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COVERINGS FOR ENSURING THE MOVEMENT OF INDIVIDUAL ENVIRONMENTAL TRANSPORT

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Abstract. This article analyzes the state and development of bicycle lanes infrastructure in European countries. Comparative data on the load of bicycle transport in some countries of the world are given in the work (number of bicycles per 100 inhabitants in the country). The article presents the most interesting, in the authors' opinion, technical solutions for ensuring the convenience of cycling operation used in Switzerland, Germany and Holland. Trends in the use of coatings for bicycle paths have been considered with a view for ensuring the safety and convenience of bicycle operation. The results of a multicriteria analysis of existing road surface materials are given in order to choose the most rational one for use on bicycle paths. The received researches have shown that the best indicators providing demanded qualities of a material for a road covering are cement concrete. High technical-economic and exploitation indicators of such coatings are largely due to rational selection of the material composition.

Keywords: ecological transport, bicycle path, cement concrete, asphalt, criteria analysis, coating, bicycle.

ПОКРИТТЯ ДЛЯ ЗАБЕЗПЕЧЕННЯ РУХУ ІНДИВІДУАЛЬНОГО ЕКОЛОГІЧНОГО ТРАНСПОРТУ

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Анотація. У даній статті наводиться аналіз стану і розвиток інфраструктури велосипедних доріжок в Європейських країнах. У роботі наводяться порівняльні дані про насиченості велосипедним транспортом в деяких країнах світу (кількість велосипедів на 100 жителів країни). В статті представлені найбільш цікаві, на думку автора, технічні рішення щодо забезпечення зручності експлуатації велотранспорту застосовувані в Швейцарії, Німеччині та Голландії. Розглянуто тенденції використання покриття для велодоріжок з метою забезпечення безпеки та зручності експлуатації велосипедів. Наведено результати багатокритеріального аналізу існуючих матеріалів дорожніх покриттів з метою вибору найбільш раціонального для використання на велодоріжках. Отримані дослідження показали, що найкращими показниками забезпечують необхідні якості матеріалу для дорожнього покриття є цементобетон. Високі техніко-економічні та експлуатаційні показники таких покриттів, багато в чому обумовлені раціональним підбором складу матеріалу.

Ключові слова: екологічний транспорт, велодоріжка, цементобетон, асфальт, критеріальний аналіз, покриття, велосипед.

ПОКРЫТИЯ ДЛЯ ОБЕСПЕЧЕНИЯ ДВИЖЕНИЯ ИНДИВИДУАЛЬНОГО ЭКОЛОГИЧЕСКОГО ТРАНСПОРТА

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Аннотация. В данной статье приводится анализ состояние и развитие инфраструктуры велосипедных дорожек в Европейских странах. В работе приводятся сравнительные данные по насыщенности велосипедным транспортом в некоторых странах мира (количество велосипедов на 100 жителей страны). В статье представлены наиболее интересные, по мнению автора, технические решения по обеспечению удобства эксплуатации велотранспорта применяемые в Швейцарии, Германии и Голландии. Рассмотрены тенденции использования покрытия для велодорожек с целью обеспечения безопасности и удобства эксплуатации велосипедов. Приведены результаты многокритериального анализа существующих материалов дорожных покрытий с целью выбора наиболее рационального для использования на велодорожках. Полученные исследования показали, что наилучшими показателями обеспечивающие требуемые качества материала для дорожного покрытия является цементобетон. Высокие технико-экономические и эксплуатационные показатели таких покрытий, во многом обусловлены рациональным подбором состава материала.

Ключевые слова: экологический транспорт, велодорожка, цементобетон, асфальт, критериальный анализ, покрытие, велосипед.

Introduction. Integration of Ukraine into the European Commonwealth (EU) requires from our country the harmonization of normative documents for the construction of roads. An essential shortcoming of the road infrastructure in our country is the lack of a developed bicycle paths network. In recent years in many cities of Ukraine (Kiev, Kharkov, Vinnitsa, Lutsk, Odessa, etc.), there is an intensive construction of bicycle paths and the infrastructure necessary for the operation of bicycle transport. This shows the relevance of the problem of construction, operation and repair of bicycle paths.

Analysis of recent research. A large number of scientists and specialists from Simon D.S., Fraser K.L., Pucher J, Buehler R., Laferrere G., Anna Goodman, Jenna Panter, Stephen J. Sharp, David Ogilvie were engaged in the development of cycling communication in the advanced countries of Europe and the world [1-4]. The development of individual ecological transport (IET) in the advanced countries of Europe began in the 70s of the twentieth century. This was due to a significant increase in traffic accidents with the death of people because of road transport [5]. To reduce the number of accidents, the legislation of the EU countries was updated in the direction of tightening traffic rules, as well as a significant restriction of cars movement in large settlements [5].

For this, necessary work was done to develop the infrastructure of the IET. One of the main IET – is bicycle transport. Figure 1 shows the number of bicycles per 100 inhabitants, in some countries of the world, and the intensity of use of this transport mode.

According to the data [5, 6], the number of bicycle trips is between 10 and 30% of the total number of vehicles traveling. The sources [1-6] state the fact of a constant increase in the number of bicycles used as means of transport. The wide distribution of bicycle transport in the EU countries is ensured with the following advantages: environmental friendliness, compactness, mobility, permanent readiness and safety. In addition to the advantages of bicycle transport, there are also disadvantages: low speed, unstable driving in difficult conditions and insecurity of the driver in the environment.

To ensure the efficiency and safety of cycling, a specialized infrastructure is needed. So the issue of infrastructure development in cities of our country is devoted to the works of Gasenko L.V., Litvinenko T.P. (Poltava NTU) [7].

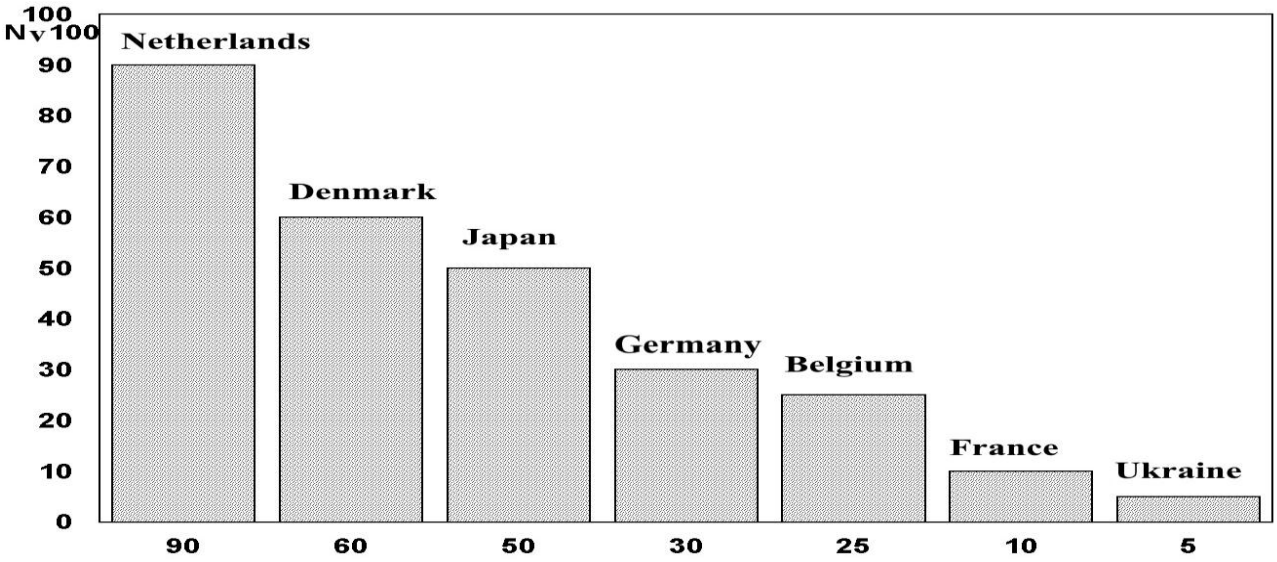


Figure 1. Number of registered bicycles per 100 inhabitants (N_{v100})

It includes: specialized bicycle paths; bicycle parking; special traffic lights and signs; points of maintenance and repair, as well as special means for stopping at intersections, etc.

The bicycle path is the main element of the IET. They are usually classified according to the following characteristics:

– depending on the location of the cycle track:

a) on the roadside;

b) on the sidewalk;

c) separately road.

– depending on the type of coating used:

a) rigid (prefabricated and monolithic coatings);

b) non-rigid (asphalt concrete, polymer concrete);

c) natural coatings (stone, primer, etc.).

– bicycle track covers can be performed: a) non-contrast (natural color coating);

b) contrasting (with the use of various paints, mastics, pigments), (Figure 2, a). Example, in Los Angeles (USA) road surfaces were painted white (Figure 2, b). This allowed: to improve safety (due to improved visibility on the roads, both during the day and at night); to reduce the level of necessary illumination of the road at night, and also to lower the temperature of the environment in large cities by 5^0C (due to the decrease in the effect of the «thermal island») [8].

a) b)

Figure 2. Coverings of bicycle paths:
a – red color; b – white color

Upcoming trend is the production of bicycle paths from water-permeable materials (Figure 3, a, b). Such materials provide effective absorption of sediments on the roads, which increase the safety of traffic. Unfortunately, for this type of material, the issue of frost resistance has not been investigated, which greatly limits its application. Research is conducted on the possibility of using coverings that are luminant at night with using phosphor (Poland, Figure 3c, d) [9].

a)

b)

c)

d)

Figure 3. Upcoming types of coating for bicycle paths:
a – permeable concrete covering; b – permeable asphalt covering;
c – coating with a phosphor in the afternoon; d – coating with phosphor at night

As the analysis shows, materials for covering bicycle paths are being intensively developed in the countries of the world. In order to develop the infrastructure of the IET successfully, it is necessary to use a coating to ensure the safe operation of cycling.

The purpose of the work was to conduct a multi-criteria analysis of existing road surface materials in order to select the most rational one for use on bicycle paths.

Main part. Evaluation of coating materials used for bicycle paths was carried out according to the following criteria: ride comfort on cycling, timing of unevenness formation, the price of construction material, contrast visibility, cost of coating installation, durability, maintainability, relative repair costs (C_{exp}/t_{exp}), adhesion coefficient, frost resistance coverage, environmental friendliness.

These criteria were chosen on the basis of logical reasoning, application experience in road construction, analysis of physical-mechanical and operational characteristics. For convenient comparison of the coating materials for each of the criteria, the corresponding comparison scales were developed (Table 1). This approach allowed conversion in the description of advantages and disadvantages of coverage for each of the criteria into a digital form.

Table 1 – Criterion and scales of rating

№	*Criterion*	*←worse*	*Comparison scale*			*best →*
		1	2	3	4	5
1	Convenience of cycling	impossible	satisfactorily	well	conveniently	comfortable
2	Time of unevennesses formation	3 months	6 months	1 year	3 years	5 years
3	The price of material for construction	very high	high	medium	low	insignificant
4	Contrast visibility	insignificant	low	medium	high	very high
5	The price of installation of the coating	very high	high	medium	low	insignificant
6	Durability	insignificant	low	medium	high	very high
7	Repairability	insignificant	low	medium	high	very high
8	Relative repair costs (C_{exp}/t_{exp})	very high	high	medium	low	insignificant
9	Coefficient of coupling of a car wheel with the road	insignificant	low	medium	high	very high
10	Frost resistance of the coating	insignificant	low	medium	high	very high
11	Environmental friendliness	insignificant	low	medium	high	very high

Coded values and description of materials bicycle lanes are presented in Table 2.

Table 2 – The compared materials of coverings

№	**Coded Material Designation**	**Description of the material**
1	M1	Monolithic concrete
2	P2	Prefabricated coatings
3	P3	Prefabricated paving elements
4	C4	Cement-concrete tile
5	A1	Asphalt concrete
6	A2	Asphalt covering with a phosphor
7	A3	Color asphalt concrete
8	A4	Water-permeable asphalt concrete
9	Cp	Coating based on polymers
10	Nc	Natural coverings
11	Pr	Unsurfaced road
12	C	Combined

Comparison of coating materials for bicycle paths was carried out by the method of expert assessments, the results obtained are given in Table 3.

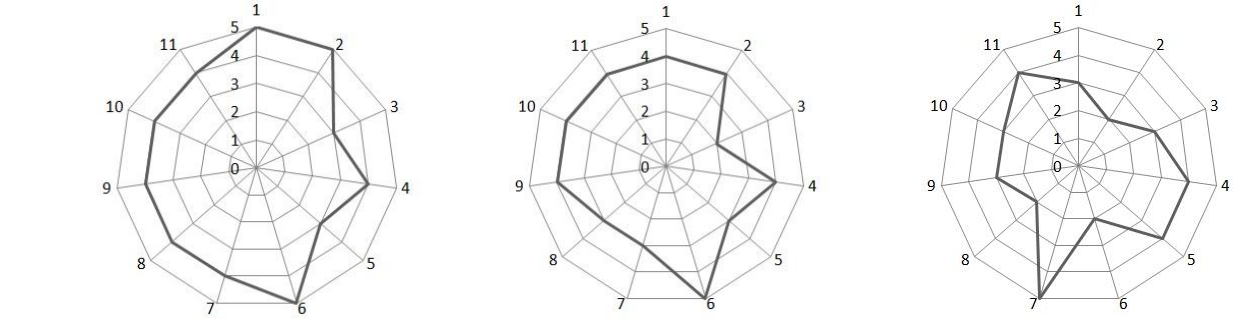
Table 3 – Comparison of coating materials for bicycle paths

Criterion	**M1**	**P2**	**P3**	**C4**	**A1**	**A2**	**A3**	**A4**	**Cp**	**Nc**	**Pr**	**C**
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***
Convenience of cycling	5	4	3	2	5	5	5	5	4	3	2	5
Time of unevennesses formation	5	4	2	2	4	4	4	3	4	5	1	5
The price of material for construction	3	2	3	3	4	1	2	4	1	1	5	2
Contrast visibility	4	4	4	4	2	5	5	2	5	2	3	2
The price of installation of the coating	3	3	4	4	4	1	2	4	2	1	5	2
Durability	5	5	2	2	3	3	3	2	4	5	1	5
Repairability	4	3	5	4	4	2	3	4	2	4	5	4
Relative repair costs (C_{exp}/t_{exp})	4	3	2	2	3	2	2	2	2	4	1	4
Coefficient of coupling of a car wheel with the road	4	4	3	3	4	3	4	5	3	3	3	4
Frost resistance of the coating	4	4	3	3	3	3	3	1	4	5	1	4
Environmental friendliness	4	4	4	4	3	1	2	4	2	5	5	3

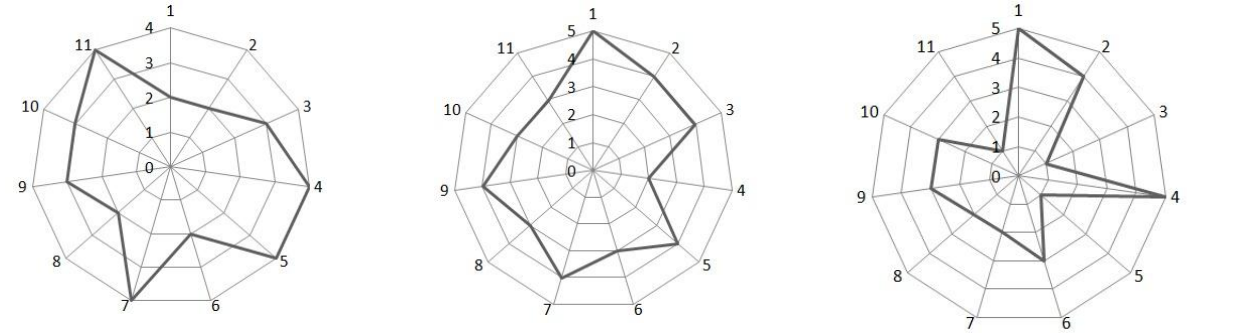
The obtained data in Table 3 graphically are represented in Figure 4. Figure 4, includes the following materials which have the best consumer properties: monolithic concrete (M1) and prefabricated coatings (P2). This is due to the fact that they have a high contrast, durability and coefficient of adhesion, as well as no tendency to form unevenness (ruts etc.). The arrangement of a covering from such material is rather expensive.

Slightly worse indicators are asphalts (Fig. 4, d). That is associated with a low contrast on the road, frost resistance, durability and the formation of ruts. The arrangement of this coating requires special equipment. Partly, these shortcomings can be eliminated when a colored polymer layer is applied (Figure 4, g, i), although the price of the coating increases. Natural stone coverings (paving stones), have disadvantages: low coefficient of adhesion, high cost, as well as vibration when driving. This coating is very durable, some roads with such a covering serve more than 100 years (Ukraine, Odesa, Pushkinskaya street). Water-permeable asphalt concrete (Figure 4, h) in Ukraine is not likely to be widely distributed, due to their low frost resistance. Unsurfaced road (Figure 4, k) has a low cost, and they are highly dependent on the environmental conditions and require constant repairs. The coating based on the phosphor (Figure 4, f) has considerable potential in their application, but, unfortunately, experience in their construction and maintenance has not yet been accumulated.

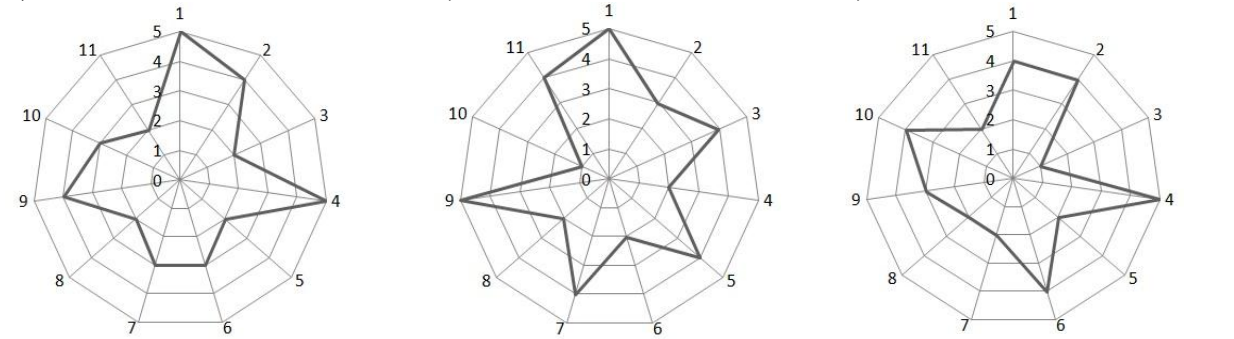
Conclusions and prospects for further research. The received researches have shown, that the best indicators providing demanded qualities of a material for a road covering is cement concrete. High technical, economic and operational indicators of such coatings are largely due to the correct selection of the composition of the material. These questions are discussed in detail in the works [10-12].



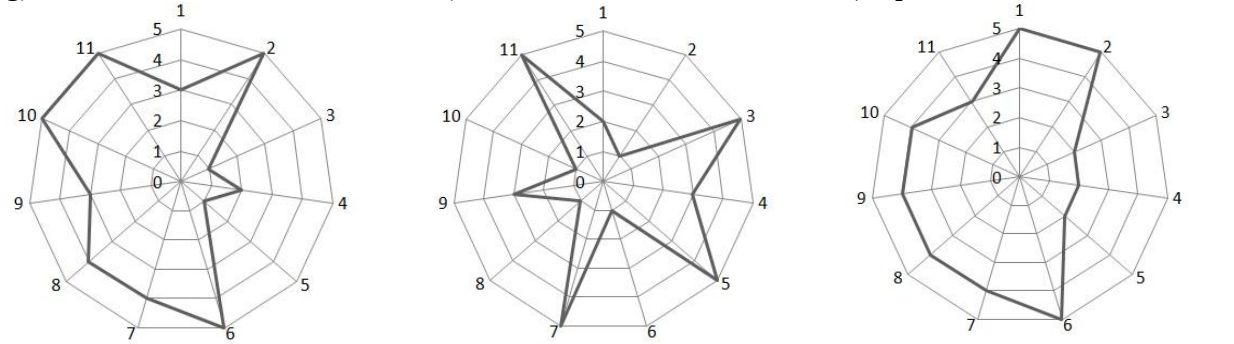
a) M1 b) P2 c) P3



d) C4 e) A1 f) A2



g) A3 h) A4 i) Cp



j) Nc k) Pr l) C

Figure 4. Multicriteria diagrams:
a – monolithic concrete; b – prefabricated coatings; c – prefabricated paving elements;
d – cement-concrete tile; e – asphalt concrete; f – asphalt covering with a phosphor;
g – color asphalt concrete; h – water-permeable asphalt concrete;
i – coating based on polymers; j – natural coverings; k – unsurfaced road; l – combined

Can a rough micro profile for increasing the adhesion between the bicycle wheel and cement concrete be used? This profile can be obtained by forming transverse grooves. For IET it is possible to apply a polypropylene fiber to improve durability, crack resistance, impact resistance and abrasion of the coating. The use of metal fiber is unacceptable, it can lead to destruction of a bicycle

tire and as a result to injuries and mutilations of people. As have shown researches of the authors [10-14] use of a glass and basalt fiber at interaction with a moving wheel of the bicycle leads to formation of fine particles with sharp sides which can get into respiratory organs and vision organs of cyclists. It is more preferable to use a polypropylene fiber as the reinforcing material [10].

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