GROUND STABILIZATION OF THE MR348 – MORRISON ROAD – GLENTANA - SOUTH AFRICA

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ABSTRACT: Ground stabilization techniques are breaking through South African pavements as cost-effective solutions achieving design performance with shallower layerworks, higher design traffic or using poor material. Morrison Road near Glentana is the first project in South Africa where ground stabilization was used increasing the support over a very soft subgrade for a 3 million E80 pavement. Original design was based on the South African Pavement Design Method (SAPDM); while the ground stabilization was based on the AASHSTO including the layer coefficient ratio (LCR). Two layer of bidirectional extruded geogrids were placed in the subbase and base achieving a reduction of the pavement from 1.2m to 0.7m maintaining the same traffic loading. The installation of the geogrids had required training of the contractor to ensure CQA achieved by extensive site supervision and modification to current South African construction methodology to ensure the geogrids would have not been damaged during installation.

Keywords: ground stabilization, roads, South Africa, AASHTO, LCR

1 INTRODUCTION – FROM PRODUCT TO TECHNOLOGY

Before the launch of the new South African Pavement Design Method (at the time of writing), extensive research was undertaken to evaluate current road pavement material performance, (design versus long term actual performance), in new materials development. However, no interest was shown towards technology which has proven to benefit a pavement by an unequalled value of up to 10 times normal traffic load, allowing a reduction in layer thickness of up to 50%. This means a category C (ES-0.01 to 0.1) road becomes a category B road (TRH 4,1996).

Geosynthetics has a record of more than 30 years of proven results and efficiency in practice. Some new materials currently used in roadworks do not have proven records over this time span. Although classified as materials or products, they represent a new technology. Geosynthetics technology is the results of designs based on proven studies, research, field tests and calibration thus developing a strong based for designing.

Geosynthetics technology was recently successful in a road rehabilitation project near Glentana in the Southern Cape in South Africa. The traditional pavement comprised a 1.2m thick layerworks which was reduce to 0.7m using two layers of extruded bi-direction polypropylene geogrids in the subbase and base which details will be presented herein.

1.1 *Background of geosynthetics in pavement*

The first recorded projects where geosynthetics were used in pavements were in the 1930s in test sections on highways in South Carolina, Rhode Island, Montana, and New Jersey. This was a collaboration between USDA and USBPR (forerunner of the FHWA). From records, it appears that the tests were very successful (FHWA, 1989). The technology, however, lay dormant until in the early 70s where in Scotland and North America, test sections were constructed to supply information on how geotextiles would perform in roadways. There was a growing interest in this application by geotextiles manufactures. The first design procedures were published by John Steward in the 70s, followed by Giroud and Noray in 1981. In the early stages the main function of geotextiles was to avoid imported material of good quality being contaminated by poor quality in-situ material. Without geotextiles, the contamination of the imported material by the poor in-situ brought to an aggregate loss which resulted in reality of an increment of thickness of the imported material (Figure 1, NHI, 1998).

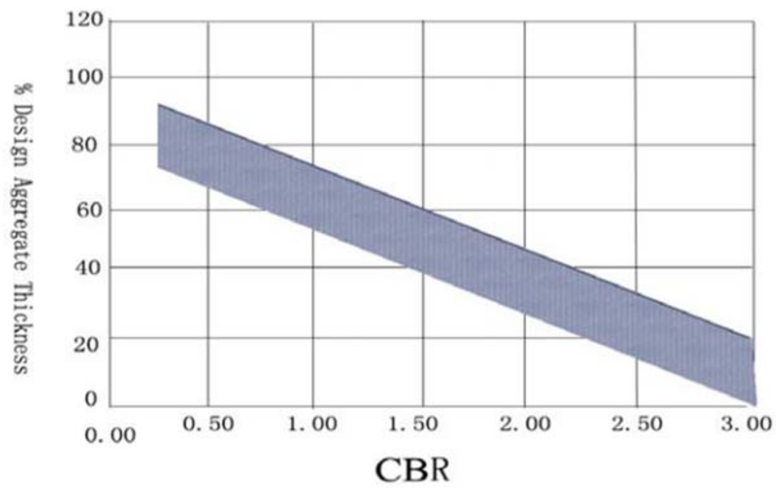

Figure 1. Aggregate loss due to weak subgrade

With the development of geosynthetics such as woven geotextiles and in particular geogrids characterized by high stiffness, a new concept was introduced which was reinforcement of soil where the geosynthetics was able to cater for tensile strength developed in soil. This resulted in a combination between soil and geosynthetic being able to sustain higher stresses, enhancing the mechanical properties of the soil up to 4 times more as shown in Figure 2 through a triaxial test on silty sand (Moghaddas, 2007)

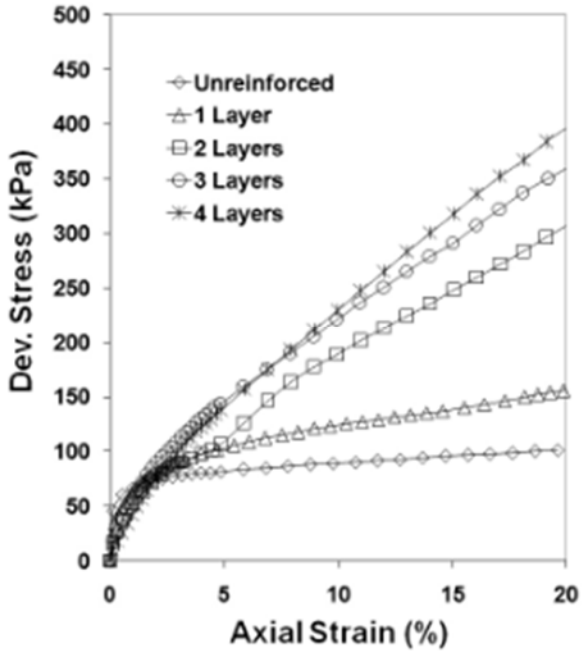

Figure2. Triaxial test on reinforced silty sand

The inclusion of geosynthetics reinforcement therefore was beneficial as it allowed reduction in thickness of structural layer work (thus shallower box cut profiles), increasing design life and reduce the overall construction time. Figure 3 shows an example of separation on the right and separation plus reinforcement on the left (Rimoldi, circa 1990).

Figure 3. Left: reinforcement (geogrid) - Right: separation (nonwoven geotextile)

The structural integrity of the imported layers is increased by the mechanical bonding between the soil particles and the geogrid. Both gravel and surfaced roads can benefit with the introduction of geogrids. Different design strategies should, however, be considered such as the Leng-Gabr design method for gravel roads where the influence of the geosynthetics is based on the stiffness of the geotextile or geogrid, taking into consideration the interlocking effect of geogrids compared to geotextiles, further increasing the reduction of the pavement of another 20% compared to the geotextiles solution (Figure 4).

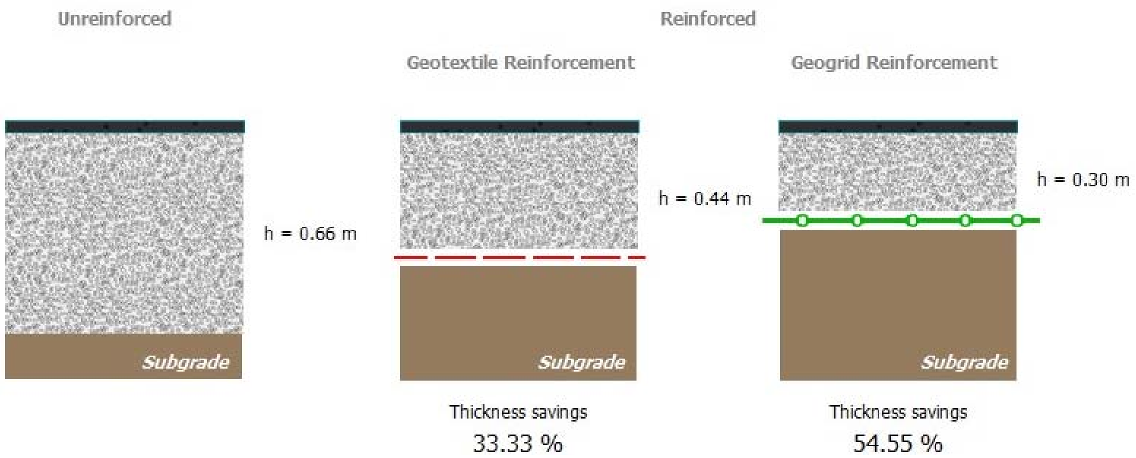

Figure 4. Reduction in layer thickness using geotextiles and geogrids (Leng, 2002)

For surfaced roads, the arithmetic formula determining layer thickness for the AASHTO 1993 was modified to include the performance of the geogrid introducing a improvement factor defined layer coefficient ratio – LCR (Perkins,2003 and Tebaldi, 2012).

1.2 *The modified AASHTO 1993 including geogrids*

The structural contribution of geogrids on a flexible pavement system can be quantified by the increment of layer coefficient in the aggregate base and subbase as follows:

$$SN = a_1 D_1 + LCR a_2 D_2 m_2 + LCR a_3 D_3 m_3 + \cdots \qquad (1)$$

Where:
LCR - Layer Coefficient Ratio;
a_n – layer coefficient for layer *n*
D_n – layer thickness for layer *n;*
m_n – layer drainage coefficient for layer *n*.
LCR value is determined based on the results from laboratory testing on flexible pavement systems with and without geogrid:

$$LCR = \frac{SN_r - \alpha_1 D_1}{SN_u - \alpha_1 D_1} \qquad (2)$$

SN_r – Structural Number – reinforced;
SN_u – Structural Number - unreinforced

SN structural number of the reinforced section, and SN, structural number of the unreinforced section are both evaluated under the same pavement conditions, i.e. same base course depth, subgrade CBR, and rut depth. LCR values are shown in the figure 5 versus the CBR of the subgrade applicable, obtained by interpolation of curves available in literature.

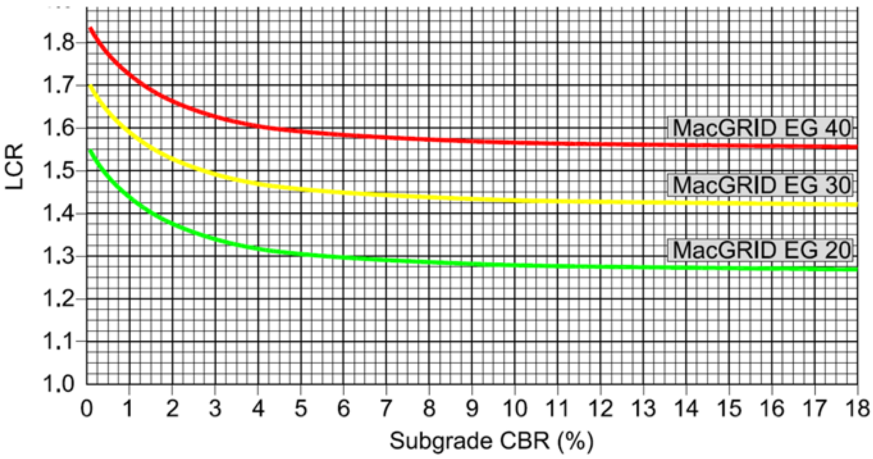

Figure 5. Layer Coefficient Ratio for Geogrids vs. Subgrade CBR (Maccaferri, 2012)

The LCR graph shows the improvement in the subgrade CBR when a geogrid is introduced. For high quality soils (high CBR-values) the improvement is constant. However, when the soil has a low strength (CBR less than 5), the improvement to the soil as a result of geosynthetics increases.

2 MR348 – MORRISON ROAD REHABILITATION NEAR GLENTANA

The investigation of the road revealed that major deep seated deformation/settlement had taken place over certain sections of the road. A geotechnical investigation using Dynamic Probe Super Heavy (DPSH) testing indicated the presence of a deep (up to 8m in certain locations), soft, low strength subgrade SPT "N" values as low as 1 was recorded in certain locations due to penetration generally occurring under self-weight of the equipment with no drop weight activation required, indicating a very poor subgrade.
From test pits the subgrade material was classified as sand containing organic decomposed material

Figure 6. DPSH testing on road subgrade

Figure 7. Subgrade consisting of sand containing decomposed organic material

Various pavement rehabilitation options were investigated during the design stage of the project. This included among other the removal and replacing of the poor subgrade material. This option was found to be unpractical considering the depth of the poor subgrade and the restrictive environment of the road. Other options investigated included the use of micro pilling but due to the high cost this option was also not considered to be viable. The rehabilitation strategy that was found to be the most cost effective was ground stabilization technique using geosynthetics in order to reduce the overburden pressure caused by the increase in pavement thickness.

2.1 *The design of Main Road 348 near Glentana – South Africa*

One of the main design criteria was to maintain an undisturbed stress state in the soft, poor subgrade material to avoid deformation and resultant failure.

Traditional design run using the South African Mechanistic Pavement Design Method - SAMPDM considering a road Category B as per TRH 4 with an ES3 (3 million ESAL) resulted to a total pavement depth of 1.2m as shown in Figure 8.

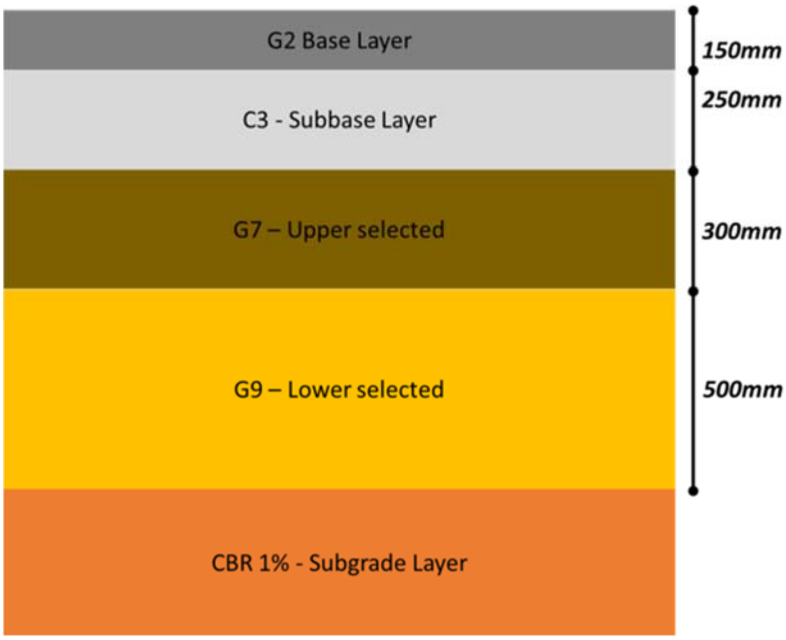

Figure 8. SAMPDM pavement structure

Where according to TRH 14:
G9 – Minimum CBR at in-situ density of 7
G7 – Minimum CBR at 93% mod AASHTO density of 15
C3 – UCSC at 7 days between 1.5 and 3.0MPa at 100% Mod AASHTO density
G2 - maximum size aggregate 37.5mm – LL 25 max, PI 6 max, up to 12% passing 0.075mm sieve

Subsequently the AASHTO 1993 model was calibrated to match the SAMPDM in unreinforced scenario (no geogrids present) in order to have a consistent design (not included in this article).

Table 1. AASHTO 1993 parameters

Layer	**Classification TRH 14**	**AASHTO 1993**	
		Layer coeff – *a*	**Drainage coeff - *d***
Surface Layer	not considered		
Base Layer	G2	0.18	1
Subbase Layer	G4	0.16	1
Selected Subgrade Layer	G7	0.06	1
Subgrade	CBR 0.5		

Note that the 250mm C3 subbase was replaced by 2x 150mm G4 (same as G2 with maximum aggregate size of 37.5mm up to 15% passing 0.075mm sieve).

The result from the model are shown in Figure 9 where two geogrids (Table 2) were placed, one in the G7 and one in the G4 base, reducing the excavation from 1.2m to 0.7m, resulting in a no-stress variance in the soft layer (which would have fail due to the overburden pressure caused by the extra layer thickness) as well as maintaining the same road surface level which was paramount due to the main intersections and road annexures.

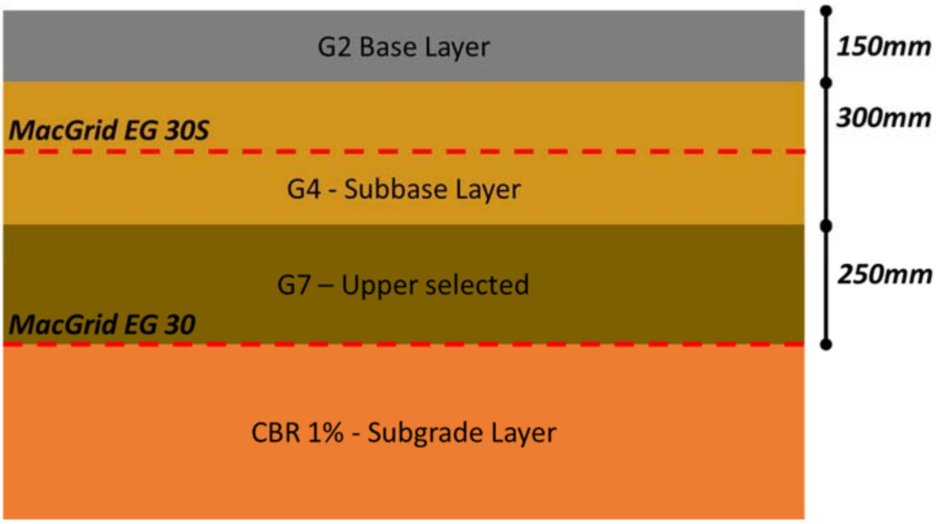

Figure 9. AASHTO design improved with geogrids

Table 2. MacGrid EG 30S – Mechanical properties

Mechanical Properties for MacGrid EG 30S			
Minimum Average Tensile Strength Longitudinal	EN ISO 10319 ASTM D 6637	kN/m	30.0
Tensile strength at 2% strain - Longitudinal		kN/m	10.5
Tensile strength at 5% strain - Longitudinal		kN/m	21.0
Typical strain at M.A.T.S. - Longitudinal		%	13
Minimum Average Tensile Strength Transverse		kN/m	30.0
Tensile strength at 2% strain - Transverse		kN/m	10.5
Tensile strength at 5% strain - Transverse		kN/m	21.0
Typical strain at M.A.T.S. - Transverse		%	10
Typical junction strength efficiency Typical value	GRI GG2/GG1	%	95

2.2 *The construction of MR348 near Glentana*

Construction commenced in March 2014. Storm water reticulation along the edges of the road prism was upgraded before proceeding with the layerworks. Due to traffic constraints the contractor was only allowed to work half widths. The contractor requested access to the full width of the road to reduce the construction time. The request was accepted by the client and traffic was redirected through the municipal areas. By constructing in full width, the contractor was able to lay down the geogrid in one operation minimizing jointing and effectively only using 3 rolls widths to cover the road prism. The first geogrid layer was placed on the road box cut and then covered with a G7 subgrade.

Figure 10 First geogrid placed beneath the G7

Particular attention was given to jointing of the geogrid. A minimum overlap of 300mm was required to ensure the tensile forces in the geogrids would be transmitted through the layer works.


Figure 11. Particular of the geogrid overlapping

The second geogrid layer was placed between a lower and upper G4 layer. A G2 base course was then constructed and sealed and the road opened to traffic. In total 40 000 sqm of geogrid was placed in the layer works. Many motorists will use this road oblivious to the fact that it was not constructed by conventional methods and that the road prism was constructed by a more efficient method saving time and cost.

3 GEOSYNTHETICS, PRODUCTS OR TECHNOLOGY?

The versatility of geosynthetics has been a controversial concept. It has grown in research, improved its product and its application in less than 30 years. It will take time to digest the incredible results that geosynthetics have achieved. A geosynthetic material, be it a geogrid, geotextile or a mat is a product, that on its own, will not create any interest. It needs to be supported by research, field testing and analytical calculations. It is not just a product, it is a technology; amazingly it is a current technology which is available to many fields of engineering, not only roads, but also landfills, water retentions, walls, erosion control and coastal protection.

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