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Optimal Formulations of Some Asphalt Concrete Roadway Protective Impregnation Compositions

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ABSTRACT

The current paper describes optimization of the formulations of asphalt concrete roadway protective impregnation compositions based on BND 60/90 bitumen modified with petroleum resin. Physicochemical, technological and operating parameters of the prepared samples of the compositions are investigated.

Key words: Bitumen, Binder, Petroleum Resin,Protective impregnation compositions Road pavement, Impregnating composition, Modifying agent.

INTRODUCTION

Asphalt concrete is the most convenient material for paving. It forms a flat, noiseless, rough surface which does not require complex repairs and care. Over freshly placed asphalt concrete traffic can be immediately started, while cement concrete requires a month to gain the necessary strength.

However, asphalt concrete paving possesses a number of significant disadvantages: moisture is penetrating into its porous surface and remaining inside them; the bitumen component undergoes oxidation under the action of moisture, temperature differences, ultraviolet, and air oxygen. High loads from heavy transport lead to the reduction of roughness of the roadway, shift resistance, and crack resistance. It leads to gradual destruction of the top of the asphalt concrete layer and as a consequence to the need of its repairs or a complete replacement.

Therefore protection of asphalt concrete roadway against unfavorable factors by protection (saturation) of its surface with a specially designed composition by spraying or pouring is becoming more and more actual.

After application onto asphalt concrete the impregnation composition must create a durable hydrophobic film on all the porous surface of a small thickness, providing protection while possessing a low consumption rate per square meter of the roadbed.

It was earlier found[1,2] that a most rational way to produce an impregnation composition that meets the above mentioned requirements is to use the products of oil processing – a modified binder based on of bitumen and petroleum resin, industrial oil based plasticizer, and a hydrocarbon solvent.

Optimal formulation of such a composition must provide quick drying on a roadbed after application (from 30 to 50 min) while preserving the functional parameters necessary for the protection of asphalt concrete against unfavorable factors and having its operating parameters suitable for traffic safety.

Thus the objective of this paper became the search for optimal formulations of impregnation compositions for protection of asphalt concrete roadways against unfavorable natural and anthropogenic factors.

Petroleum road bitumen of the BND 60/90 brand was selected as a binder component of the impregnation composition. Road bitumen BND 60/90 is an optimal material for asphalt concrete roadways at the latitudes with temperate and subtropical climate[3]. For modification of bitumen petroleum

Table 1: Composition and properties of modified binders

N° Modified binder	Samplecomposition, mass.% BND 60/90	I-30A industrial oil	PR	Penetration at 25°C, 0,1 mm	Softening temperature, °C	Ductility at 25 °C, sm
1	85	0	15	52	52	
2	82	3	15	56	51	≥100
3	80	5	15	58	51	

Table 2: Dependence of viscosity on the composition of impregnation compositions

Binder composition	Solvent	Viscosity, T=20 °C, % mass. of binder				
		0	30	50	65	70
1	1	3,1	3,5	7,0	66	
1	2	3,0	3,4	6,5	43	
1	3	2,9	3,4	6,4	44	
1	4	3,0	3,5	6,3	36	
1	5	3,0	3,3	6,5	41	
1	6	2,8	3,4	6,4	42	
1	7	2,9	3,5	6,5	45	
3	1	3,1	3,5	6,9	62	200 s
3	2	3,0	3,3	6,4	42	
3	3	2,9	3,2	6,5	43	
3	4	3,0	3,3	6,3	34	
3	5	3,0	3,4	6,2	40	
3	6	2,8	3,4	6,4	42	
3	7	2,9	3,5	6,4	44	

resin (BPR) which is a structuring additive, was chosen because it provides increased resistance of bitumen to the effect of high temperatures and water resistance[4,5] was selected. The use of petroleum resins as modifiers for bitumen are described in papers[4,6–9].It was earlier demonstrated[2] that the optimal content of petroleum resin in an impregnation composition is 15%.

Plasticizer[10] exerts significant influence on viscosity, rate of the processes of bitumen oxidation, and resistance to temperature gradients. Industrial oil I-30A was chosen as a plasticizer, as recommended in literature[1,2]. The amount of industrial oil varies in slight limits (up to 5 %) because an increase of the amount of oil in impregnation compositions influences the speed of its drying and degradation of operating parameters of asphalt concrete, in particular, reduction of the car tire grip coefficient for the roadway[11,12].

MATERIAL AND METHODS

They following materials were used in the paper: Viscous petroleum road bitumen of the of BND 60/90 «Slavneft-YANOS» brand,

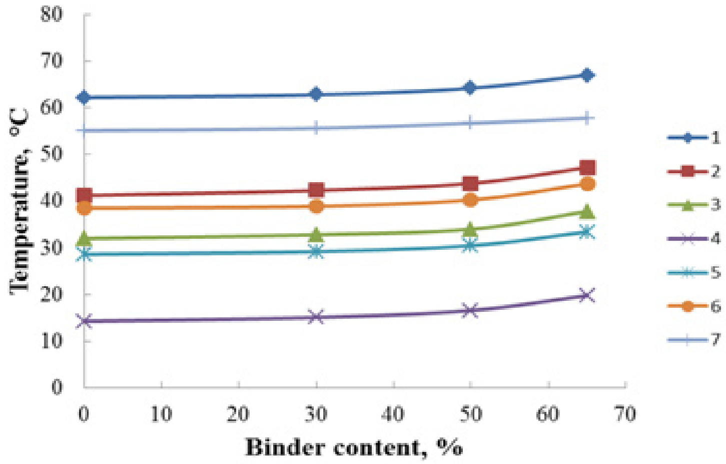

Fig.1: Dependence of viscosity on the composition of impregnation compositions (Solvents – 1. Lotoxane T_{boil} = 180 °C; 2. Lotoxane FAST T_{boil} = 160 °C; 3. Petroleum spirit 4. Hydrocarbon fractions with T_{boil} = 100– 140 °C; Hydrocarbon fractions with Tboil = 130 – 140 °C; 6 . Hydrocarbon fractions of T_{boil} = 140 – 170 °C; 7 . Hydrocarbon fraction with T_{boil} = 170 – 175 °C.)

Table 3: Dependence of flash point values on the formulation of impregnation compositions

Binder composition	Solvent	0% (flashpointofsolvent)	Flash point, °C 30% solution	50% solution	65% solution
1	1	62,2	62,8	64,2	67,0
1	2	41,2	42,3	43,8	47,2
1	3	32,0	32,8	34	37,8
1	4	14,3	15,1	16,6	19,8
1	5	28,6	29,2	30,5	33,4
1	6	40,5	41,9	4,3	43.7
1	7	55,1	55,6	56,7	57,8

“Sibplast” petroleum resin (PR), I-30À industrial oil, hydrocarbon solvents.

A general procedure for the preparation of a modified bitumen binder: Bitumen was softened and placed into a steel vessel equipped with a mechanical stirrer, thermometer, and a hotplate. The speed of the stirrer was set to 100 rpm. The bitumen was heated with stirring to 160 °C, then PR (15 mass %) was introduced and the temperature raised to 180 °C and the reaction mixture was maintained at this temperature for 90 minutes, then cooled to room temperature.

The samples containing industrial oil were obtained in the following way. The reaction mixture was cooled to the temperature of 120 ºC, industrial oil was added and the mixture was maintained for 15 min at this temperature. Subsequently in was cooled to ambient temperature.

As a result three modified binding composition were obtained. The basic properties of the binders are presented in Table 1.

To obtain impregnation compositions, samples of bitumen binders were combined using hydrocarbon solvents. The combination process

Table 4: Impregnation composition sample drying time depending on composition of a sample and thickness of the applied film

Modified binder	Solvent	Uniformity of application*		Drying time, min 400 µm		300 µm		200 µm	
		30	50	65	30	30	50	50	65
1	1	+	++	++	>120	>120	>120	>120	>120
1	2	+	++	++	35	25	35	30	35
1	6	+	++	++	45	35	45	40	50
1	7	+	++	++	>90	>90	>90	>90	>90
2	1	+	++	++	>120	>120	>120	>120	>120
2	2	+	++	++	40	30	45	40	55
2	6	+	++	++	45	35	50	45	60
2	7	+	++	++	>90	>90	>90	>90	>90
3	1	+	++	++	>120	>120	>120	>120	>120
3	2	+	++	++	40	30	45	40	55
3	6	+	++	++	45	35	50	45	60
3	7	+	++	++	>90	>90	>90	>90	>90

Table 6: Mass of water absorbed by the samples of asphalt concrete coating

Binder	Solvent	Mass of water, g Content of binder = 50 %	Content of binder = 65 %
-	-	1,0	1,0
1	2	0,22	0,21
2	2	0,21	0,19
3	2	0,22	0,19
1	6	0,22	0,21
2	6	0,21	0,19
3	6	0,22	0,19

was performed in a steel vessel equipped with a mechanical stirrer at the temperature of 100 ºC. The softened binder was placed into the vessel and at the temperature of 100 ºC the hydrocarbon solvent was added. Stirring was performed for 15-20 min before complete dissolution of the binder in the solvent was achieved.

The following solvents were used (the second digit is used in the designation of the composition)—” 1. Lotoxane T_{boil} = 180 °C; 2. Lotoxane FAST T_{boil} = 160 °C; 3. Petroleum spirit 4. Hydrocarbon fractions with T_{boil} =100 —140 °C; Hydrocarbon fractions with T_{boil} = 130

– 140 °C; 6 . Hydrocarbon fractions of T_{boil} = 140 —" 170 °C; 7 . Hydrocarbon fraction with T_{boil} = 170 – 175 °C.

RESULT AND DISCUSSIONS

such properties of the impregnation compositions were studied, as Density; flash point (physicochemical ones) Saturation with water of the asphalt concrete surface treated with a protective impregnation composition; the evenness of the application of a layer of an impregnation composition etc (protective properties);

Car tire grip coefficient for asphalt concrete after treatment with an impregnation composition; time of drying of protective impregnation composition (operational ones).

Density was measured with a portable laboratory DM-340.1 densimeter. For anhydrous impregnation bitumen compositions it is in the limits of 0.7 – 0.95 g/cm^3.

Viscosity was measured with a VUB-1 viscometer for the determination of relative viscosity of bitumen and emulsions. Modified bitumen 1 and 3 were taken for studies.

The results of the conducted experiments are presented in Table 2.

Analysis of the obtained data shows that the upper threshold content of the binder is limited by 65 – 66 %. If the concentration is raised by 5 % the viscosity increases greatly and the mixture is applied to the surface and covers it poorly.

The closed-cup flash point was determined on a semi-automatic TV3-LAB-01 apparatus.

The experiments were conducted for a single modified binder because the flash point is determined by the most volatile component, i.e. the solvent in this case. Data on the dependence of flash point value on the formulation of the impregnation compositions are presented in table 3 and figure 1.

It can be concluded that compositions that contain solvents with a boiling point above 140 °C can classified as fire-safe. Their flash temperatures exceed 40 °C (solvent 1, 2, 6, 7).

Based on the data obtained in the course of these experiments, solvents 1, 2, 6, and 7 were selected (the rest of the solvents was not considered because of significantly lower flash points). Study of evenness of application drying time was performed. Samples of impregnation compositions were applied onto a special glass with 90×120×1.85 mm dimensions. The evenness of the distribution was checked with a rod helical 100 µm applicator. The main attention was paid to the evenness of the layer after application.

Thickness of applied layers was adjusted with a universal applicator and amounted 200; 300 and 400 µm.

The drying time was measured in accordance with a standard "balance weight – paper sheet" procedure for exfoliation measurement.

The results of the studies are presented in table 4. When of solvents 1 and 7 are used in a protective impregnation composition film, the surface of the coating dries longer than films obtained for the application of impregnation compositions containing in their composition solvent 2 and 6. Use of solvents 1 and 7, which can lead to increased time of repair works and thus can significantly increase the negative impact on economic effect of repairs of asphalt concrete coating. The composition distribution study showed ideal surface distribution for all samples of the compositions.

Previously it was noted in the papers[1,2] that Lotoxane FAST with the boiling point of 160 °C was the most suitable solvent in the formulations of impregnation compositions.

As the above described experiments showed, hydrocarbon solvent with T_{boil} = 140 – 170 °C can become an analogue of such a solvent.

In terms of economic effect it is practical to replace Lotoxane FAST with a cheap hydrocarbon solvent.

To study the slipperiness of the treated roadway the compositions utilizing solvents 2 and 6 were used.

The tire grip coefficients for asphalt concrete treated by impregnation compositions with a minimum value of the applied layer thickness of 200 μm are presented in table 5.

All the samples comply with regulatory requirements for roadways because they provide grip coefficients in accordance with the requirements of GOST R 50597-93. The use of industrial oil is decreasing the grip coefficient, but its content in all the samples conform to regulatory documents.

To study saturation with moisture, 100 mm in diameter center-punches of non-treated asphalt concrete were drilled. The center-punches were dried under vacuum for 12 h. Samples of impregnation compositions were applied to the center-punches by a scraper blade. In day after the treatment the samples were weighed and placed for 72 hours on moist sand for capillary saturation. 72 hours later residual moisture was removed from the surface with filter paper and the samples were weighed. Mass of the water absorbed by the samples is given in table 6.

The results of the performed experiments show that after treatment with an impregnation composition the saturation of the coated asphalt concrete with moisture is significantly reduced.

CONCLUSIONS

The optimal concentration of the modified binder in an impregnation composition can be 50 – 65 %. The bitumen can be further modified by the addition of an industrial oil based plasticizer with the content of 3 – 5%.

Solvents for impregnation compositions must have initial boiling point value of not less than 140 °C and not above the 170 °C and a flash point of 40 °C or above. Lotoxan FAST solvents and hydrocarbon solvent with boiling point of 140 – 170 ºC meet these conditions. In terms of economic effect it is rational to use hydrocarbon solvent with the boiling point of 140 – 170 ºC instead of Lotoxan FAST.

Samples of asphalt concrete treated by such impregnation compositions meet the performance criterion of tire grip coefficient.

Saturation with moisture of the treated samples of asphalt concrete with the described impregnation compositions is significantly reduced in comparison to not treated samples.

All of this allows to make a conclusion about high hydrophobic properties of the studied impregnation composition.

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