Sydney Metro Northwest project
4 double shield TBMs excavate 15 km of twin tunnels

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Project Overview

- Rapid transit train project
- 8 new stations
- 30 km of tunnels in urban context
- 4 km elevated line
- Fully automated train system
- To be opened end 2019 with trains every 4 minutes
15 km of Twin Tunnels

- Contract awarded to Thiess - John Holland - Dragados
- 725 M€ contract
- Bored tunnels + mined tunnels
- 6.7 m diameter
- Overburden 30 to 60 m
- 4 TBMs
- 3 TBM sites & launching shafts
- Cross-passages every 240 m
- Crossover at Castle Hill
Launching TBMs 1 & 2
Bella Vista
### The TBMs – Double Shields

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation diameter</td>
<td>[m]</td>
<td>6.985</td>
</tr>
<tr>
<td>Shield length</td>
<td>[m]</td>
<td>12.4</td>
</tr>
<tr>
<td>Total length</td>
<td>[m]</td>
<td>115</td>
</tr>
<tr>
<td>Disc cutters diameter</td>
<td>[mm]</td>
<td>19&quot;</td>
</tr>
<tr>
<td>Disc cutters (single discs)</td>
<td>[nr.]</td>
<td>40</td>
</tr>
<tr>
<td>Disc cutters (twin discs)</td>
<td>[nr.]</td>
<td>5</td>
</tr>
<tr>
<td>Drive unit torque continuous</td>
<td>[kN.m]</td>
<td>2.890</td>
</tr>
<tr>
<td>Drive unit torque unlocking</td>
<td>[kN.m]</td>
<td>6.500</td>
</tr>
<tr>
<td>Total thrust</td>
<td>[kN]</td>
<td>36.000</td>
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</tbody>
</table>
Sydney Metro Northwest project

Geological context

2 main rock masses
- Hawkesbury Sandstone
- Ashfield Shale

separated by thin transitional unit (siltstone):
- Mittagong formation

Low permeability
Rock characteristics – rock strength

- **Ashfield Shale**
  - Tensile strength (Brazilian test)
  - Point load (axial)
  - Point load (diametral)
  - UCS

- **Hawkesbury Sandstone**
  - Tensile strength (Brazilian test)
  - Point load (axial)
  - Point load (diametral)
  - UCS
Rock abrasivity

**Ashfield Shale**

- Percentage of samples:
  - Low abrasiveness: 10%
  - Abrasive: 0%
  - Highly abrasive: 0%
  - Extremely abrasive: 90%

**Hawkesbury Sandstone**

- Percentage of samples:
  - Low abrasiveness: 0%
  - Abrasive: 0%
  - Highly abrasive: 0%
  - Extremely abrasive: 100%

**CERCHAR Abrasivity**

- Percentage of samples:
  - 0.3 to 0.5: not very abrasive
  - 0.5 to 1: slightly abrasive
  - 1 to 2: medium abrasiveness
  - 2 to 4: very abrasive
  - 4 to 6: extremely abrasive
  - 6 to 7: quartzitic
Excavation performance
Excavation performance

### Observed average daily advance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>TBM 1</th>
<th>TBM 2</th>
<th>TBM 3</th>
<th>TBM 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>[m]</td>
<td>16.2</td>
<td>17.0</td>
<td>16.1</td>
<td>14.2</td>
</tr>
<tr>
<td>Excluding days off</td>
<td>[m]</td>
<td>32.2</td>
<td>32.8</td>
<td>32.3</td>
<td>29.2</td>
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### Parameter

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Shift 1</th>
<th>Shift 2</th>
<th>Shift 3</th>
<th>Total Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rings</td>
<td>18</td>
<td>17</td>
<td>19</td>
<td>54</td>
<td></td>
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<tr>
<td>Advance</td>
<td>[m] 30.6</td>
<td>28.9</td>
<td>32.3</td>
<td>91.8</td>
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<tr>
<td>Excavation time</td>
<td>[hh:mm] 5:22</td>
<td>5:44</td>
<td>5:47</td>
<td>16:53</td>
<td></td>
</tr>
<tr>
<td>Thrust</td>
<td>[ton] 876</td>
<td>857</td>
<td>859</td>
<td>864</td>
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</tr>
<tr>
<td>Torque</td>
<td>[kN.m] 1971</td>
<td>1862</td>
<td>1859</td>
<td>1897</td>
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<tr>
<td>Penetration</td>
<td>[mm/rev] 18.6</td>
<td>17.6</td>
<td>17.7</td>
<td>18.0</td>
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<tr>
<td>Advance rate</td>
<td>[mm/min] 95</td>
<td>84</td>
<td>93</td>
<td>91</td>
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</tbody>
</table>

Record day 5 Aug. 2015

TBM1

Rock: Sandstone
Disc cutter wear

- Standard type 19” diameter.
- 1” tip

- 19” diameter with carbide inserts

Chipping

Flat

Tear of inserts

Tear and Wear
## Disc cutter wear

Cherrybrook to Epping

<table>
<thead>
<tr>
<th>Rock type</th>
<th>Changes TBM3</th>
<th>m³/disc TBM3</th>
<th>Changes TBM4</th>
<th>m³/disc TBM4</th>
<th>Total changes</th>
<th>m³/disc Total</th>
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</thead>
<tbody>
<tr>
<td>Shale</td>
<td>2</td>
<td>NS</td>
<td>3</td>
<td>NS</td>
<td>5</td>
<td>NS</td>
</tr>
<tr>
<td>Siltstone</td>
<td>27</td>
<td>1130</td>
<td>35</td>
<td>780</td>
<td>62</td>
<td>931</td>
</tr>
<tr>
<td>Sandstone</td>
<td>199</td>
<td>380</td>
<td>146</td>
<td>290</td>
<td>345</td>
<td>344</td>
</tr>
<tr>
<td>Total</td>
<td>228</td>
<td>643</td>
<td>184</td>
<td>613</td>
<td>412</td>
<td>629</td>
</tr>
</tbody>
</table>

Predictions for complete drive:
- 640 m³/disc
- 560 m³/disc
Influence of geology on TBM performance

Thrust

Torque
Influence of geology on TBM performance

Penetration

Advance rate
TBM production data

TBM4
Sandstone section
Conclusions

- Sydney Metro Northwest is indeed a challenging tunnel project
- Double shield TBMs achieve very high performance when properly managed and maintained
- Adapted disc cutters allows to maintain performance almost unchanged from shale to harder and more abrasive sandstone
- Project ahead of schedule
Thank you for your attention