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THE ANALYSIS OF LOADS AND RESULTS OF EXPERIMENTAL RESEARCH OF LOAD-BEARING SYSTEMS OF OVERHEAD TRAVELLING RAIL CRANES

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The article presents the analysis of the influence of standard shifts in crane loads on a supportive structure. It has been shown that the valid standards' conditions were established without carrying out suitable tests. The presented results of the experimental research have not confirmed the standards in terms of the occurrence of forces.

Keywords: crane, load, industrial objects, experimental research

1. INTRODUCTION

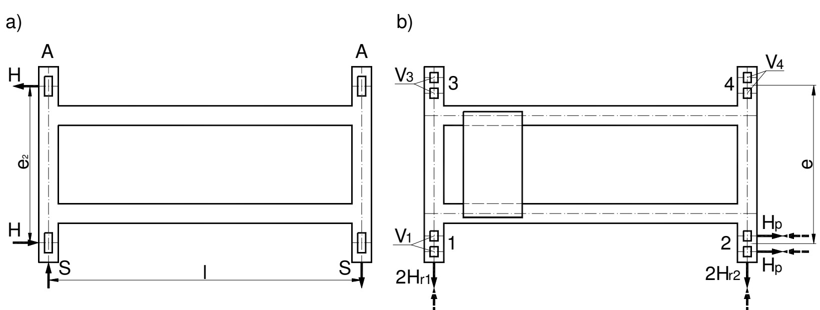

Fig. 1. Ways of imposing a load by cranes
a) according to [1], b) according to [2]

The valid standard [1] concerning the determination of loads in calculations of load-bearing structures of cranes and standard [2] concerning the determination of loads imposed by overhead travelling cranes on structures were

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elaborated by one and the same team of authors connected with load-bearing structures of cranes.

According to standard [1] a load results from rail movements acting on a load-bearing structure of a crane; the system of loading forces has been shown in fig. 1a. Whereas the influence of the crane on a crane beam according to [2] has been shown in fig. 1b.

It is worth noticing that the influence of the rail on the crane is different form the influence of the crane on the rail. The described in standards [1] and [2] conditions of the interaction between the elements of the structure do not conform the third laws of Newton, the reaction does not balance the action. Standards [1] and [2] were elaborated, as results from publication [8], on the basis of experimental research concerning imposing loads on cranes.

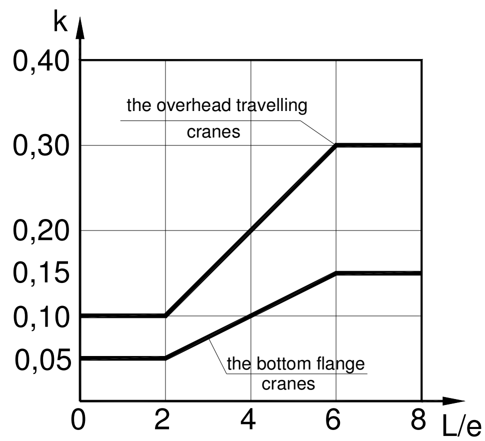

Fig. 2. Coefficient k according to [2]

According to standards [1] and [2] as well as fig. 1, forces H_P perpendicular to the axis of the crane track depend on the ratio of the span of the crane to the tread of the buffer beam. The value of the force H_P is received through multiplication of the axle load by the value of a coefficient k read from fig. 2.

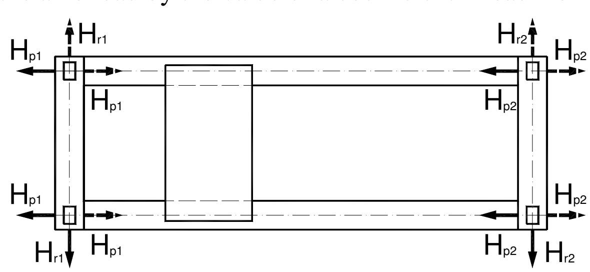

Fig.3. Force system according to [3]

The former valid standard [3] in which horizontal forces perpendicular to the axis of the track amount at one tenth of the axle load; the force system has been shown in fig. 3. The values and the force system according to standard [2] are completely different form the ones described in standard [3]. It should be also noticed that the values and the force system according to [2] are connected with a tortuous movement of the crane along the track causing chamfering, and that they do not depend on the force on inertia of the movable elements of the crane.

2. THE ANALYSIS OF THE INFLUENCE OF SHIFTS IN STANDARD LOADS IMPOSED BY OVERHEAD TRAVELLING CRANES ON STRUCTURE SUPPORTS.

Until 1986 it was assumed that the horizontal forces loading the track resulted mainly form kinetic energy of the winch and the crane. In the designed and operating objects, in that period, the phenomenon of excessive wear of the track and the wheel flange of the crane were observed. A characteristic example of that may be a processing bay for marine engines in Zakłady Przemysłu Metalowego HCP in Poznań described in [10]. Mutual shaving of the track and the wheel flanges had occurred before the track and the supporting structure were stiffened and adjusted. The wheels of the crane were replaced twice a year. Another example, described in [7], reports a repeated slide down of the crane from the substructure of the truck after devastation of the wheel flanges. The wheels wedged on the track. An excessive horizontal deformation of 3,0cm, with 1,0 cm acceptable, was reported for the discussed structure.

In the described two and many more similar structure solutions, the incorrect behaviour of the crane on the track resulted mainly from the insufficient stiffness of both the track and the supportive structure as well as a poor technical condition of the substructure of the truck and the crane and its drive.

The experimental research described in [8] resulted in a conclusion that the horizontal load of the track caused by the crane chamfering was so considerable that the load connected with forces of inertia assumed in calculations was insignificant. After the results of the research had been published in [8], prof. W. Bogucki in [5] expressed an opinion that the loads of crane beams used so far were lesser than the ones occurring in reality and it was advisable to take advantage of the results of the research.

In consequence standard [2] was elaborated where, in relation to standard [3], some additional magnitudes and a different system of horizontal forces loading the track of the crane beam were introduced. It caused also different loads on supportive structures.

Tab. 1. and tab. 2. present the results of the analysis of loads of the crane beams and the supportive structures. The ratio of the values of moments bending the structure in the horizontal plane calculated according to standard [2] to the bending moments calculated according to standard [3], has been presented in the last column of tab. 1. The ratio of the values, in the majority of cases, is higher than one and reaches the value α=2,8. It concerns the structure solutions with considerably long cranes.

Table 1

length of the crane [m]	**lifting capacity [t]**	**span of the track [m]**	**the number of cranes on the track**	**Load of a supportive structures according to diagrams** according to [3]	**Load of a supportive structures according to diagrams** according to [2]	$\alpha = \frac{M_{86}}{M_{64}}$
29,0	50,0/15,0	12,0	1	H 0,26H	1,54H	2,14
			2	H 0,26H	1,20H	1,71
	12,5	6,0	1	H 0,62H	2,32H	2,80
			2	H 0,62H	2,00H	2,20
12,0	32,0/8,0	12,0	1	H 0,36H	0,76H	0,96
			2	H 0,36H	0,43H	0,82
		6,0	1	H 0,36H	1,03H	1,20
			2	H 0,36H	1,10H	0,99

M_{86} - the bending moments according to [2]
M_{64} - the bending moments according to [3]

The increased by the standard [2] value of the bending moment is insignificant for the economy of the solution of the track, since a considerably stiff brace should be applied in the horizontal plane. The minimum height of the brace equals for the considered track spans 12,0/15=0,8m or 6,0/15=0,4m. The width of the braces, according to Technical Inspection regulations, also has to be adjusted to the dimensions of the gallery for the supervision of the substructure of the track. The higher value of the stiffness, the more correct behaviour of the crane on the track and the less influence of chamfering of the crane.

Table 2

length of the crane [m]	**lifting capacity [t]**	**span of the track [m]**	**the number of cranes on the track**	**Load of a supportive structures according to diagrams**	
				according to [3]	**according to [2]**
29,0	50,0/,15,0	12,0	1	H_1 $0{,}26H_1$ H_2 $0{,}26H_2$	$1{,}54H_1$ $1{,}54H_2$
			2	H_1 $0{,}26H_1$ H_2 $0{,}26H_2$	$1{,}20H_1$ $1{,}20H_2$
	12,5	6,0	1	H_1 $0{,}62H_1$ H_2 $0{,}62H_2$	$2{,}32H_1$ $2{,}32H_2$
			2	H_1 $0{,}62H_1$ H_2 $0{,}62H_2$	$2{,}04H_1$ $2{,}04H_2$
12,0	32,0/8,0	12,0	1	H_1 $0{,}36H_1$ H_2 $0{,}36H_2$	$0{,}76H_1$ $0{,}76H_2$
			2	H_1 $0{,}36H_1$ H_2 $0{,}36H_2$	$0{,}43H_1$ $0{,}43H_2$
		6,0	1	H_1 $0{,}36H_1$ H_2 $0{,}36H_2$	$1{,}03H_1$ $1{,}03H_2$
			2	H_1 $0{,}36H_1$ H_2 $0{,}36H_2$	$1{,}10H_1$ $1{,}10H_2$

Considerable values of moments bending the track in a horizontal plane have been calculated for the force system presented in fig. 1b. The force system presented in fig. 1a. is technically possible for the crane chamfering. The calculated bending moments for the force system are considerably smaller than the ones listed in the table 1.

The calculated horizontal reactions of the crane beam impose a load on the supportive structures. Imposing a load by horizontal forces, calculated according to standards [2] and [3], on a single-bay and a double-bay have been listed in tab. 1 and tab. 2. As results from the table, not for all the cases of the structures the load imposed on supportive structures calculated according to standard [2] (chamfering result) is higher than the one calculated according to standard [3].

3. RESULTS OF THE EXPERIMENTAL RESEARCH

The assumed in standard [2] force system imposing a load on a track of a crane beam is not convincing and has not been sensibly justified.

In [9] experimental research of an industrial bay was described. The results of the research and the conclusions prove that the loads of supportive structures calculated on the basis of standard of 1956 year, which respond with the standard [3], are overestimated.

These were the sufficient reasons for undertaking the effort to carry out further comprehensive experimental research in the operating industrial plant.

The research was carried out in the Institute of Building Structures of the former WSInż. in Zielona Góra as an order of ZPM H. Cegielski in Poznań [11]. The research was carried out in the industrial plant in operation. Five bays of various structure solutions were examined. The detailed description of the structures of three of the bays of different structures was included in [10]. Whereas a detailed description of the testing equipment used in the experiments was included in [6] and [11].

The carried out comprehensive research consisted in measurements of load forces and displacements in vibrations of columns of the transverse system of the object according to the following plan:

- cranes were placed next to the three neighbouring transverse systems respectively and were loaded with: acceleration and a sudden braking of the winch with various loads, hitting the fenders of the unloaded winch with the speed equal half of the nominal speed.
- while moving, acceleration and braking of the crane unloaded and fully loaded,
- the following were measured: impact forces of the winch hitting the fenders, shortening of the spring bumpers/fenders, displacements of the vibrations of

the columns on the track level (1, 2, 3) and on the roof level (4, 5,6) as well as the location of the crane in the bay.

Table 3

Bay number	**Loading manner**	**Displacements of vibrations [mm]**		**Fender hitting impact force**
		on the track level	**on the roof**	**[kN]**
1	Winch hitting into a fender	2,1	1,8	44,0
	Winch braking	1,8	1,1	-
	Crane movement	1,2	0,6	-
2	Winch hitting into a fender	2,8	1,7	45,00
	Winch braking	1,4	0,8	-
	Crane movement	1,5	1,0	-
3	Winch hitting into a fender	2,0	1,2	46,0
	Winch braking	1,2	0,5	-
	Crane movement	0,3	0,2	-
	Crane braking	1,2	0,6	-
4	Winch hitting into a fender	2,9	0,8	30,0
	Winch braking	1,2	0,3	
	Crane movement	0,8	0,4	-
5	Winch hitting into a fender	1,9	2,3	52,0
	Winch braking	1,7	2,0	-
	Crane movement	1,8	0,7	-

The example diagrams of the results of the displacements of the horizontal vibrations in the transverse system of the two objects have been shown in fig. 4 and fig. 5. The particular examined objects were marked with numbers 1, 2, 3 respectively according to the descriptions presented in [10]. Bays No. 4 and 5 are appointed to other objects in Zakłady Przemysłu Metalowego HCP in Poznań.

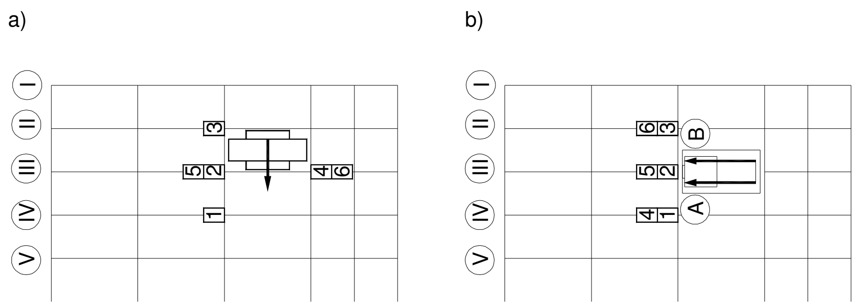

Fig.4. Location of the measuring sensors
a) crane's movement, b) braking and hitting into the fenders of the winch

In table 3 there have been listed the greatest values of the displacements of the vibrations obtained from the series of loads and impact forces caused by the winch hitting each fender for six different structures of objects.

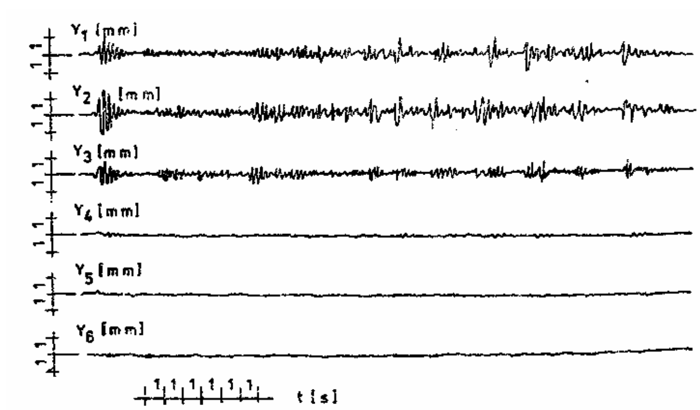

Fig.5. Results of loading bay No. 5 with the winch hitting the fenders
1,2,3,4,5,6 – numbers of measuring sensors

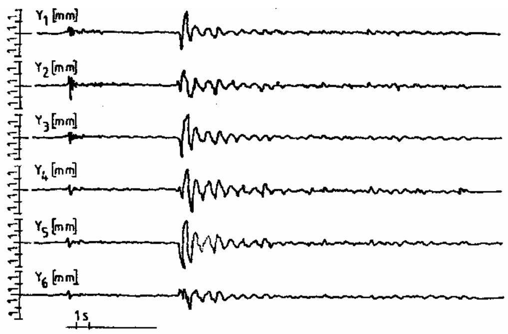

Fig.6. Results of imposing a load on bay No.1 caused by the movement of a loaded crane

4. FINAL REMARKS

The research was carried out in the objects where the track had been formerly adjusted. The technical state of the roadway was good and the stiffness of the track and the supportive structure were sufficient. It results from the presented examples of the diagrams of displacements of vibrations (fig. 5 and fig. 6) as well as from the values listed in tab. 3 that the greatest values of the displacements occurred for the winch hitting the fenders. Whereas, the results obtained for the cases of the crane movement and the winch braking are very similar to each other. It proves that the phenomenon of chamfering has not taken place during the movement of the crane along the track. It should be emphasized that the research was carried out in six objects of different structures. The results presented in tab. 1 and 2 do not confirm the authors' assumptions to standard [2] concerning the necessity of increasing the horizontal load imposed by cranes.

The considerable values of the force system, according to fig. 1b. [2], do not cause an increase in load of particular elements of an object in all the structures. In some solutions the load is smaller.

Standard [2] was not elaborated rationally. The determinations were not supported by experimental research of a bay, but just the reaction of the crane beam on the cranes. It should be advised to carry out some further experimental research in order to determine univocally the values of the horizontal forces. Little complex experimental research has been carried out so far on operating objects.

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ANALIZA OBCIĄŻEŃ I WYNIKÓW BADAŃ DOŚWIADCZALNYCH UKŁADÓW NOŚNYCH SUWNIC NATOROWYCH

S t r e s z c z e n i e

W artykule analizowano wpływ na konstrukcję wsporczą normowych zmian obciążeń dźwignicami. Wykazano, że obowiązujące warunki normowe ustalono na podstawie oddziaływania toru podsuwnicowego na suwnicę. Dźwignice obciążają obiekt budowlany, z tego względu zadanie należy odwrócić badając wpływ dźwignicy na konstrukcję budynku. Zgodnie z warunkami normy, poziome siły występujące podczas pracy suwnicy są związane z jej ukosowaniem i nie zależą od sił bezwładności. Opisane badania doświadczalne nie potwierdziły ukosowania dźwignicy a występujące siły są mniejsze od normowych.