ANNOTATION

Dissertations for the degree of Doctor of Philosophy (PhD) in the specialty 6D074500 - "Transport construction" by Asmatulaev Nursultan Borisovich on the topic: «Technologies of construction of highways at low and negative temperatures (on the example of rolled nanostructured concretes)»

Relevance of the topic: the country already has international-level highways built under the load of 13 vehicles per axle, adopted by a government decree in Kazakhstan since 2006. Unfortunately, on newly reconstructed roads, premature deformations, cracks and peeling of coatings appear. Obviously, road structures calculated according to the decreasing modulus of elasticity of the layers "from top to bottom" do not meet the constantly increasing modern traffic flow of heavy-duty vehicles with an axle load of 13 tc or more, thereby reducing the service life of roads. According to modern concepts of "eternal roads" of the USA and "roads with long life" of the EU countries [1,2], it is noted that roads pay off with their service life of 50 years or more. Experts believe that for the durability of roads, it is necessary to increase the compressive strength of coatings and the load-bearing capacity of layers of road structures "from bottom to top".

The above-listed technological difficulties can be avoided if the technology of the device of layers of road clothes made of rigid rolled concrete, based on slowly hardening binders, is applied. Concrete coatings made of rolled concrete have a lower cost, due to the use of general construction machinery, machinery and equipment used for the installation of asphalt concrete coatings. The construction costs of such coatings and bases are almost 30-50% lower than those of cement and asphalt concrete coatings and bases. However, slowly hardening binders in regulatory documents are classified as inactive binders and are used for processing stone materials and strengthening soils with a maximum strength of up to 4-6 MPa and F25 in the estimated period of 90 days. During long periods of hardening, such binders were practically not studied.

Little attention is still paid to the issues of year-round road construction, and this is 5-7 months of downtime. The dissertation work presents the results of research on the technology of winter road construction from nanostructured rolled concrete based on belite binders. The main structure–forming neoplasms in concrete are predominantly gel-like low-base calcium hydrosilicates of type C-S-H, nanoscale sizes, which ensures high manufacturability during construction and long-term operation of roads from climatic and transport loads without damage.

Scientists of the cement industry who studied the essence of hardening of Portland cement and other inorganic binders, in which the theory of hardening of these binders was revealed, put forward by A. A. Baykov and then developed by other scientists — V. A. Kind, V. N. Jung, V. F. Zhuravlev, P. P. Budnikov, P. A. Rebinder, N. A. Toropov, A. E. Sheinin, A.V. Volzhensky, etc. basically, the rapidly hardening cements and slag-Portland cements used for industrial, civil and bridge construction were studied, which was extended to road construction.

V. Michaelis [51, p.285] and others. they put forward a theory of hardening, according to which colloidal chemical phenomena are decisive when setting cement. Coagulation structures — gels have thixotropy - the ability to recover reversibly after mechanical destruction as a result of collision of particles in Brownian motion and adhesion by coagulation centers. Thixotropy, plasticity, relatively low strength and highly elastic properties of such dispersed structures are determined by the residual thinnest layers of the liquid medium in the places of adhesion between the particles of the dispersed phase. Apparently, the statement that colloidal structures have "relatively low strength" indicates that the strength of such structures has not been studied for long periods of hardening. The use of monolithic materials ensures the quality of the resulting structural layers and the reliability of their work in road clothing in various natural and climatic conditions, taking into account the growth of not only traffic intensity, but also transport loads.

Therefore, the solution of a complex problem is relevant, taking into account the conditions of the world concepts of durable roads.

The object of research: the foundation of a road structure made of belite binders, industrial waste disposal, road construction.

Subject of research: technologies of construction of highways at low and negative temperatures in Kazakhstan from industrial waste.

The purpose of the study: to study the use of belite binders in winter construction conditions. The effect of low and negative temperatures on the material.

Research objectives:

- theoretically substantiate the possibility of building durable highways from monolithic rolled concrete based on belite slag cements and binders;
- to investigate the phase compositions of neoplasms during the hardening of belite slag cements and binders based on the application of physico-chemical fundamental research and to substantiate the nano dimension of the structure of colloidal hardening of slag cements;
- to investigate and develop compositions of nanostructured rolled concretes based on belite binders, for the device of durable monolithic foundations of road clothes of highways;
- to investigate and develop a technology for the construction of highways at positive and negative temperatures from rolled nanostructured concretes based on belite slag cements and binders from man-made industrial waste for year-round construction and operation of highways;
- to carry out a feasibility study of the construction of highways from nanostructured rolled concrete based on belite slag cements and binders. Develop a regulatory and technical document and test pilot sites.

The degree of study of the topic. The research is based on the results of scientific and creative works, practical experience of domestic and foreign builders:

- The main test methods are set out in GOST, SNiP, SP RK, ST RK, as well as in various recommendations.
- Practical experience in the construction of road clothes with the reuse of materials and industrial waste were obtained from domestic scientists

- In the works of foreign scientists, hardening theories were put forward, according to which colloidal chemical phenomena are decisive when setting cement. Coagulation structures — gels have thixotropy - the ability to recover reversibly after mechanical destruction.

- The foundations for the use of industrial waste in construction were laid in the works of Soviet scientists.

Apparently, the statement that colloidal structures have "relatively low strength" indicates that the strength of such structures has not been studied for long periods of hardening.

The special properties of the resulting slag binder (high strength, reduced stiffness, slow and prolonged hardening), studied at positive temperatures, indicate the feasibility of their use in road construction. However, the issues of the influence of low positive and negative temperatures on the properties of the binder that take place in natural conditions of year-round operation of roads remain unexplored. Therefore, for a more detailed study and the possibility of using the binder during year-round construction and operation, it is necessary to study the effect of low temperatures and especially early freezing on its properties.

The scientific novelty of the work is as follows:

- the possibility of obtaining monolithic self—healing road concretes based on belite cements (Nanostructure is an ensemble of atoms or molecules, which in at least one dimension has a size of less than 100 nm and is structurally distinguishable from the environment) and binders, the main components of which are man-made mineral waste of industry (TMO), for the construction of durable and economical structures, is theoretically substantiated travel clothes;

- proposed road structures for use in foundations and coatings with a wear layer of monolithic road concrete based on belite cements under a load of 13 tons or more;

- the regularities of the formation of the structure of whitewash cements at different temperatures have been established, which make it possible to substantiate the technological features of the construction and long-term operation of highways made of road concrete based on them;

- optimal compositions of asphalt-mineral and road concretes based on belite cements and binders are proposed, including with the reuse of asphalt granulate, the novelty of which is protected by patents of the Republic of Kazakhstan No. 45589, 45869, and 48373;

A scientific hypothesis is two interrelated ideas:

- to investigate the structure formation of slowly hardening binders during long periods of hardening in conditions of road construction and road operation. Considering that colloidal hardening structures, along with thixotropy, have the property of reopexy- hardening from the action of external forces. Long-term maintenance of thixotropy and rheopexy of the structure of hardening of belite colloidal structures are accepted by working hypotheses to effectively ensure the technology of linear-flow road construction and long-term operation of roads, with constant action of transport and climatic loads.

- reducing the cost of building road coverings with monolithic foundations while increasing their durability, in the conditions of modern traffic;

- substantiation and development of compositions and technologies for the construction of road coverings made of rigid road concrete based on belite cements based on the use of multi-tonnage technogenic mineral waste from industry (hereinafter TMW) and the secondary use of asphalt scrap.

Research methods modern technologies for the construction of road coverings using inorganic binders (cements, slag, ash, slag, etc. binders) provide for the use of the following mechanized works: mixers for the preparation of road mixtures, transportation and laying of mixtures on the roadbed, compaction of the mixture materials by pressing rollers or vibratory presses of the stacker to the required density of the pavement layer. Then care work is carried out to exclude the evaporation of moisture from the laid layer and the flow of hydration and hardening of the monolithic layer. In laboratory conditions, all these technologies are followed to obtain high-quality material. The optimality of technological modes of construction is estimated by the quality of the obtained whitewashed rolled concretes.

All estimated calculations were carried out in the ABC-4 software package using the example of a/b Kalbatau-Ust-Kamenogorsk, which were presented at the technical council in Kazavtozhol.

And calculations of savings during operation for 50 years were carried out using the "Recommendations for calculating the economic effects of construction, reconstruction, repair and maintenance of highways at the macro and micro economic level of the Republic of Kazakhstan 218-139-2017. Approved and put into effect by the order of the Committee of Highways of the Ministry of Investment and Development of the Republic of Kazakhstan".

The boundaries of the study: geographical – within the Republic of Kazakhstan.

Provisions submitted for protection:

- theoretical justification of the construction of durable highways from road concretes obtained on the basis of belite cements and binders;

- results of experimental studies and surveys of experimental sections of highways constructed using road slag, sludge and ash concrete based on belite cements and binders;

- the results of experimental studies of the technology of construction of road clothes from self-healing road concrete based on slow-hardening belite cements.

Practical significance. The use of nanostructured road concrete and asphalt-mineral concrete based on belite cements, powders and binders from man-made mineral wastes of industry, as base materials and coatings (with a layer of wear) solves the problem of crack resistance, increases the strength and durability of the road structure up to 50 years or more, which meets international standards. At the same time, the cost of construction and operating costs are reduced by 2-3 times and the need for expensive cement. bitumen and stone materials, improves the environmental situation. The pace of construction of concrete coatings with a layer

of wear and asphalt concrete coatings with concrete bases is increasing, which makes it possible to more fully realize the possibilities of slow-hardening cements.

The implementation of the research results was carried out in the form of regulatory and technical documents developed by teams of authors with the participation of the applicant:

1. Recommendations for the use of road clothes made of rolled concrete based on non-burnt binders in the construction of highways and IVPP airfields" R. RK 218-314-2017. MIIR RK KAD.KazNIiPI"Dorthans". Astana, 20017.From 36.
2. ST RK 981 Technical specifications "Slag binders for road construction".
3. Design of the highway "Bypass of Petropavlovsk", using an ash-slag binder based on the ash of the Petropavlovsk thermal power plant

The reliability of scientific statements, conclusions and recommendations is confirmed by the methodological base of research based on fundamental theories and positive results of the use of road concrete based on belite cements, with confirmation of the data by the results of the survey and testing of experimental sites. Novelty is protected by patents of the Republic of Kazakhstan: №3419, № 3607, № 3913, №4110, № 4871, №6701. The applicant was awarded the gold medal of the World Intellectual Property Organization "WIPO AWARD FOR BESTYOUNGINVENTOR ASTANA"

Approbation of practical results. The main results of the work were reported and discussed at the International Scientific and Technical Conference, April 22, 2014. "Safe Roads", (Moscow, MSD, 2014), International Conference "Actual problems and prospects of development of building structures: innovations, modernization and energy efficiency in construction" (Kazakhstan State Academy of Construction and Architecture KAZGAS, Almaty, 2016), International Scientific and Practical Conference in Bishkek "Safe Highways" (2019. Bishkek MSD), the 8th International Scientific and Practical Conference "Highways and transport equipment: problems and prospects of development" dedicated to the 80th anniversary of R.A. Kabashev and the 20th anniversary of KazADI" (Almaty 2019), the 78th International scientific and methodological and research Conference of MADI, subsection "Research and road design" (MADI, Moscow 2020).

The results of the work were submitted to international competitions; the applicant was awarded the gold medal of the World Intellectual Property Organization "WIPO AWARD FOR BEST YOUNGINVENTOR ASTANA".

Publications. Based on the materials of the dissertation, 12 works were published, including 3 normative and technical documents were published with the participation of the author and 6 patents of the Republic of Kazakhstan were obtained.

Structure and volume. The dissertation consists of an introduction, 5 sections, general conclusions and a list of sources used. The main text of the dissertation is presented on 115 pages, includes 28 figures, 18 tables, a list of sources used, including 83 titles and 3 appendices with a volume of 40 pages.

THE MAIN CONTENT OF THE WORK

The first section **"The relevance of improving the technical and operational condition of highways in Kazakhstan"** examines the relevance of the topic, the main problems of construction, the raw material base for the reconstruction of roads and their description.

The main conclusions on the first section.

1. Currently, much attention is paid to the construction and repair of highways in the republic. More than two thousand roads are built and repaired annually, but despite this, road surfaces and foundations continue to collapse, since the strength of the materials used and, accordingly, the construction of road clothes cannot withstand the modern flow of high-speed and heavy-duty vehicles. It is necessary to design highways, especially of national and international importance, multilayered with the use of monolithic materials in structures.

2. The durability of highways is largely determined by the quality of the materials used in their construction. A new approach is needed to assess the suitability of materials for the construction of pavement, taking into account their resistance to multiple dynamic, vibration and temperature-climatic loads. Kazakhstan has huge resources of road-building materials from man-made industrial wastes (slags, ash, sludge, etc.). Some wastes have latent hydraulic activity. When interacting with activators (lime, cement dust, etc.), calcium hydrosilicates and hydroaluminates arise, which are the main structure-forming links in the material. Waste-based binders are used in the construction and reconstruction of roads to strengthen the materials of road clothing, and their behavior in concrete has not been sufficiently studied.

3. Priorities should be given to reinforced materials based on slow-hardening cements from man-made industrial waste having coagulation-crystallization structures that ensure self-healing of destructions that occur during the operation of road structures and neutralize the negative effects of residual deformations that appear in the layers of pavement.

In the second section **"Theoretical background and experimental studies on the use of whitewashed slag cements in rolled concrete for road construction".** The preparation of belite slag cements was carried out in a similar way by the production of Portland cement; joint grinding of clinker and additives, only instead of clinker, phosphoric granular slag was used, the chemical composition of which differs from alite Portland cement (C3S more than 65%) and refers to a belite composition, with a content of bicalcium silicate (C2S more than 85%), medium-alkaline cement dust was used as an activating additive.

The main conclusions on the second section.

1. Slag belite binders in hard pressed mixtures (for the technology of rolled concrete) has the ability to harden both at positive and at low and negative temperatures up to -10 ° C.

2. Low positive and negative temperatures further slow down the hardening process of slowly hardening belite slag binders. At the same time, in the conditions of the 5th road-climatic zone, characterized by a large number of transitions through 0 S, at the time of thawing, a significant reserve of non-hydrated binder is created, which, taking into account the deepening of the hydration process at low temperatures, ranges from 60-90% of the amount of cement. With the hydration of the specified reserve, not only "self-healing" of destructions is ensured, but also a set of strength with an excess of the final strength of normal hardening by 15-25%.

3. The properties of the studied slag belite binder indicate the possibility and expediency of its use for rolled concrete, from rigid mixtures with low water demand, for the purpose of year-round construction and operation of highways.

4. Road concretes based on belite binders, in all likelihood, do not need to be maintained in warm conditions to gain critical strength before freezing, as when using cements with normal setting times. They can be frozen at any period of hardening, the strength and deformative properties of belite cements and concretes based on them, while they will self-repair and strengthen during the operation of the road. This is justified by the fact that belite binders, like colloidal structures, have the property of long-term preservation of thixotropy – self-healing after mechanical squeezing of a part of capillary moisture and rheopexy – hardening during prolonged mechanical action.

5. When holding cement stone at low temperatures (samples 5-8), the decrease in strength is accompanied by the displacement of strongly bound water from fibrous neoplasms in the amount of 10-30% of the mass of available moisture in their capillaries, and with further exposure under normal conditions, their quantity and strength of cement stone are restored within one month. Further withstanding under normal conditions for three months, the strength and amount of strongly bound water exceeds the normal hardening time. This indicates a deepening of the processes of hydration of cement grains and an increase in the dispersion of neoplasms at low holding temperatures, which also increases the strength of cement stone.

6. However, in order to make a final judgment about the possibility of using slag white binder in the construction and year-round operation of highways, it is necessary to conduct detailed studies on rolled concrete.

In the third section, **"Experimental substantiation of the technology of road construction from rolled nanostructured concrete"**, the study of the strength and deformative properties of whitewashed rolled concrete. Research and application possibilities in year-round construction and operation, it is necessary to study the effect of low temperatures and especially early freezing on its properties.

The main conclusions on the third section.

1. Innovative rolled nanostructured concretes based on belite binders, obtained on the basis of belite binders and cements are high-tech construction materials, the novelty of which is confirmed by a number of patents for inventions.

The advantages of using rolled nanostructured concretes based on belite binders are the following:

- the pace of construction of concrete roads is accelerated due to the lack of concrete exposure before it sets the calculated strength, movement on nano-concretes can be opened immediately after the completion of compaction;

- in the production of road nano–belite binders at cement plants, the productivity of plants will increase by more than 2 times, since clinker firing, the cost of which is about 70% of the cost of cement, is excluded from the cement production cycle;

- the widespread use of large-tonnage industrial man-made deposits, amounting to more than 45 billion tons in the country, is a priority under the current law "Green Economy" and will contribute to improving the ecology of the environment. The efficiency of the construction and operation of highways, with the use of hydraulically active man-made industrial waste: fly ash of thermal power plants, phosphoric and blast furnace slags, and the reuse of secondary road construction materials and soils will improve the quality of construction, reduce cost, improve the quality of the environment and ensure environmental safety of road construction.

2. From the experience of Kazakhstan and the USA, ways to increase the durability of cement concrete coatings by adjusting the mineralogical compositions of traditional Portland cement and increasing the number of C2S hydrosilicates responsible for durability are not excluded, which will require changing the requirements for road Portland cement and concrete based on them.

3. The use of road structures with increasing strength "bottom-up" in accordance with the new world concepts will require changes in the methods of designing and calculating road clothes of non-rigid and rigid types.

4. Extensive testing of nano technology and nano materials is provided in accordance with the scientific and technical program for 2022-2024, approved by the Ministry of Foreign Affairs of the Republic of Kazakhstan, headed by the National Engineering Academy of the Republic of Kazakhstan "Development and implementation of effective environmental technologies for monolithic construction of road transport structures according to international standards with integrated disposal of industrial man-made waste and secondary raw materials".

In the fourth section, **"Experimental studies of the technology of construction of nanostructured rolled concrete at low and negative temperatures",** the study of the effect of alternating freezing and thawing on the strength properties of rolled nanostructured concrete. Investigation of the technology of road construction from rolled nanostructured concrete by the method of incomplete work and after prolonged freezing

The main conclusions on the fourth section.

The studied technological properties of nano-structured rolled cinder blocks in the construction of highways indicate the possibility of their use both at positive temperatures-during the construction season (section 3) and at low and negative temperatures, which allows extending the construction season for 3-5 months. When using nano-structured rolled cinder blocks in the production of works at low temperatures , there are the following advantages compared to the use of traditional concretes based on Portland cement:

1. Reshaping with complete destruction of the structure, after preliminary prolonged exposure at negative temperatures, has a positive effect on the strength of concrete, while the strength of concrete increases by 2-28%, depending on the amount of white binder in the rolled concrete. Consequently, when installing layers of road clothes made of rolled cinder concrete mixtures in winter conditions, if necessary, in the spring period, they can be compacted, with correction and surface finishing.

2. Rolled nanostructured concretes on aggregates from gravel-sand mixtures, based on belite slag binders, with alternating freezing-thawing, at an early age for 3 months, do not lose their properties for further hardening, since the main part of the binder participates in this process after thawing the material at positive temperatures. At the same time, freezing has a beneficial effect on the hydration processes of the belite binder, which ultimately leads to the healing of the microstructure, the formed partial loosening in the material and the strength gain without reduction. This once again confirms the possibility and expediency of using rolled cinder blocks in winter construction conditions.

3. The conducted research has established that rolled nanostructured concretes have a sufficiently high frost resistance, allowing the use of such concretes in layers of road clothes on roads of any category. The frost resistance of the rolled cinder blocks obtained after 200 freeze-thaw cycles is more than one, which meets the requirements for the construction of concrete coatings with a layer of asphalt concrete wear on roads of category 1-2.

4. The increased frost resistance of rolled nanostructured concretes is explained by the peculiarity of the structure of the hardened slag white cement stone (section 1).

5. Withstanding cinder concrete mixtures at zero and negative temperatures has a positive effect on the strength properties of materials during their further compaction and hardening under normal conditions. Therefore, it can be considered established that when installing layers of road clothes made of rolled cinder blocks in winter, sudden suspensions of work for climatic and other reasons will not have a negative impact on their strength properties.

6. As a general conclusion based on the results of the study, it should be noted that rolled cinder blocks based on belite slag cements can be used in construction almost year-round. If it is necessary to complete the work during the winter construction period, with concrete compaction by rollers to the required density and commissioning of the facility, it is necessary to use antifreeze additives.

The use of 15% aqueous concentration of NaCl and 10% CaCl2 practically has no harmful effect on the strength of slag concrete, which determines the minimum permissible temperature of slag concrete mixtures minus 15 ° C when used in winter conditions.

In the fifth section **"Results of construction and survey of experimental road sections and feasibility study of developments"**, the survey and testing of experimental road sections made of rolled nanostructured cinder blocks were carried out. Concrete compositions and construction methods are painted. The feasibility study of the construction of road clothes made of rolled nanostructured concrete has been calculated.

The main conclusions on the fifth section.

1. The strength and deformation indicators of cinder blocks correspond to the indicators of high-strength cement concrete, their most effective use in the lower layers of double-layer coatings of cement concrete or asphalt concrete of the SCHMA type, while cutting false temperature seams on them is mandatory. The test results of cores taken from the cinder concrete base after 15 years of road operation showed that the increase in the strength of cinder concrete continues and has reached a compressive strength of 48.8 MPa, and when bending - 8.6 MPa, which indicates the possibility of obtaining concrete coatings similar to high–strength cement concrete. When using asphalt granulate of more than 50% and white slag binder with polymer additive "Polydor" in the bases, the temperature seams are not cut, since asphalt-mineral rolled concrete retains the elastic-viscous properties of asphalt concrete.

2. When comparing the estimated cost of construction of traditional construction of road clothes and construction of road clothes made of rolled nanostructured concrete based on belite cements, we get savings from 28.74% to 42.14%, and when maintaining and operating roads for 50 years, cost savings range from 100.84% to 121.73%.

List of publications

1. B.Asmatulayev, R.Asmatulayev, N.Asmatulayev, Useofself-recovering slowly-hardening concrete to longevity of highways // DS ART 2019 IOP Conf. Series: Materials Science and Engineering 832. - UK 2020 г. 012019. - pp. 2-13.
2. B.Asmatulayev, R.Asmatulayev, N.Asmatulayev, Construction of durable roadsrom rolled concrete based on belite slag cement and binders // International Journal of GEOMATE. - Japan 2023 г. Vol.24 Issue 104. - pp. 27-35.
3. N.Asmatulayev, Prospects of processing and application of oil-containing and bitumen-containing materials in the construction of highways // Oil and gas – Almaty 2021 - No. 6 (126). - pp.113-127.
4. B.Asmatulayev, N.Asmatulayev, Zh.A.Amirkhanov, D.V.Bessonov, Crushed stone-mastic asphalt concrete mixture // Patent No. 3419. - Astana 2018.
5. B.Asmatulayev, N.Asmatulayev, Zh.A.Amirkhanov, D.V.Bessonov, Complex polymer dispersion-reinforcing additive // Patent No. 3607. - Astana 2018.
6. B.Asmatulayev, R.Asmatulayev, N.Asmatulayev, D.V.Bessonov, Sh.A.Shardinov, Kh.Ya.Muradov, The construction of the roadbed of the automobile and railway and its interface with the shore support of the bridge // Patent No. 3913. - Astana 2019.
7. B.Asmatulayev, R.Asmatulayev, N.Asmatulayev, R.A.Mazgutov, V.I.Chumachenko, R.R.Ezmakhunov, Zh.A.Amankosov, Construction of pavement based on nanomodified concrete // Patent No. 4110. - Astana 2019.
8. B.Asmatulayev, R.Asmatulayev, N.Asmatulayev, D.V.Bessonov, V.A.Islamov, Zh.A.Amirkhanov, "Method of road construction using milled asphalt granulate (Variants)" Patent of the Republic of Kazakhstan No. 4871 for utility model dated 21.04.2020 Byul. No. 16 // Patent No. 3607. - Astana 2018.
9. B.Asmatulayev, R.Asmatulayev, N.Asmatulayev, D.V.Bessonov, V.I.Chumachenko, V.A.Islamov, Nanostructuring mineral powder and nanostructured asphalt concrete // Patent No. 2021/0271.2. - Astana 2019.
10. B.Asmatulayev, R.Asmatulayev, N.Asmatulayev, Improving the durability of road clothes by using long-term hardening of belite cements and secondary raw materials // Scientific and Technical journal Highways and Bridges. – Minsk 2021 - No. 2 (28). - pp. 61-73.
11. B.Asmatulayev, R.Asmatulayev, N.Asmatulayev, The use of nanostructured slag-mineral concretes in the construction of highways // Journal Science and Technology in the road industry – Moscow 2022 - No. 1. - pp. 29-37.
12. B.Asmatulayev, R.Asmatulayev, N.Asmatulayev, Prospects for the use of nanomodified rolled concrete to extend the road construction season // Designing highways – Moscow 2020 - No. 78. - pp. 75-88.