International Crane Stakeholder Assembly

- Guidance -

"Mobile Crane Ground Preparation for Wind Farm Construction"

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Legal Note: *This publication is only for guidance and gives an overview regarding the assessment of risks related to mobile crane ground preparation for wind farm construction. This document is an industry best practice document that is based on the consensus of member organizations of ICSA. It is not a regulation or standard and should not be treated as such. It neither claims to cover all aspects of the matter, nor does it reflect all legal aspects in detail. It is not meant to, and cannot, replace one's knowledge of the pertaining directives, laws and regulations. Furthermore, the specific characteristics of the individual products and the various possible applications have to be taken into account. This is why, apart from the assessments and procedures addressed in this guide, many other scenarios may apply.*

CONTENT

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1. INTRODUCTION

Wind energy involves generating electricity from the naturally occurring power of wind. A wind farm is a group of large wind turbines which consist of components such as nacelles, rotor blades, and tower sections. To transport and install these components, a significant level of access to the site is required during construction, commissioning, maintenance and sometimes dismantling stages of the project. To complete a wind farm project, access roads, hardstands and relevant access facilities are required for the following equipment:

- heavy vehicles for delivery of crane components
- plant equipment used for assembling/disassembling mobile cranes
- various types of mobile cranes used for
    - erecting the tower sections, nacelle and blades
    - inspection, maintenance and repair of wind turbine components
    - assembly and disassembly of larger mobile cranes

Since most of the vehicles used for wind farm applications are special-purpose vehicles or vehicles with heavy loads, the requirements and design standards of access roads and working areas should be specified by the controlling entity during the planning stage to ensure all construction activities can be conducted safely. During the planning stage, consideration should be given to the following:

- access roads for vehicles to get to the wind power plants
- access roads within the wind farms
- crane travel paths
- soil bearing capacity
- hardstands for mobile crane lift sites and assembly/disassembly work areas (laydown areas).
- access to turn around and emergency routes
- any pedestrian walkway requirements
- other logistics-related areas such as loading/unloading points or storage areas

Risk assessments should be conducted by the controlling entity prior to crane access during wind farm applications. This includes driving or transporting cranes on public roads and site access roads, as well as operating cranes on site. Special considerations should be given to mobile cranes used to erect the large and heavy items on site, as their weight places high ground bearing pressure on the road surface, subsoil and earthwork. Inadequate dimensioning or completion of the access roads and work areas may result in a significant increase in subsequent installation and logistics costs, increase the danger of accidents and delay progress on site.

This guidance note focuses on two construction areas:

- access roads
    - ground bearing pressure for crane weight on the road
    - route path (e.g., swept path analysis to assist the determination of dimensional and clearance requirements for the crane path).
- crane working areas
    - suggestions on hardstand construction
    - ground bearing pressure for different lifting configurations
    - ground level requirements for crane working areas

2. SCOPE

This guidance document provides recommendations for the design and construction of access roads and working areas for mobile cranes used during wind farm applications. Road construction for transport of wind turbine components is not considered in this guidance document.

3. DEFINITIONS

access road – a constructed road to provide a travel path for vehicles to access crane working areas.

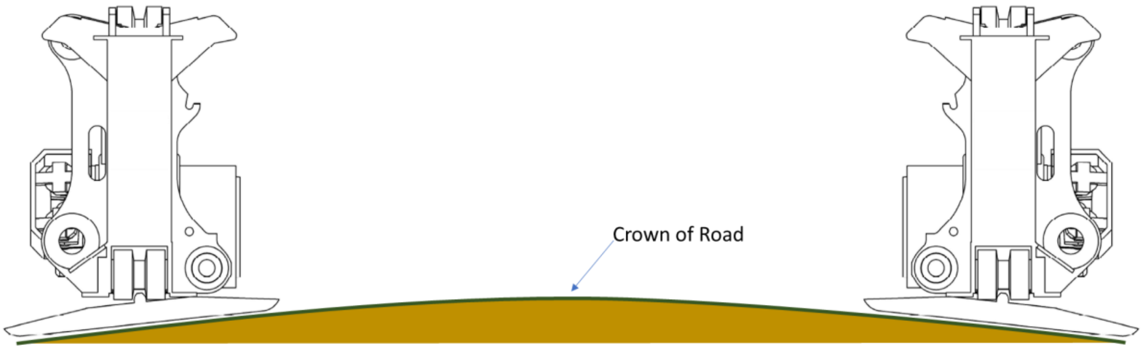
crane configuration – includes considerations such as the following: boom length, boom angle, mass and position of counterweights, lifting attachments, etc.

controlling entity – individual, organization, or any other legal entity that has overall responsibility for the wind farm construction site and oversees operations of sub-contractors.

ground level – angular slope of the surface of the ground from horizontal.

hardstand - the prepared ground for equipment operation during erection, lifting and dismantling.

road camber – curvature of the access road from the road outer edge to outer edge (laterally). The curvature can come in a variety of contours.



The crown of the road is the peak (inflection point) of the road camber.

road gradient – inclination of the access road along the path of travel (longitudinally).

single slope road – a road that is designed to facilitate drainage through the slope of the road that does not have a road crown.

soil bearing capacity – the capacity of the soil to support the load applied to the ground, often referenced in a pressure or vertical force over area.

4. ACCESS ROADS

4.1. Soil Bearing Capacity

An access road can be built in many ways, including ballasted, excavated, prefabricated or paved. Knowledge of subsoil to be built upon, arising traffic volume and stresses, and the period of use, will form the basis for choosing the manner of construction and dimensioning of roads. It is important to consult with the wind farm plant manufacturer to make sure access roads can withstand all types of loads and stresses. Final design and construction methodologies are determined by a detailed pre-construction ground investigation and consideration of any constraints relevant to all locations.

Weather conditions for the project duration should also be considered when building access roads. Seasonal changes in temperature and weather may have a key influence on the design and construction of an access road.

Mobile cranes are often configured differently for transport/travel on public roads than when working on site. For this reason, site roads should have a sufficient soil bearing capacity to provide adequate support for the cranes when configured at each phase of work.

As an example, the eight-axle rubber-tired crane shown in Example 1 is designed to travel on the road at a gross vehicle weight of 96 tonnes.

Example 1 – Eight-axle rubber-tired crane

Once the crane is assembled on site in a working configuration, the crane's gross weight can increase significantly from the weight during travel on public roads. For example, with boom, counterweight and lifting attachments installed, axle loads can increase 50% or more. Example 2 shows axle loads for two crane configurations.

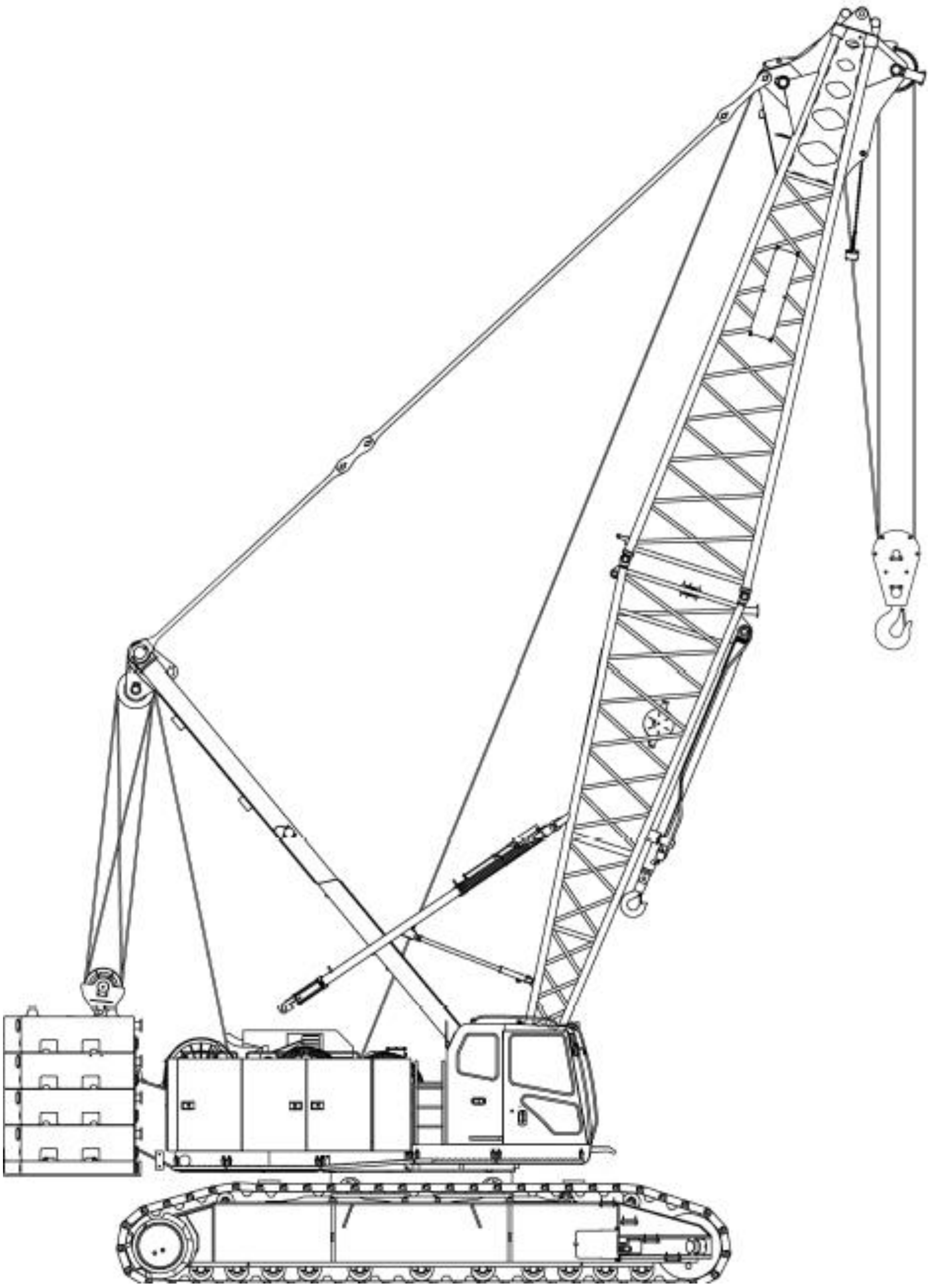
For the nine-axle rubber-tired crane shown in Example 3, the axle weights exceed travel configuration on public roads when partial counterweight, boom sections, and boom support systems are installed.

Crane Type	Crane Configuration	Total Weight of the Crane	Maximum axle load
750 tonne telescopic crane	Main boom with guying system, 66.5m luffing jib, 84 tonnes counterweight	Approx. 260 tonnes	Axles 1 through 6: 32 tonnes Axles 7 through 9: 23 tonnes
1200 tonne telescopic crane	7-part main boom with guying system, 6m luffing jib, 52 tonnes counterweight	Approx. 280 tonnes	Axles 1 through 4: 31 tonnes Axles 5 through 9: 31 tonnes

Example 2 - Axle loads for given crane configuration

Example 3 – Nine-axle rubber-tired crane with partial counterweight and boom system installed

Like rubber-tired cranes, crawler crane manufacturers provide allowable travel configurations for travel on a jobsite. Crawler cranes equipped with counterweights in a fully or partially erect configuration can impose a high load on access roads, see Example 4. The access road to the working area should have enough bearing capacity for the crane to travel in different configurations and should take into account increased loading during travel (e.g., due to sideways inclination of the access road, sideways pendulum movement of the crane during travel, etc.).



Working weight	
32 m No. 680 main boom	647 326 kg
upper boom point	
625 t hook block	
400 t counterweight	

Example 4 - Mass of crawler crane and various components

It is not appropriate to estimate soil bearing capacity of a crawler crane by considering excavators or other crawler construction equipment. The load from a crawler crane may be significantly higher. The load imposed on the ground from a crawler track will depend on if the ground is soft of firm. A soft top layer will distribute the load more evenly across the surface and does not require as high a soil bearing capacity as a firm top layer. Example 5 shows estimated track pressures. Sometimes pressure is conveyed in kilonewtons per square meter. One metric tonne (t) is approximately equivalent to 10 kilonewtons (kN). Track pressures can be obtained from the crane manufacturer for the specific travel configuration.

	Crawler Crane Track Pressures	
Crane Model	**Crane Weight**	**Typical Pressure Below Crawler**
Crane A 600t	500 t	30 – 100 t/m^2
Crane B 1600t	1300 t	50 – 140 t/m^2

	Ground Strengths
Ground Type	**Maximum Permissible Ground Pressure**
Hard Rock	200 t/m^2
Compacted Sand	20 t/m^2

Example 5 – Crane Pressures vs Various Ground Strengths

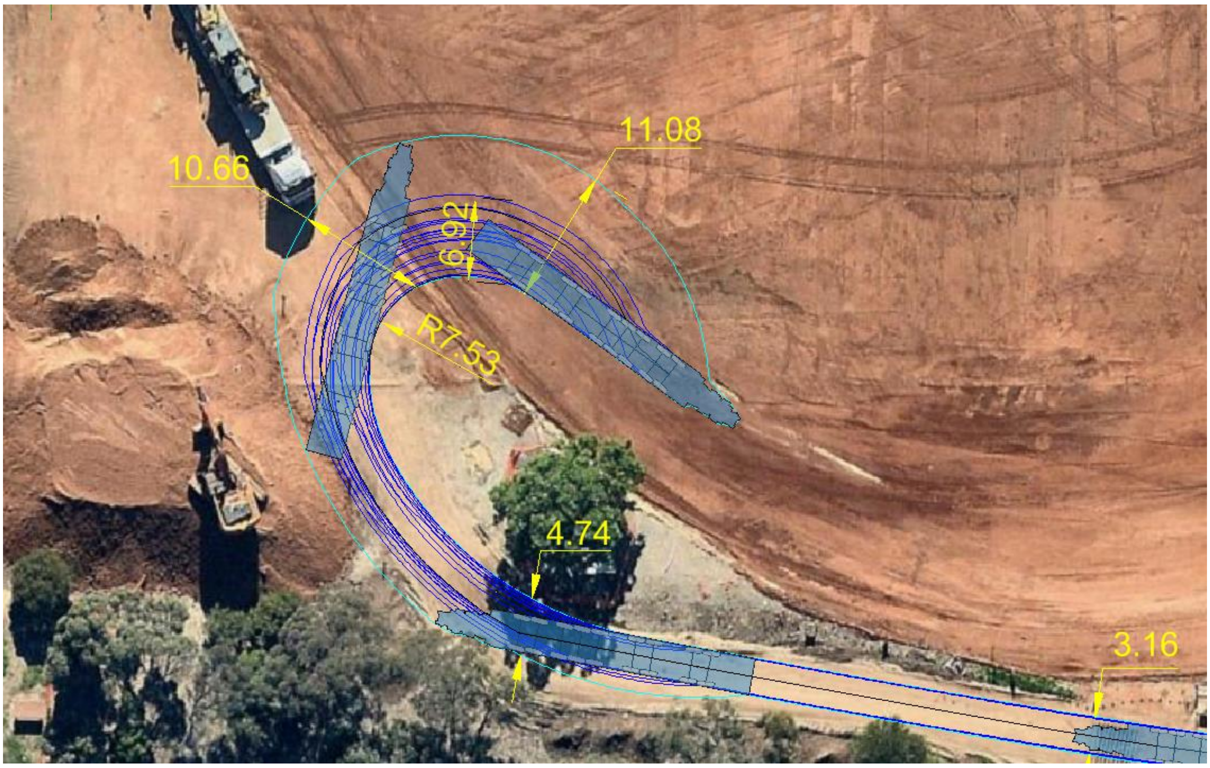
The crawler crane track pressures shown in Example 5 do not include changes in track pressure due to wind loading on the boom while travelling on access roads or from road camber or gradients as discussed in Section 4.2. These conditions can make the track pressures asymmetric and require higher soil bearing capacity. Some manufacturers include wind loading in the calculation of track pressures. Check with the crane manufacturer if the provided track pressures include effects from wind loading and what wind speed is considered.

If for any reason the crane traveling on-site needs to go on a different path other than the access road, a risk assessment should be done on the new path, see Section 5.

4.2. Configuration of Access Roads

The dimension of access roads for cranes to travel on cannot be determined by width alone, as these roads are also used by other vehicles transporting items with large dimensions. Other factors such as adequate clearances, design factors, road camber, road gradient, maneuverability of mobile cranes on site, width, height and swept path of a mobile crane's configuration also needs to be taken into account.

Access roads should be designed and constructed to accommodate the crane in its transport configuration and avoid unnecessary crane maneuvering on site. Example 6 is the result of a swept path analysis for a nine-axle rubber-tired crane when traveling on a straight road. The width of the access road required for the crane to travel is at least 4.5 meters. If the crane needs to make a turn on site to access the crane work area, then the width of the access road needs to be at least 6.92 meters wide for the crane's turning radius. To accommodate the swept path of the boom more clearances may be needed around the crane pathway for the crane to safely maneuver on the access road without hitting any obstructions on site, which will result in even wider clearance profile needed for the road (in this case 11.08 meters). Swept path analysis for crane access should be done to ensure the crane can safely access the work site. Additional swept path analysis may be required if the crane travel configuration requires the outriggers to be extended.

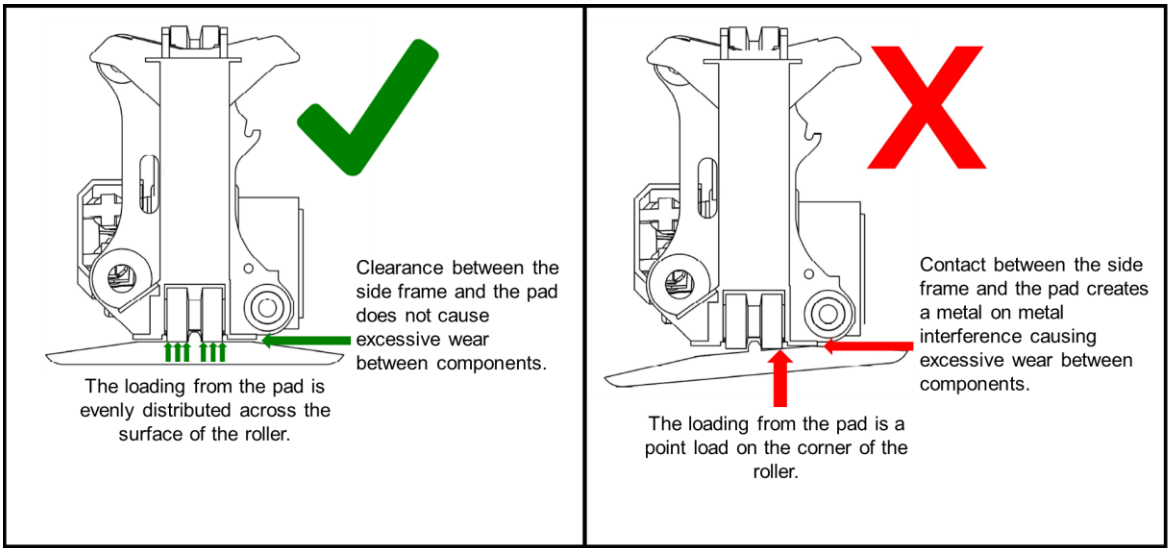


Example 6 – Nine-axle rubber-tired crane swept path analysis

In the event of required crane travel with outriggers extended, a support surface for the outriggers should be considered. As shown in Example 7, where manufacturers recommend travelling with outriggers laterally extended the road runoff area or ditch should be designed for contact by the outriggers, if necessary. For crawler cranes, road widths should be designed to facilitate travel of assembled machines between turbines.

Example 7 - Outriggers extended and corresponding road width requirement

Every crane configuration has its unique requirements. Therefore, follow the crane manufacturer's instructions regarding the maximum allowable gradients, turning radii and road camber for specific crane configurations. Throughout the access road, unless otherwise specified by the manufacturer, maintain a gradient less than 15% and road camber less than 1 degree. Failure to provide road camber on roads less than 1 degree can cause excessive wear on crawler track components (see Example 8).



Example 8 - Effects of road camber on crawler crane tracks

The use of a single slope road design would allow for drainage without causing excessive crawler track wear.

During the construction phase of the project, access roads should be regularly inspected and maintained, and the following activities should be undertaken:

- the road network should be inspected for potholes and maintenance performed to correct them.
- drainage ditches should be cleared,
- culverts, bridges, and cross-drains should be inspected and cleared,
- catchpits should be emptied on a regular basis (particularly when the road is newly constructed).

During the operation phase of wind farm applications, access roads should be maintained to a sufficient standard to enable all maintenance activities to take place and allow emergency access to the wind turbines. If cranes are required for major work on site, the roads should be inspected to check they are of sufficient strength and quality to carry out the work and, if necessary, repaired to a suitable standard.

5. TRAVEL OFF ACCESS ROADS

When travelling off access roads cannot be avoided additional factors should be considered. Travel off an access road will require a new risk assessment to ensure that the soil bearing capacity, road configuration and manufacturer's specifications are met as outlined in 4.1 and 4.2. The risk assessment should consider the present condition of the proposed path and follow manufacturer's recommendations for travelling in the approved crane configuration over uneven ground. When a different path is used other than the access road the agreed path should be clearly marked.

6. CRANE WORK AREA

6.1. Hardstand Construction

A hardstand area needs to be constructed for each wind turbine. The hardstand will be used for delivery vehicle access and crane lifting tasks for erecting the different wind turbine components.

Crane manufacturers develop rated capacity charts based on cranes standing or installed on a **LEVEL, FIRM, AND UNIFORM** supporting surface. Unless otherwise specified by the crane manufacturer, level means the surface of the supporting area for the crane has less than 1% gradient (0.57°). For cranes on outriggers, levelling the crane to the manufacturer's specifications can be achieved with outrigger adjustment to fine tune variations in the hardstand. For crawler crane operation, the track path for the crawler crane on the hardstand should be levelled within 0.5%. To get the crane level within the manufacturer's specifications on a hardstand additional matting and shimming may be required to create the required level supporting surface. The crane supplier and controlling entity should determine who will supply the matting and shimming to level the crane.

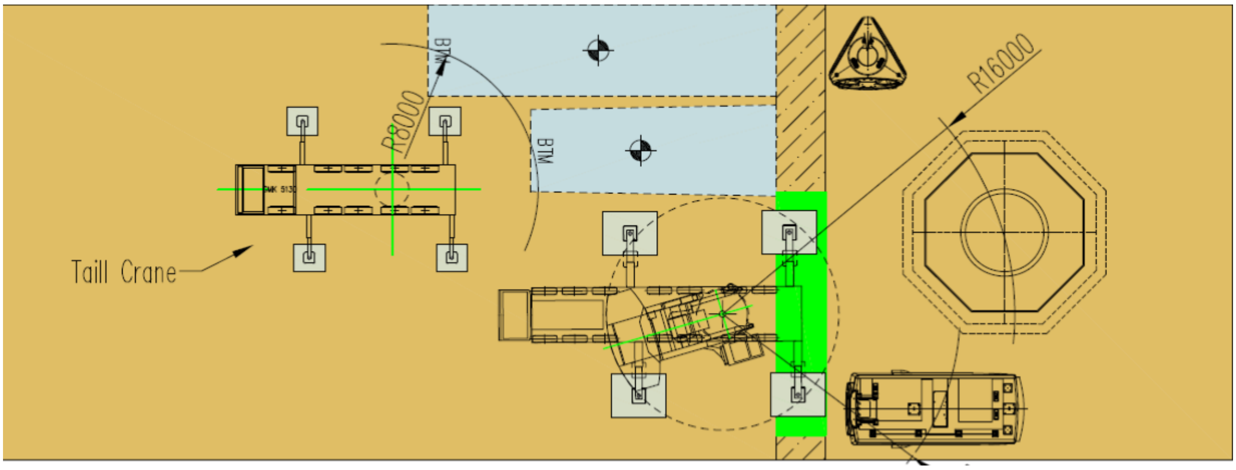
The design of the size of the hardstand is determined by factors such as:

- the site area for the crane
- the expected soil bearing pressure
- the associated soil bearing capacity
- the mounting area for the main crane
- the assembly and disassembly area of the crane
- the dimensions of the crane outriggers and the outrigger plates or crawler tracks and matting
- the slewing area of the crane
- the access areas for transport vehicles
- the storage areas for wind turbine components
- the installation method used for the turbine assembly

The design of the layout of the crane working area needs to consider factors including:

- size of the cranes selected for the project
- size and orientation of the matting for a crawler crane
- number of cranes working at the same time
- crane position in relation to the base of the wind turbine
- crane position in relation to the storage area
- derrick ballast laydown area
- prevailing direction of the wind
- out of service conditions
- precautionary boom laydown area due to high wind

Wind turbine erection usually involves multiple cranes performing lifting tasks at the same time or multiple cranes lifting the same load together (Example 9). In both cases, the size of the work area needs to allow an adequate space between the crane's outriggers. If the crane's outriggers are setup too close to each other the interfering arcs of pressure will amplify the combined pressure and could possibly cause damage to the hardstand. Also, the auxiliary crane may have to change its position several times during and after the construction work. There should always be adequate distance between the foundation and the storage areas as well as between the main crane and the auxiliary crane.



Example 9 - Multiple cranes working in the same work area

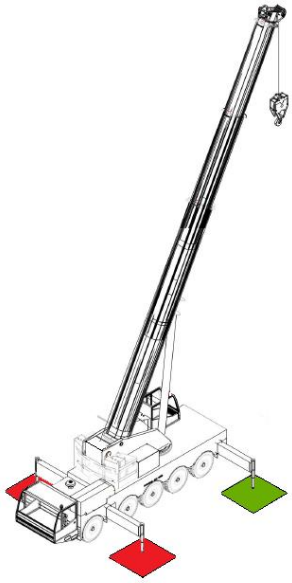
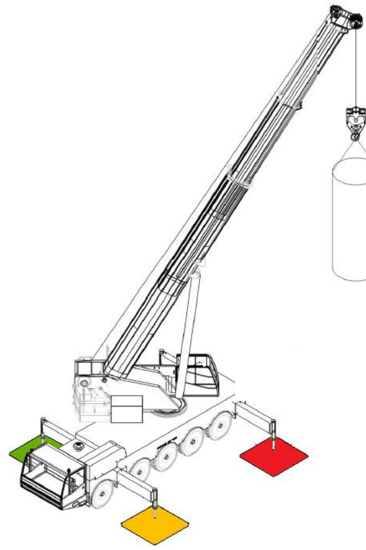
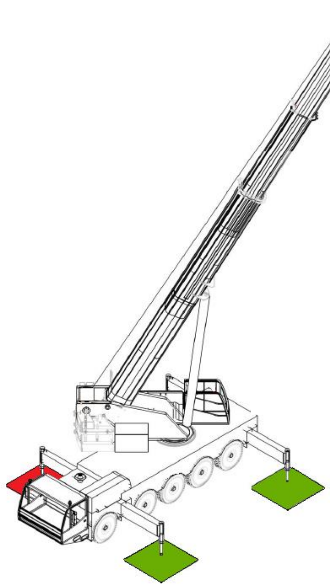
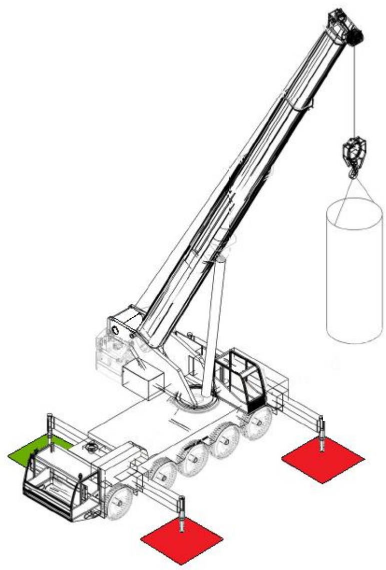
Once set up on site to perform lifting tasks follow the rated capacity chart provided by the crane manufacturer. The position and layout of the storage area (or the truck drop down area) needs to be designed such that the crane can unload the wind turbine components from the transport vehicles to the storage area or lift the components from the storage area to their installation position within the crane's lifting capacity. Once the crane has been set up on site, it may take a significant amount of time and effort to relocate the crane to another position. Therefore, the storage area and the truck access area need to be designed within the crane lifting capacity.

6.2. Soil Bearing Capacity

When setting up cranes on wind farms for lifting tasks, an important factor to be considered during the planning stage is crane stability. Crane stability often depends on the integrity of the supporting ground. Effective assessment of ground conditions is essential to assist with safe set up and operation of cranes. There are two aspects that contribute to ground integrity; the soil bearing capacity and the ground level (for ground level see Section 4.3).

To assess whether the ground has enough soil bearing capacity for the lifting task and crane erection, all load cases need to be considered, as different load cases can impose different forces to the ground (see Example 10 and Example 11). During the lifting operation, crane boom length, slew angle and slew arc vary. These factors will change the forces on the outriggers or crawlers. It is often assumed that the maximum loads and forces will occur during operation at maximum capacity, but this is not always the case. For example, outrigger loads could be at their highest without any load on the hook at minimum radius due to high boom angles and backward moment from the counterweight. In some load cases, a total load of the crane may be imposed largely on one outrigger or one crawler track when the boom or counterweight is slewed over that outrigger or over the side of that track.

The cranes that perform lifting tasks with long boom configurations can increase soil bearing pressure due to wind loading, even under normal loading condition (Example 12). In some instances, this can be an increase of 25% or more. Each individual configuration needs to be assessed. Also, manufacturers may require the rated capacity of the crane be reduced due to higher wind speeds.

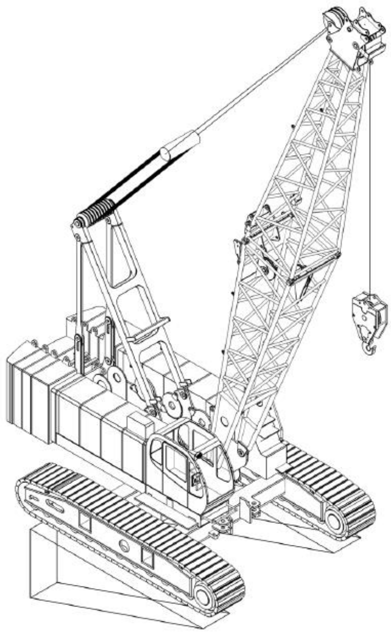
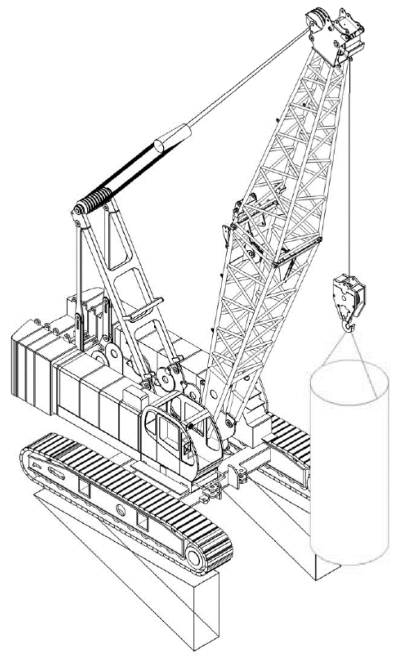
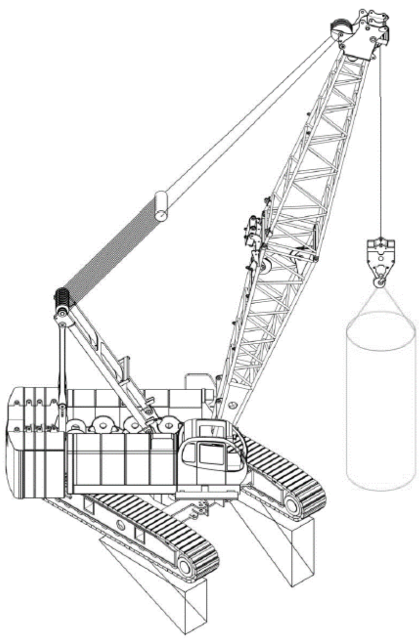
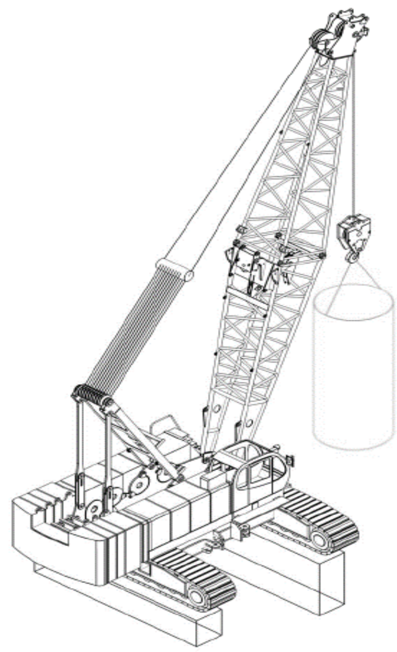
No Load On Hook	Load On Hook
	
Highest pressure under both left and right front outriggers.	**Highest pressure under rear left outrigger.**
	
Highest pressure under front right outrigger.	**Highest pressure under both front and rear left side outriggers.**

= greatest pressure imposed on this outrigger for this lifting configuration

= intermediate pressure imposed on this outrigger for this lifting configuration

= smallest pressure imposed on this outrigger for this lifting configuration

Example 10 - Outrigger pressure change due to different position and load cases

	
With no load on the hook and the boom positioned in the steepest angle, the pressure is highest under the rear of the crawler tracks.	**With the boom positioned in line with the crawler tracks and a load on the hook there will be an equal triangular or trapezoidal pressure under each track.**
	
As the boom is positioned over the end of one crawler track, the pressure increases under that end of the crawler track.	**If the boom is positioned perpendicular to the crawler tracks the pressure becomes a rectangular distribution with the track nearest the load exerting the greatest pressure.**

Example 11 - Crawler track pressure changes due to different load cases

Construct the hardstand to withstand soil bearing pressures from all the load cases. Appropriate testing methods need to be selected to verify the hardstand stiffness, bearing capacity, shear and bending limitations to ensure the hardstand is competent to take the loads. As high loads arise during the construction and operation stages, when verifying the hardstand bearing capacity, tests (i.e., bearing capacity, moisture content, etc.) need to be done to a relevant depth below the top layer to assess individual layers of the ground.

An often-neglected area in design is the section connecting the hardstand and the access road. The hardstand and the access road are designed to different standards with different profiles and have different load bearing capacities. How to consolidate the two parts should be considered in the design planning phase. Special attention should be given to height differences between the two parts. The soil bearing capacity for each part should be clearly marked.

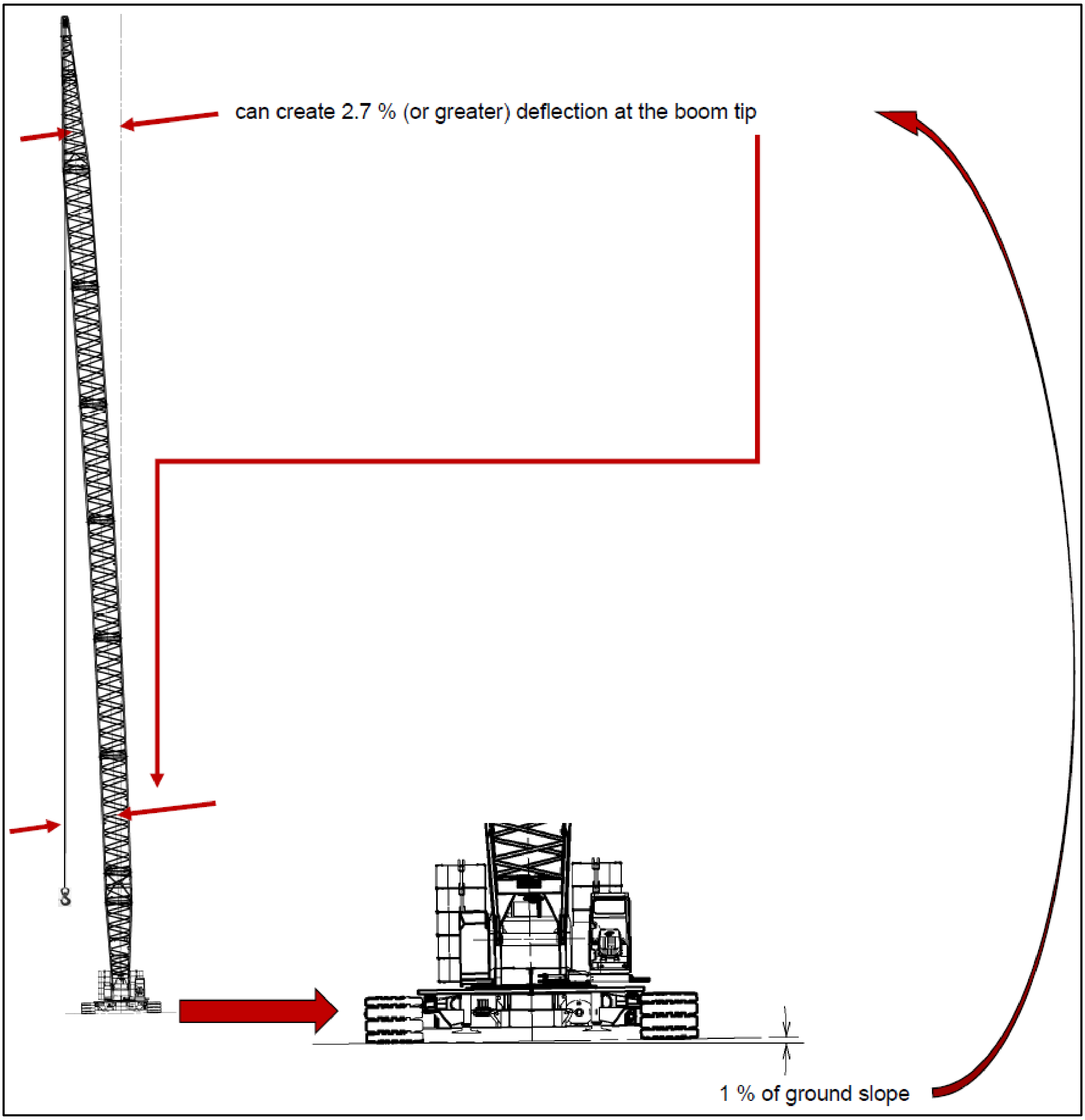
6.3. Ground Level

Crane configurations used for wind farm construction usually have high centers of gravity above the ground due to the long boom lengths. A minimal ground slope can be a major factor in causing the crane to become unstable or the crane to be overloaded. The minor variance in ground levelness can have a drastic effect on the stability of the crane, especially for crawler cranes, as all-terrain cranes can be leveled with outrigger pads, and crawler cranes typically rely on the ground with matting/shimming used for levelling.

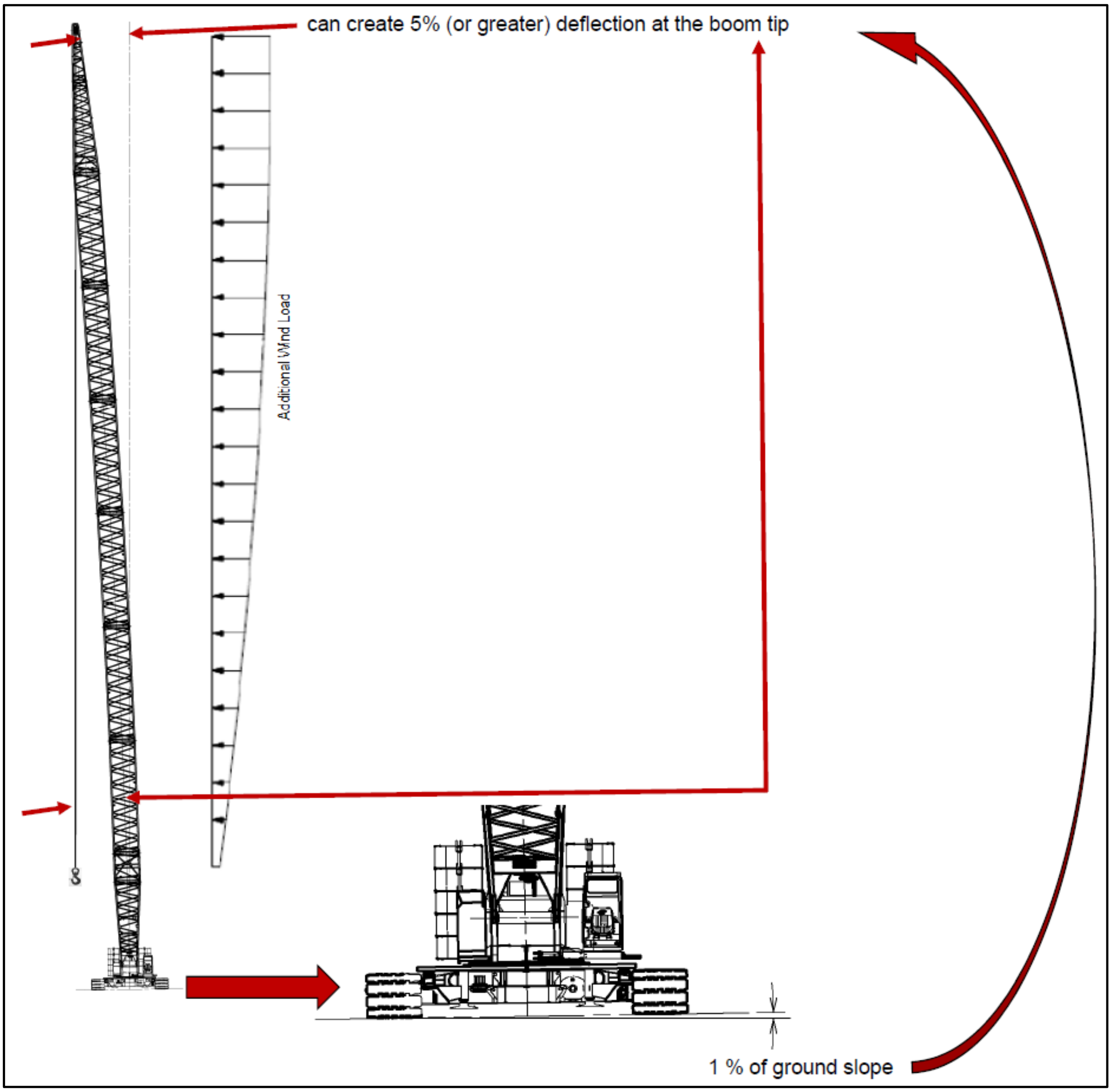
The figures below show the theoretical lateral displacement of a lattice boom crane.

- if erected on a 1% (0.57°) ground slope and configured with 100m boom, the boom head lateral displacement could exceed 2.7% of the boom length (Example 12)
- if erected on a 1% (0.57°) ground slope and configured with 100m boom, with an additional 20 m/s wind load, the boom head lateral displacement could exceed 5% of the boom length (Example 13)

For crane operations, follow the crane manufacturer's instructions for the design and construction of the crane working area hardstand ground level. If the lateral deflection of the boom/hook passes the support point (crawler track or outrigger) then soil bearing pressure can increase significantly. This increase in load should be considered when constructing the hardstand.



Example 12 - Slope effect



Example 13 – Effect of slope and additional wind load

7. REFERENCE

(1) Clean Energy Council https://www.cleanenergycouncil.org.au/technologies/wind-energy.html
(2) Wind Power, Noelle Eckley Selin, May 4, 2018, https://www.britannica.com/science/wind-power
(3) Manual of Bundesfachgruppe Schwertransporte und Kranarbeiten (BSK) on the Requirements Expected of Builders' Roads and Crane Sites for the Construction of Wind Power Plants, 15 July 2013.
(4) AS2550.5-2011 Cranes, hoists and winches – Safe use, Part 1: General Requirements.
(5) South Kyle Wind Farm Outline Construction Method Statements, Outline Construction Method Statement 1 Road and Wind Turbine Construction. July 2013
(6) Safety Issues in Wind Turbine Installation and Transportation, European Materials Handling Federation (FEM) Product Group Cranes and Lifting Equipment, FEM 5.016, April 2017.
(7) Best practice Guide for Transport and Installation of Onshore WTG Systems, ESTA & VDMA, February 2020.

8. FURTHER INFORMATION

This document has been reviewed and jointly adopted by the following member associations of the ICSA:

- **Association of Equipment Manufacturers [AEM]**
- **The Crane Industry Council of Australia [CICA]**
- **Crane Rental Association of Canada [CRAC]**
- **The European Association of abnormal road transport and mobile cranes [ESTA]**
- **European Materials Handling Federation [FEM]**
- **Japan Crane Association [JCA]**
- **Specialized Carriers & Rigging Association [SC&RA]**

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