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Improving the durability of roads in Africa – How geosynthetics are helping to improve the durability of roads.

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Abstract. It is widely known that one of the biggest challenges for Africa's development today is its infrastructure development. It is estimated that there are $2.5 trillion in active infrastructure projects which should be completed by 2025. Even if not all projects will be completed, it shows the importance of infrastructure development in the continent. This infrastructure development includes, in its vast majority, the improvement of the road network. At the same time, asphalt degradation (and road cracking) is a worldwide problem which causes a big challenge to road and transport authorities all around the world, with a big impact in Africa as it can take a big part of the budget assigned to the road network. The premature cracking of roads implies having to invest, prematurely, more funds into road rehabilitation rather than developing the actual network. For this reason, increasing the durability of roads has become a major concern in the last years. We will go through one of the highest growing solutions which is asphalt reinforcement geocomposites and how its proper design and installation can drastically improve the design life of roads. Practical examples in Africa (recent and old) will be presented to show the benefits and how we adapt to the local conditions.

1 Introduction

One of the applications where geosynthetics have helped us greatly in the past decades is in the construction of roads. Geosynthetics have become key in many applications for road construction. From subbase stabilisation, separation and filtration, platform stabilisation and up to asphalt reinforcement.

As it is well known, infrastructure development is key for a continent's growth. In the case of Africa, there is a big challenge today not only in closing the infrastructure gap, which is needed for the continent's economic development, but also in maintaining and improving the already existing infrastructure.

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Although a big part of this needed infrastructure mainly concerns the electric grid and the challenge to bring electricity to the nearly 600 million people who lack of access it, for the purpose of this paper, we will concentrate in the road infrastructure.

As explained previously, different geosynthetic solutions can be used at different stages of a road construction, in this paper, we will go more specifically on asphalt reinforcement. Asphalt cracking has become a big problem in Africa, as it is heavily impacting the road durability. This results in higher investments to be made in order to repair the existing infrastructure instead of optimising the available budget in the improvement of the total infrastructure.

2 Where do cracks come from? – Geosynthetic solutions

A recurring problem we see in the road maintenance works is that shortly after, or much earlier than they should, cracks appear again in the surface. In order to understand how to fight against these cracks, we will first expose a typical cross section as well as the main origins of cracks.

2.1 Typical cross-section

An asphalt pavement consists of several layers. The technical properties and the thickness of these layers will depend on the loads, weight of the vehicles and traffic (number of passes). With the same logic, the design of the geosynthetic solution we will use to reinforce the asphalt layer, will also depend on these parameters.

From bottom up we find:

- A prepared (compacted) subgrade
- An unbound subbase consisting of granular material (gravel)
- A bound subbase, bound by bitumen or cement (binder)
- A surface course or wearing course. This is made from Asphalt Concrete (AC)

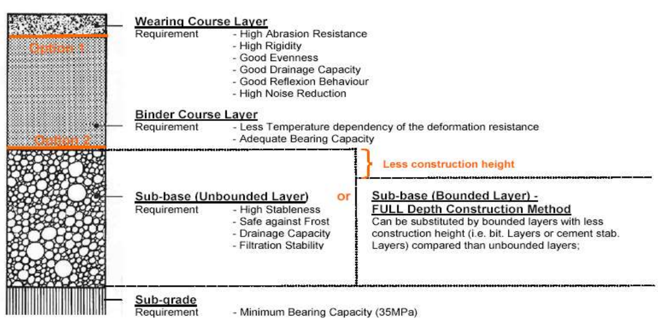

Fig. 1 Typical Cross Section

2.2 Reasons for the formation of cracks

All organic materials will change their properties with time, and this is not different for our asphalt concrete layer (usually consisting of around 95% aggregate and 5% bitumen). The main reasons for the cracks are the following:

- Traffic Loading over time (Fatigue cracking)
- Material Selection
- Quality of installation
- Reflective cracking
- Geotechnical properties of subbase/subsoil (can also be improved by the use of geosynthetics.)
- Climatic boundary conditions (thermal cracks)

One of the biggest problems comes from Fatigue reflective cracking of asphalt concrete overlays. A common solution for cracked roads is the addition of layers of asphalt concrete over the old surface with cracks. From experience, we can see that the old cracks which were present in the road, will shortly rise and appear in the new finished road. For this reason, the inclusion of a geosynthetic (asphalt interlayer) has become a popular solution for durable road rehabilitation

2.3 Asphalt interlayer system

A geosynthetic asphalt interlayer system is placed between the old, cracked asphalt layer and has the following main functions (according to the EN 15381) [1] [2]

- Stress Relief (STR) Function provided by a bitumen-saturated paving fabric (non-woven or purpose-built composite) which – when properly installed between a road surface and a new asphalt overlay – allows for slight differential movements between the two layers and thus pro-vides stress relief, which delays or arrests crack propagation in the asphalt overlay.
- Barrier (B) Function provided by paving fabrics, which act – in conjunction with a bitumen layer – as a barrier to the ingress of water and prevent or delay the deterioration of the pavement.
- Reinforcement (R) Use of the stress-strain behaviour of a geosynthetic material to improve the long-term mechanical properties of asphalt

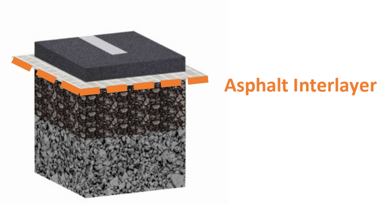

Fig. 2: Asphalt interlayer

Many tests have been performed to analyse the effects of these 3 functions on fatigue behaviour. An interesting study was done (Fatigue Laboratory Test on Asphalt interlayer Systems, Mannsbart, 2022) by testing reinforced and unreinforced specimens which showed an increase in the number of load cycles which is at least 3 – 4 times higher in the reinforced compared to the unreinforced samples. This, using the Three Point Bending Fatigue Tests (TPBFT)

3 Design – how can we predict the new lifetime?

3.1 Testing - experimental

As was referenced in the last section, we can do an empirical / experimental approach in order to predict the positive impact an asphalt interlayer can have in road rehabilitation. From experimentation (Mannsbartt, 2022), after the experiment with 3 tests, we can see the following:

Table 1. Comparison of Load cycles numbers for different tested materials (Mannsbart, 2022) [4]

Test configuration	unreinforced	PGL-G: (R)	PGM-G: (R) + (B) + (STR)
Nr of Load Cycles for a deformation of 100 Microstrain	407 167	2 114 454	3 574 449
% increase from unreinforced	-	510%	879%

2 samples of product where use, to show the impact the different functions stated by the EN 15381 have in the increase of load cycles on the road specimen.

As we can see from the results, although the Reinforcement (R) is key to improve the number of load cycles, the addition of a non-woven to the composite in order to create the barrier function (B) and stress-relief (STR) has a very big impact in the final results.

3.2 Design – calculating the cycle loads

Although it is very hard to calculate the number of load cycles which increase due to the (B) and (STR) functions, the AASHTO (American Association of State Highway and Transportation Officials) [3] proposes a formula which allows us to calculate the increase in load cycles thanks to the improvement in the structure by the reinforcement (R) function of the asphalt interlayer geosynthetic.

The AASHTO method helps evaluate the lifetime of the road by taking in account the following parameters:

- Variation of System Structures (evaluating how the geosynthetic acts upon the road structure)
- Evaluation of relevant parameters and coefficients (all parameters will be explained hereafter)
- As a standard, we use the unit of measurement of Equivalent Single Axle Loads (ESAL)

The formula proposed by AASHTO is the following

$$\log_{10}(W_{18}) = Z_R{*}S_0 + 9{,}36{*}\log_{10}(SN+1) - 0{,}20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4{,}2-1{,}5}\right)}{0{,}4+\frac{1094}{(SN+1)^{5{,}19}}} + 2{,}32{*}\log_{10}(M_R) - 8{,}07 \quad (1)$$

Where:
W_{18} = predicted number of 80 kN (18,000 lb) ESALs
Z_R = standard normal deviate ("safety coefficient")
S_0 = combined standard error of the traffic prediction
SN = Structural number (an index that is indicative of the total pavement thickness required)
= $a_1D_1 + a_2D_2m_2 + a_3D_3m_3$
a_i = i^{th} layer coefficient
D_i = i^{th} layer thickness (inches)
mi = i^{th} layer drainage coefficient
ΔPSI = difference between the initial design serviceability index p_0 and the design terminal serviceability index, p_t
M_R = sub-grade resilient modulus (in psi) ("soil-stiffness")

With this formula, we can calculate both a reinforced and an un-reinforced situation, this way, we can compare the positive impact in the number of possible cycle loads. The reinforcement (R) function is taken into account in the structural number as increased layer coefficient ai of the layer. This is interpreted as and "idealised" improvement of the Marshall value. To calculate the increase inf lifetime we will evaluate the average traffic on the road as well as the increase in traffic. This way, we will be able to evaluate in unit of time, the increase in lifetime of the road thanks to the geosynthetic. According to experimentation and design, we can state that the results from this calculation approach are usually below the results of experimental approaches. In addition, as stated before, this does not take into account the (B) and (STR) effects.

4 Installation in Africa - Ziguinchor

In order to evaluate the positive impact of a (R) geosynthetic, a sample section of PGL-G 100/100 reinforcement grid was installed in the Ziguinchor region in Senegal. The section to be reinforced concerned a newly rehabilitated road which shortly after being rehabilitated, already presented cracks. The cracks were investigated, and it was determined they were coming from the old cracks below. The following picture shows a cross section on the road at a crack location.

Fig. 3: *Cracks location*

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The approached solution was to install the PGL-G 100/100 on top of the cracked section. By doing this, we created an interlayer of reinforcement which will absorb the tension propagated by the cracks below, therefore delaying the appearance of cracks in the new built layer.

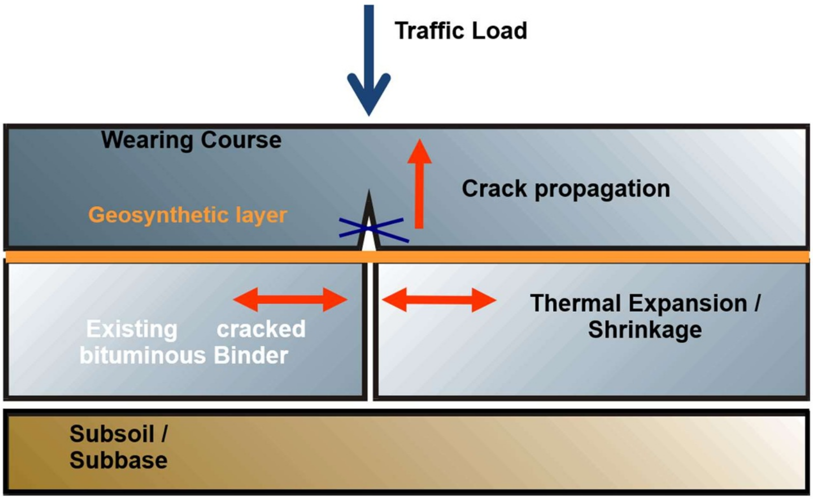

Fig. 4: *Cross section of crack propagation and prevention with a Geosynthetic layer*

The following images show the process of installation. Due to the hot tropical climate, the tack coat placed allowed a fast installation as water evaporated quickly.

Fig. 5: *PGL-G 100/100 installed*

Fig. 6: *PGL-G 100/100 installed over tack coat*

As the project concerned the rehabilitation of a road, there was no possibility of improving the foundation soil for the road's platform. This increased the importance of a high strength asphalt reinforcement to delay the cracks which could be made due to the soil deformations.

For the reinforcement product used, a geocomposite product PGL-G 100/100 was used. The product consists of a lightweight PP non-woven and a coated glass filament grid. The main properties are shown in the following table

Table 2. Properties of PGL-G 100/100 used

Properties	Standard	Unit	PGL-G 100/100
Tensile Strength MD/CD	EN ISO 10319	kN/m	100 / 100
Elongation at break	EN ISO 10319	%	3 / 3
E modulus (for fibreglass)		MPa	80 000
Melting point	EN ISO 3146	°C	400°C

Several points were important in the choice of the product:

- Glass filament gird → Allows a higher melting point which will withstand the high temperatures of installation
- Very low elongation at break → In all geosynthetic reinforcement products we are looking for very low elongations – stiffer products. This is especially important in asphalt reinforcement as deformations causing cracks are very low. So we need products with high strength at very low elongations.
- Light non-woven for installation: as only the (R) function was selected, a light non-woven adds to the grid in order to simplify the installation.

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4.1 Follow up – outcome analysis

The installation was made in April 2021. Follow-ups have been done regularly to check if any cracks have appeared.

At this moment, the road is in perfect conditions. It is to note that only several months after first installation without a geosynthetic reinforcement, cracks appeared. So, after nearly 2 years after reinforcement, we can state that the product is already providing a better result.

The evolution of the road will be tracked to monitor if any cracks appear in the future.

5 Conclusions

After comparing the results of preliminary design by the AASHTO method, experimental results in laboratory, and on-site results, we can conclude that the use of asphalt interlayer systems provide a big improvement in the durability of new and rehabilitated asphalt roads. Cracking of roads and its general maintenance is a great challenge all around the world, and Africa is no exception to this, where a higher investment in infrastructure is needed today. Geosynthetics are becoming and will become a key technology to help make this infrastructure more durable and, as demonstrated in this paper, with a big role in road durability with asphalt reinforcement.

6 References

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