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Statistical Research of Vibration Road Rollers and Perforated Operating Devices

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Abstract: The vibration road rollers belong to the machines used in rolling the road base both at the initial and at the final stage of the sealing process. World manufacturers constantly improve their products, renewing up to 30% of the manufactured equipment. New items are aimed at improving functional and technological parameters, allowing to raise the productivity and quality with account to scientific developments. Today the road sector needs the road roller able to implement the multiplicative effect, provide the "intellectual" compaction with quality control in real-time. By now over 600 models that differ both in their major parameter (weight) and in design have been created. Such an abundance represents a significant statistical material that is used to determine the dependencies between the parameters of road rollers in the form of regression equations with the correlation estimate. The new comparative evaluation is offered – the sealing capacity indicator (SCI), allowing to evaluate the ability of compaction of road concrete mixes by road rollers. The effectiveness of using the road roller with the new type of operating device – perforated rollers allowing to automatically change the amount of contact pressure and able to operate at all stages of the compaction process was found out.

Key words: Road roller · Sealing · Road concrete mix · Vibration · Perforated operating devices

INTRODUCTION

The basic characteristics of the quality of roads are durability, covering density, surface evenness, ability to adhere to car wheels. To provide the required parameters is possible only if the technology of the compaction work is strictly observed, the choice of the components of road concrete mix is correct and there is a selection of the necessary compaction equipment. At present there are a lot of different means of sealing bases and coatings. These are traditional static and vibration road rollers with smooth drums, road rollers with pneumatic tires, combined road rollers, rammers etc [1]. Preliminary sealing of asphalt concrete coatings is produced with operating devices (vibrating screed) of pavers [2].

The most progressive vibration road rollers do not fully correspond to the requirements of the road practice. But they have potential possibilities and ways for functional and technological improvement due to of the intellectual regulation of sealing force effects and the creation of more universal models [3].

MATERIALS AND METHODS

Over the past few years the views on the construction and the parameters of road vehicles slightly changed. This particularly refers to the vibration road rollers. Considering previous research one can not only get quantitative characteristics of the technical parameters, but also some of the trends in their development. Thus, the question of the maximum weight seems very interesting. Previously it has been found out that the weight of vibration road rollers grows rather significantly, that indicates the revision of the picture about the real seal capacity. However, despite a number of studies in this area, the given question is not fully explored. The comparison of the most heavy road rollers of static action and vibration road rollers may give the answer about their equivalent weights. The vibration tandem road rollers that were run by the walking operator (with the weight of up to 1.4 tons) and combined rollers were studied. The analysis was conducted with the help of "EXCEL" spreadsheets. The following types were chosen for the regression equations:

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$$y = ax^2 + bx + c \quad (1)$$

Technical parameters of road construction machinery can be described by statistical models. The processing of this information allows to get pair correlation models, the formulas where the most different parameters are expressed through one, the major one. Such models accumulate considerable engineering experience and provide the storage of large arrays of information in a compact form. It considerably increases their processing, excludes the necessity to store and to process excessive information, raises the objectivity and the quality of the data processing, levels rude subjective mistakes in assigning parameters of the vehicles, represents a form of information filtration, creates the base for the evaluation of the technical level of vehicles, is the initial material for system optimization. For the criteria of the connection between the parameters of the machines the value of the correlation coefficient (R) is usually taken. The statistical analysis even in the absence of the correlation between the parameters of machines gives the possibility by means of building cumulants, the functions of the density of distribution to develop the recommendations for choosing the most probable meanings of the parameters. It is considered that the factual values of the parameters are satisfactory in correlation fields with the average deviation of ±10…±15 % (between ±5 and ±30 %). The fact should be underlined that in all the statistical studies conducted earlier there was no attempt of collective analysis of all types of road rollers as vehicles, the result of which is obtaining the same end product.

Main Part: As a rule, the major parameter of road rollers is considered to be their weight. However, this parameter does not fully characterize the main characteristic of the road roller – its sealing capacity because the geometrical parameters of drums are not taken into consideration. The following parameters of road rollers may be considered derived:

- The diameter (D) and the width of the rolls (B);
- The relative perturbing power (P/Q) and the frequency (f) of vibrations of the vibration road rollers. P is perturbing power, Q is the weight of the road roller;
- The power-plant capacity (N).

For a more complete assessment of road rollers it is offered to implement one more major parameter that gives a comparative assessment of the sealing capacity of road rollers – the indicator of sealing capacity (SCI). It is clear that it should be derived from the joint combination of such parameters as the weight of the road roller, the width and the diameters of the drums. The equation obtained from the formula for determining the contact pressure, offered by N.Y. Haruta [4].

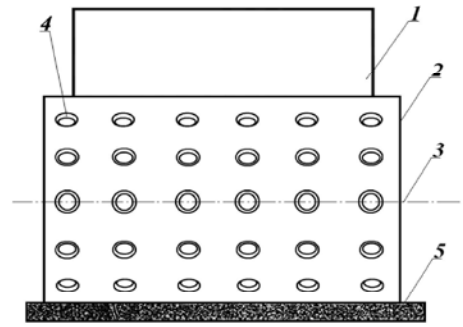

Fig. 1: The perforated drum of the road roller: \
1- frame, 2- drum, 3 – through openings, 4- compacted mixture

$$\mathrm{SCI} = \sqrt{\frac{q}{R}} \quad (2)$$

where q is the linear pressure of the roller i.e. the ratio of the weight Q per the roller to its width B; R is the radius of the roller. As stated above, at present the major type of machines for the compaction of asphalt concrete coatings are the vibration road rollers. They should be divided into three types:

- Road rollers run by the walking operator;
- Tandem road rollers;
- Combined road rollers.

According to this classification the statistical processing of the parameters of road rollers was made. The results of the statistical analysis are presented in Table 1.

The assessment criteria are the value of the correlation coefficient R. In itself the value of the correlation coefficient (between -1.0 and 1.0) does not give a possibility to say that in some part of this range the correlation model can be evaluated from excellent to unsatisfactory. One can only mention the connection between the parameters while comparing machines of the same purpose of use, but different in the main parameter or in the structural characteristics. This table does not show the dependence of this indicator from the weight of the road rollers presented by the graphs in Fig. 2, 3, 4. In these graphs the dependence of the SCI for road rollers with so called perforated drums are presented, Fig. 1.

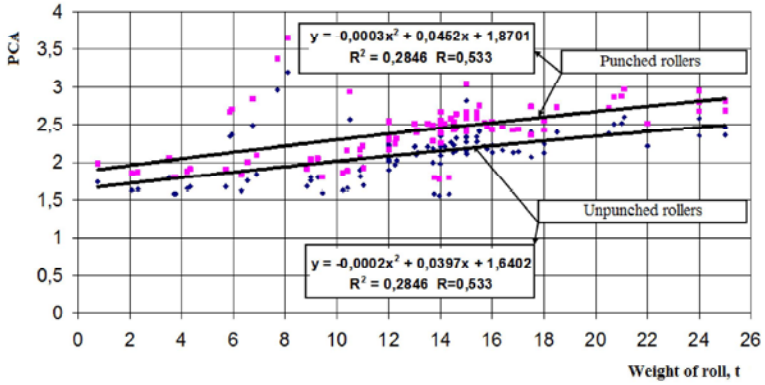

Fig. 2: The dependence of the SCI from the weights of the combined road rollers

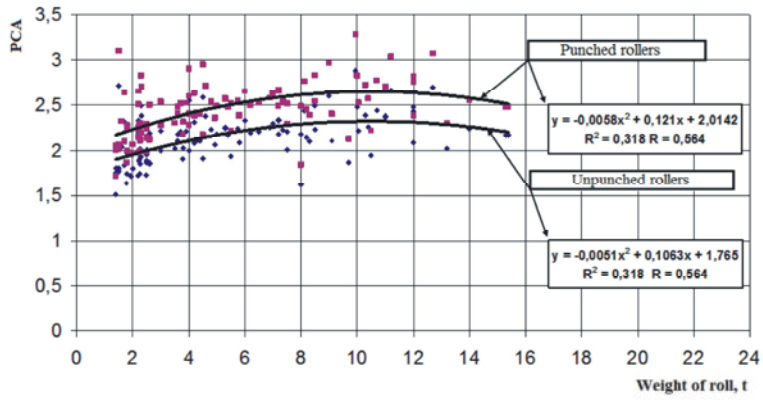

Fig. 3: The dependence of the SCI from the weights of tandem road rollers

Table 1: The results of statistical processing of main parameters of vibration road rollers

The type of road rollers	The regression equation	Sample amount	The coeffi-cient of correla-tion	The average value of the parameters		The dimensionality of parameters	
				Main	Studied	Main	Studied
Run by the walking operator	$P/Q = -1{,}91Q^2 + 3{,}3Q + 1{,}44$	94	0,192	0,93	2,67	-	-
	$D = 271Q^2 - 273{,}4Q + 599$	102	0,454	0,85	592	mm	mm
	$B = 74{,}6Q^2 - 104{,}5Q + 680$	74	0,108	0,9	655	mm	mm
	$N = -3{,}29Q^2 + 14Q - 1{,}3$	171	0,665	0,88	8,1	l/s.	l/s
	$F = 21{,}3Q^2 - 53{,}6Q + 84$	128	0,387	0,89	55	Hz	Hz
Tandem	$P/Q = 0{,}0082Q^2 - 0{,}115Q + 1{,}5$	96	0,218	5,57	1,23	-	-
	$D = -2{,}08Q^2 + 97{,}9 + 520$	155	0,827	5,33	957	mm	mm
	$B = -2{,}08Q^2 + 119{,}7Q + 518$	142	0,771	5,73	1101	mm	mm
	$N = -0{,}103Q^2 + 10{,}5Q - 7{,}1$	268	0,851	5,99	50	l/s	l/s
	$F = 0{,}02Q^2 - 1{,}65Q + 54$	203	0,423	5,4	46	Hz	Hz
Combined	$P/Q = 0{,}0005Q^2 - 0{,}03Q + 2{,}1$	111	0,178	9,75	1,78	-	-
	$D = -3{,}54Q^2 + 123Q + 580$	125	0,878	9,83	1380	mm	mm
	$B = -2{,}31Q^2 + 110Q + 904$	70	0,647	9,8	1715	mm	mm
	$N = -0{,}17Q^2 + 11Q + 12$	190	0,769	10,2	100	l/s	l/s
	$F = 0{,}02Q^2 - 1{,}1Q + 43$	131	0,299	9,53	35	Hz	Hz

By the latter we understand the drums with openings on the contact surface that form a special curvilinear shape [5].

It draws attention that the SCI for combined road rollers with perforated drums from 4 tons and more increases in comparison with this indicator in usual road rollers with the weight of more than 10 tons.

For tandem road rollers the SCI of the perforated road rollers is actually higher in the range of road rollers weight change. This shows the possibility of creation a universal road roller that will have the required value of the SCI at any stage of the sealing process. The effect from the use of the perforated drums will be even greater in road rollers run by the walking operator (Fig.4).

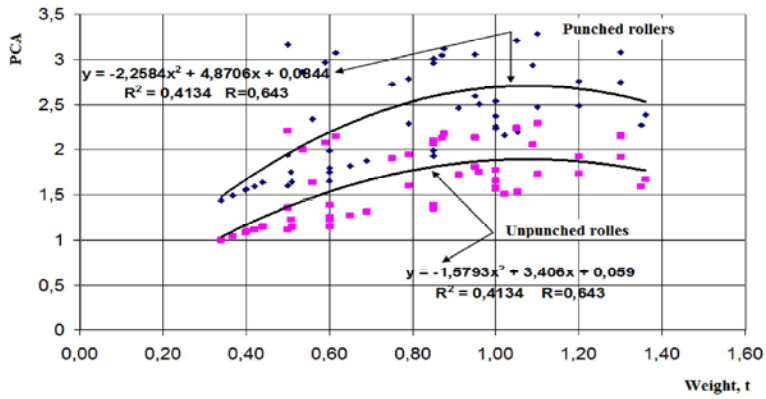

Fig. 4: The dependence of the SCI from the weights of road rollers run by the walking operator

A more detailed analysis of the obtained graphs should be made taking into account the new type of the drums. First thing that should be noted is a very slow growth of the SCI. Consequently, the considerable growth of the road roller weight does not lead to the growth of the SCI up to necessary or required. This happens as a result of the automatic growth of the geometric parameters of road rollers when the weight of road rollers increases.

It is necessary to note the following pattern. The more the weight of the road rollers is the less is the ratio of the SCI of the perforated road rollers to the SCI of the road rollers with smooth drums. Thus, the combined road roller weighing 25 tons can be replaced with the road roller with perforated drums weighing 15 tons, the relative effect – 25/15=1.67. The road roller weighing 20 tons corresponds to the perforated one weighing 10 tons with the effect of 20/10=5.

CONCLUSION

The conducted statistical research also showed the following facts. During the last 15-20 years the number of models of the vibration road rollers grew approximately by 150. The average weight of the road rollers grew by 1.5-2.0 tons. The emergence of the new models of the static road rollers reduced. This shows that at present the major type of the road roller is the vibration road roller. The conclusion about the amount of the upper value of the SCI that corresponds to the static road rollers with three drums weighing 14 tons is important. The calculations of the value of the SCI for heavier road rollers (15-18 tons) showed that they are worse in their sealing capacity. It is explained mainly by their structural design. It is also found out that the SCI of the vibration road rollers is lower than the SCI of the static road rollers for the road rollers weighing 10-12 tons, by the difference of these indicators one can determine their equivalent weights. The studies showed tendencies in the development of the road rollers design. The biggest changes in this respect have the vibration road rollers [6]. If the emergence of new models of the static road rollers is connected with the modernization of the previous models, the emergence of a large number of new models of the vibration road rollers can be explained both by their modernization and by their significant change in design [7]. For example, it was found out that in the latest models of the vibration road rollers, as a rule, both drums are vibration and leading. The vibration road rollers have the mechanisms of the smooth regulation of the perturbing force and the latest models are equipped with devices for quick reduction of the perturbing force of the vibrator for the moment of the movement reversion of the road roller. Practically all the models are equipped with hydraulic drive with hydraulic actuators of the control system. Fully hydroficated road rollers start with the weight of approximately 1.5 tons.

Initially, the introduction of the vibration road rollers was connected with the possibility to considerably reduce the weight of the compaction equipment. It was considered that the sealing force equaled the sum of the forces of gravity and the perturbing force of the vibration generator (the vibrator). That is why it was planned to create road rollers that would be light enough, approximately 2-4 tons with the corresponding compensation of the sealing force due to vibration. However, the tests of such road rollers and their use showed that only due to vibration it is not possible to raise the sealing capacity. It is necessary to optimally combine the parameters of the vibration and the weight of the road roller. Later, the increase in the weight of the vibration road rollers started with simultaneous research of the influence of different parameters of vibration on the sealing capacity of road rollers.

The German company Hamm in the creation of their vibration road rollers is guided by the recommendations of Hijboer, a famous expert. He calculated that in case of the dynamic compaction of asphalt concrete coatings the static coefficient of the vibration road roller should not exceed 0.25 kg/cm2 [8]. In Russia only first steps are made in the implementation of the "intellectual" vibration road roller on the base of DU-111.

CONCLUSIONS

As a result of the conducted work the following conclusions can be made. The increase in the sealing capacity of road rollers of any type is connected not with the increase in their weight but with different factors. Thus, the increase of the diameter of drums leads to the increase in the line of contact and consequently to the increase of the time of action of the sealing load. Along with positive qualities of the vibration road rollers the negative ones were discovered [9]. Thus, the reducing of the traction coefficient of the vibration drums with compacted surface can be considered a very serious drawback because it influenced negatively the handling and stability on slopes. There is also the impossibility of applying vibration in building bridges.

The selection of the vibration road rollers should be made according to their sealing capacity, that should correspond to the thickness of the layer, the type of asphalt concrete mixture and that should ensure the required quality of sealing [10]. Further development of technology is aimed at raising the effectiveness of the operating devices of road machines on the base of using scientific advances, technology and advanced experience.

The above analysis shows the possibility of creation of universal road rollers for the compaction of road concrete mixes, the situations appear that allow to apply vibration under mild conditions considerably reducing the complexity and the cost of these machines.

REFERENCES

1. Malutin, L., 2013. Roll to the Fullest. Road Rollers. Fixed Assets, pp: 6.
2. Ivanchenko, S.N., 1997. Scientific Basis for the Formation of Operating Devices of Road Machines for Compacting Asphalt Mixtures, PhD thesis, St. Petersburg.
3. Kostelyov, M.P., 2003. The Compaction of Asphalt Requires the Renewed Generation of Rollers. Road Equipment, pp: 12-22.
4. Harhuta, N., 1973. Machines for Soil Compaction. Mechanical Engineering, pp: 474.
5. Bykanova, A.Y. and S.M. Ugai, 2010. Patent RU 2390599 C1. The Drum of the Road Roller. Application 2009114626/03, 17.04.2009, Bull. # 15.
6. Beletsky, B.F. and I.G. Bulgakova, 2005. Construction Machinery and Equipment. Phoenix, pp: 608.
7. Yoo, T.S. and V.A. Diyaljee, 1980. Dynamics of Vibratory Roller Compaction. International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts, 17(2): 37.
8. Hamm, A.G., 2008. Compaction in Asphalt Construction and Earthworks. Tirschenreuth, pp: 142.
9. Hata, S. and K. Tateyama, 1987. Relationship between Vibratory Roller Compaction and Indoor Impact Compaction Test. Journal of Terramechanics, 24(1): 119-120.
10. Powell, W.D. and D. Leach, 1984. Transport and Road Research Laboratory report, LR 1102. International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts, 21(4): 155.