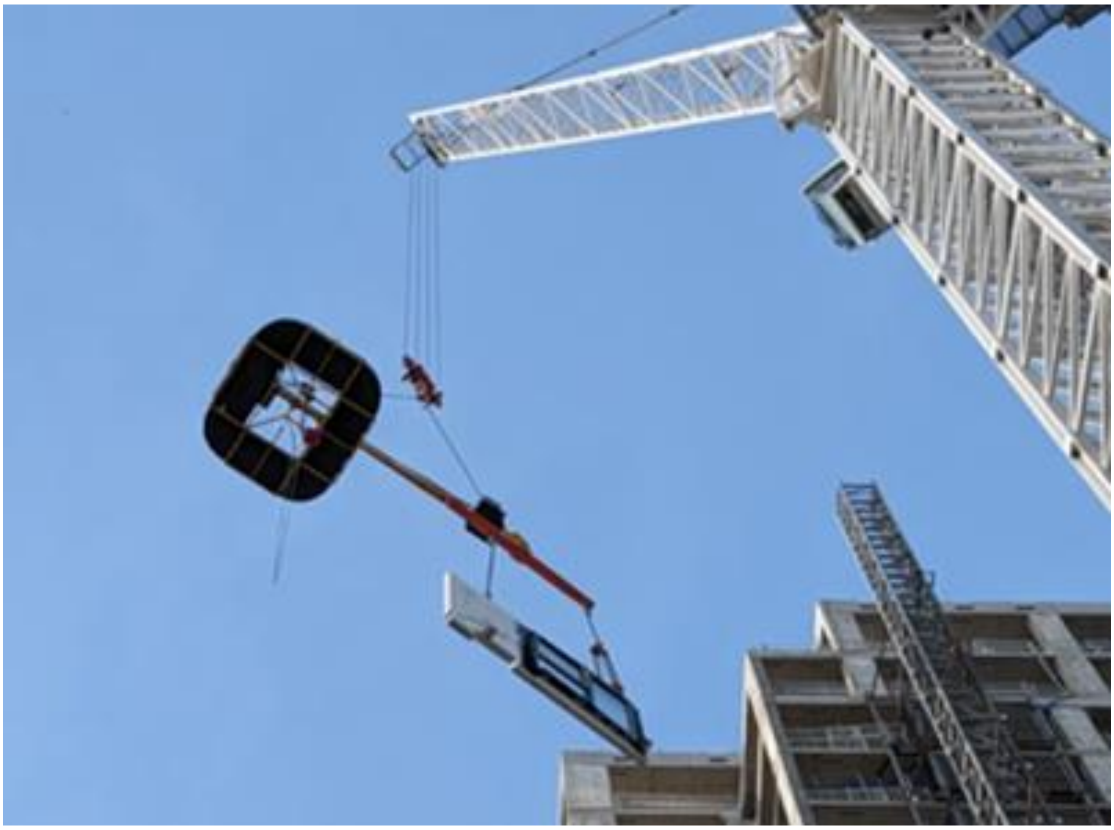
GOOD PRACTICE GUIDE

Safety Publication

Planning and Control of Lifting Operations in Wind



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Guidance on the Planning and Control of Lifting Operations in Wind

CPA Good Practice Guide

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Contents

NOTE: *Whilst every care has been taken to ensure the accuracy of the material contained within this booklet, no liability is accepted by the Construction Plant-hire Association or their consultant(s) in respect of the information given. The information was considered accurate at the time of publishing and was reviewed by the Steering Committee and broader Interest Group(s) for error and inaccuracy.*

Always seek the assistance of a competent person when planning lifting operations. This document does not claim to be complete and must be read in conjunction with the operating instructions of the particular crane and any lifting accessories.

NOTE*: Front cover photo reference: Select Plant Hire tower crane handling a cladding panel that is being balanced and steered using a 'Torquer', by remote control, such that the orientation of the load can be controlled without using a tagline.*

Foreword

Welcome to the first edition of the Construction Plant-hire Association's (CPA) publication for the Guidance on the Planning and Control of Lifting Operations in Wind. This guidance has been jointly developed under the direction of the Crane Interest Group (CIG) and the Tower Crane Interest Group (TCIG), as lifting operations in wind affects all types of cranes, particularly those that are lifting loads at or to height. We'd like to further acknowledge the input and support from members of the Industry Lifting Lead AP Group (ILLAPG).

As the title indicates, this publication provides the foundational knowledge and skills necessary for recognising and mitigating the effect of wind on lifting operations. It has been created with modern, modular construction methods in mind and further takes account of the latest technology in remote control load rotation devices, along with the potential risks posed by these new ideas of the modern construction era.

The publication goes into extensive detail around the subject of wind, the effect it has on cranes and loads and is an addition to the content in any Appointed Person training. It further provides a methodical approach in how to select the correct crane for the load and wind surface area, so that lifting operations in wind can be maximised without compromising the safety of the crane, the lifting team and the load itself.

Much time, energy and effort has gone into the devising of this good practice guide and as it states, provides good practice requirements for when wind can affect a lifting operation in some form. Given the complexity of the subject, we recognise that a significant amount of technical content is required to address it thoroughly. To support wider understanding, a Technical Information Note (TIN) has also been produced to summarise the key principles contained within this comprehensive publication.

We thank those who contributed to this publication and commend the content and practices to those specifying or carrying out lifting operations, or training activities, to ensure safety and efficient operations at all times.

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1.0 Introduction

This document has been produced through cooperation between the CPA's Crane Interest Group and the Tower Crane Interest Group and is for appointed persons planning lifting operations in wind and also those controlling a load on site. While all crane types are affected by wind, additional hazards arise when lifting loads that are lightweight and have a large surface area exposed to the wind. Potential issues include load drift, which may impose horizontal forces on the crane, hindering the ability of personnel to control and accurately position the load. In extreme cases, crane booms have failed, entire cranes have overturned, with incidents having resulted in fatalities and significant property damage.

Traditional methods of downrating or adjusting the permissible working wind speed appear to be conservative, albeit they are based on the contents of the crane design standards EN13000 and EN13001. This document examines the fundamentals of risk to the crane and provides guidance for the individual planning the lifting operation. The key element this document aims to address is identifying if the crane is potentially in danger, or if the load should become uncontrollable.

Although this document is primarily aimed at cranes - due to their susceptibility to wind-related hazards resulting from their ability to lift loads to great height, the principles also apply to lorry loaders, rotating telehandlers and other plant that suspends loads.

Wind is rarely steady. Gusts can cause a stable load to become unstable suddenly. In complex environments, wind can be funnelled between buildings or deflected, creating swirling vortices. These phenomena are not new and the lifting industry has traditionally responded using manual measures such as taglines to help stabilise loads.

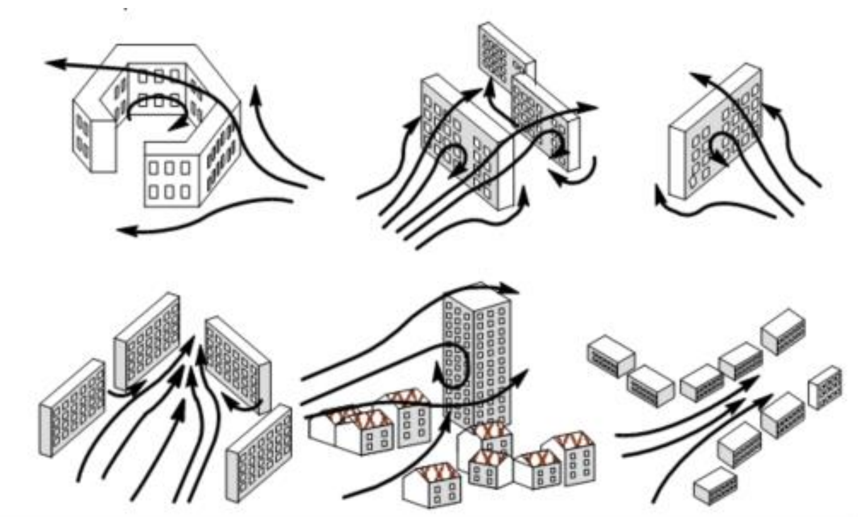


Figure 1: Extract of Manitowoc Crane Care Safety Instructions showing the effect of the local environment on the flow of wind, and hence how careful crane positioning will minimise the effect of wind on lifting operations.

As a rule of thumb, it can take about 20 minutes for the wind speed to rise from 13 m/sec (30mph / 50kmh) to 20 m/sec (45mph / 75kmh) and a further 20 minutes to reach 27m/s / (62mph / 100kmh). It is therefore important to plan lifting operations to ensure that a crane is in a safe state before reaching the in service wind speed limits.

As off-site manufacturing increases, new hazards are being added into lifting operations. Problems occur in handling bathroom pods which are light and hard to control. Equally large heavy weight panels can be difficult too as rotating the load manually can be challenging, especially when access is poor.

The industry seeks additional guidance to help identify the following items in which this guide helps to address:

- What are wind limits to the planned lifting operation?
- How windy is too windy when using a tagline?
- What is the implication to the crane if using a remote control below-the-hook electro-mechanical load-control device to control the orientation of the load?

The guide does not aim to address issues regarding temporary works checks or assessing ground conditions for the extra loads imposed in the ground by the crane as a result of lifting in wind. These are covered in other CPA publications listed at the end of this publication.

This guidance does not make any reference to the lifting of people using cranes.

2.0 Definitions

For the purposes of this good practice guide, the following definitions apply:

BS

British Standard

CIG

Crane Interest Group of the Construction Plant-hire Association

CPA

Construction Plant-hire Association

EN

Euro Norm

Drag coefficient

the factor that is applied to the projected surface area that takes into account the shape of the load and how the wind interacts with it

Gust wind speed

a temporary and sudden increase in wind speed above the mean average wind speed, often expressed as a three-second gust wind speed

Mean or mean average wind speed

the average of series of wind speed readings taken over a period of time, typically expressed as 1-second interval readings averaged over 10-minutes

OEM

Original Equipment Manufacturer

Projected surface area

the area on which the wind acts

TCIG

Tower Crane Interest Group of the Construction Plant-hire Association

TIN

Technical Information Note

3.0 Points to note about Wind, Wind Speed Readings and How to Measure Wind Speed

3.1 Understanding wind & gusts

Wind acts on the structure of the crane and on the load. It is treated slightly differently by each crane type. The manufacturer has made an allowance for the wind acting on the crane and the load whilst it is in service. The person planning the lifting operation is therefore advised to understand what these allowances are and what to do where the wind acting on the load exceeds those allowances.

3.2 *Windspeed measurement tools*

Wind speed is measured using an anemometer. The Met Office wind measuring is taken at 10m above ground to reduce the risk of the effect of local structures, trees etc. They also make their wind speed predictions and forecasts at 10m above ground. However, cranes may be 200m to 250m above ground experiencing very different wind conditions. Forecasts generally contain the mean wind speed in the prediction.

3.3 Forecasting considerations

A further point to note is that the instantaneous wind speed measured on the crane is the **gust** wind speed, rather than the **mean** wind speed. Although gusts are short in duration, they are the wind forces actually acting on the crane and load and therefore, should be used when deciding whether a lifting operation should proceed. This should not be confused with the mean wind speed, which is often used to understand overall wind trends.

The mean wind speed is an average calculated over a set period, typically expressed as a 10-minute mean. This value represents the average of wind speed readings taken every 3 seconds over the previous 10 minutes.

Gusting winds can also involve repeated fluctuations in wind intensity and/or direction, making control of the crane and load more difficult. A growing phenomenon is a pattern of gusting intervals approximately 7 seconds apart, followed by a stronger final gust from a 15 to 20-degree offset - which can be particularly destabilising during lifting operations. This variability in both intensity and direction makes accurate crane operation much more challenging.

Crane users often rely on applications via electronic devices e.g. phones or laptops to monitor wind speed. Some apps offer only forecasts, while others provide live wind speed data when connected to a crane-mounted anemometer. For example, apps can measure and provide reports every second, but this capability should be confirmed when selecting an app. Others may update every 3 seconds. The more frequently the app records, the more closely it will reflect the live display at the crane’s control station, which typically updates every second.

3.4 Interpreting readings on site

A crane operator typically receives instantaneous live wind speed at their control station, which fluctuates as the wind changes. Output to other devices or apps often expresses the mean wind speed over a ten-minute interval, along with the peak wind speed recorded during that period. As such, there may be a time lag when checking current conditions and it is important for users to understand exactly which figure is being displayed.

Hand-held anemometers can also be configured to display wind speeds in various formats. It is common to set them to provide instantaneous readings or a 3-second gust wind speed.

Some sites may install an anemometer repeater in the site office, replicating the information shown on the crane operator’s display. However, the crane operator remains the final authority on whether a lifting operation is safe to proceed, as discussed further in Section 6.4**.**

Operators are often able to feel the intensity of gusts and variations around the mean wind speed. They can also assess how well the crane responds at the current working radius and in relation to the wind direction.

This document focuses on the 3-second gust because it directly affects both the load and the crane, aligning with crane design standards.

Cranes located at different heights or in varying positions, even across the same site or adjacent sites, may report significantly different wind speeds. This is normal. Each lifting operation must be assessed individually by the crane operator, who may also consult a competent person such as the crane supervisor or appointed person.

While this document primarily addresses instantaneous gusts, references to the 3-second gust will appear in relation to forecasts and meteorological data.

4.0 Design References & Implications for the Lift Plan

4.1 Overview of Design Standards

In summary the following design standards are used:

- Most mobile crane (including crawler crane) design is governed by EN 13000:2010+A1:2014;
- Other cranes, including tower cranes to EN14439 and lorry loaders to 12999, are designed to the in service wind allowance section of EN13001-2:2021.

EN13000 uses a relevant projected surface area as the surface on which the wind pressure acts, whereas EN13001 assumes a percentage value of the load suspended below the hook.

4.2 Understanding wind area and load effects

Both are however complicated by the shape of the load. Some objects, including cylinders and balls, are aerodynamic and so the wind passes around them reasonably easily. Other objects, which are plates or cubes, might attract an extra factor of between 1.1 and 2.0. The mobile crane design standard assumes a rectangular load is lifted with a drag coefficient of 1.2. However, EN13001-2 standard suggests 2.4 ‘in the absence of detailed information’. A summary is found in the table below.

The design of cranes for wind varies by crane type.

Name of the design standard	**Cranes – Mobile cranes**	**Crane safety – General design[1]**
Number/Date of standard	EN13000:2010+A1:2014	EN13001-2:2021
In service wind clause	4.1.2.2.2	4.2.3.1
Wind area of load considered (m^2/tonne)	1.0	Greater of 0.8m^2 or 0.0005 x mass of hoist load in kilograms
Drag coefficient c_w	1.2	
Aerodynamic coefficient c_a		2.4 (unless specified otherwise)

NOTE: *When the figures are multiplied out for EN13001-2, the area to weight ratio is 0.0005*1000kg*2.4 = 1.2m2/t. However, this is only valid for loads with a c_a value of 2.4. This value can be derived for Annex A of the standard. Always refer to the OEM Instructions for. Use for actual allowances / requirements. In EN13000, the wind area x drag coefficient also gives 1.2m2/tonne for the rectangular load.*

An example of drag coefficients used for mobile crane lifting is found in Annex A of this document, which has been extracted from the Liebherr Influence of Wind document – downloadable from: https://www.liebherr.com/shared/media/mobile-and-crawler-cranes/brochures/wind-influences/liebherr-influence-of-wind-p403-e04-2017.pdf

Careful selection of factors is required, especially for complex shapes. There are very detailed coefficients given in Annex A of 13001-2:2021.

<u>In simplifying this document, all examples assume a rectangular load and whichever crane has an allowance of 1m2/tonne in common with the standards above.</u>

[1] This standard will be the basis for the design of tower cranes to EN14439, which is due to be released in 2025. This standard is also used for lorry loaders designed to EN12999.

4.3 Work examples (mobile, tower and light weight loads)

Some mobile and crawler cranes permit increased working wind speed when lifting with a reduced payload. This is discussed further in this publication along with tower cranes.

In either scenario, where the manufacturer offers special duty charts with modified wind duties, it is essential to follow the manufacturer's instructions and obey any limitations. The effect of lifting light weight or large area wind loads in such conditions must be considered when assessing if it is safe to lift.

Example for assessing permissible load area being lifted by mobile crane:

Consider where a rectangular shaped load of 3 tonnes is being lifted. What is permitted face area?

Appointed person assesses the shape to have a drag coefficient, c_w of 1.2

Allowable effective wind sail area = *1.2m²/t (from EN13000, cl 4.1.3.1.2)*

Allowable projected surface area $= \frac{Allowable\ effective\ wind\ sail\ area}{Drag\ coefficient\ (cw)}$ *x weight of load*

So, the allowable projected surface area $= \frac{1.2}{1.2} \times 3 = 3m^2$

If the load has a projected surface area of greater than $3m^2$, then it would be necessary to reduce the working wind speed. If the surface area is $3m^2$ or less, no downrating of the permissible working wind speed is required.

As in Section 4.2, Liebherr has published guidance to assist in these assessments. It explains to the user how to calculate if the planned load will have a greater effect on the crane than the crane's designer has allowed for. It further advises how to calculate any downrating. The principles in this document apply to all crane types that are designed to EN13000. By extension, it is also useful for tower cranes designed to EN14439

This approach should be adopted because Clause 6.2.2.6 of EN13000:2010+A1:2014 requires the individual planning the lift to consider the wind area in the lift plan. This is essential because if too high a wind load is applied to the crane, then the crane will be loaded beyond what the manufacturer had allowed for in the design. This can lead to minor inaccuracies in the RCI readings and has historically led to overturning or boom/jib buckling, amongst other potential longer term maintenance issues.

A load can be blown so that it is not directly beneath the boom head sheaves and so may be displaced to a different radius to what was planned as well, as that which the rated capacity indicator is indicating.

If the wind is blowing a load to an increased radius where there is already a high utilisation, then the crane could be overloaded. If a load is blown to a decreased radius and the crane is at or close to its minimum radius, then there is a risk of the load hitting the crane or tipping the crane or boom over backwards.

This means that a lift plan should contain the crane OEM's original stated working wind speed as well as an assessment of any down rating of the working wind speed, to give a revised permissible wind speed.

There are several factors that will influence the wind speed that activities can be completed in:

- **Crane type**: mobile and crawler cranes are winded off at lower speed than a tower crane, whereas a spider crane is winded off at an even lower wind speed. Hence, equipment selection in the first instance is an important criterion;
- **Load dependent**: when lifting people or when using certain pieces of lifting equipment, such as vacuum units, then lower limiting wind speeds apply and usually identified by the relevant standards (e.g. BS7121-1:2016) or by the equipment manufacturer in the user instructions and shown on warning signs; and

- **Manufacturer uplifts**: Some manufacturers allow uplifts in working wind speed where lighter loads are being lifted. Conversely, when lifting at the capacity of the machine, then the design standard windspeed applies. Equally, short main boom duties are treated differently to luffing fly jib activities.

The reality is that being able to use a crane at the winding off speed is difficult. Anecdotally, it may be argued that a tower crane has a higher in service wind speed when compared to a crawler crane. A crawler crane may have an upper in service limit of 16m/s and a tower crane is designed for an in-service wind limit of 20m/s (45mph). However, Section 14.1 of BS 7121-5:2019 indicates that the tower crane is usually winded-off at 16.5m/s (38mph) to allow time to put the crane in the manufacturer's out-of-service configuration. The reality of being able to gain much extra active lifting time when considering the difference between the two cranes may be hard to gauge, as 16m/s is considered as Beaufort wind force 7 - which is a moderate gale when whole trees are moving.

If a very light weight load is considered, such as a pack of insultation that weighs 113kg, then the crane's allowable wind speed would still need to be down-rated, even though it would appear that the lightweight insulation would likely never put the crane in danger and pull the it over.

Follow the example below:

Projected surface area = 1.2 x 2.4 = 2.88m^2

Drag Coefficient, say = 1.2

Surface area exposed to wind = 1.2 x 2.88 = 3.456m^2

If the crane has a maximum working wind speed for its configuration of v_{max} 11.1m/s, then the:

Permissible wind speed reduces to $v_{allowed}$ = $11.1\ x\ \sqrt{\frac{1.2\ x\ 0.113}{3.456}}$ = 11.1 x 0.198 = 2.1m/s

The calculation shows that this lightweight insulation pack requires a wind speed limit of 2.1 m/s, which is an 80% reduction and highlighting the potential for conservative outcomes with light, bulky loads

The relationship between wind speed and applied force is not linear, as it is based on a square of the wind speed.

The relationship is **Force (F) $\propto$ Wind Speed^2**

If the wind speed doubles, then the force is four times larger.

Wind speed (m/sec)	Pressure exerted on the load by the wind (Pascals)	Pressure in kg-force/m^2
2	2.5 Pa	1.3
10	62.5 Pa	31.9
17	180 Pa	92.2

***NOTE**: It is therefore important to consider the windspeed carefully as a small change has a big effect.*

This means that the load introduces a much larger sideways force into the crane boom / jib as the wind speed increases. Furthermore, the higher the load travels above the base of the crane, the greater the overturning effect that is applied to the crane. This will influence the combined centre of gravity of the crane and load. If this combined centre of gravity passes beyond the tipping lines of the crane, then the crane may tip over. It is also possible that the boom could fail before the crane overturns.

This type of analysis can be complex and requires accurate knowledge of the basic machine's centre of gravity, along with an understanding of how the load affects the crane. A lighter crane will be more influenced by wind forces than a larger mobile crane and the higher the load is above the ground, the greater the impact on the crane's stability.

The effects of sideways loading on the boom and the load are discussed further in Section 7.

4.4 Commentary on planning practice and misconceptions

It is generally not possible to provide clearer guidance due to the complex interaction between wind, crane type, configuration, elevation, load characteristics and local wind effects. With enhanced telemetry systems in cranes, it may become possible in future to alert lifting teams when stability could be compromised. Anecdotal evidence is that not many lifting operations are currently being planned in this way. This may be for a number of reasons:

- Tower crane and mobile crane APs may not know about the requirements;
- There is no published evidence that mobile cranes and tower cranes are suffering damage for lifting relatively small area loads when compared to the wind turbine blades that have typically caused cranes to fail;
- Lifting operations for handling large area and /or lightweight loads are often winded off because they are too difficult to control;
- APs struggle to understand the shape-factor assessment;
- Lifting teams may be undertaking their own written risk assessment based on the height of lift, the working location, local shielding/wind accelerations to assess if a lift is safe to proceed;
- There is a general understanding that very large items being handled that could swing and hit the boom / crane chassis require a careful written risk assessment, which should already adjust the wind speed; and
- Anecdotal evidence is that winding off due to wind sensitive loads is a smaller percentage than lost time due to inefficient use of load bays / site logistics.

Some organisations rely on lifting teams to assess when it is safe to proceed with operations. However, upper wind speed limits should be established for each activity to ensure the safety of both the crane and personnel. In the event of an incident, the person planning the lift must be able to demonstrate that OEM guidance and instructions for use were considered during the planning process. Other published advice with regards to cranes in wind available in the UK includes:

- CPA TCIG TIN 020 – The effect of wind on tower cranes in service. This advises a practical upper limit to tower crane operations, involving non-wind sensitive loads of 38mph to create time to put the crane safely into the OEM's out of service configuration;
- CPA TCIG TIN 022 – The use of taglines with tower cranes;
- CPA TCIG TIN 027 – Tower crane out-of-service wind speeds. This advises how to assess appropriate design wind speeds for various wind regions in the UK;
- CPA CIG TIN 101 - The effect of wind on mobile cranes in service. This advises a practical upper limit to mobile crane operations of non-wind sensitive loads of 31mph although to ALWAYS check the crane's configuration as the wind speed is frequently lower than this value; and
- CPA T/CIG TIN 110 – Planning & Control of Lifting Operations in Wind (companion document to this document)

All CPA TINs can be found at www.cpa.uk.net

5.0 How to Plan for Lifting Operations Regarding Wind

This section outlines how to plan lifting operations with wind as a key consideration, structured around crane and load characteristics, weather forecasting, and control strategies.

When planning a lift, the key considerations include the type and configuration of crane selected, the nature of the load, the site location and the surrounding environment. This document however does not cover all elements of lift planning, as these are addressed in existing CPA guidance. However, in relation to wind-specific concerns, the following non-exhaustive list of factors must be taken into account:

Characteristics of load and crane *(Section 5.1)*	1	Weight of load,
	2	Projected surface area on which the wind acts,
	3	Drag coefficient, based on shape
	4	OEM data for the permissible wind speed for the configuration of the crane selected
Site specific wind forecast for lifting operation *(Section 5.2)*	5	Weather forecast
	6	Height or depth of lifting operation
	7	Other environmental factors? including shielding, funnelling, vortices, etc.
Load geometry and load control *(Section 5.3)*	8	Position of the centre of gravity between the slinging points
	9	Ability to use a manual mechanical load control device such as tagline(s) or push-pull pole(s) effectively
	10	Ability to use a remote control below the hook, electro-mechanical device to control the orientation of the load
	11	Will only part of the load be subjected to wind?

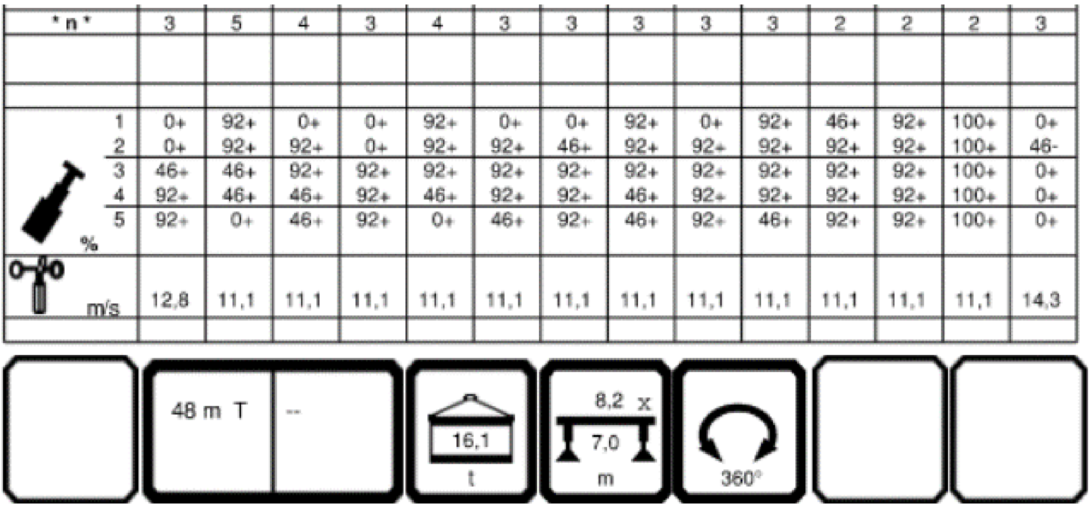
5.1 Characteristics of the load and the crane

Each crane has a different working wind speed, dependent on the way the crane is rigged.

5.1.1 Mobile & Crawler Cranes

A longer boom typically has a lower working wind speed than a shorter boom in the same configuration. Adjusting boom length not only affects the crane's height and reach, but also alters outrigger loads. These must be verified by the appointed person responsible for planning the lifting operation.

The limiting wind speed should always be sourced from the OEM's *Instructions for Use* and not from marketing-based brochures. The crane supplier should be consulted to confirm the permissible wind speed, as this forms the starting point for all wind-related assessments. Several methods for determining the maximum permissible wind speed are outlined below.



"n"	3	5	4	3	4	3	3	3	3	3	2	2	2	3
1	0+	92+	0+	0+	92+	0+	0+	92+	0+	92+	46+	92+	100+	0+
2	0+	92+	92+	0+	92+	92+	46+	92+	92+	92+	92+	92+	100+	46-
3	46+	46+	92+	92+	92+	92+	92+	92+	92+	92+	92+	92+	100+	0+
4	92+	46+	46+	92+	46+	92+	92+	46+	92+	92+	92+	92+	100+	0+
5 %	92+	0+	46+	92+	0+	46+	92+	46+	92+	46+	92+	92+	100+	0+
m/s	12,8	11,1	11,1	11,1	11,1	11,1	11,1	11,1	11,1	11,1	11,1	11,1	11,1	14,3

Figure 1: Example of a duty chart for an older mark of crane that contains the variety of permissible wind speed which varies with boom extension. Shorter booms have higher permissible wind speeds.

A recent crane type is shown below:

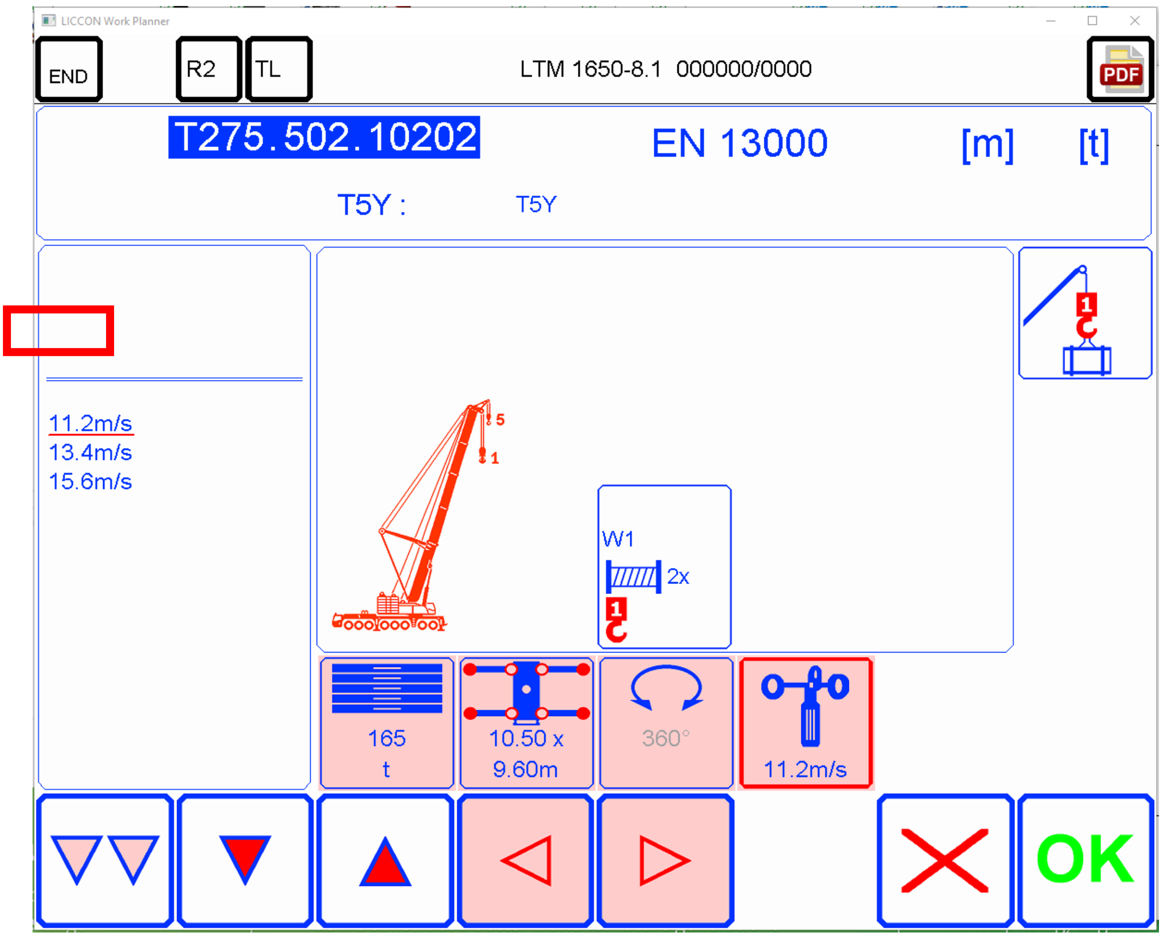


Figure 2: This crane requires the selection of the wind speed (selected in bold red box, confirmed in fine-lined red box). This is selected in the set-up phase because this then automatically adjusts the rated capacity of the machine for the chosen configuration (Outriggers at 100%, Full Ballast, Full Boom extended set at minimum radius, winch 1 (main hoist / hook).

This manufacturer provides the facility in the program that calculates the effect of the load on the working wind speed:

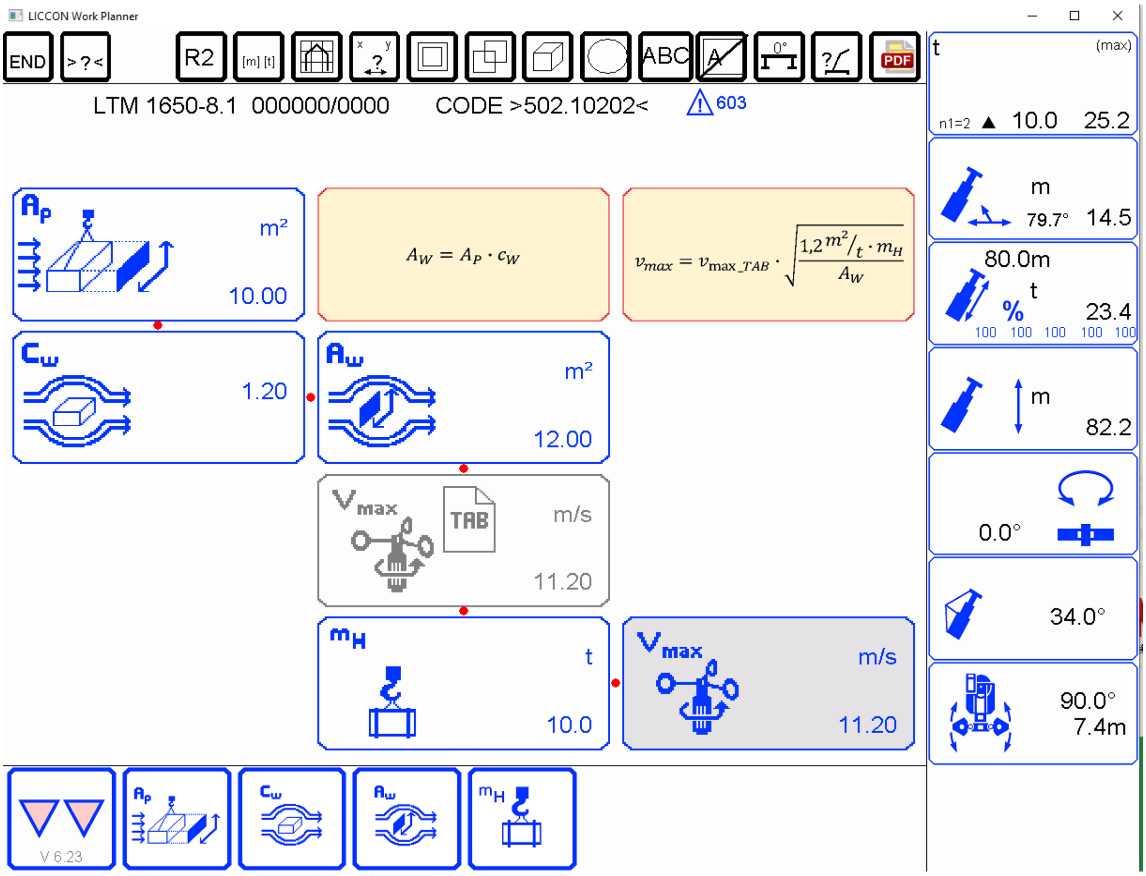


Figure 3: This screen permits the inputting of the weight of the load, the projected wind area, as well as the drag coefficient c_W. If the ratio of area to weight is below the limit, then no downrating of windspeed is required.

Some modern cranes allow adjustment of the permissible wind speed when a luffing fly jib is in use. For example, the crane referenced above permits a maximum wind speed of 13.4 m/s. Always refer to the OEM's *Instructions for Use* and load charts and not marketing-based brochures.

Below is an example of a table for a crawler crane with a luffing jib, illustrating the reduction in rated capacity based on different main boom lengths and luffing fly jib configurations. As wind speed increases, the rated capacity decreases until lifting is no longer permitted. In this specific case, the absolute upper wind speed limit is 16 m/s. For luffing fly jib lengths greater than 49.1 m, the limit is reduced to 10 m/s, with no allowance for capacity/wind speed trade-offs.

<table>
<tr><th>Main boom length</th><th colspan="3">All</th></tr>
<tr><th>Jib length</th><th>22.7 m (74 ft) to 34.4 m (113 ft)</th><th>37.4 m (123 ft) to 46.1 m (151 ft)</th><th>49.1 m (161 ft) to 78.5 m (258 ft)</th></tr>
<tr><th>Wind speed</th><th colspan="3">Reduction of load by</th></tr>
<tr><td>0 m/s (0.0 mph) to 10 m/s (22.4 mph)</td><td>0 %</td><td>0 %</td><td>0 %</td></tr>
<tr><td>10.1 m/s (22.6 mph) to 12 m/s (26.8 mph)</td><td>20 %</td><td>20 %</td><td rowspan="3">100 %</td></tr>
<tr><td>12.1 m/s (27.1 mph) to 14 m/s (31.3 mph)</td><td>30 %</td><td>40 %</td></tr>
<tr><td>14.1 m/s (31.5 mph) to 16 m/s (35.8 mph)</td><td>40 %</td><td>60 %</td></tr>
<tr><td>Above 16 m/s (35.8 mph)</td><td colspan="3">100 % = Operation prohibited</td></tr>
</table>

Figure 4: Example effect on duty chart for a crawler crane with a luffing fly jib in various wind speeds.

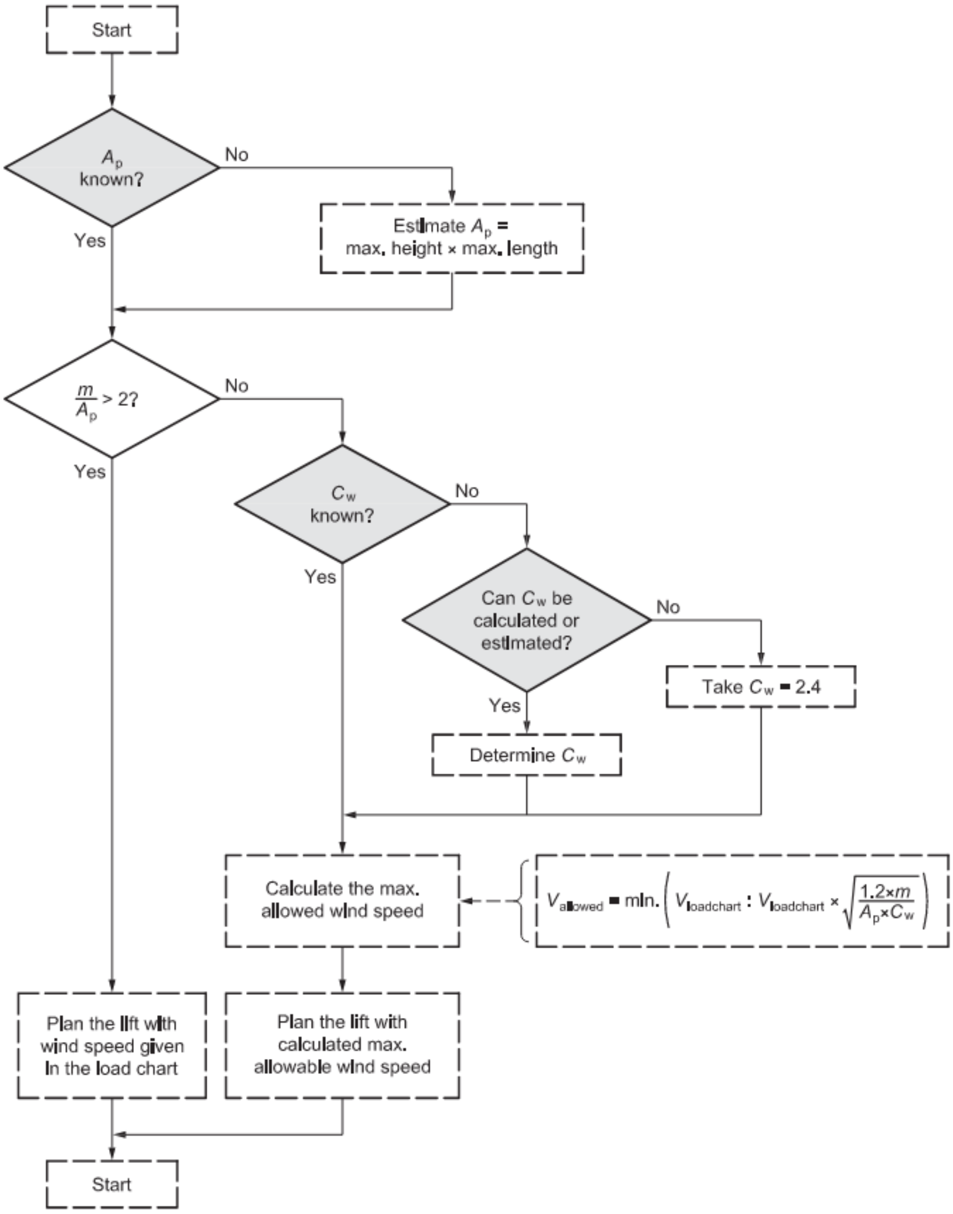
Some crane manufacturers allow unused rated capacity to be traded in order to operate in higher wind speeds. However, wind speed reductions based on the load’s surface area and weight must still be considered, along with how the load will be controlled in those wind conditions.

If a fixed or luffing fly jib is used, different wind speed limits will typically apply compared to main boom-only duties.

It is therefore essential to carefully select the crane, boom type and boom length for the specific lifting operation and to confirm the applicable wind speed limit. Any change to the crane configuration must be reviewed to determine if the permissible wind speed has also changed.

Checks should be always made with the relevant crane supplier or the OEM to verify the allowable wind speed for the planned lift.

Following the suggested Liebherr’s guidance (See Section 4.2) addresses items 1 to 4 in the table in Section 5.0 and provides a permissible wind speed for the lifting operation. This is summarised in the flowchart in Figure 5, taken from Annex D1 of BS 7121-1:2016.



Key

m	Working load (load on the hook + mass of hook and block) in tonnes (t)	$V_{allowed}$	Maximum wind speed of a 3-s gust wind at boom head in metres per second (m/s) *NOTE The allowed wind speed might not be higher than the wind speed of load chart (m/s).*
A_p	Projected surface area in square metres (m^2)	$V_{loadchart}$	Wind speed of load chart in metres per second (m/s)
C_w	Air drag coefficient (also known as C_d)		

Figure 5: Flow chart from Annex D-1 of BS7121-1:2016

5.1.2 Tower cranes

Certain tower crane activities, such as erection and alteration, have wind speed restrictions that may be limited to 13.5 m/s (50 km/h). This applies regardless of the rated capacity of the mobile crane being used for the erection. Care must also be taken if the crane is only part-assembled and a storm exceeding 13.5 m/s is forecast, as this may put the crane at risk.

Always consult the OEM if a crane is to be left partially installed, even if only mast sections are in place. Mast sections gain greater wind resistance once the slewing portion of the crane is fitted, as this creates a backward moment that helps relieve the overturning moment caused by wind.

There is also a limiting wind speed at which the crane must stop working and be placed in its out-of-service condition. This is defined in Table 1 of BS EN 13001-2:2021, which specifies a maximum wind speed of 20 m/s (45 mph / 72 km/h) and states that no special load case study shall use a figure below 14.1 m/s. Lower wind speeds may permit heavier loads to be lifted, but these values must be calculated by the OEM and not the crane user.

In the UK, tower cranes are typically taken out of service at 17 m/s (38 mph) to allow sufficient time to enter the correct out-of-service configuration.

The design standard notes that this wind speed is the “gust wind velocity averaged over a period of 3 seconds.”

The table in Figure 6 is an example of guidance provided by a tower crane manufacturer:

Permissible maximum wind speed for a load surface bigger than 1m^2/t (SM)

55 m jib

Radii		29,8	35	40	45	50	55
Load curve (in t)		7	5,4	4,3	3,4	2,7	2,15
S (in m^2)	Permissible maximum wind speed in service (in km/h)						
1		72	72	72	72	72	72
2		72	72	72	72	72	72
3		72	72	72	72	68	61
4		72	72	72	66	59	53
5		72	72	67	59	53	47
6		72	68	61	54	48	43
7		72	63	56	50	45	40
8		67	59	53	47	42	37
9		63	56	50	44	39	35
10		60	53	47	42	37	33
11		57	50	45	40	36	32
12		55	48	43	38	34	30
13		53	46	41	37	33	29
14		51	45	40	35	32	28
15		49	43	39	34	31	27
16		48	42	37	33	30	26
17		46	41	36	32	29	26
18		45	39	35	31	28	25
19		44	38	34	30	27	24
20		43	37	33	30	26	24
S = Surface of the lifted load in m^2							

Figure 6: This table is for a luffing jib tower crane with a 55m long jib. Where the crane is working at a 40m radius and is handling a load of 10m2, it is limited to a wind speed of 47km/h (or 13m/s).

The above table is reading in km/h. This manufacturer works on an area/mass ratio of 1m^2/tonne, as per EN13001.

Having identified what the limiting wind speed is – which is either the normal in-service limit for the crane or the reduced permissible value, it is now possible to assess if the operation can proceed at the planned period by examining the weather forecast.

It could be possible to examine an exposed project location and decide to build the structure using precast columns rather that adopting in-situ activities requiring the movement of light-weight shutters, because the precast columns will be easier to handle in windy conditions when compared to the shutter.

5.2 Site specific wind forecast for lifting operations

Wind speed forecasting should be regarded as not an exact science and many factors can influence it. However, the key actions for both the appointed person and the client are to:

- Understand the location of the lifting operation;
- Identify any local features that could funnel wind or cause swirling effects;
- Obtain an accurate, up-to-date wind speed forecast for both the height of the lifting operation and the height of the crane's jib;
- Assess whether the crane and load are likely to be affected by those wind speeds using the earlier calculations; and
- Provide clear instructions to the lifting team regarding both the crane's limiting wind speed and the load's limiting wind speed.

NOTE: *The client may have subscribed to a forecasting service that provides the wind speeds at various heights for the location of the building, or there may be an app available that offers a similar service. Any forecasting data used to make decisions should be recorded.*

The following section should help the appointed person understand the complexities of assessing wind, making forecasts and understanding what a forecast means as well as the imprecise nature of forecasting. Interpreting forecasts for wind speed can be difficult for the following reasons:

- Forecasts are provided at a height of 10m above ground;
- Forecasts may be given based on an instantaneous gust or based on the average wind speed, over a period of 10-minutes; and
- Forecasts are provided for the weather at the middle of a 10km x 10km grid square, so may miss local topographical features and the effects of any neighbouring buildings.

Forecast type	Duration/ definition	Use in lifting operations
Instantaneous gust	3-second peak gust speed	Used in crane design & winding off decision-making
10-minute mean	Mean average of readings taken over 10-minutes	Used in general weather forecasts

In clause 4.1.2.2 of EN13000, it states that a 3-second gust is being applied to the crane at height rather than 10-minute values applied at 10 metres above ground level. The crane operator should have a continuous live feed of wind speed data from the crane's anemometer, which usually samples the wind speed every second. The crane operator must obey the reading being shown on the crane's anemometer. Not all cranes and lifting equipment have an anemometer fitted, so a handheld device should be used to assist in the assessment of weather conditions, which should be set to show instantaneous or 3-second gust.

Where a crane's anemometer is linked to an online platform that displays and records the wind speed, it is likely that this is giving a read out that updates every 10 minutes. It is probably giving the 10 minute mean and max gust wind speed in the last ten minutes.

Height adjustment factors can be published in tables (see Section 4.2 Liebherr guidance - Table 2) and should be used to convert ground-level forecasts to expected gust speeds at crane height. This will help the appointed person to predict the wind speed acting on the tip of the crane's boom and assess if an operation should be winded off.

However, even this has complications. For example, Table 2 in the Liebherr guidance provides factors to give the likely wind speed at height above ground level (AGL).

Figures include: 1.181 at 50m AGL, 1.272 at 100m AGL and 1.329 at 150m AGL. This assumes a wind gust speed has been supplied in the forecast. If the average wind speeds however are being supplied, then the relevant factors increase significantly: 1.653 at 50m AGL, 1.78 at 100m AGL and 1.861 at 150m AGL. This allows for converting the 10-minute mean wind to a maximum gust. It is not always obvious which windspeed is being quoted in the forecast, so care must be taken when using the data.

It is important to note the need to select the correct roughness length (site profile, obstacles). Refer to Annex H to examine example parameters. The default parameters are often set at class of 0.5 – 1, which suit countryside locations and which may suit the erection and maintenance of wind turbines. However, city-centre environments would have a roughness class of 3.5 or more.

A tower crane in an urban area is in a much more complex area, with a Class +2 which means that the forecasts based on a gusting wind speed will give very high readings. Wind specialists may take a different approach, which may be to select the correct roughness Class and use the mean average wind speed to provide the wind profile with height - and then calculate the potential for maximum wind speeds.

In general, at high wind speeds, very rarely will the gust be more than 1.5 times its mean average. However, at lower wind speeds, it is possible to have 3 – 4 times the lower varying speed in a gust. So, mid-range, seemingly unremarkable wind speeds can be more dangerous, because it is harder to foresee what is coming and have a false sense of security. When high wind speeds are expected, greater care is already being taken with vigorous monitoring of the rising speeds, as the prospect of winding off is already a possibility. When the lifting team is aware that there is a risk of high wind, they should operate with extra care or not operate at all - especially for long and complex activities such as reeving the luffing ropes on the front jib of a tower crane.

If a general weather forecast or app is used, then it will not consider the local topography, shielding or the presence of significant structures. Although generally there is shielding in an urban environment, local features can cause accelerations. A site visit may help identify if this is possible, provided the visit is undertaken in similar conditions to the day of the planned activity. Such a visit will only give a superficial knowledge and allow only an anecdotal assessment. However, some assessment should be made and an entry made in the risk assessment to provide relevant mitigation measures to avoid an incident.

Some construction projects are required to undertake a pedestrian comfort study to assess the impact on the local wind flows of creating the new structure. This may give some relevant information provided the local area is representative of the study.

This information may be derived from creating a scale model and using a wind tunnel to assess the effects. However, increasingly, computational fluid dynamics (cfd) is being used. Some studies consider the full height of the building to assist in the design of the cladding. In time, this data could be used to assess the likely wind speed and hence pressure acting on the crane.

A current study has shown that although a crane manufacturer has found reduced loads on the crane due to local shielding, they will not calculate crane base and tie loads other than the zone C, 1 in 25-year recurrence period, due to concerns that it contravenes the crane design standard EN14439 / FEM1.005.

It is possible to commission studies to model complex urban environments over the height of the construction project, to include different time-slices to assess how the wind flows vary through the various phases of a project. An example is shown in Annex D.

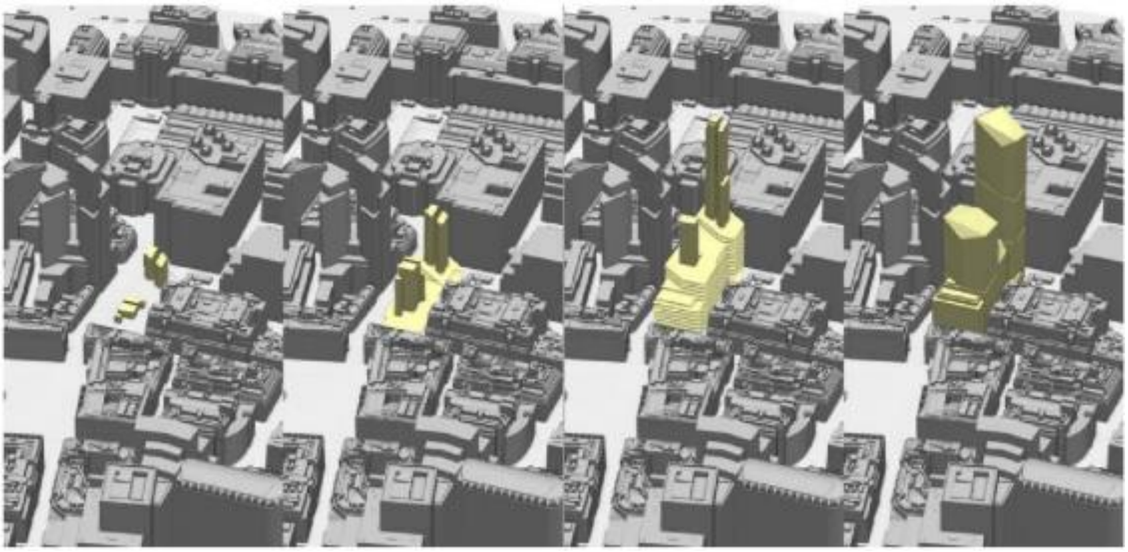


Figure 7: Example of modelling at four different phases of a project (credit: Wirth Research)

Once a study has been completed, it will be able to give factors that can be applied to an input windspeed to show what accelerations are likely to be experienced during the lifting operations at different parts of the project. This factor can then be applied to the forecast to adjust for height and the local environment. This type of analysis is in its embryonic stages but being tested currently. It is hoped that testing will show that the tower crane anemometer can be linked to the weather app to allow forecasts to be corrected for the on-site conditions, as confirmed by the crane when compared to the recent forecast.

Cranes on the same project however may experience different windspeeds to such an extent, that some cranes may be winded off and others able to operate.

Cranes at different elevations will also experience different conditions.

Different types of cranes will be required to wind-off at lower wind speeds than others by virtue of their design, or what lifting accessories they are using (such as an attachment at 8m/s / 18mph). A tower crane may wind-off at a windspeed of 12m/s to 17m/s (28mph to 38mph) even though by design, its limit is 20m/s (45mph) whereas a traditional mobile crane winds-off on average at around 9-11 m/s - depending on type and rig configuration. Lattice boom crawlers often vary between 12m/s to 16m/s - depending on configuration and boom length. Note that telescopic crawlers will be similar to mobile crane characteristics. Always consult the operator’s instructions for the permissible working wind speed as these vary by crane type, boom length and crane configuration.

Planning lifting operations on a short-term look-ahead basis, should consider the forecast. This should be briefed to the lifting teams at the daily activity briefing. Where possible, site management should aim to maximise lifting operations so that wind-sensitive lifting operations are undertaken during times of the day or periods when the wind speed is lower, allowing the lifting of heavy, more compact loads outside of this period during any forecasted windier times. When the local wind effects are understood, it may be possible to lift in the lee of adjacent structures or alter sequences e.g. concrete skipping duties are picked instead of bathroom pods. Alternatively, more difficult lifts may find steadier wind conditions early in the morning.

The wind speed is measured at the top of the crane. For example, the anemometer is usually mounted at the boom head sheave of a mobile crane and usually on the strut / a-frame or top spine of jib of a tower crane. These provide a reading only at a single point in height and therefore may not capture any interaction between the crane and the load with the wind. It is for this reason that the final decision to lift should always be with the lifting team and ultimately, the operator.

The crane team should always obey the wind speed limits imposed by the crane OEM's limiting wind speed as well as any lower limits that the appointed person has written in the lift plan.

The wind speed used in assessing whether the lift should proceed is measured at the height of the boom / jib - at the crane's anemometer. This is because it is the crane that must be protected by the in service wind speed limit. If additional readings are taken at the height of the lifting operation, then these can be used to assess if the load is likely to be controlled.

5.2.1 Wind direction in reference crawler crane boom

Crawler cranes have traditionally been selected for wind farm projects. The following information is a rule-of-thumb/estimation that crane planners use when assessing if a lifting operation is going to commence and when a lifting operation should be aborted, using the predominant wind direction in relation to the orientation of the jib

- Parallel (Front/Back) Preferred: This has lower side-loading on boom and more control over load swing;
- Perpendicular (Side-on): This wind load onto the crane provides higher lateral pressure and possible more boom deflection and load swing. When wind hits the side of the boom, it can create bigger bending and torsional forces than when parallel to it.

A crawler crane is typically most stable in the direction parallel with the tracks. Side winds challenge its lateral stability, especially with big boom and fly-jib configurations.

The risk of load swing under the influence of wind increases especially in long components like wind turbine blades.

Some project companies and manufacturers recommend adjusting the maximum operational wind speed by 20 to 30%, depending on load and wind direction. The rule-of-thumb/estimation is shown below.

45° Angles (Oblique): Risk is lower than perpendicular as it is a combination of forward pressure and side sway.

In all cases, the wind speed and direction should be monitored carefully, with a consideration of applying a reduction in the permissible working wind speed when judging the effect of the wind on the crane and load between wind parallel and wind side. Ideally, the appointed person should follow the OEM's instructions for use. If the appointed person examines long duration activities, such as bolting-up large connections, then close analysis of the forecast and actual windspeeds should also help identify if there is a risk to the crane. In all cases, estimating is difficult and following empirical rule-of-thumb reductions have historically been used on wind farm projects. However, the appointed person should make their own assessment.

The following website can provide additional information on where to site an anemometer:

https://www.windcrane.com/blog/construction/anemometer-placement-a-site-specific

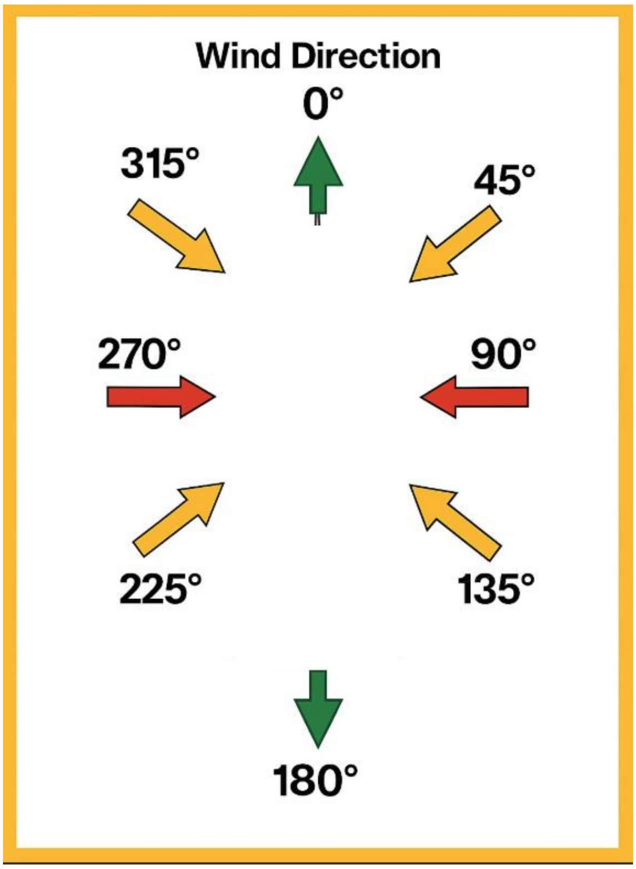


Figure 8: As a rule-of-thumb/estimation, the permissible working wind speed applied from approximately the 45, 135, 225, 315-degree angle might be reduced by 1m/s, whereas the 90 and 270 agree wind directions may attract a 2m/s reduction. (Refer to commentary in 5.2.1.)

<u>5.2.2 Forecasting using local wind studies and on-site weather stations for hyper-local forecasts.</u>

The wind speed will affect the crane differently when applied from different directions, for which there can be slight errors in the reading, depending on any shielding of the wind as it blows around the structure of the crane.

Generally, town centre locations are more shielded from wind than those sites which are located in the country or outskirts of a town. Some tower crane manufacturers will accept a reduction on the site reference wind speeds where a reputable source for the data is used. This can then be used to calculate modified tower crane foundation loads.

Some contractors have been trialling the use of forecasting, along with comparison to actual weather and using any discrepancies to make corrections to the short-term look ahead forecast to make it more accurate. This is an area of research and development that may yield more efficient lifting operations planning, as high wind speed weather periods can be alerted in advance and deliveries rescheduled. This should bring safety benefits too, as wind sensitive loads could be avoided / sequenced for better suited conditions on different days. As an example, in 2023, there was a 1:10 year storm was forecast four-days before the Met Office issued a yellow weather warning. Wind speeds of 71mph were predicted and the measured wind speed on the project was 72mph. This meant the site team were able to plan the shutting of the project and allow for all of the crawler cranes' jibs to be laid onto the ground in advance.

5.3 Load geometry and load control.

Wind acts on the face of the load that is into the wind. If uncontrolled, it will rotate to present an equal face area to each side of the centre of gravity of the load, i.e. there is a balanced force on each side of the line of action of the centre of gravity. To achieve the equilibrium, the load will swing past and then back several times to settle – assuming the wind direction is uniform.

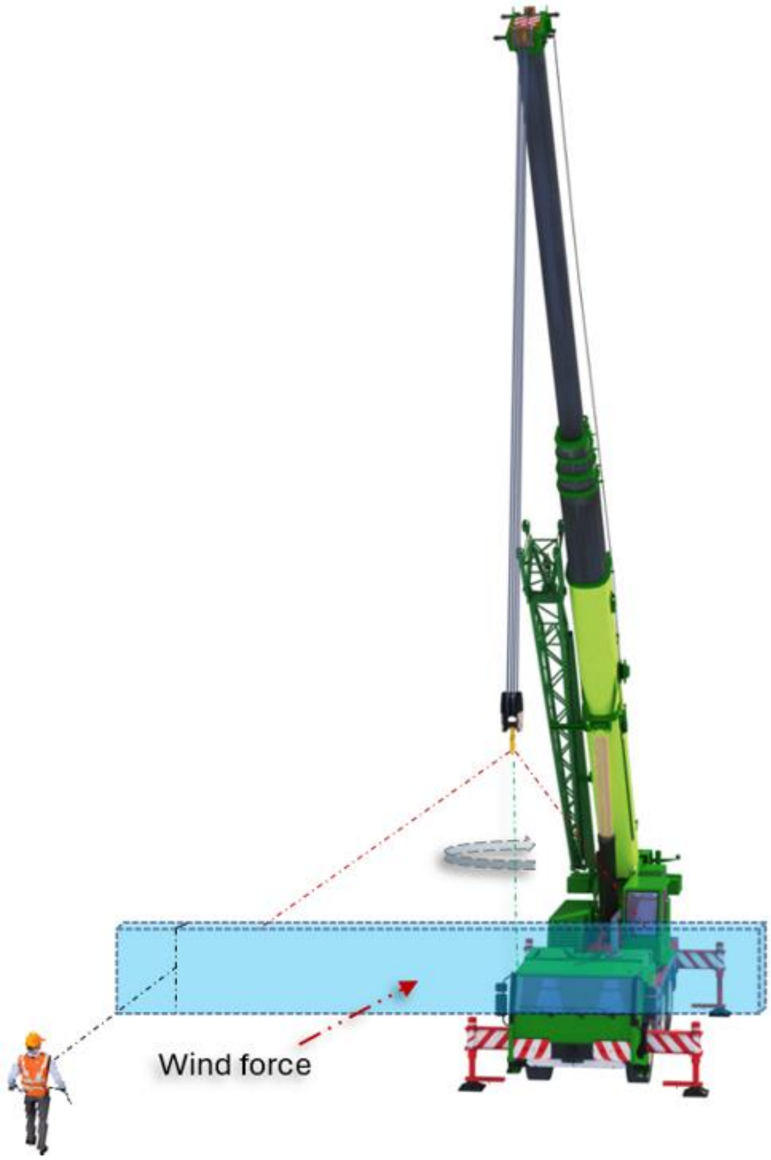


Figure 9: Image shows that because the centre of gravity of the load is not in the geometric centre of the beam, it will rotate until there is an equal projected wind area on each side of the centre of gravity, on the centre of the crane's hook.

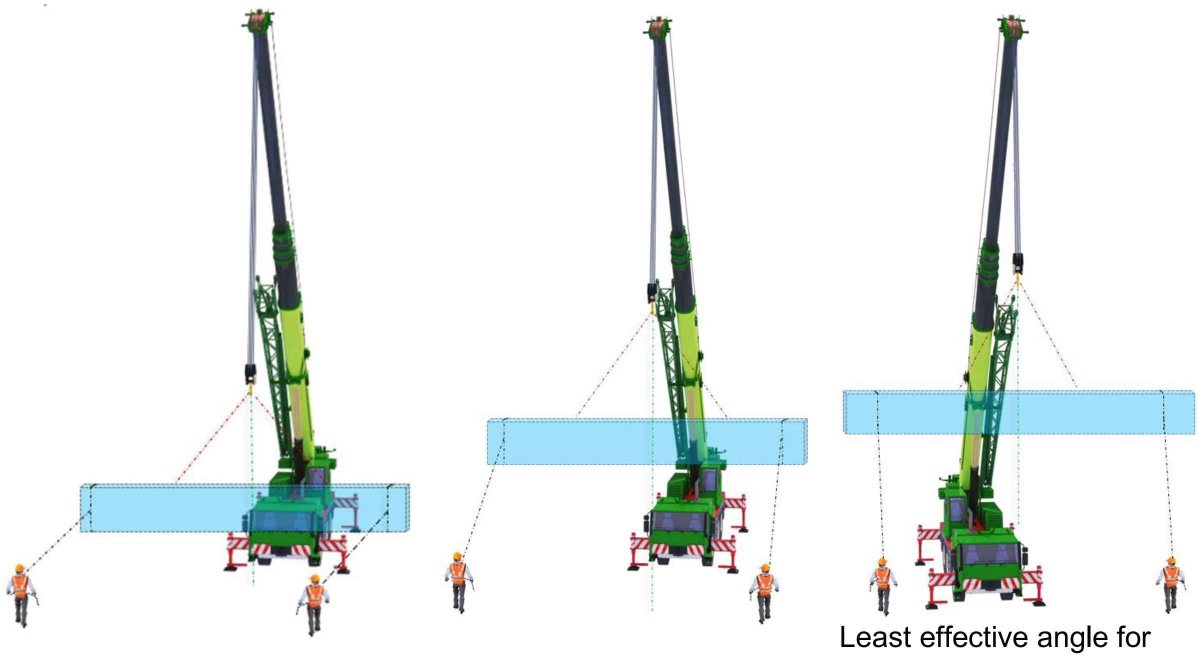
<u>5.3.1 When taglines are appropriate:</u>

Loads also need to be rotated around obstacles, or they need to rotate from the orientation they were delivered in, so that they can be positioned.

An alternative example would be a tower crane's front jib, when there is a wind sail on one end. Adding a tagline to the side that has a larger wind area should help to stabilise the load and rotate it into position provided the wind is not too strong.

The direction of the tagline needs to be in the opposite direction of the wind, as shown in Figure 9. The tagline is not to be used to wrestle with the wind, but only for final positioning or guiding between obstructions so that the slinger-signaller does not handle the load and place themselves in danger. Since the wind force is rarely uniform or steady, the lifted load does not usually settle into a steady position and some form of control is often needed, especially where careful positioning is required. Load control may be needed at both ends of the load to stop over-correction.

The taglines need to be as close to horizontal as possible to be most effective. The steeper the angle, the less effective they become as shown in the figures below:



Most effective angle for tagline

Least effective angle for the tagline. Position the slinger-signallers further from the load, with a longer tagline to decrease the tagline angle.

Figure 10: The taglines become less effective the higher the load is raised, without lengthening the line.

5.3.2 Tagline limitations & hazards:

Taglines should not be the answer to all load control problems. The following are a list factors to consider when planning to use a tagline. These could form part of a risk assessment:

- Has the user been trained in the principles of the safe use of a tagline?
- Does the risk assessment for the activity assess the risks posed by their use?
- Can the user(s) control the load given the forecasted windspeed and the wind area of the load?
- Can the user be positioned to control the load effectively and for the complete load path?
- Are additional hazards present when using a tagline(s)?
- Is the tagline designed for the purpose, rather than a length of rope?
- Is the tagline the correct strength, length and un-knotted?

- Can it be attached to end of the load that needs to be controlled, which is preferable to attaching it to the lifting accessory attachment point?

5.3.3 Content of risk assessment

Hazards to be considered should include, but may not be limited to:

- Narrow lifting corridors between buildings;
- Working on a scaffold;
- Passing a load over a building with a trailing tagline which could be snagged;
- Working at height with incorrect length and /or incorrectly positioned user(s);
- Sudden gusting wind;
- Over-reaching to gather the tagline;
- Walking under or very close to the load to retrieve the tagline;
- Using the tagline to drag a load out of radius;
- Using a tagline to guide the load against wind rather than hold and rotate the load. This suggests a tagline is not the correct tool for the task or the operation should be ceased because the wind is too high for the users to safely control the load; and
- Tagline loops around limb, entangling and then lifting or dragging the slinger-signaller up with the load.

It is important to operate under the principles of the industry initiative: Hands Off, Step Away, Safe Space when using taglines and push-pull poles. An extract of the principles is included in Annex B.

Consider the example of the lifting operation below. The following observations can be made when planning the activity of removing the truss from beside the tower:

- The load is at height and next to a building, so long taglines will be required, and the operatives will have to stand a long way off to provide effective control. Is there sufficient space?
- Has the load been checked for wind sensitivity?
- Has the crane's working wind speed been lowered to a new permissible value?
- Is the crane's anemometer working?
- Has a hold point been introduced to ensure that a clear decision is made to proceed based on the weather forecast, the current wind speeds as well as an allowance for the local conditions (e.g., height, gustiness, vortices)?
- Which direction is the wind coming from and will the users be positioned so that they can control the load?

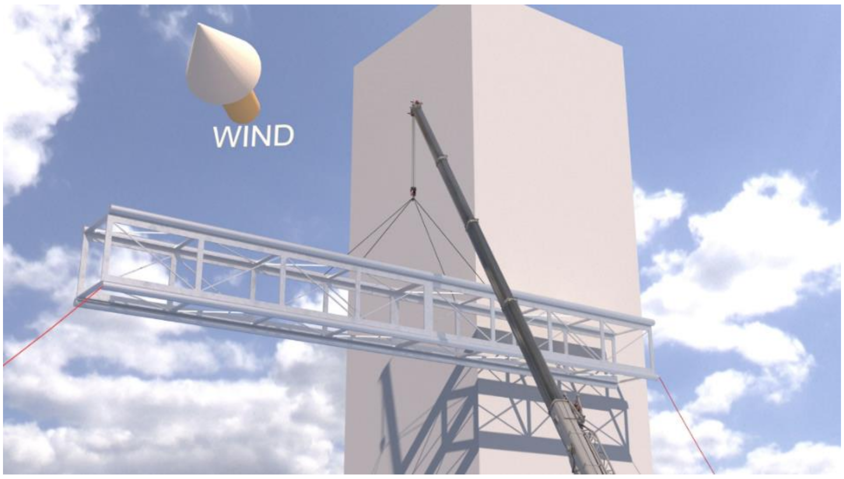


Figure 11: Wind passing from behind the tower, acts on only one half of the truss but the exposed area accelerates due to the funnelling effect of the wind near obstacles, resulting in rotation.

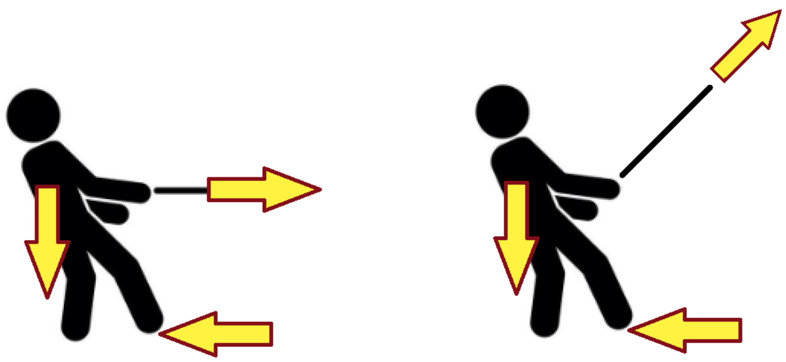
- As the truss comes in front of the tower, will one end be sheltered, and the other end be in the wind, so that even in the lightest of breezes, the load will rotate, threatening the adjacent structure?

Refer also to CPA TCIG TIN 022 - Use of Taglines with Tower Cranes, which can be downloaded at www.cpa.uk.net

5.3.4 Assessment of adequacy of a tagline.

Tagline types and lengths should be selected by the appointed person. The correct selection of tagline is important and should address the following points as a minimum:

- Strength for the anticipated wind forces;
- Elasticity - Taglines that are very long and especially where they are elastic (stretchy) have a reduced effectiveness. When compounded with poor positioning of the slinger-signaller, the load may be non-responsive to the action on it from the tagline, making the load unresponsive to the control measure;
- Diameter – can it be gripped effectively?
- Does it coil easily or form knots?
- Does it have a proprietary wide jaw hook to allow attachment around the load, with a securing clip?
- Adequate length of tagline? And
- A common tagline has a stated strength of 500kg, although should break under a much greater load. However, there is a limit that an 80kg person can hold before the tagline drags them along. This will be a factor of the individual's strength, weight, stance, shoe type, surface finish and moisture/dust on the surface. As a rule of thumb, the instantaneous restraint provided by a slinger-signaller is approximately half of their body mass, but in a longer-term sustained application of load, this reduces to approximately one third of their body mass.



Experience shows the slinger-signaller that heavy loads can be turned when the dynamic wind force is not present. However, controlling it once moving can be an issue if there is an insufficient braking force.

6.0 Lifting Activities On Site

6.1 Monitoring wind speeds & winding-off / out of service conditions

Not only does the planning phase need to consider if a load is wind sensitive, but the same care is also required in the delivery phase.

6.1.1 Wind monitoring methods

There are a number of sources for forecasts:

- Met Office or other weather forecast provider;
- Internet based weather apps; and
- Height-corrected forecasts linked to the tower crane anemometer app.

Care is required when using forecasts, noting the comments in Section 5.2.

6.1.2 Anemometer fitment and use

There is planned introduction in a future version of EN13000 that cranes with boom lengths exceeding 65m or where it takes longer than 5 minutes to stow the boom, are fitted with an anemometer.

Many mobile cranes are already fitted with an anemometer, allowing for regular wind monitoring at the cathead or boom tip. The appointed person should verify whether an anemometer is installed before selecting the crane.

Although handheld anemometers are available, they are only accurate where the user is positioned and the load and crane boom could be a significant distance away. A discussion of where, how and how often this is monitored should be covered in the risk assessment.

6.1.3 Decision making and planning for stopping lifting operations

The permissible wind speed should be shown in the lift plan and briefed to the lifting team at the pre-start briefing of the risk assessment and method statement. This will permit the crane operator to advise whether the wind is approaching any lifting limits.

The appointed person and lifting supervisor should consider how long it will take to put the crane out of service, so that it is safe before the crane's wind limit is exceeded. Sufficient time should be factored in for the lifting operation to be completed so that it is not necessary to abort a lifting operation mid-lift. This could put the crane and any site staff / operatives at risk. Equally, allowance for time to make the crane safe for out-of-service mode should be factored in. This is is especially relevant where a long luffing fly jib needs to be lowered to the ground or where there is a super-lift tray in use. This challenge increases if a crawler crane must travel to a designated jib laydown location before being placed out-of-service.

6.1.4 Crane out of service requirements

Cranes must be set in their correct out-of-service configuration, as specified in the OEM's instruction manual. Certain crane types such as mobile self-erecting tower cranes, self-erecting tower cranes and crawler cranes have added complexity - with specific requirements for being taken out of service before critical wind speeds are exceeded. The jib or boom may need to be folded away or laid down.

Cranes mounted on rails may require storm anchors to prevent them from rolling along the tracks in high winds.

It is also important to follow the rules regarding the position of the crane's hook in relation to the underside of the top sheave(s). In high winds, the hook block can swing under the influence of the wind and cause damage to the underside of the boom or jib. Following strong winds, the boom or jib tip should be inspected for potential damage. This is also a reason why all lifting accessories should be removed from the crane's hook whenever it is out-of-service

Activity	Party responsible	Supplementary check / conversation
Identify crane limiting windspeed	Appointed person	Review OEM instructions for use
Identify limiting wind speed for load / lifting accessories	Appointed person	Review OEM instructions for use
Forecast monitoring	Site management / Employer	
Live wind speed monitoring	Crane operator	Crane supervisor should also verify wind speed is OK for crane and load and check conditions with operator
Decision to wind-off	Crane operator's ultimate responsibility	May discuss with lifting team
Correct configuration of crane for the out of service wind speed	Crane Operator	Verified by crane supervisor

NOTE: Table of responsibility for making decisions related to wind

It is the crane hirer's responsibility to monitor the forecast and advise of any storm conditions that will affect the way a crane is left out of service. The operator monitors the crane immediately prior to and during use, but has no responsibility to monitor the forecast to make a decision whether the crane should be placed into the out-of-service condition - such as laying a crawler crane boom down overnight for a potential incoming storm. The crane operator should also decide whether a winded-off lifting operation can recommence - see Section 6.4 for further guidance. The hirer / principal contractor and their crane supervisor / lifting supervisor should be aware of the forecast and any developing trends to advise the appointed person if necessary and if advice is needed.

6.2 Control of load once in the air

A load should always be under control. This is particularly relevant at the load pick-up and load detachment points where the load will be close the slinger-signallers. The difficulties have been identified (see Section 5.3.1) concerning the selection and use of taglines. as well as the importance of obeying the principles of hands off, step away, safe space. The following items should be considered prior to lifting each load, with particular attention to wind:

- Security of the load within or by attachment to the lifting accessories;
- Safety of those handling the load;
- Visibility of the whole path of the load from pick-up location to placing the load; with verbal direction of the crane operator provided by the slinger-signaller(s);
- Potential for overturning the crane due to a load of large projected face area, transferring horizontal force into the hoist rope and hence the tip of the boom;
- Losing the crane's ability to control the slew due to wind pressure acting on the side of the boom and load, such that the slew brake can no longer hold the load steady;
- Direction of the slew, wind direction, and type of load;
- There are no obstacles that prevent the safe use of the load control strategy on site, especially where taglines are risk assessed for use;

- Where the load is close to the ground, it may be better to use push-pull poles. These allow the pushing of the load without needing to place a hand on the load and the retrieving of any slings that are close to, or under the load;
- Use of a below-the-hook electro-mechanical load control device to control the orientation of the load by remote control; and
- The risk assessment should address the control of long loads, with particular attention to controlling load spin where the load can strike the crane's boom/jib.

Appendix B gives further guidance when considering the principles of hands-off, step away, safe space.

6.3 Below the hook electro-mechanical load control device

There are a number of devices available for the appointed person to select from. The images in Figures 12 and 13 show a selection of varying types.

These devices can be particularly useful on congested sites where there is limited space for effective tagline use. This is especially relevant when lifting loads near façades that could be damaged by a rotating load or snagging on scaffold. A risk assessment should always be completed before selecting and using this type of equipment.

These devices operate in various ways and each has its own strengths and limitations. The appointed person must be aware of these differences as each device will require specific risk mitigation measures during use. The relevant manufacturer's datasheet and relevant risk assessments should be consulted before selecting the equipment.

Some systems use the momentum of a spinning mass (e.g. water or steel discs) or propellers to rotate the load. Most are operated via a handheld remote control, allowing the load to be steered in one-degree increments or held gyroscopically in a fixed orientation, regardless of crane or hook rotation.

Choosing the right device is critical. As the load's geometry - particularly its length - or weight increases, a more powerful device is needed.

Key benefits include the ability to steer loads through confined spaces, such as narrow shafts or bays of steelwork without needing taglines (which can snag) or requiring anyone to stand under the load.

However, because of their power, there is a risk of misusing these devices to carry out lifts beyond a crane's in service wind area allowance of 1.0 m² per tonne.

Where the load is lightweight but has a large surface area, the crane's working wind speed may need to be reduced. The operator can provide real-time wind speed readings to support any safe decision-making. A properly prepared lift plan should already state the revised down-rated wind speed limit.

These devices are intended for use in wind speed conditions where handling by tagline is unsafe, but where the wind remains within the crane's in-service limit. They should not be used to justify exceeding safe working parameters.

Note: The examples shown in Figures 11 and 12 only indicate certain types of load control units. Other brands and types are available on the market.

CIG and TCIG do not endorse any of the product types, makes and models listed.

Figure 11: Torquer HALO, Verton & Vita Load Navigator devices are examples of below the hook load control devices which allow the load to be rotated. What they won't do is increase the upper limit of the crane's in service wind speed.

There are also devices that rotate the crane's hook rather than the load, such as the Roborigger.

Figure 12: Roborigger has a finned flywheel which is powered by an electric motor. It attaches directly to the hook and turns the hook itself. The fins on the flywheel help to produce external thrust against the wind.

These devices may assist operatives trying to control the load from MEWP baskets that do not lend themselves to the use of taglines, as the basket / boom may sway a lot under the influence of sideways loads.

It is also essential that the users, who are often slinger-signallers, are familiarised in the safe use of the equipment. The familiarisation should include the following, which is a non-exhaustive list:

- Effective use of the equipment – e.g. constant running vs impulse;
- Check the correct function, including battery charge for the remote control and the device;
- Correct storage and securing procedures;
- What to do in the event of a breakdown;
- Battery charging;
- Awareness of battery damage and risk of fire, as well as how to react to a fire;

- Completing and recording daily and weekly checks for the equipment;
- Configuring for different loads;
- Hand over procedures where two different slinger-signallers are controlling the same load; one at load pick-up and a different one at load-placement/positioning; and
- Limitations of the device.

6.4 Who has the final say on winding off and returning to lifting operations?

Irrespective of the planning and control measures contained within the written lift plan, the ultimate responsibility for the safe operation of the crane is the crane operator. The operator can usually see and feel the way the crane and load are responding to the wind. The operator should also consider the ability of the slinger/signaller's to control the load safely. It is for these reasons that the crane operator has the final decision if the lift is to start, continue or be aborted. Refer to BS7121-1:2016, referring to clauses 6.2.1 & 13.2.1.3 and BS7121-5:2019 clause 14.1.1.

The site management and site lifting team should allow the appointed person to give good advice and accept the decision of the lifting team & crane operator as to whether a particular lifting operation is safe to proceed. This is especially relevant in periods when the crane remains safe to be used, but the wind speeds are increasing and becoming gustier.

All members of the lifting team have the responsibility to ensure that the load is safe to lift and position and any member of the lifting team should have the authority to abort the lift. The final decision should always however be with the crane operator.

Where the reason for stopping the lifting operation is not wind related, and the site team cannot agree that the lift plan is safe to use, the lifting supervisor should consult the appointed person.

The lifting operation should not proceed where the safety of the lifting team is in question, even though the crane's upper wind limit has not been exceeded.

The crane's manual should be referred to which gives the OEM's requirements for limiting wind speeds and the correct out of service procedures and requirements. These should be referred to in the lift plan, risk assessment and method statement.

<u>6.4.1 The crane should be winded off at the lower wind speed of the following scenarios:</u>

a. The crane's in service wind speed limit has been reached at crane's anemometer;
b. The load is being lifted using a device, such as a vacuum unit, which has a lower wind speed;
c. The AP has set a lower wind speed as per the manufacturer's instructions for area to weight ratio (1.0m^2/t); and
d. The crane operator believes the lifting operation is unsafe to continue / commence.

NOTE: Whether the wind speed is read at the load or at the jib tip.

<u>6.4.2 Putting the crane back into service</u>

A tower crane should not be put back into service until the wind has been lower than the in-service limit / load limit for at least 10-minutes. This principle has been set by BS7121-5:2019 14.1.4.2. Windspeed tends to increase quickly and decrease more slowly over time, so regular monitoring of the wind speed should be undertaken before deciding to restart any lifting operations. The lifting team should monitor the duration between gusts which should reflect the duration of the lifting operation, so a lengthy install of a structural element should be reflected in the monitoring period. This should be risk assessed by the lifting team as well as the forecast being consulted. Note that many apps only revise their forecast twice a day, so the accuracy and variability needs to be carefully considered.

A tower crane operator should not remain in the cab when the wind speed is above 20m/s (45mph) or commence climbing back up the mast until the above limit has been reached.

6.4.3 Deciding when to wind-off for the day

It is common practice to wait 30 minutes after the wind speed drops below the threshold before attempting to lift again. This waiting period may be longer for tower crane operations where the operator has descended the mast. If the wind exceeds the winding-off threshold, the timer 'resets'. After this happens three or four times, the day may need to be declared 'winded off', especially if the lifting operation involves a lengthy installation process.

If repeated wind speed readings exceed the threshold and that the forecast suggests that conditions will remain high for several hours, it may be more practical to redirect work to safer areas. Conversely, if the forecast indicates that wind speeds will decrease, waiting 30 minutes after the wind drops below the threshold may be appropriate before resuming lifting operations.

Regular wind speed monitoring both live and over a period allows the lifting team to identify trends. For example, wind speeds may be lower in the early morning, with peaks around 11 a.m. Recognising these patterns, in combination with the forecast, helps build confidence when planning lifting activity.

As always, keeping accurate records should remain essential.

7.0 Calculation for the Effect of Wind on Outrigger Loads

The person who is appointed to plan the lifting operation is required to assess the effect of the weight and area of the load and whether the load will be safe to lift in the anticipated wind conditions for a given crane type and crane configuration.

There are a number of possible approaches. Each approach has benefits, but the cost and accuracy may increase as the complexity of the analysis increases.

7.1 Standard assessment including effect of wind on outrigger loads.

All assessments should consider not only the effect on the working wind speed, but also the effect on the outrigger loads.

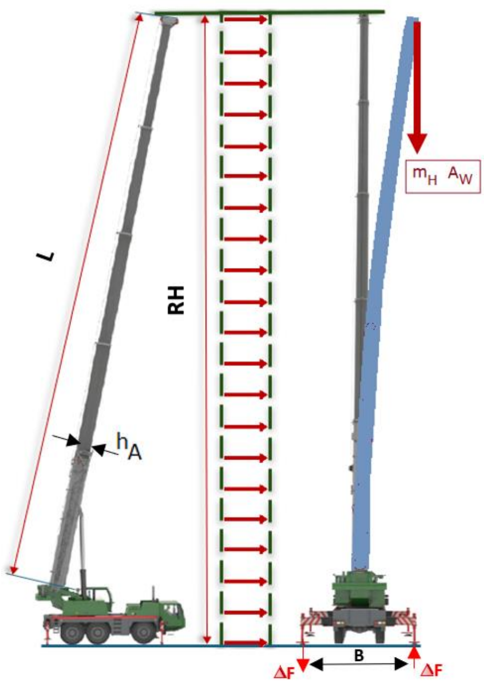
<u>7.1.1 Windspeed downrating</u>

Guidance that is often referred to in industry has been created by Liebherr and is available for download from their website as in Section 4.2.

This is based on the principles of design of cranes as specified in EN13000 and a few worked examples are contained there-in, which could be helpful when assessing a down rating for a lifting operation.

<u>7.1.2 Assessment of effect on outriggers</u>

The assessment should also consider the effect of the wind pressure on the surface area of the load, as well as the crane and the resulting effect on the outrigger loads of a mobile crane.



The crane's OEM should be consulted who will be able to provide the correct method of such an assessment.

The assessment will need to examine the elastic response of the crane to the horizontal loads from the wind acting on the following projected areas, with a further allowance for various shape factors:

- the load;
- the main boom and any fixed or luffing fly jib;
- the chassis and slewing portion of the crane.

Wind areas act at different heights, so the effect of the load at height may be significant.

A horizontal load will cause a sideways deflection in the boom, which may be appreciable. This will further affect the outrigger load due the eccentric load acting on the boom and hence the base of the crane.

If great heights and large areas are considered, such as rotor blades, then Liebherr (see Section 4.2) indicate that the increase in the outrigger load may be a further 35% increase from a standard assessment. Their memo is published in full in Annex G, be only applicable however to their products, noting their advice to use their calculator where a more accurate assessment is required.

The appointed person must carry out an appropriate risk assessment during the planning process to determine the required level of accuracy when evaluating outrigger loads.

7.2 Complex Assessment

While it is theoretically possible to calculate the wind force on a load and its transmission through a tagline, this method is rarely practical. Several variables make precise analysis extremely difficult, including:

- The level of restraint a person can realistically apply to the load;
- Variability in tagline angles;
- Ground roughness;
- Presence of moisture, dust or other friction-reducing substances;
- Orientation of the load relative to the wind;
- Accurate determination of wind force on the load;
- Wind pressure acting on the crane itself;
- Stretch in the tagline and how well it can be held under tension; and
- The tagline handler’s stance and ability to maintain control.

For these reasons, such detailed analysis is generally avoided in current lifting practice.

8.0 Conclusion

The appointed person requires an understanding of windspeed, forecasts, the effect of wind on various loads, as well as the correct way to control loads being carried by cranes - including how to make a crane safe when the wind is beyond safe operating parameters.

8.1 Wind Effects

Wind affects both cranes and loads. It can impose significant pressure, especially when lifting lightweight items with large surface areas at high elevations. Wind speed and direction can vary and are often influenced by local obstructions. It may cause the load to drift, rotate or become unstable and can impact the crane's stability, slewing control, and boom deflection.

The safety of those controlling the load is paramount. If the load cannot be safely controlled in the wind, the lift should not proceed, even if the crane's own wind speed limits have not been exceeded.

8.2 Planning Duties

The appointed person is responsible for planning lifting operations in windy conditions and must consider both the crane and load characteristics, including weight, projected surface area, drag coefficient and the crane's permissible wind speed. They should further obtain a site-specific wind forecast that reflects the height and/or depth of the lifting operation, as well as any local environmental factors that may influence wind flow.

The appointed person must prepare a suitable and sufficient lift plan in line with the requirements of the Management of Health and Safety at Work Regulations and LOLER. This plan should clearly set out the crane's limiting in service wind speed, along with any additional limits related to load area-to-weight ratio or lifting accessories.

8.3 Operational Duties

The lifting team must ensure that the load remains under control at all times and is securely connected to the lifting accessories. They should continuously monitor wind speed and direction and be ready to suspend the lift if conditions exceed the crane's limits, or the load becomes unmanageable.

Manual load control methods, such as taglines, push-pull poles or below-the-hook electro-mechanical devices may be used as appropriate. The team must adhere to the principles of hands-off, step away, safe space and ultimately respect the final decision of the crane operator.

8.4 Understand out-of-service requirements

Preparation must be made to ensure the crane can be placed into its designated out-of-service condition safely and efficiently, without putting people or plant at risk. The principal contractor or crane hirer must monitor weather forecasts and take appropriate action in advance of high winds.

9.0 Publications and Guidance

Abbreviation	Description	Link
MHSW	Management of Health and Safety Regulations	The Management of Health and Safety at Work Regulations 1999
LOLER	Safe use of lifting equipment - Lifting Equipment and Lifting operations Regulations 1998 – Approved Code of Practice and Guidance -L113	https://www.hse.gov.uk/pubns/priced/l113.pdf
PUWER	Safe use of work equipment - Provision and Use of Work Equipment Regulations 1998 – Approved Code of Practice and Guidance – L22	https://www.hse.gov.uk/pubns/priced/l22.pdf
HSG 65	Managing for health and safety – Plan, Do, Check, Act approach to managing	Managing for health and safety (HSG65) - HSE
HSG150	Health and Safety in Construction – HSG 150	https://www.hse.gov.uk/pubns/priced/hsg150.pdf
INDG401	The Work at height – a brief guide – INDG 401	https://www.hse.gov.uk/pubns/indg401.pdf
BS7121-1	BS7121-1:2016 Code of practice for safe use of cranes – Part 1: General	https://landingpage.bsigroup.com/LandingPage/Series?UPI=BS%207121
BS7121-3	BS7121-3:2017+A1:2019 Code of practice for safe use of cranes – Part 3: Mobile cranes	https://landingpage.bsigroup.com/LandingPage/Series?UPI=BS%207121
BS7121-5	BS7121-5:2019 Code of practice for safe use of cranes: Tower cranes	https://landingpage.bsigroup.com/LandingPage/Series?UPI=BS%207121
Liebherr wind guidance	Influence of wind on crane operation – training document provided by Liebherr	https://www.liebherr.com/shared/media/mobile-and-crawler-cranes/brochures/wind-influences/liebherr-influence-of-wind-p403-e04-2017.pdf
TCIG TIN 020	The effect of wind on tower cranes in service.	CPA Member Resource Library - Construction Plant-hire Association (CPA) | UK Plant-Hire Industry Leader
TCIG TIN 022	The use of taglines with tower cranes.	
TCIG TIN 025	Luffing jib cranes – working at or near minimum radius in wind	
TCIG TIN 027	Tower crane out-of-service wind speeds.	
TCIG TIN 0101	The effect of wind on mobile cranes in service.	
Plant Safety Group	Ground conditions for the safe use of construction plant	
ALLMI GN021	Determining the sail effect for Wind	ALLMI | Guidance Notes for the Lorry Loader Industry | Available to Purchase
FEM 5.016 (2nd edition)	Guideline – Safety Issues in Wind Turbine Installation and Transportation	Microsoft Word - FEM_5 016-Ed2_E_PF_Final_130228.docx

Annexes

Annex A - Example In-house Spreadsheet to Calculate Permissible Wind Speed for a Wind-sensitive Load

The following is an example of the layout of a calculation spreadsheet.

Permissible Windspeed Calculation

Hoist Load, M_H (Inc lifting accessories, hook block and any relevant portion of hoisting Cable
= tonnes

Surface Area Exposed to wind, Ap
= m²

Maximum wind speed per the load chart, V_{max_TAB}
= m/s

Coefficient of Resistance from Liebherr Wind Influences on Cranes Document (Table 1) cw
= 1.2

Surface area exposed to wind, Aw = Ap x cw.

Permissible Wind Speed Formula:

$$V_{max} = V_{max\_TAB} \times \sqrt{\frac{1.2\frac{m^2}{t} \times m_H}{A_w}}$$

Permissible Wind Speed
= #DIV/0! m/s

Body	Coefficient of resistance c_w
Plate / cube	1.1 to 2.0
Cylinders	0.6 to 1.0
Ball	0.3 to 0.4
Hemisphere (front)	0.2 to 0.3
Hemisphere (rear)	0.8 to 1.2
Wind power plant rotor	Approximately 1.6

LIEBHERR Wind Influences on Cranes
Coefficient of Resistance - Table 1

Figure 13: An example of an in-house permissible wind speed calculator based on the Liebherr wind influence document.

Note 1: *The permissible wind speed cannot be greater than the OEM's stated maximum for the crane's configuration. This is possible where the ratio of mass to wind area is greater than 0.83.*

Note 2: *Where the load has a drag coefficient, c_w, of 1.2, this cancels the crane's constant from EN13000 of 1.2, meaning that the formula simplifies be the load mass divided by load area e.g. 1m²/tonne. The EN13000 constant shall not be changed in the formula.*

Note 3: *This spreadsheet would need to be adjusted where it is being used to assess tower crane limiting wind speeds. Always seek advice from the tower crane manufacturer for their assessment.*

Annex B - Principles of Hands Off, Step Away, Safe Space

This is an industry initiative designed to encourage lifting teams to position themselves away from the load, reducing the risk of being trapped or crushed by a moving load. While some load movements are expected, others can be unpredictable. The purpose of this approach is to keep people clear of the load so that they cannot be harmed by it.

This is achieved by slinger/signallers standing clear of the load during the check lift. If the load is secure, the lift can then proceed to the landing point. At that location, the receiving slinger/signaller should remain at a safe distance until the load is lowered to a height where a tagline can be retrieved without standing beneath the load.

When the load is below shoulder height, slingers may guide it using flat palms, reducing the risk of finger entrapment.

Not all loads can be positioned without hands-on contact, so lifting teams should discuss and agree on a pragmatic approach to safe load handling.

Refer to the ‘Hands Off, Step Away, Safe Space’ guidance available from the Industry Lifting Lead Appointed Person Group at www.illapg.com

- Once happy with the arrangement, the slinger-signaller should then position themselves in the safe space and instruct the appliance operator to continue with the lifting operation.
  When directing the operator through the lifting operation, instructions must be clear and concise, using industry recognised hand signals or audible commands
  Where practicable, confirmation of understanding of the command/instruction, from the operator, should be relayed to the slinger

Final positioning or landing the load:

- As the load lowers under direction of the slinger-signaller, they must be mindful to not stand under the load or position themselves [or body part] between a fixed or temporary structure.
  The safe space principle should be maintained.
  When utilising mobile/crawler cranes, 360 telehandlers etc., they must always be aware of their positioning to ensure that they are not stood under the boom of the appliance.
- If using a mcm, then lower the load to such a height so that these can be retrieved safely.
  Stop the lift before approaching the load.
  The slinger-signaller should never retrieve a tagline or employ a push-pull pole while the load is in motion. This prevents them inadvertently being under the load, as it can be hard to judge.
  Note:
  When retrieving taglines, the slinger-signaller will keep an arm's length away so as not to position themselves under the load. Best practice in this situation would be to retrieve the line with a push-pull pole.
- The load should then be lowered to waist height, where final orientation of the load [if required] can be attended to, to allow a correct and safe landing.
  Note:
  If the slinger-signaller needs to touch the load at this point, they can but they again, must be mindful of placing hands, fingers, and feet in any potential crush points.
  As previously stated, as far as is practicable and dependant on load parameters, hands should be flat to the surface of the load and not around the lifting accessories, eliminating the potential to have any part of the hand trapped.
- The load can now be lowered to the final landing position.
- Prior to removing the accessories, the slinger-signaller should check load stability for example:
  I. Integrity of load – is it secure in its final position?
  II. If required, have wedges been employed to stop the load rolling after accessories have been removed?
  III. Can the accessories be removed easily and safely? If not, introduce appropriately sized bites / chocks.
  IV. If the load is repeatedly lifted, is there sufficient space round the load to facilitate safe re-slinging?

Annex C - A Project Specific Wind Profile at Height Study & Lessons Learned

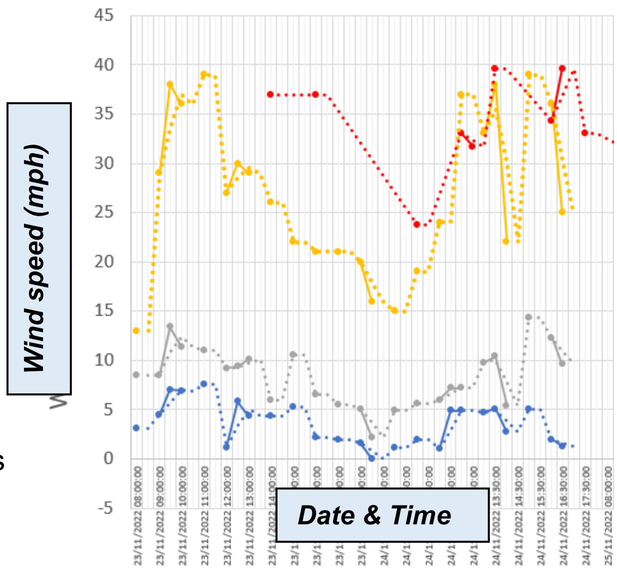
This is a case study for the variation of windspeed with height based on readings from site-based anemometers on a project in a high-rise city centre project, with cranes at different heights.

The graph gives a visual outline of the difference in wind speeds experienced in the different locations.

- Position1 (TC1) 85m height (yellow)
- Position 2 (Core 8) 25m height (grey)
- Position 3 (Courtyard) ground level (blue)

The orange lines were forecasted gusts.

The difference in wind speed experienced in each of the positions can be calculated. This can be further simplified to an average difference in the readings taken from each location at the same time.



If arithmetic differences are calculated and averaged, then a simplified variation of wind over height can be assessed.

The shielding provided by the local buildings is much greater than the factors that make some allowance for height given in 5.2. Also, the above results were read on an hourly basis rather than based on a 3-second peak gust, or a mean average in a 10-minute period. To aid accurate comparison, readings should record the 3-second gust to allow comparison with what governs the design of the crane.

It allows understanding of the wind speed applied to the crane structure, and what the possible variation of wind speed might be on the load as it is being lifted through various heights.

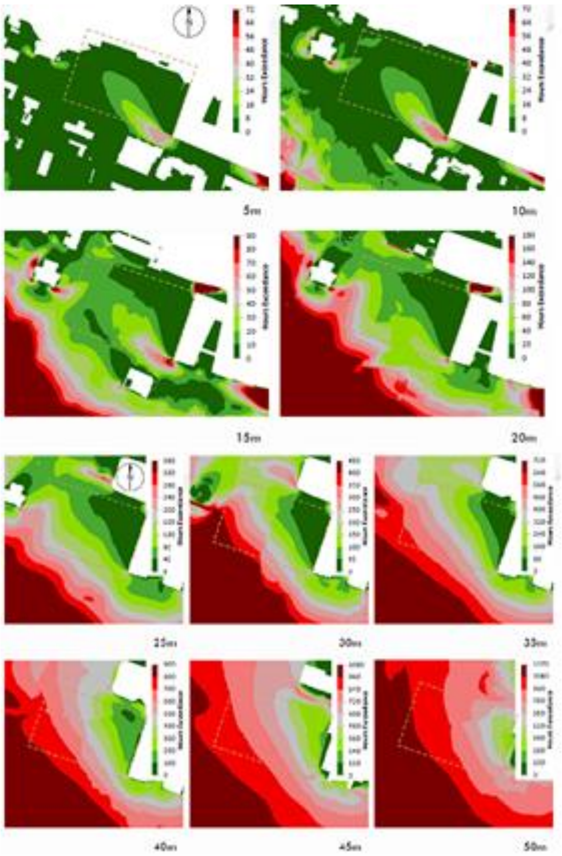
The contractor's reasoning assumed that because the crane was within its working windspeed, it was safe to lift and then they assessed the likely wind speed on the load. The interpolated windspeed was compared to the calculated winding-off speed - undertaken as per the previous wind area versus mass versus windspeed calculation.

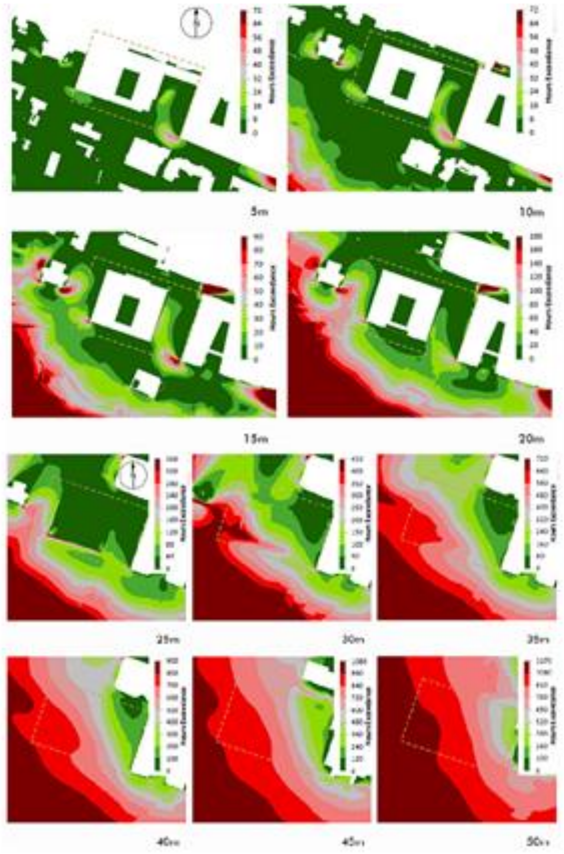
This method makes assumptions that the reduction is the same for all windspeeds and all directions. It also does not consider the non-linear nature of wind speed with height or the difference between the ratio of gust to average windspeed, but it does go some way to assessing what might be happening to the load which may be sheltered.

It is important to risk assess any such plans as the crane(s), the loads being handled and the lifting team are put at risk, if the lifting operation proceeds in wind speeds that put the lifting operation in peril. Robust control measures should be put in place in advance, making clear what the lifting limits should be and that they should be reviewed initially on a daily basis. Equally, monitoring of the wind speed at the location of the load is beneficial, with sufficient time allowances to lower the load to ground level should the wind speed approach the trigger level.

Annex D - A Project-specific Crane Wind Assessment, Wind-off Days Estimation

A case study was completed for a project at a notoriously windy coastal location in the UK to estimate the number of days and hours predicted to be lost due to wind.



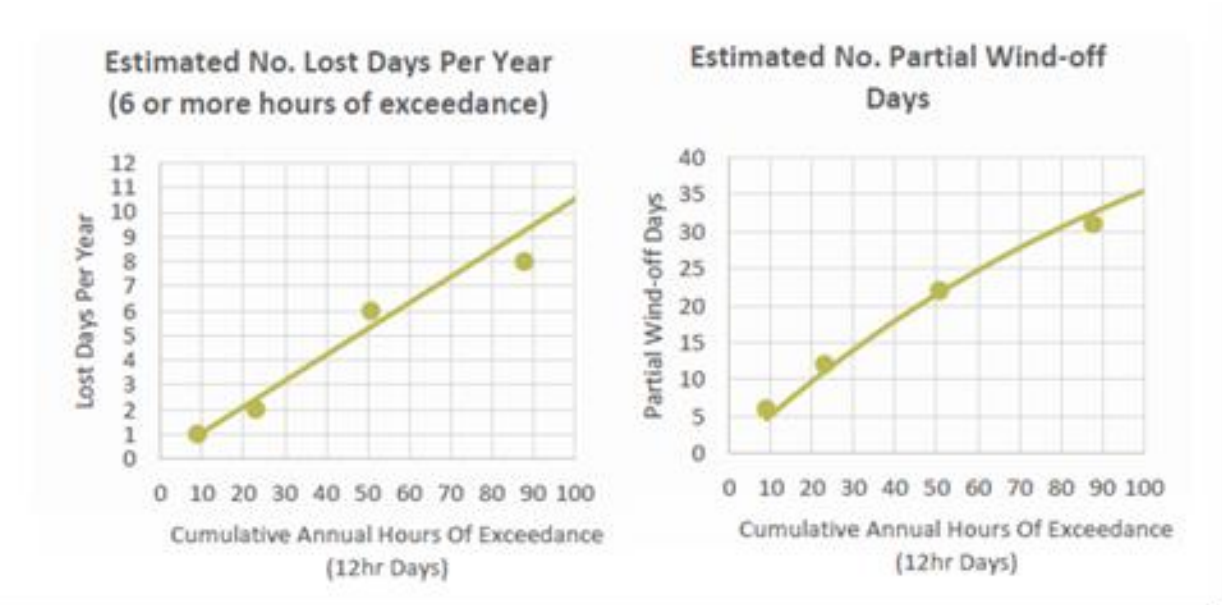


The visuals above show the predicted number of working hours (based on 12 hour shifts 7am – 7pm) for the empty site (left) and the completed site (right). This also shows the point made in Annex C, that wind at a lower altitude will be lower for more of the time than at a higher altitude. The recommended crane position for this study placed the crane in the NE corner of the site, which is showing 520 working hours per year [assuming working 365 days] (365 x 12 = 4380 hours, 520 = **11.9% winding off time**).

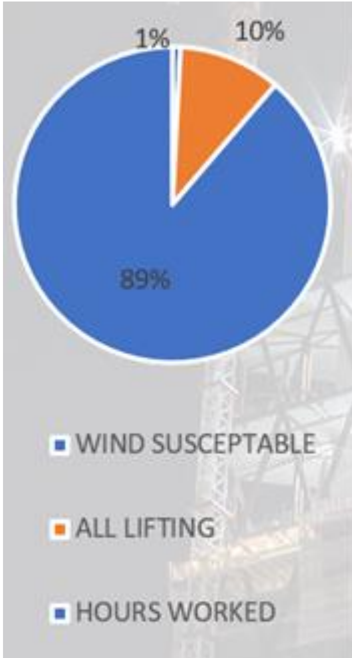
Using data from the nearby airport, the number of hours where 29 knots would typically be exceeded (based on 30 years of data) would be 100 hours, based on the gust conversion factor at the site and the winding-off speed of a tower crane (72kmh or 39 knots).

This assessment allows sufficient time to be applied to the construction programme, so that the lifting teams are not under pressure to work when they know they should be winded-off.

The graphs below show how to convert the hours expected above the target wind speed should be expected to be totally lost (more than 6 hours of wind above the crane specific winding-off speed) and partially lost (some lifting lost but <6 hours).



This shows that it could be expected to lose 10 days, where 6 or more hours is lost and then 35 days, where less than 6 hours is lost.



The pie chart is showing real recorded data from coastal cranes (such as the site discussed in this Annex) where the crane downtime was recorded and matches the 11% predicted at the coastal site above. The total time winded off was about 11% total, with only 1% coming from wind susceptible loads.

The importance of this data is to remind the lifting team that while lifting time lost to wind is demoralising, the actual implications upon the works programme are not significant. Typical crane uptime (hours where the crane is working) is less than 89%, so the ~11% loss in lifting time due to wind is vastly exceeded by crane idle time. Idle time, measured by one contractor, is in the region of 20%.

Continuously lifting on non-windy days will impact the programme drastically more than attempting to lift loads in borderline conditions.

Lifting in higher winds places increased danger on the lifting team, crane and property for small gains in programme over long durations.

For projects where the lifting window is short (e.g., road closures), then defining a clear, accurate and safe winding off scenario will reduce the likelihood of the lifting team taking risks in the heat of the moment to get the job done.

Annex E - Assessment of Limiting Wind Speed & Pressures by Type of Lifting Equipment and Example Below-the-hook Electro-Mechanical Load Control Devices

The following tables show a number of interesting points of learning, based on an analysis firstly of various sizes and weights of shutter and their effect on the working wind speed - and resulting wind pressure that acts on the load. This assessment is completed for tower cranes and mobile cranes. It uses the formulas mentioned in the main document and as shown below in Figure 14

Tower crane's working windspeed 17 m/s (38 mph), exerts a wind pressure of 180.63 Pa (or N/m2)

Although a tower crane's in-service maximum wind speed is 45mph,

it is limited to 38mph to allow time to execute winding off procedures

		Height of load	Drag Coefficient	Surface area exposed to wind	Weight of load	Is the load wind sensitive?	Permissible wind speed	In mph	Dyn. Wind pressure on the load	Force acting on the exposed wind area	Horizontal wind force
	m	m	cw	Aw, m^2	tonnes	*NOTE 1*	m/s	mph	Pascals	N	kg-force
Shutter	2.4	6.6	1.2	19.01	2.392	0.389	6.6	15	27.28	518	53
Shutter	4.8	6.6	1.2	38.02	4.803	0.389	6.6	15	27.38	1041	106
Shutter	6.45	6.6	1.2	51.08	6.786	0.399	6.8	15	28.79	1471	150
Shutter	7.2	6.6	1.2	57.02	7.215	0.390	6.6	15	27.42	1564	159
Shutter	0.8	3.3	1.2	3.17	0.4	0.389	6.6	15	27.37	87	9
Pack of Ply	2.4	0.7	1.2	2.02	0.9	0.732	12.4	28	96.76	195	20
Person basket	1.45	1.1	1.2	1.91	0.64	0.633	10.8	24	See NOTE 2		
									See NOTE 3		

NOTE 1 The formula used is sqrt (1.2m2/t x weight of load / surface area exposed to wind), where this number is less than 1, then the load is wind sensitive. If a value of greter than 1 is calculated, use 1 in the v_{max} calculation.

NOTE 2 Lifting personnel in a basket is limited 7m/s by BS7121-1:2016 (Clause 20.1.6.1.4)

NOTE 3 Wind pressure is calculated by 0.5 x air density x wind speed ^2. Also conversion 1Pa = 1N/m2

Figure 14: Tower crane table showing upper limit working wind speed & how this is reduced by load area

As the shutter size changes, the wind sensitivity does not change, because it is determined by the area-to-weight ratio. This results in an identical theoretical winding-off speed across different shutter sizes. However, the horizontal load acting on the shutter decreases in proportion to its area, making smaller shutters easier to control - often allowing for tagline use or manual guidance.

Mobile Crane's working wind speed 11 m/s (or 24.6 mph) 75.63 Pa (or N/m2)

		Height of load	Drag Coefficient	Surface area exposed to wind	Weight of load	Is the load wind sensitive?	Permissible wind speed	In mph	Dyn. Wind pressure on the load	Force acting on the exposed wind area	Horizontal wind force
	m	m	cw	Aw, m^2	tonnes	*NOTE 1*	m/s	mph	Pascals	N	kg-force
Shutter	2.4	6.6	1.2	19.01	2.392	0.389	4.3	10	11.42	217	22
Shutter	4.8	6.6	1.2	38.02	4.803	0.389	4.3	10	11.47	436	44
Shutter	6.45	6.6	1.2	51.08	6.786	0.399	4.4	10	12.06	616	63
Shutter	7.2	6.6	1.2	57.02	7.215	0.390	4.3	10	11.48	655	67
Shutter	0.8	3.3	1.2	3.17	0.4	0.389	4.3	10	11.46	36	4
Pack of Ply	2.4	0.7	1.2	2.02	0.9	0.732	8.1	18	40.51	82	8
Person basket	1.45	1.1	1.2	1.91	0.64	0.633	7.0	16	See NOTE 2		

Figure 15: Mobile crane table showing upper limit working wind speed & how this is reduced by load area

Additionally, the lifting of two persons in a crane basket using a tower crane permits a wind speed of nearly 11 m/s, whereas BS 7121 limits this activity to 7 m/s. For mobile cranes, the downrating based on weight and area typically aligns with the limiting wind speed specified in the British Standard.

1.0 CONSIDERING THE USE OF A BELOW THE HOOK ELECTRO-MECHANICAL DEVICE - GENERAL

When it comes to assessing how much torque is required to rotate a load, it's important to understand whether the wind area is balanced on either side of the centre of gravity and centre of rotation? - a consideration that applies to all load control devices.

If the wind acts symmetrically on the load, there is no net torque for the rotation device to resist. However, more often the wind acts asymmetrically, which causes the load to turn. This rotation can generate significant torque that must be overcome. For this reason, it's not possible to determine wind limits for rotation devices accurately in advance.

This makes it essential to understand the actual wind conditions during the lifting operation, as well as the load path and how exposed the load is to different wind directions throughout. Each lifting operation should be risk assessed to avoid relying on misleading calculated wind limits that may not reflect real-world exposure.

When designing or assessing a system, consider how wind may interact with the load. Questions to ask should include:

- What is weight and wind area of the load?
- Will the load be affected by the same wind speed along its length?
- Will the load be partially sheltered?
- Has the load a greater wind surface area on one side of the centre of lift (centre of gravity) than on the other, which would mean there is an increased out of balance moment on the load? See example in the figure below:

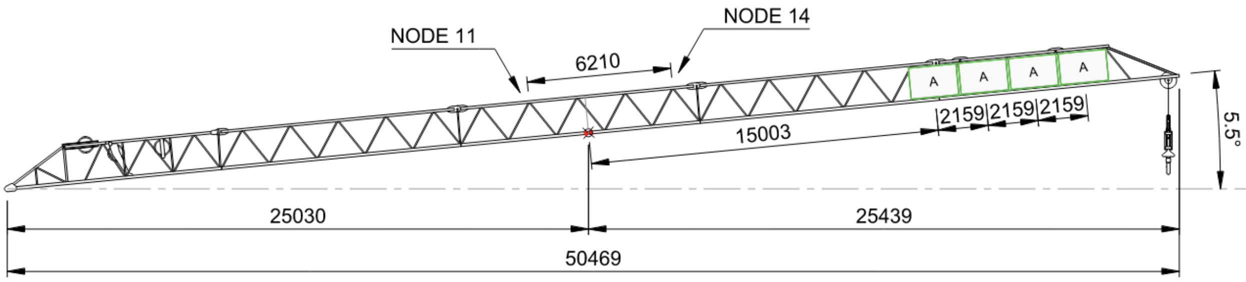


Figure 16: Additional wind moment will need to be resisted when lifting a jib which contains additional windsails at one end, along with the crane's hook block. These add nearly 11m2 of wind area, approximately 19m from the suspension point.

EXAMPLE 1: CONSIDERING THE USE OF A BELOW THE HOOK ELECTRO-MECHANICAL DEVICE SUCH AS A VITA LOAD NAVIGATOR.

Tower crane's working windspeed 17 m/s (38 mph), exerts a wind pressure of 180.63 Pa (or N/m2)
Although a tower crane's in-service maximum wind speed is 45mph,
it is limited to 38mph to allow time to execute winding off procedures

	Height of load	Drag Coefficient	Surface area exposed to wind	Weight of load	Is the load wind sensitive?	Permissible wind speed	In mph	Dyn. Wind pressure on the load	Force acting on the exposed wind area	Horizontal wind force
	m	m	cw	Aw, m^2	tonnes	*NOTE 1*	m/s	mph	Pascals	N	kg-force
Shutter	2.4	6.6	1.2	19.01	2.392	0.389	6.6	15	27.28	518	53
Shutter	4.8	6.6	1.2	38.02	4.803	0.389	6.6	15	27.38	1041	106
Shutter	6.45	6.6	1.2	51.08	6.786	0.399	6.8	15	28.79	1471	150
Shutter	7.2	6.6	1.2	57.02	7.215	0.390	6.6	15	27.42	1564	159
Shutter	0.8	3.3	1.2	3.17	0.4	0.389	6.6	15	27.37	87	9
Pack of Ply	2.4	0.7	1.2	2.02	0.9	0.732	12.4	28	96.76	195	20
Person basket	1.45	1.1	1.2	1.91	0.64	0.633	10.8	24	See NOTE 2		

Figure 17: Taken from Figure 14 [part]

When using a device to eliminate the need for the slinger-signaller to hold the tagline, such as a Vita Load Navigator, the following should be considered:

There is a risk that loads may be lifted in higher wind speeds, as the human and tagline are no longer the limiting factor. BEWARE: this introduces new hazards that must be accounted for in the risk assessment.

Select a device that will not put the crane in peril, ensuring its power output is suitable for the load area and wind speed limit. Machine torque and wind torque must not exceed the crane's ability to control the load.

The chart on the following page shows that, for a particular device, in a wind speed of 6.7 m/s (15 mph), it can safely handle a 5 x 7 m shutter.

Figure 17 sets the crane's wind speed limit at 6.7 m/s for various shutter sizes—this limit is based on increasing shutter weight as size increases.

Figure 18 assumes the same limiting wind speed and shows the permitted shutter/load areas, alongside the torque required to control the load.

System Selection	VLN-xx-15	*ite: Drop down menu to select system configuration*
Torque Rating (Nm)	1100	*output. Do not edit/change*
Wind Speed (MPH)	15	*windspeed in MPH*
Load Porosity (%)	0%	*Load porosity - a parameter that represents the known or approximate airflow through a load. Ex. a Conex box = 0%. A crane*

Performance Mapping				*Thrust consumption for wind resistance.*
Green	<=	50.00%	550	
Yellow	~	70.00%	770	
Red	>=	90.00%	990	Note: at or exceeding system limit. System can dampen load motion, but lack authority to rotate to desired orientation. Fas

Resultant Wind Torque: Box/Plate/Flat Surface Wind Loading

MPH	m/s		Load Length																
15	6.7	*ft.*	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25	27.5	30	32.5	35	37.5	40	42.5
	ft.	meters	***0.8***	***1.5***	***2.3***	***3.0***	***3.8***	***4.6***	***5.3***	***6.1***	***6.9***	***7.6***	***8.4***	***9.1***	***9.9***	***10.7***	***11.4***	***12.2***	***13.0***
	2.5	***0.8***	1	5	11	19	30	43	59	77	97	120	145	173	203	235	270	307	346
	5	***1.5***	2	10	22	38	60	86	117	153	194	240	290	345	405	470	539	614	693
	7.5	***2.3***	4	14	32	58	90	129	176	230	291	360	435	518	608	705	809	921	1039
	10	***3.0***	5	19	43	77	120	173	235	307	388	479	580	690	810	940	1079	1227	1386
	12.5	***3.8***	6	24	54	96	150	216	294	384	485	599	725	863	1013	1175	1349	1534	1732
	15	***4.6***	7	29	65	115	180	259	352	460	583	719	870	1036	1215	1410	1618	1841	2078
	17.5	***5.3***	8	34	76	134	210	302	411	537	680	839	1015	1208	1418	1645	1888	2148	2425
	20	***6.1***	10	38	86	153	240	345	470	614	777	959	1160	1381	1621	1880	2158	2455	2771
	22.5	***6.9***	11	43	97	173	[illegible]	388	529	690	874	1079	1305	1553	1823	2114	2427	2762	3118
	25	***7.6***	12	48	108	192	300	432	587	767	971	1199	1450	1726	2026	2349	2697	3069	3464

Figure 18: Permitted Shutter/Load areas

Shutters that are 5m x 7m would not normally be controllable by hand in the proposed wind speed. The area assessment should also include the wind area of the device itself.

Although the device could work in higher wind speeds, it would cause the crane to be overloaded. This could start to affect the operator's ability to control the crane through the slew brakes, as well as introducing overturning moments in the foundation / outriggers that are beyond the OEM designer's limits.

EXAMPLE 2 - CONSIDERING THE USE OF A BELOW THE HOOK ELECTRO-MECHANICAL DEVICE SUCH AS A TORQUER 'HALO'.

The Torquer HALO uses a bow thruster system with a circulating water circuit to generate forward or reverse torque. The accelerated mass of water produces torque proportional to its moment of inertia.

To determine the appropriate HALO tank size for a given load, a simple rule-of-thumb can be used: the moment of inertia of the water should be approximately 3% of the moment of inertia of the load. For example, a basic 3 m ring made from 500 mm water pipe could comfortably rotate:

- a **20-tonne load** that is **6 m long**;
- a **5-tonne load** that is **12 m long**; or
- a **45-tonne load** that is **4 m in diameter**.

This relationship between load length and torque mirrors how crane capacity decreases with increasing radius.

In general, tanks are designed to provide more power than needed, ensuring sufficient overhead to counter expected wind loads. However, if sustained wind loading is anticipated, additional fans can be added to provide continuous external thrust to hold the load at a set angle indefinitely.

Torquer has developed modelling software to calculate the required tank and fan sizes. The tank is designed around both the geometry and weight constraints of the planned load. The larger the HALO device's footprint (the black, ring-shaped pipe shown in Figure 19), the lighter the tank can be relative to the load.

The calculation allows the user to assemble a water circuit from a simple set of straights and curves to provide enough torque for any load size. Torquer can provide modelling software to allow the appropriate layout to be designed. This method provides maximum flexibility.

Depending on the scale of the load that needs to be oriented, then the number of thrusters can be increased between one, two, or more thrusters. Each thruster can exert up to 100kg of force. The water circuit and thruster(s) are the primary means of orientating the load and will be sufficient for most operations.

However, in the example below additional fans are required to counter a sustained wind load. The table below shows the calculation of fan size and number to hold a 2.4m x 6.6m shutter in a 15mph wind speed.

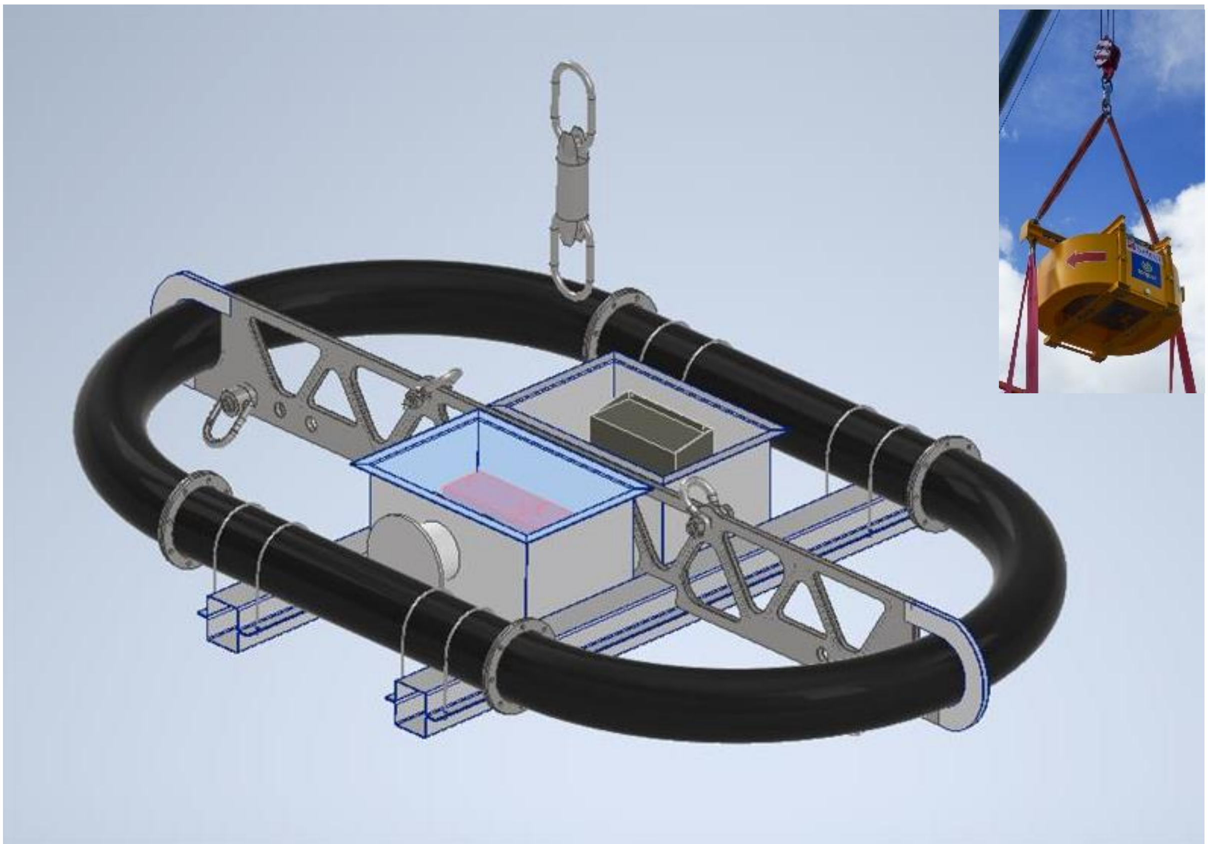


Figure 19: A typical pipe HALO, by Torquer. The alternative standard compact unit is shown in the inset.

Torquer HALO

Shutter		Units		Stabiliser Fan		Units
Height	2.4			Fan Rad	150	mm
Width (W)	6.6			Fan Pitch	45	deg
Cd	1.2			Fan RPM	4000	
Wind speed	15	mph		Efficiency	0.8	
Wind speed	6.707	m/s		Air Speed	50.266	m/s
Press	27.578	N/m2		Press	1548.825	N/m2
Force	436.831	N		Force	109.480	N
	44.529	kg			11.160	kg
Net F	53.435	kg		Lever	2	m
lever (0.25W)	1.65	m	*NOTE 1*	Fan Torque	22.320	kg.m
Assym F (0.25 Net F)	13.359	kg	*NOTE 2*	Fans	2	
Wind Torque	22.042	kg.m		Stab Torque	44.640	kg.m

NOTE 1 - worst case scenario where the wind load is only acting on one side of the shutter with an average lever arm of 0.25x shutter length.

NOTE 2 - 25% of the total wind force acting on the full area of the shutter

The above calculation assumes that the wind is only acting on half of the shutter size and so there is only a lever arm of 25% width of shutter. Fans require to be installed in pairs to avoid net side load.

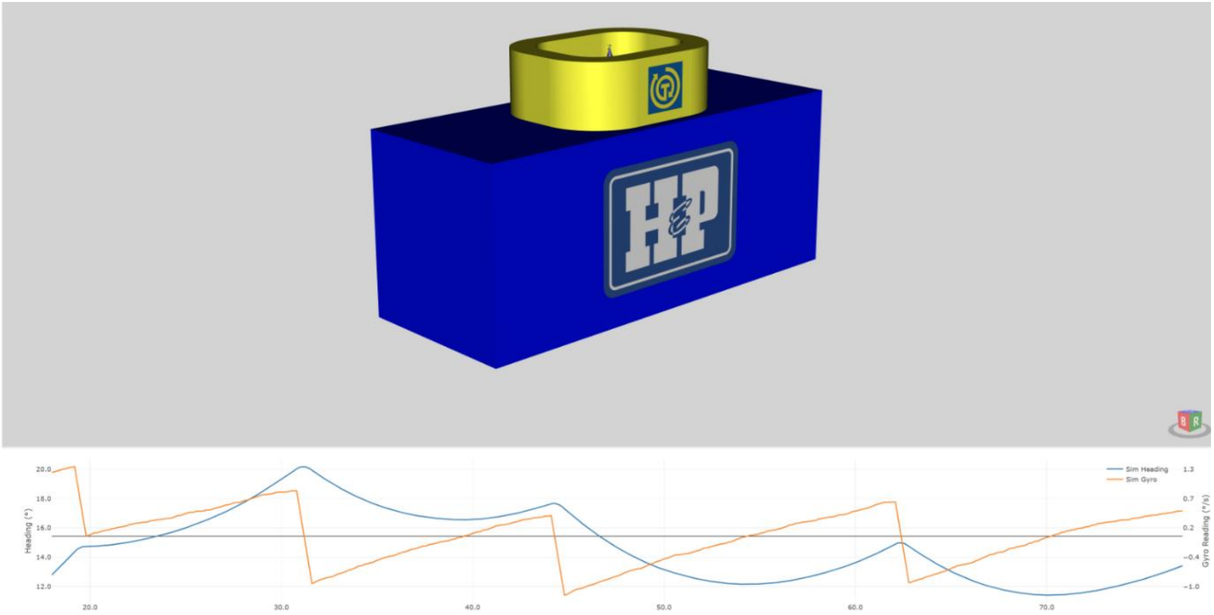


Figure 20: Torquer Halo - Tank Modelling Software

Based on the shutter weight being below 2000 kg, the Halo 2000SP could be used, which weighs approximately 1800 kg. Devices that rely on a rotating mass, such as a steel disk or water, have the following characteristics that should be assessed:

- Is there a risk of the device becoming torque-bound, where it either runs out of torque or does not have enough wind-resisting torque available? The planner should consider how long the wind is likely to act on the side of the load and whether the device can hold it for that duration. For example, a HALO device typically has a run-time of around 12 seconds to hold a load at an angle. Most wind gusts last under 7 seconds, so this may be sufficient.
- What are the implications if the device fails to control the load?
- Are additional control measures required? Are there any further mitigations needed?
- What checks can be made to ensure remote control **units** can successfully operate the load at the required height or depth?

It's also important to consider the slinging arrangement when using a below-the-hook electro-mechanical orientation control device. Ensuring there is a horizontal component between the load and the device will help prevent over-rotation or the load bouncing back when rotation stops.

For example, using a V-shaped arrangement, either on the load side (e.g. a 4-point or multi-point lift) or between the device and load (if only a 2-point lift is available), can help. This provides greater control, as the load will respond immediately to the device's movement, rather than with a delay, which can occur with simple two-sling, two-point arrangements. This control is especially important when wind is acting on the load and the device is being used to rotate or hold the load in a fixed orientation.

Always seek advice from the manufacturer and risk assess the activity, ensuring a safe system of work is created and recorded in the lift plan.

Note: The examples shown in this annex only indicate certain types of load control units. Other brands and types are available on the market. The technical specifications of the products quoted in this Annex were correct at the time of print.

CIG and TCIG do not endorse any of the product types, makes and models listed.

Annex F - Legal Requirements

Under the Construction Design & Management Regulations, it is the principal contractor's responsibility to ensure that an adequate plan for all operations has been prepared by a competent person that addresses relevant hazards. It is therefore essential that the principles laid down in relevant documents are understood and applied when planning and managing lifting operations.

Specific regulations under the Lifting Operations and Lifting Equipment Regulations 1998 (LOLER), require a suitable and sufficient plan for all lifting operations to be prepared. These regulations, which are part of the Health and Safety at Work etc. Act 1974, place duties on individuals and companies who own, operate or have control over lifting equipment. Failure to comply with LOLER can lead to legal consequences. The regulations require that all lifting operations involving lifting equipment must be properly planned, supervised and executed in a safe manner.

Equipment must also be fit for purpose, appropriately marked and subject to periodic thorough examinations. Any defects found must be reported and records of all examinations are to be maintained. It's crucial for businesses to manage and control risks to avoid injury to people or damage to property.

The above applies to all equipment used in the lifting operation; from the crane to the lifting accessories, the load and any load manipulating equipment, such as a tagline or other external means of control. All of these should be addressed, along with identifying the correct permissible working wind speed for the lifting operation such that risks to personnel and the crane are minimised and suitable control measures are in place.

The individual appointed to have control of the lifting operation, known as the Appointed Person (AP), requires appropriate skills, knowledge, attitude, training, experience and behaviours. They shall prepare the plan following the quasi-legal principles in the approved code of practice to LOLER as well as the non-legally binding guidance provided in relevant British Standards and other industry guidance. Following the contents of the ACOP and relevant parts of the British Standard should help demonstrate that the plan was suitable and sufficient.

The AP should be familiar with LOLER and PUWER, as well as their approved codes of practice to help them in their planning of lifting operations.

They should ensure that the lifting team selected for the activities are also competent for the planned activities and that the plan is reviewed periodically to ensure that the risk assessment is still current and the control measures relevant.

The AP should also ensure that any risks that cannot be controlled in the lift plan are communicated to the client, so that they provide suitable control measures. This may include stopping traffic, diverting pedestrians, providing adequate pavement gantries or investing a load control device where there is a risk of a free load rotating whilst on the hook - and then being over the public domain.

Annex G - Advice from Liebherr Regarding the Effect on Outrigger Loads of Wind on the Crane and Load Area

The attached is a two-page memo that Liebherr released to industry in February 2021 which gives advice when planning lifting operations using their own cranes in wind. Although it was brought about with particular attention to mobile cranes used in assembling wind turbines, the principles will apply to other large area – lightweight loads.

Liebherr-Werk Ehingen GmbH, Postfach 13 61, 89582 Ehingen, Germany

TO WHOM IT MAY CONCERN

Liebherr-Werk Ehingen GmbH

Mobilkrane
Mobile Cranes

Raupenkrane
Crawler Cranes

Your reference:	Your message of:	Date:	Responsible person:
		09.02.2021	Joachim Henkel / Static Department

Use of LICCON data for calculation of outrigger loadings

The calculation of outrigger loadings for Liebherr cranes can be most accurately calculated using the LICCON planner.

With specific reference to the requirements of BS7121.1 (section 12.2) and BS7121.3 (section 9.2.1), the calculation within the LICCON planner includes the following:

a) The dead weight of the crane (including any ballast)
b) The dead weight of the load and any attachment
c) A dynamic factor of 1.05 (which includes derived loadings induced by emergency stops and slewing acceleration)

Wind loadings on crane parts and the suspended load are not included in the outrigger loadings calculated with the LICCON planner, as they are site specific.

The wind loadings on the crane boom, the suspended load and the elasticity of the crane structure will increase the maximum outrigger loadings calculated with the LICCON planner.

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Liebherr have carried out extensive analysis of the applied wind loadings on the elastic crane structure across a wide variety of LIEBHERR mobile cranes (i.e. those deployed on outriggers) considering rotor designs from various Wind Turbine Manufacturers.

For LIEBHERR crane models lifting rotors with max sail areas to max. hub heights, a max. factor of 1.35 was found to be applied on the outrigger loadings calculated with the LICCON planner to take wind loadings and the elasticity of the crane´s structure into account. As this factor depends on the sail area of the load, the drag factor and the sail area /elasticity/boom length of the crane, LIEBHERR has developed a rule of thumb given in the attached spread sheet.

If the spread sheet is not used, the outrigger forces generated using the LICCON planner must be multiplied by a factor of 1.35 to cover the wind loadings and elasticity of the crane´s structure.

Liebherr are actively pursuing agreement through the European crane manufacturers united in the FEM to ensure all European crane manufacturers take the applicable wind loadings and the elasticity of the crane´s structure into account with their respective planning tools. Until there is cross party support we cannot issue formal documents to the industry but in the meantime individual clients can follow this guidance note.

Important note:

The given factor of 1.35 is valid for allowable wind speed according to the operator's manual/capacity charts.

This factor is a conservative rule of thumb; a more accurate factor can be calculated by using the formula given in the attachment, which shall only be used with mobile cranes on outriggers and working without derrick ballast.

This letter supersedes our letter dated 04.04.2012

Yours sincerely,
LIEBHERR-WERK EHINGEN GMBH

i. V.

Joachim Henkel

Annex H - Variation of Wind Speed with Height and Upwind Roughness Factor

It is important to ensure that when assessing the windspeed at a site's location, that the correct upwind roughness factor is considered. There is a much smoother wind flow in a countryside environment when compared to the suburbs or even a city centre. The following assessment could be used to help assess what the wind speed might be depending on the height of the crane and its approximate environment.

Roughness Class RC	Roughness Length, Z_0 [m]	Energy Index [%]	Local Terrain Type, Landscape, Topography, Vegetation
0	**0.0002**	100	Water surface.
0.5	**0.0024**	73	Completely open terrain with a smooth surface, such as concrete runways in airports, mowed grass.
1	**0.03**	52	Open agricultural area without fences and hedgerows and very scattered buildings. Only softly rounded hills.
1.5	**0.055**	45	Agricultural land with some houses and 8 meter tall sheltering hedgerows within a distance of about 1250 meters.
2	**0.1**	39	Agricultural land with some houses and 8 meter tall sheltering hedgerows within a distance of about 500 meters.
2.5	**0.2**	31	Agricultural land with many houses, shrubs and plants, or 8 meters tall sheltering hedgerows within a distance of about 250 meters.
3	**0.4**	24	Villages, small towns, agricultural land with many or tall sheltering hedgerows, forests and very rough and uneven terrain.
3.5	**0.8**	18	Larger cities with tall buildings.
4	**1.6**	13	Very large cities with tall buildings and sky scrapers.

Figure 21: Roughness class (similar to Table 1 from the Liebherr Influence of Wind on Cranes document), but with the associated roughness length for use in the calculation below.

The roughness class can be used create a roughness length, that is used in the formula to create a possible wind speed at height. Where the crane's anemometer is at that height, then clearly those readings can be used. Where there is no reading at height, but where there is data at different height, then the formula in Figure 21 can be used to assess the variation with height of lift.

INPUTS:	Measurement Height of Wind Speed in meters =	5.0	m	16 ft	
	Measured Wind Speed [m/s] =	6.0	m/s	13.4 mph	
	Roughness Lenth from Table bellow [m] =	**0.8**	m	2.625 ft	
	Height at which to Estimate wind speed [m] =	80.0	m	262 ft	
OUTPUT:	**ANSWER: Estimated wind speed at desired height above ground [m/s] =**	**15.1**	m/s	33.7 mph	

$$V(z) = V_{ref} \frac{\ln \frac{z}{Z_0}}{\ln \frac{z_{ref}}{Z_0}}$$

Figure 21: Sample calculator can be found at www.wind101.net which permits an approximation of the wind speed at height (80m) dependent on the local surroundings (city), the height of the reading that is available (5m). In this example the wind speed has nearly tripled from 5m height to 80m. This uses standard industry assumptions and approximations about the atmospheric boundary layer.

Always seek advice from a meteorologist or other wind specialist when undertaking planning of a complex nature, for high risk lifting activities.

Annex I - Working Group Membership

Name	Employer
Andrew Lloyd *(Lead Engineer for crawler cranes)*	Select Plant Hire
Angus Jamieson	H&P Technologies UK Torquer
Ben Garnett *(Lead Engineer for tower cranes)*	Select Plant Hire
Brendon Van Niekerk	H&P Technologies UK Torquer
Darren Biggs	Sir Rober McAlpine
Dave Shooter *(Head of Lifting – tower cranes / mobiles)*	Bowmer & Kirkland
Eduardo Estelles	Windcrane
Gerry Wiseman	H&P Technologies UK Torquer
Ian Carradice *(Contract Lift Teams Manager)*	Ainscough Crane Hire
Mark James *(Policy and Procedures Manager)*	Ainscough Crane Hire
Steve Bradby *(Engineering Lead)*	Select Plant Hire
Tom Pawson *(Costain's Designated Individual for Lifting)*	Costain
Craig Hook *(Writer)*	CPA
Katie Kelleher & Peter Brown *(Editors)*	CPA

Guidance on the Planning and Control of Lifting Operations in Wind

CPA Good Practice Guide

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