Laboratory evaluation and reproduction of geogrid in situ damage used in asphalt concrete pavement

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ABSTRACT

Geogrids are used for the rehabilitation of cracked pavements. To ensure an efficient reinforcement, it is required to know the residual mechanical properties of the geogrid after its implementation and compaction of the above asphalt concrete layer and the level of damage of the grid. This paper presents the first results of the national French project SolDuGri dealing with pavement reinforcement by geogrids. In this project, full scale tests have been performed to evaluate the in situ damage of four different types of geogrids in asphalt concrete pavements. Then, after construction, the geogrids have been recovered from different locations on the field sections, where they had been subjected to compaction. These grids have been subjected to direct tension tests in laboratory. Laboratory analyses like scanned asphalt concrete and greogrid surfaces have been performed to evaluate indenter shapes. Different sets of indenters have been made and a laboratory complete study of greogrid indentation tests has been performed with different sets of temperature, indenter shapes and indentation forces. The first conclusions are that the shape of the indenter and the temperature have the main influence on the strength and modulus of the grid which can be compared to in situ recovered grids.

Keywords: glass fiber grids, indentation test, direct tension test

1. INTRODUCTION

Geogrids are generally used for the rehabilitation of cracked pavements (semi-rigid pavements, asphalt pavements and flexible pavements), but nowadays they are also included in new pavements. To ensure an efficient reinforcement, and a reliable design of the pavement incorporating a grid, it is required to know the residual mechanical properties of the geogrid after its implementation and compaction of the above asphalt concrete layer and the level of damage of the grid. This paper present the first results of the national French project SolDuGri dealing with pavement reinforcement by geogrids. In this project, full scale tests have been performed to evaluate the in situ damage of geogrids in asphalt concrete pavements. The tests consisted in building test sections with four different types of geogrids, and two different compacted asphalt concrete layers above. After construction, the geogrids have been recovered from different locations on the field sections, where they had been subjected to compaction only, or also to construction traffic, and their residual mechanical properties have been evaluated in the laboratory. We will present the materials used and the tested sections, then the tension tests on recovered grids. In another way, we try to reproduce in laboratory this in situ damage. For this, we present the first results of laboratory indentation tests whose indenter shapes have been determined from asphalt concrete surface shapes in contact with the grids. To estimate the loss after damage by indentation, the experimental data deduced from ultimate tensile tests were compared to results obtained on new grids without any damage. We can notice that the mechanical properties are affected by the indentation effect, especially the resistance strength that is slightly reduced.

2. MATERIALS USED

2.1 Semi coarse asphalt concrete material

For this test the asphalt concrete material chosen is a standard semi coarse asphalt concrete (SCAC "AC 10 surf 35/50" according to EN 13108-1) designed with the crushed aggregates in the area where the experimentation was to be carried out. The binder is a 35/50 penetration grade bitumen according to EN 12591. The stiffness modulus, measured by two points bending tests, is 12945 MPa at 15°C and 10Hz for the hot mix (160°C).

These asphalt concretes have been used in their usual range of thickness: 5 to 7 cm. The tack coat between the asphalt layers, including the grid impregnation, was a classical cationic rapid setting bitumen emulsion, classified as C69B3 according to EN 13808.

2.2 Glass fiber grids

Four different grids, made of glass fiber coated with two different resins, of different stiffness, were chosen for the study. The first two grids (G1 and G2) had a strength of 20 kN/m for a strain of 1%, and were coated with a soft resin and a stiff resin, respectively. The two other grids (G3 and G4) had a 40 kN/m strength, and different, soft and stiff resins respectively.

3. TESTED SECTIONS

In total, five test sections were built for the Soldugri project on an existing subgrade with a load-bearing capacity higher than 100 MPa (FWD tests). One of these sections, 15 meters long, was devoted to the study of grid damage after construction. This section included the four different types of geogrids (G1, G3, G2 and G4).

A levelled asphalt concrete layer was firstly realized on the existing subgrade. Four SCAC layers, each 5 cm thick were then laid one after the other to constitute the pavement test section (figure 1).

The 20 cm thick pavement structure was chosen because a thick structure was required for other laboratory studies planned in the SolDuGri project (Godard et al., 2017). Void content measurements by a Troxler device on the surface of the 2^{nd} and 4^{th} layers indicated mean void contents of 5.7 % and 5.8 % respectively on sections made of hot mix.

The different geogrids were placed on the surface of the second SCAC layer. To study the effect of different surface conditions on the damage of the geogrids, on one half of the section, the surface of the second SCAC layer was milled, before placing the grids (to simulate the reinforcement of an old pavement – surface B), and the second part was compacted normally, to simulate a new construction (surface A). On both parts, a tack coat with 500 g/m² of residual bitumen was applied, to ensure impregnation of the geogrids. A tack coat with 300 g/m² residual bitumen was applied on the other interfaces. The full scale test sections were built using standard roadworks equipment as used on real construction sites.

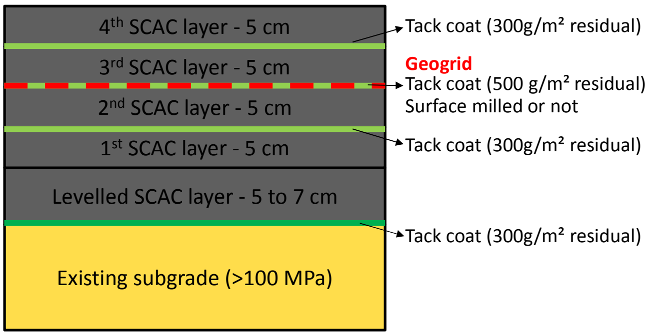

FIGURE 1 Transverse profile of test sections.

For the study of the geogrid damage after construction, a specific procedure of placement of the geogrids was adopted. The four different types of grids were cut in small sections, 72 cm x 72 cm large. After construction, when the pavement was completely cooled, the geogrids were recovered from different locations on the field sections, where they had been subjected to compaction only, or also to construction traffic, by the trucks and by the finisher. Care was taken to minimize the damage of the grids during recovery. Each grid section was located and sawed in a block of about 64×64 cm². Each block was then placed inside a large oven, and heated to 40 °C, for about 5 to 7 hours. The recovered geogrid sections were finally marked, to identify their type and their location on the field section, and sent to the laboratory, for evaluation of their residual mechanical properties.

Although great care was taken for the recovering of the geogrid sections, 100% of the yarns could not be recovered properly without any damage, due to the strong bond between the geogrids and the asphalt concrete layers. Only grids that had been damaged directly by the pavement construction process were considered for laboratory evaluation.

4 TENSION TESTS ON RECOVERED GRIDS

In total, 32 grid sections were placed in the test section, and have been recovered. 27 have been tested till now. Each section was trafficked on more than 50% of its surface by the wheels of the delivery trucks or the metallic caterpillars of the finisher while paving the test section. for Concerning the tension tests, slightly less than 50% of the yarns had been damaged only by the compaction, although a little more than 50% by both compaction and trafficking by the caterpillars or the wheels.

During recovery, the loading received by each grid was carefully identified (see table 1), and three different loading processes were distinguished:

- Grids submitted only to compaction of the upper layers, without any other loading (no loading -NL).

- Grids submitted to compaction and to loading by the wheels of the asphalt truck (tire -T).
- Grids submitted to compaction and loading by the finisher's caterpillars (cat). Due to the narrow asphalt layers, a small finisher with an overall width of the caterpillars of 1.5m was used. This width was smaller than the spacing of the truck wheels. Therefore, the zones loaded by the caterpillars were different from the zones loaded by the tires.

TABLE 1 Number of warp and filling yarns tested, per loading type and per support type (A/B).

GRID	G1 (A/B)	G2 (A/B)	G3 (A/B)	G4 (A/B)
No loading (NL)	51 (32/19)	29 (16/13)	31 (4/27)	25 (4/21)
Tires (T)	51 (27/24)	35 (17/18)	45 (14/31)	35 (12/23)
Caterpillars (C)	21 (7/14)	10 (5/5)	21 (4/17)	7 (0/7)

Each recovered grid was cut into individual warp or filling yarns, which were submitted to tension tests. The yarn samples were 29 cm long, and were tested at 20°C. For each yarn, the secant modulus was determined between the maximum force and 100N (small strain tests were also performed). The strains were measured with the press strain measurement device and a local extensometer for the small strain tests. The same tests have also been performed on new grids, coming from the manufacturer, for comparison (Chazallon et al., 2017) (Gharbi et al., 2017).

Globally, after 361 tension tests, tension tests give the following results: one observes residual strengths varying between 20% and 55% of initial tensile strengths and residual secant moduli at the maximum strength between 68% and 95% of initial secant moduli at the maximum strength.

5. REPRODUCTION OF IN SITU DAMAGE OF GEOGRIDS

In order to reproduce in laboratory, the damage observed on recovered geogrid by compaction and trafficking, the first step has consisted in the accurate analysis of the topography of real asphalt concrete blocks coming from in situ tests sections using numerical microscopy (HIROX RH 2000). Surfaces ($15*15cm^2$) of each asphalt concrete blocks which have been in contact with the geogrid have been observed. Specific peaks have been identified and then geometrically characterized (shape, characteristic lengths such as height, edge length, edge radius, opening angle). Two specific peak geometries are involved for each block surface: conical and V shape.

In figure 2 we have plotted for conical geometries the opening angle of the peak versus the tip curvature radius. Two average values can be extracted from this figure: an average opening angle of 110° and a tip curvature of 0.7 mm. From these two average values we have then designed and manufactured a wide range of conical and V-shape indenters (45 different geometries), with opening angles varying from 90° to 130°, two values of tip radius less than 0,1 mm and 0,7 mm, and for V shape indenters, edge length varying between 1 mm and 14 mm, as depicted in figure 2. The blue, red and green dots represent experimental data, designed conical and V-shape indenters, respectively. After machining, each indenter tip has been controlled using numerical microscope observations (figure 2). The material used for indenters is a hardened Ni-Cr steel to avoid or limit their plastic deformation during indentation tests.

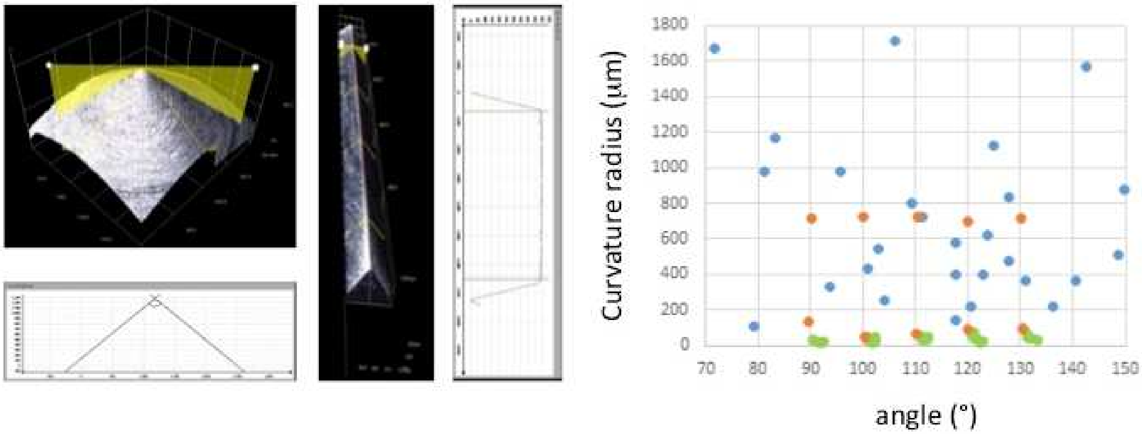

FIGURE 2 Indenter geometries designed for the study (red dot for conical indenter and green dot for the V-shape indenter). The blue dots are measures of the shape surface of top blocks.

To realize indentation tests, an universal Bruker's UMT Tribolab experimental set up has been equipped with a built-in sample holders to fix the tested geogrid yarns (figure 3). Two options are integrated to this sample holder: (i) a heating system to perform indentation test both at room temperature and also at 105°C (±5°C), and (ii) an specific plate in order to control the orientation of the geogrid during indentation tests, especially when using V-shape indenters.

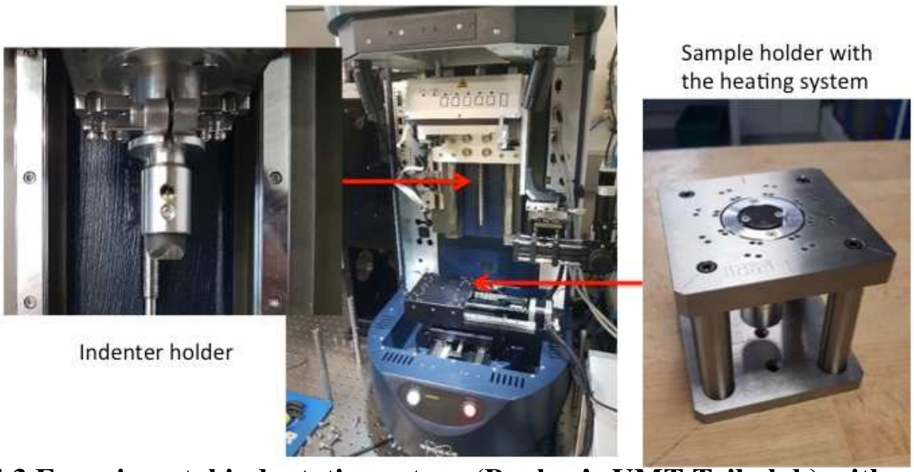

FIGURE 3 Experimental indentation set-up (Bruker's UMT Tribolab) with a focus on the indenter and sample holders.

For all indentation tests, the indenter tip is pushed in contact to the surface of the geogrid yarns. An initial preload of 2 N is applied and then a linear increasing load is imposed up to a maximal value of 900 N at a loading rate of 20 $N.s^{-1}$. After a holding time of 5 seconds, the load is linearly decreased from 900 N to 0 N at an unloading rate of 20 $N.s^{-1}$. Due to the stiffness of the experimental set-up, the measured penetration depth has to be corrected as a function of the normal applied load F_z.

In order to reproduce effects of compaction and trafficking on the mechanical properties of geogrid, damage, we have performed, using two V-shape indenters with an aperture of 90° and with edge length of 6 mm and 1 mm, respectively, one indentation in the middle of 5 new warp yarns G1 at an elevated temperature (110°C) and at two reduced penetration depth (40% and 60% of the thickness of the new geogrid warp yarns). After this indentation, tensile tests have been performed on these indented new geogrid warp yarns. Results about evolution of the mechanical properties (strength and secant modulus at the maximal strength) are presented in table 2 for the 20 indented new warp yarns.

Table 2 Evolution of the tensile strength and the secant modulus after indentation tests on G1 warp yarns, as a function of the tip geometry and the imposed penetration depth.

Indenter geometry	3D-6-90		7D-1-90	
Reduced depth Z^* (%)	40	60	40	60
Residual strength (%)	86	45	88	73
Residual secant modulus (%)	97	73	100	91

We can notice that the mechanical properties are affected by the indentation effect, especially the resistance strength that is slightly reduced. The edge length does not seem to be an important parameter. Tests with larger edge length are in progress.

6. CONCLUSION

The indentation test results are encouraging and the range of the residual strengths and secant moduli are in good agreement with what has been observed from 361 laboratory direct tensile tests performed on recovered in situ grids. These first results prove that laboratory indentation tests whose indenter characteristics are determined from field measurement can be used to estimate the loss of mechanical performances due to in situ trafficking and compaction process. We think this is a good way to characterize and to evaluate the grid quality and that this characterisation has a direct correlation with the in situ good performance of the glass fiber grids which is the consequence. These laboratory tests are to be continued in order to check the influence of the V-shape indenters' aperture and the influence of the indenter shape for all warp and filling yarns of the grids.

7. ACKNOWLEDGEMENT

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8. REFERENCES

NF EN 12591 Décembre 2009, Bitumes et liants bitumineux - Spécifications des bitumes routiers

NF EN 13108-1 Février 2007, Mélanges bitumineux - Spécifications des matériaux - Partie 1 : enrobés bitumineux

NF EN 13808 Août 2013, Bitumes et liants bitumineux - Cadre de spécifications pour les émulsions cationiques de liants bitumineux

C. Chazallon, M. L. Nguyen, P. Hornych, D. Doligez, L. Brissaud, E. Godard, *In situ damage evaluation of geogrid used in asphalt concrete pavements*, Athens, BCRRA 2017, 8 pages, 28-30 Juin 2017

M. Gharbi, M. L. Nguyen, A. Chabot, *Wedge Splitting Characterisation of the bond between asphalt layers reinforced with glass fibre grid*, BCRRA 2017, Athens, 8 pages, 28-30 Juin 2017

E. Godard, C. Chazallon, P. Hornych, A. Chabot, M.L. Nguyen, D. Doligez, H. Pelletier, SolDuGri project : *For sustainable reinforcements of infrastructures with glass fiber grids*, Revue Générale des Routes et de l'Aménagement, 949, October 2017, p 24-33,