Performance study over the use of reinforced flexible pavement with steel mesh at Brazilian road

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ABSTRACT: Brazil has a road network close to 1,118,520 miles which only 90,724.4 miles are paved. In addition, every year the roads are exposed not only to an increasing amount of traffic but also to its loads/cargo. This research was accomplished with the support of Mackenzie Research Fund (Fundo Mackenzie de Pesquisa). The purpose of this study was to develop a new technology to improve construction and whitewashing of Brazilian highways and consequently increase its durability with the use of steel mesh by analyzing its effectiveness based on the best international practices, observing its efficiency in laboratory and on an experimental section. The highway SP354 is located in São Paulo, Brazil.

1 INTRODUCTION

The increasing movement of people between various regions around the globe brought the necessity to modernize, extend and improve meshes around railways, roads, ports, airports and urban transports roads. As in most parts of Brazil we have road net consisting of flexible pavements and since the budgets available for new constructions and their maintenance is becoming more limited. It ends up finishing the construction with well-taken needs a greater attention to guarantee a good performance during the life cycle as well as in functional terms (security and comfort) and in structural terms (FORTES; RESSUTTE, 2011).

In recent years, the reinforcement of road pavements has increased quickly. These usually have gratings of polymers and fabrics, as well as steel and fiberglass. The steel mesh can be a solution to increase the capacity of the pavement to support greater loads. The type of mesh used depends on the way the pavement is compared to the structural and functional quality level intended. Around 1970, countries from north Europe established the use of steel mesh on reinforcement of flexible pavements. According to VTI (Swedish National Road and Transport Research Institute) (VTI, 2010), after the application, some roads the potential of the steel mesh was seen as reinforcement for pavements.

Thus, this technique brought the interest of organizations and led to the creation studies such as the project sponsored by the European Union called REFLEX (Reinforcement of Flexible Road Structures with Steel Fabrics for the Prolong Service Life). This project presented interesting conclusions concerning the improvements of the introduction of steel mesh as reinforcement, based on practical cases of roads in Sweden, Finland and Italy, helping to define guidelines to dimension and execute reinforcements of pavements with the use of steel mesh.

2 METHODOLOGICAL ASPECTS

A bibliographical survey on national and international specific literature was accomplished presenting the condition of art on the subject. After the survey an inspection was made in the experimental section at Gerdau installations next to the city of Araçariguama in São Paulo. In the experimental section, the performance of the steel mesh was verified through functional evaluations, mapping of cracks, condition of the steel mesh, execution of diggings and blocking to verify the condition of existing layers.

After the first diagnosis of the steel mesh behavior, an analysis was made next to the DER-SP (São Paulo State Department of Transport), in search for a highway where it would be possible to apply the steel mesh. After this analysis, acquired data were compared with the conceptual revision as well as the need to apply the mesh.

The case study was adopted as research strategy it aimed to apply the steel mesh in a highway already with work in progress. The chosen experimental section was from km 60.40 to km 60.80 of the Highway Edgard Máximo Zamboto – SP354 near São Paulo city. Technological quality control during execution and monitoring of the steel mesh performance was accomplished. Laboratory studies and field testing were made to observe the behavior of the mesh.

3 REVIEW ABOUT STEEL MESH

The use of steel mesh as reinforcement of flexible pavements in general, according to Asphalt Academy (Asphalt Academy, 2008), aims to improve the roads, giving the pavement a clear benefit for one or more structural features essentially increasing their lifetime use durability so that less natural resources are spent, as well as being more economic.

The application of steel mesh reinforcement is recommended in the bituminous layers essentially to control different settlements and increasing the capacity of the second pavement (Heavy Vehicle Simulator) HVS – Nordic (HVS, 1998). Investigation in Finland and Sweden has shown that reinforcement of flexible pavements with steel meshes is an economical construction technique to prevent the appearance of longitudinal cracks (Rathmayer, H. G. et al., 2002).

According to Cost (Cost 348, 2004), the load supported by experimental studies in laboratory and roads, also analyzed the application of steel mesh in flexible pavements during their construction and rehabilitation of roads. The use of this technology brings benefits such as increased capacity load, resistance of cracks, resistance of settlement side, reducing the risk of occurrence of cracks on the layers of reinforcement in the existing pavements, etc.

Since the 80s, Sweden has been using steel meshes in its roads. In most cases (Halonen et al., 2000) noted that the damages observed on the road cracks were due to water infiltrations through micro cracks (in the pavement), which solidify at low temperatures increasing its volume and consequently increasing the cracks.

3.1 *Reflex project*

The REFLEX project (Reinforcement of Flexible Road Structures with Steel Fabrics to Prolong Service Life), funded by the European Union began in March 1999 and was conducted over a period of three years until February 2002, according to Europe (2010). The goal of the project was to develop a new methodology for construction and restoration of roads using steel meshes, to extend the durability of road infrastructure. The proposal was to obtain an increase in its useful life, leading to a reduction in the use of natural resources that would reduce the use of natural resources, reducing the need for maintenance, reducing accidents and improving road traffic safety (ALVES, 2007).

A research conducted in Finland and Sweden indicated that the enhancement of flexible pavements with steel mesh is a low-cost method that avoid longitudinal cracks, according to Halonen et al. (2000). Field and laboratory assays still showed other applications in construction and restoration of roads to give a better final performance as increased load capacity, preventing plastic deformation, avoiding reflective cracks etc.

In Sweden, the section chosen for the application of steel mesh is a road in the north of the country. This section was chosen because it presented large ‘bumps’, several cracks and frost damage. Surveys conducted at the site showed that the constituent materials of the pavement were silts and clays (VTI, 2010).

For the application of steel mesh, the designed team decided to use a mesh with the characteristics of tensile steel fyk = 500 MPa, Ø = 5 mm, # 100 mm. As it started placing the steel mesh, it took them about three hours until the end of the installation. In the following week, the mesh was applied in the remaining segments, getting to seven study sections. During installation of the mesh, few observations were made. Due to poor positioning, it tended to be folded up considering the load applied as the trucks passed over the pavement during asphalt layer application (VTI, 2010). These defects were later corrected in each study section, applying a layer of gravel over the mesh in order to prevent future irregularity.

Several tests were performed from June 2000 to August 2001 to verify the conditions of the structural reinforcement of steel mesh. The measurements of load tests with FWD (Falling Weight Deflectometer) results showed that the ability to support improved but they do not show big differences between the various sections of the study.

At the visual inspection, it was shown that the reinforcement steel could not avoid transverse cracks resulting from frost. However, there are clear trends for reinforce steel to prevent the longitudinal split. It was also observed that the wire mesh acts as reinforcement due to its ability to control the cracks on the edges of the coating.

4 CASE STUDIES

4.1 *Mesh application in steel plants of Gerdau*

In 2005 an experimental excerpt was performed with the use of steel mesh near Araçariguama a town, in the maneuvering of Gerdau manufactures. Through this study, we investigated the performance of steel mesh as cracks pavement anti-reflection method for new layers of resurfacing. After four years, in 2009, it was observed that in the amendments between the meshes, on the edges, reflected fissures occurred, substantially in the mesh overlapping part.

In December 2012, the coating with the welded mesh was demolished and this layer of the pavement was reconstructed using conventional technology, without the use of welded mesh as shown in Figure 1. A final visual inspection was made and the material presented on that occasion showed an IGG (Indice de Gravidade Global) above 180 with several potholes, the coating was ripped of leaving the mesh in display in overlapping meshes parts (amended) and it surpassed the thickness of 3 wires.

According to the survey made on the inventory of surface and structural assessment, the pavement had the highest rate of irregularities in splicing points of welded (overlapping length). Tests made in soil collected samples in the laboratory showed that it can be classified as a silt clayey sand with gravel, with 43.14% of sand, specified as 20.43% of coarse sand, almost 38% of thinner and cohesive material 13.47% of gravel.

The material presented NL values for liquid limit and NP for the plasticity index. The index value of California Bearing Ratio (CBR) obtained is justified due to the presence of gravel (crushed) in the sample. The amount of expansion should be less than or equal to 2%.

4.2 *Mesh application in steel plants of Gerdau*

In late November 2012 the implementation of steel mesh in SP354 began. The Highway Edgard Máximo Zamboto (SP354) in the stretch between km 60.400 and km 60.800. The lane has 7, 00 m wide and has paved shoulders on both sides of the highway at approximately 2.50 m wide.

The rehabilitation project of this excerpt from SP354, located in Campo Limpo Paulista, has a length of 400 m. It is located in the north of the capital of São Paulo and joins growing sectors in economic activity it also enables the interconnection highways SP-065 and SP¬348, which are major corridors of the regional road.

The steel mesh was implanted in the lane towards Jarinu – Campo Limpo Paulista (lane with heavier traffic) where this studied passage was divided into four parts while studying it. For the purpose of this research, we used the existing piling design of SP354. The first subsection includes stake 530 +18 to 536, the second 538 +00 to 541 +00, 541 +07 to the third and fourth 547 +06 547 +07 to 551 +04.

4.3 *Paving Project*

The paving project of SP354 shows that the experimental section under study is highly demanded. The number N designed for the project period of 10 years and calculated was 2.93 E +07 (USACE) and 1.55 E +07 (AASHTO).

The Falling Weight Deflectometer (FWD) was used in order to evaluate the structural condition of pavements. It should be emphasized that the recoverable deflection values measured with the FWD were converted to corresponding values measured with the Benkelman Beam according to correlations contained in the Manual of Asphalt Pavement Restoration of Director of Road Infrastructure (DNIT). Results were mostly recoverable deflections (deflections recoverable measurements > 140 1/100 mm.

The asphalt coating pans features, patches, areas with surface wear and curl in alternating segments of the pavement. In some segments found there was almost complete deterioration of the pavement structure, with localized areas of consolidation presenting sags in places and trails runs, sags and swells on the trails and local plastic wheel well of broken interlocking type FC¬3 form “alligator”.

Through the geotechnical studies it was found that the subgrade soil types are LG’, NG’ and NS’ according to the classification of soils MCT (Miniature, Compacted, Tropical classification). There is also the bearing capacity of the soil subgrade CBR is between 1 and 25% and that the spread of these soils ranges between 0.00 and 3.60%. Note that all geotechnical tests (CBR and expansion) of the subgrade soils were performed on soil samples molded in Energy Standard Proctor.

In the segment of the test section to restore solution to be adopted was a reprofiling polymer thickness of 20 mm along with a DST (Double Surface Treatment) with another polymer layer CAP (Asphalt Cement) in thickness of 40 mm. On November 23, 2012, a revisit to the highway was made and found the presence of a much deteriorated pavement, with the presence of crocodile crack and wear track. Figure 1 shows the situation of the pavement.

Figure 1. SP354 view of the pavement in the presence of 100% defect “crocodile crack”.

4.4 *Study on welded mesh splices*

In the implementation of the experimental sections, checking the performance in the experimental section executed in Gerdau and in the tests, it was decided to use the welded mesh Q138. These studies were oriented by two publications of IBTS (Brazilian Institute of Mesh Welded) [11. 12] and ABNT NBR 16055 – concrete walls molded in locus for the construction of buildings – Requirements and Procedures [13]. Their characteristics are given in Table 1.

Table 1. Characteristics of the welded mesh Q138.

Steel	Spacing		Diameter		Dimensions	
CA-60	cm	inches	mm	inches	width (m)	length (m)
Q138	10	3.94"	0.32	0.13"	2,45	6

The study aimed to define the splice procedure to be applied in the experimental section of the SP354, on the development of technology defined as Reflex (Reinforcement of Flexible Road Structures with Steel Fabrics to Prolong Service Life). The main objective was to complement the study for development of a new technology for the construction and rehabilitation / recovery highways, using welded steel mesh in order to increase the life thereof, as well as allowing the reduction of use of natural resources.

A welded mesh panel covers a certain area on the reinforcement on the pavement, in order to perform the Reflex method, it is necessary to make an installation of welded mesh panels, so that the entire area is covered.

When the distribution of the welded mesh on the pavement surface is held, so that the reinforcement becomes continuous throughout its length, it is necessary to splice the panels, which are given by the overlap of meshes.Splices of the longitudinal reinforcement must be tied with annealed wire, in the same plane.

In the case of transversal splices, the spliced wires should also be in the same plane. Services of cutting and mooring shall be executed at the construction site. Figure 2 shows the lateral splices and the detail of the overlapping meshes. This overlapping must be avoided because it was observed that the pathologies (potholes) occurred in the coating, where the welded mesh was overlaid, resulting in a thickness of more than 3 wires.

Figure 2. Detail of overlapping meshes.

4.5 *Implementation of steel mesh in SP354*

Welded mesh Q138 were provided by the Brazilian Institute of Mesh Welded (IBTS) for the implementation of 400 m in the experimental section. The meshes were stored on the km 60 of highway SP354 next to the construction site. For comparison, the steel meshes were applied on the experimental section of higher traffic loads.

The first part was held on 02.26.2013, from the stake 530+18.00 until stake 536+0.00. This section comprises a ramp of 1.2% (slope), representing the range with more loaded traffic (to Jarinu – Campo Limpo Paulista / São Paulo): in this part were settled welded steel meshes on the existing pavement, which was very deteriorated, with the presence of FC-3 (crocodile cracking), potholes, block cracking , etc.

It should be noted that half of the runway (to Jarinu – Campo Limpo Paulista) a recapping was applied using the Q138 welded mesh in interface between the existing pavement. It was completely "crocodile cracked", with potholes in the coating layer, and only the placement of the mesh was done, applying binder painting on the placed and fixed mesh, and repaving with asphalt concrete graded "III" of DER¬SP as can be seen in Figure 3.

Figure 3. Repaving applied using asphaltic concrete.

Over the damaged pavement, the welded meshes were placed, tied with annealed wire 18. Between stake 530 +18 to stake 535, the existing pavement had the pathology FC¬3 "crocodile cracking" across its width (total area). It was applied, the emulsion painting RR¬2C ("rapid rupture" – quick reaction) with rate of approximately 0.9 mL/m².

The fixation of the mesh performed with studs was not adequate, since these studs ended up losing, and the meshes moving, due to the movement of the tipper truck on the meshes, to discharge asphalt in the paving machine. At these points, the pieces of meshes were removed.

During execution of repaving with asphalt concrete between stakes 534 and 536, from 1:35 pm to 2:30 pm, the service was held under heavy rain. Relevant technological controls, such as temperature control and thickness of the launching dough were done. Samples were also collected, for laboratory tests. Traffic was released after 5:00 pm of the same day.

The positions of the splices in traffic direction (longitudinal) and transversal to monitor the development of pathologies were marked. The following day (27.02.2013) was observed for the appearance of cracks located in the longitudinal splicing points. Defects like "crocodile crack" or "fluffy" occurred on the coating where there was mesh overlapping (more than two wires), where the same was not well attached to the existing pavement, in other words, the defect called "fluffy" was due to the movement of the meshes during the execution.

The second part was held on 02.27.2013, from stake 538+00 to stake 541 +00, on the same day as the first part: in this part, were settled steel welded meshes over the existing pavement. The difference between the executive processes of this part to the former was essentially changing the position of the mesh. Was adopted the placement of the meshes with the crossbars down and then, with the bars up, reversing the side. It was done in order to try to reduce the thickness of the meshes, avoiding the overlapping.

The overlapping in the longitudinal direction was also increased (Figure 4), which became to be one mesh. In addition, there was an improvement in setting, and attention on trimming the meshes, in the corners, where overlapping occurred on all meshes, so it would have an overlap of at least two wires.

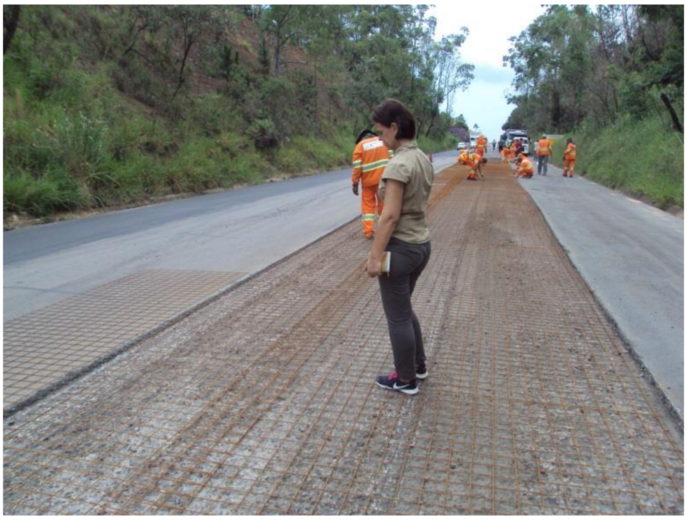

Figure 4. Repaving over the executed mesh.

The next day, it was observed that increasing the overlap of the meshes in a longitudinal direction, had a lower performance than in the first part, where there was no such overlap, because transversal cracks appeared, with thickness larger than was presented in the previous part.

The third part was held on 28.02.2013, from stake 541+07 to stake 547 +06. In this excerpt were settled steel welded meshes over the milled pavement. Milling thickness performed was of 4cm (Figure 5). The difference between the executive processes of this passage for the former was essentially the introduction of milling the existing pavement. The change of position of the meshes was adopted because it had been executed in the second part, so the placement of the mesh with the crossbars down and then with the bars up reversing the side.

This caution tries to reduce the thickness of the meshes when placing avoiding the overlapping. The coatings on the longitudinal direction, was done as in the first part without any meshes overlays. In addition, there was an improvement in setting using 5mm steel bars, driven into the milled pavement. There was also careful to cut the corners of meshes where overlapping occurred on all meshes so that there was overlap of at least two wires.

Figure 5. Fixation of the steel mesh.

On the following day of the execution, it was not observed the appearance of cracks, which leads to the idea that the fact the meshes have been placed "confined", since it was placed on the milled pavement, the movement has been reduced contributing to not generate cracks. Thus, it is concluded that besides the problem of overlapping meshes, the fixation is of paramount importance.

The fourth part was held on 13.03.2013, from stake 547+07 to stake 551+04. In this excerpt steel welded meshes on the existing pavement were settled, which appeared with a high presence of sags and "crocodile cracks" (Figure 6). The difference between the execution process from the preceding part to this one in order to lessen or even "cure" the problem of appearance of transversal cracks was essentially the removal of cross bars of the first grid, increasing fringe (removal of the peripheral wire, transversal to the direction of traffic).

Figure 6. "Crocodile cracks" on existing pavement.

The coating on the longitudinal direction was done without any mesh overlay. In addition, there was an improvement in setting, using 5mm steel bars, driven into the milled pavement. There was also careful to cut the corners of the meshes, where overlapping occurred on all meshes, so that there was overlap with a maximum of two wires in thickness.

Observing the performance of the earlier constructed sections, it was decided that this section would be built with the overlay of the mesh to the existing pavement, because this technology is likely to fill the need for recovery solution, spare milling.

4.6 *Technological control*

Deflection measurements data were collected on 01.03.2013, from stakes 531 to 547. With the results, it was observed that in the first ages of the pavement, the difference in structural behavior between sections with and without the mesh is still not significant. The propensity of the difference grows with the age of the pavement, with the best structural values for the pavement with the mesh. On the same date the inventory was conducted from the surface to check defects. Transversal cracks were observed in the longitudinal splices.

5 FINAL CONSIDERATIONS

It was observed that the appearance of cracks occurred in almost all longitudinal splices and few cracks in the direction of transversal splices, with potholes located at the splices of the four pieces of mesh. The best performance was in the experimental section where milling of existing pavement and fixation of the meshes were performed without overlapping. Thus, it avoids the movement and consequently the appearance of cracks.

Small irregularities have been removed during milling, guaranteeing flatness of the surface, resulting in a better seating of the mesh, avoiding ripples, which occur mainly due to the irregularity thereof and also during execution, due to traffic equipment (dump truck and paver) that moves the meshes. It was observed in the executed experimental sections, that where the displacement of the mesh occurred, it resulted in ondulation of the same, decreasing the overlay thickness, and the surface presented pathologies that have evolved for potholes.

On the splices, where occurred the appearance of cracks, and also due to the failure of adhesion between the underlying layer (existing pavement) and repaving, there was infiltration of rainwater through cracks and "upwelling" in the interface of the "old" asphaltic concrete and the "new" one.

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The experimental results were obtained on the eve of the expiration of the project's period execution, preventing further analysis, rigorous and conclusive. Final conclusions will be formally presented on upcoming scientific papers, produced as a result of this study, which will add new results.

6 FINAL CONSIDERATIONS

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