Yeager Airport Runway Extension: Tallest Known 1H:1V Slope in U.S.

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ABSTRACT

Yeager Airport was constructed atop mountainous terrain near Charleston, WV in the 1940's. Construction consisted of excavating 7 hilltops and filling surrounding valleys to create a flat site for the runways. Due to this dramatic terrain, development to meet FAA safety regulations was extremely difficult, and some concessions were allowed. However, the airport recently needed to extend Runway 5 approximately 150 meters (500 feet) in order to meet current FAA safety regulations.

Bridges, walls and reinforced slopes were evaluated as options to extend the runway. The geosynthetic reinforced slope option provided the most economical alternative; plus, the "green" faced system allowed for a more aesthetically pleasing alternative to blend into the surrounding green hills. The reinforced structure is a 1H:1V (45 degree) geosynthetic reinforced steepened slope, 74 meters (242 feet) high. This is the tallest geosynthetic reinforced green faced 1H:1V slope constructed in the United States.

INTRODUCTION

Yeager Airport, formerly known as Kanawha Airport, in Charleston, West Virginia was constructed atop mountainous terrain near the city limits. Completion of the airport in 1947 was the culmination of an almost 20 year evolution in air service in the state of West Virginia.

Air service for the Charleston area began in 1930 with the dedication of Wertz Field in Institute, WV, approximately 6 miles outside the city limits. In 1933, the state of West Virginia was one of only two states that did not have air mail service, until American Airlines opened passenger and mail service routes from Washington to Chicago via Charleston. As larger passenger planes began to be used, Wertz Field became more and more limited for use. The small airfield was not suitable for landing larger planes. In the late 1930's, American Airlines notified the City of Charleston that it would discontinue service to Wertz Field because of these limitations.

Charleston realized that a site for a new airport needed to be found in order to keep up with the needs of the aviation industry and to keep air service viable for the Charleston area. A committee evaluated potential sites in the greater Charleston area and determined that the valley floor offered no suitable site large enough. The committee decided "we must build on the hilltops." A series of semi-connected hill tops know as "Coonskin Ridge" was suggested by the committee as the best site option for an airport, however, significant earthwork would be required to level the site. In 1940, development plans began for the site with many obstacles to overcome. In the meantime, Charleston lost air service as Wertz Field closed in 1942 when the approaches were blocked by the construction of a synthetic rubber plant.

The need for the new site development intensified and construction finally began in October 1944. Construction consisted of excavating 7 hilltops and filing the surrounding valleys to create a flat site large enough for the airport. Earthwork proceeded continuously for 3 years and was finally completed in mid-1947. At the time, this was reported as the second largest earth moving project in history, behind only the Panama Canal. Since the airport was constructed on hilltop ridges, the ground surface slopes steeply down around the airport more than 91 meters (300 feet) to the surrounding Elk and Kanawha rivers. Due to this dramatic terrain, development to met FAA safety regulations was exceptionally difficult and some concessions were made. The airport was completed in 1947 and began operations December 1st as Kanawha Airport. The airport changed names to Yeager Airport in honor of West Virginian Chuck Yeager in 1985. Construction consisted of moving more than 6,881,000 cubic meters (9,000,000 cubic yards) of earth and rock and required more than 907,000 kilograms (2,000,000 pounds) of explosives. Grading along for the project cost approximately $4.5 million, more than 34 times the cost of the site.

In order to comply with current FAA regulations, Yeager Airport was required to upgrade its facilities. Runway 5 required a 150 m (500 ft) extension to meet the FAA requirements. The previous runway did not include the proper airplane safety and emergency stopping area. The challenge was how to extend the runway 150 meters (500 feet) out over a 91 meter (300 foot) high steep slope.

ANALYSIS AND DESIGN

Subsurface Exploration

A geotechnical evaluation of the site was performed to assess the subsurface conditions of the area. Over 100 borings were performed around the airport to evaluate the soil conditions at the slope as well as to identify excavation areas and other site development for the airport. The site soils consisted mostly of weather sandstone underlain by sandstone and some shale.

The borings showed the bearing area consisted mostly of shallow rock consisting of sandstone. The surrounding area and potential borrow sources indicated mostly weather sandstone and rock with some clay seams. Laboratory testing was performed on the site soils and rock for design parameters. Testing included Standard Proctor Compaction tests, grain size analysis, Atterberg Limits, Triaxial Shear Tests and Rock Core Compressive Strength. The results of the soil test borings and laboratory testing showed very favorable subsurface conditions.

The laboratory test results indicated that the maximum dry densities of the weathered sandstone and sand material at the site ranged from 19.2 to 20.9 kN/m^3 (122.1 to 133.1 pounds per cubic foot (pcf)) with an optimum moisture of 8.3 to 11.8 percent. The clay seams with rock fragments had maximum dry densities of 17.9 to 18.8 kN/m^3 (114.3 to 119.5 pcf) with optimum moisture contents of 12.1 to 12.6 percent. The triaxial shear tests indicated internal friction angles of the weather sandstone ranging from 38.9 to 39.6 degrees. Compressive strength testing of the rock cores indicated compressive strength of 30,405 to 97,630 kPa (4,410 to 14,160 psi).

Design Considerations

Based on the subsurface conditions at the site, the design team looked at options to extend Runway 5 the required 150 meters (500 feet). One of the key constraints was that the runway had to remain open during construction. The ground surface of the existing runway was at elevation 288 meters (946 feet). This limited the construction methods, as cranes or large equipment could not exceed elevation 283 meters (930 feet) as to not infringe on the airport's airspace. Bridge type structures, retaining walls and reinforced steepened slopes were all initially considered. A bridge structure was quickly eliminated as being too expensive, too difficult to build and not aesthetically pleasing. A retaining wall was also eliminated as an option due to expense and aesthetics. Additionally, a bridge or wall structure would have required construction cranes and other equipment that may have exceeded the height restriction for construction. Construction of the reinforced slope could be completed with traditional earthwork equipment and the height restrictions would not be an issue. A reinforced steepened slope was determined to be the best option for the project. It offered an economical solution that would be relatively easy to construct and would blend in to the surrounding green hills of West Virginia.

Several reinforced slope options were evaluated, with varying slope face angles. Ultimately it was determined that a 1H:1V green faced (vegetated) slope was the most economical slope option for the project and site conditions. The high bearing capacity of the sandstone and the high friction angle of the on site soils meant the limits of the structure could be kept to a minimum. A reinforced structure this large might require some type of bearing improvement or staging of construction to allow for settlement if not founded on rock. Since the slope would be founded primarily on rock, consolidation of the bearing strata was not a concern. Also, the high friction angle of the on site soils provided two significant benefits: 1) It eliminated the need to import borrow soil from off site, and 2) It kept the required embedment lengths of the reinforcement material to a minimum.

The design used traditional slope stability analyses and computer program modeling to select the minimum strength requirements, vertical spacing and embedment lengths of the geosynthetic reinforcement. The soil properties used as part of the design are shown below in Table 1.

Table 1. Basic Soil Properties used for Design.

Soil Layer	Unit Weight, γ kN/m^3 (lb/ft^3)	Internal Friction Angle, Φ (degrees)	Cohesion, c (lb/ft^2)
Reinforced Soil Zone	18.1 (115)	36	0
Retained Soil Zone	18.1 (115)	36	0
Bearing Soil Zone	22.0 (140)	40	0

The design of the slope resulted in three types of primary reinforcement strengths being selected. The designed embedment lengths for the tallest slope section ranged from 53 meters (175 feet) at the bottom to 44 meters (145 feet) at the top. Vertical spacing of the primary reinforcement was 0.45 meters (1.5 feet) at the bottom of the slope and 1 meter (3 feet) at the top. The minimum Long Term Design Strength (T_{al}), per Equation 1, for the primary reinforcement are shown in Table 2.

Table 2. Primary Reinforcement Strength Requirements.

Reinforcement Type	Minimum Long Term Design Strength (T_{al}), kN/m (lb/ft)
P-1	56.4 (3,861)
P-2	54.4 (3,725)
P-3	43.4 (2,971)

Where $T_{al} = T_{ult} \div (RF_{CR} * RF_D * RF_{ID})$ [1]

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

The high quality structural fill available at the project site proved to be very beneficial in the design aspect of the project. However, it also resulted in the use of a very coarse backfill in the reinforced fill zone. Since the gradation of the fill was slightly outside the typical gradations used, site specific installation damage testing was performed to verify the reduction factors used to calculate the Long term Design Strength of the reinforcement. The Mirafi Miragrid XT

Geogrids proposed for the project were tested by a third party testing laboratory to measure the reduction factors for installation damage using the proposed backfill soil for the project. The geogrids proposed were woven polyester uniaxial geogrids coated with PVC. The test results showed the geogrid was highly resistant to installation damage using the proposed rocky backfill soil. Even though the results indicated lower reduction factors could be used, the initial specified reduction factors were used. Since a lower reduction factor would result in a lower calculated minimum ultimate tensile strength of the reinforcement, the higher reduction factors for installation damage were used for consistency and added conservatism. The specified soil gradation is shown in Table 3.

Table 3. Specified Soil Gradation for Reinforced Backfill.

Sieve Size	Specified Project Backfill, Percent Passing (%)	Typical Backfill Gradation per FHWA, Percent Passing (%)
152 mm (6 in)	100	
20 mm (3/4 in)		100
4.75 mm (No. 4)	30 to 100	20 to 100
0.85 mm (No. 20)	0 to 60	0 to 60
0.075 mm (No. 200)	0 to 50	0 to 50

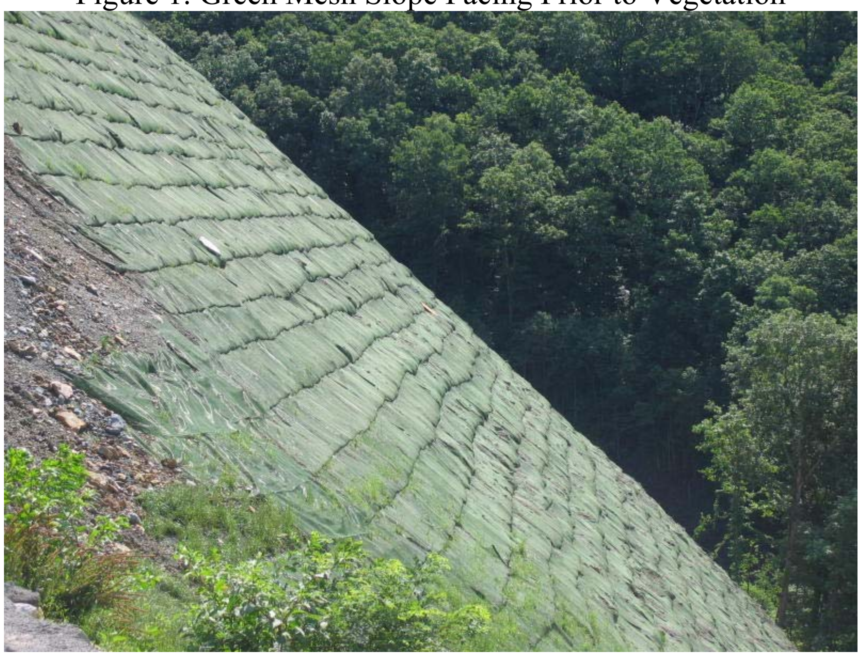
Based on the results of the laboratory testing and following the project specifications, the minimum ultimate tensile strength required for the geosynthetic reinforcement was determined for each type. Reduction factors for creep of the Miragrid XT geogrids were determined by third party laboratory testing per ASTM D5262. Using the appropriate reduction factors for the PVC coated polyester geogrids, the minimum ultimate tensile strength was calculated based on the design. The minimum tensile strength is shown in Table 4. As you can see, the required tensile strength for Reinforcement Type P-1 and P-2 are relatively close, so the same reinforcement was used for both Types. This allowed for less handling, easier placement of the reinforcement, and less waste during construction, because only two types of geogrid were used.

Table 4. Primary Reinforcement Ultimate Strength Requirements for Polyester Geogrid.

Reinforcement Type	Minimum Ultimate Tensile Strength Required (T_{ult}), kN/m (lb/ft)	Actual Ultimate Tensile Strength of Geogrid Used, kN/m (lb/ft)
P-1	160.1 (10,968)	187.9 (12,870)
P-2	154.5 (10,581)	187.9 (12,870)
P-3	123.2 (8,439)	145.2 (9,950)

The facing material for the slope is a small aperture mesh type geogrid. Erosion Control Blankets or other type of bio-degradable erosion control products were not used. Typically, 1H:1V slopes are the transition point between using an erosion control blanket on the face or having to use a wrapped face construction with reinforcing elements. Initially it was considered by the design team to use chain link fencing, draped along the face as the face treatment. However, it was realized that for the long term performance of the structure and for aesthetics, the face needed to be vegetated. Erosion control protection that also promoted fast vegetative growth was the right solution. The design team ended up selecting to embed the facing material into the slope at the primary reinforcement locations and then drape the material over the face with 0.75 meter (2.5 foot) overlaps vertically. The product was a green woven polypropylene mesh that provided erosion protection and allowed for fast germination of the vegetation on the slope face.

Figure 1. Green Mesh Slope Facing Prior to Vegetation



CONSTRUCTION

Perhaps the most notable thing about the construction of the tallest known 1H:1V slope in the United Sates was that there were no notable issues. Construction proceeded without significant problems or delays. The slope and reinforcement material performed as expected and survived several torrential rain falls during construction. The selection of a reinforced slope allowed the airport to continue operation during construction activities.

Construction of the slope was competed in just under 2 years, starting in the late summer of 2005 and finishing in spring 2007. The flexible polyester geogrid allowed for easy installation; time was not wasted having to anchor or weigh down the material to prevent recoiling. The geogrid was installed as continuous reinforcement from the face of the slope to the required embedment length. No overlapping or splicing of the geogrid in the primary reinforcement direction was permitted. Adjacent panels of reinforced were abutted together to achieve 100% coverage of the reinforcement. The geogrid used for the project was supplied in 3.6 meter (12 foot) wide rolls that allowed for the use of fewer rolls than if a narrower width geogrid was used. Custom geogrid lengths were supplied to the contractor. This allowed for less waste and reduced the amount of cutting of the geogrid to the required lengths. This sped up construction significantly. The flexible geogrids went down smoothly with very little wrinkling and did not require pre-tensioning during installation.

Figure 2. Placement of Geogrid Reinforcement in continuous layers at Bottom Layers of Slope.

The borrow source for the reinforced fill material was on the airport property, close to the reinforced slope area. The borrow material was excavated using track hoes and transported using large off road tri-axial dump trucks when possible. Some ripping with large bulldozers and some blasting was also required at the size. After blasting, the material was crushed in order to meet the gradation requirements in the specifications. Fill placement started at the face of the slope and worked back to the end of the reinforcement. Some of the approximate material quantities used to construct the slope are shown in Table 5.

Table 5. Approximate Material Quantities for the Project.

Material	Quantity, Square Meters (Sq. Yards)
Primary Geogrid, P-1 & P-2	321,073 (384,000)
Primary Geogrid, P-3	214,049 (256,000)
Secondary Green Mesh Facing	62,710 (75,000)

Figure 3. Reinforced Slope Construction

CONCLUSION

The reinforced slope constructed at Yeager Airport in Charleston, WV is the tallest 1H:1V geosynthetic reinforced vegetated slope known in the United States. It was completed in the Spring of 2007 and has been performing as expected. The green mesh facing provided an instantly aesthetically pleasing structure that allowed for quick germination of the slope. Vegetation covered the face within a few months of construction. The reinforced slope option provided fast construction, limited to no interference with airport operations, the most aesthetically pleasing structure and was the most economical. The green structure quickly blended in to the picturesque green mountains surrounding the airport.

Figure 4. Shortly after completion, already with good vegetation coverage, picture taken at mid-height of slope.

ACKNOWLEDGEMENTS

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REFERENCES

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