Testing of cement-concrete road surfaces for wear resistance

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Abstract. The article presents the results of a study of the wear resistance of cement concrete coatings of highways. The tests were carried out on the passenger module of the universal complex for testing the road surface and car tires KUIDM-2 "Carousel", built on the territory of the MADI Educational and Scientific Center (MADI ESC). On a circular stand, the real conditions of interaction of a studded tire of a car wheel with a cement concrete surface were modeled. Road pavements were arranged on the track of the universal ring complex in the form of segments - concrete slabs 100 x 120 cm in size and 10 cm thick. The concrete slabs were subjected to repeated abrasion by spiked rubber. Research has made it possible to establish the influence of the nature of crushed stone, its strength and size of fractions on the wear resistance of cement concrete pavements.

1. Introduction
The problem of rut formation on road surfaces is characteristic not only of the highways of the Russian Federation, but also of other countries of the world [1]. In contrast to non-rigid road pavements, rutting on cement concrete pavements is not a consequence of plastic and permanent deformations, but a consequence of wear and abrasion of the surface layer of the pavement, mainly in winter under the influence of studded rubber. This leads not only to a decrease in the turnaround time, but also to a deterioration in road safety [2, 3]. During the period of atmospheric precipitation, water accumulates in the track, which leads to a decrease in the adhesion qualities of the road surface and the appearance of the aquaplaning effect when vehicles are moving at high speeds. The study of the effect of the composition of concrete, the strength of crushed stone and the size of its fractions, as well as construction technology on the abrasion of cement-concrete coatings under the action of studded rubber, is an urgent task.

2. Statement of the problem
The main advantages of cement-concrete pavements of highways in comparison with asphalt-concrete ones are their high strength and durability, which directly depend on the quality of cement, strength of coarse aggregate and its fractions, operating conditions, as well as construction technology [4]. The appearance of a track on cement concrete pavements leads to high economic costs in the repair of highways. Within the framework of the study, the task was set to conduct comparative tests for abrasion by studded rubber of cement-concrete pavements with various concrete compositions. Research allows
to establish the influence of the nature of crushed stone, its strength and size of fractions on the wear resistance of cement concrete pavements.

3. Research methods and materials
To determine the effect of studded tires on the cement concrete pavement, tests were carried out on the passenger module of the universal complex for testing road pavement and automobile tires KUIDM-2 "Carousel", built on the territory of the MADI Educational and Scientific Center (MADI ESC). The universal complex KUIDM-2 "Carousel" (Fig. 1) is designed for comparative tests of road surfaces and automobile tires in conditions as close as possible to operational ones [5]. In terms of tactical and technical characteristics, it surpasses all known domestic and foreign analogues. Provides the ability to optimize the parameters of materials for road surfaces and car tires, is currently the only system in the Russian Federation that provides research of the "car-road" system in the conditions of real interaction of elements.

Fig. 1. Circular stand KUIDM-2 "Carousel" (MADI)

At the circular stand "Carousel", the real conditions of interaction of a studded tire with a cement concrete surface were modeled. Cement-concrete pavements were arranged on the track of the passenger module of the universal ring complex in the form of segments - concrete slabs 100 x 120 cm in size and 10 cm thick. The concrete slabs were subjected to repeated abrasive action of spiked rubber.

Table 1. Parameters of the passenger module of the universal ring complex

| №  | Parameters                          | Units | Values |
|----|------------------------------------|-------|--------|
| 1  | Road load                          | kg    | 550    |
| 2  | Tire pressure                       | atm.  | 2.4    |
| 3  | Linear wheel speed                 | km/h  | 85-100 |
| 4  | Wheel trajectory radius            | m     | 16     |
| 5  | Track gauge on concrete slab       | mm    | 210    |

|                             | Units | Values |
|-----------------------------|-------|--------|
| 6                            | inch  | 16     |
| 7                            | mm    | 205    |
| 8                            | %     | 65     |
| 9                            | psc.  | 90     |

Wheel parameters:
When preparing concrete mixtures for the construction of cement-concrete pavements, the following materials were used:

1. Cement PC 500-D0-N in accordance with GOST 10178-85;
2. Cement CEM I 42.5N in accordance with GOST 31108-2016.
3. Microsilica MKU-95 (bulk density 300-400 kg / m$^3$).

3. Rubble (GOST 8267-93):
   - rubble from porphyrite fraction 5-15 mm;
   - rubble from gabbro-diabase, fractions 5-10 mm and 10-20 mm;
   - rubble from gabbro-diabase after electrohydrodynamic crushing of 4-8 mm fraction;
   - rubble from granite of fraction 5-10 mm and 10-20 mm.

3. Natural coarse sand of I class (washed) (GOST 8736-2014).

4. Chemical additives:
   - air-entraining additive Micro Air 125;
   - «curing-TAL» set retarder.

Table 2. Type of crushed stone and the size of its fractions in the preparation of concrete mixes

| Concrete composition number | Rubble type          | Rubble fraction size, mm |
|-----------------------------|----------------------|-------------------------|
| №1                          | gabbro-diabase       | 4 – 8                   |
| №2                          | gabbro-diabase       | 5-10 и 10-20            |
| №3                          | granite              | 5-10 и 10-20            |
| №4                          | gabbro-diabase       | 5-10 и 10-20            |
| №5                          | granite              | 5-10                   |
| №6                          | porphyrite           | 5-15                   |
| №7                          | porphyrite           | 5-10                   |
| №8                          | porphyrite           | 5-15                   |
| №9                          | granite              | 5-10                   |

On slabs of concrete of compositions No. 3 and No. 9, the surface of freshly laid concrete was treated with a brush with a plastic bristle. Such a technological operation is often performed in the construction of cement-concrete pavements in order to increase the coefficient of adhesion of the pavement to the car wheel [6]. The surface of the cement concrete pavement of composition No. 8 was cleaned from the mortar part with a metal brush using the “Wash beton” technology to create a rough surface.

Every 25 thousand passes of the wheel with studded rubber, one track was taken to measure the track depth with a three-meter rail with a wedge gage (Fig. 2). The maximum number of wheel passes with studded tires was 250 thousand.
Fig. 2. Measurement of track depth with a wedge gage

4. Research results
The studies performed allowed us to establish that the highest wear resistance was demonstrated by concrete coatings of compositions No. 8 and No. 6, made using porphyrite of fraction 5-15 mm as a coarse aggregate. After 250 thousand passes of a wheel with studded rubber, the average track depth on cement-concrete pavements was 4.67 and 5.03 mm, respectively. In addition, it should be noted that the application of the "Wash beton" technology, "exposure" of a large aggregate on the surface of the road surface, made it possible to slow down the abrasion of concrete under the action of studded rubber, when the mortar part was removed from the surface of the coating. Low wear resistance was shown by coatings made of concrete of compositions No. 1 and No. 5, using crushed stone of fine fractions from gabbro-diabase fractions 4-8 mm and granite fractions 5-10 mm. The average track depth on the considered cement-concrete pavements was 10.50 and 8.17 mm, respectively (Fig. 3).

During the first 25 thousand passes of the wheel with studded rubber, all cement-concrete coatings, with the exception of the coating made of concrete of composition No. 8, had the highest abrasion resistance. During this period, abrasion of the mortar part formed on the surface of the cement-concrete pavement occurs during its construction. The highest abrasion after the first 25 thousand passes of the wheel was shown by the coatings made of concrete of compositions No. 3 and No. 9, made with the use of crushed granite. On these coatings, the surface of freshly laid concrete was brushed with plastic bristles. Later on, wear on these concrete pavements slowed down.

The test results showed that the strength of crushed stone and the size of its fractions have a significant effect on the wear of cement-concrete pavements under the action of studded rubber. The use of a durable filler (porphyrites) and its optimal fractions can reduce the abrasion of cement-concrete pavements under the action of studded rubber by 1.5-2 times.
**Fig. 3.** The depth of the track on cement-concrete pavements after 250 thousand passes of a car with studded rubber in one track.

**Fig. 4.** Track on the concrete pavement of the ring track.
5. Conclusion
As a result of the studies performed, it was established:

1) the size of the coarse aggregate fractions in concrete affects the wear of cement-concrete coatings. With an increase in the size of crushed stone fractions, the wear resistance of concrete increases;

2) the wear of cement-concrete pavements under the influence of spiked rubber is influenced by the strength of crushed stone. The use of a durable filler (porphyrites) and its optimal fractions in the preparation of concrete allows to reduce the abrasion of cement-concrete coatings under the action of studded rubber by 1.5-2 times. Construction of two-layer cement-concrete pavements will provide a significant reduction in the consumption of expensive crushed stone, using it only in the upper layer of the pavement;

3) removal of the weak mortar part from the surface of the coating using the "Wash beton" technology, which allows to slow down the wear of the cement-concrete coating under the action of studded rubber.

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