DESIGNING AND CONSTRUCTION OF ROADS, SUBWAYS, AIRFIELDS, BRIDGES AND TRANSPORT TUNNELS

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A. A. Zadiraka[1], N. Ye. Kokodeeva[2], A. V. Kochetkov[3]

TECHNOLOGY FOR LAYING AND STRENTHENING TRANSPORTATION FACILITIES BASED ON A POLYURETHANE COMPOSITE

Saratov State Technical University Named after Y. A. Gagarin
Russia, Saratov
[1]PhD student of the Dept. of Transportation Construction,
tel.: +7-927-629-13-06, e-mail: alex.zadiraka@mail.ru
[2]D. Sc. in Engineering, Assoc. Prof., Head of the Dept. of Transportation Construction,
Director of the Institute for Energy and Transportationation Systems,
tel.: +7-937-245-80-89, e-mail: kokodeewa@mail.ru
Perm National Research Polytechnic University
Russia, Perm, tel.: +7-906-306-95-53, e-mail: soni.81@mail.ru
[3]D. Sc. in Engineering, Prof. of the Dept. of Automobiles and Technological Machines

Statement of the problem. The technology for laying and strengthening slopes of embankments and hollows, cones of bridges and pipelines with the use of a polyurethane composition is set forth.

Results. The technology of laying and strengthening the elements of transportation structures based on the use of a polyurethane composition has been thoroughly studied. The properties of a polyurethane composition have been investigated. The advantages of employing this composition have been discussed.

Conclusions. This technology is easy to use and the materials it employs are cost-efficient. The structure appears to be an integral system that increases the times between repairs and improves the reliability of the sloping parts of highways and cones of bridges and pipelines.

Keywords: polyurethane composition, reinforcement technology, polyurethane, isocyanate, pouring of a binder, strengthening of slopes.

Introduction. As a result of a long-term effect of storm water, slopes of transportation structures deteriorate. This causes degradation, erosion and creep. Strengthening of slopes to protect them from erosion with rainfall, wind and filtration waves is essential for the stability of soil, bridge embankments and regulated slopes [5, 18].

A crucial issue facing the road industry is effective performance of operational characteristics of foundations and (or) roadway surfacing where strength of a structure depending on the traffic load is essential [14].

This article looks at the technology of laying and strengthening a transportation structure using a polyurethane-based composition. A polyurethane-based composition is a material in the form of a two-component polyurethane system obtained by means of mixing resin and solidifier. As a result, there is a mix strengthening and bonding the materials (crushed stone) forming a strong carcass structure [15—19].

1. Polyurethane-based composition technology. In order to improve the transportation and operation characteristics of transportation structures, various technologies for coating foundations and surfacing with a binder. The suggested development is based on the use of physical and mechanical properties of polyurethane compositions.

Transportation structures to be investigated can be highways, slopes, ditches, bridge cones, runways, industrial and construction sites, drainage dams, embankments, estuaries, etc.

It is well-known that transportation structures are multi-layered artificial systems perceiving multiple transportation impacts and climatic factors. A transportation structure consists of the following elements: surfacing, foundation and extra layers.

The results of the development are possible improvements in the load-carrying capacity of strengthened soils (depending on the type of soil and type of a structure) as well as a less likely short life cycle of resulting structures and fitted elements.

Based on the developed polyurethane composition, a technology of laying a foundation structure and (or) surfacing of transportation structures. This technology includes formation of grain elements on a strengthened subbase. Then a layer of grain elements is introduced by pouring a binder with discrete non-bound flows under the load effect from top to down. This way of pouring of a binder results in a carcass structure. This structure is formed by covering a shell of grain elements with a binder and vertical binder fibers in voids between shells coming into contact followed by solidification and shrinkage of a binder of a carcass structure. A polyurethane reaction mix is used as a binder which contains 57—63 % of a basic polyol-based substance, 37—43 % of a solidifying isocyanate-based component and 0.001—5.0 % of powder disperse filler.

According to the developed technology, a foundation structure and (or) roadway surfacing are obtained in the following way:

1) with distribution and compaction of a layer of fractioned grain elements on a strengthened subbase;

2) a specially prepared liquid binder is poured from a vessel;

3) a binder consumption is optimized, i.e. the upper part of the grain element is completely covered with a binder while it is being poured;

4) the binder is stored for a day so that it solidifies and shrinks.

The depth of pouring and binder consumption is calculated empirically. The depth of pouring is computed depending on the thickness of a structure of a foundation and (or) surfacing or according to the technical specifications. The binder consumption depends on the depth of pouring, fractions and microroughness of the grain elements.

As an extra layer of the grain element with a finer fraction is used in a foundation and (or) roadway surfacing, the major layer of the grain element of a larger fraction is consistently put with an extra layer of the grain element of a finer fraction followed by the binder.

The developed structure and (or) roadway surfacing and the technology of laying them can be used for strengthening solid soils (permanently frozen soils, ice on a river) and weak foundations (turf, mud, moist sand, "soil-liquid" environment).

The developed structure of foundations and (or) roadway surfacing and the technology of laying them can be utilized to strengthen solid soils such as permanently frozen soils, river ice) and weak foundations (turf, mud, moist sand, "soil-liquid" environment). Foundation structures and (or) roadway surfacing can be made of a carcass structure containing a grain element and a polyurethane reaction mix as a binder.

For superficial and structural strengthening of foundations and (or) roadway surfacing a carcass structure is designed to be a shell of a solidified binder using a grain element, vertical threads of a solidified binder coming from the bottom of the grain elements as well as voids formed as a result of point contacts of the shells.

The formation of mutually connected voids leads to water and air-penetrating properties of foundations and roadway surfacing. A solidified binder of the carcass structure allows a stable geometric and strength homogeneity of a structure but at the expense of the properties of a binder. This is due to the fact that as it covers each grain element, a binder buils up strong connections between the shells. This leads to the independence of adhesive properties of the carcass structure on the variety of acid-base characteristics of grain elements.

The formation of mutually connected voids does not compact or strengthen the soil beneath it, which causes surface water diverting into horizons of underground water, the surface of a foundation to dry due to free air circulation in it. This yields the structure draining properties providing an increase in the load-carrying capacity of a transportation structure.

A carcass structure of the transportation structure foundation contains shells of a solidified binder that completely and (or) partially covers the grain element. In order to keep the grain element safely partially covered, a relative area should be over 50 % of that of the grain element.

The carcass structure of the foundation of a transportation structure contains technological voids between one shell and the grain element formed as a binder merges with the latter. These technological voids are used to equalize the pressure caused by moist in the pores of the grain element. In the winter season they prevent the shell from breaking apart caused by ice expansion and in the summertime moist turns into vapor.

The use of a polyurethane composite as a binder allows rigid elastic fibres and strong and durable connections at the contact points of the shells of the grain element. Polyurethane composites have a high hydraulic stability, resistance to external environment in different climatic zones, frost-resistance and compatibility with different types of fraction fillers such as crushed stone, gravel, etc.

In order to strengthen a foundation and (or) cover a transportation structure, it is most advisable to utilize a binder based on a two-component polyurethane system. A two-component polyurethane system has a good compatibility with different types of fraction fillers (crushed stone, gravel) (according to the GOST (ГОСТ) 7392-2002). A binder can be modified according to special requirements. All the materials for this two-component polyurethane system are manufactured in Russia, which solves the issue of import and high material costs.

Depending on various usage conditions (temperature, humidity), the optimal viscosity and polymerization rate of a binder allow the filler particles to be covered evenly and strong and durable “connecting bridges” to form at the contact points.

A one-component polyurethane composition whose viscosity is controlled with a mineral filler. A solidified binder of the carcass structure due to no contact of the grain elements allows the use of other materials as grain elements of the carcass structure of the foundation and (or) roadway surfacing, which expands an application range of a structure as different transportation structures are being designed. Fractioned crushed stone, gravel, stone, sifts, artificial crushed stone, fractioned secondary breakage (production of crushing and sifting) of construction materials is used as a grain element. The size of the grain element of the carcass structure of a foundation and (or) roadway surfacing is 5—120 mm.

A transportation structure can contain an upper layer of grain elements with a finer fraction or their sifts with the size of the grain elements of an extra layer being 5—15 mm. This allows the grain elements of medium or small fractions to be used to be used and material and labour costs associated with strengthening soil surfaces due to a wider range of fractions of grain elements to be reduced and more basic pouring tools to be utilized. On top of the structure strengthened with a polymer binder there can be a layer of asphalt or concrete surfacing.

Polyurethane can be applied for repairing and laying crushed stone counter-corrosive structures made of solid and soft rocks of motorways as well as addressing a number of issues pertaining to strengthening slopes of crushed stone and gravel of different granulometric composition.

The system is polymerized (solidified) under the effect of natural humidity coming in contact with the air. It should be stored in insulated, tightly sealed containers respectively. A technological use time is 20 min [1].

2. Polyurethane binder used for laying and strengthening a transportation structure. Polyurethane is known to be a heteroceptive polymer material with a macromolecule containing an unprotected and (or) replaced urethane group.

Polyurethane consists of isocyanate and polyol that are obtained using raw oil. As two liquid components ready to be processed that contain different supplementary substances are mixed, there is a chemically responsive mix. Depending on the composition, a range of properties of a resulting polyurethane and rigid, soft, integral, cell (foamed) or monolith material can be obtained that is prone to aging, has a low temperature and a high level of resistance to different environmental effects. Polyurethane is resistant to abrasive wear, most organic dissolvents, ultraviolet radiation and sea water. An advantage is that their elasticity (hardness) is programmed, i.e. it can range widely depending on the proportions of used materials. Polyurethane can be one-, two-, and three-component ones.

Shrinkage of standard samples has exceptionally technological characteristics.

Polyurethane items are greatly resistant to sharp atmospheric pressure changes, resistant to beating, industrially durable and have the properties that cannot be achieved for ordinary rubber [13]:

— elasticity (a relative lengthening during breakage is two times as large as that of rubber);
— low wearability (conditional wear resistance is three times as high as that of rubber);
— high strength (is 2.5 times as high as that of rubber);
— high resistance to tear and multiple deformations;
— performance at high pressures (up to 105 MPa);
— acid resistance and stability to a lot of dissolvents;
— extremely high hardness (up to 98 on the Shore scale);
— performance in a temperature range of −50 to +80 °C (during introduction);
— resistance to microorganisms and mould;
— resistance to vibration and oil and fuel;
— elasticity at low temperatures;
— high dielectric properties;

— resistance to nitrogen;

— resistance to water.

Conclusions

1. The technology for strengthening slopes and dams, cones of bridges and pipelines based on polyurethane. This technology is easy to use and not labour-intensive (only requires staff of 1 or 2 people and no great amount of special machinery). It is also cost-effective due to its long life cycle (12 years) and its maintenance is not financially burdening.

2. This project is designed to strengthen foundations and (or) roadway surfacing, improve shear resistance, prevent migration of certain grain elements due to their varying nature, increase the load-carrying capacity of transportation structures, extension of application ranges of different construction materials and can be employed in construction, repairs, routine maintenance and renovation of transportation structure.

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