УДК 691.54+231.2:678.5/.8

A. K. Haghi, G. E. Zaikov, S. Yu. Sofina,
S. N. Rusanova

MODIFIED-GEOFIBER IN CEMENT COMPOSITES

Keywords: bitumen composites, Geofibers, Fatigue life.

Transport vehicles are increasing in number as well as magnitude, and the use of super tires and different axle configurations is increasing too. The effects of these factors tend towards increased pavement deterioration, including fatigue, resulting in increased costs to maintain road networks at an adequate level. In this paper the reinforcement mechanism of bitumen mixed with GeoFiber™ (including cellulose, rock wool and polyester) is reported.

Ключевые слова: битумные композиты, минеральные волокна, усталостная долговечность.

Растет число и размер транспортных средств, а также использование супер шин и различных конфигураций моста. Влияние этих факторов приводит к повышенному износу тротуаров, включая усталость, что приводит к увеличению затрат на поддержание дорожной сети на должном уровне. В данной работе сообщается о механизме усиления битумных смесей с минеральными волокнами (включая целлюлозу, минеральную вату и полиэфирные волокна).

Introduction

In urban areas, the crushed rock surfacing had, in many places, been replaced by stone or wood setts (blocks), or by Portland cement or asphalt concrete. These materials had not been introduced with any great concern for pavement strength, but more as surface treatments to mitigate against summer dust and winter mire.

Several authors studied the viscoelastic and elasto-plastic nature of the constituent materials in pavement design. The studies performed resulted in varying conclusions and theories, but no complete pavement design method was developed. For a pavement design procedure to be completely rational in nature, consideration should be given to three elements. These elements are prediction of the failure of distress parameter, evaluation of the pertinent material properties, and determination of the magnitude of the parameter in question to the failure or the performance level desired [1-7]. In this paper the reinforcement mechanism of bitumen mixed with GeoFiber™ (including cellulose, rock wool and polyester) is reported.

Laboratory study

The aggregate gradation that used in this experimental work is shown in table 1.

Table 1 - Gradation of used aggregate

Percentage passing	Sieve size, mm
100	19
90-100	12.5
-	9.5
44-74	4.75
28-58	2.36
-	1.18
-	0.6
5-21	0.3
-	0.15
2-10	0.075

In this laboratory study, a neat bitumen 60/70 penetration grade from Isfahan mineral oil refinery with the following characteristics (Table 2) was used.

Table 2 - Properties of bitumen used

Purity grade	99
Lose weight, %	0.75
Deflagration, 0°C	262
Plasticity index, cm	112
Flow, 0°C	51
Penetration grade, mm/10	66
Density, 25°C	1.02

The indirect tensile stiffness modulus (ITSM) test

Samples tested under this experimental work are nominally with 100 mm diameter and 70 mm height for ITSM test. Before determination of stiffness modulus, the resilient modulus of samples should be calculated [8].

Results

In Figures 1 and 2 the variation of tensile stress and tensile strain versus number of cycle for failure is shown for different specimens. It is clear that the tensile strain of reinforced samples decreased significantly. This can have positive effects on the fatigue life of specimen used.

From Figure 1 we can observe the variations of tensile stress versus number of cycle before fatigue cracking. As it can be seen obviously, the GeoFiber™ reinforcement can increase the bearing stress significantly. In contrast, the non- reinforced sample experienced less cycles before failure. In view of the above, the reinforced sample can bear more stress than non – reinforced one. That means the GeoFiber™ reinforcement can enhance the fatigue life significantly. Meanwhile for certain percentage of bitumen, the fatigue life of reinforced sample is more reliable than normal asphaltic sample. These results are shown in figure 1. It can be concluded that the use of GeoFiber™ improved the fatigue life of asphaltic sample significantly.

In Figure 2 we can observe the variations of tensile strain versus number of cycle for failure. As it can be seen, the GeoFiber™ reinforcement can decrease the tensile strain in contrast to non- reinforced sample. In certain bitumen percent, the tensile strain in reinforced sample is less than the tensile strain in non- reinforced specimen. It can be seen that the number of cycle for failure in reinforced sample is more than non – reinforced sample. Therefore, the reduction in fatigue cracks in reinforced specimen is expected. In samples with 5 and 6 percents of bitumen, the number of cycles for failure is increased significantly. It should be noted that with 5 percent of bitumen the application of GeoFiber™ can cause a better cohesion between aggregates and bitumen. While using 4% bitumen the difference between tensile strain in reinforced specimen and non-reinforced sample is poor. This is because of percent reduction in the bitumen quantity. However, for 5 percent bitumen this difference is noticeable. Although the bitumen percent used is not optimum, therefore, the GeoFiber™ reinforcement, lead to the decrease in tensile strain in contrast to non – reinforced sample. The result has shown in Figure 2.

Based on the results obtained in Figures 1 and 2, the fatigue characteristic among stress bearing and resistance against tensile strain, has been improved.

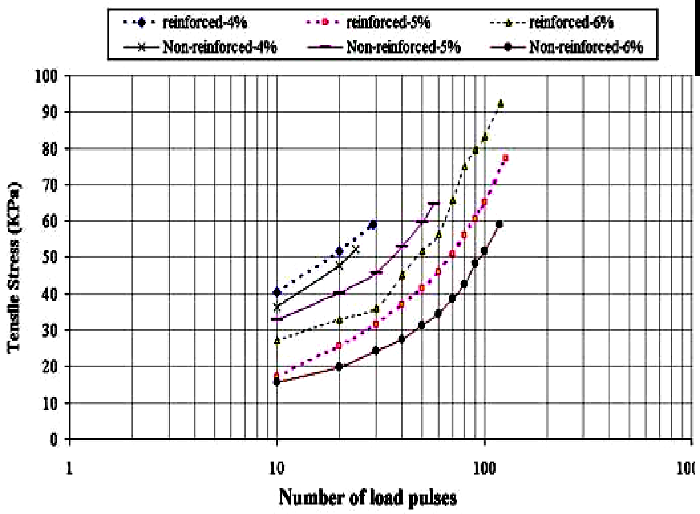

Fig. 1 - Tensile stress vs. number of load pulse

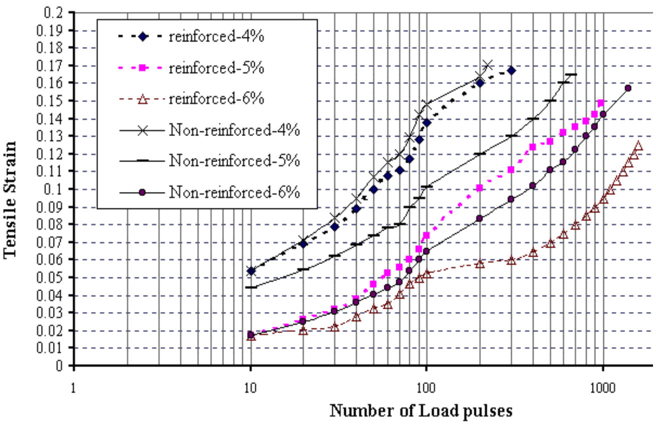

Fig. 2 -Tensile strain vs. number of load pulse

Figure 3 indicates the stiffness modulus versus bitumen percent. As it can be seen clearly, the GeoFiber™ reinforcement can improve the stiffness modulus, in contrast to non-reinforced samples. According to the experiments with certain bitumen percent, the value of stiffness modulus in reinforced specimen is more than the value of stiffness modulus in non-reinforced specimen, specially, when bitumen percent increased the cohesion between GeoFiber™ and bitumen will increase, therefore, difference between stiffness modulus at 6% bitumen in reinforced specimen and non- reinforced specimen will increase. For example, the difference between stiffness modulus at 6% bitumen in reinforced specimen and non- reinforced specimen is 60%.

Fig. 3 - Stiffness modulus vs. bitumen percent

In figure 4 we can observe the variations of stiffness modulus versus temperature at 6% bitumen. As it can be seen, the GeoFiber™ reinforcement can cause better characters in asphaltic samples.

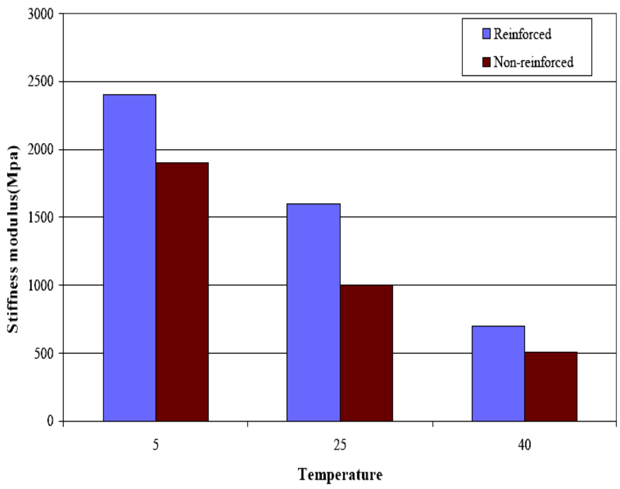

Fig. 4 - Stiffness modulus vs. temperature

The GeoFiber™ reinforcement can increase the stiffness modulus. It is clear that the reinforced sample can show a high stiffness than non-reinforced one.

As the temperature decreased, the cohesion between GeoFiber™, aggregates, and bitumen increased. Therefore, by decreasing temperature, the stiffness modulus is decreased as well. Meanwhile, stiffness modulus in temperature of 25°C is more than 40°C. This different between stiffness modulus at 25°C and 40°C is about 53%.

Figure 5 shows linear regression analysis of the ITFT result. As it can be seen obviously, regressions determine fatigue function for the asphalt mixtures. It is shown that reinforced specimen's slope is more than nonreinforced specimens. Away from GeoFiber™ reduction strain in reinforced specimens regression equation for reinforced specimen is $0.4273\varepsilon^{-0.1614}$ and for nonreinforced specimens is $0.2177\varepsilon^{-0.044}$.

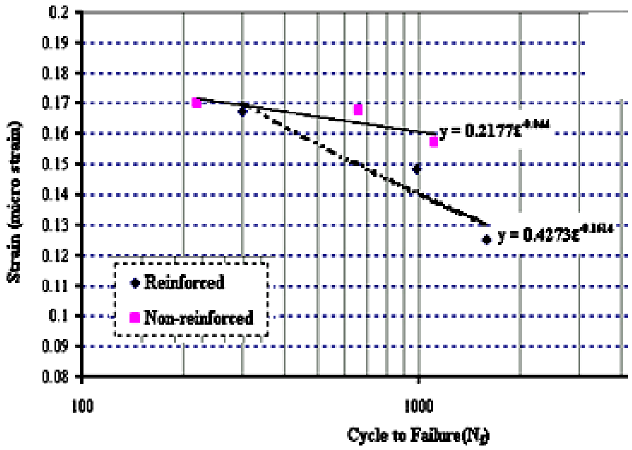

Fig. 5 - Strain vs. cycle to failure

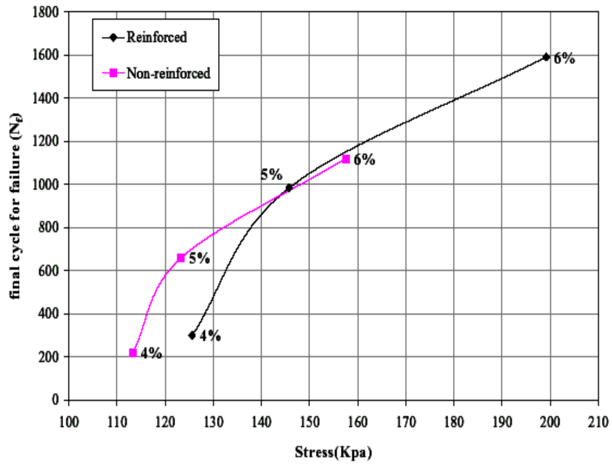

Fig. 6 - Fatigue life vs. stress

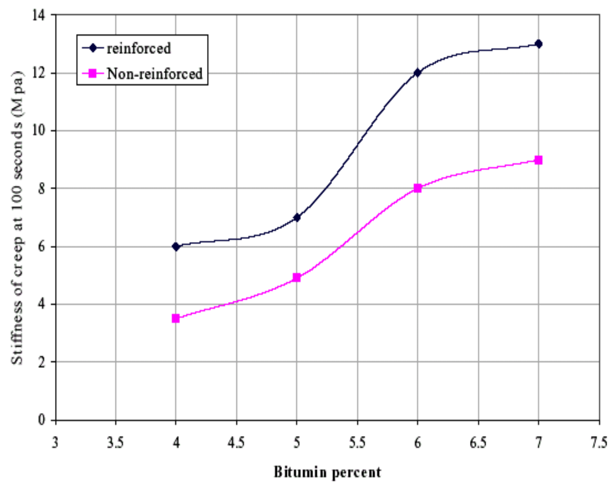

Fig. 7 - Stiffness of creep at 100 second vs. bitumen percent

In figure 6 we can observe the variations of final cycle for failure versus of stress. As it can be seen obviously, the GeoFiber™ reinforcement can increase the final cycle in contrast to non- reinforced sample. In certain bitumen percent, the final cycle in reinforced sample is more than the final cycle in non-reinforced specimen. While using 4% bitumen the difference between final cycle in reinforced specimen and non-reinforced sample is poor. In samples with 5 and 6 percents of bitumen, the final cycle for failure is increased significantly. In Figure 6 this difference is noticeable. This is because of the bitumen percent used is optimum. In Figure 7 we can observe the variations of stiffness of creep at 100 second versus bitumen percent. As it can be seen, the GeoFiber™ reinforcement can increase the stiffness of creep at 100 seconds in any percentage of bitumen. This improvement can be increased by increment in bitumen percent.

In Figure 8 the variation of percent axial strain versus number of seconds. It is clear that percent axial strain of reinforced samples in contrast to non-reinforced decreased significantly. In samples with 4 and 5 percents of bitumen, the difference between percent axial strain in reinforced and non-reinforced specimens is poor. But this difference in reinforced and non-reinforced samples with 6 percent is Noticeable. From Figure 8 we can observe that percent axial strain in reinforced sample with 6 percent of bitumen is the least. It can be concluded that the use of GeoFiber™ improved percent axial strain.

According to this experimental work, the GeoFiber™ reinforcement can obviously improve characters of asphaltic samples. Results indicate that reinforcement by GeoFiber™ to mixes made with soft bitumen reduced their permanent deformation significantly. This means that GeoFiber™ provides a strong tool for designing mixes to avert both pavement rutting and low temperature cracking in order to prolong road life.

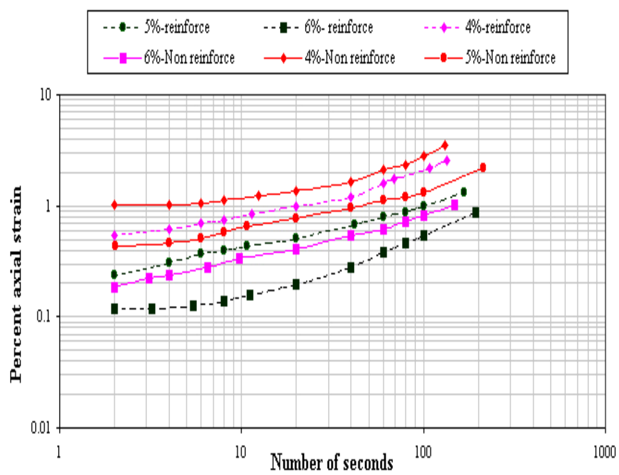

Fig. 8 - Percent axial strain vs. number of seconds

Conclusion

The primary purpose of this project reported in this chapter was to compare the behavior of the GeoFiber™-reinforced asphaltic sample with the normal asphaltic sample. From above tests, two important parameters as stiffness modulus and fatigue life in asphaltic specimen studied. In the Nottingham Asphalt Tester (NAT) system, applying a dynamic compressive load carries out the test and this loading can assist us in better analysis of asphaltic samples behavior. The software of NAT used in the conditioning pulse for decreasing the probably error in this test. The five initial pulse of dynamic loading should be used in ITSM test for kept the materials response in the liner visco-elastic (LVE) range. The dynamic loading leads to two types of deformation; namely elastic deformation and the plastic deformation. In the ITFT the vertical deformation of specimen versus number of cycle for failure is determined.

The main conclusions achieved so far are the following:

– The stiffness modulus is a function of load, stress, horizontal deformation, percentage of bitumen and Poisson ratio. The Poisson ratio's normally assumed to be 0.35 which is a representative value for most asphalt.
– In both reinforced and normal asphaltic samples, it can be seen that with increasing the bitumen percent, the stiffness modulus is increased but this increasing in reinforced samples is more than normal samples.
– In ITFT the tensile strain in reinforced asphaltic samples is less than normal asphaltic samples, also with increasing bitumen percent, this strain is decreased.
– In ITFT the capability of bearing the tensile stress in normal asphaltic samples is less than reinforced asphaltic samples, and this capability with increasing of bitumen percent is decreased.

The overall conclusion of this research indicates that the GeoFiber™ reinforcement can have a positive effect on fatigue life of the samples.

References

1. Markow, M.J., Hedrick, J.K., Brademeyer, B.D., and Abbo, E., "Analyzing the Interactions between Dynamic Vehicle Loads and Highway Pavements". Transportation Research Record 1196, TRB, National Research Council, Washington, D.C., pp. 161–169, 1988.
2. Shell Pavement Design Manual, "Asphalt Pavement and Overlays for Road Traffic", Shell International Petroleum Co. Ltd., London, U.K., 1978.
3. Shook, J.F., F.N. Finn, M.W. Witczak, and C.L. Monismith, "Thickness Design of Asphalt Pavements", The Asphalt Institute Method , In Proc., 5th International Conference on the Structural Design of Asphalt Pavements, Delft, The Netherlands, Vol. 1, 1982, pp. 17-44.
4. Jucob. U. "Evaluation of fatigue cracking", Transportation Research Record, No.1570, 1998.
5. Huang. Y. H., "Pavement Analysis and Design", Prentice HALL, University of Kentucky, USA, 1993.
6. Bodin, D., Pijaudier-Cabot, G., de La Roche, C., Piau, J.-M., "A continuum Damage Approach of Asphalt Concrete Fatigue Tests", 15th ASCE Engineering Mechanics Conference, June 2-5, 2002, Columbia University, New York, NY.
7. H. Anderson, D., Youtcheff, J., Zupanick, M., "Asphalt Binder", Committee on Characteristics of bituminous Materials Chair", Airey, G. D., "Fundamental Binder and Practical Mixture Evaluation of Polymer Modified Bituminous Materials", The International Journal of Pavement Engineering, Vol. 5 (3) September 2004, pp.137-151.
8. Annual Book of ASTM Standard, Road and Paving Materials; Vehicle- Pavement system, "Standard Test Method for Indirect Tension Test for Resilient Modulus of Bituminous Mixtures", D 4123-82, 2002.

© **A. K. Haghi** – PhD, professor, University of Guilan, Rasht, Iran, Corresponding author e-mail: Haghi@Guilan.ac.ir; **G. E. Zaikov** – DSc. Professor, Institute of Biochemical Physics, Russian Academy of Sciences; **S. Yu. Sofina** – PhD, Kazan National Research Technological University; **S. N. Rusanova** – PhD, Kazan National Research Technological University.