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Comparative trials of geosynthetic materials in the base of road pavement on the section of the Central Ring Road in the Moscow Region

Essais comparatifs de matériaux géosynthétiques dans la base du revêtement routier sur le tronçon du Périphérique Central de la région de Moscou

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ABSTRACT: During the period from 2016 to 2019, a complex comparative trial was conducted by "Russian Highways" State Company on the Central Ring Road in Moscow region. Under extremely high traffic volume of 10161 vehicles per day, 22 trial section, with various geosynthetic materials below the aggregate base layer were constructed and monitored in order to demonstrate the improvement in pavement performance. This paper describes a series of static plate loading and falling weight deflectometer tests together with rut depth measurement. On the basis field tests and monitoring, polypropylene geogrids appeared to be the most effective materials for aggregate layers stabilisation. The greatest effect from the use of polypropylene geogrids was achieved by reducing the rut depth. As a result, there is an increase in the residual life of pavement, which for polypropylene geogrids ranges from 22 to 105%, depending on the manufacturer.

RÉSUMÉ: Entre 2016 et 2019, un essai comparatif complexe a été mené par la société d'État « Autoroutes russes » sur le périphérique central de la région de Moscou. Sous un volume de trafic extrêmement élevé de 10161 véhicules par jour, 22 sections d'essai avec divers matériaux géosynthétiques sous la couche de base de granulats ont été construites et surveillées afin de démontrer l'amélioration des performances de la chaussée. Cet article décrit une série d'essais de chargement statique de plaques et de déflectomètre à poids tombant ainsi que la mesure de la profondeur de l'ornière. Sur la base des tests terrain et du suivi, les géogrilles de confinement en polypropylène sont apparues comme les matériaux les plus efficaces pour la stabilisation des couches de granulats. Le plus grand effet de l'utilisation de géogrilles en polypropylène a été obtenu en réduisant la profondeur de l'ornière. Il en résulte une augmentation de la durée de vie résiduelle du revêtement qui, pour les géogrilles en polypropylène, varie de 22 à 105 %, selon le fabricant.

Keywords: Geosynthetic materials; pavement optimization; stabilization.

1 INTRODUCTION

The current trend towards increasing axle loads and driving speeds on highways has clearly identified the problem of rapid wear of road pavement materials. The use of geosynthetic materials in the asphalt and base layers can increase the strength and stiffness of the structure, improving its service life. In 2008 Russian Federal Highway Agency approved a manual for flexible pavements with reinforced aggregate layers design. Original concept and design method for mechanically stabilized granular layers was developed in Saint Petersburg Military Engineering-Technical University (VITU) on the basis of laboratory and field tests in 1999-2002. The effect of aggregate modulus increasing using geogrid is presented by enhancement factors, incorporated into traditional pavement design procedure. Enhancement factors are calculated depending on the thicknesses and modules of the structural layers, the diameter of the wheel footprint and the brand of geogrid. Only polypropylene punched and drawn (P&D) geogrids were tested by VITU and therefore included into the design manual.

Later, in 2015, a national standard GOST R 56338 "Geosynthetic materials for reinforcing the lower layers of road pavement bases" was issued approving the minimum tensile strength required as 30kN/m.

Since then, pavement optimisation via geogrid installation has become widely spread. At the same time, construction industry explored various types of geosynthetic materials with reinforcing/stabilising functions, like hexagonal, welded and glued geogrids, woven geotextiles and geocells. The mechanism of their interaction with aggregate and the effect they produce differs significantly. Haliburton et al. identified a few mechanisms of enhancement, the main ones being lateral restrain and tensioned membrane. The first is realized due to the interlock of crushed stone particles in the rigid cells of the geogrid, and the second due to frictional contact with subsequent tension of the geosynthetic material.

State Company "Russian Highways" (an operator for toll roads in Russia) decided to run comparative research on this subject and validate the performance of different geosynthetic materials on the federal level.

2 TEST SITE

A perfect opportunity arose during the construction of a temporary bypass for the section of Central Ring Road in Moscow region in 2016. Expected traffic volume of 10161 vehicles with 22% heavies per day provided an accelerated testing with about 4 million ESALs in a two-year period. Typical road cross-section is shown on the Figure 1.

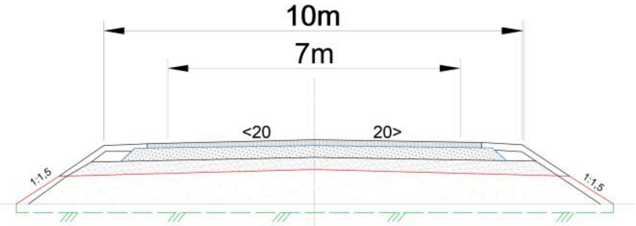

Figure 1. Road cross-section.

2.1 Pavement structure and geosynthetic materials

Pavement structure is shown, Figure 2. It consisted of two asphalt concrete layers (AC), aggregate mix type C-4 with maximum particle size of 80 mm and medium sized sand. Geosynthetic materials were placed between base and sand layers.

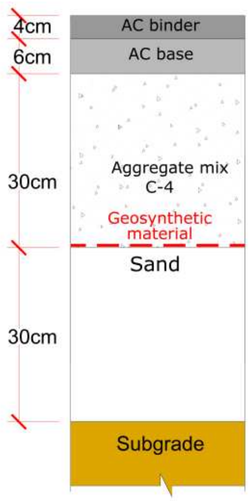

Figure 2. Pavement section.

Along 720m of test section 22 types of geosynthetic materials together with control site with no reinforcement were installed. Each reinforced section was 20m long. The following material were presented:

- 6 types of 40kN/m punched and drawn (P&D) polypropylene (PP) biaxial geogrids;
- 2 types of hexagonal (TX) geogrid 17 and 20kN/m;
- 4 woven geotextiles from 40 to 100kN/m;
- 6 types of woven polyester (PE) geogrids/composites 50kN/m;
- 2 types of basalt geogrid;
- 2 types of geocells.

The full list of geosynthetic materials is presented in the Table 1.

Table 1. List of geosynthetic materials.

Section	Description	Acronym
1	PP P&D 40kN	PPBXGG1
2	PP P&D 40kN	PPBXGG2
3	PE 50kN	PEGG1
4	PE 50kN	PEGG2
5	PP geotextile 80kN	PPGT1
6	Control	Control
7	PP geotextile 50kN	PPGT2
8	PP geotextile 40kN	PPGT3
9	PE 50kN	PEGG3
10	PE composite 50kN	PEGC1
11	PP P&D 40kN	PPBXGG3
12	PE geotextile 100kN	PEGT1
13	PP P&D 40kN	PPBXGG4
14	PP P&D Hexagonal 20kN	PPTXGG1
15	PP P&D Hexagonal 17kN	PPTXGG2
16	Geocell	GCell1
17	PE 50kN	PEGG4
18	PP P&D 40kN	PPBXGG5
19	Basalt 50kN	BGG1
20	PE 50kN	PEGG5
21	Geocell	GCell2
22	Basalt 40kN	BGG2
23	PP P&D 40kN	PPBXGG6

Materials on site are shown, Figures 3-5.

Figure 3. Geocell.

Figure 4. Geocomposite.

Figure 5. Hexagonal P&D geogrid.

Geosynthetic materials samples were taken in order to perform quality control tests on tensile strength and strain at maximum load in accordance to GOST R 55030 (equivalent to ISO 10319).

2.2 Testing

Static plate loading tests were carried out in accordance with standard STO AUTODOR 10.3-2014 (close equivalent to DIN 18134, plate diameter 300mm, maximum pressure 0.5MPa). Under this standard, E_{v1} and E_{v2} modulus are measured together with "resilient modulus", obtained from the recovered resilient part of settlement during the uploading stage. The ratio of E_{v2} to E_{v1} characterizes the quality of the layer compaction and should be less than 2.5.

First series of static plate tests was conducted on the sand subbase layer surface. Average resilient modulus appeared to be 75.15MPa and was lower than designed 108MPa value.

The second series of plate tests was conducted on the surface or aggregate base. Results for modulus are shown in the section 3.

For the further analysis, the effect of geosynthetic materials on the total resilient modulus on the surface of the asphalt concrete layers had to be evaluated. These tests were carried out with the falling weight deflectometer (FWD). The tests had been being carried out during two years, twice a year in mid-August and the third ten days of April. Typical results are shown in Section 3.

After two years in-service a rut depth measurement was performed using a mobile road diagnostic laboratory equipped with a system based on planar lasers and video cameras as shown on the Figure 6.

Figure 6. Mobile road laboratory.

At that moment, the site had passed about 4 million ESALs.

3 TEST RESULTS

3.1 Static plate tests and FWD

Test results for resilient modulus on the base surface, E_{v2} to E_{v1} ratio, and results for asphalt are shown on the Table 2. Control section modulus on the base level was 114MPa.

Table 2. Plate test results.

N	Material	Base surf. MPa	Comp. indicator	Asphalt surf. MPa
1	PPBXGG1	134	2.24	288
2	PPBXGG2	139.5	2.26	301
3	PEGG1	119.5	2.74	322
4	PEGG2	115	3.65	315
5	PPGT1	150	1.74	293
6	PPGT2	124	2.70	249
7	PPGT3	132	2.56	266
8	PEGG3	161	3.48	261
9	PEGC1	128.5	1.25	243
10	PPBXGG3	117.6	4.37	305
11	PEGT1	131.5	2.50	244
12	PPBXGG4	137	1.28	310
13	PPTXGG1	136.7	1.27	323
14	PPTXGG2	131.5	1.13	316
15	GCell1	112	2.27	288
16	PEGG4	126.5	1.04	250
17	PPBXGG5	169	1.02	265
18	BGG1	139	3.72	295
19	PEGG5	154.5	1.16	282
20	GCell2	152	1.22	149
21	BGG2	175	1.07	273
22	PPBXGG6	131	3.05	283

Due to the compatitive ethics material names were hidden from the participants. In gerenal, all section with geosynthetics had shown higher resilient modulus (up to 1.5 times higher) compared to the control before asphalt layers installation.

The average resilient modulus on the base surfest for 8 sections with punched and drawn (P&D) polypropylene (PP) geogrids appeared to be the highest one, followed by polyester geogrids and textiles. Modulus over geocell sections was not consistent, but on average the lowest one.

3.2 Falling weight deflectometer tests

Typical results of summer measurements (2019) are shown, Figure 7.

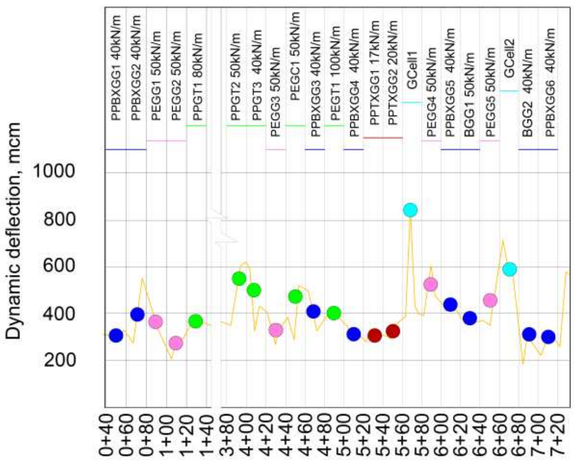

Figure 7. Typical results of FWD measurements.

In general, it was obresved that geocell materials had shown the lowest modulus, followed by geotextiles. Almost all geogrids performed better with polipropylen punched and drawn leading.

3.3 Rut depth control

Control section showed the rut depth of 17mm. Measurements for other sections are shown on the Figure 8.

The majority of sections with geosynthetic materials accumulated less rut depth that control section. This fact is related to the better base layer performance and its resistance to the structural deformation when reinforced or stabilised.

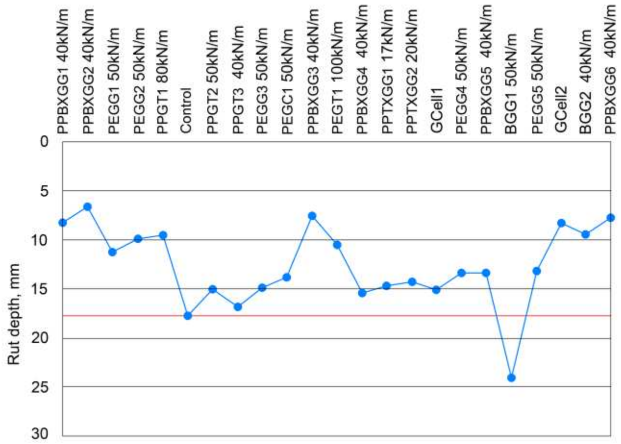

Figure 8. Rut depth measurements.

The best results had been observed along sections with punched and drawn (P&D) polypropylene (PP) biaxial geogrids.

Woven geotextiles with strength approximately equal to that of geogrids showed lower modulus values on the base and asphalt concrete, as well as deeper ruts. 80 and 100 kN geotextiles showed a high modulus at the base level, but after two years of service the modulus at the asphalt concrete surface was lower than in areas with geogrids

4 CONCLUSIONS

Whitin the described research, the most effective materials for reinforcing/stabilising discrete layers are polypropylene geogrids. The greatest effect from the use of polypropylene geogrids is achieved by reducing the rut depth. As a result, there is an increase in the residual life of road pavement, ranging from 22 to 105% depending on the manufacturer. Modulus measurements for the best performing group of geogrids are presented on the Figure 9.

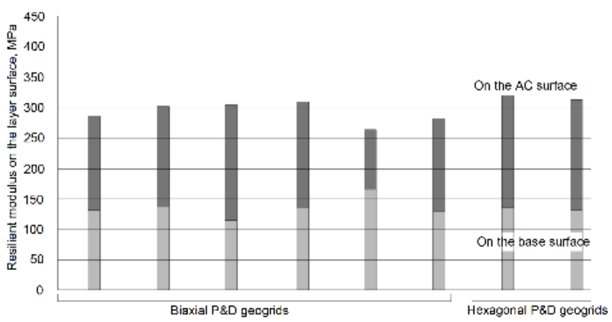

Figure 9. Resilient modulus on the top of AC and base layers.

Hexagonal geogrids having two times lower tensile strength comparing to biaxial one had shown sufficient efficiency and were included into national standard GOST R 56338 in 2023.

Geotextiles and woven geogrids, operating on the principle of a tensioned membrane, on average showed lower modules on the base surface and after two years of service, the deflection of asphalt concrete above them was greater.

Rigid geogrids, operating on the principle of limiting the lateral movement of aggregate particles, ensured high performance during construction and subsequently maintained the rigidity of the base and the entire structure as a whole.

At the moment, "Russian Highways" State Company promotes stiff stabilising geogrid installation as competitive alternative to cement or bitumen treatment.

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