Submerged Floating Tunnels
and
The largest infrastructure project in Norway…Ever…
Coastal Highway Route E39
Kjersti Kvalheim Dunham
Norwegian Public Roads Administration
The Coastal Highway Route E39

The current E39

- E39 Kristiansand-Trondheim nearly 1100 km, including 7 ferry connections
- E39 ferry connection Kristiansand-Hirtshals
- Aalborg: The E39 joins the E45 which continues to Italy
Facts about the counties along the E39

Inhabitants as of 1 Jan 2017

- 1/3 of the country’s population
- Approx. 60 % of our export value

Source: Central Bureau of Statistics (SSB)
Map details: Norwegian Mapping Authority
The E39 Coastal Highway Route

Challenging fjord crossings

<table>
<thead>
<tr>
<th>Fiord</th>
<th>Length (km)</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halsafjorden</td>
<td>2</td>
<td>5–600</td>
</tr>
<tr>
<td>Julsundet</td>
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<td>5–600</td>
</tr>
<tr>
<td>Romsdalsfjorden</td>
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<td>330</td>
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<tr>
<td>Sulafjorden</td>
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<td>500</td>
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<td>Vartdalsfjorden</td>
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<td>Nordfjorden</td>
<td>1.4</td>
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<td>Sognefjorden</td>
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<td>1250</td>
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<tr>
<td>Bjørnafjorden</td>
<td>5</td>
<td>5–600</td>
</tr>
<tr>
<td>Langenuuen</td>
<td>1.3</td>
<td>500</td>
</tr>
<tr>
<td>Boknafjorden</td>
<td>27</td>
<td>390</td>
</tr>
</tbody>
</table>

*= subsea tunnel
An improved and continuous E39 – what does that mean?

- Open road 24/7
  7 ferry connections removed
- Travel and transport time reduced from 21 hours to 11 hours
- New solutions and new competence
  - Similar bridge solutions have never been built before

Illustration: Baezeni/NPRA
Submerged floating tube bridge anchored to pontoons on the surface

Illustrations: NPRA
Knowledge helps reduce the cost and find better solutions!
Bridge constructions and Impacts on Society

- https://www.vegvesen.no/Teknologidagene
Join us now!

Facebook!
The Coastal Highway Route E39

Interactive map with information on status and progress
THANK YOU FOR YOUR ATTENTION!

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Hilsen fra Styret i NFF
What is a Submerged Floating Tunnel (SFT)?

1. Bridge
2. Submerged Floating Tunnel (SFT)
3. Immersed Tunnel (IT)
4. Rock Tunnel/Bored Tunnel
Vertical stabilization

SFT with pontoons – NPRA

SFT with tension legs anchored to the seabed – NPRA
Pontoons: Pros and Cons

Estimated ship routes for the Bjørnafjord – NPRA

Proposal for pontoons as «floating islands» – NPRA
Tension leg anchoring: Pros and Cons

Load bearing principle of tension leg anchored SFT – NPRA

Tension Leg – NPRA
Foundations for tension legs

Gravity/Suction based anchors - NPRA

Rock anchors - NPRA
Ship Impact

Concrete pontoon

Fail-safe connection

Principle of fail-safe connection for a pontoon subjected to ship impact
Submarine impact

FEM model for submarine impact on SFT – NPRA
Fire and explosion

Fire:
NPRA handbok designload: 300 MW for 2 hours

Explosion:
Gasseksplosjon most likely
Designload: 300 kPa

Max pressure from TNT detonasjon

Escaperoutes in the SFT – NPRA
Robustnes:  
– The structures ability to withstand the unexpected

- Skipskollisjon med en pontong
- Øyeblikkelig tap av en pontong. Full trafikkbelastning
- Sinkende skip som treffer rørene
- Eksplosjon i rørene i kombinasjon med andre belastninger
- Oversvømmelse i et av ballastkamrene
- Tap av et strekkstag

TNT detonation in the tunnel.
Natural reduction of wave loads

Waveloads depending on depth(normalized) for the Bjørnafjord – NPRA

Zero downtime due to weather!

15.08.2018
Landscape and noise

A teathered solution is invisible – NPRA

A pontoon solution is visible, but still free from noise pollution – NPRA
Bicycle and pedestrian path?

Cross-section SFT

SFT for the Bjørnafjord – NPRA

Bicycle and pedestrian path in SFT - NPRA
Why has an SFT not been built yet?
Feasibility study:

Høgsfjord–crossing

Sognefjord–crossing

SFT for crossing the Sognefjord - NPRA
Bjørnafjord-crossing

Digernessund-crossing

Sulafjord-crossing

Study for crossing the Digernessund - NPRA
Publications:

Development of a submerged floating tube bridge for crossing of the Bjørnafjord; Multi-Span Large Bridges; Porto 2015

Vertical stiffness for tube bridges: Comparing pontoons and tethers; IABSE; Geneve 2015

E39 - nuove tipologie strutturali per l'attraversamento dei fiordi norvegesi; Trasporti e cultura; Italia 2015

The use of wind tunnel facilities to estimate hydrodynamic data; Experimental Fluid Mechanics; Prague 2015

Mega bridges for the fjord crossing in Norway; Bridge design & Engineering; 2015

The Submerged Floating Tube Bridge: The invisible bridge crossing the Bjørnafjord; IABSE; Stockholm 2016

The Submerged Floating Tube Bridge: Design Philosophy and Concept Development; IABSE; Stockholm 2016

Hydrodynamic loads on a submerged floating tunnel bridge induced by a passing ship or two ships in maneuver in calm water; OMAE; Busan 2016

Basic design for a Submerged Floating Tube Bridge across the Digernessund; IABSE; Vancouver 2017

A submerged floating tube bridge concept for the Bjørnafjord crossing – marine operations; OMAE; Trondheim 2017

Simplified hydrodynamic design procedure of a submerged floating tube bridge across the Digernessund of Norway; OMAE; Trondheim 2017

Global Analysis of Submerged Floating Tube Bridge (SFTB): The Design Case of Crossing the Bjørnefjord in Norway; World Tunnel Congress; Bergen 2017

Submerged floating tunnels subjected to internal blast loading; Transport Research Arena; Vienna 2018

The Submerged Floating Tube Bridge as an alternative for a crossing: pros and cons; IABSE; Nantes 2018

Owners guide for SFT – ITA AITES (International Tunneling and Underground Space Association)

WG 1.2 Concrete structures in marine environment – FIB (International federation for structural concrete)
Development of offshore structures

Heidrun tension legs towing and installation – Holwech & Engebretsen
Cost comparison

![Graph showing cost comparison vs length in kilometers. The graph illustrates the cost implications of different bridge types, with a notable change in trend for Suspension Bridges and SFT.]
Risk or opportunity

Risk

Opportunity
Interest for Subemerged Floating Tunnels World Wide

Map 1: Articles
Interest for Subemerged Floating Tunnels World Wide

WIRED
YES, A 'SUBMERGED FLOATING BRIDGE' IS A REASONABLE WAY TO CROSS A FJORD

Forbes
Could Norwegian Engineers Really Build A Floating Tunnel In A Fjord?

HUFFPOST
Entre le tunnel sous-marin et le pont, la Norvège pourrait expérimenter les tunnels flottants

BBC

ACTUALIDAD

LA STAMPA

futurezone
SFT–studies in recent years

Map 2: Feasibility studies
A BIG opportunity

SFT: Construction in dry dock – NPRA

SFT: Assembly phase – NPRA

Towing of the Troll platform
The question is not if, but when...

Thank you for your attention!

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