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

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IMPROVEMENT OF THE METHODS OF SELECTION OF THE COMPOSITION OF SOILS AND ROAD PAVING MATERIALS REINFORCED WITH CEMENT IN MAINTAINING ROADS

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Statement of the problem. Currently the regulations governing the means and methods of selection of the composition of soils and materials road pavements, reinforced with cement include a number of contradictions and provisions requiring specification concerning the required physical and mechanical characteristics of a structural layer.
Results. The paper presents the rationale for the need to clarify the costs of cement, depending on the number of reasons that can lead to unattainable results by grade strength on the production from laboratory results of selection of the composition of the material (soil) strengthened with cement.
Conclusions. In choosing cement it is not only the minimum values of the likeness for a particular brand but also its optimal value taking into account reserve strength factor that should be important. The sequence of input components of a cementogenesis mixture, mixing time and required breaks between operations in the preparation of a mixture in the laboratory should be as close as possible to production. When preparing samples in the laboratory load at molding samples, the maximum density should be provided and it is also necessary to control the coefficient of consolidation of a structural layer of cement enamel material.

Keywords: road maintenance, road construction, strengthened material, cement and mineral mix, ground-cement mixture, strength.

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Introduction

In reconstruction and large-scale maintenance of highways caused by a degrading bearing capacity of road paving, disassembly of old road paving is the most likely choice in maintenance of the structural layers. Hence in the USSR the most common practice in improving the strength and operational characteristics of roadway surfacing used to construction of an asphalt layer of 4—5 cm in thickness. Its main disadvantage was that there are soon reflected cracks of an old surfacing and a new asphalt concrete layer is not thick enough to provide a required bearing capacity and performance of a road surfacing. In order to save funding and make use of local soils and materials in the 1950s in the USSR structural layers reinforced with foundation binders started being introduced into road surfacing. Recycling of materials of existing road materials and soils in combination with binders addresses a range of economic as well as technical issues of maintenance and construction of roadways. Russian scientists such as V.F. Babkov, V.M. Bezruk, A.K. Birulya, Yu.M. Vasiliev, N.V. Gorelyshev, V.Ye. Kaganovich, N.F. Mischenko, V.P. Nikitin, V.B. Permyakov, P.A. Rebinder, O.A. Slavutskiy, A.V. Smirnov, S.G. Fursov, N.A. Tsytovich, R.P. Scherbakova, etc. have dealt with the issues of strengthening (stabilizing) soils and come up with a number of guidelines as a result [1—4]. Modern conditions for road maintenance and strengthening of soils with binders taking into account current technical capacities as well as different innovative binders require that current guidelines are clarified and developed.

One of the most important issues to be made clear is the purpose and identification of physical and mechanical properties of roadways and cement-reinforced soils in road maintenance and use of materials of existing roadways [5—13].

1. Determining the effect of a strength limit coefficient on changes in the thickness of roadways and types of materials. A road structure to be repaired has structural layers of varying thickness, which is due to defects occurring in the operation of a roadway surfacing, heaving of a foundation and a lower foundation base.

In planning road repairs of regional and municipal roadways of Voronezh with the total area of 8600 km in 2015, regeneration by redeveloping structural layers 20—25 cm deep using a recycler WR240 with the addition of cement and crushed stone to achieve the required strength for M40. In its parts to be generated road structures were opened to collect samples of existing structural layer materials at the regeneration depth and its thickness was identified.

As a result, it was established that in some cases the thickness of a one-layer asphalt surfacing can deviate in an average range of 1 cm for the surfacing thickness of 5 cm, for two-layer asphalt surfacings it can vary significantly depending on the service life of road surfacing and maintenance.

The thickness of a crushed stone soil (particularly, for local heavings) can vary in thickness as well as physical and mechanical properties of crushed stone. These have to be considered concerning the thickness of a road surfacing and cement consumption in selecting a composition of a reinforced material to provide the required physical and mechanical properties of a structural layer to be maintained.

As a network roadways of Voronezh region with a hard surfacing has mainly been constructed using local and “available building materials” since the mid-20th century, it was found that current building materials do not occasionally meet modern guidelines for road surfacings. Therefore in a crushed stone soil there might be metallurgical wastes of up to 1 m and fertile field soil due to the base designed at the sides of a road ditch. Sand underlying soils were not identified for road surfacing of the total of over 80 km in all cases (Fig.).

Fig. Transverse cut of a road structure

According to the results of the monitoring of the regional roadway network of Voronezh region there are generally two typical structures for asphalt concrete pavings of roadways of Class 3 and 4 (Table 1).

Due to all of the above changes in the thickness and physical and mechanical properties of structural layers make it necessary to make corresponding alterations and introduce the safety coefficient of cement consumption on changes in the thickness of structural layers of road surfacing and types of materials to be regenerated (strengthened with cement) during the maintenance of a roadway area.

Table 1

Typical structure of areas of Class 3 roads	Typical structure of areas of Class 4 roads
Surfacing — asphalt concrete with the thickness of 7—10 cm	Surfacing — asphalt concrete with the thickness of 4—6 cm
Foundation — crushed stone with the thickness of 15—25 cm	Foundation — crushed stone with the thickness of 10—20 cm
Soil base — sandy loam, loamy soils with possible inclusion of humus (fertile soil)	Soil base — sandy loam, loamy soils with possible inclusion of humus (fertile soil)

In selecting a composition of a strengthened material on changes in the thickness of structural layers and materials respectively, the safety coefficient is generally considered to be 10%, i.e. the coefficient $K_1 = 1,10$ is introduced. Changes in the coefficient are to be specified for each case according to the results of opening of a road surfacing in selecting samples of materials to determine the cement consumption on each identical roadway area. It should be particularly noted that in maintenance of an intermediate type of surfacing of different soil compositions to be strengthened with cement, the coefficient must be as two or times as large. If there are significant changes in the thickness or type of soil, individual decisions should be made as to the consumption of cement inside each specific area of a road structure for maintenance.

2. Determining of the safety coefficient of cement consumption considering errors in laboratory equipment and testing methods. There might be errors while selecting an optimal composition of a cement mineral (cement soil) mix in laboratory research. They might be due to faults in laboratory equipment such as scales, press as well as methodological errors caused by different degrees of expertise of individuals involved. It is therefore necessary to take all of these factors into consideration which might cause an error while selecting a required strength of a cement mineral (cement soil) mix. The analysis of a number of similar results obtained in different laboratories on modern equipment by highly trained professionals showed that the laboratory data might vary by an average of no less than 5%. It is noteworthy that stages of the introduction of a binder and a mineral component should be as specified in technological process involved in strengthening the materials. Hence, for instance when both a strengthened material (soil) and an organic (polymer) and non-organic binder (cement) are introduced, some of the cement is repelled by water thus becoming a mineral powder, i.e. a disperse filler.

One of the aspects influencing the result for the strength and freeze-resistance in selecting a composition of a cement mineral or cement soil mix is which guidelines are adhered to

[1—4], i.e. which load and method are used to prepare samples of a cement mineral material. Hence in accordance to the GOST 23555 [1], to prepare and test samples of mixes with grains of no more than 20 mm, a large device Soyuzdor NII is used. The mix is poured into the device in three runs poking each layer 25 times with a metal rod with the diameter of 12 mm. Following laying of the entire mix, it is compacted in one run with 120 beats of a weight of 2.5 kg falling from 30 cm.

To prepare and test samples of mixes with grains of no more than 5 mm, a small device Soyuzdor NII is used. The mix is poured into the device poking it 25 times with a metal rod and then compacted with 20 beats of a weight of 2.5 kg falling from 20 cm.

Mixes can also be tested using a pressing method with sample cubes for a mix with grains of no more than 5 mm sized 50 and 100 mm or a small beam sized 40 × 40 × 100 mm and for mixes with grains of no more than 20 mm a small beam sized 100 × 100 × 400 mm. An approximate pressure for a mix with grains of no more than 5 mm is 15 Mpa, for no more than 20 mm it is 20 MPa, curing time is 3 min.

According to [2] for sand cement mixes, a cylinder with the diameter and height of 50 mm is used. The mix is compacted by beating with a weight of 2.5 kg falling from 30 cm, 20 beats or pressing under the pressure of 20 MPa (200 kg-force/cm^2) cured for 3 min. For crushed stone-sand-cement mixes (cement mineral materials) with crushed stone of no more than 20 mm, a cylinder with the diameter and height of 100 mm is used. The mix is compacted by beating with a weight of 2.5 kg falling from 30 cm, 120 beats or pressing under the pressure of 20 MPa (200 kg-force/cm^2) cured for 3 min. For cement mineral materials with crushed stone of no more than 40 mm and up to 30% in a fraction mix of 20—40 mm the same shapes are used as for a mix with grains of no more than 20 mm. Cubes with a rib of 200 mm can also be used if there is crushed stone in a mix and with a rib of 70 mm for sand mixes. The mix is compacted using vibration with a tightening weight with the pressure of 40 g/cm^2 until the tightening weight settles and there is some moisture (approximate vibration time is 50 to 60 sec.).

In accordance with [3], physical and mechanical properties of an asphalt granular concrete mix are determined on cylindrical samples with the diameter of 71.4 mm made by pressing under the pressure of 7 MPa. A sample is cured at a specified pressure for 3 min.

During maintenance of a roadway area when current structural layers are developed where there is crushed stone, apshalt granular concrete, sand or soil, a customer is eligible to use regulations of any of the above guidelines. Furthermore, according to the Guideline, organizations dealing with strengthening and stabilization of soils make use of making samples in cylinders with the diameter of 50—70 mm on a weight under loads of

30—40 MPa, which might contribute to more inconsistent results in selecting a cement mineral material in a laboratory.

We argue that in preparing samples in a laboratory it should be generally remembered that a load for making samples should provide a maximum density while controlling the compaction coefficient of a structural layer from a cement mineral material.

Based on the above, it is necessary to introduce a safety coefficient considering faults in laboratory equipment while selecting a cement mineral (cement soil) mix and laboratory research with the minimum K_2 = 1,05.

3. Determining the safety coefficient of strength considering reduction of the laboratory strength characteristics to actual operating conditions. While strengthening soils depending on the characteristics of an employed technological equipment providing appropriate dozes of a binder and even stirring of a cement mineral (cement soil) mix, it becomes necessary to alter the strength characteristics obtained in a laboratory in accordance with actual operating conditions for capacities of road maintenance equipment. I.e. the consumption of a binder is to be altered according to an actual achieved strength. This is because in actual operating conditions due to less proper crushing (loosening) and mixing of a mineral component than in a laboratory, an actual strength of a strengthened soil is smaller. Actual operating weather conditions also contribute to these differences and they can adversely affect the conditions for a cement mineral mix as well as technological errors which are very likely especially in spring and autumn seasons. All of these require a safety coefficient for technological and operating differences of laboratory production of a cement mineral (cement soil) mix from actual operating ones. Hence according to [4], a range of an average index of physical and mechanical characteristics depending on employed modern equipment (recyclers, soil mixing devices, modern soil milling machines) can be of up to 6 to 14 % depending on a type of a strengthened soil and employed machinery. Therefore an average coefficient K_3 = 1,10 can be used.

4. Analysis of the research and final safety coefficient. The above major factors affecting the performance of a strengthened material, i.e. safety coefficients influencing the quality of actual industrial cement mineral (cement soil) mix requires a grade safety coefficient K_{np} unlike that in a laboratory

$$K_{np} = K_1 \cdot K_2 \cdot K_3 = 1{,}10 \cdot 1{,}05 \cdot 1{,}10 = 1{,}27.$$

It should be noted that according to [1] freeze resistance grade is a number of cycles of freezing and melting where the compressive strength drops by no more than 25 % of a standard strength at a designing stage. Having looked at when in selecting a mix with the characteristics insignificantly larger than the required minimum ones for a specific grade, we see the strength drop by 25 % in freeze-resistance tests, which is in accordance with the requirements for freeze resistance but is not with the required indices of a design grade. Thus due to strength being almost linearly dependent on the content of cement, safety coefficient of 1.27 should be in accordance with that for strengthening material following a calculated number of cycles of freezing and melting and thus provide better performance.

Therefore in order to save some cement, provide grade strength and allow for possible effects of all of the above factors both individually and collectively, it is recommended that the strength limits as presented in Table 2 are to be used.

Table 2

Strength grades	Strength limit, MPa (kg-force/cm^2), no less
M20	2,54 (25,40)
M40	5,08 (5,08)
M60	7,62 (76,20)
M75	9,53 (95,30)
M100	12,7 (127,00)

Conclusions

In order to prepare samples in a laboratory it should be generally borne in mind that loading while making samples should provide a maximum density with control of the compaction coefficient of a structural layer of a cement mineral material.

A sequence of components of a cement soil mix while a mix is being prepared as well as stirring and breaks in between should be as identical to actual production during maintenance as possible.

It is not a minimum strength for a specific grade that should be crucial to the consumption of cement but an optimal one considering the safety coefficient that is specified depending on particular maintenance works.

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