Maintenance and Rehabilitation

FWD test-site monitoring of road pavement assessment with glass and carbon grids reinforcement

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Abstract

A growing need for an effective and sustainable resource management, whether economic or environmental, is an important facilitator for the development of new reinforcement and rehabilitation techniques of pavements. There are several solutions usually adopted for propagation delay and hence the surface appearance at the reinforcing layer of cracks from the underlying layers, namely impregnated geotextile, pre-bituminized grids (glass fiber and carbon fiber grids), and porous asphalt mixtures, among others, being very important the development and application of methods for assessing the strength of the bond between layers. The techniques used for the application of two-dimensional surface elements between the existing layer and the reinforced layer, are usually referred to as anti-crack interface. The primary function of these elements is to absorb the stress concentration generated at the interface between existing layers and the reinforcement, avoiding cracks propagation to upper layers. A comparative study, developed at the laboratory and in situ, regarding the behavior of the interface between the wearing course and the underlying layer by applying different reinforcement elements, has been developed in order to evaluate its influence on the pavement performance. This paper presents and discusses the major FWD results obtained from in situ tests performed under different climatic conditions, in order to assess the performance of a test-site performed with glass and carbon fibers grids applied to the reinforcement of the road pavement.

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1. INTRODUCTION

The functional and structural characteristics of the rehabilitation of flexible pavements have as major goal the recovery of their properties, either by adding new asphalt layers (reinforcement) or by removing the layers that are compromised and laying new asphalt layers, seeking to increase load capacity, performance characteristics and the life cycle of the pavements. In order to increase durability of pavements it is important to understand and improve the mechanical performance of the interface layers that are submitted to several normal and shear stresses [1].

The bonding between asphalt layers assumes a key aspect in pavement performance since a poor interlayer bonding can lead to major pavement distresses, namely premature fatigue, top down cracking, potholes, and surface layer delamination. However, it is considered that the actual causes of poor bonding have not yet been completely identified and understood. One of the most common distresses due to poor interlayer bonding is slippage failure, which usually occurs after the passage of heavy vehicles especially in places where tangential actions are important [2].

Several authors consider that the major causes for a poor interlayer bonding of asphalt pavement layers is conditioned by many circumstances, such as: type of base course material; low compaction of base course or subbase course or subgrade; segregation of base course; type of bitumen of the wearing course; size of aggregates used in the asphalt mixtures and type of asphalt mixtures and bitumen; excessive or poor tack-coat application and type of construction technology used; as well as the climate conditions during pavement construction and the water flow between layers [1 - 3].

The two-dimensional surface elements used between the existing asphalt cracked layer and the upper reinforcement asphalt layer are usually referred to as anti-crack interfaces. The main purpose of these elements is to absorb the stress concentration generated at the top of the cracked layer, near the interface. Several solutions are usually adopted to delay propagation and hence retard the appearance of cracks at the surface of the upper reinforcing layer, namely pre-bituminised grids (glass fibre and/or carbon fibre grids), impregnated geotextiles and porous asphalt mixtures, among others. Therefore, the development and application of methods for assessing the strength of the bond between layers and the final pavement structure are very important [4].

The application of different reinforcement solutions on a test-site, under real climatic and traffic solicitations, makes it possible to study the behaviour of adopted solutions. This paper addresses some results of a study developed to assess the performance of a test-site accomplished with glass and carbon fibre grids in the rehabilitation of a national road pavement. Several in situ load testing campaigns with the Falling Weight Deflectometer (FWD) were performed in order to evaluate and compare the three interlayer solutions: with glass grid, carbon grid or without grid, as reference condition.

2. MATERIALS AND METHODS

A study was performed on a test-site built on a national road pavement. The aim was to carry out a comparative analysis of the behaviour of the interface between the top asphalt layer and the underlying asphalt layer using different reinforcement elements, with a view to evaluate their influence on the pavement performance.

Two different types of pre-bituminised grids were selected: a pre-bituminised carbon grid and a pre-bituminised glass grid. A third pavement structure without any grid was also tested, as a reference condition (Table 1).

The bearing capacity of the experimental test-site sections was evaluated by loading tests performed by the Falling Weight Deflectometer (FWD). The tests were carried out on the wearing course of the track every 10 m in the area between the wheel's path. Figure 1 shows the location of the load tests as well as the structure of the tested pavement.

Three FWD load test campaigns were carried out in September 2015, still during pavement rehabilitation, and in March and September 2016, after opening the pavement to traffic. A fourth campaign was performed in September 2017, about one-year after the beginning of traffic circulation.

During FWD load tests, the air and pavement surface temperatures were also measured. The latter was measured using an infrared thermometer installed on the test equipment. Measurements of the pavement temperature at a depth of 2.5 cm were also performed.

Table 1. Studied solutions

	Test-site		
	Test section 1	**Test section 2**	**Test section 3**
Top layers	Wearing course - AC 14 surf 35/50		
	Base course - AC 20 base 35/50* envelope A with 20% RAP		
Pre-bituminized grid	***Glass grid***	***Carbon grid***	***No grid***
Underlying layer	Existing partially milled cracked asphalt layer		
Emulsion type	Termoadhesive bituminous emulsion from bitumen asphalt, cationic quick breaking, containing polymers (C60BP4**)		
Application dosage (g/m²)	450		

*- According to EN 13108-1; **- According to EN13808; RAP – Reclaimed Asphalt

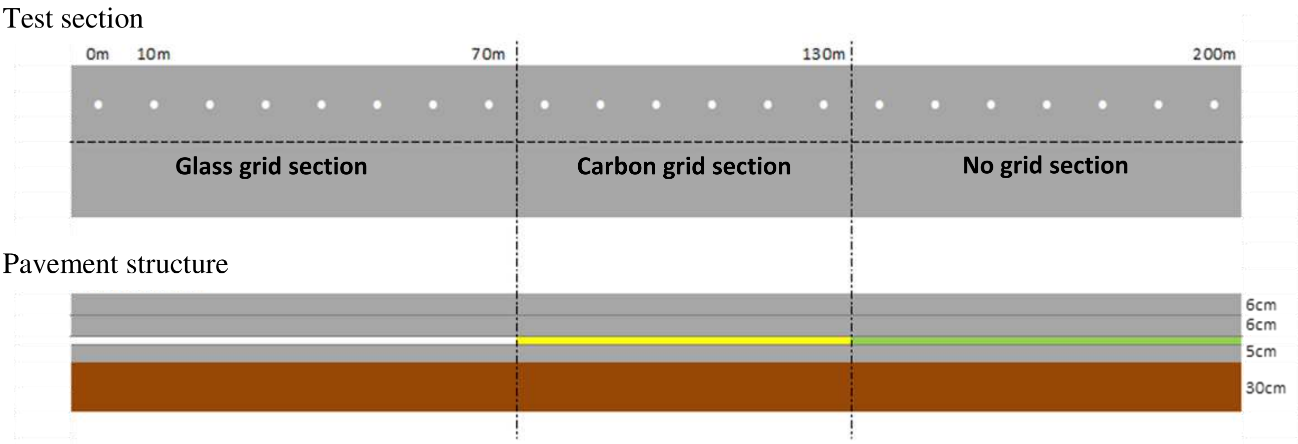

Figure 1: Test-site pavement structures

The Falling Weight Deflectometer (FWD) load test consists of applying to the pavement surface a force generated by the fall of a mass from a given height onto a set of shock absorbers and measuring the resulting deflections at the surface.

Deflections corresponding to an impact load of 65 kN, applied in a circular plate of 0,45 m diameter, were measured for the following distances, in centimetres, from the centre of the circular load area to the geophones position: 0 (D0), 30 (D30), 45 (D45), 60 (D60), 90 (D90), 120 (D120), 150 (D150), 180 (D180) and 210 (D210).

During the above tests, some slight variations in the applied peak force for a given drop height were identified. These variations can be associated with the deformability characteristics of tested materials, the existence of friction in the falling mass guidance system and with the deformability variation of the shock absorbers with temperature. In order to compensate for these variations, the measured deflections were normalized.

Figure 2 shows FWD equipment in operation at the experimental test section.

Figure 2: FWD equipment in operation

3. RESULTS AND DISCUSSION

Figures 3 to 5 present the normalized deflections obtained from FWD load tests performed on the three test sections, respectively: in March 2016, after a period of greater precipitation that usually occurs in winter; in September 2016, after the summer period of higher temperatures and less rainfall; and in September 2017, after about one year of traffic circulation.

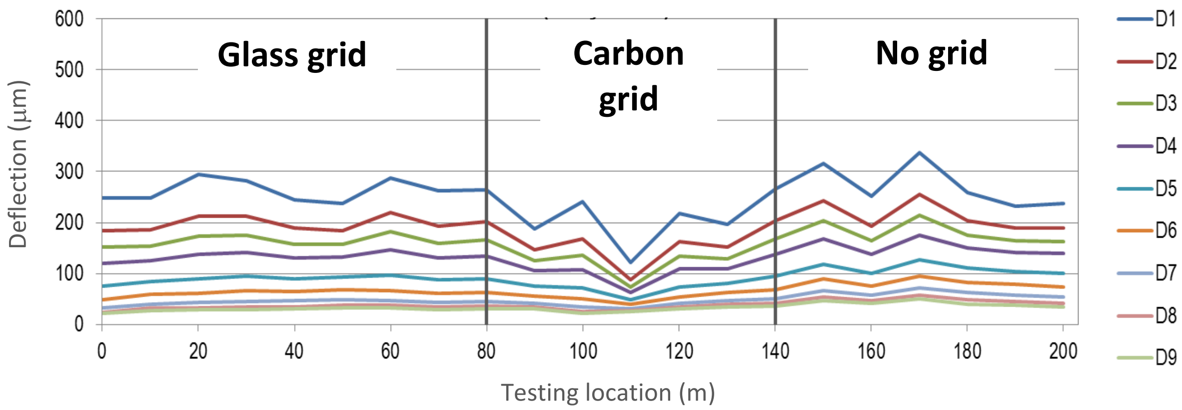

Figure 3: Normalized deflections – March 2016 (after traffic circulation opening)

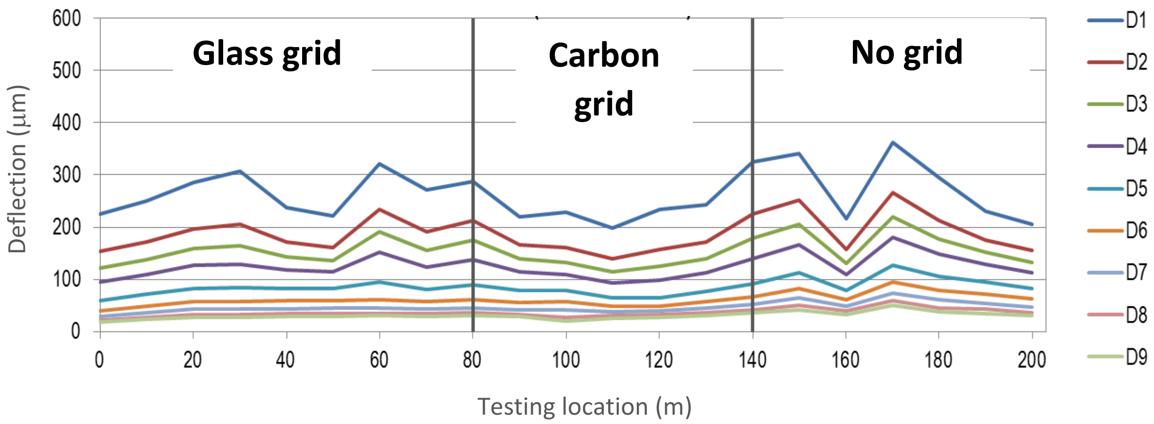

Figure 4: Normalized deflections – September 2016 (after traffic circulation opening)

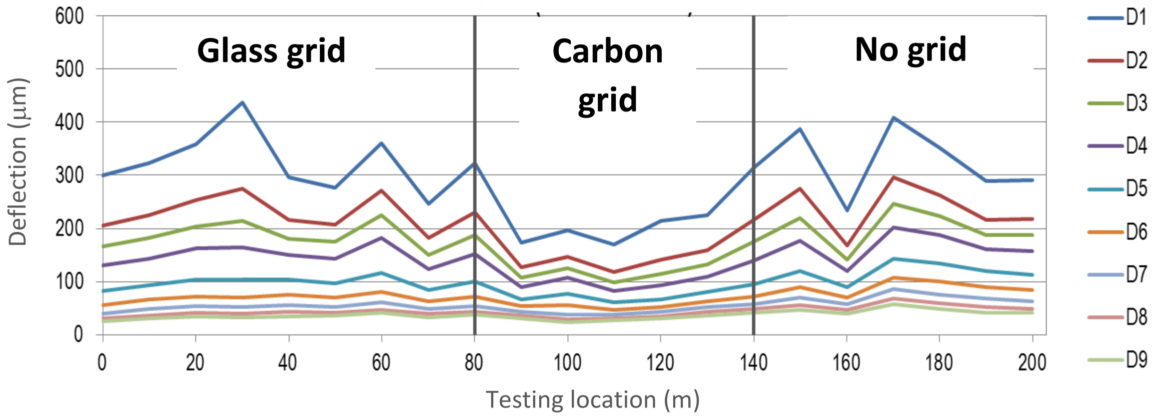

Figure 5: Normalized deflections – September 2017 (about one-year traffic circulation opening)

From the analysis of the deflections shown in Figure 3 to Figure 5, it is observed that in general, the highest normalized deflections occur in the section without grid, being less than 400 µm. An anomalous point is still considered to exist, at 160 m from the beginning of the experimental sections. This point was identified throughout the three test campaign deflections and was different from those observed in the adjacent locations, which may indicate the presence of a more rigid buried structure.

In the section where the glass grid was applied, the deflections were less than 300 µm, in March 2016 campaign. In September 2016 and 2017 campaigns, an evolution in the deflection values was observed for the points located at 30 m and 60 m. However, no significant difference was observed between the deflections measured in March and September 2016 and in September 2017 campaigns, considering the whole test section with grid glass.

In the test section where the carbon grid was applied the normalized deflections were also below 300 µm, for all campaigns. No significant difference was observed between the deflections measured in March and September 2016 campaigns. The September 2017 campaign showed a better behaviour of this test section. It is considered that there is a greater constancy of the pavement structural behaviour between 90 m and 130 m, since the other locations are assumed to coincide with limit zones, which corresponds to the change in the interface conditions.

During the FWD testing campaign performed in September 2017, a visual inspection of the test-site pavement surface was also carried out and no surface cracking or any other pathology was identified.

Figure 6 presents the deformability modulus of the new asphalt layer overlying the interface, which was obtained from the back-analysis of the FWD tests for the load tests. In the present study, given the number of tests performed for the three situations under analysis - with carbon grid, glass grid and no grid - all points where deflections were measured were considered for analysis. Figure 7 presents the deformability modulus of the asphalt layer underlying the interface, corresponding to the old pavement milled asphalt layer.

Regarding the foundation of the pavement under study, a subdivision into two layers was considered: a surface layer of which the thickness was considered to be 1.50 m and a deeper layer, semi-infinite and with a greater deformability modulus than the first one. For the Poisson coefficients of the pavement layers, the value 0.35 was adopted, which was considered to be typical for the constituent materials.

Since the FWD load tests were carried out during daytime, it was further assumed that there were thermal gradients within the pavement asphalt layers, considering that the average layer temperature was the value obtained at half the thickness of the layer.

The calculation temperature was determined on basis of the values of the monthly average air temperature for the experimental test section, and the calculation value obtained for the annual air temperature in this region was equal to 12.6ºC (March 2016), 24.5ºC (September 2016) and 25.0ºC (September 2017). This air temperature corresponds to a calculation temperature of the bituminous layers in the order of 16.5ºC (March 2016), 25.2ºC (September 2016) and 24.3ºC (September 2017), respectively, by taking into account the thickness of the layers.

The correction of the deformability modules of the bituminous layers for the calculation temperature was performed considering the following expression [5]:

$$E_t^{MB} = (1{,}635 - 0{,}0317 \times t_{med}) \times E_{20°C}^{MB} \qquad (1)$$

Et^{MB} – Asphalt modulus (MPa);

t_{med} – Asphalt average temperature (ºC);

$E_{20°CB}^{MB}$ – Asphalt modulus for the reference temperature of 20°C (MPa).

So, since the deformability modules calculated by back-analysis refer to the conditions in which the FWD load tests were performed, which are not necessarily the representative conditions of the structural behaviour of the pavements throughout the year, some corrections were necessary. In fact, the deformability modules of asphalt mixtures vary considerably with the temperature at which these layers are found. Thus, the estimated modules for asphalt layers were corrected to take into account the calculation temperature of these layers [6].

No corrections were done to take into account the effect of water conditions on the behaviour of the foundation.

Pavement layers consisting of the same type of material, either asphalt or granular materials, were considered as one layer in the adopted structural behaviour models, since the latter are multilayer models with an elastic linear behaviour.

However, and given the presence of an interface in the experimental test sections with the application of a grid, the asphalt layers respectively above and below the grid and were considered separately.

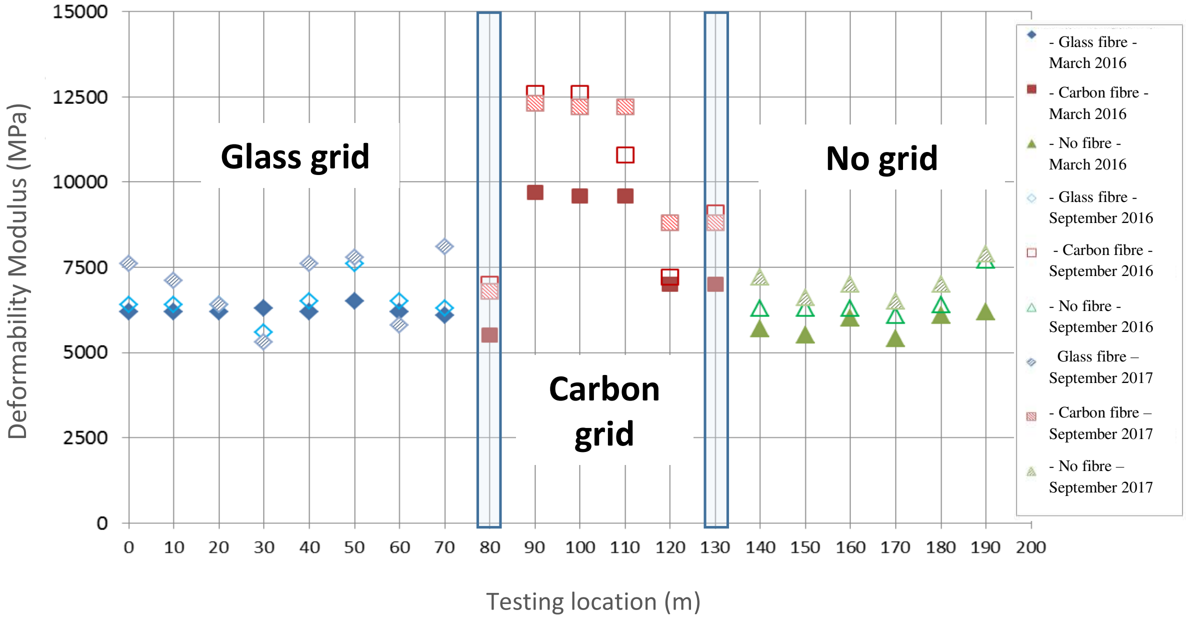

Figure 6: Stiffness modulus of new overlaying asphalt layers

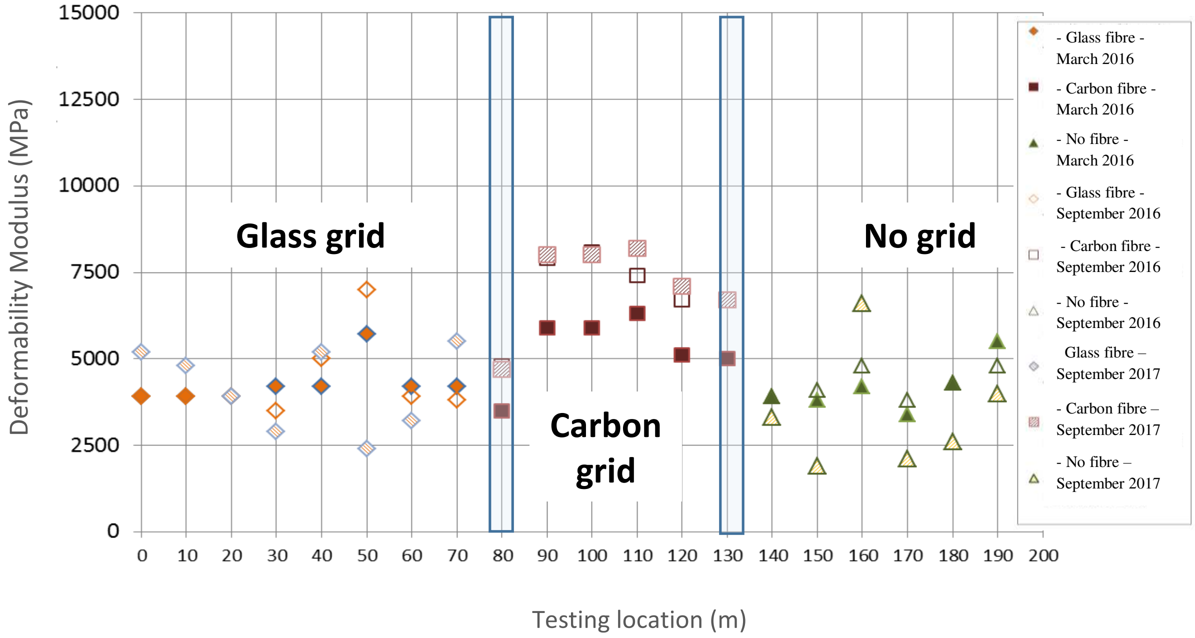

Figure 7: Stiffness modulus of old asphalt milled underlying layers

As refers to the new asphalt layers overlying the glass grid and on basis of the analysis of results from FWD load tests, it is observed that the values obtained in the area where the grid was applied are of the same order of magnitude as those observed on the test section with no reinforcement grid.

The average corrected deformability modulus of the overlying layer of the glass grid, obtained in September 2017 campaign, corresponded to about 7000 MPa, by considering that it corresponds to a layer with good integrity due to the new layer. For the test section without reinforcement application, an average corrected deformability modulus of the overlying bituminous layer of about 7000 MPa was also obtained. For the existing and milled glass grid underlay, in September 2017, the average deformability modules obtained were greater than 4500 MPa, which indicates, as expected, the occurrence of some deterioration of the layer due to it being under rehabilitation.

The results obtained are considered to be in line with recent studies [7-8] about the application and impact of glass grids on pavement reinforcement, with a view to delay crack propagation. The true-scale laboratory tests performed to evaluate the mechanical behaviour of the interface showed a significant improvement in the service life of the reinforced sections. In these studies, the glass grid was applied to new pavements, with better fatigue behaviour, and without significant impact on deflection levels and on permanent deformation behaviour.

Regarding the results obtained from the load tests with FWD, for the asphalt layers overlying the carbon grid, the values obtained in the application area (between 90 m and 130 m) have generally shown less variability when compared to the other tested sections. It is noted that in the transition zones between the various interface conditions (80 m and 140 m), as well as in the experimental stretch limit (0 m and 200 m), the pavement behaviour does not clearly reflect the existing conditions. Thus, a minimum length of application of the grids must be implemented to optimize their performance behaviour.

The average corrected deformability modulus of the layer overlying the carbon grid, obtained in September 2017 campaign, was about 10200 MPa, by taking into account that it corresponds to a layer with good integrity. This behaviour reflects the contribution of the reinforcement grid applied. The maximum values for this type of asphalt layer, obtained in FWD load tests, were about 8000 MPa, [9]. Furthermore, reference must be made to the fact that, in all the three test campaigns, a constant order of magnitude was observed for the values of the modules obtained in the section with application of the carbon grid.

An average corrected deformability modulus of the overlying bituminous layer of about 7000 MPa was obtained for the area without reinforcement grid application.

As regards the layer underlying the existing and partially milled carbon grid, an average deformability modulus of over 7200 MPa was obtained in the September 2017 campaign, although this is a layer with some deterioration. It has a higher module due to the confinement transmitted by the presence of the carbon grid associated with the overlying layer.

4. FINAL CONSIDERATIONS

This paper describes a research study performed by experimental true-scale tests, which consisted of the evaluation of the structural response of a road pavement with three different interlayers solutions by in-situ loading test series performed by FWD, with the application of glass grid, carbon grid and without grid, as the reference test section.

The results of the impact deflectometer (FWD) load tests performed on the test section with the glass grid presented deformability modules of the same order of magnitude as the one observed on the test section without incorporation of reinforcement (no grid). This made it possible to conclude that the introduction of an interface did not disturb the structural behaviour of the rehabilitated pavement.

The analysis of the results of the impact deflectometer (FWD) load tests performed on the test section constructed with the introduction of the carbon grid demonstrated that the structural behaviour had greater homogeneity, and presented some improvement after one year of traffic circulation. Taking into consideration the deformability values obtained at the limits of the test section, it is recommended that a minimum application length of the carbon fiber grid should be considered to optimize its behaviour.

It was also observed that, mainly for the carbon grid test section, the average corrected deformability modulus of the overlying layer corresponded to an asphalt layer with improved integrity, as a result of the contribution of the applied reinforcement grid.

The experimental sections constructed and studied in this paper are being monitored over time, with the execution of periodic FWD load tests to assess the evolution in the pavement behaviour.

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