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Digital Insights:

The Impact of wind speed on Crane Safety by evaluating the 32 km/h restriction against Manufacturer Recommendations

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1. ABSTRACT

Crane safety on construction sites is a serious concern, especially under high wind conditions. This study evaluates the need of the 32 km/h wind speed restriction for crane operations compared to manufacturer recommendations, which sometimes allow higher limits. We have analyzed the effects of wind gusts, safety factor calculations, and real-world scenarios to determine whether exceeding 32 km/h is permissible.

2. INTRODUCTION

Crane operation is one of the important and critical activities in the construction, oil & gas, and heavy industries, where large and heavy loads must be lifted with precision. However, these operations are highly sensitive to external factors, with wind speed being one of the most critical one. Wind imposes lateral forces on the crane structure and load, potentially causing instability, load swinging, or even tipping incidents.

To manage the risks involved in crane operations during windy conditions, industry standards have established wind speed limits such as the used 32 km/h restriction to ensure safety on site. On the other hand, crane manufacturers often specify higher allowable wind speeds in their load charts, depending on factors like the weight of the load, boom angle, and crane configuration. This difference in guidance creates uncertainty in the field, raising the question of which threshold should take priority to maintain both safety and productivity.

3. CHALLENGES

3.1 THE CHALLENGE OF BALANCING SAFETY STANDARD AND MANUFACTURER WIND SPEED LIMITS

One of the major challenges in crane operations is determining the most appropriate wind speed limit for safe lifting, while manufacturer specifications often permit operations beyond 32 km/h, regulatory bodies have imposed a stricter threshold based on broader safety considerations. This discrepancy leads to several operational and safety concerns:

- Operators face uncertainty in deciding whether to halt operations based on wind speed alone.
- Project schedules may be delayed due to conservative wind restrictions, increasing costs.

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- Over-reliance on manufacturer limits may not account for dynamic job-site conditions and wind gust unpredictability.
- Crane rental costs may increase due to prolonged downtime caused by stricter wind speed limitations.
- Different manufacturers provide varying permissible wind speeds, typically ranging from 28 km/h to 50 km/h, creating inconsistencies in lifting policies across contractors.
- Different contractors enforce different lifting policies, with some proceeding with lifts beyond 32 km/h based on their crane manufacturer's recommendations., it introduces inconsistencies and raises concerns to allow such variances.
- The complexity of calculating permissible wind speed is not well understood by ALL operators, as many are not technically trained to interpret load charts and aerodynamic effects correctly. This knowledge gap can lead to unsafe decisions in the field.
- Operating above 32 km/h adds safety risks—gusts may cause sudden instability or failure.
- Common belief among operators is that lifting in enclosed areas like pipe racks is safer, since the structures seem to block the wind. However, this perception often overlooks the effects of wind turbulence, which can actually make conditions more unpredictable and potentially hazardous.

The conflict between regulatory standard and manufacturer wind limits requires a comprehensive evaluation of real job site risks to determine a justifiable operational standard that prioritizes safety without unnecessarily hampering productivity.

Between 2000 and 2010 , there were 1,125 accidents and 780 fatalities worldwide in tower crane accidents based on American National Standards Institute (ANSI) that %23 of these accidents were caused by high winds.

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4. WIND FORCE IMPACT ON CRANE STABILITY AND SAFETY FACTOR

This section explains how wind force increases with wind speed, and how this affects the crane stability particularly the safety margin between the crane resistance and the environmental load, which is wind. We will use the industry standard formulas and assumptions to show the critical wind thresholds where operations can become unsafe.

4.1 CALCULATING WIND FORCE AND SAFETY FACTOR

The force exerted by wind on a crane and its load is an important factor in determining safe operating limits. To figure out the wind force (F), we can use wind pressure equation:

$$F = 0.5 \times \rho \times C_d \times A \times W^2$$

Where:

F = Wind force in Newtons(N)
ρ = Air density (kg/m³), typically 1.225 kg/m³ at sea level
C_{d} = Drag coefficient (dimensionless, depends on object shape) , please refer to table 1.
A = Exposed area of the crane/load to wind (m²) ; combined surface area of crane boom and load
W = Wind speed (m/s)

This equation illustrates wind force increases with the square of the wind speed. That means, a slight rise in wind speed can lead to a significant larger increase in wind force.

Let us calculate the wind force and safety factor, with the given values

Parameter	Value
Air Density (ρ)	1.225 kg/m^3
Drag Coefficient (Cd)	1.2
Exposed Area (A)	25 m^2
Wind Speed Range (W)	18 km/h = (5 m/s)
Resisting Force (Counterweight)	12,000 N *(Refer to thenote below)*

NOTE:

The Resisting force is the crane ability to resist lateral tipping or sliding caused by external forces like wind. It comes from a combination of Counterweights designed into the crane, Boom and base geometry, Stabilizers and outriggers, Ground friction or anchoring.

In this example, it was assumed the Resisting Force = 12,000 N

CALCULATION

1. CALCULATE WIND FORCE:

$$F = 0.5 \times \rho \times Cd \times A \times W^2$$

F = 0.5 x 1.225 x 1.2 x 25 x 5^2

F = 0.5 x 1.225 x 1.2 x 25 x 25

F 459

2. CALCULATE SAFETY FACTOR (SF):

From the given values:

Safety Factor (SF) = Resisting Force / Wind Force

Safety Factor (SF) = 12,000 N / 459 N

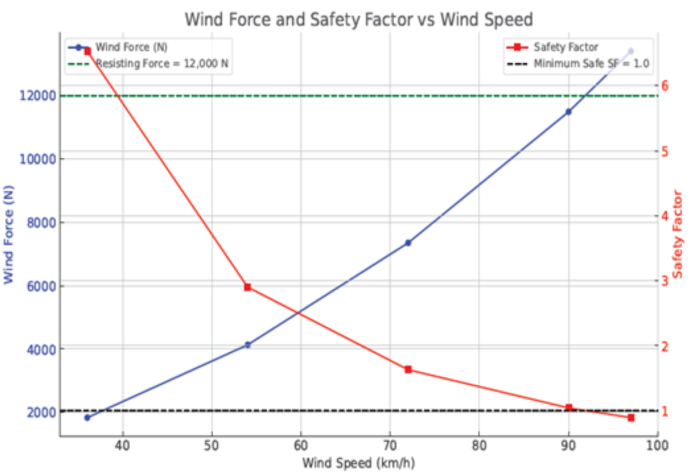
Safety Factor (SF) = **26.12**

The resisting force represents how much lateral force the crane can withstand before tipping or sliding (from counterweights, foundation friction, etc.). As wind force increases, the safety factor decreases.

Table 1.0 - Summary of Table calculation of different wind speed parameters:

Wind Speed (km/h)	Wind Speed (m/s)	Wind Force (N)	Safety Factor
18	5	459.4	26.12
36	10	1837.5	6.53
45.6	12.7	2963.7	4.05
54	15	4134.4	2.90
72	20	7350.0	1.63
90	25	11484.4	1.04
97	27	13395.4	0.90

Figure 1 - The Graph illustrating the relationship between windspeed, wind force and Safety Factor



- A wind speed of 54 km/h already reduces the safety factor to below 3.
- At 90 km/h, the safety factor is nearly 1.0 no margin left.
- Beyond this point, the crane is likely unstable under lateral wind loa

WHAT THIS MEANS FOR OPERATIONS:

Even though manufacturers may allow higher wind speeds (e.g., 72–50 km/h), in reality:

- Gusts, large surface loads, and confined areas reduce the true safety margin.
- Staying below 32 km/h ensures wind forces remain within the safe range
- Even if calculations show a **Safety Factor** (**SF**) **> 32 ,1.5** km/h is still the standard safe limit

because of the following:

1. Gusts Are Unpredictable

- Wind speeds are not constant — they can spike %50–40 in seconds.
- A wind measured at 32 km/h may suddenly gust to 50–45 km/h, potentially doubling the wind force.

2. Real-World Conditions Are Not Ideal

- Calculations are based on theoretical values (perfect surface, uniform load, stable base).
- Site conditions vary: uneven ground, surrounding structures, human error.

3. Dynamic Loads Change the Game

- Lifting operations involve movement, not static loads.
- Wind during load rotation or slewing causes amplified swing, increasing instability.

5. HOW EFFECT OF WIND LOAD ON CRANE STABILITY IN OPEN VS. CONFINED ENVIRONMENTS

Crane operations, particularly during periods of strong wind, present significant challenges even if there is no load being lifted. The wind creates lateral forces that affect not just the load but also on the crane boom, jib, and exposed surfaces. If these forces are not considered, they can compromise the crane structural integrity and stability, especially under specific environmental conditions at the site.

This section compares the impact of wind force on crane stability in two distinct scenarios: an open area (such as a pipeline corridor) and a confined area (such as a structural pipe rack or confined area). In confined spaces, wind behavior becomes less predictable due to turbulence, channeling effects, and structural obstructions, which amplify the actual force acting on the crane.

To quantify this, a standard 250-ton crane with the following configuration is used:

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GIVEN VALUES:

Legend	Parameter	Value
W	Rated Crane Capacity	250 Tons or 250,000 kg
g	Gravitational Acceleration	9.81 m/s^2
r	Boom Radius	10 m
F	Wind Force	8000 N
G_f	Wind Amplification Factor (open area)	1 (i.e., +30%) – open area and steady wind

THE MAIN FORMULA OF STABILITY FACTOR IS:

Stability Factor (**SF**)= (Lifting (Resisting) Moment / Overturning Moment due to Wind)

SCENARIO 1: OPEN AREA

Calculation using the above values:

1. COMPUTE THE LIFTING (RESISTING) MOMENT M1

M_1 =W×g×r

$\boldsymbol{M_1}$ =250,000 × 9.81 ×10=**24,525,000** Nm

2. WIND FORCE (NO GUST FACTOR)

F = 8000N (No adjustment needed)

3. COMPUTE OVERTURNING MOMENT MO

$\boldsymbol{M_o = F \times r}$

M_o = 8000 x 10 = *80,000 Nm*

4. COMPUTE STABILITY FACTOR (SF)

$\boldsymbol{SF = M_1 / M_0}$

SF= 24,525,000 / 80,000 = **306.56**

SCENARIO 2: CONFINED AREA (PIPERACK)

Given values:

Legend	Description	Value
W	Rated Crane Capacity	250 Tons or 250,000 kg
g	Gravitational Acceleration	9.81 m/s^2
r	Boom Radius	10 m
F	Wind Force	8000 N
G_f	Wind Amplification Factor (Confined area)	1.3 (i.e., +30%) – Gust Factor (G_f) of closed area

Calculation:

1. CALCULATE THE CRANE'S LIFTING MOMENT M1

$M_1 = W \times g \times r$

$M_1 = 250{,}000 \times 9.81 \times 10 =$ **24,525,000 Nm**

2. APPLY GUST FACTOR TO WIND FORCE

$F_{amplified} = F \, X \, G_f$

$F_{amplified} = 8000N \times 1.3 =$ **10,400N**

3. COMPUTE OVERTURNING MOMENT DUE TO WIND (M):

$M_o = F_{amplified} \times r$

$M_o = 10{,}400 \times 10 = 404{,}000$ Nm ∘

4. COMPUTE STABILITY FACTOR (SF)

$SF = M_1 / M_0$

$SF = 24{,}525{,}000 / 104{,}000 = \mathbf{235.82}$

Interpretation of Result:

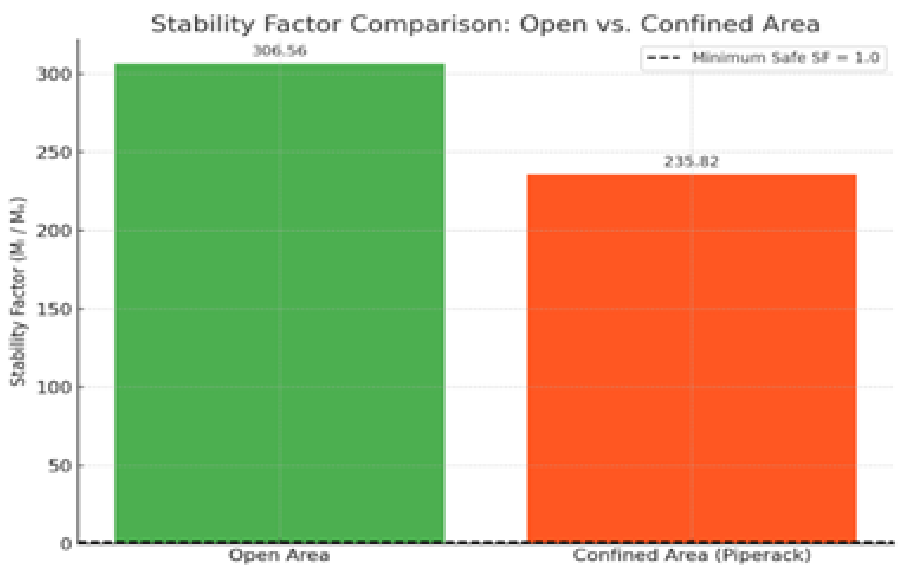
A Low Stability Factor (like 235.82 compared to 306.56) suggest that the crane is at greater risk of tipping or becoming unstable when exposed to lateral wind forces. This doesn't solely about how high is the boom, it is really the side force (the wind) in relation to the crane ability to resist tipping.

In open area, when we say "Risk of instability is low" it means the crane has a "Higher stability factor" (306.56);

- The crane has a large safety margin before it becomes unstable.
- It is less prone to tilting, tipping, or swaying dangerously, even in windy condition.
- Small wind changes or gusts won't easily affect the crane's off balance.

On the Other Hand — What a "Low Stability Factor" means (like 235.82 in Piperack):
The crane has a narrower margin of safety. It can become unstable more quickly due to increase in wind speed and changes in direction, uneven ground, or if the operator makes sudden move.

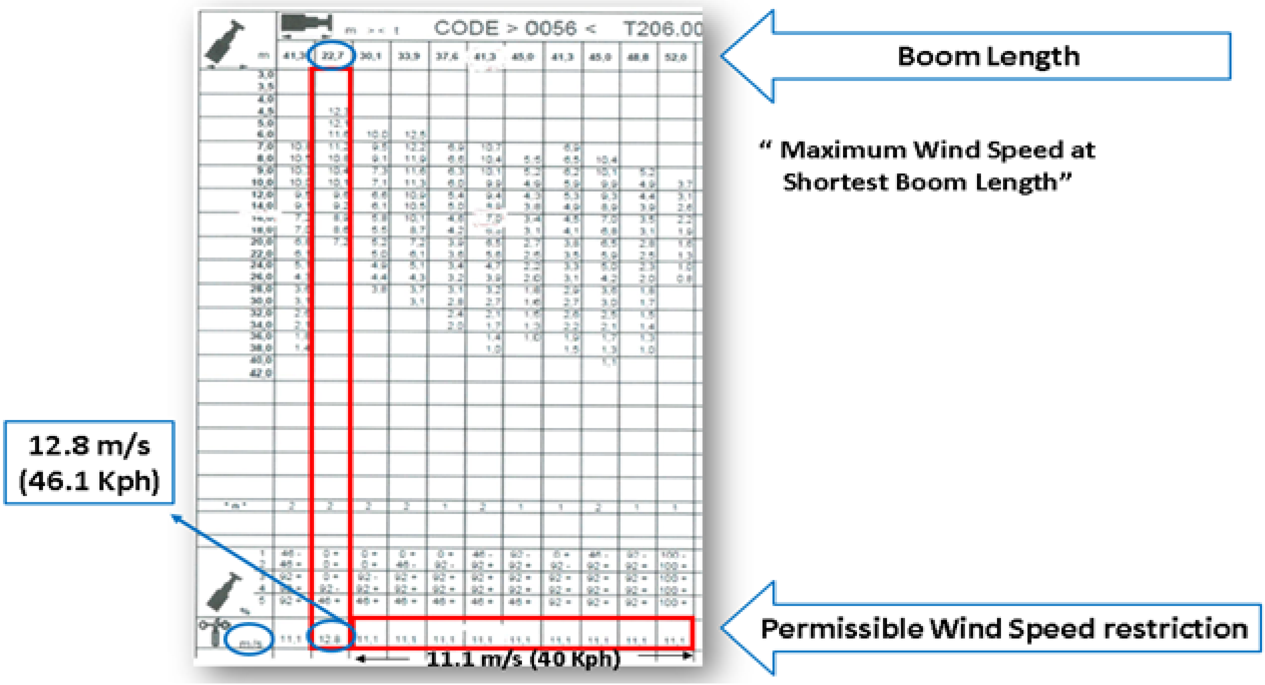
Figure 2- The graph illustrates the comparison of stability factor between a crane in open area and on confined area. It shows that the open area has higher stability factor compared to closed or confined Area.



6. EXPLANATION OF PERMISSIBLE WIND SPEED CALCULATION GIVEN THE LOAD CHART

Understanding the allowable wind speed for crane operations is important for lifting safety and equipment stability. This calculation considers several factors such as the crane rated capacity, boom radius, exposed surface area, drag coefficient and wind amplification factors in various environments. By applying the wind force formula and comparing it against the crane's lifting moment capacity, field safety compliance and operator can assess whether the lifting operation stays within safe limits. The permissible wind speed reflects the maximum environmental condition under which a crane can safely operate without compromising structural integrity or increasing the risk of overturning ensuring operations adhere to manufacturer load charts and international lifting standards. In the sample load chart below (Figure 3), we will calculate the permissible wind based on five (5) different scenarios to see how these variables affect operations on site.

Figure 3 - Sample load chart using permissible value in m/s with corresponding boom



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SCENARIO 2: CONFINED AREA (PIPERACK)

$V_{\text{Permissible}} = V_{\text{Max per Load Chart}} \times \sqrt{(1.2 \times GW) / (AW \times Cd)}$

Note: 1.2 value in the is a factor applied for additional safety. Please refer to Table 2. Safety Factor

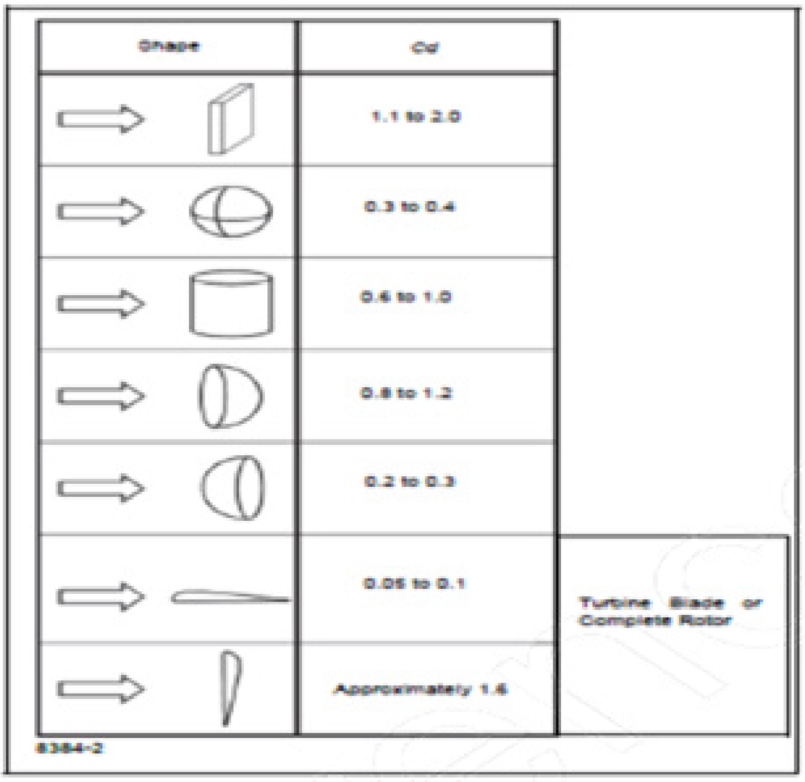
GIVEN VALUES:

Legend	Description
$V_{\text{Max per Load Chart}}$	Maximum wind speed as per the crane's load chart (given as 12.8 m/s or 46.1 km/h). Refer to *Figure 3-* Sample load chart
GW	Gross weight of the lifted load (in tons).
AW	Wind-exposed area of the load (in square meters).
Cd	Drag coefficient (typically based on the shape of the object, given as 1.7 for a flat steel plate). Please refer to **Figure 4**. Drag coefficient value of different load shapes

TABLE 2.0: SAFETY FACTOR

Source / Standard	Typical Safety Factor (SF)	Application	Notes
Manufacturer Guidelines	1.1 - 1.5	Mobile, Crawler, and Tower Cranes	Varies by crane model; check OEM manual
OSHA 1926.1431 (U.S.)	1.2 - 1.3	General crane lifting	Stops operations beyond safe limits
ANSI/ASME B30.5	1.2 - 1.5	Mobile and locomotive cranes	Adjusted based on wind conditions
ISO 4302 (International)	1.1 - 1.4	Wind load assessment on cranes	Covers environmental wind considerations
FEM (European Standards)	1.2 - 1.5	Tower and Mobile Cranes	Conservative factors used
API RP 2D (Offshore Lifting)	1.5 - 2.0	Offshore Cranes (rigs, vessels)	Used for high-wind marine environments
Wind Gust Adjustment	1.4 - 1.6	All Cranes	Adjusts for sudden wind gusts (40-50% over avg. wind)

Figure 4: Drag coefficient value of different load shapes (Ref. Grove Crane GRT8100 Manual)



Shape	Cd	
	1.1 to 2.0	
	0.3 to 0.4	
	0.6 to 1.0	
	0.8 to 1.2	
	0.2 to 0.3	
	0.05 to 0.1	Turbine Blade or Complete Rotor
	Approximately 1.6	

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SAMPLE CALCULATION (SCENARIO 1): RECTANGULAR STEEL PLATE (3M X 5M X 1 INCH)

GIVEN VALUES:

Legend	Description	Value
Load	Rectangular Steel Plate	Plate (3m x 5m x 1 inch) ; (1inch=0.025m)
AW	Area	$3m \times 5m = \mathbf{15m^2}$ (exposed to wind)
Volume	Volume	$3m \times 5m \times 0.025m = \mathbf{0.375m^3}$
GW	Gross Weight	$0.375m^3 \times 7850kg/m^3 = 2{,}944kg$ = **2,944kg (2.944 tons)**
Cd	Drag Coefficient	1.7
V_{Max}	Maximum Wind Speed	**12.8 m/s** (Value in Load chart permissible wind speed – Figure 3)

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CALCULATION PERMISSIBLE WIND SPEED:

$V_{\text{Permissible}} = V_{\text{Max per Load Chart}} \times \sqrt{(1.2 \times GW) / (AW \times Cd)}$

$V_{\text{Permissible}} = 12.8 \times \sqrt{(1.2 \times 2.944) / (15 \times 1.7)}$

$V_{\text{Permissible}} = 12.8 \times \sqrt{(3.5328 / 25.5)}$

$V_{\text{Permissible}} = 12.8 \times 0.3722 =$ **4.76** m/s ≈ **17 km/h** **Note:** (1 m/s = 3.6 km/h)

The permissible wind speed for this load is 17 km/h (4.76 m/s) is lesser than the Permissible wind speed in the load chart which is 12.8 m/s.

SAMPLE CALCULATION (SCENARIO 2): RECTANGULAR STEEL PLATE (3M X 5M X 2 INCH)

GIVEN VALUES:

Legend	Description	Value
Load	Rectangular Steel Plate	Plate (3m x 5m x 2 inch) ; (2 inch=0.05m)
AW	Area	$3m \times 5m =$ $\mathbf{15m^2}$ (exposed to wind)
Volume	Volume	$3m \times 5m \times 0.05m =$ $\mathbf{0.75m^3}$
GW	Gross Weight	$00.75m^3 \times 7950kg/m^3 = 5{,}962kg$ = **5.962 tons**
Cd	Drag Coefficient	1.7
V_{Max}	Maximum Wind Speed	**11 m/s** (Value in Load chart permissible wind speed– Figure 3)

CALCULATION PERMISSIBLE WIND SPEED:

$V_{\text{Permissible}} = V_{\text{Max per Load Chart}} \times \sqrt{(1.2 \times GW) / (AW \times Cd)}$

$V_{\text{Permissible}} = 12.8 \times \sqrt{(1.2 \times 5.962) / (15 \times 1.7)}$

$V_{\text{Permissible}} = 12.8 \times \sqrt{(7.1544 / 25.5)}$

$V_{\text{Permissible}} = 12.8 \times 0.5296 =$ **6.77** m/s ≈ **24.37 km/h** **Note:** (1 m/s = 3.6 km/h)

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The permissible wind speed for this load is 24.37 km/h (6.77 m/s) is lesser than the Permissible wind speed in the load chart which is 11 m/s.

SAMPLE CALCULATION (SCENARIO 3): LARGE PIPE LIFT WITH GW OF 7.3 TONS

GIVEN VALUES:

Legend	Description	Value
Load	Large Pipe Lift	Outer Diameter (OD) : 1.5m Wall Thickness : 20 mm (0.02m) Length : 10m Density : 7,850 kg/m^3
AW	Area	47.12 m^2 **(exposed to wind)**
Volume	Volume	0.93m^3
GW	Gross Weight	7,300kg = 7.3 **tons** (see below Gross Weight (GW) calculation)
Cd	Drag Coefficient	0.9
V_{Max}	Maximum Wind Speed	**12.8 m/s** (Value in Load chart permissible wind speed – Figure 3)

CALCULATION OF GROSS WEIGHT (GW) AND AREA (AW):

OUTER DIAMETER (OD) : **1.5M**

WALL THICKNESS : **20 MM (0.02M)**

LENGTH : **10M**

DENSITY : **7,850 KG/M3**

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FORMULA TO CALCULATE VOLUME:

$V = \pi \times (R^2_{outer} - R^2 inner) \times L$

Where

R_{outer} (Outer Radius) = OD /2 = 1.5m /2 = **0.75m**

R_{inner} (Inner Radius) = OD-Wall Thickness= 0.75m – 0.02m= **0.73m**

L (Pipe length) = **10m**

$V = \pi \times (0.75^2 - 0.73^2) \times 10$

V = 3.1416 x (0.5625 -0.5329) x 10

V= 3.1416 x 0.0296 x 10

V = 0.93**m^3**

FORMULA TO CALCULATE GROSS WEIGHT:

GW = V x Density where V= Volume

GW = 0.93**m^3** x 7,850 kg/m^3

GW = **7,300kg or 7.3 Tons**

FORMULA TO CALCULATE THE AREA (EXPOSED AREA TO WIND)

AW= Outer Circumference x Pipe Length

AW = $(2\ \pi R_{outer}) \times L$

AW = (2x 3.1416 x 0.75) x 10

AW= (4.7124) x 10

AW= **47.12m^2**

CALCULATION OF PERMISSIBLE WIND SPEED:

$V_{\text{Permissible}} = V_{\text{Max per Load Chart}} \times \sqrt{(1.2 \times GW) / (AW \times Cd)}$

$V_{\text{Permissible}} = 11 \times \sqrt{(1.2 \times 7.3) / (47.12 \times 0.9)}$

$V_{\text{Permissible}} = 11 \times \sqrt{(8.76 / 42.40)}$

$V_{\text{Permissible}} = 11 \times 0.4545 = \mathbf{4.99}$ m/s ≈ **17.96 km/h** **Note:** (1 m/s = 3.6 km/h)

The permissible wind speed for this load is **17.96 km/h.**

The permissible wind speed for this load is 17.96 km/h (4.99 m/s) is lesser than the Permissible wind speed in the load chart which is 12.8 m/s.

SAMPLE CALCULATION (SCENARIO 4): STEEL BEAM

GIVEN VALUES:

Legend	Description	Value
Load	Steel Beam	$2m \times 1m$
AW	Area	$2m \times 1m = 2m^2$ **(exposed to wind, small surface area)**
GW	Gross Weight	$5{,}000kg$ = 5 **tons**
Cd	Drag Coefficient	1.5 (Typical Compact Objects)
V_{Max}	Maximum Wind Speed	**11 m/s** (Value in Load chart permissible wind speed– Figure 3)

CALCULATION OF PERMISSIBLE WIND SPEED:

$V_{\text{Permissible}} = V_{\text{Max per Load Chart}} \times \sqrt{(1.2 \times GW) / (AW \times Cd)}$

$V_{\text{Permissible}} = 11 \times \sqrt{(1.2 \times 5) / (2 \times 1.5)}$

$V_{\text{Permissible}} = 11 \times \sqrt{(6 / 3)}$

$V_{\text{Permissible}} = 11 \times 1.4142 = \mathbf{15.55}$ m/s ≈ **55.98 km/h** **Note:** (1 m/s = 3.6 km/h)

CALCULATION OF PERMISSIBLE WIND SPEED:

The calculated permissible wind speed is 55.98 km/h (15.55 m/s) — which is higher than the manufacturer's load chart limit of 11 m/s, does not automatically mean it is safe to proceed with lifting.

The load chart limit is conservative and accounts for multiple dynamic risks e.g. worst-case scenarios, like sudden wind gusts, unexpected load sway, or less-than-ideal crane setup e.g. boom angle and boom length.

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SAMPLE CALCULATION (SCENARIO 5): 40 FT SHIPPING CONTAINER

GIVEN VALUES:

Legend	Description	Value
Load	Shipping Container	40 ft Container
AW	Area	$12m \times 2.35m = 13.9m^2$ **(exposed to wind, Large Surface Area)**
GW	Gross Weight	2000kg (**2 tons)**
Cd	Drag Coefficient	2 (higher because of large flat surfaces)
V_{Max}	Maximum Wind Speed	12.8 m/s (Load chart permissible wind speed)

CALCULATION OF PERMISSIBLE WIND SPEED:

$$V_{\text{Permissible}} = V_{\text{Max per Load Chart}} \times \sqrt{(1.2 \times GW) / (AW \times Cd)}$$

$$V_{\text{Permissible}} = 12.8 \times \sqrt{(1.2 \times 2) / (13.9 \times 2)}$$

$$V_{\text{Permissible}} = 12.8 \times \sqrt{(2.4 / 27.8)}$$

$V_{\text{Permissible}} = 12.8 \times 0.29 = 3.71$ m/s ≈ **13.36 km/h** **Note:** (1 m/s = 3.6 km/h)

The permissible wind speed for this load is 13.36 km/h (3.71 m/s) is lesser than the Permissible wind speed in the load chart which is 12.8 m/s.

THE INTERPRETATION OF CALCULATED PERMISSIBLE VALUES:

All five (5) calculated scenarios, the permissible wind speeds were found to be lower than the manufacturer's load chart limit, except in the case of a compact load (e.g., steel beam). This emphasizes how real site factors such as increased exposed surface area, boom radius, and wind amplification in confined environments like pipe racks or open areas can significantly reduce the actual safe wind threshold for lifting operations, compared to the idealized values in manufacturer specifications.

OBSERVATIONS FROM THE SAMPLE FIVE (5) SCENARIOS:

1. Heavier loads result in a higher gross weight (GW), which in turn raises the permissible wind speed. This is because a more massive system provides greater resistance to wind-induced overturning moments.

2. As the wind-exposed area (Aw) increases—such as when lifting wide panels or bulky equipment—the permissible wind speed drops. This makes the crane more vulnerable to instability, even at moderate wind levels.

3. Load with high drag coefficients (Cd), like flat plates or cages, catch more wind. This leads to a significant reduction in permissible wind speed, even if the actual weight of the load is relatively low.

This comparison shows the importance of site-specific wind assessments and supports the conservative application of safe lifting limits such as 32 km/h especially under different conditions.

7. FINAL CONCLUSION AND RECOMMENDATIONS

The results findings show the importance of not depending solely on the load chart wind speed rating when planning lifts, especially in environments where wind behavior is more intense, such as confined spaces or open fields area. While manufacturers set general wind limits based on actual conditions on site, it often demand a more cautious approach.
The 32 km/h restriction serves as a practical safeguard and baseline. It accommodates gusts, turbulence, and load-specific risks that may not be reflected in generic manufacturer charts. Even though compact loads might technically withstand higher winds (as per the calculation), the likelihood of unpredictable gusts or swinging still justifies the adherence the 32 km/h threshold.

In conclusion, the calculated safety factors and wind thresholds support the 32 km/h limit as a reasonable safety guideline. This helps to avoid untoward incident and consistency of operation especially conditions can be unpredictable.

7.1 RECOMMENDATIONS

Based on the result calculation, the following are practical recommendations to consider:

- Setting a standard speed limit of 32 km/h aligns with best practices, ensuring safety enforcement across contractors.
- To have a real-time wind monitoring, stop-work criteria, and provide operator training in preventing wind-related crane failures.
- Implementation of permit-to-lift systems ensures pre-lift wind speed are verified before any lift and the decision making is accountable.
- Continuously monitor the weather prior to any critical lifting activity.
- Always perform load specific calculation before each lift using load chart permissible parameter, boom and load configuration to ensure crane in safe operating limits.

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