The process of laboratory tests of the sleeper

For testing the reinforced concrete sleepers the pendulum impact machine with experimental striker was used (Photo 1). The experimental striker is made of standard striker of the given impact machine. The part of the railway wheel was attached to the striker in such a way that when one installs it in the impact machine, the sleeper would impacted by the tip of the wheel flange.

Ten test samples were cut for research from the middle part of reinforced concrete sleepers of the type SH-1-1. The samples were installed in the impact machine so that the direction of the impact of striker coincided with the direction of railway wheel impact when moving along the track panel.

Each sample was tested three times – from the lift height of the mass center of the striker over the impact site 0.36; 0.93; 1.52 m. The striker with the weight 500 N developed the energy 180; 465; 720 J correspondingly.

As a result of the impact there remained the characteristic marks on the sleeper, with a certain depth in the direction of the impact h_c, length along the edge of the sleeper l_c, the maximum width along the upper and lateral b_c edges of the sleeper and the volume of material that was broken off V_c (Photo 2).

Using the developed software, the mentioned parameters of the mark were determined automatically. The obtained value of linear parameters (h_c, l_c, a_c, b_c) were tested by measuring with caliper. The software calculation of the volume was tested as follows: each site of the impact was filled with plastic material, it was reproduced the sleeper form and the plastic material after separation from the sleeper was placed in a graduated cylinder filled with water.

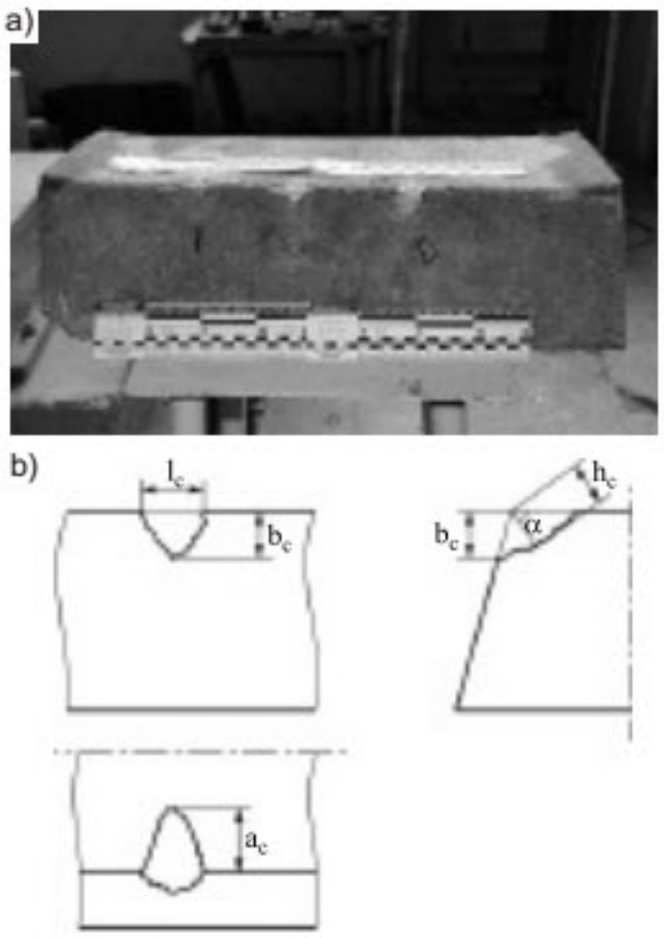

Photo 2. Impact marks (a) and their parameters (b)
Fot. 2. Ślady uderzeń (a) i ich parametry (b)

Laboratory tests of mechanical properties of building materials are a classic case of discrete random variable, which is subjected to the normal law of distribution [5, 6]. In this regard, the experimental data are tested for the conformity to normal law of distribution by the Pearson criterion.

The results of the parameters check h_c, l_c, a_c, b_c, V_c for the conformity to the normal law of distribution are summarized in the Table. The same Table presents the results of calculation of the energy absorbed by the sleeper and the average value of the parameter $\overline{y}$. In the Table the values χ^2 for the significance level 0.9 and more are shown in bold.

Summary results of the parameters inspection for compliance with the normal distribution law
Podsumowanie wyników badania w zgodności z prawem rozkładu normalnego

Parameter	H	E	$y \cdot 10^{-3}$	χ^2
h_c	0,36	180	7,72	**0,196**
	0,93	465	10,61	**0,117**
	1,52	760	12,99	**0,196**
l_c	0,36	180	34,73	**0,044**
	0,93	465	51,01	**0,177**
	1,52	760	55,91	**0,148**
a_c	0,36	180	18,85	0,474
	0,93	465	30,44	0,392
	1,52	760	37,65	**0,165**
b_c	0,36	180	26,59	0,403
	0,93	465	28,25	0,355
	1,52	760	33,48	0,227
V_c	0,36	180	2,87	**0,148**
	0,93	465	6,31	0,408
	1,52	760	9,54	0,823

As it is shown in the Table, for the parameter h_c (the depth of the mark in the direction of impact) and the parameter l_c (the length of the mark along the edge of the sleeper) the check for normal law of distribution is carried out at the level of significance 0.9 for all values of the energy absorbed by the sleeper. Therefore, these parameters should be taken as signs in determining the value of the energy absorbed by the sleeper.

Conclusions

The device and methodology of the mark measurements left by the railway wheel flange during the impact with sleeper were developed in the research. It was carried out the experiment, in which the sleeper was subjected to impact loading equivalent to the loading, which affects the sleeper when the derailed railway wheel is moving along the track panel. With the developed device, the algorithm and software the impact mark parameters were measured. The measurement results are checked by traditional measuring tools.

During the research statistical processing of the measurement results of geometric parameters of the mark and their check for compliance with the normal law of distribution were conducted. It was found that the distribution of values of the mark depth measured in the direction of the impact h_c and the width of the mark a long the edge of the sleeper l_c corresponds to the normal law of distribution with a significance level $\alpha > 0.9$. As the evaluation criterion of the energy value absorbed by the sleeper it is recommended to use the parameter h_c as that with the smaller variation of values.

The directions for future research include improving the device design to make it possible to use it for the measurements directly on the railway track.

References

[1] Bodnar B., Ya. Bolzhelarskyi, I. Laushnyk. 2016. „Mathematical model of the derailed train wheel motion". VIII International Conference. *Transport Problems* pp. 60-69. [in English].

[2] Bolzhelarskyi Ya. V. 2016. „Nablyzhene vyznachennia dodatkovoho oporu rukhu poizda v avariinomu rezhymi. konferentsii" *Problemy mekhaniky zaliznychnoho transportu*. [Approximate determination of the additional train movement resistance in the emergency mode. Conference „Problems of Railway Transport Mechanics"]. Dnipropetrovsk, pp. 24-25. [in Ukrainian].

[3] Esmaeili M., S. A. S. Hosseini, M. Sharavi. 2016. Experimental assessment of dynamic lateral resistance of railwayconcrete sleeper. *Soil Dynamics and Earthquake Engineering* 82: 40-45. [in English].

[4] Kaewunruen S., A. M. Remennikov. 2011. „Experiments into impact behaviour of railway prestressedconcrete sleepers". *Engineering Failure Analysis* 18: 2305-2315. [in English].

[5] Luchko Y. Y., Ye. H. Ivanyk. 2010. *Systemnyi analiz protsedury obroblennia eksperymentalnykh danykh vyprobuvan mashynobudivnykh ta budivelnykh materialiv i konstruktsii* [System analysis of processing procedure for experimental data of testing the engineering and building materials and structures]. Kameniar. Lviv. [in Ukrainian].

[6] Luchko Y. Y., O. S. Raspopov. 2014. Budivelna mekhanika sterzhnevykh system [Structural mechanics of bar systems]. Kameniar. Lviv. [in Ukrainian].

[7] Sokol E. N. 2007. *Krusheniya zheleznodorozhnykh poyezdov (Sudebnaya ekspertiza. Elementy teorii i praktiki)* [Train accidents (Forensic Science. Elements of theory and practice)]. Kyiv: Feniks. [in Russian].

Przyjęto do druku: 27.09.2016 r.