CLEANRATH WIND FARM

Formation Approval Report T1, T3, T4, T5, T8

N117-2400 IEC3a Foundations

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Document History

Doc Name	Rev	Details	Author	Checked	Approved
CNRH r027.3	A	Initial Issue	Cormac Ó Dubhthaigh	John Shanahan	Cormac Ó Dubhthaigh
CNRH r027.3	B	Turbine numbering revised	Niamh Moore	Cormac Ó Dubhthaigh	Cormac Ó Dubhthaigh

CNRH r027.3 Cleanrath N117-2400 IEC3a Formation Approval Report Rev B

Confidentiality

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Addressee

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CONTENTS

1. INTRODUCTION

Ionic Consulting was appointed by Mid Cork Electrical Ltd. to carry out formation approval for all wind turbine foundation bases at Cleanrath Wind Farm in Co. Cork. The wind farm comprises 15 no. Nordex turbines, including 6 no. N100 3.3MW 100mHH Class IEC1a turbines, 4 no. N117 91mHH 3.6MW Class IEC2a turbines and 5 no. N117 91mHH 2.4MW Class IEC3a turbines.

This report relates to the 5 N117 2.4MW IEC3a turbines which are numbered T1, T3, T4, T5 and T8.

The N117-2400 turbines are located in the eastern portion of the eastern cluster at Cleanrath, whereas the remaining N117 turbines are located to the west of that cluster and the N100 turbines are in a separate cluster 2km to the west at Derragh. The project includes the two clusters but is collectively known as Cleanrath Wind Farm.

As part of the site supervision works, Ionic assessed the founding formation strata for all gravity bases to ensure it met the required design criteria. This report summarises the ground conditions encountered within each of the turbine foundation excavations and has been prepared with reference also to the Geotechnical Investigation Report CNRH r007.1 undertaken by Ionic Consulting. The inspections undertaken at each formation location included a visual inspection, assessment of levels and widths, photographic recording and in-situ plate bearing testing where required.

Ionic previously carried out a detailed design of the turbine foundations based on the Nordex N117 91mHH 2.4MW Class IEC3a wind loading documents and insert arrangements details, coupled with the site investigation data detailed in the aforementioned geotechnical report.

A foundation design report has been produced alongside the foundation calculations covering the structural and geotechnical analysis of the site conditions.

Note that this document has been updated for the purposes of inclusion in a Remedial Environmental Impact Assessment Report for Cleanrath Wind Farm as part of a substitute consent application to An Bord Pleanála. The updates to the document relate only to the turbine numbering where it reverts to the original numbering system used when the project was originally proposed for planning permission.

2. FOUNDATION DESIGN

The initial geotechnical investigations were undertaken by Ionic Consulting in May-June 2019, including a site walkover and assessment of earlier site investigation documents from planning stage. The detailed geotechnical investigation consisted of borehole drilling at a total of 7 locations and was carried out between March and April 2019, along with physical and chemical testing of samples taken. Due to ground conditions which include extensive rock outcrop on higher ground a number of turbine locations were selected for borehole drilling thereby providing a representative outline of ground conditions across the site. The chosen turbine locations ensured that boreholes were carried out in each sub-cluster and for each turbine type. The borehole drilling confirmed findings of shallow bedrock at most locations as generally encountered during initial base excavations. The boreholes relevant to this report were drilled at the lower lying turbines within or adjacent to the valley east of the hill at T3 and T4. The borehole logs and laboratory testing results are provided in the appendices of the Geotechnical Investigation Report *(CNRH r007.1)*. The information gathered during the geotechnical investigations assisted the designers in the design of the wind turbine foundations, and at formation approval stage any assumptions on strength and stiffness were confirmed.

Wind loads used in the design of the foundation are detailed within Nordex N117 91mHH 2.4MW Class IEC3a loading document ref: K0822_066224_IN_R01_Fundament_N117_R91opt_DIBT. One standard partially buoyant gravity foundation design was provided for these 5 turbine locations T1, T3, T4, T5, and T8, based upon the ground conditions encountered and the high groundwater table. The level of the buoyant gravity base is set with the underside of tower bottom section at +1.1m relative to original ground level, and the design water level is taken as original ground level which results in a partially submerged scenario for the foundation. The ultimate design bearing resistance was conservatively estimated based on the ground investigation data to be greater than 500kN/m^2 for the siltstone bedrock at formation level. Given the shallow depth to bedrock at all locations with the exception of T4 direct blinding on bedrock is proposed at 4 of the 5 locations with no additional engineering fill material required to bring it to foundation level. The base at T4 was excavated to bedrock at an average depth of 5.9m, and 3.5m of 6N engineering fill was required to bring to the required foundation level. The maximum applied bearing pressure at ultimate loads ranged from 120 to 146kN/m^2 for the gravity foundations, all well below the ultimate bearing capacity.

Site inspections were carried out on each formation to confirm these findings, as described in detail in the following chapters. Plate testing to confirm stiffness and estimate strength was not required on the natural formation given the visually evident strength and stiffness of bedrock which typically required rock breaking to excavate. Plate testing was required however on the 6N engineering upfill at T4, results are included within Appendix C to confirm adequate compaction.

3. FORMATION INSPECTIONS

3.1 General Details

The formation strata of each proposed turbine base, was inspected by a suitably qualified Engineer from Ionic Consulting between the 20th of May 2019 and the 17th of June 2019.

Each turbine formation excavation was logged and photographed in accordance with BS5930, IS EN 1997 (Eurocode 7) and Site Investigation Steering Group (SISG) recommendations published in the "Specification of Ground Investigations" published by the ICE (1993).

Full details and photographs are given in the formation inspection log sheets provided in Appendix A of this report.

3.2 Ground Conditions

The ground conditions encountered during the inspections generally confirmed the findings of earlier geotechnical investigations. The following ground conditions were encountered during trial pitting and borehole drilling and broadly confirmed during the turbine formation inspections:

3.2.1 Superficial Geology

Within the trial pits and boreholes at N117-2400 gravity base locations the superficial deposits consisted generally of shallow peat with rootlets on weathered bedrock, with the exception of T4 which had fine to coarse silty sandy gravel to a depth of up to 6.4m.

3.2.2 Solid Geology

According to the GSI National Generalised Bedrock Map, and the 100k Solid Geology Map, the substation site is predominantly underlain by purple siltstone and fine sandstone of the Bird Hill Formation.

Weathered or intact solid bedrock was generally encountered during excavation and/or drilling within the minimum required founding depth for the turbine foundation of 1.8m below original ground level at 4 of the 5 bases. The formation depth at T4 was significantly deeper at approximately 6m, built-up with 6N engineering fill to the required foundation level. Also notable was a significant 4m drop-off in bedrock level at the western edge of the T8 formation which required a wider excvavation and 4m of leanmix concrete locally to provide the equivalent strength and stiffness across the entire foundation footprint area.

3.2.3 Groundwater

Groundwater was encountered at a shallow level during excavation and borehole drilling, therefore buoyant bases were adopted for all turbine locations. Note that as Nordex N117 tower bottom sections are set at +1.1m relative to original ground level the design water level is set 917mm below the top of ballast level at original ground level. Technically therefore a partially buoyant gravity base is provided as the upper ballast which is above original ground level is not considered under a submerged scenario.

3.3 Summary

In principal the following table summarises the geology of the formation strata encountered during the formation inspections.

WTG	Formation Strata Description
T1	SILTSTONE bedrock
T3	SILTSTONE bedrock
T4	SILTSTONE bedrock
T5	SILTSTONE bedrock
T8	SILTSTONE bedrock

Table 3.1 **Summary of formation level conditions – N117-2400 formations**

4. IN SITU TESTING

Based upon the conditions encountered detailed in-situ tests were not required on the excavated formations. Generally plate testing would be carried out to validate and quantify the findings of the geotechnical testing which in this case included trial holes and borehole drilling, however it was considered of limited value as the formations were on intact bedrock where no displacements would occur. Similarly due to direct leanmix concrete blinding on bedrock there was no 6N engineering upfill required apart from T4 and therefore plate testing in layers to confirm compaction was only carried out at T4; results are provided in Appendix C.

By inspection the strength of each of the turbine formations on siltstone bedrock was well in excess of the required minimum bearing capacity.

Similarly the stiffness of the underlying siltstone bedrock is well above the required minimum stiffness and the static rotational stiffness ($K_{\Phi stat}$) and dynamic rotational stiffness ($K_{\Phi dyn}$) is well in excess of the minimum required stiffness of 22,500MNm/rad and 90,000MNm/rad respectively.

The values shown in *Table 4.1* below indicate the estimated rotational stiffness on siltstone bedrock based on published lower bound values for elastic modulus of siltstone 3000MPa, but reduced to 500MPa to account for the 3m of 6N engineering fill below the T4 foundation.

Foundation Type	**Diameter**	**Estimated Elastic Modulus**	**Estimated Rotational Stiffness**	**Min Required Rotational Stiffness (Nordex document)**
	(m)	(MN/m2)	(MNm/rad)	(MNm/rad)
Nordex N117 91m HH IEC2a	20.8	500	940,300	90,000

Table 4.2 Summary of Rotational Stiffness – N117-2400 formations

5. SUMMARY

Based on the formation inspections it is concluded that the turbine foundations are founded on strata capable of meeting the performance criteria specified in the turbine foundation calculations for Nordex N117 91mHH 2.4MW Class IEC3a turbines.

The bearing capacity and rotational stiffness requirements have been satisfied.

Certificates associated with the formation inspection are included in Appendix B of this report.

APPENDICES

APPENDIX A – Formation Inspection Log Sheets

FORMATION INSPECTION SHEET

Report Ref CNRH r027.3

A		B		C		D	
Depth (m)	Description	Depth	Description	Depth	Description	Depth	Description
0.00 - 0.30	Dark brown fibrous PEAT	0.00 - 0.30	Dark brown fibrous PEAT	0.00 - 0.30	Dark brown fibrous PEAT	0.00 - 0.30	Dark brown fibrous PEAT
0.30 - 2.80	Strong thinly laminated purple fine and medium grained SILTSTONE	0.30 - 2.20	Strong thinly laminated purple fine and medium grained SILTSTONE	0.30 - 1.30	Strong thinly laminated purple fine and medium grained SILTSTONE	0.30 - 1.70	Strong thinly laminated purple fine and medium grained SILTSTONE

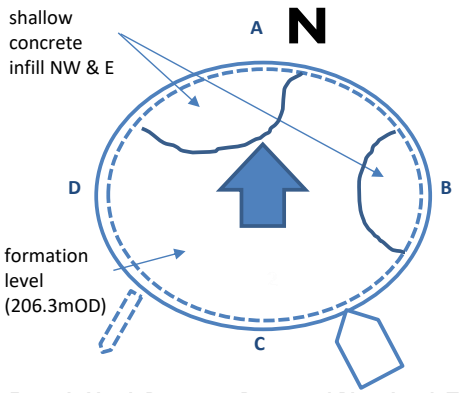

Figure1: North Direction, Ramp and Plate Load Test Locations

Engineer	C Ó Dubhthaigh
Date	05/06/2019
Tests	No Plate Bearing Tests required (solid bedrock)
Conducted	N/A
Ref	N/A
Easting	120871
Northing	70057
Level	206.3mOD

Water	Some surface water ponding at formation level and within recessed central area for slab downstand. Drainage temporarily through duct channel and pumping where required prior to placement of leanmix blinding.
Notes	22m diameter circle with steep rockface up to 2.5m on north and east. Plate tests not required due to formation on solid bedrock.

Notes (cont'd)	Due to some overbreaking and jagged excavated surface the excess excavation depth was infilled with available C35/45 concrete from adjacent completed concrete pour. Up to 7m^3 was placed locally on north west and east to depths up to 250mm. Direct blinding with minimum 100mm of C16/20 leanmix to be carried out above this and above the remaining bedrock across the entire footprint area.

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Project	**CLEANRATH WIND FARM**	Base	**T1**

FORMATION PHOTOGRAPHS

Report Ref CNRH r027.3

North Wall

East Wall

South Wall

West Wall

View of entire formation area from hardstanding

View of formation area from above facing SW

Bedrock profile following rock breaking

Up to 250mm depth of concrete placed in SW

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Project	CLEANRATH WIND FARM	Base	T1

FORMATION INSPECTION SHEET

Report Ref CNRH r027.3

A		B		C		D	
Depth (m)	Description	Depth	Description	Depth	Description	Depth	Description
0.00 - 0.20	Dark brown fibrous PEAT	0.00 - 0.20	Dark brown fibrous PEAT	0.00 - 0.20	Dark brown fibrous PEAT	0.00 - 0.20	Dark brown fibrous PEAT
0.20 - 1.20	Strong thinly laminated purple fine grained SILTSTONE	0.20 - 2.30	Strong thinly laminated purple fine grained SILTSTONE	0.20 - 2.20	Strong thinly laminated purple fine grained SILTSTONE	0.20 - 1.50	Strong thinly laminated purple fine grained SILTSTONE

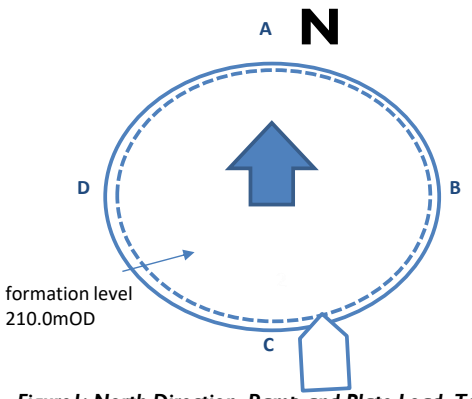

Figure1: North Direction, Ramp and Plate Load Test Locations

Engineer	C Ó Dubhthaigh	Water	Excavation entirely dry at time of excavation. Minimal overburden consisting of 0.2m of peaty topsoil across the wider area. No perimeter drain required for construction stage.	Notes (cont'd)	Minimal crossfall across the footprint area, low point to north west where bedrock levels are approximately 1m lower. Direct blinding with minimum 100mm C16/20 leanmix will be carried out across the entire footprint area to provide the blinding surface for foundation construction.
Date	05/06/2019				
Tests	No Plate Bearing Tests required (solid bedrock)				
Conducted	N/A				
Ref	N/A				
Easting	121213	Notes	22m diameter circle with steep rockface up to 2.1m on south and 2.0m on east. Plate tests not required due to formation on solid bedrock.		
Northing	69913				
Level	210.0mOD				

	Ionic Consulting The Hyde Building The Park Carrickmines Dublin 18 Ireland	Project	**CLEANRATH WIND FARM**	Base	**T3**

FORMATION PHOTOGRAPHS

Report Ref CNRH r027.3

North Wall

East Wall

South Wall

West Wall

Bedrock profile after rock breaking

Bedrock profile after rock breaking

Overview of entire formation area

Formation area relative to hardstanding

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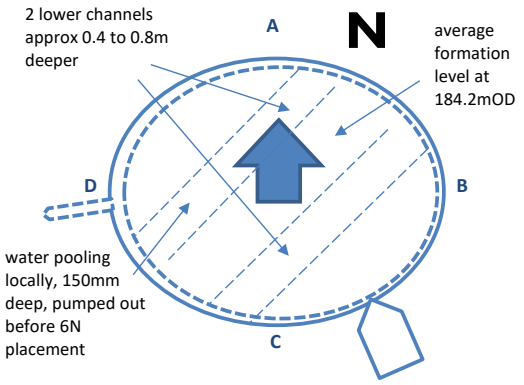
Project	CLEANRATH WIND FARM	Base	T3

FORMATION INSPECTION SHEET

Report Ref CNRH r027.3

A		B		C		D	
Depth (m)	Description	Depth	Description	Depth	Description	Depth	Description
0.00 - 1.40	Dark brown fibrous PEAT	0.00 - 0.30	Dark brown fibrous PEAT	0.00 - 0.30	Dark brown fibrous PEAT	0.00 - 1.20	Dark brown fibrous PEAT
1.40 - 6.10	Fine to coarse brown silty sandy siltstone and sandstone GRAVEL	0.30 - 5.90	Fine to coarse brown silty sandy siltstone and sandstone GRAVEL	0.30 - 5.90	Fine to coarse brown silty sandy siltstone and sandstone GRAVEL	1.20 - 6.40	Fine to coarse brown silty sandy siltstone and sandstone GRAVEL
6.10 - 6.20	Strong thinly laminated purple fine and medium grained SILTSTONE	5.90 - 6.00	Strong thinly laminated purple fine and medium grained SILTSTONE	5.90 - 6.00	Strong thinly laminated purple fine and medium grained SILTSTONE	6.40 -	Strong thinly laminated purple fine and medium grained SILTSTONE
 ***Figure1: North Direction, Ramp and Plate Load Test Locations***		Engineer Date	C Ó Dubhthaigh 17/06/2019	Water	A sump and 150mm pump was set up in the west of the formation area. Some pooling of water remained locally within an inner area towards the NW of the formation area - this was pumped out with an extended pump back to the nearby sump prior to placement of engineering fill.	Notes (cont'd)	Overburden consisted of saturated silty sandy gravel, crossfall of up to 1.5m from top of gravel, though peat depth significantly deeper on low side. Entire overburden excavated to bedrock due to unsuitability of material for dynamic loading. Average excavation depth of 5.9m. Bedrock level approx 0.4 to 0.8m deeper in two broadly parallel channels approx 1.5-2m wide as shown on Fig.1. Due to depth of 6N engineering fill required no leanmix required within channels. No plate testing required on natural bedrock formation, but 7 layers of 6N testing will be required at 0.5m intervals to confirm compaction of engineering fill. Leanmix blinding concrete to be laid across the top 6N fill layer.
		Tests Conducted Ref	No Plate Bearing Tests required (solid bedrock) N/A N/A				
		Easting Northing Level	121200 69411 184.2mOD	Notes	28m diameter circle within deep excavation of up to 6.4m, side slopes battered back to 45°, peat up to 1.4m deep on north and west, significantly reduced peat averaging 0.3m on south and east. Bedrock level undulating but relatively horizontal across the entire footprint area.		

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FORMATION PHOTOGRAPHS

Report Ref CNRH r027.3

North Wall

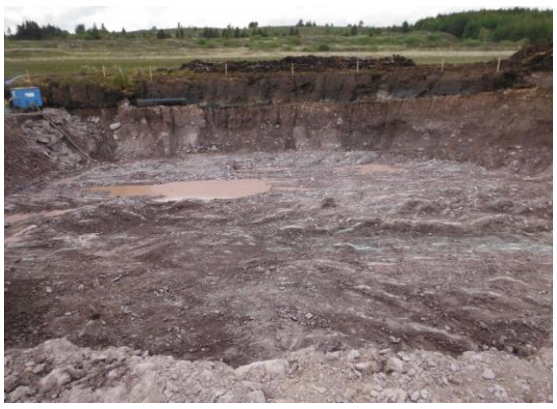
East Wall

South Wall

West Wall

Solid bedrock formation

Solid bedrock formation



View looking north west of entire formation area

Sump and pump in west, shallow water pooling locally in foreground prior to pumping

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Project **CLEANRATH WIND FARM**

Base **T4**

FORMATION INSPECTION SHEET

Report Ref CNRH r027.3

A		B		C		D	
Depth (m)	Description	Depth	Description	Depth	Description	Depth	Description
0.00 - 0.50	Dark brown fibrous PEAT	0.00 - 0.50	Dark brown fibrous PEAT	0.00 - 0.50	Dark brown fibrous PEAT	0.00 - 0.50	Dark brown fibrous PEAT
0.50 - 4.10	Strong thinly laminated purple fine and medium grained SILTSTONE	0.50 - 1.40	Strong thinly laminated purple fine and medium grained SILTSTONE	0.50 - 1.50	Strong thinly laminated purple fine and medium grained SILTSTONE	0.50 - 3.40	Strong thinly laminated purple fine and medium grained SILTSTONE

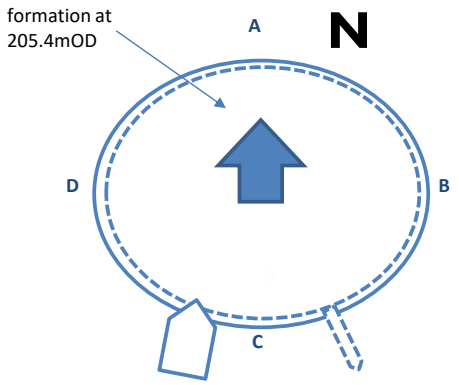

Figure1: North Direction, Ramp and Plate Load Test Locations

Engineer	C Ó Dubhthaigh	Water	Some surface water ponding along northern edge of formation area due to local dip of 0.2m in excavated bedrock level. Natural drainage possible through duct channel excavated to south east. To be drained prior to leanmix placement. Suitable fall to south east for gravity drainage from foundation level.	Notes (cont'd)	Due to bedrock excavation level on the north which was 0.2m below the approved formation blinding level over an area of approximately 20m2, additional dry leanmix will be required to bring the entire footprint area to the required level of 205.4mOD. Once the entire area is brought to the required level, and after placement of the ducts for the power cables within the ducting channel to south east, the entire footprint area will be blinded with wet C16/20 leanmix concrete to provide the required blinding surface for construction of the foundation.
Date	20/05/2019				
Tests	No Plate Bearing Tests required (solid bedrock)				
Conducted	N/A				
Ref	N/A				
Easting	120682	Notes	22m diameter excavated circle suitable for 20.2m diameter foundation. Steep rockface on 2 sides, up to 4m to north. Plate tests not required due to formation on solid bedrock.		
Northing	69553				
Level	205.4mOD				

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Project	Base
CLEANRATH WIND FARM	**T5**

FORMATION PHOTOGRAPHS

Report Ref CNRH r027.3

North Wall

East Wall

South Wall

West Wall

View over entire formation area

View of downslope (eastern) side with stockpiled ballast material

View of formation relative to hardstanding level

Excavated duct channel with gravity drainage

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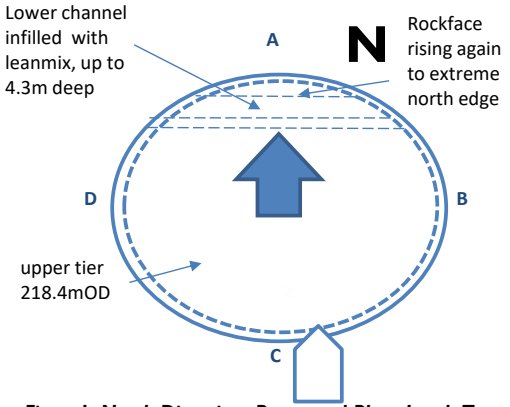
Project	CLEANRATH WIND FARM	Base	T5

FORMATION INSPECTION SHEET

Report Ref CNRH r027.3

A		B		C		D	
Depth (m)	Description	Depth	Description	Depth	Description	Depth	Description
0.00 - 0.40	Dark brown fibrous PEAT	0.00 - 0.40	Dark brown fibrous PEAT	0.00 - 0.40	Dark brown fibrous PEAT	0.00 - 0.40	Dark brown fibrous PEAT
0.40 - 4.10	Clayey sandy gravel	0.40 - 0.80	Weathered siltstone	0.40 - 0.80	Weathered siltstone	0.40 - 0.80	Weathered siltstone
4.10 - 4.30	Strong thinly laminated purple fine and medium grained SILTSTONE	0.50 - 1.80	Strong thinly laminated purple fine and medium grained SILTSTONE	0.50 - 3.50	Strong thinly laminated purple fine and medium grained SILTSTONE	0.50 - 1.80	Strong thinly laminated purple fine and medium grained SILTSTONE
 ***Figure1: North Direction, Ramp and Plate Load Test Locations***		Engineer	C Ó Dubhthaigh	Water	Some surface water ponding locally at formation level in south east following rainfall. Water accummulating within the lower channel on north after deep excavation of overburden at edge of steep fall off in bedrock level. Water to be pumped prior to placement of dry leanmix within lower tier.	Notes (cont'd)	Due to a significant level difference up to 4m for the outer 2m of the base sub-formation an excavated radius of 15m was provided to the north to provide the minimum 1:1 leanmix concrete build-up for the foundation radius of 10.1m. From R13.8m the bedrock rises again. The bedrock at R8.0m was squared up vertically to avoid outward lateral forces being induced. The lower tier excavated effectively as a channel as from R13.8m to R15.0m the bedrock level rises, which also provides additional lateral support to the leanmix infill. Direct blinding on bedrock across 5/6th of the footprint area, remaining area to north infilled to same level with leanmix concrete.
		Date	07/06/2019				
		Tests	No Plate Bearing Tests required (solid bedrock)				
		Conducted	N/A				
		Ref	N/A				
		Easting	120493	Notes	Minimum 10.5m radius formation area provided on south, east and west with steep rockface up to 3.5m on south. Steep crossfall from high point on south, sudden and very steep level drop at 8m from centre of turbine on the north. Lower channel excavated by 4m to bedrock.		
		Northing	69178				
		Level	218.4mOD				

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FORMATION PHOTOGRAPHS

Report Ref CNRH r027.3

North Wall

East Wall

South Wall

West Wall

View of overall formation area looking east

Formation area showing sharp drop off from 8m north of centre

Lower channel before pumping, squared rock profile (RHS), bedrock rising to extreme north (LHS)

Initial placement of dry leanmix to lower channel

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Project	CLEANRATH WIND FARM	Base	T8

APPENDIX B – Formation Approval Certificates

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FORMATION APPROVAL

Project :	**Cleanrath Wind Farm**		
Turbine	**T1**		
Reference:	**CNRH r027.3 Appendix B**	Date :	**5 June 2019**
Contractor/Client :	**Mid Cork Electrical Limited**		
Formation Report Reference	**CNRH r027.3 RevB**		

The formation associated with the above foundation has been inspected and tested in accordance with the contract specification, foundation design and WTG suppliers requirements and found to meet said requirements. Remedial or construction actions instructed at the time of excavation and inspection have been conducted by the contractor to the approval of Ionic Consulting.

Signed

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Civil Engineering Manager

Ionic Consulting

Approved

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Civil Engineering Manager

Ionic Consulting

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FORMATION APPROVAL

Project :	**Cleanrath Wind Farm**		
Turbine	**T3**		
Reference:	**CNRH r027.3 Appendix B**	Date :	**5 June 2019**
Contractor/Client :	**Mid Cork Electrical Limited**		
Formation Report Reference	**CNRH r027.3 RevB**		

The formation associated with the above foundation has been inspected and tested in accordance with the contract specification, foundation design and WTG suppliers requirements and found to meet said requirements. Remedial or construction actions instructed at the time of excavation and inspection have been conducted by the contractor to the approval of Ionic Consulting.

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Civil Engineering Manager

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FORMATION APPROVAL

Project :	**Cleanrath Wind Farm**		
Turbine	**T4**		
Reference:	**CNRH r027.3 Appendix B**	Date :	**17 June 2019**
Contractor/Client :	**Mid Cork Electrical Limited**		
Formation Report Reference	**CNRH r027.3 RevB**		

The formation associated with the above foundation has been inspected and tested in accordance with the contract specification, foundation design and WTG suppliers requirements and found to meet said requirements. Remedial or construction actions instructed at the time of excavation and inspection have been conducted by the contractor to the approval of Ionic Consulting.

Signed

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FORMATION APPROVAL

Project :	**Cleanrath Wind Farm**		
Turbine	**T5**		
Reference:	**CNRH r027.3 Appendix B**	Date :	**20 May 2019**
Contractor/Client :	**Mid Cork Electrical Limited**		
Formation Report Reference	**CNRH r027.3 RevB**		

The formation associated with the above foundation has been inspected and tested in accordance with the contract specification, foundation design and WTG suppliers requirements and found to meet said requirements. Remedial or construction actions instructed at the time of excavation and inspection have been conducted by the contractor to the approval of Ionic Consulting.

Signed

Cormac Ó Dubhthaigh

BE MEngSc CEng MIEI

Civil Engineering Manager

Ionic Consulting

Approved

Cormac Ó Dubhthaigh

BE MEngSc CEng MIEI

Civil Engineering Manager

Ionic Consulting

IONIC CONSULTING LTD

FORMATION APPROVAL

Project :	**Cleanrath Wind Farm**		
Turbine	**T8**		
Reference:	**CNRH r027.3 Appendix B**	Date :	**11 June 2019**
Contractor/Client :	**Mid Cork Electrical Limited**		
Formation Report Reference	**CNRH r027.3 RevB**		

The formation associated with the above foundation has been inspected and tested in accordance with the contract specification, foundation design and WTG suppliers requirements and found to meet said requirements. Remedial or construction actions instructed at the time of excavation and inspection have been conducted by the contractor to the approval of Ionic Consulting.

Signed

Cormac Ó Dubhthaigh

BE MEngSc CEng MIEI

Civil Engineering Manager

Ionic Consulting

Approved

Cormac Ó Dubhthaigh

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Civil Engineering Manager

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APPENDIX C – Plate Bearing Tests Results (T4 upfill)

Ionic Consulting
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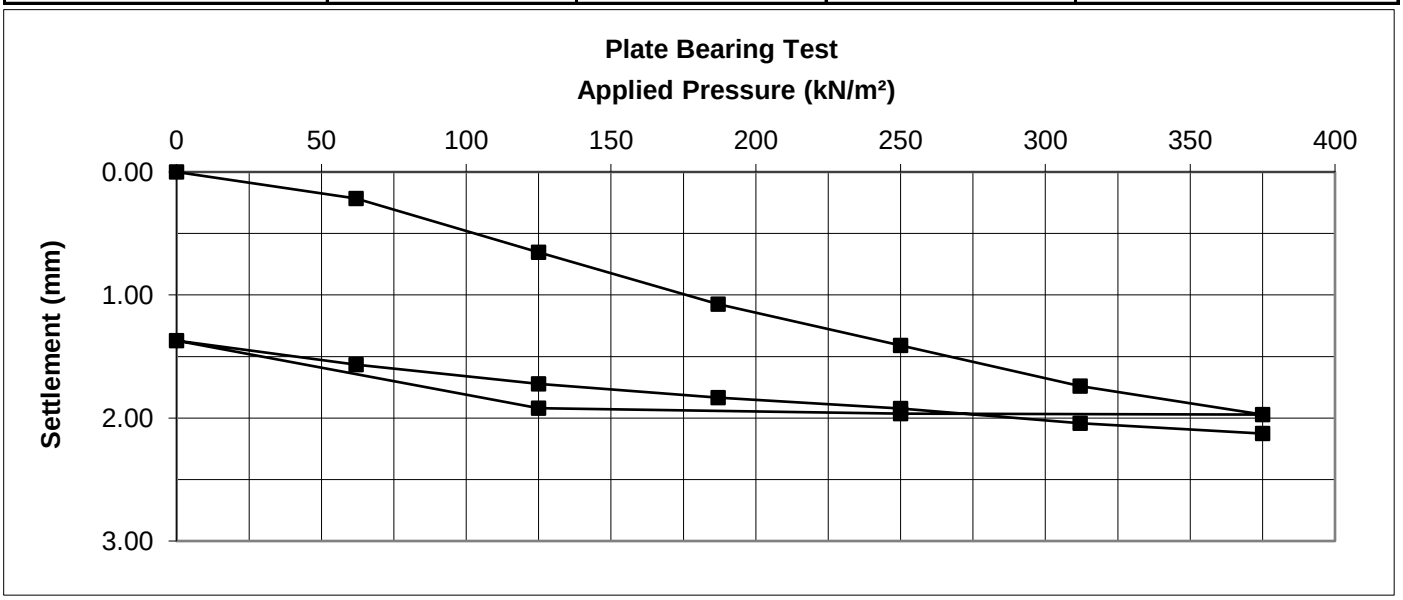
Tel: 01 8455031
Fax: 01 8455612
www.ionicconsulting.ie

Report Date: July 2019
Report No: CNRH r027

Plate Bearing Test in accordance with EN 1997-2:2007, EN ISO 22476-13 and DIN 18134:2001-09
CBR values derived from empirical relationship in NRA DMRB Volume 7 HD 25-26 Clause 3.6.3

Project:	Cleanrath Wind Farm	Client:	Mid Cork Electrical
Location:	T4 +0.5m SE	Plate Diameter:	450mm
Test Date :	20/06/2019	Material:	6N Engineering Fill
Tested By :	S. O'Mahony	Turbine Supplier:	Nordex

Applied Pressure	Dial Gauge A	Dial Gauge B	Dial Gauge C	Average Settlement
[kN/m²]	[mm]	[mm]	[mm]	[mm]
0	0.00	0.00	0.00	0.00
62	0.11	0.34	0.20	0.22
125	0.46	0.96	0.54	0.65
187	0.82	1.48	0.92	1.07
250	1.12	1.88	1.23	1.41
312	1.41	2.27	1.54	1.74
375	1.62	2.54	1.76	1.97
250	1.64	2.49	1.76	1.96
125	1.64	2.36	1.76	1.92
0	1.22	1.69	1.20	1.37
62	1.29	2.03	1.38	1.57
125	1.42	2.22	1.53	1.72
187	1.51	2.36	1.63	1.83
250	1.58	2.48	1.71	1.92
312	1.66	2.60	1.87	2.04
375	1.76	2.76	1.86	2.13



Results:

Modulus of Subgrade Reaction, Initial Load (k_1) =	**122154**	kN/m²/m
Elastic Modulus (E) =	**61**	MN/m²
Deformation Modulus, Initial Load (Ev_1) =	**56**	MN/m²
Deformation Modulus, Reload (Ev_2) =	**162**	MN/m²
Ev_2/Ev_1 (Load / Reload) Ratio =	**2.9**	
Estimated CBR value =	**40**	%

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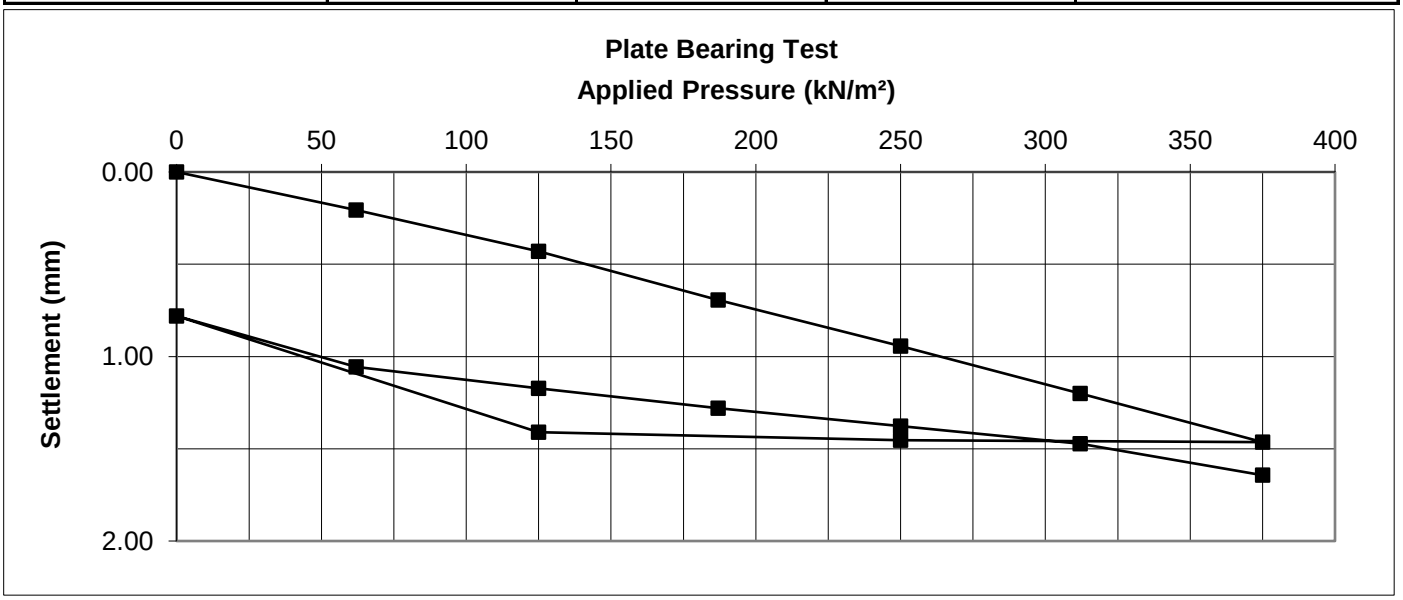
Plate Bearing Test in accordance with EN 1997-2:2007, EN ISO 22476-13 and DIN 18134:2001-09
CBR values derived from empirical relationship in NRA DMRB Volume 7 HD 25-26 Clause 3.6.3

Project:	Cleanrath Wind Farm	Client:	Mid Cork Electrical
Location:	T4 +1.0m W	Plate Diameter:	450mm
Test Date :	20/06/2019	Material:	6N Engineering Fill
Tested By :	S. O'Mahony	Turbine Supplier:	Nordex

Applied Pressure	Dial Gauge A	Dial Gauge B	Dial Gauge C	Average Settlement
[kN/m²]	[mm]	[mm]	[mm]	[mm]
0	0.00	0.00	0.00	0.00
62	0.08	0.27	0.27	0.21
125	0.23	0.55	0.51	0.43
187	0.43	0.87	0.78	0.69
250	0.63	1.18	1.02	0.94
312	0.81	1.52	1.27	1.20
375	1.01	1.85	1.53	1.46
250	1.02	1.81	1.53	1.45
125	1.02	1.68	1.53	1.41
0	0.50	0.99	0.85	0.78
62	0.66	1.34	1.17	1.06
125	0.75	1.48	1.29	1.17
187	0.83	1.62	1.39	1.28
250	0.89	1.75	1.49	1.38
312	0.96	1.88	1.58	1.47
375	1.09	2.09	1.75	1.64



Results:

Modulus of Subgrade Reaction, Initial Load (k_1) =	**164727**	kN/m²/m
Elastic Modulus (E) =	**82**	MN/m²
Deformation Modulus, Initial Load (Ev_1) =	**85**	MN/m²
Deformation Modulus, Reload (Ev_2) =	**163**	MN/m²
Ev_2/Ev_1 (Load / Reload) Ratio =	**1.9**	
Estimated CBR value =	**67**	%

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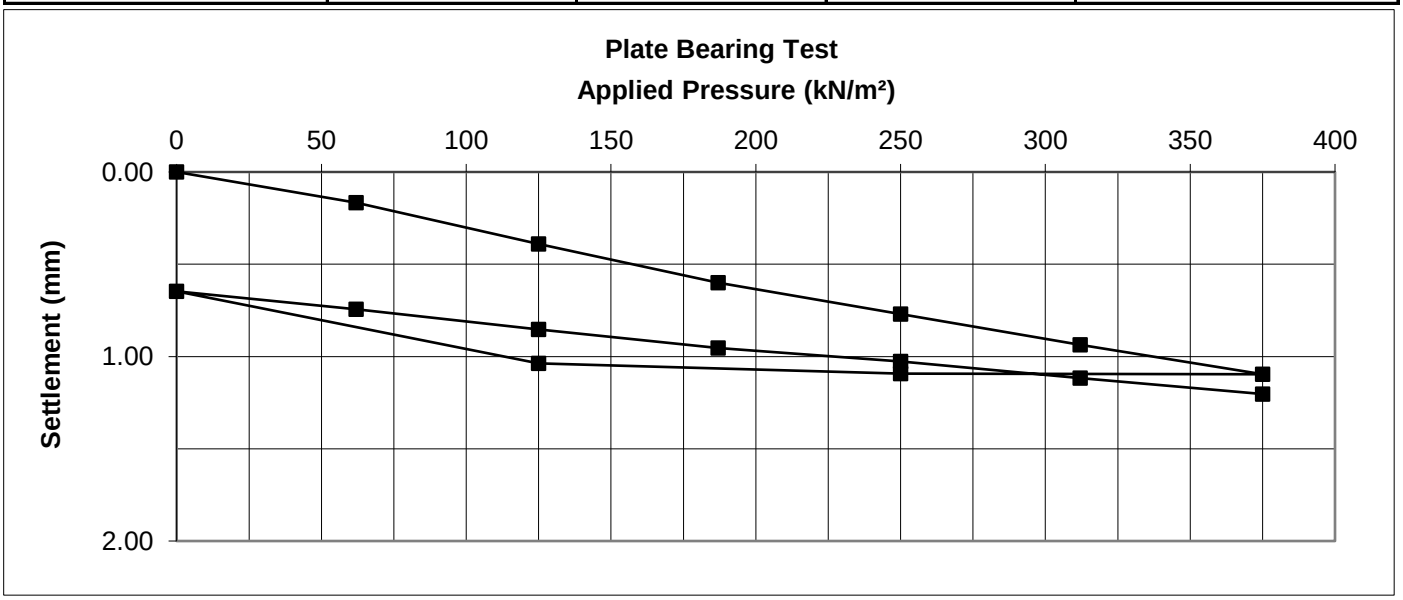
Plate Bearing Test in accordance with EN 1997-2:2007, EN ISO 22476-13 and DIN 18134:2001-09
CBR values derived from empirical relationship in NRA DMRB Volume 7 HD 25-26 Clause 3.6.3

Project:	Cleanrath Wind Farm	Client:	Mid Cork Electrical
Location:	T4 +1.5m NW	Plate Diameter:	450mm
Test Date :	20/06/2019	Material:	6N Engineering Fill
Tested By :	S. O'Mahony	Turbine Supplier:	Nordex

Applied Pressure	Dial Gauge A	Dial Gauge B	Dial Gauge C	Average Settlement
[kN/m²]	[mm]	[mm]	[mm]	[mm]
0	0.00	0.00	0.00	0.00
62	0.18	0.18	0.14	0.17
125	0.45	0.37	0.35	0.39
187	0.69	0.56	0.55	0.60
250	0.88	0.71	0.72	0.77
312	1.06	0.85	0.90	0.94
375	1.23	0.99	1.07	1.10
250	1.25	0.96	1.07	1.09
125	1.24	0.80	1.07	1.04
0	0.80	0.43	0.71	0.65
62	0.92	0.57	0.74	0.74
125	1.03	0.71	0.82	0.85
187	1.13	0.82	0.91	0.95
250	1.21	0.89	0.98	1.03
312	1.28	0.97	1.10	1.12
375	1.41	1.05	1.15	1.20



Results:

Modulus of Subgrade Reaction, Initial Load (k_1) =	**219802**	kN/m²/m
Elastic Modulus (E) =	**110**	MN/m²
Deformation Modulus, Initial Load (Ev_1) =	**109**	MN/m²
Deformation Modulus, Reload (Ev_2) =	**224**	MN/m²
Ev_2/Ev_1 (Load / Reload) Ratio =	**2.0**	
Estimated CBR value =	**110**	%

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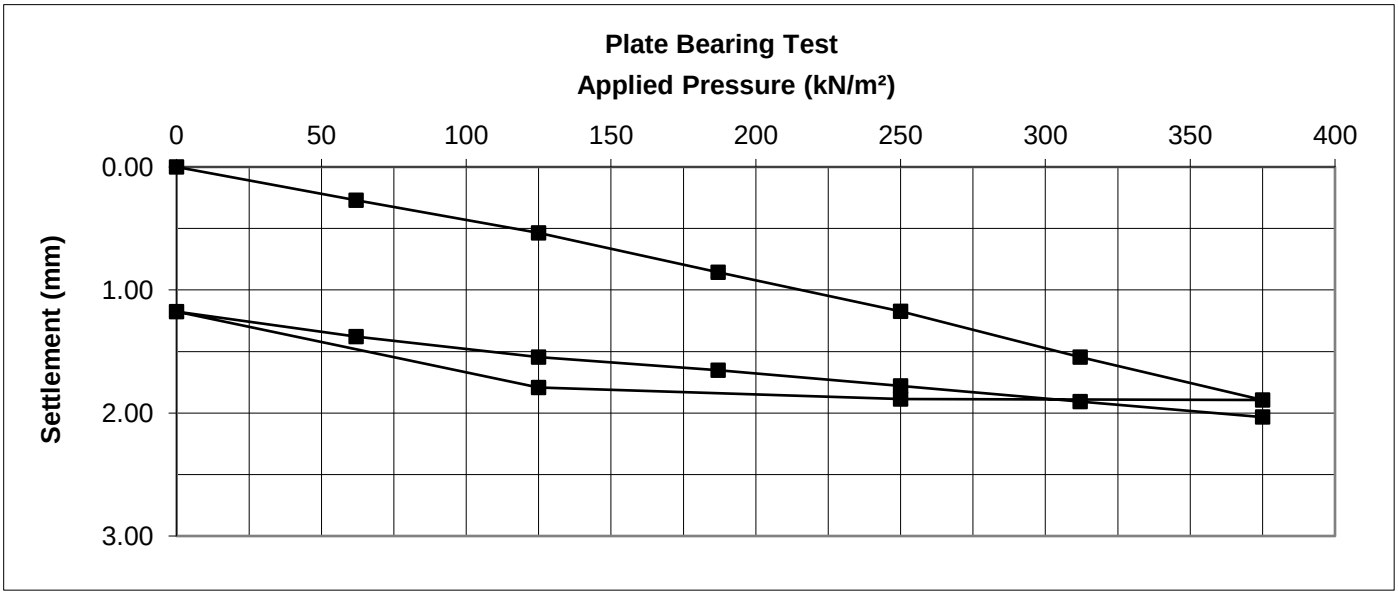
Plate Bearing Test in accordance with EN 1997-2:2007, EN ISO 22476-13 and DIN 18134:2001-09
CBR values derived from empirical relationship in NRA DMRB Volume 7 HD 25-26 Clause 3.6.3

Project:	Cleanrath Wind Farm	Client:	Mid Cork Electrical
Location:	T4 +2.0m NE	Plate Diameter:	450mm
Test Date :	20/06/2019	Material:	6N Engineering Fill
Tested By :	S. O'Mahony	Turbine Supplier:	Nordex

Applied Pressure	Dial Gauge A	Dial Gauge B	Dial Gauge C	Average Settlement
[kN/m²]	[mm]	[mm]	[mm]	[mm]
0	0.00	0.00	0.00	0.00
62	0.25	0.27	0.29	0.27
125	0.54	0.56	0.51	0.54
187	0.88	0.89	0.80	0.86
250	1.16	1.14	1.22	1.17
312	1.48	1.38	1.78	1.55
375	1.77	1.65	2.26	1.89
250	1.79	1.61	2.26	1.89
125	1.78	1.51	2.09	1.79
0	1.18	1.00	1.35	1.18
62	1.32	1.21	1.61	1.38
125	1.47	1.36	1.81	1.55
187	1.56	1.45	1.95	1.65
250	1.66	1.54	2.14	1.78
312	1.76	1.64	2.32	1.91
375	1.86	1.75	2.49	2.03



Results:

Modulus of Subgrade Reaction, Initial Load (k_1) =	**127315**	kN/m²/m
Elastic Modulus (E) =	**64**	MN/m²
Deformation Modulus, Initial Load (Ev_1) =	**67**	MN/m²
Deformation Modulus, Reload (Ev_2) =	**149**	MN/m²
Ev_2/Ev_1 (Load / Reload) Ratio =	**2.2**	
Estimated CBR value =	**43**	%

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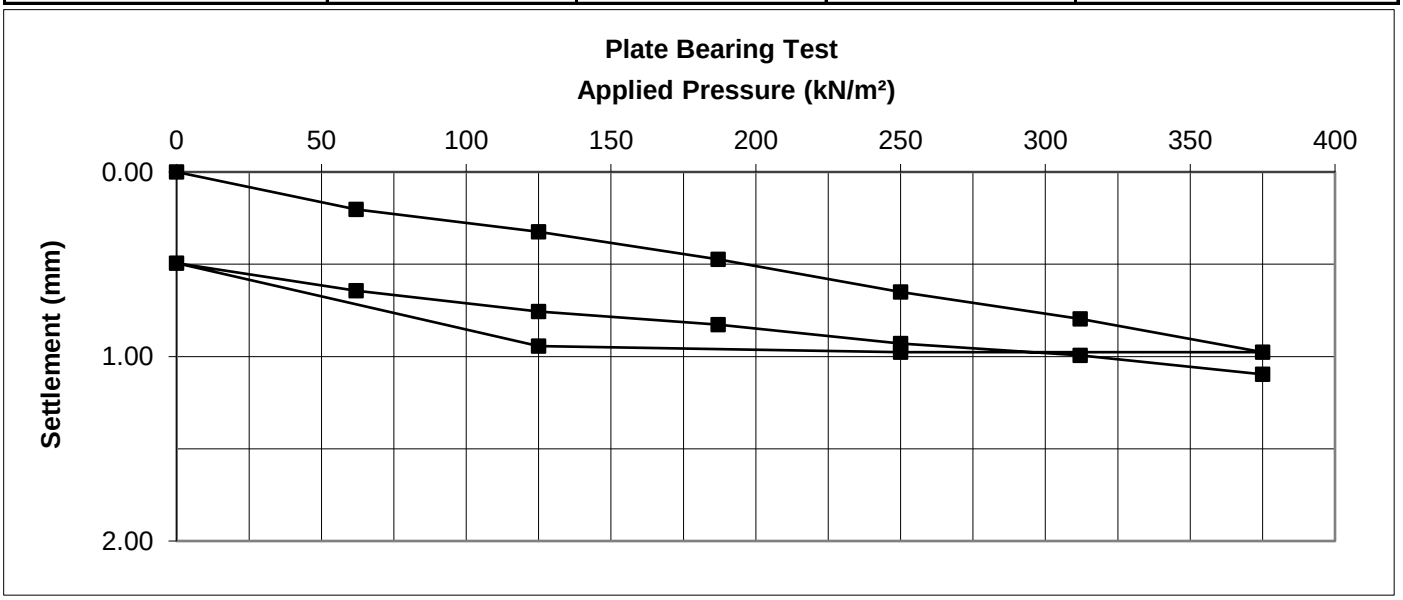
Plate Bearing Test in accordance with EN 1997-2:2007, EN ISO 22476-13 and DIN 18134:2001-09
CBR values derived from empirical relationship in NRA DMRB Volume 7 HD 25-26 Clause 3.6.3

Project:	Cleanrath Wind Farm	Client:	Mid Cork Electrical
Location:	T4 +2.5m S	Plate Diameter:	450mm
Test Date :	24/06/2019	Material:	6N Engineering Fill
Tested By :	S. O'Mahony	Turbine Supplier:	Nordex

Applied Pressure	Dial Gauge A	Dial Gauge B	Dial Gauge C	Average Settlement
[kN/m²]	[mm]	[mm]	[mm]	[mm]
0	0.00	0.00	0.00	0.00
62	0.18	0.27	0.16	0.20
125	0.31	0.39	0.27	0.32
187	0.46	0.55	0.41	0.47
250	0.63	0.74	0.58	0.65
312	0.77	0.92	0.70	0.80
375	0.95	1.11	0.87	0.98
250	0.97	1.09	0.87	0.98
125	0.97	0.99	0.87	0.94
0	0.59	0.45	0.44	0.49
62	0.67	0.72	0.54	0.64
125	0.78	0.85	0.64	0.76
187	0.84	0.94	0.70	0.83
250	0.94	1.05	0.80	0.93
312	1.00	1.12	0.86	0.99
375	1.10	1.24	0.95	1.10



Results:

Modulus of Subgrade Reaction, Initial Load (k_1) =	**246809**	kN/m²/m
Elastic Modulus (E) =	**123**	MN/m²
Deformation Modulus, Initial Load (Ev_1) =	**140**	MN/m²
Deformation Modulus, Reload (Ev_2) =	**215**	MN/m²
Ev_2/Ev_1 (Load / Reload) Ratio =	**1.5**	
Estimated CBR value =	**135**	%

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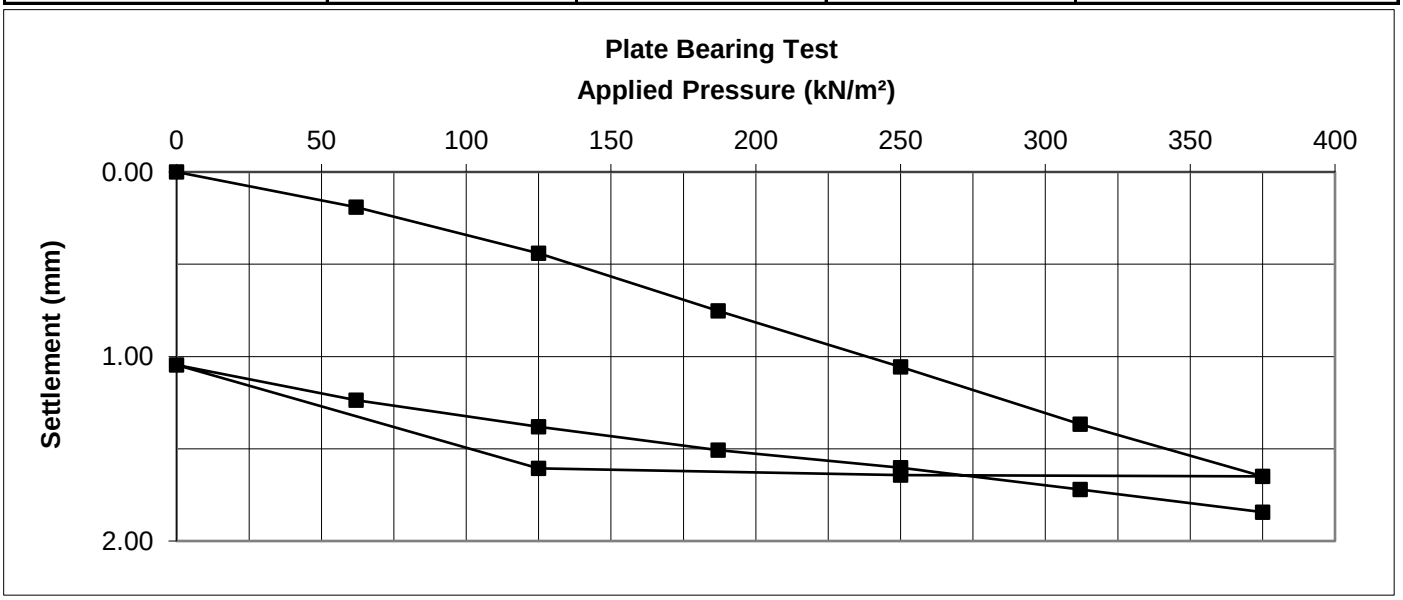
Plate Bearing Test in accordance with EN 1997-2:2007, EN ISO 22476-13 and DIN 18134:2001-09
CBR values derived from empirical relationship in NRA DMRB Volume 7 HD 25-26 Clause 3.6.3

Project:	Cleanrath Wind Farm	Client:	Mid Cork Electrical
Location:	T4 +3.0m W	Plate Diameter:	450mm
Test Date :	24/06/2019	Material:	6N Engineering Fill
Tested By :	S. O'Mahony	Turbine Supplier:	Nordex

Applied Pressure	Dial Gauge A	Dial Gauge B	Dial Gauge C	Average Settlement
[kN/m²]	[mm]	[mm]	[mm]	[mm]
0	0.00	0.00	0.00	0.00
62	0.16	0.27	0.14	0.19
125	0.38	0.57	0.37	0.44
187	0.72	0.89	0.65	0.75
250	1.05	1.18	0.94	1.06
312	1.39	1.48	1.23	1.37
375	1.67	1.74	1.54	1.65
250	1.67	1.72	1.54	1.64
125	1.67	1.62	1.53	1.61
0	1.05	1.09	1.00	1.05
62	1.20	1.35	1.16	1.24
125	1.35	1.49	1.30	1.38
187	1.47	1.62	1.43	1.51
250	1.56	1.72	1.53	1.60
312	1.66	1.84	1.66	1.72
375	1.77	1.98	1.78	1.84



Results:

Modulus of Subgrade Reaction, Initial Load (k_1) =	**146091**	kN/m²/m
Elastic Modulus (E) =	**73**	MN/m²
Deformation Modulus, Initial Load (Ev_1) =	**72**	MN/m²
Deformation Modulus, Reload (Ev_2) =	**161**	MN/m²
Ev_2/Ev_1 (Load / Reload) Ratio =	**2.2**	
Estimated CBR value =	**54**	%

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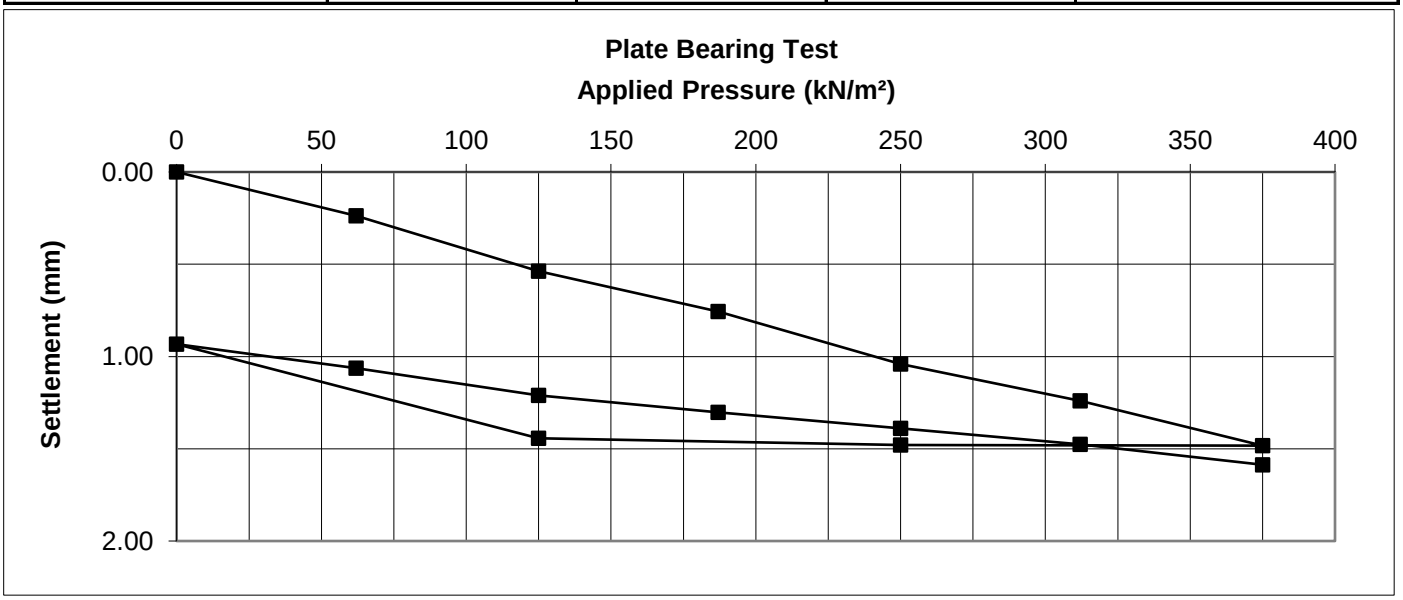
Plate Bearing Test in accordance with EN 1997-2:2007, EN ISO 22476-13 and DIN 18134:2001-09
CBR values derived from empirical relationship in NRA DMRB Volume 7 HD 25-26 Clause 3.6.3

Project:	Cleanrath Wind Farm	Client:	Mid Cork Electrical
Location:	T4 +3.5m Final Layer SE	Plate Diameter:	450mm
Test Date :	24/06/2019	Material:	6N Engineering Fill
Tested By :	S. O'Mahony	Turbine Supplier:	Nordex

Applied Pressure	Dial Gauge A	Dial Gauge B	Dial Gauge C	Average Settlement
[kN/m²]	[mm]	[mm]	[mm]	[mm]
0	0.00	0.00	0.00	0.00
62	0.24	0.29	0.18	0.24
125	0.65	0.53	0.43	0.54
187	0.94	0.70	0.63	0.76
250	1.30	0.89	0.93	1.04
312	1.54	1.05	1.13	1.24
375	1.80	1.24	1.41	1.48
250	1.80	1.22	1.42	1.48
125	1.80	1.12	1.41	1.44
0	1.34	0.56	0.90	0.93
62	1.44	0.76	0.99	1.06
125	1.59	0.91	1.13	1.21
187	1.69	1.01	1.21	1.30
250	1.78	1.10	1.29	1.39
312	1.88	1.18	1.37	1.48
375	2.01	1.26	1.49	1.59



Results:

Modulus of Subgrade Reaction, Initial Load (k_1) =	**162506**	kN/m²/m
Elastic Modulus (E) =	**81**	MN/m²
Deformation Modulus, Initial Load (Ev_1) =	**83**	MN/m²
Deformation Modulus, Reload (Ev_2) =	**195**	MN/m²
Ev_2/Ev_1 (Load / Reload) Ratio =	**2.3**	
Estimated CBR value =	**65**	%

APPENDIX D – Nordex N117-2400 loading & stiffness document

Lastspezifikation / *Load Specification*

Fundament / *Foundation*

N117/2400 R91opt IEC3a/DIBt2

Rotorblatt / Rotor blades: NR58.5

Klimatische Bedingungen / *Climate conditions*: NCV & CCV

Dokumentnummer / *Document number*

K0822_066224_IN

Revision / *Revision*

01

Datum / *Date*

07.04.2016

Verantwortliche Abteilung / *Department responsible*

MTE / MTF

Klassifikation / *Classification*

Nordex intern (IP)

Status / *Status*

AST

9994

Ersatz für Revision / *Replaces Revision*

00

Ersteller / *Created*:

A. E. Dang/MTF

Prüfer / *Checked*:

A. Schröder/MTF

Freigabe / *Released*:

H.Timm/MTF

Dokument wird elektronisch verteilt. Original mit Unterschriften bei SCE / SDQ
Document published in electronic form. Original at SCE / SDQ.

ÄNDERUNGSINDEX / *REVISION INDEX*

Änderung / ***Revision***	**Datum** / ***Date***	**Bearbeiter** / ***Author***	**Modifikation (Sektion)** / ***Modification (Section)***	**AST**
Rev.01	07.04.2016	A.E. Dang	Korrektur Markov-Matrizen/ revision of Markov-Matrices, Ergänzungen Kapitel 2.1.2	9994
Rev.00	02.03.2015	A.E. Dang	Erstellt / *Created*	9994

INHALTSVERZEICHNIS / *TABLE OF CONTENT*

1. ALLGEMEINES / *GENERAL*

1.1 Gültigkeitsbereich / *Scope*

Diese Lastspezifikation stellt die Basisinformation für die Bemessung von Fundamenten für folgende Windenergieanlage der Firma Nordex dar. Darin sind die technischen Basisdaten sowie die Bemessungslasten für die Klimatischen Bedingungen NCV & CCV enthalten.

This specification serves as input information for the design of foundations for the following Nordex wind turbine. Therefore it defines its main parameters and the design loads for the different climate conditions NCV & CCV.

Typ / T*ype*: **N117/2400**
Nabenhöhe / *Hub height*: **91m**
Turm / *Tower*: **R91opt**
Windklasse / *Wind class*: **IEC3a/DIBt2**
Rotorblätter / *Rotor blades*: **NR58.5**

1.2 Referenzen / *References*

Dokumentennr., Revision, Ausgabe / ***Document Number, Rev. / Edition***	**Bezeichnung** / ***Description***
	Nordex Dokumente / ***Nordex Specifications***
K0817_031613_DE_R00	Lastbericht_N117_R91MT_NR585_DIBt2
K0817_031786_DE_R00	Lastbericht_N117_R91MT_NR585_IEC3a
K0817_031788_DE_R00	Lastbericht_CCV_N117_R91MT_NR585_IEC3A
K0802_055079_DE	Bemessung Stahlrohrturm N117 R91 opt TiT
K0802_055131_DE	Bemessung Stahlrohrturm N117 R91 opt TaT
	Normen / ***Standards***
GL IV-1:Edition 2010	Guideline for the certification of wind turbines. Hamburg : Germanischer Lloyd WindEnergie, 2010
EN 1998-1:2010	Eurocode 8 - Design of structures for earthquake resistance Part 1: General rules, Seismic action and rules for buildings
IEC 61400-1 (Ed.3)	Windturbine generator systems. Part 1: Safety requirements
DIBt RiLi 2012-10	DIBt Richtlinie für Windenergieanlagen - Einwirkungen und Standsicherheitsnachweise für Turm und Gründung

2 LASTEN / *LOADS*

2.1 Technische Basisdaten / *Parameters*

f_0 [Hz] =	**0.276**	1. Biegeeigenfrequenz / *First eigenfreqency in bending*
$k_{\varphi,dyn}$ [MNm/rad] =	**110000**	berücksichtigte Bodendrehfeder / *respective rotating spring rate*
$k_{\varphi,stat}$ [MNm/rad] =	**27500**	statische Bodendrehfeder / *static rotating spring rate*
Schiefstellung Turm [mm/m] / Inclination tower [mm/m] =	**10.1**	
h_{TB} [m] =	**1.1**	Höhe Unterkante Turmfuß über Geländeoberkante / *Position of tower bottom respective to top ground surface*
m_{tower} [t] =	**ca. 186**	Turmmasse inkl. Einbauten / *Mass of tower incl. Tower interiors*
$m_{nacelle}$ [t] =	**ca. 147**	Gondelmasse (inkl. Rotorblätter) / *Total mass of nacelle incl. blades*

2.1.1 Bedingungen für Erdbeben / *Earthquake conditions*

Norm / *Standard*: EN 1998-1:2010

Bodenklasse / *Soil class*: **A, B, C, D, E**

a [m/s²] =	**0.3*g**	(DIBt)	Bodenbeschleunigung / *peak ground acceleration (PGA)*
a [m/s²] =	**0.3*g**	(IEC)	Bodenbeschleunigung / *peak ground acceleration (PGA)*

2.1.2 Klimatische Bedingungen / *Climate conditions*

NCV : Normal climate version (englisch). "Normal climate" bedeutet volle Produktion bis -10°C und Stillstand bzw. Trudeln zwischen -10°C und -20°C./ *"Normal climate" is defined as full production down to -10°C and/or idling between -10°C and -20°C.*

CCV : Cold climate version (englisch). "Cold climate" bedeutet volle Produktion bis -10°C, reduzierte Produktion zwischen -10°C und -30°C und Stillstand bzw. Trudeln zwischen -30°C und -40°C./ *"Cold climate" is defined as reduced production between -10°C and -30°C and standstill or idling between -30°C and -40°C.*

Die jeweils maßgebenden Lasten aus NCV und CCV Lasten sind bei der Fundamentauslegung zu berücksichtigen./ *The decisive load cases from NCV and CCV loads have to be considered for the foundation design.*

2.2 Zusammenfassung der Lasten / *Summary of Loads*

2.2.1 Extremlasten / *Extreme Loads*

System TB Definition: Turmfuß / *Tower Bottom*

Extremlasten (absolute Maxima) inkl. Erdbebenlastfälle inkl. Sicherheit /
Extreme Loads (absolute maxima) *incl. earthquake + synchrone components (including safety-factors)*

LC	LC-Def.	FXTB	MXTB	FYZTB	MYZTB	ΔMres	M_{res}	γ_f
		kN	kNm	kN	kNm	[kNm]	[kNm]	-
8.1	08010000_ZY_D_0_17_01_(N117_F	**5560**	759	88	6325	2783 *	9108	1.65
2.1	02010204_ZY_A_20_10_(50)_(N117	4835	**-5715**	297	27963	2783 *	30746	1.35
2.2	02020204_ZZ_A_20_10_(60)_(N117	3956	-837	**898**	75189	2783 *	77971	1.10
1.5	01050000_ZY_B_0_10_(N117_R91I	4737	531	828	**75398**	2783 *	**78180**	1.35

Extremlasten (absolute Maxima) inkl. Erdbebenlastfälle exkl. Sicherheit /
Extreme Loads (absolute maxima) *incl. earthquake + synchrone components (excl. safety-factors)*

LC	LC-Def.	FXTB	MXTB	FYZTB	MYZTB	ΔMres	M_{res}	γ_f
		kN	kNm	kN	kNm	[kNm]	[kNm]	-
5.2	05020000_ZZ_B_08_01_(60)_(N117	**4625**	-3	292	23939	2783 *	26722	1.00
2.2	02020204_ZZ_B_10_07_(60)_(N117	3560	**-5042**	92	7976	2783 *	10759	1.00
5.2	05020000_ZZ_B_08_13_(60)_(N117	3610	38	**885**	47482	2783 *	50264	1.00
2.2	02020204_ZZ_A_20_10_(60)_(N117	3597	-788	814	**68427**	2783 *	**71209**	1.00

Extremlasten (absolute Maxima) exkl. Erdbebenlastfälle inkl. Sicherheit /
Extreme Loads (absolute maxima) *excl. earthquake + synchrone components (incl. safety-factors)*

LC	LC-Def.	FXTB	MXTB	FYZTB	MYZTB	ΔMres	M_{res}	γ_f
		kN	kNm	kN	kNm	[kNm]	[kNm]	-
8.1	08010000_ZY_D_0_17_01_(N117_F	**5560**	759	88	6325	2783 *	9108	1.65
2.1	02010204_ZY_A_20_10_(50)_(N117	4835	**-5715**	297	27963	2783 *	30746	1.35
2.2	02020204_ZZ_A_20_10_(60)_(N117	3956	-837	**898**	75189	2783 *	77971	1.10
1.5	01050000_ZY_B_0_10_(N117_R91I	4737	531	828	**75398**	2783 *	**78180**	1.35

Extremlasten (absolute Maxima) exkl. Erdbebenlastfälle exkl. Sicherheit /
Extreme Loads (absolute maxima) *excl. earthquake + synchrone components (excl. safety-factors)*

LC	LC-Def.	FXTB	MXTB	FYZTB	MYZTB	ΔMres	M_{res}	γ_f
		kN	kNm	kN	kNm	[kNm]	[kNm]	-
6.5	06050000_ZY_A_0_39_(N117_R91I	**4625**	-3	292	23939	2783 *	26722	1.00
2.2	02020204_ZY_B_10_11_(50)_(N117	3560	**-5042**	92	7976	2783 *	10759	1.00
2.2	02020204_ZZ_A_20_10_(60)_(N117	3610	38	**885**	47482	2783 *	50264	1.00
2.2	02020204_ZZ_A_20_10_(60)_(N117	3597	-788	814	**68427**	2783 *	**71209**	1.00

*) maximaler ΔMres- Wert aus Vorauslegung N117 R91opt IEC3a/DIBt2 / max ΔMres value from preliminary design N117 R91opt IEC3a/DIBt2 K0802_055079_DE und K0802_055131_DE

Ständige Lasten (klaffende Fuge) für eine Überschreitenswahrscheinlichkeit von 1750 Stunden in 20 Jahren nach DIBt- Richtlinie 2012-10 Kap. 12.2.3.2
Permanent Loads (gaping joint) for an exceedance probability of 1750 hours in 20 years acc. to DIBt 2012-10, chapter 12.2.3.2

FXTB	FYZTB	MXTB	MresTB
[kN]	[kN]	[kNm]	[kNm]
3780	424	1664	39647

2.2 Zusammenfassung der Lasten / *Summary of Loads*

2.2.1 Extremlasten CCV / *Extreme Loads CCV*

System TB Definition: Turmfuß / *Tower Bottom*

Extremlasten (absolute Maxima) inkl. Erdbebenlastfälle inkl. Sicherheit /
Extreme Loads (absolute maxima) *incl. earthquake + synchrone components (including safety-factors)*

LC	LC-Def.	FXTB	MXTB	FYZTB	MYZTB	ΔMres	M_{res}	γ_f
		kN	kNm	kN	kNm	[kNm]	[kNm]	-
7.1	N_CCV_07010000_ZY_F_30_01	**5046**	-2062	200	11134	2783 *	13917	1.10
6.2	N_CCV_06020000_ZY_T_37_01	3914	**4701**	479	39622	2783 *	42405	1.10
6.2	N_CCV_06020000_ZY_A_37_01	3891	-2888	**732**	61910	2783 *	64693	1.10
6.2	N_CCV_06020000_ZY_A_37_01	3888	-2907	729	**62058**	2783 *	**64841**	1.10

Extremlasten (absolute Maxima) inkl. Erdbebenlastfälle exkl. Sicherheit /
Extreme Loads (absolute maxima) *incl. earthquake + synchrone components (excl. safety-factors)*

LC	LC-Def.	FXTB	MXTB	FYZTB	MYZTB	ΔMres	M_{res}	γ_f
		kN	kNm	kN	kNm	[kNm]	[kNm]	-
7.1	N_CCV_07010000_ZY_F_30_01	**3738**	-1527	148	8248	2783 *	11030	1.00
6.2	N_CCV_06020000_ZY_T_37_01	3558	**4274**	435	36020	2783 *	38803	1.00
6.2	N_CCV_06020000_ZY_A_37_01	3537	-2625	**666**	56282	2783 *	59064	1.00
6.2	N_CCV_06020000_ZY_A_37_01	3535	-2643	663	**56417**	2783 *	**59199**	1.00

Extremlasten (absolute Maxima) exkl. Erdbebenlastfälle inkl. Sicherheit /
Extreme Loads (absolute maxima) *excl. earthquake + synchrone components (incl. safety-factors)*

LC	LC-Def.	FXTB	MXTB	FYZTB	MYZTB	ΔMres	M_{res}	γ_f
		kN	kNm	kN	kNm	[kNm]	[kNm]	-
7.1	N_CCV_07010000_ZY_F_30_01	**5046**	-2062	200	11134	2783 *	13917	1.10
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6.2	N_CCV_06020000_ZY_A_37_01	3891	-2888	**732**	61910	2783 *	64693	1.10
6.2	N_CCV_06020000_ZY_A_37_01	3888	-2907	729	**62058**	2783 *	**64841**	1.10

Extremlasten (absolute Maxima) exkl. Erdbebenlastfälle exkl. Sicherheit /
Extreme Loads (absolute maxima) *excl. earthquake + synchrone components (excl. safety-factors)*

LC	LC-Def.	FXTB	MXTB	FYZTB	MYZTB	ΔMres	M_{res}	γ_f
		kN	kNm	kN	kNm	[kNm]	[kNm]	-
7.1	N_CCV_07010000_ZY_F_30_01	**3738**	-1527	148	8248	2783 *	11030	1.00
6.2	N_CCV_06020000_ZY_T_37_01	3558	**4274**	435	36020	2783 *	38803	1.00
6.2	N_CCV_06020000_ZY_A_37_01	3537	-2625	**666**	56282	2783 *	59064	1.00
6.2	N_CCV_06020000_ZY_A_37_01	3535	-2643	663	**56417**	2783 *	**59199**	1.00

*) maximaler ΔMres- Wert aus Vorauslegung N117 R91opt IEC3a/DIBt2 / max ΔMres value from preliminary design N117 R91opt IEC3a/DIBt2 K0802_055079_DE und K0802_055131_DE

Ständige Lasten (klaffende Fuge) für eine Überschreitenswahrscheinlichkeit von 1750 Stunden in 20 Jahren nach DIBt- Richtlinie 2012-10 Kap. 12.2.3.2
Permanent Loads (gaping joint) for an exceedance probability of 1750 hours in 20 years acc. to DIBt 2012-10, chapter 12.2.3.2

FXTB	FYZTB	MXTB	MresTB
[kN]	[kN]	[kNm]	[kNm]
3780	424	1664	39647

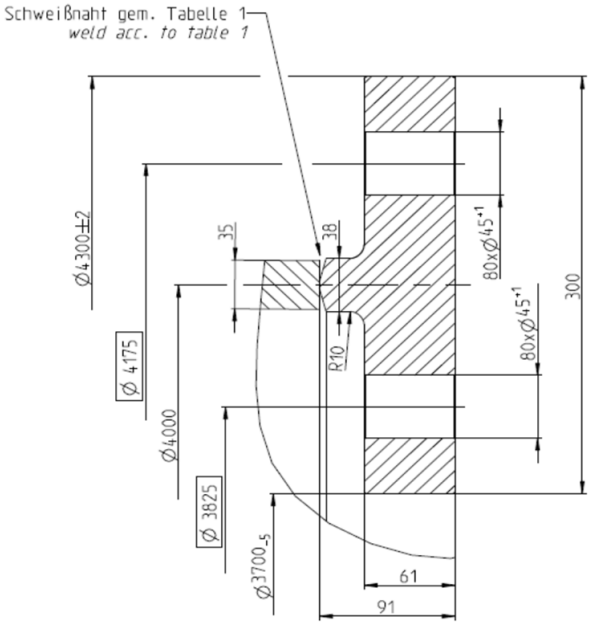
2.2.3 Betriebslasten Turmfuß / *Fatigue Loads Tower bottom*

Betriebslasten Schädigungsäquivalente ESK / ***Fatigue Loads*** *Damage Equivalent Load Spectrum*					
N	**m**	**FXTB**	**FZTB**	**MXTB**	**MYTB**
Lastspiele *Cycles*		kN	kN	kNm	kNm
1.00E+07	3	109	338	3900	22400
1.00E+07	4	86	300	3367	21661
1.00E+07	5	78	294	3235	22105
1.00E+07	6	75	298	3250	22923
1.00E+07	7	75	306	3325	23913
1.00E+07	8	75	317	3425	25027
1.00E+07	9	77	330	3534	26250
1.00E+07	10	78	345	3646	27563
1.00E+07	11	80	361	3767	28929
1.00E+07	12	82	377	3898	30304
gamma-f - FAT		1.0	1.0	1.0	1.0
Mittellast *Mean load*		3537	254	30	21944

Die RFCs und Markov-Matrizen werden bei Bedarf als Excel-Datei beigefügt. /
The rain flow counts (RFCs) and Markov-matrices will be attached as excel-files if required.

3. TURMANBINDUNG / CONNECTION TO THE TOWER

Voraussichtliche Anbindung an den Turm



CLEANRATH WIND FARM

Formation Approval Report T6, T7, T9, T10

N117-3600 IEC2a Foundations

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Document History

Doc Name	Rev	Details	Author	Checked	Approved
CNRH r027.2	A	Initial Issue	Cormac Ó Dubhthaigh	John Shanahan	Cormac Ó Dubhthaigh
CNRH r027.2	B	Turbine numbering modified	Niamh Moore	Cormac Ó Dubhthaigh	Cormac Ó Dubhthaigh

CNRH r027.2 Cleanrath N117-3600 IEC2a Formation Approval Report RevB

Confidentiality

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Addressee

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Disclaimer

Ionic Consulting have performed the consultancy services as described in this report in accordance with a standard of best practice available within the industry. Ionic Consulting do not make any representations or warranty, expressed or otherwise as to the accuracy or completeness of the source data used in this report, and nothing contained herein is, or shall be relied upon, as a promise or representation, whether as to the past or the future in respect of that source data.

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CONTENTS

1. INTRODUCTION

Ionic Consulting was appointed by Mid Cork Electrical Ltd. to carry out formation approval for all wind turbine foundation bases at Cleanrath Wind Farm in Co. Cork. The wind farm comprises 15 no. Nordex turbines, including 6 no. N100 3.3MW 100mHH Class IEC1a turbines, 4 no. N117 91mHH 3.6MW Class IEC2a turbines and 5 no. N117 91mHH 2.4MW Class IEC3a turbines.

This report relates to the 4 N117 3.6MW IEC2a turbines which are numbered T6, T7, T9 and T10.

The N117-3600 turbines are located in the western portion of the eastern cluster at Cleanrath, whereas the remaining N117 turbines are located to the east of that cluster and the N100 turbines are in a separate cluster 2km to the west at Derragh. The project includes the two clusters but is collectively known as Cleanrath Wind Farm.

As part of the site supervision works, Ionic assessed the founding formation strata for all gravity bases to ensure it met the required design criteria. This report summarises the ground conditions encountered within each of the turbine foundation excavations and has been prepared with reference also to the Geotechnical Investigation Report CNRH r007.1 undertaken by Ionic Consulting. The inspections undertaken at each formation location included a visual inspection, assessment of levels and widths, photographic recording and in-situ plate bearing testing where required.

Ionic previously carried out a detailed design of the turbine foundations based on the Nordex N117 91mHH 3.6MW Class IEC2a wind loading documents and insert arrangements details, coupled with the site investigation data detailed in the aforementioned geotechnical report.

A foundation design report has been produced alongside the foundation calculations covering the structural and geotechnical analysis of the site conditions.

Note that this document has been updated for the purposes of inclusion in a Remedial Environmental Impact Assessment Report for Cleanrath Wind Farm as part of a substitute consent application to An Bord Pleanála. The updates to the document relate only to the turbine numbering where it reverts to the original numbering system used when the project was originally proposed for planning permission.

2. FOUNDATION DESIGN

The initial geotechnical investigations were undertaken by Ionic Consulting in April-May 2019, including a site walkover and assessment of earlier site investigation documents from planning stage. The detailed geotechnical investigation consisted of borehole drilling at a total of 7 locations and was carried out between March and April 2019, along with physical and chemical testing of samples taken. Due to ground conditions which include extensive rock outcrop on higher ground a number of turbine locations were selected for borehole drilling thereby providing a representative outline of ground conditions across the site. The chosen turbine locations ensured that boreholes were carried out in each sub-cluster and for each turbine type. The borehole drilling confirmed findings of shallow bedrock at most locations as generally encountered during initial base excavations. The borehole relevant to this report was drilled at turbine T9. The borehole logs and laboratory testing results are provided in the appendices of the Geotechnical Investigation Report *(CNRH r007.1)*. The information gathered during the geotechnical investigations assisted the designers in the design of the wind turbine foundations, and at formation approval stage any assumptions on strength and stiffness were confirmed.

Wind loads used in the design of the foundation are detailed within Nordex N117 91mHH 3.6MW Class IEC2a loading document ref: K0822_077548_IN_3_EC05_IN_Fundament-N117-3600-TS91-IEC2a-DIBt3. One standard partially buoyant gravity foundation design was provided for these 4 turbine locations T6, T7, T9 and T10 based upon the ground conditions encountered and the high groundwater table. The level of the buoyant gravity base is set with the underside of tower bottom section at +1.1m relative to original ground level, and the design water level is taken as original ground level which results in a partially submerged scenario for the foundation. The ultimate design bearing resistance was conservatively estimated based on the ground investigation data to be greater than 500kN/m^2 for the siltstone bedrock at formation level. Given the shallow depth to bedrock at these locations direct blinding on bedrock is proposed with no additional engineering fill material required to bring it to foundation level. The maximum applied bearing pressure at ultimate loads ranged from 115 to 142kN/m^2 for the gravity foundations, all well below the ultimate bearing capacity.

Site inspections were carried out on each formation to confirm these findings, as described in detail in the following chapters. Plate testing to confirm stiffness and estimate strength was not required given the visually evident strength and stiffness of shallow bedrock which required rock breaking to excavate.

3. FORMATION INSPECTIONS

3.1 General Details

The formation strata of each proposed turbine base, was inspected by a suitably qualified Engineer from Ionic Consulting between the 9th of April 2019 and the 26th of June 2019.

Each turbine formation excavation was logged and photographed in accordance with BS5930, IS EN 1997 (Eurocode 7) and Site Investigation Steering Group (SISG) recommendations published in the "Specification of Ground Investigations" published by the ICE (1993).

Full details and photographs are given in the formation inspection log sheets provided in Appendix A of this report.

3.2 Ground Conditions

The ground conditions encountered during the inspections generally confirmed the findings of earlier geotechnical investigations. The following ground conditions were encountered during trial pitting and borehole drilling and broadly confirmed during the turbine formation inspections:

3.2.1 Superficial Geology

Within the trial pits and boreholes at N117-3600 gravity base locations the superficial deposits consisted generally of shallow peat with rootlets ranging in depth from 0.2m to 0.6m.

3.2.2 Solid Geology

According to the GSI National Generalised Bedrock Map, and the 100k Solid Geology Map, the substation site is predominantly underlain by purple siltstone and fine sandstone of the Bird Hill Formation

Weathered or intact solid bedrock was generally encountered during excavation and drilling within the minimum required founding depth for the turbine foundation of 1.8m below original ground level at each of the 4 bases. Formation strata at T6, T7, T9 and T10 were therefore generally on weathered or intact siltstone at 1.8m bgl relative to the centre of the turbine but varying otherwise with the crossfall.

3.2.3 Groundwater

Groundwater was encountered at a shallow level during excavation and borehole drilling, therefore buoyant bases were adopted for all turbine locations. Note that as Nordex N117 tower bottom sections are set at +1.1m relative to original ground level the design water level is set 917mm below the top of ballast level at original ground level. Technically therefore a partially buoyant gravity base is provided as the upper ballast which is above original ground level is not considered under a submerged scenario.

3.3 Summary

In principal the following table summarises the geology of the formation strata encountered during the formation inspections.

WTG	Formation Strata Description
T6	SILTSTONE bedrock
T7	SILTSTONE bedrock
T9	SILTSTONE bedrock
T10	SILTSTONE bedrock

Table 3.1 **Summary of formation level conditions – N117-3600 formations**

4. IN SITU TESTING

Based upon the conditions encountered detailed in-situ tests were not required on the excavated formations. Generally plate testing would be carried out to validate and quantify the findings of the geotechnical testing which in this case included trial holes and borehole drilling, however it was considered of limited value as the formations were on intact bedrock where no displacements would occur. Similarly due to direct leanmix concrete blinding on bedrock there was no 6N engineering upfill required and therefore no associated plate testing in layers to confirm compaction.

By inspection the strength of each of the turbine formations on siltstone bedrock was well in excess of the required minimum bearing capacity.

Similarly the stiffness of the underlying siltstone bedrock is well above the required minimum stiffness and the static rotational stiffness ($K_{\Phi stat}$) and dynamic rotational stiffness ($K_{\Phi dyn}$) is well in excess of the minimum required stiffness of 22,500MNm/rad and 90,000MNm/rad respectively.

The values shown in *Table 4.1* below indicate the estimated rotational stiffness on siltstone bedrock based on published lower bound values for elastic modulus of siltstone of 3000MPa.

Foundation Type	**Diameter**	**Estimated Elastic Modulus**	**Estimated Rotational Stiffness**	**Min Required Rotational Stiffness (Nordex document)**
	(m)	(MN/m2)	(MNm/rad)	(MNm/rad)
Nordex N117 91m HH IEC2a	21.8	3000	6,495,000	90,000

Table 4.2 Summary of Rotational Stiffness – N117-3600 formations

5. SUMMARY

Based on the formation inspections it is concluded that the turbine foundations are founded on strata capable of meeting the performance criteria specified in the turbine foundation calculations for Nordex N117 91mHH 3.6MW Class IEC2a turbines.

The bearing capacity and rotational stiffness requirements have been satisfied.

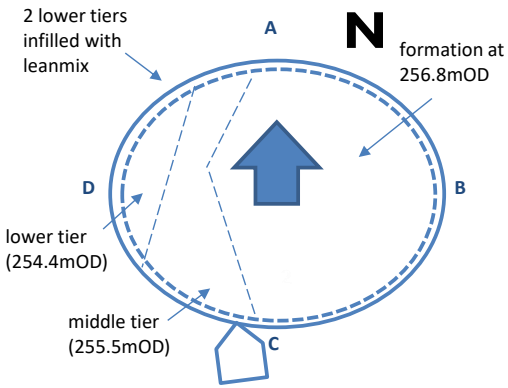
Certificates associated with the formation inspection are included in Appendix B of this report.

APPENDICES

APPENDIX A – Formation Inspection Log Sheets

FORMATION INSPECTION SHEET

Report Ref CNRH r027.2

A		B		C		D	
Depth (m)	Description	Depth	Description	Depth	Description	Depth	Description
0.00 - 0.20	Dark brown fibrous PEAT	0.00 - 0.20	Dark brown fibrous PEAT	0.00 - 0.20	Dark brown fibrous PEAT	0.00 - 0.20	Dark brown fibrous PEAT
0.20 - 0.50	Weathered siltstone	0.20 - 0.50	Weathered siltstone	0.20 - 0.50	Weathered siltstone	0.20 - 0.50	Weathered siltstone
0.50 - 2.80	Strong thinly laminated purple fine and medium grained SILTSTONE	0.50 - 5.00	Strong thinly laminated purple fine and medium grained SILTSTONE	0.50 - 3.10	Strong thinly laminated purple fine and medium grained SILTSTONE	0.50 - 0.70	Strong thinly laminated purple fine and medium grained SILTSTONE
 ***Figure1: North Direction, Ramp and Plate Load Test Locations***		Engineer	C Ó Dubhthaigh	Water	Some surface water locally within the lower tiers within angular ridges of rock where all overburden material was excavated. Suitable fall to west for gravity drainage, water displaced or pumped out prior to placement of leanmix.	Notes (cont'd)	Direct blinding on bedrock across 3/4 of the footprint area at a level of 256.8mOD, remaining area to west infilled to same level with dry leanmix concrete in two lower tiers of 255.5mOD and 254.4mOD. Initially dry leanmix brought to the level of the bedrock to the east before wet leanmix laid across the entire footprint area to provide the blinding surface for foundation construction. Leanmix placed with maximum shoulder slope of 45 degrees, with surrounding quarry run material. Bedrock level on outside edge of lower tier up to 0.4m higher locally providing additional keyed support to leanmix. Plate tests not required due to formation on solid bedrock on east and leanmix infill to west.
		Date	26/06/2019				
		Tests	No Plate Bearing Tests required (solid bedrock)				
		Conducted	N/A				
		Ref	N/A				
		Easting	119466	Notes	Minimum 11.3m radius with steep rockface on east up to 5m. Significant crossfall in excess of 7m across the excavated formation area, therefore two lower tiers introduced with steps of 1.3m and 1.1m below the broader formation level, resulting in a radius up to 13.7m on west.		
		Northing	69620				
		Level	256.8mOD				

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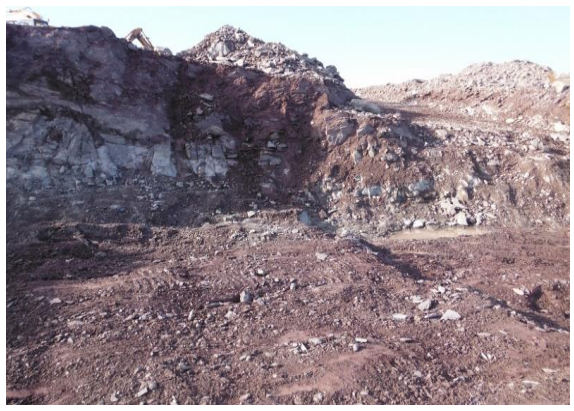
FORMATION PHOTOGRAPHS

Report Ref CNRH r027.2

North Wall

East Wall



South Wall

West Wall

Lower tiers to west benched horizontally, higher point locally on west edge of lower tier (RHS in photo)

Placement of leanmix infill to northwest

Placement of leanmix on lower tiers to west

Final blinded formation area being prepared

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Carrickmines
Dublin 18
Ireland

Project	CLEANRATH WIND FARM	Base	T6

FORMATION INSPECTION SHEET

Report Ref CNRH r027.2

A		B		C		D	
Depth (m)	Description	Depth	Description	Depth	Description	Depth	Description
0.00 - 0.30	Dark brown fibrous PEAT or topsoil	0.00 - 0.30	Dark brown fibrous PEAT	0.00 - 0.30	Dark brown fibrous PEAT	0.00 - 0.30	Dark brown fibrous PEAT
0.30 - 2.80	Strong thinly laminated purple fine and medium grained SILTSTONE	0.30 - 3.80	Strong thinly laminated purple fine and medium grained SILTSTONE	0.30 - 2.40	Strong thinly laminated purple fine and medium grained SILTSTONE	0.30 - 1.20	Strong thinly laminated purple fine and medium grained SILTSTONE

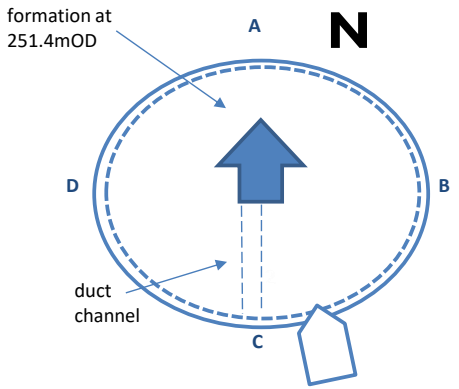

Figure1: North Direction, Ramp and Plate Load Test Locations

Engineer	C Ó Dubhthaigh
Date	20/05/2019
Tests	No Plate Bearing Tests required (solid bedrock)
Conducted	N/A
Ref	N/A
Easting	119610
Northing	69250
Level	251.4mOD

Water	Minimal surface water ponding locally but more significantly within the duct channel, to be pumped prior to duct and leanmix placement. Suitable fall to west for gravity drainage from foundation level. All bases designed for buoyant conditions to original ground level.
Notes	22.5m diameter circle with steep rockface primarily to the east. Significant crossfall downslope to west - southwest. Plate tests not required due to formation on solid bedrock.

Notes (cont'd)	Channel excavated from centre of base to south to enable cable ducting to be placed. Channel to be infilled with dry leanmix after placement of ducts. Entire footprint area then to be blinded with leanmix concrete to provide the required blinding for foundation construction.

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Project	Base
CLEANRATH WIND FARM	**T7**

FORMATION PHOTOGRAPHS

Report Ref CNRH r027.2

North Wall

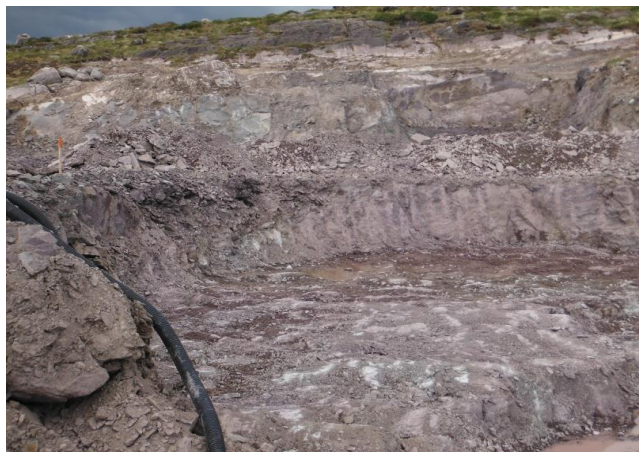
East Wall

South Wall

West Wall

View across entire formation area

Bedrock profile and local undulations



High bedrock to east

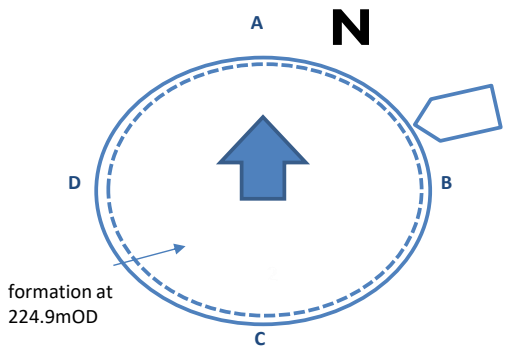
View looking northwest towards T7

Ionic Consulting The Hyde Building The Park Carrickmines Dublin 18 Ireland	Project	**CLEANRATH WIND FARM**	Base	**T7**

FORMATION INSPECTION SHEET

Report Ref CNRH r027.2

A		B		C		D	
Depth (m)	Description	Depth	Description	Depth	Description	Depth	Description
0.00 - 0.30	Dark brown fibrous PEAT	0.00 - 0.30	Dark brown fibrous PEAT	0.00 - 0.30	Dark brown fibrous PEAT	0.00 - 0.30	Dark brown fibrous PEAT
0.30 - 2.60	Strong thinly laminated purple fine and medium grained SILTSTONE	0.30 - 2.20	Strong thinly laminated purple fine and medium grained SILTSTONE	0.30 - 0.90	Strong thinly laminated purple fine and medium grained SILTSTONE	0.30 - 2.20	Strong thinly laminated purple fine and medium grained SILTSTONE



formation at 224.9mOD

Figure1: North Direction, Ramp and Plate Load Test Locations

Engineer	C Ó Dubhthaigh
Date	09/04/2019
Tests	No Plate Bearing Tests required (solid bedrock)
Conducted	N/A
Ref	N/A
Easting	119952
Northing	68981
Level	224.9mOD

Water

Significant ponding of water following heavy rainfall. Perimeter drainage channel not excavated through bedrock for construction stage. Dewatering required by pumping prior to placement of engineering fill and leanmix.

Notes

23m diameter circle with steep rockface on 3 sides, shallow to south due to bedrock crossfall, low point to south. Due to the crossfall and the nature of rock breaking additonal leanmix up to 300mm required to bring to required foundation level. Plate tests not required due to formation on solid bedrock across the entire footprint area.

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Project

CLEANRATH WIND FARM

Base

T9

FORMATION PHOTOGRAPHS

Report Ref CNRH r027.2

North Wall

East Wall

South Wall

West Wall

Formation area viewed from hardstanding

Pooling of water prior to pumping

Bedrock profile indicating extent of rock breaking

Formation on solid bedrock

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Project	CLEANRATH WIND FARM	Base	T9

FORMATION INSPECTION SHEET

Report Ref CNRH r027.2

A		B		C		D	
Depth (m)	Description	Depth	Description	Depth	Description	Depth	Description
0.00 - 0.30	Dark brown fibrous PEAT	0.00 - 0.30	Dark brown fibrous PEAT	0.00 - 0.80	Dark brown fibrous PEAT	0.00 - 0.30	Dark brown fibrous PEAT
0.30 - 5.20	Strong thinly laminated purple fine and medium grained SILTSTONE	0.30 - 1.80	Strong thinly laminated purple fine and medium grained SILTSTONE	0.80 - 2.20	Loose clayey sandy gravels and cobbles of sandstone and siltstone	0.30 - 1.80	Strong thinly laminated purple fine and medium grained SILTSTONE
				2.20 - 2.40	Strong thinly laminated purple fine and medium grained SILTSTONE		

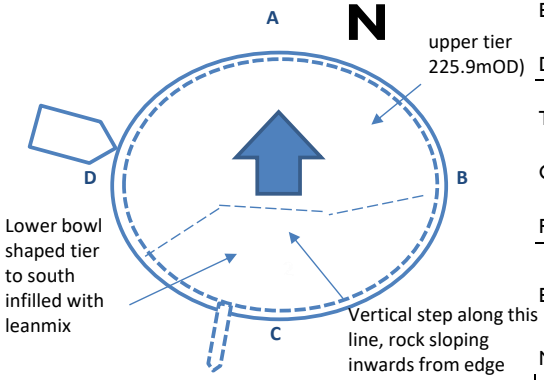

Figure1: North Direction, Ramp and Plate Load Test Locations

Engineer	C Ó Dubhthaigh
Date	01/07/2019
Tests	No Plate Bearing Tests required (solid bedrock)
Conducted	N/A
Ref	N/A
Easting	120288
Northing	68725
Level	225.9mOD

Water	Some surface water ponding within the bowl shaped lower tier. Bedrock level rises outward from centre of lower tier thereby trapping the surface water; bedrock at southern edge not broken out in order to retain the structural integrity and support provided to the sub-formation. To be drained by directly pumping prior to infilling with leanmix concrete.
Notes	Minimum 23m diameter circle provided with steep rockface to north of up to 5m. Significant crossfall and undulations in bedrock level across the foundation footprint area. Entire area excavated to bedrock, with lower tier provided due to local soft spots in south and central areas.

Notes (cont'd)	Direct blinding on bedrock at foundation level across >2/3 of the footprint area, remaining areas generally to south to be infilled with leanmix concrete to bring to the same level 225.9mOD. A step of up to 1.6m with squared vertical edge provided, however the bedrock level within the lower tier rises radially outwards from the centre of the base, thereby effectively resulting in a basin providing additional lateral support on all sides to the leanmix infill. Initially dry leanmix brought to the level of the upper bedrock level to north before wet leanmix laid across the entire footprint area to provide the blinding surface for foundation construction.

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Project	**CLEANRATH WIND FARM**
Base	**T10**

FORMATION PHOTOGRAPHS

Report Ref CNRH r027.2

North Wall

East Wall

South Wall

West Wall

Significant rock breaking into rock face to north

Rock breaking along north face

Overall view indicating bedrock throughout

Final clearing out of loose rock prior to leanmix infill of low points to south

Ionic Consulting The Hyde Building The Park Carrickmines Dublin 18 Ireland	Project	**CLEANRATH WIND FARM**	Base	**T10**

APPENDIX B – Formation Approval Certificates

IONIC CONSULTING LTD

FORMATION APPROVAL

Project :	**Cleanrath Wind Farm**		
Turbine	**T6**		
Reference:	**CNRH r027.2 Appendix B**	Date :	**26 June 2019**
Contractor/Client :	**Mid Cork Electrical Limited**		
Formation Report Reference	**CNRH r027.2 RevB**		

The formation associated with the above foundation has been inspected and tested in accordance with the contract specification, foundation design and WTG suppliers requirements and found to meet said requirements. Remedial or construction actions instructed at the time of excavation and inspection have been conducted by the contractor to the approval of Ionic Consulting.

Signed

Cormac Ó Dubhthaigh

BE MEngSc CEng MIEI

Civil Engineering Manager

Ionic Consulting

Approved

Cormac Ó Dubhthaigh

BE MEngSc CEng MIEI

Civil Engineering Manager

Ionic Consulting

IONIC CONSULTING LTD

FORMATION APPROVAL

Project :	**Cleanrath Wind Farm**		
Turbine	**T7**		
Reference:	**CNRH r027.2 Appendix B**	Date :	**20 May 2019**
Contractor/Client :	**Mid Cork Electrical Limited**		
Formation Report Reference	**CNRH r027.2 RevB**		

The formation associated with the above foundation has been inspected and tested in accordance with the contract specification, foundation design and WTG suppliers requirements and found to meet said requirements. Remedial or construction actions instructed at the time of excavation and inspection have been conducted by the contractor to the approval of Ionic Consulting.

Signed

Cormac Ó Dubhthaigh

BE MEngSc CEng MIEI

Civil Engineering Manager

Ionic Consulting

Approved

Cormac Ó Dubhthaigh

BE MEngSc CEng MIEI

Civil Engineering Manager

Ionic Consulting

IONIC CONSULTING LTD

FORMATION APPROVAL

Project :	**Cleanrath Wind Farm**		
Turbine	**T9**		
Reference:	**CNRH r027.2 Appendix B**	Date :	**9 April 2019**
Contractor/Client :	**Mid Cork Electrical Limited**		
Formation Report Reference	**CNRH r027.2 RevB**		

The formation associated with the above foundation has been inspected and tested in accordance with the contract specification, foundation design and WTG suppliers requirements and found to meet said requirements. Remedial or construction actions instructed at the time of excavation and inspection have been conducted by the contractor to the approval of Ionic Consulting.

Signed

Cormac Ó Dubhthaigh

BE MEngSc CEng MIEI

Civil Engineering Manager

Ionic Consulting

Approved

Cormac Ó Dubhthaigh

BE MEngSc CEng MIEI

Civil Engineering Manager

Ionic Consulting

IONIC CONSULTING LTD

FORMATION APPROVAL

Project :	**Cleanrath Wind Farm**		
Turbine	**T10**		
Reference:	**CNRH r027.2 Appendix B**	Date :	**26 June 2019**
Contractor/Client :	**Mid Cork Electrical Limited**		
Formation Report Reference	**CNRH r027.2 RevB**		

The formation associated with the above foundation has been inspected and tested in accordance with the contract specification, foundation design and WTG suppliers requirements and found to meet said requirements. Remedial or construction actions instructed at the time of excavation and inspection have been conducted by the contractor to the approval of Ionic Consulting.

Signed

Cormac Ó Dubhthaigh

BE MEngSc CEng MIEI

Civil Engineering Manager

Ionic Consulting

Approved

Cormac Ó Dubhthaigh

BE MEngSc CEng MIEI

Civil Engineering Manager

Ionic Consulting

APPENDIX C – Nordex N117-3600 loading & stiffness document

Fundament / *Foundation*

N117/3600 TS91 IEC2a/DIBt3

Rotorblatt / Rotor blades: NR58.5

Klimatische Bedingungen / *Climate conditions*: NCV & CCV

Dokumentnummer / *Document number*

K0822_077548_IN

Revision / *Revision*

03

Datum / *Date*

11.01.2017

Verantwortliche Abteilung / *Department responsible*

MTE / MTF

Klassifikation / *Classification*

Nordex intern (IP)

Status / *Status*

AST

10627

Ersatz für Revision / *Replaces Revision*

02

Ersteller / *Created*:

A. E. Dang/MTF

Prüfer / *Checked*:

A. Schröder/MTF

Freigabe / *Released*:

H. Timm/MTF

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ÄNDERUNGSINDEX / *REVISION INDEX*

Änderung / ***Revision***	**Datum** / ***Date***	**Bearbeiter** / ***Author***	**Modifikation (Sektion)** / ***Modification (Section)***	**AST**
Rev.03	11.01.2017	A.E. Dang	Ergänzung horizontale Wegfeder, redaktionelle Änderungen/ *addition of horizontal spring stiffness, editorial changes*	10627
Rev.02	02.12.2016	A.E.Dang	Korrektur Temperaturbereich Kapitel 2.1.2, Spezifikation Betonfestigkeitsklassen Kapitel 3/ *Modification temperature range chapter 2.1.2, specification concrete strength classes chapter 3*	10627
Rev.01	01.08.2016	A.E. Dang	Datum auf Deckblatt angepasst/ *modification date on 1st page*	10627
Rev.00	19.05.2016	A.E. Dang	Erstellt / *Created*	10627

INHALTSVERZEICHNIS / *TABLE OF CONTENT*

1. ALLGEMEINES / *GENERAL*

1.1 Gültigkeitsbereich / *Scope*

Diese Lastspezifikation stellt die Basisinformation für die Bemessung von Fundamenten für folgende Windenergieanlage der Firma Nordex dar. Darin sind die technischen Basisdaten sowie die Bemessungslasten für die Klimatischen Bedingungen NCV & CCV enthalten.

This specification serves as input information for the design of foundations for the following Nordex wind turbine. Therefore it defines its main parameters and the design loads for the different climate conditions NCV & CCV.

Typ / T*ype*: **N117/3600**
Nabenhöhe / *Hub height*: **91m**
Turm / *Tower*: **TS91**
Windklasse / *Wind class*: **IEC2a/DIBt3**
Rotorblätter / *Rotor blades*: **NR58.5**

1.2 Referenzen / *References*

Dokumentennr., Revision, Ausgabe / ***Document Number, Rev. / Edition***	**Bezeichnung** / ***Description***
	Nordex Dokumente / ***Nordex Specifications***
K0801_077633_EN R00	Technical Report Loads Report N117/3600 TS91 NR58.5 50/60Hz IEC2a(Ed.3) / DIBt3, NCV
K0801_077723_EN R00	Technical Report Loads Report N117/3600 TS91 NR58.5 50/60Hz IEC2a(Ed.3) CCV (Idling/CCV-B)
E0002857206_DE R00	Bemessung Stahlrohrturm N117/3600 TS91 TiT IEC2a/DIBt3
E0002864330_DE R00	Bemessung Stahlrohrturm N117/3600 TS91 TaT IEC2a/DIBt3
	Normen / ***Standards***
GL IV-1:Edition 2010	Guideline for the certification of wind turbines. Hamburg : Germanischer Lloyd WindEnergie, 2010
EN 1998-1:2010	Eurocode 8 - Design of structures for earthquake resistance Part 1: General rules, Seismic action and rules for buildings
IEC 61400-1 (Ed.3)	Windturbine generator systems. Part 1: Safety requirements
DIBt RiLi 2012-10	DIBt Richtlinie für Windenergieanlagen - Einwirkungen und Standsicherheitsnachweise für Turm und Gründung

Die referenzierten Dokumente dienen nur der Nordex-internen Dokumentation und werden für das Fundament-Design nicht benötigt.

The above-mentioned documents are only for Nordex internal use and not required for the foundation design.

2 LASTEN / *LOADS*

2.1 Technische Basisdaten / *Parameters*

f_0 [Hz] =	**0.240**	1. Biegeeigenfrequenz / *First eigenfreqency in bending*
$k_{\varphi,dyn}$ [MNm/rad] =	**90000**	berücksichtigte Bodendrehfeder / *respective rotating spring rate*
$k_{\varphi,stat}$ [MNm/rad] =	**22500**	statische Bodendrehfeder / *static rotating spring rate*
$k_{hor,dyn}$ [MN/m] =	**1180**	horizontale Wegfeder/ *horizontal spring stiffness*
Schiefstellung Turm [mm/m] / Inclination tower [mm/m] =	**11.1**	
h_{TB} [m] =	**1.1**	Höhe Unterkante Turmfuß über Geländeoberkante / *Position of tower bottom respective to top ground surface*
m_{tower} [t] =	**191**	Turmmasse inkl. Einbauten / *Mass of tower incl. Tower interiors*
$m_{nacelle}$ [t] =	**186.6**	Gondelmasse (inkl. Rotorblätter) / *Total mass of nacelle incl. blades*

2.1.1 Bedingungen für Erdbeben / *Earthquake conditions*

Norm / *Standard*: EN 1998-1:2010

Bodenklasse / *Soil class*: **A, B, C, D, E**

a [m/s²] =	**0.3*g**	(DIBt)	Bodenbeschleunigung / *peak ground acceleration (PGA)*
a [m/s²] =	**0.3*g**	(IEC)	Bodenbeschleunigung / *peak ground acceleration (PGA)*

2.1.2 Klimatische Bedingungen / *Climate conditions*

NCV : Normal climate version (englisch). "Normal climate" bedeutet Produktionsbetrieb bis -20°C und Stillstand bzw. Trudeln zwischen -20°C und -30°C./ *"Normal climate" is defined as production down to -20°C and standstill or idling between -20°C and -30°C.*

CCV : Cold climate version (englisch). "Cold climate" bedeutet Produktionsbetrieb bis -30°C und Stillstand bzw. Trudeln zwischen -30°C und -40°C./ *"Cold climate" is defined as production down to -30°C and standstill or idling between -30°C and -40°C*.

Die jeweils maßgebenden Lasten aus NCV und CCV Lasten sind bei der Fundamentauslegung zu berücksichtigen./ *The decisive load cases from NCV and CCV loads have to be considered for the foundation design.*

2.2 Zusammenfassung der Lasten / *Summary of Loads*

2.2.1 Extremlasten NCV / *Extreme Loads NCV*

System TB Definition: Turmfuß / *Tower Bottom*

Extremlasten (absolute Maxima) inkl. Erdbebenlastfälle inkl. Sicherheit /
Extreme Loads (absolute maxima) *incl. earthquake + synchrone components (including safety-factors)*

LC	LC-Def.	FXTB	FYZTB	MXTB	MYZTB	ΔMres	M_{res}	γ_f
	nur für interne Identifikation/ *for internal identification only*	kN	kN	kNm	kNm	kNm	kNm	-
8.1	IEC_Ed3_NCV_00_08010000_D_(	**5987**	117	-131	13175	3205 *	16380	1.60
5.2	IEC_Ed3_NCV_60_05020000_A_(	3567	**1318**	-826	58622	3205 *	61827	1.00
2.1	IEC_Ed3_NCV_60_02010204_B_(	5123	235	**9447**	15533	3205 *	18738	1.35
6.1	IEC_Ed3_NCV_00_06010000_C_(	4984	1034	-2908	**91564**	3205 *	**94769**	1.35

Extremlasten (absolute Maxima) inkl. Erdbebenlastfälle exkl. Sicherheit /
Extreme Loads (absolute maxima) *incl. earthquake + synchrone components (excl. safety-factors)*

LC	LC-Def.	FXTB	FYZTB	MXTB	MYZTB	ΔMres	M_{res}	γ_f
	nur für interne Identifikation/ *for internal identification only*	kN	kN	kNm	kNm	kNm	kNm	-
5.2	IEC_Ed3_NCV_50_05020000_A_(	**4628**	295	-732	30374	3205 *	33579	1.00
5.2	IEC_Ed3_NCV_60_05020000_A_(	3567	**1318**	-826	58622	3205 *	61827	1.00
2.2	IEC_Ed3_NCV_60_02020000_B_(	3721	217	**7385**	20750	3205 *	23955	1.00
2.3	IEC_Ed3_NCV_60_02030000_C_(	3909	825	-1510	**73814**	3205 *	**77019**	1.00

*) maximaler ΔMres- Wert aus Turmbemessung N117/3600 TS91 IEC2a/DIBt3 / max ΔMres value from tower design N117/3600 TS91 IEC2a/DIBt3

Ständige Lasten (klaffende Fuge) für eine Überschreitenswahrscheinlichkeit von 1750 Stunden in 20 Jahren nach DIBt- Richtlinie 2012-10 Kap. 12.2.3.2
Permanent Loads (gaping joint) for an exceedance probability of 1750 hours in 20 years acc. to DIBt 2012-10, chapter 12.2.3.2

	FXTB	FYZTB	MXTB	MYZTB
	kN	kN	kNm	kNm
50Hz DIBt3	4094	512	2237	46316
60Hz IEC2a	4095	513	2239	46420

Bemessungssituation nach DIN EN 1997-1 bzw. 1054
Design load cases according to EN 1997-1 and 1054

	FXTB	FYZTB	MXTB	MYZTB	ΔM_{res}	M_{res}	γ_f
	kN	kN	kNm	kNm	kNm	kNm	-
BS-P	4984	1034	-2908	91564	3205 *	94769	1.35
BS-T	4185	398	-798	36430	3205 *	39635	1.10
BS-A	4295	899	-1635	81020	3205 *	84225	1.10

2.2 Zusammenfassung der Lasten / *Summary of Loads*

2.2.2 Eingehüllte Extremlasten NCV und CCV / *Envelope Extreme Loads NCV and CCV*

System TB Definition: Turmfuß / *Tower Bottom*

Extremlasten (absolute Maxima) inkl. Erdbebenlastfälle inkl. Sicherheit /
Extreme Loads (absolute maxima) *incl. earthquake + synchrone components (including safety-factors)*

LC	LC-Def. nur für interne Identifikation/ *for internal identification only*	FXTB kN	FYZTB kN	MXTB kNm	MYZTB kNm	ΔMres [kNm]	M_{res} [kNm]	γ_f -
8.1	IEC_Ed3_NCV_00_08010000_D_01	**5987**	117	-131	13175	3205 *	16380	1.60
5.2	IEC_Ed3_NCV_60_05020000_A_01	3567	**1318**	-826	58622	3205 *	61827	1.00
2.1	IEC_Ed3_NCV_50_02010204_B_02	5050	400	**9463**	26690	3205 *	29895	1.35
6.1	IEC_Ed3_CCVi_00_06010000_C_01	4960	1057	-1870	**94207**	3205 *	**97412**	1.35

Extremlasten (absolute Maxima) inkl. Erdbebenlastfälle exkl. Sicherheit /
Extreme Loads (absolute maxima) *incl. earthquake + synchrone components (excl. safety-factors)*

LC	LC-Def. nur für interne Identifikation/ *for internal identification only*	FXTB kN	FYZTB kN	MXTB kNm	MYZTB kNm	ΔMres [kNm]	M_{res} [kNm]	γ_f -
5.2	IEC_Ed3_NCV_50_05020000_A_03	**4628**	295	-732	30374	3205 *	33579	1.00
5.2	IEC_Ed3_NCV_60_05020000_A_01	3567	**1318**	-826	58622	3205 *	61827	1.00
2.2	IEC_Ed3_NCV_60_02020000_B_02	3721	217	**7385**	20750	3205 *	23955	1.00
2.3	IEC_Ed3_CCVB_50_02030000_B_0	3900	895	-975	**81188**	3205 *	**84393**	1.00

*) maximaler ΔMres- Wert aus Turmbemessung N117/3600 TS91 IEC2a/DIBt3 / max ΔMres value from tower design N117/3600 TS91 IEC2a/DIBt3

Ständige Lasten (klaffende Fuge) für eine Überschreitenswahrscheinlichkeit von 1750 Stunden in 20 Jahren nach DIBt- Richtlinie 2012-10 Kap. 12.2.3.2
Permanent Loads (gaping joint) for an exceedance probability of 1750 hours in 20 years acc. to DIBt 2012-10, chapter 12.2.3.2

	FXTB kN	FYZTB kN	MXTB kNm	MYZTB kNm
50Hz DIBt3	4094	512	2237	46316
60Hz IEC2a	4095	513	2239	46420

Bemessungssituation nach DIN EN 1997-1 bzw. 1054
Design load cases according to EN 1997-1 and 1054

	FXTB kN	FYZTB kN	MXTB kNm	MYZTB kNm	ΔM_{res} kNm	M_{res} kNm	γ_f -
BS-P	4984	1034	-2908	91564	3205 *	94769	1.35
BS-T	4185	398	-798	36430	3205 *	39635	1.10
BS-A	4295	899	-1635	81020	3205 *	84225	1.10

2.2.3 Betriebslasten Turmfuß / *Fatigue Loads Tower bottom*

DIBt3 50Hz

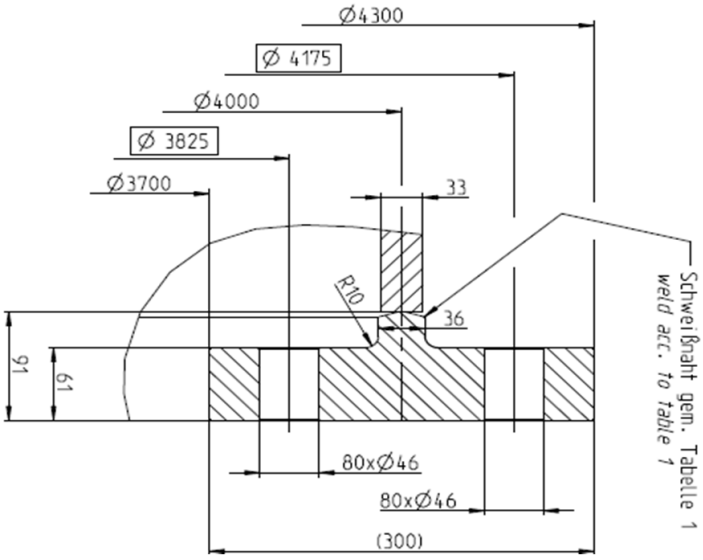
Betriebslasten Schädigungsäquivalente ESK / ***Fatigue Loads*** *Damage Equivalent Load Spectrum*					
N Lastspiele *Cycles*	**m**	**FXTB** kN	**FZTB** kN	**MXTB** kNm	**MYTB** kNm
1.00E+07	3	132	335	5134	20252
1.00E+07	4	106	290	4369	19880
1.00E+07	5	99	281	4182	20463
1.00E+07	6	98	284	4214	21301
1.00E+07	7	101	290	4340	22209
1.00E+07	8	105	297	4505	23150
1.00E+07	9	110	306	4685	24146
1.00E+07	10	116	315	4866	25251
1.00E+07	11	121	326	5043	26516
1.00E+07	12	127	339	5213	27952
gamma-f - FAT		1.0	1.0	1.0	1.0
Mittellast *Mean load*		3863	298	-136	29316

IEC2a 60Hz

Betriebslasten Schädigungsäquivalente ESK / ***Fatigue Loads*** *Damage Equivalent Load Spectrum*					
N Lastspiele *Cycles*	**m**	**FXTB** kN	**FZTB** kN	**MXTB** kNm	**MYTB** kNm
1.00E+07	3	132	333	5132	20094
1.00E+07	4	106	289	4367	19837
1.00E+07	5	98	280	4181	20415
1.00E+07	6	98	283	4214	21269
1.00E+07	7	101	289	4340	22184
1.00E+07	8	105	296	4505	23134
1.00E+07	9	110	305	4683	24151
1.00E+07	10	116	315	4862	25297
1.00E+07	11	122	326	5036	26624
1.00E+07	12	127	339	5204	28132
gamma-f - FAT		1.0	1.0	1.0	1.0
Mittellast *Mean load*		3861	318	-141	29466

Die Markov-Matrizen werden bei Bedarf als Excel-Datei beigefügt. /
The Markov-matrices will be attached as excel-files if required.

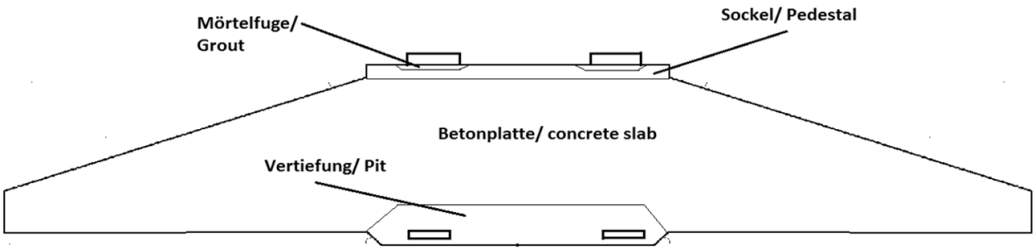
3. TURMANBINDUNG / CONNECTION TO THE TOWER



Ankerbolzen/ *anchor bolts*:	2x80xM42-8.8
	Fv=580kN

Mindestbetonfestigkeitsklasse nach DIN EN 1992-1-1/ Minimum *Concrete Strength Class according to EN 1992-1-1*	
Mörtelfuge/ *Grout*	C80/95
Sockelbeton unter Mörtelfuge/ *Pedestal concrete below grout*	C40/50
Betonplatte/ *concrete slab*	C30/37
Beton in Vertiefung über Ankerblech/ *concrete in pit above anchor plate*	C50/60

Wird eine geringere Betonfestigkeitsklasse verwendet, sind die Extrem- und Ermüdungsnachweise an diesen Stellen im Fundament für die neu gewählte Betonfestigkeitsklasse zu führen. / *If the chosen concrete strength class(es) are lower than the above specified concrete strength class(es), the related foundation area(s) must be verified (for extreme and fatigue loads) for the chosen concrete strength class.*



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