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BITUMEN COMPOSITIONS FOR COLD APPLIED ROOFING PRODUCTS

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Abstract. Physico-chemical characteristics of three-component composition BNB 70/30 bitumen : linseed oil : SBS rubber have been investigated. The composition may be used for the production of rolled roofing, the installation of which does not require heating operation. The dependence of the softening temperature, ductility, penetration, adhesion, elasticity and water resistance of bitumen compositions on their structure has been examined.

Keywords: bitumen, bitumen composition, linseed oil, roofing products, insulating material.

1. Introduction

Nowadays there are many types of insulation and roofing, which are made of bituminous materials. Bitumen based soft roofing is widely used for the roofs of buildings to protect them from atmospheric precipitation. In modern building more than 80 % of the roofs are made of soft roofing products [1]. New type of rolled roofing products is cold applied roofing, installation of which, unlike the classical rolled materials, does not require heating [2]. The advantages of these materials are that they are easily applied, do not require special surfaces preparation and have a relatively low cost, short term of preparatory work and easiness of repair. [3] The disadvantage of all bitumen based materials is their fragility. Therefore, all bituminous materials used for roofing production must be characterized by good elasticity, high heat resistance, low-temperature flexibility and high adhesion to hard surfaces.

Ordinary construction bitumen does not meet the above requirements and therefore it is necessary to use special additives to produce cold applied bitumen materials. To improve operational characteristics of bitumen (hardness, freezing point) they may be modified by polymers [4]. Known method is bitumen modification by polymer latex Butonal [5] and SBS type polymers [6]. The use of such modifiers allows to increase the elasticity of bituminous materials. Bitumen modification by petroleum resins is also a known method, but the brittleness temperature of resulting products increases, that is undesirable for roofing bitumen [7].

Apart from known polymer modifiers, a rubber crumb obtained during the processing of worn car tires, the number of which is growing every year, can be used for bitumen modification [8]. The use of this secondary product for bitumen modification allows to obtain high quality rubber-bitumen binder and solve a major environmental problem – utilization of worn tires. [9]

Popular roofing or insulation cold applied materials consist of a base (usually glass fiber) filled with bituminous materials [2, 10]. One side of the rolled material surface is covered by foil, and the second – by protective polyethylene film. This film is removed immediately before installation, the surface is covered by coating and rolled with a roller. To ensure high efficiency and durability of the coating bitumen composition, which is its basis, must meet the following requirements:

- high adhesion to hard surfaces – not less than 5 N/cm^2;
- high softening temperature – not less than 343 K;
- flexibility without cracking at negative temperatures – below 248 K;
- heat resistance at 333 K.

However known bitumen compositions have insufficient adhesion to hard surfaces, ductility and elasticity within a wide temperature range. Moreover, the installation of bitumen based rolled materials needs heating both of the surface and coating or additional adhesive materials [10, 11].

The aim of this work was to study the obtaining of high quality bitumen composition with improved adhesion, high-temperature and low-temperature properties, which can be used for the production of cold applied rolled roofing.

2. Experimental

The starting material for the researches was construction petroleum bitumen BNB70/30 with the following characteristics:

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• softening temperature – 355 K;
• ductility at 298 K – 2 cm;
• penetration at 298 K – 17·0.1 mm;
• low-temperature flexibility at 248 K – fails the test.
• heat resistance at 333 K – stands the test.

The choice of bitumen type is caused by a high softening temperature and general availability necessary for the possible industrial implementation of the developed technology.

To obtain cold applied bitumen compositions we used linseed oil (LO). Linseed oil is a vegetable oil, which is extracted from flax seeds. It belongs to the drying oils. This ability is provided by a high content of unsaturated fatty acids, namely alpha-linolenic (60 %), linoleic (20 %), oleic (10 %) and other saturated fatty acids (10 %). The third component of the bitumen composition was styrene-butadiene-styrene rubber (SBS) of Kraton D1192ESM type.

Two- and three-component mixtures were obtained at the laboratory mixing plant at 443–463 K. For the resulting products we determined a softening temperature (by "ring and ball" method), ductility, penetration, elasticity, heat resistance, water absorption by standardized methods. To determine the low-temperature flexibility at 248 K the sample was applied as a thin layer on the foil, cooled to 248 K, and then bend around a wooden bar with a diameter of 25 mm. The surface of a bitumen composition was examined. After bending a bitumen surface should be smooth, without cracks, breaks, *etc*. Adhesion was determined by measuring the mechanical forces during tearing off the metal seal from the surface covered with the bitumen composition.

3. Results and Discussion

To provide necessary properties required for cold applied bitumen compositions, in particular combination of high adhesion characteristics (adhesiveness) with the high ductility at low temperatures, heat resistance and sufficient hardness we studied the properties of two-component mixtures (construction bitumen BNB70/30 and linseed oil (LO), which belongs to the group of "drying" oils). Previous studies have found high effectiveness of LO compared to other vegetable oils (sunflower, rapeseed, *etc.*).

To prepare two-component mixture "bitumen : linseed oil" LO was added to bitumen, gradually increasing oil amount. The main quality parameters, including the softening temperature, ductility, penetration, elasticity, flexibility, heat resistance, adhesion and water absorbing were determined according to the standsardized methods.

Table 1 shows the change of the main quality indices of two-component mixtures with increasing content of linseed oil in it.

The increase in the LO content (Table 1) decreases the softening temperature and elasticity but increases penetration. This indicates the effect of bitumen "softening" when adding linseed oil. It was established that the addition of LO to bitumen increases its adhesion to hard surfaces. So, it is the effect of bitumen "adhesiveness" at room temperature, allowing to use it without heating. The increase in the LO content above 15.0 wt % decreases adhesion, apparently caused by bitumen composition excessive dilution.

An important index of cold applied bitumen compositions is elasticity at low temperatures. It was established that resulting bitumen composition obtained by the LO addition in the amount of 15 wt % and more meets the requirements for frost resistance and low-temperature flexibility at 248 K. Heat resistance of bitumen composition decreases with increasing content of linseed oil. If the LO content is above 10 wt %, the composition does not meet the requirements for heat resistance.

Table 1

Characteristics of two-component composition bitumen : linseed oil

Index	BNB 70/30 bitumen	Linseed oil content, wt %				Requirements for bitumen composition
		3	10	15	20	
Softening temperature, K	355	353	338	330	325	> 343
Ductility at 298 K, cm	2	3	4.5	7.0	7.5	–
Penetration at 298 K, 0.1 mm	17	19	48	93	131	–
Elasticity, %	50	40	23	21	20	> 20
Low-temperature flexibility at 248 K	fails the test	fails the test	fails the test	stands the test	stands the test	stands the test
Heat resistance at 333 K	stands the test	stands the test	fails the test	fails the test	fails the test	stands the test
Adhesion, N/cm^2	–	2.0	5.0	12.0	9.5	> 5.0
Water absorbing, %	0.06	0.07	0.08	0.27	0.12	< 1.0

Table 2

Characteristics of three-component composition bitumen : linseed oil : SBS (LO content 10 wt%)

Index	BNB 70/30 +10 wt% LO	SBS content, wt%			Requirements for bitumen composition
		3	5	10	
Softening temperature, K	338	351	361	371	> 343
Ductility at 298 K, cm	4.5	5	3.5	7.5	–
Penetration at 298 K, 0.1 mm	48	31	29	28	–
Elasticity, %	23	60	71	80	> 20
Low-temperature flexibility at 248 K	fails the test	fails the test	fails the test	fails the test	stands the test
Heat resistance at 333 K	fails the test	stands the test	stands the test	stands the test	stands the test
Adhesion, N/cm^2	5.0	4.8	2.4	2.2	> 5.0
Water absorbing, %	0.08	0.12	0.12	0.13	< 1.0

Table 3

Characteristics of three-component composition bitumen : linseed oil : SBS (LO content 15 wt%)

Index	BNB 70/30 +15 wt% LO	SBS content, wt%			Requirements for bitumen composition
		3	5	10	
Softening temperature, K	330	345	357	369	> 343
Ductility at 298 K, cm	7.0	5.5	6.0	8.0	–
Penetration at 298 K, 0.1 mm	93	43	39	34	–
Elasticity, %	21	55	83	87	> 20
Low-temperature flexibility at 248 K	stands the test	stands the test	stands the test	fails the test	stands the test
Heat resistance at 333 K	fails the test	fails the test	stands the test	stands the test	stands the test
Adhesion, N/cm^2	12.0	8.0	7.0	3.5	> 5.0
Water absorbing, %	0.27	0.10	0.10	0.10	< 1.0

Table 4

Characteristics of three-component composition bitumen : linseed oil : SBS (LO content 20 wt%)

Index	BNB 70/30 +20 wt% LO	SBS content, wt%			Requirements for bitumen composition
		3	5	10	
Softening temperature, K	325	341	349	365	> 343
Ductility at 298 K, cm	7.5	6.0	7.0	10.5	–
Penetration at 298 K, 0.1 mm	131	62	58	37	–
Elasticity, %	20	58	85	87	> 20
Low-temperature flexibility at 248 K	stands the test	stands the test	stands the test	stands the test	stands the test
Heat resistance at 333 K	fails the test	fails the test	stands the test	stands the test	stands the test
Adhesion, N/cm^2	9.5	7.0	4.4	4.0	> 5.0
Water absorbing, %	0.12	0.12	0.13	0.15	< 1.0

Table 5

Characteristics of bitumen composition for cold applied roofing products

Index	Values	Requirements for bitumen composition
Softening temperature, K	353	> 343
Ductility at 298 K, cm	4.0	–
Penetration at 298 K, 0.1 mm	48	–
Elasticity, %	25	> 20
Low-temperature flexibility at 248 K	stands the test	stands the test
Heat resistance at 333 K	stands the test	stands the test
Adhesion, N/cm^2	5.6	> 5.0
Water absorbing, %	0.1	< 1.0

The increase in the LO content to 20 wt % actually does not change water absorbing of bitumen composition. This value for all two-component mixtures meets the requirements (less than 1 %).

It is impossible to obtain bitumen composition which meets all requirements using two-component mixtures. Therefore a third component should be added allowing to increase hardness, softening temperature, elasticity and frost resistance of the bitumen composition. At the same time this component should not worsen other indices. It is known that introduction of rubber, namely SBS, provides such an effect. Therefore we studied three-component composition containing BNB70/30 bitumen, LO and SBS rubber in different proportions. The experimental results are shown in Tables 2-4.

The dependence of softening temperature of three-component mixture on its composition (Tables 2-4) demonstrates the mutual influence of the components. The increase in SBS content and decrease in the linseed oil content increases softening temperature and penetration. Ductility of three-component mixture increases with increasing the LO content. The maximum value of ductility is observed at SBS and LO content of 10 and 20 wt %, respectively. Maximum elasticity is achieved with a maximum content of SBS and minimum content of linseed oil. The increase in LO content decreases elasticity.

The value of low-temperature flexibility at 248 K stands the test with the LO content of 15 wt % and more and SBS content till 10 wt %. If these conditions are not fulfilled the bitumen composition becomes brittle. Value adhesion passes through a maximum when the LO content is 15 wt %. Addition of SBS decreases adhesion.

Analyzing the results and using the triangular diagram we set the area of compounds optimal composition, which provides the required standard indices for cold applied bitumen material (Fig. 1).

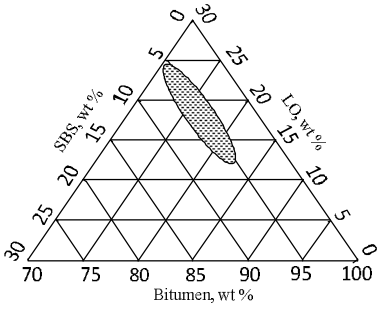

Fig. 1. Optimum composition of three-component mixture bitumen : linseed oil : SBS while its using as cold applied bitumen material

The content (wt %) of BNB70/30 in such compositions should be 70.5–83.5; linseed oil 12.5–23.0 and SBS 4.0–6.5. Based on the obtained results the optimum composition BNB7030 : LO : SBS was found to be (wt %): 77.5 : 17.0 : 5.5. This optimal ratio is in the middle area of the optimal composition (Fig. 1). Characteristics of this composition are given in Table 5.

The developed bitumen composition for cold applied roofing products meets the requirements and even exceeds existing analogues relative to the softening temperature [2]. Due to the high softening temperature the developed roofing and insulation materials have high thermal stability in hot climate.

4. Conclusions

On the basis of obtained experimental dependence of the three-component system BNB70/30 : linseed oil : SBS properties on its composition a new type of bitumen composition for cold applied roofing products was developed. The optimum intervals of bitumen composition (wt %) was found to be BNB70/30 : LO : SBS = = (70.5–83.5) : (12.5–23.0) : (4.0–6.5).

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ОДЕРЖАННЯ БІТУМНИХ КОМПОЗИЦІЙ ДЛЯ ПОКРІВЕЛЬНИХ МАТЕРІАЛІВ ХОЛОДНОГО НАНЕСЕННЯ

Анотація. *Наведено результати досліджень фізико-хімічних характеристик трикомпонентної бітумної композиції «бітум БНБ 70/30 : лляна олія : каучук СБС», яка може використовуватися для одержання рулонних покрівельних матеріалів, для монтажу яких не потрібно використовувати операцію нагрівання. Вивчено залежність температури розм'якшення, дуктильності, пенетрації, адгезії, еластичності та водостійкості бітумних композицій від їхнього складу.*

Ключові слова: *бітум, бітумна композиція, лляна олія, покрівельний матеріал, ізоляційний матеріал.*