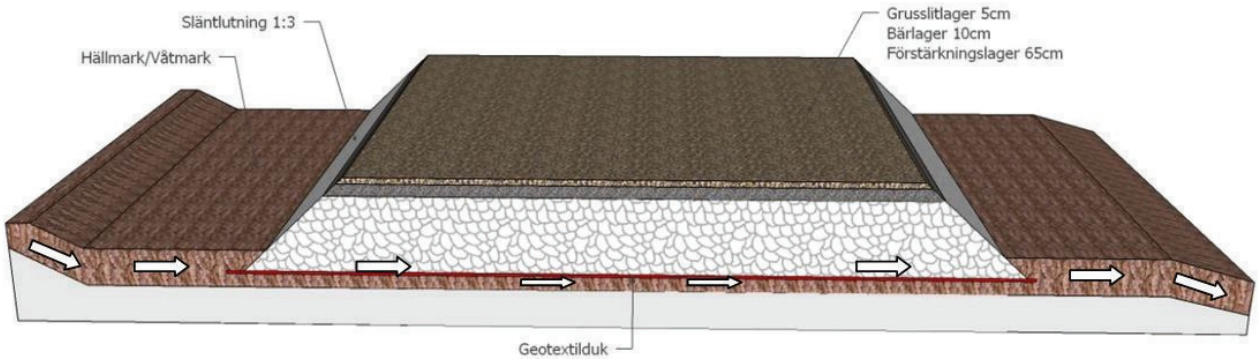
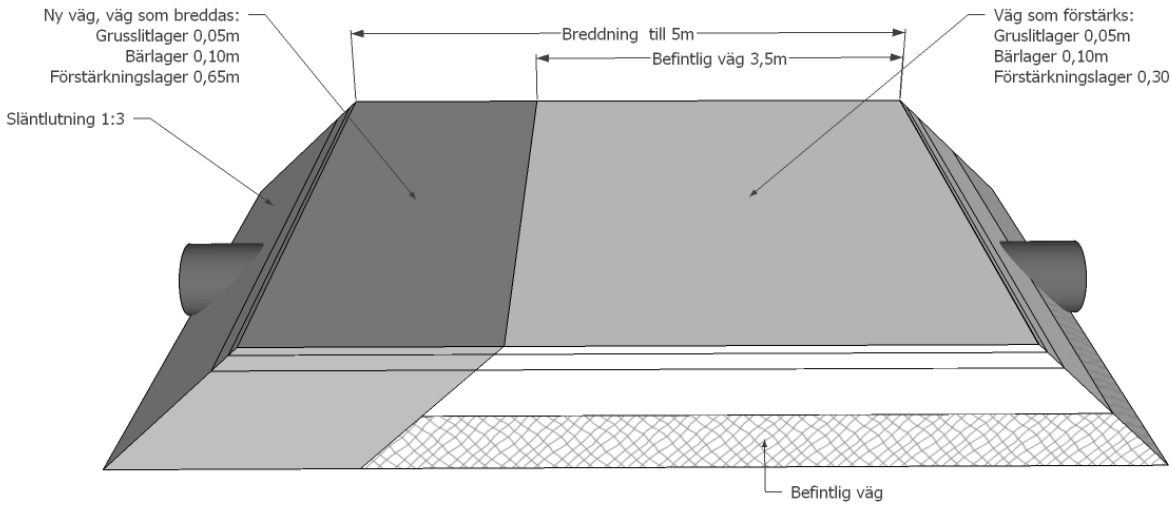
2

Exempel på typritningar för fundament, vägar och uppställningsplatser.

Typritningar olika vägtyper



Genomsläpplig/flytande väg för att bibehålla vattenflöden



Väg med trumma för att bibehålla vattenflöde vid exempelvis våtmark

Road, Crane Pad and Hardstand Specifications V105/V112/V117/V126/V136

History of this Document

Version. no.	Date	Description of changes
00	2013-06-18	First edition, valid for Sweden only. Based on document 0006-5131 V04 and 0006-4198
01	2013-06-19	Corrected reference to figures
02	2013-07-04	Corrected reference to figures. Other minor editorial changes
03	2013-07-17	Valid for Northern Europe, modified to make consistent with other documentation and additional specifications
04	2013-09-19	Updated to include V110
05	2013-10-16	Specification for area around the Turbine
06	2013-10-17	Updated wording in section 3.6
07	2013-12-06	Updated to include LDST Tower and V105
08	2013-12-09	Update bookmark error in 3.12
09	2014-05-21	Updated section 5 and included appendix 1 and 2
10	2016-09-29	Added V136, moved V110 to 0040-8951, updated the entire document

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1. Introduction

In the drive for increased economic performance from Wind Turbines there has been a move towards larger equipment and higher hub heights, both of these factors have a large influence on the Civil Works necessary to erect and operate these Wind Turbines both safely and efficiently.

This document sets out the options and possible solutions that are necessary when these larger Wind Turbines are to be installed and operated and is intended as a guideline for the minimum requirements.

This document is not sufficient in and of itself to construct Roads, Crane Pads and Hardstands and must be supplemented for each project and site before construction work commences in order to ensure the specifications and the final choice of crane and transport equipment are aligned with the site requirements.

Once the agreed specifications have been agreed, based on the Turbines selected, the Ground Conditions and the Topography it is suggested that these are then incorporated into the contract between Vestas and the Employer.

The exact design of Roads, Crane Pads and Hardstands must be agreed with Vestas in writing prior to start of construction. Testing and documentary evidence will also be required to demonstrate that the Civil Works have been completed to the required level before Wind Turbine Installation commences.

It is important to emphasise that the Civil Works directly affect both the way the Wind Turbines will be erected and the safety of everyone involved.

In all situations safety will be the ruling factor.

2. Abbreviations and Definitions

This specification is applicable for the V105, V112, V117, V126 and V136 for Hub Heights up to 147m.

The document is verified for use in Northern Europe.

The following words, abbreviations and expressions shall have the meanings stated below:

2.1. Access Road(s)
Refers to a road, existing or purpose-built, which leads from any public road system to the Site Entrance.

2.2. Allowable Bearing Capacity
The ultimate bearing capacity of the materials below the supporting surface divided by the Bearing Capacitor Factor of Safety.

2.3. Assist Crane
Refers to the crane that will assist rigging the Main Crane and lifting various wind turbine components alongside the Main Crane.

2.4. Bearing Capacity
Magnitude of uniformly distributed contact pressure of designated configuration on the supporting surface corresponding to the allowable bearing capacity of the materials below the supporting surface. A road, existing or purpose-built, that connects the site entrance to an existing road.

2.5. Bearing Capacity Factor of Safety
Ratio of ultimate bearing capacity to allowable bearing capacity to be determined by a qualified Civil Engineer; however Vestas requires a bearing capacity factor of safety value of not less than one point five (1.5).

2.6. Bend and turn radius
Refers to the dimension of the turn radius.

2.7. Blade laydown area
Refers to an area in level with the hardstand, flat and free of obstacles for blade storage.

2.8. Blade fingers
Refers to two constructed “fingers” for safe support of the blade frames.

2.9. Boom assembly area

Refers to an area in level with the road, free of obstacles for safe assembly of the crane boom.

2.10. Boom support

Refers to supporting structures during boom assembly.

2.11. Compound Area

The area where the Site Offices, Drying Room, Canteen, Toilets, Washing Facilities, Container Storage and Car Parking will take place.

2.12. Crane Pad

Refers to a hardstand area in connection with the erection or service of a wind turbine or met mast.

2.13. Crane Walks

Temporary carriageways used primarily by crawler cranes to travel the shortest distance between Crane Pads.

2.14. Eurocode 7: Geotechnical design

The European Standard for the design of geotechnical structures, using the limit state design philosophy. It is published in two parts; "General rules" and "Ground investigation and testing". It was approved by the European Committee for Standardization (CEN) on 12 June 2006. It became mandatory in member states in March 2010.

2.15. Foundation top

Refers to the top of the foundation defined as the top of the concrete plinth.

2.16. Hardstands

Refers to any area where wind turbine components and transport and installation equipment is stored, placed or parked and includes vehicle parking areas, lay-down and storage areas, compounds and other agreed working areas.

2.17. Hook assembly area

Refers to a free area for safe mounting of the crane hook.

2.18. Lay-bys

Refers to a parking/waiting area parallel to the site road where a vehicle can safely pull off to allow another vehicle to pass by in a safe manner.

2.19. Main Crane

Refers to the crane that will lift the wind turbine components into final position.

2.20. Method Statement (MS)

A work method statement, sometimes called a "safe system of work", is a document that details the way a work task or process to be completed. The method statement should outline the hazards involved and include a step by step guide on how to do the job safely. The method statement must also detail which control measures have been introduced to ensure the safety of anyone who is affected by the task or process.

2.21. Overhead obstruction
Refers to obstacles such as overhead lines, bridges, tree etc.

2.22. Position of tower door
Refers to the orientation of the tower access including tower stairs.

2.23. Pre-installation crane
Refers to the crane used for unloading/preparation of components and installation of the tower base(s) prior to main installation with the main crane.

2.24. Public Road(s)
Refers to any national or rural road which is maintained by the local authorities and is in urban or rural areas in common use by the travelling public.

2.25. Risk Assessment (RA)
A systematic process of evaluating the potential risks that may be involved in a projected activity or undertaking.

2.26. Roads
Refers to any Access and/or Site Roads.

2.27. Rut Depth
Maximum vertical distance between adjacent high and low points along a wheel path or track path.

2.28. Service path way
Refers to a 5 meter access road around/behind the turbine tower for safe service and installation access.

2.29. Site
Refers to all areas where the permanent works are to be executed and to which turbines and all associated equipment and materials are to be delivered, and any other areas that may be specified in the contract as forming part of the Site.

2.30. Site Entrance
The official entrance(s) to the site for all types of traffic.

2.31. Site Road(s)

Refers to any road built to carry traffic from the Site Entrance to the Crane Pads, sub-station or compound within the site boundaries.
If Public Road(s) are considered as a part of the Site Road(s), then the Site Road(s) requirement will apply for the Public Road(s).

2.32. Storage area

Refers to storage unloading area for components on site.

2.33. Tag lines

Refers to a rope attached to the components during installation for safe control of the components during lifting.

2.34. Turning area

Refers to areas used for turning of vehicles/transports, either loaded or un-loaded.

2.35. Ultimate Bearing Capacity

The uniformly distributed surface contact pressure of designated configuration corresponding to local shear or punching shear bearing capacity failure as calculated from bearing capacity theory based on the thickness and properties of aggregate cover material, if any, above the subgrade surface and properties the soils below the subgrade surface.

3. Public, Access, Site Roads Preparations and Design

DANGER

Risk of death and severe material damage exists due to overturning of cranes, transport equipment and loads.

This occurs in situations where road construction or turning radius on Road is not adequate.

Assessment/calculations must be prepared based on the actual transport and crane configurations specified for each site.

3.1 The design and construction of the roads shall be undertaken by the Employer in accordance with Eurocode 7 (Both EN 1997-1 Geotechnical Design and EN1997-2 Ground Investigation and testing) and any Local Laws, Rules and Regulations that apply.

3.2 All Access and Site Roads shall be completed before wind turbine component delivery and all roads shall be maintained during the construction and installation period. Refer to the service contract for road maintenance during the service period. The following specifications apply to every surface upon which delivery or similar truck is expected to travel in order to deliver the relevant turbine component and the Cranes specified.

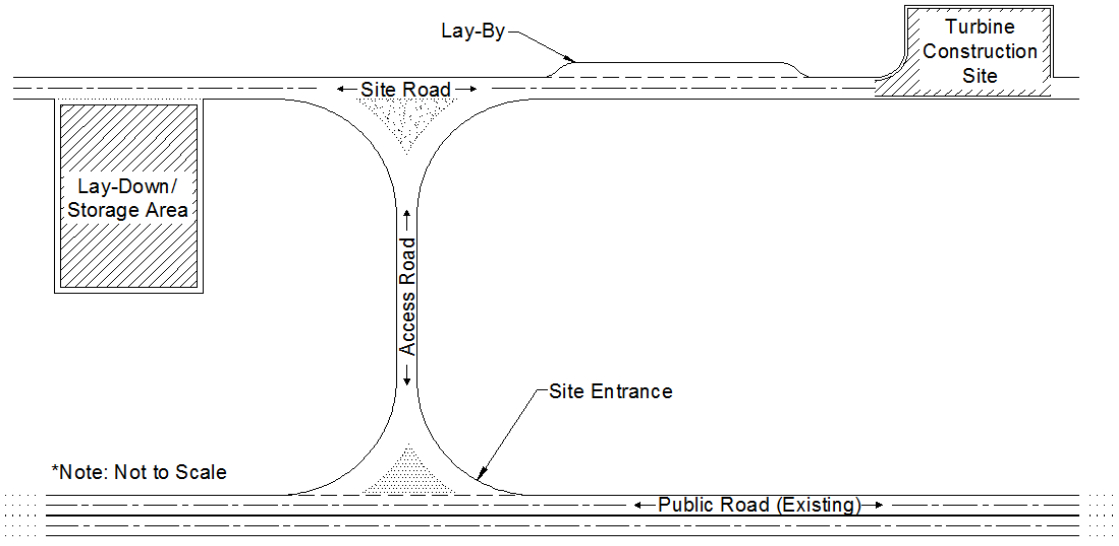
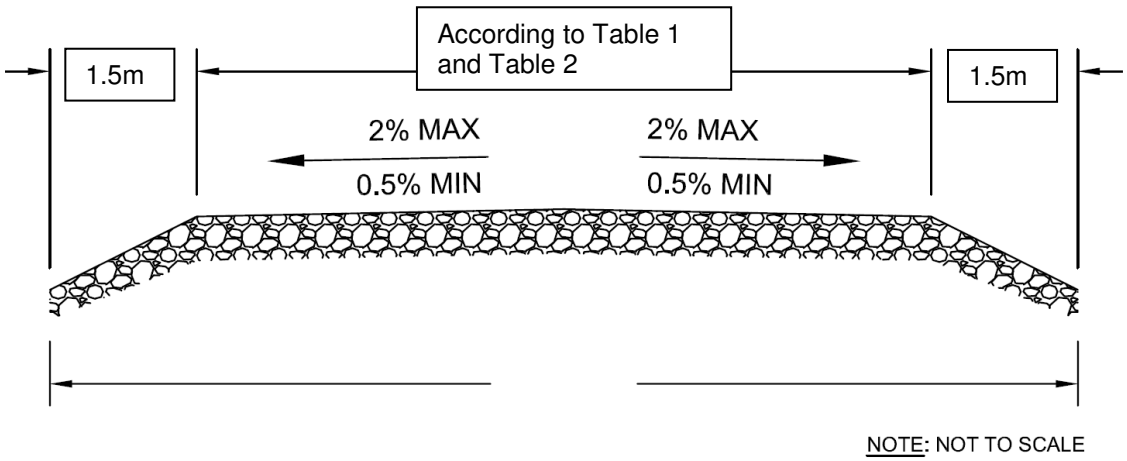


Figure 1 - Site and Access Road Diagram

For the purposes of this road specification we are not considering the use of Crawler Cranes except in a pedestal configuration where the Site Roads will be used to move it between

Turbine locations, consequently Crane Walks are not relevant. If a Crawler Crane is required then this will be considered separately and the requirements will be in addition to this specification.

3.3 The Road running lane width on roads shall be according to Table 1 and Table 2. The figures refer to full driveable surface with full axle load requirement. A clearance width of at least 1.5 (one point five) metres is required on both side of the road, this might be subject to site specific assessment.
When the road is part of the Hardstand, then the Hardstand requirements will apply.



NOTE: NOT TO SCALE

Figure 2 - Typical Access/Site Road Cross Section

The Roads shall have a maximum lateral cross-fall grade of two per cent (2%).

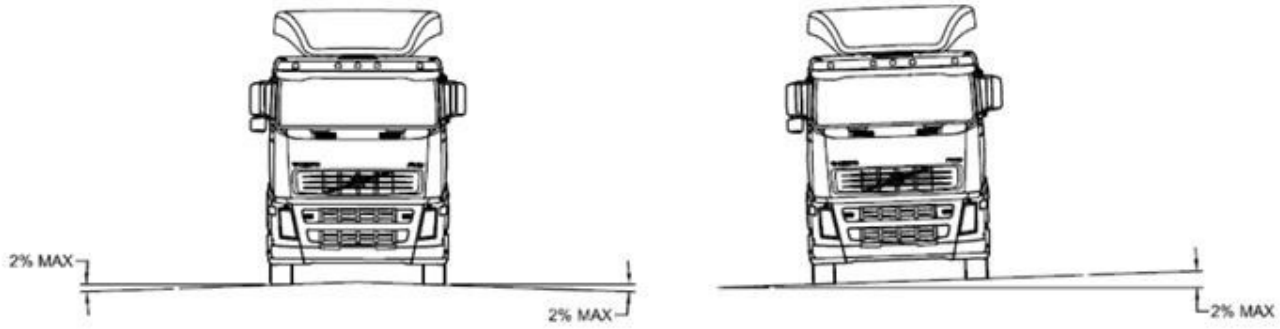


Figure 3 - Road cross-slope limitations

Gradient	Min. Road Width (Straight road)	Min. Road Width (1-25 degrees bend)	Min. Road Width (26-35 degrees bend)	Min. Road Width (36-45 degrees bend)	Pulling Assistance
<4%	4.5m	5.0m (R40/R45)	5.0m (R40/R45)	6.0m (R40/R46)	No
<10%	5.0m	5.5m (R40/R45.5)	5.5m (R40/R45.5)	6.0m (R40/R46)	No*
<14%	6.0m	6.5m (R40/R46.5)	6.5m (R40/R46.5)	7.0m (R40/R47)	Yes**
<20%	6.0m	6.5m (R40/R46.5)	7.0m (R40/R47)	7.5m (R40/R47.5)	Yes**
>20%	Project Spec.	Project Spec.	Project Spec.	Project Spec.	Yes**

Table 1 - Minimum road width dimensions with drivetrain

Gradient	Min. Road Width (Straight road)	Min. Road Width (1-25 degrees bend)	Min. Road Width (26-35 degrees bend)	Min. Road Width (36-45 degrees bend)	Pulling Assistance
<4%	4.5m	5.0m (R40/R45)	5.0m (R40/R45)	6.0m (R40/R46)	No
<10%	5.0m	5.5m (R40/R45.5)	5.5m (R40/R45.5)	6.0m (R40/R46)	No
<14%	5.0m	6.0m (R40/R46)	6.0m (R40/R46)	6.5m (R40/R46.5)	No*
<20%	6.0m	6.0m (R40/R46)	6.5m (R40/R46.5)	7.0m (R40/R47)	Yes**
>20%	Project Spec.	Project Spec.	Project Spec.	Project Spec.	Yes**

Table 2 - Minimum road width dimensions without drivetrain

* Pulling assistance might be needed if turn or bends are present before gradient/slope starts - All RA-MS - Additional insurance in place before final approval

** Gradients have to be evaluated and approved between all parties - RA-MS including additional insurance has to be in place before final approval. Specifications in the table are related to constructed and drivable surface/area - Specifications for clearance and overhang is according to shown illustration in appendix 3. On project critical spots additional detailed swept path check might be needed

Roads shall have a vertical grade no higher than ten per cent (10%) when the Drive Train is mounted in the Nacelle. For the situation where the Drive Train is not mounted then the acceptable Gradient can be increased to fourteen per cent (14%). A vertical grade above ten/fourteen per cent (10/14%) may be accepted if a suitable pulling vehicle is available (Employer Scope), or the road surface is improved to a higher standard of finish (e.g. Asphalt) or both. See figure 4 and 5 for further details.
Note that maximum gradient for LG1750 travelling with SS (super structure) mounted is 13%. Above ten/fourteen per cent (10/14%) gradients Vestas standard insurance cover has to be extended at additional Employer cost and further approved by the insurance company.

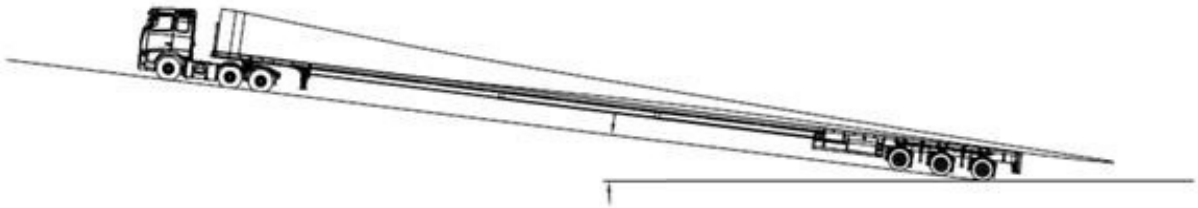


Figure 4 - Road grade illustration

Please note that 20m before and after a horizontal curve the general road width must be five (5) metres. When reversing the road width shall be minimum five (5) meter.

3.4 Where there is a bridge or underground culvert, the road has to be straight, including the bridge or underground culvert, for forty (40) metres before and forty (40) metres after as shown.

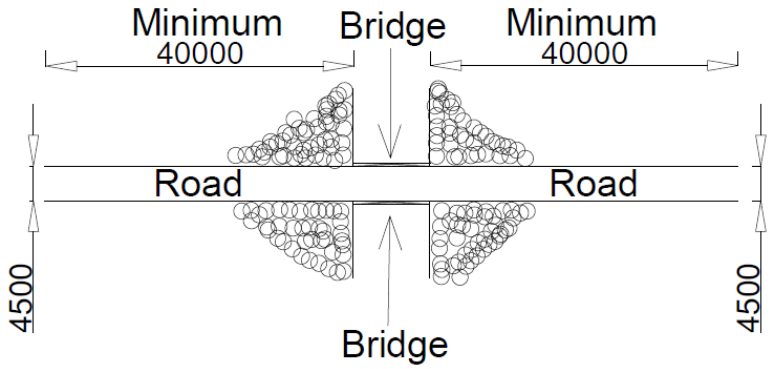


Figure 5 - Road width dimensions for bridge/underground culvert

3.5 Where the use of a very large Crane is specified (project specific) e.g. Demag cc6800 or similar in pedestal configuration, then the road width will be increased to seven (7) metres between all the Crane Pads where the use of a Goldhofer Transport or equivalent system will be used to move the Crane. Additional clearance of three (3) metres on both sides of the road will be required to allow passage of the Crane.

3.6 When specifying the road loading limits all of the following shall be considered:

a) The typical wheeled Crane used for erecting these Turbines is a Liebherr LG 1750 and the pre-installation crane will be a 500/700t crane LTM1500/1750 or similar; both crane types will be driven to site on Public Roads in a configuration with an individual axle load of maximum 12 Te. To reduce the number of lifts for safety reasons, when rigging and de-rigging the Cranes, the axle load will be increased to

20 Te per axle when on site. Where the Site ground conditions allow then this can be increased to 22-30 Te per axle in order to optimise crane movement between hardstands.
Axle load below 20Te will require additional installation time and cost.

b) For the Transport of Turbine components the maximum axle load will be 12 Te, note that total loads and lengths will vary depending on how the Wind Turbine is to be built and the Hub Height.

c) The minimum load bearing capacity required is two hundred (200) kN/m^2.

Please note that the relevant safety factors will have to be added to the above figures

3.7 All vertical curves shall have longitudinal radii (convex or concave) a minimum of four hundred (400) metres (five hundred (500) metres for V136).

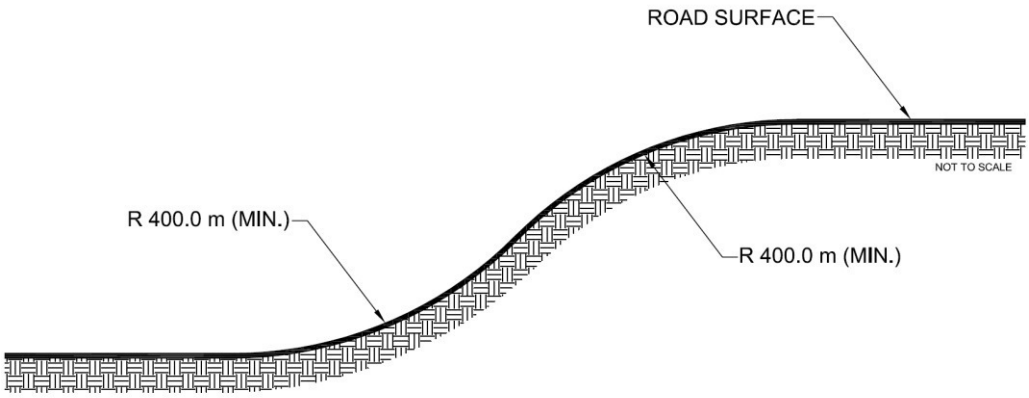


Figure 6 - Vertical Curve Radii Illustration

By the use of special transport equipment (subject to additional cost) such as the Super Wing carrier it might be possible to reduce these dimensions, this is to be discussed and agreed prior to any Contract signature.

3.8 Irregularities in access roads shall have a maximum relative rise or fall of no more than one hundred fifty (150) millimetres within any thirty (30) metres section.

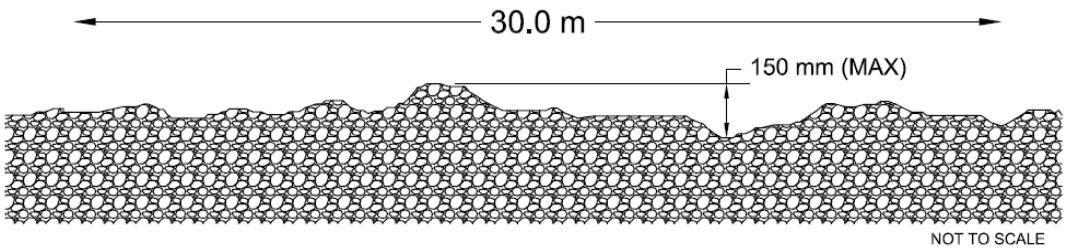


Figure 7 - Maximum Rise/Fall over 30m Span

3.9 The intersections of access roads, public roads, and site roads shall be modified to accommodate long loads. Temporary access roads shall be constructed with a minimum inside turning radius and a minimum road width with suitable culverts and associated road widening as needed to complete turns, see Table 1, Table 2 and Appendix 6. Temporary access areas shall be constructed to a ground bearing capacity in accordance with the requirements for the Site Roads.

3.10 All Roads shall be free from overhead and side obstructions to provide a clear corridor. The shaded regions shall be clear of all overhead and side obstructions.
Required safety distance to obstacles, power lines etc. will be added to the below figures.

- Nacelle transport with DT and completed roof / Overhead clearance min. 5.5m
- Nacelle transport with DT and completed roof including cooler / Overhead clearance min. 9.5m
- Tower transport with tower diameter Ø5m / Overhead clearance min. 5.5m
- Hub and blades / Overhead clearance min. 5.5m
- Transport of LDST tower sections min. 8m

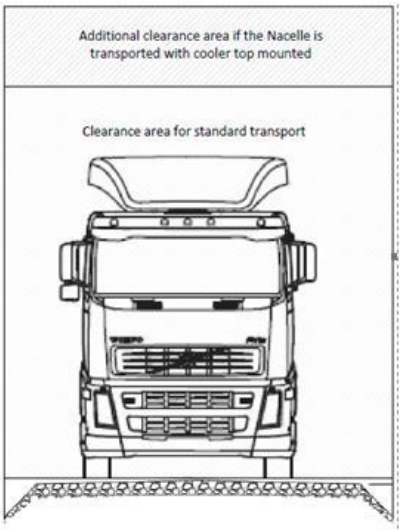


Figure 8 - Road clearance standard transport

The crane requires 8m clearance with the SS (super structure) mounted and maximum 20 Te axle load.

For Access and Site Roads, any overhead obstructions or hazards, including overhead power lines, shall have “goal posts”, demarcation and warning signs as required under country specific legislation to allow safe access and egress. All “goal posts”, demarcation and warning signs shall be maintained for the duration of the construction and installation period.

Figure 9 – Goal posts

For Large Diameter Steel Towers (LDST) there are additional requirements for access clearance as set out below; if they are to be transported in a fully assembled configuration either on Public or Site roads. The tower diameter can vary depending on tower type/height, so this have to be evaluated for the specific site. The below figure is an example showing a diameter of 6500mm.

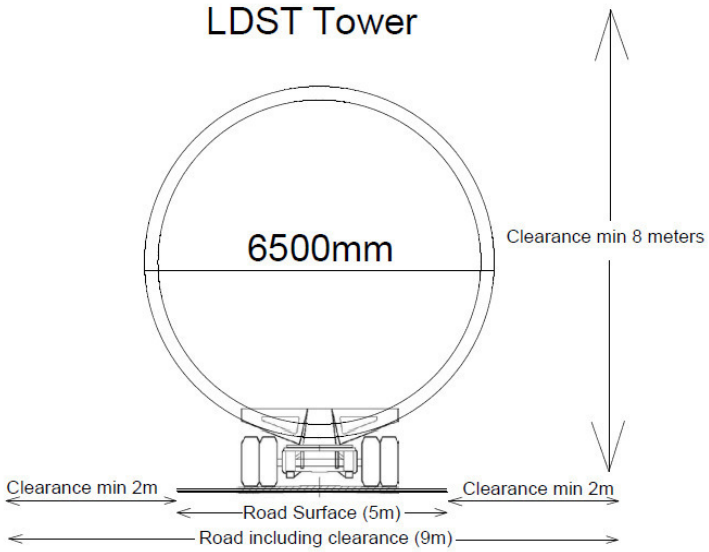


Figure 10 - Road clearance for LDST option

All overhead obstructions shall be removed by the Employer prior to start of turbine equipment deliveries and construction activities. For each electrical transmission line under which the equipment will pass an assessment is to be made and a safe clearance agreed.

3.11 Drainage systems for roads (including shoulders), crane pads, and laydown areas shall be designed to control and mitigate the flow of surface water along and under the roads so as to self-drain.

3.12 Due to general HSE precautions/regulations reversing activities with un-loaded vehicles shall always be reduced to an absolute minimum, preferable avoided. If reversing activities is unavoidable provisions shall be made for a turnaround or other suitable and safe turning facility within a maximum of two hundred (200) metres from each crane pad. The turning area sizes and positions will be determined for each Site once the road layout and turbine locations have been finalised.
Reversing activities with loaded vehicles is in general not allowed and if unavoidable this shall be evaluated and agreed project specific (requires additional MS and RA). Please note that reversing activities with loaded vehicles is not allowed in dark conditions, this requires additional lights/pilots.

3.13 All Lay-bys shall be a minimum of fifty (50) metres long and five (5) metres wide to accommodate road transport on all access and site roads. Lay-bys shall be established every one (1) kilometre for site roads, access roads and at critical points.
Additional requirements might appear if turbine access point is directly from public road. The requirement will be parking facilities for the transports arriving in order to avoid blocking of the road/hardstand access.
All Lay-bys shall be flat, free draining, and clear of debris.
Lack of lay-bys will affect the normal workflow and will be subject to additional installation time and cost.

3.14 Roads and Lay-bys shall be marked with snow poles where applicable.

3.15 Embankments shall be constructed to maintain stability throughout the project lifespan.

4. Crane Pad and Laydown/Storage Area Specifications and Design

Risk of death and material damage due to overturning of Crane.

The possible risk of death and severe material damage exists due to any overturning of the crane or loads in situations where applied loading is not resisted by properly strengthened ground.

Assessment/calculations must be prepared based on specific lift plans.

4.1 The design and construction of the Crane Pads and Hardstands shall be undertaken by the Employer in accordance with Eurocode 7 (Both EN 1997-1 Geotechnical Design and EN1997-2 Ground Investigation and testing) and any Local Laws, Rules and Regulations that apply.

4.2 When laying out the Crane Pad and other facilities a number of issues have to be considered:

a) The Hub Height, location of the foundation both vertically and horizontally from the Crane Pad and weights of the Turbine components to be erected. This will facilitate the determination of the specification and model of Crane to be used.

Important *there may be a requirement for the use of Super Lift; for the Liebherr LG 1750 this occurs above Hub Height of 94m but can varies depending on the type and model/configuration of Crane used.*

b) Where the components to be lifted are placed: on the crane pad or if “just in time” solution/delivery is used.

c) How the Main Crane is to be built as the Boom has to be laid out horizontally for the Hub Height plus twenty-five (25) metres with access for both vehicles to deliver the boom sections and a further Crane to build the Main Crane. Due to general HSE precautions/regulations it is not allowed to block the road with the boom. If super lift configuration has to be used, the boom and super lift requires to be build/assembled in a straight line, preferable along the access road. Please note that the boom cannot be placed on top of the outrigger.

d) The reach of the Crane used to build the Main Crane will determine the locations and numbers of additional Pads required to build the main Crane. The size of the helping crane pads will vary depending of the main crane configuration. Normally the

helping crane pads shall accommodate a mobile crane in the size of 100-250 ton, the size will depend on the main crane boom configuration. See Appendix 2 Level requirements foundation/boom assembly for details.

e) Where the Nacelle is to be prepared for lifting; either locally at the crane pad, or at a central location and delivered to the Main Crane “just in time”. For the nacelle/ hub preparation area, 3 meters around the components is required for scaffolding and storage. Normal practice is to deliver the nacelle with the drive-train (DT) included. The drive-train (DT) is only separated from nacelle due to unchangeable lifting limited or delivery restrictions.

f) The location of the Assist Crane when lifting the Tower sections.

g) What can be taken as temporary works for Construction purposes e.g. Blade Fingers, Nacelle build area, Assist Crane Pads.

h) Ground Topography when building the Boom; it has to be flat and in level permitting safe access. If the boom is to be built in connection with gradients or negative slope, booms support points will be required. The location of the boom supports points will be determined by the crane type and configurations used for the specific project.
The boom support surface has to be in level with the hardstand surface.
Due to general HSE precautions/regulations the maximum distance from ground level to underneath the boom is general maximum 6 meters.
If the distance from ground level to underneath the boom is more than 6 meter, the task will require additional equipment and time for crane movements. This has to be evaluated and agreed project specific (requires additional MS and RA).

4.3 The minimum load bearing capacity required for all areas of the Crane Pad, Assist Crane Pads and areas where storing or building components shall be two hundred (200) kN/m^2. Please note that the relevant safety factors shall be added to this figure.

4.4 For the Crane Pads and Offloading areas the maximum lateral slope shall be one per cent (1%) and minimum zero point five per cent (0.5 %).

4.5 For the Crane Pads and Offloading areas the maximum longitudinal slope shall be one per cent (1%) and minimum zero point five per cent (0.5 %).

4.6 The Crane Pad and Offloading area shoulder slopes shall be maximum forty-five (45) degrees.

4.7 The Crane Pad drainage shall be designed to control the flow of surface water on, alongside and around the Crane Pads so as to self-drain.

4.8 Provisions shall be made for the safe and proper lay-down and storage of wind turbine components at, or adjacent to the Crane Pad, within the operating radius of the main crane and the assist crane/unloading cranes.

4.9 If the Main Crane has a lattice boom or lattice jib, the rigging area for the Main Crane shall have a minimum length equal to wind turbine hub height plus twenty-five (25) metres added to this length, starting from the Main Crane and parallel to the Site Road. The usable width shall be minimum five (5) metres. Due to HSE general precaution/regulations it is not allowed to block the road with the boom

4.10 If the Main Crane has a lattice boom or lattice jib a construction area will be required parallel to the Site Road with additional Crane Pads for the Assist Crane depending on the Boom length required for the Main Crane. These Crane Pads will be to the same specification as the Main Crane, with typically dimensions of fifteen (15) metres by twelve (12) metres each at a twenty seven (27) metres spacing, see appendix 3 and appendix 4 for details. The location of the boom supports will be determined by the crane type and configurations used for the specific project

4.11 Off-loading and preparation area for nacelle shall be minimum seven (7) metres by fifty (50) metres and within the working radius of the Main Crane if not a" just in time" delivery is used in combination with a site storage area (If nacelle is unloaded on transport legs). Alternative the nacelle can be off-loaded with the pre-installation crane if crane capacity allows.

4.12 Off-loading area for blades shall be flat and accessible and minimum twenty (20) metres by up to eighty (80) metres depending on the blade length, with two fingers having a Bearing capacity of one hundred and fifty (150) kN/m^2 to support the Blade Frames including safe access for a forklift to prepare them before lifting. This will be within the working radius of the Main Crane unless a "just in time" delivery approach is used in combination with a site storage area. The area around the blade laydown area is considered as a working zone, wheel tracks and footprint in the area/field can be expected.

4.13 Provision shall be made for the safe and proper lay-down and storage of parts in a suitable secure location. Parts include and are not limited to: lifting tools, service platforms (lifts), uninterruptible power supply, tower cables, nose cone parts, stairs, steps, ladders, boxes of bolts and parts containers.
Storage area (lay-down yard) size should be designed on a per-project basis based on available locations and the size of the project.

4.14 Compounds, Storage and Lay-Down areas shall be clear of all debris, and the area shall be in level and free draining and to have the same bearing capacity and proof testing as the Crane Pad.

4.15 It is important that the elevation difference between the top of the foundation plinth and the top of the Crane Pad is maximum zero point five (0.5) metre.

4.16 Compacted area with a radius of five (5) metres is required behind the turbine tower for installation/service purposes in level with the hardstand. The area in front of the tower is considered as a part of the hardstand.

The below description of installation methods, are based on a main crane of the type LG1750.

Below 94m hub height (including 94m):

Pre Installation:
The installation of the Wind Turbine takes place in the following sequence:

1. The base section and typically one mid-section will be pre-installed with a 400-500t crane and a 130Te assist crane, delivery of the sections will be JIT; the crane will be placed at radius 10-16m from the centre of the foundations. Depending on the chosen crane type, the crane will have a footprint of approx. 9m to 12m, between outriggers and support plates.
2. The blades will be unloaded using two cranes, a 500t and a 130t crane placed next to the hardstand, the blade laydown area needs to be flat, free of obstacles and within the lifting radius of the Main Crane.
3. The nacelle will delivered using a standard flatbed trailer, the nacelle will be unloaded using a 500Te crane and placed within the main cranes working radius (20-22m) in such a position that it does not interfere with the later build and operation of the main crane. Where the drive train is delivered separately then additional space has to be provided to allow for the storage of the drive train prior to being lifted into the Nacelle during the preparation phase. For the Nacelle sufficient space (3 m) has to be provided around it to allow for scaffolding used during the preparation prior to final erection.
4. As an alternative the Nacelle could be unloaded using the transport legs and if within the lifting radius of the crane, it may then be prepared where it is situated, or it could then be moved as above using a 500Te crane.
5. The hub will be unloaded with a 100-130t crane and placed within main crane working radius.
6. The remaining tower sections will be delivered “just in time” unless specific additional lay down space has been provided.

Main Installation:
Once the base tower has been erected, grouted and the Nacelle, Blades and Hub have been prepared, then the main crane will be brought to the Pad. The main crane will probably be a Liebherr LG1750 or similar, the distance between outriggers will be approx. 16m x 16m plus support plates, the erection sequence will be as follows:

1. The main crane will be placed at a radius 20-22m from the centre of the foundation, the crane requires approx. HH + 20m of free space for boom assembly which takes place in a “straight” line, usually along the road, the boom cannot be placed above the outriggers. The crane pads along the road will be used by a small crane to assemble the boom.
2. Once assembled the main crane will commence the erection of the remaining tower sections with a 130t assisting or tailing crane. The tower transports need a free area of approx. 6m x 30m within the main crane and assisting crane working radius. The Towers will be lifted directly off the Trailers; space has to be allowed for a working platform to be used to safely attach the lifting gear to the Towers before lifting. Additional lifts for the bolts will be necessary before the next Tower section is lifted.
3. The Nacelle will then be lifted from the position on the pad where it has been prepared, the hub will then follow.
4. The blades will be the last to be lifted from the location where they have been prepared.
5. The crane is disassembled and moved to the next location.

Above 94m hub height (excluding 94m)

Pre Installation:
This will be the same as the case where the HH is below 94m, except that now the main crane will be placed at a lifting radius of 24-32m from the centre of the foundation, this then sets the distances for the unloading of the equipment for preparation.

Main Installation:
Once the base tower has been erected, grouted and the Nacelle, Blades and Hub have been prepared, then the main crane will be brought to the Pad. The main crane will probably be an LG1750 or similar, the distance between outriggers will be approx. 12m x 12m plus support plates. The crane will use a super lift at a radius of 21m.

1. The main crane will be placed at a radius 24-32m from the centre of the foundation, the crane requires approx. HH + 20m of free space for boom assembly which takes place in a “straight” line with the super lift attached, usually along the road, the boom cannot be placed above the outriggers. The crane pads along the road will be used by a small crane to assemble the boom.
2. Once assembled the main crane will commence the erection of the remaining tower sections with a 130t assisting or tailing crane. The tower transports need a free area of approx. 6m x 30m within the main crane and assisting crane working radius. The Towers will be lifted directly off the Trailers; space has to be allowed for a working platform to be used to safely attach the lifting gear to the Towers before lifting. Additional lifts for the bolts will be necessary before the next Tower section is lifted.
3. The Nacelle will then be lifted from the position on the pad where it has been prepared, the hub will then follow. Depending on the crane configuration and the HH

it may be that the Nacelle is lifted in without the Drivetrain which is a separate lift. Best practice is to do as much work as possible at ground level so we will only lift the Drivetrain separately when there is no other option.

4. The blades will be the last to be lifted from the location where they have been prepared.
5. The crane is disassembled and moved to the next location.

Examples and conditions for the hardstand design and compound area can be found in appendix 3 and appendix 4.

4.17 Typical Compound including welfare facilities and waste management for the use of the Installation team is required. The size will vary depending on the number of main cranes used. Storage of turbine parts/components not included in the below sizes. On large Sites multiple Compounds may be required.

- 1 main crane: 30m x 45m
- 2 main cranes: 30m x 90m (might be separate depending of the site setup)
- 3 main cranes: 30m x 135m (might be separate depending of the site setup)
- In situations where more than 3 main cranes are required, this will agreed for the specific project

If the compound should be used for storage of turbine parts/components, the needed space will be added to the dimensions. (To be agreed for each specific project)

Example of a standard compound for 1 main crane is shown below.

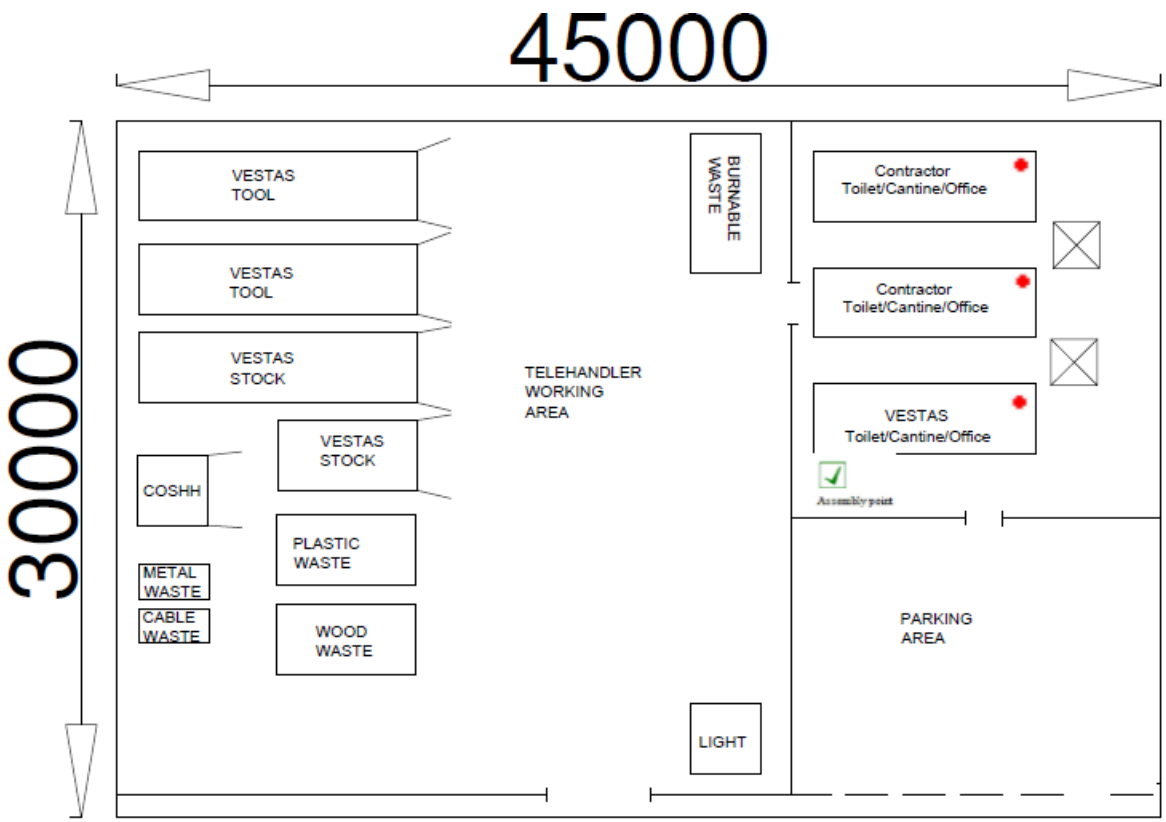


Figure 11 - Installation Compound Example

5. Testing and Inspection

Any Roads, Crane Pads or Hardstands shall not be taken into use until measurements and results of agreed tests proving the ground bearing capacity of the Access Roads, Site Roads, Crane Pads, and Hardstands have been finalized and Appendix 7 Access and Site Road Requirements Checklist and Appendix 8 Crane Pad Requirements Checklist are signed and handed over to the Contractor's representative. The tests shall as a minimum include:

a) Proof roll record for any area subjected to loading showing that the ground has been rolled and compacted sufficiently to resist deformation and rutting due to the applied loads.

b) Plate bearing test (to BS 1377 or local equivalent) results showing that minimum bearing capacity is achieved, the compaction should be to ninety eight (98) Percent modified Proctor. For all the Crane Pads tests will be performed at the four corners and in the centre with less than ten (10) mm settlement observed.

c) An inspection of the work has been completed with documentary evidence, including test results, demonstrating compliance with these requirements.

   A test-run has been successfully performed on the Roads by using a vehicle of equivalent longest length which would be employed on transportation during construction and installation.

6. Other Requirements

Provision must be made for:

a) Sufficient area for safe parking of vehicles outside exclusion zone at each crane pad

b) Any required gates at the point of access to site

c) Any required signage at or on the approaches to the point of access to the site.

d) All excess overburden or topsoil etc. to be stored on the lower slope side of the Site Road and Laydown areas.

e) Provision of a level, compacted area with a radius of 5 metres wide around the turbine tower is required to assist future maintenance.

f) Area around the Turbine shall be built to allow clear access from the road. This area will be used for installation and grouting teams, and lowering and raising equipment and tools using the Nacelle Crane to a Service Van, as shown on the figure below

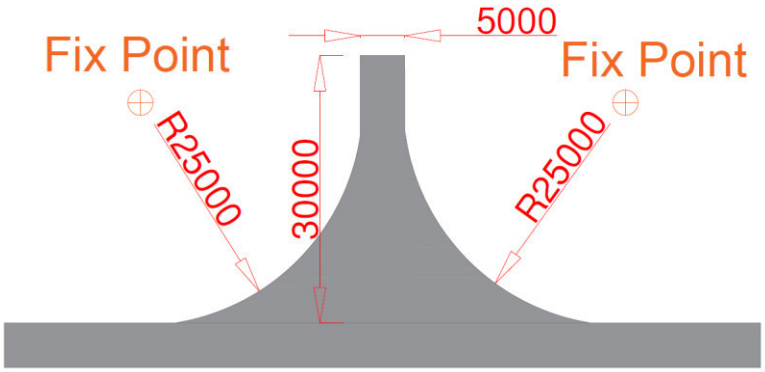
g) At the entrance to each crane pad/hardstand clearly marked with signage with location number.

h) The site entrance to be marked with a site map, site regulations and contact numbers.

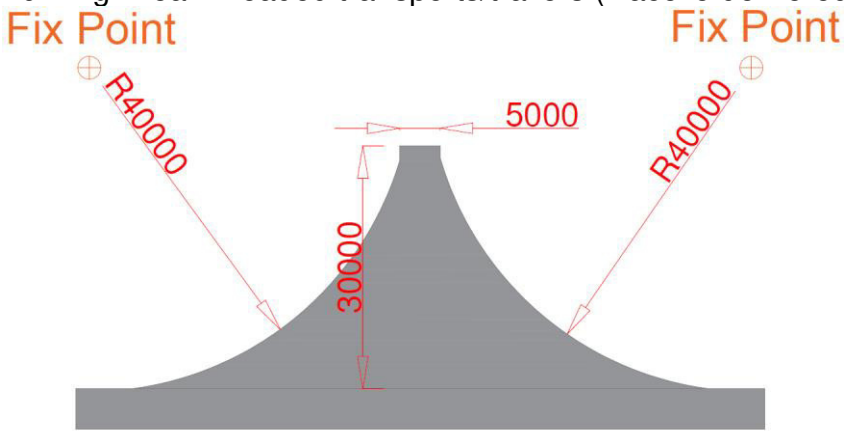
Figure 12 - Turbine access on completion

7. Appendix 1: Specification of Turning Areas

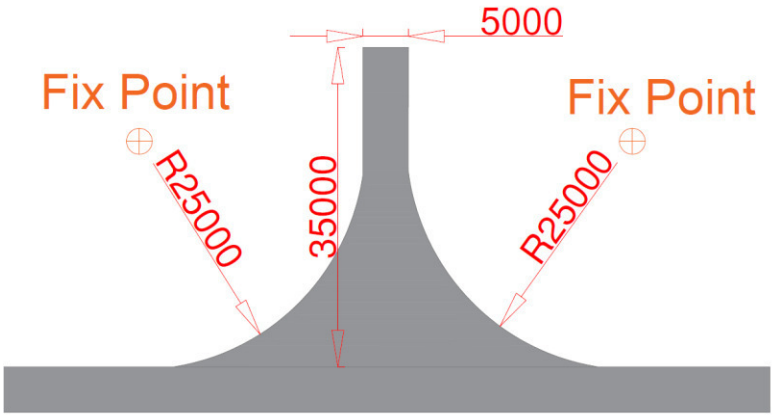
Turning Area – Unloaded transports/trailers (Nacelle delivered without DT)



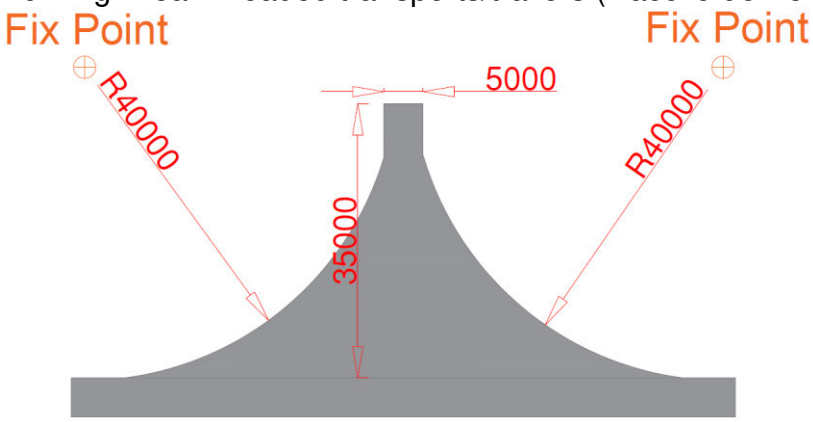
Turning Area – Loaded transports/trailers (Nacelle delivered without DT)



Turning Area – Unloaded transports/trailers (Nacelle delivered with DT)

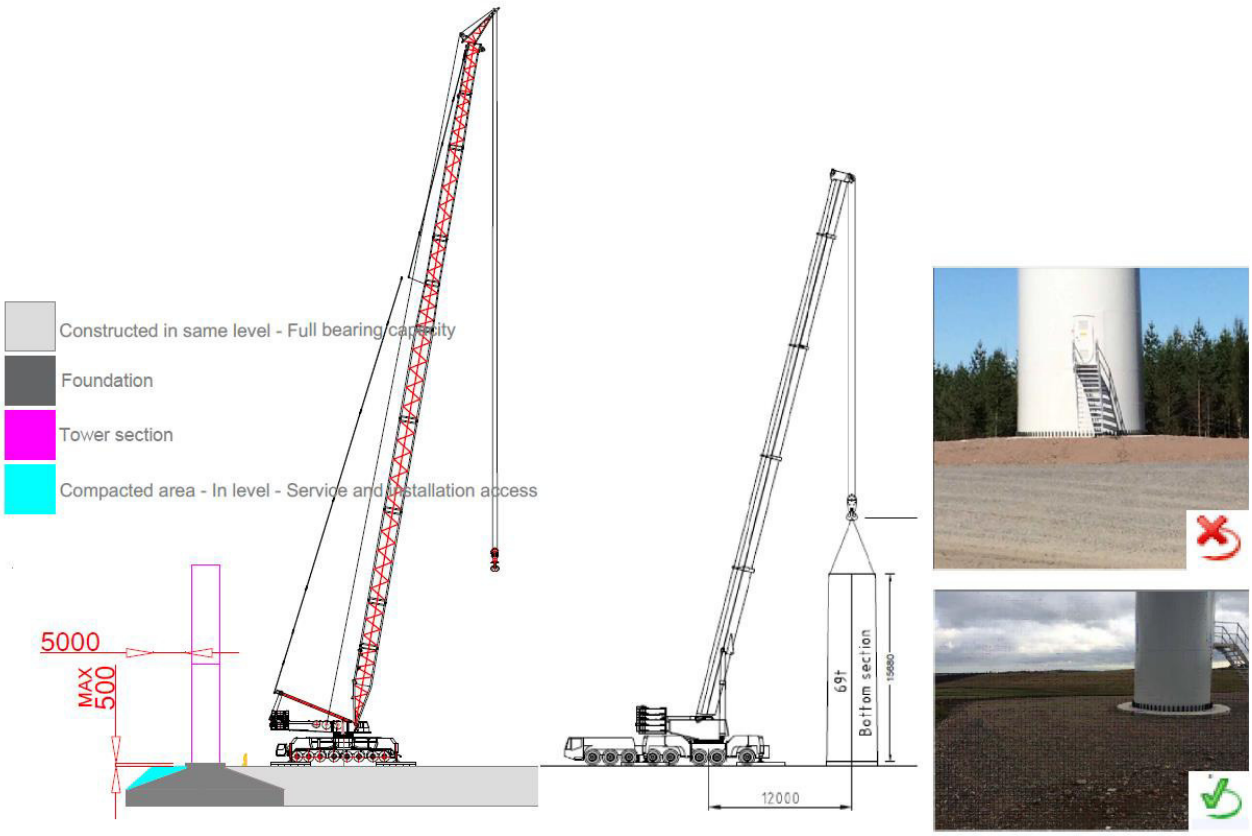


Turning Area – Loaded transports/trailers (Nacelle delivered with DT)

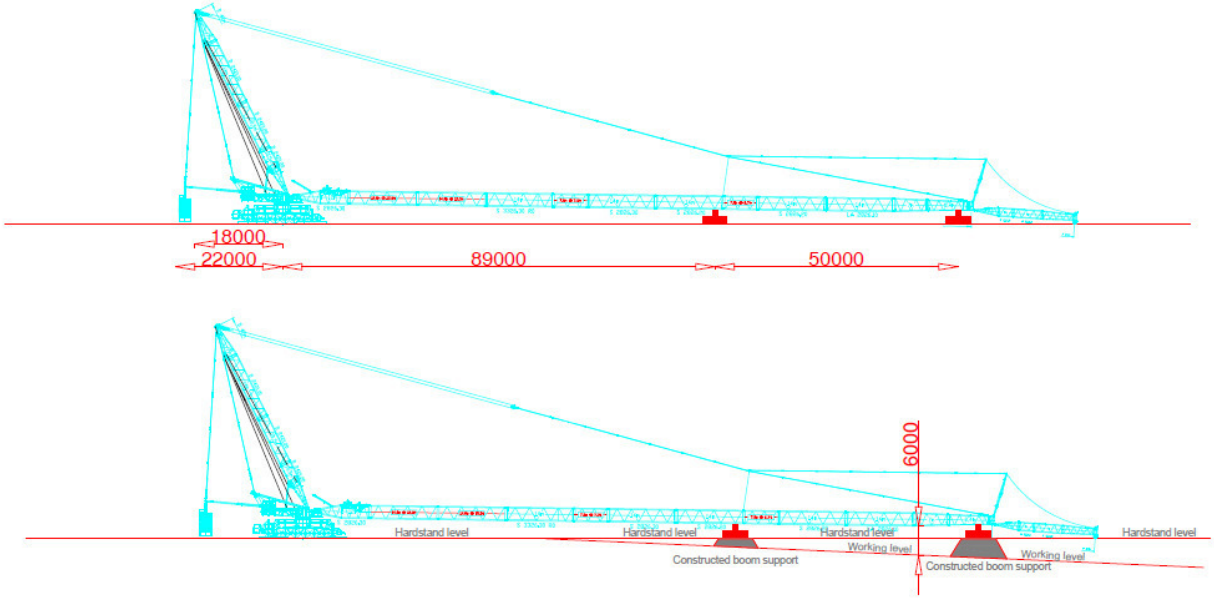


8. Appendix 2: Level Requirements Foundation/Boom Assembly

Foundation/Plinth level requirements



Boom Assembly – Support points
Example below is an indication only showing the concept. Correct location will vary and should be determined project specific.



9. Appendix 3: Hardstand Examples – Standard Solutions

General information to hardstand/layout examples shown below are as follow:

TAGLINES

- To perform a safe and controlled lift of components, a manual tagline set up is used.
- Two (2) or up to four (4) taglines will be attached to the component, the taglines will be manually controlled by the ground personnel.
- The orientation of taglines can vary due to local conditions, such as wind direction and speed.
- The direction/orientation can be challenging in conditions with inaccessible areas such as peat/water/trees etc.
- Safe direction/walking route of taglines shall always be considered and agreed prior to each lift.

BLADE LAYDOWN AREA

- Blade laydown area has to be flat and free of obstacles, the area need to allow safe access for preparation and mounting/dismounting of lifting/transport equipment. The location and distance between blade fingers will vary depending of the turbine type (Blade length and COG)

BOOM ASSEMBLY AREA

- Boom assembly area has to be free of obstacles and allow safe access for personnel and equipment during assembly. If boom assembly area is combined with gradients or slope boom supports is needed. The location of boom supports can vary depending of crane type and configuration. The amount and location of boom supports shall always be evaluated and agreed project specific.

NACELLE PREPERATION AREA/LOCATION

- During preparation of the nacelle a scaffolding setup will be used around the nacelle, the scaffolding will require min 3m of free space around the nacelle. This area is indicated with a grey line on the examples.
- The area need to allow safe access for preparation and mounting/dismounting of lifting/transport equipment.

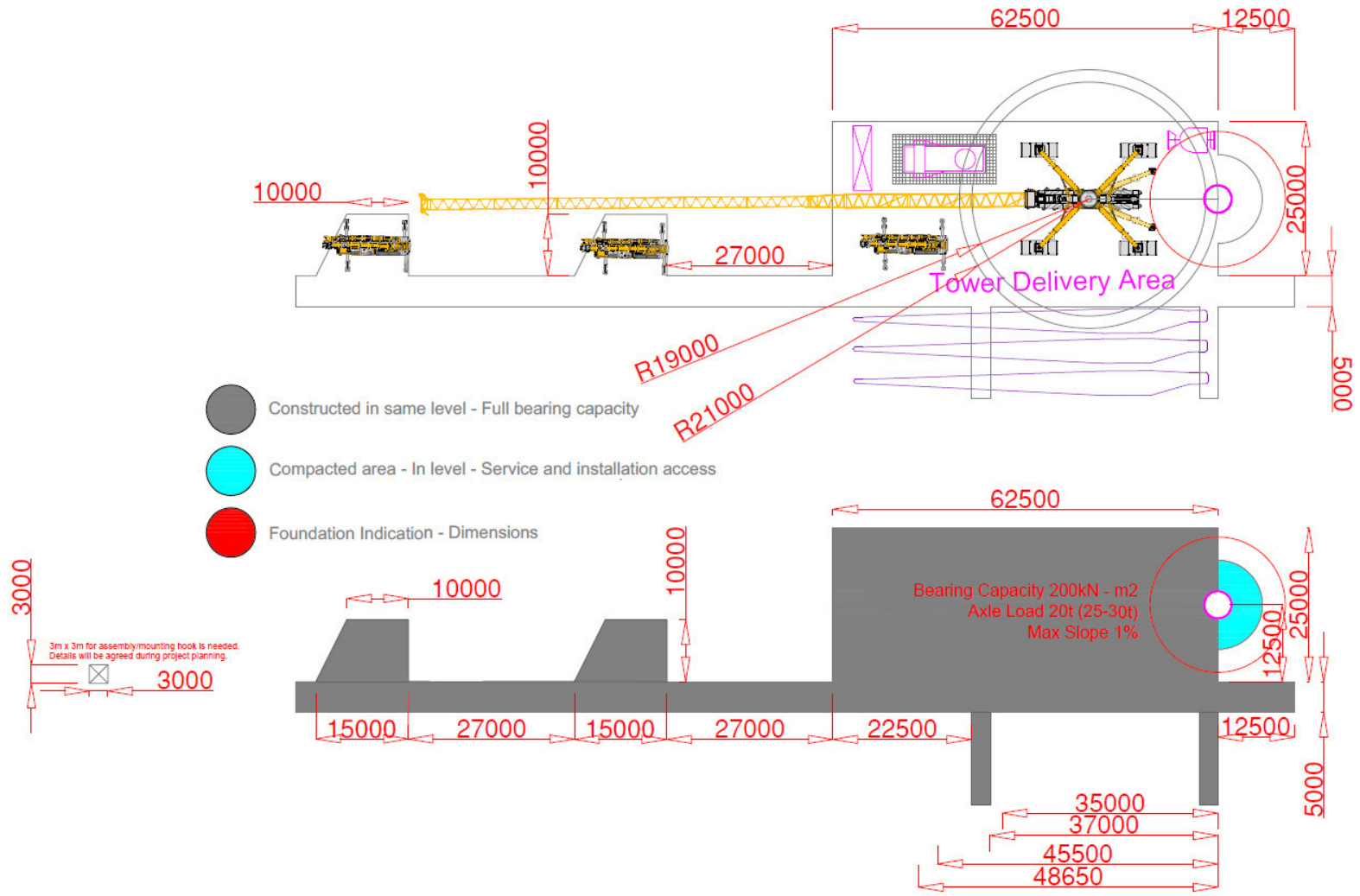
HUB PREPERATION AREA/LOCATION

- During preparation of the hub, the hub will be placed in two preparation stands. The hub will require min 2m of free space around the hub. The area need to allow safe access for preparation and mounting/dismounting of lifting/transport equipment.

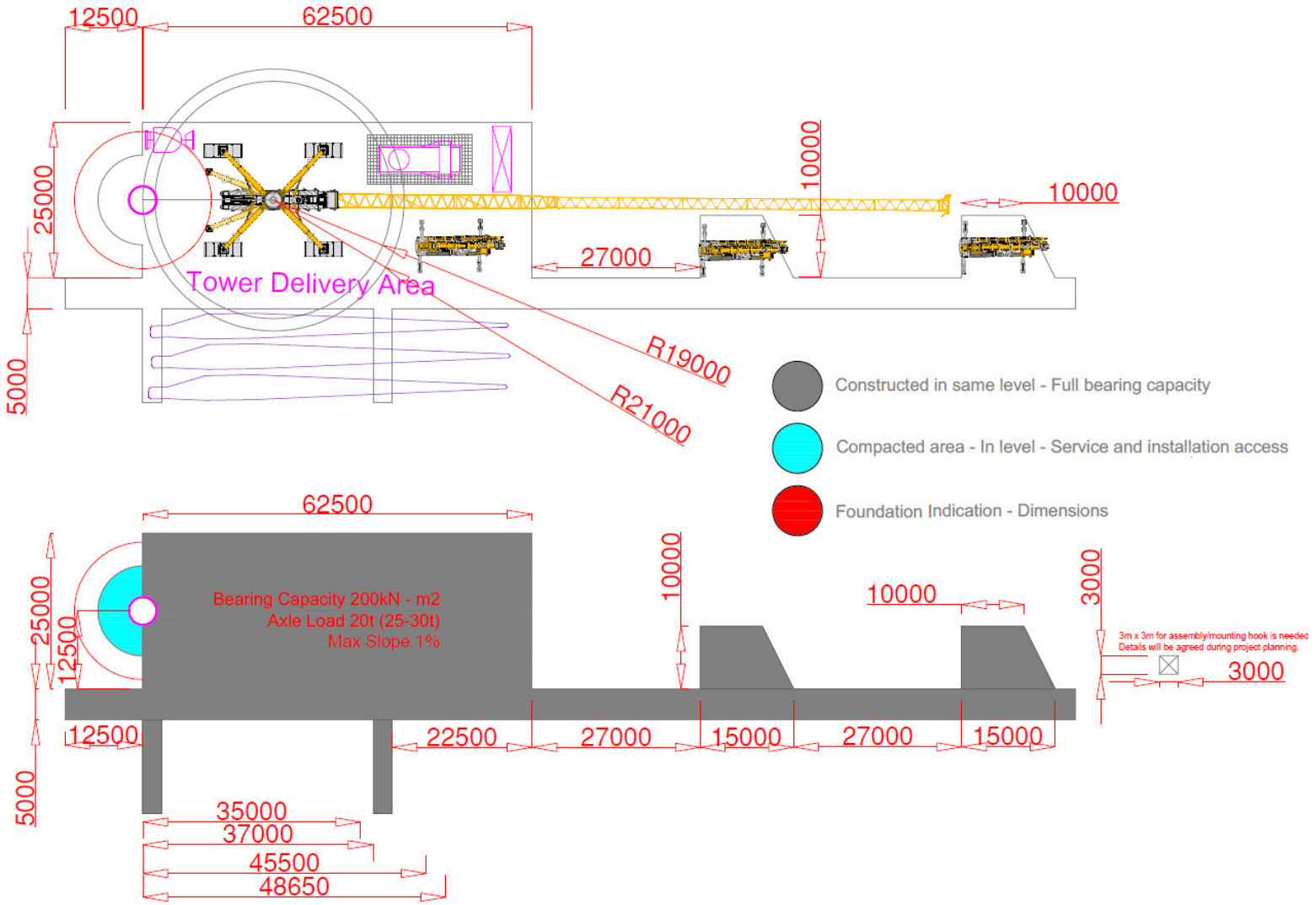
HARDSTAND DIRECTION OF TRANSPORT

- The transports will approach the hardstand area in a forward position. This means that the empty transport units have to either reverse or turn around before leaving the hardstand area. The maximum reverse distance is 200m, but ideal would be zero. For safety reasons reverse activities should always be kept to absolute minimum.

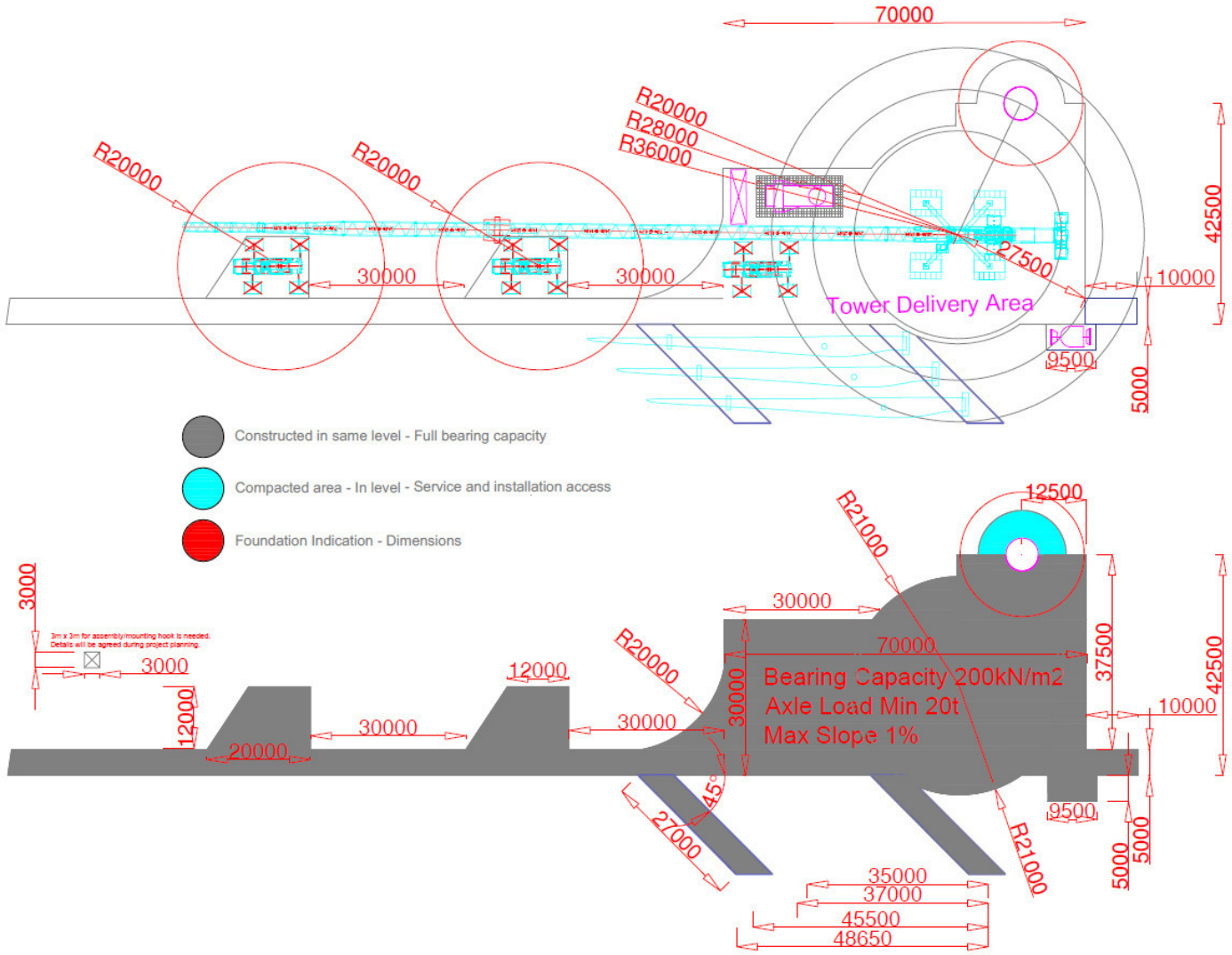
V105-V112-V117-V126-V136 – Standard Hardstand (60m HH – Max. 94m HH – OPTION 1)



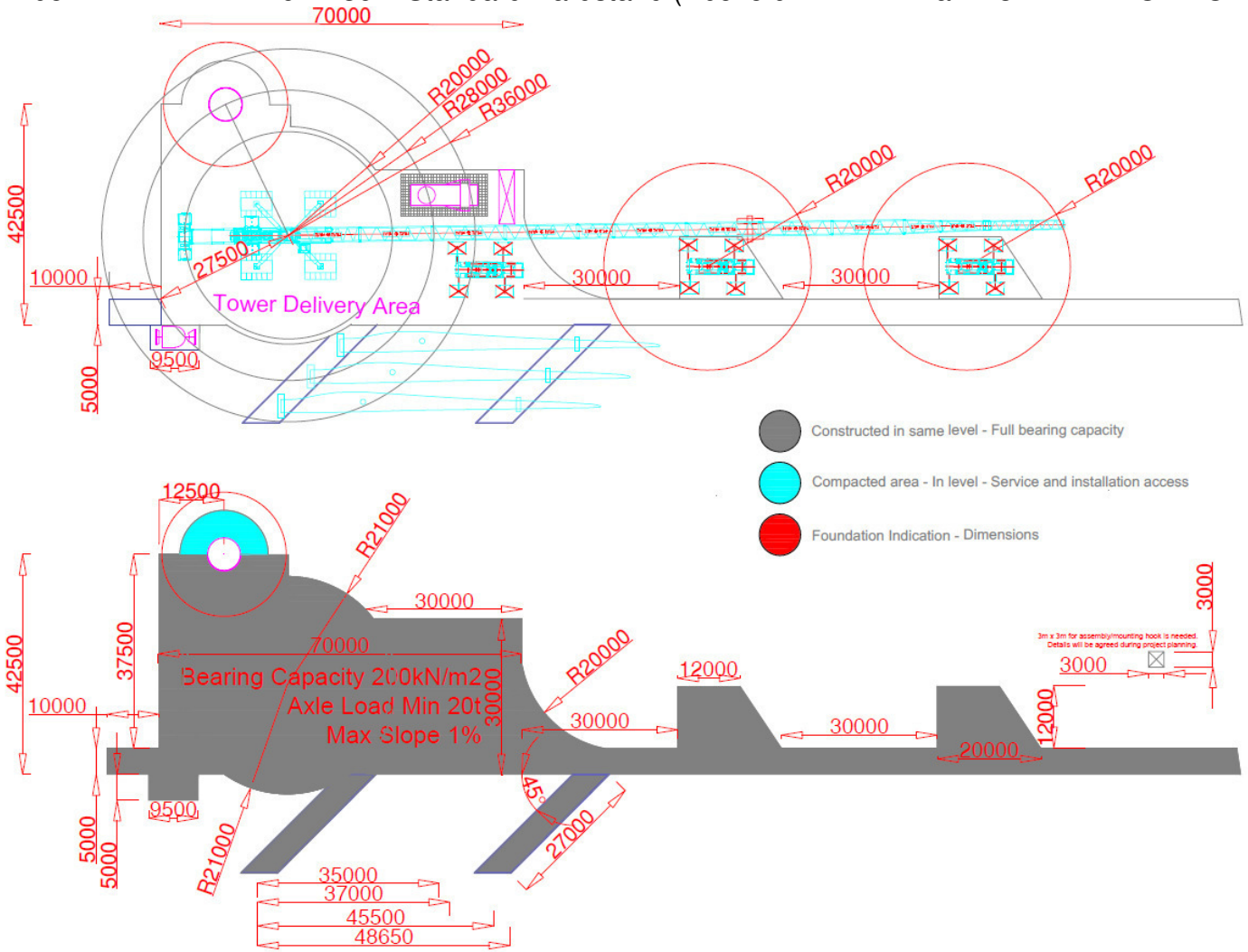
V105-V112-V117-V126-V136 – Standard Hardstand (60m HH – Max. 94m HH – OPTION 2)



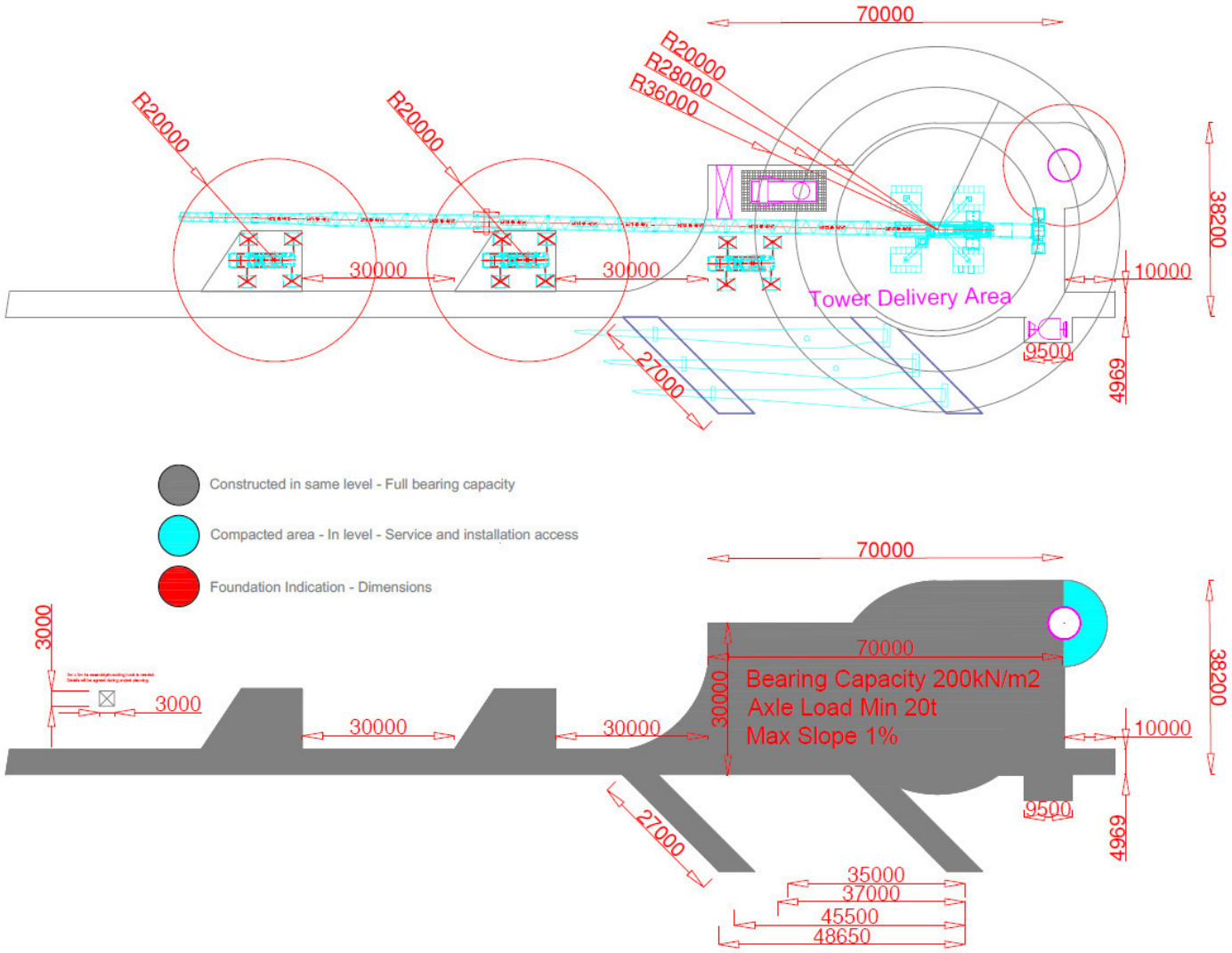
V105-V112-V117-V126-V136 – Standard Hardstand (Above 94m HH – Max. 137m HH – OPTION 1)



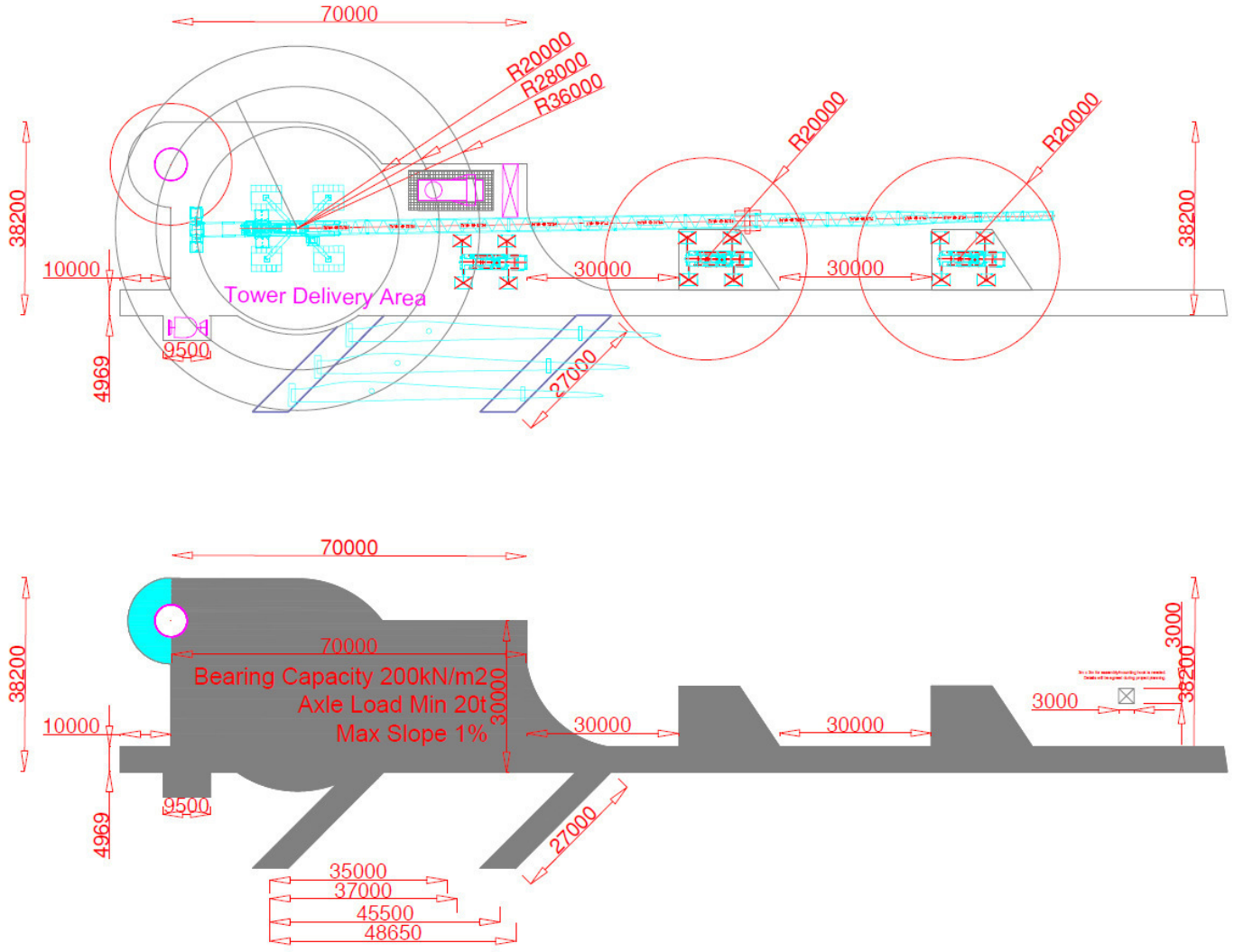
V105-V112-V117-V126-V136 – Standard Hardstand (Above 94m HH – Max. 137m HH – OPTION 2)



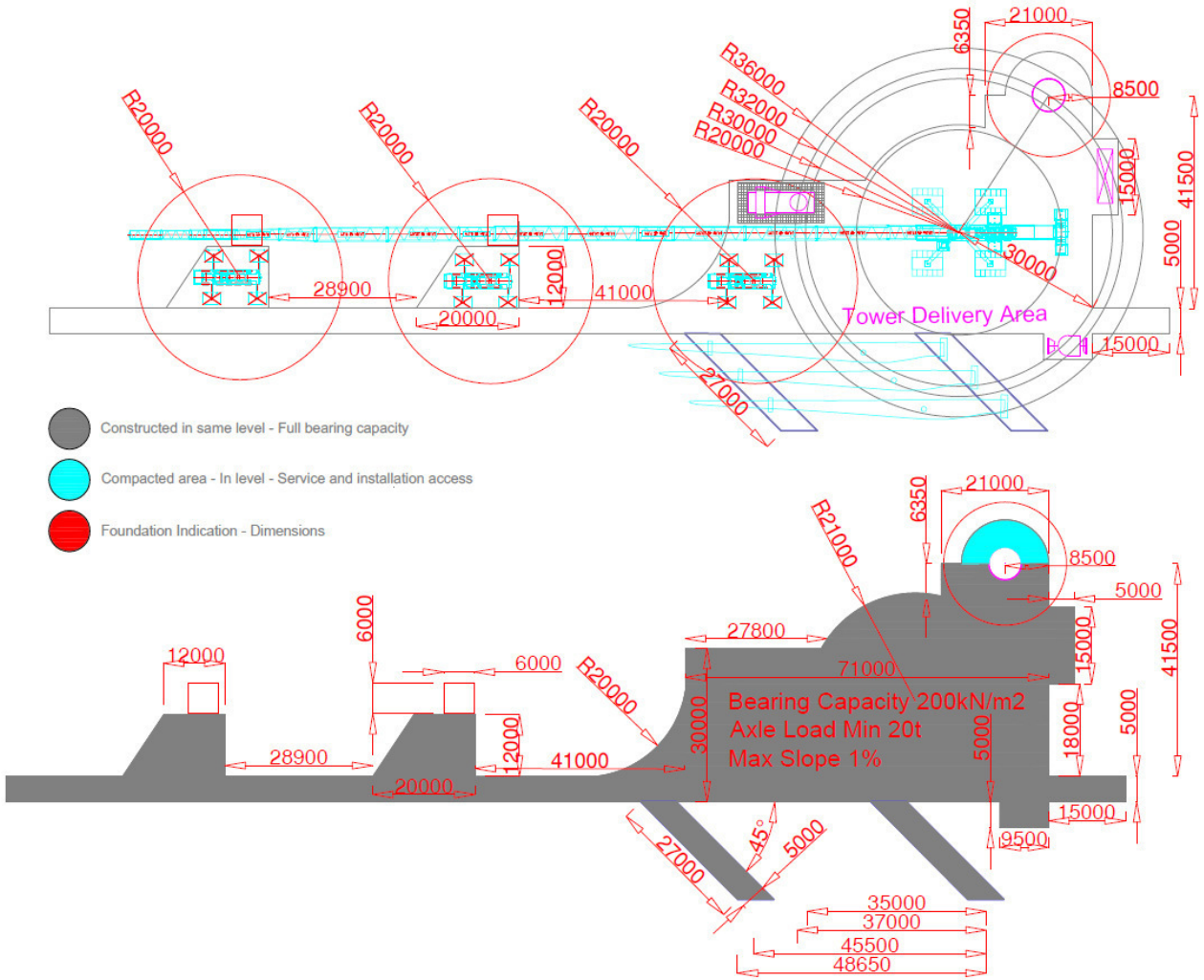
V105-V112-V117-V126-V136 – Standard Hardstand (Above 94m HH – Max. 137m HH – OPTION 3)



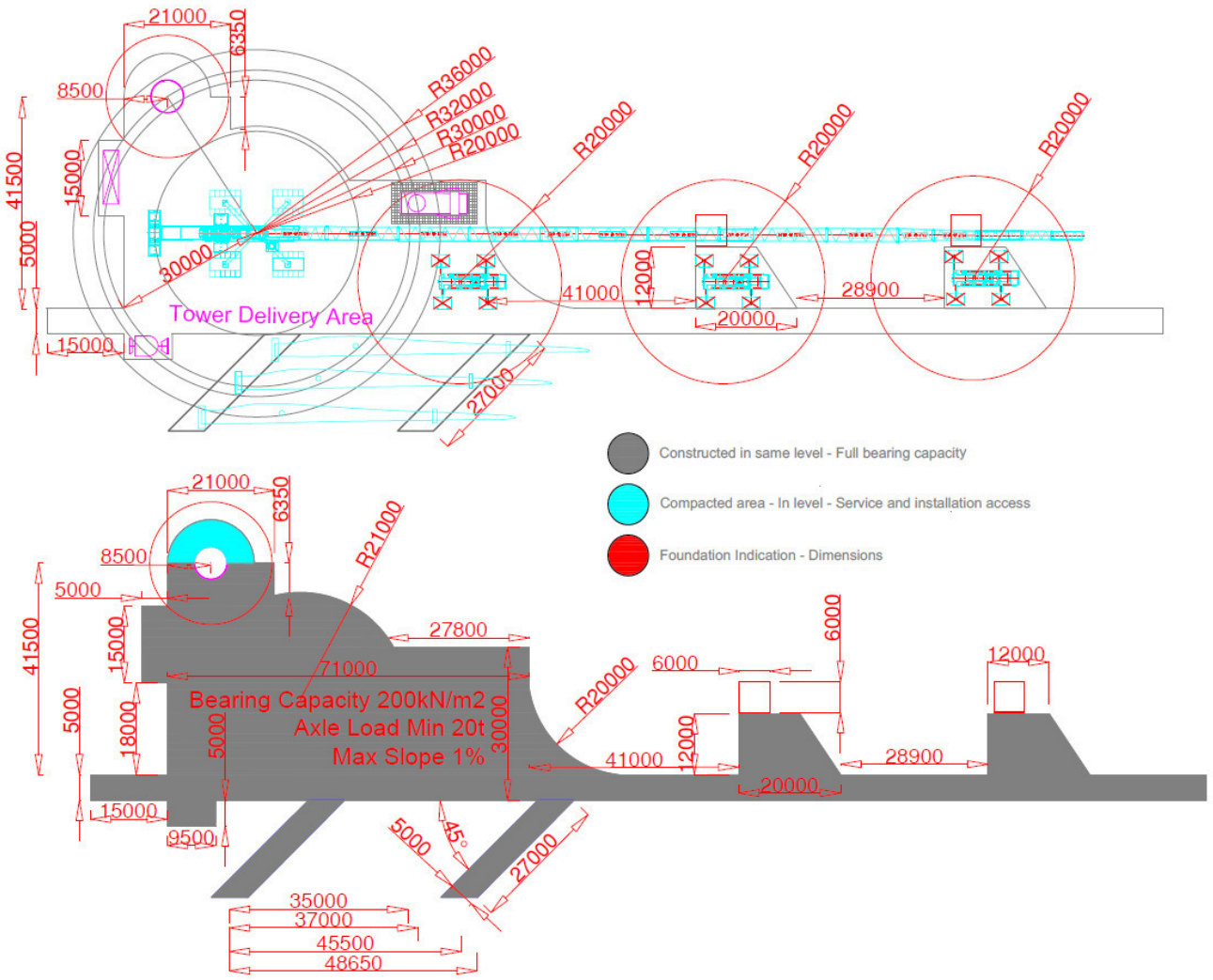
V105-V112-V117-V126-V136 – Standard Hardstand (Above 94m HH – Max. 137m HH – OPTION 4)



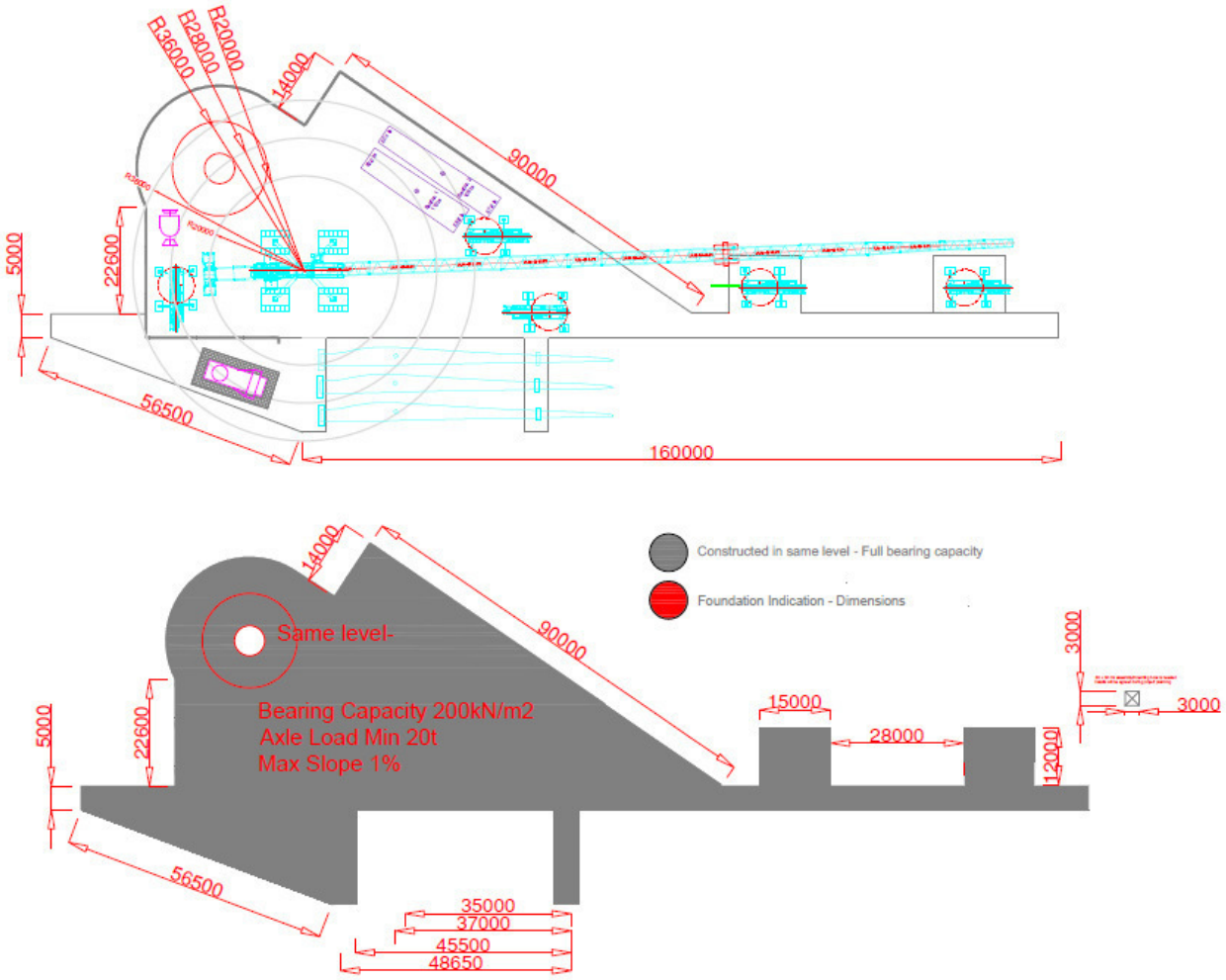
V105-V112-V117-V126-V136 – Standard Hardstand (Above 137m HH – Max. 147m HH – OPTION 1)



V105-V112-V117-V126-V136 – Standard Hardstand (Above 137m HH – Max. 147m HH – OPTION 2)



V105-V112-V117-V126-V136 – Standard Hardstand (60m HH – Max. 147m HH)
LDST Assembly / Tower Storage / Self unloading nacelle



10. Appendix 4: Hardstand Examples – Just in Time Delivery / Combination with Additional Preparation Area

General information to hardstand/layout examples shown below are as follow:

TAGLINES

- To perform a safe and controlled lift of components, a manual tagline set up is used.
- Two (2) or up to four (4) taglines will be attached to the component, the taglines will be manually controlled by the ground personnel.
- The orientation of taglines can vary due to local conditions, such as wind direction and speed.
- The direction/orientation can be challenging in conditions with inaccessible areas such as peat/water/trees etc.
- Safe direction/walking route of taglines shall always be considered and agreed prior to each lift.

BLADE LAYDOWN AREA

- Blade laydown area has to be flat and free of obstacles, the area need to allow safe access for preparation and mounting/dismounting of lifting/transport equipment. The location and distance between blade fingers will vary depending of the turbine type (Blade length and COG)

BOOM ASSEMBLY AREA

- Boom assembly area has to be free of obstacles and allow safe access for personnel and equipment during assembly. If boom assembly area is combined with gradients or slope boom supports is needed. The location of boom supports can vary depending of crane type and configuration. The amount and location of boom supports shall always be evaluated and agreed project specific.

NACELLE PREPERATION AREA/LOCATION

- During preparation of the nacelle a scaffolding setup will be used around the nacelle, the scaffolding will require min 3m of free space around the nacelle. This area is indicated with a grey line on the examples.
- The area need to allow safe access for preparation and mounting/dismounting of lifting/transport equipment.

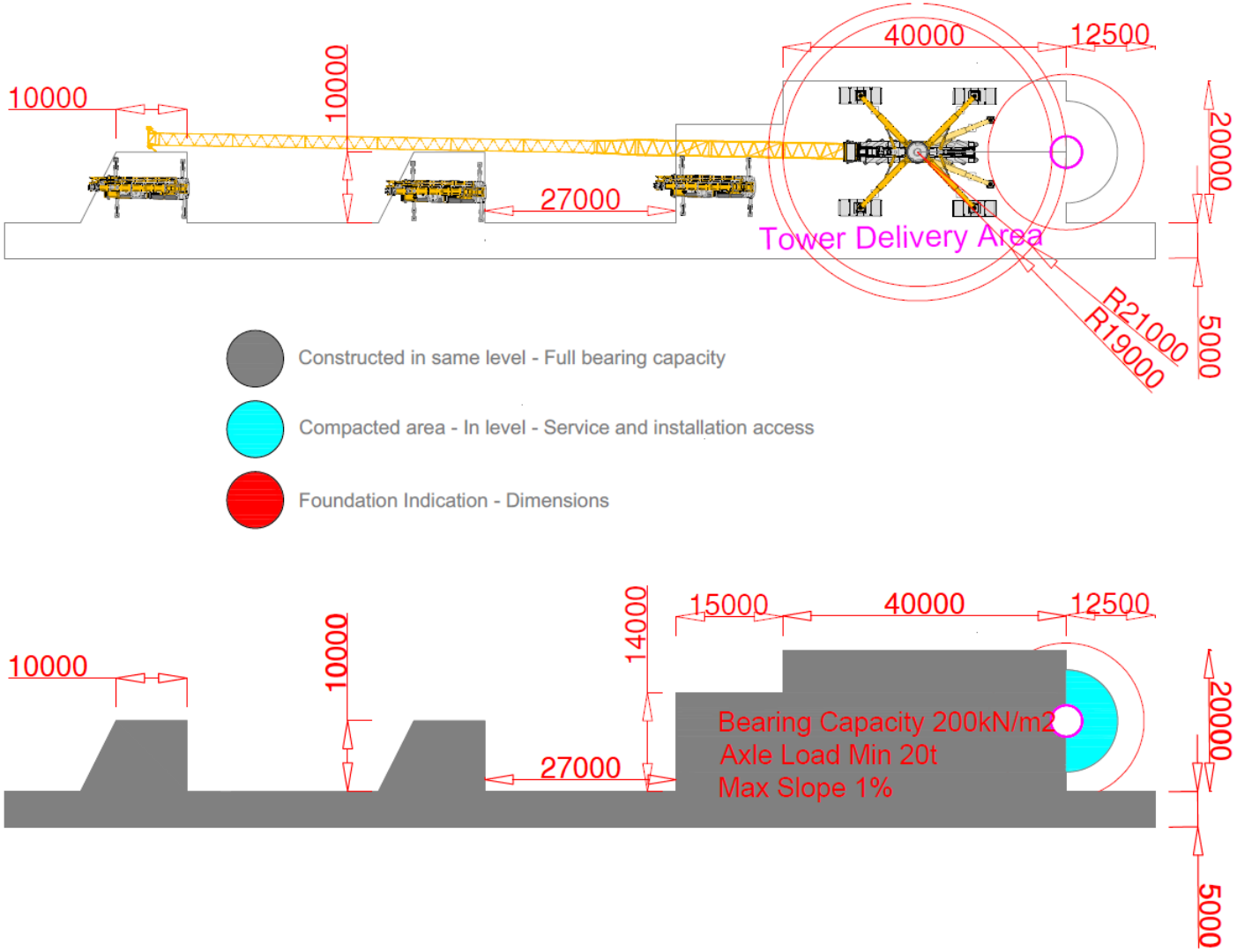
HUB PREPERATION AREA/LOCATION

- During preparation of the hub, the hub will be placed in two preparation stands. The hub will require min 2m of free space around the hub. The area need to allow safe access for preparation and mounting/dismounting of lifting/transport equipment.

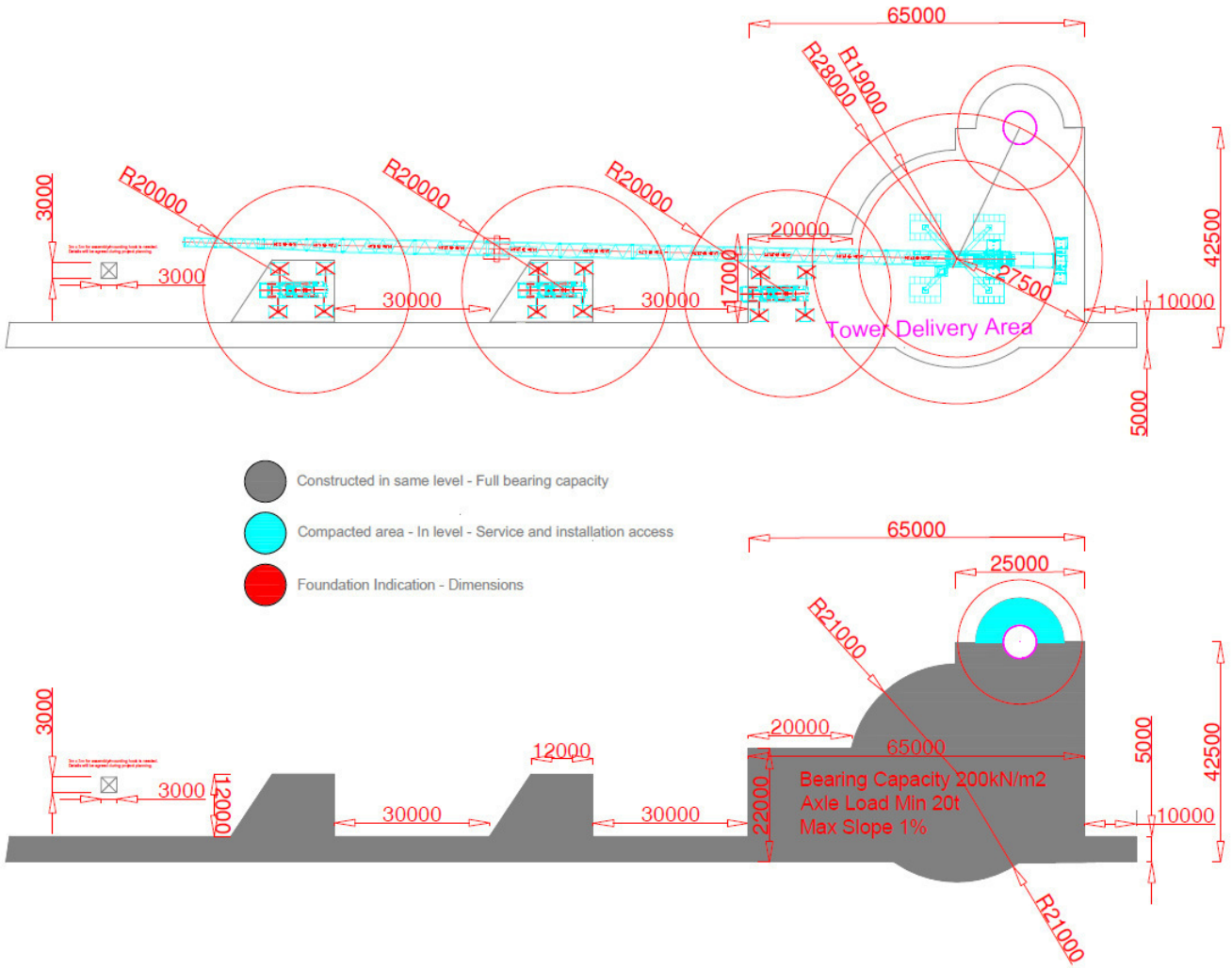
HARDSTAND DIRECTION OF TRANSPORT

- The transports will approach the hardstand area in a forward position. This means that the empty transport units have to either reverse or turn around before leaving the hardstand area. The maximum reverse distance is 200m, but ideal would be zero. For safety reasons reverse activities should always be kept to absolute minimum.

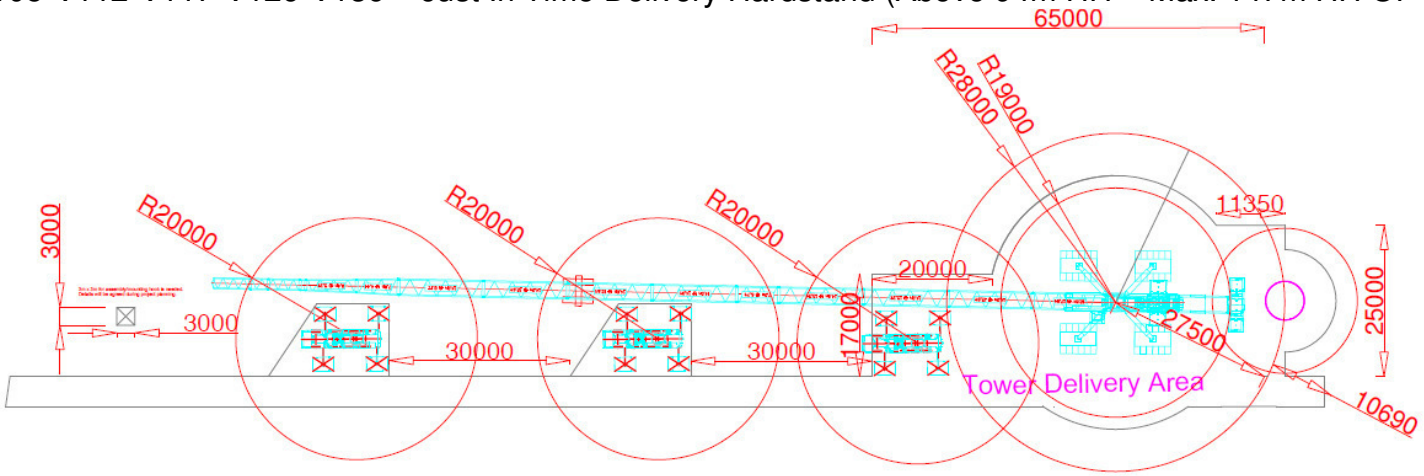
V105-V112-V117-V126-V136 – Just In Time Delivery Hardstand (60m HH – Max. 94m HH)



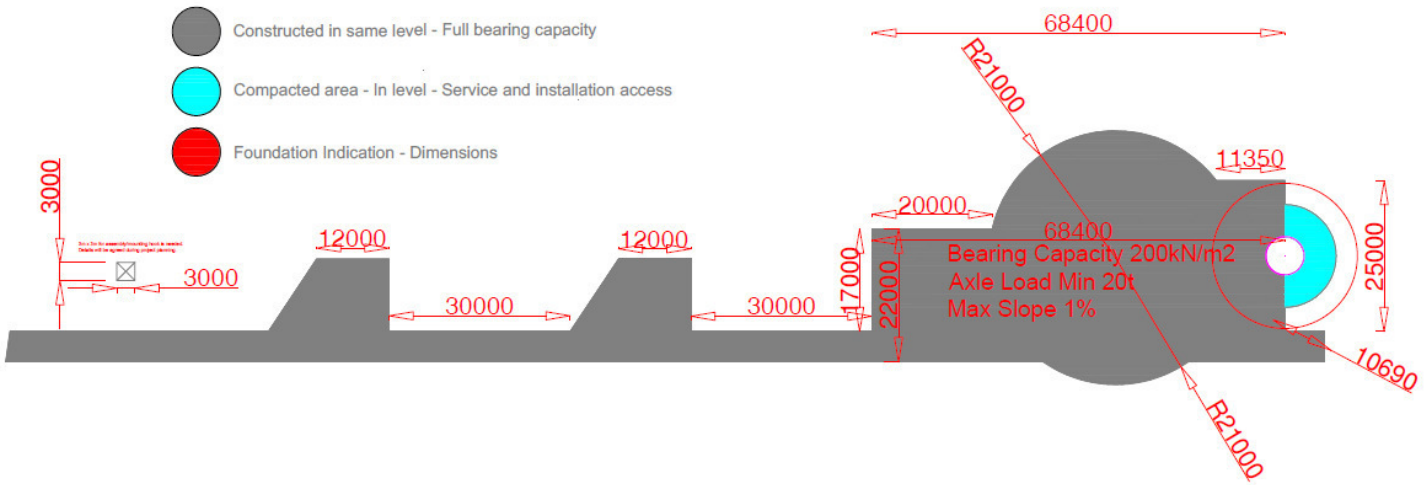
V105-V112-V117-V126-V136 – Just In Time Delivery Hardstand (Above 94m HH – Max. 147m HH OPTION *1)*



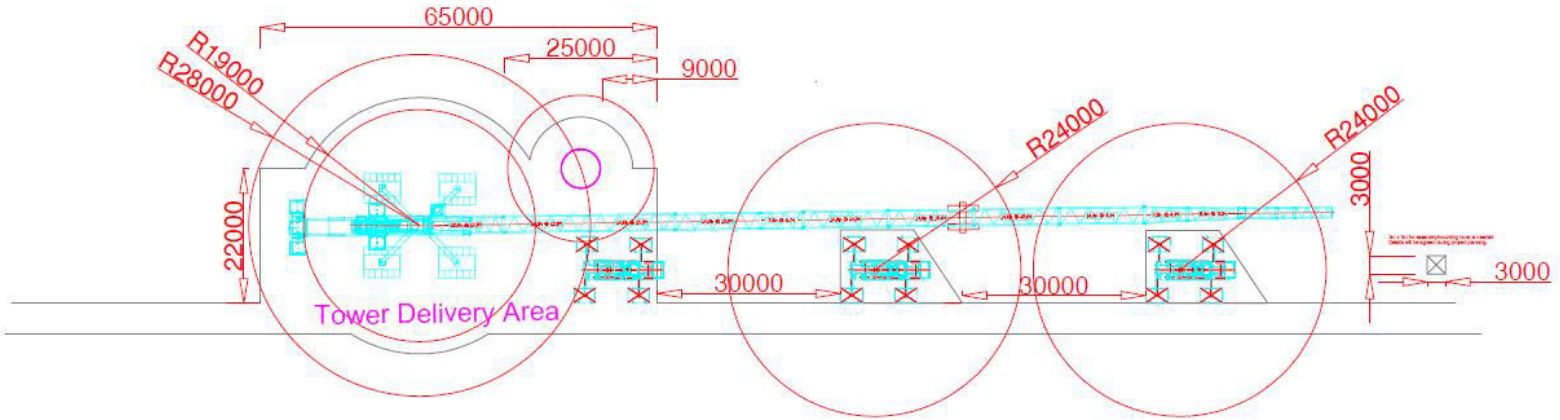
V105-V112-V117-V126-V136 – Just In Time Delivery Hardstand (Above 94m HH – Max. 147m HH OPTION 2)



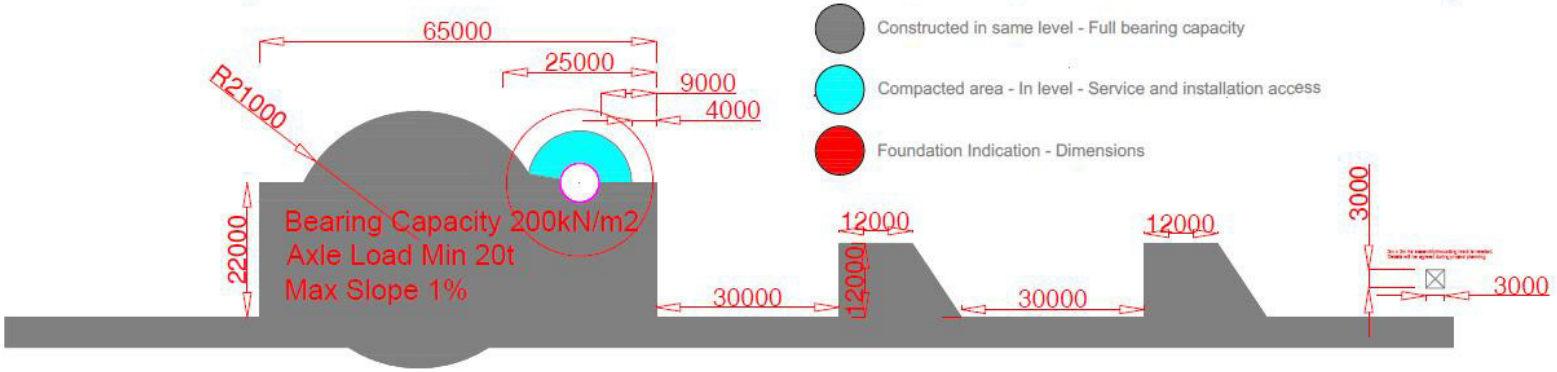
1. Super lift is placed on top of foundation
2. Outside position of tower stairs/access has to be considered, due to location of super lift.



V105-V112-V117-V126-V136 – Just In Time Delivery Hardstand (Above 94m HH – Max. 147m HH OPTION 3)

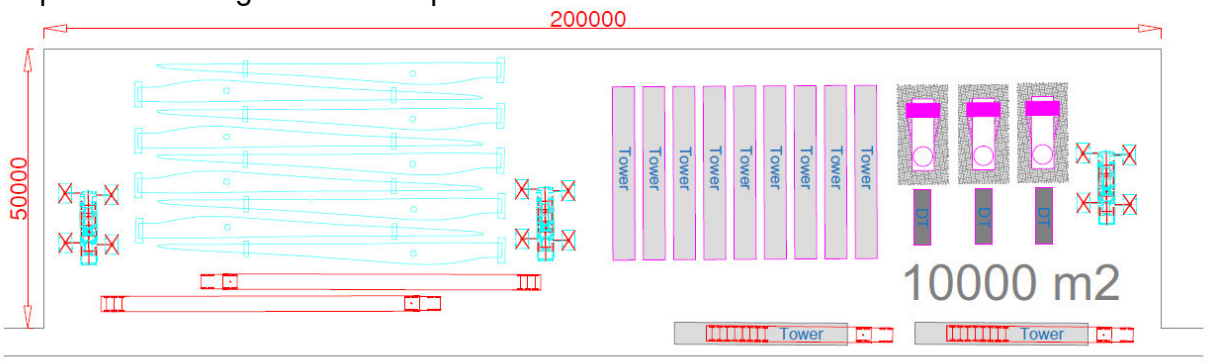


1. Outside position of tower stairs/access has to be considered, due to pre-installation and boom assembly

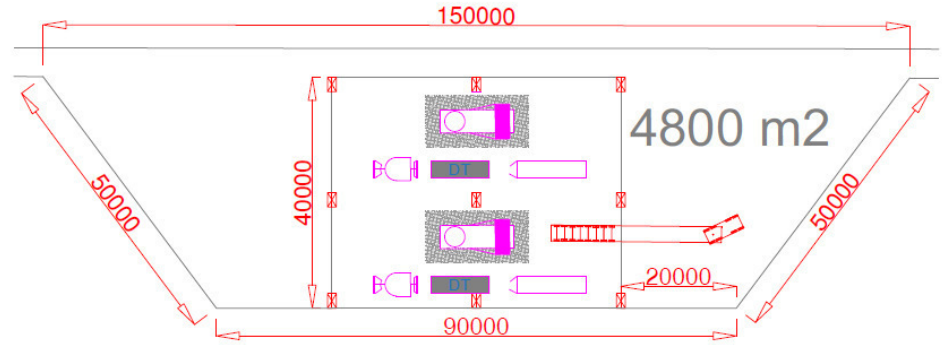


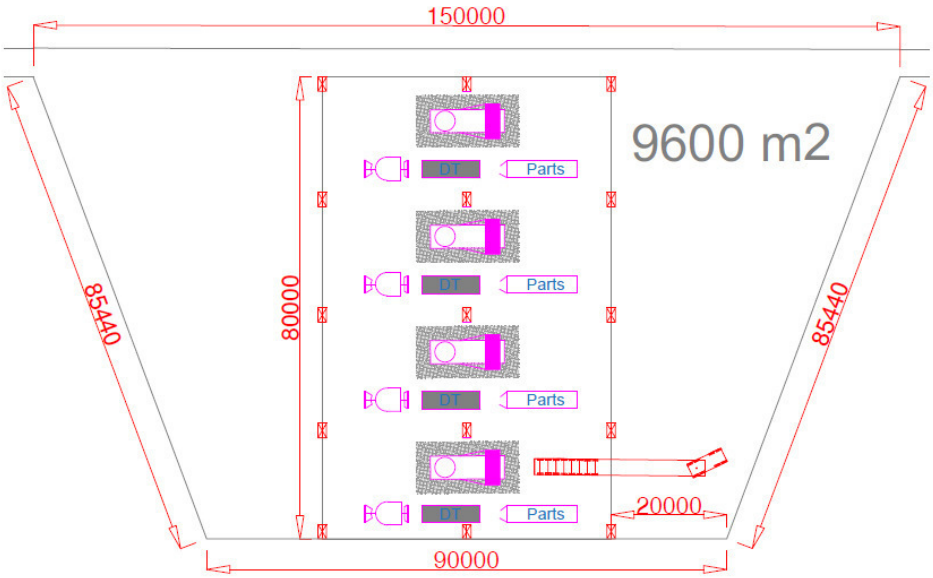
11. Appendix 5: Preparation Area Examples / Solutions

Preparation/storage area example 1

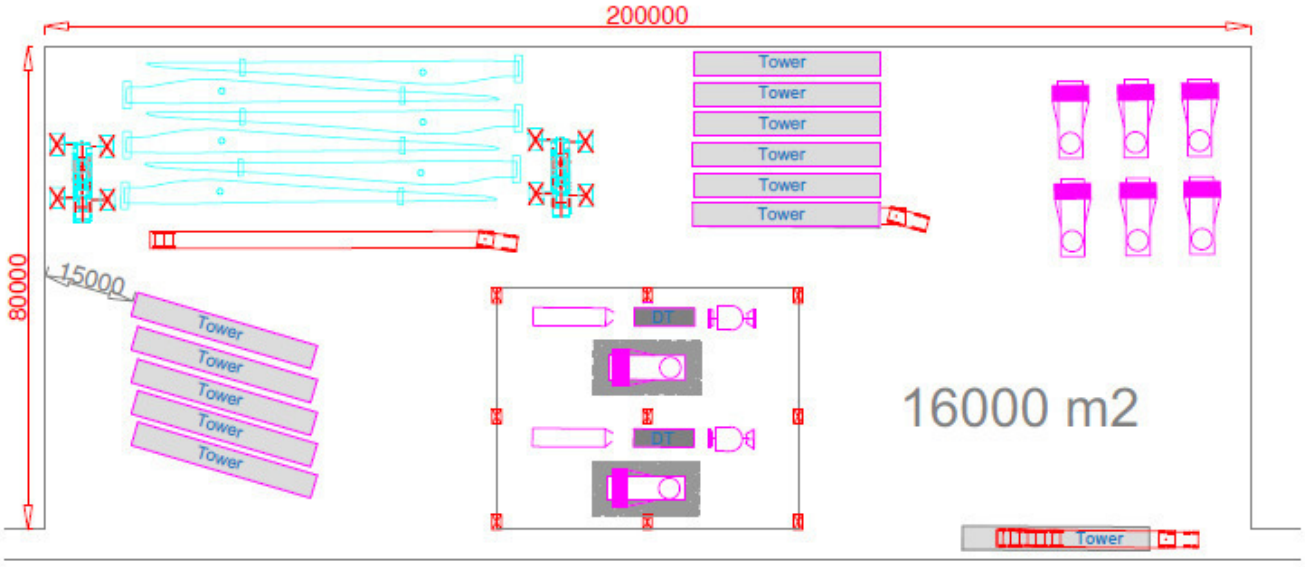


Preparation area example 2 (shown with tent solution)

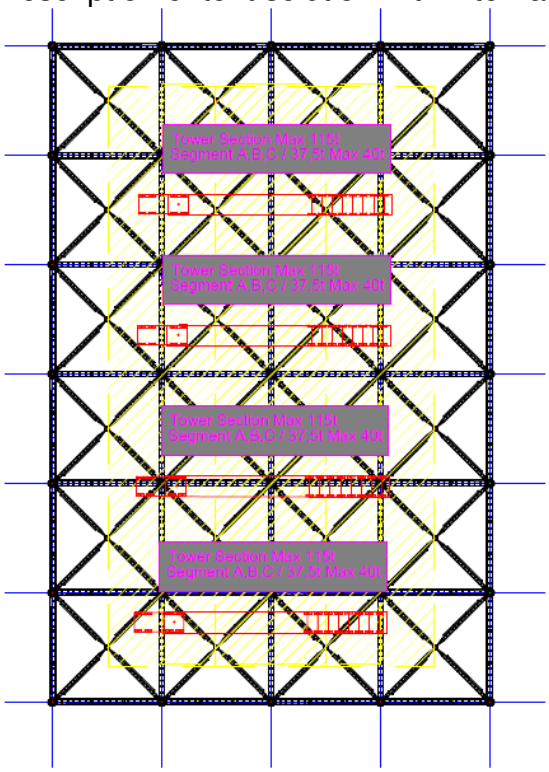




Preparation/storage area example 3 (shown with tent solution)



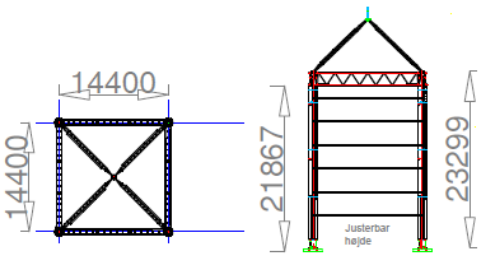
Description of tent solution with internal traverse cranes (for LDST assembly):



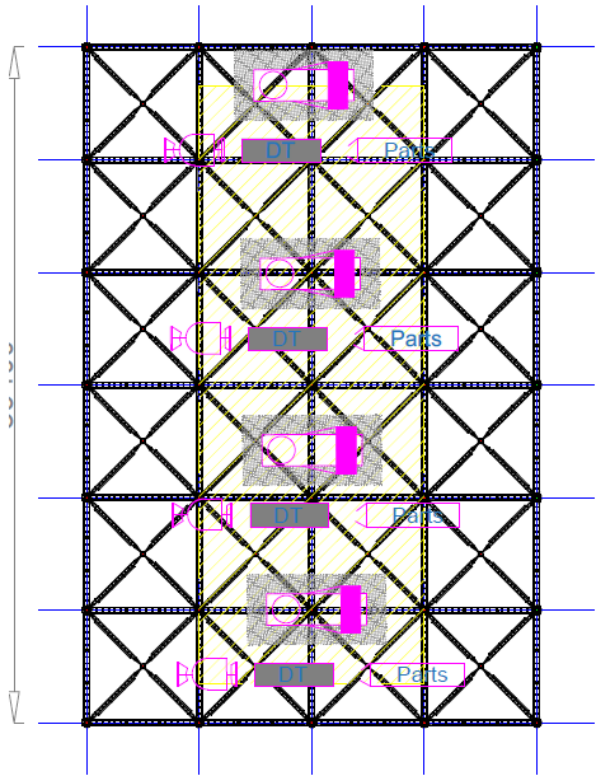
On Site soft building example - Drive in/out solution

1. 2 x Traverse crane SWL 30t - Min Hook Height 15m
2. Entrance and departure points - 13m (width) 10m (Height)

Yellow Area = 2 x Traverse Cranes Working Zone SWL-30t

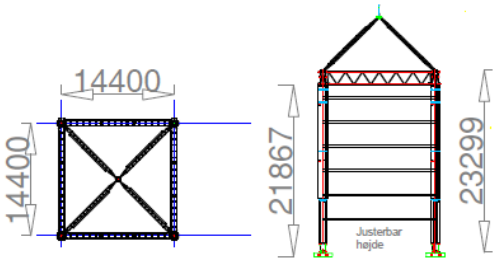


Description of tent solution with internal traverse crane (for nacelle preparation):



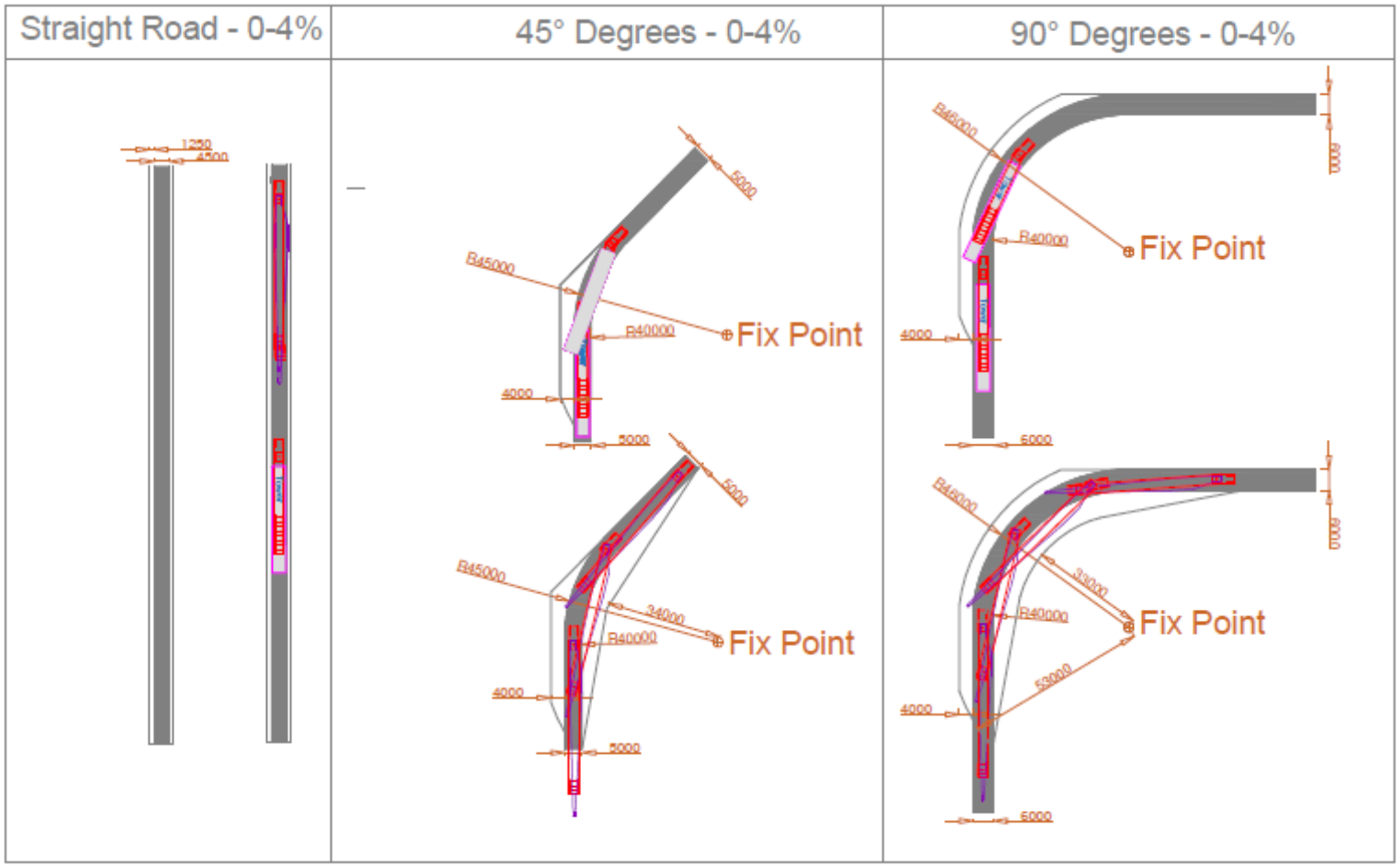
On Site soft building example - Drive in/out solution
1. Traverse crane SWL 65t - Min Hook Height 15m
2. Entrance and departure points - 13m (width) 10m (Height)

Yellow Area = Traverse Crane Working Zone SWL-65t

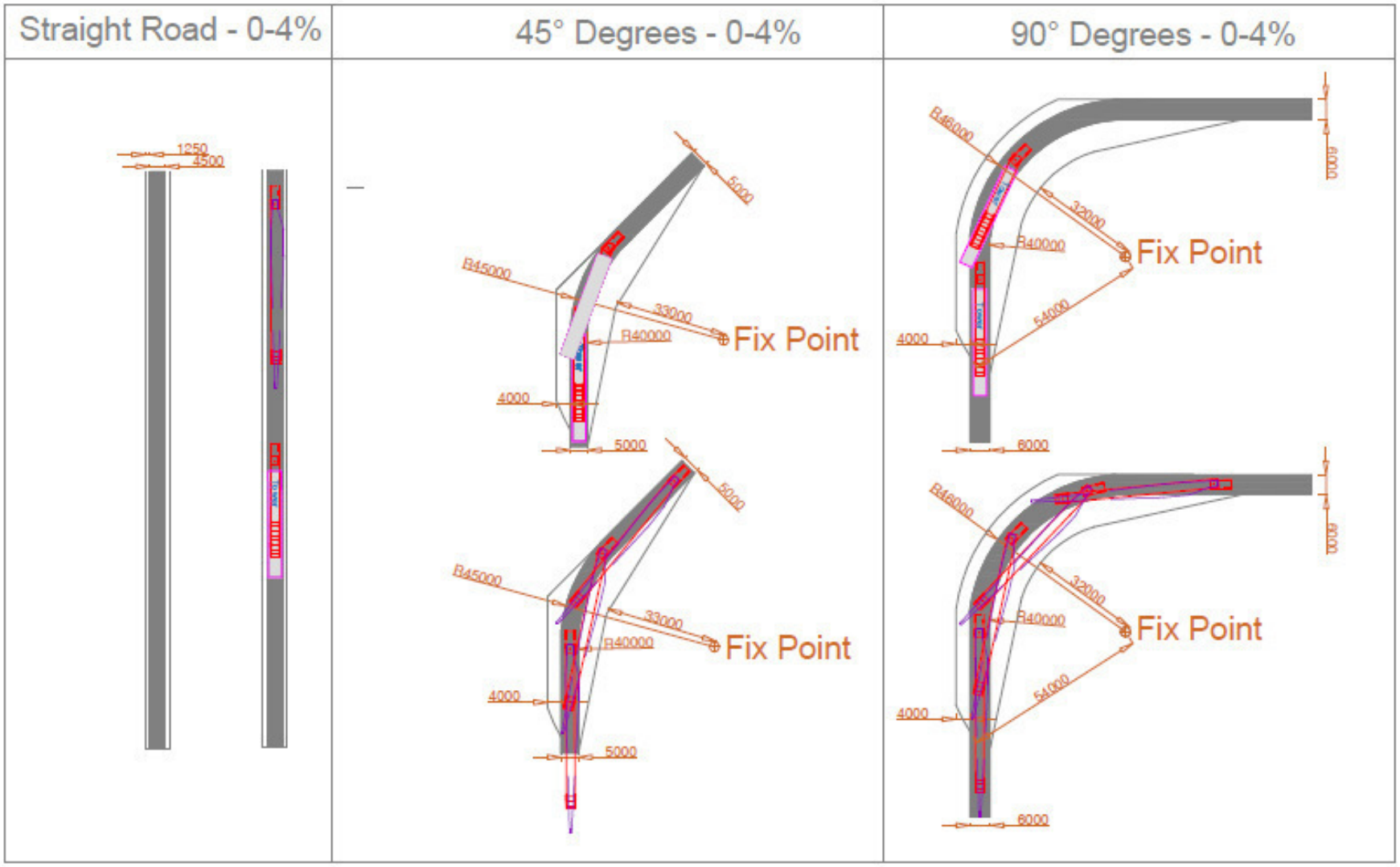


12. Appendix 6: Swept Path Examples

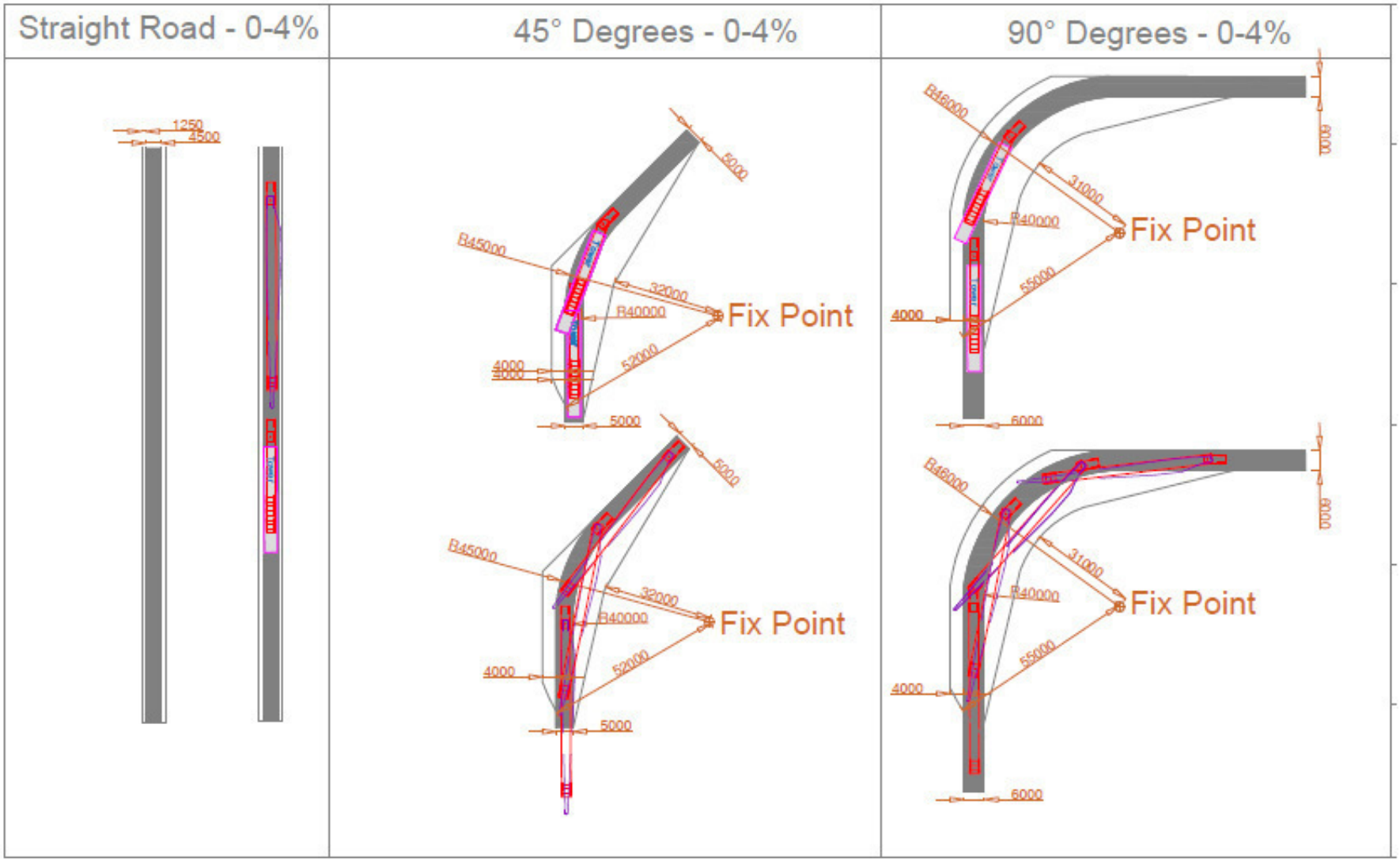
V105



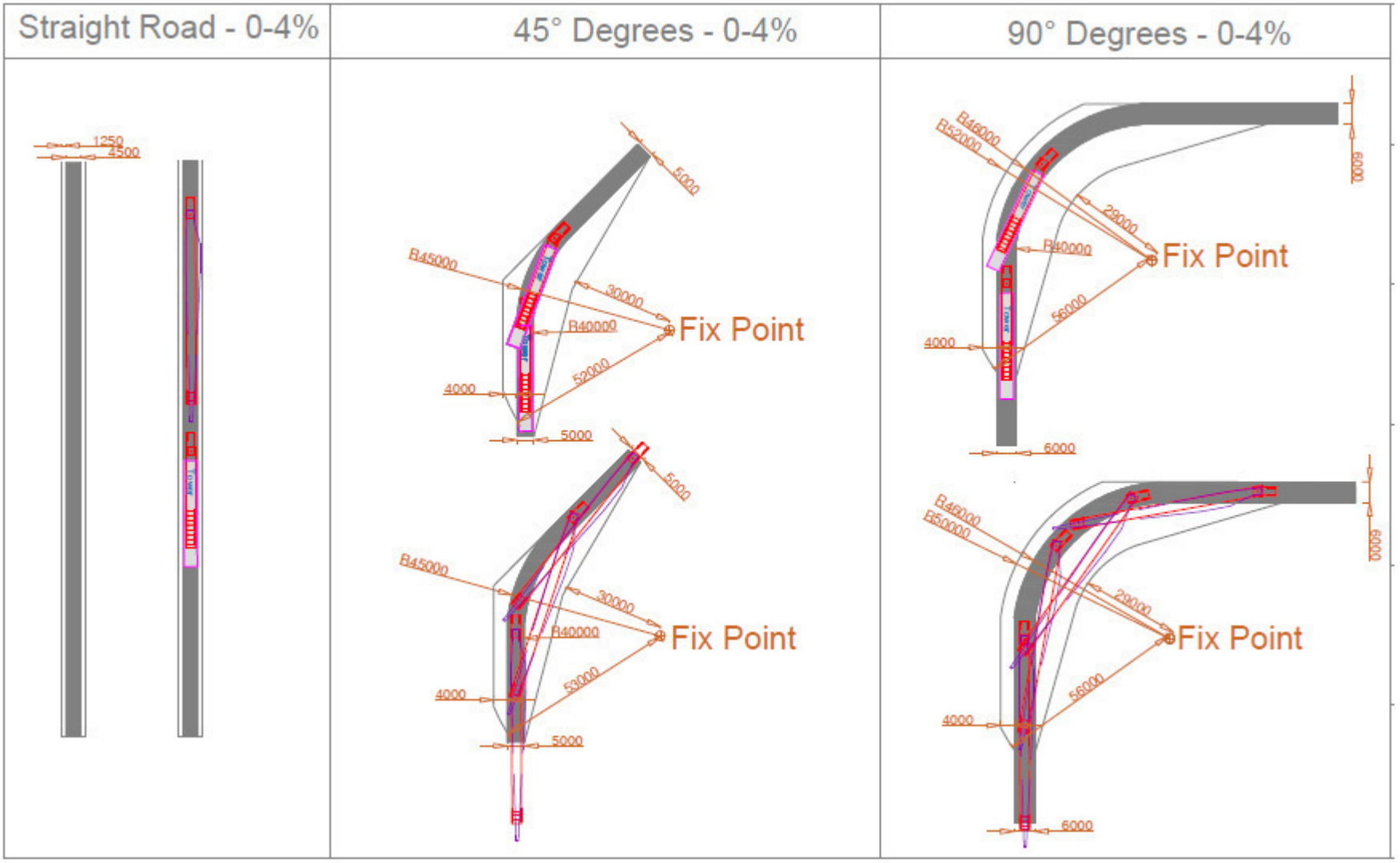
V112



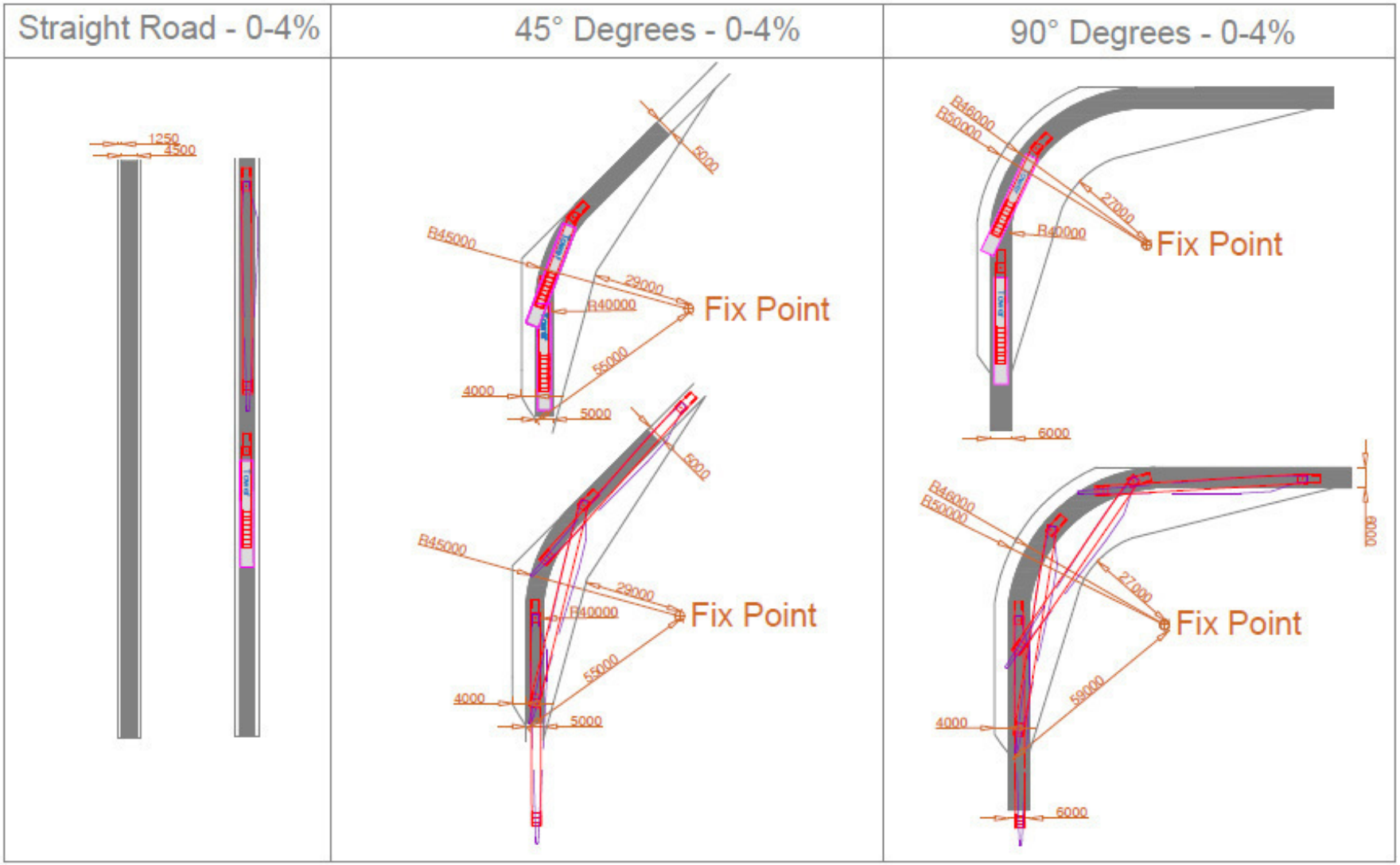
V117



V126



V136



13. Appendix 7: Access and Site Road Requirements Checklist

Wind Power Plant		Date	
Wind Turbine No.			

CHECKS PERFORMED (Relevant documentation to be attached)

	Inspection prior to Wind Turbine Erection	Specification	Result
1	Road width (Straight Roads)	4.5 / 5m	
2	Longitudinal slope	Max. gradient 8°/14°	
3	Lateral slope	Max. gradient 2%	
4	Load bearing capacity	20Te per axle	
5	Vertical Radius (Convex or Concave)		
6	Overhead clearance, including safety zone, with “goal posts” installed for immovable obstructions		
7	Grading after compaction, type 1 (Specification for Highway Works)	32mm to fines	
8	California Bearing Ration (CBR) or local requirements (Eurocode 7)	≥60%	
9	Plasticity Index (PI) or local requirements (Eurocode 7)	<10%	
10	Self-draining of roads, review catch drains, side drains, culverts, head and end walls, underground drains, pits, erosion control, devices etc.		
11	Review all bends according to the requirements	Road/Bends R__ Overhang Clearance R__	
12	Review Turning Areas	Typically 200m from hardstand/ unloading areas	

REMARKS:

Customer (or customer’s representative) signature		Date	

14. Appendix 8: Crane Pad Requirements Checklist

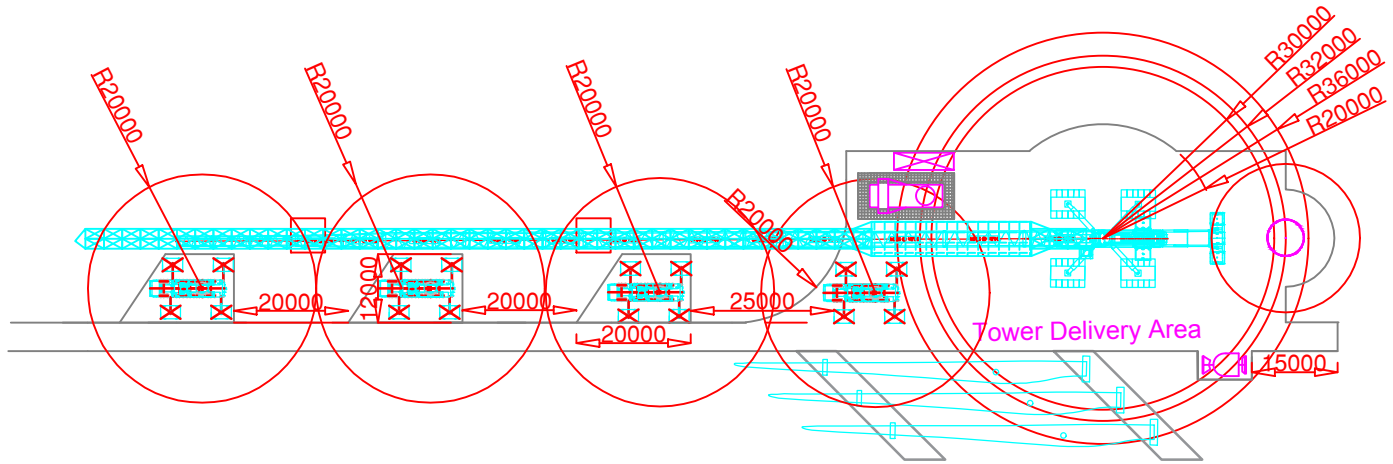
Wind Power Plant		Date	
Wind Turbine No.			

CHECKS PERFORMED (Relevant documentation to be attached)

	Inspection prior to Wind Turbine Erection	Specification	Result
1	Dimensions are a minimum of the agreed specification (excluding the road)		
2	Longitudinal slope	Max. gradient 1%	
3	Lateral slope	Max. gradient 1%	
4	Load bearing capacity (Delete as applicable)	Minimum of 200 / 250 kN/m^2	
5	Compaction or local requirements (Eurocode 7)	Min. 98% (modified Proctor)	
6	Shoulder slopes	Maximum 45°	
7	Drainage review (Control of storm water flow along and under and around the crane pads so as to self-drain)		
8	Suitable area for blade unloading and laydown		
9	Sufficient working space (5m radius) and finish around the turbine base for access pathway and future maintenance		

REMARKS:

Customer (or customer's representative) signature		Date	



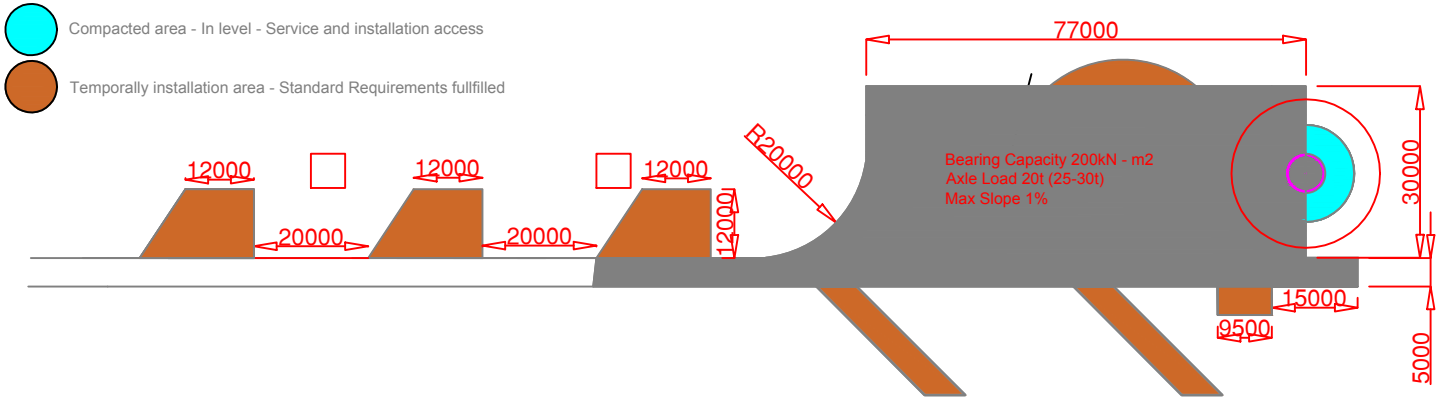
Constructed in same level - Full bearing capacity

Foundation Indication

Compacted area - In level - Service and installation access

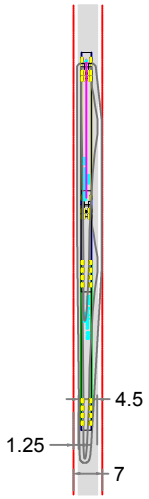
Temporally installation area - Standard Requirements fullfilled

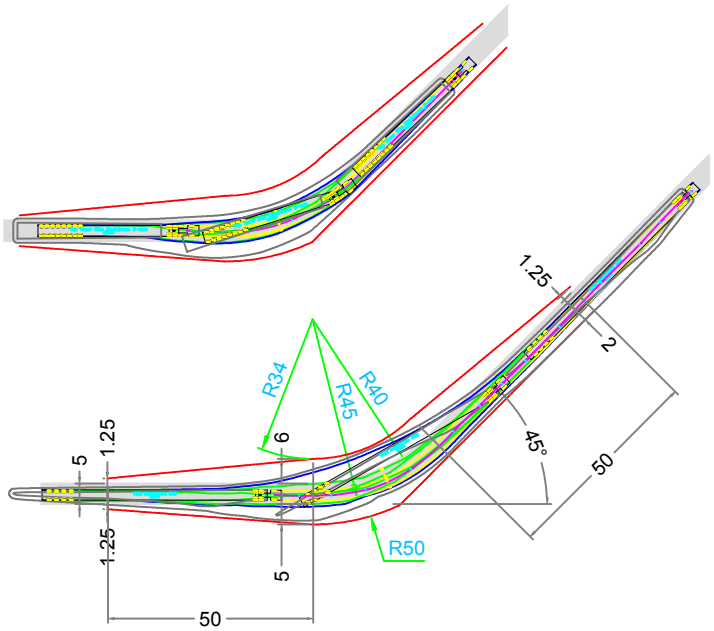
- Crane configuration is indicative

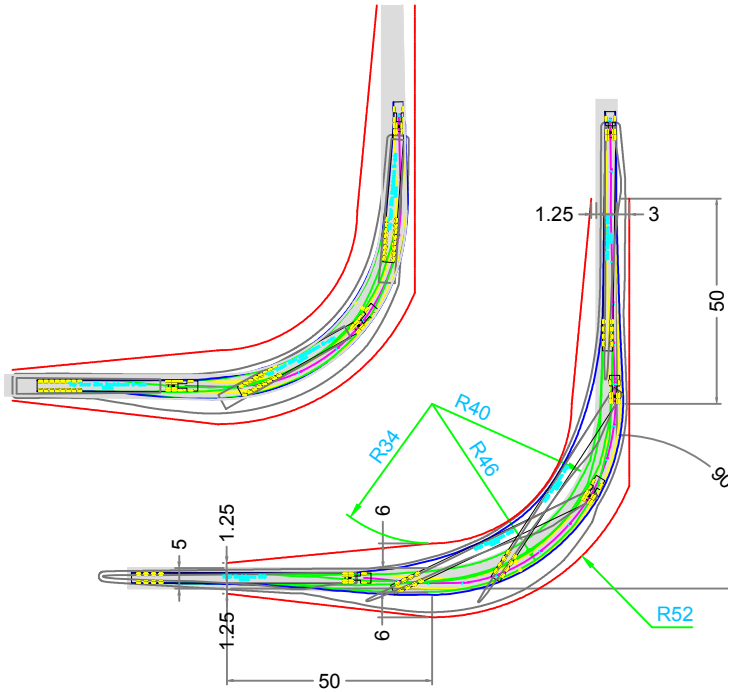


- Distance/Location between/of blade fingers will vary all due to turbine type and blade length.

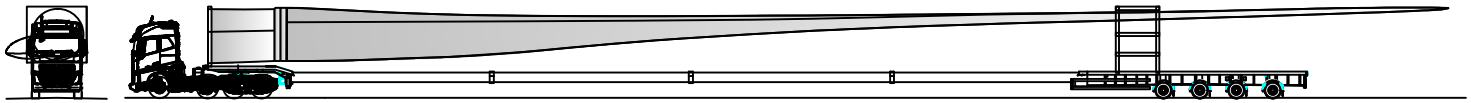
Vestas Northern Europe A/S			Project: Hardstand V150 max 166m HH	
CONSULTANT: JBOE			ADDRESS: Appendix to 0038-8194.V10	
LAST REV.DATE: 19-06-2017	SIGN.: JBOE	APPD.: 19-06-2017		
DATE: 19-06-2017	SIGN.: JBOE	APPD.: 19-06-2017	DRAWING NO.: V150 max 166m HH	REV.: 00



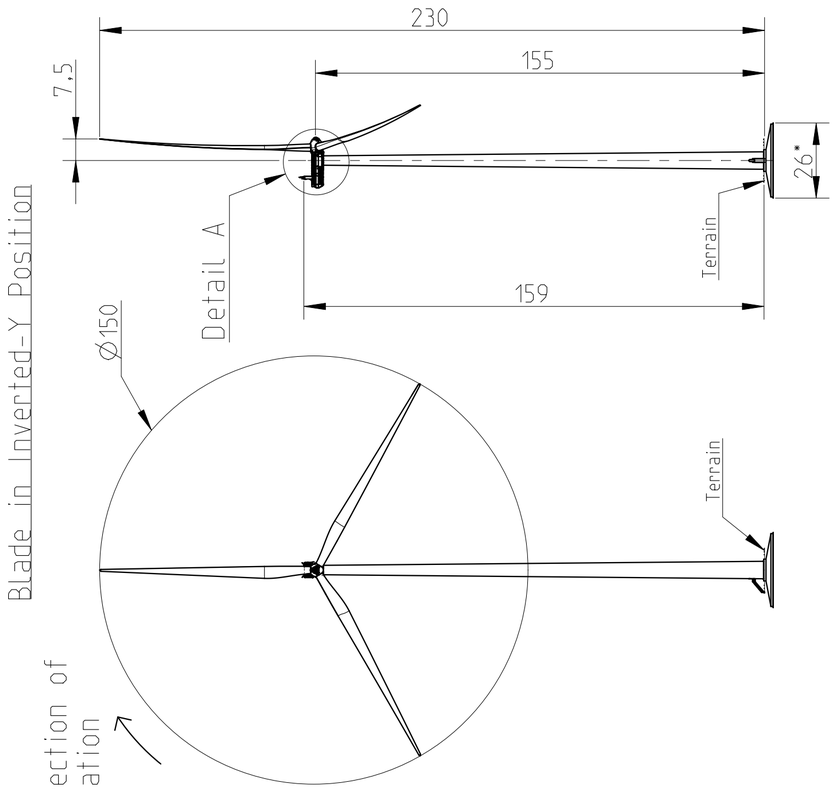


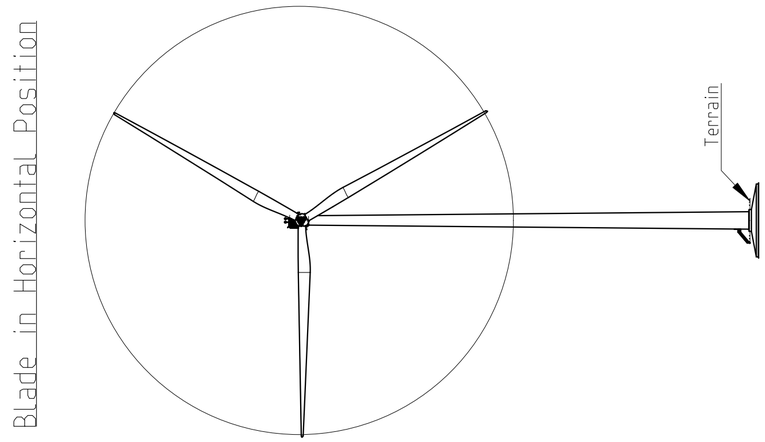


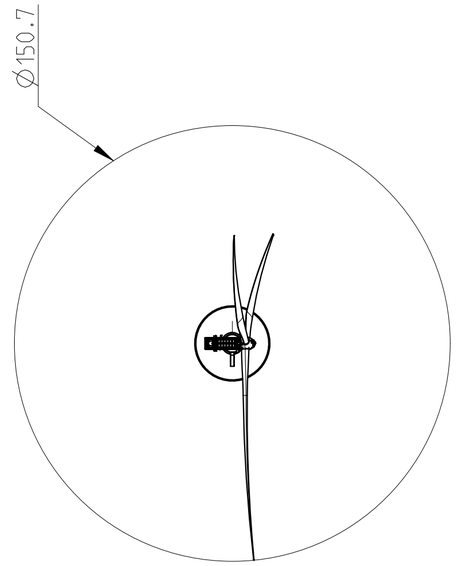
***Vestas*® V126**

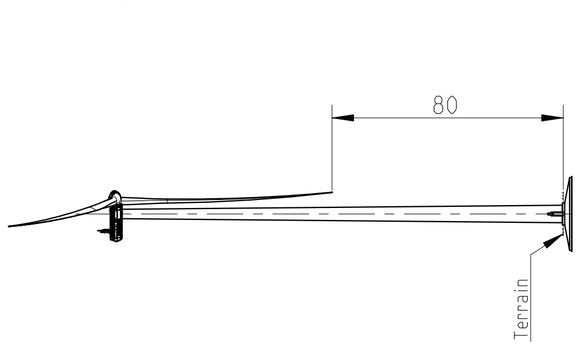


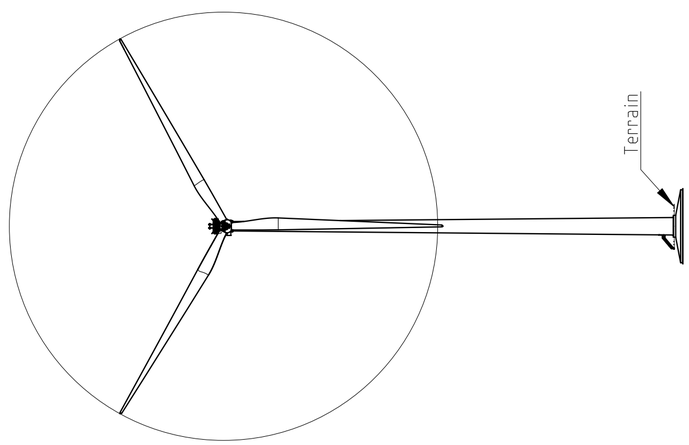
Vestas Northern Europe A/S			Project: V150 Swept Path	
CONSULTANT: JBOE			ADDRESS: Appendix to 0038-8194.V10	
LAST REV.DATE: 19-06-2017	SIGN.: JBOE	APPD.: 19-06-2017		
DATE: 19-06-2017	SIGN.: JBOE	APPD.: 19-06-2017	DRAWING NO.: V150 Swept Path	REV.: 00

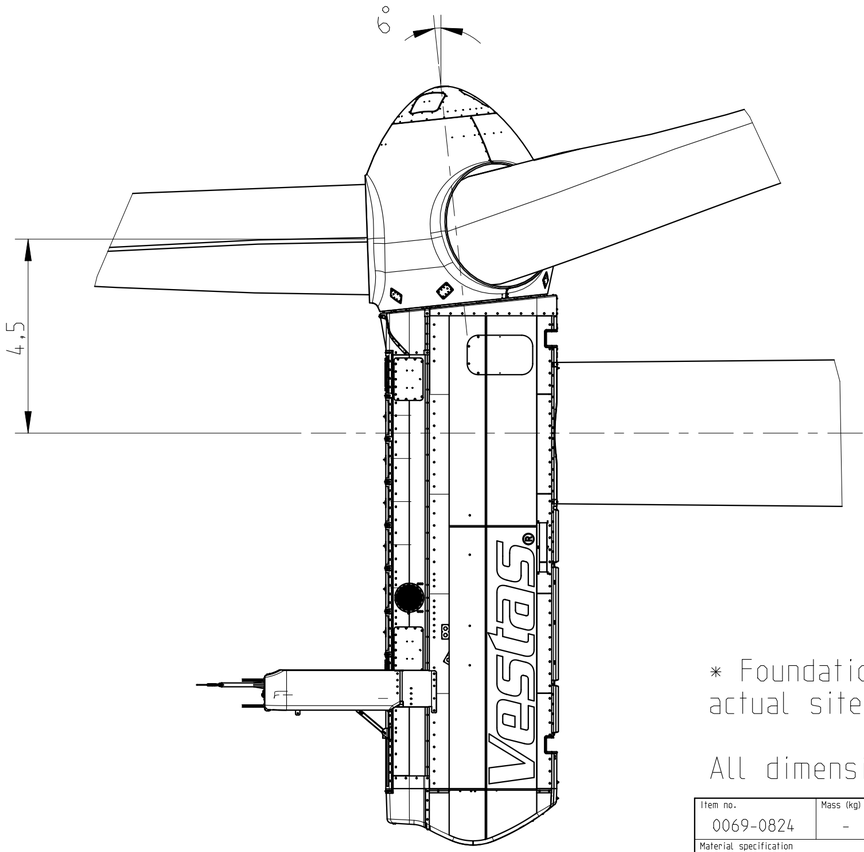












* Foundation diameter is indicative and depends on actual site condition

All dimensions are shown in meters

Item no.	Mass (kg)	Certificate	Format	Status	Revised by	Created date	Created by
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Material specification			Scale	Change no.	PDM ver.	Reviewed date	Reviewed by
–			1:1500		–	–	–
			Proj.	Item description			
			Pro/E	V150 HH155 –			
Vestas® vestas.com			Metric Dimensions shown in mm unless otherwise specified	Replaces / Copy of –	Drawing no. 0069-0824	Ver. 0	Sheet 1 of 1