JEATSA JOURNAL
JOURNAL OF ENGINEERING ADVANCES AND TECHNOLOGIES FOR SUSTAINABLE APPLICATIONS
Volume 1, Issue 2 (April, 2025)
Print ISSN: 3062-5629 Online ISSN: 3062-5637
Open Access
https://jeats.journals.ekb.eg/

A Methodology To Enhance Tower Crane The Operational Safety Against Wind During The Construction Of Tall Buildings

Mostafa Shaaban, Ashraf Ahmed Talaat
Civil Engineering Department,Giza Engineering institue

How to cite this paper: Author 1, Author 2, & Author 3 (2021). Paper Title. ****, *, **-**.
https://dx.doi.org/10.21608/JEATSA.2021.******

Received 29-09-2024
Revised 16-10-2024
Accepted: 1-11-2024
Published: April-2025

Copyright © 2021 by author(s) and Journal Of Engineering Advances And Technologies For Sustainable Applications
This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
http://creativecommons.org/licenses/by/4.0/
Open Access
Print ISSN: 3062-5629
Online ISSN: 3062-5637

Abstract

This study presents a comprehensive methodology for ensuring the safe operation of tower cranes against wind forces during the construction of tall buildings. Tower cranes are critical for high-rise construction projects, but their susceptibility to strong winds poses significant risks to both personnel and equipment. The proposed methodology integrates wind load assessment, crane design optimization, and operational safety protocols to enhance safety measures. First, a detailed analysis of wind patterns and their effects on crane stability is conducted, utilizing both historical data and real-time meteorological observations. This analysis informs the development of a robust wind load assessment framework tailored for various crane configurations and site conditions. Next, the methodology emphasizes the importance of crane design adjustments, including the selection of appropriate counterweights, the use of advanced materials, and modifications to crane height and structure to enhance resistance to wind forces. Furthermore, the study outlines operational safety protocols, including real-time monitoring of wind conditions, operator training programs, and the establishment of clear guidelines for crane operations during adverse weather events. By combining these elements, the proposed methodology aims to minimize risks and improve safety in the operation of tower cranes, ultimately contributing to the successful and safe construction of talls. The implementation of this methodology is expected to foster a safer construction environment, reduce accidents, and enhance overall project efficiency.

Keywords: Towere crane,crane safety,tall building,wind speed

. Introduction

1.1 Nature of Wind

The Earth continuously releases into the atmosphere the heat it receives from the sun, but this release is uneven. In areas where more heat is released, the air warms, its density decreases, and it rises. Conversely, in cooler regions, the air pressure increases, drawing cooler air to flow over the Earth's surface. Air moves from high-pressure areas to low-pressure areas, and this movement of air masses between different regions is known as wind [1].Fig.1, show the formation of wind.

JEATSA JOURNAL
JOURNAL OF ENGINEERING ADVANCES AND TECHNOLOGIES FOR SUSTAINABLE APPLICATIONS
Volume 1, Issue 2 (April, 2025)
Print ISSN: 3062-5629 Online ISSN: 3062-5637
Open Access
https://jeats.journals.ekb.eg/

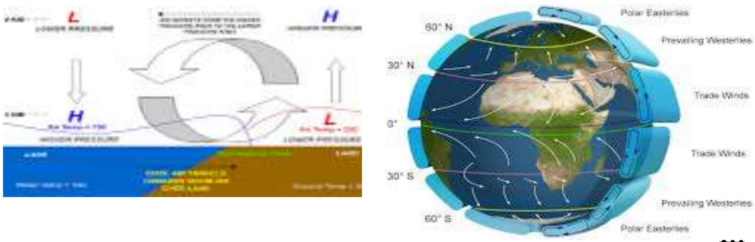


Fig.1.Formation of wind

1.2 Wind Speed Forecasting

Various methods have been employed to forecast wind speed, with most of these approaches relying on support vector machines (SVM), artificial neural networks (ANN), and genetic algorithms (GA). Support vector machines (SVM) were applied by [2] to predict wind speed, achieving the lowest mean square error compared to back-propagation neural networks. A hybrid wind speed prediction model incorporating wavelet transform has been proposed [3]. Additionally, a short-term wind speed forecasting model based on an artificial neural network and wavelet packet decomposition was introduced [4]. This model achieved the lowest mean absolute percentage error when compared with other hybrid methods. An empirical mode decomposition algorithm combined with a neural network has also been applied for wind speed forecasting [5], with results indicating that the suggested model had the lowest statistical error in terms of mean absolute error.

1.3 Wind Effects on Crane Operation

The crane is considered the primary equipment in the construction of tall buildings, playing a crucial role in lifting and handling various materials. Wind forces act upon both the tower crane and the lifted load, potentially affecting both the crane's durability and stability as well as the safe handling of the load. One of the most catastrophic crane accidents, the Big Blue collapse on the Miller Park Stadium project, was primarily due to wind and poor ground conditions [6]. However, considering the effect of wind during lift analyses in crane operations is not yet a widely adopted practice.

The stability of a truck crane is influenced by both metrical and load conditions [7]. A mathematical del has been developed to identify the dynamic es acting on the slewing crane structure during load sport [8]. Additionally, a mathematical model that udes numerical simulation of tower crane operation been established to minimize crane swings [9]. practice, tower cranes may become unstable due to the penetration of outriggers into the soil, and approximately 20% of overturning incidents have occurred when the hook load was less than the rated load [10]. Therefore, this research presents a methodology to improve the safe operation of tower cranes when lifting parts of a wind turbine in high wind speed conditions.

2.Problem Statement

Tall buildings are typically constructed in high wind speed regions. Along with the weight, shape, and size of the load, wind speed and direction significantly impact crane stability and the lifting process. Strong winds can pose safety concerns, as high wind speeds can lead to crane overturning, especially during fluctuating wind conditions and gusts. Furthermore, crane overturning often results in the cancellation of lifting operations, causing delays in the project schedule.

3.Research Objective

The primary objective of this research is to present a methodology to enhance and optimize tower crane safety in the erection of structures on tall buildings. This methodology is based on genetic algorithm techniques and will serve as an operational planning tool, allowing an assessment of safety implications for performing a lift on any given day.

4.proposed methodology

To achieve the stated objectives, the following subsections outline the foundational elements of the proposed methodology. The steps of the proposed methodology are as follows:

4.1 Wind speed prediction

The prediction of wind speed is done based on the

JEATSA JOURNAL
JOURNAL OF ENGINEERING ADVANCES AND TECHNOLOGIES FOR SUSTAINABLE APPLICATIONS
Volume 1, Issue 2 (April, 2025)
Print ISSN: 3062-5629 Online ISSN: 3062-5637
Open Access
https://jeats.journals.ekb.eg/

next formula [12].This forecasts wind speed at any time (t) using data of wind speed at a previous time (t−1).

$Y_t = a_0 + a_1 Y_{(t-1)} + a_2\ Y_{(t-1)} t^2 + ... + a_n\ Y_{(t-1)} t^n$

Where Y_{t-1} is the wind speed of the previous hour and the coefficients a_0, a_1, a_2,….., a_n can be obtained by using the Least Square method.

4.2 Computation the forces affecting both crane and load

4.2.1 Computation the overturning forces

If the wind hits the load,then it swings in the direction of the wind,consequently the load no longer acts vertically downwards on the boom. Also, the swing of load causes the crane boom to swing, this swinging of the boom causes the cranes loading to increase. Wind forces affecting the crane and the lifted load as shown in Fig.2 are calculated using the general equation:

$$F = 0.5\ \rho\ .V_z^2.\ C_w.\ A_p \qquad (1)$$

Where: ρ = Air density =1.25 kg /m^3

Vz = Wind speed (m / s) at a height (Z) above ground

$$Vz = \{ (Z/10)^{0.14} + 0.4\} * V_f \qquad (2)$$

Where V_f is the mean forecasted wind speed determined at 10 m above ground level as mentioned before.

C_w = Drag coefficient or wind resistance factor, depending on shape of load.

A_p = Projected surface of a lifted load

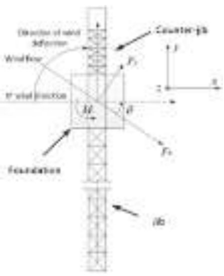
F_b = Wind force on boom ,Hb = Height from ground to central of boom

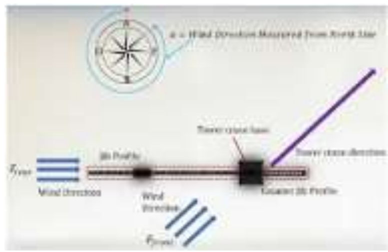
F_j = Wind force on job , Hj = Height from ground to central of jib

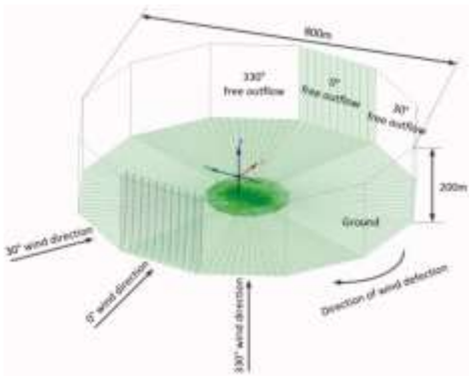
F_l = Wind force on lifted load, Hj = Height from ground to central of lifted load

The overturning moment:

$$M_{wi} = \sum F_x.H_x = F_b.H_b + F_j.H_j + F_l.H_l \qquad (3)$$







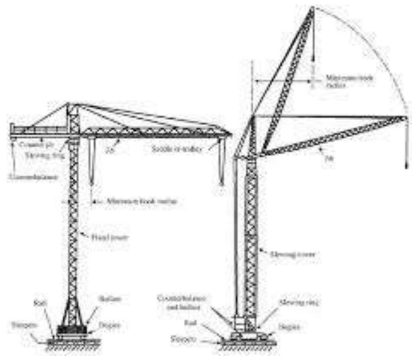


Fig. 2. Effect of wind on towere crane

4.2.2 Computation the stabilizing forces

The overturning moment Mw is counteracted by the stabilizing moment Mu with an opposite direction , the crane is stable if the stabilizing moment Mu is greater than the overturning moment Mw by the value of ΔM ≥ 0,Where :

The stabilizing moment :

$$Mui = \sum_{i=1}^{n} (Gj * dij - R_{yb} * x_b) \quad (4)$$

Gj = weight of the crane parts, (e.g. Weight of the the outrigger system, crane base weight, weights of hydraulic cylinders, and hook weight etc...), and R_{yb} is the vertical reaction of the outrigger system.

dij = distance of the centroid of the element j from the tip-over axis i in the projection on the horizontal plane.

x_b = distance from the centroid of outrigger to the crane's center of gravity.

4.3 Allowable Wind Speed for Crane Operation

The maximum allowable wind speed for lifting any load with mass of (mi) and projected surface area (Ap) can be calculated with a formula of European Standard for towere cranes (EN13000, 2010) :

$$V_p = Min.\ of \{Vmax\text{-}chart\ or\ Vmax\text{-}chart * (1.2\ m_i / C_w.A_p)^{\wedge 0.5} \} \quad (5)$$

Where:

mi =The load mass (including; lifting load, hoist load, and hook block)

A_W = The surface area exposed to wind = $C_w.A_p$

$V_{max\text{-}chart}$ =The maximum wind speed per the load chart of the selected towere crane.

4.4 The mathematical model

The above problem is formulated as assignment linear programming as follows:

The objective is to maximize the total crane safety (CS) :

$$Max.\ f = \sum_{i}^{n} CS \quad (6)$$

Subject to:

Carrying capacity(crane capacity) constraint:

$$mc > mi \quad (7)$$

Constraint of allowable wind speed for crane operation:

$$V_p > V_f \quad (8)$$

Stabilizing Constraint:

$$Mu > Mw \quad (9)$$

Rigging height constraint: $Hr/tan\Theta \geq b$ (b = load breadth/2) (10)

Crane configuration constraints:

$$Rmin \leq R \leq Rmax \quad (11)$$

$$Lmin \leq L \leq Lmax \quad (12)$$

$$\Theta min \leq \Theta \leq \Theta max \quad (13)$$

Where:

R = is the operating radius which is defined as the distance between the centroid of the lift and the center of rotation of the crane.

L = is the boom length,which is defined as the distance from the crane's pivot to the centroid of the load.

Θ = is the lift angle which is defined to be the boom to ground operating angle.

R, L, and Θ have a minimum and maximum range as defined in the specifications of the selected towere crane.

5. Conclusion

The suggested methodology presents the critical elements affecting stability and safety of towere cranes in erection wind turbine. This methodology provides a

JEATSA JOURNAL
JOURNAL OF ENGINEERING ADVANCES AND TECHNOLOGIES FOR SUSTAINABLE APPLICATIONS
Volume 1, Issue 2 (April, 2025)
Print ISSN: 3062-5629 Online ISSN: 3062-5637
Open Access
https://jeats.journals.ekb.eg/

systematic approach to enhance the safety of tower crane operations against wind forces during tall construction. By integrating wind load assessments, design optimizations, operational protocols, and training, it aims to mitigate risks and ensure the safety of personnel and equipment on construction sites. Regular updates and adjustments to the methodology should be made based on advancements in technology and feedback from operational experiences.

Rrreferences

1. Danish Wind Industry Association. (n.d.). *Guided tour on wind energy*. Retrieved from http://www.windpower.org/en/tour/wres/index.htm
2. Zhao, P., Xia, J., Dai, Y., & He, J. (2010). Wind speed prediction using support vector regression. In *Proceedings of the 5th IEEE Conference on Industrial Electronics and Applications* (pp. 882–886). Taichung, Taiwan.
3. Liu, D., Niu, D., Wang, H., & Fan, L. (2014). Short-term wind speed forecasting using wavelet transform and support vector machines optimized by genetic algorithm. *Renewable Energy, 62*, 592–597.
4. Meng, A., Ge, J., Yin, H., & Chen, S. (2016). Wind speed forecasting based on wavelet packet decomposition and artificial neural networks trained by crisscross optimization algorithm. *Energy Conversion and Management, 114*, 75–88.
5. Wang, J., Zhang, W., Li, Y., Wang, J., & Dang, Z. (2014). Forecasting wind speed using empirical mode decomposition and Elman neural network. *Applied Soft Computing, 23*, 452–459.
6. Ross, B., McDonald, B., & Saraf, S. E. V. (2007). Big Blue goes down: The Miller Park crane accident. *Engineering Failure Analysis, 14*, 942–961.
7. Hasan, S., Al-Hussein, M., Hermann, U. H., & Safouhi, H. (2009). Integrated module for tower crane dynamic instability analysis and supporting system design. In *Proceedings of Construction Research Congress* (pp. 386–395). ASCE, Seattle, WA.
8. Jerman, B. (2006). An enhanced mathematical model for investigating the dynamic loading of a slewing crane. *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science, 220*(4), 421–433.
9. Klosinski, J. (2005). Swing-free stop control of the slewing motion of a tower crane. *Control Engineering Practice, 13*(4), 451–460.
10. Tamate, S., Suemasa, N., & Katada, T. (2005). Analyses of instability in tower cranes due to ground penetration by outriggers. *Journal of Construction Engineering and Management, 131*(6), 689–704.
11. Martinez, E., Sanz, F., Pellegrini, S., & Jimenez, L. (2009). Life cycle assessment of a multi-megawatt wind turbine. *Renewable Energy, 34*, 667–673.
12. Box, G. E. P., & Jenkins, G. M. (1976). *Time series analysis: Forecasting and control*. San Francisco, CA: Holden-Day.