produsert av	COWI AS
	COWI
PROF-nummer	02E0006b__101
Arkivnummer	-
Byggverksnummer	02-1782
Målestokk A1	SOM VIST
Tegningsnummer/ revisjonsbokstav	K030-01

Utarbeidet av	Kontrollert av	Godkjent av	Konsulentarkiv
JMKJ	BJAK	BJAK	121842

Format: A1 Filnavn: P:\121\121842 E6 Dal-Minnesund\20_Tegninger\K030_Statsrådveien bru\Statsrådveien bru\Views\BRU-Oversikt.dwg

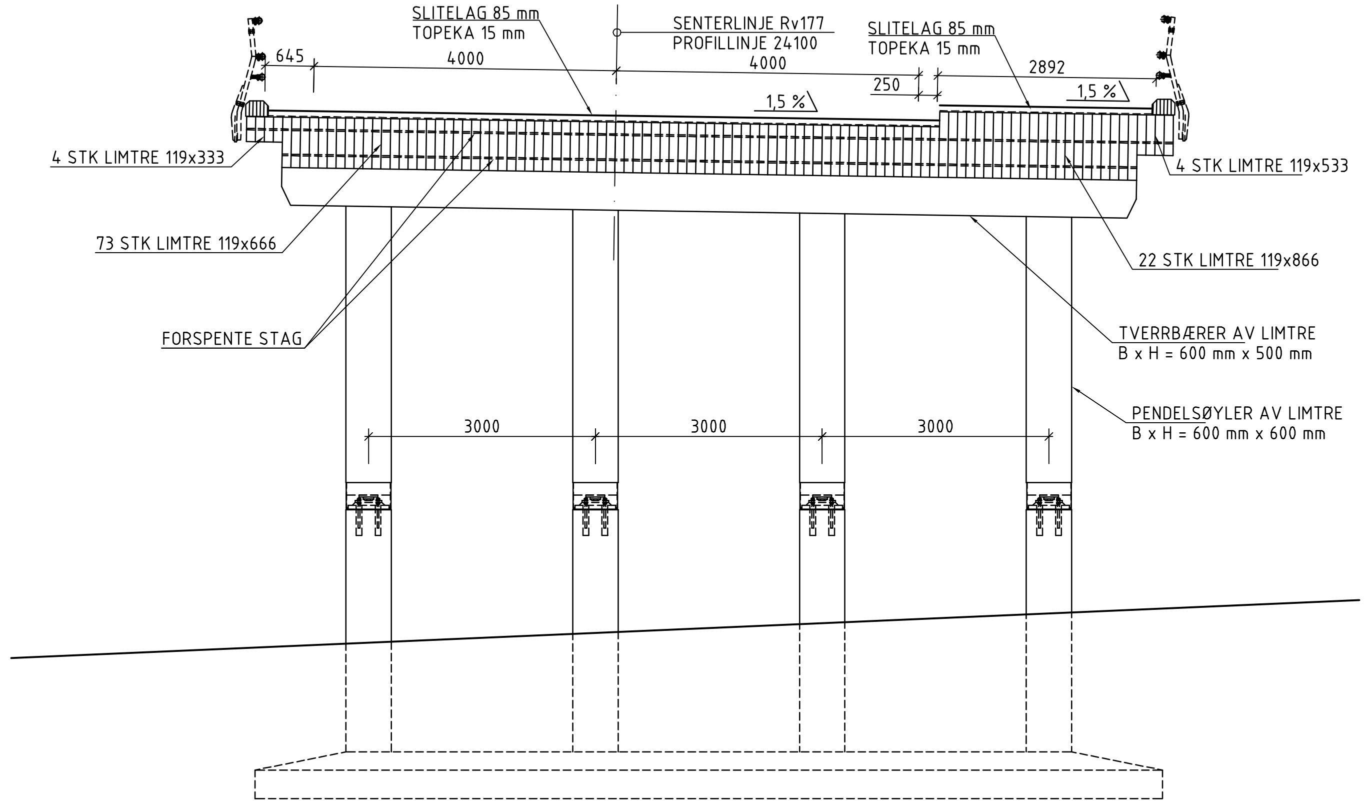
Plot: jmkj 27.05.2009 15:16

PROFILNUMMER	520	530	540	550	560
PROFILHØYDE	179,96	180,11	180,16	180,11	179,96
TERRENGHØYDE	176,54	173,67	173,49	173,13	175,78
VERTIKALKURVE			R=1000		
HORISONTALKURVE			R=∞		



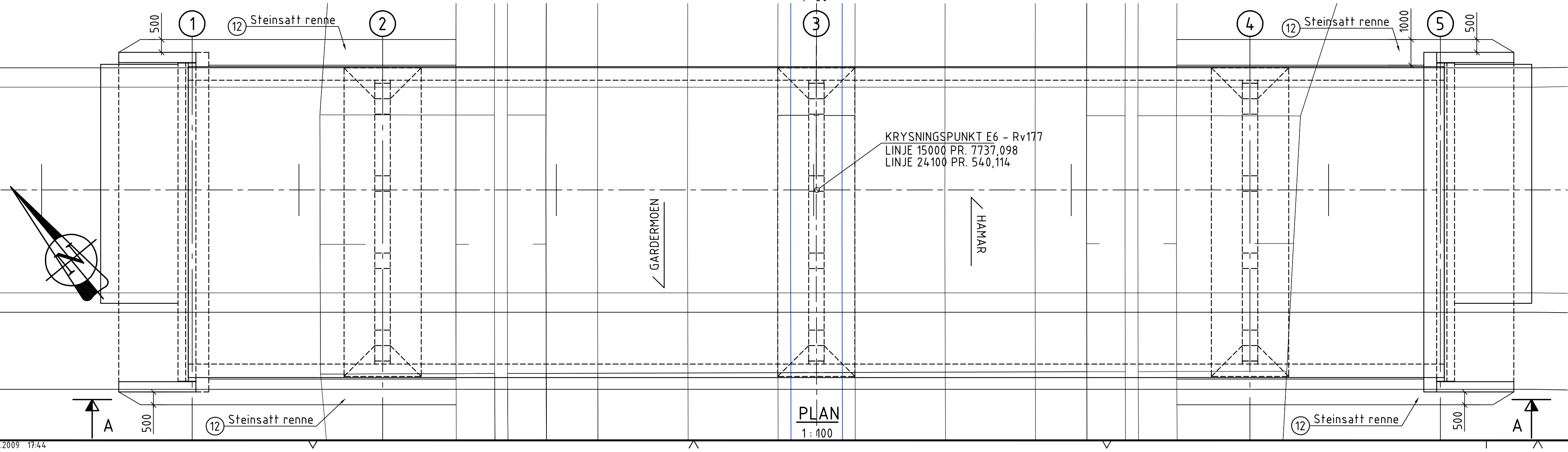
OPPRISS A-A

1 : 100



SNITT B-B

1 : 50



PLAN

1 : 100

HENVISNINGER:

PLAN OG PROFIL: LINJE 15000 PR 7350 - 8100 C010

PLAN OG PROFIL: TRONDHEIMSVEIEN N, LINJE 24100 D011

ANMERKNINGER:

1. PROSJEKTERINGSGRUNNLAG:
   PROSJEKTERINGSREGLER:
   - STATENS VEGVESENS HÅNDBOK 026 PROSESSKODE 2, VERSJON NOVEMBER 2007
   - STATENS VEGVESENS HÅNDBOK 185 PROSJEKTERINGSREGLER FOR BRUER. HØRINGSUTGAVE DATERT 28.05.2006
   - TILHØRENDE NORSKE STANDARDER

   LASTFORSKRIFTER:
   - STATENS VEGVESENS HÅNDBOK 185 PROSJEKTERINGSREGLER FOR BRUER. HØRINGSUTGAVE DATERT 28.05.2006

   BELEGNING:
   - BELEGNINGSKLASSE A3 IHT STATENS VEGVESENS HÅNDBOK 145 (HØRINGSUTGAVE 2006) ASFALTSLITELAG MED FULL FUKTISOLERING
   - DIMENSJONERENDE BELEGNINGSVEKT: 3.0 kN/m²
2. UTFØRELSE I SAMSVAR MED PROSESSKODE 2
3. KONTROLLKLASSE - UTVIDET KONTROLL, NS3465
4. VEGTYPE S1, ÅDT 2250, FARTSGRENSE 60 km/t
5. ALLE MÅL I mm. ALLE KOTER I m.
6. BETONG: B45 SV-40, PROSESSKODE 2 (2007)
7. ARMERING: B 500 NC, NS3576, DEL 3
8. STÅL:
   - GENERELL STÅLKVALITET: S355 N iht NS-EN 10025-3
   - GENERELL BOLTEKVALITET: 8.8
   - HVIS IKKE ANNET ER OPPGITT SKAL ALT STÅL VÆRE VARMFORSINKET
9. LIMTRE:
   - SØYLER OG TVERRBÆRERE: GL36c (L40)
   - BRUDEKKE: GL36c (L40)
   - BRUDEKKE, YTTERSTE LAMELLER: GL36h (L40)

(10) FUNDAMENTERING PÅ KOMPRIMERT SPRENGSTEINSFYLLING. DET LEGGES LAG MED TYKKELSE 1 m. MAKS STEINSTØRRELSE 60 cm. HVERT LAG KOMPRIMERES MED 7 TONN VALS OG 6 OVERFARTER.

(11.) FORBELASTNING BESTÅENDE AV 3,5 m JORD ELLER GRUS OVER MINIMUM 1 MÅNED.

(12.) PLASTRING I REGNSKYGGE AV BRUA. AVSLUTTES MOT SIDENE MED STEINSATT RENNE 1 m BRED SENTRERT OM FORLENGELSEN AV VINGEMURENS YTTERKANT.

Revisjon	Revisjonen gjelder	Utarb	Kontr	Godkjent	Rev. dato

Godkjent som arbeidstegning ifølge notat fra Vedirektoratet:	Saksnr. XXXXXX — XX.XX.2009
Statens vegvesen	Tegningsdato: 01.05.2009
	Bestiller: NILS LYSBAKKEN
	Produsert for: REGION ØST
E6 HP: 14 Boksrud x181 - Minnesund x33	Produsert av: COWI AS
Parsell BOKSRUD - MINNESUND	COWI
FREDHEIM BRU	PROF-nummer: 02E0006b_102
OVERSIKT	Arkivnummer: -
	Byggverksnummer: 02-1798
KONKURRANSEGRUNNLAG	Målestokk A1: SOM VIST

Utarbeidet av	Kontrollert av	Godkjent av	Konsulentarkiv	Tegningsnummer/revisjonsbokstav
JMKJ	LULE	BJAK	121842	K200-01

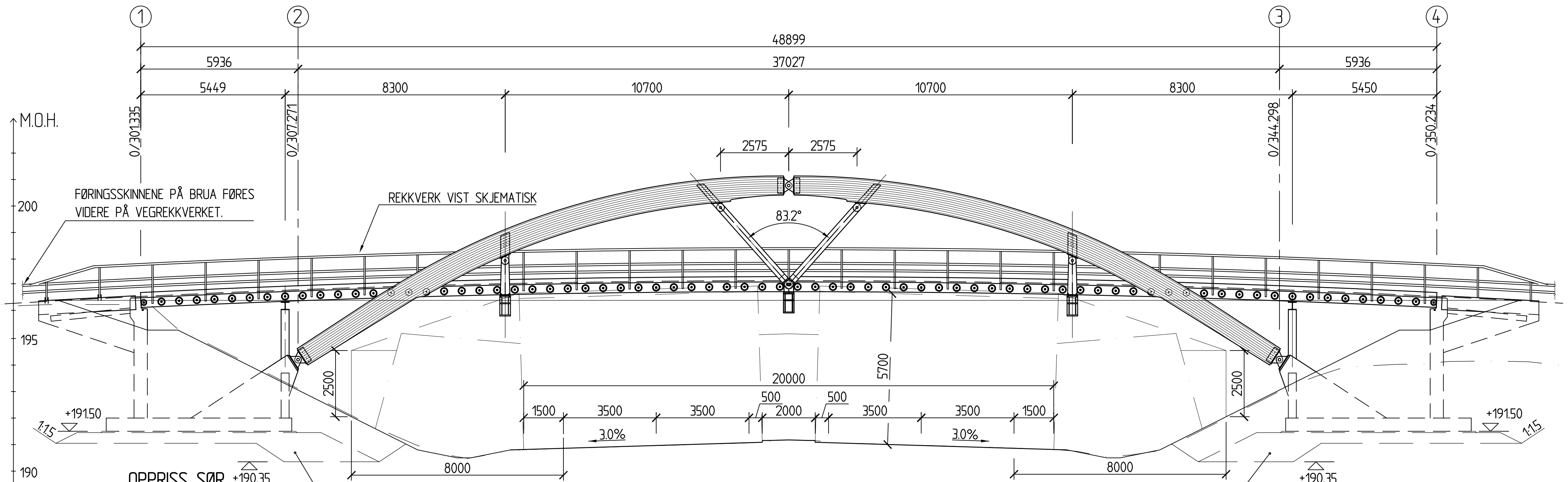
Format: A1 Filnavn: P:\121\121842 E6 Dal-Minnesund\20 Tegninger\K200 Fredheim bru\Ny tykkelse\K200-01.dwg Xref: T_GEOM_001.dwg

Plot: jmkj 14.05.2009 17:44

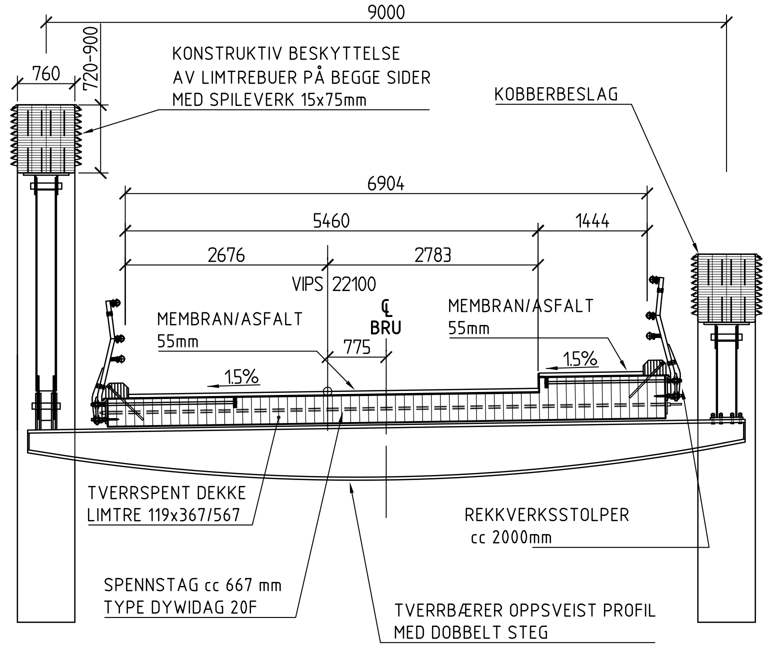
PROFILNUMMER	0/300	0/290	0/280	0/270	0/260	0/250
PROFILHØYDE	+196.571	+196.987	+197.202	+197.218	+197.034	+196.649
VERTIKALKURVE	R = 500					
HORISONTALKURVE	R = ∞					

HENVISNINGER:

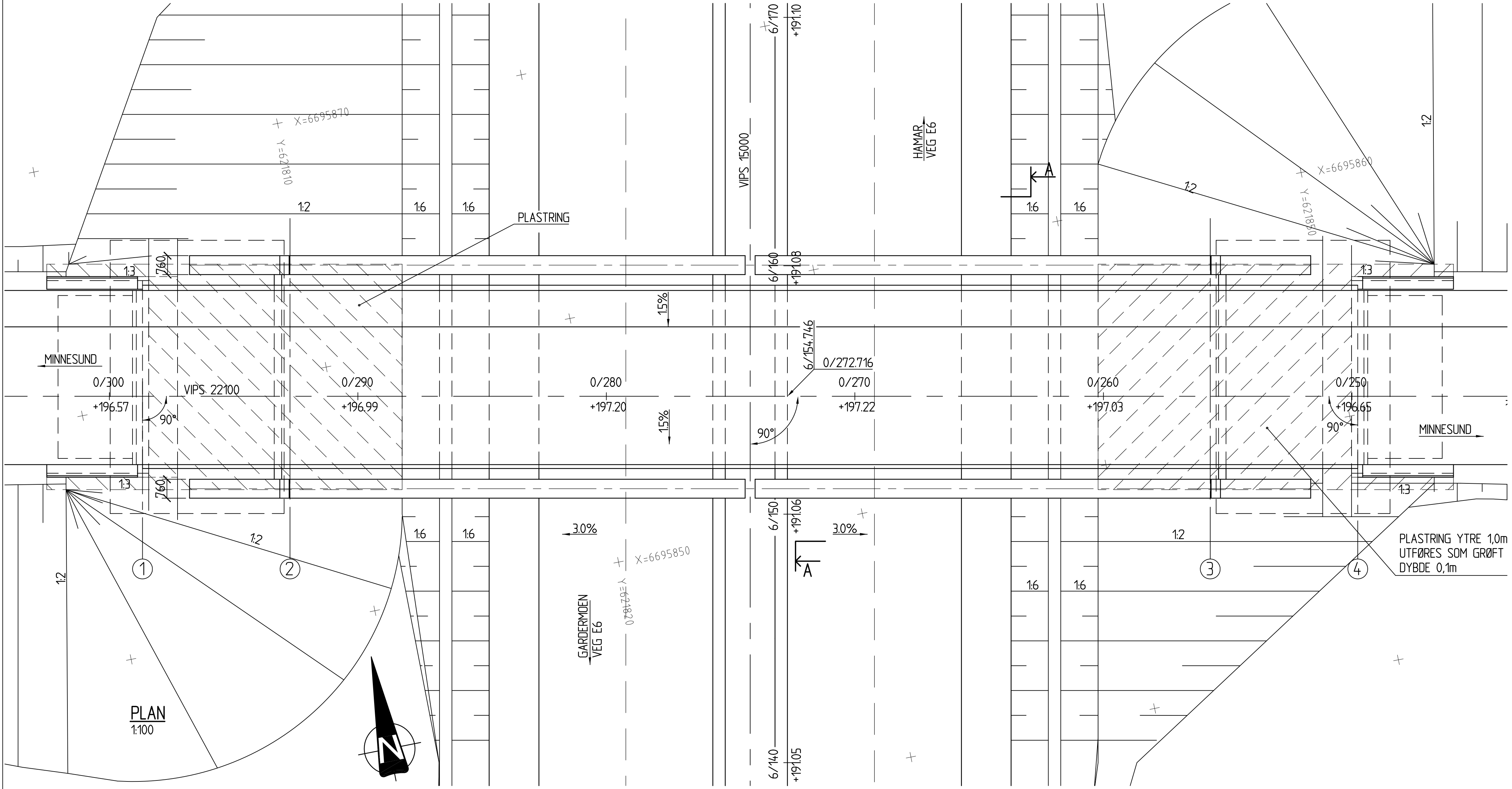
PLAN OG PROFIL 5850 - 6600	TEGN. C008
PLAN OG PROFIL LINJE 22100	TEGN. D008
BRU, FORMTEGNINGER	TEGN. K180-02 - K180-09
BRUREKKVERK	TEGN. K180-10
BRU, ARMERINGSTEGNINGER	TEGN. K180-21 - K180-22



OPPRISS SØR
1:100



SNITT A-A
1:50



PLAN
1:100

ANMERKNINGER:

1. VEGTYPE KOMMUNAL, FARTSGRENSE 50 km/t
2. PROSJEKTERINGSGRUNNLAG:
   - STATENS VEGVESENS HÅNDBOK 026 PROSESSKODE 2, VERSJON NOVEMBER 2007.
   - STATENS VEGVESENS HÅNDBOK 185 PROSJEKTERINGSREGLER FOR BRUER. HØRINGSUTGAVE DATERT 28.05.2006
   - TILHØRENDE NORSKE OG INTERNASJONALE STANDARDER

   LASTFORSKRIFTER:
   - STATENS VEGVESENS HÅNDBOK 185 PROSJEKTERINGSREGLER FOR BRUER (HØRINGSUTGAVE 2006)

   BELEGNING:
   - BELEGNINGSKLASSE A3 IHT HÅNDBOK 185 (HØRINGSUTGAVE 2006) ASFALTSLITELAG MED FULL FUKTISOLERING
   - DIMENSJONERENDE BELEGNINGSVEKT : 2,0 kN/m²
3. UTFØRELSE I SAMSVAR MED PROSESSKODE 2 (2007)
4. KONTROLLKLASSE - UTVIDET KONTROLL, NS 3465
5. BETONG: B45 SV-40, PROSESSKODE 2 (2007)
6. ARMERING: B500 NC, NS3576, DEL 3
7. STÅL: S355 N, NS-EN 10025-3
8. LIMTRE: GL36c (L40)
9. FUNDAMENTERING: AKSE 1, 2, 3 OG 4 PÅ LØSMASSER
10. ALLE MÅL I mm. ALLE KOTER I m.

Revisjon	Revisjonen gjelder	Utarb	Kontr	Godkjent	Rev. dato

Godkjent som arbeidstegning ifølge notat fra Vegdirektoratet

Saksnr. xxxxxx	xx.xx.2009
Tegningsdato	01.05.2009
Bestiller	Nils Lysbakken
Produsert for	Region øst
Produsert av	SWECO
PROF-nummer	02e0006b_102
Arkivnummer	
Byggverksnummer	02-1796
Målestokk A1	1:100, 1:50
Tegningsnummer/ revisjonsbokstav	K180-01 -

Statens vegvesen

E6 HP: 14 Boksrud x181 - Minnesund x33
Parsell Boksrud - Minnesund

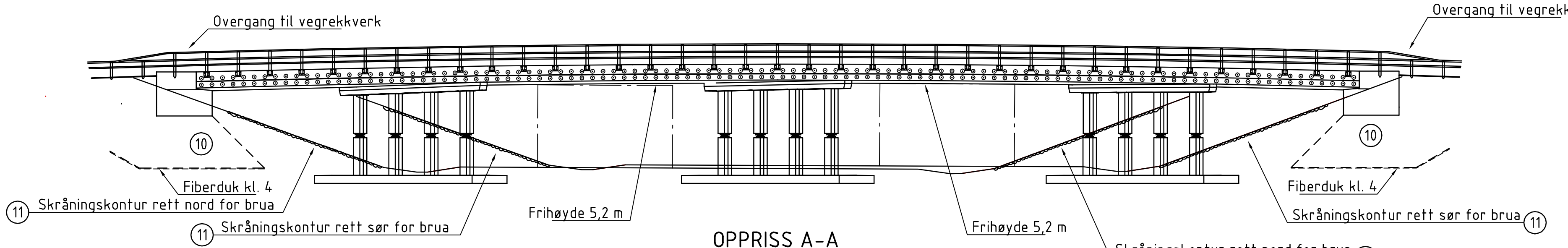
SETRE BRU
OVERSIKT

KONKURRANSEGRUNNLAG

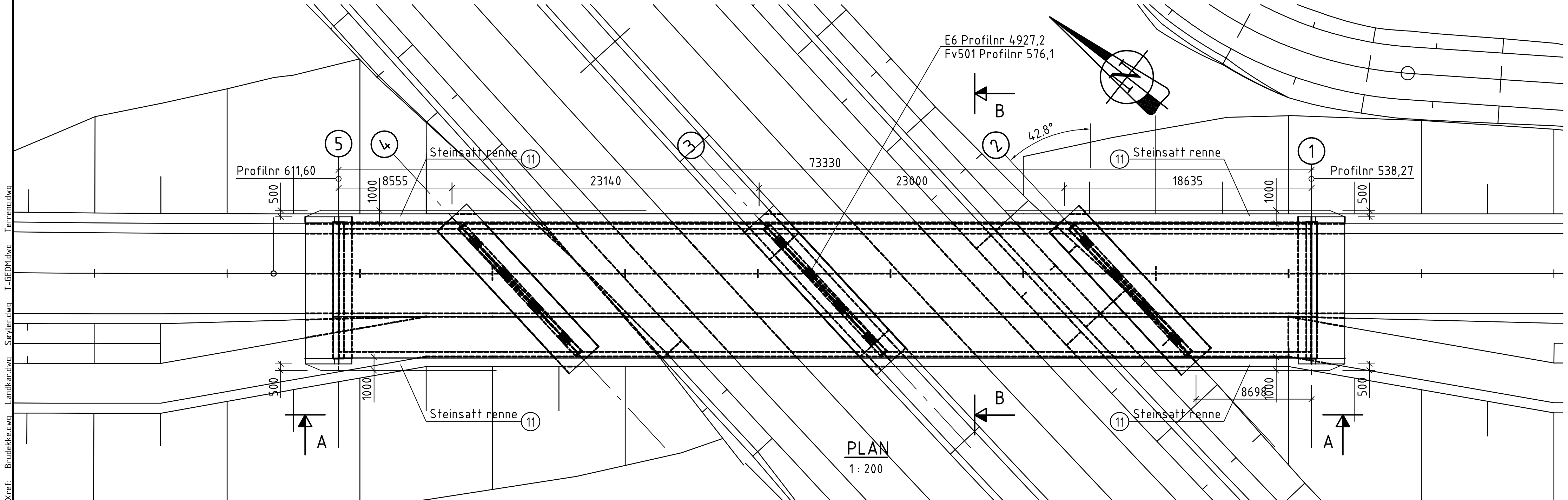
Utarbeidet av	Kontrollert av	Godkjent av	Konsulentarkiv
NJ	RBA	PM	236470

Current road project: 21100 TRONDHEIMSVEGEN

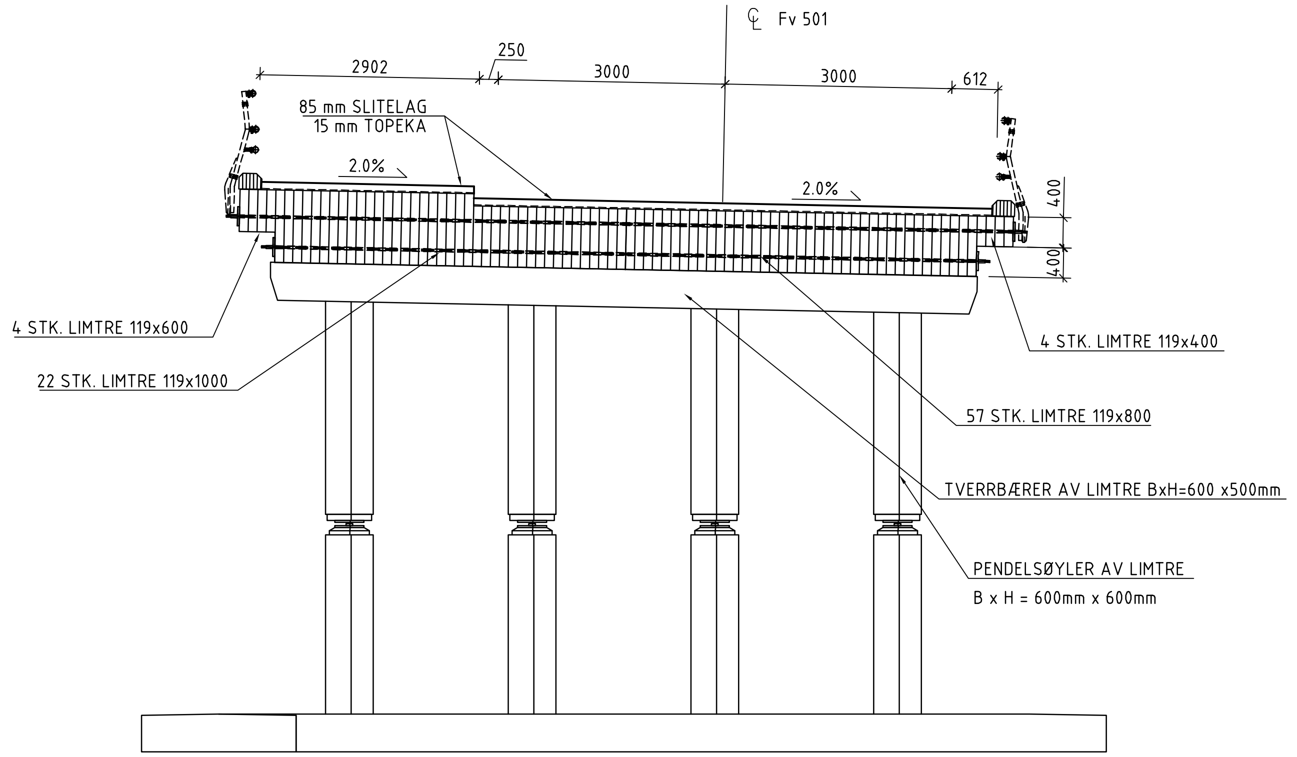
PROFILNUMMER	620	610	600	590	580	570	560	550	540	530
PROFILHØYDE	193.237	193.530	193.751	193.901	193.980	193.987	193.923	193.787	193.580	193.302
TERRENGHØYDE	188.60	188.30	187.78	186.92	187.59	187.43	187.08	189.05	189.88	189.63
VERTIKALKURVE	R = 1400 m									
HORISONTALKURVE	A = 145.00	R = ∞								



OPPRISS A-A
1 : 200



PLAN
1 : 200



SNITTB-B
1 : 50

HENVISNINGER:
PLAN OG PROFIL: LINJE 21100 D007

ANMERKNINGER:

1. PROSJEKTERINGSGRUNNLAG:
   PROSJEKTERINGSREGLER:
   - STATENS VEGVESENS HÅNDBOK 026 PROSESSKODE 2, VERSJON NOVEMBER 2007
   - STATENS VEGVESENS HÅNDBOK 185 PROSJEKTERINGSREGLER FOR BRUER. HØRINGSUTGAVE DATERT 28.05.2006
   - TILHØRENDE NORSKE STANDARDER

   LASTFORSKRIFTER:
   - STATENS VEGVESENS HÅNDBOK 185 PROSJEKTERINGSREGLER FOR BRUER. HØRINGSUTGAVE DATERT 28.05.2006

   BELEGNING:
   - BELEGNINGSKLASSE A3 IHT STATENS VEGVESENS HÅNDBOK 145 (HØRINGSUTGAVE 2006) ASFALTSLITELAG MED FULL FUKTISOLERING
   - DIMENSJONERENDE BELEGNINGSVEKT: 3.0 kN/m²
2. UTFØRELSE I SAMSVAR MED PROSESSKODE 2
3. KONTROLLKLASSE - UTVIDET KONTROLL, NS3465
4. VEGTYPE H2, ÅDT 2750, FARTSGRENSE 80 km/t
5. ALLE MÅL I mm. ALLE KOTER I m.
6. BETONG: B45 SV-40, PROSESSKODE 2 (2007)
7. ARMERING: B 500 NC, NS3576, DEL 3
8. STÅL:
   - GENERELL STÅLKVALITET: S355 N iht NS-EN 10025-3
   - GENERELL BOLTEKVALITET: 8.8
   - HVIS IKKE ANNET ER OPPGITT SKAL ALT STÅL VÆRE VARMFORSINKET
9. LIMTRE:
   - BRUDEKKE: GL36c (L40)
   - SØYLER OG TVERRBÆRERE: GL36c (L40)
   -

(10) FUNDAMENTERING PÅ KOMPRIMERT SPRENGSTEINSFYLLING. DET LEGGES 1 m TYKKE LAG MED MAKS STEINSTØRRELSE 60 cm OG HVERT LAG KOMPRIMERES MED 7 TONN VALS OG 6 OVERFARTER.

(11) PLASTRING I REGNSKYGGE AV BRUA. AVSLUTTES MOT SIDENE MED STEINSATT RENNE 1 m BRED SENTRERT OM FORLENGELSEN AV VINGEMURENS YTTERKANT.

Revisjon	Revisjonen gjelder	Utarb	Kontr	Godkjent	Rev. dato

Godkjent som arbeidstegning ifølge notat fra Vedirektoratet: Saksnr. XXXXXX XX.XX.2009

Statens vegvesen

E6 HP: 14 Boksrud x181 - Minnesund x33
Parsell BOKSRUD - MINNESUND

K170 TØMTE II BRU

OVERSIKT

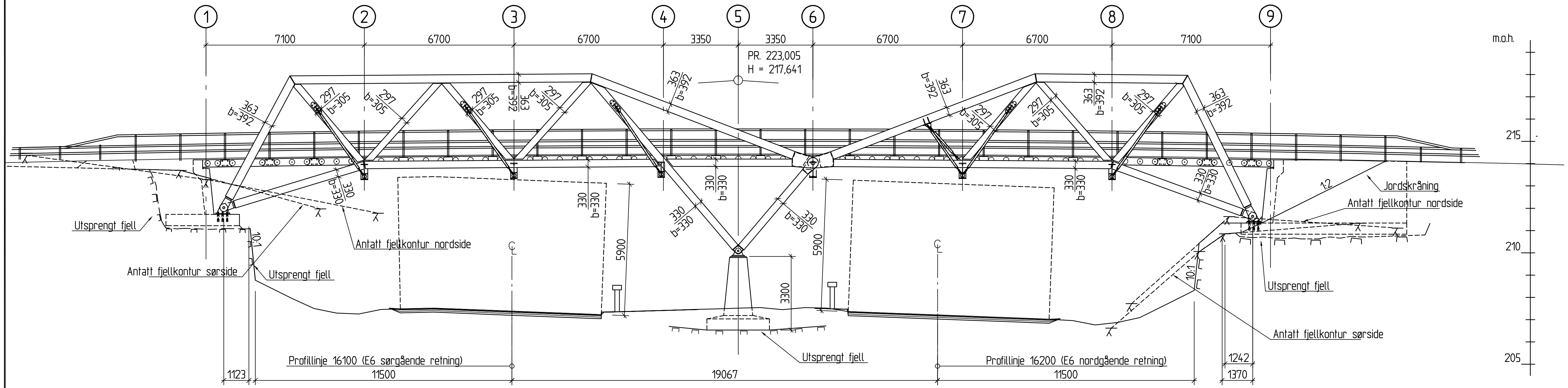
KONKURRANSEGRUNNLAG

Tegningsdato	01.05.2009
Bestiller	NILS LYSBAKKEN
Produsert for	REGION ØST
Produsert av	COWI AS
PROF-nummer	02E0006b__102
Arkivnummer	-
Byggverksnummer	02-1795
Målestokk A1	SOM VIST
Tegningsnummer/ revisjonsbokstav	K170-01

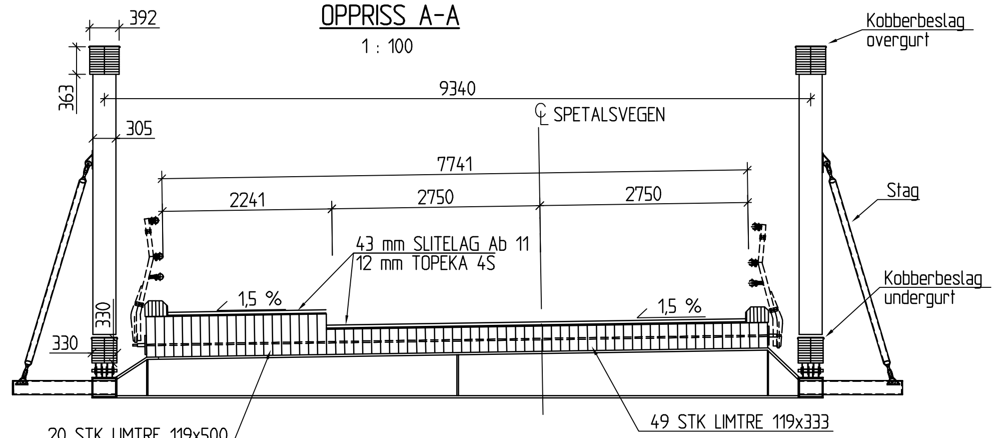
Utarbeidet av	Kontrollert av	Godkjent av	Konsulentarkiv
BJSA	JMKJ	BJAK	121842

Plot: jmkj 28.05.2009 18:45

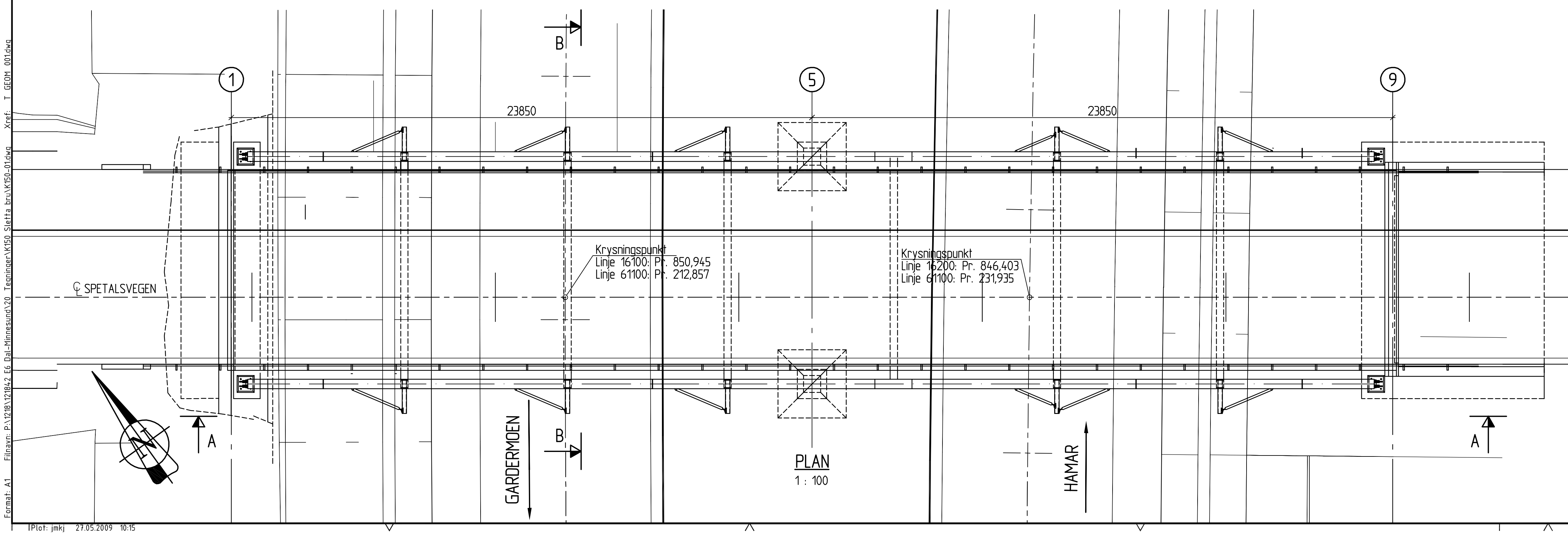
PROFILNUMMER	200	210	220	230	240	250
PROFILHØYDE	214.25	214.37	214.43	214.42	214.34	214.18
TERRENGHØYDE	211.59	207.45	207.33	207.25	206.78	211.50
VERTIKALKURVE	R=1400					
HORISONTALKURVE	R=∞					



OPPRISS A-A
1 : 100



SNITT B-B
1 : 50



PLAN
1 : 100

HENVISNINGER:

PLAN OG PROFIL: LINJE 16200 PR 820 - 1350	C001
PLAN OG PROFIL: LINJE 61100	D003
MÅLTEGNING	K150-30
MÅLTEGNING	K150-31

ANMERKNINGER:

1. PROSJEKTERINGSGRUNNLAG:
   PROSJEKTERINGSREGLER:
   - STATENS VEGVESENS HÅNDBOK 026 PROSESSKODE 2, VERSJON NOVEMBER 2007
   - STATENS VEGVESENS HÅNDBOK 185 PROSJEKTERINGSREGLER FOR BRUER. HØRINGSUTGAVE DATERT 28.05.2006
   - TILHØRENDE NORSKE STANDARDER

   LASTFORSKRIFTER:
   - STATENS VEGVESENS HÅNDBOK 185 PROSJEKTERINGSREGLER FOR BRUER. HØRINGSUTGAVE DATERT 28.05.2006

   BELEGNING:
   - BELEGNINGSKLASSE A3 IHT STATENS VEGVESENS HÅNDBOK 145 (HØRINGSUTGAVE 2006) ASFALTSLITELAG MED FULL FUKTISOLERING
   - DIMENSJONERENDE BELEGNINGSVEKT: 3.0 kN/m²
2. UTFØRELSE I SAMSVAR MED PROSESSKODE 2
3. KONTROLLKLASSE - UTVIDET KONTROLL, NS3465
4. KOMMUNAL VEG, ÅDT 100, FARTSGRENSE 50 km/t
5. ALLE MÅL I mm. ALLE KOTER I m.
6. BETONG: B45 SV-40, PROSESSKODE 2 (2007)
7. ARMERING: B 500 NC, NS3576, DEL 3
8. STÅL:
   - GENERELL STÅLKVALITET: S355 N iht NS-EN 10025-3
   - GENERELL BOLTEKVALITET: 8.8
   - HVIS IKKE ANNET ER OPPGITT SKAL ALT STÅL VÆRE VARMFORSINKET
9. LIMTRE:
   - FAGVERK: GL36c (L40)
   - BRUDEKKE: GL36c (L40)

Revisjon	Revisjonen gjelder	Utarb	Kontr	Godkjent	Rev. dato

Godkjent som arbeidstegning ifølge notat fra Vedirektoratet: Saksnr. XXXXXX XX.XX.2009

Statens vegvesen

E6 HP: 14 Boksrud x181 - Minnesund x33
Parsell BOKSRUD - MINNESUND

SLETTA BRU

OVERSIKT

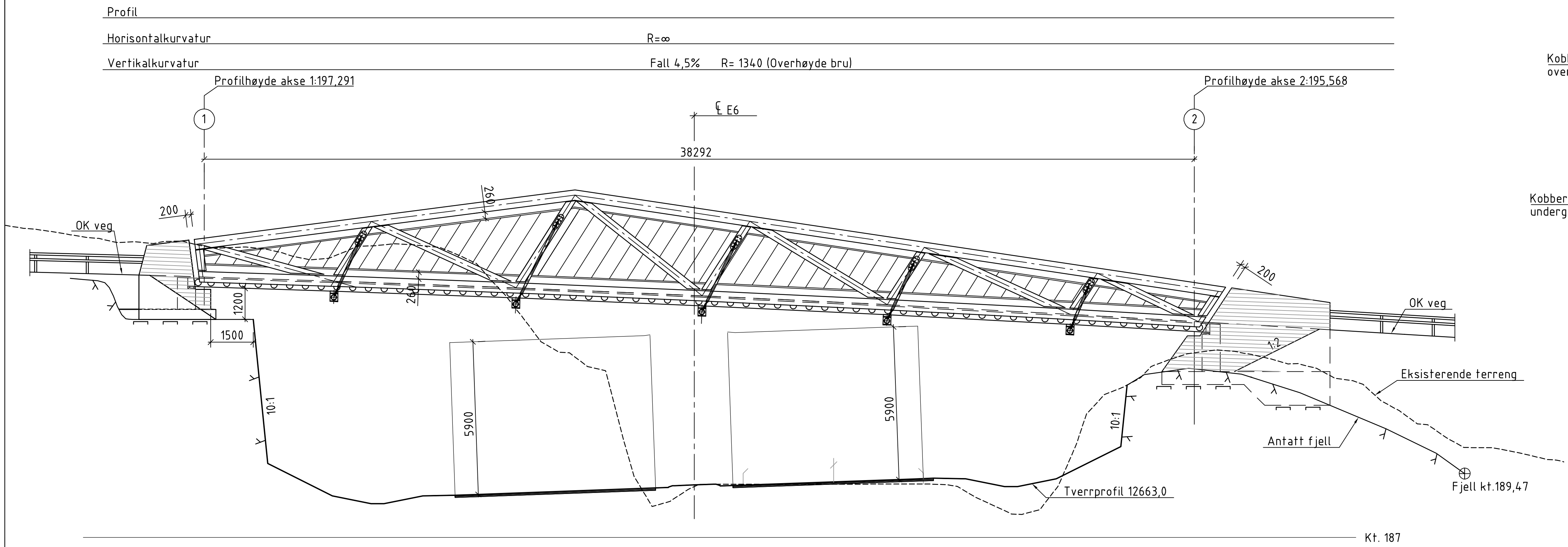
KONKURRANSEGRUNNLAG

Utarbeidet av	Kontrollert av	Godkjent av	Konsulentarkiv
JMKJ	LULE	BJAK	121842

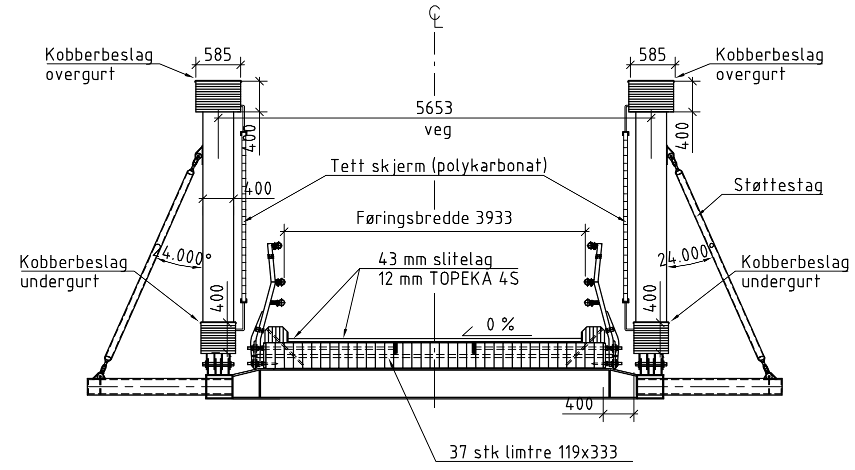
Tegningsdato	01.05.2009
Bestiller	NILS LYSBAKKEN
Produsert for	REGION ØST
Produsert av	COWI AS
PROF-nummer	02E0006b_102
Arkivnummer	-
Byggverksnummer	02-1794
Målestokk A1	SOM VIST
Tegningsnummer/revisjonsbokstav	K150-01

Format: A1 Filnavn: P:\121842\121842 E6 Dal-Minnesund\20 Tegninger\K150 Sletta bru\K150-01.dwg Xref: T_GEOM_001.dwg

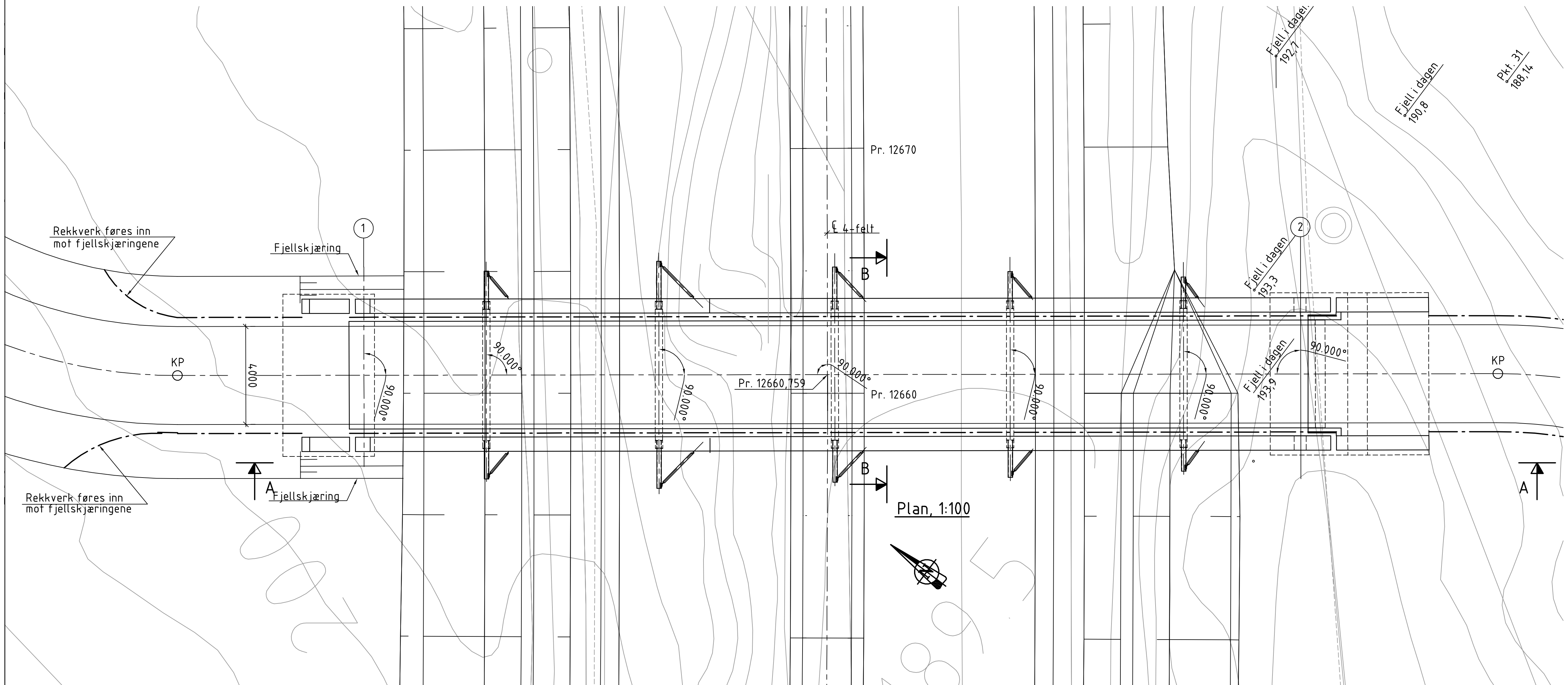
Plot: jmkj 27.05.2009 10:15



Oppriss A-A, 1:100



Snitt B-B, 1:50



Plan, 1:100

Merk.:

Lastbestemmelser og prosjekteringsregler:
Statens vegvesens håndbok nr. 185, Prosjekteringsregler for bruer. Høringsutgave datert 28.05.2006.
Maks. belegningsvekt 2,0 kN/m2 (80mm)
Utføres i samsvar med prosesskode 2, hovedprosess 8
Kontrollklasse - utvidet

Fundamentering: På fast fjell
Opplagring fagverk:
Akse 1: Ensidige bevegelige glidelagre
Akse 2: Fastlagre

Limtre:
Kvalitet GL36c, NS3470

Betong: B45 SV-40

Armering: B500 NC

Stål:
Generell stålkvalitet: S355N NS-EN 10025-3
Skruekvalitet: 8.8, hvis ikke annet er oppgitt
Treskruer: 4.6
Hvis ikke annet er oppgitt skal alt stål være varmforsinket.
De deler / overflater som skal støpes inn påføres epoxy som sandstrøs.

Revisjon	Revisjonen gjelder	Utarb	Kontr	Godkjent	Rev. dato

Statens vegvesen

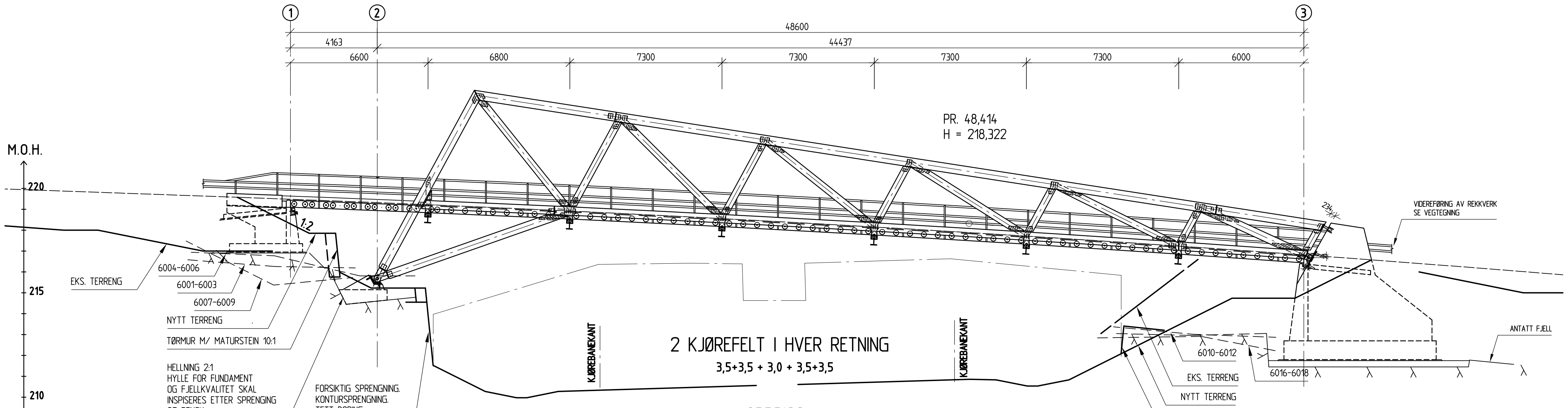
Tegningsdato	01.05.2009
Bestiller	Nils Lysbakken
Produsert for	Region øst
Produsert av	COWI
PROF-nummer	02E0006b_101
Arkivnummer	-
Byggverksnummer	02-1790
Målestokk A1	Som vist
Tegningsnummer/ revisjonsbokstav	K110-01

E6 HP:13 Mogreina sør - Boksrud x181
Parsell Dal-Boksrud
K110 Blakkisrud bru
Oversikt

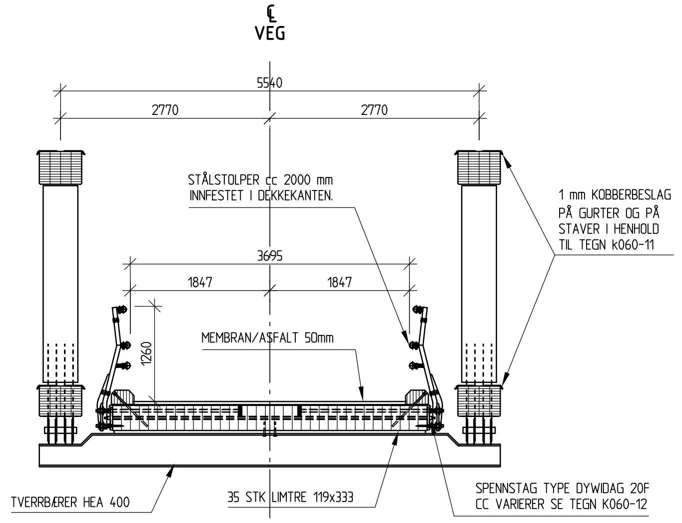
KONKURRANSEGRUNNLAG

Utarbeidet av	Kontrollert av	Godkjent av	Konsulentarkiv
FRB	JMKJ	BJAK	121842

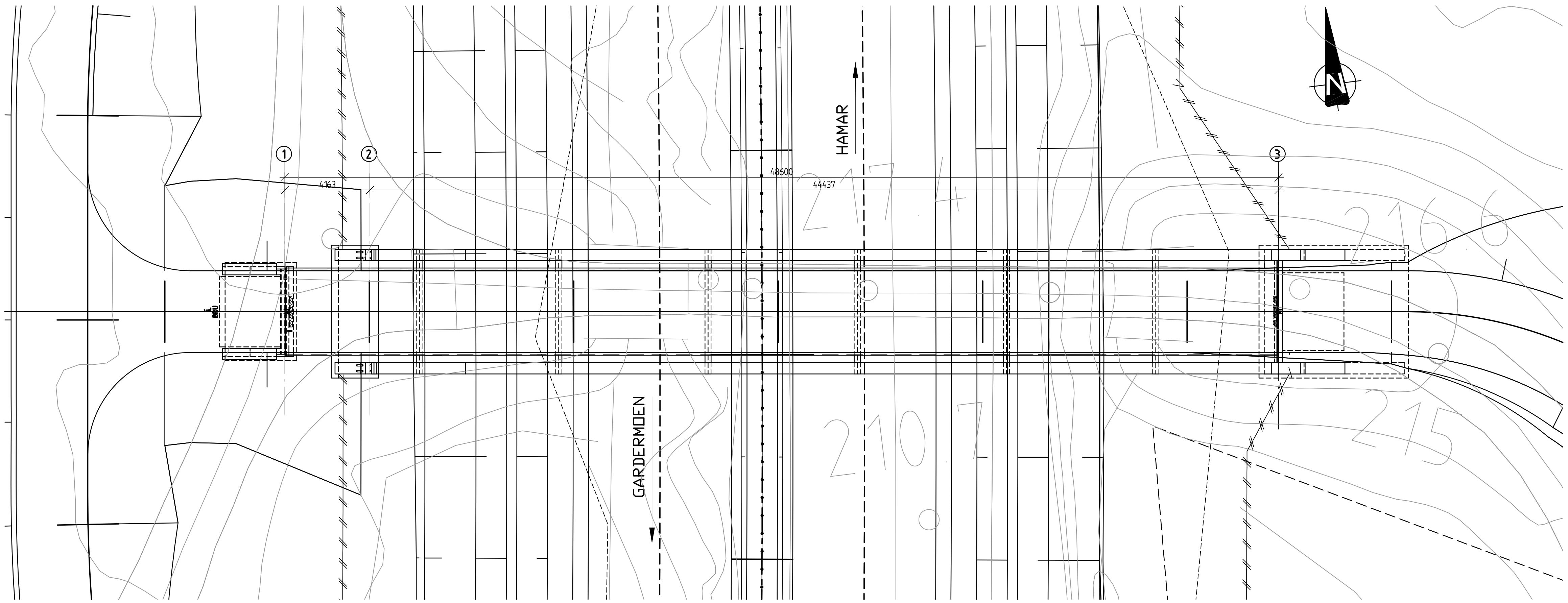
PROFILNUMMER	10	20	30	40	50	60	70
PROFILHØYDE	219,69	219,32	218,88	218,37	217,79	217,13	216,41
TERRENGHØYDE	217,46	217,02	210,31	210,41	210,78	216,75	216,23
VERTIKALKURVE	R = ∞	R = 1400					
HORISONTALKURVE	R = ∞						R = 20



OPPRISS
1:125



SNITT
1:50



PLAN
1:125

ANMERKNINGER:

1. VEGTYPE PRIVAT, ÅDT <100, FARTSGRENSE 50 km/t
2. PROSJEKTERINGSGRUNNLAG:
   - STATENS VEGVESENS HÅNDBOK 026 PROSESSKODE 2, VERSJON NOVEMBER 2007.
   - STATENS VEGVESENS HÅNDBOK 185 PROSJEKTERINGSREGLER FOR BRUER. HØRINGSUTGAVE DATERT 28.05.2006
   - TILHØRENDE NORSKE OG INTERNASJONALE STANDARDER

   LASTFORSKRIFTER:
   - STATENS VEGVESENS HÅNDBOK 185 PROSJEKTERINGSREGLER FOR BRUER (HØRINGSUTGAVE 2006)

   BELEGNING:
   - BELEGNINGSKLASSE A3 IHT HÅNDBOK 185 (HØRINGSUTGAVE 2006) ASFALTSLITELAG MED FULL FUKTISOLERING
   - DIMENSJONERENDE BELEGNINGSVEKT : 2,0 kN/m²
3. UTFØRELSE I SAMSVAR MED PROSESSKODE 2 (2007)
4. KONTROLLKLASSE - UTVIDET KONTROLL, NS 3465
5. BETONG: B45 SV-40, PROSESSKODE 2 (2007)
6. ARMERING: B500 NC, NS3576, DEL 3
7. STÅL: S355 N, NS-EN 10025-3
8. LIMTRE: GL36c (L40)
9. FUNDAMENTERING: AKSE 1 OG 3 PÅ GRUSPUTE PÅ BERG
   AKSE 2 PÅ BERG
10. ALLE MÅL I mm. ALLE KOTER I m.

HENVISNINGER:

PLAN OG PROFIL 9250 - 10000	TEGN. C009
LENGDEPROFIL FJELL-LEET BRU	TEGN. D007

Revisjon	Revisjonen gjelder	Utarb.	Kontr.	Godkjent	Rev. dato

Godkjent som arbeidstegning i følge notat fra Vegdirektoratet

Saksnr.	xxxxxxx xx.xx.2009
Tegningsdato	01.05.2009
Bestiller	Nils Lysbakken
Produsert for	Region øst
Produsert av	SWECO

Statens vegvesen

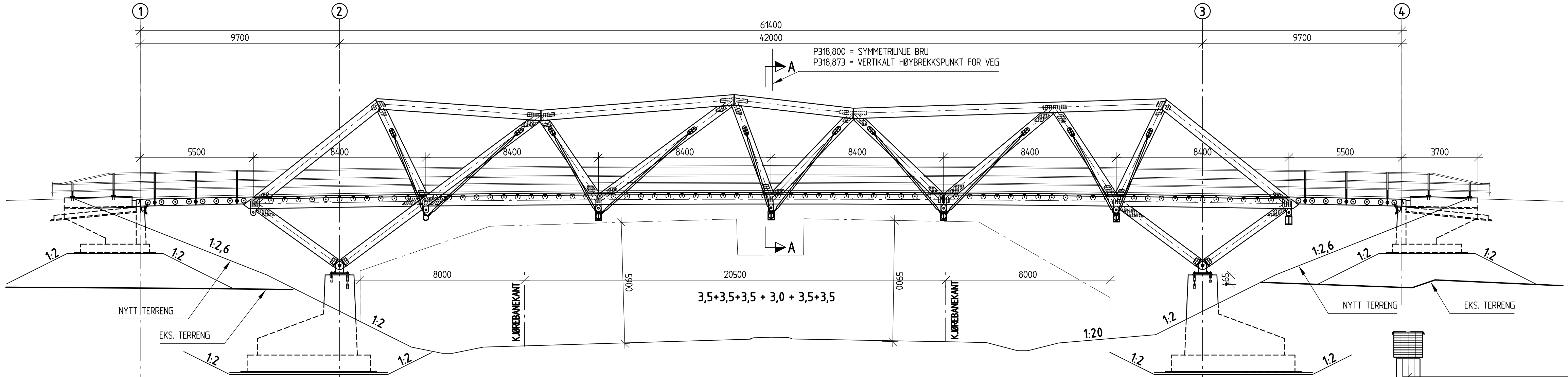
E6 HP: 13 Mogreina sør - Boksrud x181
Parsell Dal - Boksrud
FJELL-LEET BRU
OVERSIKT

KONKURRANSEGRUNNLAG

PROF-nummer	02e0006b_101
Arkivnummer	
Byggverksnummer	02-1786
Målestokk A1	1:125, 1:50
Tegningsnummer/revisjonsbokstav	K060-01 -

Utarbeidet av	Kontrollert av	Godkjent av	Konsulentarkiv
PGV	RBA	PM	236470

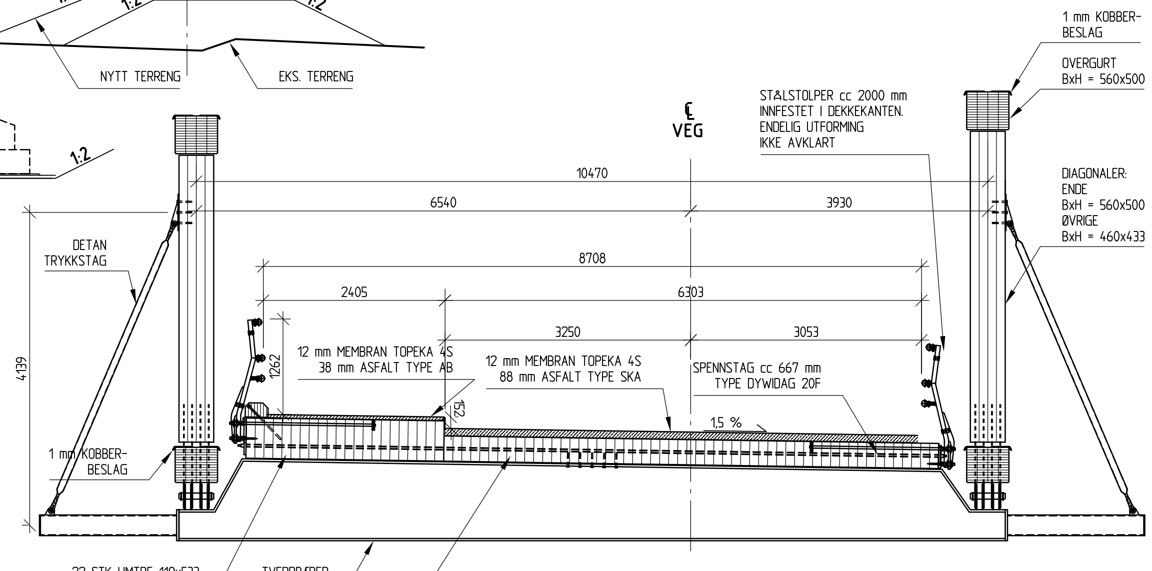
PROFILNUMMER	290	300	310	320	330	340	350
PROFILHØYDE	186,82	186,99	187,09	187,12	187,08	186,96	186,77
TERRENGHØYDE	182,69	180,13	179,64	179,68	179,56	182,03	182,03
VERTIKALKURVE	R = 1400						
HORISONTALKURVE	R = ∞						



OPPRISS (VIST SØNDRE FAGVERK)
1:125

HENVISNINGER:

PLAN OG PROFIL 7000 - 7750	TEGN. C006
PLAN OG PROFIL Fv 507 SUNDBYVEIEN	TEGN. D004
PLAN OG PROFIL RASTEPLASS ANDELVA	TEGN. D005
BRU, FORM- OG DETALJ-TEGN.	K040-02 - K040-30



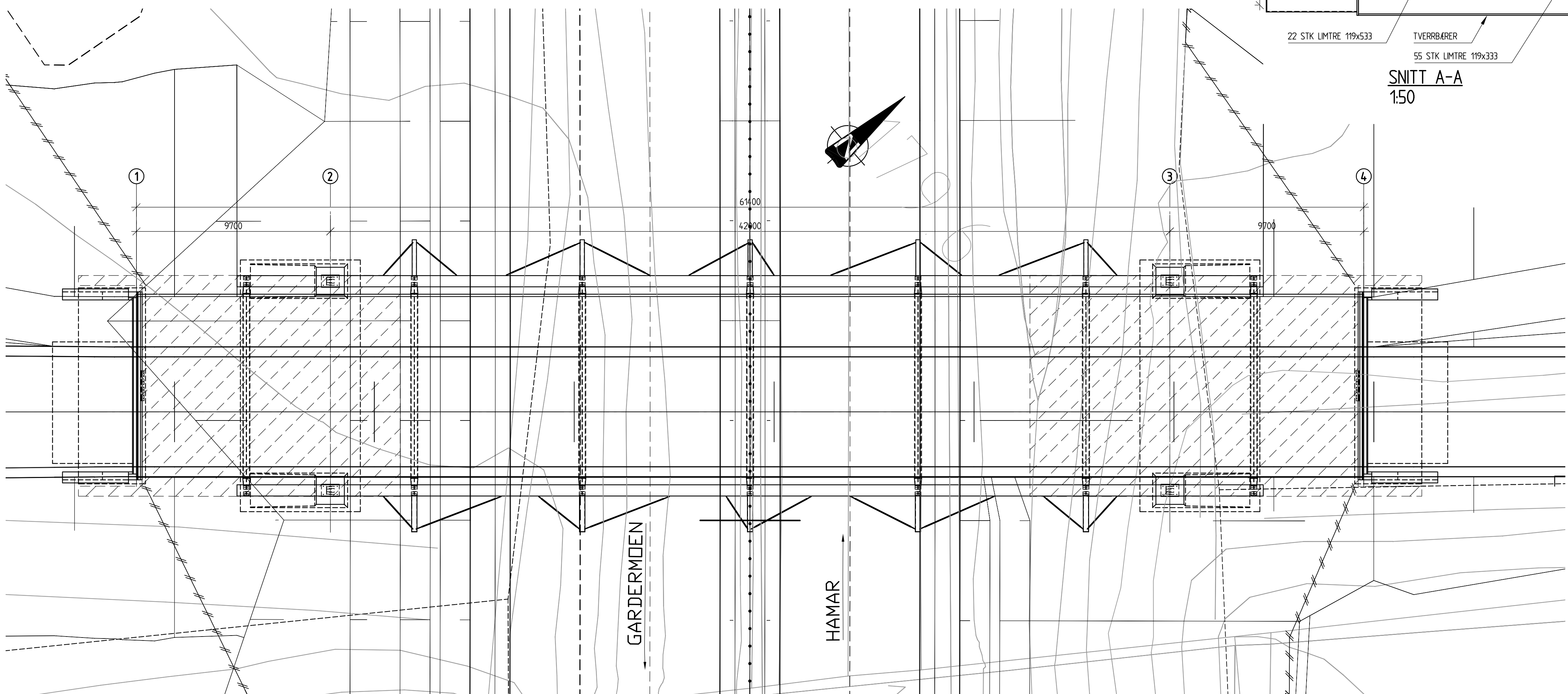
SNITT A-A
1:50

ANMERKNINGER:

1. VEGTYPE H, DIM. KL. H1, ÅDT 1400, FARTSGRENSE 80 km/t
2. PROSJEKTERINGSGRUNNLAG:
   - STATENS VEGVESENS HÅNDBOK 026 PROSESSKODE 2, VERSJON NOVEMBER 2007.
   - STATENS VEGVESENS HÅNDBOK 185 PROSJEKTERINGSREGLER FOR BRUER. HØRINGSUTGAVE DATERT 28.05.2006
   - TILHØRENDE NORSKE OG INTERNASJONALE STANDARDER

   LASTFORSKRIFTER:
   - STATENS VEGVESENS HÅNDBOK 185 PROSJEKTERINGSREGLER FOR BRUER (HØRINGSUTGAVE 2006)

   BELEGNING:
   - BELEGNINGSKLASSE A3 IHT HÅNDBOK 185 (HØRINGSUTGAVE 2006) ASFALTSLITELAG MED FULL FUKTISOLERING
   - DIMENSJONERENDE BELEGNINGSVEKT : 2,5 kN/m²
3. UTFØRELSE I SAMSVAR MED PROSESSKODE 2 (2007)
4. KONTROLLKLASSE - UTVIDET KONTROLL, NS 3465
5. BETONG: B45 SV-40, PROSESSKODE 2 (2007)
6. ARMERING: B500 NC, NS3576, DEL 3
7. STÅL: S355 N, NS-EN 10025-3
8. LIMTRE: GL36c (L40)
9. FUNDAMENTERING: PÅ LØSMASSER
10. ALLE MÅL I mm. ALLE KOTER I m.



PLAN
1:125

Revisjon	Revisjonen gjelder	Utarb	Kontr	Godkjent	Rev. dato

Godkjent som arbeidstegning ifølge notat fra Vegdirektoratet	Saksnr. xxxxxx	xx.xx.2009
Statens vegvesen	Tegningsdato	01.05.2009
	Bestiller	Nils Lysbakken
	Produsert for	Region øst
E6 HP: 13 Mogreina sør - Boksrud x181 Parsell Dal - Boksrud SUNDBYVEIEN BRU OVERSIKT KONKURRANSEGRUNNLAG	Produsert av	SWECO
	SWECO	
	PROF-nummer	02e0006b_101
	Arkivnummer	
	Byggverksnummer	02-1783
	Målestokk A1	1:125, 1:50

Utarbeidet av	Kontrollert av	Godkjent av	Konsulentarkiv	Tegningsnummer/ revisjonsbokstav		
RBA	PGV	PM	236470		K040-01	-