Appendix 4-4

Foundations Construction Methodology

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ESB Wind Development Ltd and Bord na Móna Powergen Ltd

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Contents

1 Introduction

The following document presents the construction methodology for the main foundations for the proposed solar farm at Timahoe North, Co. Kildare.

The proposed development site is located in north County Kildare, approximately 6.5 km (kilometres) north of the village of Allenwood, 6 km east of Carbury and 3 km south of Johnstownbridge. The site is accessed from the south via the Derrymahon-Drehid local road L1019, which adjoins the R402 Regional Road to the west of the site.

The proposed development comprises an application for planning permission for the development of a large scale solar PV farm with a capacity of approximately 70 Megawatts (MW). It will consist of a solar photovoltaic array and associated infrastructure, inverters, access roads and parking, site compounds and security fencing, amenity trails and landscaping, peat and spoil storage areas, site drainage and all associated works. The proposed development will also include the construction of a 110 kV substation within the site with a 20 MW battery storage compound adjacent this. It is then envisaged to connect from this substation to the Derryiron-Maynooth 110 kV overhead line that traverses the southern section of the Timahoe North site.

The report provides a construction methodology for the likely foundation solutions suitable for the project and describes how these foundations shall be constructed.

2 Site Investigation

2.1 General

Preliminary site investigations have been carried out at the site. The purpose of the site investigations was to broadly determine the ground conditions across the site. This information was then used to identify the most likely foundation solution for the structures on the site including roads, substation, solar panel frames and ancillary structures which are minor in extent. The information that will be acquired from a detailed site investigation will identify specifically what foundation solutions could and will be employed across the site.

This document covers the approach and high level work methodology which would be adopted for various foundation solutions.

The preliminary Site Investigation data for the project is contained as part of the planning submission.

2.2 Scope of Works

The preliminary site investigation consisted of 25 No. shell and auger boreholes, 96 No. trial pits and extensive peat probing across the site.

The shell and auger boreholes provide valuable information on the upper subsoil strata such as soil strength and permeability. Shell and auger boreholes were carried out to between 5.2 m below ground level (bgl) and 12.6 m bgl.

The trial pits allow a visual inspection of the ground across the site to determine the depth of peat and the nature of the upper mineral soil, if encountered.

Peat probing provides the depth of peat at the location of the peat probe.

2.3 Ground Conditions

Ground conditions at the site generally consists of peat over glacial deposits interbedded with glacio-fluvial deposits over possible bedrock.

The peat across the site has been harvested resulting in residual peat depth varying between 0.1 m bgl and 4.7 m bgl.

The glacial deposits generally consist of soft to very stiff grey gravelly clay/silt. These deposits are interbedded with gravels and sands within the stratum. These are generally over consolidated strata. The consistency of these strata typically tends to improve with depth.

The following Table 1 briefly summaries the ground conditions at the site based on the shell and auger boreholes:

Stratum	Depth to top (m bgl)	Thickness (m)
Peat	0.0	0.7 – 4.7
Glacial Till (grey clay/silt sands and gravels)	0.7 – 4.7	3.0 – 10.5
Possible Bedrock	5.2 – 12.6	-

Table 1 – Summary of Ground Conditions

Ground water was observed in most trial pits and boreholes. In the permeable materials, water ingress was rapid however water ingress is generally described as slow.

3 Foundation Design

3.1 General

The following section discusses the foundation options for the substation and solar panel frames.

3.2 Solar Farm Infrastructure

3.2.1 Solar Panel Frames

The function of the solar panel frame foundation is to transfer all the actions, i.e. vertical and horizontal forces and moments generated by the frame, to the ground. The frame will be designed to transfer all the actions from the solar panels and the frame itself to a foundation through the frame legs.

Based on the site investigation it is anticipated that in the main foundation solutions for the solar panel frames will consist of piled foundations.

A cross section through a typical solar panel frame is presented in drawing QS-000218-01-D453.

3.2.2 Inverters

It is planned that the construction of standalone inverters will form part of the development. Depending on the ground conditions encountered at the final positioning of the inverter, access requirements and loadings, different piling techniques may be adopted to support the inverters.

These will consist of either driven, bored or self-drilled piles broadly in line with those various types outlined below.

3.3 Grid Connection Infrastructure

3.3.1 Substation

The substation foundation actions are usually considered to be relatively low in magnitude. Generally shallow pads/rafts/strip footings are employed in areas where shallow ground conditions provide reasonable resistances.

Based on the site investigation it is anticipated that piled foundations will be employed in the area of the substation. However there is a possibility that shallow foundations may be employed in areas of the substation where the detailed site investigation reveals suitable bearing strata at shallow depth.

3.3.2 Overhead Lines (OHL)

It is planned that the construction of OHLs will form part of the development. Depending on the ground conditions encountered at the final positioning of the OHL mast and pole set loadings, different piling techniques may be adopted to support the masts.

These will consist of either driven, bored or self-drilled piles broadly in line with those various types outlined below.

3.4 Foundation Selection

The final foundation scheme selection for the component of the development will be based on the ground conditions and site and environmental considerations. It is likely that different foundation solutions will be employed in different areas across the site in particular for the solar panels.

Given the depth of peat across the site it is likely that most, if not all, of the solar panel frames will be supported on piles. Similarly it is likely that foundations in the substation and inverters will be piled. The OHL support structures are also likely to be piled in areas.

The piling options have been categorised into four, namely:

a) Large bored piles – those constructed by boring methods (e.g. Continuous Flight Auger (CFA) or rotary bored) and with concrete and reinforcement steel

b) Large driven piles – those constructed by driving methods (e.g. impact hammer or vibratory hammer) and with precast concrete or preformed steel sections

c) Self-drilled mini-piles – those constructed by boring methods (e.g. heli piles or other screw type piles) and with preformed steel sections

d) Driven mini-piles – those constructed by driving methods and with preform steel sections

While the peat is unlikely to provide sufficient resistance to support the solar panels, in areas it may be suitable to place the panels on lightweight floating foundations and anchor these foundations by means of cable anchors to the underlying subsoils.

The piles supporting the foundation bases will be required to support the compression, tension and horizontal loads from the various structures.

3.5 Large bored pile options

Various pile options have been considered for the substation site. Given the likely magnitude of the loads that will be transferred to the piles, mini piles are unlikely to be suitable for the substation.

Large reinforced concrete piles may be selected to support the loads. These types of piles can be constructed in a number of ways such as; bored Continuous Flight Auger (CFA), bored displacement, rotary or Odex piles. Large bored piles employed on the substation site are likely to be in the order of 450-900 mm in diameter.

The following sections outline the advantages and disadvantages for the various piling options considered with respect to this site. It may result that a combination of the options below may be required at the site given the irregular nature of the subsoil and thicknesses in the area of the substation.

3.5.1 Continuous Flight Auger (CFA) Piles

CFA piles have been considered for this project. CFA piles are the fastest large bored pile technique in terms of actual construction time. CFA piles are likely to refuse on top or marginally into the bedrock which will be unsuitable where deep embedment into the rock would be required. This technique will however be suitable for other situations i.e. embedment into deep stiff/dense subsoils.

CFA piling is a relatively quiet low vibration piling technique however, this does require a supply of wet mix concrete in order to construct the piles.

3.5.2 Bored Displacement Piles

Bored displacement piles have been considered for the proposed site, in particular for the piles that will be constructed onto rock or into the deep subsoil. However displacement piles are unlikely to penetrate the deep stiff subsoils and are likely to be unsuitable for construction on this project.

Bored displacement piling is a relatively quiet low vibration piling technique however this does require a supply of wet mix concrete in order to construct the piles.

3.5.3 Rotary Bored Piles

Rotary bored piles have also been considered for this project. The advantage of these piles is that the rig/auger will have the capability of being able to penetrate medium sized shallow boulders and the stiff/dense subsoils.

Where required by the design, rock sockets can be developed by using an alternative rock boring drill bit.

During drilling a temporary casing supports the pile hole until the reinforcement and concrete has been placed.

This pile option would be suitable for the piles where bearing into the rock is required or rock is very deep with the pile gaining resistance from the dense glacial tills at depth.

Rotary bored piling is a relatively quiet low vibration piling technique however this does require a supply of wet mix concrete in order to construct the piles.

3.5.4 Odex Piles

Odex piles are specifically used for the construction of piles into rock or very hard strata. This piling technique will be capable of penetrating the rock, where shallow, in order to develop the required loads as it uses an Odex drill bit.

The piles are constructed using a temporary casing which follows the Odex drill bit to the base of the hole. This supports the pile hole until the reinforcement and concrete has been placed.

While there is a risk of the Odex drilling being affected by the stiff clays, this can be overcome by using alternative methods to progress the pile hole to the top of the rock. From thence, the Odex drilling can progress the hole.

3.6 Large driven pile options

Large driven precast reinforced concrete piles or preformed steel piles may be selected to support the loads.

The following sections outline the advantages and disadvantages for the various piling options considered with respect to this site. It may result that a combination of the options below may be required at the site given the irregular nature of the subsoil and thicknesses in the area of the substation.

The detailed design of the piles will be the responsibility of the piling contractor.

3.6.1 Driven Precast Piles

Driven piles have been considered for the substation. Driven piles cause relatively large ground borne vibrations which could lead to nuisance noise issues, however this is unlikely to be an issue at this site given the distance to receptors. Driven piles are generally driven to a hard stratum like rock, very stiff clay or dense gravels. However they also can “refuse” at shallower depths than required if they encounter large boulders during driving.

An advantage of this piling option is the relative speed of which these piles can be constructed and that materials are installed “dry”. Furthermore there is no spoil generated from this piling technique. Typical driven pile sizes for such an application vary between 225 mm and 350 mm.

3.7 Self-Drilled Mini-piles

There are many different types of self-drilled mini piles available in the market currently. Self-drilled mini piles have been considered to support the solar panel frames. These piles would consist of screw piles, Heli piles or other similar pile types. Such piles would be installed to a required depth based on the site investigation and detailed design. Generally these piles are small diameter piles typically 50 mm – 150 mm. These piles are typically self-drilling piles (the drilling element forms part of or is the final pile installation) and are installed by means of drilling the piles with augers suitable for the pile type.

The advantages of these piles include the following:

- Piles can be installed with low pressure rigs and thereby reducing the requirement for temporary access to be constructed
- Installation is a relatively low noise and vibration technique
- Pile materials are typically “dry” (although some self-drilling piles may require some annulus grouting) consisting of performed steel sections

The disadvantages of these piles for this application are:

- Piles provide low lateral resistances due to their size which is particularly pertinent where the peat is deep
- Additional measures may be required to deal with the lateral loads from the support frames e.g. anchoring

3.8 Driven Mini-piles

There are many different types of driven mini piles in the market currently. Driven mini-piles have been considered to support the solar panel frames. These piles would consist of circular hollow steel sections (with or without concrete infill) or cold rolled preformed sections (typically in “top hat”, sigma, Z or C cross section). Such piles would be installed to a required depth based on the site investigation. Generally these piles are small diameter piles typically 50 mm – 150 mm. These piles are typically installed by means of driving the piles with hand held or machines operated hammer equipment suitable for each pile type.

The advantages of these piles include the following:

- Piles can be installed with low pressure rigs or by hand and thereby reducing the requirement for temporary access to be constructed
- Pile materials are typically dry (although circular steel piles require infilling with concrete/grout) consisting of performed steel sections

The disadvantages of these piles for this application are:

- Piles provide low lateral resistances due to their size which is particularly pertinent where the peat is deep
- Additional measures may be required to deal with the lateral loads from the support frames e.g. anchoring
- Some driving techniques can generate noise and vibrations

4 Construction Sequence

4.1 General

The following section provides the construction sequence for the four piling schemes:

- Bored large piles
- Driven large piles
- Self-drilled mini-piles
- Driven mini-piles

Conventional pad, strips and raft foundation construction is also presented below which may be constructed in areas where ground conditions are suitable.

4.2 Preliminaries

All construction works will be undertaken in accordance with the Erosion and Sediment Control Plan developed for the project. Drainage and sediment control works comprising settlement ponds and drainage channels will be established. Runoff and dewatering from any excavation works associated with foundation construction will be directed to the drainage control system through the settlement ponds.

All equipment will be provided with spill trays for vehicle refuelling purposes and crews will be provided with spill clean-up kits and trained in their use.

The following preliminaries are also required in order to facilitate the construction of the piles. These are generally provided by the main contractor.

- Water supply
- Suitable Access
- Firm level working piling platform
- Setting out points
- Removal of obstructions

For the large bored and driven piles a piling platform will be constructed to support the piling rig to allow safe installation of the piles.

It is not envisaged that permanent access or piling platforms will be provided for the installation of the mini-piles supporting the solar panel frames although temporary access/platforms may be installed as required.

4.3 Plant/Equipment – large piles

The exact plant/equipment for the pile construction will depend largely on the method employed for the works, i.e. different piling techniques as mentioned above will have different plant however in broad terms the following plant/equipment will be provided:

- Tracked piling rig – CFA, rotary, driven

- Drill augers/drill heads (Odex, Toothed Open Barrel for rock socket construction or similar)
- Excavator to remove any spoil developed during the pile construction
- Prefabricated reinforcement cages
- Precast concrete pile section
- Mobile cranage to support the installation of the pile material
- Concrete pump (for bored piles only)
- Compressor
- Stores Container
- Bunded Fuel Tank
- Site Cabins
- Concrete Delivery Trucks (for bored piles only)

4.4 Plant/Equipment – mini-piles

The exact plant/equipment for the pile construction will depend largely on the method employed for the works i.e. different piling techniques as mentioned above will have different plant however in broad terms the following plant/equipment will be provided:

- Low ground pressure tracked piling rig or hand held installation equipment
- Excavator/low ground pressure transportation vehicles for material(s)
- Prefabricated pile sections
- Compressor
- Stores Container
- Bunded Fuel Tank
- Site Cabins

4.5 Piling Platform

The construction sequence for large piles in the area of the substation will commence with the construction of a piling platform to the required pile cut-off level. The piling platform will consist of a compacted stone fill make-up which will be designed based on the rig size and ground conditions as determined during the detailed site investigation. It is proposed to excavate the peat to locate a suitable formation stratum for the piling platform. Based on the preliminary site investigation it is generally not envisaged that the ground water table will be encountered above a suitable formation level in this area. Where this is not the case and ground water ingress cannot be comfortably controlled by conventional pumping an alternative piling platform solution will be considered such as a floating platform.

Piling platforms for the mini piling works will be provided as required by means of temporary proprietary floating platforms/mats.

It may be the case that due to equipment type and functionality, piling of various areas across the site may be restricted to particular months of the year in order to maximise production and minimise the requirement to provide temporary access.

4.6 Conventional foundations bearing on ground

The first foundation option will consist of a conventional pad, strip or raft foundations supported directly on the exposed ground. This will be constructed as per any typical ground bearing foundation. Such foundations may be feasible in the area of the substation and other specific areas across the site where ground conditions facilitate such construction, although unlikely to be extensively adopted for this site.

Firstly the ground will be excavated to a suitable founding stratum. The detailed site investigation will confirm the depth to the suitable bearing stratum. Excavated material will be side cast to a specified depth in suitable locations or used for landscaping or disposed of in the on-site repositories. The suitability of the founding stratum will be confirmed by the site engineer. Where necessary, temporary pumps and sumps may be required to maintain a dry, clean formation. Pumped water will be directed to the settlement ponds prior to entering the drainage system.

A blinding layer of lean mix concrete shall then be placed on to the formation in order to protect it from degradation due to rain and to provide a firm clean level platform for the reinforcement to be tied for the base.

Cover spacers will be laid on the formation and the reinforcement will then be tied in accordance with the detailed design drawings and rebar schedules. The side shutters with cover spacers will then be erected.

The base will then be cast in the sequence stipulated by the structural design engineer.

When the concrete has been cured for the required period the base shutters will then be stripped and the excavation will be suitably backfilled with granular material to tie in with the required level. All necessary rising or superstructure elements shall be fixed to the foundation as required by the detailed design.

4.7 Base supported on large piles

This foundation option will include a base similar to a ground bearing pad (discussed in Section 4.6) supported on piles. Such foundations are most likely to be adopted in the area of the substation and/or for OHL masts at suitable locations across the site.

Firstly the surface layer of the ground will be stripped aside. Excavated material will be side cast to a specified depth in suitable locations or used for landscaping. A piling platform will be constructed above the groundwater level.

The function of the piles will be to transfer load to the deep stiffer subsoils and to facilitate the construction of the base.

The piles will be arranged in a designed layout beneath the base. While the final piling option will be determined on completion of the detailed site investigation the following outlines the methodology in the case that they will consist of CFA piles, rotary piles or driven piles.

CFA Option

The piling rig will then commence by setting up at the first pile location. Using the CFA method piles will be bored to the required depth using a continuous auger. There will be ongoing monitoring of the flighting and penetration rates in order to ensure that over flighting does not occur during the boring. Once the auger has reached the required pile depth, concrete will be pumped by means of a tremie pipe down the stem of the auger. The extraction rate of the pile will be such that the rate of concrete flow will fill the annulus of the pile hole left behind. This will be monitored to ensure that the bore will be protected from collapse.

When the pile hole has been filled with concrete to the required depth and the auger fully retracted the rig is moved back slightly from the hole and the rig is then used to crane a prefabricated rebar cage into the pile hole. The prefabricated cage is fitted with circular spacers to ensure that the required cover is provided to the rebar cage in the hole. Spoil is then removed and the rig sets up at the next pile location. Rebar will protrude beyond the pile cut off level to tie into the new base.

The next pile location will be a minimum of 3 pile diameters away from the previous to ensure that there is no interference between the 'wet' pile holes.

Rotary Pile Option

Using the rotary pile technique the hole is bored by means of a short auger which is trailed by a temporary casing. As the auger fills and penetrates the ground the casing trails the auger and maintains support to the pile hole. Once the auger is filled the auger is retracted and the soil material is removed. This sequence is repeated until the pile hole is bored to the required depth.

When the hole is bored to the required depth the prefabricated reinforcement cage is then installed with circular spacers in order to ensure the correct cover is provided to the rebar. Concrete is then pumped in to the hole and the spoil is removed from the area. Rebar will protrude beyond the pile cut off level to tie into the new base. The temporary casing is then removed.

The next pile location will be a minimum of 3 pile diameters away from the previous to ensure that there is no interference between the 'wet' pile holes.

Driven Piles

Using the driven piling option the piling rig is set up over the pile location. The precast pile section is then craned onto the rig normally by means of a rig mounted crane/pulley. The pile section is then positioned correctly of the pile location. The impact or pneumatic hammer proceeds to drive the pile to the required set/depth. If one pile segment length is insufficient to reach the target depth or set then further sections are mounted on top of the driven section(s) and jointed to the head of the previously driven section normally by means of sockets and pins.

Base construction

Once all the piling for base has been completed the piles are checked to ensure that their cut off level is coincident with the required base of the foundation. If this is not the case some pile head cutting may be required. When all piles are to the required level the area is lean-mixed and the foundation base rebar is tied and concrete is poured as described in section 4.6.

4.8 Mini-pile, self-drilled or driven

It is anticipated that the frames supporting the solar panels will be fixed directly to the heads of mini-piles. For some piles this may mean a direct fixing arrangement, for other piles the head may need to be modified or a proprietary head arrangements fixed to the head of the pile to allow the frames to be fixed.

The function of the piles will be to transfer load to the deep stiffer subsoils and to facilitate the construction of the base.

The piles will be arranged such that each leg of the supporting frame is directly supported. While the final piling option will be determined on completion of the detailed site investigation, the following outlines the methodology in the case that they will consist of driven or drilled mini-piles.

Driven Piles

Using the driven piling option the piling rig is set up over the pile location. The pile section is then lifted into the correct position on the ground and its verticality is ensured to be within allowable tolerances. The impact or pneumatic hammer proceeds to drive the pile to the required set/depth. If one pile segment length is insufficient to reach the target depth or set then further sections are mounted on top of the driven section(s) and jointed to the head of the previously driven section.

Self-Drilled Piles

Using the self-drilled piling option the piling rig is set up over the pile location. The drilling equipment proceeds to drill the pile to the required depth. If one pile segment length is insufficient to reach the target depth or set then further sections are mounted on top of the installed section(s) and jointed to the head of the previously drilled section.

4.9 Pile testing

Static and dynamic pile load testing will be carried out at the site prior to base pour/fixing of frames. Pile testing for piles supporting the solar panels will be carried out throughout the works. Static and dynamic testing will be carried out in accordance with IS EN 1997 in order to confirm the ultimate limit state and serviceability limit state of the piles. The number and location of static load tests will be determined on completion of the detailed site investigation and the findings therein.

All piles will be integrity tested.

During construction of the piles, drilling records will be maintained by the piling subcontractor. Drilling records will record information such as rate of penetration, difficulty/ease of drilling, depth etc. which will enable the operative of the rig achieve the required embedment and thus load capacity.

5 Environmental Controls

The following environmental controls will be put in place during foundation construction and piling operations:

- A Construction & Environmental Management Plan will be in place and implemented during the construction process.
- Prior to construction of the substation foundation the drainage and sediment control plan will be fully implemented with the required settlement pond and interceptor drains put in place.
- Excavated material will not be stockpiled within 10 m of any watercourse and will be side cast on permanently in the designated repositories to a specified depth in a controlled manner.
- All fuels and oils will be stored in bunded storage areas.
- Spill trays will be provided for vehicle refuelling purposes and spill clean-up kits and training in their use will be provided to construction crews
- Spoil from piling operations shall be placed upstream of a cut-off drain and settlement pond as part of the drainage control system. Alternatively this material will be placed in a designated repository.

6 Summary

The following briefly summaries the contents of this report:

- Site investigations have been carried out across the Timahoe North Solar Farm site in order to determine the likely foundation requirements for the proposed development.
- Foundation construction methods for the substation foundation are envisaged to consist of ground bearing foundation or piled foundation.
- Foundation construction methods to support the solar panel frame are envisaged to consist of driven mini-piles or self-drilled mini piles.
- A number of options have been considered for large piles to support the loads from the substation including CFA, Rotary Piles, Displacement Piles, Driven Pile and Odex Piles.
- A number of different piling options have been considered for the solar panel supporting frame including Heli piles, screw piles, driven circular piles, driven preformed cold rolled piles.
- The final foundation type selection for each area of the site will be dependent on the detailed site investigation results and the encountered ground conditions.
- A testing scheme for the piles will be developed based on the detailed site investigation.
- Environmental controls will be put in place prior to construction.