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ASSESSMENT OF THE STRAIGHTNESS CONDITION OF THE OVERHEAD CRANE TRESTLE IN A STEEL STRUCTURE

Summary

The article presents a geodetic method of assessing the straightness condition of an overhead crane trestle made in a steel structure. In particular, control measurements of overhead cranes and a course of action aimed at determining deviations of beam axles from design assumptions, as well as deviations from the planned range of the axles of the overhead crane rails have been discussed. The measurements were made using classic geodetic methods, and two methods - graphical and analytical - were used to develop the results. The graphic interpretation of the obtained results is also presented.

Key words: overhead crane trestle, straightness, control measurements of overhead cranes

INTRODUCTION

Control measurements and continuous geodetic monitoring of industrial facilities, including overhead cranes, is an important element allowing proper and safe operation of structures, devices and machines. Measurements can be made using classic geodetic methods, as well as more advanced methods like laser scanning [Osada 2001; Kwaśniewski, Molski 2010; Bartkowiak, Gessner 2014, Leń et al. 2017]. The information obtained in this way may be a source of data for the development of the object model in BIM technology [Uchański, Karsznia 2017]. Overhead cranes are mainly used for conveying material in production halls and storage of raw materials, goods and finished goods on storage yards. Overhead

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cranes consist of a supporting structure, built from a bridge or a bridge with supports. The entire structure moves along the tracks, which form two rails located on the ground or on the supporting structure. On the bridge of the overhead crane there is a trolley with a lift moving perpendicularly to the direction of the runway. Overhead cranes are equipped with an electric motor, which together with a set of gears creates a drive system ensuring its movement on the runway. The mechanisms of the trolley and its jack operate independently, using a separate drive unit [Gocał 2010, Praca zbiorowa 1980]. One of the criteria for the division of overhead cranes is the location of the runway, according to this criterion the following overhead cranes can be distinguished: gantry cranes, semi-portal cranes, cantilever cranes, bridge cranes.

Overhead cranes cannot work without associated infrastructure, including trestles and tracks. An overhead crane trestle most often used on external storage yards (store of materials and finished products) is a construction designed for handling loading and unloading stands. There is also the possibility of using an overhead crane trestle inside the production hall as a construction that is completely independent of it, and thus without loads for the bearing system of the object in which it is located [Matysiak, Grochowska 2016; Kozłowski 2017]. The overhead crane is an independent structure composed of a crane track in the form of a system of two parallel crane beams and supporting pillars, most often with a cantilever scheme. Its breadth depends mainly on the supported technological process, which determines the breadth of the crane dedicated to specific activities and the type of the hall. So, the lifting capacity, lifting height, the number of overhead cranes are further aspects resulting from the nature of the work performed, and thus the technological process, which, what is extremely important, has a significant impact on the number of tracks [http://jnprojekt.pl/pl/oferta/suwnice/].

When installing the crane, as well as in operation, certain geometrical conditions must be observed regarding the rails and structural elements forming the crane roadway and the crane bridge. These conditions are subject to geodetic verification, and in the process of exploitation, periodic geodetic monitoring is also carried out. Deviations from certain geometrical conditions given in the standards and technical guidelines [PN-91/M-45457; PN-87/M-06513; PN-81/2912-01], should be determined using geodetic methods with accuracy one order higher than the tolerance given in the standards. In the case of crane roadways, the most important geometric conditions to be checked are:

- straightness of the rails in the horizontal and vertical plane,
- parallelism of rails and their proper spacing,
- levelness and required height of rails,
- preservation of the determined gauge of the overhead crane [Gocał 2010].

CHARACTERISTICS OF MEASUREMENT WORKS

The straightness was measured on a crane located in a warehouse in Stare Kramsko, Lubuskie province. The length of the crane track was 60 m, the designed distance between rail axles was 16.5 m, and the length of the crane beams was 6 m. Surveying work was carried out using the constant reference method. To this end, the geodetic control network points were stabilized, marked in Fig. 1 as I, II, III and IV. The horizontal coordinates of the geodetic control network points were determined on the basis of the measured lengths and angles in the construction closed traverse, while the ordinates of the points marked on the beams in the vertical planes I-II and III-IV were determined using the precise levelling method. To measure deviations from straightness, a levelling rod was applied horizontally and perpendicularly to the beam, so that its origin coincides with the marked points of its axle.

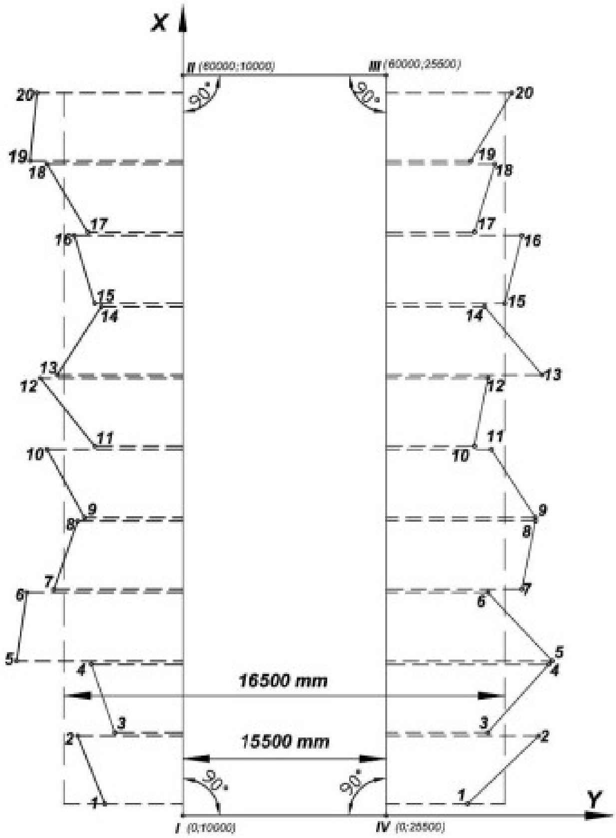

Fig. 1. Scheme of the geodetic control network and distribution of controlled points [Kubicki 2018]

Based on the data obtained from the measurement, deviations of the beam axles from the designed rail axles are determined. These deviations are calculated in such a way as to simultaneously obtain data for determining the assembly indicators of crane track. These indicators should lie on two straight lines parallel to each other and spaced by the planned wheelbase of the rails [Osada 2001]. For this purpose, it is necessary to fit two straight parallel lines, distant from each other by the designed distance of the track gauge, into a set of points marked on the axis of the beams. The most common method is the fit that meets the condition of the minimum sum of squares of beam axles deviations from their designed axles.

INTERPRETATION OF TEST RESULTS

After the measurements made on the basis of the levelling rod readouts on the crane beams, the coordinates y_L and y_P were calculated in the local coordinate system. Next, the coordinates of the centres of the sections between the points determined on the beams in the same cross-sections were calculated from the following formula:

$$y_0 = \frac{1}{2}(y_L + y_P). \tag{1}$$

The co-ordinates of the sections centres were reduced by their average value calculated on the basis of all cross-sections.

In the analytical and graphic work, having coordinates, a graph is made, on which the theoretical axis of the track is marked with a centred straight line (Fig. 2). Using this graph, the coordinates Y_0 of the points lying on the theoretical axis of the track in particular cross-sections are graphically determined and the coordinates of the points on the theoretical axles of the left and right beams are calculated from the following formulas:

$$Y_L = Y_0 - \frac{1}{2}s \tag{2}$$

$$Y_P = Y_0 + \frac{1}{2}s \tag{3}$$

where s is the projected wheelbase of rails.

Deviations from the straightness of beam axles at controlled points from centred theoretical axles, are calculated from the following formulas:

$$v_L = y_L - Y_L \tag{4}$$

$$v_P = y_P - Y_P, \tag{5}$$

whereas the deviations of the wheelbase of beams in individual cross-sections are determined as:

$$v_S = v_P - v_L. \tag{6}$$

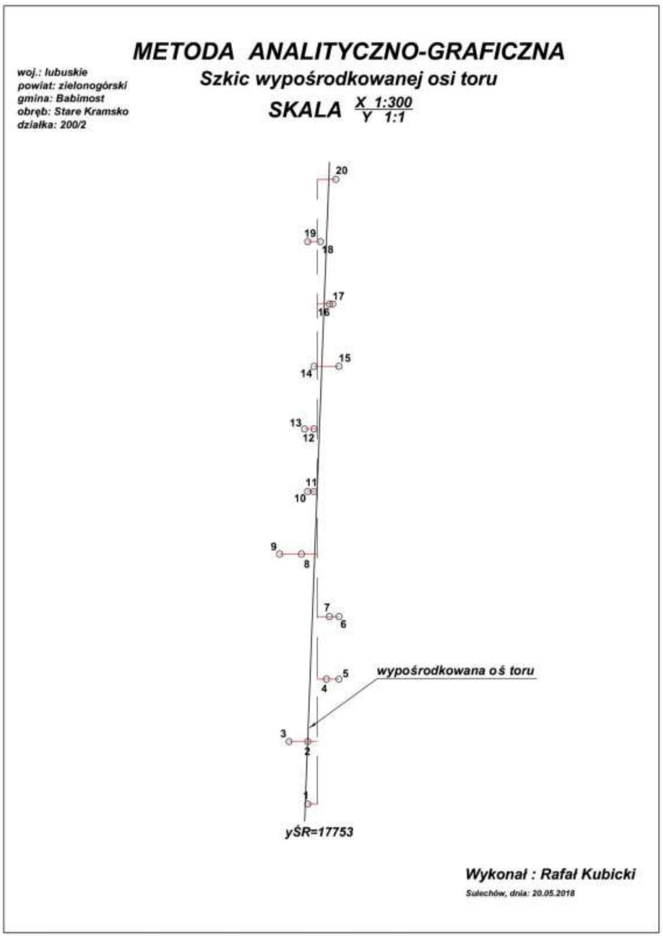

Fig. 2. Sketch of fitting the axles of the track [Kubicki 2018]

In the analytical study, the approach to determine the theoretical axles of the track and the coordinates on Y_0 is based on the assumption that in the horizontal plane the crane rails are straight parallel lines. Therefore, correction equations should be arranged for all controlled points in the following form:

$$v = ai + b + y_{śr} - y_0, \tag{7}$$

and then the parameters of the line a and b should be determined using the method of least squares [Osada 2001]. In the formula (7), the individual symbols mean:

a , b - parameters of the straight line illustrating the course of the crane track axis, and - the ratio of the number of the distance of the considered point from the beginning of the route to the distance between adjacent points marked on the beam, $y_{śr} - y_0$ - the free expression of the system of correction equations. The other calculations are the same as in the analytical and graphic method. The comparison of results obtained using the analytical and graphical as well as analytical method is summarized in Table 1. Analysing the obtained results, it can be noticed that the deviations from the straightness of the beam axles at the controlled points keep the same tendency towards the deviation, but show a difference in terms of values. Deviations in the wheelbase of beams axes in individual cross-sections are identical in both methods, which is extremely important from the point of view of the later correct operation of the crane.

The calculated deviations of the controlled points are marked on the crane beams and are the place where the rails are installed. The sketch of corrections for routing of the crane rail axles is shown in Figure 3. Before installing the rails, the height deviations of the upper beam from the common level should be determined using a leveller. After assembling the crane track rails on the beams according to the axles defined by the traced indicators, a control measurement should be made. The measurement results are used to calculate the deviations of the assembled rails from the theoretical axles and possible re-fitting of the theoretical axles of the rails with the system of points marked on the rails of the crane track [Grala, Kopijewski 2003]

Table 1. Deviations from the theoretical axles and deviations of the wheelbase of beams [Kubicki 2018]

Section no.	Analytical and graphic method			Analytical method		
	v_L	v_P	v_s	v_L	v_P	v_s
1	-3	4	7	-4	3	7
2	-1	2	3	-3	0	3
3	1	-12	-13	-1	-14	-13
4	8	4	-4	7	3	-4
5	9	10	1	8	9	1
6	8	12	4	6	10	4
7	9	4	-5	7	2	-5
8	-6	1	7	-8	-1	7
9	-5	-13	-8	-7	-15	-8
10	-2	1	3	-5	-2	3
11	3	0	-3	0	-3	-3
12	-3	6	9	-6	3	9
13	-3	1	4	-6	-2	4
14	4	-1	-5	0	-5	-5

15	3	17	14	-1	13	14
16	3	11	8	0	8	8
17	-2	13	15	-5	10	15
18	-1	6	7	-5	2	7
19	-2	0	2	-6	-4	2
20	3	13	10	-1	9	10

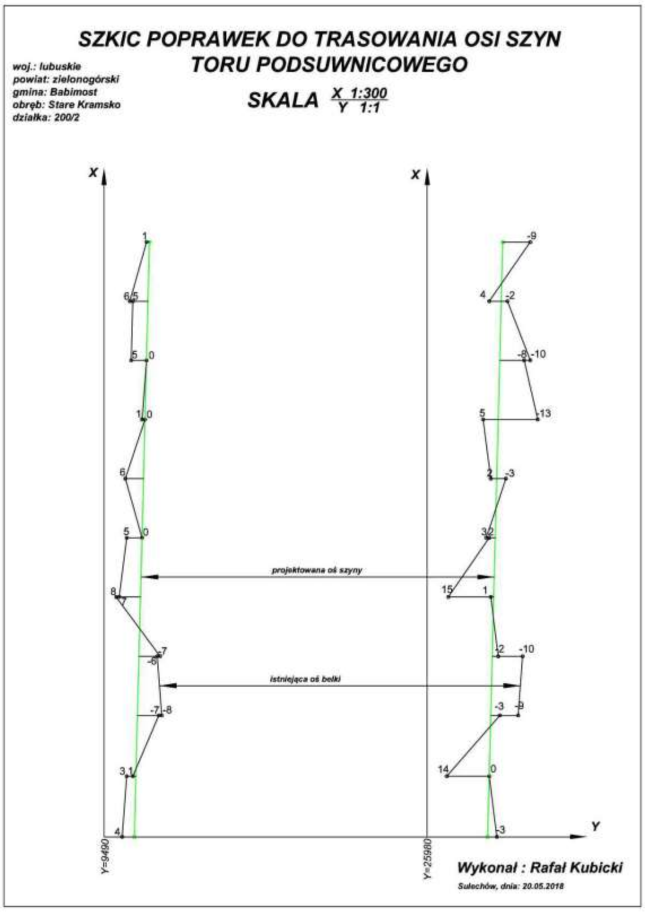

Fig. 3. The sketch of corrections for routing axles of the crane track rails - analytical method [Kubicki 2018]

CONCLUSIONS

The article presents the method of geodetic measurement of the straightness of the crane track and the development of the results of these measurements, which are a significant and inseparable part of the correct and safe operation of the crane. The method of measuring the crane roadway presented in the work is a commonly used method, but it is time-consuming and has many hazards for employees performing measurements at heights. In the literature on the subject, you can also find descriptions of other solutions - first of all, suggestions to use laser light and screens equipped with light-sensitive details and moving along the rails. However, these methods are not approved in routine surveying work. The presented methods of elaborating the results of classic geodetic measurements give convergent results, and the possible differences are within the limits of the accuracy of measurements.

It should be emphasized that geodetic works during the implementation and operation of buildings and equipment are very important. The surveyor delineates objects in the field, conducts construction and assembly operations, performs measurements of displacements and deformations, as well as an inventory of the entire investment after its completion and prepares an as-built map for the acceptance of the facility by the construction supervision.

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