Presentation to Engineers Ireland - Geotech Society

The Foundation Piling Aspects of the Dublin Waste to Energy Project

4th November 2015: Paul Coghlan – PM Group
Mark McKeown – FK Lowry Piling
Contents

• Introduction
• Project overview (Paul Coghlan)
  – The Dublin Waste-to-Energy (DWT E) Facility
  – The DWT E Facility Project team
  – DWT E Timeline

• FK Lowry Piling (Mark McKeown)
  – Chronology
  – Geology, Ground Conditions, Soil Parameters
  – Preliminary Testing, Pile Design & Review
  – Challenges & Solutions
Introduction DWTtE Facility

- Thermal Treatment Plant to treat municipal waste
- 600,000te waste p/a
- ~60 MW electrical output (80,000 homes)
- ~96MW heat for future District Heating (50,000 homes)
- PPP between DCC and Covanta ~ €400m Project
- Planning Permission received in 2007
- PM Group became involved on the project with Covanta in late 2013
Site Location
Site Location
Massing Comparison

1. 194m
2. 118m
3. 59m

59m

52m
Massing Comparison

48m 52m

FK Lowry Piling
<table>
<thead>
<tr>
<th></th>
<th>Technical Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Waste Reception Hall</td>
</tr>
<tr>
<td>2</td>
<td>Waste Bunker</td>
</tr>
<tr>
<td>3</td>
<td>Bottom Ash Collection</td>
</tr>
<tr>
<td>4</td>
<td>Boiler</td>
</tr>
<tr>
<td>5</td>
<td>Steam Turbine and Electricity Generator</td>
</tr>
<tr>
<td>6</td>
<td>Fly Ash Collection</td>
</tr>
<tr>
<td>7</td>
<td>Stack</td>
</tr>
</tbody>
</table>
The DWtE Facility Project Team

EPCM Contract – Civil Works

Site Establishment

Piling Works

Concrete Works

Slip forming Works

Structural Steelwork

Upper Floors

Roofing & Cladding

Hitachi Zosen INOVA

EPC Contract - Process Systems

Boiler/Grate, APC, Stack, TG, Cranes

BOP Equipment

Start-Up & Commissioning

Performance Testing & Guarantees
Project timeline

- Notice to Proceed: 19 Sept 2014
- Construction Start: 22 Sept 2014
- First Handover to HZL: 23 June 2015
- Handover Substation to ESB: 13 November 2015
- Power On: 4 July 2016
- Civil Works (PM Group Scope): Complete 31 December 2016
- First Waste Fire: Mid January 2017
- Plant Operational: 19 June 2017
View from Sandymount- After Construction
View from North of Liffey – Before Construction
View from North of Liffey - After Construction
Site Progress – November 2014
Site Progress – March 2015
Site Progress – October 2015
Piling Aspects, Mark McKeown - FK Lowry Piling
Foundation Piling - Chronology

- 1999: Feasibility & Scheme Design commenced
- 2010: FKLP secured Piling Scheme & Enabling Works Commenced
- 2010: Pile Design carried out by Byrne Looby Partners (BLP) to BS:8110 (to a Jacobs Piling Specification)
- 2010: Preliminary Pile Testing took place using Continuous Flight Auger & Bored Displacement Piling
- 2010: Pile Design appraised and verified
• 17th Century: Land reclamation commenced
• 1715: Dublin City Assembly authorised the building of an embankment from Ringsend, into what would be known as the South Bull Wall.
• 18th Century: Land reclamation continued on the peninsula.
• 1948: Irishtown Tip Head opened and remained so until 1978 when it was “Capped”
• The overburden Made Ground consisting of Municipal Waste and general Construction & Demolition Waste.
2010 Pile Design

- Pile Design based upon;
- Geotechnical & Environmental Services (GES) Factual Report – March 2009
- Earlier Site specific investigations carried out in 2003 & 2005.
- The Soil Profile and parameters chosen were as follows:

<table>
<thead>
<tr>
<th>Strata</th>
<th>Level (mAOD)</th>
<th>Bulk Density (kN/m³)</th>
<th>Friction Angle</th>
<th>Cu (kPa)</th>
<th>Stiffness – Drained E (Mpa)</th>
<th>Stiffness – Undrained E (Mpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Made Ground/Loose Sand</td>
<td>GL to -1</td>
<td>18</td>
<td>30</td>
<td>-</td>
<td>-</td>
<td>35</td>
</tr>
<tr>
<td>MD-Dense. Sand/Gravel</td>
<td>-1 to -15.25</td>
<td>19</td>
<td>33 to 35</td>
<td>-</td>
<td>-</td>
<td>75</td>
</tr>
<tr>
<td>Glacio Marine Clays</td>
<td>-15.25 to &gt;20</td>
<td>20</td>
<td>-</td>
<td>105</td>
<td>33 to 53</td>
<td>50 to 80</td>
</tr>
</tbody>
</table>
Pile Design Criteria:

- 60 Year Design Life
- Allowance for additional Negative Skin Friction (NSF) of 100kN per Pile
- Settlement Criteria:
  - @ DVL = 10mm
  - @ DVL+50% (SWL) = 20mm
- Design Factor of Safety (FOS) of 2
- Design to be based upon piles founded in a competent Sand & Gravel Layer
**Geology & Soil Parameters**

- Made Ground/Fill/Loose Sands
- MD-D. Sand & Gravels
- Glacio Marine Clays
- Existing Site Levels: +4.5m AOD
- Ground Water Level: +0.5m AOD
- Approx. Site Dimensions: 340m x 160m

<table>
<thead>
<tr>
<th>Strata</th>
<th>Level (mAOD)</th>
<th>Bulk Density (kN/m³)</th>
<th>Friction Angle</th>
<th>Cu (kPa)</th>
<th>Stiffness – Drained E (Mpa)</th>
<th>Stiffness – Undrained E (Mpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Made Ground/Loose Sand</td>
<td>GL to -1</td>
<td>18</td>
<td>30</td>
<td>-</td>
<td>-</td>
<td>35</td>
</tr>
<tr>
<td>MD-Dense. Sand/Gravel</td>
<td>-1 to -15.25</td>
<td>19</td>
<td>33 to 35</td>
<td>-</td>
<td>-</td>
<td>75</td>
</tr>
<tr>
<td>Glacio Marine Clays</td>
<td>-15.25 to -20</td>
<td>20</td>
<td>-</td>
<td>105</td>
<td>33 to 53</td>
<td>50 to 80</td>
</tr>
</tbody>
</table>

Site Location – Covanta, Pigeon House Rd. Dublin
2010 Preliminary Pile Testing

- Test Piles installed using Continuous Flight Auger (CFA) & Bored Displacement (BDP) methods
- 13 No. Test Piles installed to design depth within MD-D Sands & Gravels to -14.0m AOD
- Pile Testing undertaken by Lloyd Acoustics.
- Correlation of Dynamic Testing Results to PTP Results
- Below is a Table summarising the No. & Type of Test

<table>
<thead>
<tr>
<th>Pile Type</th>
<th>Compression Test (DVL + 100% SWL)</th>
<th>Lateral Load Tests (150% SWL)</th>
<th>Tension Load Test (DVL+100%SWL) (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.of Tests</td>
<td>SWL (kN)</td>
<td>DVL (kN)</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>1000</td>
<td>1200</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>750</td>
<td>950</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>500</td>
<td>700</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>2150</td>
<td>2350</td>
</tr>
</tbody>
</table>
2010 Preliminary Pile Testing

- 600mm (SWL: 2350kN) complied with performance criteria & Pile Length of 18.75m (-14.25m AOD) adopted
- 450mm (SWL: 1200kN) complied with performance criteria: Pile Length of 17m (-12.5m AOD) adopted
- Recorded settlements < than piling specification

<table>
<thead>
<tr>
<th>Pile Type</th>
<th>Compression Test (DVL + 100% SWL)</th>
<th>Lateral Load Tests (150% SWL)</th>
<th>Tension Load Test (DVL+100%SWL) (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Tests</td>
<td>SWL (kN)</td>
<td>DVL (kN)</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>1000</td>
<td>1200</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>750</td>
<td>950</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>500</td>
<td>700</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>2150</td>
<td>2350</td>
</tr>
</tbody>
</table>

FK Lowry Piling
2010 Pile Design

- Back analysis carried out to determine stiffness of material at pile toe and to estimate proportion of load taken by shaft and base of pile
- Predicated ultimate capacities and FOS calculated using:
  - (Fleming 1992) “Best Fit” pile settlement analysis by inputting:
  - Revised material stiffness
  - Pile Test Settlements
  - Pile Test Loads
- Finally, a Schedule of Pile Diameters, Depths & Working Loads produced

<table>
<thead>
<tr>
<th>Pile Type</th>
<th>CFA Diameter (mm)</th>
<th>Minimum Pile Toe (mAOD)</th>
<th>SWL (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>600</td>
<td>-14</td>
<td>1600</td>
</tr>
<tr>
<td>6a</td>
<td>600</td>
<td>-14</td>
<td>1600</td>
</tr>
<tr>
<td>6b</td>
<td>600</td>
<td>-14</td>
<td>1600</td>
</tr>
<tr>
<td>7</td>
<td>450</td>
<td>-14</td>
<td>1100</td>
</tr>
<tr>
<td>8</td>
<td>300</td>
<td>-12.25</td>
<td>500</td>
</tr>
</tbody>
</table>
2010-14: Scheme placed on hold

Jul.’14: Engaged by PM Group to revisit our initial Pile Design

Due to the introduction of Eurocode EC7, BLP re-assessed the previous design.

Applied Ground Engineering Consultants (AGEC) engaged by PM Group to undertake a Geotechnical Review of the BLP Pile Design.

Sept. ‘14: Dublin City Council and Covanta signed off on a Project Agreement to re-commence works on the project
• BLP Pile Design based upon:

• Geotechnical & Environmental Services (GES) Factual Report – March 2009

• Earlier Site specific investigations carried out in 2003 & 2005.

• However, following AGEC review of Pile Design, SI and new Site Investigation information, the information suggested that the top of Glacio Marine Clay was higher than initially thought (-15.3 mAOD)
2014 Review of Pile Design to Eurocode EC7
2014 Review of Pile Design to Eurocode EC7

- Together with the existing and the New Information, allowed us to identify deeper deposits of Made Ground & its interface with the granular deposits
- Plot and Contour these strata
• We were also able to plot and contour the top of the Glacio Marine Clay.

• Following review of the new information, in conjunction with the existing data from 2010, suggested that, in certain areas, the top of Glacio Marine Clay was higher than initially thought (-15.3 mAOD)

• Particularly in the “Reception Hall” & “Flue Gas Technology Area” to the South & North respectively.
2014 Review of Pile Design to Eurocode EC7

- AGEC & BLP identified the risk of “punching” through to weaker underlying cohesive material
- Potential risk of excessive deflections under working loads.
- Pile Design reviewed
- Pile Toe Levels subsequently raised to -11m AOD
- Preliminary Testing carried out in late 2014
- Test data then back analysed to determine stiffness of material at -11m AOD.
Lead-in Time/Procurement

- Running concurrently with this Design Review & the Assessment was the finalising & detailing;
- Pile Layout Drawings
- Loading Schedules
- Reinforcement Schedules
- H&S Method Statements
- Risk Assessments
- Work Procedures
- Procurement of Supply Chain
- Quality Assurance measures
- Site Probing in the Made Ground
Challenges & Solutions

- **Obstructions** in the Fill/Made Ground –
- Had we the correct Piling Technique & Piling Equipment

- **Lead-In Time/Procurement** - In light of the EC7 Design Review, Procuring our Supply Chain, Sourcing of correct Plant.
- Could we deliver and meet the Clients expectations in terms of start dates and “Milestones”? 

- **New Ground Investigation information**
- What were the implications on the Design, Programme & Costs

- **Project H&S Ethos**
- Could we roll this out to ALL staff and ensure their “Buy-In”.
To mitigate the risk of the Made Ground, a series of Trial Pits took place to verify & determine:

- The depths of Fill deposits
- The composition/make-up of the Fill
- The pile type required in order to overcome and penetrate through the Fill and into the underlying bearing strata
Challenges & Solutions: Obstructions

Typical examples of Obstructions within the Made Ground – Nov.’14
Challenges & Solutions: Obstructions

Typical examples of Obstructions within the Made Ground – Nov.’14
Rotary Bored Piling (ROT) was considered due to being able to provide:

- A range of Pile Diameters

- High Torque Piling Rigs readily available

- A depth capability of up to 35-45m

- Utilize Rock Augers & Core Barrels to penetrate through Obstructions in the Made Ground

- Temporary segmental casing to “Case Off” the Made Ground and underlying Dense Gravels

Risk: Labour & Plant Intensive – Costly!
Not meeting Clients Programme – Slower than other available techniques
Driven Precast Piling (DPC) was considered due to being able to provide:

- A range of Pile Sections: 250mm, 270mm, 350mm Sq.
- Use of 5t accelerated hammers
- High production capability
- Immediate follow-on works
- Displacement Method – No Spoil
- Conducive to Brownfield Sites

Risk:
Limited in terms of moment & tension capacity - Design
Potential of Breaking Piles within the Made Ground - Cost
Bored Displacement Piling (BDP) was considered due to being able to provide:

- A nominal 450mm Pile

- High Torque Piling Rigs readily available within our fleet, capable of “Crowding” in an oversized enlarged head tool

- Up to < 80 % less Pile Spoil than conventional CFA

- On Brownfield Sites, this could provide significant Client Savings

- Quiet, Vibration Free technique

Risk: Early refusal in Made Ground – Not achieving Design Depth
Limited in terms of Diameter and Working Load
CFA was considered due to being able to provide:

• Available diameters; 300mm, 450mm, 600mm, 750mm, 900mm

Piles

• High Torque, Soilmec SR-75 Piling
Rigs readily available

• Proven ability of achieving design depth

• Suitable for soft/loose strata with high water table

• Rig availability
The High Torque Soilmec SR-75 was chosen due to:

- Efficiency of mobilisation – Self erecting
- Dual discipline capability – CFA, BDP & ROT
- < 300kNm Torque and our ability to mitigate the Risk of refusals and to overcome obstructions
- Max. CFA Diameter – 1200mm
- Max. CFA Depth – 29m

Soilmec SR-75 Piling Rig in CFA Mode
Challenges & Solutions: Obstructions

• The Correct Choice of Piling Technique and the appropriate Piling Plant & Equipment - mitigated the risk of refusal

• The extent of the obstructions is clear in the following images
Challenges & Solutions: Obstructions

- Reinforcement
- C&D Fill
Occasionally, refusals were encountered, as-built survey information provided by FKLP – Replacement positions sought

This assisted PM Group in designing/detailing of Pile Caps to cater for any of the out of tolerance Piles.
Challenges & Solutions: Lead-In Time/Procurement & Delivery

- PM Group used a global document management system (A-Site)
- Design Information provided in “real time” from Polish & Dublin Design Offices
- Construction information issued, registered, materials ordered and delivered almost instantaneously
- Lead-In times for materials are typically 2-3 days
- Hence, from design information being released to final pile installation, lead-in has been “fast-tracked” to just 24 Hours.
- Approach highlights the strategic management, planning, coordination of the Design Team, Supply Chain and Operations Teams on site
Challenges & Solutions: Lead-In Time/Procurement & Delivery

- Key driver to successful delivery;
- The use of locals suppliers e.g.
- Concrete Supplier – 300m from Site at Ringsend - < 350m³/Shift
- Reinforcement Supplier – Co. Kildare Based – Occasional 24Hrs/Day < 100 Cages/Day
- Materials Testing – Dublin
- Hire of ancillary plant & equipment - Dublin
- Completed ahead of Programme & to Budget!
The availability of the additional Site Investigation information was highlighted by AGEC during their extensive review of the 2010 and 2014 Pile Designs.

Geological Survey of Ireland (GSI) – Excellent resource for Geological Information.

The result of this new information created the possibility of a more thorough and comprehensive design.

Resulted in savings to the Client in terms of Costs and Programme.
Challenges & Solutions: New Ground Investigation Information

- Based upon circa. 4,100 No. Piles
- Revised -11m OD Pile Toe Level reduced overall linear meterage by circa 12,300 m.
- Resulting in client savings of circa. €720K (20% of Project Value) and reduction in programme of up to 60 Rig Shifts
- Adopting the review of the SI and the revised Design, significant savings in terms of Cost & Programme
In Feb. ‘15 the Federation of Piling Specialists conducted their 3 yearly Industry Audit.

WtE Project was selected for the Project element of the Audit.

“A good overall performance especially with regard to Health and Safety”

FPS Audit Report – Feb.’15

Ground Engineering Awards 2015 – Finalist!
Project Figures

30,000m De-Bonding Foam

3 No. Piling Rigs

12,000 Linear Meters of Savings

12,000+ Safe Man Hrs Worked

1000 t of Reinforcement

65,000 Linear M of CFA Pile

18,000 m³ of Concrete

4,100 No. Piles

Circa €720,000 Savings to Client

FK Lowry Piling
“From the outset, FK Lowry's Piling commitment to the project was excellent”

“Their commitment to serving the challenging requirements of the project has been exceptional”

“Their adoption of our Health & Safety programme was embraced throughout the contract and we are thankful for their collaborative partnering approach on the Covanta project”

Diarmaid O’Sullivan – Construction Manager, PM Group, Dublin
Thank you for your attention

Mark McKeown – FK Lowry Piling
&
Paul Coghlan – PM Group