Building Ireland’s Longest Tunnel

Geotechnical Seminar 23rd April 2015

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Senior Civil Engineer (Shell)
Paul Kieran….Personal and Career Overview

09 March 2016
The Corrib Gas Field is located approximately 83km off the west coast of Ireland. It was originally discovered by Enterprise Energy in 1996, which was bought by Shell in 2002. Shell E&P Ireland Limited will operate the field on behalf of its other Partners, Statoil and Vermilion.

The field is one of only three gas fields discovered in Ireland and is classed as a medium-sized gas field, estimated to yield approximately one trillion cubic feet of natural gas over an operating life of fifteen to twenty years. This will provide 60% of Ireland’s natural gas needs (at peak production).

The Corrib Project is made up of the following elements:

1) Offshore operations (incl the wellheads).
2) Offshore pipeline
3) Onshore pipeline.
4) Gas processing plant at BBGT, Co. Mayo.
Sruwaddacon Bay, Co. Mayo

- 4.2mOD, 4.9km long tunnel extending from Aughoose to Glengad.
- Contract awarded to BAM Wayss & Freytag JV in Feb 2011.
- Constructed using Segmental Lining Method.
- Cover to crown of tunnel varies from 5.5m to 12m.
- Ground Investigation and Geophysical Information was utilised in selection of the alignment.
PHASE 1: TUNNELLING PREPARATIONS
Ground Investigation Works

- GI Works conducted in 2010 by IDL with the aim of supplementing available geophysical data.

- Executed scope consisted of:
  A) 26 no. cable percussive boreholes
  B) 31 no. rotary core boreholes
  C) 61 no. CPT’s
  D) Laboratory and in-situ testing

- Works were facilitated in the inter-tidal Sruwaddacon Bay by 2 no. jackup platforms.

- This tunnel is located in both rock and overburden:
  - 73% Overburden
  - 6% Rock / Overburden
  - 21% Rock
The geotechnical data gathered was used within the following elements prepared by BAM W&F Designers:

- Alignment
- Separation & Filter Press Design
- Plant TBM Design (incl. cutter head and jaw crusher)
- Face Stability
- Segment Design
- Surface Settlement Analysis
- Preliminary scheduling (design progress rates based on extent of rock / overburden)

Design information reviewed by SEPIL and consultants [De La Motte, AGEC, RPS (as PSDP)].
AUGHOOSE TUNNELLING COMPOUND

Start Shaft & Ramp Area
Mortar Silos
Filter Press
Tunnel Arisings
Surface Water Treatment Plant
Separation Plant
Generator Bank

09 March 2016
Tunnel Start Compound (Aughoose) Preparations...As Built
75,000m³ of peat removed from the Aughoose compound

09 March 2016
### Tunnel Start Compound (Aughoose) Preparations

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet Piles No.</td>
<td>7805</td>
<td>MHs No.</td>
</tr>
<tr>
<td>Kelly Blocks No.</td>
<td>686</td>
<td>Klargesters Interceptors No.</td>
</tr>
<tr>
<td>Pavement</td>
<td>3608m³</td>
<td>Foul Tank No.</td>
</tr>
<tr>
<td>Acoustic Barrier</td>
<td>3013m²</td>
<td>Kerbs</td>
</tr>
<tr>
<td>Acoustic Posts No.</td>
<td>246</td>
<td>Pond Liners</td>
</tr>
<tr>
<td>Freestanding Acoustic Posts No.</td>
<td>36</td>
<td>Heavy Duty Channel</td>
</tr>
<tr>
<td>Aco Drains</td>
<td>1597m</td>
<td>Palisade Fence around monitoring stations</td>
</tr>
<tr>
<td>Service Culvert</td>
<td>300m</td>
<td>Precast Wall Segments No.</td>
</tr>
<tr>
<td>Lighting Posts No.</td>
<td>35</td>
<td>Precast Pond Segments</td>
</tr>
<tr>
<td>Ducts</td>
<td>6140m</td>
<td>V Drain</td>
</tr>
<tr>
<td>Pipes</td>
<td>430m</td>
<td>Concrete Bases</td>
</tr>
<tr>
<td>SW Pipe</td>
<td>850m</td>
<td>RC Walls</td>
</tr>
<tr>
<td>150mm Watermain</td>
<td>675m</td>
<td>RC Slabs</td>
</tr>
<tr>
<td>HDPE Pipework</td>
<td>615m</td>
<td></td>
</tr>
</tbody>
</table>
June 2012 - Separation Plant and BAM site offices
Start Shaft Design & Construction

A Start Shaft and ramp (95m long, 9m wide and 12m deep) required to facilitate TBM installation and the commencement of tunnelling works.
TBM & Associated Trailers

Trailers 7-14

Trailers 1-7
Tunnel Segment Manufacture

- 25,950 segments were manufactured by Shay Murtagh’s (Co Westmeath).

- 6 segments used to form one ring of the tunnel.

- Segment moulds were manufactured in Herrenknecht, Germany.

- Shay Murtagh have since supplied tunnel segments to CrossRail Project in London.
TBM Delivery

- https://www.youtube.com/watch?v=JT3Q1EJwuRI#t=13
- _FIONNUALA' and the Corrib tunnel.mov

From 1min 45 to 5min
TBM Delivery – 3km from site...
Ready for the off...(Jan 2013)
PHASE 2: TUNNEL OPERATIONS
Tunnel Entrance—View Trailer No. 14—TBM at 140m

Tunnel Worker
TBM Bentonite Slurry Operations

Separation Plant

I : MAB 400
II : MAB 500
III : 4 x slurry circuit tanks
IV : belt conveyor system
V : 2 x filterpresses approx. 4-6 tTS/h, flocculation plant, pH-Neutralization

Feeding Pumps

P1.1 on surface
P1.2 in tunnel
P1.3 in tunnel

Discharge Pumps

P 2.1 on TBM back-up
P 2.2 in tunnel
P 2.3 in tunnel
P 2.4 in tunnel
P 2.5 in tunnel
The First Arisings (Jan 2013)

Below 4 mm

Above 4 mm and up to 75 mm

Three distinct streams of material were generated as the tunnel advanced:
(1) sand (2) gravel and (3) filter cake (clay/silt)
Inside TBM cutter head
Entry into the excavation (for cutting tool exchange and face inspection) only feasible under compressed air (up to 2 bar).

Each intervention was designed to ensure face stability balancing earth and water pressures.
Cutting discs – before and after
Ongoing Geotechnical Review during Tunnel Advance
The tunnel material was systematically inspected, raked and metal detected for traces of human, animal, plant and other organic remains. It is then photographed, surveyed and recorded.

All samples are stored onsite in Aughoose and appropriate sample were sent for specialist environmental analysis, eg. C14 Dating, ID and pollen analysis.
Due to the wetland environment, any organic material encountered was well preserved.

Archaeological investigation has revealed wood, hazel nut shells, pine cones and a single animal bone.

C14 dating of recovered organics has identified material up to 8000 yrs old.
Tunnel Entrance & Associated Services Installed Daily

1. 1 kV
2. 20 kV
3. Bentonite F&R lines
4. Compressed air lines
5. Fire Water lines
Logistics: Keeping Fionnuala on the move every day

- 8 no. crew (2 No. 12 hour shifts)
- Food, tea/coffee (toilet waste out)
- 140m$^3$ of bentonite in, and 180m$^3$ of bentonite and spoil out
- Segments (60 No. daily average)
- Ventilation duct (every 100m)
- Water hoses (2 No. 250mm dia. 3 No. 100mm dia. every 6m)
- Electrical cable (1 kV and 20 kV every 100m)
- Waste water out
- Grease (lube for tail skin and bearings 1000 litres daily)
- Rail track (every 6m)
- External grouting (2.4m$^3$ every 1.2m of tunnel)
Segment Delivery and Installation

- Segments are carried to the front of the machine using a conveyor system.
- 6 segments are used to form one complete ring.
- The TBM is propelled forward using rams that push against the last constructed ring.
Advance Rates Along Tunnel Drive

<table>
<thead>
<tr>
<th>ROCK</th>
<th>OVERBURDEN</th>
<th>ROCK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand/Silts</td>
<td>Glacial</td>
<td>Sands</td>
</tr>
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</table>

- **Advance Rate (mm/min)**

Chainage chart: Average Value from 0.0 to 4898.68 (m)

- **Advance Speed [mm/min]**

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During tunnelling the following logistical back up was provided by RBL

<table>
<thead>
<tr>
<th>Material</th>
<th>Total (Tonnes)</th>
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<tbody>
<tr>
<td>Tunnel Arising By-product</td>
<td>110,706 Tonnes</td>
</tr>
<tr>
<td>Tunnel Arisings Waste Filter cake/Grout</td>
<td>50,514 Tonnes</td>
</tr>
<tr>
<td>Tunnelling Waste Water</td>
<td>93,318 m³</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tunnel Segments</th>
<th>Truck Loads</th>
</tr>
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<tr>
<td>23,640 segments</td>
<td>1,329 loads</td>
</tr>
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In total 49,733 truck movements to and from Aughoose all within the confines of the Traffic Management Plan
Tunnelling – A life underground [VIDEO]

The Breakthrough Team
PHASE 3: TUNNEL FIT OUT & GROUTING
- 5 Km. Gas Main
- 10 Km. Waste Water
- 20 Km. Umbilical's
- 20 Km. FO Cables
- 10 Km. Signal Cables
- 18 Km. Back Grout Pipes
- 45 Km. Pipework
- 30 Km. Cables
Pipe String loading onto Rolling Stock – 9 Man Operation
Rolling Stock about to leave Aughoose – Safety Checks

Pipe anchor both ends
Services in Tunnel
Tunnel Back Grouting – Site Setup
~ 43,000m³ Grout
Low Strength, Cement Bentonite Mix

Pumped at 80m³/hour

Logistics Challenge
Water 1800m³ / day
Cement 270 t / day
Bentonite 90 t / day
Scale Testing of Grout Flow
Grouting - in Tunnel Monitoring

Camera Overview 16 CCTV feeds

Grout Filling Stage 1 – 0m

Grout Filling Stage 2 – 2.5m

Grout Filling Stage 3 – 2.8m
Grout works complete and shafts backfilled

Glengad (grouted tunnel)
Aughoose Tunnel Compound - Reinstatement Progress
Start Shaft Area

Arisings Storage / Separation Plant
Site Reinstatement….making good and keeping promises

Aug 2015

Nov 2015
Thank you and Questions?