SOIL AND BEDROCK CONDITIONS TO BE EXPECTED IN TALLINN – HELSINKI TUNNEL CONSTRUCTION

Geological Survey of Finland
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Strait Crossing 2013, Bergen
Based on compilation and analysis of existing geological data in tunnel area in Estonia, the work is done by Geological Survey of Estonia, 2012
Commissioned by Geotechnical Division of the City of Helsinki and Geological Survey of Finland
Main objective was to create a preliminary 3D –model of the geological main units near the coast of Tallinn for tunnel construction suitability estimation of the bedrock
The Helsinki-Tallinn railway tunnel

- The idea of a rail tunnel was created at the Finnish Geotechnical Society in 1992
- first preliminary feasibility study by Usko Anttikoski in 2007
- The debate about the tunnel construction has been intensive (2011 – 2013), critical voices have been strong, but the tunnel has got more and more acceptance.
- The political acceptance of the idea by decision makers is also growing, and the idea has developed from fantasy to vision.
- on the basis of the meeting of the mayors of the cities of Helsinki and Tallinn a Feasibility Study Working Group was established
- Only a few geological investigations have been done in the sea area
6 million yearly passengers
12,000 weekly commuters from Estonia
20 daily connection

TWIN CITY TALSINKI
Technical overview

• The world’s longest undersea tunnel (vision, “extreme grossing”)

• Two alternatives: 70 km long (58 km undersea) Kirkkonummi-Tallinn tunnel and 85 km long (73 km undersea) Helsinki – Tallinn tunnel

• Shallows on both coasts will be used (artificial islands) to build access tunnels service shafts and ventilation exhaust

• The construction costs of the tunnel have been estimated to be €2.3 – 2.7 billion (preliminary feasibility study, Anttikoski, 2007)

• The type of tunnel system would be two track tunnels (2 x 70 square metres) and a separate service tunnel (30-40 square metres)

• The lowest point of the tunnels is estimated to be about 220 meters below the sea, maximum tunnel longitudinal inclination about 1.2 – 2.0 %.

Possible tunnel lines according to U. Anttikoski, 2007
Possible tunnel lines according to U. Anttikoski, 2007
Build rock tunnels in Helsinki district

Helsinki: more than 300 km built rock tunnels

Helsinki - Espoo metro tunnels, >20 km

Savio Rail Tunnell, 13.5 km

The Päijänne Water Tunnel, 120 km

Cleaned waste water outlet tunnels, 8 km, undersea

Planned Helsinki-Tallinn tunnels

70 km

85 km

Gulf of Finland

Tallinn
Good and hard bases for the underground construction in Finland

Precambrian crystalline bedrock provides a good bases for the underground construction

Various Precambrian shields of Earth
Schematic cross-section through the Gulf of Finland
Bedrock outcrops

Finland

Estonia

Blue Caly of Lontova [http://www.klint.envir.ee/klint/eng/12.html]

Photo: http://www.klint.envir.ee/klint/eng/12.html

Photo: O. Ikävalko
Geology of Estonian coast, Baltic klint and buried valleys
3D model of main geological units in front of Tallinn

Study area

Surface of Crystallinen basement (Precambrian)

Surface of bedrock (Ediacaran-Cambrian)

www.gtk.fi
Cross-section of the Gulf of Finland based on the 3D-model

Helsinki

Kotajärvi

60°N

Tallinn

Munkkisaari

J22

Blue Clay

Bedrock

Ediacara

Relief

Basement

1.5 %
### Physical-mechanical properties of different formations along the Tallinn-Helsinki tunnel

1= volumetric weight, 2= compressive strength, 3= porosity, 4= P-wave velocity ca. 6000-6500 m/s, 5= thickness of formation.

<table>
<thead>
<tr>
<th>Formation</th>
<th>1 (G/Cm³)</th>
<th>2 (Mpa)</th>
<th>3 (%)</th>
<th>4 (m/2)</th>
<th>5 (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precambrian gneisses</td>
<td>A 2.65 - 2.75</td>
<td>110 - 240</td>
<td>0.1 - 0.2</td>
<td>6000 - 6300</td>
<td></td>
</tr>
<tr>
<td>Rapakivi granites</td>
<td>B 2.65</td>
<td>100 - 200</td>
<td>0.1</td>
<td>6000 - 6500</td>
<td></td>
</tr>
<tr>
<td>Weathered crystalline basement</td>
<td>C 2.0 - 2.6</td>
<td>1 - 100</td>
<td>1 - 20</td>
<td>2000 - 5000</td>
<td>1 - 20</td>
</tr>
<tr>
<td>Sandstones</td>
<td>D 2.0 - 2.3</td>
<td>1 - 25</td>
<td>10 - 20</td>
<td>2000 - 3000</td>
<td>n. 60</td>
</tr>
<tr>
<td>Siltstone</td>
<td>E 2.25 - 2.35</td>
<td>5 - 25</td>
<td>10 - 15</td>
<td>2500 - 3500</td>
<td>1 - 2</td>
</tr>
<tr>
<td>Sandstones</td>
<td>F 2.1 - 2.2</td>
<td>1 - 5 Mpa</td>
<td>20 - 25</td>
<td>2500 - 3000</td>
<td>15</td>
</tr>
<tr>
<td>Blue clay</td>
<td>G 2.3 - 2.4</td>
<td>2 - 4 Mpa</td>
<td>8 - 10</td>
<td>2000 - 2500</td>
<td>45</td>
</tr>
<tr>
<td>Limestone</td>
<td>H 2.55 - 2.65</td>
<td>100 - 150</td>
<td>0.1 - 5.5</td>
<td>4000 - 5500</td>
<td>20</td>
</tr>
<tr>
<td>Glauconite sandstone</td>
<td>I 1.95 - 2.1</td>
<td>1 - 20</td>
<td>1 - 10</td>
<td>2500 - 3000</td>
<td>2</td>
</tr>
<tr>
<td>Alum shale</td>
<td>J 1.9 - 2.0</td>
<td>40 - 50</td>
<td>1 - 10</td>
<td>3500 - 4000</td>
<td>3.5</td>
</tr>
<tr>
<td>Sandstones</td>
<td>K 2.1 - 2.8</td>
<td>1 - 40</td>
<td>1 - 20</td>
<td>2500 - 3500</td>
<td>3 - 8</td>
</tr>
<tr>
<td>Quaternary loose sediments</td>
<td>L 1.5 - 2.2</td>
<td>&lt; 1</td>
<td>10 - 30</td>
<td>1500 - 2000</td>
<td>0 - 60</td>
</tr>
</tbody>
</table>

A= Rocks of Jägala complex, B= Naissaar and Neeme rapakivi, C= Weathered crystalline rocks. D= Ediacaran sandstones, E= Ediacaran siltstone, F= Cambrian quartzose sandstones of the Tiskre formation, G= Cambrian blue clay of the Lontova formation, H= Ordovician limestone, I= Ordovician glauconite sandstone of the Leetse formation, J= Ordovician alum shale of the Türisalu formation, K= Ordovician sandstones of the Kallavere and Ülgase formations, L= Quaternary deposits.
Physical-mechanical properties of the rocks divided into 8 groups.

Complexes from 2 to 6 represent the sedimentary rocks, collectively called bedrock. Bedrock is, partly or completely, eroded by later processes.)

<table>
<thead>
<tr>
<th>Complex no.</th>
<th>Thickness (m)</th>
<th>Properties (tbl. 1)</th>
<th>Construction conditions</th>
<th>Tunnel km incl. 1.5 %</th>
<th>Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 - 60</td>
<td>L</td>
<td>Very difficult outside tunnel</td>
<td>Quaternary deposits;</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>H</td>
<td>Good outside tunnel</td>
<td>Ordovician limestones;</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>J,I</td>
<td>Very challenging outside tunnel</td>
<td>Lower-Ordovician alum shale and glauconitic sandstone</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>15 + 10</td>
<td>I,K</td>
<td>Very challenging 2</td>
<td>Lower-Cambrian and Lower-Ordovician sandstones;</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>60</td>
<td>G</td>
<td>Good 4</td>
<td>Blue clays (Lükati and upper part of Lontova formations);</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>D, E</td>
<td>Very challenging 4</td>
<td>Ediacaran silt- and sandstones (Kroodi formation);</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>15</td>
<td>C</td>
<td>Challenging 1</td>
<td>Weathered crust of basement</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>(km)</td>
<td>A, B</td>
<td>Very good 63</td>
<td>Precambrian basement metamorphic and igneous rocks</td>
<td></td>
</tr>
</tbody>
</table>

Physical-mechanical properties of the rocks divided into 8 groups.
Investigation to be done in the future

Use of different methods to measure:
- Depth of bedrock surface
- Weakness zones in bedrock

Continuous seismic reflection profiling provides information in the sedimentary sequences overlying the bedrock and/or crystalline basement.
Thank you for Your attention!

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