The Effects of Geosynthetics on Mitigation of Rutting in Flexible Pavements

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ABSTRACT

One of the important problems associated with asphalt concrete pavements is rutting. This phenomenon is mostly illustrated as a surface depression in the wheel paths due to load-induced conditions as well as improper mix design or insufficient compaction of hot-mix asphalt. Some of the latest techniques for mitigating the severity and/or decreasing of permanent deformations on asphalt concrete pavements, in other words, preventing the occurrences of wheel path ruts include incorporating geosynthetic products into pavement structure. The purpose of this study is to investigate the benefits of applying geosynthetic reinforcement for rutting mitigation in asphalt concrete pavements by testing several combinations of geosynthetic reinforcement types and pavement types.

In this experimental study, rut depth measurements have been taken from a "Wheel Tracking" test using Hamburg Wheel Tracking Device (HWTD). The HWTD measures the combined effects of rutting and moisture damage by rolling a rubber coated wheel across the surface of an asphalt concrete specimen that is immersed in heated water.

In the tests to understand the effect of the pavement type, three types of mix designs has been used: 1) Stone Mastic Asphalt (SMA), 2) Dense Graded Hot Mix Asphalt (HMA), and 3) Dense Graded Binder HMA. SMA, Dense Graded HMA and Dense Graded Binder HMA mixes were prepared in laboratory from beginning to end. Controlled material samples were used for specimens in the same group. Mix gradation of all Asphalt Specimens was designed according to EN standards. Four different types and brands of geosynthetic materials were used as reinforcement to provide a resistance against rutting. Two Polyster geogrids from different producers and two Fiber Glass geogrids again from different producers have been used in the study.

The contribution of this study to the state of the art is to present a new laboratory study and its findings to help better understand rutting occurrence in asphalt concrete layer and its mitigation with the use of geosynthetic reinforcement. Test results have shown that the benefit obtained by using geosynthetic reinforcement cannot be directly linked to the tensile strength or stiffness of the geosynthetic reinforcement.

Keywords: Asphalt, Fibres, Membranes, Permanent Deformation, Ultra Thin Asphalt Layers

INTRODUCTION

The pavement is the only portion of the highway that is visible to the drivers. The condition and adequacy of the highway is often judged by the smoothness or roughness of the pavement. Bad pavement conditions can result in increased user costs and travel delays, braking and fuel consumption, vehicle maintenance repairs and probability of increased crashes. The pavement life is substantially affected by the number of heavy load repetitions applied, such as single, tandem, tridem and quad axle trucks, buses, tractor-trailers and equipment.

Flexible pavements under the application of freight traffic are exposed to high magnitudes of stress and strain conditions. Rutting is the permanent deformation in the wheel path occurring because of accumulated permanent strains due to the complex heterogeneous nature of asphalt concrete materials (Uzan, 2004). Therefore, owing to its complicated occurrence mechanism, rutting prediction becomes more difficult under repeated axial loading. Besides, asphalt concrete under the influence of heavy loading and high temperature shows a viscoelastic behavior due to the properties of asphalt binder. Due to the temperature and humidity of the material which differ in repeated load cycles; the mechanisms of rut formation is complex and highly dependent on the types of materials used, applied traffic loads and the climatic effects (Laurinavičius and Oginskas, 2006).

Rutting is also a serious safety issue for road users. Wheel path ruts are treated as dangerous defects since they might cause danger for traffic, especially when the surface is wet. By considering its effects on driving safety and driver comfort, many countries define different allowable rut depths according to highway road failure criteria defined in their specifications and standards. To minimize vertical stress/strain on top of each pavement layer, the solution is to endeavor reinforcement in the base course to increase its elastic modulus (Archilla and Madanat, 2000). Geosynthetics are utilized for many purposes in asphalt concrete pavements such as reduction of reflective cracks in HMAs. Such an application can also prevent moisture intrusion into the underlying pavement structure. The geosynthetic material is used to prevent reflective cracking by acting as an interlayer between the old pavement and the overlay (Ling and Liu, 2001). Geosynthetics also are widely used in new road constructions in order to extend life cycle of pavements by inhibiting of distresses such as cracking. Besides, geosynthetics are used in various ways to mitigate rutting of Asphalt Concrete (AC) pavements.

Determining the most cost-effective maintenance or rehabilitation strategy for an existing pavement is very important. However, a life cycle cost analysis (LCCA) provides a means for comparing treatment strategies over an analysis period of 20 to 40 years.

In a LCCA, all costs experienced to be incurred over the life of pavement are identified and converted to a single point in time using economic equations that represent the time value or money. Because all costs are converted to a single point in time, different treatment strategies with different performance lives can easily be compared.

LCCA allows an agency to consider both agency costs and user costs in the same analysis. Agency costs are represented by direct cost to the agency for construction, maintenance, and rehabilitation. User costs, which are not always considered in a LCCA, represent the cost born by the users under each scenario.

RUTTING

A rut as seen in Figure 1 is a surface depression in the wheel paths that may also have transverse displacement along the side of the rut. Rutting is caused by consolidation or lateral movement of any of the pavement layers or subgrade material under induced traffic loads. It may be caused by insufficient design thickness of the pavement, lack of compaction of the subgrade, weakness in the pavement layers due to moisture infiltration, weak asphalt mixtures, or load induced stresses.

Figure 1. High severity asphalt rutting on highway

USE OF GEOSYNTHETICS IN ASPHALT PAVEMENTS

Over the past few decades, geosynthetic usage has increased tremendously. Reasons for this include the ease of installation, quality control in manufacturing, cost competiveness, and their ability to replace raw materials in designs (Koerner, 1998). The term geosynthetic is a broad term used to encompass several different classifications of materials. The four most common classifications are geotextiles, geogrids, geocomposites and geomembranes. Of these, only geotextiles and geogrids are of interest herein. They are the only geosynthetics used in this study, and are described in more detail in the following sections.

The concept of using geosynthetics to provide reinforcement in flexible pavement systems was introduced and developed in the late 1980’s. Since then, numerous experimental studies have been conducted to examine the performance of flexible pavement systems reinforced with geosynthetics (Perkins and Ismeik; 1997 a, b; Berg et al.; 2000). The primary purpose of incorporating the use of geosynthetics in the pavement design process is to reduce reflective cracking in HMA overlays and to resist moisture intrusion into the underlying pavement structure. Geosynthetics can be part of an overall rehabilitation strategy that will, as a minimum, include the placement of a new wearing/surface course of hot mix asphaltic concrete (HMAC). By increasing pavement construction materials and construction costs, and compulsive environmental protection requirements make it important to inquire of finding alternative construction methods with longer service life but at the same time cost efficient (Leng, 2002).

Geosynthetics provide tensile reinforcement through frictional interaction with base course materials, thereby reducing applied stresses on the subgrade and preventing rutting caused by subgrade overstress. By improving the performances of the pavement structure, geosynthetic incorporation can help extend the service life of the system, or reduce the base course thickness such that a pavement of equal service life is constructed with a smaller fill height. Benefits of reducing base course thickness are realized if the cost of the geosynthetic is less than the cost of the reduced base course material, and construction associated with a reduced base thickness (Leng, 2002).

Geosynthetic materials are being used as reinforcement for preventing the occurrence of cracking and rutting in asphalt concrete pavements. Methods for controlling reflective cracking and extending the life of overlays consider the importance and effectiveness of overlay thickness and proper asphalt mixture specification. Sometimes, increasing overlay thickness and modifying the asphalt mixture might not provide satisfying results for crack prevention. The “solutions” is found to be either marginally effective or extremely costly. The most basic way to slow down the reflective cracking is to increase the overlay thickness. In general, as the overlay thickness increases, its resistance to reflective cracks increases. Limits on the thickness of an overlay are the expense of asphalt and the increase in the height of road structure. (Shukla and Yin, 2004)

EXPERIMENTAL STUDY

Flexible specimens of Stone Mastic Asphalt (SMA), Dense Graded Hot Mix Asphalt (HMA), and Dense Graded Binder HMA, were prepared in the laboratory to prepare specimens. SMA, Dense Graded, HMA and Dense Graded Binder HMA mixes were prepared in laboratory from beginning to end. Controlled material samples were used for specimens in the same group. Mix gradation of all Asphalt Specimens was designed according to EN standards. The detailed properties of the various layers have been given in Atalay (2010).The three type of mixtures tested in the experimental program are:

- Dense Graded Asphalt Concrete (DGAC)
- Gap Graded Asphalt Concrete (GGAC)
- Ultra Thin Asphalt Concrete (UTAC)

Four different types of geosynthetic materials were used as reinforcement to provide resistance against rutting. In this paper Geosynthetic 1 is “Aspha Glassgrid”, Geosynthetic 2 is “Hatelit C 40 17”; Geosynthetic 3 is “Synteen Glass Bitutex Composite Geosynthetic” and Geosynthetic 4 is “Tensar Glasstex”. Table 1 includes comparison of the geosynthetics according to their technical specifications.

As can be seen from Table 1, the tensile strength of the geosynthetic materials are in the order of 100 kN/m for products 1, 3 and 4. The geosynthetic material No. 2 has a tensile strength of only half of the others, namely 50 kN/m. The geosynthetic No. 2has also much higher strain at nominal tensile strength.

Geosynthetics were cut according to slab dimensions and installed in asphalt slab interfaces by using a tack coat for sticking. Figure 2 shows installation stages of the geosynthetic material.

Figure 2. Preparation of specimen for test: Installing of geosynthetics

Aggregate and modified or normal bitumen were mixed in big mixer according to EN 12697-35 standard. Figure 3 shows mixing stage of asphalt in mixer.

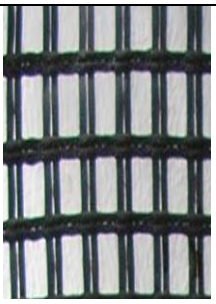
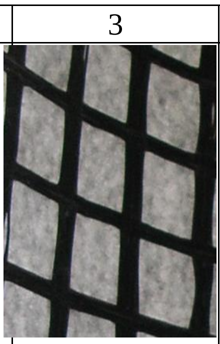
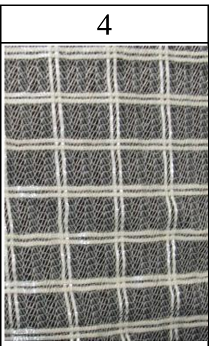
The flexible base parts of specimens were fabricated in Segmental Compactor according to EN-12697-33 standard. Figure 4 shows compaction of slabs in segmental compactor. Then geosynthetics were cut suitable for dimension of specimens and then placed onto whole surface of below element by using tack-coat as a sticker. Upper part of asphalt concrete specimen was applied after two days of curing.

AC mixes were designed according to Marshall Design Concept and the reference standard is TS-EN-12697 (TS-EN is a standard code for the adaptation of European Norms to Turkish Standards). Aggregate gradation design by sieve analysis and TS 3530-EN 933-1 were regarded as reference standard.

Figure 3. Mixing stage of aggregate and bitumen

Figure 4. Compaction of slabs in segmental compactor

Table 1. Comparison of technical specifications of geosynthetic materials

Geosynthetic No.	1	2	3	4
Picture				
Product:	Woven Geogrid	Nonwoven-Geogrid	Nonwoven-Geogrid	Nonwoven-Geogrid
Raw Material	Fiber Glass	Geogrid: PET	Fiber Glass	Geogrid: PET
Coating	bituminous	bituminous	bituminous	bituminous
Weight	~ 650 g/m²	~ 270 g/m²	~ 400 g/m²	~ 430 g/m²
Ultimate tensile strength				
longitudinal	100 kN/m	>50 kN/m	115 kN/m	100 kN/m
transversal	100 kN/m	> 50 kN/m	115 kN/m	100 kN/m
Tensile strength at 3% strain				
longitudinal		>12 kN/m	107 kN/m	35kN/m
transversal		>12 kN/m	96 kN/m	35kN/m
Strain at nominal tensile strength				
Longitudinal	3%	12%	3%	3%
Transversal	3%	12%	3%	3%
Mesh size of geogrid	10 x 10 mm	40 x 40 mm	20x20 mm	40x40 mm
Heat resistance	up to 320 °C	up to 190 °C	up to 850 °C	

The Hamburg Wheel Tracking Device (HWTD) apparatus consists of two measuring places with rolling wheel units working in opposite directions. Rutting tests are conducted on two identically plastered specimens to show that the results are repeatable. The wheels are driven by a slider crank with a frequency controlled motor with a constant levering load system. The wheel units are guided by anti-dumping elements. The number of crossings, the track groove depth of both wheels, and the temperature inside are recorded by a Windows software program with online display (Figure 5). Sample dimensions are 260x320 mm. Sample height was 80 to 100 mm. Rolling wheel is coated with 20 mm rubber coating. Rolling wheel width is 50 mm and rolling section is about 230 mm. Measuring section of device is between 65mm and 165 mm. Tests were carried out at a temperature of 60 °C under the application of a constant tire weight of 710 N for up to 10.000 load cycles (20.000 crossings).

The procedure for preparation of test specimens for the DGAC and GGAC was as follows: First a 60 mm dense graded binder course and then a 40-mm dense graded wearing course were overlapped. Thicknesses are same for geosynthetic installed specimens and the specimens without geosynthetic. A small amount of tack coat was sprayed between layers to increase adhesion. For the UTA specimens a 60 mm dense graded binder course was used and a 20-mm ultra thin wearing course was overlapped. A little tack coat was also sprayed between layers to increase adhesion.

Figure 5. Rutting Test of Two Identically Plastered Specimens in HWTD

TEST RESULTS

Fifteen specimen pairs were prepared for wheel tracking test program. These specimens were simply named based on asphalt concrete mix design type, and the geosynthetic used. For example test name DGAC-1 means that Dense Graded Asphalt Concrete mix has been used with Geosynthetic number 1. DGAC-C is the reference test where no geosynthetic has been used. The measured average rut depths are given in Table 2. On the same table the difference between the two rut measurements are given. Also for each asphalt specimen type, the percent improvement obtained by different reinforcement types are given in Table 2.

Table 2. Rut Depth Values of all Specimens

Test Name	Average Rut Depth	Difference between left and right rut	Percent improvement relative to unreinforced specimen
	[mm]	[mm]	[%]
DGAC-C	3,08	0,27	
DGAC-1	2,86	0,64	7,1
DGAC-2	2,69	0,67	12,7
DGAC-3	3,06	0,09	0,6
DGAC-4	3,62	0,13	-17,5
GGAC-C	2,98	0,62	
GGAC-1	2,37	0,25	20,5
GGAC-2	2,16	0,36	27,5
GGAC-2	2,75	0,35	7,7
GGAC-4	3,51	0,32	-17,8
UTAC-C	1,53	0,61	
UTAC-1	1,05	0,1	31,4
UTAC-2	1,01	0,7	34,0
UTAC-3	1,3	0,2	15,0
UTAC-4	1,9	0,3	-24,2

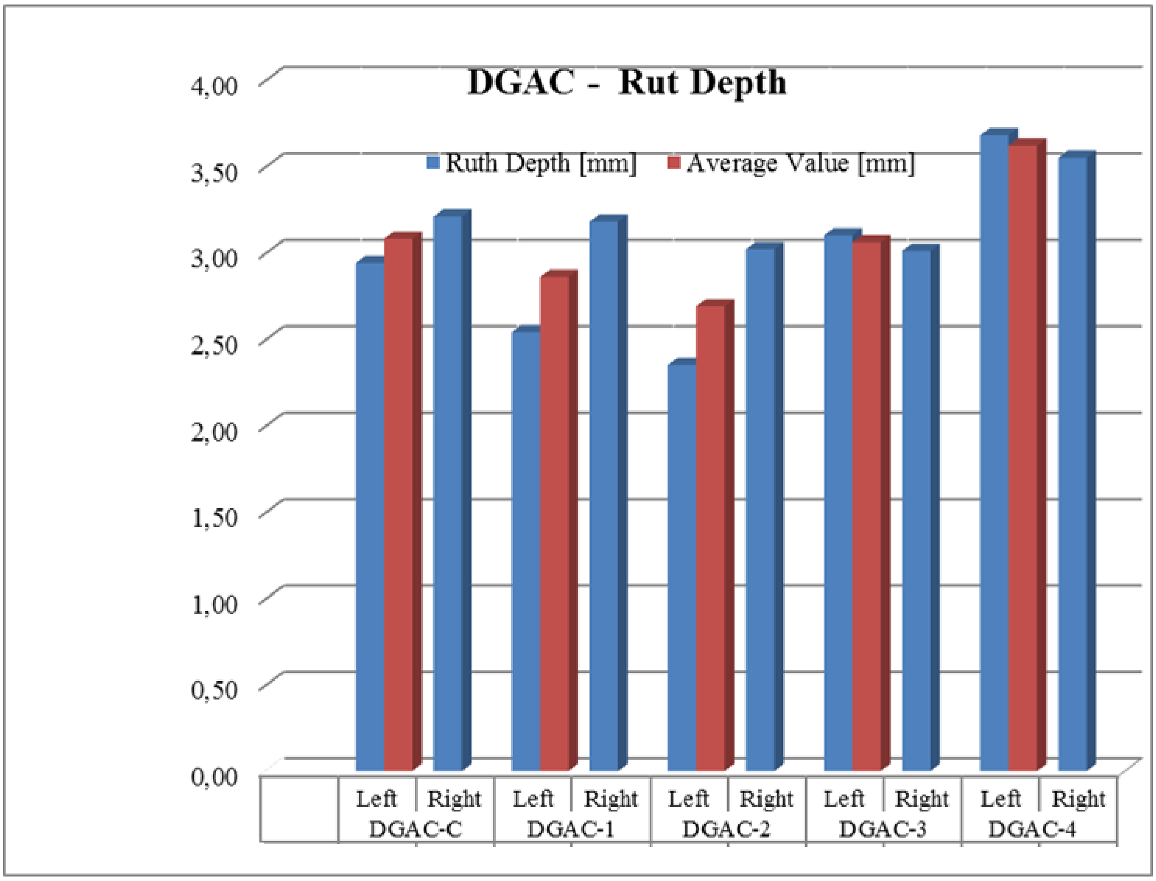


Figure 6. DGAC- Rut Test Result Chart

As can be seen from Figure 6 DGAC-2 specimen has shown largest resistance to rutting occurrence compared to other specimen types. The improvement obtained relative to the unreinforced specimen was 12.7% (Table 2).DGAC-1 also showed lower rut depth value compared to the reference specimen. DGAC-3 gave almost the same rut depth as the reference sample. However the specimen where geosynthetic 4 has been used (DGAC-4) showed a rut depth even larger than the specimen without any geosynthetics. Despite having a geosynthetic which has substantially similar technical specification as DGAC-1 and DGAC-3, the DGAC-4 has shown lower performance than reference specimen for rutting resistance. One of the possible causes can be that the geosynthetic 4 was not as stiff as the other geosynthetics. The installation of Geosynthetic 4 into asphalt slabs was also too difficult so this can also be the reason for the poor behavior. Moreover; with this material it was not possible to provide enough fixations despite applying enough tack coat and waiting for its curing.

In general GGAC specimens have shown better performance compared to DGAC specimens (Figure 7). This was an expected result because, upper course of GGAC specimens were SMA and it has better resistance ability for rutting occurrence and it is more durable than conventional HMA.

Among GGAC specimens the highest durability against rutting was observed for the GGAC-2 specimen when compared to other specimens. The improvement obtained relative to the unreinforced specimen was 27.5% (Table 2). It can also be concluded for geosynthetic types 1, 2 and 3 the percent improvement relative to unreinforced samples was much higher for GGAC specimens compared to DGAC specimens.

GGAC-1 and GGAC-3 have also lower rut depth values than the reference specimen. GGAC-4 specimen has shown lower performance than the reference specimen for rutting resistance.

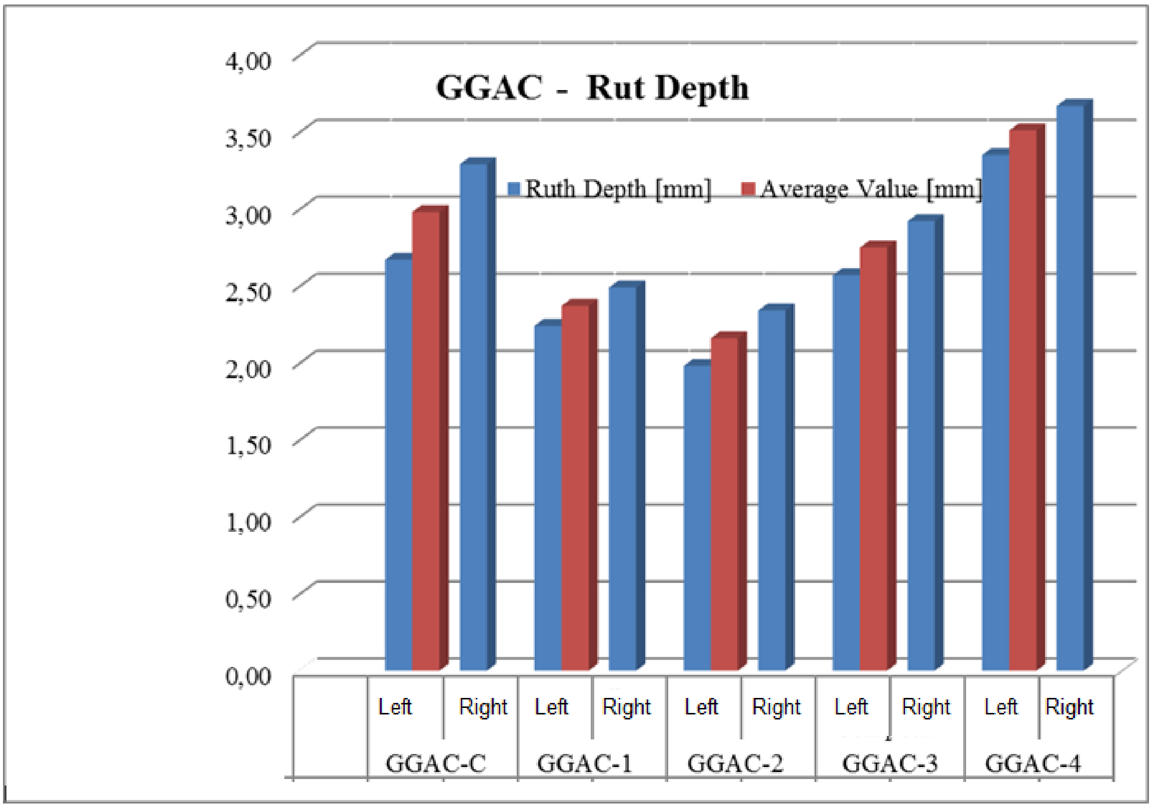


Figure 7. GGAC- Rut Depth Result Chart

The result of the UTAC specimens are shown in Figure 8. UTAC rutting test results were consistent with the results obtained for DGAC and GGAC specimens. In this configuration UTAC-1 and UTAC-2 specimens showed the best behavior and UTAC-4 specimen still had a rutting lower than the reference specimen. The improvement obtained for UTAC-2 specimen relative to the unreinforced specimen was 34.0% (Table 2). It is also observed that for all UTAC specimens 1, 2 and 3 the highest improvement was achieved among the tested specimens regardless of the geosynthetic type. Similar to the other test results, UTAC-4 specimen experienced even more rutting than the reference specimen.

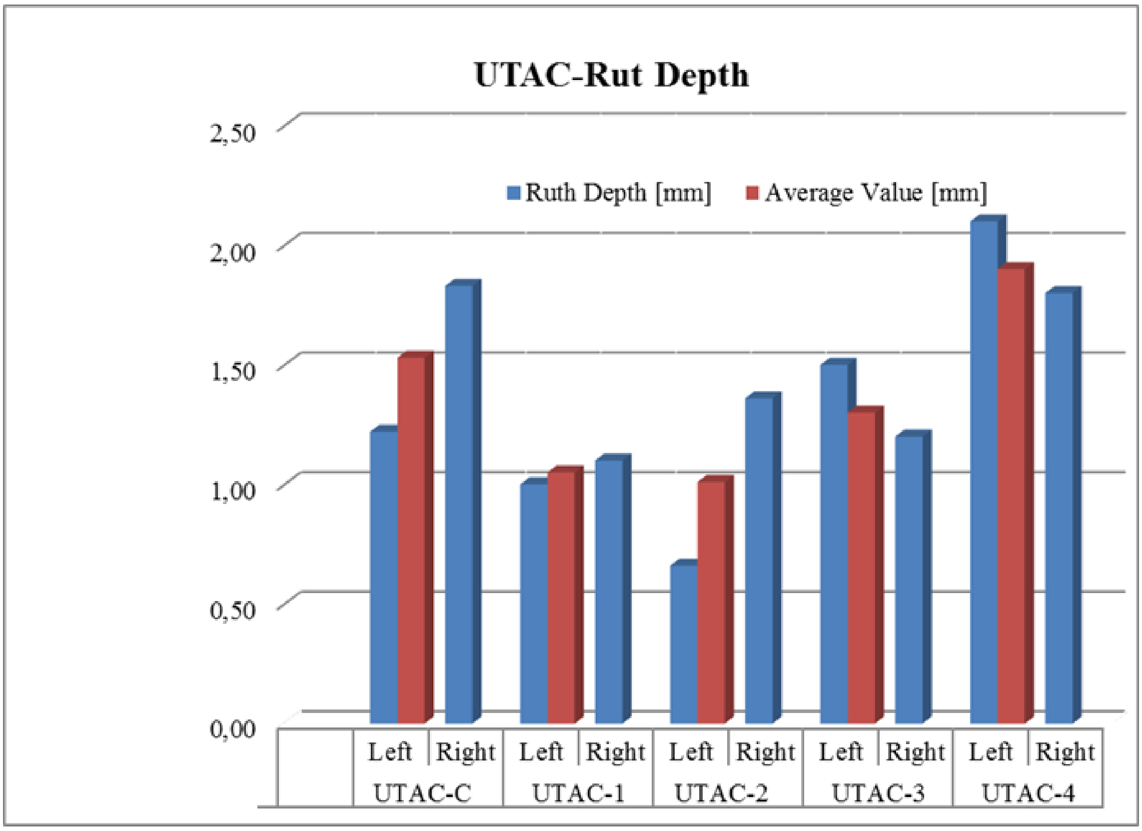


Figure 8 UTAC- Rut Depth Result Chart

CONCLUSIONS

Rutting is one of the main distress types to lead to pavement failure and is difficult to track and simulate with deformation/strain measurements in majority of materials of asphalt concrete. The purpose of this research study was to investigate the effectiveness of using geosynthetics in mitigation of rutting in asphalt concrete pavements**.** The expected contribution of this study to the state of the art was to present a laboratory study and a better understanding on how different geosynthetic products effect the rutting behavior for different pavement types. The following conclusions can be drawn from results of the undertaken experiments;

i) Dense Graded Asphalt Concrete (DGAC), Gap Graded Asphalt Concrete (GGAC) and Ultra Thin Asphalt Concrete (UTAC) tests has revealed that geosynthetic usage reduce rutting potential of pavements if a suitable geosynthetic product is used.

ii) The in-isolation tensile strength of the geosynthetic is not the major parameter that affects the pavement behavior. This was seen by the fact that the geosynthetic that has the lowest in-isolation tensile strength provided the best improvement.
iii) Installation ease is an important part of geosynthetic usage. Despite having good technical specification for reinforcement, due to installation difficulties in the Hamburg Wheel Tracking Device, Geosynthetic 4 incorporated specimen did not provide good performance for rutting mitigation.
iv) Hamburg Wheel Tracking Device appears to provide a means to quantify geosynthetic installed sandwich specimens' rutting potential. However rutting is too complicated for a small composite sample produced in the laboratory to accurately predict how it will perform in the field. Therefore definitely full size field tests are necessary for a more precise evaluation.
v) Using geosynthetics in Ultra Thin Asphalt Concrete (UTAC) provided good performance for rutting in the laboratory tests. However this can be due to the design of the Hamburg Wheel Tracking Device which causes less rutting in a thinner section.

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