Stone mastic asphalt with the use of a stabilizing additive from hydrolytic lignin

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Abstract. The experience of using hydrolytic lignin in domestic and foreign literature allows us to consider it as a stabilizing additive in the production of crushed stone-mastic asphalt concrete mix. For this purpose it is necessary to conduct laboratory tests of raw materials and asphalt concrete mixtures with different percentage of hydrolytic lignin. On the basis of the obtained results, to draw a conclusion about the use of waste from the hydrolysis industry for the device of the top layers of coatings from rubble-mastic asphalt concrete at construction, reconstruction, overhaul of highways. Stone mastic asphalt (SMA) - artificial road-building material, which is a mixture of mineral materials (rubble, sand from screenings of crushing and mineral filler), oil road bitumen, used as a binder and stabilizing additive used for resistance to delamination and uniformity of SMA. Hydrolytic lignin is a waste of biochemical production of cellulose. Application of hydrolytic lignin as a stabilizing additive for stone-mastic asphalt mixture (SMAS), allows to stabilize the crushed stone-mastic asphalt concrete mix, to increase the adhesion of bitumen to the surface of the mineral material and to improve the physical and mechanical properties of crushed-stone and mastic asphalt concrete. At the present stage of scientific and technological development, economy and rational use of material resources is becoming the main condition for increasing production efficiency. The use of hydrolytic lignin as a stabilizing additive will improve the performance properties of crushed stone-mastic asphalt, as well as reduce the cost of construction, reconstruction and overhaul of highways.
Introduction

Road construction is the most important part of the economic system. The territory of Russia is estimated at tens of thousands of kilometers.

With the development of infrastructure, the intensity of the flow of road transport has increased, which has led to an increase in traffic and speed on the roads that adversely affect the state of the road pavements.

During operation, the upper layers of asphalt concrete are subjected to numerous repetitive loads from motor vehicles, rain, snow and other types of temporary loads, which contributes to a decrease in service life and the formation of defects.

At the current time when forming the top layer of the coating road structure with more heavy traffic use stone mastic asphalt.

The history of the creation of stone mastic asphalt (SMA) falls on the second half of the 60s. He appeared as a result of the struggle of the road services of Germany, with the intensive destruction of the roadway and tracking due to the massive uses by motorists of studded tyres in winter. SMA demonstrated its excellent performance and in 1984 Germany’s national standard for its specification and application was adopted. Since then, this type of asphalt concrete pavement has found its application both in Europe and in many parts of the world.

The process of preparation and styling SMAS is functional, economical and does not require any special additional technical devices. At the same time, it provides excellent performance characteristics of the pavement, while maintaining high stability and durability, as well as the possibility of laying layers of lesser thickness, compared with the thicknesses of asphalt concrete layers [1].

The production of SMA is associated with significant material consumption, in particular the use of a stabilizing additive.

In the Irkutsk Region, which became the leader in terms of logging volumes among the regions of Russia even in Soviet times, it was a lot of accumulated wastes of wood processing. Among them is hydrolytic lignin, that is, a natural polymer of which walls of plant cells. Its quantity is estimated differently: modest data can be found in a modern information base, according to which 2-3 million tons of such waste accumulated under the Zima, Tulun and Ust-Kut, but the figure of 3 million tons left after bankruptcy the Zima hydrolysis plant, which was liquidated in 2003, is slightly less stored in the dumps of the Tulun hydrolysis plant, which was shut down in 2006.
Hydrolytic lignin, at the same time, constituted a valuable raw material for the chemical industry. The processing of lignin into organic fertilizer is an initial component for the formation of humus. Its undeniable merits include simplicity and low cost, but there is one drawback: this method does not allow processing large volumes of lignin, which are stored at the sites of the closed hydrolysis plants [2].

1. Material

SMA is a crushed stone-bitumen mixture consisting of a crushed stone skeleton, in which all the voids between large crushed stones are filled with a mixture of bitumen with crushed sand.

The principal difference between SMA and conventional asphalt concrete is that the tolerance for the size of rubble in the asphalt concrete mixture is much wider than in SMA, the high content of bituminous binder (6-7%), the presence of a stabilizing additive.

The increased content of crushed stone (70-80%) is due to the presence of a larger volume of voids in the asphalt concrete mixture, which must be filled with smaller fractions. In SMA, the main structure is large crushed stone, and the small one serves only to create a 'mastic' that fills the empty space in the crushed stone skeleton.

The structure of SMA is very similar to the structure of porous asphalt, which also formed a large stone material, but in porous asphalt the space between the stone material is filled only at 80% of the volume, while in SMA the amount of unfilled space is no more than 3-6%.

Due to its rigid skeletal structure, when the load from the surface is transferred to the underlying layers through individual large particles of stone material directly in contact with each other, the SMA layer is subjected to smaller deformations, both in the transverse and in the longitudinal directions. As a result, high resistance of SMA to tracking. Studies have shown that the compressive strength index for SMA is 1.5-4 times higher than for conventional asphalt concrete [1].

One of the components of the cell wall of vascular plants is lignin. Comparatively recently, a part pyro ligneous acid wood, which does not dissolve when it is treated with 72% sulfuric acid or 42% hydrochloric acid, was conditionally called lignin [3]. Lignin is a complex (reticulated) aromatic natural polymer that is part of terrestrial plant organisms, a product of biosynthesis. Lignin ranks second after cellulose for the prevalence among polymers on earth. The variety of bonds arising between the
individual structural elements during the formation of lignin leads to the creation of a polymer of irregular structure, the so-called lignin polymolecule. According to the theory of Freidenberg [4], a polymolecule should be understood as a molecule formed from repeating optional monomers of the same type. It is believed that in a vegetative fabric is not lignin, and lignin substances [5], just as in nature there is not a protein, but protein substances. Softwood wood contains about 23-38% lignin, while hardwood contains from 14 to 25%, cereal straw contains about 12-20% by weight. Lignin is found in the cell walls, as well as in the space between the cells. Thus, it fastens cellulose fibers. During the physicochemical methods of processing plant fibers, the molecular weight of lignin decreases several times, but its chemical activity increases. Hydrolytic lignin is formed during the processing of timber with concentrated hydrochloric or sulfuric acid, while the temperature is maintained at 180 - 185 ° C and the pressure is about 1216 - 1418 kPa. Hydrolytic lignin is characterized by its calorific value, which is 5500-6500 kcal / kg for absolutely dry lignin [6]. In terms of physico-chemical characteristics, hydrolytic lignin is a polydisperse system with a ribbon structure of filaments, with particle sizes from a few millimeters to microns and less (Fig. 1). Studies obtained on samples of lignin from various plants have shown that their composition is characterized on average by the following content of fractions: with a size of more than 250 microns - 54-80%, less than 250 microns - 17-46%, less than 1 micron - 0.2-4.3 % [7].

![Image](image1.jpg)

**Figure 1.** The structure of hydrolytic lignin under the microscope.

### 2. Results and methods
Subject by GOST 31015 and methodological recommendations for the construction of the top layers of pavements made of stone-mastic asphalt (SMA), projected 4 compositions stone-mastic asphalt with the use of a stabilizing additive from hydrolytic lignin with different percentages [8,10].

Table 1. Prescription compositions of SMA-15.

| №, name of materials | The composition of the mineral part of the mixture (bitumen, hydrolytic lignin in excess of 100%) |
|----------------------|--------------------------------------------------------------------------------------------------|
| 1                    |                                                                                                  |
|                      | 50                                                 4                                                   45                                           45                                                |
|                      | 20                                                 2                                                   23                                           20                                                |
|                      | 19                                                 2                                                   20                                           24                                                |
|                      | 11                                                 1                                                   12                                           11                                                |
|                      | 0.7                                                0,                                                  0,5                                         0,5                                               |
|                      | 6                                                 6,                                                  6,3                                         6,2                                               |

According to the grain composition, each composition meets the requirements of GOST 31015.

During the preparation of the asphalt mix, the quality of all components, the temperature of the bitumen preparation, the temperature of the finished asphalt mix and its quality, the bitumen and the stabilizing additive were monitored, guided by the operating instructions of the respective equipment.

The content of bitumen and stabilizing additive is pre-prescribed on the basis of recommendations [8], after which a test composition of an asphalt-concrete mixture weighing 3 kg is prepared in the laboratory. A sample of the hot mix is tested for draindown. At value of measurements draindown above 0.2% increase the content of the stabilizing additives on -0.1 0.05% or reduce the amount of bitumen.

Table 2. The stability of the mixture to delamination on a parameter draindown.

| Recommendations of GOST 31015-2002 | № prescription composition |
|------------------------------------|-----------------------------|
|                                   | 1   | 2   | 3   | 4   |


Parameter of draindown from 0.07-0.15%

As a result of testing the stability of the mixture to delamination on a parameter draindown composition №2 does not meet the requirements ГОСТ 31015.

According to prescription composition №1, 3, 4, prepared samples are molded into samples using a combined compaction method in accordance with ГОСТ 12801 [9].

Manufactured samples are weighed in air and in water, and then tested on water-filled porosity. Having determined the average and true density of the asphalt concrete and the mineral part, the residual porosity in the samples and the porosity of the mineral composition are calculated [8,9].

Table 3. Indicators of physicomechanical properties of the compositions of SMA-15.

| Name of the indicator | Value of the GOST 31015-2002 | № prescription composition |
|-----------------------|------------------------------|-----------------------------|
|                       |                              | 1   | 2     | 3     |
| The porosity of the mineral part, % | 15 to 19                  | 17,5| 18,57 | 16,89 |
| Residual porosity, %  | 1,5 to 4,0                  | 4,03| 4,64  | 2,94  |
| Water-filled porosity, % by volume: samples, molded from mixes | 1 to 3,5                   | 3,42| 2,42  | 2,54  |

Based on the data obtained, it was established that if the residual porosity does not correspond to the normalized value, then the required bitumen content is calculated from the obtained characteristics. With the calculated amount of bitumen, the mixture is again prepared, the rate draindown, make two or three samples and determine the residual porosity or water-filled porosity of asphalt concrete. If the indicator porosity and water saturation index is 1-3.5%, then the calculated amount of bitumen is taken as a basis. Otherwise, repeat the procedure for selecting the content of the binder.

As a result of the tests, it was found that composition №1, № 3 does not meet the requirements of ГОСТ 31015.

The projected composition of crushed stone-mastic asphalt with the use of a stabilizing additive from hydrolytic lignin № 4 meets the requirements...
of GOST 31015 on the porosity of the mineral part, residual porosity, water-filled porosity by volume molded from the mixture.

By projected composition № 4 were manufactured samples to determine the compressive strength at a temperature of 50° c and 20° c

Table 4. Indicators of physical and mechanical properties on determine the ultimate strength in compression.

| Name of the indicator | Value of the GOST 31015-2002 | Composition № 4 |
|-----------------------|------------------------------|-----------------|
| Compressive strength, MPa, not less: at a temperature of 20 ° C | 2,0 | 3,36 |
| at a temperature of 50 ° C | 0,6 | 1,82 |

It has been established that the projected composition of crushed stone-mastic asphalt with the use of a stabilizing additive from hydrolytic lignin No. 4 not only meets the requirements of GOST 31015, but also surpasses the indicators of GOST by a factor of 1.5-3.

Determination of shear stability characteristics.

Shear stability refers to the ability of asphalt concrete to resist irreversible plastic deformation under repeated application wheel-load.

The essence of the method consists in determining the maximum loads and the corresponding limit deformations of standard cylindrical specimens under two stress-strain states (Fig. 2): under uniaxial compression (1) and under compression with a special crimping device according to Marshall scheme (2).

Figure 2. Schemes for testing the shear stability: 1 - with uniaxial compression; 2 - under compression according to the Marshall scheme.

Table 5. Indicators of physical and mechanical properties on the determination of shear resistance at a temperature of 50 ° C.
Table 6. Indicators of physical and mechanical properties of crack resistance, at a temperature of 0 °C.

| Name of the indicator | Value of the GOST 31015-2002 | Composition № 4 |
|-----------------------|-----------------------------|---------------|
| Tensile strength at splitting at 0 °C | not less than 2.0 no more than 5.5 | 3,64 |

Projected composition № 4 meets the requirements of GOST 31015. Determination of fastness to water with prolonged water-filled porosity. The essence of the method consists in determining the ratio of compressive strength of the samples after exposure to water for 15 days to the original strength of parallel samples.
Table 7. Indicators of physical and mechanical properties by definition of prolonged water-filled porosity.

| Name of the indicator                                | Value of the GOST 31015-2002 | Composition № 4 |
|------------------------------------------------------|-------------------------------|-----------------|
| Fastness to water with prolonged water-filled porosity, not less | 0,90                          | 0,90            |

Projected composition № 4 meets the requirements of GOST 31015.

Conclusion

The developed composition of SMA was first obtained using waste from the hydrolysis industry of the Irkutsk region.

At the analysis of existing results we can conclude that the use of hydrolytic lignin as a stabilizing additive will improve the performance properties of stone-mastic asphalt, increase the physicomechanical properties of stone mastic asphalt, selected percent-size, is a promising direction in sphere of manufacture of SMAS in road construction.

The use of hydrolytic lignin as a stabilizing additive for stone mastic asphalt mixture will replace the stabilizing additives traditionally used in stone mastic asphalt with wood processing waste, reduce the negative impact on the environment through the disposal of industrial waste, and will also reduce the cost of construction, reconstruction and overhaul of highways without decrease in operational qualities.

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