ISSN 1846-6168 (Print), ISSN 1848-5588 (Online)
https://doi.org/10.31803/tg-20190421134423

Professional paper

THE EQUIPMENT FOR DETERMINING THE IMPACT OF TRAFFIC ENVIRONMENT ON ROAD PAVEMENT

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Abstract: The article presents the classification of equipment developed by the author for the research of the operational characteristics of road pavement. The equipment was classified according to the following criteria: type of equipment; type of contact element; mode of interaction with the supporting surface; type of fixture of the suspension element; number of contact elements; sample type; type of load. For illustrations, the classification of the most common equipment was carried out. The research was conducted to compare and select the most rational equipment to study the effect of traffic environment on the road pavement. The research was carried out by the multi-criteria analysis. Based on the conducted research, the most rational installations for conducting experiments were determined.

Keywords: classification; installation; load; multi-criteria analysis; road pavement; traffic environment; wheel

1 INTRODUCTION

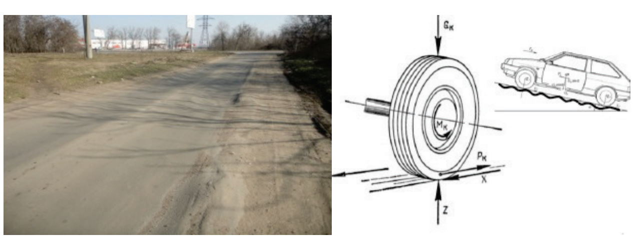
The condition of roads is mainly determined by the quality of the road pavement. Basically, the road pavement is influenced by:

- the traffic environment, which depends on the intensity and the combination of vehicles;
- the climatic conditions determined by the location of the examined length of the road (temperature, humidity).

A moving traffic environment, acting on the road pavement, causes various types of defects (wear-at, abrasion, formation of plastic crack, chipping, peeling, etc.) [1-3]. The reason behind the formation of defects depends on the properties of the road pavement materials, the design features of the wheel running gear of cars and the speed of traffic.

The most widespread roads are with a pavement of cement concrete and asphalt concrete. Each of the examined materials of the pavement has its own type of wear and tear. On asphalt, over time, due to the usage of pavements, rutting (plastic deformation of the covering caused by the impact of the wheel) appears on roads.

Rutting leads to a decrease in vehicle traffic safety and impairs vehicle handling (Fig. 1a and 1b) [2, 4].



a) b)

Figure 1 Rut on the road: a) the rut on the road; b) wheel action on the road pavement

On roads with asphalt concrete, there are other types of deformations for road pavement: waviness (occurs because of the longitudinal deformations of the road pavement); cracks; pits (caused by vertical deformations of the road pavement).

For hard road surface (cement concrete), the most typical types of wear are: chipping, peeling (caused by the effect of the freeze-thaw temperature); abrasion (occurs to the abrasive effect of the wheels).

2 RESULTS AND DISCUSSION

The study of the influence of the impact of wheel running gear on the road pavement is most often carried out on installations and devices that create dynamic effects on the material pavement. As a rule, these are: laboratory, testing bench, full-size.

Analysis of works [1-13] showed that there is currently no classification for this type of equipment.

The purpose of the research was to develop a classification of equipment that is used to study the effect of transport on road pavements.

To achieve the above-mentioned purposes, the following **problems were resolved**:

- to propose a block diagram of classifications;
- to propose a methodology for the use of classifications;
- to conduct a multi-criteria analysis of the existing stands and equipment;
- to develop a criterion for assessing the properties of the equipment;
- to develop a rating scale of the equipment;
- to develop recommendations for the selection of rational equipment.

In the paper, a classification for the equipment presented in Tab. 1 is proposed. The classification is carried out according to the following criteria: type of equipment; type of contact element; mode of interaction with the supporting surface; type of attachment of the suspension element; number of contact elements; sample type; type of load. Each criterion is divided into classes: With the sample heating; Without the sample heating; Mobile; Rotative; Landfills;

Natural; Flat contact element; Wheel non-deformable; Wheel elastic; The wheel to which the torque is applied; Wheel that is free to roll; Not flexible; Moving translational, Moving rotational, Free, One, Two, More than two; Cuboid, Cylinder, Cuboid and Cylinder; Vertical, Vertical + Horizontal, Vertical + Horizontal + Centrifugal.

Table 1 Classification of the equipment for the study of the operational characteristics of road pavements

No.	Classification of the equipment by signs	Classes of signs
I	TYPE OF EQUIPMENT	
I_1	Laboratory	
I_{12}		With the sample heating
I_{13}		Without the sample heating
I_2	Test-bench	
I_{21}		Mobile
I_{22}		Rotative
I_3	Full-scale	
I_{31}		Landfills
I_{32}		Natural
II	TYPE OF CONTACT ELEMENT	
II_1		Flat contact element
II_2		Wheel non-deformable
II_3		Wheel elastic
III	MODE OF INTERACTION WITH THE MOUNTING SURFACE	
III_1		The wheel to which the torque is applied
III_2		Wheel that is free to roll
IV	TYPE OF ATTACHMENT OF THE SUSPENSION ELEMENT	
IV_1		Not flexible
IV_2		Moving translational
IV_3		Moving rotational
IV_4		Free spin
V	NUMBER OF CONTACT ELEMENTS	
V_1		One
V_2		Two
V_3		More than two
VI	SAMPLE TYPE	
VI_1		Cuboid
VI_2		Cylinder
VI_3		Cuboid and Cylinder
VII	TYPE OF LOAD	
VII_1		Vertical
VII_2		Vertical + Horizontal
VII_3		Vertical + Horizontal + Centrifugal

The combination of the criteria and classes allows you to describe the equipment that is being considered. Example:

$$I_1 + II_2 + III_2 + IV_2 + V_1 + VI_1 + VII_1,$$

Where: I_1 – laboratory; II_2 – wheel non-deformable; III_2 – wheel that is free to roll; IV_2 – the suspension is movable; V_1 – one contact element; VI_1 – the test sample has the form of a cuboid; VII_1 – the load that acts vertically on the contact element.

The examples of the classifications of the existing laboratory equipment are shown in Fig. 2.

Fig. 2 shows installations which have the following characteristics:

- The testing bench for assessing the rutting of the road pavement material - Wheel Tracking Device (Fig. 2a). The testing bench has: the speed of wheel contacts with a sample of pavement in one minute - 42, with a vertical load on the wheel of 520 N, the covering temperature is 60 °C, the pavement thickness is from 40 to 120 mm [2, 4].

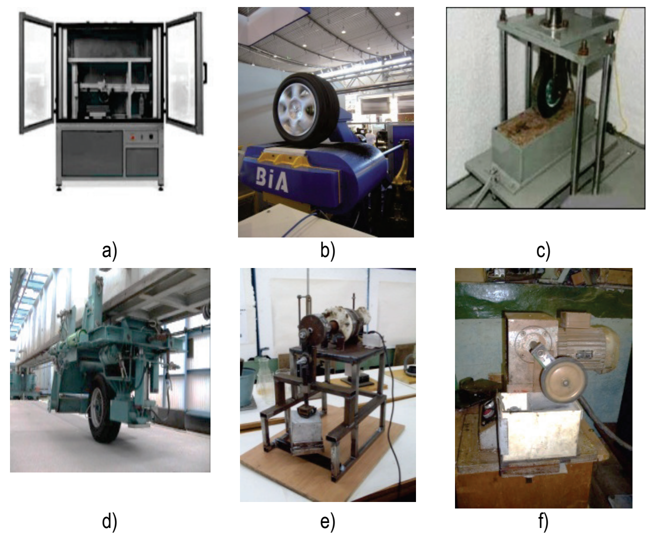


Figure 2 The name of the installation (formula by classifications): a) the testing bench Wheel Tracking Device ($I_1 + II_2 + III_2 + IV_2 + V_1 + VI_1 + VII_1$); b) the testing bench dynamometer BIA ($I_{13} + II_3 + III_1 + IV_1 + V_1 + VI_2 + VII_2$); c) the testing bench of the State Research Institute, Ukraine ($I_{13} + II_3 + III_2 + IV_2 + V_1 + VI_1 + VII_2$); d) one-wheeled installation Lintrack, Netherlands ($I_{13} + II_3 + III_1 + IV_2 + V_1 + VI_1 + VII_2$); e) developed the testing bench by the author BUSOL-1, Odessa, Ukraine ($I_{13} + II_1 + IV_2 + V_1 + VI_3 + VII_1$); f) the testing bench developed by the author BUSOL-2 ($I_{13} + II_3 + III_2 + IV_3 + V_1 + VI_3 + VII_2$)

- The testing bench - the dynamometer BIA, Tolyatti at the plant of LLC "Bia". The testing bench is designed to study the interaction of the vehicle suspension with the road pavement. For road pavement testing, the sample can be made in the form of a cylinder. The testing bench has a wheel load of 7 kN and a treadmill speed of up to 250 km/h (Fig. 2b) [14].
- Installation of the State Research Institute, Ukraine (Fig. 2c). The installation uses reciprocating movements of the tray with the road pavement material with a frequency of 48 passes per 1 minute (50 km/h) [2, 4].
- One-wheel installation Lintrack in the Netherlands. The installation has a wheel load from 15 to 100 kN and a speed of up to 20 km/h (Fig. 2d)) [4].
- The author has developed the testing benches BUSOL-1 and BUSOL-2 (Fig. 2e and 2f) [5]. The testing benches are designed to assess the abrasion and deformation of the road pavement of various types, both in the dry and wet state.

Due to the mobile test benches, research of the physicomechanical and operational characteristics of the road on any of its parts (Fig. 3a) [2, 4] can be conducted.

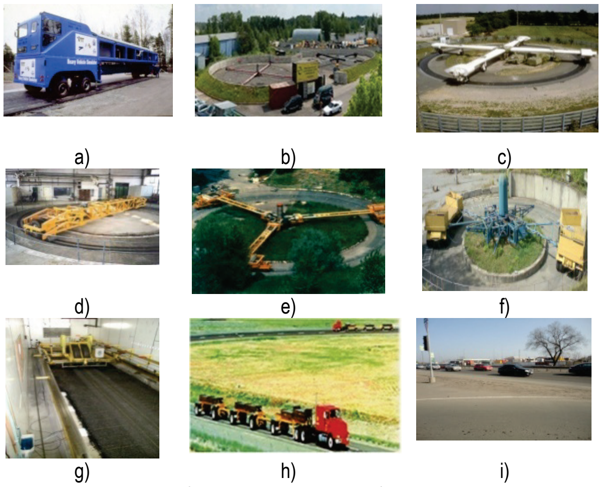


Figure 3 Installations for pavement research: a) The mobile test benches HVS- Mark IV, USA ($I_{21} + II_3 + III_1 + IV_2 + V_1 + VI_1 + VII_1$); b) The one-wheeled vehicle "Carousel" MADI, Moscow, Russia ($I_{22} + II_3 + III_2 + IV_3 + V_3 + VI_1 + VII_2$); c) The four-wheeled installation LCPC, France ($I_{22} + II_3 + III_1 + IV_2 + V_3 + VI_1 + VII_2$); d) The two-wheeled installation in Romania, the city of Iasi ($I_{22} + II_3 + III_2 + IV_2 + V_3 + VI_1 + VII_2$); e) The two-wheeled installation Vuis-Cestu, Slovakia ($I_{22} + II_3 + III_1 + IV_2 + V_3 + VI_1 + VII_2$); f) The circular testing bench in Kiev, Ukraine ($I_{22} + II_3 + III_1 + IV_2 + V_3 + VI_1 + VII_2$); g) The two-wheeled installation Danish Road Testing Machine, Denmark ($I_{13} + II_3 + III_1 + IV_2 + V_1 + VI_1 + VII_2$); h) The landfills MinRoad, USA ($I_{31} + II_3 + IV_4 + V_3 + VI_1 + VII_3$); i) The road pavement testing in full-scale conditions ($I_{31} + II_3 + IV_4 + V_3 + VI_1 + VII_2$)

The use of full-size installations allows a more adequate assessment of the impact of traffic environment on road pavement. They are performed in the form of a rotating installation. Let us examine some of them:

- The one-wheeled installation KUIDM-2 "Carousel" in Moscow, Russia provides a speed of up to 80 km/h (Fig. 3b).
- The four-wheeled rotating installation Laboratoire Central des Ponts and Chaussees (LCPC) was made in France. The installation has: a diameter of rotation of 30 and 40 m; a wheel load of up to 75 kN; the maximum speed of movement of up to 105 km/h (Fig. 3c).
- The two-wheeled installation in Iasi, Romania (Fig. 3d).
- The two-wheeled installation Vuis-Cestu in Slovakia. The installation has: a diameter 32 m; a wheel speed of up to 50 km/h (Fig. 3e).
- The circular testing bench in Kiev, Ukraine. The installation has: a wheel load of up to 75 kN, a wheel speed of up to 40 km/h (Fig. 3f).
- The two-wheeled installation Danish Road Testing Machine (DRTM). The unit has: a wheel load of up to 65 kN; a speed of up to 30 km/h (Fig. 3g).

Apart from the rotating testing bench for the research of the properties of road pavement, test landfills with heavy equipment can be used (Fig. 3h), and testing can be carried out in full-scale conditions (Fig. 3i).

The installations that were shown in the Figs. 2 and 3 were evaluated according to the following criteria: the equipment cost; the research cost; the need for control from the operator's side; the maintenance and repair costs; the price of manufacture and installation of the sample; the ease of use; the measured parameters; the number of the types of coverage; the regulation of sample tests conditions; the protection from environmental exposure; the wheel speed; the cycling of the load.

For the ease of comparison of the testing bench and the installations for each of the criteria, appropriate comparison scales were developed (Tab. 2).

The coded values, descriptions of the testing bench and installations researched in the work are presented in Tab. 3.

Table 2 Criteria and scale rating criteria

No.	Criterion	←the worse	Comparison scale	the best →		
		1	2	3	4	5
1	The equipment cost	very high	high	medium	low	insignificant
2	The research cost	very high	high	medium	low	insignificant
3	The need for control from the operator's side	two or more people	constant	periodic	start and end of the experience	not required
4	The maintenance and repair costs	very high	high	medium	low	insignificant
5	The price of the manufacture and installation of the sample	very high	high	medium	low	insignificant
6	The ease of use	very low	low	average	high	very high
7	The measured parameters	one	two	three	four	five or more
8	The number of the types of pavement*	one	two	three	four	five or more
9	The regulation of sample tests conditions	unregulated	depending on the environment	temperature change	temperature and humidity	temperature, humidity and contact pressure
10	The protection from environmental exposure	none	from precipitation	partially	in a heated laboratory space	completely
11	The wheel speed	missing	low	medium up to 50 km/h	high 50 km/h and more	very high more than 100 km/h
12	The cycling of the load	there are no 10	low 10-20	average 20-50	high 50-100	very high

one - non-rigid; two - non-rigid, rigid; three - H, R, pavement; four - H, R, P, ground pavement; five - H, R, P, G, paving elements, etc.

The comparison of testing benches and installations were carried out by the method of expert assessments, the results are shown in Tab. 4. The data obtained in Tab. 4 are graphically represented in Fig. 4.

As it was shown by the results of the research presented in Tab. 4 (Fig. 4), the most rational equipment for determining the impact of traffic environment on the road pavement is:

- The laboratory equipment: the Wheel Tracking Device (Fig. 4a); the State Research Institute, Ukraine (Fig. 4b); BUSOL-1, Ukraine (Fig. 4k); м) BUSOL-2 (Fig. 4l).
- The testing bench equipment: the mobile test benches HVS- Mark IV, USA (Fig. 4d); the one-wheeled vehicle "Carousel", Russia (Fig. 4f);
- The natural research: the road pavement testing in full-scale conditions, Odessa, Ukraine (Fig. 4j).

For the first of the installations examined, the disadvantage is the need for the heating of the sample of the material that is being tested. Such installation cannot be used for other types of coverage.

Table 3 The compared testing bench and installations

No.	Formulas of the testing bench and installations	Name of the testing bench and installations
1	$I_{12} + II_2 + III_2 + IV_2 + V_1 + VI_1 + VII_1$	The Wheel Tracking Device, EU (Fig. 2a)
2	$I_{13} + II_3 + III_2 + IV_2 + V_1 + VI_1 + VII_2$	The State Research Institute, Ukraine (Fig. 2f)
3	$I_{12} + II_3 + III_1 + IV_1 + V_1 + VI_2 + VII_2$	The dynamometer stand BIA, Russia (Fig. 2b)
4	$I_{21} + II_3 + III_1 + IV_2 + V_1 + VI_1 + VII_1$	The mobile test benches HVS-Mark IV, USA (Fig. 2a)
5	$I_{13} + II_3 + III_1 + IV_2 + V_1 + VI_1 + VII_2$	The one-wheeled installation Lintrack, Netherlands (Fig. 2d)
6	$I_{22} + II_3 + III_2 + IV_3 + V_3 + VI_1 + VII_2$	The one-wheeled vehicle "Carousel", Russia (Fig. 2b)
7	$I_{22} + II_3 + III_1 + IV_2 + V_3 + VI_1 + VII_2$	The four-wheeled installation LCPC, France (Fig. 2c)
8	$I_{22} + II_3 + III_1 + IV_2 + V_3 + VI_1 + VII_2$	The circular testing bench, Ukraine (Fig. 2f)
9	$I_{31} + II_3 + IV_4 + V_3 + VI_1 + VII_3$	The landfills MinRoad, USA (Fig. 2h)
10	$I_{31} + II_3 + IV_4 + V_3 + VI_1 + VII_2$	The road pavement testing in full-scale conditions (Fig. 2i)
11	$I_{13} + II_1 + IV_2 + V_1 + VI_3 + VII_1$	BUSOL-1, Ukraine (Fig. 2e)
12	$I_{13} + II_3 + III_2 + IV_3 + V_1 + VI_3 + VII_2$	BUSOL-2, Ukraine (Fig. 2f)

Table 4 The comparison of the testing benches and installations

The criterion	1	2	3	4	5	6	7	8	9	10	11	12
The equipment cost	5	3	2	2	4	2	1	2	1	3	5	5
The research cost	4	5	3	3	4	2	1	2	1	4	5	5
The need for control	3	4	2	2	3	2	1	1	1	3	4	4
The maintenance and repair costs	4	4	3	3	3	2	1	2	1	4	4	5
The price of the manufacture and installation of the sample	5	4	3	2	3	2	1	2	1	3	5	5
The ease of use	4	3	4	2	4	3	2	2	3	3	4	5
The measured parameters	5	3	3	4	4	3	2	2	2	5	4	5
The number of the types of pavement*	1	2	2	5	2	2	3	2	3	5	3	4
The regulation of sample tests conditions	4	4	3	2	3	1	1	1	1	1	4	5
The protection from environmental exposure	5	5	5	2	5	1	1	1	1	1	5	5
The wheel speed	3	3	5	3	2	5	5	1	3	5	3	4
The cycling of the load	3	3	5	3	3	4	4	4	5	4	3	5

The installation of the State Scientific Research Institute, Ukraine (Fig. 4b) is deprived of the disadvantages of the above mentioned equipment. The disadvantage of this installation is the low speed of movement of the chute with a sample of material. The equipment BUSOL-1 (Fig. 4b), BUSOL-2 (Fig. 4l) is deprived of the drawbacks of the installations that were examined earlier. Due to it, it is possible to explore samples of asphalt, cement concrete and other types of road pavement. For the experiments, samples of cubic and cylindrical shapes can be used. The samples can be tested dry and wet.

The examined rotating installation (Fig. 4f) provides a speed of up to 50 km/h. The disadvantage of this installation is: very large, occupied space; the high cost of research; the insufficient speed for modeling the interaction of the wheel and the coverage on highways; influence of climatic conditions.

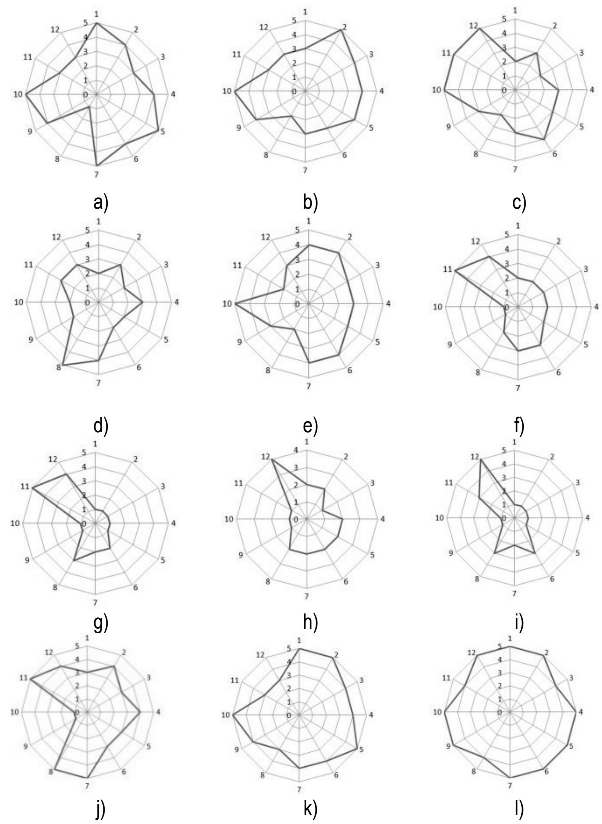


Figure 4 Multicriteria diagrams equipment:
a) The Wheel Tracking Device, EU; b) The State Research Institute, Ukraine; c) The dynamometer stand BIA, Russia; d) The mobile test benches HVS-Mark IV, USA; e) The one-wheeled installation Lintrack, Netherlands; f) The one-wheeled vehicle KUIDM-2 "Carousel", Russia; g) The four-wheeled installation LCPC, France; h) The circular testing bench, Ukraine; i) The landfills MinRoad, USA; j) The road pavement testing in full-scale conditions, Ukraine; k) BUSOL-1, Ukraine; l) BUSOL-2, Ukraine

For a field study (Fig. 4j), the shares should have devices that provide for the number of vehicles: its type, the speed of moving and load on the wheel. The disadvantage of this research is: the inability to control the speed and intensity of the traffic environment; the influence of climatic conditions.

3 CONCLUSIONS

The concluded research enabled the following:

- to offer a classification of equipment for the research of the operational characteristics of road pavements;
- to conduct a multi-criterion analysis of the existing testing benches and installations intended for the study of the road pavement material;
- Based on a multi-criteria analysis, it was recommended to use the following equipment in the scientific and engineering practice: the Wheel Tracking Device; the testing bench of the State Research Institute, BUSOL-1, BUSOL-2; HVS-Mark IV, KUIDM-2 "Carousel" and field study on road pavement.

The use of the considered equipment will significantly reduce the cost and time to conduct research.

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