Stabilizing an unstable world!	Project:	Ahoada - Abua - Degema Road in Rivers State	Section:	01
	Technology:	Neoloy Tough-Cells Load Support	Design:	NE-LP-14052026
	Eng. Contact:		Date:	May, 2026

-Confidential-

Dear Project Owner,

Following your Design Review Request received in April 2026, we are pleased to share with you our detailed design evaluation for your Ahoada - Abua - Degema Road in Rivers State project in **Nigeria** utilizing the Neoloy Tough-Cells.

The Tough-Cell technology offered within this report is manufactured from Neoloy® nano-composite polymeric alloy, providing a high-strength (>19 kN/m), high-stiffness (>525 MPa at 60°C), and creep-resistant (<2% deformation) cellular confinement system designed for long-term durability over the project design life.

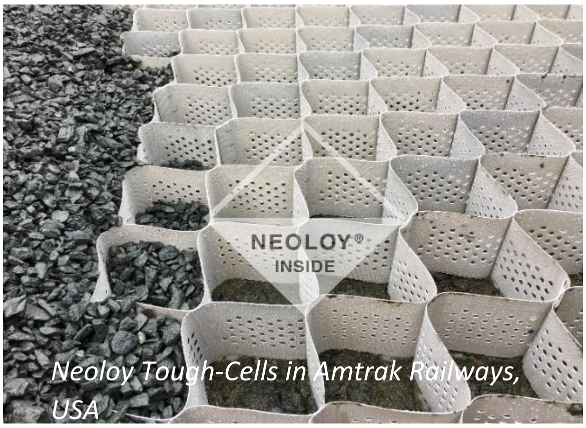
The design improvement factors presented in this report are based on the mechanical and durability properties stated above. Any alternative material or system should demonstrate equivalent performance characteristics; otherwise, the design assumptions and expected performance may not be applicable.

We can also share installation guides, case studies of similar projects, and more.

1 Project Input

• Application:	Paved Road
• Subgrade CBR:	≥6%
• Design Life:	≤20 years
• Design wheel load	Standard axle load is 80kN (20kN single wheel load)
• Estimated traffic:	ESALj=26.912*10^6
• Available material(s):	Asphalt concrete, crushed stone for base material and sand for subbase material.

2 Neoloy-Based Tough-Cells Technology



Neoloy Tough-Cells in Amtrak Railways, USA

Neoloy Tough-Cells System is a soil confinement, stabilization and reinforcement solution developed, manufactured and marketed by PRS Geo-Technologies. The Neoloy Tough-Cells is comprised of three-dimensional, perforated and textured honeycomb cells. When filled with soil, aggregate or concrete, a new geosynthetic composite structure comprised of the Tough-Cell and infill is created, with enhanced physical and mechanical properties.

The Neoloy Tough-Cells is composed of a multi-layer nano-composite polymeric alloy. The Neoloy® alloy combines the flexibility of HDPE with the dimensional stability for elastic and plastic (permanent) deformation resistance of polyamide polymers. This Neoloy alloy is high-modulus, creep-resistant, non-degradable, resistant to chemicals, flames, and water, and due to its low thermal expansion, it retains its properties under thermal cycling at very low and high temperatures. The Neoloy Tough-Cells is fabricated in sections with the cell seams welded ultrasonically utilizing certified quality control manufacturing and testing processes.

Neoloy is an advanced polymer that is part of the Novel/Nano Polymeric Alloy (NPA) family of polymers.
NPA was developed mainly for the Tough-Cell industry to meet the applied loads and/or long-term durability in infra projects by enhanced tensile capabilities at low deformation levels.

3 Design Notes

The Neoloy Tough-Cells (NPA) technology design methodology in road pavements has been studied in hundreds of universities, published in more than 115 research articles, and validated by local and international standards. Neoloy Tough-Cells (NPA) are fully established with advanced correlations between Tough-Cell properties and layer improvement capabilities according to acceptable design failure modes.

The core **mechanism** Tough-Cells technology in pavement structures is based on the ability of the cells to **restrain lateral movement** of reinforced material particles when vertically loaded. In order to validate Tough-Cell confinement effect in pavements, low deformation levels must be guaranteed for the entire design life under designed loads.

Figuur 1-6 Schematisatie van spanningen in een geocel

Core Mechanism- Confinement. A) Applied Vertical Stress (left) B) Lateral stresses (middle) C) Confinement by Hoop Tensile Capabilities at Low Deformation Levels (right). Source: Dutch Design Standards

Our methodology is based on NPA Tough-Cells **3D Mechanical Stabilization** of the reinforced pavement according to the world recognized Pokharel Method (Modified Giroud & Han Methodology for NPA Tough-Cells) and the Dutch Guidelines for Tough-Cells in Pavements. The Pokharel Method considers the bearing capacity of the subgrade and calculates a rutting (or permanent deformation) of the pavement surface. The Dutch Guidelines for Tough-Cells in Pavements specifies a method to calculate the modulus of the reinforced layer by means of MIF (Modulus Improvement Factor) and SIF (Support Improvement Factor). Once the elastic moduli of all layers are calculated, we proceed with the traditional Mechanistic Empirical method in which we model the pavement structure and measure the deformations (Fatigue, rutting, deflection) in specific pavement locations.

Fig.2- Neoloy Tough-Cells in Large-Scale Moving Wheel Test, USA

The NPA Tough-Cell design method was established following a large-scale research for high-modulus Neoloy Tough-Cell, and conducted by:

1. **Prof. Jie Han, Xiaoming Yang, and Robert L. Parsons**

Department of Civil, Environmental, and Architectural Engineering
The University of Kansas, USA

2. **Prof. Dov Leshchinsky**
Department of Civil and Environmental Engineering
The University of Delaware, USA

The research utilized several methods to examine the improvement elements, whereas the main one included the **Large-Scale Moving Wheel Test, USA.**

4 Design Evaluation

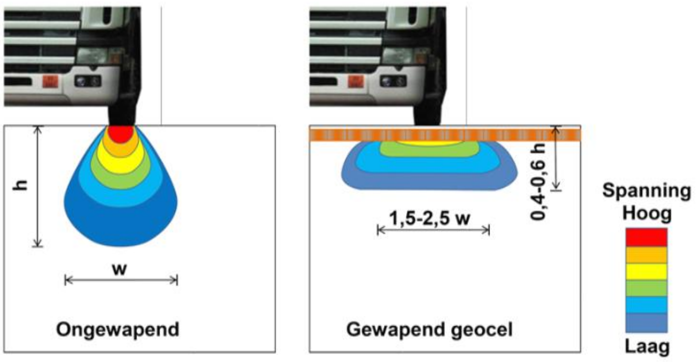
4.1 <u>Design Objectives:</u>

- Rut depth: max. 75mm

4.2 <u>Design Concept</u>

4.2.1 Design Model #1 for Neoloy Tough-Cells

Neoloy Tough-Cells MECHANICALLY Reinforces granular materials, and increases its overall stiffness by applying the high-modulus TENSILE capabilities of the Neoloy system.



Figuur 2-6 Verbetering lastspreiding door hoog gelegen geocel

De hoogte van een geocel bedraagt bij toepassing als funderingswapening normaliter 0,10 m tot 0,20 m. Bij sommige geocellen wordt een bodem aan de wanden ingewerkt. Geocellen worden net als geogrids in diverse varianten en kwaliteitsniveaus geproduceerd. Zo bestaan er bijvoorbeeld geocellen met stijve wanden die weinig rek hebben (zie Figuur 2-7), maar er bestaan ook geocellen met flexibele wanden (zie Figuur 2-8).

translation
Figure 2-6 Improved load distribution through elevated geocell

When used as foundation reinforcement, the height of a geocell is normally 0.10 m to 0.20 m. In some geocells, soil is incorporated into the walls. Like geogrids, geocells are produced in various variants and quality levels. For example, there are geocells with rigid walls that have little elongation (see Figure 2-7), but there are also geocells with flexible walls (see Figure 2-8)

Fig. 3 – Due to the higher stiffness of the NPA Tough-Cell reinforced layer there is a wider stress distribution. Source: Dutch Standards

4.3 Design Criteria

1. Standalone design for required thickness method

5 Design Evaluation

The first part of this Chapter evaluates the performance of the conventional pavement, and the second part evaluates the performance of the Neoloy Tough-Cells reinforced pavement.

On weak support, it is impossible to reach the maximum E-Moduli of a specific material, as the support compaction reaction is too low, therefore, insufficient.

The upper limit of E-Moduli of available materials for sufficient support strength is provided by the project's owner:

Emax Base material = 291 MPa

Emax Subbase material = 155 MPa

The actual E-Modulus should be calculated; there are several well-known correlations to evaluate the layer modulus, Ei; one of them is introduced as the Austroads AGPT02/10 p. 102 (Determination stiffness per sub-layer of granular material):

Austroads model unbound granular layers

The modulus of granular materials is dependent not only on the intrinsic characteristics of these materials, but also on the stress level at which they operate and the stiffness of the underlying medium. As a result, the modulus of pavement materials subjected to vertical loading will decrease with depth to an extent influenced by the stiffness of the subgrade. Iterative analyses with a finite element model would permit allowance to be taken of the stress-dependent nature of the modulus of granular material; however, it would not make allowance for the degree of support provided by underlying layers. In addition, as such models are not readily available to pavement designers, the procedure in the Austroads model utilises a linear elastic layer model, with the granular layers partitioned into several sublayers and each assigned a modulus value according to the following guidelines. The approach is only valid for unbound layers.

1. Enter the stiffness modulus of the support in MPa (= Es). This might be the stiffness of the subgrade but also the equivalent stiffness of all layers under the layer under investigation.
2. Enter the layer thickness of the layer on top of the supporting medium in mm (= h).
3. Enter the maximum stiffness modulus that the layer on top of the supporting medium might reach under optimal conditions in MPa (= Emax).
4. Divide the total thickness of the layer on top of the supporting medium into five equi-thick sublayers in which sub-layer 1 is the lowest sub-layer.
5. Compute the stiffness modulus of the top sub-layer by using the following equation (beware:

this is not the final stiffness modulus of the sub-layer):

$$E_{sub\ 5} = E_s \cdot 2^{(h/125)}$$

6. Compute the ratio of stiffness moduli of adjacent sublayers as follows

$$R = \left(\frac{E_{sub\ 5}}{E_s}\right)^{0.2}$$

7. Compute the stiffness modulus of each sublayer; this is the maximum stiffness modulus Emax or the result of the following equation, whichever is smaller:

$$E_{sub\ i} = R \cdot E_{sub\ i-1}$$

8. The mean stiffness modulus of the layer on top of the supporting medium is the arithmetic mean of the stiffness moduli of the five sublayers.

Palmer-Barber equivalent stiffness

The two-layer model developed by Palmer and Barber is an easy-to-use model to compute the equivalent stiffness modulus of a two-layer system. The centre deflection is used as equivalency criterion. The centre deflection of the layered system must be equal to the centre deflection of the equivalent semi-infinite system. The approach of Palmer and Barber is as follows:

1. Enter the stiffness modulus E2 (in MPa) of the semi-infinite supporting medium (this may be the stiffness modulus of the subgrade but also that of the substructure if the equivalent stiffness modulus of subsoil and sub-foundation has already been determined in an earlier calculation).
2. Enter the stiffness modulus E1 of the layer on the semi-infinite medium (in MPa).
3. Enter the layer thickness h of the layer on the semi-infinite medium (in mm).
4. Enter the radius a (in mm) of the load contact surface on top of the layer on the supporting medium; preferably use a value of 150 mm for representing the radius of the base plate of a falling weight deflectometer.
5. Compute the factor F2 as follows:

$$F2 = \frac{a}{\sqrt{a^2 + h^2 \cdot \sqrt[3]{E_1^2/E_2^2}}} \cdot \left(1 - \frac{E_2}{E_1}\right) + \frac{E_2}{E_1}$$

6. Compute the equivalent stiffness modulus of the aggregate system as follows:

$$Eeq = \frac{E2}{F2}$$

Palmer and Barber is a world-wide acceptable method, adopted by the Dutch Design Guide, Israeli DoT, South African pavement Design Guide, etc. *Palmer and Barber* is considered as the most precise evaluation for an equivalent surface stiffness modulus; in additional to vertical stresses, it also considers the radial and shear stresses, and the additional effect of them to the surface deflection.

Other methods may not consider the above stresses and deflection effect, such as the *IVANOV Method*, therefore, the EV2 result received by those methods are permissive by means of excessive surface modulus (under-designed values).

Read more at Page 114- Link: http://onlinepubs.trb.org/Onlinepubs/hrr/1965/71/71-006.pdf

5.1 Unreinforced design based on:

Highway Manual Part 1: Design, Volume III: Pavements and Materials Design, 2013

- **Road category – A**

Table 3.1 Typical Structural Design Periods for Various Road Categories

Road Category	Design Period
A	20
B	20
C	15
D	10

- **Subgrade CBR = 6% → 62.6 MPa**

Conversion of CBR to Resilient Modulus (M_r) is done as follows:

$$M_r(MPa) = 10.342 * CBR \quad \text{......... Equation 8-1}$$

- **Subgrade Classification – S3**
- **Traffic Classification – T8**

KEY TO STRUCTURAL CATALOGUE

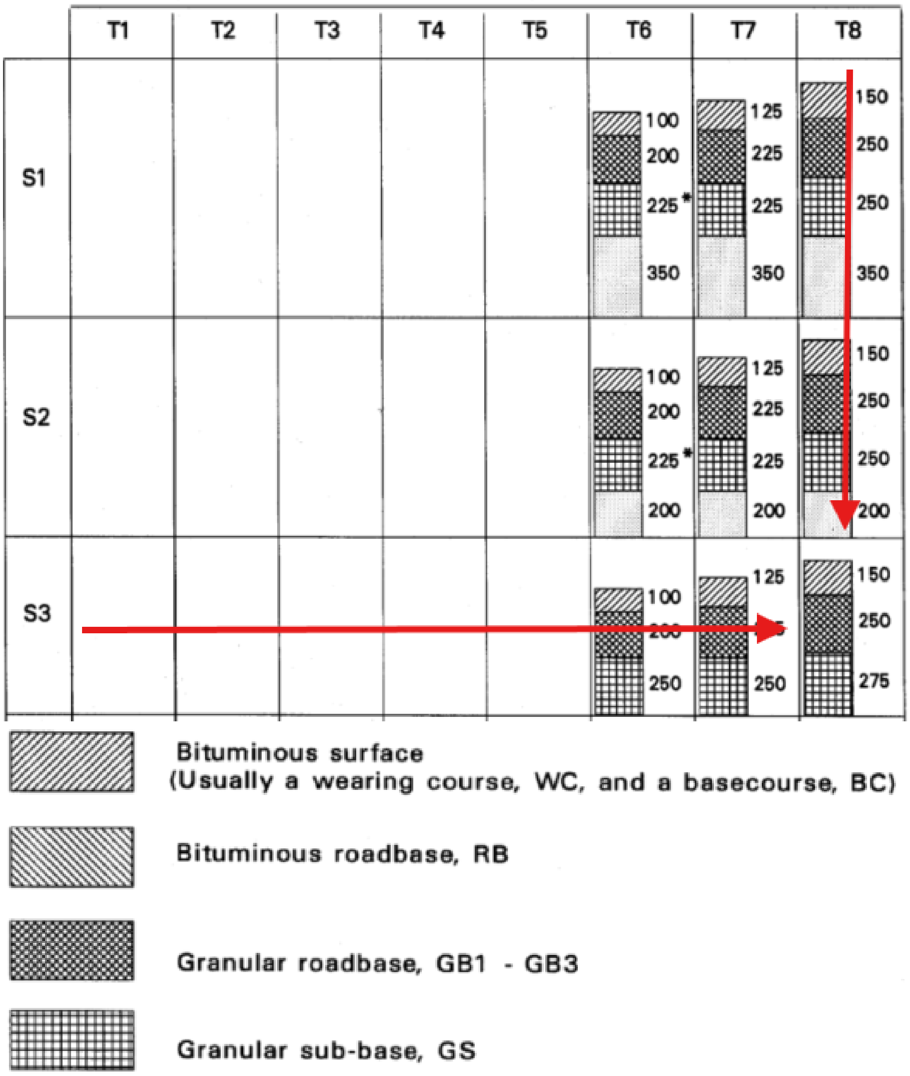
Traffic classes
(10^6 esa)

T1 = < 0.3
T2 = 0.3 - 0.7
T3 = 0.7 - 1.5
T4 = 1.5 - 3.0
T5 = 3.0 - 6.0
T6 = 6.0 - 10
T7 = 10 - 17
T8 = 17 - 30

Subgrade strength classes
(CBR%)

S1 = 2
S2 = 3 , 4
S3 = 5 - 7
S4 = 8 - 14
S5 = 15 - 29
S6 = 30+

Appendix C – Chart 5 Granular Road base



- **Conventional Design:**

Layer	Material	Thickness	CBR (%)	Emax (MPa)	Elayer (MPa)	EV2 (MPa)
Top	Aspahlt	150 mm		2500	2500	2500
Base	Granular Base	250 mm	80	290.7	212.7	138
Subbase	Granular Subbase	275 mm	30	155.2	132.9	92.1
Subgrade	Subgrade	Semi-infinite	6	62.6	62.6	62.6

5.2 Neoloy Pavement Performance Evaluation

Neoloy-reinforced pavement configuration:

Layer #	Type	Thickness
1	100mm well Asphalt Concrete (AC)	100 mm
2	**200mm PRS-NEOLOY-330-150-C** filled with Crushed stone material (CBR >=80%) Compacted to 98% MDD	200mm
3	200mm Sand material (CBR>=30%) Compacted to 97% MDD	200 mm
-	Non-Woven geotextile (>250kg/m2)	-
4	Compacted Subgrade (CBR >6%)	-

Moduli Evaluation:

5.2.1 Elastic-Modulus of Layer #4 – Subgrade:

E_4 = 10.342 x CBR = 62.6 MPa

5.2.2 Layer Modulus of layer #3:

Max. E-Modulus of base layer: Emax2 = 290 MPa

Support E-Modulus for Layer #2: Es2 = 62.6 MPa

Layer Height: h2 = 200mm

Parameter	Result
E support (MPa)	62.6
Thickness layer on support (mm)	200
E max layer on support (MPa)	155
Output	
E sub5 (MPa) upper sublayer	155
E sub4 (MPa)	152
E sub3 (MPa)	122
E sub2 (MPa)	98
E sub1 (MPa) lowest sublayer	78
Mean E sub 1 thru E sub 5 (MPa)	121

Austroads model unbound granular layers.

E-modulus for base layer #2, E2 = 121 MPa

5.2.3 Equivalent Surface Moduli on top of layer #3:

Final E-Modulus of #3 Layer: E3 = 121 MPa

Base Layer Height h3= 200mm

Parameter	Result
E support (= E2) (MPa)	62.6
Thickness layer on support (= h) (mm)	200
E layer on support (= E1) (MPa)	121
Radius of contact area on layer (= a) (mm)	150
Output	
E equivalent medium (MPa)	82

Equivalent surface Modulus on top of base layer (Layer#3):

Equivalent surface modulus on top of the base layer #3: **Es2 = 82 MPa**

5.2.4 **Elastic-Modulus of Layer #2 <u>reinforced with Neoloy technology</u>:**

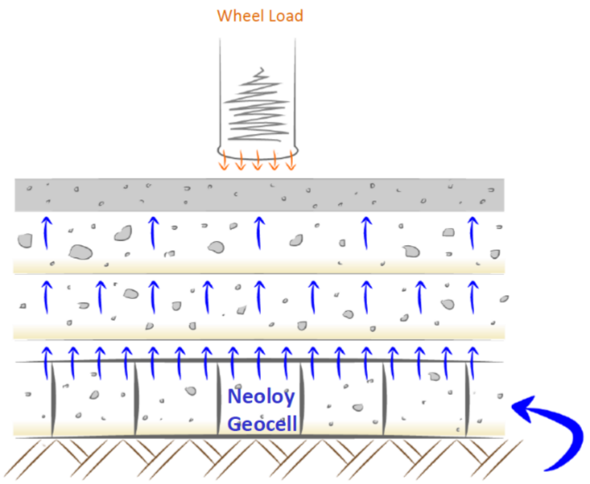
In this stage, the actual modulus of layer # 2 is evaluated, this is the reinforced modulus with Tough-Cells Neoloy.

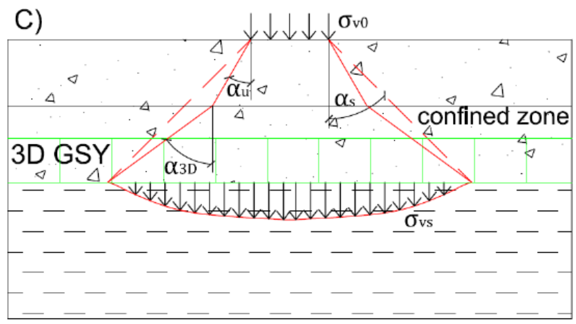
The calculation will consider two improvement factors:

- **MIF:** Modulus Improvement Factor

- **SIF:** Support Improvement Factor

The final design value will be taken as the minimum between MIF and SIF.**Calculation with SIF Factor:**





Neoloy Tough-Cells is the only proven mechanical geosynthetic technology to stabilize a deficient sub-component with a 10 (1,000%) Support Improvement Factor (SIF).

This unique improvement factor is achieved due to the rigidity of Neoloy itself, utilizing a high dynamic and elastic rigidity and resistance to long-term permanent deformation, less than 2% for the lifetime of the project. These crucial properties are defined in published ISO standards

(ISO/TR 18228-5)

Support Modulus E^s_2 = 82 MPa

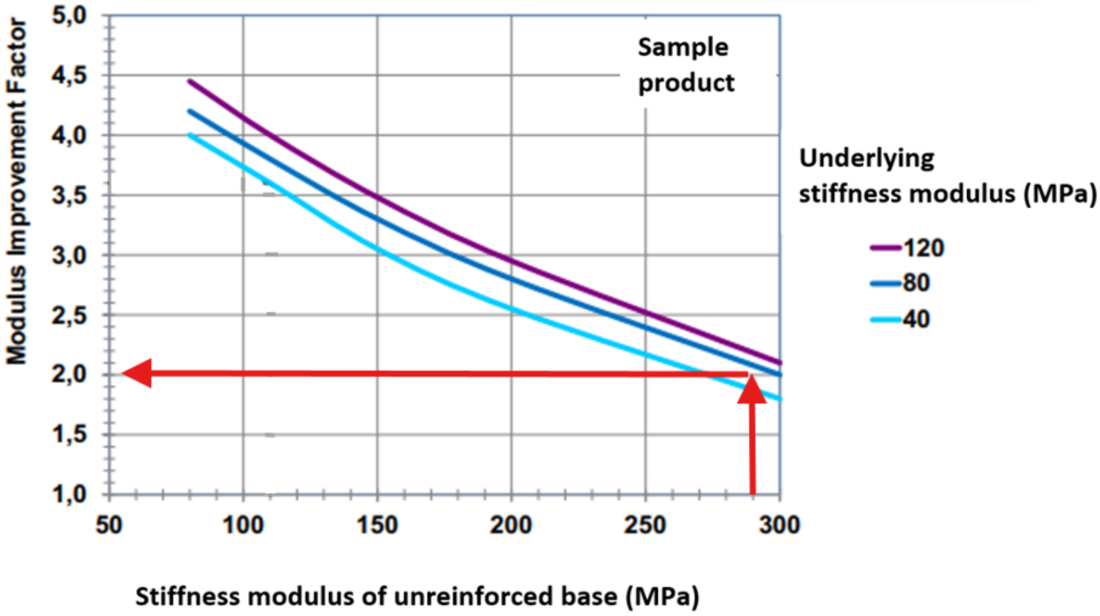
SIF = **7.6**

Reinforced Layer Modulus = 62.6 x 7.6 = **623 MPa = E_2**

5.2.5 Neoloy Tough-Cell Modulus Improvement Factor (MIF)

MIF values, from Dutch standards.

(Geosynthetics for Reinforcement of Unbound Base and Subbase Pavement Layers, 2018)



Where:

Native modulus of sand= 290 MPa (80% CBR)

Underlying Modulus (support modulus) = 82 MPa

MIF = 2.03

Reinforced modulus = 290 x 2.03 = **592 MPa**

Finally, the Layer #2 Modulus will be defined as the minimum value between MIF and SIF reinforced modulus:

SIF= **623 MPa**

MIF= **592 MPa**

Therefore, it is taken as the final design value:

E2 = 592 MPa That is now the E Modulus of layer #2

5.2.6 Equivalent Surface Modulus on top of layer #2:

Final E-Modulus of Neoloy subbase layer: E_3 = 592MPa

Reinforced Layer Height h_2 = 200mm

Equivalent surface Modulus on top of the reinforced layer (Layer#2):

Parameter	Result
E support (= E2) (MPa)	82
Thickness layer on support (= h) (mm)	200
E layer on support (= E1) (MPa)	592
Radius of contact area on layer (= a) (mm)	150
Output	
E equivalent medium (MPa)	182

Equivalent surface modulus on top of reinforced layer #2: **E^s_1 = 182 MPa**

Design Criteria #1: Surface modulus on top of the base layer, Es1 = 182 MPa

5.2.7 Actual E-Moduli Configuration of unreinforced Pavement:

Layer #	Type	Thickness	Layer modulus (MPa)
1	100mm well Asphalt Concrete (AC)	100 mm	2500
2	**200mm PRS-NEOLOY-330-150-C** filled with Crushed stone material (CBR >=80%) Compacted to 98% MDD	200mm	592
3	200mm Sand material (CBR>=30%) Compacted to 97% MDD	200 mm	121
-	Non-Woven geotextile (>250kg/m2)	-	-
4	Compacted Subgrade (CBR >6%)	-	62.6

5.3 Pavement stiffness and design criteria's

For deeper analysis and comparison of the Reinforced pavement we calculated and compared three design criteria's using the Layered Elastic Theory (LET). The criteria's are:

- **Displacement -** on top of the AC layer
- **Fatigue -** Horizontal tensile strain at the bottom of the asphalt layer
- **Rutting** - Vertical compressive strain at the top of the subgrade

5.3.1 Displacement on Top of the AC Layer

The max displacement on top of the AC layer is calculated by Using the

According to LET the calculated Max displacement on top of the AC layer is 0.465mm.

- **0.447mm in the conventional design, 0.018mm delta.**
  Neoloy solution displacement:

Layer	Modulus	Poisson	Thickness	
1	2,500	0.35	100.0	
2	592	0.35	200.0	
3	121	0.35	200.0	
4	1	0.45	0.0	
5	63	0.45	semi-inf	
Load#	Stress	Radius	X	Y
1	0.55	108.00	0.00	0.00
2	0.55	108.00	300.00	0.00
	x	y	z	
Evaluation Point	300.00	0.00	0.00	Layer= 1
Direction	Stress	Strain (microstrains)	Displacement	
X	9.72E-01	159	-1.59E-02	
Y	1.09E+00	223	0.00E+00	
Z	5.51E-01	-68	4.65E-01	
YZ	0.00E+00	0		
XZ	-1.90E-07	0		
XY	0.00E+00	0		

Conventional solution displacement:

Layer	Modulus	Poisson	Thickness	
1	2,500	0.35	150.0	
2	213	0.35	250.0	
3	133	0.35	275.0	
4	1	0.45	0.0	
5	63	0.45	semi-inf	
Load#	Stress	Radius	X	Y
1	0.55	108.00	0.00	0.00
2	0.55	108.00	300.00	0.00
	x	y	z	
Evaluation Point	300.00	0.00	0.00	Layer= 1
Direction	Stress	Strain (microstrains)	Displacement	
X	9.17E-01	144	-1.72E-02	
Y	1.04E+00	212	0.00E+00	
Z	5.51E-01	-54	4.47E-01	
YZ	0.00E+00	0		
XZ	-2.96E-08	0		
XY	0.00E+00	0		

5.3.2 **Fatigue -** Horizontal tensile strain at the bottom of the asphalt layer

The Calculated Horizontal tensile strain at the bottom of the asphalt layer is 153

- **205 in the conventional design.**

Neoloy solution fatigue strain:

Layer	Modulus	Poisson	Thickness		
1	2,500	0.35	100.0		
2	592	0.35	200.0		
3	121	0.35	200.0		
4	1	0.45	0.0		
5	63	0.45	semi-inf		
Load#	Stress	Radius	X	Y	
1	0.55	108.00	0.00	0.00	
2	0.55	108.00	300.00	0.00	
	x	y	z		
Evaluation Point	300.00	0.00	99.90	Layer=	1
Direction	Stress	Strain (microstrains)	Displacement		
X	-3.17E-01	-106	5.13E-03		
Y	-4.05E-01	-153	0.00E+00		
Z	2.52E-01	202	4.56E-01		
YZ	0.00E+00	0			
XZ	3.33E-02	18			
XY	0.00E+00	0			

Conventional solution fatigue strain:

Layer	Modulus	Poisson	Thickness		
1	2,500	0.35	150.0		
2	213	0.35	250.0		
3	133	0.35	275.0		
4	1	0.45	0.0		
5	63	0.45	semi-inf		
Load#	Stress	Radius	X	Y	
1	0.55	108.00	0.00	0.00	
2	0.55	108.00	300.00	0.00	
	x	y	z		
Evaluation Point	300.00	0.00	149.90	Layer=	1
Direction	Stress	Strain (microstrains)	Displacement		
X	-5.20E-01	-132	1.44E-02		
Y	-6.55E-01	-205	0.00E+00		
Z	1.12E-01	209	4.32E-01		
YZ	0.00E+00	0			
XZ	1.73E-02	9			
XY	0.00E+00	0			

5.3.3 Rutting - Vertical compressive strain at the top of the subgrade

The calculated Vertical compressive strain at the top of the subgrade is 341.

- **253 in the conventional design.**

Neoloy solution rutting strain:

Layer	Modulus	Poisson	Thickness		
1	2,500	0.35	100.0		
2	592	0.35	200.0		
3	121	0.35	200.0		
4	1	0.45	0.0		
5	63	0.45	semi-inf		
Load#	Stress	Radius	X	Y	
1	0.55	108.00	0.00	0.00	
2	0.55	108.00	300.00	0.00	
	x	y	z		
Evaluation Point	300.00	0.00	500.10	Layer=	5
Direction	Stress	Strain (microstrains)	Displacement		
X	1.78E-03	-134	2.19E-02		
Y	3.50E-04	-167	0.00E+00		
Z	2.23E-02	341	3.39E-01		
YZ	0.00E+00	0			
XZ	3.39E-03	79			
XY	0.00E+00	0			

Conventional solution rutting strain

Layer	Modulus	Poisson	Thickness		
1	2,500	0.35	150.0		
2	213	0.35	250.0		
3	133	0.35	275.0		
4	1	0.45	0.0		
5	63	0.45	semi-inf		
Load#	Stress	Radius	X	Y	
1	0.55	108.00	0.00	0.00	
2	0.55	108.00	300.00	0.00	
	x	y	z		
Evaluation Point	300.00	0.00	675.10	Layer=	5
Direction	Stress	Strain (microstrains)	Displacement		
X	9.06E-04	-104	1.67E-02		
Y	2.00E-04	-121	0.00E+00		
Z	1.63E-02	253	2.87E-01		
YZ	0.00E+00	0			
XZ	2.20E-03	51			
XY	0.00E+00	0			

5.3.4 comparison analysis

Pavement structure	**Unreinforced**	**Reinforced**
Total thickness	675mm	500mm
AC thickness	150mm	100mm
Base thickness	250mm	200mm
Subbase thickness	275mm	200mm
Displacement	0.447mm	0.465mm
Fatigue	205	153
Rutting	253	341
Nf	13,743,250	39,000,215
Nr	519,292,988	134,181,128

N_f = Number of allowable 8200 kg ESAL applications,

ε_t = Horizontal tensile strain at the bottom of the asphalt layer

E = dynamic modulus of the asphalt concrete in PSI.

N_r = Number of allowable 8, 200 kg ESAL application.

ε_v = Vertical compressive strain at the top of the subgrade

- The equations in the Nigerian standard are based on the dynamic modulus “E” expressed in PSI, while our calculation models and calibration parameters are defined in MPa, a direct and reliable conversion between the datasets could not be established. Consequently, the Indian model, which is also referenced within the Nigerian standard, was adopted for the analysis. The parameters Nr and Nf (allowable ESALs) were therefore calculated in accordance with this model.
- Indian model equations:

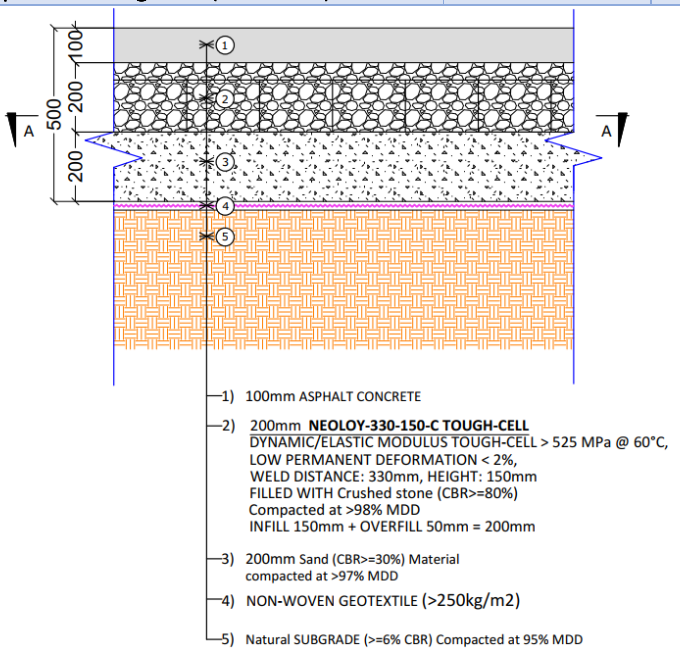
$$N_f = 0.1001(\varepsilon_t)^{-3.565}(E)\hat{} - 1.4747$$

$$N_r = 2.56X10^{-8}(\varepsilon_v)^{-4.5337}$$

- Displacement difference is less than 5% - OK.
- Improvement in fatigue over 25% - Very good.
- Calculated rutting for both pavement structures provide much more ESALs then needed for the project – OK.
- The Nigerian standard specifies a minimum asphalt layer thickness of 125 mm. However, based on the results of our calculations, an asphalt thickness of 100 mm is also expected to provide satisfactory structural performance under the considered loading conditions. Nevertheless, should it be decided to increase the asphalt thickness to comply with the standard requirement or for additional conservatism, such modification would not affect the design or required thicknesses of the remaining pavement structure layers.

5.4 Recommended pavement configuration

Layer #	Type	Thickness	Layer modulus (MPa)
1	100mm well Asphalt Concrete (AC)	100 mm	2500
2	**200mm PRS-NEOLOY-330-150-C** filled with Crushed stone material (CBR >=80%) Compacted to 98% MDD	200mm	592
3	200mm Sand material (CBR>=30%) Compacted to 97% MDD	200 mm	121
4	Non-Woven geotextile (>250kg/m2)	-	-
5	Compacted Subgrade (CBR >6%)	-	62.6



6 Conclusions

The proposed pavement is recommended to be mechanically reinforced with the **stiff 3D Neoloy Tough-Cells technology**.

The high-modulus Neoloy Tough-Cell effectively retains the Aggregate Material infill against lateral movement at low deformation levels for the entire design life (less than 2% permanent deformation. Tested by ASTM D6992, as recommended by the published Dutch Standards (Geokunststoffen als Funderingswapening in Ongebonden Funderingslagen).

<u>Main Contribution of Neoloy Tough-Cells solution:</u>

1) Max. rut depth < 20mm
2) Enables the use of locally available granular materials such as sand
3) Wider load distribution results in lower effective stresses on subgrade
4) Thin pavement
5) Lower differential settlements

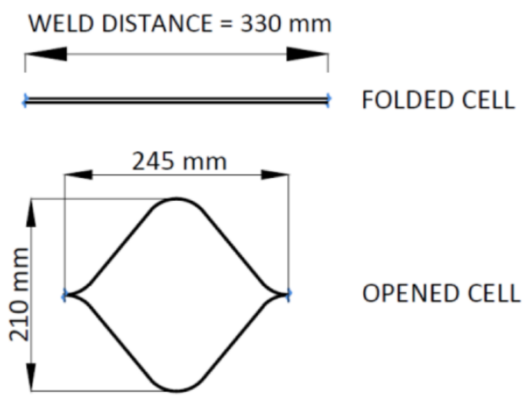
7 Neoloy Tough-Cells - Product Specification

The design is based on the following Tough-Cell product specification:

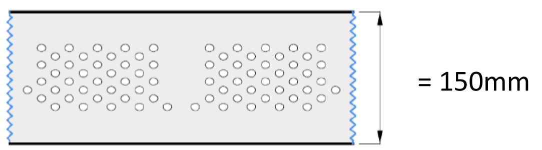
Property	Value	Test Method	Importance of Property
Net Elastic (Dynamic) Modulus at: 60ºC (accelerated method):	>525 MPa	ISO 6721-1 ASTM E2254 (DMA)	• Correlated to high MIF (Modulus Improvement Factor) of reinforced material
Accumulated Creep Deformation for 80 Years design life (at 6.1 kN/m load): (±10%)	<3.0%	ASTM D6992 (SIM)	• Maintains the Modulus Improvement Factor of reinforced material for entire design life • Validating design
Strength at Yield of Wide-Width Perforated Strip	>19 kN/m	ISO 10319	• Withstands applied loads on cell strips
UV & Oxidation Resistance: >75 years, by an accelerated method	>1600 minutes	ASTM D5885 (HPOIT @ 150°C)	• Oxidation durability for entire design life • UV durability

Neoloy Tough-Cells – Geometry Specifications:

Property	Value
Weld Distance (±2.5%):	330 mm
Cell Height (±5%):	150 mm
Recommended Opening Cell Dimensions, W x L (±3%):	210 x 245 mm
Typical Tough-Cell Section Dimensions, W x L (±3%):	2.5 x 8 m



Recommended Opening Cell Dimensions



Cell Height

The proposed design is preliminary and based on the specific PRS Neoloy Tough-Cell system technical specifications and physical and chemical properties. Any unauthorized use or implementation of this design with a different Tough-Cell system renders all engineering assumptions, parameters and calculations invalid, erroneous, misleading and unsafe and constitutes a violation of legally binding engineering responsibility and statuary requirements, and represents professional negligence

SPECIFICATIONS FOR TOUGH-CELLS
(CELLULAR CONFINEMENT SYSTEM)

Tough-Cells is a type of cellular confinement system designed for engineering applications, which fully complies with design and technical requirements in international pavement design Standards and guidelines:

- ASTM D8269 – 21: Standard Guide for the Use of Geocells in Geotechnical and Roadway Projects
- ISO TR18228-5: Design using geosynthetics
- SBRCURnet (Dutch): Geosynthetics for Reinforcement of Unbound Base & Subbase Pavement Layers
- Sabita (South Africa) TG3 Part C: The use of geosynthetics in pavement – Design with geosynthetics

Table 1: Minimum Technical Specifications for Tough-Cells

Item No	Minimum Technical Requirements	Value(1)	Units	Toler-ance	Test Method	Bidder's offer ☐ Yes ☐ No
1.1	**SYSTEM PHYSICAL DESCRIPTION**					
1.1.1	Tough-Cells - 3D honeycombed sections extruded from engineered polymers into welded strips, which expand to form stiff yet flexible cellular confinement system					☑Yes ☐ No
1.1.2	Material – novel polymeric alloy (NPA) or equivalent					☑Yes ☐ No
1.1.3	Cell wall surface is textured and perforated in semi-uniform perforation along and across the entire cell wall for proper drainage. The hole size should be small enough (diameter <=10mm) to prevent aggregate partition across cells.					☑Yes ☐ No
1.1.4	Traceability – each section marked for full detailed traceability					☑Yes ☐ No
1.2	**MECHANICAL DURABILITY**					
1.2.1	Cumulative permanent deformation (creep) @ 3 steps: 44°C, 52°C and 58°C: *Stepped Isothermal Method (SIM), modified sample size, wide-width perforated strip at fixed load*	<3% at fixed load of 6.1 kN/m	%	±10%	ASTM D-6992 (SIM)	☑Yes ☐ No
1.3	**DYNAMIC (ELASTIC STIFFNESS) MODULUS**					
1.3.1	Dynamic Mechanical Analysis (DMA) at sample elevated temperatures: +30°C +45°C +60°C	≥775 ≥675 ≥500	MPa	±5%	DMA ISO 6721-1 / ASTM E2254	☑Yes ☐ No
1.4	**TENSILE PROPERTIES**					
1.4.1	Strength at Yield (Wide-Width – perforated), rate 100 mm/minute at 23°C.	≥19	kN/m	±7%	ISO 10319 - width wide	☑Yes ☐ No
1.5	**PHOTOCHEMICAL & OXIDATION RESISTANCE**					

1.5.1	UV Resistance (HPOIT @150°C)	≥1600	minutes		ASTM D-5885 per GRI GM13	☑Yes ☐ No
1.6	**CELL & SECTION NOMINAL DIMENSIONS**					
1.6.1	Cell wall heights (depth)	120	mm	±5%		☑Yes ☐ No
1.6.2	Cell weld distances (seams)	330	mm	±3%		☑Yes ☐ No

1. VALIDATION OF PRODUCT PERFORMANCE

The design engineer needs to review and approve the following validation of product performance, as part of the tender approval

Table 2: Validation Requirements of Product Performance

Item No	Validation Requirements	Bidder's offer ☐ Yes ☐ No
2.1	**Testing Results Validation**	
2.1.1	Certified Testing Laboratories: The specification tests must be performed by a certified laboratory accredited by Laboratory Accreditation Authority (ILAC https://ilac.org) that has up-to-date accreditation by **ISO 17025** to test each specification test mentioned in Table 1 above.	☑Yes ☐ No
2.2	**Tough-Cells Manufacturer**	
2.2.1	Final Product Declaration: the manufacturer shall submit a notarized performance declaration, which guarantees that: 1) all products supplied to the project comply with the specifications (Table 1); 2) all products supplied to testing laboratories were produced from the same production line that will be used to supply to the project.	☑Yes ☐ No
2.2.2	Design Values Declaration: the manufacturer shall submit a notarized performance declaration, which guarantees that its proposed product was tested in leading research facilities for- 1) Accelerated Pavement Testing (APT), including Large-scale Moving Wheel Test 2) Product-based Modulus Improvement Factor supported by minimum 10 research publications	☑Yes ☐ No
2.2.3	Manufacturer Experience: at least 5 years of proven experience in supplying Tough-Cells for large-scale transportation and infrastructure projects (larger than 100,000 sqm)	☑Yes ☐ No
2.2.4	Client Testimonial: at least 5 official testimonials from clients confirming product successful performance in large-scale infrastructure projects (larger than 100,000 sqm)	☑Yes ☐ No
2.2.5	Quality Control: The Tough-Cells Manufacturer must meet the following international standards for manufacturing production and confirm that the certificates are up to date: ○ ISO 9001:2015 – Quality System Management ○ ISO 14001:2015 – Environmental Management System.	☑Yes ☐ No