Experimental Performance of Fiberglass Geogrid in Asphalt Pavements

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ABSTRACT

This study performed an experimental investigation of asphalt concrete with and without fiberglass geogrid reinforcement, using specimens in the laboratory and in situ. A 100kN/m fiberglass geogrid was used. The results showed that with the fiberglass geogrid reinforcement, the flexural strength of the asphalt increased by 24.82%, deformation was significantly reduced, and the elastic modulus did not improve significantly. In addition, using the Hamburg Wheel Tracker test, the fiberglass geogrid reinforced asphalt samples had a 7.41%reduced rutting depth. Finally, two segments in situ were also tested showing that the flexural strength of asphalt concrete increased by 24.27% and the structural strength of the pavement increased by 25.24%. These results show that pavement structures are significantly improved when reinforced with fiberglass geogrid.

Keywords-asphalt pavement; fiberglass geogrid; flexural strength; elastic modulus; Hamburg Wheel Tracker

I. INTRODUCTION

Asphalt pavement, or flexible pavement, is widely used worldwide due to its excellent characteristics, such as favorable construction conditions, comfortable exploitation, and convenient maintenance [1]. In summary, asphalt pavement is popularly used as Hot Mix Asphalt (HMA), containing a mixture of approximately 94-95% stone, sand, filler, and 5-6% bitumen. The asphalt mixture is heated, mixed properly, placed on the base and subbase layer, compacted using a heavy roller, ready to be used when it cools. There are one or more HMA layers for the surface course to design flexible pavement. The asphalt pavement is significantly affected by heavy traffic loading and seasonal temperatures. Many types of damage, such as rutting, cracking, and raveling [2-3], occur on asphalt pavements. Due to its importance, researchers and material experts try to find the best way to improve pavement rehabilitation with low cost and low use of raw materials. In general, to renovate an old road pavement, an overlay layer is usually paved over the existing surface to cover the existing cracked layers. However, the disadvantage of this method is sustained by the crack propagation of the current layer, which is known to be complex. With the recent development of new technologies and materials, geogrids are applied to reinforce asphalt pavements to improve stiffness, stability, and service life and reduce the thickness of additional pavement layers resulting in material and cost savings [4-14]. The mechanical properties of asphalt pavements are significantly affected by the properties and positioning of geogrids, the stiffness of the asphalt layer, the characteristics of the subgrade, the aggregate base course, and the HMA [4-6, 8, 15]. In [15], it was shown that a higher-strength geogrid is more effective in improving asphalt pavement. For rehabilitation, geogrid can be used as an effective method to counteract the reflective crack of the existing surface [16]. In addition, the geogrid improves the flexible pavement in two ways, by reducing the surface rutting potential and by decreasing the base course [4].

This study aims to investigate the properties of glass geogrid-reinforced asphalt pavement in the laboratory and in situ. Specimens were prepared by a semi-automatic roller compactor. The geogrid used was commercial fiberglass with a tensile strength of more than 100kN/m provided by a local company. Flexural strength, elastic modulus, and Hamburg wheel tracking tests were conducted in the laboratory. In addition, geogrid reinforcement was applied in situ to investigate the current situation, construction technology, resilient modulus, compacted asphalt layer, and flexural strength from boreholes. The results obtained provide guidelines for researchers, engineers, and designers in improving the method of designing reinforced asphalt pavements with fiberglass geogrid.

II. MATERIALS AND METHODS

A. Asphalt Concrete

Figure 1 shows the grain size distribution of the aggregate mix, which followed the requirements of TCVN 8819 [17]. A bitumen 60/70 grade was applied, which satisfied the current Vietnamese standard. The mineral filler had a grain size less than 0.071mm and 2.731g/cm^3 specific gravity. Table I shows the basic properties of the asphalt concrete.

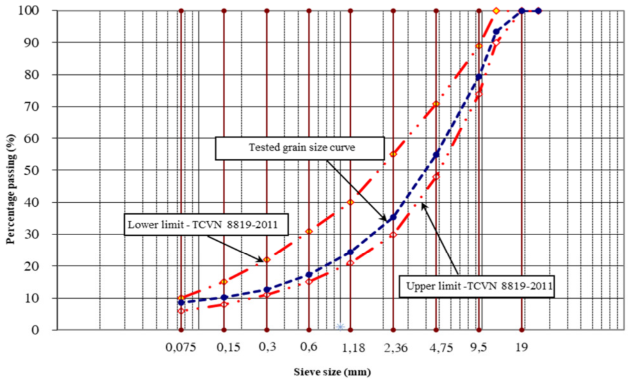

Fig. 1. Grain size distribution of the aggregates.

TABLE I. BASIC PROPERTIES OF ASPHALT CONCRETE

No	Characteristics	Unit	Results	Requirement
1	Bitumen content	%	5.32	-
2	Compressive strength	kN/cm^2		
	t = 20^{0}C		51.44	-
	t = 50^{0}C		21.54	-
3	Marshall stability	kN	11.96	8.0
4	Flow measurement	mm	3.62	2-4
5	Voids in the total mix	%	4.42	3-6
6	Voids in mineral aggregates	%	16.70	min 15

B. Fiberglass Geogrid

The fiberglass geogrid used is shown in Figure 2 and had 100kN/m tensile strength. Table II shows its mechanical properties provided by the manufacturer.

TABLE II. PROPERTIES OF FIBERGLASS GEOGRID

No	Properties	Method	Unit	Result
1	Tensile strength (MD)	ASTM D6637	kN/m	≥ 100
2	Tensile strength (CMD)	ASTM D6637	kN/m	≥ 100
3	Elongation (MD)	ASTM D6637	%	≤ 3
4	Elongation (CMD)	ASTM D6637	%	≤ 3
5	Coating with asphalt			Visual
6	Color	Black		

MD is machine direction, CMD is the cross-machine direction

Fig. 2. Fiberglass geogrid used.

C. Sample Preparation

Figure 3 shows the asphalt samples with and without fiberglass geogrid reinforcement.

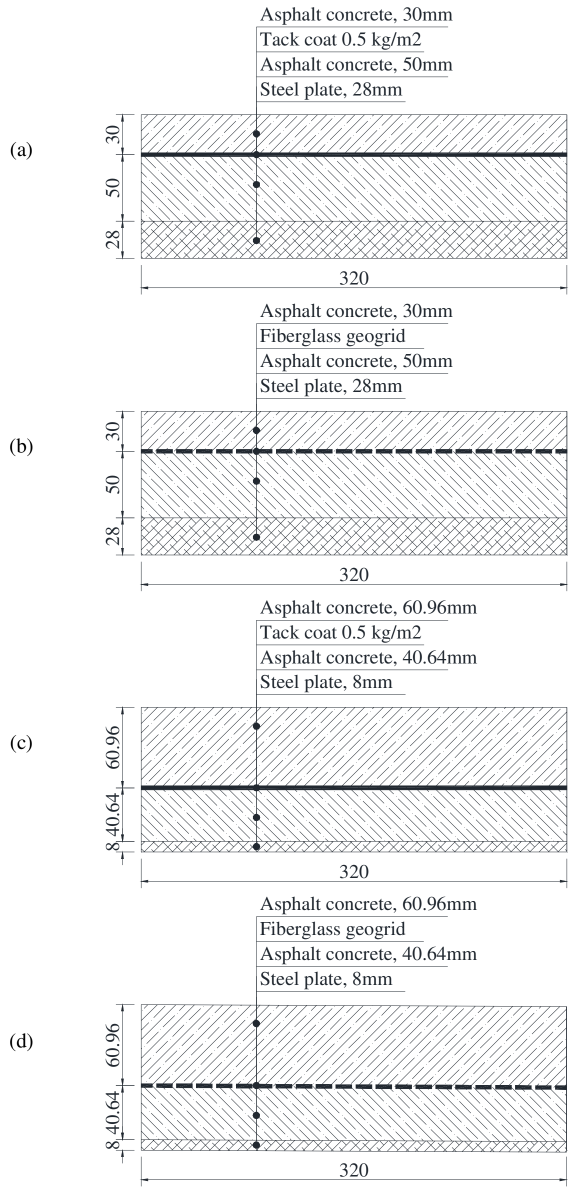

Fig. 3. Sample with different dimensions: (a, b) 320×260×80mm for flexural strength and wheel tracking tests; (c, d) 320×260×101.6 mm for elastic modulus test.

Specimens with dimensions of 320×260×80mm, denoted by M1, were prepared for flexural strength and wheel tracking tests. Similarly, specimens with dimensions of 320×260×101.6mm were prepared for the elastic modulus test, denoted by M2. The specimens were compacted by a semi-automatic roller compactor SYD 0703 with a 500mm wheel radius and a width of 300mm. The highest compaction pressure was 30kN/cm^2, the roller compaction cycle was at least 12 times/1 minute, using a fully heated roller compactor plate.

Subsequently, each specimen was cut into 5 small specimens with dimensions of 50×50×200mm for flexural strength, and d×h=101.6×101.6mm for elastic modulus tests. The temperatures used were 15, 30, and 50°C for flexural strength, elastic modulus, and wheel tracking tests, respectively. The repeated loading was performed with a frequency of 25±2.5 cycles per minute and a pressure of 0.7MPa.

III. RESULTS AND DISCUSSION

A. Flexural Strength

Table III shows the test results for the flexural strength of asphalt concrete samples with (MGC) and without fiberglass geogrid reinforcement (MKGC). Figure 4 shows that the flexural strength values of the asphalt concrete with and without fiberglass geogrid reinforcement were 2.48 and 3.08MPa, respectively, indicating an increase of 24.82%. This can be explained as follows: at a temperature of 15°C, the asphalt concrete becomes hard under the influence of loading, which causes cracks and destruction. The fiberglass geogrid in asphalt concrete samples absorbs part of the load and distributes it over a larger area. On the other hand, the tensile strength of the fiberglass geogrid-reinforced asphalt is higher, slowing down the deformation and failure of the sample. Therefore, asphalt concrete samples with fiberglass geogrid reinforcement have higher tensile strength when bending than the unreinforced ones.

TABLE III. FLEXURAL STRENGTH OF ASPHALT CONCRETE WITH AND WITHOUT FIBERGLASS GEOGRID

No	Sample	Dimension (mm)			Deformation (mm)	Flexural strength (MPa)	Average strength (MPa)	Average deformation (mm)
		Wide	Length	Height				
1	MKGC 1	53.0	200	54.7	1.67	2.5	2.5	1.66
2	MKGC 2	54.0	200	54.0	1.6	2.2		
3	MKGC 3	53.3	200	54.7	1.7	2.6		
4	MKGC 4	51.7	200	54.3	1.58	2.5		
5	MKGC 5	51.3	200	55.7	1.75	2.5		
6	MGC 1	50.0	200	54.0	2.29	3.2	3.1	2.29
7	MGC 2	50.7	200	55.3	2.3	3.2		
8	MGC 3	53.3	200	55.3	2.32	3.2		
9	MGC 4	54.7	200	54.7	2.22	2.9		
10	MGC 5	51.0	200	55.7	2.32	2.9		

As shown in Figure 5, asphalt concrete samples without fiberglass geogrid reinforcement had a lower deflection than the reinforced ones when subjected to maximum load. The average deflection of the unreinforced samples was 1.66mm, while the average of the reinforced samples was 2.29mm, an increase of 37.89%. This can be explained by the fact that the fiberglass geogrid participates in the bending along with the asphalt concrete, thereby increasing the deflection of the sample. This means that the failure of the reinforced samples will take place more slowly, reducing the cracks in the concrete. In [18], it was shown that the flexural behavior of various geogrids (e.g. fiberglass, polyester, and geomembrane geogrids) had a significantly improved resistance to cyclic loading from 66 to 100%.

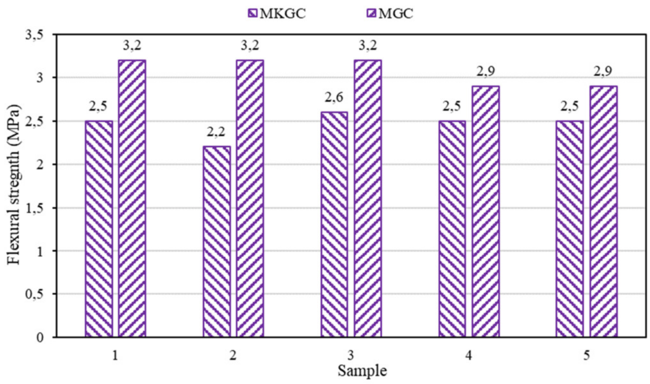

Fig. 4. Flexural strength of asphalt concrete.

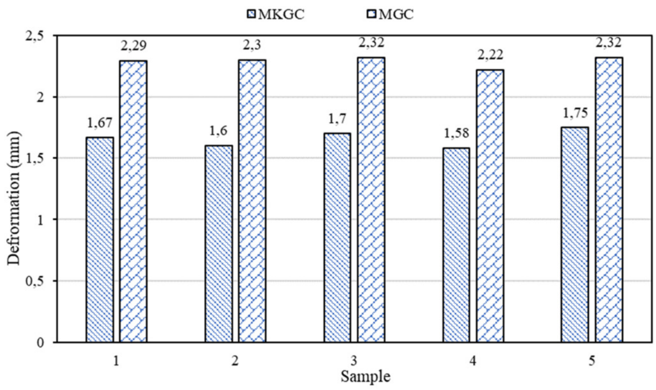

Fig. 5. Deformation of asphalt concrete.

B. Elastic Modulus

Table IV shows the elastic modulus of asphalt concrete samples with and without fiberglass geogrid reinforcement. These results show that the average elastic modulus of the samples reinforced with fiberglass geogrid increased from 508 to 521MPa, an increase of 2.6%. Overall, the elastic modulus of fiberglass geogrid-reinforced samples did not change significantly. The explained is that when the samples were compressed, the area of the presser was equal to the contact area of the sample and the glass geogrid, so the influence of the fiberglass geogrid in this experiment was not significant. However, the results of this experiment do not accurately reflect the ability to increase the elastic modulus of the asphalt sample because the sample was small, so there are only one or two grid cells in the sample.

C. Hamburg Wheel Tracker (HWT) Test

The HWT test was conducted to investigate the rutting potential of asphalt concrete. The specimens were conditioned at a temperature of less than 25°C and the test conditions included water of 50°C and 15.000 cycles. Figures 6 and 7 show the results for both types of specimens at various positions (left, right, and average). The horizontal axis is the cross of the wheel passing the specimen, and the vertical axis is the depth of the specimen. For normal asphalt concrete, the rutting depth was 7.26mm, 5.50mm, and 6.38mm for left, right, and average, respectively. For fiberglass geogrid reinforced asphalt concrete, the rutting depth was 6.76mm, 5.12mm, and 5.94mm for left, right, and average, respectively.

TABLE IV. ELASTIC MODULUS OF ASPHALT CONCRETE WITH AND WITHOUT GLASS GEOGRID

No	Sample	Dimension (mm)		Pressure (MPa)	Deformation (mm)	Elastic modulus (MPa)	Average (MPa)
		Height	Diameter				
1	MKGC 1	104.0	101.6	0.5	0.100	520.0	508
2	MKGC 2	104.0	101.7	0.5	0.103	507.3	
3	MKGC 3	104.0	101.7	0.5	0.105	495.2	
4	MGC 1	104.2	101.7	0.5	0.098	534.4	521
5	MGC 2	104.1	101.6	0.5	0.100	520.5	
6	MGC 3	104.2	101.5	0.5	0.103	508.3	

For asphalt concrete samples reinforced with fiberglass geogrid, the depth of the wheel track was reduced by 7.41% compared to those without reinforcement. When the number of cycles increased to 8000, the average settlement of the two samples was almost the same (MGC: 4.25mm and MKGC: 4.47mm). At this point, the resistance against the wheel track was taken by the asphalt concrete. Furthermore, increasing the number of load cycles from 8000 to 15000 times, the MGC settlement increased on average from 4.25 to 5.94mm and the MKGC increased from 4.47 to 6.93 on average, showing that the reinforced concrete samples had less settlement. When the asphalt concrete samples were loaded vertically and the application time was continuously increased, the wheel pressure would be transmitted from layer 2 (thickness 30mm) to layer 1 (thickness 50mm). For the unreinforced concrete samples, this settlement was to assess the resistance of concrete to wheel load. Regarding the reinforced concrete samples, when the load transmitted through concrete layer 2 (thickness: 30cm) and meets the glass fiber mesh, the mesh would receive and redistribute the load evenly throughout the sample surface, leading to a reduction in the load. The pressure was transmitted to layer 1 of asphalt concrete, thereby reducing the depth of the wheel track. However, this decrease in rutting depth was not significant, approximately 7.41%. In the same way, in [12], it was concluded that geogrid reinforcement reduced the horizontal movement of the granular material, especially in the longitudinal direction.

D. Evaluation Of Applying Fiberglass Geogrid In Situ

This study selected two segments in the Kien Giang province, southern Vietnam, to investigate the potential of using fiberglass geogrid reinforcement in road construction in situ. Two damaged road sections, with reflection cracks and turtle shells, on Tran Khanh Du Street, including 100m from Km 15+660 to Km15+760 and 100m from Km 15+760 to Km 15+860 located in the territory of Rach Gia city, were selected. This route is densely populated. The road surface is degraded, damaged, and deformed, and the width of the road is not uniform, making it difficult for people and vehicles to travel. Therefore, repairing the existing road surface by reinforcing the asphalt concrete pavement and unifying the width of the road surface was an important issue. After improvement, the road would be smooth and continuous, develop a complete transport network, create favorable conditions for people to travel, and promote commercial activities, tourism services, and industrial development.

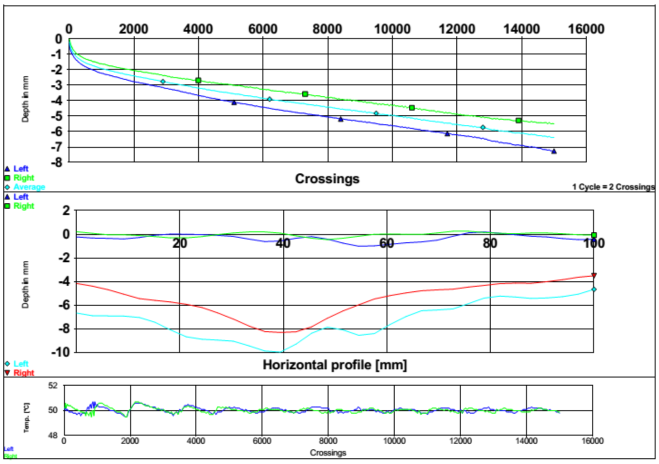

Fig. 6. HWT tests without fiberglass geogrid reinforcement.

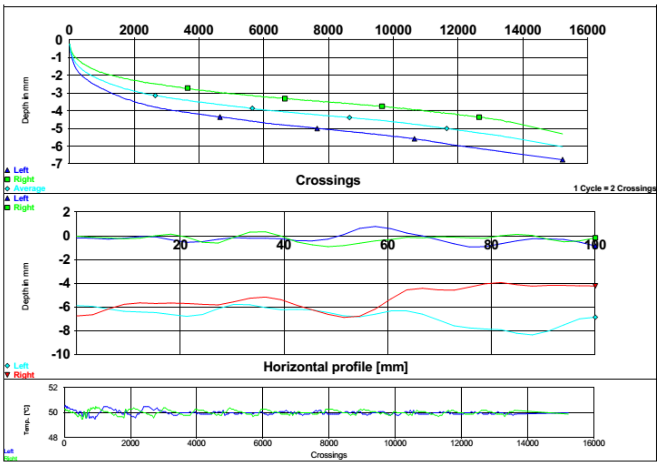

Fig. 7. HWT test with fiberglass geogrid reinforcement.

Some specific steps were followed to improve the current pavement surface, such as blowing dust to clean the existing road surface, applying the tack coat, placing the hot mix asphalt compensation layer, installing the fiberglass geogrid, placing the hot mix asphalt, and compacting the asphalt pavement. Similarly, a reference segment was also investigated without installing a fiberglass geogrid. After finishing the pavement improvement, the engineering properties of the asphalt concrete were investigated. The elastic modulus was measured by the Benkelman apparatus. The specimens were cut off from the site and prepared to test their flexural strength.

After the construction was completed, the street was put into operation for some time. Laboratory experiments were carried out to evaluate the quality and the technical efficiency of the fiberglass geogrid reinforcement on the asphalt pavement.

TABLE V. ELASTIC MODULUS OF FIBERGLASS GEOGRID REINFORCED ASPHALT PAVEMENT

Segment	**Station**	**Deformation (0.01mm)**	**Elastic modulus (MPa)**	**Characteristic deflection (0.01mm)**	**Characteristic elastic modulus (MPa)**
Km15+760 - Km15+860	Km15+760	63.9	200.1	75.8	168.7
	Km15+765	68.2	187.6		
	Km15+770	63.9	200.1		
	Km15+775	68.2	187.6		
	Km15+780	72.5	176.6		
	Km15+785	59.7	214.4		
	Km15+790	68.2	187.6		
	Km15+795	59.7	214.4		
	Km15+800	68.2	187.6		
	Km15+805	72.5	176.6		
	Km15+810	72.5	176.6		
	Km15+815	63.9	200.1		
	Km15+820	68.2	187.6		
	Km15+825	63.9	200.1		
	Km15+830	68.2	187.6		
	Km15+835	72.5	176.6		
	Km15+840	68.2	187.6		
	Km15+845	68.2	187.6		
	Km15+850	63.9	200.1		
	Km15+855	72.5	176.6		

TABLE VI. ELASTIC MODULUS OF NORMAL ASPHALT PAVEMENT

Segment	**Station**	**Deformation (0.01mm)**	**Elastic modulus (MPa)**	**Characteristic deflection (0.01mm)**	**Characteristic elastic modulus (MPa)**
Km15+660 - Km15+760	Km15+660	85.2	150.1	95.0	134.7
	Km15+665	89.5	142.9		
	Km15+670	81.0	158.0		
	Km15+675	85.2	150.1		
	Km15+680	89.5	142.9		
	Km15+685	89.5	142.9		
	Km15+690	85.2	150.1		
	Km15+695	76.7	166.8		
	Km15+700	81.0	158.0		
	Km15+705	85.2	150.1		
	Km15+710	76.7	166.8		
	Km15+715	85.2	150.1		
	Km15+720	85.2	150.1		
	Km15+725	81.0	158.0		
	Km15+730	81.0	158.0		
	Km15+735	89.5	142.9		
	Km15+740	89.5	142.9		
	Km15+745	85.2	150.1		
	Km15+750	81.0	158.0		

At first, the specimen without reinforcement was tested, and the results showed that the degree of compaction was equal to or greater than 0.98 which is compatible with the requirements of the Vietnamese standards. The Benkelman test in situ indicated that when using geogrid, the strength of the pavement structure increased from 134.7MPa to 168.7MPa, an increase of 25.24%, as shown in Tables V and VI. This shows the technical efficiency of re-enforcing the asphalt concrete pavement with fiberglass geogrid. It is noted that the current elastic modulus of the surface pavement was about 120MPa.

The obtained experimental results show that the average flexural strength of the asphalt concrete reinforced with fiberglass geogrid increased from 2.39 to 2.97MPa, an increase of 24.27%. Figure 8 shows the detailed results and proves the technical efficiency of the reinforced asphalt concrete pavement with fiberglass geogrid. This increased flexural strength means that the crack resistance of asphalt pavement improved.

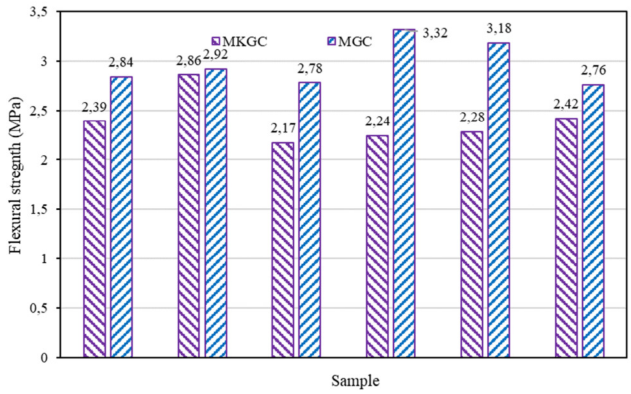

Fig. 8. Flexural strength obtained in situ.

IV. CONCLUSION

The following conclusions can be drawn based on the results obtained in the laboratory and in situ:

- The flexural strength of asphalt concrete reinforced with fiberglass geogrid and without it was 2.48 and 3.08MPa, respectively, an increase of 24.82%. The deflection, when subjected to the maximum load of the fiberglass geogrid reinforced asphalt concrete increased by 37.89% compared to the unreinforced because the fiberglass geogrid participates in bending together with the concrete, thereby increasing deflection. This means that the failure process of the samples reinforced with fiberglass geogrid takes place more slowly and reduces the cracks in the asphalt concrete.
- The elastic modulus of the samples reinforced with fiberglass geogrid did not change significantly, because when the sample was compressed, the area of the presser was equal to the contact area of the sample, as well as the fiberglass geogrid. Therefore, the influence of the fiberglass geogrid was not significant. However, the results of this experiment do not reflect the ability to increase the elastic modulus of the asphalt sample because the sample was small.
- The average rutting depth of asphalt concrete without and with a fiberglass geogrid was 6.38 and 5.94mm, respectively. The rutting depth of fiberglass geogrid reinforced asphalt concrete was reduced by 7.41%. The

results also show that the resistance to rutting of the fiberglass geogrid reinforced asphalt concrete sample improved.

- When reinforcing asphalt concrete pavement with fiberglass geogrid in the studied segment, the flexural strength of the asphalt concrete increased by 24.27%, and the structural strength of the pavement increased by 25.24%. These results show that the pavement structure was greatly improved when reinforced with a fiberglass geogrid.

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