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УДОСКОНАЛЕННЯ ГЕОДЕЗИЧНИХ МЕТОДІВ ОЦІНЮВАННЯ НЕРІВНОСТЕЙ ОСНОВИ І ПОКРИТТЯ ДОРОЖНЬОГО ОДЯГУ

IMPROVEMENT OF GEODESIC METHODS FOR ROUGHNESS ASSESSMENT OF THE BASE AND PAVEMENT STRUCTURE

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Abstract. The article is about the results of the research and development work of highways and airfields laboratory of the National Transport University, namely the development of an experimental sample of a microleveler for evaluating the unroughness of the base and road surface on the basis of an already existing device for measuring the rutting (transverse roughness) of the road surface.

The general appearance, main technical characteristics and the algorithm for working with the device are given. The performance of the device was tested by conducting control measurements in parallel with a level of a traditional design on the surface of an asphalt concrete pavement under natural conditions.

On the territory of the National Transport University, a series of experimental studies was carried out using known measures of length, accepted as reference ones.

Further research and implementation of the device described in the article into the practice of the road industry in Ukraine will make it possible to quickly monitor the construction and repair of road surfaces and coatings and to make corrections in technological processes, to purposefully manage quality, to assess the condition of road surfaces and coatings that are in operation, and to identify local sections of roads with unsatisfactory levelness, which in turn will contribute to the reduction of road accidents associated with unsatisfactory road conditions.

At the same time, it is expected that the cost of a domestic microleveler for evaluating the unroughness of the base and covering of road clothing may be several dozen times lower, compared to foreign analogues, under the condition of mass production.

Keywords: road structure, roughness of road surfaces, longitudinal equality, transverse equality, geometric leveling, microleveling, International Roughness Index IRI.

Introduction. The issue of improvement and development of means for evaluating the transport and operational indicators of road structures has always been and is relevant and extremely important for the road industry of Ukraine.

The accuracy and objectivity of the assessment of the operational state of road structures makes it possible to timely identify sections of roads with insufficient strength and take measures to strengthen them, which contributes to the improvement of the transport and operational state of highways.

At the same time, a detailed analysis of the state of the problem of determining the operational properties of road surfaces and deformation characteristics of road structures in different countries of the world showed that one of the main indicators characterizing the quality of the road structure is also equality.

There are about 50 fundamentally different designs of devices for assessing the uniformity of coatings and several hundred of their various modifications. There are much fewer equality assessment methods.

Materials and methods.

A group of American scientists from the University of Michigan, which included: Michelle Sayers, Steven Karamigas, etc., based on the results of the review, suggested dividing the existing devices for assessing the uniformity of coatings into 4 classes according to the methods underlying them.

According to the international classification, methods (equipment) for assessing equality are divided into 4 classes. In contrast to our standards, the fourth class is present abroad - equipment for expert and visual evaluation of equality.

Analysis of domestic and foreign experience of equality assessment shows that the highest quality equality assessment can be obtained only with the help of methods (equipment) of the 1st and 2nd classes.

Large-scale studies conducted in the 80s of the 20th century conclusively proved the inability of traditional methods and devices (which mostly belong to the 3rd and 4th classes) to qualitatively assess the roughness of road surfaces.

Based on the analysis of scientific and technical sources, it was established that the most reproducible are the data of profilometers, which use the principle of scanning the surface of the road surface using mainly ultrasonic and laser systems. Therefore, they received further development all over the world. But the main drawback of this equipment is its extremely high cost.

Therefore, in the road industry, more accessible, albeit less productive, methods of assessing equality continue to be widely used to this day, including geodesic. Along with the traditional geodetic methods of measuring the unroughness of the base and road surfaces, such as geometric (technical) or trigonometric leveling, it is also possible to use such a specific method as microleveling.

Microleveling is widely used in the installation and calibration of technological equipment. But its use is justified only when the distance between control points is within 1 m. For example, to monitor the stability of beams, trusses, foundations, technological equipment. This method is characterized by simplicity and high accuracy of measurements.

The electronic microleveler Dipstick-2000 (Fig. 1), developed by Face Construction Technologies, USA, is known in the world for assessing the roughness of concrete floors [1].

Figure 1 – Microleveler Dipstick-2000
Рисунок 1 – Мікронівелір Dipstick-2000

The Dipstick-2000 microleveler consists of a DS 2000 measuring unit, a Palmtop HP200LX computer for recording and storing measurement data, a long handle with a bracket for attaching a computer, power cells inside and a handle for convenient repositioning of the device [2].

The handle is rigidly fixed with the measuring block, which is mounted on the surface with the help of two supports. The Dipstick-2000 kit includes two pairs of supports. One pair has a larger contact area with the surface and is used for coatings with high roughness (asphalt concrete, cement concrete). The other has the shape of a needle and is used with smooth surfaces (metal, tiles). The distance between the supports can vary, but is usually 305 mm [2].

The technical characteristics of the device are given in the table 1.

Table 1 – The main technical characteristics of the microleveler Dipstick-2000 [2]
Таблиця 1 – Умови проведення лабораторних випробувань [2]

Name	Value
Distance between supports, mm	variable
Measurement range of excesses, mm	± 80
Permissible zero setting error, mm	± 0,1
Permissible error of measuring the excess at the station, mm	± 0,1
Permissible measurement error of excesses of the leveling stroke, mm	$\pm (0,1 + 0,2 \times 10^{-4} \times D)$ where D – the length of the leveling stroke
Nutrition	Ni-Ca battery
The term of work, hours, not less	10
Overall dimensions, mm	560 × 350 × 990
Weight, kg	10,9

The essence of the measurements is as follows. With the help of a precision electronic accelerometer installed in the measuring unit, the angle of inclination of the device is fixed. The distance between the supports is known and constant. Using these data, the computer of the device calculates the excess between the supports of the microleveler (Fig. 2).

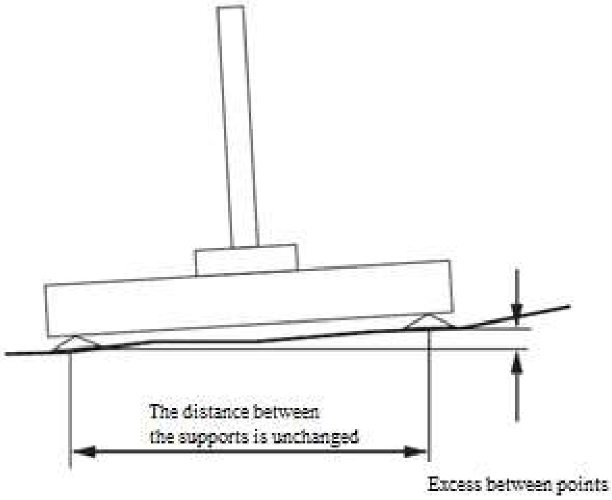

Figure 2 – The essence of measurement using a microleveler Dipstick-2000
Рисунок 2 – Сутність вимірювання за допомогою мікронівеліра Dipstick-2000

The measurement takes place as follows. First, the profile marking is performed, along which the survey of elevation marks of the pavement will be carried out, and data about the work site is entered into the computer. Next, the performer moves the device along the measured line so that one of the two supports remains stationary, while the other describes an arc of 180° and is set on the measured profile (Fig. 3).

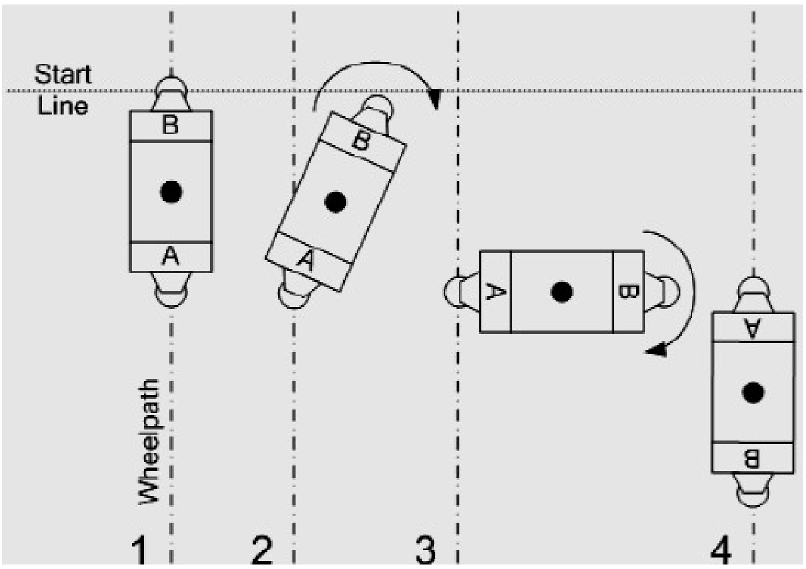

Figure 3 – The process of measurement using a microleveler Dipstick-2000
Рисунок 3 – Процес вимірювання із використанням мікронівеліра Dipstick-2000

After the system has stabilized, the device records the data and calculates the excess between the points above which the supports are located.

According to [2], 12 to 15 hours of continuous work is spent when measuring a longitudinal profile 2,500 m long with a survey step of 0.5 m with a Dipstick-2000 microleveler.

Later, a newer device Z-250 Reference Profiler was developed by the ROMDAS company in New Zealand for high-precision measurement of longitudinal profiles [3].

The raw data can be automatically processed by the Z-250 (Fig. 4) to calculate the International Identity Index (IRI) or further analyzed using standard, freely available software such as ProVal.


Figure 4 – Z-250 Reference Profiler
Рисунок 4 – Z-250 Reference Profiler

Z-250 can be used for:

– calibration or testing of other devices for measuring the roughness of coatings;
– monitoring the condition of roads, highways, bridges, etc.;
– data collection for accurate identification of vulnerable places on the coating;
– data collection for research purposes.

The Z-250 consists of two main components: a measuring unit and a portable computer that functions as a data logger. The measuring unit contains a battery, an accurate inclinometer and a power circuit. Detailed technical characteristics of the Z-250 are given in the table 2.

Table 2 –The main technical characteristics of the microleveler Z-250 [3]
Таблиця 2 – Основні технічні характеристики мікронівеліра Z-250 [3]

Name	Value
Accuracy class	1st class of accuracy of devices for measuring surface irregularities
The distance between the supports	250 mm
Measurement method	high-precision inclinometer
Permissible error of measuring the excess at the station	0,05 mm
Battery life	14 hours (continuous measurements)
Overall dimensions	250 mm × 80 mm × 140 mm
Mass	3 – 5 kg without battery

The principle of measurement in Z-250 is the same as in Dipstick-2000. During shooting, the Z-250 displays the distance traveled and the current height (in mm). After passing 30 m, the device will additionally display the IRI value in real time. After the measurement is completed, the final IRI value is displayed on the screen. The user also has the opportunity to build a coverage profile (Fig. 5).

Figure 5 – Display of measurement results on a PC
Рисунок 5 – Відображення результатів вимірювання на ПК

For each measurement, two files with extensions are created:

- .txt – a text file containing 3 columns: distance, coverage elevations, and summary or longitudinal profile data;
- .erd – the .ERD file can be imported into software such as ProVal or RoadRuf for further analysis of road profiles.

The advantages of Z-250 are:

- registration of roughness and longitudinal profiles of the coating with high accuracy;
- free data formats;
- connection to the data logger via Bluetooth connection;
- intuitive and convenient interface.

Results. On the basis of the device for measuring the rutting of the road surface [4-8] in the laboratory of highways and airfields of the National Transport University, an experimental sample of the device was developed, similar in principle to the Dipstick-2000 microleveler (Fig. 6).

Figure 6 – Microleveler based on the NTU laser profilograph
Рисунок 6 – Мікронівелір на базі лазерного профілографа НТУ

The device is a metal frame on two hinged supports with a platform attached to it, on which the measuring carriage of the laser profilograph is installed. The distance between the supports is 500 mm. The angle of inclination is measured using a laser sensor installed in the profilograph carriage. The measurement procedure is the same as when using Dipstick-2000. The difference is that the values of the angle of inclination are recorded manually by the operator. To do this, you need to go to the «Displays of sensors» item in the main menu of the profilograph and find the line «Inclination».

In order to check the performance of the experimental sample of the device, a number of control measurements were carried out in parallel with the measurements using a leveler of a traditional design.

The research was conducted on the surface of the asphalt concrete pavement under natural conditions on the territory of the National Transport University (Fig. 7).

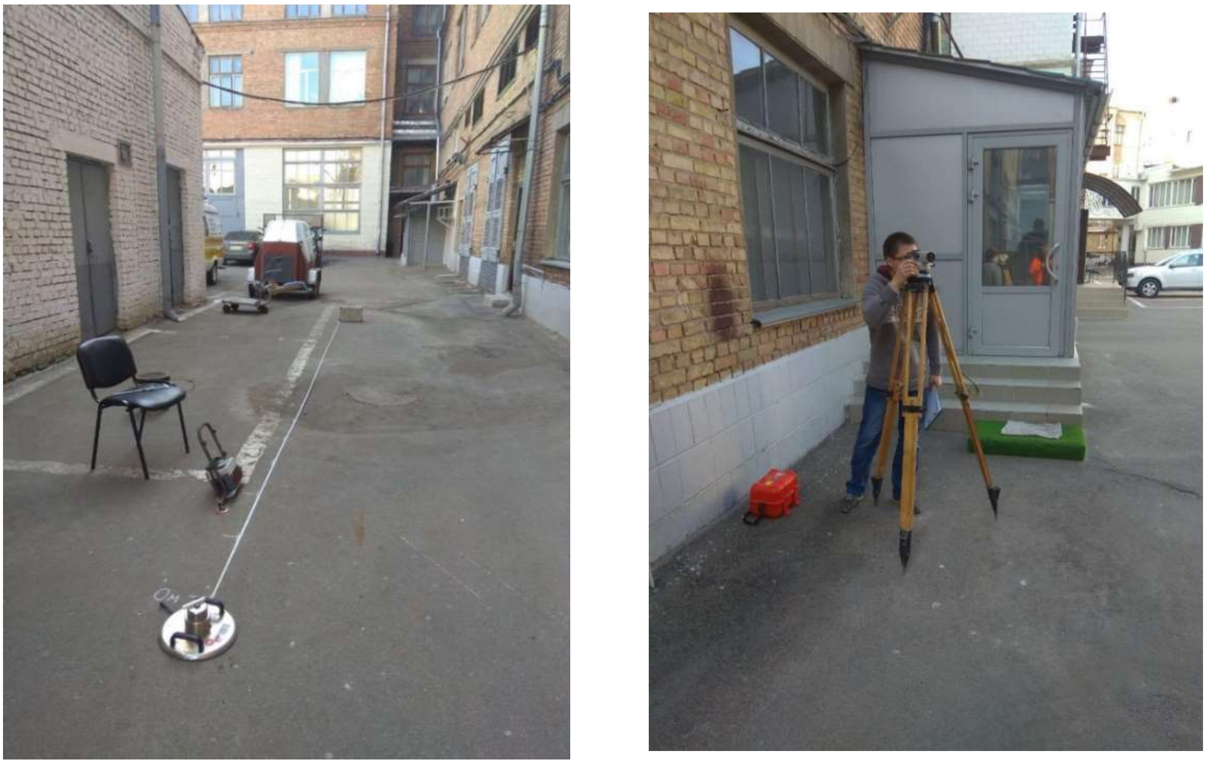

Figure 7 – The process of conducting experimental research in natural conditions
Рисунок 7 – Процес проведення експериментальних досліджень у натурних умовах

A marking was made along the line of the measured profile using a measuring tape. The leveling rail was placed on the heels of the microleveler at each measurement. The obtained results are shown in the table 3.

Table 3 – Measurement results
Таблиця 3 – Результати вимірювань

<table>
<tr><th rowspan="2">Picket</th><th colspan="2">Readout</th><th colspan="2">Excess, mm</th></tr>
<tr><th>Level, mm</th><th>Microleveler, degree</th><th>Level</th><th>Microleveler</th></tr>
<tr><td>0</td><td>4695</td><td rowspan="2">+ 0,334</td><td rowspan="2">+ 3</td><td rowspan="2">+ 2,91</td></tr>
<tr><td>0,5</td><td>4698</td></tr>
<tr><td>1,0</td><td>4700</td><td>+ 0,340</td><td>+ 2</td><td>+ 2,97</td></tr>
</table>

The excess on the microleveler was found by the following formula:

$$h = l \cdot \sin i \tag{1}$$

where *i* – tilt angle;
h – sought excess;
l – distance between points.

Since the distance between the supports of the microleveler is known (500 mm), formula (1) takes the form:

$$h = 500 \cdot \sin i \tag{2}$$

As follows from the table 3, the values of excesses obtained using a leveler and a microleveler do not differ significantly. So, we can say that the experimental sample of the microleveler was in working condition.

In the future, a series of experimental studies was also carried out using known measures of length, accepted as reference ones.

The research was conducted on a tiled surface (Fig. 8).


Figure 8 – Experimental studies using known measures of length
Рисунок 8 – Експериментальні дослідження з використанням відомих мір довжини

With the help of an electronic level, it was established that the surface of the tile is clearly horizontal and can be used as a reference.

With the same parking points of the heels of the device, zeroing of the readings of the microlevel was carried out by bringing the readings in the forward and reverse directions to the same, but diametrically opposite values.

The following were used as reference measures:

- 24 mm thick metal weight;
- polyethylene plate with a thickness of 3 mm;
- plastic plate 1 mm thick.

The results of measurements are given in table 4.

Table 4 – Results of measurements using known measures of length
Таблиця 4 – Результати вимірювань з використанням відомих мір довжини

Measure, mm	Indication		Excess, mm		Absolute error, mm	Relative error, %
	Level, mm	Microleveler, degree	Level	Microleveler	Microleveler	
0	1188	0	-	-		
24	1163	2,803	25	24,45	0,45	2
3	1182	0,339	6	2,95	0,05	2
1	1186	0,115	2	1	0	0

As follows from the table, the relative error of measurements of excesses using a microleveler is within 2%, which is significantly less than the maximum permissible value of 5%.

Conclusions and Recommendations.

Based on the device for measuring the rutting of the road surface, an experimental sample of a new domestic device has been developed, which is similar in principle to the Dipstick-2000 microleveler and the method of evaluating the unroughness of the foundations and road surface with its use.

The microleveler has successfully passed a number of experimental studies, proving itself as a device that is simple and easy to use and maintain.

The relative error of measurements of excesses using a microleveler was within 2%, which is significantly less than the maximum permissible value of 5%.

After successful experimental research, the work started can be continued in the future in the direction of manufacturing a microleveler prototype, developing a technical project and working design documentation with the aim of serial production of this new measuring equipment to improve the quality of road construction.

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УДОСКОНАЛЕННЯ ГЕОДЕЗИЧНИХ МЕТОДІВ ОЦІНЮВАННЯ НЕРІВНОСТЕЙ ОСНОВИ І ПОКРИТТЯ ДОРОЖНЬОГО ОДЯГУ

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Анотація. В статті йдеться про результати дослідно-конструкторської роботи лабораторії автомобільних доріг та аеродромів Національного транспортного університету, а саме розробку експериментального зразка мікронівеліру для оцінювання нерівностей основи і покриття дорожнього одягу на базі вже існуючого пристрою для вимірювання колійності (поперечної рівності) дорожнього покриття.

Наведено загальний вигляд, основні технічні характеристики та алгоритм роботи з приладом. Виконано перевірку працездатності приладу при проведенні контрольних вимірювань паралельно з нівеліром традиційної конструкції на поверхні асфальтобетонного покриття у натурних умовах.

На території Національного транспортного університету проведено серію експериментальних досліджень з використанням відомих мір довжини, прийнятих у якості еталонних.

Подальші дослідження та впровадження описаного в статті приладу в практику дорожнього господарства України дадуть змогу оперативно контролювати будівництво і ремонт дорожніх одягів та покриттів і вносити корективи в технологічні процеси, цілеспрямовано керувати якістю, оцінювати стан дорожніх одягів та покриттів, що знаходяться на стадії експлуатації і виявляти локальні ділянки доріг з незадовільною рівністю, що в свою чергу буде сприяти зменшенню ДТП, пов'язаних з незадовільними дорожніми умовами.

В той же час, очікується, що вартість вітчизняного мікронівеліру для оцінювання нерівностей основи і покриття дорожнього одягу може в декілька десятків разів бути нижчою, порівняно з закордонними аналогами, за умови серійного виробництва.

Ключові слова: дорожня конструкція, рівність дорожніх покриттів, поздовжня рівність, поперечна рівність, геометричне нівелювання, мікронівелювання, Міжнародний індекс рівності IRI.

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