ENGLISH VERSION...

Evaluation of reflective cracking under dynamic loads interposing geosynthetic materials at different levels of the asphalt reinforcement layer

Valoración de la fisuración refleja ante cargas dinámicas interponiendo geosintético a diferentes niveles de la capa de refuerzo asfáltico

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Abstract
Load demands on pavements, due to repeated vehicle loads and environmental conditions, generate a constant deterioration of the structure, which causes the loss of mechanical properties, thereby producing a structural and functional loss on the road. Nowadays, one of the most common problem, which is difficult to control due to these load demands, is reflective cracking, a phenomenon that explains the propagation of existing cracks in lower layers or coinciding with joint movements of an aged pavement, towards the new reinforcement layer, which copies the pathology of the same. The study evaluates the behavior of reflective cracking while varying the location of the geosynthetic material between each asphalt mix layer, and subjecting the system to dynamic loading. The geosynthetic reinforcement considerably delays the progression of the crack, and the greatest effectiveness is obtained when this material is located nearest to the most stressed fiber of the reinforcement layer.

Keywords: *Restoration, geosynthetic, reflection crack, pavement, reinforcement*

Resumen
Las solicitaciones producidas sobre los pavimentos, por cargas repetidas de vehículos y las condiciones ambientales, generan un deterioro continuo sobre la estructura, generando pérdidas de las propiedades mecánicas, ocasionando una pérdida estructural y funcional del camino. Uno de los problemas más comunes y de difícil control actualmente es la fisuración refleja debido a las solicitaciones mencionadas, fenómeno por el cual se propagan las fisuras existentes en capas inferiores o en coincidencia con movimientos de juntas de un pavimento envejecido, hacia la nueva capa colocada como refuerzo, copiando la patología de las mismas. El trabajo evalúa el comportamiento de la fisuración refleja variando la posición de un material geosintético entre capas de mezcla asfáltica, sometiendo el sistema a carga dinámica. El geosintético logra un considerable retraso en la progresión de una fisura, alcanzando mayor efectividad cuando se localiza lo más cercano a la fibra más traccionada de la capa de refuerzo.

Palabras clave: Restauración, geosintético, reflejo de fisura, pavimento, refuerzo

1. Introduction

One of the most common problems in pavement restoration is cracking or other types of overlay failures. Cracks cannot only affect the appearance of a structure, but can also reflect significant structural failures (Al-Qadi et al., 2003). In this respect, reflective cracking is one of the biggest concerns of road authorities and, currently, the main concern in pavement engineering (Peshkin et al., 2004).

Reflective cracking is a phenomenon that explains the propagation of existing cracks in lower layers or coinciding with joint movements of an aged pavement, towards the new reinforcement layer, as a consequence of traffic and/or environmental demands, thereby reflecting the pathology of the same in the overlay (Virgili et al., 2009), Figure 1.

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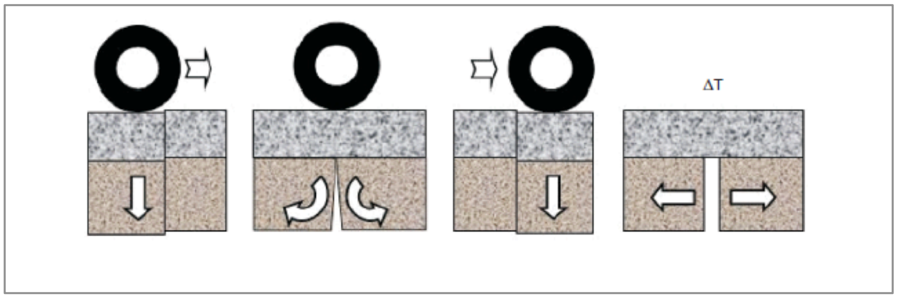


Figure 1. *Load demands on the pavement structure*

The reason why the crack reflects towards the overlay is because, under the effect of different loads, the edges of the existing crack cause a concentration of stresses which transfer this movement to the overlay; due to fatigue of the asphalt reinforcement layer, a crack is produced and rapidly grows upwards to the overlay (Laerte, 1993).

Research on geosynthetic materials, regarding its interposition between the pavement layers, affirms that the thickness of the layers of the structural package can be reduced. However, this reduction can be somewhat arbitrary, since it depends on several factors such as: type of material composing the layer (soil, concrete, asphalt mix), particle size distribution of the aggregates forming the layers, characteristics of the asphalt mix used for reinforcements, climate conditions and type of traffic loads.

The LEMaC Road Research Center has carried out studies addressing the issue of reflective cracking in asphalt or concrete pavements, through accredited research projects and agreements with companies of the productive sector, in on-site applications and follow-ups.

The work presented herein selected a geosynthetic material sold in Argentina, with the purpose of studying the reflective cracking phenomenon.

The following lines describe the materials used for making the test specimens that represent the behavior of a pavement subjected to dynamic load.

2. Materials, experimental development

Specimens were made in the laboratory for each system to be tested; the test specimen's materials are described below:

2.1 Asphalt mix

The test specimens were made with conventional hot mix asphalt concrete with maximum size of 19 mm, which is characterized by the requirements stipulated in the General Technical Specifications of the Argentine National Road Department, in section D VIII. Hot-prepared bases and asphalt layers (Dirección Nacional de Vialidad, 1998).

The characteristics of the mix, according to the Marshall test and in accordance with the VN – E9 – 86 (Norma de Ensayo de Vialidad Nacional, 2008) standard, are indicated in Table 1.

Table 1. *Parameters of the asphalt mix*

Test	Unit	Result	Demand
Marshall Density	g/cm^3	2,347	-
Rice Density	g/cm^3	2,432	-
Voids	%	3.5	3 - 5
Bitumen/Voids Ratio	%	77	68 - 78
Averange Binder	%	4.9	5
Mineral Aggregate Voids	%	15	> 14
Stability	Kg	919	> 800
Stability/Fluency Ratio	Kg/cm	3465	2500 - 4500

2.2 Asphalt emulsion

The test specimens were made with an asphalt emulsion modified with a SBS-type polymer (ECRR-M), which was supplied by the YPF oil company. The characterization tests were made on this emulsion and the parameters obtained are shown in Table 2.

2.3 Geosynthetic material

The selected material is a 40x40 mm mesh grid, formed by polyester fibers attached to a polypropylene mat, Figure 2.

Table 2. *Parameters considered emulsion*

Test	Unit	IRAM* Standard	Result
Saybolt Furol viscosity at 25°C	SSF	6721	33.7
Asphalt residue from distillation	g/100g	6719	65.3
Settling	g/100g	6716	1.7
Water content	g/100g	6719	37.5
Particle charge	-	6690	Positiva
Residue on 850 mm IRAM sieve	g/100g	6717	0.06
Tests on distillation residue			
Residue penetration	0.1 mm	6576	70
Ductility	cm	6579	>100

* Argentine Standardization Institute

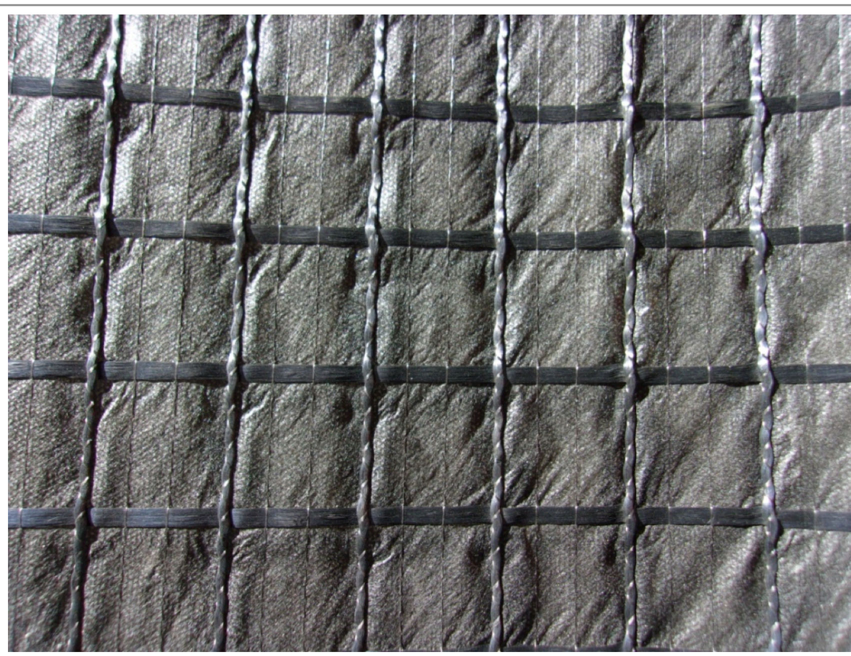


Figure 2. *Geosynthetic material*

The geosynthetic material works inside the structural package by absorbing the stresses generated in the lower fiber of the reinforcement layer upon which the material is installed, thereby fulfilling the function of sewing the existing cracks on a deteriorated pavement or in accordance to the joints of a concrete pavement (Delbono, 2015). Therefore, the stress test is carried out first, according to the IRAM 78012 standard (Norma IRAM, 2001), using the tensile strength machine EMIC DL 10000, which delivers a stress-strain curve of the material, through its constant recording software. Results are indicated in Table 3.

2.4 Preparation of the test specimens

In a mold of 30x30 cm, the lower layer of asphalt mix is compacted; its thickness is variable according to the relative position in which the geosynthetic material is located, and the compacting temperature (160°C). The Roller Compact machine, Model STCX-2 is used for the molding of the asphalt mix; the equipment was set up at 150°C and was run 24 times. The layer was cooled down and then the asphalt emulsion coating was applied at a proportion of 0.5 l/m², according to the recommendation of the General Technical Specifications of the Argentine National Road Department (under the title of sealing surface bituminous treatment: Section D.III); once the emulsion was cured, the geosynthetic material was applied, making sure that no wrinkles were left, and then the upper layer of asphalt mix was compacted until the specimens were 120 mm thick.

Once the test specimens were prepared, a cut of 2 cm high was made in the lower part of the base, which represents a crack or joint under the location of the geosynthetic material; then, the specimens were cut perpendicular to the created "crack", thereby obtaining three specimens of 10 cm width by 30 cm length for each system to be tested.

Table 3. *Tensile strength results for the geosynthetic material*

Testing Direction	Max. Load (KN/m)	Max. Strain (mm)	Failure Strain (mm)
Parallel to the roller	31.79	19.26	23.06
Perpendicular to the roller	25.25	15.88	20.36

Figure 3. *Roller Compactor*

Figure 4 indicates the location of the geosynthetic material inside the system. In the 1st diagram, the material is located 40 mm above the base of the lower layer, and the compacted asphalt mix over the geosynthetic material is 80 mm thick. In the 2nd diagram, the geosynthetic material is located at 60 mm, and the compacted asphalt mix over the geosynthetic material is 40 mm thick, while in the 3 diagram, the geosynthetic material is located at 80 mm and the compacted asphalt mix over the geosynthetic material is 40 mm thick.

2.5 Modulus of rigidity test

The specimens prepared with the previously described procedures were put above the support system, consisting in plain steel rods of 25 mm diameter in the ends, Figure 5. This support represents the deformation and work capacity of the crack subjected to test loads, which simulate the traffic's dynamic load.

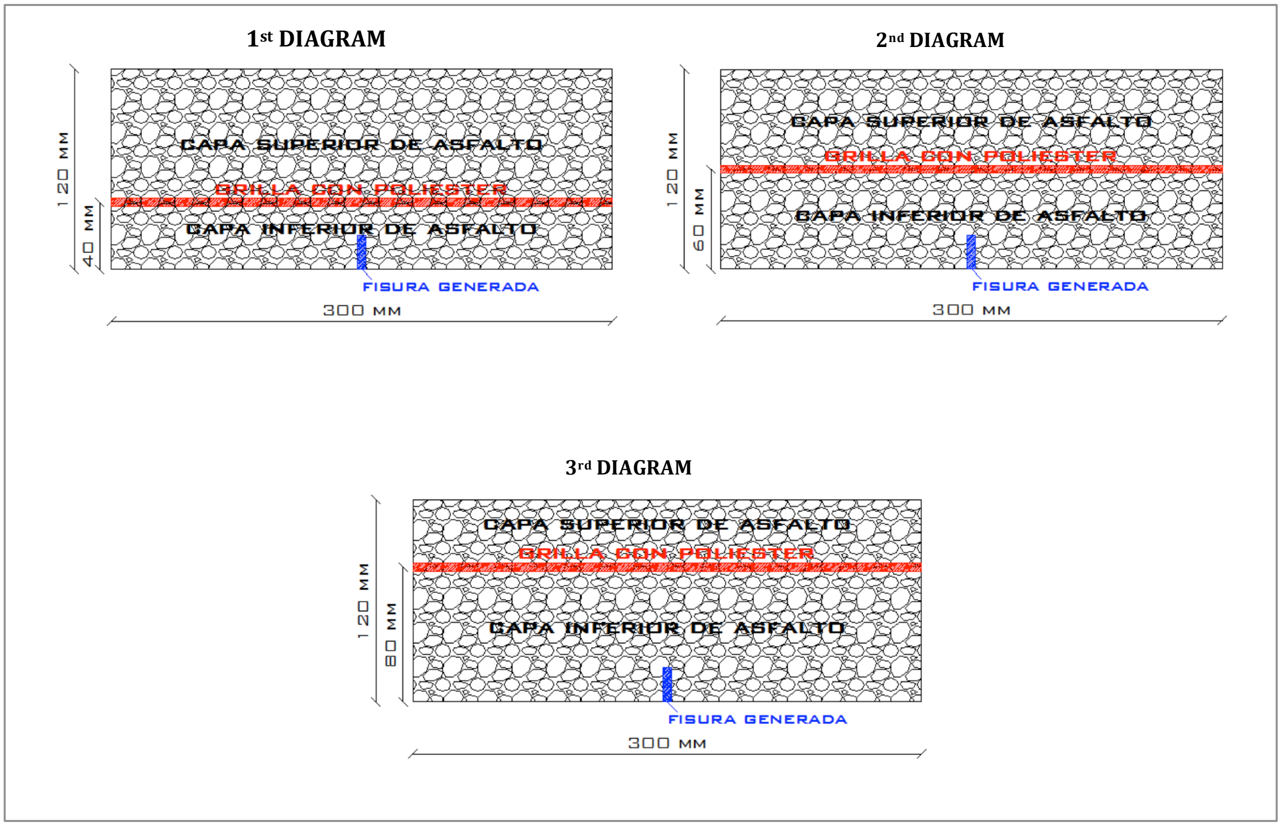


Figure 4. *Location diagrams of the geosynthetic material*

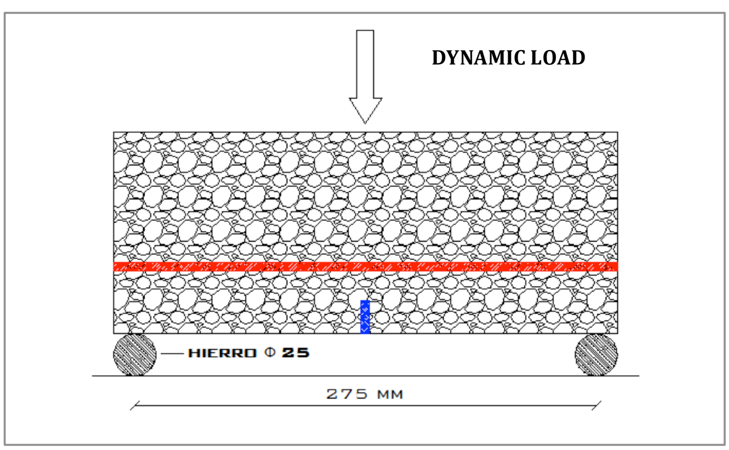


Figure 5. *Diagram of the support system*

The specimens were treated for 4 hours at a temperature of 25°C in the device called Modulus of Rigidity, and then they were tested under the following characteristics: load of 500 Kg at a frequency of 1 Hz, Figure 6.

3. Results

Table 4 presents the results obtained with the reflective cracking phenomenon, interposing the geosynthetic material at different levels of the structural package. These results are compared with the specimen with no interposition of geosynthetic material.

The last column of Table 4 shows the material's effectiveness factor (FEf) according to its location. In the proposed test, this coefficient is determined as the ratio between the number of cycles causing the failure in the specimens with geosynthetic material (Nr) divided by the number of cycles causing the failure in the specimens without geosynthetic material (Nn). This factor takes values higher than 1 if the material improves the reinforcement, and values lower than one if it does not make any contribution to the reference system.

The traffic to be used in the reinforcement calculation is reduced by the effectiveness factor, FEf. In this case, the values of the reinforcement thicknesses are lower than in the case of no application of geosynthetic material, according to the used material (Koerner, 2005).

The effectiveness factor, FEf, is defined as follows:

$$FEf = Nr/Nn$$

Where:

FEf = effectiveness coefficient of the geosynthetic material.

Nr = number of load cycles that cause the failure in specimens with geosynthetic material.

Nn = number of load cycles that cause the failure in specimens without "Reference" geosynthetic.

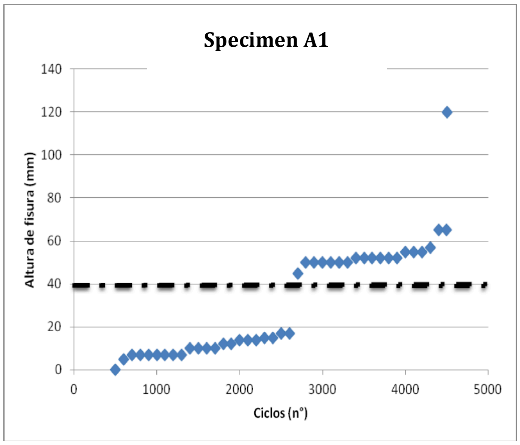
Figure 7 shows the height, in millimeters, in which the crack develops for the different numbers of applied load cycles. Figure 8 shows the failure of the specimens, where it is possible to observe how the crack works its way up to the overlay surface.

Figure 6. *Modulus of rigidity device*

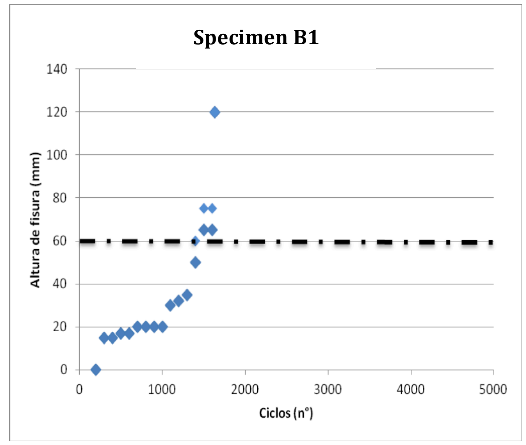
Table 4. *Results of crack propagation when interposing a geosynthetic material*

Location from the base (mm)	Load Cycles (nº)	FEf (Nr/Nn)
Without geosynthetic	12	1
40 mm (specimens A)	3424	285
60 mm (specimens B)	1830	152
80 mm (specimens C)	792	66

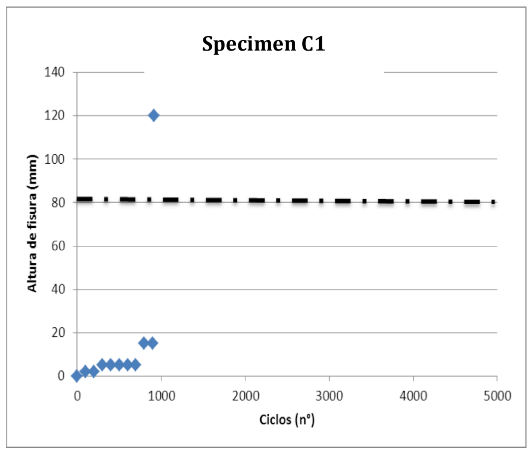
Note: the results are an average of three assessments per each location level of the geosynthetic material.



Geosynthetic located at 40 mm



Geosynthetic located at 60 mm

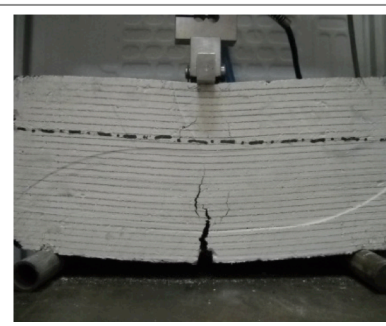


Geosynthetic located at 80 mm

Figure 7. *Trajectory of the crack for each level of the geosynthetic material*

40 mm

60 mm



80 mm

Figure 8. *Propagation of the crack for different locations of the geosynthetic material*

In some cases, a lack of bond between the layers was evidenced; this phenomenon constitutes a relevant factor in the assessment of the results, Figure 9.

When there is a poor bond between the layers and the geosynthetic material, evidence shows that the system does not work monolithically. Because the layers are not well bounded, they work independently one from the other, thereby reducing the system's bearing capacity.

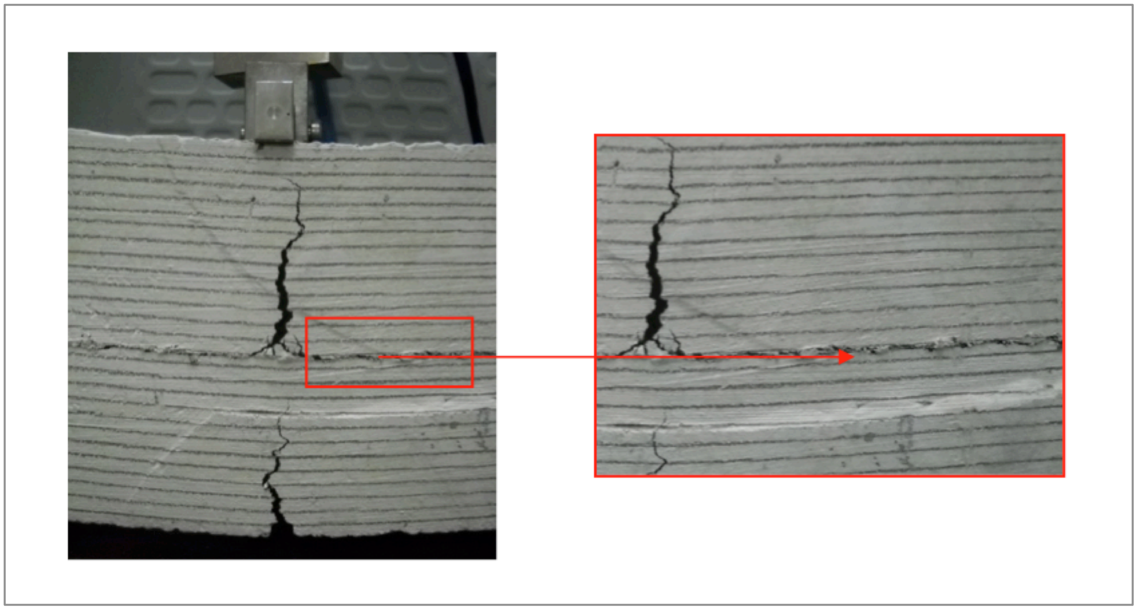


Figure 9. *Lack of bond between the layers and the geosynthetic material*

4. Conclusions

- *The tensile strength results for the geosynthetic material give an idea regarding the load and deformation that the material is capable of developing in order to sew an existing crack in the pavement. Depending on the pavement's condition and joint movements, it can be inferred which type of geosynthetic material is most efficient to work with, among a wide range of possibilities in the market.*
- *The geosynthetic material considerably delays the progression of a crack that will inevitably tend to propagate as a consequence of the repeated load application. Depending on the location of the geosynthetic material, a greater effectiveness of the material is achieved, according to its location within the structural package.*
- *The level showing the best behavior of the geosynthetic material is the one located nearest to the most stressed fiber of the reinforcement layer, underneath the system's neutral line, where it is expected to start working as soon as the crack begins to grow.*
- *The bond between the layers and the geosynthetic material plays a relevant role in the behavior of the structural package. The geosynthetic material must be adequately bonded to the layers in order to absorb the crack's propagation energy; otherwise, the layers behave individually, which entails a bad or null distribution of the stresses in the pavement's total thickness.*

5. References

Al‑Qadi I. L., Elseifi M. A., Leonard D. (2003), Development of an overlay design model for reflective cracking with and without steel reinforcement. Journal of the Association of Asphalt Pavement Technologists, 72: 388‑423.

Delbono H. L. (2015), Estudio de grillas poliméricas en sistemas anti reflejo de fisuras bajo solicitaciones dinámicas. Tesis Doctoral. ISBN: 978-987-1896-38-7. La Plata. Universidad Tecnológica Nacional, Facultad Regional La Plata.

Dirección Nacional de Vialidad (1998), Pliego de Especificaciones Técnicas Generales. 166.p. http:/www.vialidad.gov.ar/corredores%20viales/archivos/2_llamado%20licitacion/PETG.pdf

Guia Maroni, Laerte (1993), *El uso de Geotextiles en Repavimentación Asfáltica. Una Experiencia Reciente. El Fenómeno de la Fisuración de los Pavimentos. "Las Fisuras Reflejas". Carreteras Año XXXVIII N°140, Mayo 1993. Pp.57-66 http://www.aacarreteras.org.ar/uploads/pdf/pdf_Revts/140.pdf*

Koerner R. M. (2005), Designing with Geosynthetics. Fifth edition. p. 796 New Jersey. Pearson Prentice Hall. p. 280-281. ISBN 0-13-145415-3.

Norma de ensayo de Vialidad Nacional (2008), VN – E9 – 86. Ensayo de Estabilidad y Fluencia por el Método Marshall. Dirección Nacional de Vialidad. Dirección Nacional de Vialidad – Edición 2008 1º Distrito Buenos Aires. Argentina.

Norma IRAM (2001). IRAM 78012. Ensayo de tracción con probetas anchas. Instituto Argentino de Normalización y Certificación (IRAM). Primera edición 20-4-2001.

Peshkin D. G., Hoerner T. E., Smith K. D., Bruinsma J. E. and Seeds S. B. (2004), Pavement Preservation: Design and Construction of Quality Preventive Maintenance Treatments, Reference Manual, National Highway Institute, Federal Highway Administration, NHI Course 131103, FHWA-NHI-04-171. Washington, DC.

Virgili A., Canestrari F., Grilli A., Santagata F. A. (2009), Repeated load test on bituminous systems reinforced with geosynthetics. Geotextiles and Geomembranes, 27: 187-195. doi:10.1016/j.geotexmem.2008.11.004