The Storebælt Link

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A Presentation for the ACI Technical Session:

«The Legacy of Per Fidjestøl»
Location
Project Parameters.

• Eliminate Ferry Traffic
  • The journey time was approximately 1 hour

• Greatly increase travel flow
  • Fast traffic road
  • Full Rail Connection

• Permanent, long term link as part of the European Road Network.

• That is – a minimum 100 year design life (no major maintenance).
<table>
<thead>
<tr>
<th>Materials Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cement type:</strong></td>
</tr>
<tr>
<td><strong>Fly Ash:</strong></td>
</tr>
<tr>
<td><strong>Silica Fume:</strong></td>
</tr>
<tr>
<td><strong>Gravel:</strong></td>
</tr>
<tr>
<td><strong>Sand:</strong></td>
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</tbody>
</table>
## Concrete Parameters

**Design life:** 100 years

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strength:</strong></td>
<td>50 MPa</td>
</tr>
<tr>
<td><strong>w/cm:</strong></td>
<td></td>
</tr>
<tr>
<td>Mix A:</td>
<td>max. 0.35 (max. 135 kg)</td>
</tr>
<tr>
<td>Mix B:</td>
<td>max. 0.45 (max. 140 kg) (less severe exposure)</td>
</tr>
<tr>
<td><strong>Cement:</strong></td>
<td>min. 300 kg/m³</td>
</tr>
<tr>
<td><strong>Fly Ash:</strong></td>
<td>min. 15% of total binder</td>
</tr>
<tr>
<td><strong>Silica Fume:</strong></td>
<td>4 - 8% of total binder</td>
</tr>
<tr>
<td><strong>FA + SF:</strong></td>
<td>max. 25% of total binder</td>
</tr>
</tbody>
</table>
# Concrete Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air (&lt; 0.035mm)</td>
<td>max. 20% - min. 8% (of paste volume).</td>
</tr>
<tr>
<td>Entrapped air</td>
<td>max. 7% (of paste volume).</td>
</tr>
<tr>
<td>Specific Surface</td>
<td>min. 25mm$^2$/mm$^3$.</td>
</tr>
<tr>
<td>Chlorides</td>
<td>0.1% of total powder.</td>
</tr>
<tr>
<td>Alkalis</td>
<td>3kg/m$^3$.</td>
</tr>
</tbody>
</table>
## Cementitious Blends

<table>
<thead>
<tr>
<th>kg/m³</th>
<th>East Bridge</th>
<th>Tunnels</th>
<th>West Bridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>315</td>
<td>335</td>
<td>320</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>40</td>
<td>40</td>
<td>38</td>
</tr>
<tr>
<td>Silica fume</td>
<td>23</td>
<td>20</td>
<td>23</td>
</tr>
</tbody>
</table>
The Low Bridge

Two parallel 6,500m bridges
Passage height: 18m
Concrete volume: 430,000 m³
The Low Bridge
The Rail Tunnels

Two parallel 8,500m sub sea tunnels = 62,000 precast concrete lining elements

Concrete volume: 250,000m³ + backfill
The Island ‘junction’

From the western shore, the twin bridges part company on the island
Length of free span: 1,624m
Height of pylons: 254m
Main channel clearance: 65m
Concrete volume: 380,000m³
The High Bridge
Bearing Out The Legacy

• One of Per’s major research areas was Marine Concrete: to improve the durability, strength and lifetime in that harsh environment.

• That research work – and the development of mixes on the Storebælt Project has led to the major use of binary, ternary, and even quaternary blends, on some of the major infrastructure bridges in the world.

• The durability and lifetimes of the spectacular bridges stand as statement to the work that Per initiated and worked on, along with respected colleagues from around the world, who have continued to develop these high durability concretes.

• Here are just 4 of those:
The Øresund Connection

Copenhagen
Artificial peninsula 430 m
Immersed tunnel 3,510 m
Artificial Island 4,055 m

Total length of the bridge 7,845 m
High bridge 1,092 m
Western approach bridge 3,014 m
Eastern approach bridge 3,739 m

Denmark
Sweden
Concrete requirements:
- **Service life 100 years**
- $w/cm < 0.40$
- Low alkali cement
- Crack width $< 0.20$ mm
- High quality aggregates

Danish side: Concrete contains 15% fly ash and 5% silica fume
Swedish side: Concrete contains 5% silica fume

Approximately 2 million cubic metres of concrete.
The Øresund bridge
Tsing Ma Bridge, Hong Kong

80MPa: 390kg mix at 30% OPC, 65% GGBS and 5% SF - Slipformed Chloride Diffusion at less than $10^{-14}$
The Bandra-Worli Sea Link, Mumbai

4.5 km twin bridge, two shipping channels

50 / 60 MPa mixes:
OPC/SF
OPC/FA/SF

Strength and Marine durability:

75MPa at 28 days
RCPT – 600 coulombs
Water (Din 1048) - Zero
Four Lanes of Mumbai Traffic…
Shanghai East-Sea Bridge

32.5km road bridge.
35MPa and 50MPa
High Durability
Shanghai East-Sea Bridge

*Loading test*

**Design life:** 100 years
Quad blend (PC/GGBS/FA/SF)
Built in less than 3 years.
Speed limit 50mph…
THANK YOU.

Any Questions?