UDC 625.7/8

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POTHOLE MAINTENANCE OF NON-RIGID PAVING SURFACES USING THE INJECTION FLOW METHOD

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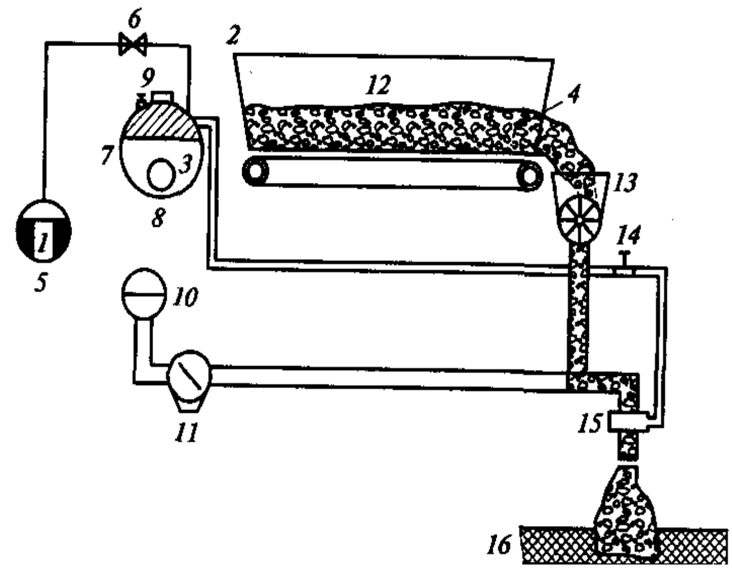
Statement of the problem. The objective of the paper is to determine the influence of the technology of laying and compaction of the biomineral mixture on the quality of repair potholes of road surface of non-rigid type in production conditions using the injection flow method.
Results. The analytical dependence of the influence of technological modes of laying a mixture on its internals in the pothole of the road surface was determined using the factor analysis. It is proved that to improve the quality of repairs by means of the injection flow method, it is necessary to additionally compact the mixture with the use of compacting machines.
Conclusions. The parameters of the bituminous mineral mixture (water saturation, compaction ratio) for laying using the injection flow method considering the technological modes of operation during patching of potholes of coatings (of different depths) of a non-rigid type were identified. The analytical dependencies of the influence of technological modes of supplying the mixture on its quality of laying into a pothole were determined. At around 20 % of the emulsion content in the mixture, the water saturation value is below the norm (the mixture is excessively mobile). The increase in the height of the working element of the machine and the speed of the supplied mixture into the pothole does not significantly affect the compaction ratio of the mixture at a constant thickness of the laying layer. As the depth of the layer of packing material in the pothole increases, there is a small decrease in the compaction ratio.

Keywords: injection flow method, pothole maintenance of non-rigid paving surfaces, bituminous mineral mixture, water saturation, production conditions, compression ratio.

Introduction. One of the directions to take in order to improve the life cycle of a roadway surfacing is to carry out qualitative works to maintain and repair highways. It is known that after a highway has started being used, after a while there are defects occurring in roadway surfacing due to violations of a construction technology. Untimely removal of defects results in degradation of surfacing and thus higher maintenance costs. It was found that delayed maintenance leads to a 2 or 3-fold increase in maintenance costs [4]. Therefore it is of importance to address the quality of road repairs using new technology and improving existing ones [2, 10, 16]. Depending on particular conditions of maintaining a highway, various technological schemes are employed in order to remove surfacing defects [17]. Timely and high-quality repairs for addressing potholes improve travel safety (reduce emergency rates) and contribute to the cost-effectiveness of road works [5, 7, 14, 20, 23, 24, 27—29]. Lately for pothole repairs of non-rigid surfacing the liquid-injection method has been employed that is an emergency repairs method. In terms of its cost and time, it is considered most effective in comparison with traditional methods of pothole repairs (using poured and hot mixes). Potholes are filled with crushed stone preliminarily processed with bitumen emulsion in a mixing chamber. The efficiency of bitumen mineral mixes for pothole repairs of materials with various physical and mechanical properties has been described in technical literature [3, 11, 19]. A mix is laid into a pothole due to a replacement of a material particle at a specified rate and it is compacted by means of pressing material particles during laying (Fig. 1).



1 is a liquid for washing pipes;
2 is the airвоздух;
3 is a bitumen emulsion ;
4 is crushed stone;
5 is a vessel for a washing liquid;
6 is a tap of a washing liquid;
7 is a vessel for an emulsion;
8 is heating of an emulsion;
9 is a protective air valve;
10 is an air filter;
11 is an airblower;
12 is a bin with crushed stone and a transporter;
13 is an air-lock;
14 is an emulsion tap;
15 is a mixing chamber with an emulsion;
16 is a potholed surfacing

Fig. 1. Technological scheme of a setup for repairing potholes using the liquid-injection method

According to the existing guidelines, an advantage of the technology is that there is no compaction while a material is laid down into a pothole [3, 12, 21, 22, 25, 26, 30]. Further compaction is due to travelling vehicles. The material is fed from the height of 0.60 m from the pothole surface at the rate of 30—32 m/sec with 20 % bitumen emulsion in a mix. There is no compaction as a material fractioned from 2.5 mm to 10 mm is fed into a pothole at a rate providing even and dense compaction of the material into the pothole. However, this was not experimentally proved. The experimental data [17] suggest that if these guidelines are followed and the technology is employed and the specified bitumen emulsion content is present in a mix, the strength characteristics and water saturation of asphalt concrete in a pothole does not comply with the GOST (ГОСТ) 9128-2009 requirements.

1. Methods of conducting an industrial experiment. In order to identify the strength of asphalt concrete in a pothole, following the laying of a mix special forms that were filled with a mix using road construction equipment *Madpatcher* MP 6.5 WD were prepared. It was found that a strength limit of such samples can barely be identified due to their failure (Fig. 2a). For insignificant traffic intensity and a low axial load on a laid material in the pothole a strength limit is within 0.4—0.6 MPa.

In order to specify the effect of an axial load on an increase in the strength of a material in a pothole, chips were taken from a roadway with a high traffic intensity repaired in 2014 and 2015 (Fig. 2a, b).

a) b)

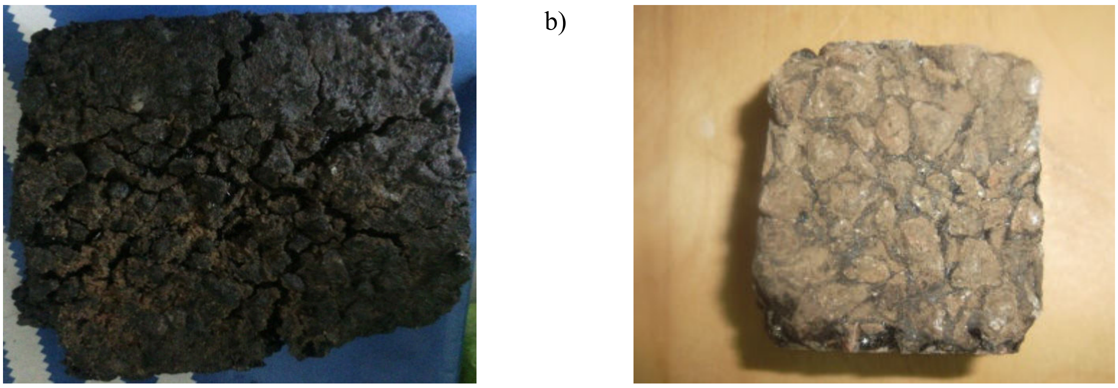


Fig. 2. Appearance of the samples in a pothole selected under industrial conditions:
a) following the laying of a mix with no traffic impact; b) under a traffic impact

Visual examination revealed no external damage on a surface of patched potholes. It was found that a compressive strength limit of asphalt concrete ranges from 1.2 to 1.7 MPa, which is below the requirement of GOST (ГОСТ) 9128-2009. The strength limit of the samples of the mix for a standard test and at the temperature of 20 ºC complies with that ranging from

2.1 to 2.3 MPa, which is in accordance with the GOST (ГОСТ) 9128-2009. Therefore the use of the liquid-injection method with no extra compaction of a mix does not provide a required material strength. Based on that, it can be concluded that in order to increase the efficiency of the liquid-injection method and reach maximum density of the material laid down into a pothole, it is necessary to specify the modes for laying mixes or to compact a material after it has been laid down into a pothole.

Studies were conducted in order to identify the effect of laying modes of a bitumen mineral mix on the strength characteristics of asphalt concrete during pothole patching in industrial conditions. Using a road cutter, spots for laying a mix that were filled with it were found (Fig. 3).

Fig. 3. Preparing areas of surfacing for laying a mix using the liquid-injection method and filling potholes with a bitumen mineral mix

In order to specify the effect of the thickness of a material layer in a pothole and height of feeding the material on the compaction coefficient as well as water saturation of asphalt concrete, special areas (potholes of varying depths) were prepared (0.03, 0.05, 0.07, 0.10 and 0.13 m) that were filled with a mix at different heights of feeding a material (0.3, 0.6 and 0.8 m). Percentage proportion of the emulsion in the mix was 20 % according to “The Methodology Guidelines for Preparing and Using Catione Bitumen Emulsions” (approved by the ruling of the Ministry of Transportation of the Russian Federation № ОС-805-р from September 15, 2003) followed by transportation institutions when finalizing their industrial regulations for pothole patching.

The characteristics of asphalt concrete in a pothole (density, water saturation and strength limit) for the recommended modes of laying a mix were determined following 90—100 days after the laying by taking chips from the site. The samples were tested in accordance with GOST (ГОСТ) 12801-98. The obtained values were compared with the normative characteristics according to the GOST (ГОСТ) 9128-2009. In order to specify the effect of a compaction method on the compaction coefficient of asphalt concrete, the laid mix was compacted using a vibration plate DPU 3050H, pneumatic tyre (vehicle GAZ-3302 "Gazel") and a ramming machine [18]. The compaction coefficient was measured with the non-destructive method using the tool PAB-1. The results for compacting a material layer of 0.05 m are presented in Fig. 4.

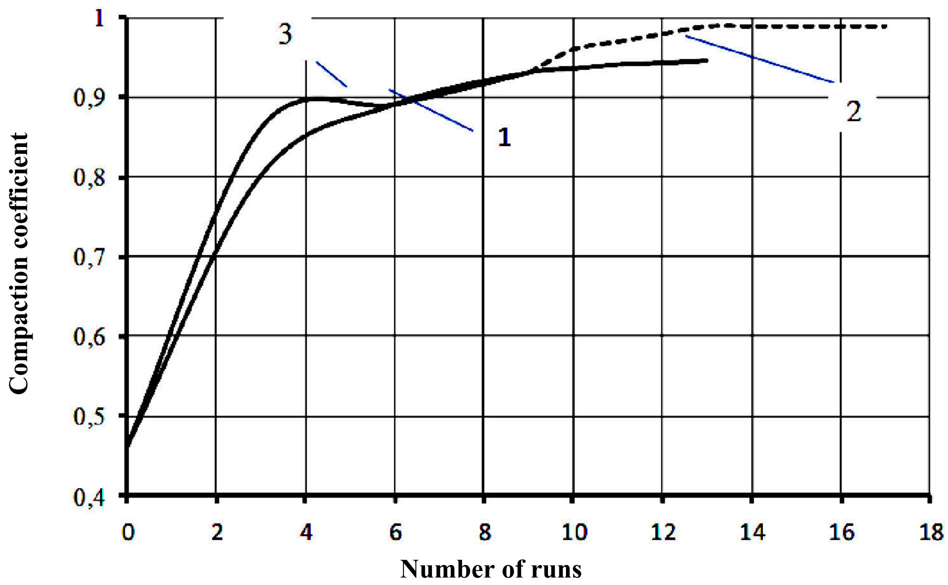


Fig. 4. Dependence of the compaction coefficient on the number of runs of the ramming machine at the thickness of the layer of 0,05 m:
1 is a vibration plate; 2 is a percussive-action machine; 3 is a vehicle

The data suggest that the use of the liquid-injection method of laying and compacting a mix does not provide a required strength of a material in a pothole. Due to an axial load of vehicles, a required coefficient of compaction of a material in a pothole depends on contact stresses in the pneumatic tyre and a material and traffic intensity. A low compaction coefficient of a mix under the effect of a vehicle ("Gazel") indicates an insufficient stress strain of a material in the area of contact of a wheel and a material surface in a pothole. As a heavy-weight vehicle moves, the compaction coefficient and thus the strength reach higher compaction. The use of compaction machines allows for higher characteristics of a compacted material depending on the parameters of compaction machines.

Tests of the samples for standard compaction showed that as the size of crushed stone of a mix increases, the strength of a mix drops. During laying using the liquid-injection method and a mix with crushed stone fractioned 5—20 mm the strength limit is 0.51—0.76 MPa, for 5—15 mm the strength limit corresponds to 1.01—1.53 MPa and for 3—10 mm the strength limit is within 2.04—2.24 MPa.

2. Results and evaluation of the credivility of a complete multifactor experiment. The results were processed using a complete factor experiment. The factors that influence compaction for the constant parameters of a machine were the thickness of a layer of a bitumen mineral mix (a minimum and maximum value $x_1^- = 3$, $x_1^+ = 13$) and the height of feeding the material from the nozzle of the machine to the surface (a minimum and maximum value $x_2^- = 60$, $x_2^+ = 80$).

According to the plan of experimental studies, a number of experiments (n = 4) their repetitions (m = 3) was specified considering the influencing factors. The investigated parameters were the density ρ, g/cm^3, water saturation r, %, and the compaction coefficient k. During the experiment it was necessary to design the regression equations for the investigated parameters (considering the combination of factors), to test the resulting models and interpret them. According to the obtained values, the dependence of the effect of variable factors on final compaction was determined [1, 6, 8, 9, 13, 15].

Fig. 5 shows the behavior of the function of water saturation r, %, on the factor x_1 (the thickness of a pothole layer, cm) for the fixed factor x_2 (the height of feeding a material, cm). Fig. 6 shows its dependence on the factor x_2 (the height of feeding a material, cm), for a fixed factor x_1 (the thickness of a pothole layer).

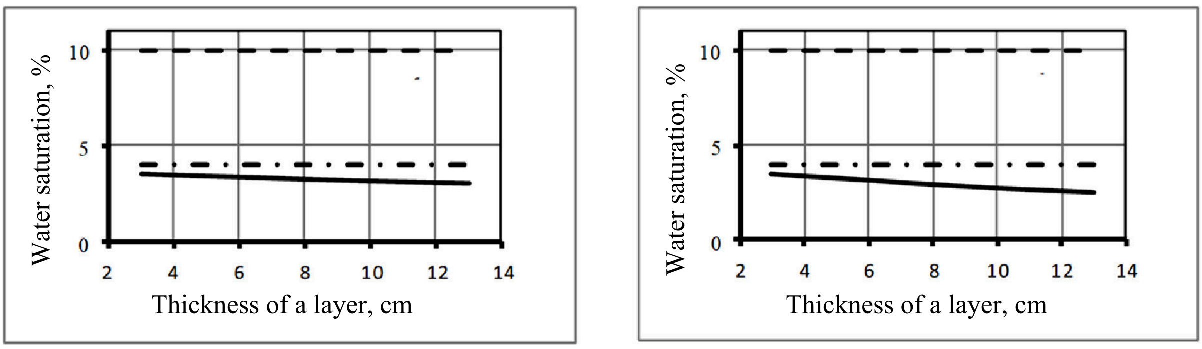


Fig. 5. Water saturation functions:

——— is water saturation;

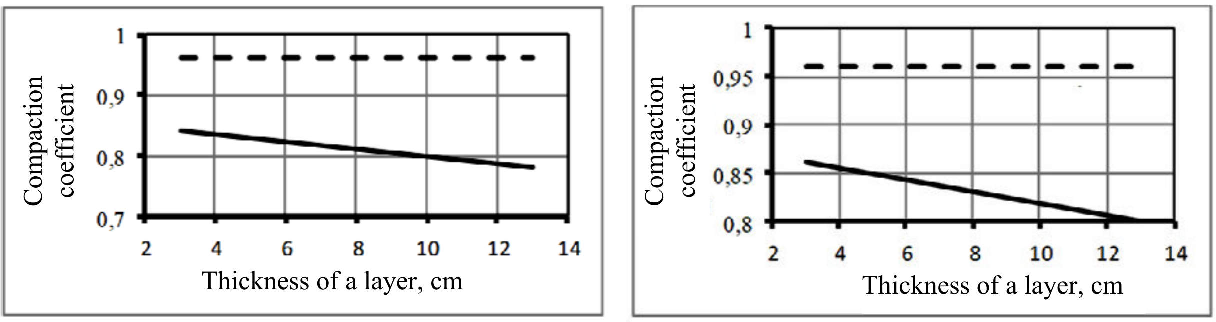
– · – · is a normative value of a water saturation index of 4 % according to the GOST (ГОСТ) 9128-2009;

– – – is a normative value of a water saturation index of 10 % according to the GOST (ГОСТ)

The graphs in Fig. 5 suggest that the obtained indices of water saturation of a material correspond with the required standard value according to the GOST (ГОСТ) 9128-2009 that for this type of porous mixes should range from 4 to 10 % of the volume. For a 20 % emulsion in the volume the water saturation is lower than the normative one (a mix is extremely mobile). Change in the thickness of a pothole layer and the height of feeding the material has no significant effect on water saturation of a bitumen mineral mix.

Fig. 6 shows the behavior of the function of compaction coefficient on the factor x_1 (the thickness of a pothole layer, cm) for a fixed factor x_2 (the height of feeding a material, cm) and Fig. 7 shows its dependence on a factor x_2 (the height of feeding a material, cm) for a fixed factor x_1 (the thickness of a pothole layer, cm).

The graphs in Fig. 6, suggest that the obtained compaction coefficient of a material does not correspond with the required normative value according to the Road Safety Code (СП) 78.13330.2012 that for asphalt concrete from cold mixes should not be lower than –0.96.

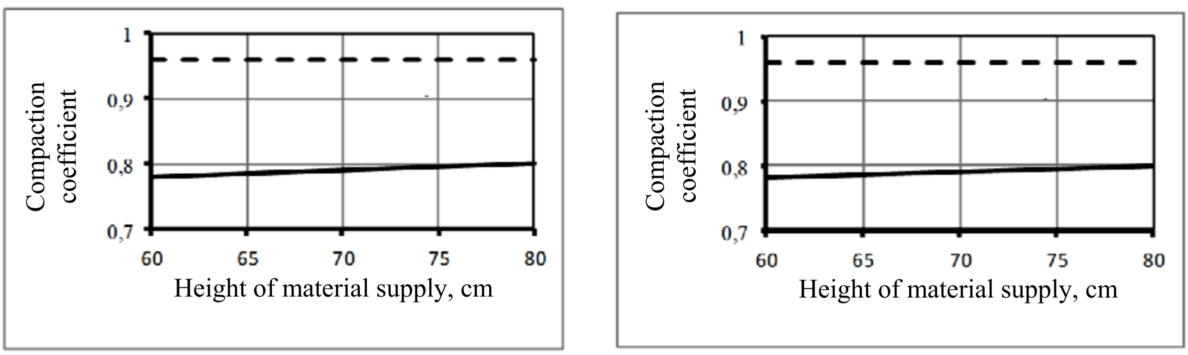


a) x_2 = 60 см b) x_2 = 80 см

Fig. 6. Function of a compaction coefficient:

——— is a compaction coefficient;

– – – is a normative value K of compaction according to the Road Safety Code (СП) 78.13330.2012 — 0.96



a) x_1 = 3 см b) x_1 = 13 см

Fig. 7. Function of a compaction coefficient:

——— is a compaction coefficient;

– – – is a normative value K of compaction according to the Road Safety Code (СП) 78.13330.2012 — 0.96

As a result of processing the experimental data, the regression equations for the investigated parameters were obtained [1, 6, 8, 9, 13, 15]:

$$\rho = 1.91 - 0.014x_1 + 0.0007x_2, \quad (1)$$

$$r = 3.25 - 0.064x_1 + 0.0047x_2, \quad (2)$$

$$k = 0.798 - 0.006x_1 + 0.001x_2. \quad (3)$$

Tests of the obtained equations using the Fisher's criteria showed that the calculation criteria are smaller than those in the table, which allows us to conclude that the obtained equations are credible. It was found that the final result for laying a bitumen mineral mix with the use of the injection-liquid method depends on the rate of feeding a material from a nozzle of a machine. The height of feeding a material has no significant effect on the compaction coefficient. The obtained values of the parameters are different from the average ones in the accepted range (Table).

Table

Results of testing the equations

The calculated values of the parameters			Average values of the parameters		
ρ_j density, g/cm^3	r_j water saturation, %	k_j compaction coefficient	$\tilde{\rho}_j$ density, g/cm^3	$\tilde{r}_j$ water saturation, %	$\tilde{k}_j$ compaction coefficient
1.91	3.10	0.84	1.91	3.33	0.837
1.77	2.46	0.78	1.78	2.71	0.783
1.92	3.11	0.86	1.93	3.44	0.863
1.78	2.47	0.80	1.78	2.79	0.797

Conclusions

1. The obtained experimental data deny the existing opinion of manufacturers and users of equipment for the liquid-injection method that it has the advantage of no compaction needed for laying a material in a pothole [14—20, 22, 24, 25].

2. In order to improve the life cycle of a repaired surface of roadways it is proved that extra compaction of a mix in a pothole with compaction machines is necessary.

3. The physical and mechanical properties of a bitumen mineral mix (water saturation, compaction coefficient) are determined for laying using the liquid-injection method considering technological modes of operation during patching non-rigid potholes (of varying depths).

4. The analytical dependencies of the effect of technological modes of feeding a mix on its laying quality in a pothole are identified. For a 20 % content of an emulsion in a mix water saturation is lower than the normative one (a mix is extremely mobile). As an emulsion con-

tent drops with crushed stone fractioned 5—15 and 5—20 mm, an emulsion content in mixes with crushed stone fractions grows from 6 to 9 %. For mixes with crushed stone fractioned 3—10 mm for an emulsion content of 15 to 20 % water saturation is over the accepted value.

5. An increase in the height of feeding a material does not have a significant effect on the compaction coefficient and as the thickness of a compacted material layer into a pothole rises, there is an insignificant drop in the compaction coefficient.

6. The obtained results of the factor experiment are credible.

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