Use of carbon fiber grids in pavements restoration

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ABSTRACT: This paper describes a real case about the performance of carbon fiber grids used as reinforcement of the asphalt cover layer in restoration process from trench opening in vehicle traffic routes. For this study was chosen two ditches recomposed by the same team-work and in the same rolling track, a ditch with application of reinforcement and the other without it. Thus, it can be admitted that the load applied on the two rearrangements is the same and ensure a reliable comparison, in a test carried out in real conditions of use of the vehicle traffic route. The degree of compaction and moisture content of the base layers and backfill, in addition to other characteristics of the materials used, were monitored during the closing of trial trenches by tests laboratory. After two different periods of time – 99 and 421 days – of the restoration of the pavement, and the route released for general traffic vehicle during all this period, a reassessment was performed in order to analyze the current pavement conditions. In this step were observed the paving health conditions of both rearrangements and held sample extraction hood for tests (extraction performed in the restoration without reinforcement to avoid breakage of the grid that can be monitored over time). The results showed good performance of carbon fiber grid in preventing the reflection of cracks in the application area and the need to adjust executive procedures, especially in relation to forming joints between the original pavement and the recomposed one.

Keywords: geosynthetic material, carbon fiber grid, pavements restoration

1 INTRODUCTION

The search for new technologies of materials and operational processes, which involve reconstruction works of pavements resulting from trench openings, have been the target of the concessionaires responsible for urban infrastructure networks. This fact due to the recurrent pathologies arising from the use of inappropriate materials and executions in disagreement with specifications and technical standards.

According to the Basic Sanitation Company of the State of São Paulo - SABESP (2010), the choice of appropriate materials for the process of trench composition is essential to avoid rework and to guarantee safety and comfort to users of vehicular traffic routes. Considering this, one recomposition of experimental pavement was carried out, where the pre-bituminated carbon fiber grid was used as reinforcement of the composite layer.

In Brazil this technique is used in the execution of new roads or in specific pavement recovery works, according to the local traffic requirement, and it can also be used in works to rebuild specific and continuous ditches, in which places that base and sub-base present materials of poor quality or insufficient compaction. In European countries - such as Germany, Austria, Portugal and Switzerland - the carbon fiber grid is also being used as reinforcement in asphaltic pavements.

2 OBJECTIVE

The study aims to evaluate the performance of the pre-bituminous carbon fiber grids used as reinforcement of the asphalt layer in the process of restoration of pavements, due to the opening of trenches, during 421 days in real conditions of use of the vehicle traffic route.

3 METHODOLOGY

For this test, a strategy was designed to evaluate the performance of the Carbophalt pavement reinforcement, developed by S & P Clever Reinforcement Brasil Ltda, with two ditches recomposed by the same teams (with backfill and asphalt cover replacement) and under the same conditions of traffic; one ditch with reinforcement application and, the other without it. This methodology had as objective to minimize the interference of the human factor during the restoration of the pavement, keeping similar executive characteristics in both trenches.

In this way, it can be affirmed that the load applied on both recompositions were exactly the same, becoming possible a reliable comparison from one test performed in real conditions of use in a route of traffic of vehicles.

It was tried to ensure the minimum conditions of the process of layers recomposition of backfill and base, in accordance with the specifications and current standards. The technological control was made by the jar of sand for base, according to ABNT NBR 7185 (2016), and cylinder crimping for backfill layer, according to ABNT NBR 9813 (2016).

The follow-up was carried out at the time of the trench restoration, which took place on 05/18/16 and after a period of 421 days, during which there was free transit of vehicles on the reconstructed pavement located at 237 Niterói St., Itaquaquecetuba, São Paulo, Brazil.

4 CHARACTERISTICS OF CARBON FIBER GRID

Carbophalt® G is a pre-bituminised asphalt reinforcement grid made of carbon and glass fibers for local and/or complete surface reinforcement of bituminous surfaces. It is used to:

- ✓ prevent crack reflection;
- ✓ increase the durability of asphalt surfaces;
- ✓ increase the load bearing capacity of asphalt surfaces;
- ✓ guarantee the required layer bonding between old and new road surfaces.

The carbon fiber grid presents some advantages, such as:

- ✓ increases the load-bearing capacity;
- ✓ measurable improvement of the structural value due to high tensile strength at small elongation;
- ✓ minimises crack formation and prevents crack reflection;
- ✓ reduces fatigue and thermal cracks;
- ✓ grid structure freely moveable through heat application (no fixed knots);
- ✓ local application on existing cracks or complete surface application;
- ✓ no waiting time - immediate road construction possible;
- ✓ lower consumption of tack coat thanks to the pre-bituminised grid;
- ✓ easy and efficient application with unrolling equipment;
- ✓ effectiveness at a cover layer of minimum of 2 cm;
- ✓ can be milled and recycled without problems.

Figure 1 – Carbon fiber grid (S&P, 2018)

5 PROCESS OF RECOMPOSITION OF THE EXPERIMENTAL VALUE

The sub-base recomposition was carried out in 3 layers of soil with same thickness - approximately 0,24 meter - and the base was recomposed with a layer with thickness of 0,23 meter. The compaction was performed by the use of pneumatic type compactor; to verify the compaction quality, it was used the method of drilling of a cylinder for backfill and of the bottle of sand for base layer; moisture content of the material was determined by frying pan method.

For this event a 0,30 meter cut of the asphalt layer was made from the opening edge of the trench, to ensure the anchorage of the pre-bituminous carbon fiber grid.

After compacting the layers, the service continued with the application of the binder asphalt primer; the RR-2C cation emulsion was used and the pre-bituminated carbon fiber grid was placed in the sequence, which was heated with a torch and adhered to the primer. Finally, a 0,05 meter thick layer of hot-rolled asphalt concrete, range V, was applied at a temperature of 160℃, compacted with a vibrating plate - as specified in Execution Instruction N°03 (MUNICIPAL MAYOR OF SÃO PAULO, 2009) - and a sample of this material was collected to perform - Marshall test in laboratory.

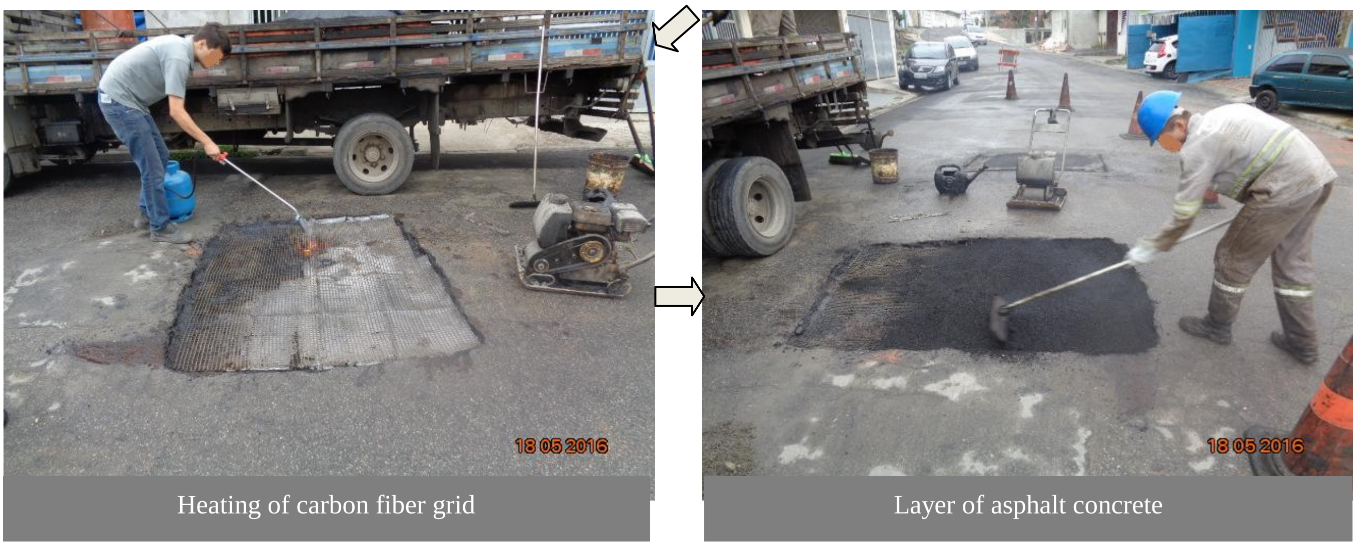

Figure 2 – Executive sequence of the cover recomposition (Prepared by the authors, 2016)

In addition to the evaluation of the process of recomposition of the experimental trench, with application of the carbon fiber grids, a post-service intervention was elaborated after 421 days of trench closure. In this reassessment, aspects of the integrity of the composite pavement were observed, in particular with regards to the emergence of possible pathologies; a sample of the asphalt layer from the recomposition made without the reinforcement was extracted, in order to avoid grid rupture and to monitor performance over time.

6 RESULTS OF LABORATORY TESTS RESULTS

In order to carry out the technological tests in the pavement recomposition phase, samples of pavement, including the soil of basecoat and backfill layers, were collected as well as bituminous mixtures used to compose the pavement cover.

In relation to the backfill (soil) and base layers, the results of the cylinder and sand bottle crimping tests indicated the degree of in situ compaction, as shown in Table 1:

Table 1: Determination of the degree of compaction and moisture deviation "in situ" using the crimping cylinder and the sand bottle.

Location	Layer type	Kind of material	Kind of test	w_{dc} (%)	w_{dl} (%)	γ_{dc} (Kg/m³)	γ_{dl} (Kg/m³)	Δ_w (%)	DC (%)
237 Niterói St. Itaquaquecetuba	Sub-base	Soil classified as clayey sand	Drilling Cylinder	14,4	16,0	1551	1773	**-1,6**	**87,5**
	Base	Graduated stone	Sand bottle	6,4	6,2	2100	2230	**0,2**	**94,2**

w_{dl} = Laboratory moisture content; w_{dc} = Field moisture content; γ_{dc} = Field specific dry mass; γ_{dl} = Laboratory specific dry mass; Δw = Moisture deviation; DC= Degree of compaction

The degree of in situ compaction of the soil layer was 87.4%; this value is lower than that specified by SABESP (2010), which is 95%. The moisture deviation was within the acceptable range (-2% to + 2%). The degree of compaction and the moisture deviation observed were: DC=94.2% and Δw=0.2%.

The characteristics of the bituminous mixture used as cover of the pavement were also analyzed; the results of the test, compared with the Marshall project, are presented in Table 2:

Table 2 - Tests performed on bituminous mixtures collected during its application

Evaluation criteria	Results		Specifications
Apparently density	2286 kg/m³		2350 kg/m³
Bitumen content	6,6%		5,8% (+/- 0,3%)
Fixed Stability	3148 kgf		≥ 800 kgf
Fluency	3,2 mm		2 - 4 mm
Temperature at the time of application	160℃		≥ 120ºC
	Screens	Passant	Range "V" MMSP
Granulometry (Range "V" MMSP)	9,51 mm	100,0%	100%
	4,76 mm	94,8%	75% - 100%
	2,00 mm	66,1%	50% - 90%
	0,42 mm	35,8%	20% - 50%
	0,177 mm	23,8%	7% - 28%
	0,075 mm	10,1%	3% - 10%

In addition, a sample of asphalt recoating layer without reinforcement was collected by rotating extractor, in order to perform density assessments in laboratory; Thickness of the cover, bitumen content and bituminous mixture granulometry after application "in loco" were analyzed. In addition, a visual evaluation was performed to verify the integrity of the recompositions, and the results are presented as follows:

- Evaluation of the asphalt layer in the laboratory

Based on tests results, a variation was observed in bitumen content, which was above the specified in the Marshall project and also in relation to the granulometry of the mixture, especially in passing percentage in the 0.075mm sieve, according to Table 3.

Table 3 - Evaluation of Hot-Rolled Asphalt Concrete

Evaluation criteria	Results		Specifications
Apparently density	2119 kg/m³		2350 kg/m³
Thickness of the graduated gravel layer	0,23 m		≥ 0,14 m
Asphalt layer thickness	0,085 m		≥ 0,035 m
Bitumen content	7,1%		5,8% (+/- 0,3%)
	Sieve opening	Passant	Range "V" MMSP
Granulometry (Range "V" MMSP)	9,51 mm	100,0%	100%
	4,76 mm	93,9%	75% - 100%
	2,00 mm	65,2%	50% - 90%
	0,42 mm	37,9%	20% - 50%
	0,177 mm	25,1%	7% - 28%
	0,075 mm	14,5%	3% - 10%

7 ON SITE EVALUATION

After 421 days of the test trench closure, some aspects were observed in relation to the conditions of the composite pavement, among which can be highlighted ripple on the surface of the asphalt layer, a fissure that circumvents the entire perimeter of the recomposition area and an overlap of the new pavement compared with the old one. Figure 3 below illustrates the occurrences reported; it is important to notice that the edges of the trench are spaced 0.30m from the perimeter of the recomposition, where no cracks were found. The comparative trench (without grid application) also presented a small ripple in the surface of the asphalt layer overlapping and reconstruction, although no cracks were observed.

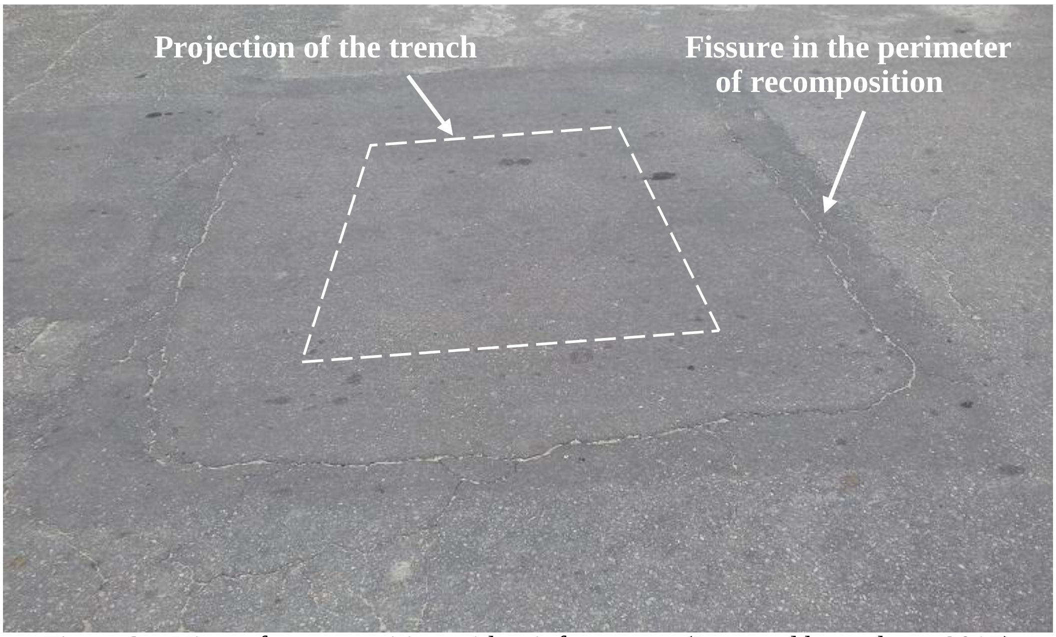

Figure 3 – View of recomposition with reinforcement (Prepared by authors, 2017)

8 FINAL CONSIDERATIONS

After 421 days of the test application and based on the information obtained after the reassessment of the composite pavement, it was concluded that the pre-bituminous carbon fiber grid, used as reinforcement of asphalt layer, met the expected expectations, as it avoided the occurrence of possible cracks and fissures near the region of trench edges, a situation that compromises the durability and useful life of the pavement. This application has an approximate cost of R $ 70.00 / m² (reference January / 2018), totaling in this test the value of R $ 217.00, a value that can be considered high for general applications, but can be considered feasible for situations (heavy traffic), where routine interdictions are undesirable and impactful, since avoiding the occurrence of cracks increases the shelf life of the recomposition, avoiding new interventions in the pathways.

It is important to note that the degree of compaction observed at the time of closure of the test trench in both the sub-base layer and the base layer did not reach the minimum values acceptable in the service specification (sub-base = 87.5% and base = 94.2%). It should be remembered that for soils (sub-base layer), the compaction degree ≥95% is compared to that obtained under optimum conditions in the laboratory. For granular materials, such as simple graded gravel (base layer), the degree of compaction should be ≥98%. This fact, concomitant to the load applied by the vehicular traffic, caused a slight sinking of the box, generating a fissure located in the perimeter of the recomposition, a region without performance of the grid, evidencing clearly the benefit of reinforcement in the region of projection of the trench, which did not allow reflection of the fissure.

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