Geogrids - Proper Use in Pavement Structures

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Overall Goal

- Provide resources and tools to improve the quality of flexible pavements
  - Improved economics
    - Immediate costs
    - Long term rehab and reconstruct costs
  - Reduce construction impacts

Defining a Geogrid

Uniaxial Geogrids
(Slopes and Walls)

Biaxial and Triaxial Geogrids
(Pavements)

Outline of Objectives

- Mechanics of how a Geogrid works in Pavement Applications
- Applications
  - Subgrade Stabilization
  - Structural Contribution (Pavement Optimization, Base Reinforcement)
  - Overview of Relevant Proof needs
- Installation

Defining the Problem

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Defining the Problem – Subgrade Stability

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Defining the Problem – Subgrade Stability

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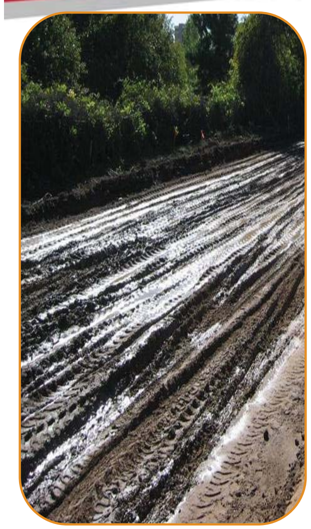

Engineering Terms

Vertical Stresses exceed the plastic limit (ultimate bearing capacity) of the subgrade soils.

Defining the Problem – Subgrade Stability

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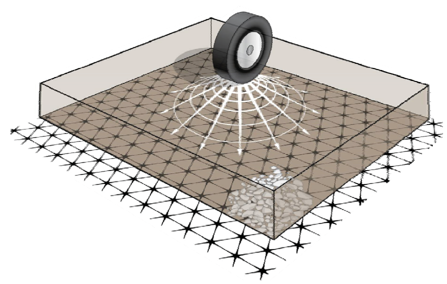


- Wheel loadings produce both vertical and outward stresses into a pavement.
- Loadings that exceed the elastic limit of the soils can cause “local” permanent shearing of the subgrade (possible contamination).
- If vertical stresses exceed the plastic limit (ultimate bearing capacity), complete shear failure results.

(J.P. Giroud & Jie Han, 2004)

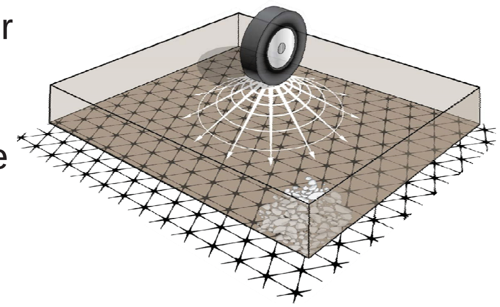
Defining the Problem – Subgrade Stability

"According to the classical result of the theory of plasticity, outward shear stresses decrease the bearing capacity of the subgrade whereas inward shear stresses increase the bearing capacity of the subgrade."

(J.P. Giroud and Jie Han, 2004)

Defining the Problem – Subgrade Stability

"...shear stresses induced by vehicular loads tend to be oriented outward, which decreases the bearing capacity of the subgrade."



(J.P. Giroud and Jie Han, 2004)

Defining the Problem – Lateral Movement

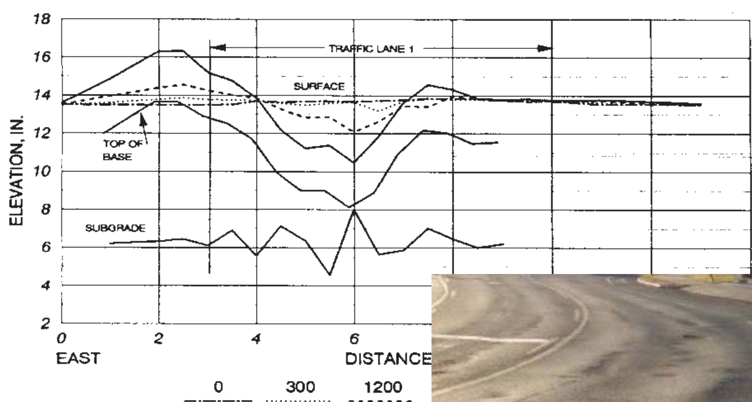


FIGURE 36. TYPICAL CROSS SEC
(CONTROL, 2 IN. AC,

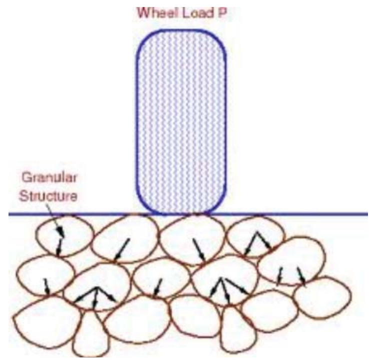
Defining the Problem – Lateral Movement

"In geotechnical engineering, the solution of a slab-on-grade soil-structure interaction problem has been simplified. Concrete pavements and foundations are generally treated as an elastic plate and the soil supporting the pavement or foundation is assumed to be linear, elastic, isotropic and homogeneous. In reality, the stress-strain behavior of the soil is non-linear, irreversible, anisotropic, and inhomogeneous."

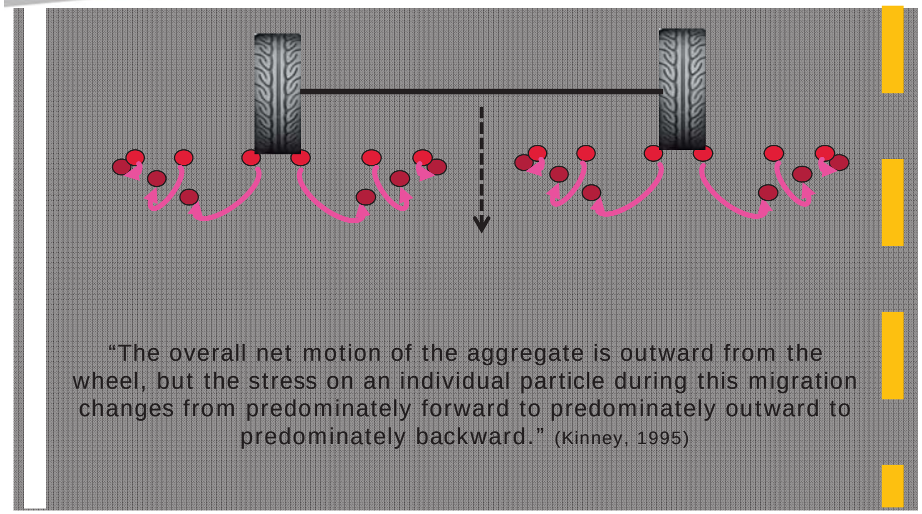
Taken from White et al… (2005)

Defining the Problem – Lateral Movement

- Stresses produced by wheel loadings create lateral displacements within the stress-dependent base course.
- Since the materials are not elastic – over time plastic deformation occurs.
- "The overall net motion of the aggregate is outward from the wheel, but the stress on an individual particle during this migration changes from predominately forward to predominately outward to predominately backward." (Kinney, 1995)



Defining the Problem – Lateral Movement

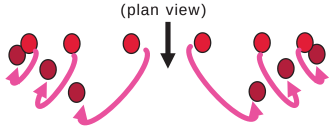


Defining the Problem – Lateral Movement

"Major Findings… (#3 of 5)"

"… About 91% of the rutting occurred in the pavement itself: 32% in the surface, 14% in the base, and 45% in the subbase. Thus, only 9% of the surface rut could be accounted for by rutting of the embankment. Data also showed that changes in thickness of the component layers were caused not by the increase in density, <u>but primarily by lateral movements of the materials</u>."
(*Pavement Analysis and Design*, Yang H. Huang)

Wheel Loading
(plan view)



Mechanisms

- Lateral Restraint
- Improved Bearing Capacity
- Tension Membrane Effect

Mechanisms – Tensioned Membrane Effect

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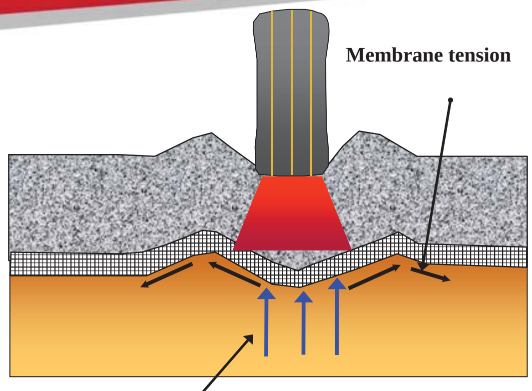

Source: USACOE ETL 1110-1-189

Mechanisms – Tensioned Membrane Effect

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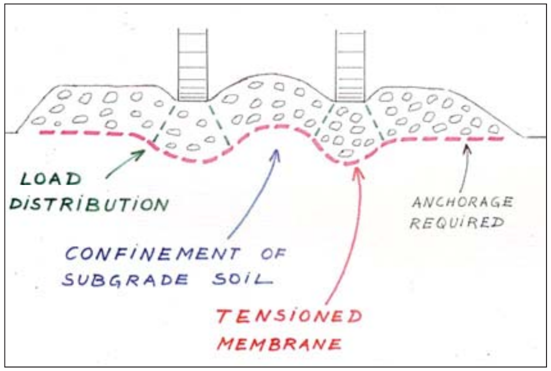

- Requires anchorage
- Develops based on modulus of the product
- Requires elastic or plastic deformation of the subgrade to put product in "tension"

Mechanisms – Improved Bearing Capacity

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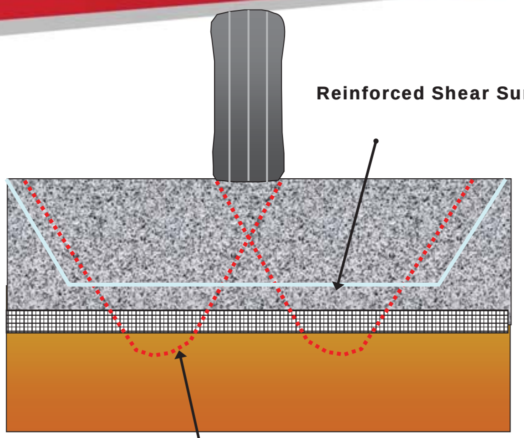

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Mechanisms – Improved Bearing Capacity

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Outward stresses induced by wheel loading reduce the bearing capacity of the subgrade…..

Geogrid changes the orientation of shear stresses.

Interlocking between geogrid and the aggregate has two benefits:

1) Lateral movement of the aggregate is reduced or eliminated decreasing or eliminating outward stresses to the subgrade.
2) Aggregate striking through the geogrid creates a frictional surface that opposes lateral movement of the subgrade, creating inward shear stresses which improve the bearing capacity.

(J.P. Giroud and Jie Han, 2004)

Improved Bearing Capacity – Flexible Pavements

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Top – Trafficked Surface Rutting Profiles

Unreinforced | Geogrid 1 | Geogrid 2

Mechanisms – Lateral Restraint

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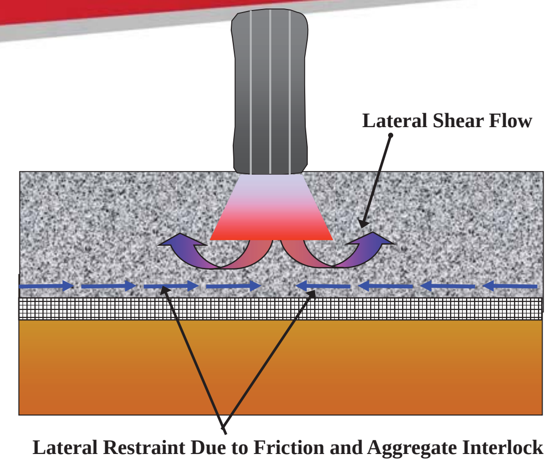

"...lateral restraint has been identified as the primary reinforcement mechanism..."

(ETL 1110-1-188 page 2 Section 1.2)

Source: USACOE ETL 1110-1-189

Mechanisms – Lateral Restraint

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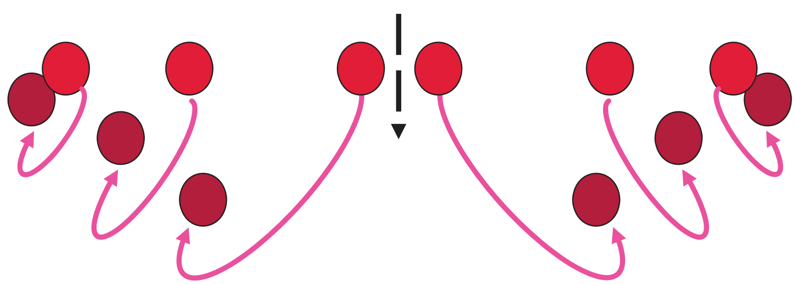
Direction of Wheel Path



Fishhook Pattern

Mechanisms – Lateral Restraint

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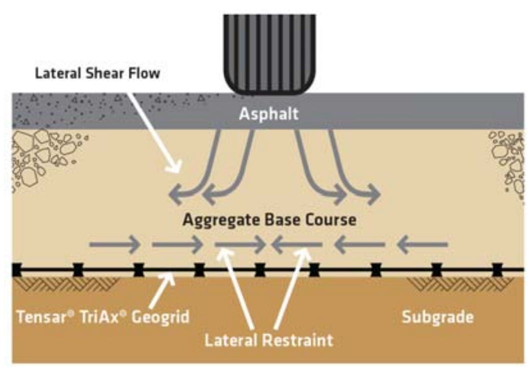


Source: USACOE ETL 1110-1-189

- Reduction in outward stresses to the subgrade
- Inward stresses are generated that increase the subgrade bearing capacity

(J.P. Giroud and Jie Han, 2004)

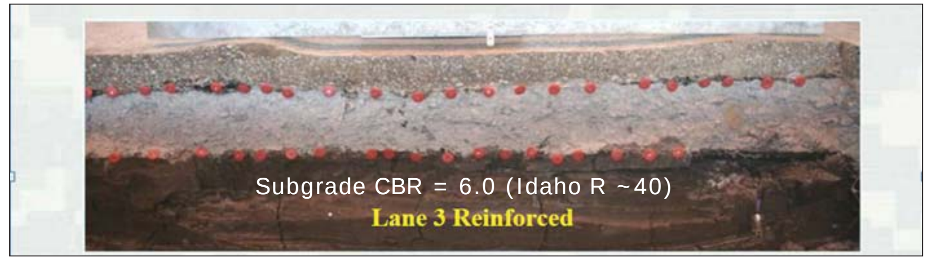
Mechanisms – Lateral Restraint

Unconfined Video

Partially Confined Video
(Stiff ribs, square ribs, packing arrangement)

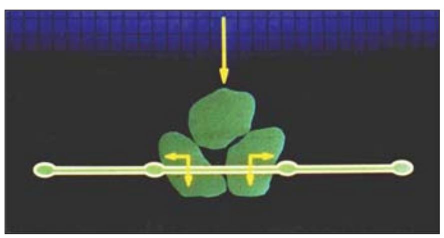
Fully Confined Video
(Stiff ribs, square ribs, packing arrangement, stiff junctions)

Mechanisms – Lateral Restraint



Mechanisms – Lateral Restraint

The amount of aggregate confinement achieved is determined by the efficiency of the stress transfer that occurs between the individual aggregate particles and the geogrid under traffic loading.



Applications

- Subgrade Stabilization
- Pavement Optimization

Application and Intent

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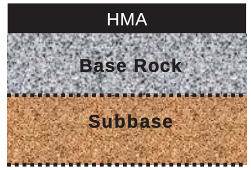
- Structural Contribution (Pavement Optimization, Base Reinforcement,…)
  - Reduce Structural Thicknesses
  - Improve Pavement Performance
  - Combination of above



- Subgrade Stabilization (Subgrade Improvement, Soft Spot Repair,…)
  - Constructability
  - Variability of Subgrade Soils
  - Improving Uniformity

Overview of Geogrid Mechanisms for Roadway Applications

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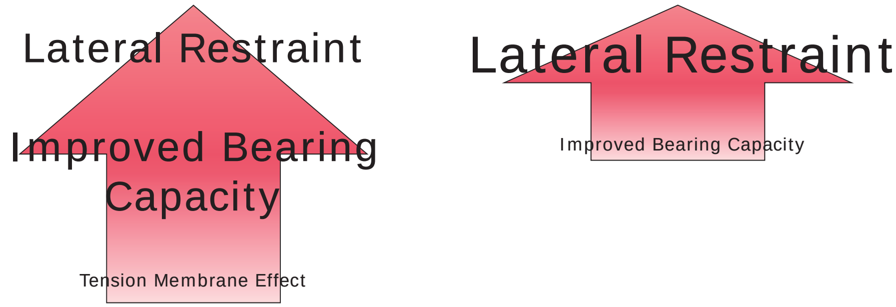
Subgrade Stabilization
Building "platform" over soft soils

Pavement Optimization
Improving performance over good soils or stabilized soils



Subgrade Stabilization

- Defining the Problem
- Geogrid Mechanisms of Reinforcement
- Methodologies

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Defining the Application – Pavement Foundations

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- ***Subgrade strength can be highly variable in the field***, both by location and over time as conditions change
- A subgrade failure will result in a complete failure of the pavement section – ***it is not possible to fix a bottom up problem with a top down remedy***
- Avoidance of subgrade failure is the ***most important element of minimizing the life cycle cost*** of pavements, because it ***moves the critical failure higher*** in the pavement section, where it can be dealt with more cost effectively

Subgrade Stabilization

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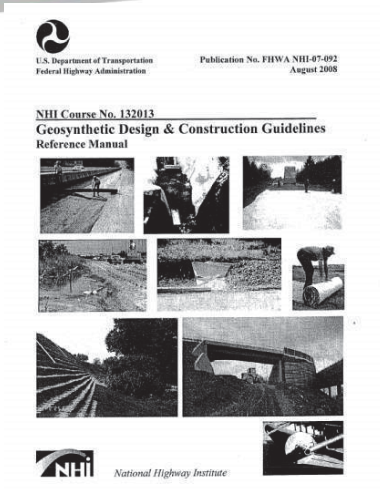

- USFS Method (1977) – Bearing Capacity Method: Unpaved
- USACOE (2003) – Bearing Capacity Method: Unpaved
- Giroud-Han (2004) – Serviceability Method: Unpaved

Subgrade Stabilization

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ETL 1110-1-189
14 Feb 03

USE OF GEOGRIDS IN
PAVEMENT CONSTRUCTION

1.0 Introduction

Engineers are continually faced with maintaining and developing pavement infrastructure with limited financial resources. Traditional pavement design and construction practices require high-quality materials for fulfillment of construction standards. In many areas of the world, quality materials are unavailable or in short supply. Due to these constraints, engineers are often forced to seek alternative designs using substandard materials, commercial construction aids, and innovative design practices. One category of commercial construction aids is geosynthetics. Geosynthetics include a large variety of products composed of polymers and are designed to enhance geotechnical and transportation projects. Geosynthetics perform at least one of five functions: separation, reinforcement, filtration, drainage, and containment. One category of geosynthetics in particular, geogrids, has gained increasing acceptance in road construction. Extensive research programs have been conducted by the U.S. Army Engineer Research and Development Center (ERDC) and non-military agencies to develop design and construction guidance for the inclusion of geogrids in pavement systems. This document describes the use of geogrids in flexible pavement systems including design charts, product specifications, and construction guidance.

A geogrid is defined as a geosynthetic material consisting of connected parallel sets of tensile ribs with apertures of sufficient size to allow strike-through of surrounding soil, stone, or other geotechnical material (Koerner 1998). Existing commercial geogrid products include extruded geogrids, woven geogrids, welded geogrids, and geogrid composites. Extruded geogrids are formed using a polymer sheet that is punched and drawn in either one or two directions for improvement of engineering properties. Woven geogrids are manufactured by weaving polymer fibers, typically polypropylene or polyester, that can be coated for increased abrasion resistance (Berg et al. 2000). Welded geogrids are manufactured by welding the junctions of woven segments of extruded polymers. Geogrid composites are formed when geogrids are combined with other products to form a composite system capable of addressing a particular application. Extruded geogrids have shown good performance when compared to other types for pavement reinforcement applications (Cancelli et al. 1996, Miura et al. 1990, and Webster 1993). Extruded geogrids can be divided into two broad categories based upon their formation and principle application, uniaxial and biaxial. Extruded geogrids that are pre-tensioned in one direction are called uniaxial geogrids and are typically used in geotechnical engineering projects concerning reinforced earth and retaining walls. Extruded geogrids that are pre-tensioned in two directions are referred to as biaxial geogrids and are typically used in pavement applications where the direction of principle stress is uncertain. Most geogrids are made from polymers, but some products have been manufactured from natural fibers, glass, and metal strips. This document, however, will focus exclusively on polymer-based geogrids.

- 1 -

- CORPS ETL 1110-189
- Design method based on empirical testing at WES and other facilities
- Discussion on relevant mechanisms based on multiple full-scale trials
- Based on 2” rutting at 1,000 passes.

Giroud-Han Methodology (2004)
ASCE Geotechnical Journal

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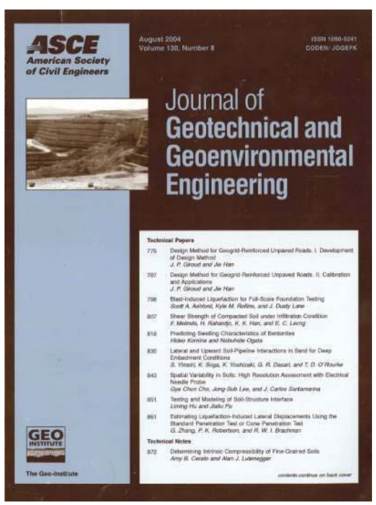
- Method Officially Published in August 2004
- Calibrations & Applications Published August 2004
- Discussion of Method and Proper Calibration outlined for any product (2006)
- Generic model which can be used with any product with appropriate calibration (2012).
- 4-step calibration process outlined (2012)



Giroud-Han Methodology

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Even though the G-H design method has been adopted by consultants and geosynthetic manufacturers, a number of issues have arisen, which are clarified in this article. In particular, this article clearly indicates the equations that are generic—and can be used with any geosynthetic with appropriate calibration—and the equations that were calibrated for specific geosynthetics. This distinction between generic and calibrated equations is crucial because it was not clear to some readers of the original publications of the G-H method.

Giroud-Han Methodology

The use of the terms *reinforced* and *reinforcement* in the context of unpaved roads does not imply that the geosynthetic simply adds force (i.e., simply adds its strength) to the unpaved road structure. As shown in the original publication (Giroud and Han, 2004a), a geosynthetic improves an unpaved road through complex mechanisms that mostly do not involve the strength of the geosynthetic per se. Therefore, in the context of unpaved roads, *reinforced* and *reinforcement* should be regarded only as convenient terms established by tradition.

Giroud-Han Methodology

The process includes four steps:

1) selecting a relevant property (or several relevant properties) of the considered geosynthetic—i.e., one or several properties (not necessarily *J*) likely to give good correlation with the performance of an unpaved road incorporating that geosynthetic.

2) obtaining an expression for *k* similar to **Equation 3**, but where *J* is replaced by the selected property (or properties).

3) obtaining an equation similar to **Equation 4**, by combining **Equation 2** with the expression obtained for k in the preceding step.

4) deriving an equation similar to **Equation 5** by validating **Equation 4** using field tests.

Giroud-Han Methodology

cations. Physical or mechanical properties that are important for one form, type, or family of geosynthetics may not apply to other forms, types, or families of geosynthetics. If several geosynthetics appear to be similar, the method must be calibrated for each one. Furthermore, the applicability of the method for each of these geosynthetics must be validated using full-scale tests.

Calibration based only on small-scale tests and the index properties of the geosynthetic could lead to a false sense of security that the unpaved road design will meet performance expectations. Based on the limitations of the G-H method, as presented in this article, the designer should always verify that geosynthetic-specific full-scale testing along with case histories, for which a calibrated and validated G-H equation was utilized, resulted in satisfactory performance of the constructed unpaved road.

Subgrade Stabilization

- Calibration of Aggregate Thicknesses (Giroud-Han)

Subgrade Stabilization

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Subgrade Stabilization

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Structural Contribution with Geogrid

(Pavement Optimization, Base Reinforcement,…)

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Structural Contribution

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- Standard of Practice - AASHTO R50-09 Outlines the need for testing and review.
- GMA White Paper II Outlines the procedures for designing with geogrid.

Standard Practice for

Geosynthetic Reinforcement of the Aggregate Base Course of Flexible Pavement Structures

AASHTO Designation: R 50-09[1]

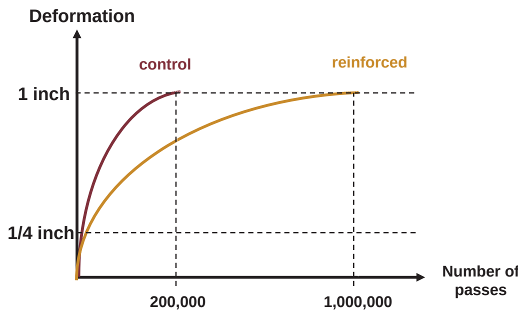
1. SCOPE

2. REFERENCED DOCUMENTS

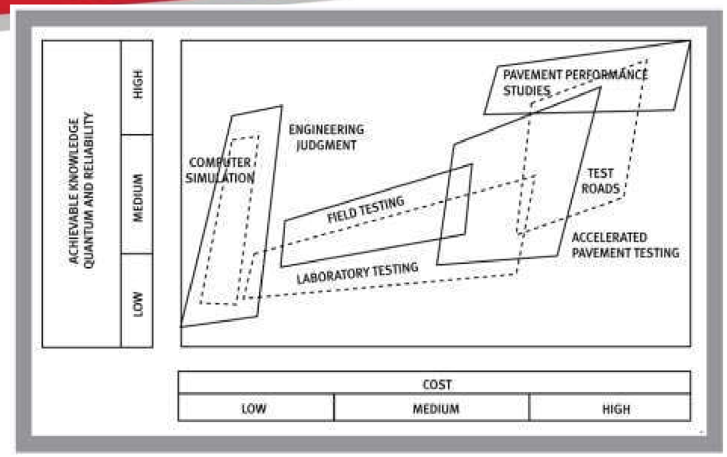
5.2. Design procedures use experimentally derived input parameters that are often geosynthetic specific. Thus, computed engineering designs and economic benefits are not easily translated to other geosynthetics. Therefore, users of this document are encouraged to affirm their designs with field verification of the reinforced pavement performance, both in engineering design and economic benefits.

Structural Contribution

- Defining the Benefit
  - Traffic Benefit Ratio (TBR)
  - Base Course Reduction Ratio (BCR ratio)
  - Layer Coefficient Ratio (LCR)



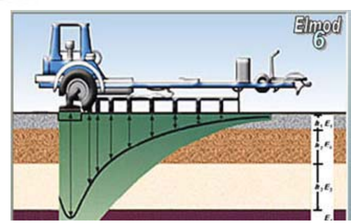
Structural Contribution



Interrelationship between pavement engineering facets that collectively and individually contribute to knowledge (Hugo et al. 1991).

Repetitive Static Plate Load Testing – ASTM D1195

Structural Contribution



Purpose and Concept

- Used to Measure a Pavement Structural Condition.
- Monitoring of sections over time

Structural Contribution

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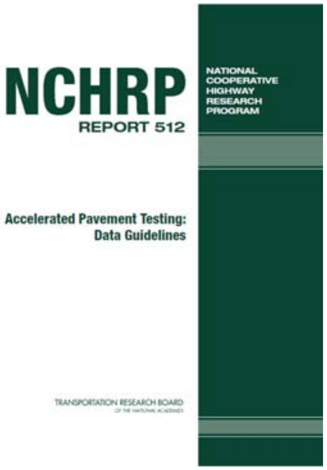

- Ensures proper interpretation of data and establishes proper tolerances for testing (material characterization, environmental conditions and impacts, tolerances…)
- Promotes compatibility of results

Structural Contribution - APT

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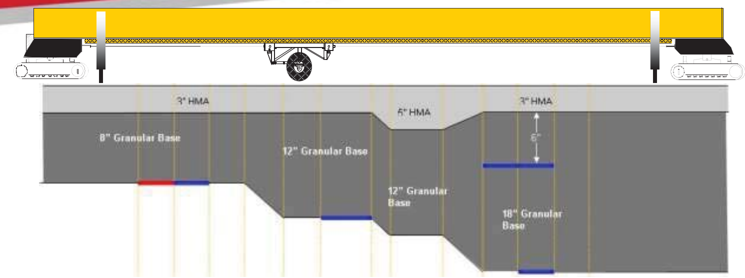

Structural Contribution - APT

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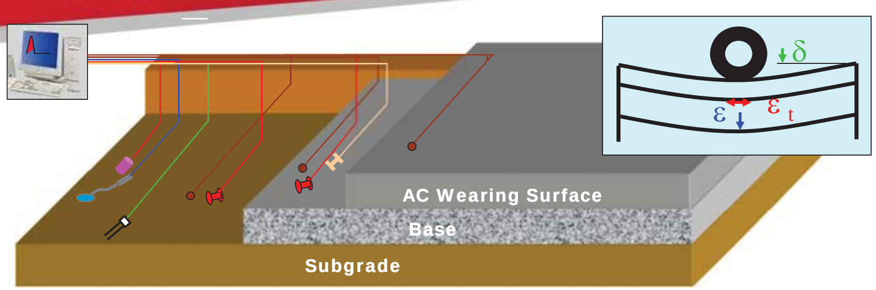
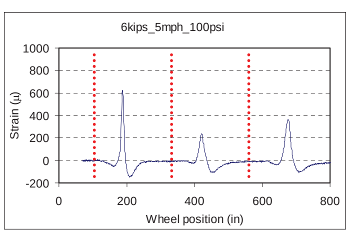
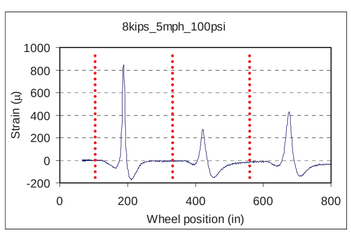




A3 Control | A2 Type 2 | A1 Type 1



A3 Control | A2 Type 2 | A1 Type 1

Structural Contribution - APT

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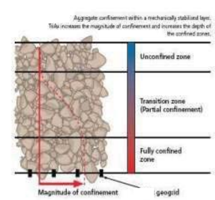

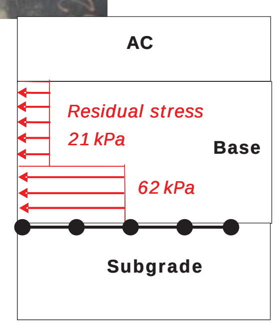

Structural Contribution

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Section #	Loading Type	Subgrade CBR (%)	Base Thickness (in)	Asphalt Thickness (in)
1	30,000 lb single wheel load	8	10	2
2		3	14	2
3		3	14	2
4		3	14	2
5		3	14	2
6		3	14	2
7	10,000 lb dual wheel single axle	3	8	2
8	Cyclic non-moving load with a peak value of 40 kN	1.5	12	3

	0.25" Rutting		
Section #	Control	Reinforced	TBR
1	300	300	1.0
2	30	30	1.0
3	30	30	1.0
4	30	60	2.0
5	30	30	1.0
6	30	30	1.0
7	1200	24360	20.3
8	20	700	35.0

	0.50" Rutting		
Section #	Control	Reinforced	TBR
1	3000	3000	1.0
2	60	80	1.3
3	60	80	1.3
4	60	80	1.3
5	60	65	1.1
6	60	70	1.2
7	5400	100000	18.5
8	3333	200000	60.0

	1.00" Rutting		
Section #	Control	Reinforced	TBR
1	15000	100000	6.7
2	106	170	1.6
3	106	500	4.7
4	106	285	2.7
5	106	100	0.9
6	106	97	0.9
7	19500	300000	15.4
8	11429	800000	70.0

- Differences in testing methods and materials can create variations in results
- Failure criteria can differ (rutting, …)
- Variations in thicknesses of HMA and associated failure mechanisms, moisture conditions, …
- Differences based on product geometry and type.

Structural Contribution

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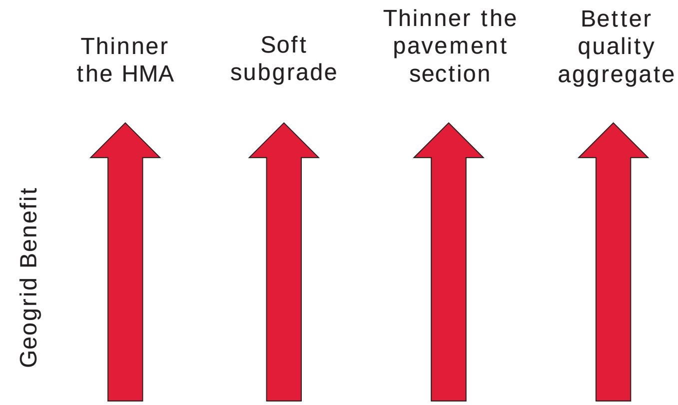

Structural Contribution – Expert Review

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Ryan R Berg & Associates

ARA

Installation

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Installation

- Installation Guide
- On-site instruction for site inspectors, contractors and engineers (include this is spec)

Installation

Overlaps range from 1-3 feet.
Options for keeping geogrid in place (if needed):

- Zip-ties
- Stakes (nails with a washer)

Installation

Questions?