Geotextiles and Geomembranes 46 (2018) 681–683

Contents lists available at ScienceDirect

Geotextiles and Geomembranes

journal homepage: www.elsevier.com/locate/geotexmem

Reply

"Laboratory tests on the engineering properties of sensor-enabled geobelts (SEGB)"- A reply to the discussion

Xin-zhuang Cui*, She-qiang Cui, Yi-lin Wang, Jun Li

School of Civil Engineering, Shandong University, Jinan, 250061, China

1. Introduction

The authors thank Yazdani and Hatami (2018) for their discussions related to our work (Cui et al., 2018) on sensor-enabled geobelts (SEGB). In our paper, CB, known to be the most commonly used conductive filler in industrial applications, were used as filler materials to modify geosynthetics and develop the SEGB specimens. In CB-filled HDPE composite (i.e. SEGB), HDPE was filled the conductive masterbatch (masterbatch of CB) by different weight. The physical mixture of HDPE and CB pellets was provided to describe that HDPE pellets were mixed with CB pellets as fully as possible in the mixing procedure. For the results of slow tensile tests, the fitting equations were revised. For the results of creep tests and in-soil test, study details and explanations were provided. On the basis of the discussion from Prof. Yazdani and Prof. Hatami, we have made specific responses in the following sections.

2. Experiments

2.1. Materials, electrical conductivity and percolation behavior

For the super conductive carbon black (masterbatch of CB) used for the SEGB specimens were provided by commercial manufacturers, the physical properties of CB were disclosed by the supplying company. Thus, the filler content of the CB-filled SEGB specimen in this paper was the mixing ratio of the conductive masterbatch to the virgin polymer (HDPE) instead of the actual contents. In our paper, HDPE was filled the conductive masterbatch (masterbatch of CB) by different weight.

According to the discussers' comments, a dispersion state in our paper described as "uniform" or "good" for CB individuals in the aggregate scale might be a misleading or inaccurate description of their dispersion state in micro- or macro-scale systems, where CBs are typically found in the form of agglomerates. We are sorry for the misleading induced by the inaccurate description. We checked the original paper and believed that the inaccurate description might refer to the sentence "All the polymer pellets in the batch should be preheated and melted completely and uniformly". Actually, this sentence aimed to describe that HDPE pellets were mixed with CB pellets as fully as possible in the mixing procedure, as shown in Fig. 1. The description "completely and uniformly" in the paper referred to the physical mixture between the HDPE and CB pellets while not the dispersion state of CB and HDPE particles induced by chemical reaction.

2.2. In-isolation tests on SEGB

2.2.1. Slow tensile tests

The discussers pointed out the inaccuracy of the fitting equations of the normalized resistance-strain curves in Tables 2 and 3 in our paper (Cui et al., 2018). We acknowledge the inaccuracy of the fitting equations and appreciate discussers for identifying the mistakes. Previously, these linear functions were fitted with the data in the strain range of 0–2%, and quadratic polynomial functions were fitted with the data in the strain range of 0–5%. Due to technical reasons, these linear fitting functions were inaccurately applied for the 0–7% strain and quadratic polynomial functions were inaccurately applied for the 0–10% strain, shown in Fig. 6 and Fig. 10 in our paper (Cui et al., 2018). With overall check-up, the fitting functions are revised in the following Table 1 and Table 2.

The authors agree that dynamic loads have an influence on the tensoresistivity response of SEGB. To study the effects of dynamic loads on the tensoresistivity performance of SEGB, a series of cyclic loading tests have been performed to simulate different magnitudes earthquake. Before cyclic loading, different prestrains were applied to simulate the deformation of SEGB in soil before earthquake. The results in our studies indicate that the tensile strength and elongation at break of SEGB after cyclic loading decrease with the number of loading cycles and strain amplitude of cyclic load, though the prestrains have a limited influence on the reduction of mechanical properties of SEGB. For the tensoresistivity response of SEGB after cyclic loading, the electrical conductivity of SEGB becomes more sensitive to strain by increasing number of loading cycles, amplitude of cyclic load and prestrains. Based on the test results, a preliminary model was proposed to evaluate the tensoresistivity performance of SEGB after cyclic loading. In addition, other factors (e.g. thermal oxidation, UV radiation and corrosion) also have influences on the tensoresistivity response of SEGB. In our studies (Li at al., 2018), three accelerating degradation tests (thermal

* Corresponding author.
E-mail addresses: cuixz@sdu.edu.cn (X.-z. Cui), 1914569734@qq.com (S.-q. Cui), eason_wyl@163.com (Y.-l. Wang), forzaapis@126.com (J. Li).

https://doi.org/10.1016/j.geotexmem.2018.06.002
Received 19 May 2018; Accepted 30 May 2018
Available online 27 June 2018
0266-1144/ © 2018 Elsevier Ltd. All rights reserved.

(a) HDPE pellets (b) CB pellets

(c) Physical mixture of HDPE and CB pellets

Fig. 1. Mixing procedure of HDPE and CB pellets.

oxidation, UV radiation and corrosion) on the tensoresistivity of SEGB were conducted. The results indicated that the electrical resistance of SEGB displayed a sharp increase trend after the strain exceeded a certain number, which means the sensitivity of tensoresistivity improves.

2.2.2. Creep tests

Thanks for the discusser's remarks related to the results of creep tests on SEGB in our paper. The corresponding stress to the tensile loads (0.1 KN) is 2 MPa, which is 15% per cent of tensile strength of SEGB. The creep testing procedures strictly followed the Test Methods of Geosynthetics for Highway Engineering (JTG E50-2006 (MOTPRC, 2006)). The discussers also mentioned that the maximum creep strain (14%) is too large for geotechnical engineering applications. However, we believe that there are several factors should be discussed here. The creep behavior of geosynthetics could be affected by many factors such as material of geosynthetics, confining pressure, temperature and stress level (Wang et al., 2004; Wang, 1994; Lan, 2015). In engineering applications, the creep strains of geosynthetics are usually subjected to the creep strains of soil, which are generally smaller. Moreover, in terms of design and construction, the creep strains of geosynthetics should be large enough to guarantee the Safety Factor.

2.3. In-soil tests

The discussers pointed out that it was impossible to confirm the accuracy of strain calculated from tensoresistivity by strain gauges due to its limited measurement range of 2%, and the results in Figures 16a and 18 of (Cui et al., 2018) are expected to be the same. Indeed, the strain gauges have limitations on its elongation. However, there lacks effective methods for the measurements of the deformations of geosynthetics inside soil. Some other widely-used measurements (e.g. extensometers or FBG) have sorts of limitations including small range or vulnerability. Conversely, it is one of the advantages of SEGB as providing a new method for the measurements of in-soil deformations. The results in the Figures 16a and 18 were actually the same, and they were just exhibited with different coordinate range.

The discussers also pointed out that the tensoresistivity might be influenced by confining pressure, because higher confining pressure may reduce the thickness of layer and result in increment of CB concentration. However, no change on electrical resistance was observed during the loading process in the tests, meaning that the influences of confining pressure on tensoresistivity could be ignored or not sensitive enough for the measurement accuracy. Besides, the largest confining pressure in pullout tests was 400 kPa. In tensile stress-strain response of SEGB, the tensile strain corresponding to tensile stress of 400 kPa was pretty small (less than 0.5%). Compared to the tensile response, the compressive strain induced by compressive stress of 400 kPa would be much smaller than tensile strain.

2.4. Industrially-fabricated, sealed SEGB

The authors appreciate the discusser's remarks related to the appreciable slippage at the interface between SEGB and hot pyrocondensation pipes (HPP). The tensile load-strain curves of different SEGB specimens are shown in Fig. 2. The tensile load-strain curves

Table 2
Fitting equations of the normalized resistance-strain curves of the industry-fabricated SEGB.

SEGB	Filler content (%)	Quadratic polynomial fitting equation	Linear fitting equation
CB/HDPE	45	$y = 0.01599x^2 + 0.1853x + 1$ ($R = 0.999$)	$y = 0.27704x + 1$ ($R = 0.997$)
	46	$y = 0.01172x^2 + 0.0102x + 1$ ($R = 0.999$)	$y = 0.07882x + 1$ ($R = 0.996$)
	47.5	$y = 0.01865x^2 + 0.0149x + 1$ ($R = 0.997$)	$y = 0.12815x + 1$ ($R = 0.997$)

Note: R is the correlation coefficient.

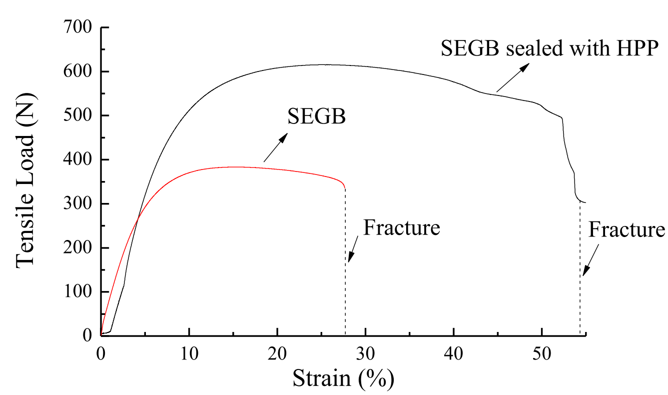

Fig. 2. Tensile load-strain curves of the SEGB specimens with and without HPP.

Table 1
Fitting equations of the normalized resistance-strain curves of the laboratory-fabricated SEGB.

SEGB	Filler content (%)	Quadratic polynomial fitting equation	Linear fitting equation
CB/HDPE	44	$y = 0.00783x^2 + 0.609x + 1$ ($R = 0.989$)	$y = 0.63386x + 1$ ($R = 0.985$)
	45	$y = 0.0118x^2 + 0.00337x + 1$ ($R = 0.949$)	$y = 0.07221x + 1$ ($R = 0.993$)
	47.5	$y = 0.06792x^2 - 0.0983x + 1$ ($R = 0.956$)	$y = 0.27543x + 1$ ($R = 0.991$)
	50	$y = 0.00271x^2 + 0.03781x + 1$ ($R = 0.989$)	$y = 0.05336x + 1$ ($R = 0.996$)

Note: R is the correlation coefficient.

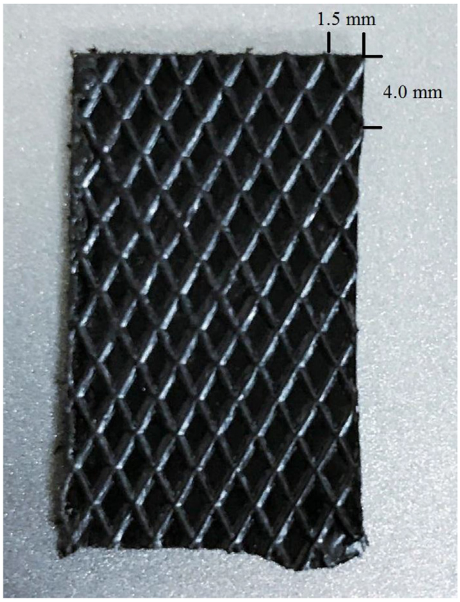

Fig. 3. Diagram of SEGB surface.

show that the tensile load of the SEGB specimen sealed with HPP is increased by 69.4%, compared to the one without HPP. It means that the tensile resistance of the SEGB/HPP composite is improved. The results shown in Fig. 22 of Cui et al. (2018) indicate that the tensile strength of the SEGB specimen sealed with HPP was decreased by 5.27%, compared to the one without HPP. This is because that the cross-section area of the SEGB specimen sealed with HPP is 43.2 mm^2, while the cross-section area of the one without HPP is 25.5 mm^2.

Furthermore, the interfacial connection between SGEB and HPP plays an important role in the interfacial shear performances of SEGB/HPP. To enhance the frictions between SEGB and HPP, the texture of SEGB was designed as rhombuses shown in Fig. 3. The long and short diagonals were 4.0 mm and 1.5 mm, respectively. The modification of SEGB surface can improve the interfacial shear strength between SEGB and HPP. To enhance the adherence between the SGEB and HPP, hot melt adhesives were uniformly daubed on the inner surface of the HPP. As a result, the interfacial shear strength between SEGB and HPP was significantly improved.

Based on Mohr-Coulomb theory, the shear strength can be calculated by the following equation:

$$\tau_f = c + \sigma' \tan \varphi$$

where τ_f is soil shear strength; c is cohesion; σ' is effective normal stress; φ is friction angle.

Compared to the interfacial shear strength between soil and HPP, due to the hot melt adhesives, the cohesion between SEGB and HPP is greater. In addition, the rhombic surface of SEGB also improves the frictional angle. Therefore, the interfacial shear strength between SEGB and HPP is greater than that between soil and HPP. Before the failure of soil, there is no slippage between SEGB and HPP, and the deformation between them is the same.

References

Cui, X.-Z., Cui, S.-Q., Jin, Q., Wang, Y.-L., Zhang, L., Wang, Z.-X., 2018. Laboratory tests on the engineering properties of sensor-enabled geobelts (SEGB). Geotext. Geomembranes 46 (2018), 66–76.
Li, J., Cui, X.Z., Jin, Q., Su, J.W., Cui, S.Q., Wang, Y.L., 2018. Laboratory investigation of the durability of a new smart geosynthetic material. Construct. Build. Mater. 169, 28–33.
Lan, T., 2015. Creep of geogrid in reinforced soil in consideration of stress level. J. Yangtze River Sci. Res. Inst. 32 (7), 89–93.
MOTPRC (Ministry of Transport of the People's Republic of China), 2006. JTG E50–2006: Technical Standard of Highway Engineering. China Communications Press, Beijing (in Chinese).
Wang, Z., 1994. The creep tests of geosynthetics. Chin. J. Geotech. Eng. 16 (6), 1–7.
Wang, Z., Li, L.H., Wang, X.Q., 2004. Creep properties and testing methods of geosynthetics. Rock Soil Mech. 25 (5), 723–727.
Yazdani, H., Hatami, K., 2018. Laboratory tests on the engineering properties of sensor-enabled geobelts (SEGB) – a discussion. Geotext. Geomembranes 46 (in this issue).