TBM APPLICATIONS II

THE FOLLO LINE TBM TUNNEL

Acciona Ghella Joint Venture

Fernando Vara

Bergen, 6 - 7 June
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1. ABOUT THE COMPANIES
Leading corporation, front-runner in energy, construction, water, industrial and services, oriented towards sustainable development and social wellbeing.

Listed on the Madrid stock exchange index Ibex-35 and Dow Jones Sustainability World Index.
Founded in 1894, with its unique skills and experience in underground works Ghella is a leading Company in the construction of major infrastructure projects worldwide.

**BACKLOG BY ACTIVITIES**
- Railways 44%
- Concessions 18%
- Subways 17%
- Roads 10%
- Hydraulic works 8%
- Other 3%

**BACKLOG BY AREAS**
- Venezuela 43%
- Italy 23%
- Argentina 20%
- Brasil 5%
- Costa Rica 2%
- Other 7%
Legacy Way

Prestigious TBM-project – excavation of new road tunnel

- 4.6 km road tunnel connecting the east and western part of Brisbane in Australia
- Joint Venture between Ghella, Acciona and BMD Construction
- Two 12m diameter TBMs made the tunnels
- World record on distance bored in one day - 49.7 metres
- 38,700 pre-cast concrete segments to line the tunnel walls and over 1,200 concrete piles
- The project earned several prices, including the prestigious “2013 International Tunnelling Project of the year”
- More about the project.
Guadarrama Tunnel, Spain

Project information: South Tunnels. Largest public work project carried out in Spain to date.
Type of TBM: Double Shield TBM (HK & Wirth, 9.54 m in diameter).
Type of material: Hard rock Granite. Duration: 31 months.
Saint Marten La Port – Turin Lyon High Speed Railway : SMLP Tunnels, France

Project information: Design and construction of the 9km TBM Tunnel+1Km D&B for the Turin-Lyon High Speed Railway Project.

Type of TBM: Single Shield TBM (NFM, 11.14 m in diameter).
Type of material: Grey Schist, Sandstone. Duration: 108 months
2. AGJV TEAM
Building a powerful organisation

Acciona Ghella Joint Venture

- International, highly skilled and motivated employees
- About 800 people to be employed by AGJV
- Develop common company culture in an international environment
- Project office at the construction site Åsland, Oslo
Management group with comprehensive experience

Fernando Vela Ortiz De La Torre - Project Director
Matteo Ortu - Construction Director
Jesus Espinosa - Design Coordination Manager
Gry Jedestøl - HR Manager
Line Fredriksen - Community and Stakeholder Manager

Francesco Bertagnolli - Commercial Manager
Pablo García Caramés - Financial Manager
Jostein Kjørstad - Environmental Manager
Javier Francisco Cuenca Bravo - OH&S Manager
Karsten Ramon Parbo - Completion Manager
Bengt Åge Fjørtoft - Quality & Systems Manager
3. PROJECT OVERVIEW
The Follo-Line project
The most significant transport project in Norway

• 22 km double railway track, high-speed, between Oslo and Ski
• New Ski station, twin tunnel and connection to Oslo Central Station
• Reduces travel time from 22 to 11 min
• Commissioned by the Norwegian National Railway Administration (Jernbaneverket)
Follo Line EPC Civil Works Contracts
Follo Line EPC TBM Contract #3 Scope

- D&B access: 300,000 m³ in 10 months
- D&B escape tunnel: 745,000 m³ in 14 months
- TBM excavation: 4 drives, 36,500 m² in 24 months
- Track and systems: 426,000 m² in 24 months
- Commissioning: 6 months
- Total Duration: 78 months
4. GEOLOGY
4. GEOLOGY

Follo Line Geological Profile

- Largely tonalitic to granitic gneiss
- Average compressive strength: 142 MPa - peak above 300 MPa
- Mixed Face conditions: 15% of alignment amphibolite 250 MPa & gneiss UCS 100 MPa
- Average quartz content: 28% - peak above 50%
- Maximum overburden: 150m
- Groundwater level is generally 2 - 3 m below terrain
2. GEOLOGY

**Ground Water**

<table>
<thead>
<tr>
<th>Km</th>
<th>Location</th>
<th>Area classification of pore pressure sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.3 – 4.0</td>
<td>Below Ekeberg (to Holtet)</td>
<td>Small sensitivity</td>
</tr>
<tr>
<td>4.0 - 5.0</td>
<td>Holtet - Lambertseter</td>
<td>Moderate sensitivity</td>
</tr>
<tr>
<td>5.0 – 7.8</td>
<td>Nordstrandsplataet</td>
<td>Sensitive</td>
</tr>
<tr>
<td>7.8 – 8.5</td>
<td>Ljanselva - Gjersrudbekken</td>
<td>Small sensitivity</td>
</tr>
<tr>
<td>8.5 – 9.0</td>
<td>Bjørnerud</td>
<td>Moderate sensitivity</td>
</tr>
<tr>
<td>9.0 – 11.2</td>
<td>Grønliåsen north</td>
<td>Small sensitivity</td>
</tr>
<tr>
<td>11.2 – 12.0</td>
<td>Grønliåsen</td>
<td>Moderate sensitivity</td>
</tr>
<tr>
<td>12.0 – 15.7</td>
<td>Snipejtern - Assurdalen</td>
<td>Sensitive</td>
</tr>
<tr>
<td>15.7 – 18.9</td>
<td>Assurdalen - Sloraveien</td>
<td>Moderate sensitivity</td>
</tr>
<tr>
<td>18.9 – 20.6</td>
<td>Sloraveien – Ramstad S</td>
<td>Very sensitive</td>
</tr>
<tr>
<td>20.6 – 21.3</td>
<td>Ramstad – Portal Langhus</td>
<td>Moderate sensitivity</td>
</tr>
</tbody>
</table>

- Impact on ground water levels is main concern
- Sensitivity classification
- 4 classes
5. SITE LAYOUT
6. LOGISITC & AUXILIARY INSTALLATIONS
Segment Design

- Outer Diameter: 9.55 m
- Inner Diameter: 8.75 m
- Thickness: 400 mm
- Segment Length: 1.8 m
- Segments + Key: 6 + 1
- Total Concrete: 500,000 m³
- Backfilling: two component grout
Segment Supply with MSVs

- Load capacity: 125 t
- Length: 45 m
- Turning radius: 15 m
- Engine: 405 kW, Euro IV
- Operational grade: +/- 10%
- Retarder system
- Winter provisions
- Suitable for two complete rings with invert segments
Underground Structures Layout and Ventilation Concept

Adit North is air exhaust, conveyor and vehicle route out

Adit South is air intake and vehicle route in
Conveyor System to Surface

Common conveyors

- Conveyors: 5 x 2 systems
- Belt width: 1400 mm
- Capacity: 2000 t/hr
- Level change: 112 m
- “Four on one” capability to switch over TBM conveyors
Systems in TBM Tunnels

- Conveyor belt 850 t/hr
- Ventilation duct 2.8 m
- Lines for grout A + B component
- Lines for water supply, dewatering, cooling
- Invert segment for MSV traffic
7. TBM CONFIGURATION
3. TBM DESIGN

TBM Cutterhead Design

- Adapted to high rock strength
- Jernbaneverket input based on Norwegian experience
- 71 Cutter rings 19” on 70 tracks
- Heavy structure, stiff support
- Main bearing size increased to Ø 6.6 m
3. TBM DESIGN

Provisions for Systematic Grouting

- Specific drill rig setup
- Independent grouting system driven to TBM
Tunnel Boring Machine

*Four machines to excavate the twin tunnel*

- TBMs arrive from spring 2016
- Work starts in September 2016
- Diameter machine/tunnel: 9.96 m/8.75 m
- Length of machines: 150 m
- Weight: 2400 tons
- Installed Power: 6200 kW
- No of Cutters: 71
- Average excavation speed: 12-15 m/day
- Made by the German company Herrenknect
8. TBM ASSEMBLY SEQUENCE
9. PROJECT SCHEDULE
A project with many phases
From drill and blast to complete tunnel

- Excavation: Excavate assembly hall and transport tunnels; Drill and blast
- TBM assembly: Underground TBM assembly; Transporting parts, use gantry crane to mount
- Segment production: Concrete factory on site; Produce segments, transported to tunnels
- Tunnel boring: Four TBMs to excavate two parallel tunnels; Start from site at Åsland in Oslo
- Lining of tunnel: Lining with concrete segments; Creating a strong and smooth wall
- Finished tunnel: System installation; Scandinavia’s longest railway tunnel; Ready for use in 2021

2015 ➔ 2021
THANK YOU FOR YOUR ATTENTION