Experimental researches on roadbed structural reinforcement with geogrid on automobile road

Sergey Kudryavtsev^{1,}, Viacheslav Shvartfeld¹, Elena Goncharova¹, Roman Mikhailin¹, Zhanna Kotenko¹, Danil Grigoriev¹*

¹Far Eastern State Transport University, Seryshev St., 47, Khabarovsk, 680021, Russia

Abstract. The paper considers experimental and theoretical researches on layers reduction in the pavement base structure using geogrids on the Amur automobile road (Chita – Khabarovsk). The calculations on transverse elasticity limits are carried out, and some structural designs of a regular pavement and a new one with reduced base layers are offered. A geotechnical modelling with the finite element methods in the software package FEM-models is carried out to evaluate a rational design. The experimental researches on determining the pavement elasticity modulus by the stamp proves both designs being equal in terms of their deformability. The experimental researches on determining the pavement base stress strain behavior caused by the operational loads show a reduction of stresses under the geogrid. The survey of deformations in the embankment and the pavement are presented.

1 The experimental researches on a roadbed structural reinforcement with a geogrid on a section of 15 km of the Amur automobile road (Chita – Khabarovsk)

The railroad poles of the overhead structures are made of weather withstanding materials that do not change under the temperature fluctuations.

In 2007 the first experimental and theoretical researches for changing a regular design of the pavement base started. They were aimed to make the construction works more technologically advanced without worsening the deformability parameter of a design or load-carrying ability in general as well as achieving the cost reduction [3-5]. A reinforcing layer of Tensar SS30 geogrid (England) was used to improve the structural layers characteristics.

2 Calculations on transverse elasticity limits

According to the Regulations for Projecting Non-rigid Pavement [1] the necessary elasticity modulus for the road of the third category with a permanent surface is 200 MPa.

A pavement structure shown on Figure 1 is chosen to meet this demand.

* Corresponding author: olgakudr56@mail.ru

Fig. 1. Regular pavement design.

A required design-level of elasticity of this pavement structure is 252 MPa. To withstand this parameter the thickness of crushed stone layers is reduced by 46% due to a geogrid reinforcement of the base with the modulus elasticity ratio of 3.5. The new offered design is shown on Figure 2.

Fig. 2. New reinforced design of pavement.

The calculated total elasticity modulus in the new pavement design is identical to the

regular one and equals 252 MPa.

This technique is comparable with the method of increasing the general elasticity modulus of a reinforced road design using α_1 [2]:

$$E_{general}^{reinforced} = \alpha_1 \cdot E_{general} \quad (1)$$

This way the calculated total elasticity modulus of the new reinforced design accounts 286 MPa, which is 13.5% greater than the numerical modeling result.

The numerical modeling of the designs is carried out for determining the elasticity modulus of the automobile road pavement base reinforced with the geogrid according to the method offered.

3 Geotechnical modeling

Geotechnical modeling of the pavement designs is carried out using the software package FEM-models to evaluate the optimal geotechnical solution.

The main evaluation index of a durable stability and strength of the design is a direct parameter that is referred as peak values of elastic strains in the structure under loading which is received by mathematical modeling.

The elastic-plastic model of limiting surface of yielding is used to describe the road structure behavior. The choice is justified by the model parameters that can be taken from the standard geological engineering survey of the available materials. In this setting the calculations are well correspondent to the traditional engineering techniques of calculating the deformations, and they describe a stress strain behavior of the structures fairly accurate.

When considering the solutions of the given tasks the numerical modeling of a stress strain behavior of the structures with and without the geogrid SS-30 is carried out on the two-lane rural highway Amur, the load on axle being 100 kN. The stress strain properties of the embankment are taken according to the registered standards of basic engineering design data for all kinds of materials.

The numerical modeling results of the regular and the improved road designs show that the maximum deformations in both structures are almost equal and constitute up to 5 mm (Figure 3).

Fig. 3. Isolines of vertical deformations in geogrid reinforced design under required loading.

The isolines of the vertical “zero” deformations in the projected structure are shifted to the bank line of road. Unlikely, in the offered structure reinforced with the geomaterial SS the isolines are shifted closer to the pavement edge that proves a positive effect of the reinforcement. In this case some reduction of deformations is observed on the surface of traffic way along the road axis.

4 Experimental researches on determining the pavement modulus of elasticity

The strength of the constructed structure on the Amur federal rural highway with the asphalt concrete pavement is evaluated together with an independent examination company “Azimut”, PLC. The pavement field testing technique is used and carried out according to the regulations for the second climatic zone for road building.

The field test is conducted using a stamp equipment of the «TESTING» company (Figure 4). The stamp of a round shape and 300 mm in diameter is used to control the quality of consolidation.

Fig. 4. Testing pavement by stamp.

The surveyed section of a regular pavement structure (without reinforcement) indicates a factual elasticity modulus from 259.60 MPa to 281.66 MPa, which is by $3.0 \div 11.8$ % greater than the required 252 MPa.

The surveyed section of less structural layers reinforced with the geomaterial indicates a factual elasticity modulus from 254.93 MPa to 295.47 MPa, which is by $1.2 \div 17.3$ % greater than the required 252 MPa.

Thus, the above presented data show that both designs are practically equal from the deformability point of view.

5 The experimental research on determining stresses in the pavement base

The stresses are determined using dynamometers connected to a digital station that records the measurement results. The dynamometers are set in two cross-sections of the pavement on the boundary between the crushed stone layer and the macrofragmental soil (working layer). Three dynamometers are placed in every cross-section, two of which measure the horizontal stresses (on the axle and under the wheels) and another one measured the vertical stresses (under the wheels). The first cross-section corresponds to the regular pavement structure and the second one is relevant to the offered pavement structure reinforced with the geogrid. The experimental cross-sections are located in the beginning, at middle and in the end of the section.

Fig. 5. Setting dynamometers.

The stress research in the pavement base gives the following results: the horizontal stresses decrease from 13 % to 41 % and vertical stresses decrease from 36 % to 39 %.

6 The deformation survey in the embankment and the pavement

The nine points of survey are set on the embankment slope to make measurements by leveling. The results of four years of survey show waning and decreasing of the vertical deformations in the geogrid reinforced structure from 27 % to 46 %, while in the non-reinforced structure none of these processes takes place by the fourth year of exploitation.

7 Conclusions

1. The improved design of the pavement structure with the base thickness reduced by 46 % is offered for the experimental section of the federal automobile road Amur.
2. The required elasticity modulus of the reinforced pavement is provided despite the number of layers is reduced.
3. The experimental researches in the pavement base show decreasing of the horizontal deformations from 13 % to 41 % and the vertical ones from 36 % to 39 % under the geogrid.
4. The results of four years of survey show waning and decreasing of the vertical deformations in the geogrid reinforced structure from 27 % to 46 %, while the vertical deformations in the non-reinforced structure show none of these processes by the fourth year of exploitation.
5. The numerical modeling of stress strain behavior of the reinforced pavement structure shows the total deformation up to 5 mm, thus confirming the given structural solution effective.

References

1. V.M. Ulitsky, V.N. Paramonov, S.A. Kudryavtsev, A.G. Shashkin, K.G. Shashkin, *Frost Heave Soil* (Geotechnique, Winnipeg, 2002)
2. V.M. Ulitsky, V.N. Paramonov, S.A. Kudryavtsev, K.G. Shashkin, M.B. Lisyuk, *Contemporary geotechnologies providing safe operation of railway embankments in permafrost conditions* (Current Research and New Informational, Zurich, 2003)

3. S.A. Kudryavtsev, Y.B. Berestyanyy, E.D. Goncharova, *Engineering and Construction of Geotechnical Structures with Geotechnical Materials in Coastal Arctic Zone of Russia* (Polar Engineering Conference Anchorage, Alaska, 2013)
4. S.A. Kudryavtsev, Y.B. Berestianyi, T.Y. Valtseva, A.V. Kazharskyi, E.D. Goncharova, *Sciences in cold and arid regions* **5**, 404-407 (2013)
5. S.A. Kudryavtsev, A.V. Kazharskyi, *Geotechnical engineering for disaster prevention & reduction* **22-24**, 176-180 (2013)
6. S.A. Kudryavtsev, V.N. Paramonov, I.I. Sakharov, *The freezing and thawing of ground* (Saint-Petersburg, 2014)
7. S.A. Kudryavtsev, Y.B. Berestianyi, T.U. Valtseva, R.G. Mikhailin, E.D. Goncharova (Polar Engineering Conference, Bussan, 2014)
8. S.A. Kudryavtsev, Y.B. Berestianyi, A.V. Kazharskyi, E.D. Goncharova, *Sciences in cold and arid regions* **6**, 474-478 (2014)
9. S.A. Kudryavtsev, T.U. Valtseva, R.G. Mikhailin, E.D. Goncharova, *Using designs of variable rigidity on weak soils roads* (Madras, 2015)
10. V.M. Ulitskii, V.N. Paramonov, I.I. Sakharov, S.A. Kudryavtsev, Springer New York Consultants Bureau **0038-0741**, 1-7 (2015)
11. V.N. Paramonov, I.I. Sakharov, S.A. Kudryavtsev, MATEC Web of Conferences **05002**, 15 (2016)
12. I.I. Sakharov, V.N. Paramonov, S.A. Kudryavtsev, MATEC Web of Conferences **05007**, 15 (2016)
13. S.A. Kudryavtsev, A.V. Kazharskyi, E.D. Goncharova, T.U. Valtseva, Zh.I. Kotenko, *Procedia Engineering* **165**, 1080–1086 (2016)
14. S.A. Kudryavtsev, Yu.D. Maleev, D.G. Tsvigunov, E.D. Goncharova, *Procedia Engineering* **165**, 1858–1865 (2016)