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The Use of Polymer Materials in the Composition of Asphalt Concrete

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Abstract. The research presented in the article shows the possibility of using some polymer materials in the composition of asphalt concrete. The analysis of scientific works in the field of asphalt concrete design shows the efficiency of using plastic waste to obtain asphalt concrete with specified physical, mechanical and operational properties. This technology allows not only to reduce the amount of accumulated plastic waste, but also to improve the condition of highways by increasing the strength of asphalt concrete. Polymers PP and LDPE were selected for the study. As PP samples, we used a nonwoven material used for the production of disposable medical masks, which is suitable for creating linear or dispersed reinforcement of asphalt concrete. LDPE was used as the second polymer sample. The obtained asphalt concrete samples differ from the traditional composition by their increased compressive strength at high temperatures while maintaining plasticity at low temperatures.

For the implementation of a number of state programs of the Russian Federation, in particular "Development of the transport system" and the national project "Safe and high-quality highways", it is necessary to solve a large number of tasks. The main goal of which is aimed at increasing the speed of goods movement, reducing the cost of transportation, improving road safety and improving the quality of highways. To fulfill the tasks set in these programs, large volumes of high-quality road-building materials, in particular asphalt concrete, are required, which would satisfy the growing external loads and have a low cost. It is possible to reduce the cost by using industrial and consumer waste in the structure of asphalt concrete, which makes it possible to obtain asphalt concrete with increased physical and mechanical properties at a low cost. [1-5]

The composition of the asphalt concrete mixture includes a large mineral aggregate (crushed stone), which constitutes the main power frame of the asphalt concrete, small mineral materials (sand, mineral powder) that regulate the mobility of bitumen and fill the voids in the structure. Bitumen of various viscosity is used as a binder material, which combines mineral materials of various sizes into a single monolith. To impart targeted properties, additives are used in the asphalt mixture. Additives can have various purposes, in particular stabilizing (TOPCEL, ITER PPS, KMA), dispersed reinforcement (FORTAFI), adhesive (ITERLENE PE, BN-1401b, APGS-1), plastomers and others. As a rule, additives have a structure and chemical composition different from rocks and bitumen, an increase in the characteristics of asphalt concrete is achieved by

changing the structure or physical and mechanical properties of the raw materials used in the composition of the asphalt concrete mixture.

Analysis of scientific literature shows that one of the promising waste for regulating the processes of structure formation in asphalt concrete is polymer waste. They make it possible to obtain asphalt concrete with physical and mechanical properties that meet regulatory requirements and reduce the cost of producing asphalt concrete by saving natural raw materials. [6-10] The use of polymer waste (plastic) in asphalt concrete also solves the issue of waste disposal. The technology of replacing a part of natural raw materials in the composition of asphalt concrete and regulating the physical and mechanical properties with wastes of various nature is known and widely used. In particular, the following are used as mineral components: metallurgical slags; construction waste; waste molding sands; ash from solid fuel combustion; waste from drilling oil and gas wells; chemical production waste and other types of industrial waste with a similar structure to rocks. [11-15] Efficient use of the material resource of waste is possible if the physical-mechanical, chemical and environmental properties of the waste will be close to the properties of the substituted raw material. It is possible to use the specific properties of waste with a structure different from the structure of rocks, which can increase the strength or other characteristics of asphalt concrete. The involvement of waste in the technology of asphalt concrete production requires scientific justification and a large number of preliminary tests of samples of the resulting asphalt concrete, as well as the creation of pilot sites to clarify the operational properties.

Studies published in recent years show the efficiency of using plastic waste to obtain asphalt concrete with specified physical, mechanical and operational properties. [16-17] This technology allows not only to reduce the amount of accumulated plastic waste, but also to improve the condition of roads by increasing the plasticity of asphalt concrete. The optimal content of plastic waste in the composition of asphalt concrete, when part of the bitumen is replaced, is from 5% to 10%. This variation in content is due to the difference in the chemical composition of the plastics. Different types of plastic have different chemical composition, density, and melting point. The properties of the most common groups of plastics are presented in table. 1.

Table 1. *Properties of the most common groups of plastics.*

Plastic type	PET	HDPE	PVC	LDPE	PP	PS
Chemical composition	$(C_{10}H_8O_4)_n$	$(C_2H_4)_n$	$(C_2H_3Cl)_n$	$(C_2H_4)_n$	$(C_3H_6)_n$	$(C_8H_8)_n$
Melting temperature, °C	260	129-145	150-220	125-140	160-170	240
Density g/cm ^{3}	1,38-1,40	0,96	1,35-1,43	0,93-0,97	0,90-0,92	0,90-0,92

The melting point of plastic largely determines the technology of its use in the composition of asphalt concrete. The temperature for preparing the asphalt concrete mixture ranges from 140 to 160 ° C, depending on the type of bitumen used. In this case, two points must be taken into account. The use of higher temperatures in the preparation of asphalt concrete mix leads to rapid aging of bitumen, with a loss of binding, adhesive and plastic properties. Heating plastics increases the risk of formation and release of environmentally hazardous chemicals that are added to plastics to add color, UV resistance, and strength. Studies show that when PET plastics are heated, antimony (a toxic substance of hazard class II) and other carcinogenic compounds are released. Plastics HDPE, LDPE are less hazardous, when they are heated up to 160 ° C, no hazardous substances are released. PVC plastics are one of the most dangerous plastics in existence, since when they are

heated to a temperature of 160 ° C and above, carcinogens and lead compounds are released into the atmosphere. PP plastics are considered to be quite safe, however, under some conditions, polypropylene, when heated to more than 160 ° C, can release a biocide into the atmosphere. Polystyrene (PS) is hazardous due to the fact that when it is heated above 100 ° C, styrene is released, which belongs to the III hazard class. In this regard, HDPE, LDPE and PP plastics are the most suitable groups of plastics for the technology of producing asphalt concrete mixtures with ensuring environmental safety. Other groups of plastics can also be effectively used in the technology of producing asphalt concrete mixture, but for its implementation it will be necessary to change the technological scheme and modernize technological equipment to prevent environmental pollution.

The technologies for the use of plastics in the composition of asphalt concrete considered above use only material resource plastics in the form of a melt, replacing part of the volume of bitumen in the composition of an asphalt concrete mixture or acting as a modifier of bitumen, changing its physical and mechanical properties. Currently, there is the formation of polymer waste in the form of: disposable medical masks; a sheet; napkins; overalls; robes, as well as non-woven material used for the needs of agriculture, which are characterized by a homogeneous fine-fiber structure. This makes it possible to consider these wastes as a material for dispersed reinforcement or as a stabilizing component, which is a more efficient technology for using the material resource of the waste. Exposure for 30 minutes at 70 ° C and above effectively destroys the viruses that cause COVID-19.

The study involved medical masks made of spunbond nonwoven material, according to the standard GB 19083-2010 Technical requirements for protective face mask for medical use, manufactured by TESTE (China). The basis of the material is polypropylene. This material is part of the outer and inner layers of the mask. The appearance of the material is shown in Fig. 1. The outer layers of the disposable medical mask are made of larger PP threads, the inner layer is made of thinner PP. A cross-section of a three-layer disposable medical mask is shown in Fig. 2.

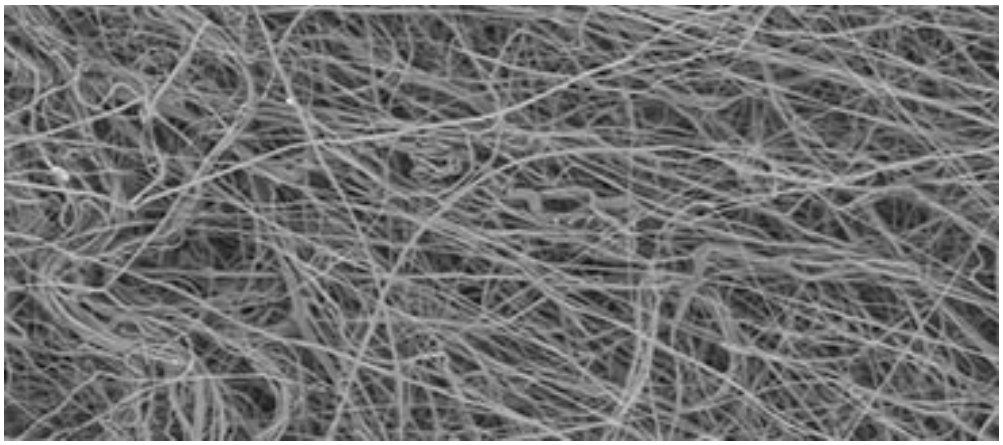

Fig. 1. *Outer layer of the medical mask. Increased 100 times.*

The structure of the nonwoven fabric used for the production of disposable medical masks is suitable for creating linear or dispersed reinforcement of asphalt concrete. Initially, before adding to the asphalt concrete mixture, you can adjust the length of the threads, which will be determined by the size of the pieces into which the material will be cut. Thus, it is possible to create linear or dispersed reinforcement of the asphalt concrete structure.

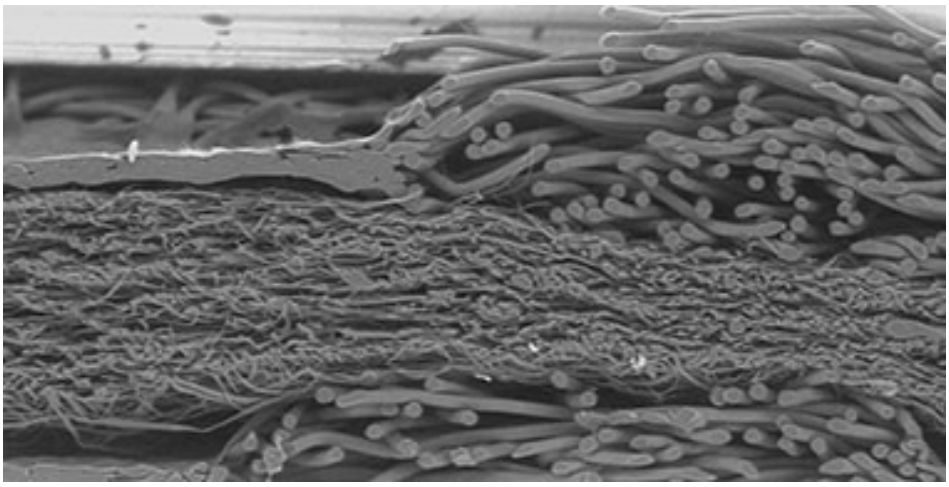

Fig. 2. *Cross section of a three-layer medical mask. Increased 300 times.*

The second plastic was polyethylene, plastic of the LDPE group (Polyethylene film, ST GOST 10354-82), 0.15 mm thick. The choice is justified by the fact that it is used in large volumes, the melting temperature is sufficient for the transition to a plastic state, linear reinforcement of asphalt concrete is possible, as well as partially dispersed. In view of the fact that the melting point is close to the temperature of preparation of the asphalt concrete mixture, it is possible that part of the mass of the film passes into the composition of bitumen, with the formation of modified bitumen.

The most widely used type of asphalt concrete mixture B, the second grade, was chosen as the basis for designing the composition of asphalt concrete samples. The composition of the mixture was used: crushed stone of igneous rocks, fractions 5-20 mm, quarry "Khromisty", Alapaevsk, Sverdlovsk region; sand from screenings of crushing of igneous rocks, fraction 0-5 mm, open pit "Volkovsky mine", Kushva, Sverdlovsk region; activated mineral powder from sedimentary rocks, open pit "Vereskovy", Nevyansk, Sverdlovsk region. BND 100/130 bitumen was used as a binder component of the asphalt concrete mixture. The amount of binder in all formulations was the same - 4.9% over the mineral part. Shredded medical masks and polyethylene were added in an amount of 0.5% by weight of bitumen. Forming and testing of asphalt concrete samples were carried out in the accredited laboratory of LLC Road Service Company, Alapaevsk, Sverdlovsk region in accordance with GOST 12801.

For a preliminary assessment of the performance of bitumen, in which polyethylene was partially dissolved, in particular, strength (shear, bursting), elasticity (determining frost resistance and durability of asphalt concrete), adhesion indicators that determine adhesion properties with mineral particles). With partial dissolution of plastic in bitumen, the obtained indicators of bitumen: the softening temperature of bitumen by KiSh was 58.6 ° C; penetration index 0.94; extensibility at 25 ºC - 71 cm, at 0 ºC - 4.5 cm.

The data obtained indicate that when plastic is introduced into bitumen, it is partially modified with an improvement in its elasticity at low temperatures and increased resistance to external loads at high temperatures. The modification took place in part due to the low heating temperature of the bitumen of 155 ° C, which was not enough to completely melt the plastic.

Comparative tests were carried out of asphalt concrete samples obtained from traditional raw materials (composition 1), using polyethylene in the form of pieces of 10x10mm film with a thickness of 0.15 mm (composition 2) and using pre-crushed (up to 20x20 mm) disposable medical

masks (composition 3) .The main physical and mechanical parameters of the obtained asphalt concrete samples of various compositions are presented in table. 2.

Table 2. *Physical and mechanical properties of asphalt concrete samples*

Indicator name	Requirement of GOST 9123	Content 1	Content 2	Content 3
Average density, g/cm^3	Not standardized	2,53	2,51	2,51
Water saturation, %	from 1.5 to 4.0	2,69	3,12	3,12
Compressive strength: at t = 50ºC, MPa	not less than 1.0	1,80	2,18	1,98
at t = 20ºC, MPa	not less than 2.2	4,03	4,15	4,10
at t = 0ºC, MPa	no more than 12.0	8,85	8,25	7,83
Water resistance	not less than 0.85	0,92	0,90	0,89

The above test results of asphalt concrete samples allow us to conclude that polyethylene (LDPE) and used disposable medical masks (plastic type PP) can be used as a structure-forming element in technologies for producing various types and grades of asphalt concrete. The obtained asphalt concrete samples differ from the traditional one by increased compressive strength at high temperatures (strength limit at 50 ° C) and a reduced strength index at low temperatures (strength limit at 0 ° C). This indicates the best performance properties of the asphalt concrete pavement to external loads in summer and winter. This is achieved through dispersed reinforcement of the asphalt concrete structure and bitumen modification.

It is planned to continue research on the effect of plastics of the LDPE and PP group on the structure formation of asphalt concrete, on the change in physical, mechanical and operational properties. During the study, various results were obtained with different technologies for introducing plastics into the composition of the asphalt concrete mixture. The best results were achieved by heating and mixing bitumen and LDPE together.

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