Ground Stabilization using Geosynthetics

D. Herbst[1], T. Naidoo[2]
F. Lewis[3], C. Gewanlal[4]

[1]Kaytech, Pretoria, Gauteng, Danieh@kaytech.co.za
[2]Kaytech, Edenvale, Gauteng, Tyronen@kaytech.co.za
[3]Nyeleti, Polokwane, Limpopo, Flewis@Nyeleti.co.za
[4]Tensar, Johannesburg, Gauteng, Cgewanlal@tensar.co.za

Abstract

The use of stiff triangular aperture stabilization geogrid technology decreases the capital costs and construction duration of new and rehabilated roads, allowing Municipalities and Road Authorities to service a larger community.
In comparison to conventional design methods, the following factors are particularly advantageous when stabilization geogrids are considered:

- Free-to-use in-situ fill material can often be used, saving time and money on importing material
- Execution of construction is simplified resulting in shorter construction durations
- Material costs are decreased
- Long term maintenance requirements are decreased
- Longevity of the project is increased
- No specialized/skilled labour nor machinery is required
- Labour based construction methods are fostered and can form part of EPWP projects.

This paper describes the application of the geosynthetic product and the method of installation. The paper highlights the working mechanism of the stabilization geogrid used in the Senwabarwana gravel Road upgrade project in contrast to conventional construction methods. It also describes how stabilization geogrids can complement projects by reducing overall lifecycle costs and time spent on construction. Long term testing and trial records of stabilization geogrids provide beneficial changes from tedious conventional construction processes to simpler methods. Industry benefits are shown by the comparative costs of stabilization geogrid vs. conventional methods.

Keywords: *Soil stabilization, stabilization geogrids, Geosynthetic replacement, Conventional method.*

1 Introduction

Today more and more geosynthetic solutions are being used in road construction. Globally these geosynthetic solutions have become widely accepted and are taught to students as part of their civil engineering curricula all around the world by internationally acclaimed academics. Road materials and pavement layers are now often replaced or mechanically stabilized using specialist open geogrid or composite geogrid technology (Jenner, 2000).

It was found that the cost of imported material negatively impacted the budget allocation to this project. By using a specialist geogrid, costs were significantly reduced and construction methods were streamlined to allow construction of an improved road within budget.
This paper details how these improvements were achieved in comparison to the conventional design. The manufacture and installation of the geogrid, long term traffic tests and proprietary software utilized in the design of pavements are also discussed.

2. Project description

Senwabarwana is a lower to middle income residential suburb situated within the Capricorn district of Blouberg Municipality in the Limpopo Province. Much of the suburb is traversed by gravel roads and in this project, the municipality undertook to upgrade two of the main internal streets to an asphalt surfaced road standard. According to the Red Book: "Guidelines for Human Settlement Planning and Design", both roads could be classified as Local / Access roads in terms of the UTG series. The roads were designed to a Class D (rural access road) technical specification using the TRH4 (Table1, Technical recommendations for Highways, 1996). Due to the extent of service delivery required in the municipality, a limited amount of funds were allocated to the project. Thus some new, innovative methods had to be investigated in order to make the project feasible.

2.1 Design Parameters

The proposed road, was a continuation of an existing surfaced road and also a new access to the existing residential stands. The road starts at the end of the existing surfaced road. The total length of the roads that were upgraded is approximately 600m. The road traverses a predominantly built-up area and the combination of these two factors posed challenges with the upgrading. The Technical Recommendations for Highways (TRH4, Structural Design of Flexible Pavements for Interurban and Rural Roads, 1996) was used. According to the TRH4 the road can be classified as Road Category D (Rural Access roads). The traffic loading was used to calculate the required pavement bearing capacity. The pavement design was based on a ten year structural design period and light medium traffic volumes with very few heavy vehicles, producing a pavement class ES1 (Table 4, TRH4, 1996).

Table 1. TRH 4 Definition of Road Categories

TABLE 1
Definition of the road categories

ROAD CATEGORY				
	A	B	C	D
Description	Major interurban freeways and major rural roads	Interurban collectors and rural roads	Lightly trafficked rural roads, strategic roads	Rural access roads
Importance Service level	Very important Very high level of service	Important High level of service	Less important Moderate level of service	Less important Moderate to low level of service
TYPICAL PAVEMENT CHARACTERISTICS				
RISK	**Very low**	**Low**	**Medium**	**High**
Approximate Design Reliability (%) *	95	90	80	50
Total Equivalent Traffic Loading (E80/lane) **	3 - 100 x 10^6 over 20 years	0,3 - 10 x 10^6 Depending on design strategy	< 3 x 10^6 Depending on design strategy	< 1 x 10^6 Depending on design strategy
Typical Pavement Class ***	ES10 - ES100	ES1 - ES10	ES0.003 - ES3	ES0.003 - ES1
Daily Traffic: (e.v.u) ****	> 4000	600 - 10 000	< 600	< 500
Constructed Riding Quality: PSI ***** HRI (mm/m or m/km) ***Terminal Riding Quality:*** PSI HRI (mm/m or m/km)	 3,5 - 4,5 1,5 - 1,0 2,5 2,7	 3,0 - 4,5 2,0 - 1,0 2,0 3,5	 2,5 - 3,5 2,7 - 1,5 1,8 3,9	 2,0 - 3,5 3,5 - 1,5 1,5 4,5
Warning Rut Level (mm) Terminal Rut Level (mm)	10 20	10 20	10 20	10 20
Area / length of road exceeding terminal conditions (%)	5	10	20	50

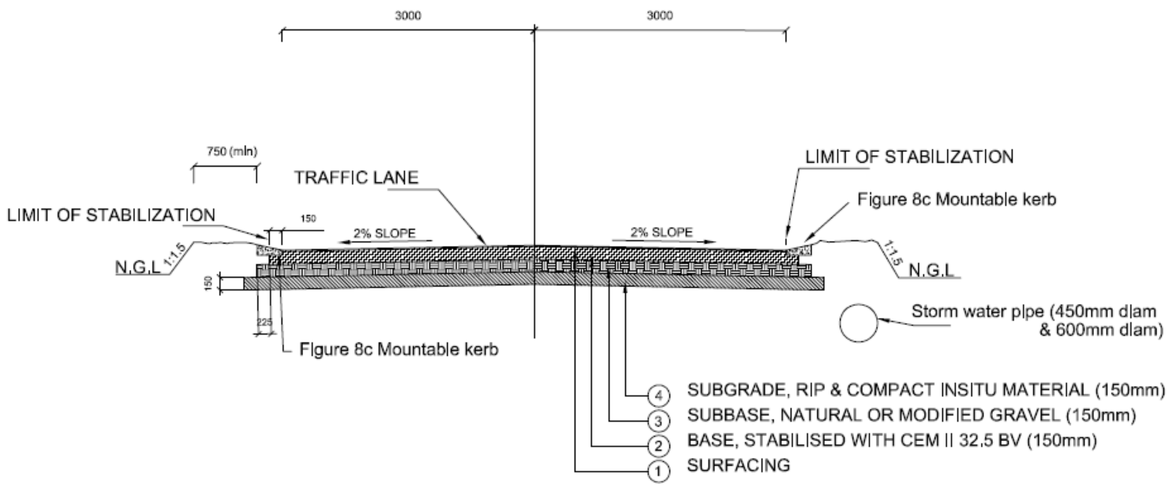
Table 2. Classification of pavements and traffic for structural design purposes

TABLE 4

Classification of pavements and traffic for structural design purposes

Pavement class*	Pavement design bearing capacity (million 80 kN axles/lane)	Volume and type of traffic**	
		Approximate v.p.d. per lane***	Description
ES0.003	< 0,003	< 3	Very lightly trafficked roads; very few heavy vehicles. These roads could include the transition from gravel to paved roads and may incorporate semi-permanent and / or all weather surfacings.
ES0.01	0,003 - 0,01	3 - 10	
ES0.03	0,01 - 0,03	10 - 20	
ES0.1	0,03 - 0,10	20 - 75	
ES0.3	0,10 - 0,30	75 - 220	
ES1	0,3 - 1	220 - 700	Lightly trafficked roads, mainly cars, light delivery and agriculture vehicles; very few heavy vehicles.
ES3	1 - 3	> 700	Medium volume of traffic; few heavy vehicles.
ES10	3 - 10	> 700****	High volume of traffic and / or many heavy vehicles.
ES30	10 - 30	> 2200****	Very high volume of traffic and / or a high proportion of fully laden heavy vehicles.
ES100	30 - 100	> 6500****	

2.2 Conventional design



TYPICAL PAVEMENT CROSS-SECTION

Fig 1. Conventional design

2.3 Alternative design (Geogrid)

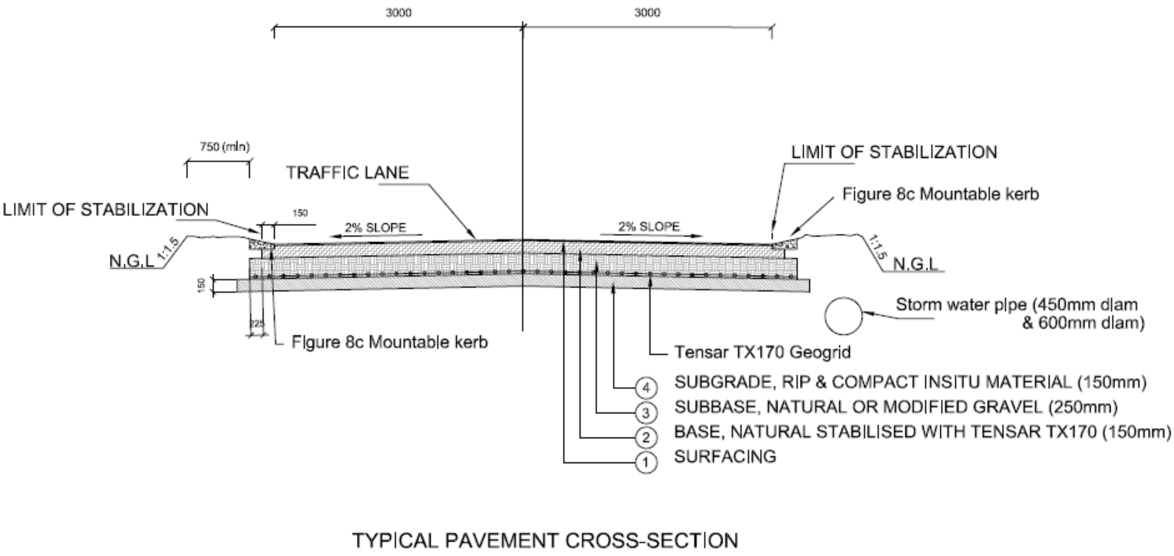


Fig 2: Geogrid design

3. Different construction methods to designs

3.1 Conventional design TRH4

TRH4 specifies a standard design life of ten to fifteen years according to the traffic volume and road classification. Using the TRH4 design catalogue for cemented bases in a dry region, the recommended pavement structure was as Figure 1 above.

3.2 Geogrid design

By applying the proprietary TensarPave® design approach the engineer proposed using the TriAx hexagonal geogrid to construct a mechanically stabilized pavement layers using in-situ material. The design was recommended to the client and accepted as this delivered a cost saving on the project.

4. Description of Geogrid used in the Construction

The geogrid is an advanced product specifically designed for trafficked surfaces. The geogrid's multi-directional properties leverage off triangular geometry, one of the most stable and widely utilized shapes in structural engineering. The triangular structure, coupled with improved rib and junction strength yields a full 360 degree radial stiffness not easily offered by the more common bi-axial geogrids. This gives the roads industry an improved alternative to conventional materials and practices. The manufacturing process is explained in Section 4.1 below.

Index Properties	Longitudinal	Diagonal	Transverse	General
▪ Rib pitch[2], mm (in)	40 (1.60)	40 (1.60)	-	
▪ Mid-rib depth[2], mm (in)	-	1.6 (0.06)	1.4 (0.06)	
▪ Mid-rib width[2], mm (in)	-	1.0 (0.04)	1.2 (0.05)	
▪ Rib shape				Rectangular
▪ Aperture shape				Triangular
Structural Integrity				
▪ Junction efficiency[3], %				93
▪ Radial stiffness at low strain[4], kN/m @ 0.5% strain				300
(lb/ft @ 0.5% strain)				(20,580)
Durability				
▪ Resistance to chemical degradation[5]				100%
▪ Resistance to ultra-violet light and weathering[6]				70%

Fig 3. Properties of the Geogrid (TX160)

4.1 Manufacturing process

The geogrid is manufactured from a punched polypropylene sheet oriented in multiple, equilateral directions to form its triangular apertures, resulting in high radial stiffness throughout the full 360 degrees, which is then oriented in three equilateral directions so that the resulting ribs of the triangular apertures have a high degree of molecular orientation. This feature yields a more efficient product that delivers optimal in-service stress transfer from the aggregate to the stabilizing geogrid. The geogrid is manufactured in accordance with a management system which complies with the requirements of BS EN ISO 9001:2008.

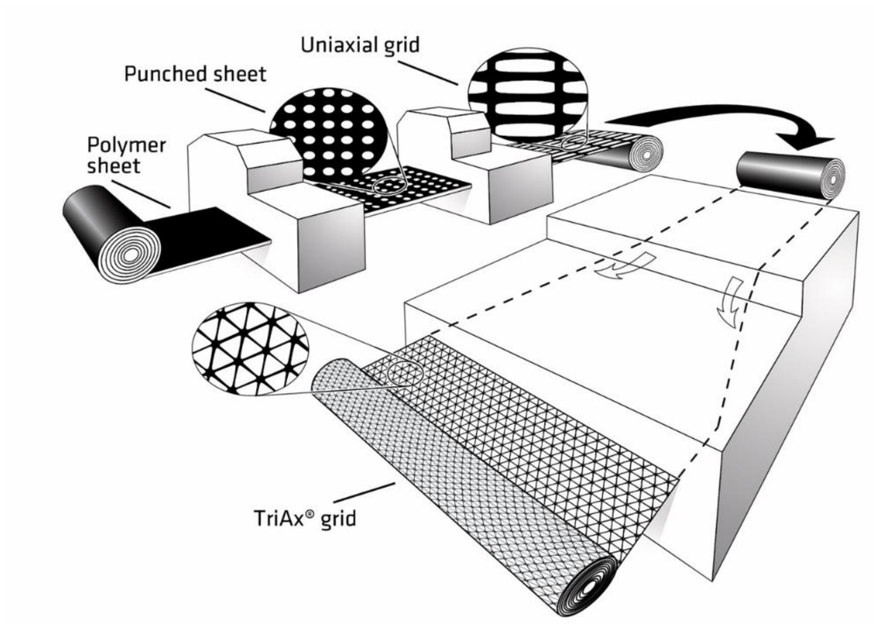
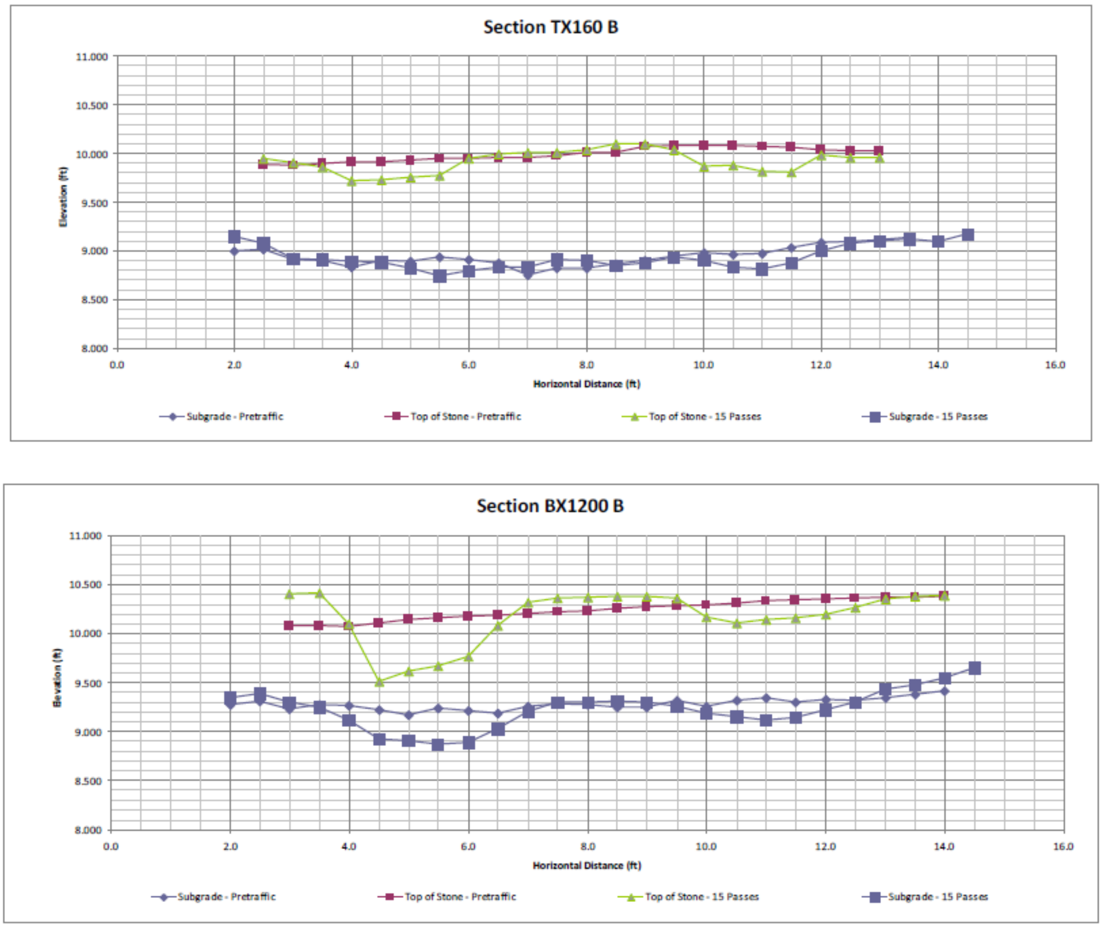


Fig 4: Manufacturing process of Hexagonal Geogrid

4.2 Full Scale Testing and Validation of Geogrid

Several design methods to estimate the benefit of including geosynthetic reinforcement into pavements exist. In the USA, most designers now accept the approach prescribed by AASHTO (2010) (Wrigley, 2013). A field study in West Virginia under the control of Vertex design group was set up to investigate the performance of triaxial grids in their most common applications - stabilization and compare performance to a bi-axial geogrid. This was done by cutting transverse trenches in the test section and measuring the post-trafficking profiles. Measurement of strain in the geogrid is an important parameter that can be used to compare geogrids to one another as well as help develop predictive numerical models to one another as well as help develop predictive numerical models of pavements stabilized using geogrids (Norwood and tingle, 2013).



Graph 1. Comparison of post trafficking profiles for TriAx TX160 and BX1200

The graph shows that TX160 controlled deformations on the surface better than the biaxial grid also used in the test section as a control. This test established that the triaxial geogrids improved performance in full scale testing

5. Software Analysis and Validation

The propriety software, TensarPave®, developed by Tensar allows a design engineer to evaluate options and optimize the pavement performance using the triangular aperture geogrids. The software allows designers to take advantage of knowledge developed by Tensar over 30 years of performance testing and evaluation. The software enables designers to:

- Design for a specific level of performance
- Analyze a variety of support and loading conditions and serviceable limits
- Evaluate and compare designs and costs

The method proposed by the manufacturer in the software received third party endorsement verifying that the software is in compliance with 1993 AASHTO Guide for Design of Pavement Structures methodology. The design program allows an engineer to rapidly produce designs to compare cost savings using a triangular geogrid. It is important to note that the software does not use the characteristics of the geogrid itself but models the effect of the stabilization factors unique to the geogrid to determine the required mechanically stabilized layer (MSL) thickness. These factors have been derived from extensive full scale testing that have been subject to third party verification.

The design life of the road is typically measured in terms of traffic capacity.

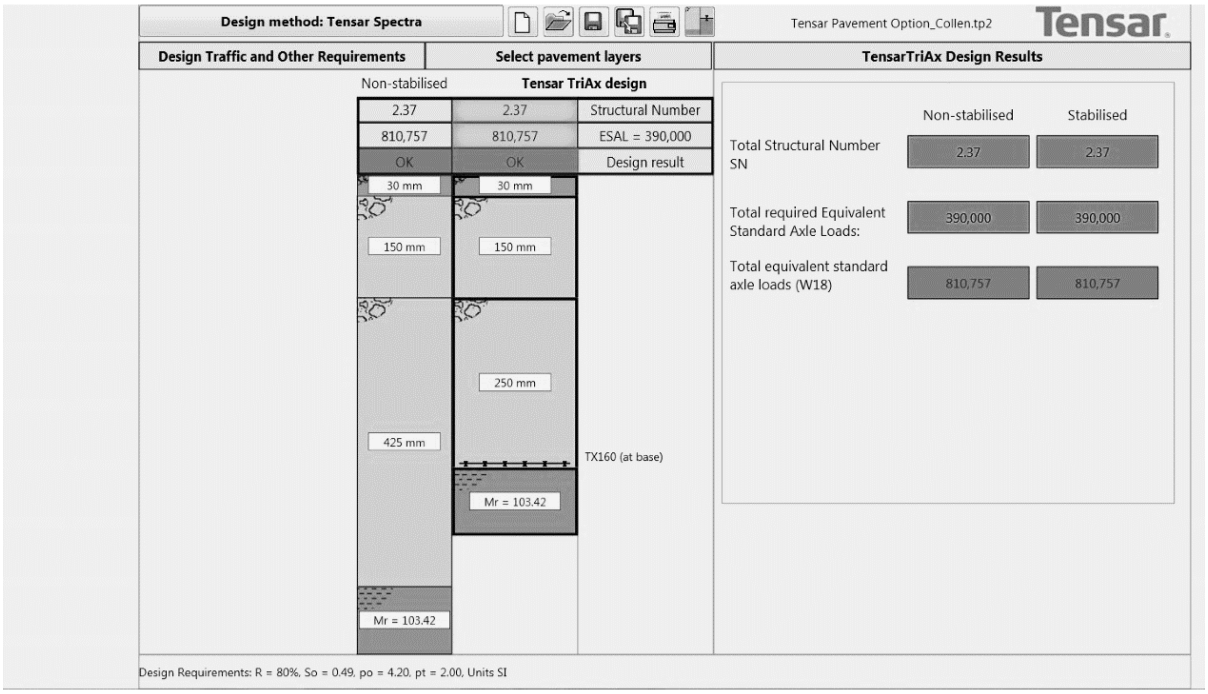


Fig 5. Snippet from TensarPave® software

The snippet above shows the reducing of layers afforded to the project in question. This shows a large reduction in material needed as well as the in-situ material being applicable to the design instead of needing to import of external sites.

6. Installation methods

6.1 Conventional method

The conventional method would have involved clearing the site of debris, ripping and then re-compacting the in-situ material to 93% Mod AASHTO. The sub-base would be a 150mm modified gravel, G6/G7, mixed on site, and compacted to 95% Mod AASHTO. The base, was designed as a 150mm cement stabilized C4 layer compacted to 97% Mod AASHTO. The overlay surfacing was to be a 30mm continuously graded medium grade asphalt.

6.2 Manufacturer's Guideline

The manufacturer calls for an initial site preparation, as do all construction sites. The site needs to be cleared, grubbed and all top soil stripped. All deleterious debris and unsuitable material needs to be removed. Then grade and compact the exposed soils to create a uniform and smooth surface. Where material is especially clayey or very soft the surface needs to be as even as possible.
Place the geogrid on the prepared surface and unroll manually. The placing of the geogrid should allow a minimum overlap of 300mm between rolls. The overlaps can be mechanically fixed with cable ties where necessary. Before unrolling anchor at the geogrid at the middle and corners of the roll with small piles of aggregate.

Generally at least 300mm is required for the initial lift thickness of aggregate fill over geogrids. However, for very soft conditions, a thicker fill layer may be required to mitigate rutting and prevent bearing capacity failure of the underlying subgrade soils. Over relatively competent subgrades, aggregate fill may be dumped directly onto the geogrid. Standard, rubber tired trucks may drive over the geogrid at very slow speeds (less than 20km/h) and dump aggregate fill as they advance, provided this construction traffic does not cause significant rutting of the bare subgrade. Turns and sudden starts and stops should be avoided.

6.3 Site Adapted Conditions

The contractor appointed for this project had little experience with geosynthetics. Fortunately with on-site training the contractor was easily taught how to follow the manufacturer's guidelines. The site preparation consisted of clearing the original area of debris and creating a smooth uniform surface. 150mm of the G8/G7 subgrade was ripped and re-compacted to 93% Mod AASHTO. The geogrid was laid, overlapped and secured with small piles of aggregate to keep the sheets in place. Due to this road being a class D road, the width of 6.0m created a situation where the overlap was increased to allow two rolls each of 4.0m width to simultaneously be laid along the length of the road. The overlaps were secured and 250mm of G6 in-situ gravel was end-tipped on to the geogrid. It was then smooth graded, compacted and tested to obtain the minimum 95% Mod AASHTO specification required. The base layer, a 150mm thick G7, was placed and compacted to 97% Mod AASHTO. The final surfacing comprised a 30mm continuously graded medium asphalt.

As can be seen from the site operations the program was cut shorter as the mixing and curing time for the C4 layer was removed from the process. The need for the costly development of a borrow pit and cartage of imported material was avoided by utilizing the in situ material.

7. Cost comparison

Fig 6. Cost comparison of conventional design vs Geogrid design (Actual Costs)

Description	Conventional Design	Geogrid Design	Saving / Loss	Comment
CONTRACTOR'S ESTABLISHMENT ON SITE & GENERAL OBLIGATION	R 625 000,00	R 560 800,00	-R 64 200,00	1 Month saving on program
OVERHAUL	R 327 367,93	R 42 000,00	-R 285 367,93	
BORROW MATERIALS	R 64 500,00	R 0,00	-R 64 500,00	
PAVEMENT LAYERS OF GRAVEL MATERIAL	R 172 799,75	R 251 044,84	R 78 245,09	
STABILISATION	R 225 818,38	R 390 400,00	R 164 581,62	Cement vs Geogrid
			-R 171 241,22	
EIA - ROD Application	R 44 200,00	R 30 000,00	-R 14 200,00	
			-R 185 441,22	**Saving**

8. Conclusions

Although it is recognized that conventional methods are universally accepted serious consideration should be given to using the aforementioned geogrid design and technology. Given the properties and mechanisms afforded by the geogrid to an application like this project the benefits outweigh most disadvantages. These benefits include savings in material costs by reducing imported layer thicknesses or even in some cases eliminating them altogether and the valuable reduction in program time.

References

Technical Recommendations for Highways (TRH4, Structural Design of Flexible Pavements for Interurban and Rural Roads, 1996)

Guidelines for Human Settlement Planning and Design, 2000, Compiled under the patronage of the Department of Housing by CSIR Building and Construction Technology

Tensar Information Bulletin IB/TriAx_traffic/25.02.11 27 June 2011

Product specification – TriAx TX160 Geogrid patent No.7,001,112

Colin Gewanlal, 16/04/2018, Introduction to Tensar Products and Services Presentation.

Nigel Wrigley, Roads Design and Associated Full-Scale Geogrid Testing, 2013

Chris Jenner, The Reinforcement of Granular Layers of Roads and Railways, 2000

Gregory J. Norwood and Jeb S. Tingle, Performance of Geogrid-stabilized Gravel Flexible Base with Bituminous Surface Treatment, September 2013

Tensar TriAx (TX) Geogrid Installation Guideline, TX_IG_9.16