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ESTIMATION OF FUEL RESISTANCE OF ASPHALT CONCRETE AND POLYMER MODIFIED ASPHALT CONCRETE

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Досліджено закономірності зміни паливостійкості асфальто- и асфальтополімербетонів при чистому згині в умовах одночасної дії статичного навантаження і дизельного палива. Вивчено вплив консистенції в'яжучих і способу модифікації бітуму полімером типу СБС на стійкість асфальтобетонів до дії палива. Показано, що технологія модифікації бітуму полімером, що передбачає попередній пластифікацію СБС індустріальним маслом, негативно відбивається на паливостійкості асфальтополімербетону

Ключові слова: бітум, асфальтобетонні покриття, бітум модифікований полімером, асфальтополімербетон, паливо, паливостійкість

Исследованы закономерности изменения топливоустойчивости асфальто- и асфальтополимербетонов при чистом изгибе в условиях одновременного действия статической нагрузки и дизельного топлива. Изучено влияние консистенции вяжущих и модификации битума полимером типа СБС на устойчивость асфальтобетонов к действию топлива. Показано, что технология модификации битума полимером, предусматривающая предварительную пластификацию СБС индустриальным маслом, отрицательно отражается на топливоустойчивости асфальтополимербетона

Ключевые слова: битум, асфальтобетонные покрытия, битум модифицированный полимером, асфальтополимербетон, топливо, топливоустойчивость

1. Introduction

In spite of its high technological and service properties asphalt concrete (hereinafter referred to as asphalt) has one essential drawback, in particular it is susceptible to the dissolution when exposed to the action of fuels and lubricants. This drawback is very dangerous for asphalt pavements in airports, parking lots and car service centers, where different fuels and lubricants, in particular kerosene, petrol (gasoline), diesel fuel and different oils of a petrolic origin have a good chance to affect the pavement.

The fuel resistance of asphalt pavements can be improved due to the use of high-consistency bitumen or through the modification of bituminous binders by the additives that increase the dissolution resistance of such pavements. The goal-seeking development of asphalt concretes that have an increased resistance to the action of fuels and lubricants can only be efficient in case of the availability of objective criteria used for the estimation of their fuel resistance. In this connection the problem of the studies of destruction processes that occur in asphalts and polymer modified asphalts (PMA) exposed to fuel environments is rather topical.

2. References Review and Problem Statement

For the patches of pavements exposed to the action of fuels and lubricants special binding agents are used; very frequently these are of a coal origin [1, 2]. The availability of styrene copolymer in the asphaltic binder also increases its resistance to the action of fuels and lubricants [3].

It is known that the modification of bitumen with styre-ne-butadiene-styrene (SBS) improves both the shearing resistance and crack growth resistance of the asphalt [4, 5]. However, the issue related to the influence of SBS on the fuel resistance of asphalt requires additional studies.

It is readily apparent that the technology used for the production of polymer modified bitumen (PMB) that requires the addition of easily soluble plasticizer [6] to bitumen will result in a decrease of the fuel resistance of PMA. In spite of the fact that the problem of the solubility of asphalt pavements is rather topical the research done to solve it has an episodical nature.

The influence produced by fuels and lubricants on the operability and the properties of asphalt has not been given proper consideration and current normative documents that regulate its properties have no appropriate information. EU countries use the standard [7] to estimate the resistance of asphalt and PMA exposed to fuels and lubricants. According to this standard we determine the mass loss of the specimens exposed to the action of fuel for a certain time that were preliminary abraded with special brushes under the specific pressure. However, CIS have no appropriate techniques for the estimation of the resistance of asphalt exposed to the action of fuels. This circumstance prevents us from the objective selection of the optimal compositions of asphalt that would provide its efficient operation in the environment of fuels and lubricants. It is reasonable to perform tests under the joint action of the specific environment and tensile stresses that maximally meets the performance conditions of asphalt in the road pavement [8]. The most reasonable and simple scheme for such tests provides the determination of time prior to the collapse of asphalt specimens immersed into the fuel environment and exposed to the fixed-load bending stress. The advantage of these tests is that the time factor is used as an estimation criterion, which is more appropriate for the assessment of the composition and structure of the asphalt and the action of the aggressive media to which it is exposed in comparison with traditional strength indices [9].

3. Objectives and the Research Tasks

The purpose of this scientific paper is to determine the influence produced by the bitumen consistency and its modification with polymer of SBS type on the fuel resistance of asphalt and PMA. To reach this goal the following problems were solved:

– studying the mechanisms of a change in fuel resistance indices of asphalt concrete depending on the bitumen consistency and also the mechanisms of introduction of SBS polymer to its composition;

– estimating the influence of the technology that uses polymer to modify bitumen on the fuel resistance of asphalt concrete.

4. Materials and Criteria for the Estimation of the Fuel Resistance of Asphalt and PMA

The criteria of the estimation of the fuel resistance of asphalt and PMA were as follows:

1) fuel resistance indices K^{R}_{DF}, defined as a ratio of the compression strength of cylindrical specimens (∅7 cm) subjected preliminary to the vacuum compaction in diesel fuel (DF) for one hour and exposed to it during one hour, 5, 10 and 15 days to that of dry test specimens;

2) fuel resistance indices, defined as the time ratio prior to the destruction of beam specimens (4×4×16 cm) subjected to the bending stress in the diesel fuel and in the air (Fig. 1).

All tests were carried out at a temperature of 22±0,5 °C.

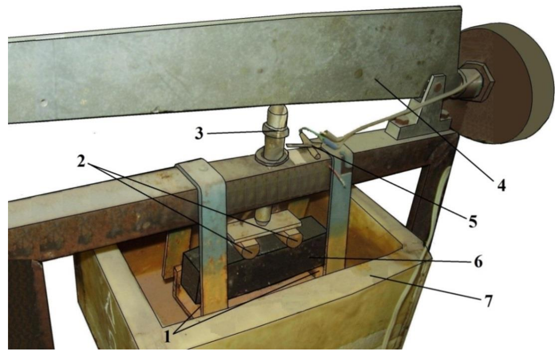


Fig. 1. The lever press used to determine the time test prior to the destruction of beam specimens subjected to the pure bending: 1, 2 — the lower and upper supports; 3 — the transmitting rod; 4 — the loading lever; 5 — the clockwork switch; 6 — the beam specimen (4×4×16 cm); 7 — the fuel tank

During the experiment we used bitumen of three grades with the penetration of 64×0,1 mm, 103×0,1 mm and 160×0,1 mm; PMB on their basis with 3 % and 6 % SBS obtained using the technology of the direct introduction of polymer to bitumen; PMB with 3 % SBS obtained using the technology of the preliminary plasticization of polymer in industrial oil I-40A with further mixing of the obtained polymer solution (PS) of 30 % SBS containing with the modified bitumen.

Asphalt of the sandy granulometry (maximum size of a grain is 5 mm) was used for the investigation. The content of the binding agent was equal to 5.5 % for all cases. Though this condition does not satisfy the optimal content of the binders of a different consistency present in asphalt concrete, nevertheless it provides relatively similar values of water saturation for studied asphalt concretes, which is very important for the availability of comparable test conditions in the fuel environment.

The influence of fuels and lubricants on the resistance of asphalts and PMAs was studied in this paper using diesel fuel. The use of DF allowed for the saturation of specimens through the vacuum compaction (by analogy to the standard technique of the water saturation) without the loss of the specimen shape, which is impossible in the case of use of kerosene or petrol. The obtained data given in [10] also speak in favor of the choice of DF for the tests according to which an increase in the dissolving capacity of the fuel medium results in the enhancement of the dependence of the mass loss of specimens exposed to the medium on their residual porosity. Thus, the slope of this relationship for the samples exposed to the petrol is equal to 6,3 and for the specimens exposed to DF it is equal to 0,8. Therefore one can assume that the use of DF will contribute to the minimization of the scatter of data related to the variation of the water saturation index for asphalts considered in this scientific paper.

5. The Results of the Determination of Fuel Resistance Indices for Asphalts and PMAs Exposed to Diesel Fuel and Their Discussion

It was shown in the paper [11] that the objectiveness of the determination of environment resistance indices of asphalts of a different strength in terms of time factors prior to the specimen destruction in the medium and in the air is increased. This allows us to considerably draw together the time factors prior to the destruction of asphalts of a different strength. Nevertheless, such an approach has justified itself insufficiently in the case of the tests using DF, because even insignificant deviation in the test duration significantly affects defined indices. In this connection this paper will give consideration to the indices , reduced to the same test duration in the air, equal to 9 hours. Table 1 gives the experimental data of the research done.

As the bitumen consistency is increased the average molecular mass of the compounds contained in bitumen is also increased, which, in its turn, promotes a decrease of their solubility [12]. The obtained data show that the fuel resistance of asphalt is increased as the bitumen penetration is decreased. When we change over from bitumen B(160) to bitumen B(64) a gain in indices of and after 5, 10 and 15 days made up 0,07–0,11.

A direct introduction of polymer into bitumen considerably increases the fuel resistance of asphalt in terms of the index . Thus, the introduction of 3 % SBS to bitumen taken for the investigation results in an increase of this index by 0,16–0,13, and the introduction of 6 % SBS to bitumen results in an increase of this index by 0,18–0,20. Probably such an increment is conditioned by an increase in the consistency of the petrolene component (which is notably subjected to the dissolution by fuels and lubricants) due to the consumption of oils for the plasticization and swelling of SBS molecules [13]. At the same time the polymer system formed in bitumen, which is saturated with bitumen oil, can easily be dissolved in organic solvents. Thus, a decrease in the solubility of PMB is probably conditioned by an increase in the consistency of the petrolene component of bitumen that functions as "the protection" for the formed polymer system. At the same time such a standpoint allows for the explanation of a decrease in the indices for PMAs after 10 and 15 days in comparison with those for asphalts based on the original bitumen, because a long exposure of specimens to the medium creates conditions for the softening of the petrolene component of PMB, which results in the intensive dissolution of its polymer component. These results are unusual and therefore the in-depth control of the time decrease kinetics of the resistance of PMAs exposed to the fuel media is required.

A comparison of asphalts and PMAs based on bitumen and PMB of a similar penetration shows that the indices for the pairs B(64) and; B(64) and ; B(103) and B^{3P}_{160}(107); B(64) and B^{6P}_{103}(53); B(64) and are equal to 0,24 and 0,40; 0,24 and 0,36; 0,23 and 0,30; 0,24 and 0,41; 0,24 and 0,37 respectively. Therefore, the resistance of bitumen-based asphalts modified by a direct introduction of polymer in considerably increased in the DF, however, the degree of this increase is reduced with a decrease in the consistency of binding agents.

The data obtained for PMB-based PMA made of bitumen and the PS confirmed our anxiety over the fuel resistance. As for the index it yields significantly (0.09) to its PMB-based counterpart. This can be explained by a better solubility of the petrolene medium of the composed PMB in comparison with the medium formed through the direct introduction of polymer to bitumen.

Taking into account the fact that the fuel resistance of asphalts and PMAs depends mainly on the solubility of binding agents included in their composition we developed the method used for the estimation of the solubility rate of bitumen binders in fuel media. Particularly, this method is intended for the determination of the relative loss of the specimen mass (∅ 2 cm), composed of granite sand fraction (100 %) of 0.071 to 0.14 mm and the test binder (plus 15 % in addition to 100 % of sand). Such a content of the binder provides the production of rather "thick" films of a binding agent (according to Duriez [14] the film thickness in this case is equal to 100÷150 m), which eliminates the influence of structured bitumen layers at the boundary with the rock material on the test data. A schematic diagram of the test procedure and the data obtained using it is given in Fig. 2.

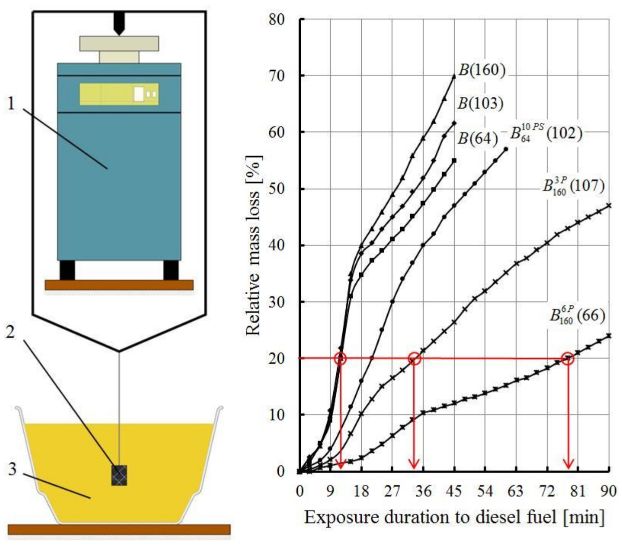
Table 1

Resistance Indices of Asphalts and PMAs Exposed to DF

Binder Index	Water saturation, %	K^t_D	In relevance to time duration of specimen tempering in DF			
			1 hour	5 days	10 days	15 days
B(64)	5,5/3,9	0,24	0,80	0,54	0,43	0,38
B^{3P}_{64}(52)	5,0/3,0	0,40	0,85	0,53	0,41	0,36
B^{10PS}_{64}(102)	4,9/3,3	0,21	0,69	0,40	0,28	0,20
B(103)	5,7/4,5	0,23	0,79	0,47	0,37	0,32
B^{3P}_{103}(74)	4,1/2,9	0,36	0,82	0,42	0,29	0,25
B^{6P}_{103}(53)	4,6/3,2	0,41	0,82	0,46	0,30	0,25
B(160)	5,4/3,5	0,17	0,80	0,41	0,32	0,27
B^{3P}_{160}(107)	4,9/3,3	0,30	0,82	0,40	0,27	0,19
B^{6P}_{160}(66)	5,0/2,9	0,37	0,83	0,44	0,30	0,22

Remark: the binder index shows the penetration (in the brackets); the polymer content – above; the initial bitumen penetration – below; in the "Water saturation" column the numerator gives the indices for cylindrical specimens used to determine the indices , and the denominator gives the indices for the specimens of the beams used to determine K^t_{DF} indices

The data obtained during this test prove not only qualitatively but also quantitatively the tendencies revealed using asphalts specimens. Thus a direct introduction of 3 % and 6 % of SBS to bitumen B(160) results in 2.5 times and 6.5 times increase of time required for the dissolution of 20 % of the specimen mass, accordingly. At the same time the solubility of specimens based on PMB that includes the plasticizing agent is much higher than that of specimens based on PMB , obtained using the technology of the direct introduction of polymer to bitumen.



a *b*

Fig. 2. Determination of the dissolution rate of bitumen binders: *a* — is the test scheme; *b* — is the relationships of the specimen dissolution as a function of the exposure to DF; 1 — the scales (VLKT 500); 2 — the specimen; 3 — the DF

6. Conclusions

Experimental data obtained during the tests allow us to come to the following conclusions:

– the direct introduction of polymer to bitumen facilitates an increase in the resistance of asphalt exposed to the action of the DF. At the same time the PMB-based asphalts produced using the technology of the direct introduction of SBS to bitumen display higher resistance to the action of fuel in comparison to those on pure bitumens of a similar consistency;

– the PMA preparation technology using the oil solution of polymer results in a significant decrease of the fuel resistance of polymer modified asphalt concrete in comparison with the technology of the direct introduction of polymer to bitumen.

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