Second Pan American Geosynthetics Conference & Exhibition
GeoAmericas 2012
Lima, Perú - May 2012

Deformation Analysis of a Geogrid-Reinforced Pavement

C.A.T. Carmo, M.Sc. Civil Ing., Huesker Ltda, São José dos Campos, Brazil,
C.A. D'Ávilla, Director, Stonenge Consulting and engineering projects Ltda., Vitória, Brazil
E.F.Ruiz, Civil Ing., Huesker Ltda, São José dos Campos, Brazil

ABSTRACT
In the last decades, geosynthetics for pavement base and subgrade reinforcement have been used with increasing tendency worldwide, enabling the reduction of layers thickness and time of construction. The advantageous effect of the inclusion of geosynthetic reinforcement can be quantified by incorporating the geogrid properties into conventional design methods for different subgrade conditions. However, the most of the available approaches are concerned about laboratory studies since just a few numbers of field experiences that take into account the real conditions of the structure during its service life can be found in literature.

This article presents a measurement and monitoring program which was carried out in a polypropylene geogrid-reinforced pavement section during the construction period and after the operational traffic opening. Besides, it shows the results of a deflection analysis obtained by using Benkelman beam tests, confirming the efficiency of the reinforcement in the reduction of layers thicknesses and in the improvement of the general structural behavior of the pavement.

RESUMO
Atualmente, há uma crescente aplicação de geossintéticos no reforço de bases e sub-bases de pavimentos, por possibilitarem a redução da espessura das camadas ou aumento da vida útil do mesmo. A inclusão de parâmetros da geogrelha nos métodos de dimensionamento tradicionais permite quantificar o ganho estrutural obtido pelo uso do reforço em condições adversas do leito de assentamento da estrutura. O monitoramento e avaliação de pavimentos reforçados possibilitam o levantamento de informações acerca do comportamento estrutural e conseqüente influência do reforço na estrutura do pavimento. Este artigo apresenta o acompanhamento da execução de um pavimento reforçado com geogrelha e a análise estrutural realizada a partir de resultados de ensaios de Viga Benkelman executados antes da fase executiva e após a passagem de tráfego. Os resultados obtidos demonstram a eficiência da aplicação da geogrelha na redução da estrutura do pavimento e no comportamento da estrutura implantada.

1. INTRODUCTION

The use of geosynthetics as reinforcement base layer and layer of asphalt flexible pavements improves the performance of this type of geotechnical structures. In base reinforcement, the insert can be positioned either at the interface between the subgrade and the base, it is approximately half the height of the base layer. Regardless the position of inclusion, it is expected that this technic could promotes an increasing resistance of the pavement and a wider distribution of loads on the subgrade. Therefore, the geosynthetic needs to be closely united to the surrounding soil. This condition becomes more efficient the higher the stiffness of the inclusion.

The increasing in shear strength of the floor is consequence of the traction of the geogrid. With this, a significant decrease of the shearing effects would be transmitted to the subgrade due to traffic. So, the use of a geogrid increases the angle of spreading tension, causing the soil subgrade to be requested by lower tensions. The benefits of building makes more evident the lower carrying capacity of the subgrade (Koerner, 2005; Triches and Bernucci, 2004).

Besides of being positioned at the interface of the base layer to the subgrade, it is also common the geogrid to be place in the lower third of the base layer, because from a certain depth of the reinforcement fails to create benefits to the structure. Thus, due to soil-aggregate contact that occurs in the mesh opening acts including confining material and improves its characteristics of strength and stiffness. Therefore, the greater economy the strengthening can generate is to reduce the thickness of the base.

Among the several existing methods for the design of geosynthetic-reinforced pavements should highlight those based on the AASHTO method. These methods consider the benefit obtained by increasing the parameters that qualify the gain provided by structural reinforcement, being the most frequently used the TBR (Traffic Benefit Ratio) and LCR (Layer Coefficient Ratio).

As existing methods are, in general, empirical or mechanistic-empirical, so, it is required a calibration for the equations used for the region which will run the floor and depending on the type of geosynthetics, reinforcement placement, among other factors. Therefore, it is necessary a database from experimental passages or passage in real traffic conditions, in order to obtain equations consistent with the Brazilian reality.

2. FEATURES OF CONSTRUCTION

2.1 Location

The pavement analysis is located close to the metropolitan region of Vitória city, in the city of Viana, in the state of Espírito Santo.

Figure 1. Location of construction (Google Maps).

The pavement is inserted in a section implemented by DER-ES,in order to give mobility to the region that includes several carriers. This route is known as Via Southwest. The area where the geogrid was installed to reinforce Fornit J600 has a deck length of 850 meters.

2.2 Structure of Pavement

Geotechnical studies undertaken diagnosed that the subgrade (bed carriageway) consisted of a surface layer with thickness varying from 0.00 to 0.25 m gross mixing slag with clay and CBR in the order of 15%. This layer was based on a non-compacted clay layer of variable thickness of 0.85 m and CBR equal to 7%. The water level at 0.70 m from the surface lets to infer that the landfill site, was launched on clay wetland. This was proved by checking the degree of compaction of the layer showing values below 70%.

Below the layer of fill was found still thick layer of highly compressible organic clay with natural moisture above 80%.

Figure 2 shows the structure of the existing subgrade, which was being used as an unpaved.

It is possible to see in Figure 2 that the subgrade consists of clayey material with presence of slag. Although the CBR of this layer has good resistance to the implementation of the pavement structure, it can be seen in Figure 3 the high deflection of the subgrade.

For a better view of the deflections were excluded from Figure 4 deflections greater than 300 hundredths of a millimeter.

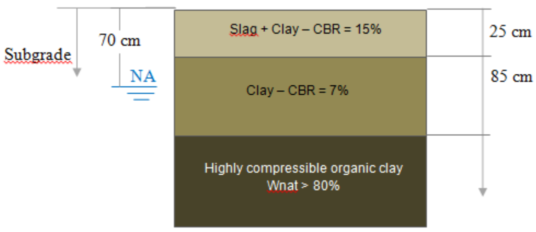

Figure 2. Section of the existing unpaved road.

3. THE SOLUTION ADOPTED

The choice of a flooring solution reinforced with geogrid was driven by the need to pave a path in the urban area of Areinha, Viana / ES. The region of insertion of the pathway involves a segment already deployed, active on both sides. The sprawl has resulted in sill quotas of the buildings not exceeding 0.20 m from the bed quota of existing street. Keeping the habitability conditions, the elevation of the grid consisted of impossibility.

The structure of the subgrade (Figure 2) showed no large waves, but it was found that the option of removing layers of the pavement for deployment explained another problem. As the excavation deepened, the moisture increased due to the proximity of the NA. Another aspect is that the resistant layer were be removed and the bed of the settlement would assume some instability.

In this context, we sought to a deploy solution that would allow pavement structure to remove no more than 0.10 m from the existing layer (subgrade) and the deployment of the pavement structure could be very thin coated with HMA (Hot Mix Asphalt Concrete), considering the impossibility of rising the grid due to sill quotas of the bordering buildings.

The Figures 03 and 04 present the deflections at the site to be paved. The surveys were carried out under the deflection of the subgrade layer.

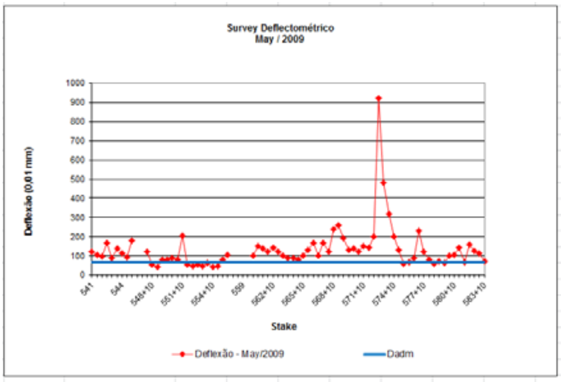

Figure 3. Survey of deflection measurement of the pavement to be deployed.

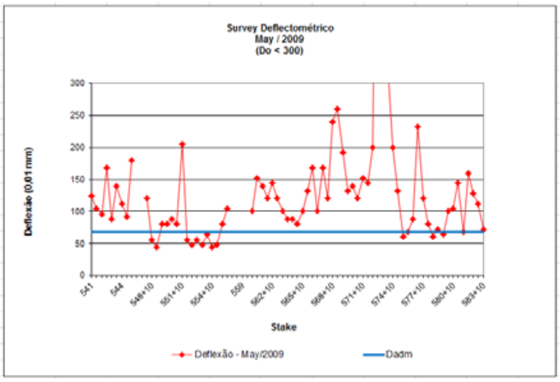

Figure 4. Survey of deflection measurement of the pavement to be deployed (Do < 300).

3.1 Geosynthetics

The Brazilian Standard NBR 12553 defines geosynthetics [G] as: "Generic name for a polymer product (synthetic or natural), industrialized, developed for use in geotechnical works, performing one or more functions, among which are: strengthening, separation ... ".

This application of reinforcement geosynthetics pavement structure used have the following functions: a geogrid [GG] has the function of reinforcing [R], this is the use of the mechanical properties of the geogrid to improve the mechanical behavior of the structure and the woven geotextile [GTW] has the responsibility to prevent the mixing of adjacent materials.

The technical characteristics of geosynthetics used as reinforcement of pavement are presented in Table 1.

Table 1. Properties of geosynthetics used.

Characteristics	Units	Specification	
		Fornit J600	GTW[1] 55/55
Product description	--	biaxial geogrid	biaxial woven geotextile
Raw material	--	polypropylene	polypropylene
Modulus of rigidity to 2% deformation (J)	kN/m	≥ 600	≥ 270

[1]GTW, woven geotextile

3.2 Pavement Design

3.2.1 Design Parameters

Based on the survey carried out on the road to be paved (Figure 2) and deflection measurement surveys (Figures 3 and 4) can be performed a retro-analysis with the Elym5 program, in order to determinate the modules of existing layers (Table 2).

Table 2. Module resisliência determined with the aid of Elym5.

Layer	CBR (%)	Thickness (cm)	MR (kgf/cm^2)
Slag + Clay	15	25	950
Clay	7	85	450
Organic Clay (W_{ant} > 80%)	3	1000	220

The volume of traffic for the project period (N) determined by the method of DNER-PRO 11/79 was 5.0E+6, which is the equivalent of approximately 1.7E+6 by the method of AASHTO (Equation 1).

$$N_{AASTHO} \cong \frac{1}{3}.N_{DNER} \qquad [1]$$

3.2.2 AASHTO Method

The dimension of the reinforcement with geosynthetics is based on the method of AASHTO 1993. The AASHTO method is based on a regression obtained from results of experimental tracks and uses the structural number (SN) that quantifies the structural strength required by the pavement for a given combination of soil support, active and traffic levels of reliability and service.

The structural contribution of geosynthetic in a flexible pavement is quantified in the method by increasing the structural coefficient of the base layer through the LCR parameter (Layer Coefficient Ratio). This parameter is obtained through laboratory testing.

The design of the structure is done by the equations below.

$$\mathrm{SN} = a_1.D_1 + a_2.D_2.m_2.LCR + a_3.D_3.m_3 \qquad [2]$$

Where:
SN = structural number;
a1 = structural coefficient of the asphalt concrete;
a2 = structural coefficient of the base;
a3 = structural coefficient of de subbase;
D1 – thickness of the asphalt concrete;
D2 = thickness of the base;
D3 = thickness of the subbase;
m2 = drainage coefficient of the base;
m3 = drainage coefficient of the subbase;
LCR = Layer Coefficient Ratio which is given by Equation 3.

$$LCR = \frac{SN_r - \alpha_1.D_1}{SN_u - \alpha_1.D_1} \qquad [3]$$

Where:
SNr = structural number of reinforced section;
SNu = structural number of non-reinforcement section;

α1 = parameter obtained under test..

For geogrid used in this work the value of the CSF was determined by Figure 5.

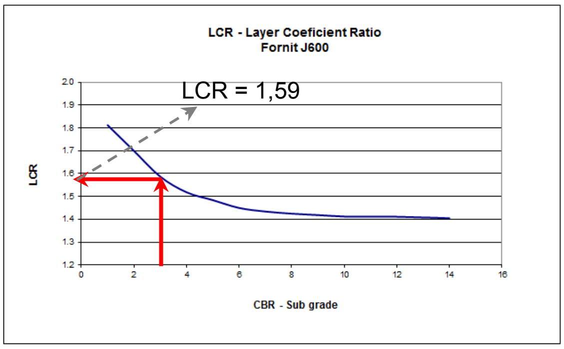

Figure 5. Determination of LCR for the geogrid Fornit J600. (Adapted from Baillie, 2002).

$$9{,}36\log_{10}(SN+1)+\frac{\log_{10}\left(\frac{\Delta PSI}{4{,}2-1{,}5}\right)}{0{,}40+\frac{1094}{(SN+1)^{5{,}19}}}+Z_R S_0-\log_{10}(W_{18})+2{,}32\log_{10}(M_R)-8{,}07=0 \quad [4]$$

$$\Delta PSI = P_0 - P_f \quad [5]$$

Where:
ΔPSI = usefulness loss expected during the Project period (Equation 5);
P_0 = initial rate of usefulness;
P_f = final index of usefulness;
W_{18} = number of requests to the equivalent standard axle of 82 kN, calculated with the coefficients of AASHTO;
Z_R = standard deviation for the probability of success you want for the struture;
S_0 = standard deviation that takes into account the uncertainties of the measured variables and the construction process;
M_R = Modulus of Resilience;
SN = structural number considering the contribution of the geogrid (Equation 2).

3.2.3 Pavement Structure Reinforced

Figure 6 shows the structure of the implanted surface

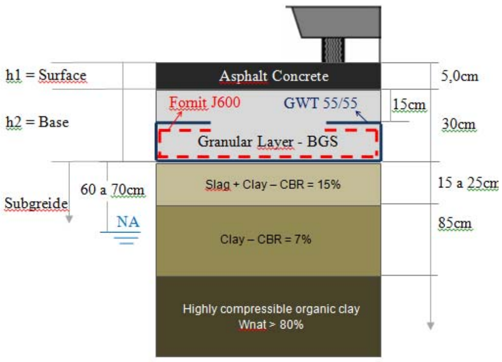

Figure 6. Section of flexible pavement deployed. HMA = hot bituminous concrete and BGS = crushed stone graded.

3.2.4 Construction of Pavement

The implementation of the pavement was held in 2009. Figures 7, 8, 9, 10, 11 and 12 show the construction stages reinforcement pavement.


Figure 7. Regularization of the subgrade for the installation of geotextile [GTW] and geogrid [GG].


Figure 8. Installation of woven geotextile [GTW].


Figure 9. Installation of geogrid [GG] Fornit J600.


Figure 11. Compaction of base of BGS (graduated gravel).


Figure 10. Construction base with BGS (graduated gravel).


Figure 12. Constructio of asphalt concrete

Figure 13. Pavement in operation and in perfect condition (December/2011).

4. STRUCTURAL EVALUATION

The test for pavement structural evaluation was performed with the Benkelman Viga.

The work was completed in July 2009 and the Benkelman tests were carried out 14 and 28 months after completion of the work which corresponds respectively to the months of September 2010 and November 2011. Figure 14 shows the surveys to monitor the pavement.

Figure 15 presents a comparison between the initial deflection measurement survey (Figures 3 and 4) and surveys obtained after the implementation of enhanced pavement (Figure 14).

Based on traffic volume design N_{DNER} = 5.0E+6 deflection was determined admissible for this paved road.

The allowable deflection was calculated by the equation is the standard of DNER-PRO-11/79.

$$\log D_{adm} = 3{,}01 - 0{,}176.\log N_{projeto} \quad [6]$$

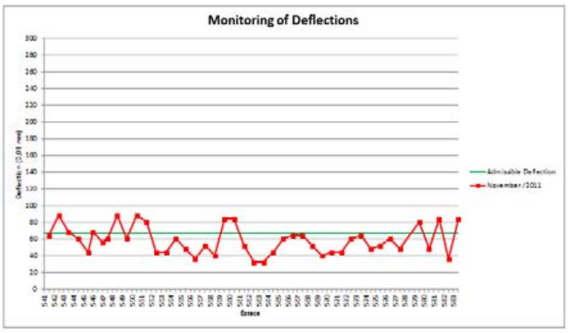

Figure 14. Deflectométrico test conducted in November 2011.

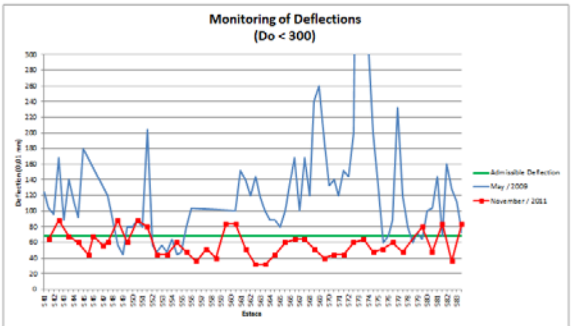

Figure 15. Comparative reduction of the deflection of the pavement after deployment.

The Figure 14 shows that the deflections of the pavement were enhanced close to the calculated admissible deflection.

In order to make an evaluation of the performance of the pavement geogrid, it was performed, with the aid of the Elsym5 (Elastic Layer System Model) program, a simulation trying to establish the base thickness of graded gravel to reach the admissible deflection.

Figure 16 shows the deflection measured in the field, as the pavement was performed (Table 3) and simulation with the Elsym5 program to estimate the thickness of the pavement base to meet the specification of admissible deflection (D_{adm}) of 67.76 x 10 - 3 mm.

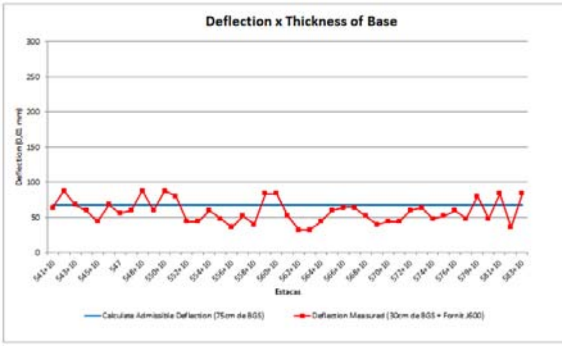

Figure 16. Deflection verses thickness of the base.

Figure 17 outlines what is presented in Figure 16, the floor run with the use of geogrid (Fornit J600) and Figure 17 (b) represents the floor if it were being run without the use of geogrid.

It is possible to observe the difference in thickness that would be needed to meet the assumptions of the project, without taking into account the constraints in the urban road.

Table 3. Resilient module of the pavement layers.

Layer	CBR (%)	Thickness (cm)	MR (kgf/cm^2)
Asphalt Concrete	--	5	30000
Granular Layer	--	30	2000
Slag + Clay	15	25	950
Clay	7	85	450
Organic Clay (W_{ant} > 80%)	3	1000	220

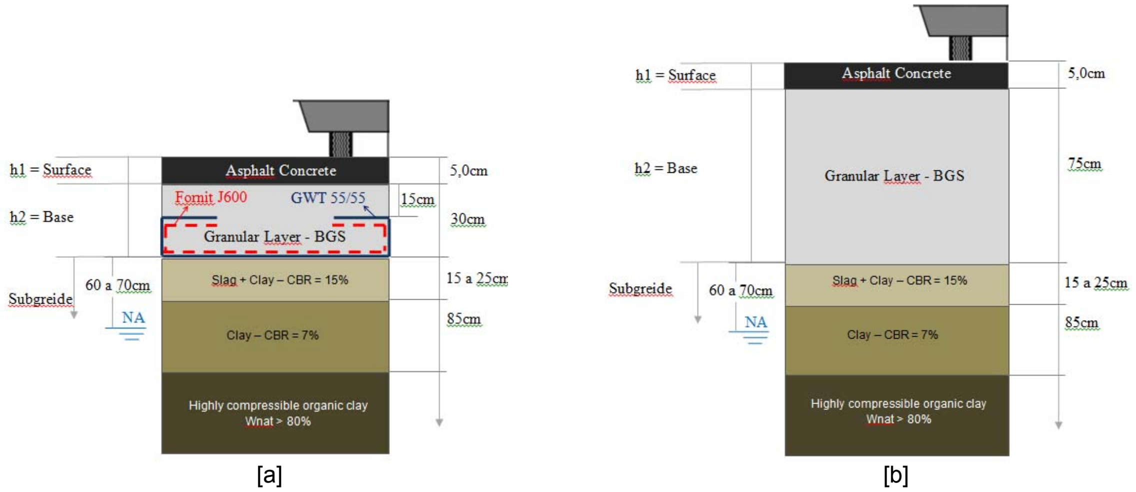

Figure 17. (a) Structure of the geogrid reinforced pavement and (b) Structure of the deck without geogrid

With the deflections bowls measured in the pavement in November 2011 was also carried out a retro-analysis to estimate the new value of resilient modulus of base layer, ie, determine how much gain did the polypropylene geogrid give to layer of graded gravel .

Table 4. Resilient modulus of the pavement layers, considering the reinforcement with geogrid.

Layer	CBR (%)	Thickness (cm)	MR (kgf/cm^2)
Asphalt Concrete	--	5	30000
Granular Layer	--	30	6500
Slag + Clay	15	25	950
Clay	7	85	450
Organic Clay (W_{ant} > 80%)	3	1000	220

5. CONCLUSIONS

Based on the study pavement was found that the use of polypropylene geogrid as reinforcement of base pavement is an excellent solution for locations where the subgrade has low bearing capacity and also in places where the pavement structure has to be thin due to urban interference, thanks to the high modulus of rigidity of geogrid that allows a considerable reduction in the deflections of the reinforcement pavement.

The method used for the design of the structure proved to be very efficient, indicating a thin structure and excellent structural coefficient.

Despite the deflections in some stakes were above what is allowable, the solution perfectly fits the expectations of the project because of the urban interference, as can be seen in Figure 7, it was not possible to run higher than the base layer performed with geogrid.

In addition (Table 4), the polypropylene geogrid promoted an increase of 2.25 times the stiffness of the module of graded gravel.

6. ACKNOWLEDGEMENTS

Thanks to the DER-ES support in monitoring the deflections of the pavement.

REFERENCES

AASHTO (1993). *AASHTO Guide for Design of Pavement Strutures*. Americam Association of State Highway and Transportation Officials.

ABNT (2002). *NBR 12553 – Geossintéticos – Terminlogia.* Associação Brasileira de Normas Técnicas.

Baillie, B. (2002). *Fornit – Biaxial Geogrid Reinforcement. Reference manual for the desing of flexible pavement strutures.* Techical Reference Fornit-DN-1. Huesker, Inc.

DNER (1979). *Avaliação Estrutural dos Pavimentos Flexíveis – DNER-PRO 11/79.* Departamento Nacional de Infra-Estrutura de Transportes. Brasil.

Ferreira, C.J. et. all (2009). *Procedimentos de Execução e Análise de Pavimentos Experimentais Reforçados com Geossintéticos*. I Simpósio de Prática de Engenharia Geotécnica na Região do Centro-Oeste. Anais. Goiânia, Brasil.

Ferreira, C.J. at all (2009). *Avaliação Estrutural de um Pavimento Experimental Reforçado com Geogrelha.* IV Simpósio Internacional de Avaliação de Pavimento e Projeto de Reforço. ABPv. Anais. Fortaleza, Brasil.

Koerner, R. M (2005). *Designing with Geosynthetics*. 5ª edição, Prentice-Hall, United States of América.

Trichês, G. e Bernucci, L.B. (2004). *Reforço de base de pavimento*. Manual Brasileiro de Geossintéticos. Editado por Vertematti, J.C., pp. 153-169, Brasil.

US. Army Corps of Engineers (2003). *Use of geogrid in pavement construction*. Technical Report: ETL 1110-1-189. Washington, D.C.