Yeager Airport Runway Extension: Tallest Known Geosynthetic Reinforced 1H:1V Slope in N.A.

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Mirafi® Geosynthetics

TenCate™ materials that make a difference
Yeager Airport History

• Yeager Airport in Charleston, WV, formerly known as Kanawha Airport, was completed in 1947.

• The Airport was constructed atop 7 semi-connected hilltops known as “Coonskin Ridge”.

Yeager Airport History

Grading operations 1946
Yeager Airport History

• Earthwork consisted of 6.8 million cubic meters (9 million cubic yards) of soil and rock. More than 900,000 Kg (2 million pounds) of explosives.

• Second largest earth moving project in the world, behind only the Panama Canal.
Yeager Airport History

Airport at Grade, 1947
Yeager Airport Expansion

• Due to FAA Safety Requirements it was necessary to extend Runway 5 approximately 150 meters (500 feet).

• The challenge: how to extend the runway out over a 91 meter (300 feet) slope?
  – Bridge, Wall and Slope Structures were all considered.
Yeager Airport Expansion

Existing Runway 5

Existing Slope

Elev. 940'

Elev. 930'

Elev. 700'

Required Runway Extension
Yeager Airport Expansion

Runway 5
Slope Area
Subsurface Exploration

• Over 100 borings were performed.

• Extensive Laboratory Testing Including:
  – Proctors, gradations, Atterberg Limits, Triaxial Shear and Rock Core Compressive strengths.

• Site consisted of primarily of fill, colluvial and shallow rock.
Subsurface Exploration

• Slope bearing area consisted mainly of colluvial and sandstone rock.
  – RQD of Sandstone mostly above 70%.

• Borrow area consisted mainly of weathered sandstone, sandstone and some claystone.
  – Max. Dry Density of sandstone: 122 – 133 pcf.
  – Internal Friction Angle: 38.9 – 39.6 degrees.
Soil Properties for Design

<table>
<thead>
<tr>
<th>Soil Layer</th>
<th>Unit Weight, $\gamma$ kN/m³ (lb/ft³)</th>
<th>Internal Friction Angle, $\Phi$, degrees</th>
<th>Cohesion, $c$ kPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforced Soil Zone</td>
<td>18.1 (115)</td>
<td>36</td>
<td>0</td>
</tr>
<tr>
<td>Retained Soil Zone</td>
<td>18.1 (115)</td>
<td>36</td>
<td>0</td>
</tr>
<tr>
<td>Bearing Soil Zone</td>
<td>22.0 (140)</td>
<td>40</td>
<td>0</td>
</tr>
</tbody>
</table>
Reinforced Slope Design

<table>
<thead>
<tr>
<th>Reinforcement Type</th>
<th>Minimum LTDS (T_{al}), kN/m (lb/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-1</td>
<td>56.4 (3,861)</td>
</tr>
<tr>
<td>P-2</td>
<td>54.4 (3,725)</td>
</tr>
<tr>
<td>P-3</td>
<td>43.4 (2,971)</td>
</tr>
</tbody>
</table>

Where, \( LTDS (T_{al}) = \frac{T_{ult}}{(RF_{CR} \times RF_{D} \times RF_{ID})} \)

\( T_{ult} = \) Ultimate Tensile Strength of Reinforcement
\( RF_{CR} = \) Reduction Factor for Creep
\( RF_{D} = \) Reduction Factor for Durability
\( RF_{ID} = \) Reduction Factor for Installation Damage
## Reinforced Slope Design

<table>
<thead>
<tr>
<th>Reinforcement Type</th>
<th>Minimum Ultimate Tensile Strength Required ( (T_{ult}) ) ( \text{kN/m (lb/ft)} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PP</td>
</tr>
<tr>
<td>P-1</td>
<td>338.4 (23,166)</td>
</tr>
<tr>
<td>P-2</td>
<td>326.4 (22,350)</td>
</tr>
<tr>
<td>P-3</td>
<td>260.4 (17,826)</td>
</tr>
</tbody>
</table>

Typical Total Reduction Factors \( (RF_{CR} \times RF_{D} \times RF_{ID}) \) per FHWA:

- \( PP = 4.84 \) (21% of Ultimate)
- \( HDPE = 3.15 \) (32% of Ultimate)
- \( PET = 2.0 \) (50% of Ultimate)
### Reinforced Slope Design

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Specified Project Backfill, % Passing</th>
<th>Typical Backfill per FHWA, % Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>152 mm (6 in)</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>20 mm (3/4 in)</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>4.75 mm (No. 4)</td>
<td>30 to 100</td>
<td>20 to 100</td>
</tr>
<tr>
<td>0.85 mm (No. 20)</td>
<td>0 to 60</td>
<td>0 to 60</td>
</tr>
<tr>
<td>0.075 mm (No. 200)</td>
<td>0 to 50</td>
<td>0 to 50</td>
</tr>
</tbody>
</table>

Due to allowance of up to 152 mm (6 inch) diameter rock fill, project specific installation damage testing was performed on proposed Miragrid reinforcement material.
### Reinforced Slope Design

<table>
<thead>
<tr>
<th>Reinforcement Type</th>
<th>Geosynthetic Used</th>
<th>Ultimate Tensile Strength, ((T_{\text{ult}})) kN/m (lb/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-1</td>
<td>Mirafi Miragrid 20XT</td>
<td>187.9 (12,870)</td>
</tr>
<tr>
<td>P-2</td>
<td>Mirafi Miragrid 20XT</td>
<td>187.9 (12,870)</td>
</tr>
<tr>
<td>P-3</td>
<td>Mirafi Miragrid 10XT</td>
<td>145.2 (9,950)</td>
</tr>
</tbody>
</table>

Even though Miragrid XT Geogrids showed lower Reduction Factors for Installation Damage based on third party testing using the proposed coarse fill material, the higher reduction factors in the Specification were used for conservatism.
Slope Cross Section

- **Primary Geogrid Reinforcing**: See profile for type and spacing.
- **Proposed Final Grade** (Typ.):
- **Existing Ground** (Typ.):
- **Reinforced Zone**: See profile.

Station

840
840
820
820
800
800
780
780
760
760
740
740
720
720
700
700
680
680
0+00
1+00
2+00
3+00
4+00
5+00
5+30
Slope Cross Section

Primary Reinforcement - Mirafi Miragrid 20XT

Secondary Reinforcement – Mirafi MiraMesh GR

Min. 2.5' Overlap

Min. 3' embedment

1.5' Vertical Spacing at bottom
3' Vertical Spacing at top
Reinforced Slope

- Embedment Lengths of Primary Reinforcement ranged from 53 to 44 m (175 to 145 feet).
- Approximately 765,000 cubic meters (1 Million Cubic Yards) of Fill.
- 321,000 SM (384,000 SY) of Miragrid 20XT
- 214,000 SM (256,000 SY) of Miragrid 10XT
- 63,000 SM (75,000 SY) of MiraMesh GR
Reinforced Slope Construction
Yeager Airport Expansion
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Engineered Material Arrestor System

Does it work?
On January 19, 2010 a US Airways flight bound for Charlotte aborted takeoff……..

……the CRJ 200 aircraft could not stop before the end of the runway…………
Engineered Material Arrestor System
Engineered Material Arrestor System

The jet was stopped approximately 150 feet from the edge of the slope by the EMAS.....
Engineered Material Arrestor System
All 34 passengers and crew survived the incident with only minor injuries reported.
Yeager Airport Expansion

**Owner:**
Central West Virginia Regional Airport Authority

**Design Engineer:**
Triad Engineering, St. Albans, WV

**Contractor:**
Cast & Baker, Canonsburg, PA - Rich Castagna

**Material Supplier:**
JMD Company, Pittsburgh, PA – Denny Long
Questions?

Thank You!

Presented by:
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