Sustainable Slope Stabilization using Recycled Plastic Pin

October 23, 2019
Asif Ahmed, Ph.D., P.E.
China Plastic Ban

CHINA WASTE IMPORT BAN

'Not a dustbin': Cambodia to send plastic waste back to the US and Canada
Country vows to return 1,600 tonnes of waste as south-east Asian countries revolt against an onslaught of rubbish shipments

Incentive To Innovate: China Will No Longer Take Our Junk For Recycling

China Says No to Your Trash
Banned waste includes plastics, cotton, ash

China's Trash Import Ban came into effect in 2018
www.wionews.com
Plastics Pile Up as China Refuses to Take the West’s Recycling

Americans' plastic recycling is dumped in landfills, investigation shows

Consumers’ efforts to be eco-friendly go to waste at facility in Costa Rica last June. EZEQUIEL BECERRA/AFP/GETTY IMAGES

Piling Up: How China’s Ban on Importing Waste Has Stalled Global Recycling

China’s decision to no longer be the dumping ground for the world’s recycled waste has left municipalities and waste companies from Australia to the U.S. scrambling for alternatives. But experts say it offers an opportunity to develop better solutions for a growing throwaway culture.
NY Waste Statistics

Ohio, South Carolina

- Export for Disposal: 22%
- Recycle/Compost: 36%
- Combustion: 8%
- Landfill: 34%

21 to 25 years
Facts about Plastic Bottles!

- 50 Billion Water Bottle end up in US Landfill Each Year
- It takes 700 year to decompose plastic bottles
- Ecosystems and wildlife are negatively impacted by plastic debris.
Background

- **Recycled Plastic Pin (RPP)**
  - Mainly Polymeric Materials
  - Fabricated from Recycled Plastics

- **Advantages**
  - Commercially Available
  - Use of RPP Reduces Waste Volume
  - Resistant to Biological Exposure

- **Typical Composition**
  - HDPE : 55-90%
  - LDPE : 5-10%
  - PP, PET, PS : 1% - 10%
  - Misc. : 0 – 5%

A 10’ long RPP can replace 500 Soda Bottles
Shallow Landslides in Highway Slopes

Shallow Landslides in Clay Soil
Traditional Repair
Factor of Safety: Without Reinforcement
FS = Mr/Md
Site Investigation

Resistivity Profile: RI-1

Resistivity Profile: RI-2

Plasticity Chart

- BH-1
- BH-2
- BH-3

Plasticity Index

Liquid Limit

Shear Stress

Peak O-C

Fully Softened

Peak N-C

Residual

Displacement
Design of Slope Stabilization

<table>
<thead>
<tr>
<th>Back Calculated Soil Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Type</td>
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<tr>
<td>-----------</td>
</tr>
<tr>
<td>1</td>
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<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
</tbody>
</table>

Soil Type:
- Soil 1
- Soil 2
- Soil 3
- Soil 4

Soil Properties:
- Soil 1: Friction Angle 10°, Cohesion 100 psf, Unit Weight 125 pcf, Elastic Modulus 100000 psf
- Soil 2: Friction Angle 23°, Cohesion 100 psf, Unit Weight 125 pcf, Elastic Modulus 150000 psf
- Soil 3: Friction Angle 15°, Cohesion 250 psf, Unit Weight 130 pcf, Elastic Modulus 200000 psf
- Soil 4: Friction Angle 35°, Cohesion 3000 psf, Unit Weight 140 pcf, Elastic Modulus 250000 psf

Back Analysis of Unreinforced Slope: FS = 1.05

Reinforced Section 1: FS = 1.43

Reinforced Section 2: FS = 1.48

Reinforced Section 3: FS = 1.54
RPP Layout

US 287 N
GUARD RAIL

REINFORCED SECTION-1 | CONTROL SECTION | REINFORCED SECTION-2
---|---|---
- 10 ft RPP @ 3 ft c/c | 8 ft RPP @ 5 ft c/c | 10 ft RPP @ 4 ft c/c
- 10 ft RPP @ 6 ft c/c | 10 ft RPP @ 4 ft c/c | 8 ft RPP @ 6 ft c/c
- 8 ft RPP @ 6 ft c/c | 8 ft RPP @ 4 ft c/c | 

CONTROL SECTION-2 | REINFORCED SECTION-3
---|---
- 10 ft RPP @ 4 ft c/c | 10 ft RPP @ 3 ft c/c
Installation of RPP: Reinforced Section 1 and Reinforced Section 2

- Equipment: Klemm 802 Drill Rig
- Hammer Type: KD 1101
Installation of RPP: Reinforced Section 1 and Reinforced Section 2
Installation of RPP: Reinforced Section 3
Instrumentation

- Rain Gauge
- Instrumented RPP
- Surveying
- Inclinometer
- Moisture Sensor
- Water Potential Probe
Slope Crest Movement (5 Years)

Settlement at the crest of slope: US 287

Distance along Roadway (ft)

Settlement (in)

R - 01
R - 02
R - 03
Settlement at Control Section

R. Section 1

Control Section 2

Settlement: 9 in

Control Section

Settlement: 15 in

R. Section 3
Inclinometer
Inclinometer

Comparison of Horizontal Movement at US 287 Slope

- Rainfall
- 2.5 ft-Inc1
- 2.5 ft-Inc 3

Date

Rainfall (inch)

Displacement (inch)
Inclinometer

Inclinometer - 1: Cum Displacement A-A with Time

Rainfall

Movement during the failure of Northbound slope

Movement during the failure of Northbound slope
Comparison of Performance
Northbound and Southbound (Reinforced) Slope
Comparison of Performance
Northbound and Southbound (Reinforced) Slope

<table>
<thead>
<tr>
<th>Failure Location</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure Location-1</td>
<td>October 2013</td>
</tr>
<tr>
<td>Failure Location-2</td>
<td>October 2013</td>
</tr>
<tr>
<td>Failure Location-3</td>
<td>June 2015</td>
</tr>
<tr>
<td>Failure Location-4</td>
<td>June 2015</td>
</tr>
</tbody>
</table>

Failure Location 3
Failure Location 4

NORTH BOUND SLOPE
GUARD RAIL

REINFORCED SOUTH BOUND SLOPE

US 287 N
US 287 S

Reinforced Section-1
Control Section
Reinforced Section-2
Control Section-2
Reinforced Section-3
Traditional Repair
Northbound and Southbound (Reinforced) Slope

September 2015
Shotcrete Wall

North Side

October 2015
Failure of Northbound Control Slope After Repair

Control Slope Failed on 1st week of November, 2015

Graph showing precipitation (inch):
- 0/1/2015
- 11/1/2015

Graph inset indicating:
- Precipitation (inch)
- Failure of Northbound Control Slope After Repair
Comparison between RPP slope and Reconstructed Slope

Northbound slope

Southbound slope (RPP stabilized)
Previous RPP Layout and settlement at the crest

Old Control Section

Distance along Roadway (ft)

Settlement (in)

- 6.6.12
- 10.6.12
- 12.13.12
- 7.1.13
- 5.15.14
- 12.24.14
- 6.18.15
- 12.15.2015
- 6.15.2016
- 9.15.2016
- 10.15.2016
- 11.15.2016
- 12.15.2016
- 01.15.2017
- 2.15.2017
- 3.15.2017
- 4.15.2017

- 6.6.12
- 10.6.12
- 12.13.12
- 7.1.13
- 5.15.14
- 12.24.14
- 6.18.15
- 12.15.2015
- 6.15.2016
- 9.15.2016
- 10.15.2016
- 11.15.2016
- 12.15.2016
- 01.15.2017
- 2.15.2017
- 3.15.2017
- 4.15.2017
US 287 RPP installation
Installation of RPP
I 35 Slope
Inclinometer Locations

(1V : 3H)

Location of Drilled Shaft

I-2  I-1  I-3

Inclinometer
Drilled Shaft
<table>
<thead>
<tr>
<th>Year 01</th>
<th>Year 02</th>
<th>Year 03</th>
<th>Year 04</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.64</td>
<td>0.82</td>
<td>0.38</td>
<td>0.30</td>
</tr>
</tbody>
</table>
Location of SH 183 (1V :2.5H)
### SH 183

#### Incremental Settlements (inches)

<table>
<thead>
<tr>
<th>Reinforced Section</th>
<th>Year 01</th>
<th>Year 02</th>
<th>Year 03</th>
<th>Year 04</th>
</tr>
</thead>
<tbody>
<tr>
<td>0' - 15'</td>
<td>1.66</td>
<td>0.11</td>
<td>0.06</td>
<td>0.10</td>
</tr>
<tr>
<td>15' - 45'</td>
<td>1.16</td>
<td>0.09</td>
<td>0.05</td>
<td>0.41</td>
</tr>
<tr>
<td>45' - 60'</td>
<td>1.22</td>
<td>0.36</td>
<td>0.42</td>
<td>0.25</td>
</tr>
</tbody>
</table>
RPP Installation in 2019!
## Cost Comparison

<table>
<thead>
<tr>
<th>Location</th>
<th>Total Number of RPP</th>
<th>Area of Slope Stabilization (sft)</th>
<th>Total Cost (USD)</th>
<th>Cost per sft (USD/sft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforced Section 1</td>
<td>182</td>
<td>2000</td>
<td>12222</td>
<td>4.4</td>
</tr>
<tr>
<td>Reinforced Section 2</td>
<td>11</td>
<td>1200</td>
<td>1110</td>
<td>3.5</td>
</tr>
<tr>
<td>Reinforced Section 3</td>
<td>6</td>
<td>600</td>
<td>600</td>
<td>1.0</td>
</tr>
</tbody>
</table>

### Construction Unit Cost

- **Soil Nailed Walls**: 111 per sq-m, 92.5 per sq-ft
- **Walls**:
  1. Concrete Retaining
  2. Metal Bin
  3. Gabion
  4. MSE
  5. Sheetpile
  6. Ground Anchor
  7. Slurry Wall
  8. Secant and Tangent Pile
  9. Soil Mixed

### Construction System

- 0 to 1200
- 0 to 1200
- 0 to 1200
- 0 to 1200
Cost Comparison

- Time
- Cost of Equipment
- Labor
- Traffic Control
- Materials Cost

Several Weeks to Months 1 week

$900,000 $150,000
Recently Published Book

Sustainable Slope Stabilization using Recycled Plastic Pins

Sahadat Hossain
Sadik Khan
Golam Kibria

Landslides and slope failure are common in the US and rest of the world. A sustainable and cost-effective option to stabilize the slope using recycled plastic pins (RPP) is presented in this book. The recycled plastic pins are made from recycled plastic bottles and other plastic waste. Several demonstration projects already prove the effectiveness of RPP as an alternative solution to fix slope failure, with a maximum failure depth of 7-8 ft. In this book, every detail of the slope stabilization technique using recycled plastic pin, including the design techniques, construction methods, and several case studies, are included.

Key Features:
- Outlines the basics of slope failures and different slope stabilization techniques
- Features the physical and mechanical properties of recycled plastic pins
- Describes the mechanism of slope stabilization technique using recycled plastic pins
- Shows design techniques using design charts and hand calculation examples
- Includes several practical case studies of this technique used in the field

Selected Contents:
1. Introduction
2. Current slope stabilization methods
3. Generation and recycling of plastics/plastic bottles
4. Recycled plastic pins
5. Design methods
6. Field installation technique
7. Case studies and performance monitoring: RPP for slope stabilization
8. Summary and conclusion

Visit www.crcpress.com for more information.
Special Specification 4101
Install Recycled Plastic Pins (RPP)

1. DESCRIPTION

Construct reinforced slope with recycled plastic pins, also known as recycled plastic lumber.

2. MATERIALS

Provide recycled plastic pins manufactured from polyolefin with a minimum of 20% of fiberglass additives. Length of pins will vary from 8, 10, and 12 ft. long as indicated in the plans. Materials should satisfy the following strength properties, listed in Table 1. Besides, only rectangular cross section of the RPP is recommended in Slope Stabilization. Sectional Requirements are presented in Table 2.

<table>
<thead>
<tr>
<th>Properties</th>
<th>ASTM Test</th>
<th>Minimum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexural Strength</td>
<td>D6109</td>
<td>2,750 psi</td>
</tr>
<tr>
<td>Flexural Modulus (Secant @ 1% strain)</td>
<td>D6109</td>
<td>288,000 psi</td>
</tr>
<tr>
<td>Compressive Strength (parallel to grain)</td>
<td>D6108</td>
<td>2,800 psi</td>
</tr>
<tr>
<td>Compressive Modulus (Secant @ 1% strain)</td>
<td>D6108</td>
<td>54,000 psi</td>
</tr>
<tr>
<td>Shear Strength</td>
<td>D2344</td>
<td>800 psi</td>
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</table>
The Value of Research Task Force is pleased to announce this year’s selections for the “Sweet Sixteen.” States selected with a Sweet Sixteen award were invited to give a poster session presentation at the Sweet Sixteen session at the 2019 AASHTO RAC/TRB Representative Annual Meeting in Santa Fe, New Mexico.

<table>
<thead>
<tr>
<th>REGION 1</th>
<th>Connecticut DOT</th>
<th>Pedestrian Safety Guide</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Massachusetts DOT</td>
<td>Performance of Adhesive and Cementitious Anchoring Systems</td>
</tr>
<tr>
<td></td>
<td>New Jersey DOT</td>
<td>New Protocol for Accepting Over-Coating Paint on Steel</td>
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<tr>
<td></td>
<td>Vermont Agency of Transportation</td>
<td>VTrans Employee Retention and Knowledge Management Study</td>
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<th>Effectiveness of High-Early Strength Concrete as a Cost-Effective Alternative for Connection of Precast Elements in Accelerated Bridge Construction</th>
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<th>Impact of Missouri’s Public Ports</th>
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Summary and Conclusions

- **RPP provided resistance against shallow slope failure**
- A Crawler-Mounted Rig, Equipped with a Mast-Mounted Pseudo Vibratory Hammer, Worked Effectively to Install RPPs
- On Average, a RPP Can be Installed within 4 Minutes, and a Total of 100 to 120 RPPs can be Installed in a Single Day.
- Settlement at Control Section is 15 inch
- Settlement at Reinforced Section 1 is 2.5 inch.
- Closer RPP Spacing at Crest Provided Higher Resistance against Slope Deformation
- RPP can save the stabilization cost up to 60% - 80% of conventional technique, and have potential to be a **effective sustainable alternative** to stabilize shallow slope failure.
(1) One 10 ft. long single RPP can replace how many no. soda bottles?

(a) 10
(b) 100
(c) 150
(d) 500

(d) 500
(2) Cost of fixing highway slopes with RPP is______

(a) 10-12 USD/sq. ft.
(b) 90-100 USD/sq. ft.
(c) 5-6 USD/sq. ft.
(d) 50-60 USD/sq. ft.

(c) 5-6 USD/sq. ft.
(3) On average, one RPP can be installed in ______ minutes.

(a) 10 minutes
(b) 4 minutes
(c) 20 minutes
(d) 15 minutes

(b) 4 minutes
Thank You