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Full Length Research Paper

Study on the impact of geotextiles on fatigue life of asphalt specimens

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In this research, four types of geotextiles were selected and their impact on fatigue life and average flexural stiffness of hot mix asphalt (HMA) specimens was investigated. Fatigue tests were implemented by four-point bending beam test at strain control condition with haversine wave and 10 Hz frequency. The fatigue tests were carried out in four strain levels 250, 400, 650 and 1000 micro strain. Based on test results, the fatigue life of all specimens reinforced by four types of geotextiles was increased, but this increase in specimens of Geot Type 1 and Geot Type 2 was more than that of Iranian ones. Fatigue life was different at various strain levels for any type of geotextile materials and results showed that specimens made of reinforced geotextiles had higher performance at high strain levels. Results also expressed that geotextiles may reduce or increase the average flexural stiffness of specimens but they totally cause the improved quality of the asphalt pavement.

Key words: Fatigue life, geotextiles, bending beam test, strain levels, flexural stiffness.

INTRODUCTION

Cracking and rutting are two main reasons for structural failure of asphalt pavements. Rutting is generally induced by traffic loads due to excessive shearing stress imposed to the pavement. But cracks usually appear due to traffic loads developed by normal loads of vehicles as well as contraction and expansion of pavements due to temperature changes. Among these two distresses, fatigue cracks are usually observed on layers of asphalt pavements (Mahrez and Karim, 2010). Fatigue is defined as the failure due to repetition of loading which is lower than the ultimate static strength of hot mix asphalt (HMA) specimens. By fatigue resistance of asphalt mix, the mixture would be liable to confront repetitive loads without failure. Fatigue cracks are usually developed due to environmental changes, specially the temperature changes and repetitive loading (Amara et al., 2001). Fatigue cracks are divided into three categories: Longitudinal, transverse and crocodile cracks.

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Propagation of these cracks take place in three stages: The first stage is the beginning of the cracking where the fine cracks are initiated by stress concentration. At the second stage, fine cracks initiated at the first stage start to grow and therefore large cracks appear. The 3rd and final stage is the failure stage (Hosseini et al., 2009). Various research studies have shown that by application of some new materials e.g. geotextiles, the tensile strain of asphalt pavements would possibly decrease and as a result, early and fatigue cracks, and their propagation will be prevented. The field observations on pavements reinforced by geotextiles show that the reinforcing layers cause improvement of drainage, increase the service life of pavements, keep the cracks adjacent, also prevent the local settlements and finally reduce rutting (Al-Qadi et al., 2003). The principal functions of geotextile reinforcement in bituminous mixes are to provide additional tensile strength and to increase strain energy absorption of the bituminous mix to inhibit the propagation of cracks. The idea was based on the general concept that if Hot Mix Asphalt (HMA) is strong in compression and weak in tension, then reinforcement materials could be used to provide required resistance to tensile stresses (Khodaii et al., 2009).

Geotextiles are synthetic fibers that are produced in woven and nonwoven forms. These materials are usually used with soil, stone or other relevant geosynthetic materials in civil engineering projects (SHRP, 1994).

Variation of different geotextile brands has always caused to circumstances where the effectiveness of these materials would be doubted. Therefore the installation location and the type of (HMA) are amongst factors that affect the performance of geotextile materials to a large extent. It is therefore required to study their effect on service life of asphalts mixes.

In an experimental project in 2001, Sarraf studied the effect of reinforcing on fatigue life of HMA specimens. Results showed that the fatigue life of asphalt, reinforced by geocomposites will considerably increase. He showed that geotextiles have a significant effect on increased service life of HMA specimens (Sarraf et al., 2001).

Ling and Liu (2001) implemented some experimental tests to show the effect of geotextiles on reinforcement of HMA in which three types of loadings were used, static, repetitive and dynamic loading. Test results showed the improved performance and reduced deflections of reinforced asphalt, compared to that of non-reinforced asphalt (Ling and Liu, 2001).

Austin and Gilchrist used composition of polypropylene geogrids and geotextiles for reinforcement of asphalt pavements. Two significant issues regarding their research were as follows:

1. Performance of pavements reinforced by geocomposites on a poor subgrade.
2. Prevention of crack propagation.

In this research 3 specimens were tested:

1. Control sections which are not reinforced by 80 mm thick Dense Bitumen Macadam (DBM).
2. Placement of composite in the middle of DBM.
3. Placement of composite material beneath the DBM and on the base.

The interesting point in results of this research is the poor performance of geocomposite where it is located in the middle of the layer. The strain developed for the conditions where the geocomposite is located in the middle of the specimen is more than that of non-reinforced specimen when the tire passes 25000 times. The specimen reinforced by geocomposites shows a strain half of the non-reinforced specimen at the bottom of the specimen (Austin and Gilchrist, 1996).

Cancelli and Montanelli (1996) did a research study to determine the structural impact of geogrids of flexible pavements under repeated loading. The repeated loading was applied to the specimen by a circular plate with the diameter of 300 mm. Results of this test showed that placement of reinforcing geogrid between the layers of base and bedding causes the increased service life of pavement and monotones the traffic load distribution on the subgrade (Cancelli et al., 1996).

Jaecklin and Sherer (1996) investigated the effects of reinforcing HMA by addition of geotextiles reinforced by glassfibres. Test results showed that the application of geosynthetic materials increases the service life of asphalt pavements 7 to 8 times (Jaecklin and Sherer, 1996). Cho and colleagues (2001) studied the response of geosynthetic reinforced HMA that is placed between overlays and base layers. Test results showed that the fatigue life of reinforced specimens is 8 times higher than that of unreinforced specimens and if HMA is made of Styrene-Butadiene-Styrene (SBS) modified bitumen, the fatigue life is 12 times higher than that of non-reinforced one (Cho et al., 2001). Sobhan and colleagues' studies (2005) showed that the best location of geosynthetic materials in order to reduce the reflective cracks is in the middle of the top layer. Results of their studies showed that existence of geotextile in the middle of the specimen increases the fatigue life of HMA specimens 10 times and the strains are also reduced to 40%, compared to the former situation (Sobhan et al., 2005).

Hosseini and colleagues (2009) indicated that specimens reinforced by geosynthetics gained improved stability and integrity compared to non-reinforced specimens. Also the cracks width is reduced. This occurs due to the fact that, at the end of the fatigue life of reinforced asphalt specimen, the layers of geogrids and geotextiles are almost intact. According to this research, it can be concluded that geotextiles and geogrids cause delayed propagation and accumulation of primary micro cracks and, also, the development of macro cracks in asphalt pavements (Hosseini et al., 2009).

The main problem in using the coating layers in flexible pavements is the speedy reflection of cracks in the surface layer. Utilization of geotextiles is one of the best alternatives for postponing the development of reflective cracks in the overlay. The development of reflective cracks in the overlay is due to the repeated traffic loads and environmental changes. In many of the roads in Iran, different geotextiles have been used for postponing the development of cracks. In this research, the fatigue performance of the most prevalent geotextiles in Iran has been studied by the four point bending beam test. By using the results of this research project, it would be possible to study on the effect of (some types of) fibers used in geotextiles, for increasing the fatigue life of the overlay.

According to the following reasons, the used geotextiles are the most important options for decision making of the road construction managers (in choosing the road materials) in our country:

1. These geotextiles have had the standard specification limit in road construction, according to AASHTO M-288.

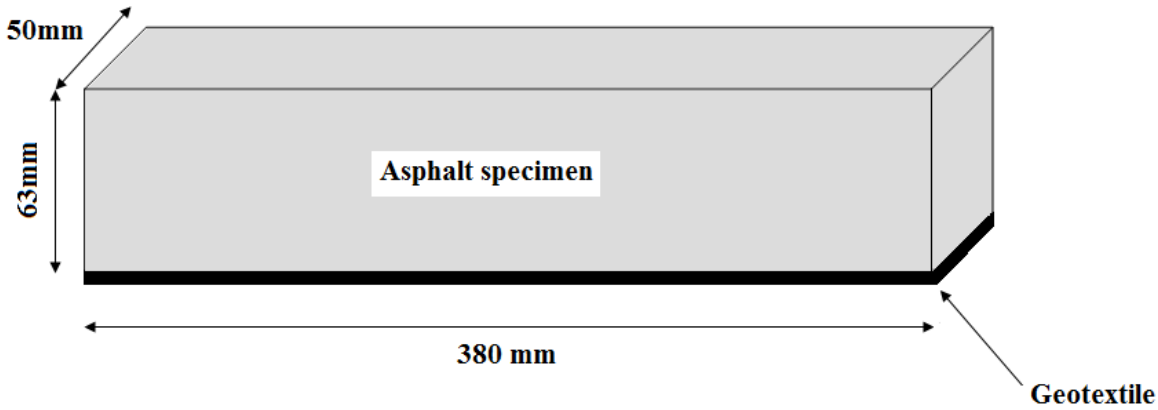

Figure 1. The specimen dimensions and the location of geotextile.

Table 1. Grading of asphalt mix used in the project.

Sieve size (mm)	Passing percent
19	100
12.5	95
4.75 (No 4)	63
2.36 (No 8)	39
0.3 (No 50)	9
0.075 (No 200)	5

2. These geotextiles have suitable prices.
3. The production manufacturers have satisfactory after sale services.
4. Results of fatigue test create suitable circumstances for technical evaluation of the used geotextiles specimens in this research. Taking into account the cost of the products, scientific decision making regarding the application of geotextiles based on technical and economic evaluations, would be taken by authorities.

For determination of fatigue life of asphalt pavements, various test methods are used including indirect tension, and direct tension and bending beam, amongst which the bending beam test is the most appropriate method which has been used in present research project. In this paper the effect of geotextile materials on increasing the service life of asphalt pavements and also performance evaluation of geotextiles in asphalt pavements is discussed. And the object of this study is evaluating the laboratory performance of geotextiles use in Iranian roads.

RESEARCH METHODS

For evaluation of geotextiles effect on increasing the fatigue life of asphalt pavements, two types of geotextiles produced overseas and two types of Iranian made geotextiles were studied. The location of geotextiles (in the bottom of specimens) and thickness of the specimens is so predicted that will have the best compatibility with real situation in Iran. The specimens' dimensions and the location of geotextile are shown in Figure 1.

Properties of the used materials

Grading of the aggregates used in this study is shown in Table 1. This type of grading has the most application according to available standards in the country.

Geotextiles used in this research project are four specimens. Two of these specimens are manufactured by foreign producers and two of them are made by Iranian manufacturers. In this paper these are referred to, as Geot Type 1 and Geot Type 2 (for the foreign made products) and IRGeot Type 1 and IRGeot Type 2 (for Iranian made Geotextiles). Geot Type 1 and Geot Type 2 are the same in textile type but Geot Type 2 is reinforced by glassfibre. This production is used in Iran in wide range. Standard tests of geotextile materials used in this study are mass per unit, melting point; grab tensile strength, thickness at 2 kN/m^2 load, grab elongation and asphalt retention. Results are presented in Table 2.

In addition to the standard tests, the performance bitumen tests according to AASHTO: M320 specifications were performed on the bitumen used in this project. The performance test results showed that the bitumen used and tested has the PG 64-22 performance grade. This research was implemented in Tehran area climatic conditions. Therefore for determination of climatic specifications of this area, the meteorological records of Tehran area were obtained through the nearest Meteorological Station. According to these data the average pavement temperature of the 7 hottest days was 40^{o}C with 1^{o}C standard deviation and the average coldest day temperature was -5^{o}C with 3^{o}C standard deviation. Based on this information, the bitumen with performance specifications of PG 64-16 is suitable for this area. Therefore the application of bitumen PG 64-22 is confirmed.

For determination of the optimal amount of bitumen in the asphalt mix design, first of all, that percentage of bitumen which is similar to 4% of air voids in asphalt mix was chosen. Then other specifications of bitumen in the asphalt mixture were evaluated. If the percentage of bitumen is complied with all the relevant criteria and specifications, then this quantity will be chosen as the optimal amount in the mix design. This quantity is economic and has all the required specifications too. Therefore the optimal amount of bitumen was determined as 5.5%.

Table 2. Geotextile material properties.

Property	Standard	Unit	Geot Type 1	Geot Type 2	IRGeot Type 1	IRGeot Type 2
Mass per unit area	ASTM D5261	g/m^2	150±7	307±5	195±5	210±10
Melting point	ASTM D276	ºC	160	161	250	210
Grab tensile Strength	ASTM D632	N	539±78	883±59	514±39	532±42
Grab elongation	ASTM D4632	%	>50	>50	>50	>50
Asphalt retention	ASTM D6140	Kg/m2	1.1	1.1	1.25	1.35
Thickness at $2kN/m^2$ load	EN ISO 9863-1	mm	1.0	1.0	1.1	1.22
Manufacture method	-	-	Nonwoven	Nonwoven	Nonwoven	Nonwoven
Fiber type	-	-	Polypropylene	Polypropylene	Polypropylene @ polyester	Polypropylene @ polyester

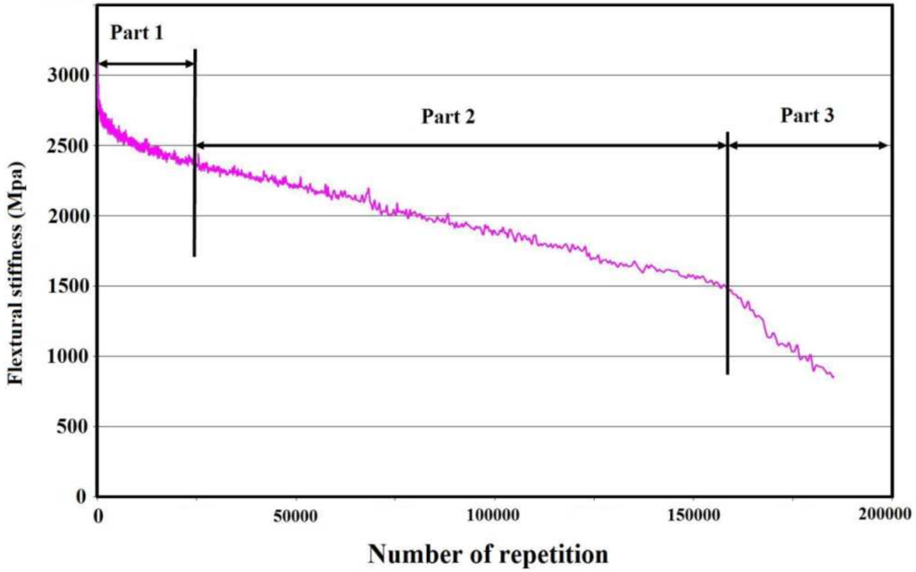

Figure 2. Flexural stiffness diagram against the repetition of loading.

Test method

The fatigue test on bending beam may be implemented according to AASHTO T321 standard in two controlled stress and strain conditions. In controlled stress condition, the specified stress is applied until the failure stage starts, but in controlled strain condition, the feedback system in the loading apparatus of the beam fatigue test modifies the stress after each repetition of loading, in a way that strain is kept constant. Flexural stiffness diagram against the repetition of loading which has been obtained within the fatigue tests with constant strain can be divided into 3 parts (Figure 2):

Part 1: The significance of this part is rapid reduction of the

Figure 3. The general view of the bending beam fatigue apparatus.

stiffness of the specimen. This part includes about 10% of the fatigue life.

Part 2: The significant point of this part is linear reduction of the stiffness of the specimens which includes about 90% of the fatigue life and is the stage of expansion and distribution of fine cracks.

Part 3: The significance of this part is the sudden loss of the stiffness of the sample, which gets closer to failure point, and it is in this phase that the large cracks disperse.

In the controlled strain condition, due to reduced stress, the specimen may remain in the third stage for a long time without considerable reduction of the specimen stiffness. Due to this reason, the failure point is usually defined as the reduction of stiffness to a percentage of the initial stiffness (usually fifty percent). AASHTO T321 has specified the amount of this reduction up to fifty percent, but due to the difference among the initial stiffness measurements and sometimes the difference existing in dispersion of results, the best criterion for specifying the failure point of the specimen is the diagram regarding reduction of stiffness against repetition of loadings.

Bending beam fatigue test apparatus

The general view of this apparatus is shown in Figure 3. This equipment is able to apply the repeated loads to the HMA specimens or other materials and computes the applied load and obtains the deformation. Test may be done at controlled stress or controlled strain condition. In the controlled stress condition, the applied loads are assumed constant and deformations are recorded.

Specimens production method

The geotextile layer is practically used under the overlay in the field.

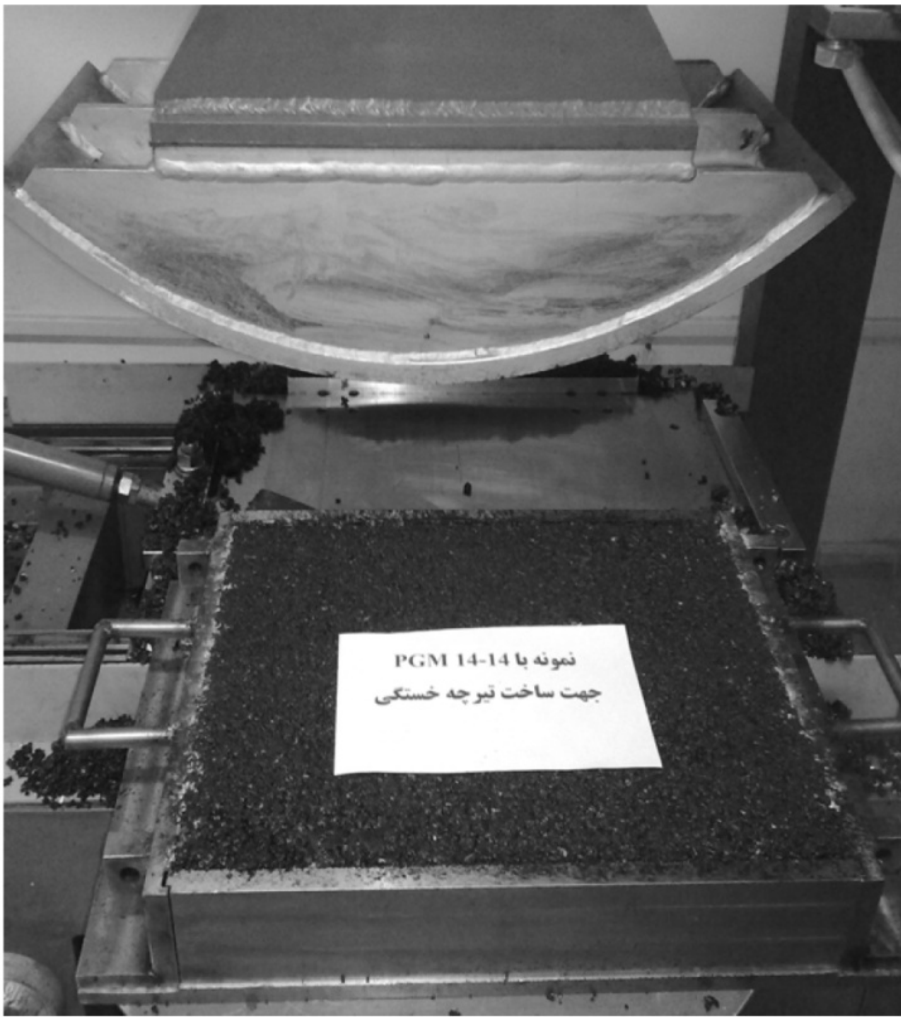

Figure 4. One of the slabs made from the HMA and geotextile.

For simulation of this operation, the geotextile layer was placed under the 6 cm thick asphalt specimen, based on AASHTO standard in laboratory. These specimens were experimentally built by Rolling Compaction Apparatus in laboratory. In order to prevent adhesion of the specimens to the bottom of the apparatus some aluminum foils were used. In this way, HMA slabs with dimensions 300 mm × 400 mm and 60 mm. depth were built and from each of them 4 fatigue beams were cut. These 4 specimens which were all made of the same geotextile and HMA were tested in four strain levels 250, 400, 650 and 1000 micro strain. Therefore to study the fatigue behavior of geotextile specimens, 5 batches of test specimens, each containing 4 fatigue beams including control HMA specimens and four geotextile types were made. The Geot Type 1 slab is illustrated in Figure 4.

RESULTS AND DISCUSSION

Fatigue cracks appear due to the tensile strain beneath the asphalt pavement layer, and its propagation will be upwards, towards the surface of the road and vice versa. The reason of destruction is due to the numerous loadings and repeated occurrence of tensile strain in this area. In laboratory, one can calculate the required loading times for developing of fatigue cracks on an asphalt specimen. The difference of geometrical and loading conditions causes that cracks in actual conditions occur more repeatedly compared to laboratory environment. It is therefore required that for compliance of laboratory and field conditions, the appropriate coefficients are taken and used.

The failure of fatigue cracks may either be prevented by increased thickness of joint layers or an asphalt mix may be used to resist the developed strains. The fatigue cracks are a series of continuous cracks that are propagated due to the destruction of fatigue of the asphalt surface which is under loading conditions. After repeated traffic loading the cracks join together and develop polygonal sections with sharp angles which finally create a surface similar to crocodile's skin.

Fatigue life of asphalt specimens

Using destruction models and Miner theory it would be possible to determine the remained life of the pavement in a way that the number of passing load is obtained by destruction models. Then considering the number of passing of the vehicles up to now, it would be possible to obtain the number of permitted passes until the destruction of the pavement. The extent of fatigue cracks is obtained through Equation 1:

$$N_f = f_1(\varepsilon_t)^{-f_2}(E_1)^{-f_3} \quad (1)$$

Where: N_f: The number of repeated loading until failure, ε_t: Tensile strain beneath the asphalt layer

E_1: The modulus of elasticity of the asphalt layer, f_1, f_2 and f_3 are constants that are obtained from fatigue tests and are used for correction of results.

In Equation 1 ε is the maximum tensile strain occurring in loading turns and is acquired according to the Equation 2 (AASHTO, 2007).

$$\varepsilon = \left(\frac{12DH}{3L^2-4a^2}\right) \quad (2)$$

D = Maximum deflection at center of beam, in m; H = Average specimen height, in meters; L = Length of beam between outside clamps, in m; A = Space between inside clamps, in m.

This equation is calculated by the equipment software at the time of loading. The fatigue test method in this research is in a way that during repeated loadings the ε has to remain constant.

The Asphalt Institute assigned the f_1, f_2 and f_3 constants for standard mix, respectively 0.0796, 3.291 and 0.854. The figure 0.0796 is 0.0636 for layers thinner than 10 Cm. These constants are 0.0685, 5.671 and 2.363 in specifications of the Shell Institute. According to the test results, the thinner the asphalt layer, the lesser the repeat would be. Since the f_2 is much bigger than f_3 and the impact of ε on N_f is quite considerable, therefore placement of E_1 is ignored and Equation 1 can be written as:

$$N_f = f_1(\varepsilon_t)^{-f_2} \quad (3)$$

Transport and Road Research Laboratory in UK, has suggested equation 4:

$$N_f = 1.66 \times 10^{-1}(\varepsilon_t)^{-4.32} \quad (4)$$

Belgium Road Research center has suggested Equation 5:

$$N_f = 4.92 \times 10^{-14}(\varepsilon_t)^{-4.76} \quad (5)$$

The f_2 and f_1 in the above equations are obtained by laboratory experiments. The variation of these constants is due to the different materials, different laboratory conditions and actual environments. The pavement remained life depends on special cracks and specific destructions. For example for pavements with asphalt layers the type of fatigue cracks on the surface of asphalt must be considered (Huang, 2005).

The Miner hypothesis is a linear series which calculates the fatigue destructions through Equation 6:

$$\sum_{i=1}^{n}\frac{n_i}{N_i} < 1 \quad (6)$$

Where: n_i: The number of repeated loading; N_i: The asphalt fatigue life or the allowable number of repeated loading

Equation 6 is provided for calculation of fatigue life for amplitude of loads and temperatures. When the pavement is used, its life is reduced after passing of vehicles. In a time phase, it would be possible to determine the remained life of the pavement by the traffic range and also by destructions of the road.

To study the results and to achieve an experimental model for specifying the changes of the fatigue life against initial tensile strain, the model presented in Equation 7 has been used.

$$\ln(N_f) = a - b \times \ln(\varepsilon) \quad (7)$$

In this equation ε *is* the initial tensile strain and *a, b* are the constant coefficients and N_f is the fatigue life based on the number of loadings. In this equation after drawing the dispersion of fatigue life data against the initial strain in logarithmic scale, Equation 1 may be computed using the trend line equation.

All the test batches of specimens were tested in four strain levels and their reduced stiffness was reached to half of the initial stiffness. Accordingly the fatigue life of full-depth HMA control specimens, the foreign specimens 1 (produced with geotextile Geot Type 1) and 2 (produced with geotextile Geot Type 1) and the Iranian specimens were evaluated.

In order to obtain the coefficients of Equation 1 on the test results of each batch of specimens, the logarithmic regression was implemented. The diagram of fatigue life against the level of strain in logarithmic scale for five batches of control specimens, the Geot Type 1 and Geot Type 2 and the Iranian specimens are shown in Figure 5. The correlation coefficient and constant coefficients (a and b) for each batch of specimens is obtained and presented in Table 3.

Analyses of Figure 5 shows that the existence of geotextile causes reduction of the coefficient (a) in

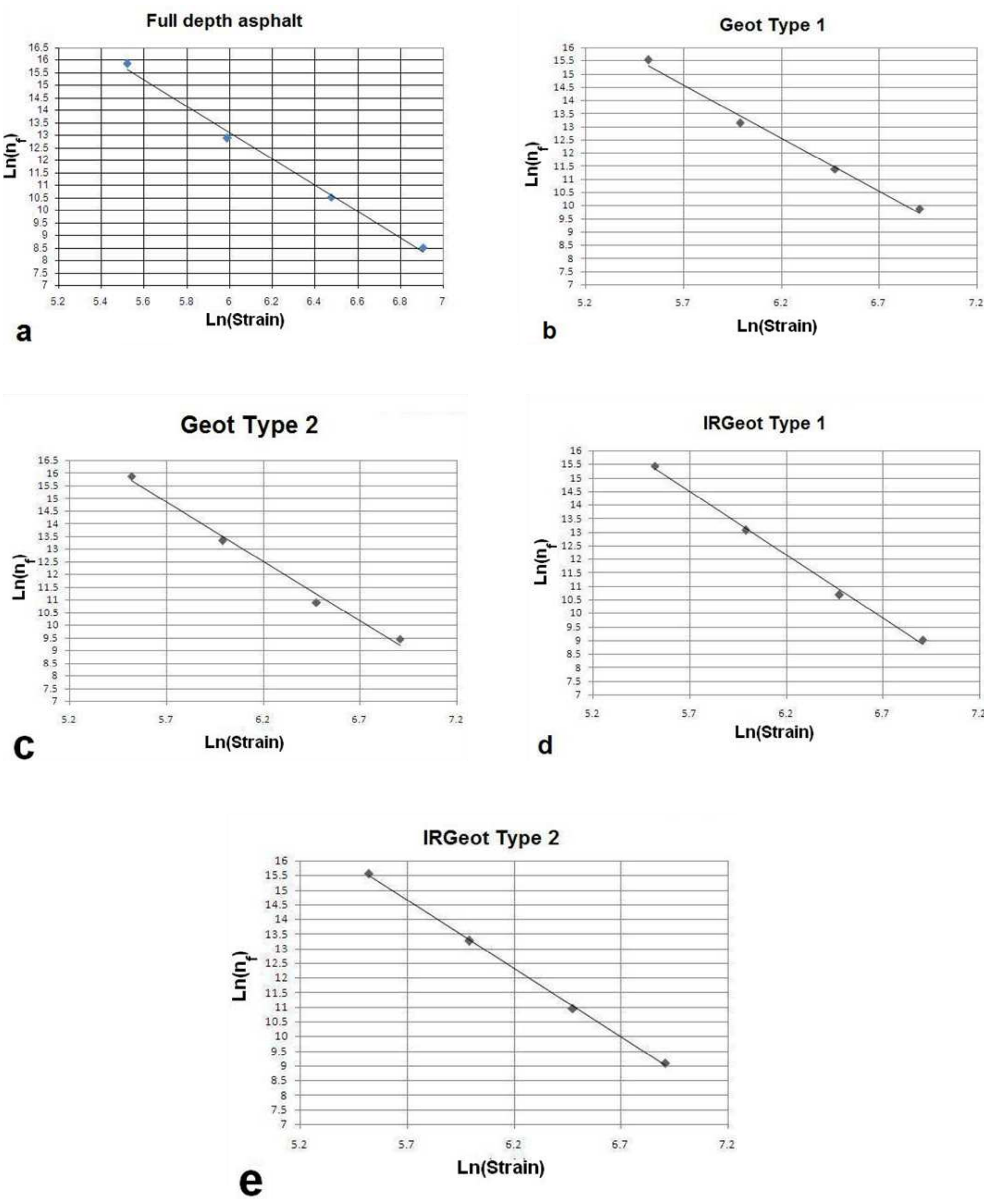

Figure 5. Fatigue life against strain level of five types of specimens.

Table 3. The fatigue equation and correlation coefficient of five batches of specimens.

Geotextile name	Fatigue equation	Correlation coefficient
Full-depth HMA	$\ln(N_f) = 44.6725 – 5.2598 \times \ln(\varepsilon)$	0.995
Geot type 1	$\ln(N_f) = 37.594 – 4.036 \times \ln(\varepsilon)$	0.991
Geot type 2	$\ln(N_f) = 41.531 – 4.6829 \times \ln(\varepsilon)$	0.990
IRGeot type 1	$\ln(N_f) = 41.120 – 4.6712 \times \ln(\varepsilon)$	0.997
IRGeot type 2	$\ln(N_f) = 41.382 – 4.6873 \times \ln(\varepsilon)$	.999

equations as shown in Table 3 and therefore increases the fatigue life of the geotextile reinforced specimens. In their research studies, Saraf and Kim have also noted the increased stiffness in geotextile reinforced specimens (Kim et al., 1996; Sarraf et al., 1996).

In Figure 5(a), the b coefficient is -5.260 showing that the Asphalt Institute model for the full-depth HMA specimens used in this project, predicts less fatigue compared to its actual amount. Therefore the performance of used HMA in this project against fatigue has been better than that of used HMA in the Asphalt Institute model.

In the 5 models shown in Table 3, the b coefficient has an important role in expressing the fatigue behavior of the HMA. When the b coefficient is reduced and in boundary conditions when it gets closed to zero, the fatigue life is no longer dependent on the amount of strain and has a constant amount in all conditions. All the equations of Table 3 in this situation, predict a very long fatigue life for the considered object and in fact, an object with very high strength towards fatigue has been modeled which does not exist in actuality.

In relation to boundary conditions, our discussion expresses that by reduced b coefficient the performance of the specimen is improved and since the full-depth HMA specimen has allocated the biggest amount of the b coefficient, it has the weakest performance compared to that of 4 asphalt specimens reinforced by geotextiles. Since the materials of the asphalt mixture are identical therefore in all situations where geotextiles were applied, geotextiles have caused the increased the fatigue life of asphalt mixes. The best performance in this relation is that of Geot Type 1 and the IRGeot Type 1 and Geot Type 2 and IRGeot Type 2 are located as the next priorities, accordingly.

The mix design of the HMA in this research has been done according to Marshall Method and the average flow of Marshall specimens in optimum bitumen content in this HMA mix design is 3.2 mm which is within the permitted limits. The diameter of Marshall specimens is 100 mm. Therefore it may be concluded that the maximum compressive strain which can be resisted in the asphalt mix is 3% or 30000 microstrain (It is assumed that the strain is monotonously distributed in the diameter of the specimen), while the discussed failure in this research is due to tensile strain and a smaller tensile strain is resisted in asphalt mixes compared to compressive strain.

On the basis of the lab data, full-depth asphalt specimens, have a resistance equal to 4200 times loading within the 1000 microstrain. By increased strain, the number of loading resistible for HMA specimens is reduced in a way that in 3000 microstrain it gets to the minus of 10 times loading and in many cases even one turn of loading in 4000 microstrain strain causes the failure of the specimen. Therefore in higher strains, Table 3 models have no use any longer. The appropriateness of fatigue models is the fatigue life of more than 100 turns or the strain less than 2000 microstrain.

By reduction of the strain, fatigue life of asphalt specimens is increased in a way the samples which were loaded by 150 microstrain level did not reach a failure after 10 million times loading (more than ten days), and therefore due to the longer periods of testing, the tests were stopped. Usually, the obtained results for this amount of strain and less than that are not usually appropriate and the specimens in many cases and due to the healing will never reach the failure phase. Therefore the appropriateness of the above models is within 100 to 10 million turns of repeated loading or within the 150 to 2000 microstrain.

The correlation coefficients in Table 3 show the reliability of modeling method. This modeling reliability is confirmed by many researchers. The correlation coefficients in Table 3 are much closer to 1, and their total are bigger than 0.99.

Majority of existent pavements in the main roads of the country which are reinforced by geotextile should bear the heavy traffic loads. Most of the time, the traffic load reaches to some million equivalent axle load (8.2 tones) per pavement life. Therefore the low strains which are associated by high fatigue life become significant in laboratory tests. In this situation any equation in which the coefficient (a) has lower power will show the high effectiveness of geotextiles. Based on this fact the geotextile Geot Type 1 has had the highest efficiency and the IRGeot Type 1, Geot Type 2 and the IRGeot Type 2 obtain the next priorities accordingly. The control specimens have had the lowest efficiency for the roads of the country.

Geotextiles and the required bitumen for adhesion to the asphalt specimen cause prevention and delay of fine

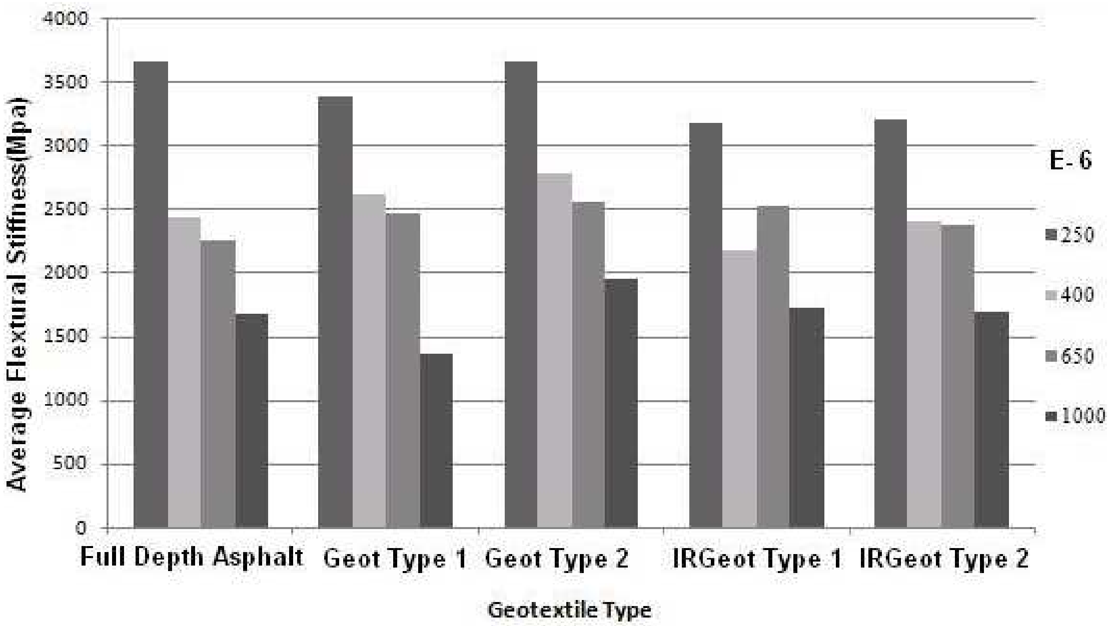

Figure 6. The average flexural stiffness versus the specimen's types.

crakes in the specimens. The lower parts of HMA specimens bear the highest tensile strain and are exposed to the cracks due to this strain. The most important factor for increased fatigue life is prevention of fine cracks and their dispersion due to geotextile materials. Fatigue equation for Geot Type 2 reinforced specimens in Table 3 shows that the glassfibres reinforced geotextiles have had more satisfactory performance at high strain levels, compared to other specimens.

Based on the data of Table 3, the fiberglass has the maximum tensile modulus and after fiberglass the highest tensile modulus belongs to polyester fibers. Polypropylene fibers have the lowest tensile modulus and therefore the Geot Type 2 has the highest tensile modulus. But the fatigue test showed that at high tensile modulus Geot Type 2 do not have a good functioning, which may somehow be related to the non-adhesiveness quality of fiberglass. The increase of tensile modulus is not always a positive parameter increased; therefore the type of geotextile should be selected according to the type of the road, environmental conditions and the extent of traffic volume on the road.

Laboratory investigations on the fatigue life of geotextile reinforced asphalt specimens show that these specimens bear higher fatigue loads, compared to non-reinforced specimens. The higher the strain and the bigger the applied loads to the specimens, the more the increased amount of fatigue life of specimens would be, in a way that at 1000 micro strain level and higher, the fatigue life of geotextile reinforced specimens will become many times higher than that of ordinary non-reinforced specimens. In lower strain levels, the increased amount of fatigue life will reduce. At 400 microstrain level the existent geotextiles have caused increased fatigue life up to 56% and by reduced strain the increased changes in the test results, will make the logical interpretation of results difficult. At such strain level difficulties, the repetition of tests and access to statistical interpretable community is quite a difficult job.

Average flexural stiffness of specimens

In all the fatigue tests, flexural stiffness for each loading is calculated. The failure point in this study is 50 percent reduction in stiffness relative to initial stiffness. Flexural stiffness is averaged for all loading application in fatigue test (approximately over one million loading). All the fatigue tests is in the control strain condition, therefore the average flexural stiffness shows the static stability of specimens and along with the fatigue life represent the quality of the specimens.

Figure 6 shows the average flexural stiffness for five batches of HMA specimens at 250, 400, 650 and 1000 micro strain condition. It is observed that in all cases of reduced strain, the average flexural stiffness is increased. This means that by increased strain the loading resistance of HMA specimens will be increased accordingly.

The experimental data shows that specimens reinforced by Geot Type 2 have the highest average flexural stiffness and the unreinforced control specimens fall in the next grade. The suitable amount of average flexural stiffness of unreinforced control specimens is due to the lower content of bitumen in these specimens. For making non-reinforced control specimens, bitumen in tack coat which is usually used for adhesion of geotextile to asphalt specimens, is not required. Average appropriate flexural stiffness of samples reinforced by Geot Type 2 shows the high tolerance and quality of these specimens and the glassfibre existence in the Geot Type 2 causes increased average flexural stiffness of the specimens. The Geot Type 1 specimens had the lowest average flexural stiffness.

Conclusion

Evaluation of fatigue life of 4 geotextile specimens in level of 1000 micro strain shows average of 109% fatigue resistance increase which can be up to 280% for geotextile Geot Type 1. Also these specimens in strain level of 650 microstrain had average of 64% fatigue resistance increase which can be up to 139% for geotextile Geot Type 1 and finally they had average of 38% fatigue resistance increase which can be up to 56% for geotextile Geot Type 2 in strain level of 400 micro strain.

The amount of coefficient (a) in Table 3 has a descending trend like the coefficient (b) due to more satisfactory quality of geotextile materials and shows that in lower strain levels the fatigue diagrams will eventually cross each other and this means that if the strain level is too low there would be no need to use the geotextile materials. In general, it may be concluded that the application of geotextile materials will, in any case, be useful for increasing the fatigue life of flexible pavements.

The average flexural stiffness of the specimens shows the appropriate behavior of Geot Type 2 specimens. In additions to suitable average flexural stiffness at 1000 microstrain condition, these specimens have also showed the best fatigue behavior. The full-depth HMA control specimens show the highest average flexural stiffness, after of Geot Type 2 specimens. As regarding fatigue tests, these specimens had the lowest fatigue life at all strain levels. Combination of these two behaviors in laboratory shows the rigidity of full-depth HMA specimens, compared to other types. Therefore existence of geotextiles causes increased flexibility of asphalt pavements and their resistance against contraction cracks. The Geot Type 1 specimens have the lowest average flexural stiffness, but they have suitable fatigue life, and are recommended to be used in asphalt pavements.

According to the data obtained from the fatigue tests, the tensile modulus and tensile strength of the geotextiles are not the mere parameters to evaluate geotextiles and the geotextile interaction with the asphalt layer and the tack coat should also be considered too.

REFERENCES

AASHTO T321-07 (2007). Determining the Fatigue Life of Compacted Hot-Mix Asphalt (HMA) Subjected to Repeated Flexural Bending. American Association of State Highway and Transportation Officials.

Al-Qadi IL, Elseifi M, Leonard D (2003). Development of an overlay design model for reflective cracking with and without steel reinforcing nettings. J. AAPT. 72:388-423.

Amara L, Al-Qadi I, Bhutta S, Flintsch GW (2001). Evaluation of geosynthetics when used as separation. TRR Transportation Research Record: J. Trans. Res. Board 1687:104-111.

Austin R, Gilchrist A (1996). Enhanced Performance of Asphalt Pavements Using Geocomposites. Geotextiles Geomembranes 14(3):175-186.

Cancelli A, Montanelli F, Rimoldi P, Zhao A (1996). Full Scale Laboratory Testing On Geosynthetics Reinforced Paved Roads. Proc. Int. Sym. Earth Reinforcement pp.573-578.

Cho S D, Lee DY, Han SK, Kim NH (2001). The Effect of Glass-Sheet Reinforcement On Crack Resistance Of Asphalt Concrete. Korea Institute of Construction Technology.

Hosseini H, Darban A, Fakhri M (2009). The effect of geosynthetic reinforcement on the damage propagation rate of asphalt pavements. Sci. Iranica 16(1):26-32.

Huang H (2005). Pavement analysis and design. Prentice Hall.

Jaecklin FP, Scherer J (1996). Asphalt Reinforcing Using Glass Fiber Grid. Reflective Cracking In Pavement, RILEM, London.

Khodaii A, Fallah S, Moghadas NF (2009). Effects of Geosynthetics on Reduction of Reflection Cracking in Asphalt Overlays. Geotextile Geomembrane 27(1):1-8.

Kim KW, Churl YP, Seok YK (1996). Tensile reinforcement of asphalt concrete using polymer coating. Construction and Building Materials, V. J. Constr. Build Mater. 10:141-146.

Ling HI, Liu Z (2001). Performance Of Geosynthetic-Reinforced Asphalt Pavements. J. Geotech. Geoenviron. Eng. 127(2):177-184.

Mahrez A, Karim MR (2010). Fatigue characteristics of stone mastic asphalt mix reinforced with fiber glass. Int. J. Phys. Sci. 5(12):1840-1847.

Saraf CL, Majidzadeh K, William T (2001). Effect of reinforcement on fatigue life of asphalt beams. J. Trans. Res. Rec. Board 1534(-1):66-71.

SHRP (1994). A-404. Fatigue response of asphalt-aggregate mixes. Strategic Highway Research Program, A-404. National Research Council.

Sobhan K, Genduso M, Tandon V (2005). Effects of geosynthetic reinforcement on the propagation of reflection cracking and accumulation of permanent deformation in asphalt overlays. Third LACCEI international latin American and Caribbean conference for engineering and technology (LACCET2005) "Advances in engineering and technology: A global perspective". Cartegena, Columbia, pp.1-9.