Ottawa LRT Tunnel Construction Update

Tom Middlebrook, Humberto Ferrer
DRAGADOS CANADA
Oct 5th, 2015
Agenda

Self Introduction
Dragados
Ottawa LRT Tunnel
Station Construction Techniques
Tom Middlebrook

Sr. Vice President, Business Development – Eastern Canada
Dragados Canada

Previously…
MMM Group – Urban Mobility
MRC – Transit Consultant
Toronto Transit Commission – Chief Engineer
Smaller Construction Companies
**Tunnelling Association of Canada (TAC) – Ontario Chapter**

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**Today**

**#1 global contractor with sales reaching € 35 bn**

Leading international contractor, highly diversified in terms of geographies and contracting activities

**EBIT 14 € 1.6 bn (margin 4.6%)**

**Net Debt 1H15 € 3.5 bn**

**210,000 employees**

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**Enr.com August 24/31, 2015**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Firm</th>
<th>2014 Revenue $ mil</th>
<th>Intl.</th>
<th>Total</th>
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<tr>
<td>1</td>
<td>ACS, ACTIVIDADES DE CONSTRUCCION Y SERVICIOS SA, Madrid, Spain</td>
<td>38,707.5</td>
<td>46,081.1</td>
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<td>2</td>
<td>HOCHTIEF AKTIEN GESELLSCHAFT, Essen, Germany</td>
<td>28,209.3</td>
<td>31,118.8</td>
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<td>3</td>
<td>BECHTEL, San Francisco, Calif, USA</td>
<td>21,414.0</td>
<td>28,302.0</td>
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<td>4</td>
<td>VINCI, Rueil Malmaison, France</td>
<td>19,879.9</td>
<td>51,888.8</td>
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<td>CHINA COMMUNICATIONS CONSTRUCTION GRP. LTD, Beijing, China</td>
<td>15,827.0</td>
<td>60,314.8</td>
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<td>6</td>
<td>TECHIMP, Paris, France</td>
<td>14,223.6</td>
<td>14,343.6</td>
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<td>7</td>
<td>BOUYGUES SA, Paris, France</td>
<td>14,201.0</td>
<td>32,335.0</td>
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<td>8</td>
<td>SKANSKA AB, Stockholm, Sweden</td>
<td>14,049.7</td>
<td>17,687.2</td>
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<td>9</td>
<td>STRABAG SE, Vienna, Austria</td>
<td>13,970.0</td>
<td>16,470.0</td>
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<td>10</td>
<td>SAIPER, San Donato Milanese, Italy</td>
<td>13,283.4</td>
<td>13,831.9</td>
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<tr>
<td>11</td>
<td>POWER CONSTRUCTION CORP OF CHINA, Beijing, China</td>
<td>11,833.4</td>
<td>38,699.6</td>
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<tr>
<td>12</td>
<td>FLUOR CORP, Irvine, Calif, USA</td>
<td>11,524.1</td>
<td>16,924.9</td>
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<tr>
<td>13</td>
<td>CONSTRUCTORA ROMBERTO ODEBRECHT SA, Sao Paulo, Brazil</td>
<td>10,199.7</td>
<td>14,042.9</td>
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<tr>
<td>14</td>
<td>HYUNDAI ENGINEERING &amp; CONSTRUCTION CO. LTD, Seoul, S. Korea</td>
<td>9,687.4</td>
<td>16,386.6</td>
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<td>15</td>
<td>FERROVAL, Madrid, Spain</td>
<td>8,365.6</td>
<td>11,618.8</td>
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</tbody>
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Challenges and Innovations in Tunnelling
Tunnelling Association of Canada (TAC) – Ontario Chapter
Challenges and Innovations in Tunnelling
Dragados - Global Presence

- Argentina
- Australia
- Canada
- Chile
- Colombia
- Ireland
- Greece
- Peru
- Poland
- Portugal
- Spain
- United States
- United Kingdom
- Venezuela

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Challenges and Innovations in Tunnelling
Dragados in North America

December 2005

✓ In December 2005, Dragados USA began operating in the United States.

January 2008

✓ Dragados Canada opened its headquarters office in Toronto

North American Companies Acquired

- SCHIAVONE
- JPP CONTRACTORS
- POLICE CONSTRUCTION INC.
- PRINCE
- J.F. WHITE CONTRACTING CO.

Tunnelling Association of Canada (TAC) – Ontario Chapter
Services and Areas of Expertise

- Major Projects
- Alternative Project Delivery
- Design-Build
- Public Private Partnership (P3)

Transportation Infrastructure
- Bridges
- Highways and roads
- Railroads
- Mass transit
- Underground
- Airports

Water and Underground
- Canals
- Caverns
- Dams
- Hydroelectric Power Plant
- Water Tunnels
- Water Supply

Water and Marine
- Concrete structures
- Coastal Work
- Dredging and Fill
- Marine Work
- Beach Regeneration
- Floating Equipment
- Ports
- Docks
CITY BELOW THE CITY

Create new urban spaces in congested areas

Increase the quality of life
Sustainable growth

Free surface for citizens
Underground infrastructures

Create new urban spaces in congested areas

Increase the quality of life
Sustainable growth

Free surface for citizens
Underground infrastructures
NEW INFRASTRUCTURE IS BUILD FOR THE USER’S BENEFIT HOWEVER DURING CONSTRUCTION THE NEIGHBOURHOOD IS DISTURBED

AMONG THE MULTIPLE TECHNOLOGIES WE ARE OBLIGED TO LOOK FOR THE LESS DISRUPTIVE ONES
Traffic management

**Social cost**
Fuel consumption
Longer journeys
Higher carbon footprint
Higher risk of accident
Utilities relocation

- Water
- Gas
- Sewage
- Phone
- TV
- Communications
- Traffic control
- Confidential org.
- Unknown

Request Permits Approvals Relocation by others Final green light

Project schedule and cost (Lack of control)
Business loss – SOCIAL COST
Confederation Line, Ottawa
OTTAWA LRT TUNNEL
Confederation Line
Rideau Transit Group

Sponsors

Equity Developers

Project Co

Design Build Joint Venture

Maintenance Team

Engineering Joint Venture

Challenges and Innovations in Tunnelling
Confederation Line LRT
12.5 km project with 10km at grade in existing BRT Right-of-Way.
Biggest problem for the BRT was downtown – this has been solved by a
2.5 km tunnel from between uOttawa and Pimisi
Underground works
2.530 m running tunnel twin track
3 mined stations: Lyon, Parliament and Rideau
OTTAWA Geology

Sound limestone interbedded with shale from the Lindsay and Verulam formations

Compress strength varies from 50 to 90 MPa and its RQD from 30 to 90

Overlaying this sedimentary ground, glacial deposits of clay and fines including a paleovalley at Rideau
### DESIGN SCHEME

<table>
<thead>
<tr>
<th></th>
<th>Pros</th>
<th>Cons</th>
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<tbody>
<tr>
<td><strong>SINGLE TUNNEL</strong></td>
<td>Lower Cost Flexibility in operation</td>
<td>Higher risk of settlement minimize by rock quality</td>
</tr>
<tr>
<td><strong>TWIN TUNNEL</strong></td>
<td>Multiple faces Overlapping of construction activities</td>
<td>Higher cost and schedule Potential impact on building basement</td>
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</tbody>
</table>
## EXCAVATION PROCEDURES

<table>
<thead>
<tr>
<th></th>
<th>Pros</th>
<th>Cons</th>
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<tbody>
<tr>
<td><strong>TBM</strong></td>
<td>Speed</td>
<td>Paleovally</td>
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<tr>
<td></td>
<td>Open mode</td>
<td>Possible damage to building basement</td>
</tr>
<tr>
<td></td>
<td>One pass lining</td>
<td>Coordination with stations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5-2 years TBM procurement</td>
</tr>
<tr>
<td><strong>Drill &amp; Blast</strong></td>
<td>Speed</td>
<td>Urban restrictions</td>
</tr>
<tr>
<td></td>
<td>Economy</td>
<td>Noise</td>
</tr>
<tr>
<td></td>
<td>Multi face</td>
<td>Vibrations</td>
</tr>
<tr>
<td><strong>Mechanical</strong></td>
<td>Flexibility, Geometry</td>
<td>Lower speed / face</td>
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<tr>
<td></td>
<td>Multiple faces</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mobilize quickly</td>
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</table>
MECHANICAL EXCAVATION

<table>
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<tr>
<th>QUALITY</th>
<th>EXCELLENT</th>
<th>GOOD</th>
<th>MEDIUM</th>
<th>POOR</th>
<th>VERY POOR</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>COMPRESS STRENGTH</th>
<th>SOIL</th>
<th>TRANSITION</th>
<th>VERY WEAK ROCK</th>
<th>WEAK ROCK</th>
<th>MEDIUM ROCK</th>
<th>HARD ROCK</th>
<th>VERY HARD ROCK</th>
</tr>
</thead>
</table>

R.Q.D. (%)

0.2 0.6 2 6 12 20 60 150

RCs (MPa)

SPOVEL  RIPPER  BREAKER  ROAD HEADER  SPLITTER
MECHANICAL EXCAVATION

Net Cutting Rate for ATM 105-IC (300 kW installed cutter head power) equipped with Cutter Head 105-G 38 or 105-G 57+ or 105-G 72 or 105-G 87 and 22 mm TC Insert Picks according to Uniaxial Compressive Strength for Intact to Moderately Fractured Rock Mass

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Challenges and Innovations in Tunnelling
SITE ORGANISATION

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Challenges and Innovations in Tunnelling
Tunnelling Association of Canada (TAC) – Ontario Chapter

Challenges and Innovations in Tunnelling
Intermediate shaft
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EAST PORTAL

Ottawa University

Apartment complex

East Portal

University residential complex

Challenges and Innovations in Tunnelling
Challenges and Innovations in Tunnelling

Running tunnel
Running tunnel

Challenges and Innovations in Tunnelling
Running tunnel
Innovations in Tunnelling

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Challenges and Innovations in Tunnelling
Station Construction Challenges

• Large Span ~18 m
• Low Overburden ~10 m
• Significant Potential for impact on buildings
• Obstructions: rock dowels & tie backs
• Mixed Ground Conditions
Utilities
Low rock cover
Rock bolts and tie backs
Adjacent buildings

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Challenges and Innovations in Tunnelling
Key Design Issue

Potential Load transfer onto the buildings
Solution – Tension Ties
Confirmation – FE Analysis

Tension ties / No ties

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Sequencing
LYON Station

PARLIAMENT Station

Excavation stages

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Building assessment

LYON Station

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Challenges and Innovations in Tunnelling
Building assessment

PARLIAMENT Station

CBC BUILDING

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Challenges and Innovations in Tunnelling