FOUNDATIONS OF CIVIL AND ENVIRONMENTAL ENGINEERING

No. 11 2008

Wojciech GRABOWSKI*, Andrzej POZARYCKI
Poznan University of Technology, Department of Civil Engineering,
Piotrowo Street 5, Poland

ENERGY ABSORPTION IN LARGE DIMENSION ASPHALT PAVEMENT SAMPLES REINFORCED WITH GEOSYNTHETICS

Received: 15 May 2007
Accepted: 16 April 2008

This paper investigates the test results of fatigue crack propagation of large dimension asphalt pavement samples reinforced with geocomposite and geogrid. The large dimension samples were cut from the test section of the asphalt pavement structure. Laboratory scale testing has been carried out in terms of multiple repeated loading and constant temperature. An original method of making large dimension asphalt pavement samples has been described. Crack propagation tests have been carried out on a special unit for fatigue testing. The evaluation of fatigue crack propagation was based on the analysis of the reinforcement efficiency index expressed by a function of the load cycles number and energy absorbed in the volume of the tested samples. Considering that the higher reinforcement efficiency index is desirable for better resistance to fatigue crack propagation, the test results give some indications on better fatigue crack resistance behavior for a sample reinforced with geocomposite in relation to a sample reinforced with geogrid.

Key words: geogrid, geocomposite, fatigue crack propagation, asphalt pavement samples, energy absorption

*Corresponding author. Tel.: 0616652487; fax: 0616652478.
E-mail address: wojciech.grabowski@put.poznan.pl

ISSN 1642-9303

1. INTRODUCTION

The asphalt pavement resistance to crack initiation and propagation can be considered to be one of the major mechanical characteristics. Geosynthetics reinforcement of the pavement structures can improve the prevention of crack initiation and propagation. It is appropriate that the verification process of the geosynthetics efficiency for the pavement reinforcement becomes an important issue.

In the technical journals measurable benefits from the research studies pertaining to the application of geosynthetics as reinforcement were described among others, by [1], [2]. In those studies the bending beam test was used in order to determine the reinforcement efficiency of the crack propagation process in laboratory conditions. The testing of the samples for their susceptibility to crack resistance was conducted under both static and multiple repeated loading. The samples were also fabricated in laboratory conditions.

A significant progress in the evaluation of asphalt pavement reinforcement efficiency with geosynthetics was made by Tschegg [3]. The basis for his research were cylindrical samples of 150 i 200 mm in diameter cut from the geocomposite reinforced asphalt pavement structure. From his research two major features of the reinforced asphalt pavement can be drawn. The first- using the wedge split method, the bonding strength of the notched sample reinforced with geocomposite was evaluated. The second- tensile strength of the reinforced samples was introduced

Another major advanced verification study can be found in [4]. Laboratory fabricated samples 60 cm x 9 cm x 18 cm reinforced with glass grid fibers were used. The research program included the dynamic bending beam test, measuring the force while pulling-out the geogrid from the sample and behavior investigations of the samples subjected to wide range of temperatures.

The test results description of crack reflection propagation in asphalt pavement structures can be found in [5]. The subject of the research were the samples 100 cm x 20 cm x 8 cm, reinforced with a polypropylene grid. The samples with the initial notch of 1 cm in width were subjected to multiple repeated loading under a moving wheel.

The four year pavement tests and observations have been carried out by [6]. Their subject of the research were two federal roads in the USA repaired with the glass fibers geogrids. The experimental works showed the real pavement resistance to crack propagation.

2. RESEARCH OBJECTIVE

The main objective of the presented research study is to explore the knowledge about crack propagation process in asphalt pavement layers. This paper also investigates the evaluation of asphalt pavement reinforcement efficiency with both geocomposite (made of glass fibers and polypropylene geotextile) and geogrid (made of glass fibers). The experimental plan was designed to investigate the behavior of the large dimension asphalt pavement samples. In order to achieve the plan objectives the research scope was as follows:

- construction the in situ asphalt pavement test section divided into sections reinforced with geocomposite and geogrid and those non-reinforced with geocomposite and geogrid . Considerable effort has been made to validating the real paving conditions such as mixture laying and compaction process.
- Nondestructive field testing with FWD application to measure the bearing capacity all of the pavement courses,
- Cutting the large dimension samples from the pavement structure of the test section. Quadratic slabs with dimensions 1.0 x 1.0 m were considered in order to evaluate crack propagation on the fatigue test stand.

Fig. 1. The strip of 1m width in the middle part of the test pavement cross-section, designed for sampling

3. PAVEMENT STRUCTURE OF THE TEST SECTION

The Asphalt pavement structure consisted of the following three layers:

- 7 cm base course with a maximum nominal aggregate size of 22 mm,
- 6 cm binder course with a maximum nominal aggregate size of 16 mm,
- 5 cm wearing course with a maximum nominal aggregate size of 12.8 mm.

Asphalt concrete layers were lain on the mechanically stabilized base course 20 cm thick with a maximum nominal aggregate size of 31.5 mm. The performed pavement structure meets typical Polish standards [7] for KR3 traffic class.

The selected areas of the performed test section were reinforced with geosynthetics made of glass and polypropylene geotextile. Geosynthetics were delivered by different manufacturers. The reinforcement was installed on both the base and the binder courses of the asphalt pavement test section. This paper investigates the test results of the sample reinforced with goecomposite made of glass and polypropylene geotextile and the sample reinforced with geogrid made of glass fibers. In this study only the reinforcement installed on the binder course has been discussed.

4. RESEARCH ON THE EFFECT OF GEOSYNTHETICS REINFORCEMENT ON FATIGUE CRACK PROPAGATION

4.1. Research framework

The framework has been developed exploring the idea of the asphalt pavement reinforcement efficiency using geocomposite and geogrid materials in preventing fatigue crack propagation. The multiple bending test on a special unit for fatigue evaluation of large dimension asphalt pavement samples was conducted.

4.2. Large dimension asphalt pavement samples fabrication.

Experimental plan was designed for the evaluation of geosynthetics reinforcement efficiency assuming the similar dimensions of the tested reinforced and non-reinforced samples.

According to the plan of the presented research, the samples should precisely meet the typical Polish paving standards. To achieve this, significant effort has been made to provide the samples of homogenous characteristics. Assuming the plan considerations, the samples were cut from the middle part of the test pavement cross section as shown in figure 1. An original method[1] of making large dimension asphalt pavement samples has been performed. The quadratic slabs 1.0 m x 1.0 m were cut. In relation to the depth of the asphalt layers of the test section the samples are 5 + 6 + 7 = 18cm in thickness.

4.3. Experimental procedure

The crack propagation testing was conducted under constant displacement rate measured along the loading axis. The displacement rate was found experimentally and its value was at 1 mm/hour. To reach an assumed displacement rate the span of the applied load extreme values (F_{max}–F_{min}) in a single cycle was at 14 kN. Loading frequency was at 10 Hz.

The support configuration of the tested samples has been shown in figure 2. The span between the steel pipes was 90 cm.

An average temperature measured on the wearing of non-reinforced sample was at 13.2 ± 0.4 ºC. An average temperature of the other two tested samples was 13.4 ± 0.7 ºC (figure 4).

4.4. Criteria of asphalt pavement reinforcement efficiency

The theoretical considerations are based on energy absorption theory described among others by Drewnowski [9]. It is said there that for damage description any of the elements of the construction subjected to multiple repeated loading energy absorbed by these elements can be used.

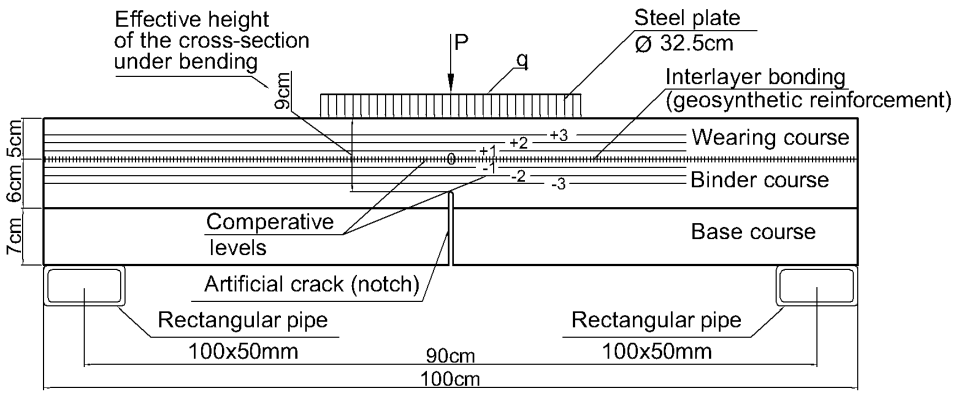

Fig. 2. Testing arrangement for fatigue crack propagation on large dimension asphalt pavement sample

[1] Fabrication method of large dimension asphalt pavement samples was reported to Patent Office in RP

In this study, the value of the absorbed energy for a given length of the crack was assumed to be one of the component of the reinforcement efficiency criterion. The values of the energy absorbed by the tested samples have been calculated and compared for a given length of the crack projected on the *y* axis- the so called comparison or conventional observations levels (figure 3). The beginning of the crack was assumed to start with the front of the notch. The tests were conducted under multiple repeated bending loading. In the cross-section of the sample the *y* axis scale was given by four parallel lines. The lines located in the binder course (below the interlayer bonding level or reinforcement level) were marked with -4, -3, -2, -1. The lines located in the wearing course (above the interlayer bonding level or reinforcement level) were marked with +1, +2, +3, +4. Exploring the idea of easy fatigue crack propagation description, the span between those lines was assumed to be 1cm (figure 3).

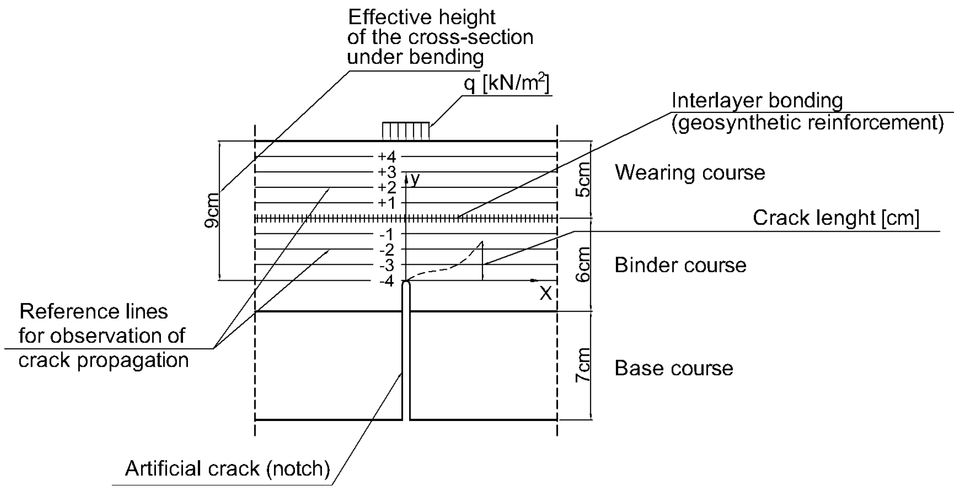

Fig. 3. Cross-section of large scale specimen (reference lines for observation of fatigue crack propagation are indicated)

The geosynthetics reinforcement efficiency index η_j of asphalt pavement structure has been introduced below

$$\eta_j = \frac{(E_z \cdot N_z)_j}{(E \cdot N)_j} \cdot 100\%, \tag{4.1}$$

where: *j* – conventional observation level for *j* iterator (the symbol of reference lines location with respect to the interlayer bonding between the binder and the wearing courses , *j* = -4, -3, -2, -1, 0, 1, 2, 3, 4), η_j – reinforcement efficiency index for a given *j* conventional observation level, %, $(E_z \cdot N_z)_j$ – the product of the energy absorbed by a reinforced sample and corresponding load cycles number for a given *j* conventional observation level, J (Joul), $(E \cdot N)_j$ – the product of the energy absorbed by a non-reinforced sample and corresponding load cycles number for a given *j* conventional observation level, J (Joul)

4.5. Laboratory tests and results analysis

An experimental work led to the results of fatigue crack propagation shown in figure 4.

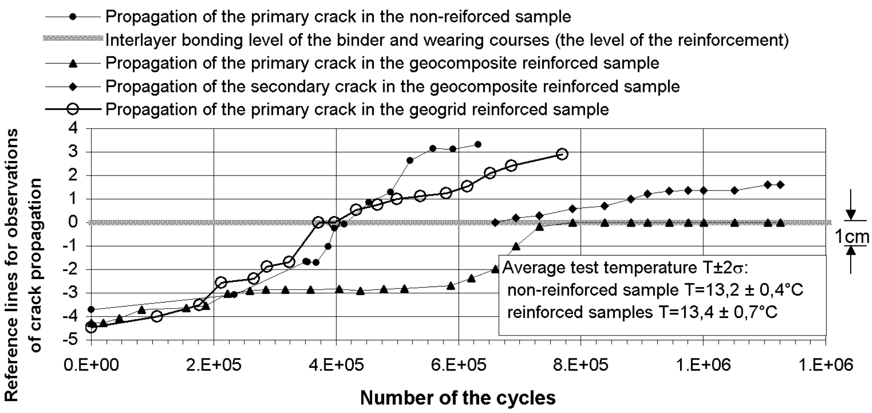

Fig. 4. Crack propagation in large dimension asphalt pavement samples with geocomposite and geogrid reinforcement and without reinforcement

The fatigue crack analysis of the effective bending cross section of the binder and the wearing courses with respect to the load cycles number enable to indicate the three major stages of fatigue crack propagation in macro scale:

- The initiation of the primary crack starting at the notch front and further propagation in the binder course,
- A stage in which the crack tip faces the interlayer bonding level between the binder or the wearing courses (or reinforcement level),
- Further continuous increase of the primary crack in the wearing course of the both non-reinforced sample and the sample reinforced with geogrid. In the sample reinforced with geocomposite the further continuous increase of the secondary crack was observed. In the sample reinforced with geocomposite two main cracks were observed.

The primary crack starts at the notch front and after the reinforcement level was faced, further continuous horizontal increase in the binder course was observed. The reason of that could be energy dissipation at this level of crack propagation observation. The secondary crack initiation process had a relatively large time delay when compared to the initiation process of the primary crack. It started after 700 thousand loading cycles number. It is also worth noticing that the moment of the secondary crack initiation equals the last conventional level of crack propagation observation in the non-reinforced sample. The aforementioned last comparison level was assumed to be at the reference line marked with +1.5 cm. In the sample reinforced with geogrid at the comparison level +1.5 cm further continuous increase of the primary crack was noted .

Assuming that the crack starts at the notch front, the plots of the crack length in relation to the applied load have been done. The length of the crack was assumed to be the angular projection of the crack tip vector (with its beginning at the notch front) along the direction of the y axis as shown in figure 3.

Using the described discrete relation $F_i(a_i)$, the energy absorbed in the volume of particular tasted samples have been calculated. The formula is given below

$$P = \int_{a_0}^{a_i} F_i(a_i) da_i \qquad \text{for } i = 1,2, \dots, n, \tag{4.2}$$

where: P – the value of total energy absorbed by the tested samples (area on the chart $F_i(a_i)$, (figure 5a, 5b, 5c)), n – number of the calculation points at which the length of the crack was given, a_0 – the initial length of the crack (a_0 = 0 cm), a_i – the length of the crack for a given *i* calculation point, $F(a_i)$ – linear interpolation function (shows intervals between particular calculation points).

A graphic interpretation of the total energy values absorbed by particular tested samples, defined as the area under discrete relation chart F(a) is shown in figure 5.

The comparison of the energy absorbed values at a given conventional fatigue crack observation levels are shown in figures 6 and 7.

Non-thermal effects on fatigue crack propagation have been considered in this study. The research was conducted under steady state temperature conditions as shown in figure 4

By definition of the reinforcement efficiency index ηj, according to formula 4.1, at given conventional crack observation levels, the qualitative assessment of the influence of geosynthetics reinforcement of the tested asphalt pavement samples on the crack propagation resistance was obtained when compared to the non-reinforced samples. An evaluation of the reinforcement efficiency calculated at all analyzed crack propagation levels is shown in figure 8.

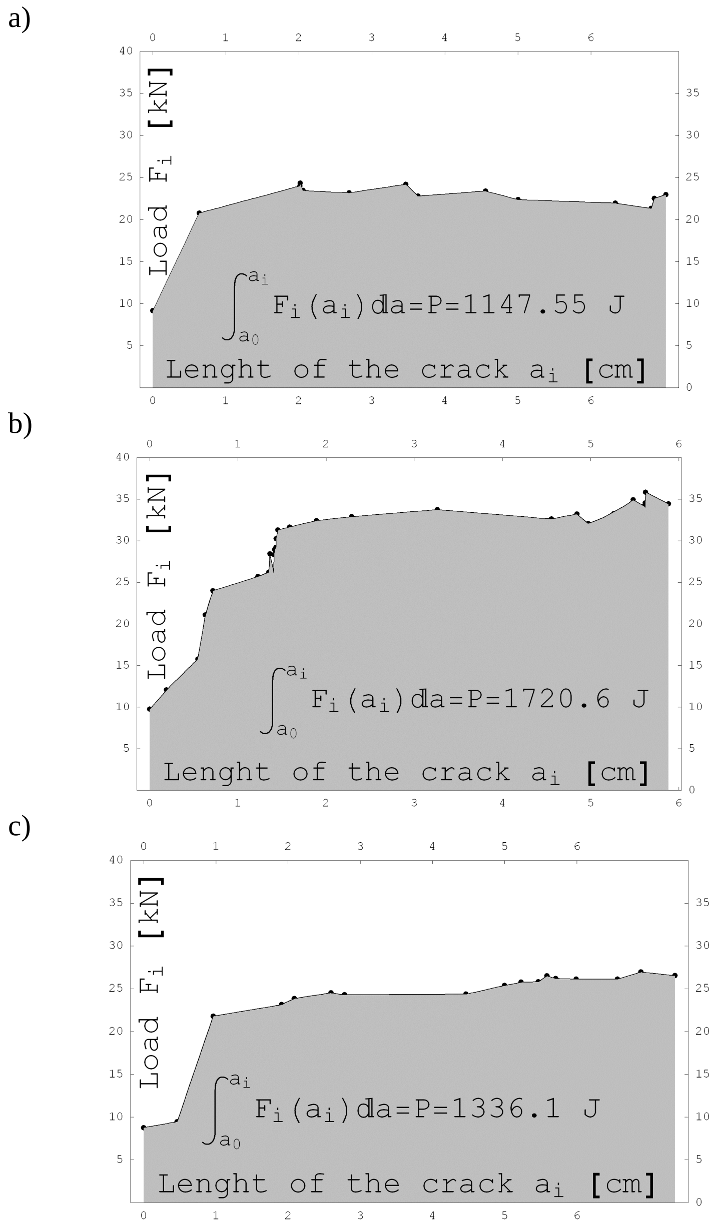

Fig. 5. The areas representing the total energy absorbed in the volume of: a) non-reinforced sample, b) reinforced with geocomposite, c) reinforced with geogrid,

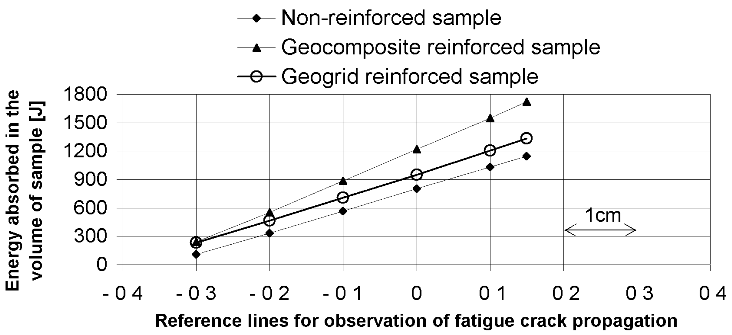

Fig. 6. The increase of energy absorbed in reinforced and non-reinforced samples

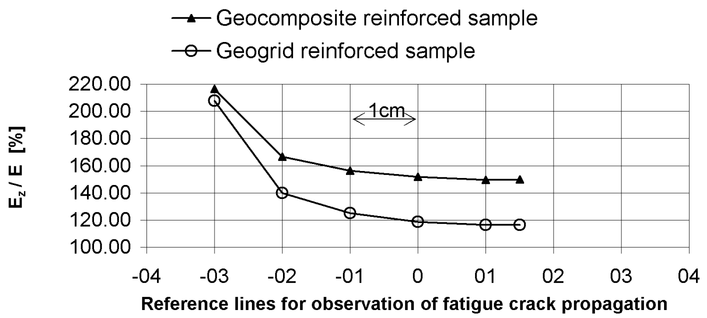

Fig. 7. The energy ratio (Ez/E) corresponding to particular crack propagation levels

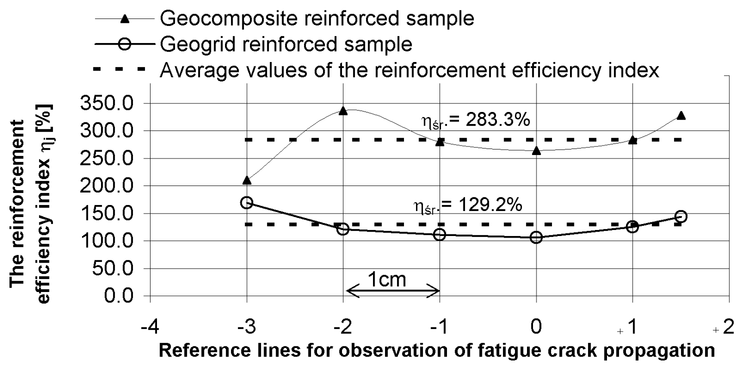

Fig. 8. The reinforcement efficiency index ηj corresponding to particular conventional crack observation levels

5. CONCLUSIONS

On the basis of the performed test results the following conclusions can be drawn:

1. Significant increase of energy absorbing capacity in samples reinforced with both geocomposite and geogrid has been noticed when compared to the non-reinforced sample.
2. An average value of the reinforcement efficiency index (figure 7) obtained for the sample reinforced with geocomposite varies at 283% and obtained for the sample reinforced with geogrid varies at 129%. Following the indicated findings, the reinforcement significantly increased the fatigue crack propagation resistance in relation to the non-reinforced sample.
3. The presented investigation for the sample reinforced with geogrid resulted in significantly smaller fatigue crack propagation resistance against the sample reinforced with geocomposite.

BIBLIOGRAPHY

1. Francken L.: Laboratory simulation and modeling of overlay systems, Proc. of RILEM Conf. Reflective Cracking in Pavements, Liege, 1993, pp 75-99.
2. Jaccklin F.P.: Geotextile use in asphalt overlays – design and installation techniques for successful operation, Proc. of RILEM Conf. Reflective Cracking in Pavements, Liege, 1993, pp 100-111.
3. Tschegg E.K.: An Efficient Fracture Test Method for Bituminous Materials and Layer Bonds, Proc. of the Fifth Intern. RILEM Symposium on Mechanical Tests for Bituminous Materials, Lyon 1997, pp 405-411.
4. Jaecklin F.P.: Scherer J., Asphalt reinforcing using glass fiber grid "Glasphalt". Proc. of Third International Conference on Reflective Cracking in Pavements, Maastricht 1996, pp 269-277.
5. Gilchrist A.J.T.,Brodrick B.V., Austin R.A.: The development of grid/geotextile composite for bituminous pavement reinforcement, Proceedings of Third International Conference on Reflective Cracking in Pavements, Maastricht 1996, pp 269-277.
6. Darling J.R.,Woolstencroft J.H.: Fiberglass geogrid performance evaluation for retarding reflective cracking, Proceedings of Fourth International Conference on Reflective Cracking in Pavements, Ottawa 2000, pp 403-412.
7. Working Group IBDiM: Typical Polish flexible and semi rigid pavement structures guidelines, GDDP, Warsaw 1997.

8. Lugmayr R.G., Drzaszcz R.C.: The use of geosynthetics in paving application, factors influencing the reflective cracking, Int. Conf. "Modern Technologies in Highway Engineering", Poznan 2001, pp. 157-168.
9. Drewnowski S.: About energy concentration in the element of structures (in Polish), Wydawnictwa Politechniki Czestochowskiej, Czestochowa 2004.
10. Grabowski W., Pozarycki A.: Cracks propagation tests of asphalt pavements samples under multiple repeated loading in laboratory condition (in Polish), III Int.Conf. „Modern Technologies in Highway Engineering", Poznan 2005, pp. 130-142.