Mechanical Stabilisation for Permanent Roads

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Effect of geogrid on particle movement

SmartRock™
Effect of geogrid on particle movement under cyclic loading
Particle translational acceleration

- **PARTICLE TRANSLATIONAL MOVEMENT** was significantly reduced with the inclusion of TX190L geogrid.
- **PARTICLE ROTATION** was significantly reduced with the inclusion of TX190L geogrid.
Definition of Stabilisation?

Proposed Definition by ISO TC221 - WG2

- **Stabilisation**: Improvement of the mechanical behaviour of an unbound granular material by including one or more geosynthetic layers such that the deformation under applied loads is reduced by minimizing soil particle movement.

- Perhaps **Mechanical Stabilisation** is a more appropriate description – distinguishes from Chemical Stabilisation, Lime Stabilisation and others
Why do we need a stabilisation function?
There are three perfectly well understood functions of geosynthetics
• Filtration
• Separation
• Reinforcement

Why do we now need a new function?
Is this just a marketing gimmick?
What is the problem?
Challenges

Lower costs 33%
- Reduction in the initial cost of construction and the whole-life cost of built assets

Lower emissions 50%
- Reduction in greenhouse gas emissions in the built environment

Faster delivery 50%
- Reduction in the overall time, from inception to completion, for new build and refurbished assets

Improvement in exports 50%
- Reduction in the trade gap between total exports and total imports for construction products and materials

Our vision for 2025

Working together, industry and Government have developed a clear and defined set of aspirations for UK construction.

The global construction market is forecast to grow by over 70% by 2025.

Global Construction 2025, Global Construction Perspectives and Oxford Economics (July 2013)
Lower Costs
Reducing whole-life cost

New or Reconstructed Pavement

Only Surface Course Treatment Required

Extended life = Reduced Costs
Reduce costs
Lower construction cost for same life
One of the ways in which the performance of permanent roads can be increased
How can we design mechanically stabilised permanent roads?
Tools already exist to design for design of mechanically stabilised permanent roads

Tensar has developed three software tools*:

➢ TensarPave – Spectra
➢ SpectraPave4-Pro
➢ Spectra M-E

*other manufacturers may have developed similar software
All of these tools are independently validated.

Each of these software tools incorporate the stabilisation effect of a specific geogrid type.

Why is that?
Incorporating the geogrid effect into M-E Design

- Layer modulus - algorithm accounts for:
  - location of geogrid
  - variation of confinement effect with distance from geogrid

- Life-Shift Factors - required for:
  - asphalt and subbase
  - based on reduction in rate of degradation observed
How can we quantify the geogrid effect and develop design parameters?
What influences the geosynthetic effect?

Tensile strength has no relation to trafficking performance

Source: Giroud and Han, 2006
What influences the geosynthetic effect?

Geosynthetic form has an influence on performance
What do we know?

After 30+ years of research on geogrid performance in roadway applications:

- No single index property positively correlates to performance

- A combination of several important features influences performance

- Designs need to be based upon performance of the stabilised layer – not geogrid properties
Benefit of including geosynthetics in pavement is recognised to:
- Improved life
- Reduced thickness

Benefits of a specific geosynthetic cannot be derived theoretically

Designs not easily translated to other geosynthetics

Test sections are necessary to obtain benefit quantification
Extensive research and APT testing

...to characterise the MSL properties
US Corps of Engineers - Full scale APT studies

- Project in 3 Phases phases
- Set up for Phase 1:
  - CBR=3%
  - Dual wheel. 2.08 ESAL
  - 0.8m wander pattern
  - Constant temperature
Full Scale Evaluation with APT
Phase 1

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>geogrid stabilised base 50mm asphalt</td>
<td>non-stabilised 50mm asphalt</td>
<td>non-stabilised 75mm asphalt</td>
</tr>
</tbody>
</table>

- **A**
  - Geogrid stabilised base
  - 50mm asphalt

- **B**
  - Non-stabilised
  - 50mm asphalt

- **C**
  - Non-stabilised
  - 75mm asphalt

Layer Details:

- **Dense-Graded Asphalt Concrete (AC) Surface**
- **80-100 CBR Crushed Limestone**
- **3 CBR CH Subgrade**
- **Geogrid**
USCoE trials, Phase 1 – Trafficking Results

- **50mm AC TriAx**
- **50mm AC control**
- **75mm AC control**

**Surface deformation (mm)** vs **Axle passes (ESAL)**

- **A**
- **B**
- **C**

- Geogrid
USCoE trials, Phase 1 – Surface Modulus
Incorporating the stabilization effect into design tools

- We need to develop a design tool that can incorporate the stabilisation benefit

- One approach is to modify a proven Empirical method (e.g. AASHTO ‘93)

AASHTO Method:

- Empirical methodology

- Based on AASHTO Road Test
Developing an Empirical Design Method
Modified AASHTO ’93

- Incorporating the geogrid effect
  \[ SN = a_1d_1 + a_2d_2m_2 + a_3d_3m_3 \]
  \( d = \) layer thickness, \( m = \) drainage coefficient

- Mechanical stabilisation effect is included as an enhanced “a” value for the base layer. Where ‘a’ is a variable

Pavement condition given by its present serviceability index PSI (p)

Traffic given by number of 18 kip (80kN) ESA \( W_{18} \)

Pavement layers represented by their structural number \( SN \)

Subgrade represented by its resilient modulus \( M_R \)

\[ \log_{10} W_{18} = Z_R S_0 + 9.36 \log_{10}(SN+1) - 0.2 + \frac{\Delta \text{PSI}}{4.2 - 1.5} + 2.32 \log_{10} M_R - 8.07 \]

AASHTO ’93 Controlling equation
What is the mechanism for stabilisation?
How does a geogrid stabilise?
How does a geogrid provide mechanical stabilisation?

- **Unconfined Zone**
- **Transition Zone** (Partial confinement)
- **Fully Confined Zone**

**Magnitude of confinement**

**geogrid**
Evidence of the Zone of Confinement

Crushed stone (0.40 m)
Geogrid or geogrid + geotextile
Sand (0.10 m)
Elastic sub-layer

Multi-Level Shear Box Testing – with Geogrid

(Horvat, Klompmaker :2014)
DEM Modelling to demonstrate the effect of particle confinement and lateral restraint
DEM Multi-layer shear model

stabilisation effect
DEM - Confinement effect in a plate-load test
DEM - Confinement effect in a plate-load test

Biaxial geogrid model

Rectangular Plate
Load cycled five times
L1 to L5

Stress condition examined within seven separate layers

Manufactured soil (5/32)
Confinement effect in a plate-load test

**Stress state** $(\sigma_{xx})$

**Loaded condition** (L1 and L5)

*directly below plate*
Moving wheel load simulation

- 10 wheel crossings (500 N, 0.5 m/s)
  - 5 kPa normal stress is applied on load walls during the test
Y-Z displacements - cross section

Comparing stabilised with non-stabilised section

No grid - 9th run

TX160 - 9th run

[\text{[m]}]

- 0.0000E+00
- 2.0000E-03
- 4.0000E-03
- 6.0000E-03
- 8.0000E-03
- 1.0000E-02
- 1.2000E-02
- 1.4000E-02
- 1.6000E-02
- 1.8000E-02
- 2.0000E-02
- 2.2000E-02
- 2.4000E-02
- 2.5000E-02
In-plane (XY) Displacement of The Geogrid

Biaxial geogrid 8th to 10th run

Multi-axial geogrid 8th to 10th run

Scale: 200

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Forces in the Geogrid Under a Wheel Loading

SS20 9th run

$F_{\text{max}} = 0.49 \text{ kN/m}$

TX160 9th run

$F_{\text{max}} = 0.27 \text{ kN/m}$
So how does stabilisation differ from reinforcement?
Stabilisation and Reinforcement Functions in Roadways

Reinforcement

Particle confinement not developed – geosynthetic acts as tensioned membrane

Stabilisation

Efficient particle confinement results in stabilisation
Stabilisation and Reinforcement Functions in Roadways

Reinforcement function

Incorporates a tensile element as a separate component in the system

Stabilisation function

Changes behaviour of the granular layer to create a composite material
Trafficking Trials - UK Transport Research Laboratory

- Soft subgrade approx. 2% CBR
- 40kN wheel (equal to 1 ESAL)

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N = 100

- Depth below datum (m)
- Distance across section (m)
- Mean rut depth (mm)

- Membrane
- Confinement
- Control

- Control
- Membrane
- Stabilised
Mean rut depth (mm) vs. Distance across section (m) for Control, Membrane, and Stabilised conditions. Depth below datum (m) is also plotted. N = 500 passes are indicated.
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Mean rut depth (mm)

N = 2,000

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Mean rut depth (mm) vs. distance across section (m) for Control, Membrane, and Stabilised options after 2000 passes. N = 5,000.
N = 9,000

Subgrade profile

Mean rut depth (mm) vs. passes for Control, Membrane, and Stabilised conditions.
Note:
The membrane reinforcement geosynthetic has twice the strength of the stabilization geosynthetic.
The stabilisation ‘phase’ reinforcement ‘phase’ hypothesis

Maximum allowable deformation

Serviceability Condition

- Stabilisation ‘phase’
- Stabilisation failure

- Reinforcement ‘phase’
- Tensile failure

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Can we specify stabilisation?
OK – so stabilization is a real function and different from the reinforcement function

But a geogrid is a geogrid - why should I have to change the way I specify geogrids?
The purpose of a specification

- A specification must protect the design
- If certain performance characteristics have been assumed in the design, the specification must protect these assumptions
Specifying for stabilisation

- For permanent roads, surface deformations are critical
- Pavement design seeks to control surface deformation
- Correctly designed mechanically stabilised roads have reduced deformations.
- We are not interested in the effect of the geogrid at high strains – At high surface deformations THE ROAD WILL ALREADY HAVE FAILED.
- We need to specify to ensure that a stabilisation function is provided and performance assumptions in the design are met.
- We should be specifying performance of the stabilised layer
Performance specification?
Public Sector Procurement and EU Law

Article 41 of the Public Contracts Directive (2014/24/EU)

- This dictates how technical specifications should be developed for
  - Works
  - Services
  - Supplies

- Implementation into national legislation of each Member state was 18th April 2016
Included within the key principles

Article 42 allows the Contracting Authority to set out specification requirements by reference to:

- Performance or Functional requirements
- European or other technical specifications (in a specific order)
- A combination of both
Order of acceptable technical specifications

- Harmonised Standards (CEN)
- ETA
- International standards (ISO etc.)
- Other technical references established by European standardisation bodies
- National standards
- National technical approvals or specifications
So performance can be specified

Or use technical specifications where they exist:

- Harmonised Standard,
- ETA etc.
Do the Harmonised Standards help for specification of stabilisation function?

EN 13249 lists the following functions of geosynthetics:
- Separation
- Filtration
- Reinforcement

<table>
<thead>
<tr>
<th>Essential Reinforcement Characteristics</th>
<th>Requirement Clauses in this European Standard</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Tensile Strength</td>
<td>4.1, Table 1(1) and 5.1</td>
<td>kN/m</td>
</tr>
<tr>
<td>2 Elongation</td>
<td>4.1, Table 1 (2) and 5.1</td>
<td>%</td>
</tr>
</tbody>
</table>
Two routes to CE Marking

Harmonised Standard

2 Equal Routes to a CE Mark

European Technical Approval (ETA)
### ETA for stabilisation?

#### ETA for Hexagonal Geogrid Stabilisation of Unbound Layers

<table>
<thead>
<tr>
<th>No.</th>
<th>Product Characteristic</th>
<th>Method of Testing</th>
<th>Unit or Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Radial Secant Stiffness at 0.5% strain</td>
<td>TR 041 B.1</td>
<td>kN/m</td>
</tr>
<tr>
<td>2</td>
<td>Radial Secant Stiffness Ratio</td>
<td>TR 041 B.1</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Junction Efficiency</td>
<td>TR 041 B.2</td>
<td>%</td>
</tr>
<tr>
<td>4</td>
<td>Hexagonal Pitch</td>
<td>TR 041 B.4</td>
<td>mm</td>
</tr>
</tbody>
</table>
Giroud - describing geosynthetic mechanisms 10 years ago

“Functions of Geosynthetics in Road Applications”

The only mechanism of reinforcement that is effective in paved roads is the load distribution improvement that results from lateral restraint because this mechanism works with small deformation.

Lateral restrain = mechanical stabilisation
Summary

- Stabilisation function is different to the reinforcement function

- There are real economic benefits to be gained from correct use of mechanical stabilization in permanent roads

- Proven design methods exist based upon performance – We should specify performance
Thank you