CQA Validation Report Reference: CE1005/01
October 2014

# CONSTRUCTION QUALITY ASSURANCE VALIDATION REPORT

## CONSTRUCTION OF CELL 3 UPPER WESTERN SIDEWALL LINER

## HAFOD LANDFILL SITE

Prepared for
CORY ENVIRONMENTAL (CENTRAL) LIMITED

Stratus Environmental Limited
Red Hill House
Hope Street
Chester
CH4 8BU

Project Quality Assurance
Information Sheet

**CQA Validation Report for the Cell 3 Upper Western Sidewall Liner Construction Works**

**Report Number** : CE1005/01 REV 0 **Report Status** : Draft

**Report Date** : October 2014

**Prepared for** : Cory Environmental (Central) Limited
Hafod Landfill
Bangor Road
Johnstown
Wrexham
LL14 6ET

**Issued by** : Stratus Environmental Limited
Red Hill House
Hope Street
Chester
CH4 8BU

**Prepared by** :

Richard Clarke
Principal Engineer

**Approved by** :

Andrew Coxon
Engineering Director

CONTENTS

# 1 INTRODUCTION

1.1.1 Stratus Environmental Limited (Stratus) were requested by Cory Environmental (Central) Limited (Cory) to carry out Construction Quality Assurance (CQA) supervision and testing during the construction of Cell 3 Upper Western Sidewall (an area of approximately 4,000m$^2$) at Hafod Quarry Landfill Site.

1.1.2 The construction works were carried out in accordance with the CQA Plan Version 1.0 dated September 2013, subsequently superceded by Version 2.0 dated August 2014.

1.1.3 The works were undertaken using plant and labour resources provided by Cory, who undertook the construction work in two phases (October 2013, and August-September 2014).

1.1.4 The construction works incorporated the following elements:

(i) clearance of vegetation and unsuitable materials from the existing sidewall;
(ii) installation of groundwater collection system, comprising counterfort drains, toe drain and drainage geocomposite;
(iii) placement of suitable engineering fill to design formation profile;
(iv) installation of 1000mm minimum thickness engineered clay liner as an artificially established geological barrier (AEGB); and
(v) installation of 1000mm minimum thickness engineered clay liner as an artificial sealing layer (ASL).

1.1.5 The Stratus CQA Engineer was Kelechi Osuchukwu, who provided supervision and quality assurance for the works.

1.1.6 Survey control and recording was provided throughout the project by StafSurv, an independent survey company appointed by Cory.

1.1.7 This CQA Validation Report represents a record of the site works undertaken at Hafod Quarry Landfill Site, and includes a record of all the in-situ and laboratory testing undertaken.

1.1.8 The extent of construction covered by this document is shown on the as-built drawings presented in Appendix 1.

# 2 THE SITE

2.1.1 Hafod Quarry Landfill Site is situated approximately 4km southwest of Wrexham, at National Grid Reference SJ311458.

# 3 PREPARATORY WORKS

## 3.1 Formation Works

3.1.1 The existing quarry face was cleared of vegetation and loose/unsuitable material prior to installation of the groundwater collection system.

## 3.2 Installation of Counterfort Drainage System

3.2.1 An extensive network of counterfort drains was installed on the cleared formation surface, intercepting all visible wet areas within the Glacial Till whilst also maintaining a minimum spacing of 6m between drains, in accordance with the SRAR.

3.2.2 The counterfort drains comprised 1000mm (deep) x 600mm (wide) trenches excavated in the slope surface and lined with a filtration geotextile (Terrex NW9, supplied by ABG) and filled with coarse drainage gravel (recycled rail ballast).

3.2.3 The counterfort drains discharged to a collection drain excavated in the Ruabon Marl at the base of the Glacial Till, comprising a 150mm twinwall pipe installed in a 450mm wide x 750mm deep trench. The pipework was connected using push-fit collars. The collection drain flows northwards at a nominal gradient of 1:100, and discharges to an open ditch at the northern extremity of the current works.

3.2.4 Three rolls of NW9 were delivered and used within the works, each roll having dimensions of 4.5 x 100m (total gross area delivered was 1,350m$^2$). The CQA Engineer took a sample of this material and submitted it to the laboratory for testing in accordance with the requirements of Table 2 of the Specification.

3.2.5 The geotextile test certificates are presented in Appendix 5 and summarised in Appendix 4. For the primary parameters of puncture resistance, pore size and perpendicular permeability, the material was found to be in accordance with the specified requirements; the reported values for tensile strength and elongation are discussed within Section 6 below.

3.2.6 323 tonnes of drainage gravel were delivered to the works, equating to 202m$^3$ at an assumed density of 1.6tonnes/m$^3$. The CQA took a sample of the gravel and submitted it for testing in accordance with the requirements of Table 3.

3.2.7 The gravel test certificates are presented in Appendix 5, and summarised in Appendix 4. The ten percent fines strength and horizontal permeability are in accordance with the specified requirements; the reported value for the particle side distribution, which is marginally outside the specified range, is discussed in Section 6 below.

### 3.3 Drainage Geocomposite

3.3.1 The groundwater collection geocomposite comprised Protexia FC6-2, a cuspated drainage geocomposite manufactured by Geofabrics Limited. A total of fourteen rolls of FC6-2 were delivered to site, with eight being used within the current works (the remaining six rolls have been placed into storage). Each roll had dimensions of 4.8m x 100m, giving a gross installed area (including anchor trenches and overlaps) of 3,840m$^2$.

3.3.2 The geocomposite was delivered to site before Stratus had mobilised to site, and were offloaded and placed into storage on a prepared area at the side of the tarmac access road by Cory personnel. The CQA Engineer subsequently supervised handling and deployment of the geocomposite. The CQA Engineer inspected the rolls of geocomposite and confirmed that no damage had occurred to them during transportation to site and unloading/storage.

3.3.3 The CQA Engineer obtained the manufacturer's quality control and product data sheets that accompanied the batch of rolls delivered to site, and assessed these as acceptable against the requirements of Table 1 of the Specification. The MQC data sheets and delivery note are presented in Appendix 3.

3.3.4 The sub-grade on which the geocomposite was deployed was prepared using a hydraulic excavator fitted with a ditching bucket. The CQA Engineer inspected successive areas of the subgrade, to ensure that no potentially deleterious materials would be in contact with the geocomposite, and that no damp areas remained at the formation surface. Throughout the geocomposite installation, the surface was deemed to be satisfactory.

3.3.5 The geocomposite was deployed using the hydraulic excavator. The CQA Engineer oversaw placement of the drainage geocomposite and ensured that seam overlaps of 300mm were maintained. Panels were installed with no significant wrinkles.

3.3.6 Two samples of the geocomposite were taken from randomly-selected rolls during deployment and despatched for testing at BICS Laboratory in Huddersfield. Testing was undertaken to confirm:

(i) tensile strength;
(ii) CBR puncture resistance;
(iii) in-plane water flow;
(iv) thickness;
(v) geotextile permeability; and
(vi) geotextile pore size.

3.3.7 The laboratory testing was undertaken under UKAS accreditation for all the tests carried out. The laboratory results are presented in Appendix 5, and confirm that both samples of geocomposite were in accordance with the specified values; the results are summarised in Appendix 4.

# 4 ENGINEERED FILL

## 4.1 General

4.1.1 Selected engineered fill was placed in layers above the installed geocomposite in accordance with the requirements of the Specification for Highway Works Tables 6/1 – 6/4, using a Bomag BW213DH self-propelled padfoot roller. The fill material was categorised as being in accordance with Class 2A (wet cohesive) of Table 6/1, and was subject to 9 passes of the roller working in 250mm layers (compacted thickness). The thickness of fill material placed varied across the works, with a maximum of ~1.5m and a minimum of ~0.4m.

4.1.2 Survey control was employed to ensure a resultant profile of 1:3 was achieved, in accordance with the design and SRAR.

# 5 ENGINEERED CLAY LINER (ECL)

## 5.1 Acceptance Criteria

The acceptance criteria were derived from laboratory test results undertaken prior to commencement of the works as part of the source evaluation prepared by Egniol Limited in 2008. The acceptance criteria are essentially an envelope within which the field dry density and moisture content results should fall in order to achieve the desired in-situ permeability. The boundaries of the envelope for the acceptance criteria are above the 5% air voids line, and between the upper and lower moisture content limits.

5.1.1 The lower moisture content limit was set at 12% and the upper moisture content was set at 20%.

5.1.2 The 5% air voids line was calculated using the average particle density derived from the collection of laboratory results within the source evaluation (2.63 $Mg/m^3$).

5.1.3 The minimum clay content was set at 10%, with a maximum particle size of 125mm.

## 5.2 Field Trial

5.2.1 Prior to the commencement of construction of the engineered clay liner, a compaction trial was carried out with the CQA Engineer in attendance, in accordance with the Specification for Highway Works Tables 6/1 – 6/4 to confirm that the proposed compaction and construction methodology would achieve the required specification.

5.2.2 The methodology for carrying out the trial was as follows:

(i) deposition of selected suitable clay on the trimmed surface of the engineered fill placed above the drainage geocomposite;

(ii) blading out the clay material to a uniform nominal uncompacted thickness of 300mm; and

(iii) compaction of the clay using a Bomag BW213DH self-propelled vibratory padfoot roller, to determine the number of passes required to achieve the necessary dry density;

(iv) On completion of placement and sampling of the first layer, a second layer of clay was placed and compacted before being sampled.

5.2.3 A third layer was placed and compacted and subject to on-site testing only.

5.2.4 The field trial was carried out on an area at the southern end of the works area. On completion of testing and review of the results, it was determined that eight passes of the Bomag roller were required to achieve compliance with the air voids criterion.

5.2.5 Following completion of the field trial, the CQA Engineer excavated the corner of the trial section to check for adequate interlayer bonding between the first and second layers. The CQA Engineer was satisfied that adequate bonding had been achieved within the field trial construction.

### 5.3 Assessment of Field Trial

5.3.1 The field trial was constructed in accordance with the requirements set out in the CQA Method Statement. The field trial confirmed that the selected cohesive material could be successfully placed and compacted to form an engineered clay liner.

### 5.4 Compacted Mineral Liner Construction

5.4.1 The mineral lining works were undertaken by placing and compacting selected suitable cohesive material in a progressive manner.

5.4.2 All engineered clay liner construction work was carried out using the method confirmed by the field trial. A total of eight layers of clay were placed to provide the 2m minimum clay thickness required.

5.4.3 Before placement of a subsequent ECL layer, the CQA Engineer ensured that the surface of the previous layer was suitably scarified, to provide adequate inter-bonding between the layers.

5.4.4 For construction of the tie-in to the existing sidewall liner, and where construction joints within the proposed liner were necessary, the CQA Engineer ensured that off-set (stepped) joints were employed.

5.4.5 All unsuitable materials were removed from the (lining area) works to the satisfaction of the CQA Engineer. Throughout the works the only unsuitable materials identified were occasional oversize materials (brickbats and tile fragments) and (where necessary) these were hand-picked and removed from the works.

### 5.5 Monitoring, Testing and Sampling

5.5.1 A programme of intensive monitoring, testing, and sampling was undertaken by the CQA Engineer during the construction period to check compliance with the requirements of the CQA Plan.

5.5.2 Quality control testing consisted of moisture content and density measurements of the emplaced material using core samples which were processed using a site oven and balance. In-situ shear strength measurements were recorded using a hand shear vane. Additional cores of compacted clay were taken and subjected to constant head permeability testing in the laboratory, while bulk samples were taken for classification testing.

5.5.3 The in-situ testing and sampling was undertaken at random locations (within a 20m x 20m reference grid) over the cell and are considered representative of the entire thickness and area of emplaced liner. The total volume of clay placed to the engineered clay liner (AEGB + ASL) was approximately 8,000m³. The in-situ testing and material sampling was undertaken in accordance with the testing and sampling frequencies stated in Table 4 of the CQA Plan.

**TABLE 1 : ASSESSMENT OF CONFORMANCE TEST FREQUENCY ACHIEVED (FOR 8,000m³)**

| Test Property | Test Frequency | Number of Tests Required | Number of Tests Undertaken |
|---|---|---|---|
| Liquid Limit | 1/500 m³ | 16 | 16 |
| Plastic Limit | | | |
| Plasticity Index | | | |
| Particle Size Distribution | | | |
| Clay Content | | | |
| Compaction Core | 1/250 m³ | 32 | 32 |
| Air Voids | 1/250 m³ | 32 | 32 |
| Permeability | 1/1000 m³ | 8 | 8 |
| Hand Shear Vane | 1/250 m³ | 32 | 32 |
| Undrained Shear Strength | 1/1000 m³ | 8 | 2* |

* See Section 6

5.5.4 The CQA Engineer did not allow placement of subsequent layers of clay until the previously placed layer had demonstrated the requisite shear strength.

## 5.6 Assessment of Testing

5.6.1 Site testing of the compaction core samples yielded dry density results of between 1.80 and 1.94 Mg/m³, together with moisture contents between 12% and 17%. Air voids range from -2.6% to 4.0% (based on use of the average particle density of 2.63Mg/m³. The moisture content and density results are summarised in Appendix 4 and presented in Appendix 6. All samples are at or above the minimum moisture content of 12% and are therefore deemed acceptable. A number of samples indicate negative air voids percentages (up to -2.6%), which is likely to be due to slight variations in the particle density above the average value taken for plotting the air voids lines.

5.6.2 Hand shear vane testing of the compacted clay gave results of between 60kPa and 110kPa. All the test results are greater than the specified minimum in-situ shear strength of 55kPa, and were therefore deemed to be acceptable. Hand shear vane measurements are summarised in Appendix 4 and presented in Appendix 6.

5.6.3 Atterberg Limits testing demonstrated an average plasticity index of 16%, within the normally-specified range of >10% and <65%. The average liquid limit of 34% was also below the specified maximum of 90%. The range of plastic limits recorded by the laboratory testing is 16% to 18%.

5.6.4 Particle density results ranged from 2.60 to 2.66Mg/m$^3$, with an average of 2.63Mg/m$^3$; the average particle density for the works was used for calculation of the percentage air voids for compaction samples.

5.6.5 Particle size distribution analyses indicated an average clay content of 32%, ranging from 26% to 36%. This is significantly greater than the 10% minimum required, and is therefore deemed acceptable. No particles greater than 37.5mm were recorded.

5.6.6 The laboratory results of the classification testing demonstrate that the material is of a consistent nature, and meets the requirements of the CQA Plan. The laboratory results for the classification testing are summarised in Appendix 4 and presented in Appendix 7.

5.6.7 The laboratory results of the constant head permeability tests from core samples taken from the emplaced clay at locations within a grid across and throughout the full depth of the liner, range between $k=8.10 \times 10^{-11}$ m/s and $k=9.7 \times 10^{-11}$ m/s. These results demonstrate that the target permeability of $k=1.0 \times 10^{-9}$ m/s was achieved in the field. The results of the constant head permeability testing are summarised in Appendix 4 and presented in Appendix 8.

## 5.7 Assessment of Procedures

5.7.1 The CQA Engineer monitored all lining material placement and compaction, and was satisfied with the placement methodology and the final quality of the engineered clay liner.

5.7.2 The working procedures adopted throughout the duration of the works, in terms of layer thickness and the numbers of passes of the compaction plant, were in accordance with the CQA Plan and the compaction field trial, and therefore were deemed satisfactory. All the clay mineral material utilised in the construction of the engineered clay liner was placed satisfactorily. All the laboratory testing was undertaken at a laboratory with UKAS accreditation for the tests undertaken. The laboratory details are included with each result sheet presented in the respective appendices.

5.7.3 The CQA Engineer ensured that the engineered clay liner was constructed to the lines and levels shown on the design drawings in conjunction with Cory's appointed surveyor. A topographical survey of the works area was undertaken prior to, and following construction of the ECL. The surveys confirm that a minimum perpendicular thickness of 2000mm of clay has been laid on the side slopes of the cell in accordance with the CQA Plan. The maximum vertical height of the emplaced liner is 13m. The thickness of the clay is shown on the as-built drawing presented in Appendix 1.

# 6 NON-CONFORMANCES AND THEIR TREATMENT

## 6.1 Filtration Geotextile

6.1.1 The sample of filtration geotextile failed to achieve the specified tensile strength and elongation (Specification targets of >20kN/m and >40%, compared to 8kN/m and 34% reported by the lab); the reported values for puncture resistance, pore size and perpendicular permeability are all in accordance with the Specification.

6.1.2 It is considered that little or no tension within the geotextile is likely to be experienced in service, as the material will be supported within a drainage trench; damage from placement and subsequent minor settlement of the drainage gravel should be accommodated by the material's puncture resistance. The provision of a high tensile strength would have consequential negative effects on both the pore size and permeability of the geotextile, and as these are considered the primary parameters on which the geotextile should be selected, such effects would be counter to the design function. The filter geotextile is therefore deemed acceptable for use in this situation.

6.1.3 On grounds of protecting the emerging groundwater drain from damage and/or contamination from runoff, it was decided later during the construction period to extend the collection toe drain a further 8m from the edge of the lining system. As there was insufficient NW9 filter geotextile remaining with which to achieve this extension, a part-roll of Lotrak Base geotextile was utilised for its construction. This is a black woven geotextile, better suited to separation than filtration. A sample was taken by the CQA Engineer, and when tested this was found to have a similar tensile strength (8kN/m) and puncture resistance (1350N) to the Terrex NW9 material, but a larger pore size (117μm) and lower perpendicular permeability (11l/m$^2$/s). The use of this alternative geotextile is considered acceptable for the short length of drain constructed, as the toe drain is situated within the Ruabon Marl and is therefore not acting as a filter drain.

## 6.2 Drainage Gravel

6.2.1 The sample of drainage gravel submitted for PSD analysis was found to be slightly below the grading envelope specified in Table 3, with 78% passing the 40mm sieve (permitted range 30-65%) and 35% passing the 31.5mm sieve. The results for horizontal permeability and ten percent fines are in accordance with the Specification.

6.2.2 Whilst the material tested was found to be slightly outside the grading envelope, it is recognised that a particularly coarse grading specification has been proposed. In comparison with the Guidance grading parameters for a 40-20mm drainage gravel (for use in a leachate drainage blanket), or with Type B filter media (used in highway drainage systems), the recycled aggregate is found to be well within grading limits. The high permeability reported (1.7 x $10^{-1}$ m/s, compared with > 1 x $10^{-4}$ m/s required) in combination with the resistance to crushing demonstrated by the high ten percent fines value achieved (230kN) further confirms that the material will provide acceptable levels of drainage when in service, and can therefore be considered acceptable.

### 6.3 Geocomposite

6.3.1 The results reported for the two samples of geocomposite tested were all found to be in accordance with the requirements of Table 1 of the Specification/CQA Plan, although the exact test criteria for measurement of the in-plane water flow were not followed. Version 1.0 of the CQA Plan only stipulated a constraining pressure of 20kPa on the geocomposite during test. Version 2.0 of the CQA Plan, issued on 8 August, added a hydraulic gradient (i=0.5) to the test criteria. By this date, the CQA Engineer had already sampled and scheduled the geocomposite, installation of which was complete on 1 August, and therefore did not refer to the revised Table 1 as he believed works covered by this section of the Specification had been completed.

6.3.2 The Specification required a minimum in-plane water flow of 0.20l/m/s at 20kPa, at a hydraulic gradient of i=0.5 The samples were tested at 20kPa, but with a hydraulic gradient of i=1, at which they achieved water flows of 1.35 and 1.39 l/m/s. Review of the manufacturer's data sheet for the material quotes a flow rate of 1.45 l/m/s at 20kPa for i=1, a flow rate of 0.99 l/m/s for 20kPa and i=0.5, and a flow rate of 0.35l/m/s at 20kPa and i=0.1. For all three hydraulic gradients listed, the flow capacity varies little with the constraining pressure; at 200kPa and i=0.1, a flow capacity of 0.35 l/m/s is quoted by the manufacturer, a value which is significantly in excess of that required by Table 1 of the Specification. It is therefore considered that the results obtained for the two samples of geocomposite can be accepted.

# 7 LIAISON WITH AUTHORITIES AND REPORTING

7.1.1 The NRW was informed of the commencement of work on site and were given the opportunity to visit the site throughout the works to check any aspects of the works. The NRW was kept regularly informed of the site development.

7.1.2 Informal progress meetings were held between Stratus and Cory site personnel, at which construction, design, and CQA issues were discussed.

7.1.3 As a visual record of the works, the CQA Engineer supervising the works kept on-going photographic records. Appendix 9 represents a selection of photographs showing different aspects of the construction works.

7.1.4 The CQA Engineer maintained daily records throughout the duration of the works. These daily records highlighted any problems encountered, the solutions adopted, and the detailed day-to-day site operations. The daily records are presented in Appendix 10.

# 8 CONCLUSIONS

8.1.1 PREPARATORY EARTHWORKS – The preparatory earthworks were carried out to the lines and levels indicated on the Design Drawings, and the formation was prepared in accordance with the CQA Plan.

8.1.2 GROUNDWATER COLLECTION SYSTEM – The groundwater collection system was installed in accordance with the Design Drawings. The manufacturer's quality assurance certificates and results of laboratory testing show that the geocomposite incorporated into the works conforms to the requirements of the CQA Plan.

8.1.3 ENGINEERED CLAY LINER – The engineered clay liner has been placed and compacted in accordance with the CQA Plan. All compliance testing indicates that the emplaced clay liner achieves the values specified in the CQA Plan.

8.1.4 The construction of Cell 3 Upper Western Sidewall at Hafod Quarry Landfill Site has been carried out satisfactorily and in accordance with the approved CQA Plan.

# APPENDIX 1 : AS-BUILT DRAWINGS

# APPENDIX 2 : NRW CORRESPONDENCE

# APPENDIX 3 : MATERIALS RECEIVED AND MQC CERTIFICATES

# APPENDIX 4 : CQA RESULTS SUMMARY

## APPENDIX 5 : GEOSYNTHETIC CONFORMANCE TESTING RESULTS

# APPENDIX 6 : ENGINEERED CLAY LINER – ON-SITE TESTING RECORDS

# APPENDIX 7 : ENGINEERED CLAY LINER – LABORATORY CLASSIFICATION RESULTS

# APPENDIX 8 : ENGINEERED CLAY LINER – LABORATORY PERMEABILITY RESULTS

# APPENDIX 9 : PHOTOGRAPHIC RECORD

# APPENDIX 10 : DAILY SITE RECORDS