XVIII Brazilian Conference on Soil Mechanics and Geotechnical Engineering
The Sustainable Future of Brazil goes through our Minas
COBRAMSEG 2016 — 19-22 October, Belo Horizonte, Minas Gerais, Brazil

Adhesion evaluation between asphalt and geosynthetic layers using microscopy technics

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SUMMARY: Geossynthetics have been commonly used as asphalt reinforcement during new pavement construction or overlay in order to form an anti-reflective cracking interlayer. Asphalt coat is usually applied at the interface to ensure proper bond between layers, being tack coat type (e.g. RR-1C) and application rate critical parameters to guarantee an acceptable adhesion between layers. Scanning electron microscopy was the technique used to analyze adhesion between asphalt and geosynthetic layers. Asphalt samples reinforced with geosynthetic and previously submitted to bending test were analyzed by scanning electron microscopy with the purpose of a better understanding of bending and shear effects. This work aims to define the most appropriate way to prepare samples of a highly heterogeneous material, reinforced asphalt concrete. The images obtained via SEM showed that geosynthetic fibers are not always perfectly covered with asphalt binder. Moreover, the reinforcement layer has porosity that can difficult the traffic load distribution, which may be an indication of decreased shear strength in asphalt layers reinforced with geosynthetic.

KEYWORDS: pavement, reinforcement, adhesion, asphalt, geosynthetic, SEM

1 INTRODUCTION

Materials of construction have properties that are highly influenced by its own microstructure. Strength, toughness, and high/low temperature behavior are some examples of physical properties that can be changed if materials show microstructural defects. Microscopy techniques are therefore a powerful tool that helps scientists understand different and, in many cases, controversial behavior of materials.

Asphalt concrete is one of the most used materials of construction in the whole word and its constituent materials have been analyzed by several microscopy techniques. Loeber *et al.* (1996) analyzed samples of asphalt binder utilizing scanning electron microscopy and also atomic force microscopy; their work included developing sample preparation of asphalt binder. Samples of unmodified and modified asphalt binders containing polyphosphoric acid were studied by surface (microscopy) techniques (Dourado e*t al*., 2014).

The surface layer of flexible pavements is composed of asphalt concrete, thus the large scale of usage of such material. As an example, Brazilian road system, which is composed of flexible pavements, was responsible for the transportation of 60% of all goods produced in the country throughout the decades of 1990 e 2000 (IPEA, 2010). Considering the importance of correct maintenance of pavements for people safety, vehicle preservation and shipping costs, several lines of work try to evaluate geosynthetic as pavement reinforcement (Komatsu *et al.* (1998), Khodaii *et al.* (2009), Montestruque, (2002), Pereira (2002), Fonseca (2015)).

To prevent or reduce reflective cracking from underlying layers, protect asphalt layers against traffic induced cracking and to avoid or reduce development of rutting in asphalt layers it is very important to ensure bonding between pavement layers and geosynthetic reinforcement (Pereira, 2002). Fonseca (2015) has shaped a series of asphalt concrete samples (some samples were reinforced with geosynthetics, and others had no reinforcement) to conduct direct shear tests and tensile strength in bending.

The results obtained showed that inclusion of geotextile or geogrid significantly reduces shear strength between layers, which may mean that adhesion between asphalt layers and reinforcement layer is not happening effectively. At the same time, there was a significant gain in tensile strength in bending and further investigation it's thus needed to better understand the test's results. The asphalt concrete specimens were then analyzed by scanning electron microscopy (SEM).

2 MATERIALS AND METHODS

2.1 Selection of Materials

This study investigated asphalt concrete specimens shaped and tested over the research developed by Fonseca (2015). The specimens were made aiming to evaluate the performance of reinforced systems with use of geogrid and geotextile. Another important aspect valued was the influence of tack coat type (RR-1C and RR-2C) and the application rate of asphalt emulsion applied at the interface between asphalt layers.

Other available studies highlight that adherence between geosynthetic and asphalt concrete layers significantly interfere with the quality of the reinforcement system. Regarding pavement construction and rehabilitation, the service that provides proper bond between layers is asphalt tack coat, which has an ideal application rate for each individual case. Low asphalt tack coat application rates can cause loss of adhesion between layers at the same time that higher application rates can promote a bituminous material residue film, which can generate decrease in shear strength.

Fonseca (2015) has shaped a total of fifteen specimens of asphalt concrete beams, (45 cm x 15 cm x 10 cm) in order to be tested over tensile strength in bending: five specimens had geotextile as reinforcement (Figure 1), five had geogrid as reinforcement (Figure 2) and, the other five specimens had no reinforcement.

Figure 1: Type of Geotextile used to reinforce asphalt concrete specimens.

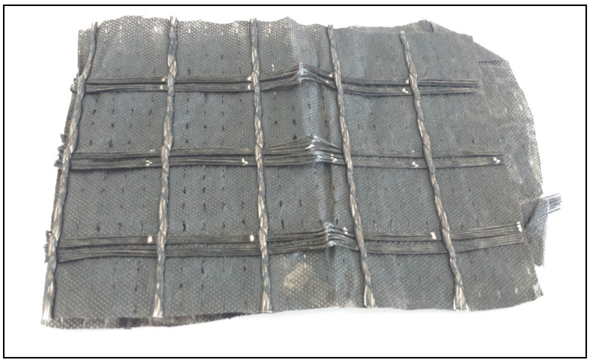

Figure 2: Special type of Geogrid used to reinforce asphalt concrete specimens.

Four specimens with higher values of tensile resistance in bending were chosen to be analyzed over scanning electron microscopy; two specimens have geogrid reinforcement and, the other two specimens have geotextile reinforcement. Table 1 presents information regarding specimens chosen to be analyzed by SEM. One can note that specimens that have used emulsion RR-2C as asphalt tack coat had higher tensile strength in bending. The diluted emulsion RR-2C has improved adhesion for this type of test (Tensile strength in bending).

Table 1. Specimen's data

Specimen number	Emulsion type	Application rate (l/m^2)	Tensile Strength (Mpa)
4 (geogrid)	RR-2C	0.36	3.23
5 (geotextile)	RR-2C	0.35	3.37
6 (geogrid)	RR-1C	0.84	2.86
14 (geotextile)	RR-1C	0.90	2.78

2.2 Sample selection and preparation

Microscopy analyses are usually based on comparing samples with standards. In this case, a standard sample would be an asphalt concrete sample that was not submitted to a tensile strength in bending test. However, the specimens were submitted to weathering prior to testing in order to simulate aging effects on pavements, which would prevent the deadline of this present work if new samples had to be shaped. It was thus defined that two regions from the asphalt concrete specimen would be analyzed by scanning electron microscopy: (1) the area located under the support of beam, subjected to minimum bending moment and maximum shear force; (2) the area near the site of specimen breaking, which in thesis would be more affected by the experiment. Two samples were taken from each asphalt concrete specimen being one sample near the support of the beam (identified by 'i') and, the other sample near of the specimen breaking (identified by 'e') totalizing eight samples analyzed by SEM. The acquisition schem of the eight samples analyzed over SEM is presented on Figure 3.

The asphalt concrete specimens were first cut to remove slices approximately 5 cm thick, as shown in Figure 4. After that, the asphalt concrete slices were cut to sample size suitable for microscopy analysis, with dimensions close to 1 cm, similar to the test sample that can be seen in Figure 5.

Sample sectioning was done by diamond cutting wheel and water was utilized for lubrication and cooling the cutting process. Polishing is not indicated for this type of material because asphalt binder may melt during polishing process. After sectioning, samples were submitted to carbon coating and then analyzed via scanning electron microscopy through the microscope Quanta FEI 200.

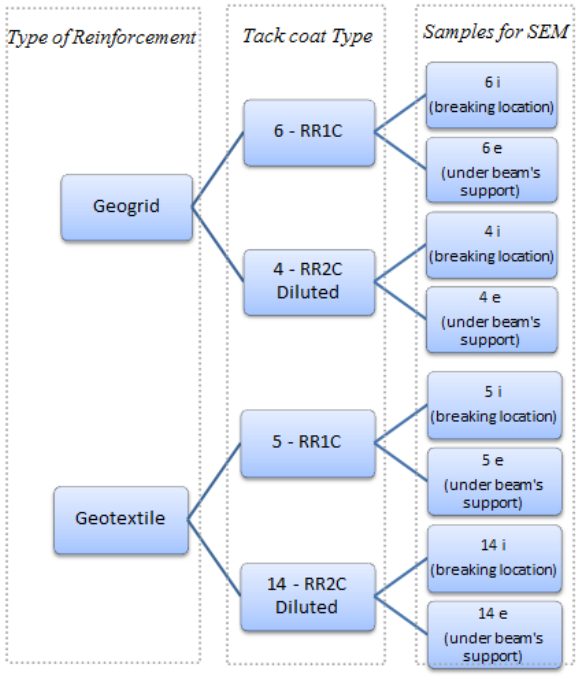

Figure 3: Sample selection for scanning electron microscopy from asphalt concrete specimens reinforced with geogrid and geotextile.

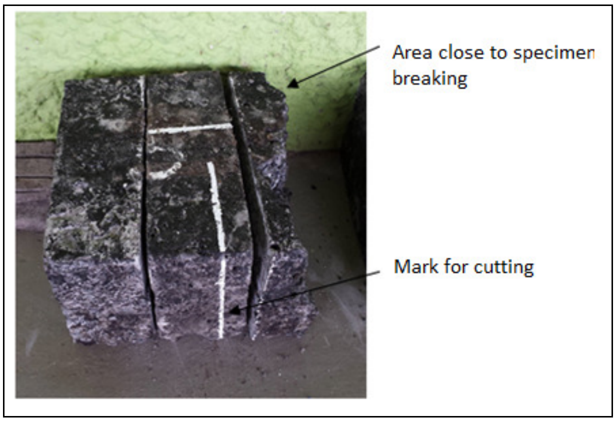

Figure 4: Delimitation of cutting site for specimen number 5.

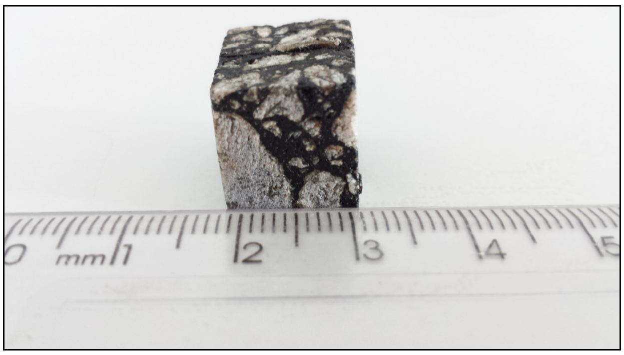

Figure 5: Asphalt concrete test sample with dimensions close to one centimeter.

3 SCANNING ELECTRON MICROSCOPY IMAGES ANALYSIS

Before analyzing SEM images, it is very important to define adequately which plan from the asphalt concrete specimen is being seen. A longitudinal cut from the asphalt concrete specimen is shown on Figure 6 and this is exactly what the following images are going to show: on the bottom, a layer of asphalt concrete followed by a geosynthetic layer of reinforcement and a top layer of asphalt concrete. However, the point of interest is the highlighted circle in the center of the image, which is the contact area of geosynthetic and asphalt layers.

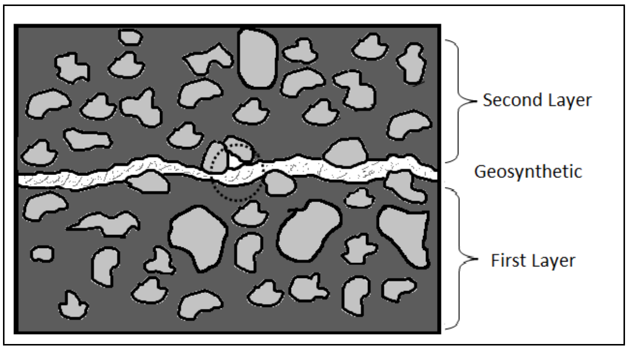

Figure 6: Asphalt and geosynthetic layers diagram

This present study evaluates the relationship between a numbers of variables related to the reinforced asphalt samples. For this paper, it was chosen to compare samples taken from the area located under the support of beam, with samples taken from the area near the site of specimen breaking.

Sample number 4, which has geogrid reinforcement, is the first sample to be analyzed. Figures 7 and 8 display, respectively, images with an increase of 30 times of sample 4e (taken from the area located under the support of the asphalt concrete beam) and 4i (taken from the area near the site of specimen breaking). There was apparently a detachment in sample 4e (Figure 7), because there is a gap among the geogrid fiber and the asphalt layer shown by the white arrows.

Sample 4i (Figure 8) appears to be attached more uniformly to the layer of asphalt and its aggregates, especially in the area indicated by the white circle.

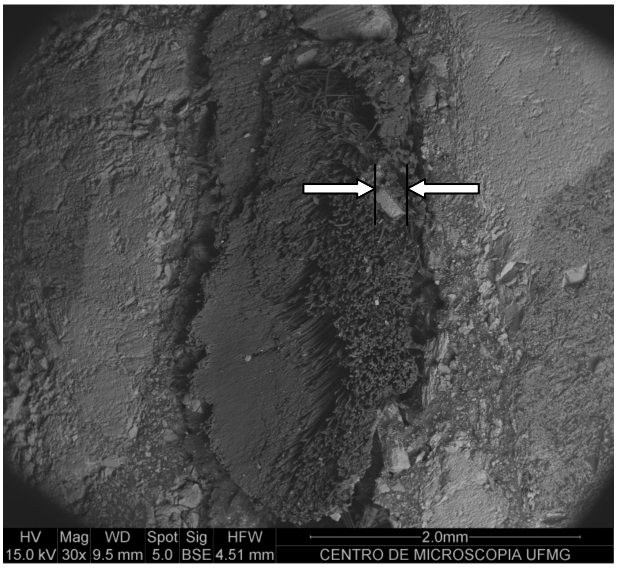

Figure 7: SEM image of sample 4e (30x zoom)

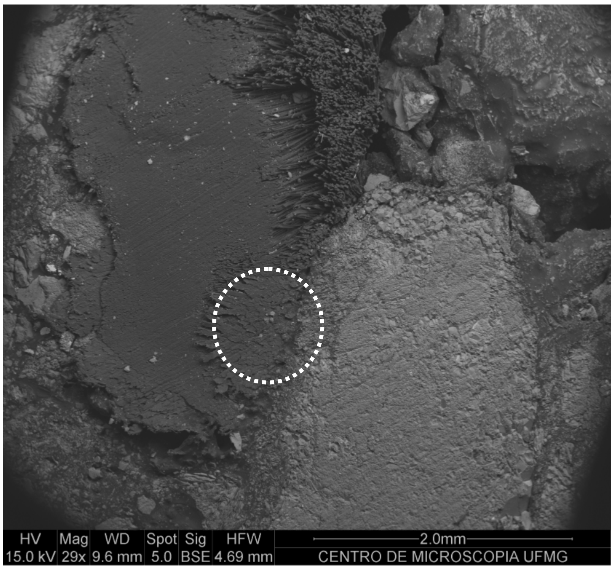

Figure 8: SEM image of sample 4i (30x zoom)

The areas demarked in Figures 7 and 8 were then expanded to show more details of the geosynthetic-asphalt layer interface. Figures 9 and 10 are showing an increase of 150 times of samples 4e and 4i, respectively. It is clear that geogrid fibers shown in sample 4e are not adhered to the asphalt layer while it is possible to see in Figure 10 that fibers are well bonded to an asphalt matrix aggregate.

The fact that a sample taken near the breaking area of the specimen has better adhesion among geogrid fibers and asphalt layer supports the idea that the sample has probably broken during the cutting process.

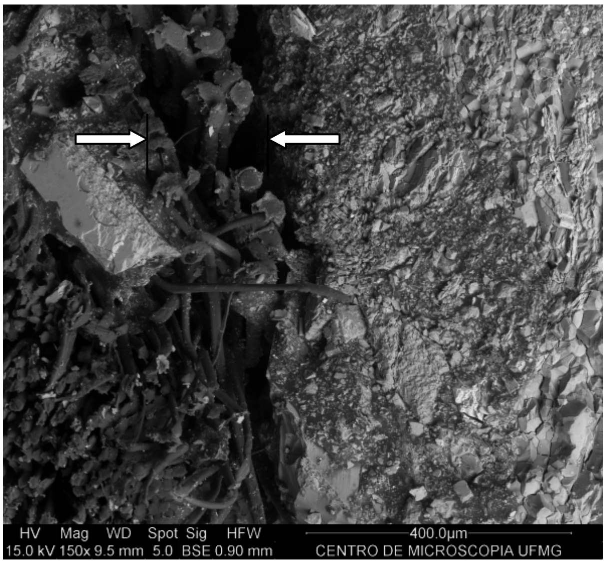

Figure 9: SEM image of sample 4e (150x zoom)

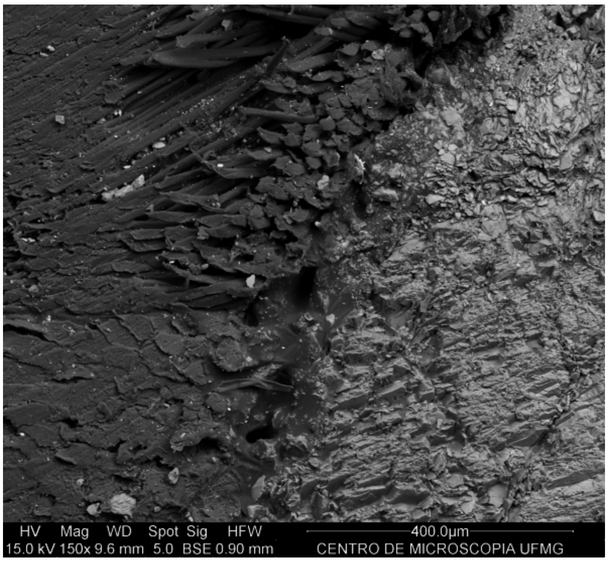

Figure 10: SEM image of sample 4e (150x zoom)

The next sample to be analyzed in this work is sample number 5, which has geotextile reinforcement. Figures 11 and 12 display, respectively, images with an increase of 40 times of sample 5i (taken from the area near the site of specimen breaking) and a 30 times increase image of sample 5e (taken from the area located under the support of the asphalt concrete beam).

The image shown on Figure 11 displays the geosynthetic layer surrounded by a more fragmented asphalt layer, probably due to the proximity of the local breakage of asphalt concrete samples submitted to a bending test prior to this microscopy analysis.

The dashed line in Figure 12 marks the location of the geotextile reinforcement from sample 5. The asphalt layer does not seem as fragmented as shown in sample 5i (Figure 11). In fact, it seems to be well adhered to the reinforcement layer.

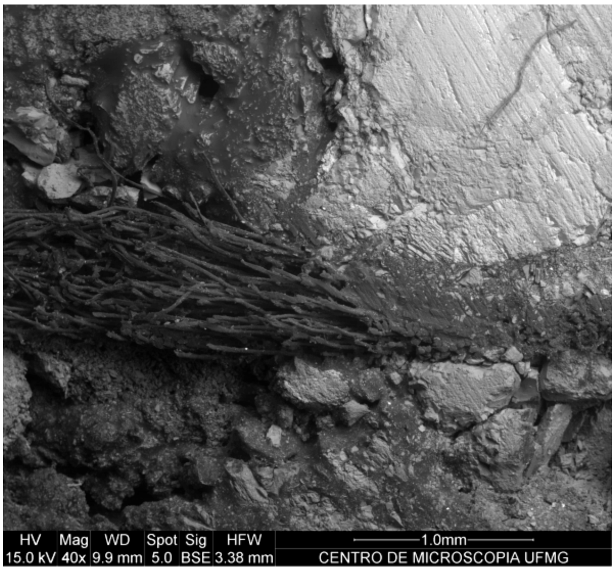

Figure 11: SEM image of sample 5i (40x zoom)

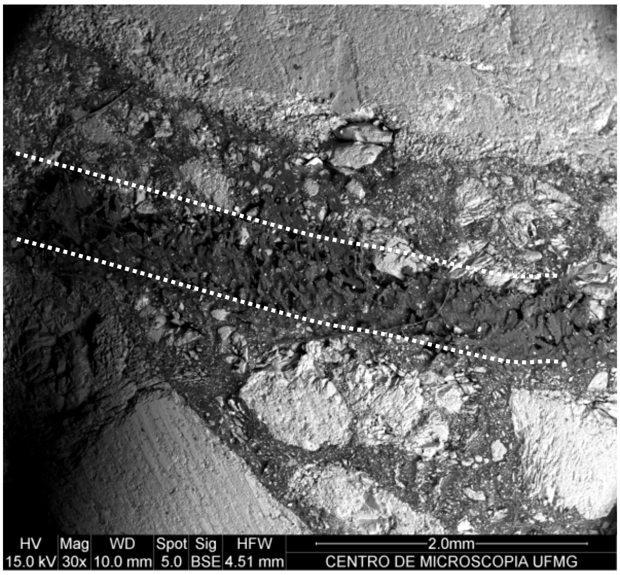

Figure 12: SEM image of sample 5e (30x zoom)

To get more information on geotextile reinforcement, an increase of 150 times is shown on Figures 13 and 14. Figure 13 shows in more detail the porosity of the geotextile fibers and how these are not perfectly coated with asphalt binder. Although geotextile fibers shown in Figure 14 are fully covered with asphalt binder, it is possible to visualize a small gap between the geotextile layer and the asphalt layer, outlined by a dashed line.

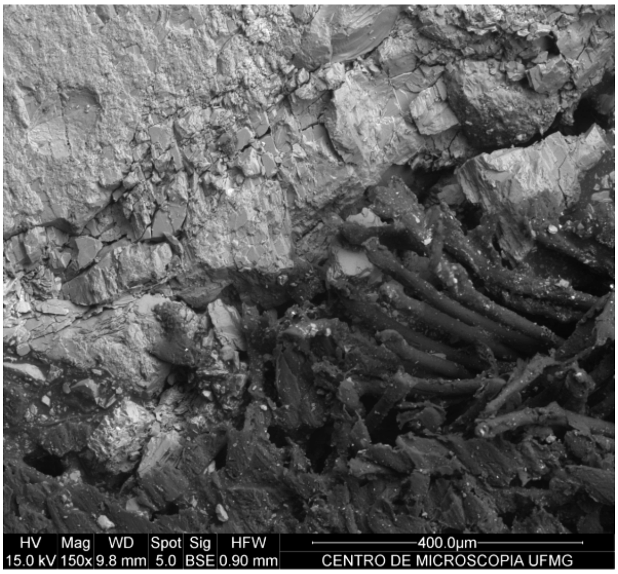

Figure 13: SEM image of sample 5i (150x zoom)

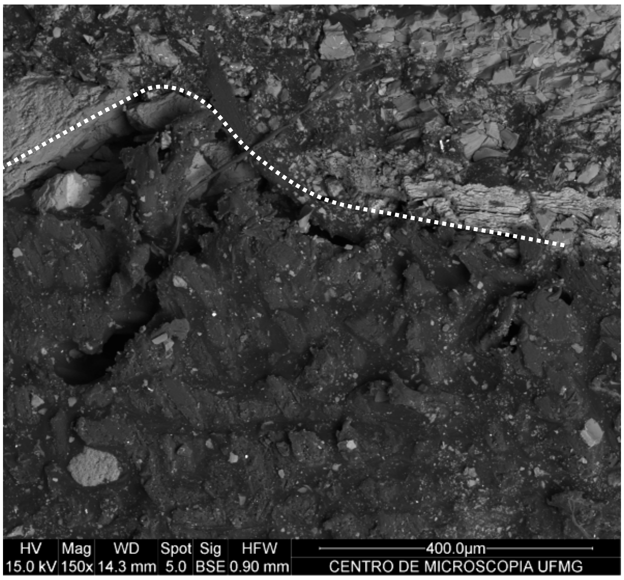

Figure 14: SEM image of sample 5e (150x zoom)

CONCLUSIONS

Sample preparation is the most important step of a microscopy analysis. It is important to obtain a flat surface in order to get high quality samples, mainly when analyzing materials. The cutting process must be done carefully, especially for very heterogeneous materials, such as asphalt concrete that is made of literally glued stones by asphalt binder.

The objective proposed in this work was to develop an appropriate way to prepare samples of asphalt concrete and observe the geosynthetic reinforcement layer with respect to the asphalt matrix. A sample may have been broken during the cutting procedure indicating that the process can be improved to perform further analyzes in other asphalt concrete specimens.

The images obtained via SEM showed that geosynthetic fibers are not always perfectly covered with asphalt binder. Moreover, the reinforcement layer has porosity that can difficult the traffic load distribution, which may be an indication of decreased shear strength in asphalt layers reinforced with geosynthetic

ACKNOWLEDGEMENTS

The authors are indebted to the following institutions: CNPq (Brazilian National Research Council) and Fapemig (Support Foundation of Research of Minas Gerais). They also thank Microscopy Center at UFMG, *Laboratório de Laminação (CPMTC)* from Geosciences Institute at UFMG and *Viatest* for their support on sample preparation. The authors would like to thank the Huesker Company for providing samples of geogrids for research.

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