TEKA. COMMISSION OF MOTORIZATION AND ENERGETICS IN AGRICULTURE – 2014, Vol. 14, No. 4, 113–118

Research on Properties of Bitumen Modified with Polymers Used for Asphalt Concrete Pavement on Bridges

Arthur Onischenko, Mykolay Kuzminets, Sergey Aksenov

National Transport University, Ukraine, Kyiv, str. Suvorova 1,
e-mail: Artur_onish@bigmir.net, Vectra16i@i.ua, Kabysik@bigmir.net

Received December 01.2014; accepted December 17.2014

Summary. There are given the investigation results of bitumen modified with the polymer (SBR) latex Butonal NS 104 depending on temperature, time and the modifying agent amount, taking into account the manufacturing company BASF recommendations. The carried out research has shown the possibility to produce bituminous polymer on the polymer latex Butonal NS basis that meets the Ukraine technological normative requirements. On the conducted investigations basis there have been established the rational parameters of bituminous polymer binding agent production process thus allowing for the determination of the requirements for the polymer latex Butonal NS 104 application under domestic production conditions.
Key words: paving bitumen, polymer latex Butonal NS, bituminous polymer preparation process, binding agent properties.

INTRODUCTION

In road-building industry bitumen modification with polymers is one of the most effective ways to extend service life of the road-building materials produced on the organic binding agents [1-10].

The most effective and recognized are the styrene-butadiene-based polymers [3-8]. Among the polymers of this type the polymer latexes of the Butonal NS 104 series (BASF production, USA) advantageously differ due to their properties [9-10].

Taking into consideration the fact that domestic paving bitumens differ from those used in the USA, a necessity emerged to study influence of such modifying agents on the properties of the paving bitumens used in Ukraine. Cationic latex Butonal NS 198 became one of the first modifying latexes used in Ukraine. On the basis of previous investigations performed by the Derzhdor research institute and KNARU research teams the effect was determined of the polymer latex Butonal NS 198 on the paving bitumen properties [5, 14]. The laboratory test results confirmed the enhancement of the binding agent physical-mechanical properties depending on the polymer amount. This research allowed to apply the Butanol NS 198 polymer at the following highways and bridges construction: Kyiv, Kyiv – Odessa (km 217 – 236, km 247 – 236, km 247 – 252); Kharkov – Simferopol (km 536 – km 538); Kyiv – Chop (km 331 – km 335), and the other objects (Fig. 1).

Fig. 1. South bridge across the Dnieper in Kiev

Recently one more type of polymer latex appeared in Ukraine – Butonal NS 104 designed to enhance the paving bitumens modifying efficiency. However, it is obvious that to achieve the maximum benefit of the polymer use and to study its influence on the bitumen physical-mechanical properties the preparation process rational parameters should be determined taking into account operating conditions. In this paper the influence is investigated of the modified with polymer latex Butonal NS 104 bitumen preparation parameters on the paving bitumen properties. The experimental investigation was conducted to determine the following:

– rational polymer consumption for bitumen modification;
– influence of the bituminous polymer preparation temperature and time on its main characteristics;

– influence of the preparation temperature and time on the bituminous polymer homogeneity.

To perform this work the sample preparation procedures were developed. The experiments were carrying out using samples of bitumen with the polymer latex Butonal NS 104 provided by the BASF representatives – "International chemical production, Ltd.". The research was performed in the Prof. G.K. Sunya laboratory "Transport Construction Materials and Designs" of the Road Building Materials and Chemistry Department at the National Transport University.

PROCEDURE OF THE BITUMINOUS POLYMER PREPARATION BEFORE TESTING

To determine the influence of the polymer latex Butonal NS 104 on the bituminous polymer's physical-mechanical properties, during these investigations the petroleum paving bitumen 90/130 was used as one of the most common in Ukraine. The polymer latex was added to this bitumen to determine its amount and other process-dependent parameters which are relevant to production of the bituminous polymer according to domestic requirements.

Output paving bitumen 90/130 had the following output data (Table 1).

Bituminous polymer samples were prepared containing 2%, 4% and 6% of the Butonal NS 104. Temperature during preparation varied from 160 ºC to 200 ºC. The bituminous polymers' preparation duration varied from 1 to 8 hours. Such extended range of the modifying parameters is used also to determine their limit values under the operating conditions.

Table 1. The output data of paving bitumen 90/130

Parameters description	Unit	UNSt 4044 requirements to petroleum paving bitumen 90/130	Parameter value
Needle penetration depth at 25 ºC	0,1 mm	91 to 130	97
Softening temperature according to R&B	ºC	47 to 53	49,0
Stretchability (shortness) at temperature of 25 ºC	cm	minimum 55	82,6
Properties change after heating: residual penetration softening temperature change	% ˚C	minimum 60 maximum 6	95 2
Fragility temperature	˚C	maximum -10	-22
Flash temperature	˚C	minimum 240	240
Adhesion	%	-	90

To modify bitumen binding agent, a blade mixer installation was developed, (Fig. 2) which allowed for performing the process with the specified technological modes.

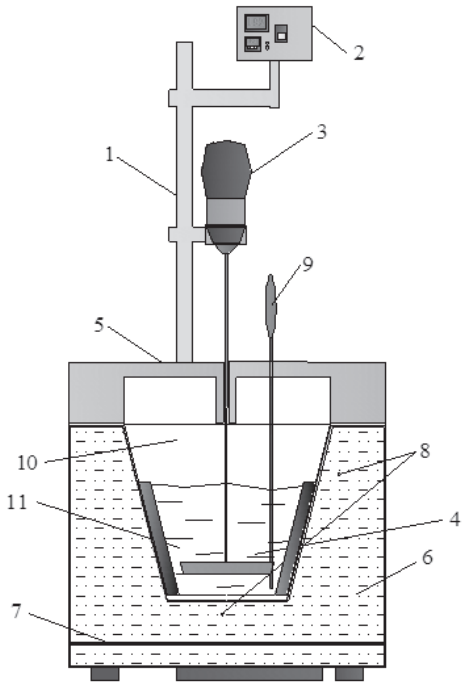

Fig. 2. Laboratory blade mixer (side-view)
1 – tripod, *2* – control unit, *3* – electric motor, *4* – blade agitator, *5* – oil thermostat *6* – oil tank *7* – electric tensor, *8* – thermocouple in the oil thermostat, *9* – thermocouple for modified bitumen, *10* – metal container according to DSTU 3277, *11* – bitumen binder.

LABORATORY RESEARCH RESULTS

The tests on the output bitumen as well as bitumen modified with polymer were carried out according to applicable regulations [9-15]. The output and modified bitumen test results are shown in Fig. 3-5.

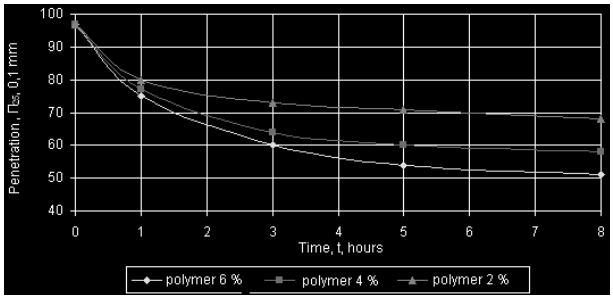

Fig. 3. Bituminous polymer penetration dependence (at 25 ºC) upon the preparation time at various polymer amounts

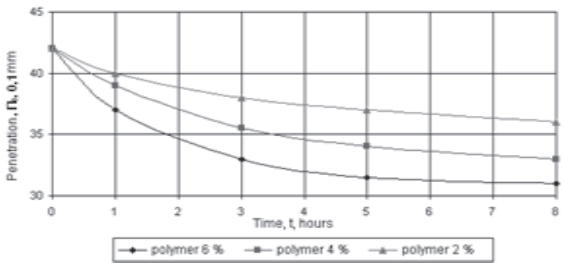

Fig. 4. Bituminous polymer penetration dependence (at 0 ºC) upon the preparation time at various polymer amounts

On the basis of these results the conclusion can be made that to establish the bituminous polymer viscosity factor it is sufficient to modify the binding agent during three hours and after this time period it is possible to determine its grade. While analyzing the bituminous polymer viscosity change in case of the preparation temperature change from 160 ˚C to 200 ˚C it is seen that at its increase the viscosity value increases, too (Fig. 5).

As it may be seen, at the preparation temperature of 160 ˚C with 2 % of polymer the observed viscosity reduction ($П_{25}$) equals 16 %, with 4 % of polymer – 18 %, with 6 % of polymer – 20 %. At the temperature of 180 ˚C with 2 % of polymer the observed viscosity reduction equals 25 %, with 4 % of polymer – 34 %, with 6 % of polymer – 37 %; and at the temperature of 200 ˚C – respectively 28 %, 38 % and 48 %. On the basis of such results it is possible to assume that while preparing the bituminous polymer at the temperature of 160 ˚C, the modifying process did not take place completely, which corresponds to BASF recommendations (the recommended range is 170-180 ˚C).

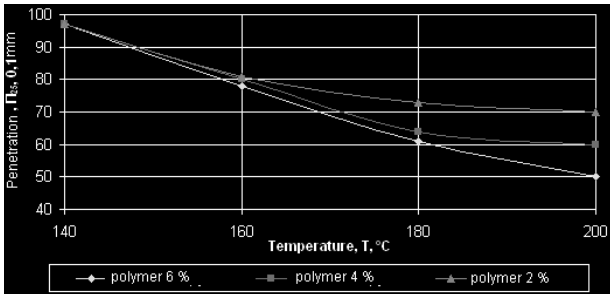

Fig. 5. Bituminous polymer penetration dependence (at 25 ˚C) upon the preparation temperature at various polymer amounts

Decrease of the penetration value of the bituminous polymer prepared at temperatures of 180 ˚C and 200 ˚C is virtually the same, however it can also be assumed that under such conditions simultaneously with the binding agent modifying process the intensive processes of its deterioration occurs. It is important also to note that at the preparation temperature increase and especially at polymer amount increase (up to 6 %) the bituminous polymer may transfer to a more viscose state. This feature of the produced bituminous polymer should be taken into consideration during preparation, placement and consolidation of polymer road concrete mix.

The results of determination of the bituminous polymer softening temperature dependence upon the preparation temperature and time showed its changeable character (Fig. 6, 7) similar to the penetration changeability.

In case of 2 % polymer concentration, already after the first hour of bituminous polymer bending agent preparation (Fig. 6) the heat resistance value increased by 5 ˚C and remained virtually constant at its further maturing in the reactor (Fig. 6).

In case of 4 % polymer concentration the main increase in the heat resistance value took place during the first hour of bituminous polymer bending agent preparation and corresponded to 10 ˚C. After 8 hours of the bituminous polymer bending agent preparation this increase was equal to 14 ˚C.

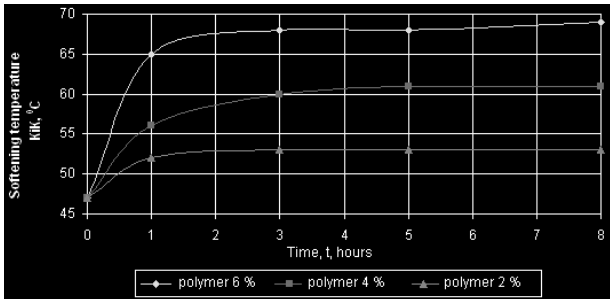

Fig. 6. Bituminous polymer softening temperature dependence upon the preparation time at various polymer amounts

In case of 6 % polymer concentration these parameters were equal to 15 ˚C and 21 ˚C. It is necessary to note that the bituminous polymer bending agent was prepared at the temperature of 180 ˚C according to BASF recommendations. In case of the bituminous polymer bending agent preparation at the temperature reduction from 200 ˚C to 160 ˚C (Fig. 7) the softening temperature value respectively increased by 1 ˚C and decreased by 3-5 ˚C.

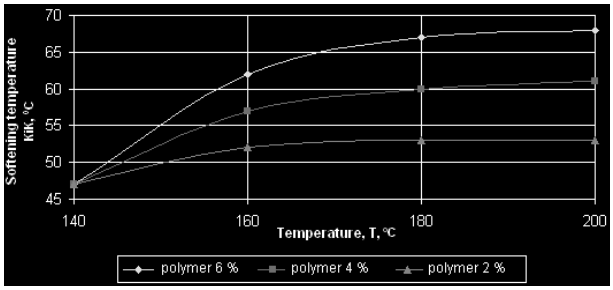

Fig. 7. Bituminous polymer softening temperature dependence upon the preparation temperature at various polymer amounts

It confirms the previous assumption that the bituminous polymer bending agent preparation temperature of 160 ˚C is insufficient for quick polymer integration to get the homogeneous mixture, and the heat resistance slow increase at the preparation temperature of 200 ˚C ensures that the deterioration processes do not develop.

To examine the possible bituminous polymer bending agent deterioration at too high temperatures, the bituminous polymer bending agent elasticity change in a range of the temperatures and preparation time periods was measured. The following results were obtained:

The elasticity occurrence even at the small amount of polymer and modifying time (at 2 %, after 1 hour of preparation (Fig. 8) confirms the possibility of the bituminous polymer bending agent elastic properties considerable enhancement.

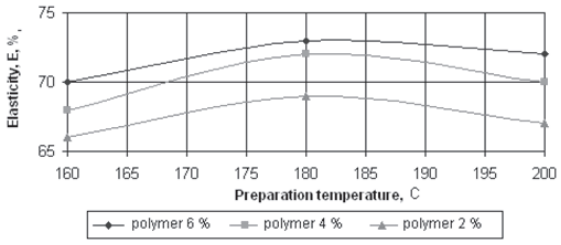

Fig. 8. Bituminous polymer elasticity dependence upon the preparation temperature at various polymer amounts

In case of 2 % polymer concentration after the first hour of preparation the elasticity factor was equal to 62%, after 3 hours – 69 %, and it remained constant at the maximum time of the bituminous polymer bending agent – 8 hours. Similar increase of the elasticity factor was found at modifying 4 % of polymer respectively by 66 % and 73 %, and at 6 % of polymer – 67 % and 73 %. Thus the polymer amount increase even up to 6 % virtually did not influence the increase of the elasticity factor which is also sufficiently high at a smaller amount of the polymer.

It is especially important to note that the elasticity value at the high temperatures of the bituminous polymer bending agent preparation remained virtually invariable (Fig. 9) as compared with the preparation at low temperatures. These results confirm the previous statements concerning the new binding agent deterioration resistance.

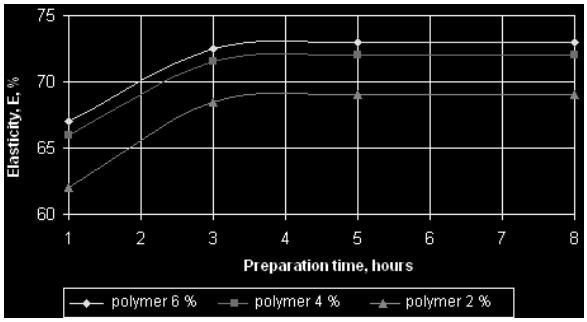

Fig. 9. Bituminous polymer elasticity dependence upon the preparation time at various polymer amounts

The bituminous polymer bending agent important parameters which characterize its processability, usability in production conditions, and also determine the produced binding agent quality, are the bituminous polymer bending agent properties changes after heating and disintegration during storage. Therefore, in this work, investigations were conducted and the results obtained which confirmed the very slight change of such properties at given modifying temperatures.

It may be seen that the bituminous polymer bending agent heat resistance factor change after heating at various polymer amounts and time of its modifying is very slight. After the first hour of modifying at preparation temperature of 180 ˚C this parameter was higher by 2-4 ˚C as compared to the output bituminous polymer bending agent, which is explained by the non-modified bending agent, while after 3 hours of modifying this parameter did not exceed 3 ˚C (Fig. 10), i.e. it met the applicable requirements.

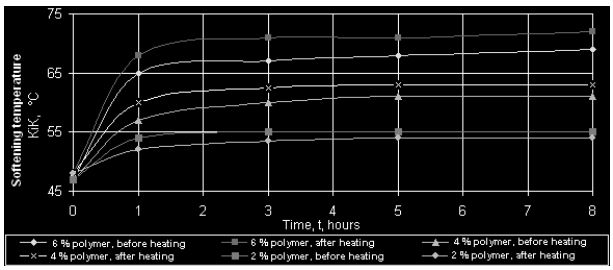

Fig. 10. Bituminous polymer softening temperature change dependence upon the preparation time at various polymer amounts

At lowering the bituminous polymer bending agent preparation temperature to 160 ˚C this parameter remained the same, and at the temperature increase up to 200 ˚C its maximum value was 5 ˚C (Fig. 11), which also met the requirements [8-11].

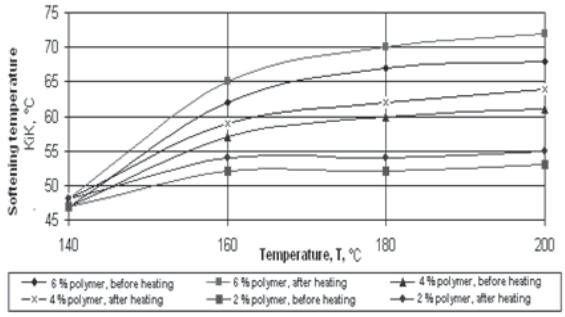

Fig. 11. Bituminous polymer softening temperature change dependence upon the preparation temperature at various polymer amounts

Dependence of the bituminous polymer bending agent disintegration factor during storage (according to penetration factor) on the polymer amount, the preparation time and temperature showed its slight change during modifying both at low temperatures and at high ones (5-7 degrees of penetration) (Fig. 12, 13).

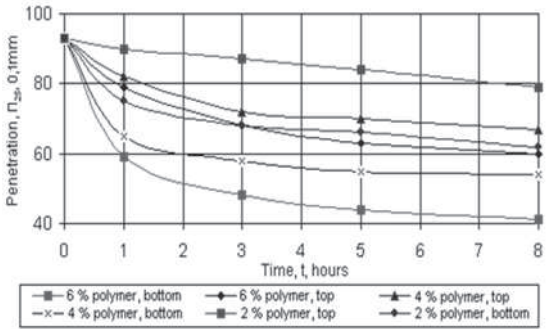

Fig. 12. Bituminous polymer disintegration during storage (according to penetration factor) dependence upon the preparation time at various polymer amounts

Although this parameter is not rated the obtained results show the sufficient homogeneity of produced binding agent after modifying. Dependence of the bituminous polymer bending agent disintegration factor during storage (according to softening temperature) upon the polymer amount and its preparation time showed slight change of this parameter that additionally confirmed the obtained bituminous polymer bending agent homogeneity as well as the ability to be processed. However, it is necessary to note that at the polymer amount increase, the disintegration factor value increases too, although remaining within the allowable limits.

At the polymer concentration of 2 % the KiK factor difference depending on the preparation time varied from 1 to 4 ˚C, while at the polymer concentration of 6% this difference was equal to 3-5˚C (Fig. 14, 15).

Such results are observed in the entire range of the bituminous polymer bending agent preparation temperature change.

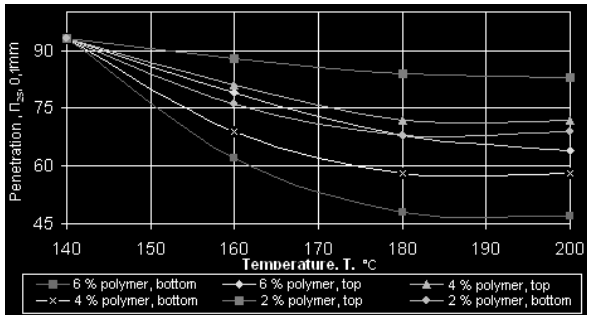

Fig. 13. Bituminous polymer disintegration during storage (according to penetration factor) dependence upon the preparation temperature at various polymer amounts

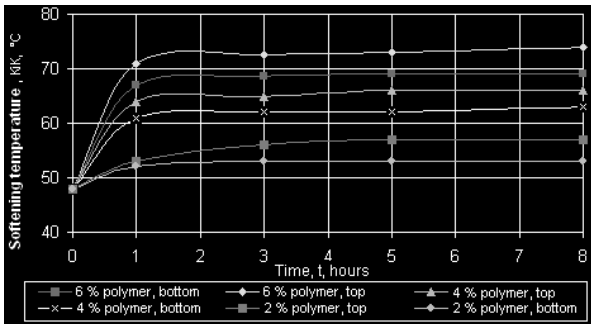

Fig. 14. Bituminous polymer disintegration during storage (according to softening temperature) dependence upon the preparation time at various polymer amounts

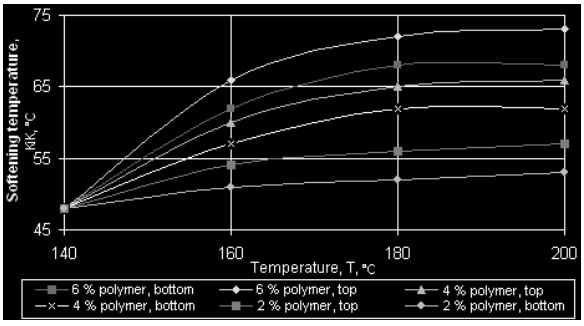

Fig. 15. Bituminous polymer disintegration during storage (according to softening temperature) dependence upon the preparation temperature at various polymer amounts

CONCLUSIONS

1. The bituminous polymer bending agent on the basis of the Butanol NS 104 polymer latex in compliance with all standard parameters meets the requirements to bitumen modified with polymers.
2. The bituminous polymer bending agent physical-mechanical properties change in the wide limits (by 50-100 %) depending on the polymer amount and the preparation process parameters shows the possibility of its properties active regulation under the particular operating conditions.
3. The bituminous polymer bending agent properties resistance and stability under the high process temperatures influence shows the possibility of its sufficiently long-term storage under the production conditions with the original properties retained.
4. Short time of this bituminous polymer bending agent preparation (on average 2-3 hours) allows for the saving of the considerable energy resources and advantageously distinguishes it from the bituminous polymer bending agents produced with the other modifiers. .
5. The Butanol NS 104 polymer latex rational amount for modifying the bitumen of this grade constitutes 2-3 %, the preparation time is within the limits of 2-3 hours, and the optimal preparation temperature is close to 170-180 ˚C.

REFERENCES

1. **SOU 42.1- 37641918 – 100:2013.** “Bitumen, modified using laboratory blade mixer. Methods for process control modifications.
2. **Zolotarev** V.A**., 2009.** Polymer modified bitumen and asfalt polimer cements // Dorozhnaia tehnika. 88-95.
3. **Zolotarev** V.A**., 2003.** Properties of bitumen, SBS polymer-modified type // Avtoshlyahovik of Ukraine. – Issue 3. -Kyiv. 29-31.
4. **King G.N., Radovskii B.S., 2004**. Properties of polymer bitumen binders in the U.S. and methods of testing // Scientific and Technical Information Kit. Novosti v dorozhnom dele – Issue 6.-Moscow. 1-28
5. **King G.N., Radovskii B.S., 2004**. Materials and technology company Koch Materials for the construction and repair of road surfaces// Scientific and Technical Information Kit. Novosti v dorozhnom dele – Issue 6.-Moscow. 28-62
6. **Hochman L. M., 2004.** Complex organic binders based on block copolymers SBS type. – Moscow: “Ekoninform” JSC – 510.
7. **Kirichek Y.A., Dem’yanenko V.V., Suhorebryy O.A., 2008.** Experimental study of the properties of modified bitumen used in road construction // Bulletin of Prydniprovska State Academy of Construction and Architecture. – Dnepropetrovsk: PSABA, -№ 6-7. 14-17.
8. **Onishchenko A.M., 2008.** Improving durability of asphalt layers by the use of polymer latexes. Theses Candidate of sciences 05.22.11. Kyiv, 229.
9. **DSTU B V.2.7-135: 2007** “Bitumen modified with polymers. Specifications “ Zolotarev V.A., Mozgovoy V.V., Zhdanyuk V.K., and other.
10. **DSTU 4044-2001** “Bitumen road viscous. Specifications“
11. **Basov G., Kireev A., Kireeva M., 2010** “Improvement of the ultrasonic diagnosing of axes of the wheeled pairs of rolling stock of railways” // Lublin, Poland, TEKA, XA... 21-28
12. **Druz O., Gitnaya S., 2011** “Choice of the economical method of welding at making of steel constructions” // Lublin, Poland TEKA, XIA... 45-56
13. **Kravchenko A., Sakno O., 2011** “Tire life adjustment on the coefficients of operational and road conditions” // Lublin, Poland, TEKA, XIA... 121-129
14. **Sumorek A., Buczaj M., 2012** “New elements in vehicle communication “media oriented systems transport” protocol» // Lublin, Poland, TEKA, XII_1... 275-281

15. **Kulig R., Skonecki S., Łysiak G., Laskowski J., Rudy S., Krzykowski A., Nadulski R., 2013** "The effect of pressure on the compaction parameters of oakwood sawdust enhanced with a binder" // Lublin, Poland, TEKA, XIII_1... 83-89
16. **Korop G., 2013 "**Development of structure and the concept of functioning the modernized logistic system of service industrial enterprise by railway" // Lublin, Poland, TEKA, XIII_4... 99-107

ИССЛЕДОВАНИЕ СВОЙСТВ БИТУМОВ МОДИФИЦИРОВАНЫХ ПОЛИМЕРОМ ДЛЯ ИСПОЛЬЗОВАНИЯ АСФАЛЬТОБЕТОННЫХ ПОКРЫТИЙ НА МОСТАХ

Аннотация. В работе приведены результаты исследования битума, модифицированного полимерным латексом типа СБР Butonal NS 104, в зависимости от температуры, времени и количества модификатора, с учетом производственных рекомендаций компании BASF. Проведенные исследования показали возможность производства модифицированного битума латексом Butonal NS 104, который соответстует технологическим и нормативным требованиям стандартов Украины. На основе результатов исследований были установлены рациональные параметры модификации битумного вяжущего полимерным латексной Butonal NS 104 в производственных условиях.

Ключевые слова: дорожный битум, полимерный латекс Butonal NS, процесс подготовки битума модифицированного полимером, связывающие свойства битума.