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Geosynthetics

Landscaped English beauty built with geosynthetics

Reinforcing the world's largest human form at Northumberland

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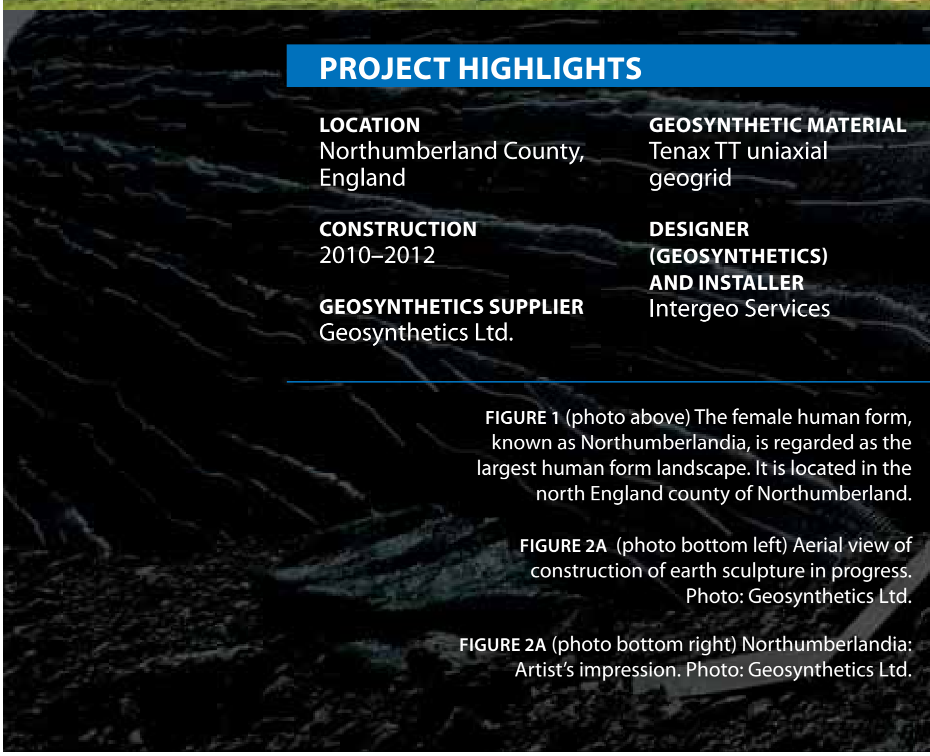

PROJECT HIGHLIGHTS

LOCATION
Northumberland County, England

CONSTRUCTION
2010–2012

GEOSYNTHETICS SUPPLIER
Geosynthetics Ltd.

GEOSYNTHETIC MATERIAL
Tenax TT uniaxial geogrid

DESIGNER (GEOSYNTHETICS) AND INSTALLER
Intergeo Services

FIGURE 1 (photo above) The female human form, known as Northumberlandia, is regarded as the largest human form landscape. It is located in the north England county of Northumberland.

FIGURE 2A (photo bottom left) Aerial view of construction of earth sculpture in progress. Photo: Geosynthetics Ltd.

FIGURE 2A (photo bottom right) Northumberlandia: Artist's impression. Photo: Geosynthetics Ltd.

The largest human form sculpted into the landscape

Geosynthetic solutions for Northumberlandia

By Patricia Guerra Escobar

1. Introduction

1.1 Project concept

Northumberlandia is the world's largest human form sculpted into the landscape, designed by renowned landscape architect and artist, Charles Jencks.

The woman earth sculpture is lying at the entrance of a surface coal mine in southeast Northumberland, near Cramlington, in the north of England. Northumberlandia is 400m (525yd) long and 34m (112ft) in height at her highest point. It takes about 20 minutes to walk the 1,162m-long path around the landform.

The earth sculpture is the centerpiece for a 19-hectare (47-acre) public park in this north part of England. The artist was appointed to create a sculpture using the machinery and skills of the mining industry, and with residual materials from operations in the mine.

This project started in 2010 and most of the sculpture work was completed in 2011. The park opened to the public in autumn 2012.

1.2 Description

For the construction of the earth sculpture, about 1.5 million tonnes (1.7 U.S. tons) of soils (mudstone, sandstone, shale, and clay) were transported and used from the adjacent Shotton surface mine **(Figures 1, 2).**

To construct the most challenging parts of the sculpture such as the chin, nose, nostrils, and eyebrows, reinforced soil slopes with geogrids and gabions were used because of their flexibility and efficiency. Compacted weathered mudstone with no

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cohesive material was used as reinforced fill and compacted mudstone was used as foundation material. The finished slopes were protected with permanent erosion control blankets to ensure a vegetated face.

2. Reinforced soil wall/slope (RSW/RSS)

2.1 Definition

A retaining wall is a structure designed to resist the lateral pressure of soil that it is holding back and a defined external load above the wall.

It is possible to construct a retaining wall with soil using layered geogrids as reinforcement. When soil and reinforcement are combined a "reinforced soil" with high compressive and tensile strength is produced. The geogrids can provide steeper slopes than otherwise would be possible and improve the stability of the structure. The angle of the slope will have some influence on the method of analysis to be employed; it will also determine the type of facing and the method of construction to be used.

The RSW or RSS are very flexible compared with conventional gravity structures, adaptable to a wide range of conditions, and the most cost-effective solution compared to other types of retaining walls.

2.2 Design method

Soils normally have a high resistance to compressive forces but they are not so good under the application of tensile forces.

Soils can be reinforced with geogrids, which are specially designed to absorb tensile forces. The combination soil-geogrid can resist both compressive and tensile stresses to obtain a structure with much greater resistance. The extra strength provided is principally due to shear stresses produced by the friction and interlocking between the geosynthetic material and the adjacent layers of soil.

Various design methodologies exist for the reinforcement of soil walls using geosynthetics. In this case, a methodology was used as proposed by Robert M. Koerner (*Designing With Geosynthetics*, 4th Ed.) and by Robert D. Holtz, Barry R. Christopher, and Ryan R. Berg (*Geosynthetic Engineering*).

Fundamental to this methodology are the design principles of Whitcomb and Bell (1979), which state that you don't consider hydrostatic pressure in the design calculations and the active failure surface should be a plane surface defined by the ranking methodology.

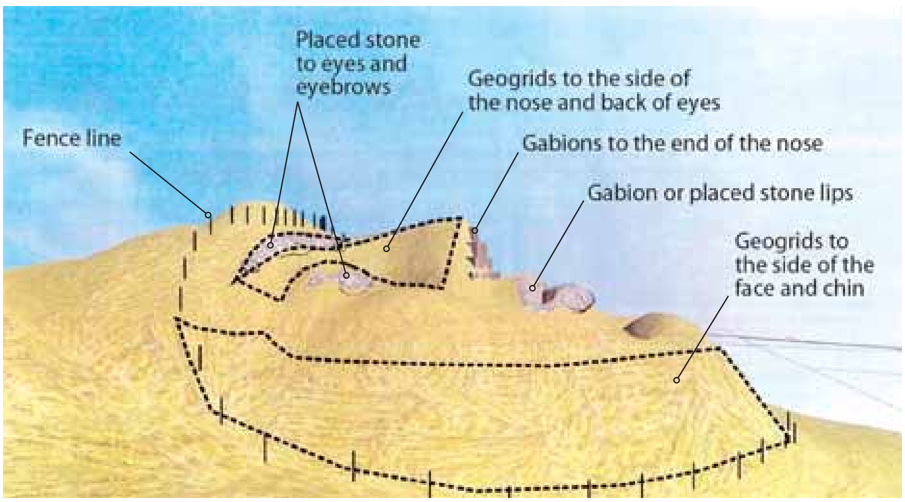

FIGURE 3 Face details with reinforced soil slopes and gabion walls. Photo: Geosynthetics Ltd.

2.3 Design method steps

The design methodology for soil walls, or slopes reinforced with geosynthetics, consists of three steps:

- **Step 1: Internal stability.** Determine the vertical space between layers, the length of the geogrids, and the design strength of the geogrid for each layer.
- **Step 2: External stability.** Analyze the overall structure using the Limit Equilibrium approach to verify the safety factors of base sliding, overturning, and bearing capacity.

- **Step 3: External conditions.** Determine the type of wall face and the drainage and subdrainage systems for the wall.

2.4 Standards

The internal stability of the reinforced soil slopes for Northumberlandia was designed according to the British Standard BS 8006:1995 "Code of practice for strengthened/reinforced soils and other fills."

The two limit states considered in the design are the ultimate limit state and the serviceability limit state. Ultimate limit states are associated with collapse or failure of the structure.

Margins of safety are used with the inclusion of partial material factors and partial load factors. Disturbing forces are increased by load factors to produce design loads. Restoring forces are decreased by material factors to obtain design strengths.

Serviceability limit states are achieved if the deformations during the design life exceed prescribed limits. The load factors are different from those used in the ultimate limit state.

Global stability of the reinforced soil slopes was analyzed in accordance with BS EN 1997-1:2004–"Eurocode 7:Geotechnical design."

3. Gabion wall

3.1 Definition

A gabion wall is also a gravity wall, so consideration of the interaction between the ground and the structure is required.

It's necessary to determine the overall proportions and the geometry of the structure necessary to achieve equilibrium under the relevant earth pressures and forces. The permeability and flexibility of gabions make them suitable where the retained material is likely to be saturated and where the bearing quality of the soil is poor.

3.2 Design method

For the equilibrium of the wall, the retained soil will apply active pressure over the entire wall height, with no hydrostatic pressure.

The cross section of the wall should be proportioned so the resultant force at any horizontal section lies within the middle third of that section. The thrust applied by the backfill acts as an angle to the perpendicular of the wall.

The design method for gabion walls consists of four steps:

- **Step 1:** Determine the forces acting on the wall.
- **Step 2:** Check overturning stability: the resisting moment exceeds the overturning moment by a defined safety factor.
- **Step 3:** Check sliding stability: the sliding resistance exceeds the active horizontal force by a defined safety factor.
- **Step 4:** Check that the resultant force is within the middle third of the wall base and check the bearing pressure stability.

The wall stability is checked at the base and at each course.

3.3 Standards

The gabion walls for Northumberlandia were designed according to the British Standard BS 8002:1994 "Code of practice for earth retaining structures." Overturning, sliding, bearing, and global stability were analyzed in accordance with BS EN 1997-1:2004–"Eurocode 7: Geotechnical design."

4. Retaining structures for Northumberlandia

4.1 Objective

To construct the head and face of the earth sculpture required a solution to achieve steep slope angles and different shapes for the chin, nose, nostrils, and eyebrows **(Figure 3).**

Reinforced soil slopes and gabions were the most suitable solutions for these

A gabion wall is also a gravity wall, so consideration of the interaction between the ground and the structure is required.

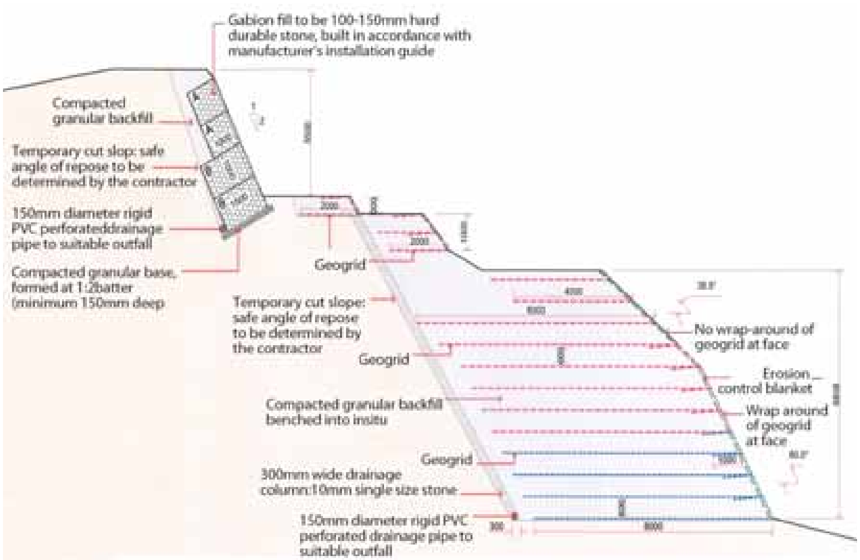

FIGURE 4 Result reinforced soil slope section E-E. Photo: Geosynthetics Ltd.

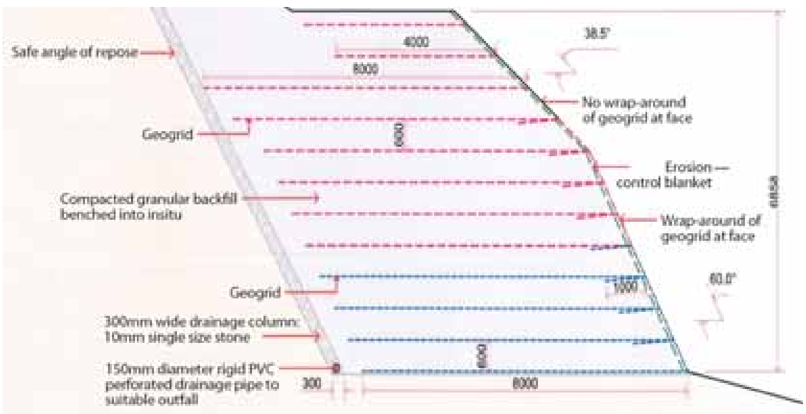

FIGURE 5 Result reinforced soil slope and gabion wall for Section E-E. Photo: Geosynthetics Ltd.

>> For more, search **geogrids** at www.geosyntheticsmagazine.com

sections because of their flexibility and efficiency. With a reinforced soil slope, it was possible to design the structure according to the properties of the soils found in the coal mine and, at the same time, to have the same vegetated face as the rest of the sculpture.

Compacted weathered mudstone with no cohesive material was used as reinforced soil and compacted mudstone was used as foundation material. The finished slopes were protected with permanent erosion control blankets to ensure a vegetated face.

4.2 Reinforced soil slope and gabions: Design considerations

The design was based on Section E-E **(Figure 4)**, with a maximum reinforced slope height of 6.9m and a maximum gabion wall height of 3.5m.

4.2.1 Soil properties and surcharges

Reinforced soil:

- Soil type: compacted weathered mudstone
- Friction angle: 0 = 27°
- Cohesion: c = 0
- Unit weight: 0 = 19 kN/m^3

Foundation soil:

- Soil type: compacted mudstone
- Friction angle: 0 = 35°
- Cohesion: c = 0
- Unit weight: 0 = 20 kN/m^3

Gabion fill:

- Soil type: selected granular fill, hard durable stone (Class 6G)
- Grading between: 100mm–150mm
- Los Angeles coeff: LA>50
- Porosity: 40%
- Unit weight: 0 = 24.2 kN/m^3

Surcharge load:

- Maximum live load = 5 kN/m^2

Groundwater:

- Assumed all the structure is maintained in a fully drained condition

4.3 Geogrids for reinforcement

The geogrids used for the design and construction of the reinforced soil slope have the following properties:

Geogrid type 1 RW:

- Ultimate tensile strength = 60 kN/m
- Long-term design strength = 28.3 kN/m
- Junction strength = 50 kN/m

Geogrid Type 2 RW:

- Ultimate tensile strength = 45 kN/m
- Long-term design strength = 21.2 kN/m
- Junction strength = 36 kN/m

4.4 Reinforced soil slope and gabion results

The results for the retaining structures analyzed for section E-E are as follows:

4.4.1 Reinforced Soil Slope

- Maximum height = 6.90m
- Base = 8.00m (min. length for the geogrids)
- Slope angle: max. 60°, 38.5° for top slope

Reinforcement:

- 4 layers each 600mm with geogrid Type 1 RW
- 8 layers each 600mm with geogrid Type 2 RW
- **Face:** wraparound geogrid and permanent erosion control blanket (turf reinforcement mat) for each layer.

Figure 4 shows the result of the reinforced soil slope for Section E-E.

FIGURE 6 Installation geogrid and erosion control blanket at the face of the reinforced soil slope (RSS). Photo: Geosynthetics Ltd.

FIGURE 7 Construction of the gabion wall on top of the RSS. Photo: Geosynthetics Ltd.

FIGURE 8 Close-up of the Northumberlandia face at near-completion.

4.4.2 Gabion wall

- Maximum height = 3.50m
- Base = 1.50m
- Slope angle: 63.43° (lR: 2V)

Figure 5 shows the result of the reinforced soil slope and the gabion wall on top for Section E-E.

4.5 External considerations

For the construction of retaining structures, it is important to check the actual properties of the soils used on-site and to compare the values with assumed values for the design.

The preparation of the foundation soil and the base of the structures are very important for the stability and behavior of the retaining systems. It is also essential to have a correct compaction of the reinforced fill and backfill and adequate drainage systems.

For the drainage, 150mm-diameter perforated PCV drainage pipe was installed at the rear of the reinforced soil slope at the base of a 300mm wide drainage column, with a fall to a suitable outlet. This drain is connected to a suitable outfall before the reinforced soil reaches a height greater than 2.0m, and is maintained thereafter.

At the rear of the gabion wall, 150mm-diameter perforated PVC drainage pipe with a fall to a suitable outlet was installed.

5. Conclusions

Northumberlandia is designed to be an iconic landscape sculpture for the north of England.

The design offered a number of engineering challenges, including the construction of steep soil slopes, to represent features such as the chin, nose, and eyebrows of the sculpture. These soil slopes needed to be highly stable, vegetated, resistant to erosion, and long-lasting.

Reinforced soil slopes with geogrids and gabions walls provided an adaptable and cost-effective solution to the challenges faced. **Figures 6-9** show the construction process of the face of Northumberlandia.

Northumberlandia is another example of the technical and economic advantages of solutions using reinforced soil walls and slopes with geosynthetics. These solutions are attractive because their flexibility allows the design to be adapted to suit the specific conditions of the project: soil properties, loading conditions, geometry, landscape features, and environment.

The reinforced soil slopes designed and constructed at Northumberlandia include the use of uniaxial geogrids and gabions on top of the slopes. The finished slopes are protected with a permanent erosion control blanket to ensure sustained vegetation.

Northumberlandia and the surrounding park is a wonderful place to enjoy.

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