Experimental investigation of the stabilization performance trends of two geogrids constructed on low bearing capacity subgrade

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ABSTRACT: Experiments were carried out on real size samples in the laboratory to investigate the geogrid stabilization performance in highway pavement applications. A moving wheel load was applied on representative pavement samples constructed on low bearing capacity subgrade with and without geogrids. Two types of geogrids were used to construct the pavement sample configurations. Resistance to plastic (permanent) deformation was recorded as a performance indicator to compare structural performance trends of the pavement samples. For this objective, surface deformations were measured after certain wheel load repetitions. Rut depths were calculated from surface profiles measured with a laser profiler. Layer thicknesses were varied to observe differences in the deformation trends. When appropriate conditions were reached in the trial configurations, all layer thicknesses were kept constant during the tests. The two geogrid types constructed with the same granular materials and varying layer thicknesses were used in different layer interfaces to search for the most optimum solution. According to the study findings, the use of geogrid over soft subgrade with low CBR values has been shown to extend the life of the pavement by reducing the rut depth.

Keywords: Pavement, geogrid, geosynthetics, wheel load simulator, CBR

1 INTRODUCTION

The main geosynthetic types are permeable geotextiles and practically impermeable geomembranes. There are geogrid, geonet, geocell, geostrip, geomat and geospacer under the permeable products called "geotextile related products". Geomembranes can be polymeric (thermoplastic and elastomeric) and bituminous. Geosynthetic clay coatings containing clay (bentonite) are also impermeable products. Types produced using more than one geosynthetic are called geocomposites. The International Geosynhetics Society (IGS) does not give a classification, but it also describes some other types, such as geomattress, geofoam, geoform, and geobar. The functions of geosynthetics are separation, filtration, drainage, strengthening, sealing, protection, respectively. In many applications geosynthetics can perform one or more secondary functions at the same time, while being a prominent function of geosynthetics. In almost all applications, for example, geosynthetics have the function of separation. (Wasti, 2007).

Geosynthetics are used either for new road construction or for repairing existing roads with separation, filtration and / or reinforcement purposes. Cost -- effective use of geosynthetics in these applications requires accurate analysis, research and an experience -- based approach.

In terms of applications of geosynthetics, roads can be treated in two categories as paved and unpaved ways (Wasti, 2007). It has been observed by Yang et al. (2012) that a significant effect of the use of geosynthetics is in the provision of durability in unpaved roads and in reducing permanent deformations.

In pavement design, choosing the right layer thicknesses and the most suitable place to install the geogrid is important for reducing the depth of the wheel traces that may occur in the superstructure (Haas et al., 1988).

When geosynthetics (geogrid and geotextile) are used between subgrade and base layers; it is possible to prevent the mixing of subgrade soil and granular base materials by providing the separation of the two layers. Furthermore, the geosynthetics used between the base layer and subgrade layer, increases the bearing capacity of the subgrade and stiffens the base layer by strengthening the applied layers (Giroud and Han, 2004).

Figure 1 shows the differences in load distribution with and without the use of geosynthetics in pavements.

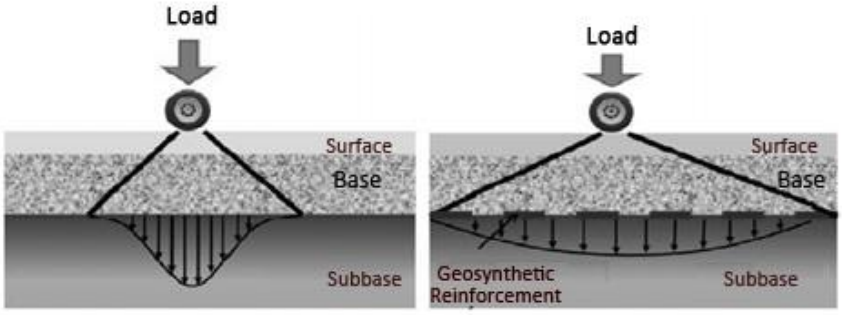


Figure 1. The differences in load distribution with and without geogrid use (Zornberg, 2012)

The benefits of geosynthetics to strengthen asphalt are as follows: Extension of fatigue crack life, reduction of asphalt settlement, strengthening the asphalt overlays and prevention of reflection cracks in overlays. If cracks are formed in the asphalt overlay, geotextiles will be beneficial especially in terms of water insulation (Tutumluer, 2012).

As a result of systematic experiments in West and North Alaska, a new method of soil stabilization has been developed. In this new technique developed, it was tried to increase the carrying capacity of the subgrade by using geofiber and synthetic liquid. The performance of the developed technique was determined by the CBR test and the dynamic three-axial test. As a result of these laboratory studies, it has been determined that the use of geofibers and synthetic fluids on silty soils increased the carrying capacity and flexibility significantly. In study, synthetic fluid was used for the first time with geofiber (Hazirbaba and Connor, 2009).

Accelerated Pavement Tester is a very effective method for evaluating coating performance by applying controlled wheel load under environmental conditions. Yang et al. (2012) conducted tests on stabilized road sections containing sand reinforced geocells with a total of 4 different stabilized road sections. In the first and fourth sections, sand was used in the base layer which was not used in geocell, but after it failed, the base layer prepared with sand was replaced with aggregate. In sections second and third, the lower part of the aggregate-covered layer was reinforced with a new polymer alloy (NPA) geocell. Rut depths at the end of certain wheel pass numbers (100, 200, 300, 400, 1000, 2000, 3000, 4000, and 5000) were followed. While the rut depth measurements at section 1, 2, and 4 were stable, in section 3 has been continued to increase significantly. The horizontal stresses at different locations where NPA was applied were displayed with a strain gauge and it was found that test results showed a significant effect on the stability of the stabilized roads and the reduction of permanent deformations (Yang et al. 2012).

2 PRODUCTION OF SAMPLES

2.1 *Materials used in experiments*

-Subgrade Soil

In this study, the physical and mechanical properties of the subgrade soil were determined by conducting the following tests in the laboratory: Sieve analysis, Atterberg limits, standard Proctor compaction and CBR.

Table 1 lists the soil classification and Atterberg limits (liquid limit, plastic limit and soil classification)

Table 1. Atterberg limits.

Liquid limit	46	(TS 1900-1 AASHTO T – 89)
Plastic limit	17	(TS 1900-1 AASHTO T – 90)
Soil classification	CL	Unified Soil Classification

The results of sieve analysis (wet) for the subgrade soil are given in the Table 2.

Table 2. Sieve analysis results of subgrade soil.

Sieve No	Sieve Opening (mm)	Percent Passing (%)
3/8"	9,53	100,00
No 4	4,760	99,48
No 10	2,000	99,18
No 40	0,425	94,93
No 200	0,075	56,35

As a result of the standard Proctor test, the maximum dry density value was 1.83 g / cm^3 and the optimum water content value was found to be 15.3%.

- *Granular Base and Subbase Material*

The materials to be used in the subbase and base layers are provided by KGM (Turkish General Directorate of Highways). The properties of the materials supplied by KGM are given in Tables 3 and, 4, respectively.

Table 3. Base and subbase course Proctor compaction test results.

		Base	Subbase	Standard
Maximum Dry Density (t/m3)	Standard			
	Modified	2.286	2.236	AASHTO T 180, TS 1900-1
	Vibrating	2,331	2,277	TS 1900-1, BS 1377
Optimum Moisture Content(%)	Standard			
	Modified	5,1	5,0	AASHTO T 180, TS 1900-1
	Vibrating	3,7	3,7	TS 1900-1, BS 1377
Methylene Blue Test (%) max.		1,75	2,25	TS EN 933-9

When the samples have been preparing, the results obtained from the modified Proctor experiment given in Table 3 were used. The results of the methylene blue test given in Table 3 show how much the clay is in the base and subbase materials. It has been observed that the clay ratios determined by the tests conducted are in accordance with the values determined in the KGM specifications. (Base MB≤3,0 – Subbase MB≤4,0)

Table 4. Sieve analysis results of base and subbase course material.

		Base	Subbase
Sieve No	Sieve Opening (mm)	Percent Passing (%)	Percent Passing (%)
3"	75	-	
2"	50	-	100
1 1/2"	37,50	100	97
1"	25,40	90,4	85
3/4"	19,05	78,2	75
3/8"	9,53	60,4	57
No 4	4,760	48,5	44
No 10	2,000	32,4	34
No 40	0,425	12,9	15
No 200	0,075	5,3	7

2.2 - *Geogrid properties*

Tensile tests were performed on geogrids to determine their mechanical properties. The results obtained are as follows: Tensile strength, tensile elongation, tensile strength at 2% elongation and tensile strength at 5% elongation (see Tables 5 and 6).

Table 5. Longitudinal and transverse tensile test results for Type-2 geogrid (rib opening size 40x40 mm).

Nr	L0 (mm)	Tensile strength kN/m		Tensile elongation %		Force-F-%2 kN/m		Force-F-%5 kN/m	
		Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
1	100,00	23,50	19,75	12,00	11,12	8,03	7,14	15,09	13,41
2	100,00	23,31	20,30	13,31	12,13	7,90	7,22	14,57	13,45
3	100,00	23,16	20,75	12,07	15,52	8,43	7,32	15,47	13,34
4	100,00	22,87	20,55	12,40	14,08	8,63	7,59	15,42	13,79
5	100,00	23,37	19,95	13,97	13,46	7,45	6,64	13,75	13,41

Table 6. Longitudinal and transverse tensile test results for Type-2 geogrid (rib opening size 40x40 mm).

Nr	L0 (mm)	Tensile strength kN/m		Tensile elonga-tion %		Force-F-%2 kN/m		Force-F-%5 kN/m		Force-F-%10 kN/m	
		Longi-tudinal	Trans-verse	Longitu-dinal	Trans-verse	Longitu-dinal	Trans-verse	Longitu-dinal	Trans-verse	Longitu-dinal	Trans-verse
1	100,00	17,26	16,95	12,29	10,63	4,68	5,66	9,52	11,63	15,44	16,73
2	100,00	17,15	17,38	11,77	11,56	4,64	5,67	9,40	11,49	15,88	16,93
3	100,00	17,15	17,75	11,88	11,03	4,60	5,68	9,35	12,10	15,73	17,41
4	100,00	17,07	17,79	11,82	11,65	4,79	5,79	9,52	12,05	15,87	17,26
5	100,00	17,20	17,55	10,71	10,68	4,72	5,16	10,04	11,67	16,55	17,27

3 PREPARATION OF SAMPLES

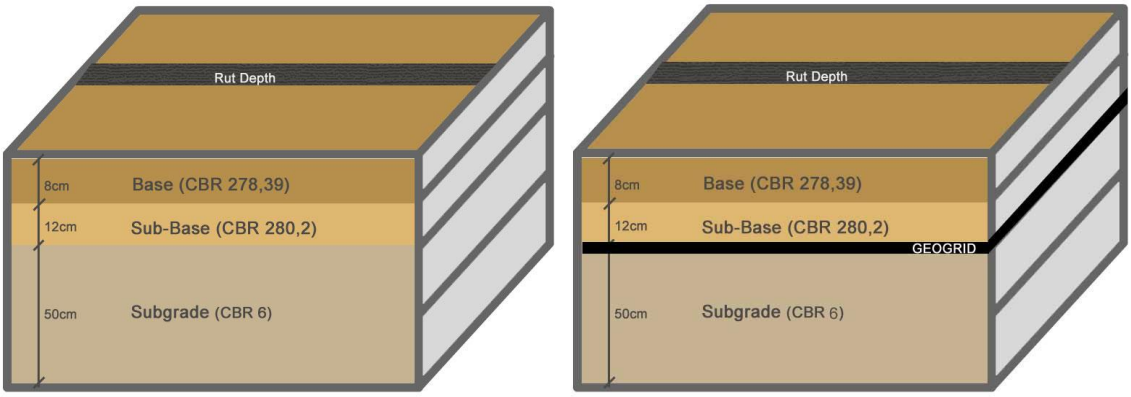
There are two sets of materials used in the experiments in which base course, subbase course and subgrade materials were placed (Model test setup dimensions is 140 cm longitudinally, 100 cm transverse and 74 cm height). These model test setups consist of interwoven wings of different heights. The fixed wing is 30 cm and the other removable wing is 20 cm and 12 cm high. The model test setups are prepared this way; it facilitates the placement of materials and offers the possibility to work at different heights (see Figure 2).

Figure 2. Model test setup used in experiments

The subgrade, subbase and base course materials prepared at their optimum moisture contents were compacted by placing them separately in the sample model test setup. After compaction 95-99% compac-

tion density was achieved using both a plate compactor and a hand compactor. In addition, the DCP experiments had been performed at four pilot points on the subgrade and the obtained graphs were compared it was observed whether the compactions on the samples were equal at each point.

Layer thicknesses used in the experiments were as follows: Subgrade 50 cm, subbase 12 cm, base 8 cm. The subgrade layer having a layer thickness of 50 cm was compressed into three layers separately so that it could not be compressed into a layer. The quantities of the materials to be used were calculated according to the mass density volume of the optimum water content. Three samples were prepared in this study. Since the hot mix asphalt (HMA) layer is not used in our samples; the wheel load to reach the base surface was calculated and the calculated new load values were calibrated and entered into the digital control panel and the samples were subjected to the tests. The first sample was prepared without geogrid and on other samples the two geogrid types were used (see Figure 3).



Sample 1 (Without Geogrids) Sample 2 and 3 (Type-1,Type-2 Geogrids)

Figure 3. Model test setup used in experiments

With APT (Accelerated Pavement Testing) shown in Figure 2, desired wheel loads can be applied dynamically on the samples prepared using special model test setups. The amount of load to be applied, the lines on which the wheel is to be operated and the counts can be controlled from the control panel. The wheel positions can be controlled by the linear ruler on the device and the movement system of the device is hydraulic. The wheel load value applied in the tests was determined as 340 kg and the same load value was applied to all samples.

4 RESULTS

After each pre-determined number of wheel repetitions, the rut depths were measured with the laser surface profiler tester and the data collected were transferred to a database on the computer. By using the generated database, the rut depth profiles formed on the surface were determined and various graphics were created.

4.1 *Surface profile measurement results*

After the samples were prepared, the depths of the wheels were measured with the laser surface profiler before the test with the APT and after certain wheel pass numbers (50, 150, 250, 500, 750, 1000, 2500, 3500, 7500, 9500, 11500, 13500, 20000).

As a result of these tests, the surface profile measurements were recorded and the rut depths on the surface of the base layer were determined. The rut depths in the third sample prepared using the Type-2 geogrid is less than the second sample prepared using the Type-1 (see Figure 4).

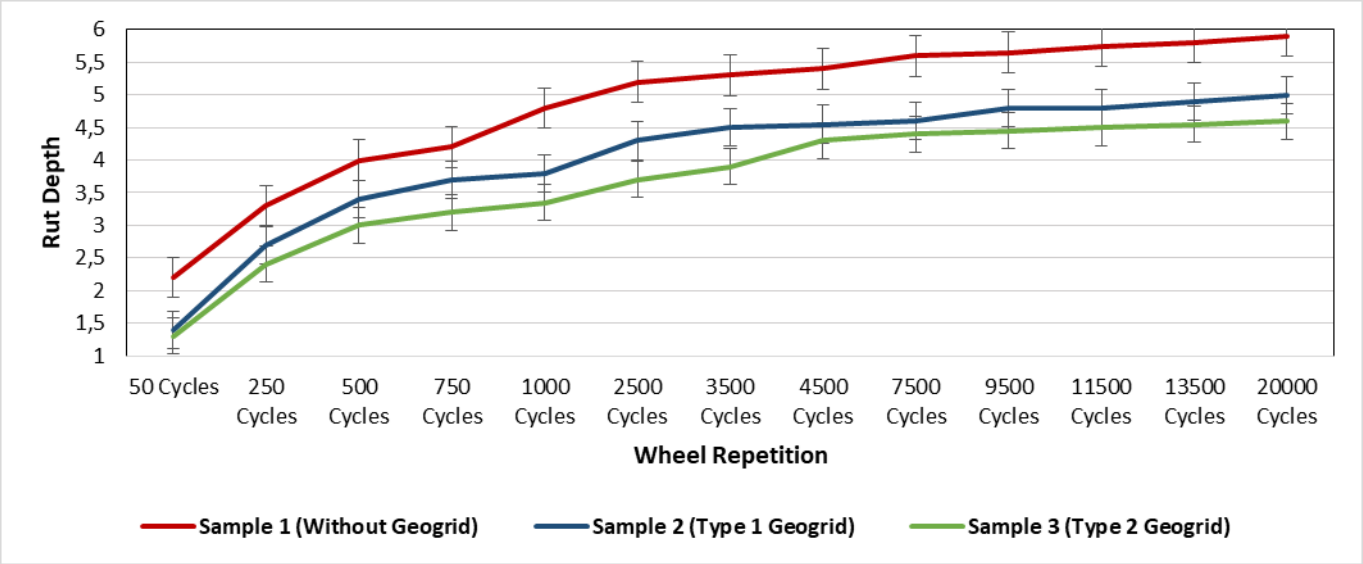


Figure 4. Measured maximum rut depths formed on the surface of the base layers (cm)

The measurements made after a certain number of cycles have been compared among themselves to determine the extent to which the changes of the rut depths and the changes between certain cycles differ (see Table 7).

Table 7. Change of surface profile measurement values between 50-20000 cycles (cm).

	50-250	50-500	120-500	250-500	500-750	750-1000	1000-2500	2500-3500	3500-4500	4500-20000
Sample 1, Without Geogrid	1,1	1,8	3,05	0,7	0,2	0,6	0,4	0,1	0,1	1,45
Sample 2, Type-1 Geogrid	1,3	2	3,4	0,7	0,3	0,1	0,5	0,2	0,05	0,45
Sample 3, Type-2 Geogrid	1,1	1,76	3,06	0,66	0,26	0,13	0,35	0,2	0,2	0,4

As indicated in Table 7, the rut depth measurements are more stable and decreased as the number of turns increases, compared to the samples that do not use geogrid.

5 CONCLUSIONS

As a result, the rut depths that are formed after repetitive wheel loads applied on the samples prepared using geogrid on the subgrade with low CBR value are lower than the samples prepared without using geogrid. In addition, the rut depths after wheel run numbers are reduced more steadily than the samples without geogrid. Along with the use of geogrids, in the remaining layers above the point where geogrid is placed the elasticity increases and the formation process of the plastic deformations that can be formed by the applied loads can be delayed.

As a result of certain wheel pass numbers applied to the samples prepared using geogrids with the same rib openings but different physical and mechanical properties, it was observed that the rut depth formed in the sample prepared using Type-2 was less than that of the sample prepared using Type-1. As the type-2 geogrid, which has less tensile strength values than the other, gives better results in experiments on prepared samples; it is thought that the manufacturing method is better designed than the other.

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