Geotechnical Solutions for Transportation Infrastructure: A Web-based Information and Guidance System

Vern Schaefer – Iowa State University

Arizona Pavements / Materials Conference
Arizona State University, Tempe, AZ
November 16, 2011
What are Geotechnical Solutions?  
*(Construction Options)*

**Geoconstruction and Ground Improvement**  
**Methods and Systems**

- Methods to alter poor soil/ground conditions to meet project requirements
- Variety of methods, often categorized by densification, reinforcement or stabilization
R02 Project Elements

1. Construction of new embankments and roadways over areas of unstable soils

2. Widening and expansion of existing embankments and roadways

3. Improvement and stabilization of the support beneath the pavement structure
Project Team

Project Principals

Vern Schaefer, ISU
David White, ISU
George Filz, VT
Jie Han, KU
Jim Mitchell, VT
Linbing Wang, VT
Ryan Berg, Consultant
Barry Christopher, Consultant
Jim Collin, Consultant
Donald Bruce, Consultant
Gary Fick, Consultant
Dennis Turner, Consultant

VT, ISU & KU Students/Researchers
# Advisory Board Members

## State DOT Representatives

<table>
<thead>
<tr>
<th>Name</th>
<th>DOT/Agency</th>
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<tbody>
<tr>
<td>James Brennan</td>
<td>Kansas DOT</td>
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<tr>
<td>David Horhota</td>
<td>Florida DOT</td>
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<tr>
<td>Mark Morvant</td>
<td>Louisiana TRC</td>
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<td>Hooshmand Nikoui</td>
<td>Caltrans</td>
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<td>David Shiells</td>
<td>Virginia DOT</td>
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<td>John Siekmeier</td>
<td>Minnesota DOT</td>
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## Design/Build Contractor Representatives

<table>
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<tr>
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<tr>
<td>Allen Cadden</td>
<td>Schnabel Engineering</td>
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<tr>
<td>Mike Cowell</td>
<td>GeoConstructors, Inc.</td>
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<tr>
<td>Seth Pearlman</td>
<td>DGI-Menards, Inc.</td>
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<tr>
<td>Steve Saye</td>
<td>Kiewit Engineering</td>
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<tr>
<td>Al Sehn</td>
<td>Hayward Baker Inc.</td>
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Phase 1 Overview
Oct 2007 to Sept 2008

- Task 1 – List of technologies & categorized bibliography
- Task 2 – Technical Issues
- Task 3 – QA/QC procedures
- Task 4 – Constraints
- Task 5 – Mitigation Strategies
- Task 6 – Report & Phase 2 Plan
46 Technologies Addressed

- Aggregate Columns
- Beneficial Reuse of Waste Materials
- Bio-Treatment for Subgrade Stabilization
- Blast Densification
- Bulk-Infill Grouting
- Chemical Grouting/Injection Systems
- Chemical Stabilization of Subgrades & Bases
- Column-Supported Embankments
- Combined Soil Stabilization with Vertical Columns
- Compaction Grouting
- Continuous Flight Auger Piles
- Deep Dynamic Compaction
- Deep Mixing Methods
46 Technologies Addressed (cont.)

- Drilled/Grouted & Hollow Bar Soil Nailing
- Electro-Osmosis
- Excavation & Replacement
- Fiber Reinforcement in Pavement Systems
- Geocell Confinement in Pavement Systems
- Geosynthetic Reinforced Construction Platforms
- Geosynthetic Reinforced Embankments
- Geosynthetic Reinforcement in Pavement Systems
- Geosynthetic Separation in Pavement Systems
- Geosynthetics in Pavement Drainage
- Geotextile Encased Columns
- High-Energy Impact Rollers
- Hydraulic Fill + Vacuum Consolidation + PVDs
- Injected Light-Weight Foam Fill
46 Technologies Addressed (cont.)

- Intelligent Compaction
- Jet Grouting
- Light Weight Fills
- Mechanical Stabilization of Subgrades & Bases
- MSE Walls
- Micro-Piles
- Onsite Use of Recycled Pavement Materials
- Partial Encapsulation
- PVDs & Fill Preloading
- Rapid Impact Compaction
- Reinforced Soil Slopes
- Sand Compaction Piles
- Screw-In Soil Nailing
- Shoot-In Soil Nailing
- Shored MSE Walls
- Traditional Compaction
- Vacuum Preloading w/ & w/o PVDs
- Vibrocompaction
- Vibro-Concrete Columns
Phase 2 Work Tasks
Nov 2007 to Dec 2011

Six tasks:

8. Test and evaluate the effectiveness of mitigation methods
9. Develop a catalog of materials & systems for rapid renewal
10. Refine/develop design procedures, QA/QC processes & guidance for geotechnical materials & systems
11. Develop methods for estimating costs of geotechnical & materials systems
12. Develop sample guide specifications for geotechnical & materials systems
13. Final report
End User Products

• Main product: Web based information and guidance system

• Development project reports

• Within the G&S system, for each of 46 technologies:
  ❖ Technology Fact Sheets
  ❖ Photographs
  ❖ Case Histories
  ❖ Design Procedures
  ❖ Quality Control/Quality Assurance Procedures
  ❖ Cost Estimating
  ❖ Specifications
  ❖ Bibliography
Audience

• Public agency personnel at local, state and federal levels
  ❖ Primarily Geotechnical Engineers
  ❖ Civil/Structural/Bridge Design & Construction Engineers, Pavement Design & Construction Engineers
  ❖ Project Managers, Procurement, Research, Maintenance, District Engineers
• Consultants, General Contractors, A/E groups, Academics/Students
Product Use

• Web site
  ❖ Learn about technologies, both technical and nontechnical users
  ❖ Investigate candidate solutions, by category classification or using selection system
  ❖ Locate design methods, quality methods
  ❖ Develop cost estimates
  ❖ Develop specifications
  ❖ Technical summaries

• Locate additional information in references
Goal of Information & Guidance System

To make geotechnical solutions more accessible to public agencies in the United States for rapid renewal and improvement of the transportation infrastructure.

“Project Vision”
Objectives of the System

1. Identify potential technologies for design and construction for the following transportation applications:
   - Construction over UNSTABLE soils
   - Construction over STABLE or STABILIZED soils
   - Geotechnical pavement components (base, subbase, and subgrade)
   - Working platforms
Objectives of the System

2. Provide guidance to develop a ‘short-list’ of applicable technologies
3. Provide guidance for detailed project-specific screening of technologies with consideration of SHRP 2 Renewal Objectives
4. Provide an interactive, programmed system
5. Provide current, up to-date information
System Mandates

• The information and guidance system should be:
  ❖ Simple
  ❖ Functional
  ❖ Completely populated
  ❖ Selection system should guide user to a short-list of potential, unranked technologies.
  ❖ Should be easily updatable
Considerations for Selection System Development

• Framework required addressing five areas:
  1. Overall system characteristics
  2. The user
  3. The knowledge
  4. The operating system
  5. Approach to the system
Getting Started…

• What is the application?
• What is the soil condition that needs to be improved?
• To what depth do the unstable soils extend?
Value Added

• Main product: Web based information and guidance system

• The primary value of the system is that it collects, synthesizes, integrates, and organizes a vast amount of critically important information about geotechnical solutions in a system that makes the information readily accessible to the transportation agency personnel who need it most.
Construction over Unstable Soils

EMBANKMENT

UNSTABLE SOILS

SOLUTIONS ABOVE OR BELOW GRADE

Construction over Unstable Soils
Construction over Stable/Stabilized Soils
Geotechnical Pavement Components (Base, Subbase, and Subgrade)
WORKING PLATFORM SOLUTIONS

GROUND SURFACE

UNSTABLE SOILS

UNSTABLE SOILS
OR
STABLE SOILS

Working Platforms
Information and Guidance System
Overview and Examples

http://www.intrans.iastate.edu/geotechsolutions/index.cfm

Expected to be open to public in summer 2012
Geotechnical Solutions for Transportation Infrastructure is a SHRP 2 project developed to make geotechnical solutions more accessible to public agencies in the United States. This website is a toolkit of geotechnical information to address all phases of decision making from planning to design to construction to allow transportation projects to be built faster, to be less expensive, and/or to last longer. Anyone involved in planning, design, and construction of transportation infrastructure will benefit from the information and resources available here.

Geotechnical Design Process
Prior to technology selection, site-specific conditions and constraints must be identified. The geotechnical design process presents an overview of the considerations involved in evaluating site conditions and implementing a geosynthetic technology.

Catalog of Technologies
The Catalog of Technologies provides a listing of all the technologies. For each technology, the following information is available:
- Technology Fact Sheet
- Photos
- Case Histories
- Design Guidance
- QC/QA Procedures
- Cost Estimating
- Specifications
- Bibliography

Technology Selection
Technology Selection is an interactive tool to identify candidate technologies for specific geosynthetic applications using project information and constraints. Final technology selection requires project-specific engineering. Technologies can also be accessed by classification or through a catalog of specific technologies.

Glossary
This website contains technical terms and industry-specific jargon. A glossary has been compiled to assist in understanding the terminology used throughout this website and in its documents.
Interactive Selection System

Select an Application

Begin the interactive selection system by selecting one of the applications to the right. These inputs are the basic information required for screening potential technologies.

The technologies shown in the far right-hand column are all the potential solutions available in this system. After selecting one of the applications below, a short list of potential solutions for the selected application will appear in the right hand column. As additional inputs are entered, potential technologies are highlighted and eliminated technologies are faded.

Technologies

- Aggregate Columns
- Beneficial Reuse of Waste Materials
- Bio-Treatment for Subgrade Stabilization
- Blasting Densification
- Bulk-Infill Grouting
- Chemical Grouting/Injection Systems
- Chemical Stabilization of Subgrades and Bases
- Column-Supported Embankments
- Combined Soil Stabilization
- Combined Soil Stabilization with Vertical Columns
- Compaction Grouting
- Continuous Flight Auger Piles
- Deep Dynamic Compaction
- Deep Mixing Methods
- Drilled/Grouted and Hollow Bar Soil Nailing
- Electro-Osmosis
- Excavation and Replacement
- Fiber Reinforcement for Slopes
- Fiber Reinforcement in Pavement Systems
- Geocell Confinement in Pavement Systems
- Geosynthetic Reinforced Construction Platforms
- Geosynthetic Reinforced Embankments

? are found throughout the interactive selection system to provide additional information regarding each selection.
Technology Selection Application

Each screen will prompt for an input. These inputs are the basic information required for screening potential technologies. The technologies shown in the right-hand column are potential solutions for the selected application. As additional inputs are entered, potential technologies are highlighted and eliminated if technologies are faded.

Your selections so far

Click on an item to return to a previous selection.

Selected Application: Geotechnical Pavement Components (Base, Subbase, and Subgrade)

Click on a response that best represents project conditions

Select Purpose of Technology Application

- Stabilization of Pavement Support Layer(s)
- Use of Alternative or Recycled Materials in Pavement Support Layer(s)
- Void Filling
Each screen will prompt for an input. These inputs are the basic information required for screening potential technologies. The technologies shown in the right-hand column are potential solutions for the selected application. As additional inputs are entered, potential technologies are highlighted and eliminated technologies are faded.

**Your selections so far**

Click on an item to return to a previous selection.

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**Selected Application:** Geotechnical Pavement Components (Base, Subbase, and Subgrade)

> **Purpose of Technology Application:** Stabilize Pavement Support Layer(s)

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**Click on a response that best represents project conditions**

- **Select Pavement Support Layers to Be Improved**
  - Base/Subbase Layer
  - Subgrade Layer
  - Deeper Subgrade Treatment (This selection links to the Construction Over Unstable Soils portion of the interactive selection system.)
  - In-situ Treatment with Pavement Surface In Place

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**Technologies**

- Beneficial Reuse of Waste Materials
- Bio-Treatment for Subgrade Stabilization
- Bulk-Infill Grouting
- Chemical Grouting/Injection Systems
- Chemical Stabilization of Subgrades and Bases
- Electro-Osmosis
- Excavation and Replacement
- Fiber Reinforcement in Pavement Systems
- Geosynthetic Reinforced Construction Platforms
- Geosynthetic Reinforcement in Pavement Systems
- Geosynthetic Separation in Pavement Systems
- Geosynthetics in Pavement Drainage Systems
- Hydraulic Fill + Vacuum Consolidation
- Geocomposite Drains
- Injected Lightweight Foam Fill
- Intelligent Compaction
- Mechanical Stabilization of Subgrades and Bases
- Onsite Use of Recycled Pavement Materials
- Partial Encapsulation
- Traditional Compaction
- Vacuum Preloading with and without PVDs
Technology Selection Application

Each screen will prompt for an input. These inputs are the basic information required for screening potential technologies. The technologies shown in the right-hand column are potential solutions for the selected application. As additional inputs are entered, potential technologies are highlighted and eliminated technologies are faded.

Your selections so far

Click on an item to return to a previous selection.

Selected Application: Geotechnical Pavement Components (Base, Subbase, and Subgrade)

> Purpose of Technology Application: Stabilize Pavement Support Layer(s)
> Layers to Be Improved: Subgrade Layer

Click on a response that best represents project conditions

Select Subgrade Soil Type

- High-plasticity (CH, MH) soils
- Low-plasticity (CL, ML) soils
- Plastic sands and gravels (GC, SC)
- Silty sands and gravels (GM, SM)
- Clean sands and gravels (SP, SW, GP, GW)
- Rock fill
Technology Selection Application

Each screen will prompt for an input. These inputs are the basic information required for screening potential technologies. The technologies shown in the right-hand column are potential solutions for the selected application. As additional inputs are entered, potential technologies are highlighted and eliminated technologies are faded.

Your selections so far

Click on an item to return to a previous selection.

Selected Application: Geotechnical Pavement Components (Base, Subbase, and Subgrade)

> Purpose of Technology Application: Stabilize Pavement Support Layer(s)
> Layers to Be Improved: Subgrade Layer
> Subgrade Soil Type: Low-plasticity (CL, ML) soils

Click on a response that best represents project conditions

Select Property for Improvement

- Increase strength/stiffness and reduce deformation
- Mitigate moisture/drainage problems
- Increase freeze/thaw durability
Techology Selection Application

Each screen will prompt for an input. These inputs are the basic information required for screening potential technologies. The technologies shown in the right-hand column are potential solutions for the selected application. As additional inputs are entered, potential technologies are highlighted and eliminated technologies are faded.

Your selections so far

Click on an item to return to a previous selection.

Selected Application: Working Platforms

- unstable soils
- unstable soils or stable soils

Click on a response that best represents project conditions

Select Type of Working Platform

- Permanent/deformation control
- Temporary/provide platform to support construction traffic over soft soil
- Construction platform in areas outside of traffic

Technologies

Chemical Stabilization of Subgrades and Bases
Excavation and Replacement
Geosynthetic Reinforced Construction Platforms
Geosynthetic Reinforcement in Pavement Systems
Mechanical Stabilization of Subgrades and Bases
Prefabricated Vertical Drains and Fill Preloading

The links below open PDFs in a new window. The documents provide information about the selected technology.

- Technology Fact Sheet
- Photos
- Case Histories
- Design Procedures
- Quality Control/Quality Assurance
- Cost Estimating
- Specifications

The SHRP2 R02 ratings for this technology are as follows:

<table>
<thead>
<tr>
<th>Degree of Technology Establishment</th>
<th>Potential Contribution to SHRP2 Renewal Objectives</th>
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<tbody>
<tr>
<td>5</td>
<td>Rapid Renewal of Transp. Facilities 2</td>
</tr>
</tbody>
</table>

(Rating Scale: 1 = not established or low applicability, 5 = well established or high applicability)
Products Available for each Technology (Information Transfer)

• For each technology:
  - Technology Fact Sheet
  - Photographs
  - Case Histories
  - Design Procedures
  - Quality Control/Quality Assurance
  - Cost Estimating
  - Specifications
  - Bibliography
Interactive Selection System

Each screen will prompt for an input. These inputs are the basic information required for screening potential technologies. The technologies shown in the right-hand column are potential solutions for the selected application. As additional inputs are entered, potential technologies are highlighted and eliminated technologies are faded.

Your selections so far

Click on an item to return to a previous selection.

- embankment
- unstable soils

Selected Application: Construction Over Unstable Soils

Select a response that best represents project conditions

Select Unstable Soil Condition

- Unsaturated and Saturated, Fine Grained Soil
- Unsaturated, Loose Granular Soils
- Saturated, Loose Granular Soils
- Voids – Sinkholes, Abandoned Mines, etc.
- Problem Soils and Sites – Expansive, Collapsible, Dispersive, Organic, Existing Fill, Landfills

*For guidance on combining technologies, see White Paper on Integrated Technologies for Embankments on Unstable Ground.
Interactive Selection System

Each screen will prompt for an input. These inputs are the basic information required for screening potential technologies. The technologies shown in the right-hand column are potential solutions for the selected application. As additional inputs are entered, potential technologies are highlighted and eliminated technologies are faded.

Your selections so far

Click on an item to return to a previous selection.

- embankment
- unstable soils

Selected Application: Construction Over Unstable Soils
Unstable Soil Condition: Unsaturated and Saturated, Fine Grained Soil

Select a response that best represents project conditions

Depth Below Ground Surface To Which Unstable Soils Extend

- 0 - 5 ft
- 5 - 10 ft
- 10 - 30 ft
- 30 - 50 ft
- Greater than 50 ft

*For guidance on combining technologies, see White Paper on Integrated Technologies for Embankments on Unstable Ground.
## Project-Specific Technology Selection

This will display selections made and the next set of questions.

### Selections Made

The following selections have been made so far. Click on an item to return to a previous selection.

- **Selected Application:** Construction over unstable soils
- **Unstable Soil Condition:** Unsaturated/Saturated, Fine Grained Soils
- **Depth Below Ground Surface:** 10 - 30 ft

### Select Project-Specific Characteristics

- Select unstable soil condition that best describes site:
- Are sufficiently thick peat layers present that will affect construction and settlement?
- Are water bearing sands present in the soil to be improved?
- Would any subsurface obstruction cause drilling difficulty, such as cobbles or boulders?
- Purpose of Improvement:
- Select Project Type:
- Site Characteristics:
- Size of Area to be Improved:
- Project Constraints:

[Create PDF of your selections and results]

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### Technologies

- Aggregate Columns
- Blasting Densification
- Chemical Grouting/Injection Systems
- Column-Supported Embankments
- Combined Soil Stabilization with Vertical Columns
- Compaction Grouting
- Continuous Flight Auger Piles
- Deep Dynamic Compaction
- Deep Mixing Methods
- Electro-Osmosis
- Excavation and Replacement
- Geosynthetic Reinforced Embankments
- Geotextile Encased Columns
- High-Energy Impact Rollers
- Injected Lightweight Foam Fill
- Jet Grouting
- Lightweight Fills
- Micro-Piles
- Prefabricated Vertical Drains and Fill Preloading
- Rapid Impact Compaction
- Sand Compaction Piles
- Vacuum Preloading with and without Prefabricated Vertical Drains
- Vibrocompaction
- Vibro-Concrete Columns
Project-Specific Technology Selection

This will display selections made and the next set of questions.

Selections Made

The following selections have been made so far. Click on an item to return to a previous selection.

- **Selected Application:** Construction over unstable soils
- **Unstable Soil Condition:** Unsaturated/Saturated, Fine Grained Soils
- **Depth Below Ground Surface:** 30 - 50 ft

Select Project-Specific Characteristics

Select unstable soil condition that best describes site:
- Unstable soil extends from surface to treatment dept: Yes/No

Are sufficiently thick peat layers present that will affect construction and settlement?
- No

Are water bearing sands present in the soil to be improved?
- No

Would any subsurface obstruction cause drilling difficulty, such as cobbles or boulders?
- ------------------------------ Make your selection ------------------------------

Purpose of Improvement:
- Increase Strength

Select Project Type:
- Embankment Widening

Site Characteristics:
- Constrained, developed sites

Size of Area to Be Improved:
- From 10,000 ft² (930 m²) to 50,000 ft² (4,600 m²)

Project Constraints:
- ------------------------------ Make your selection ------------------------------

Create PDF of your selections and results

Technologies

- Aggregate Columns
- Blasting Densification
- Chemical Grouting/Injection Systems
- Column-Supported Embankments
- Combined Soil Stabilization with Vertical Columns
- Compaction Grouting
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- Jet Grouting
- Lightweight Fills
- Micro-Piles
- Prefabricated Vertical Drains and Fill Preloading
- Rapid Impact Compaction
- Sand Compaction Piles
- Vacuum Preloading with and without Prefabricated Vertical Drains
- Vibrocompaction
- Vibro-Concrete Columns
Aggregate Columns
The links below open PDFs in a new window. The documents provide information about the selected technology.

Technology Fact Sheet
Photos
Case Histories
Design Procedures
Quality Control/Quality Assurance
Cost Estimating
Specifications

The SHRP2 R02 ratings for this technology are as follows:

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(Rating Scale: 1 = not established or low applicability, 5 = well established or high applicability)
Prefabricated Vertical Drains and Fill Preloading

The links below open PDFs in a new window. The documents provide information about the selected technology.

- Technology Fact Sheet
- Photos
- Case Histories
- Design Procedures
- Quality Control/Quality Assurance
- Cost Estimating
- Specifications

Clear  Create Zip File

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<tbody>
<tr>
<td>5</td>
<td>Rapid Renewal of Transp. Facilities 2  Minimal Disruption of Traffic 1  Production of Long-Lived Facilities 4</td>
</tr>
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</table>

(Rating Scale: 1 = not established or low applicability, 5 = well established or high applicability)
Submit a Comment

Use the form below to submit a comment regarding this website to the project team. For inquiries regarding submission of technology specific information, please see the Frequently Asked Questions below:

FAQs
- How do I submit a case history for a technology?
- How do I submit a photograph or video for a technology?
- How do I submit a specification for a technology?
- How do I submit cost information for a technology?
- How do I submit a reference for a technology?

To submit documents, go to the Submit Technology-Specific Information page.

Fields marked with * are required.

*Name: 

E-mail address: 

Reconfirm E-Mail: 

Technology: Aggregate Columns 

Comment regarding: Other 

Comment: 

Submit Comment
Technology Selection Application

Each screen will prompt for an input. These inputs are the basic information required for screening potential technologies. The technologies shown in the right-hand column are potential solutions for the selected application. As additional inputs are entered, potential technologies are highlighted and eliminated technologies are faded.

Your selections so far

Click on an item to return to a previous selection.

Selected Application: Construction Over Stable or Stabilized Soils

Click on a response that best represents project conditions

Select Purpose of Technology Application

- Enhance Compaction Process
- Slope Stabilization and Earth Retention
- Use of Alternative or Recycled Materials

Technologies

Beneficial Reuse of Waste Materials
Drilled/Grouted and Hollow Bar Soil Nailing
Fiber Reinforcement for Slopes
High-Energy Impact Rollers
Hydraulic Fill + Vacuum Consolidation
Geocomposite Drains
Intelligent Compaction
Lightweight Fill, EPS Geofoam, Low-Density Cementitious Fill
MSEW
Onsite Use of Recycled Pavement Materials
Rapid Impact Compaction
Reinforced Soil Slopes
Screw-in Soil Nailing
Shoot-in Soil Nailing
Shored Mechanically Stabilized Earth Wall System
Traditional Compaction