Materials used in the construction of roads

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Abstract. There is a huge variety of materials and technologies used in the implementation of construction and restoration work. They are also used in the construction of roads. It is impossible to consider all their varieties and give them a description. Therefore, we consider only the most effective in our opinion. This article describes and reviews some types of modern building materials and technologies used in the restoration of roads. Some varieties of these materials are listed. Their brief description is given. Their advantages and disadvantages are considered. The introduction contains the significance of materials in construction work. The optimal and most economical materials to use are listed in the summaries and conclusion. Certain types of materials and technologies are described in the article.

1. Introduction
Humidity is a natural destroyer of any roads. It destroys the foundation of the road structure and, when frozen in microcracks, breaks the coating. Therefore, when designing, the level of groundwater is always considered. It is possible to build a solid highway in marshy areas. However, special advanced technologies and appropriate building materials are needed here. Under normal climatic conditions, there are the following restrictions: at high humidity it is not recommended to use materials such as dusty sand, fine sandy loam, and dusty loam in the construction of roads [1]. Such types of soil are used exclusively in dry places, since when wet, they quite reduce the bearing property of the roadway and lead to its deformation.

2. Methods and materials
2.1. Road cake
According to the construction technology, the road is a kind of cake from several layers, each of which has its own task.

A layer of soil. The lowest layer is the soil layer. It is the basis on which the whole structure is based, the road service life and its condition depend on its reliability and stability. Soils are divided into two large groups:

- incoherent or loose, which include – sand, gravel, rocky;
- cohesive, which are clay soils.

For the construction of the road embankment, it is necessary to use soils that do not change under the influence of natural factors, while maintaining stability during freezing and thawing. The following types of soil are included in the list of suitable for road construction:

- large sandy loam, draining sand, gravel, coarse, rocky soils;
- light sandy loam, silty, non-draining sands;
- clay.

Do not use too wet and excessively saline clay, silt, peat, and the upper soil layer with many plant roots to organize roads.

Sand pillow. This layer of sand is laid on the ground. It has several functions. For example, drainage and depreciation. Sand cushion softens the impact of vehicles on the roadway and increases its service life.

To increase the strength of roads, under the sand layer, you can lay a geogrid on it, which will not allow sand and gravel to mix, increasing the service life of roads.

Layers of macadam. The main supporting layer in the road cake consists of crushed stone. Its thickness and structure of the material depend on the type of road and the load on it. As a rule, during the construction of highways, three layers of crushed stone are laid: lower, middle, and upper.

The prepared road base is poured with a mixture of bitumen. The final stage is the laying of the final coating, thickness and characteristics of which depend on the load on the road. The better the coating, the longer the service life of the road.

Basically, asphalt is used for topcoat; cement concrete is chosen for roads with intensive operation and high load [1].

2.2. Stone materials

The need for road construction materials is very high. So, for the construction of 1 km, 1,600 tons of asphalt mix, 170 tons of black gravel (covered with bitumen), as well as 2,400 m$^3$ of white or ordinary gravel and 2,500 m$^3$ of sand are consumed in category II roads with asphalt concrete pavement. For the manufacture of asphalt concrete and black gravel, in addition, 190 tons of bitumen and 320 tons of mineral powder will be required [8].

Up to 50–60% of the estimated cost of the constructed road is spent on the purchase and transportation of building materials to the place of work [8].

Natural stone materials include rocks, which are used in road construction in the form of loose and crushed masses. The following types of loose rocks: sand-gravel raw material, pit gravel material, regular gravel – sand-gravel material with sand and gravel grains. There is medium regular gravel and large; gravel varietal (fractionated) obtained by crushing ordinary gravel through a sieve with holes; crushed stone obtained by mechanical crushing from rock fragments. Crushed stone after crushing is sorted into fractions. Depending on the size, the crushed stone differs in the following fractions: very large, large, medium, small, wedge, stone fines, sowing. Crushed stone of these fractions is used in the following structural layers of the roadway: very large – when arranging the lower layers of the base; large – in the upper layers of the base; middle – in the upper layers of the base and lower layers of the coating; a small wedge, stone fines and seeding – in the upper layers of coatings, as well as for the installation of road wear mats. Crushed stone is prepared from different rocks – hard and soft [1].

Hard rocks include boundaries, diorites, basalts, gabbros, andesites, porphyries, and soft rocks include dolomites, limestones and sandstones. Mineral binders, depending on the hardening conditions, are divided into two groups: hydraulic and air. Hydraulic binders include Portland cement, hydraulic lime; to air – air lime, gypsum [2]. Portland cement is an astringent that hardens in water and air. It is obtained by fine grinding a marl of a certain composition and mixture, calcined before sintering, and a mixture consisting of limestone and clay components, which ensure the formation of calcium silicates in the resulting clinker. The fineness of grinding is very large. Construction air lime is an astringent obtained by roasting not before sintering carbonate rocks (calcium and dolomitic limestones, chalk, dolomites), followed by quenching with water or grinding to powder. Hydraulic lime is a hydraulic binder obtained by moderate firing, which does not lead to sintering of marly limestones containing from 8 to 20% clay impurities. Organic binders used in road construction include oil and shale bitumen, tar. It should be noted that in the Chechen Republic, fine-grained asphalt is used for the construction of pavement. In addition, apply sand, gravel, gravel, bitumen mixture.
2.3. New materials in road construction

Materials to strengthen the base of the pavement. Strengthening the bottom layer of the roadway and the lateral sides of the soil can be done effectively using geotextiles and polymer geosynthetics. The range of these materials is very wide: woven and non-woven geotextiles, geogrids, fiberglass, plastic grilles, meshes, geomembranes, drainage geocomposite (geodrainage) and other geosynthetic materials. Road construction in Russia using geotextile materials has been actively developing recently. A few years ago, almost no one knew about the existence of the above-listed geosynthetics. Nowadays, these materials are used both by individuals for laying tracks on a summer cottage, and by large road companies for the construction of highways. Geosynthetics – a type of building materials designed to improve the physical, mechanical and hydraulic properties of soils. The main purpose of the use of geosynthetic materials is to ensure the reliable functioning of the road, its individual elements in difficult natural and climatic conditions of construction and operation, as well as in the presence of technical and economic advantages in relation to traditional technologies. The main starting polymers for most geosynthetics are polyester, polyethylene, polypropylene, polyamide, polyaramide.

The main functions of geosynthetics:

- stiffening is a reinforcement of road structures due to the redistribution of stress forces arising in the soil mass and in pavement when exposed to loads from vehicles and their own weight;
- separation is an obstacle to the interpenetration of particles of contacting materials in the technological layers of the roadway;
- protection is a prevention or inhibition of erosion of soil particles and other particles along the slope surface;
- filtration is a prevention of penetration of soil particles into drains and their removal, reverse filtration;
- drainage is an acceleration of water drainage from layers of pavement and soil massifs [3].

The most popular material in this category is geogrids, which are flat polymer web materials with a mesh structure. The mesh is produced from high-strength bundles of threads by fastening in knots with the help of a stitching thread, weaving, gluing, fusion. In this case, cells, whose dimensions are larger than the edges that form the grid, are formed. To improve properties and increase stability, they are treated with special compounds.

Currently, geogrids are divided into different types:

- according to the quality of the material (polyethylene, polyamide, polyester);
- by scope of application (geogrids for asphalt concrete and soil);
- according to the method of cell orientation (mono-oriented grids, dual-orientation grids).

Worldwide, non-woven geotextiles are made from polypropylene. Polyester non-woven geotextile is offered as one of the varieties of the base brand based on polypropylene.

**Modification of bitumen by emulsifiers.** Since the main organic binder used in the production of asphalt concrete is petroleum bitumen, the most common way to improve its properties is to modify various active substances. Bitumen emulsion is a dark brown liquid, which is obtained by dispersing bitumen in water with the addition of an emulsifier. Bitumen emulsions are more often used in Russia as a binder, film-forming material in the construction and repair of roads. Bitumen emulsions are classified as direct emulsions in which the mass fraction of bitumen (30–70 %) in the form of tiny droplets is distributed in a continuous dispersed medium – water. In reverse type emulsions, water is dispersed in astringent bitumen or tar, the mass fraction of which is 70–80 %. Emulsifiers are substances that give stability to emulsions. In other words, stabilizers. As emulsifiers can be surface-active substances (SAS), soluble in both phases of the emulsions or in one of them, or solid highly dispersed mineral powders (clays, oxides, carbonates and sulfates, cement, soot). Solid emulsifiers are used mainly in the manufacture of bituminous pastes and rarely for road emulsions. Emulsions on solid emulsifiers in their composition contain 50–60 % bitumen (tar), 30–45 % water and 6–12 % solid emulsifier. Water-soluble emulsifiers, i.e. surfactants, which include anionic and cationic surfactants, are most often used for the manufacture of road emulsions. When using anionic
substances, anionic and alkaline emulsions are obtained, when using cationic substances, cationic and acidic ones are obtained. Bitumen emulsion has its own advantages over bitumen. These include profitability, manufacturability, environmental friendliness. The emulsion requires less cash investment, allows you to save bitumen by 30–40 %, electricity and half the time. Bitumen emulsion can remain in liquid form and, unlike bitumen, is fire and explosion proof. The emulsion can be used on wet mineral materials, which allows to extend the construction season. But bitumen emulsions are not suitable for the construction of highways with high load; their qualities are most suitable for local repair work [4–6].

Modification of bitumen with polymers. Significantly improve the quality of bitumen when modified with polymers. Polymer-bituminous binders (PBB) mean binders obtained by combining bitumen and polymers. Recommendations for the use of modified bitumen instead of conventional bitumen are explained by their improved properties. Modified bitumens have increased elasticity, this important quality allows to withstand large loads, resist cracking and slows down the process of wear of asphalt concrete pavement. Also, polymer bitumen has a wide range of operating temperatures: the difference between the softening temperature and the brittle temperature reaches 100 °C (ordinary bitumen up to 60 °C).

Currently, due to the variety of polymer compounds offered by petrochemical industries, there is a wide selection of bitumen used for modification. They can be divided into three groups:

- thermoplastics or plastomers;
- elastomers;
- thermoelastic materials.

From the category of thermoplastics, polyethylene and atactic (stereo-random) polypropylene (APP) are often used [7, 9]. Thermoplastics consist of linear or low-branched polymers that soften when heated. A prerequisite for obtaining high-quality material is the compatibility of bitumen with APP, which is determined by the ratio of the components of bitumen. Elastomers consist of long polymer chains with wide branches. They are flexible over a wide temperature range: from low to 200 °C. When elastomers are added to bitumen, its viscosity increases, and elasticity improves. However, these systems are also unstable during storage. Constant mixing is required to prevent phase separation between bitumen and artificial material. Bitumen modified with elastomers can be called bitumen with an elastic filler. As elastomers, it is customary to use natural or regenerated rubber and polybutadiene. Thermoelastic polymers soften at temperatures above ordinary workers and are well deformed in this state. The most famous representative of the group of thermoelastic materials is styrene-butadiene-styrene (SBS) or artificial rubber. It is a block copolymer consisting of styrene and polybutadiene blocks. SBS gives bitumen excellent flexibility at low temperatures. Heat resistance is slightly lower than the APP, but when using a high-quality SBS modifier, it can reach 100 °C. SBS polymers have good adhesion and excellent resistance to cyclic alternating loads. Bitumens modified with SBS polymers correspond to climatic features of the main part of the territory of our country. The addition of this material to bitumen is from 3 to 6 of the total mass of the finished binder. The required amount of added material depends on the dispersed state of the introduced substance: if SBS is introduced into bitumen in a finely dispersed form, then the flow rate decreases, if in a finely dispersed form, then more modifier is required. Both in Russia and in world practice, it is precisely the SBS class polymers that are the main starting polymer to produce PBBs. The use of other polymers for these purposes is much lower. For example, in France, in addition to SBS, the polymer EVA (ethyl vinyl acetate) is used, but its use does not significantly increase the brittle temperature, which is very important for the climatic conditions of Russia. It is worth noting that in the Russian Federation bitumen of the same brand, but released at refineries in different places, may differ from each other. Thus, bitumen with the addition of high-quality polymers in practical studies show an obvious advantage compared to unenriched materials. Particularly large operational effect is shown by asphalt concrete on PBB in coatings of heavily loaded roads such as autobahns. In Russia, the use of PBB is spreading very slowly, not universally and amounts to several percent of the total consumption of road binders [10].
Modification of bitumen with rubber crumb. As a bitumen modifier, crumb rubber or a rubber asphalt modifier can be used. Small particles of 0.5–1.5 mm in size are added to bitumen with this system from 7 to 12 % by volume. At the outer working layer of the roadbed with interspersed rubber, physical and mechanical indicators are significantly improved: increased resistance to cracking and elasticity, high level of noise absorption, coefficient of frost resistance, which has a positive effect on the material, whose service life is increased by 2–3 times. Depending on the production method, a mixture of rubber with bitumen exhibits various properties. This mixture may have the following properties: a high degree of viscosity compared with ordinary bitumen, low heat sensitivity, a high degree of adhesion [10]. A mixture of fine rubber dust and small granules in the outer layer of the coating provides high stability during night frosts on the street. The rubber layer remains elastic and destroys the ice layer lying on it as soon as a vehicle passes over it, providing contact between the tire and the coating. The number of accidents on the streets equipped with such coatings during night frosts is much lower. If the pavement is made of coarse rubber granules or gravel, the risk of slipping on water is reduced, because, due to porosity, precipitation is easier and faster to absorb. A mixture of rubber and bitumen is also an ideal material for healing cracks on roads, while repaired sections of the road may be available for immediate movement. The volume of consumption of rubber crumb is 15–20 tons per 1 km of the roadbed. The first attempts to change the properties of bitumen by adding rubber granules were made in the late 1960s – early 1970s. In the late 1970s in Europe and especially in Belgium there was a special interest in the process of combining bitumen and rubber. There, this technology was first introduced in the early 1980s. And in 1979 there was applied porous asphalt from a mixture of rubber with bitumen as a street coating. This experiment clearly showed all the advantages expected from the use of new technology. Further technologies in this area have been developed. Very fine rubber dust was mixed with bitumen using experimental equipment. This method has opened the possibility of batching already in the production of bitumen, and not directly in the road-building machine. The difference between this classic wet method is lower temperatures, smaller particle size, and shorter reaction times. In 1994, a cement coating was developed for the streets with the addition of rubber particles of worn tires. This mixture consists of 5–15 % homogeneous and easily modified rubber, the presence of which does not interfere with the final kneading. Later, a mixture of rubber and bitumen (porous asphalt) began to be widely used in other European countries. Now this technology is making its way in Russia [10].

3. Results
The road must fulfill its purpose and be durable. This requires materials, both structural and finishing. In the technical and economic evaluation of planning and design solutions, design options must be compared. The most effective material, in our opinion, is geogrids, since they are the most stable and have high strength.

4. Conclusion
Geogrids are also an effective type of material for use in the Chechen Republic in terms of climatic conditions. Moreover, in this region the most elevated climate humidity, there are phenomena of frequent rainfall. Due to this fact, there occurs a sudden formation of cracks in the roadway and its deformation. And the iron mesh contained inside the canvas will just contribute to enhancing the quality of the road.

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