G-Tech : Journal of Applied Technology
Vol. 9, No. 1, 2025, p. 211-219
E-ISSN: 2623-064X | P-ISSN: 2580-8737

Crawler Crane Productivity Analysis on Erection Girder Work for Toll Road Construction Solo - Yogyakarta

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Article Information

Article History

Received : December 04, 2024
Revised : December 20, 2024
Published : January 06, 2025

Keywords:

Productives;
Erections;
Cranes;
Load Charts.

ABSTRACT

The construction of the Solo–Yogyakarta Toll Road aims to enhance connectivity between Solo and Yogyakarta and reduce traffic congestion. This study examines the productivity of crawler cranes in girder erection work to provide recommendations for optimizing crane usage in similar projects and improving construction efficiency. A quantitative approach was used, analyzing technical parameters such as lifting capacity, load charts, and operational safety, in accordance with SNI 6910-2022 standards. The findings revealed that the IHI CCH2800 crawler crane, with a maximum capacity of 280 tons, successfully handled a total load of 44.61 tons using a lifting frame. With a Dynamic Amplification Factor (DAF) of 1.05, the crane achieved a safe lifting capacity of 46.84 tons. The optimal configuration included a boom length of 33.50 meters, a lifting radius of 13 meters, and a sling capacity of 182.72 tons, resulting in a maximum lift capacity of 82.3 tons. This study highlights the importance of accurate lifting radius calculations and load chart optimization to ensure productivity and operational safety. The findings offer practical recommendations for application in future large-scale infrastructure projects.

INTRODUCTION

The construction of the Solo–Yogyakarta Toll Road is part of the Indonesian government's strategic policy to improve connectivity between regions on the island of Java. The project is designed as a solution to reduce traffic congestion on the national road connecting Solo City and Yogyakarta, especially during the holiday season and on big days. This toll road is expected to be able to accelerate the distribution of goods and services, as well as reduce travel time between regions. With fast and efficient transportation access, the construction of this toll road will be a top priority in the government's efforts to reduce the traffic burden on alternative roads. This toll road provides more benefits to the community along the route by encouraging regional development and creating new economic centers. The work of the Solo-Yogyakarta toll road involves various stages of construction, including earthworks (landfills and excavations), drainage works (drainage channels and box culverts), work on rigid pavement, and structural work that includes box underpasses, overpasses, tunnels, retaining walls, and erecting girders for toll bridges (Dewantari & Rasidi, 2023).

Work erection girder The Solo-Yogyakarta Toll Road construction project is one of the stages that functions to support the main structure of the bridge. Process erection girder requires detailed planning to ensure lifting and installation of the girder are performed with a high level of precision. Work erection was used in this project using the crane. Because it can make the work easier and faster depending on the conditions in the field. Method Crane means a method or method used in the implementation of erection girder or installation girder with the help of heavy equipment crawler crane. Method Crane at erection girder It is also expected to maximize

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productivity and minimize risks during the lifting process of the girder. The success of the implementation of this work will have a significant impact on the smooth construction of the entire toll road so that this project can be completed according to the target and provide optimal benefits for the user community (Umar & Naibaho, 2022).

Crawler cranes have an important role in the job of erecting girders for bridges. This machine can lift large loads with its flexible mobility at the project site, making it an efficient solution in the lifting and installation process of the girder. The superiority of a crawler crane lies in the variation in its lifting capacity, which allows this tool to contribute to maintaining the quality and safety of construction. Productivity crawler crane Several factors, including the load weight, supporting equipment, lifting radius, and capacity load chart, greatly influence productivity. The weight of the load lifted must correspond to the maximum capacity of the crane to guarantee safe and efficient operation (Jaya, W., Sutandi, 2019). Supporting equipment such as seat ropes and stabilization systems are essential to maintaining stability in the crane and speeding up the lifting process. Capacity load charts, which provide information about a crane's lifting ability based on tool configuration and boom length, aid in proper planning. In addition, the lifting radius greatly affects the maximum lifting capacity; the larger the radius, the less lifting capacity the crane has. Therefore, effective management and careful consideration are indispensable to increasing productivity with crawler cranes overall (Fortuna, B.I. et al., 2021).

Research has been conducted on the implementation methods and productivity of girder erection. There has been extensive research on the use of crawler cranes. The method of using a crawler crane has proven to be more efficient in terms of time and cost compared to using a launcher gantry. This advantage is due to the ability of the crawler crane to operate in difficult locations and its flexibility in moving on the Cimanggis-Cibitung toll road project (Hasdian et al., 2021). Factors such as weather and location conditions also affect productivity. Bad weather conditions can cause delays in the erection process of crawler cranes, so it's crucial to consider various factors to minimize risks and ensure a smooth project (Wahidin, 2017). The Tamblang Dam project utilized a crawler crane. Increase productivity and efficiency in the absence of safety incidents (Laksmiwati, 2023). The crawler crane's boom lattice, designed optimally, enhances both structural performance and operational safety. This design allows the crane to withstand heavier loads and reduce the risk of damage during lifting the girder (Li et al., 2021). Furthermore, the implementation of the erection girder system has proven to be effective. Using a crawler crane has proven effective in increasing productivity and efficiency during the lifting process of the girder. Using a crawler crane is a good choice in large projects that require the lifting of heavy and complex structural elements (Kamila, 2022).

Based on observations in the field by paying attention to actual conditions, the implementation of work erection girder using the crane is the right choice, especially since the crane has a large lifting capacity. This allows a crane to handle heavy loads that cannot be lifted manually or with other tools. In addition, the use of Crane It is very time-efficient, as the lifting process can be completed faster than other methods, helping to speed up the overall project schedule. Crawler cranes are very flexible on job sites because they can operate in narrow or confined areas by maintaining their mobility and stability. With these various advantages, Crane is the main choice in projects that require heavy lifting, such as Girder, and is able to provide high precision in the implementation process (Siswanto, A. B. et al., 2022). The results of the study are expected to provide relevant recommendations in optimizing the use of crawler cranes on similar projects in the future, as well as contributing to improving efficiency in overall infrastructure construction. Proper management is expected to increase operational effectiveness of crawler cranes so as to produce more efficient performance in the field. This study aims to analyze the productivity of the crawler crane in the job of erecting the girder on the Solo–Yogyakarta Toll Road project, focusing on four main aspects, namely load weight, supporting equipment, lifting radius, and capacity load chart. The goal is to minimize factors that affect productivity, ensuring operations run at maximum capacity, and reducing potential obstacles in construction (Izza et al., 2019)

RESEARCH METHODS

This study utilizes secondary data, specifically technical field data from the even semester MBKM internship at PT. Adhi Karya Persero Tbk., which was collected during the Solo-

Yogyakarta Toll Road construction project. A quantitative approach is used to measure the productivity of crawler cranes, with the aim of obtaining relevant load chart values. The results of the study are expected to provide an objective analysis of the effectiveness and productivity of the use of crawler cranes in the erection girder process. This study obtained the following technical data.

Table 1. Technical Data Girder

Girder Technical Data	
Girder length	40,80 meters
Girder weight	40112,50 kg
Girder height (Hp)	2,1 meters

Table 2. Technical Data of Supporting Tools

Weight of Support Equipment	
Lifting sling	200 kg
Main sling weight	1000 kg
Lifting frame	80000 kg
Shackle	55000 kg

Table 3. Technical Data Erection

Erection Technical Data	
Building height from base elevation (Hb)	4,02 meters
Clearance elevation distance (Hcl)	3,00 meters
Vertical distance of lifting sling (Hs)	3,00 meters
Jerk Vertical Hoist (HH)	20,80 meters

This study examines the effectiveness and productivity of heavy equipment crawler cranes, specifically focusing on productivity cranes that meet the technical specifications of job erection girders, using the technical data calculation method. Therefore, the following research flow chart describes the research process from the beginning to the end to provide a clear picture of the methodology and approach used in analyzing productivity crawler cranes on the job erecting girders (Maddeppungeng, A. et al., 2023). The following are the stages of analysis that were used.

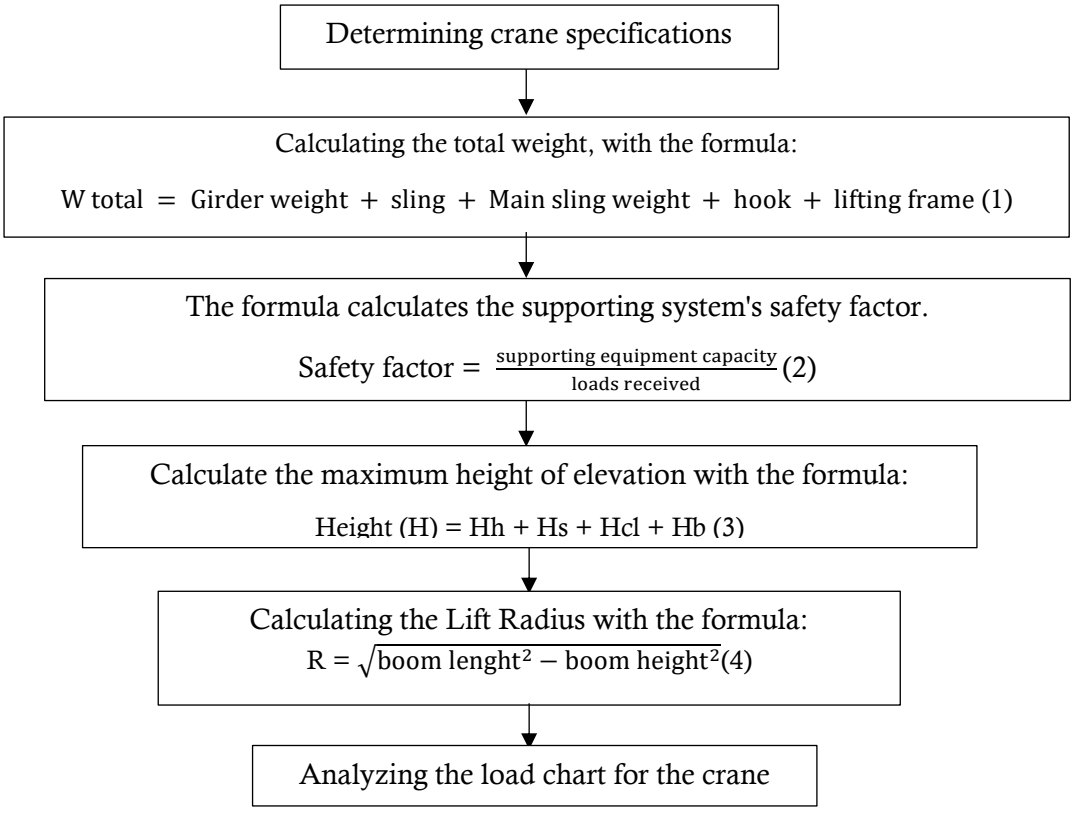

Figure 1. Analysis Chart Crawler Crane

This stage is crucial for ensuring that the crane can safely and precisely lift the load, while also being suitable for the lifting radius. This study refers to SNI 6910-2022 as a guideline for the use of heavy equipment, considering safety factors. Data is collected directly to analyze crane productivity, identify work efficiency, and provide recommendations for optimizing machine usage. Furthermore, the crane load chart determines the crane's maximum lifting capacity based on the obtained radius and angle of the boom. The Solo–Yogyakarta Toll Road project uses a load chart and radius to ensure safe and optimal crane operations, with Figures 2 and 3 serving as guides to determine the maximum lifting capacity at various ranges and lifting angles.

RESULTS AND DISCUSSION

This chapter presents the results of the analysis of the productivity and effectiveness of the use of crawler cranes in the erection girder work on the Solo–Yogyakarta Toll Road project. The results of the calculation include the lifting capacity of the crane, the weight of the load received, the supporting equipment, and the lifting radius that will be discussed in detail. This analysis uses crane and girder technical data and is based on the SNI 6910-2022 standard to ensure work safety. The results of field observations are expected to provide recommendations for optimizing the use of cranes in similar projects in the future.

Crawler Crane

The implementation of erection girders typically involves the use of crawler cranes, particularly when considering site conditions in the field. An in-depth understanding of crawler crane parts and specifications is essential for determining the type or types that suit the project needs and site conditions.

Table 4. Tool specifications Crawler Crane 280 Tons

Crawler Crane 280 Ton	
Tool Type	Crawler Crane
Brand / Type	IHI/CCH2800
Serial No. / Hull No.	CCO180 BJ0809 CCH2800
Maker Country. Year	China. 2018
Capacity	280 Tons

The IHI brand crawler crane, type CCH2800, serial number CCO180 BJ080 CCH2800, has a maximum lifting capacity of 280 tons.

Binding Method

Fastening methods in work erection girder It is very important to ensure Girder are lifted and installed safely and stably. The right selection of a tie strap should consider the length of the span girder and load capacity to prevent the binding from coming off during the lifting process (Shaikh, 2016) :

Table 5. PCI Girder Binding Method

No.	PCI Girder Spans	Number of cranes	Binding Method
1.	PCI Girder Span < 30 meters	1	Speader Beam
		2	Wire Rope
2.	PCI Girder Span >30 meters	2	Lifting frame

In the process erection girder with span length girder 40,8 meters, used fastening method lifting frame to ensure safety and stability at the time of lifting (Lin et al., 2015). Here's an examination of the lifting frame:

$$\text{Safety Lifting frame} = \frac{\text{Capacity Lifting frame}}{\text{girder weight}} = \frac{80000}{40112.50} = 1.99 \text{ (OK, SF > 1.5)}$$

The inspection of the lifting frame showed a safety factor of 1.99, calculated from the lifting frame capacity of 80000 kg and the girder weight of 40112.50 kg. These results are in accordance with applicable safety standards.

Hooks

The hook functions to connect the girder and sling, ensuring that the lifting process is stable and safe according to the set lifting capacity.

Table 6. Hooks

Hooks (ton)	Weight (kg)
250	4200
150	2300
70	1200
35	900
13,5	450

Based on the fastening method using a lifting frame, a hook with a capacity of 150 tons and a weight of 2300 kg was determined. Here's the check for hooks:

Loads received = weight girder + sling + lifting frame
= 40112.50 + 200 + 1000 = 41312.50 kg

Safety factor hook $= \frac{\text{Capacity hook}}{\text{loads received}} = \frac{150000}{41312.50} = 3.63$ (OK, SF > 2)

The examination of the hook showed a safety factor of 3.63, calculated from the lifting capacity of the frame of 150000 kg and the weight of the girder of 41312.50 kg. These results are in accordance with applicable safety standards.

Total Weight

The total weight in the erection girder work is an important component that must be considered to ensure that lifting takes place safely and efficiently. The calculation of the total weight of the load includes the weight of the girder, sling, main sling, hook, and lifting frame. The total weight of the erection girder work is calculated as follows:

Total weight = 40112.50 kg + 200 kg + 1000 kg + 2300 + 1000 kg
Total weight = 44612.50 kg = 44.61 tons

By knowing the total weight, it can be ensured that the crane used has enough lifting capacity to handle the load when lifting, to minimize the risk of accidents and ensure work safety.

Dynamic Amplification Factor

Dynamic Amplification Factor (DAF) is a factor that responds to the dynamics of girders or structures that are lifted due to dynamic loads, such as vibration cranes and movement girders. Application of DAF in erecting girders It is very important to ensure the removal of the girder and the installation are carried out safely, as well as taking into account all possible dynamic effect (Deng et al., 2019).

Table 7. Dynamic Amplification factor

Static Hook Load (Ton)	DAF Onshore	DAF Inshore	DAF Offshore
50 – 100	1.10	1.15	1.3
100 – 1000	2.05	1.10	1.2
1000 – 2500	2.05	1.05	1.15
>2500	1.05	1.05	1.10

Source: (DNV-OS-H205, 2014)

Based on the total weight of 44.61 tons, the Dynamic Amplification Factor (DAF) value obtained is 1.05 (onshore). The value is taken from table 7 because the total weight exceeds 2500 tons and the work is carried out on land. Furthermore, to calculate the weight of the load lifted on the erection girder work, the following formula is used:

Weight of Lifted Load = Total weight of load x DAF
Weight of Lifted load = 44,612.50 x 1.05 = 46843.13 kg = 46.84 tons

Based on the calculation of the weight value of the load lifted to 46843.13 kg. This calculation is important to ensure that the capacity of the crane and other equipment can safely handle dynamic loads during the lifting process.

Wire Rope Sling

The ideal angle for a sling angle is between 60° and 90°. An angle that is too small can increase the load on the strap, while an angle that is too large can reduce the stability of the lift.

Table 8. Sling Angle dan Sling Angle factor

Sling Angle(θ)	Sling Angle Factor (ε)	Sling Angle(θ)	Sling Angle Factor (ε)	Sling Angle(θ)	Sling Angle Factor(ε)
90°	1.000	60°	1.155	30°	2.000
85°	1.004	55°	1.221	25°	2.366
80°	1.015	50°	1.305	20°	2.924
75°	1.035	45°	1.414	15°	3.864
70°	1.064	40°	1.555	10°	5.759
65°	1.103	35°	1.742	5°	11.47

Source : (ASME, 2014)

This analysis establishes the rope-tying angle at 60 degrees by multiplying the sling angle by 1,155 to prevent excessively steep corners. The wire rope sling has a lifting capacity of 182.72 tons (Standard, 2002). The wire rope sling is examined as follows:

Loads received = 23736.31 kg

Safety wire rope sling = $\frac{\text{Capacity wire rope sling}}{\text{loads received}} = \frac{182.72}{23736.31} = 7.70$ (OK, SF > 5)

Based on Permenaker No. 8 of 2020 Article 131, the use of wire rope slings must meet the requirements with a minimum safety factor of 5. The calculation reveals that the used wire rope sling, with a safety factor value of 7.70, surpasses the minimum requirements, ensuring its safe use during load lifting.

Shackle

A shackle serves as a tool for connecting, slinging, and guaranteeing the lifting of a load without any risk of failure during the connection process. Shackle inspection is essential to guarantee safety and effectiveness during the lifting process. Next, the calculation incorporates the shackle examination :

Loads received = $\frac{\text{girder weight}}{2} = \frac{40112.50}{2} = 20056.25$ kg

Safety factor Shackle = $\frac{\text{Capacity Shackle}}{\text{Loads received}} = \frac{55000}{20056.25} = 2.74$ (OK, SF > 2)

Based on calculations, the capacity of the shackle is 55000 kg, and the weight received is 20556.25. The safety factor was obtained at 2.74, this value met the standard so that the shackle could be used safely in the lifting process.

Radius

To determine the maximum radius crane, first calculate the building's height. Based on technical data erection girder, each parameter should be carefully calculated (Lee, D. . et al., 2021). The long boom used is 33.50 meters. Furthermore, the height calculation is carried out as follows:

Tinggi (H) = 20.80 m + 3 m + 3 m + 4.02 m = 30.82 m

The calculation above yielded a total height of 30.82 m for the erection girder work. This radius calculation is important to determine the optimal position of the crane during the lifting and placement of the girder without exceeding the crane capacity limit. The following formula is required for the radius calculation:

$R = \sqrt{33.50^2 - 30.82^2} = \sqrt{1122.25 - 949.8724} = \sqrt{172.3776} = 13$ meters

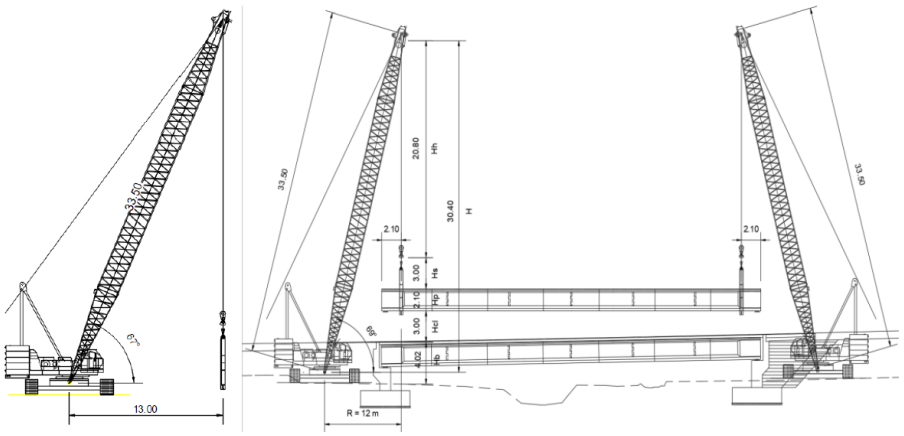

Figure 2. Radius Crawler Crane 280 Ton

After calculations, based on the field, the length of the sub crane boom used is 33.50 meters, which allows lifting the load. The angle of inclination of the boom to the ground is set at 67 degrees to determine the lifting power and load range of the crane. The lifting radius for the horizontal distance from the center point of the crane to the lifted load is 13 meters. It is important to note that the larger the lifting radius, the smaller the crane's lifting capacity.

Load Chart Crane

A load chart is a table that shows the maximum lifting capacity of a crane based on various combinations of boom length and lifting radius. Load charts are important to ensure that cranes can safely lift loads under certain conditions. Based on Figure 3, the first column lists the length of the boom crane in meters, while the second column displays the lifting radius, which is the horizontal distance from the center of the crane to the lifted load. The figures in the table show the maximum lifting capacity in tons for each combination of boom length and lifting radius.

■ **Rated lifting loads** (87ton counterweight, 16ton weight for body) (Unit : Metric ton)

Boom length(m) / Working radius(m)	18	21	24	27	30	33	36	39	42	45	48	51	54
No. of Part line	20	14	14	12	11	12	11	10	9	9	7	7	6
5.0	280.0	5.6m ×175.0											
6.0	195.8	175.0	6.1m ×175.0	6.6m ×150.0									
7.0	167.0	166.3	161.2	150.0	7.2m ×137.5	7.7m ×142.8							
8.0	146.9	146.2	145.9	145.6	137.5	142.8	8.2m ×137.5	8.7m ×125.0					
9.0	130.3	130.4	130.1	129.7	127.7	130.6	128.5	125.0	9.2m ×112.5	9.8m ×110.2			
10.0	117.0	116.9	117.2	116.9	117.2	117.3	116.8	114.8	109.1	107.5	10.3m ×87.5	10.8m ×87.5	11.3m ×75.0
12.0	89.8	90.4	90.7	91.0	91.5	91.3	91.4	91.2	90.9	87.8	86.0	85.7	75.0
14.0	72.2	72.0	72.6	72.7	73.5	73.3	73.3	73.1	72.8	72.7	71.3	69.9	69.8
16.0	60.5	60.0	60.5	60.7	60.5	60.5	61.0	60.8	60.5	60.3	59.1	58.8	58.6
18.0	17.2m ×64.0	51.2	51.0	50.7	51.7	51.7	51.9	51.7	51.4	51.3	50.2	49.9	49.7
20.0		19.8m ×45.2	44.4	44.0	44.5	44.6	44.9	44.9	44.5	44.4	43.4	43.1	42.9
22.0			39.1	38.8	39.2	38.9	39.3	39.3	39.1	39.0	38.1	37.8	37.6
24.0			22.4m ×38.2	34.6	34.9	34.6	34.6	34.7	34.5	34.4	33.8	33.4	33.3
26.0				25.0m ×32.7	31.5	31.1	31.1	30.8	30.8	30.6	30.2	29.9	29.7
28.0					27.6m ×29.2	28.2	28.1	27.9	27.5	27.4	27.3	26.9	26.8
30.0						25.7	25.6	25.4	25.0	24.8	24.7	24.4	24.3
32.0						30.2m ×25.4	23.5	23.2	22.8	22.7	22.6	22.3	22.1
34.0							32.8m ×22.6	21.4	21.0	20.8	20.7	20.4	20.3
36.0								35.4m ×20.2	19.4	19.2	19.1	18.8	18.7
38.0									18.0	17.8	17.7	17.4	17.2
40.0										16.5	16.4	16.1	15.9
42.0										40.6m ×16.1	15.3	15.0	14.8
44.0											43.2m ×14.7	13.9	13.8
46.0												45.6m ×13.2	12.8
48.0													12.0
50.0													48.4m ×11.8

Figure 3. Load Chart Crawler Crane 280 Ton

Source: (Kato Works Co., n.d.)

Figure 3 shows the load chart of a 280-ton crawler crane with a boom length of 33.50. Based on data, the maximum capacity at a working radius of 12 meters (R1) is 91.3 tons (C1), while at a working radius of 14 meters (R2) the capacity drops to 73.3 tons (C2). Using the linear interpolation formula, the capacity of 13 meters can be calculated as follows:

$$C = C_1 + \left(\frac{C_2 - C_1}{R_2 - R_1}\right) x\,(R - R_1)$$

$$C = 91{,}3 + \left(\frac{73.3-91.3}{14-12}\right) x\,(13 - 12)$$

$$C = 91.3 + \left(\frac{-18}{2}\right) = 91.3 - 9 = 82.3 \text{ ton}$$

These results based on the field show that the crane's lifting capacity is 82.3 tons at a boom length of 33.50 meters and a working radius of 13 meters. These results indicate that the maximum capacity of the crane is highly dependent on the combination of the working radius and the length of the boom used. These results confirm the importance of selecting the right crane for erection girder work, as it is crucial to consider the appropriate lifting capacity and ensure the work is carried out safely and efficiently.

CONCLUSIONS AND SUGGESTIONS

Conclusion

Based on the results of the research, the use of crawler cranes in the erection girder work for the construction of the Solo–Yogyakarta Toll Road is in accordance with the SNI 6910-2022

standard to ensure work safety. With **a maximum lifting capacity of 280 tons**, the crane can handle a total load of 44.61 tons using a lifting frame to ensure safety and stability. The crane achieved a Dynamic Amplification Factor (DAF) value of 1.05, lifting **a total weight of 46.84 tons**. The rope-tying angle is set at 60°, and the wire rope sling capacity reaches 182.72 tons, indicating the parameter setting for efficiency and safety. With a boom length of 33.50 meters and a working radius of 13 meters, **the maximum measured lifting capacity of the crane is 82.3 tons.**

Suggestion

Based on the conclusion, the researcher recommended adjusting the crane selection to the lifting capacity, girder weight, and supporting equipment to ensure safety factors. Periodically optimizing the accuracy of the lifting radius and load chart calculations is necessary, as the combination of the working radius and boom length determines the crane's maximum capacity. Furthermore, careful planning can optimize the productivity of crawler cranes in toll bridge erection girder work, leading to improved construction efficiency.

ACKNOWLEDGMENTS

The researcher expressed his gratitude to PT. Adhi Karya (Persero) Tbk. for the opportunity provided and support during the implementation of this research. The Yogyakarta National Institute of Technology and the entire academic community have been instrumental in providing a forum for knowledge acquisition.

REFERENCE

ASME. (2014). ASME B30.9-2014: Slings. New York: The American Society of Mechanical Engineers. Retrieved from https://ipieco.ir/wp-content/uploads/2018/05/ASME-B30.9-2014.pdf

Deng, Z. ., Gao, Q. ., Dong, H., & Li, L. . (2019). Dynamic responses of the shallow foundation of an onshore wind turbine. International Journal of Physical Modelling in Geotechnics, 19(5), 247–260. https://doi.org/10.1680/jphmg.17.00078

Dewantari, R. ., & Rasidi, N. (2023). Comparison of Implementation Methods of PCI Girder Erection on Broken Bridge 2 of the Solo-Yogyakarta Toll Road Project. Online Journal of Construction Engineering Management Thesis (JOS-MRK), 4(3), 130–135. Retrieved from http://jurnal.polinema.ac.id/index.php/jos-mrk/article/view/3414

DNV-OS-H205. (2014). Offshore Standard DNV-OS-H205—Lifting Operations. Oslo, Norway.

Fortuna, B.I., Sucita, I.K., & Rizal, R. S. (2021). Time and Cost Analysis of Erection Box Girder Comparison Using Crane and Launcher Method. Scientific Journal of Civil Engineering, 18(2), 100–112. https://doi.org/10.30630/jirs.v18i2.627

Hasdian, E., Maulana, M. A., & Fertilia, N. C. (2021). Analysis Comparissons of Erection Girder Implementations Methods Using Launcher Gantry and Crawler Crane Based on Cost and Time:(Case Study: Cimanggis-Cibitung Toll Road Project Section II Cibubur Area). ADRI International Journal of Sciences, Engineering and Technology, 6(2), 78–88. Retrieved from https://pdfs.semanticscholar.org/3fe2/4e3c6c0f63172362f1cb295f7d5bf9e4af44.pdf

Izza, F. K., Praditama, M. A., Kirana, C. N., Setyono, K. J., & Sudarmono, S. (2019). Study of the Completion Time of the Crane Method and the Launcher Method in the Implementation of Bridge Girder Erection (Case Study: Construction of the Semarang-Solo Toll Road Salatiga-Boyolali Section Sta 40+ 409–Sta 71+ 785). Civil Journal Forum; Journal of Civil Engineering Development, 24(1), 47–59. http://dx.doi.org/10.32497/wahanats.v24i1.1606

Jaya, W., Sutandi, A. (2019). Productivity Analysis of Heavy Equipment Auger Drilling Machines, Crawler Cranes, and Excavators in Projects a and b. JMTS: Journal of Civil Engineering

Partners, 11–18. https://doi.org/10.24912/jmts.v2i1.3030

Kamila, A. A. (2022). Analisis Perbandingan Biaya Dan Waktu Erection Slab On Pile Antara Metode Launching Gantry Dan Crawler Crane (Comparative Analysis Of Cost And Time Of Erection Slab On Pile Between Launching Gantry And Crawler Crane Methods)(Studi Kasus Pembangunan. Retrieved from https://dspace.uii.ac.id/handle/123456789/38677

Kato Works Co., L. (n. d. . (n.d.). CCH2800 Crawler Crane Specifications. Diakses dari https://www.kato-works.co.jp/china/products/crawler_crane/hicom_pdf/CCH2800.pdf

Laksmiwati, A. I. (2023). Implementation Method and Productivity of Crawler crane in Steel Girder Erection Work (Case Study: Intake Service Bridge, Tamblang Dam). (Doctoral Dissertation, Gadjah Mada University). Accessed from https://etd.repository.ugm.ac.id/penelitian/detail/229886

Lee, D. ., Kang, J. ., Kim, T., Oh, C., Kim, J., & Kim, J. (2021). Analysis of roller load by boom length and rotation angle of a crawler crane. Journal of the Korean Society of Manufacturing Process Engineers, 20(3), 83–91. https://doi.org/10.14775/ksmpe.2021.20.03.083

Li, J., Bai, L., Gao, W., Shi, N., Wang, N., Ye, M., & Liu, J. (2021). Reliability-based design optimization for the lattice boom of crawler crane. In Structures. Elsevier, 29, 1111–1118. https://doi.org/10.1016/j.istruc.2020.12.024

Lin, G. Y., Li, Z. Y., Wang, Z. G., & Li, K. X. (2015). A Calculation of the Crawler Crane Boom System′ s Dynamic Load in the Lifting Process. Journal of Northeastern University (Natural Science), 36(5), 699–703. 10.12068/j.issn.1005-3026.2015.05.020

Maddeppungeng, A., Asyiah, S., Intari, D. E., Hakim, B. I., & Setiawati, D. N. (2023). Analysis of Heavy Equipment Productivity Tower Crane in The Construction Project of Sultan Maulana Hasanudin State Islamic University Building. Fondasi: Jurnal Teknik Sipil, 12(2), 147–183. http://dx.doi.org/10.36055/fondasi.v12i2.21982

Shaikh, A. A. (2016). ifting capacity enhancement of a crawler crane by improving stability. Journal of theoretical and applied mechanics. 54(1), 219–227. 10.15632/jtam-pl.54.1.219

Siswanto, A. B., Salim, M. A., & Nurwidiyanti, A. (2022). Comparative Analysis of Erection Girder Beam Work with Launcher and Crawler Crane Method for the Batang Integrated Industrial Estate Project. Journal of Civil Engineering, 15(2), 23–36. https://doi.org/10.56444/jts.v15i2.217

Standard, B. (2002). Terminations for steel wire rope-Safety. Badan Standardisasi Nasional, EN 13414. Retrieved from https://growsafehse.com/wp-content/uploads/2024/05/BS-EN-13411-3-2004Terminations-For-Steel-Wire-Ropes-Safetys-min.pdf

Umar, A. R., & Naibaho, P. R. T. (2022). Comparative Analysis of the Implementation of Erection Girder Underpass on National Roads with Crane Method and Launchere Method. Asian Journal of Mechatronics and Electrical Engineering, 1(1), 1–12. https://doi.org/10.55927/ajmee.v1i1.1122

Wahidin, F. N. (2017). Implementation Method and Analysis of Crawler Crane Productivity in Erection Girder Construction Overpass Interchange Construction Project Solo-Ngawi Toll Road Construction Pt. Waskita Karya (Persero) Tbk. (Doctoral Dissertation, Gadjah Mada University). Retrieved from https://etd.repository.ugm.ac.id/penelitian/detail/115009