International Journal of Engineering & Technology, 7 (3.2) (2018) 36-39

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper



Comparative Analysis of Loads from the Travelling Cranes of Different Producers

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Abstract

The comparative analysis of travelling cranes of national and foreign producers is given in the paper. The travelling cranes of concern Demag were taken into consideration among the foreign cranes. The operation conditions of cranes were analyzed according to different codes of practice. The geometrical parameters, load and weight characteristics of overhead cranes were also compared. For the calculation the horizontal and vertical loads of cranes the most unfavorable schemes of location of bridge cranes on the structures of a production building were defined. According to these schemes, the maximum loads on the frame of the building were calculated and the maximum efforts in the crane beams were determined. Using obtained internal efforts the cross sections of crane girders with a span of 6 and 12 m were calculated. The results of the comparison showed the advantages of the modern cranes in materials saving of steel structures of industrial buildings.

Keywords: *Overhead travelling cranes; operation conditions; crane loads; internal forces, crane girders; columns.*

1. Introduction

The use of overhead travelling cranes determines the efficiency of modern production, and the level of mechanization of technical production - the degree of excellence and productivity of the enterprise. Recently, enterprises of our country have started the use of modern crane equipment, including the company Demag, which is one of the largest German enterprises and has sales offices on all continents. Travelling cranes Demag are characterized by high technological and lightweight structures, which allows to reduce materials of load-bearing structures of buildings [16, 17].

2. Analysis of Recent Researches and Publications

The question of studying the nature of crane influences and the problems of normalizing the travelling cranes loads are covered in the works [1 – 5, 21]. Analysis of the values of crane loads regulated by various design requirements are considered in works [6 – 8, 19, 22]. The problems of buildings reliability with crane equipment are determined in [9, 16, 18, 20].

An overview of load-lifting facilities and crane-building history development of was carried out in [19], where the state of modern crane-building was highlighted. Detailed analysis of the weight characteristics of bridge cranes, regulated by the norms of GOST 3332-54, GOST 25711-83 and the cranes of the company Demag are shown in work [20]. The impact of light (load-carrying capacity up to 20 t) of bridge cranes on the construction of one-storey production buildings (OSPB) was analyzed in work [22], where national bridge cranes and foreign cranes were considered. In the given work, the impact of cranes was determined according to SNiP 2.01.07-85 [23], DBN V.1.2-2: 2006 [15] and Eurocode 1 [1]). It has been found that the use of advanced lighter modern cranes will reduce the load on transverse frames and crane tracks of industrial buildings and increase their efficiency.

3. Advantages of Modern Cranes

Experts of company Demag have developed innovative gear-reduction structures, which are characterized by ideally suited braking efforts for engines of all sizes and a high range of gear ratios. Special characteristics are not only motors, but also transducers. Dedrive frequency converters have a number of advantages in lifting, lowering, rotating and moving loads and are characterized by reliable operation with rapid change in load conditions and reliable braking with the help of the built in brake interrupt modulator.

Due to the improvement of the chassis, modern cranes are characterized by increased efficiency and operational readiness. Modern working wheels (fig. 1) of cranes made of high-strength alloy (with spheroidal graphite inlays) can withstand a heavy load and are characterized by low wear and require less power of the drive.

The main and most significant benefits of the Demag cranes are their small overall dimensions and simplicity of construction of bridge cranes. This opens the possibility of equipping buildings with new equipment with a higher load capacity in buildings with outdated crane equipment (in the presence of sufficient reserves of bearing structures). The current problem is the comparison of weight characteristics of cranes and loads from the influences of outdated cranes with the modern Demag cranes.

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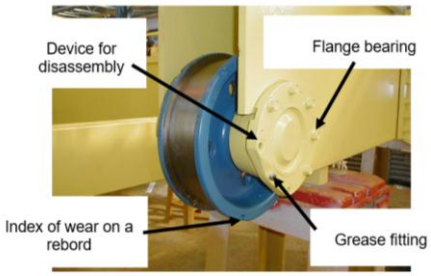


Fig. 1: Wheelpair design principle

3.1. Cranes Operation Modes

The operation mode is a complex characteristic that takes into account the nature of external loads and the duration of their operation and is regulated by different standards. In particular, for determining the operation mode of crane mechanisms, the norms [10, 11] are used. To a large extent, these standards are linked to the international standard [12]. Operating modes of foreign cranes regulate the document [1], which takes into account the following factors:

- mode of loading (the frequency of lifting loads with the maximum weight and light loads for a certain period of time);
- class of use (determined according to the number of lift cycles during the service life of a crane).

The approximate correspondence of groups of cranes and mechanisms operating modes, according to different standards is given in Table 1.

Table 1: Approximate correspondence of groups of operating modes of cranes and mechanisms

	Standard			
	ISO 4301	FEM 9.511	GOST 25835-83	GOST 6711-81
Crane mode	M2	1Cm	-	-
	M3	1Bm	1M	K3
	M4	1Am	2M	K4
	M5	2m	3M	K5
	M6	3m	4M	K6
	M7	4m	5M	K7

3.2. Weight Characteristics Comparison

In this work four-wheel bridge cranes with a carrying capacity of 32 t of average operation mode are considered. Parameters of national cranes are taken in accordance with GOST 25711-83 [15] and characteristics of bridge cranes ZKKE (Fig. 2) by the documentation given by Demag company.



Fig. 2: Demag travelling crane with a carrying capacity of 32 t

The comparison of geometric parameters showed that national cranes are much wider (by 1509 mm) than the foreign cranes and respectively heavier. The weight of national cranes by 55% exceeds the weight of foreign cranes, and the weight of trolleys by 195% (Table 2). The comparison of loads on crane wheels revealed that vertical loads from the influences of national cranes by 8,2% exceed the loads from the foreign cranes; horizontal loads predominates by 43%.

Table 2: Comparison of weight characteristics and loads of travelling cranes with a carrying capacity of 32 t

Weight characteristics				Load on the wheel, kN			
Weight of the crane, G_{cr}		Weight of crab, G_c		Vertical, F^n_{max}		Horizontal, H_k	
kN	%	kN	%	kN	%	kN	%
282,4 / 181,7	55,4	85,3 / 24,9	195	225 / 207,9	8,2	21,1 / 14,8	43
Note. The numerator indicates the value from the national cranes according to GOST 25711-83, in the denominator - the value from the Demag cranes, alongside - the difference in values in percent							

By reducing the overall dimensions of the cranes, foreign engineers managed to reduce dead weight of the construction of travelling cranes (Table 2). The weight of the crane bridge is 40600 kg, which is 146% less than the weight of the crane bridge according to the norms [13]. Significantly lower weight (up to 195%) have also crabs of foreign cranes.

4. Loads of Four-Wheel Travelling Cranes

In the paper, the influences of four-wheel travelling cranes with load carrying capacity from 10 to 32 t were analysed. For the comparison of the modern and national cranes, the cranes with the same span and carrying capacity were chosen [13] and the loads on the transverse frame (Fig. 3) and on the crane beams were calculated. The results are presented in Fig. 4.

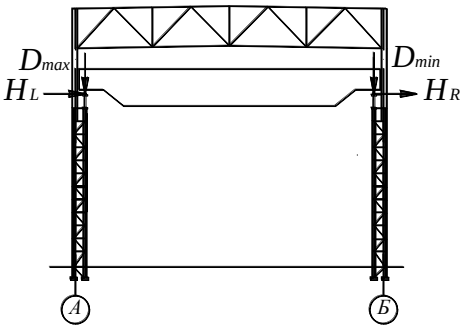


Fig.3: Application of crane loads on the transverse frame

It was determined that the maximum vertical loads on the column (D_{max}) of modern cranes are 1,1 ... 1,5 times smaller than the loads from the national cranes by [13] (Fig. 4). Minimum loads (D_{min}) are 1,1 ... 1,7 times smaller than the loads from cranes by GOST. The analysis of horizontal loads showed that the loads on the column of the transverse frame is 1,3 ... 2,2 times lower compared with the loads by GOST.

In order to calculate bending moments on OSPB structures, bridge cranes were placed in the most unfavorable way. Bending moments from vertical loads modern cranes were 1,1 ... 1,7 times less than the moments of cranes by [13], and 1,1 ... 1,8 times for the horizontal loads, respectively (Fig. 5).

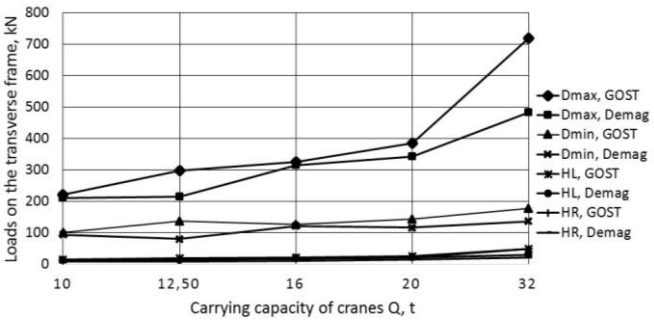


Fig. 4: Loads on the transverse frame of the building

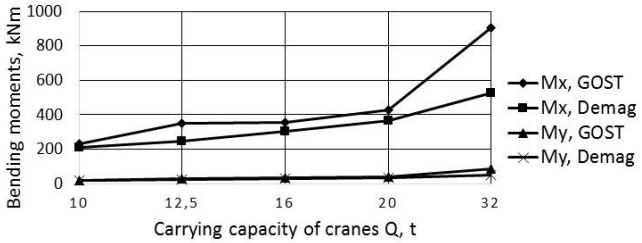


Fig. 5: Bending moments in crane girders with a span 6 m

The bending moments in the left column of the OSPB transverse frame from the loads of the foreign cranes were 1,1 ... 1,8 times smaller than the loads from the cranes according to GOST. The comparative analysis of loads and internal forces in OSPB structures from travelling cranes of different producers showed a significant reduction of the influences from the modern highly effective and technological travelling cranes compared to cranes according to GOST [13].

5. Loads of Multi-Wheel Travelling Cranes

A significant reduction in weight of travelling cranes has led to a decrease of loads on OSPB structures. To determine the load values it was necessary to conduct preliminary calculations. The value of vertical loads on the wheels of bridge cranes is regulated for the national cranes by a document [14], and for Demag cranes, values of loads are provided by the manufacturer. In particular, national norms specify the maximum vertical load on wheels F_1 and F_2, minimum loads are calculated by equation (2), while Demag gives load on a separate wheel on each side of the crane. The checking calculation of the vertical loads of the foreign cranes was carried out. As a result of the comparison of the given and calculated values we obtained significantly divergent results.

$$F_{\max} = \frac{G_M}{2} + \frac{(Q+G_B)*(L_{kr}-a)}{L_{kr}} * \frac{1}{n_0} =$$
$$= \frac{398,15}{2} + \frac{(784,53+109,98)*(22-2,4)}{22} * \frac{1}{4} = 249,0\ \kappa H, \quad (1)$$

were F_{max} – maximum vertical load per wheel;
G_{crab} – weight of crab;
G_{cr} – – weight of crane;
Q – lifting capacity of crane;
n_0 – number of wheels of the crane;
L_{cr} – crane span;
a – maximum closure of the crane hook to the column.

The maximum value of the vertical pressure F_{max} on wheel of foreign cranes is 272,2 *kN*, which exceeds the calculated value by 9,3%.

The minimum vertical load of the crane wheel was calculated in accordance with uniform distribution of the bridge weight between all wheels:

$$F_{\min} = (G_M + Q + G_B) * \frac{1}{n_0} =$$
$$= 398,15 + 784,53 + 109,98 * \frac{1}{4} = 74,2\ \kappa H. \quad (2)$$

The calculated minimum load of the crane wheel (F_{min} = 70,17 *kN*) may differ from the given value by 6%. Thus, it can be affirmed that in case the crane loads per wheel are not given, these loads could be calculated using equations (1), (2).

The comparison of the vertical loads F_{max} on the crane wheels showed that the loads on the wheel from the impact of the foreign cranes was 27% smaller than the impacts of national travelling cranes (Table 3).

Horizontal loads were calculated according to the codes [14]. The loads from the foreign cranes were 43% lower due to the light weight of this cranes. For multi-wheel cranes, this load is determined by the codes [14] as 0,1 from the vertical load on the wheel, calculated with a load equal to the passport capacity of the crane at the location of the trolley in the middle of the bridge.

Table 3: Loads of travelling cranes with a load capacity of 80/20 t

Load per wheel, kN				Load on frame, kN				
Vertical F_{max}		Horizontal $H_к$		Column spacing	Vertical D_{max}		Horizontal $H_к$	
kN	%	kN	%	m	kN	%	kN	%
347,0 / 272,3	27	21,1 / 14,8	43	6	963,1 / 805,6	20	56,0 / 4,3	27
				12	1689,0 / 1190,5	42	97,9 / 75,6	30

Note. The numerator has the value of weight characteristics and loads from national cranes according to the norms [14], in the denominator - the loads from the Demag cranes, alongside the difference of values in percent

The obtained values of bending moments (Table 4) from the vertical loads of the modern cranes are 20 - 29% lower than the bending moments from the cranes according to GOST [14], from the horizontal loads – by 21 - 37%. The transverse forces from the loads of the foreign cranes also have lower values in comparison with the national cranes, 32 - 38% from the vertical loads and 25 - 44%, respectively, from the horizontal ones.

On the received values of internal forces selected transversal sections of crane beams (Table 4) for OSPB with two variants of travelling cranes were calculated. The crane girders were designed in two variants, with spans 6 and 12 *m*.

Table 4: Design internal forces in crane girders

Girder span, m	M_x		M_y		Q_x		Q_y	
	kNm	%	kNm	%	kN	%	kN	%
6	860,3 / 666,9	29	51,8 / 37,8	37	719,3 / 543,8	32	39,7 / 31,7	25
12	2784,1 / 2338,0	19	173,8 / 145,0	20	1097,4 / 797,8	38	68,1 / 51,2	33

Note. The numerator indicates the value of internal forces from the loads of national cranes according to the norms [14], in the denominator - the value of internal forces from the loads of the Demag cranes, alongside - the difference in values in percent

The comparison of cross-sectional areas of the girders showed that with the installation of modern travelling cranes, it is possible to achieve savings in materials for the girder span of 6 m to 21% and up to 10% for 12 *m* span girders. A lower savings the steel was obtained for 12 *m* span girders due to the fact that all the wheels of the cranes are located on the girder in this case, as well as the necessity of adhering to the limit of flexibility of the girders.

6. Statistical Modelling of Vertical Loads

One of the most advanced approaches in the study of crane loads is the numerical statistical modelling. For the calculation of vertical loads of a travelling crane with a load capacity of 50/12,5 t, the program, created by prof. A.V. Perelmuter, was used [17]. This program deals with the random variables, such as weights of the lifted loads, the position of the cranes in the span of building and position of the trolleys on the cranes bridge.

The results of loads simulation are shown as a polygon of values which are normalized by the value of sum - $Q + G_{crane} + G_{crab}$.

The values of loads on the crane wheel were also calculated with different location of crane and different lifting weight (Fig. 6):

1 - crab without weight near the right range of columns;
2 - crab with weight near the right range;
3 - crab without weight, near the left range;
4 - crab with weight, crab located in the middle of span;
5 - crab with weight near the left range of columns, weight is equal to the average of carrying capacity Q_{av} (average value of carrying capacity);
6 - crab with a weight near the left range of columns, weight is equal to $Q_{av} + 2,5Q_{st}$ (Q_{st} – standard value of carrying capacity);
7 - crab with a weight near the left range of columns, weight is equal to $Q_{av} + 3,5Q_{st}$.

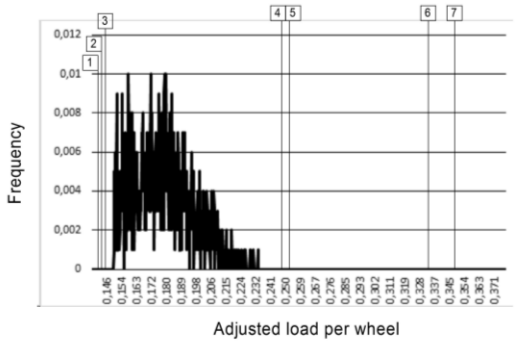


Fig. 6: Polygon of vertical loads per wheel

Most of the values of the polygon are located between the calculated values of the items 1 and 4 (Fig. 6). And the normative value of the vertical load, calculated according to the requirements of the norms [15] (item 5), is in the zero zone, i.e. is realizing rarely.

7. Conclusion

The comparison of the effects of travelling cranes on the OSPB design was performed. The analysis of the load and weight parameters of national cranes according to the norms [13, 14] and the international travelling cranes of the Demag concern showed high technology and advantages of light foreign cranes. The use of lightweight bridge cranes in existing buildings will allow the use of crane equipment with a higher load capacity. In the design of new buildings, the installation of foreign cranes will have economical effect from reducing the material content of bearing structures of industrial buildings.

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