Effect of Phenol-Cresol-Formaldehyde Resin on Adhesive Properties of Road Bitumen

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Abstract – The phenol-cresol-formaldehyde resin (PhCR-F) obtained from phenolic fraction of coal tar has been synthesized via the polycondensation method of "raw" phenols with formaldehyde. The modification of road bitumen by this resin was carried out. PhCR-F in different concentrations was found to be effectively used as a modifier of road bitumen. It was shown that PhCR-F is an effective adhesive additive for road bitumen.

Keywords – bitumen, adhesion, modifier, phenol-cresol-formaldehyde resin.

Introduction

The main reasons for the destruction of road coatings are the increase in traffic volume, the growth of freight transport volumes, the masses of vehicles, axial load, as well as the weather impact. Today, traditional asphalt concrete based on unmodified bitumen is not able to provide the necessary physico-mechanical properties of coatings and their durability under existing density of traffic [1,2].

On the basis of previous studies [1,2] it was established that phenol-formaldehyde resins (PhFR) may be the effective modifiers of bitumen. But these resins, which are produced from pure phenol, are not widely used as polymer modifiers first of all due to their high cost. On the other hand, the phenolic fraction containing about 65 % of phenols and cresols is one of the products of coking process. Its cost is by 35–40 times lower than a pure phenol cost [2]. Therefore, this work is devoted to the detailed study of the possible improving the bitumen adhesion properties with the help of PhFR, obtained from cheap raw materials – the phenolic fraction of coal tar. The changes in colloidal structure of bitumen after adding PhFR, and thus the changes in the rheological properties, have been examined as well.

Experimental

The phenolic fraction of coal tar was withdrawn at JSC "Zaporizhkoks" (Ukraine).

To obtain the modified bitumen, we used the oxidized bitumen BND 60/90 produced by PJSC "Transnational financial and industrial oil company Ukrtatnafta" (Kremenchuk, Ukraine).

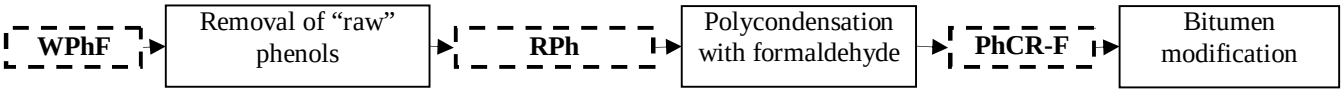

Fig.1. Scheme of researches: WPhF – wide phenolic fraction; RPh – "raw" (technical) phenols; PhCR-F – phenol-cresol-formaldehyde resin.

Novolac phenol-cresol-formaldehyde resin was obtained according to the scheme given in Fig.1 by the method of formaldehyde condensation polymerization with the "raw" phenols extracted from these fractions. As recommended by [3], the obtaining of novolac phenol-formaldehyde resins requires maintaining the mole ratio of phenol to formaldehyde at 1.12–1.42, while for novolac cresol-formaldehyde resin it should equal 2.27. Considering that the "raw" phenols that were derived from the phenolic fraction of coal tar, contain both phenols and cresols

at various ratios, the synthesis was carried out at the molar ratio “raw” phenols:formaldehydes equal to 1.42.

Results

In accordance with industrial requirements the amount of modifier approx. 1 wt % is technically and economically feasible; so we studied bitumen modification adding 1 wt % of PhCR-F and compared the results with previously obtained. Characteristics of the obtained PMB are given in Table 1

Table 1

Physico-mechanical parameters of pure and modified bitumen

Bitumen	Parameters							
	T_s, K	P_{298}, 10^{-4} m	D_{298}, $m \cdot 10^{-2}$	T_b, K	PR, K	I_p	Adhesion to	
							crushed stone, points	glass, %
BND 60/90	319	70	63	255	337	-1.5	3	33
BND 60/90 + PhCR-F (1.0 wt %)	321	68	46	255	339	-0.9	5	87
BND 60/90 + PhCR-F (2.4 wt %)	322	61	25	255	340	-1.0	5	94

The modification of BND 60/90 bitumen by different amount of modifier slightly increases the softening point, ***i.e.*** increases its heat resistance, reduces penetration and ductility, increases its hardness. However, the main effect of PhCR-F is a significant increase in bitumen adhesion to the crushed stone and glass (Fig. 2). The adhesion to crushed stone for BND 60/90 + PhCR-F (1.0 wt %) increases from 3 to 5 points, and the adhesion to glass – by more than 2.6 times. With increasing amount of PhCR-F additive (2.4 wt %), the value of adhesion to glass is somewhat higher (94 % ***vs.*** 87 %). Taking into account all mentioned above, the modifier amount of 1.0 wt % was acceptable for further investigations.

Conclusion

“Raw” phenols were extracted from the phenolic fraction of coal tar with the yield of 32.3 wt %. Phenol-cresol-formaldehyde resin (yield is 29.65 wt % relative to phenolic fraction) was synthesized ***via*** polycondensation of “raw” phenols with formaldehyde. The synthesized resin was used to modify oxidized road bitumen. The addition of modifier slightly increases the softening point of bitumen and significantly increases the adhesion to crushed stone and glass. The increase in modifier amount from 1 to 2.4 wt % does not significantly affect the adhesion, therefore the content of 1.0 wt % should be considered as an optimum one.

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