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Full scale tests on grid reinforced flexible pavements on the French fatigue carrousel

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Abstract. Grids are increasingly used. They have proved their efficiency, but there is presently no widely accepted design method to predict the long term life of grid reinforced pavements. This paper describes a full scale experiment carried out on the large pavement fatigue carrousel of IFSTTAR, to test simultaneously 3 pavement sections with different types of grids, in comparison with an unreinforced pavement structure. The tests are carried out on typical French low traffic pavement structures. Results up to approximately 800 000 loads are presented. The experiment is planned to continue to load the test sections up to at least 1 million loads. During the experiment, the behaviour of the pavement sections has been followed by deflection and rut depth measurements, and surface distress analysis (observation of cracks and other degradations). As observed on the circular APT for low traffic pavements with thin bituminous layers, crack development was following a transversal orientation. This experiment shows the necessity to better understand the grid behaviour by means of modelling, experiments and use of new measurement techniques as planned in the new Rilem TC-SIB and TC-MCD.

Introduction

Grids are increasingly used, both for reinforcement of existing pavements, and for improving fatigue and reflective cracking resistance of new pavements. These techniques have proved their efficiency, but require attention to achieve a good bonding between the system and the pavement layers during construction. There is presently no widely accepted design method to predict the long term life of grid reinforced pavements. Therefore, full scale tests are needed to evaluate both the construction procedures and the long term performance of these products [1] [2].

This paper describes a full scale experiment carried out on the large pavement fatigue carousel of IFSTTAR in Nantes, to test simultaneously 3 pavement sections with different types of grids, in comparison with an unreinforced pavement structure. The paper presents the construction, instrumentation of the pavements, and the first results of the tests.

Description of the full scale experiment

The objective of the experiment is to test and compare simultaneously the fatigue behaviour of 4 flexible pavement sections, under typical French axle loading (half axles loaded at 6.5 tons with dual wheels), for a total of 1 million load cycles. The pavement fatigue carousel of IFSTTAR is a large scale circular outdoor facility, unique in Europe by its size (120 m length, 6 m width) and loading capabilities (maximum loading speed 100 km/h, loading rate 1 million cycles per month, 4 arms equipped possibly with different wheel configurations, lateral wandering of the loads to reproduce real traffic) [3].

Test sections and material characteristics

The tests are carried out on typical French low traffic pavement structures [4] consisting of an 80 mm thick bituminous wearing course, over a granular subbase (300 mm thick), and a sandy subgrade soil, with a bearing capacity of about 80 MPa. Four structures, each 10 m long, are tested, representing 1/3 of the whole test track. Structures A and B are reinforced with grids incorporating a special film designed to ensure good bonding and replacing the tack coat. Structure C is reinforced with a traditional grid with a tack coat. Structure D is a reference structure without reinforcement. The three different grids are placed in the lower part of the bituminous layer, 2 cm above the interface (Figure 1).

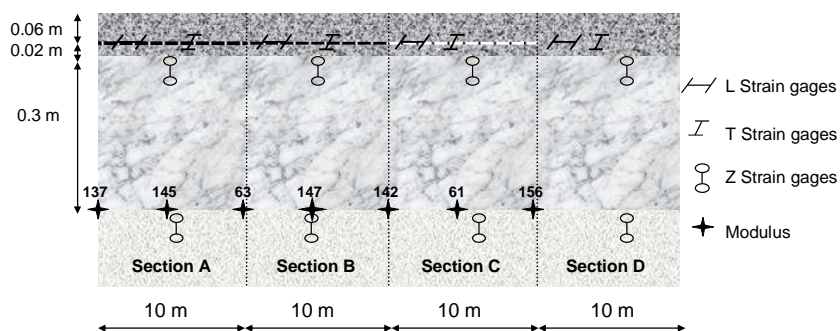


Figure 1. Pavement test sections and implementation of sensors

The bituminous mix is a standard French 0/10 mm wearing course bituminous material, (BBSG 0/10). This material contains 5.5 % of grade 35/50 bitumen. The

mechanical behaviour of this mix was characterised by classical complex modulus and fatigue tests on trapezoidal specimens (EN 12697-31 and EN 12697-24). The specimens had an average void content of 6.2 %. The reference complex modulus of the mix at 15°C and 10Hz is 11320MPa. The Huet Sayegh viscoelastic model parameters obtained for this mix are presented in Table 1. These parameters can be used for viscoelastic pavement structure calculations [5].

Table 1. Material characteristics

E_0 (MPa)	E_{inf} (MPa)	δ	k	h	A_0 (s)	A_1 (s.°C ⁻¹)	A_2 (s.°C ⁻²)
10.0	27180	2.29	0.22	0.65	4.0617	-0.38792	0,0016399

The fatigue law of the mix is approximated by Eqn. (1).

$$\varepsilon/\varepsilon_6 = \left(N/10^6\right)^b \quad (1)$$

With: ε_6 , the strain leading to failure for 1 million loads, and b, the slope of the fatigue curve. Experimentally, the fatigue parameters obtained for the mix are $\varepsilon_6 = 116 \mu\text{strains}$ and $b = -0.206$.

Characteristics of the tested grids

The three grids tested are all a high-strength open fiberglass geogrid custom knitted in a stable construction and coated with a patent-pending elastomeric polymer and self-adhesive glue (Tensile Strength: 100kN/m×100kN/m). The mesh of grid from test section A is half smaller than those from test section B and C (25×25mm²). Grids of the test section A and B contain a patent-pending, highly engineered film designed to replace the need for a tack coat. These two new grids have shown a better behaviour during specific 3 point bending fatigue tests [6].

Construction and instrumentation of the test sections

The pavement structures were built on the existing subgrade of the test track, which is a sand with 10 % fines, sensitive to water. The granular base consisted of 30 cm of 0/31.5 mm unbound granular material (UGM). After construction, this base was covered by a spray seal. A 2 cm thick bituminous layer was first laid and compacted on all 4 sections. This layer cooled rapidly down to about 10 °C (ambient temperature - March 1st, 2011). On sections A and B, the grids were placed without tack coat, due to the adhesive film. On sections C and D (see Figure 2 a-c) a tack coat with 300g/m² of residual bitumen, was applied. Then, longitudinal and transversal strain gauges were put in place (Figure 2.d). The final 6 cm thick bituminous layer was laid on the 4 sections, and compacted successively with a steel drum vibrating roller and a rubber-tyred roller. To ensure

melting of the film attached to grids from section A and B, the bituminous mix was put in place at temperatures above 150°C. After compaction, the average in situ void content of the mix was about 7.0 % (0.8 % more than for the specimens tested in the laboratory). The 4 test sections were instrumented with longitudinal and transversal strain gauges placed on the top of the grids (at 6cm depth – see Figure 2.d); temperature sensors and vertical strain gauges at the top of the UGM layer and of the subgrade (Figure 1).

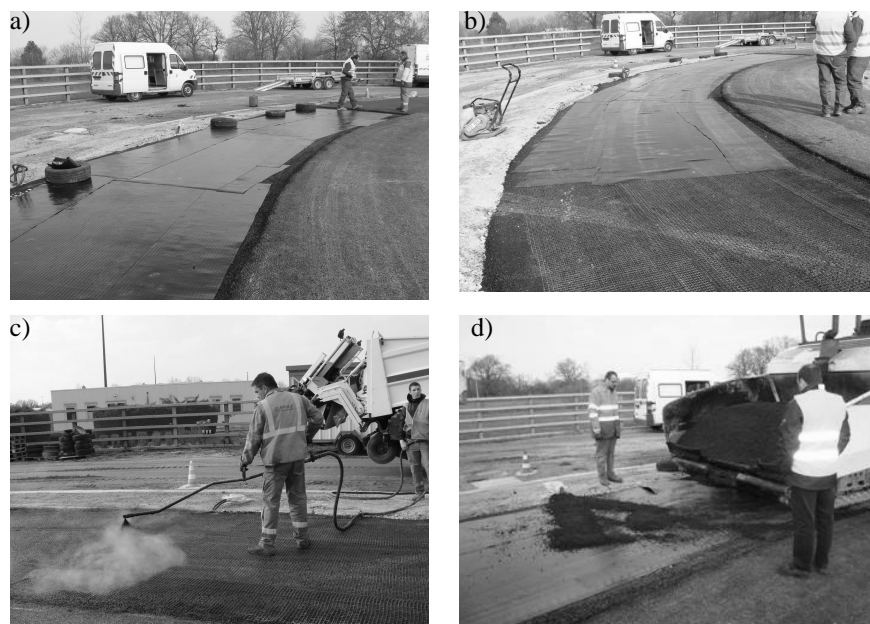


Figure 2. Construction: a) Grids of section A and B ; b) Grids after compaction; c) Tack coat application; d) Placement of strain gauges before overlay.

The circular shape of the test sections required to cut the grids in relatively narrow bands, 5 m long by 1.5 m wide. To cover the test section, one 1.5 m wide band was placed in the centre of the wheelpath, and then two smaller bands on each side (see figure 2 a). Due to this layout, some construction problems occurred on section A, and potentially on section B, during the laying and compaction of the bituminous overlay, and the results obtained on section A will not be presented. Thorough investigations will be made on section B after completion of the testing to verify the state of the grid and of the interface.

Initial measurements and test programme

The modulus of the subgrade has been measured with dynamic plate load test and results are shown on Figure 1. These moduli have been measured during

construction, during a rainy period, and it is probably the reason of their variability. After construction, drainage has taken place, and the bearing capacity has become more homogeneous. Controls after construction have indicated an average thickness of the bituminous layer of 70 mm, instead of 80 mm. The end of section D is thinner than the other sections, because it is the end of the construction zone, and the transition with another existing pavement structure, which makes the control of the thickness more difficult.

The loading programme started in April 2011. Until September 2011, approximately 800 000 loads have been applied. During the experiment, loading has been stopped approximately every 100 000 cycles to perform various distress measurements. Response of internal transducers has also been recorded regularly. The ambient temperature conditions were practically constant throughout the tests, with daily temperatures in the range 10 to 28°C (mild summer). The rainfall on the test site is presented on Figure 3. It can be noticed that around 600 000 cycles, the rainfall level was 2.5 higher than during the other periods.

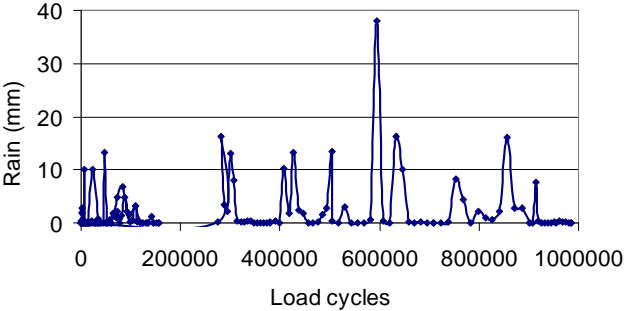


Figure 3. Rainfall measurements on the test site

The four arms of the fatigue carousel have been equipped with standard dual wheels, loaded at 65 kN (standard French equivalent axle load). The tyres used are Dunlop 1200 R20 SP321, inflated at 850 kPa (Figure 4). The loading speed was 6 rounds/minute (43 km/h). Its lateral wandering was +/-52.5 cm. Between 50000 and 150000 load cycles, one arm was also equipped with a wide single tyre; loaded at 40 or 50 kN, in order to compare strain distributions under single and dual tyres. Measurements under the wide single tyre will not be discussed here.

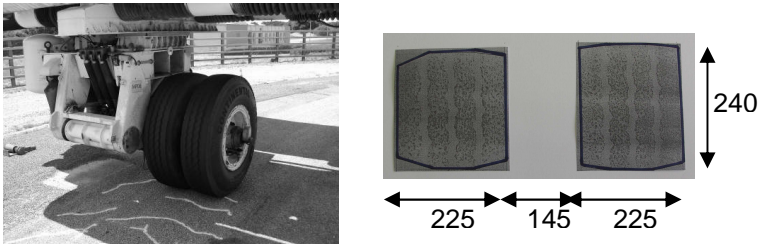


Figure 4. Dual wheel load and its dimensions in mm

First results

Deflection measurements:

Deflection measurement between the two wheels was performed every 3 meters using a Benkelman beam, under the 65 kN load at about 2 km/h. For temperatures varying between 20 and 28°C, Figure 5 shows that up to 381 000 load cycles, the mean deflection levels were close to 70 mm/100 on the three sections with some scatter which may be due to temperature variations. No significant difference in deflection was observed between the reinforced sections (B, C) and the unreinforced section (D). After 537 000 load cycles, the mean deflection on section B increased to 83 mm/100. On sections C and D, the deflection level remained practically constant up to 813 000 loads. There seems to be some relationship between deflection levels and pavement cracking. On section B, the first cracks appeared after 600 000 cycles, and simultaneously, an increase of the deflection was observed. On sections C and D, where very little cracking was observed, the deflections remained constant.

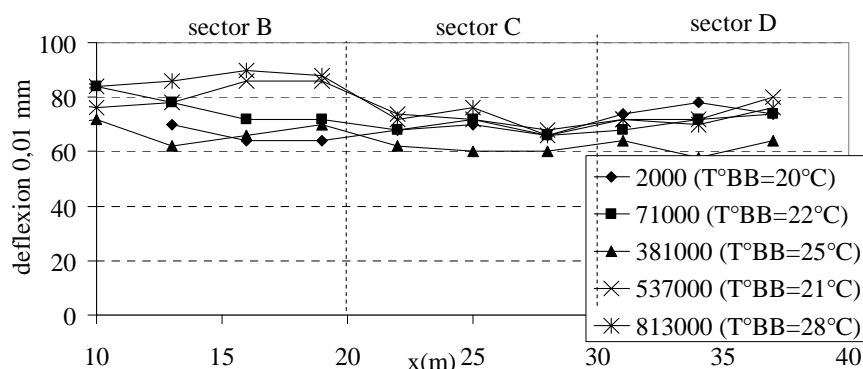


Figure 5. Results of deflection measurements on the 3 sections

Rut depth measurements

Due to the lateral wandering of the loads, the width of the circulated area is approximately 1.6 m. The transversal profile of the pavement is measured using a 2 meters long ruler, every 3 meters. For each measurement point, the maximum rut depth is determined as the maximum vertical distance between the ruler and the pavement surface. Maximum rut depths measured on the 3 sections, at different load levels are presented on Figure 5. These measurements indicate that, at the beginning, sector B presents a lower rut depth than the other sections, until about 600000 cycles. At this stage, heavy rainfall occurred (Figure 3), and this may explain an increase of the rate of rutting on section B. At, 600000 cycles, section B already presented some cracks (Figure 6), which allowed water to infiltrate in the pavement foundation contrary to the other sections which still presented no

damage. On sections C and D, the rut depths are very similar. After 600 000 cycles, the evolution of rutting is the same on all 3 sections, with an average final rut depth of 14.3 mm.

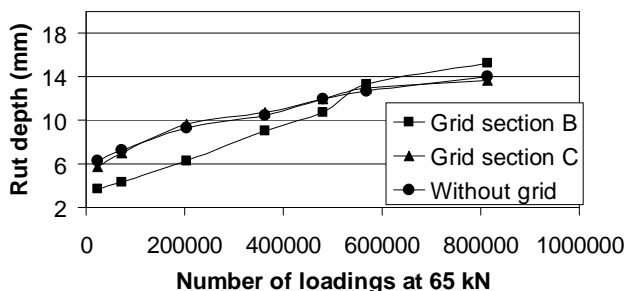


Figure 6. Rut depth evolution on the 3 sections

Crack monitoring

The first cracks were observed on section B, after about 600 000 load cycles, and then on section D after 800 000 load cycles. Section C presents no cracking up to now. Crack patterns were very similar on sections B and D: first, very fine isolated transversal cracks appeared. Then, under traffic, these cracks started to open, and fines started to come out. Other thin transversal cracks developed nearby. The transversal orientation of the cracks is typical of fatigue cracking observed on the carousel, for pavements with thin bituminous layers [7]. Figure 7 presents the evolution of the extent of cracking, as a function of the level of traffic. It corresponds to the percentage of the length of the pavement affected by cracks (for a transversal crack, the affected length is considered, arbitrarily, to be 500 mm).

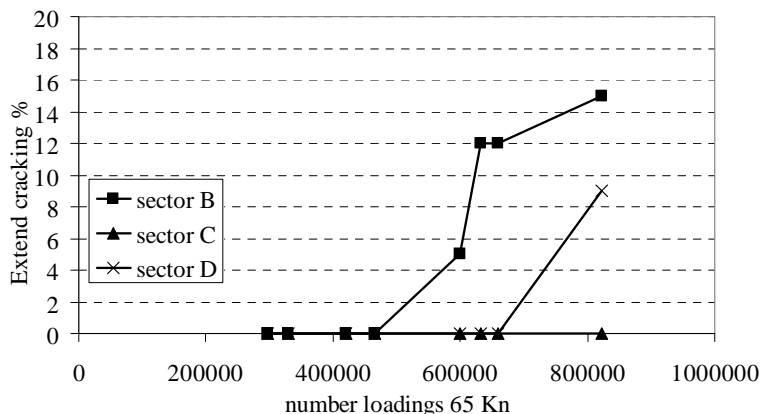


Figure 7. Extent of cracking, in percent, on the 3 sections

Strain measurements

Longitudinal and transversal strain measurements, for a temperature of about 20°C (at 40 mm depth) and a loading speed of 43km/h, are presented on Figure 8. On section C, no measurements are available because the strain gauges were broken during the compaction. The sensors were located in the middle of the wheel path, at position $y = 0$ mm, and their measurements were recorded for different lateral positions of the dual wheels, varying between -550 and + 550 mm. Positions $y = -210$ mm, and + 210 mm correspond to the situation when the centre of one wheel is located on the top of the sensors (Figure 4).

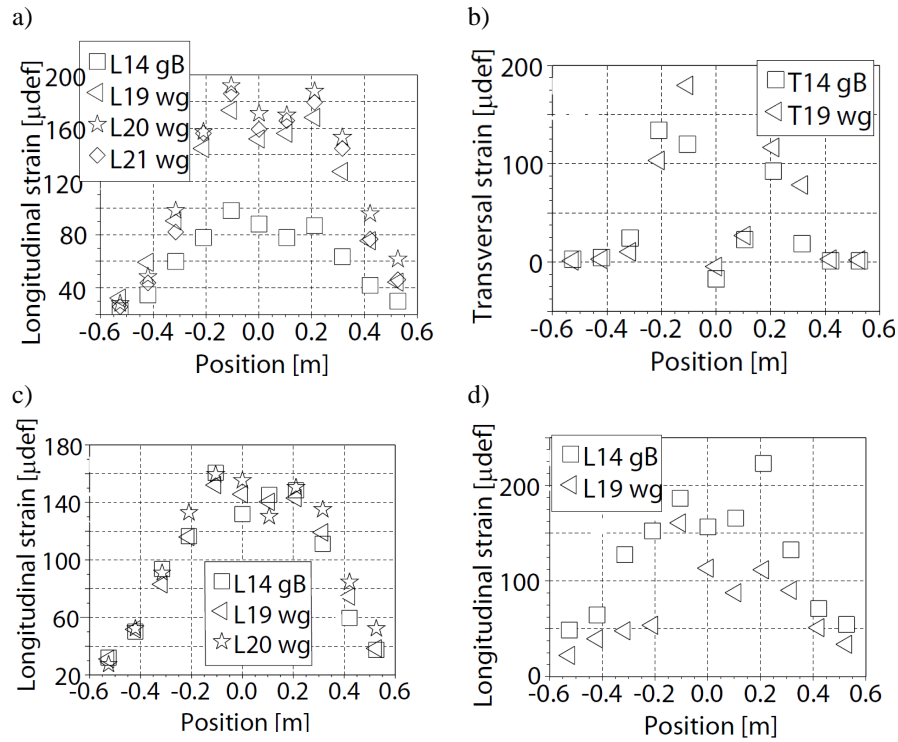


Figure 8. Maximum longitudinal ϵ_L and transversal ϵ_T strains measured:

- a) and b): ϵ_L and ϵ_T at 12000 cycles, 19.2°C; c) ϵ_L at 152000 cycles, 21.1°C;
d) ϵ_L at 676000 cycles, 21.6°C

At the beginning of the test, at 12000 cycles, (Figure 8 a-b), longitudinal strains measured on section B (gB) (gauge L14) are around half the longitudinal strains measured on section D without grid (wg) (gauges L19, L20, L21). For transversal strains, there is no clear difference between the measurements on section B (gauge T14) and on section D without grid (gauge T19). On section D, longitudinal and

transversal strains are of the same level of magnitude. On the reinforced section, longitudinal strains are lower.

At 152000 (Figure 8.c), the longitudinal strains on sections B have increased and they are similar to those on section D without grid. At 676000 cycles (Figure 8 d), the longitudinal strains measured on section B are greater than those measured on section D. The same trend is observed for the deflection (Figure 5), which is higher on section B, after 530 000 cycles, than on section D. This increase of the strains and deflection can be due to the development of cracks as shown on Figure 7. For transversal strains, no significant evolution is observed at the different load levels, and the response of sections B and D remains similar.

Elastic back calculations have been made to estimate the moduli of the unbound granular material and of the soil from deflection measurements. The ALIZE design software used is based on Burmister's multi-layer linear elastic model [8]. Simulations have shown that the soil modulus is 80MPa. According to the French pavement design method, the modulus of the unbound granular materials has been taken equal to 200 MPa (modulus of the soil multiplied by 2.5). The longitudinal strains ϵ_L and transversal strains ϵ_T calculated under the centre of the dual wheel axle (position $y = 0$) are respectively $\epsilon_L = 89\mu\text{def}$ and $\epsilon_T = 15\mu\text{def}$. These results are of the same order of magnitude as the strains measured at the start of the experiment, on section B. After a significant level of traffic, the measured strains increased on section B, indicating a probable deterioration of this section, due to traffic.

Conclusion

In this experiment, several different grids were tested as reinforcement of new pavements, with relatively thin bituminous layers (80 mm); the objective was to compare the behaviour of the reinforced sections, in comparison with a reference section without grid.

During construction, there were some difficulties to place the grids on the circular test track, which obliged to cut the grids in relatively narrow bands. Due to this layout, some construction problems, leading possibly to debonding of the reinforced layer, occurred on section B.

Concerning the behaviour of the pavements, it was found that:

- Cracking appeared first on section B after a rainy period, after around 60000 cycles, and section D (without grid) after 800 000 cycles. Section C presents no cracking up to now. The worse performance of section B may be related with the construction problems.
- Rutting was somewhat lower on section B up to 600 000 cycles, and after that, the levels of rutting were very similar on the 3 sections;
- Strain measurements indicated lower longitudinal strains on the reinforced sections at the beginning of the experiment, but this difference disappeared after about 150 000 cycles, leading to similar deformations on all sections.

As the experiment is not finished, it is only possible to conclude that a positive effect of the grids on the resistance to cracking is observed on one section (C). It is planned to continue the loading until at least 1 million loads, in order to attain higher levels of damage, and confirm the differences between the 3 tested sections. At the end of the experiment, detailed investigations (cores, trenches, FWD) will be made to understand the possible cracking scenarios, and explain the behaviour of section B in particular, which may be due to debonding problems.

These observations, as those reported elsewhere [9-10-11], will also be completed by means of additional modelling, and non destructive testing, in relation with the two new Rilem Technical committees TC-SIB (TG4 – Advanced interface Testing of Geogrids in Asphalt Pavements) and TC MCD (Mechanisms of Cracking and Debonding in asphalt and composite pavements) in TG 3 on “Advanced Measurement Systems for Crack Characterization”

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