MOTT MACDONALD

Swanworth Quarry Extension

Engineered Clay CQA Plan

May 2023

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Contents

Tables

1 Introduction

This document provides the Construction Quality Assurance (CQA) procedures that will be undertaken during the construction of the base and below ground side lining for the restoration of Swanworth Quarry.

1.1 Background

Suttle Stone Quarry Ltd (Suttles) operates Swanworth Quarry (Site) for the extraction of Portland Stone limestone. The Site is located close to the southern coast of the Isle of Purbeck peninsula, Dorset, being centred upon National Grid Reference (NGR) 3970, 0782, some 630 metres (m) northwest of Worth Matravers, 1.67 kilometres (km) southwest of Kingston and 3.3km south of Corfe Castle.

The existing site comprises an active consented limestone quarry with a boundary area of some 37.3ha, situated within a rural landscape dominated by live-stock grazing and arable farming. The current main area of mineral extraction is located within the north-eastern part of the site where workings have progressed over a number of benches to a lowest floor elevation of some 70mAOD across a relatively small basal floor area of approximately 3,800 square metres (m^2).

Site offices, weighbridge and car parking facilities are situated to the north of the current main area of mineral extraction, adjacent the quarry entrance road which parallels the northern boundary. The south-western section of the current site contains the mineral processing plant, mineral stocking yard, quarry operations offices, maintenance workshops, welfare facilities and vehicle parking, these elements of the quarry residing within a relatively level area of former quarrying at some 80mAOD.

The upper benches along the quarry's eastern boundary have previously been restored to regular slopes using imported inert waste materials and quarry waste stone. The south-eastern section of the Site is currently undergoing restoration; as with the formerly restored eastern boundary, imported inert waste materials and quarry waste stone are being used to create regular slopes across the exhausted quarry faces in this area.

1.2 Scope

A "Hydrogeological Risk Assessment" was developed by BCL Consultant Hydrologists Limited in December 2021. This identified that a clay liner would be installed with an attenuating effect equivalent to a barrier of permeability $1x10^{-7}$ metres per second [m/s] at 1m thickness.

This CQA plan describes the method for selecting, testing and approving the lining material, planning the method of placement, and monitoring of placement. The CQA plan also describes the method of recording the selection, placement and monitoring process.

The works will include the following (from bottom to top):

a) Preparation of the foundation surface
b) Construction of a 600mm thick engineered clay layer (ECL) with a hydraulic conductivity $<1x10^{-9}$m/s;

1.3 Description of Works

The works involve the following:

a) All setting out necessary for the works;

b) All clearing necessary for carrying out of the works, including removal of fauna and flora;
c) Cut/fill to suitable side slope formation levels;
d) The construction of associated temporary access roads;
e) The excavation, transportation and disposal of reject material; and
f) Placement and compaction of a 600mm thick ECL.

All material and workmanship shall comply with the appropriate British Standard Specification as described in the British Standard Year Book, or other standards as approved by the CQA Engineer.

The abbreviation BS is used when referring to a British Standard and CP when referring to a Code of Practice.

1.4 Responsibilities

It is the responsibility of Suttles to employ an experienced Contractor to install the lining system, an Engineer to supervise the construction and a CQA Engineer to monitor that the lining system has been laid in accordance with this Plan. All Contractor personnel will be inducted by Suttles at the start of the works, in addition to any induction carried out by the Contractor.

The Contractor is responsible for the following:

- Provision of a summary of the Contractor's Construction Quality Assurance procedures, including any method statements;
- Provision of evidence of personnel experience / training;
- Site clearance;
- Undertaking a pre-characterisation assessment of a clay source to be used for lining purposes;
- Provision of necessary samples of materials selected by the CQA Engineer for contamination testing, if required;
- Construction of a temporary access road;
- Arranging third party testing of the liner material by an independent laboratory to demonstrate the effectiveness of the clay liner. This includes carrying out the sampling and testing described in this CQA Plan and any extra sampling as determined by the CQA Engineer. The independent laboratory is to be agreed with the CQA Engineer in advance of material being sampled and the testing being undertaken;
- Assurance that the formation layer is prepared prior to the placement of the ECL;
- Placement of the ECL against the subgrade formation;
- Provision of conformance tests undertaken to demonstrate the effectiveness of the placed materials. This includes carrying out sampling and third-party laboratory testing as described in this CQA Plan and extra sampling and testing that the CQA Engineer deems necessary;
- Survey of levels; and
- Provision of as-built drawings. Information should be presented that identifies the date and time of installation of the lining system, the weather conditions and the site operatives involved.

The CQA Engineer and his inspectors are responsible for the following:

- Notification to the Environment Agency within at least one week prior to placement of material;
- Alongside the Contractor, visually inspecting the subgrade formation and acceptance of the finished surface for the ECL;

- Monitoring the ECL placement and testing activities;
- Alongside the Contractor, visually inspecting the ECL and acceptance of the ECL surface;
- Certifying whether the work has been carried out in accordance with this CQA Plan and to provide written confirmation of this;
- Identifying to the Contractor any work and/or materials that are not compliant with the requirements of this Plan and requesting, through the Engineer, that the Contractor make good;
- Submitting a copy of the CQA report to the Environment Agency for their approval upon completion of works; and
- With the support of the Contractor, provision of a 'Test Location' drawing showing where test samples were taken.

The Engineer, as defined in the Conditions of Contract, is responsible for the following:

- Ensuring that the work is carried out in accordance with the technical specification; and
- Formally rejecting and/or approving all work undertaken under the Contract, having taken advice from the CQA Engineer.

1.5 Quality Control Personnel

Staff from Mott MacDonald shall carry out Quality Control during the construction of the lining system, and the CQA Engineer shall have relevant experience in landfill construction and earthworks control.

The CQA Engineer shall report to the Engineer and report any unusual or unexpected occurrences immediately for discussion and/or direction. Full records shall be kept by the CQA Engineer on a day-to-day basis detailing all site operations, tests carried out and the site conditions. The records will be made available for inspection by representatives of the Environment Agency.

The CQA Engineer may delegate some of their responsibilities to CQA Inspectors, but must be cognisant of the activities being undertaken and retain responsibility for the overall assessment of the works.

2 Management

The Quality Assurance monitoring and certification shall be the responsibility of the CQA Engineer. He/she may either monitor the construction of the basal and internal sidewall lining and/or receive reports from CQA inspectors who monitor construction.

The CQA Engineer should maintain an awareness of day-to-day matters and the progress of site operations. All CQA personnel must be familiar with the contents of the CQA Plan and must sign a confirmation of familiarity form, which has been appended to this document as Appendix A.

The CQA Engineer is responsible for the certification of the works, but may delegate inspection and recording to his inspectors. The term CQA Engineer forthwith in this plan includes the Engineer and his Inspectors.

2.1 Daily Meeting

A daily meeting shall be held on site between the CQA Engineer and the Contractor's representative.

The purpose of the meeting is to:

a) Review the work activity and location for the day;
b) Note the Contractor's installation personnel for the day/shift;
c) Review the previous day's work activity;
d) Review the work schedule;
e) Discuss any interfacing with other contractors and/or normal site operations; and
f) Discuss and/or highlight any problems and solutions.

2.2 CQA Engineer's Reporting, Forms and Certificates

The CQA Engineer's site personnel will have to provide details of site operations in the following reports:

2.2.1 Daily Summary Reports

Daily Summary Reports will be prepared, to include the following;

- Date, project name, location, personnel involved;
- Description of weather conditions, including temperature, cloud cover and precipitation;
- Summaries of meetings held and actions recommended or taken;
- Location on site of construction/installation undertaken during day;
- Contractor's equipment and personnel being utilised;
- Quantity and description of materials supplied to site;
- Calibrations or recalibrations of test equipment;
- Details of the work accomplished;
- Identification of samples tested, test methods and provision of approximate location;
- Records of observations, and descriptions of the adequacy of the work;
- Decisions made regarding approval of work and corrective actions required;
- Records of relevant CQA interested parties visiting the site; and
- Signature of the CQA Engineer.

Each day's progress shall be recorded in the form of a marked up copy of a site plan, showing approximate locations of the test areas noted with an approximate northing and easting.

A typical report form is appended to this document as Appendix B.

2.2.2 Corrective Measures Reports

If the material placed fails to meet the specification within this CQA Plan due to the workmanship or quality of source material, a corrective measures report shall be produced with a unique identification number, which will include the following information:

- Location of the problem;
- Reason for failure, giving probable cause;
- How and when the problem was located;
- Notes of any disagreement between the Contractor and the CQA Engineer, as to whether a problem exists;
- Suggested corrective action;
- Description of corrective action undertaken;
- Suggestions on how methodology can be altered to prevent reoccurrence of the problem; and
- Signature of the CQA Engineer.

The corrective action can be proposed by either the Contractor or the CQA Engineer, but the CQA Engineer must state, prior to the works being undertaken, whether the proposed remedial works will meet the overall requirements of this CQA Plan. The signature of the CQA Engineer demonstrates that the remedial work proposed meets the overall requirements of this CQA Plan document and has been undertaken as described in the report.

A typical report form is appended to this document as Appendix C.

2.3 Contractor's Reporting Requirements

2.3.1 Formation Acceptance Reports

A formation acceptance report will be developed prior to placing the ECL.

These reports shall include a description of the area accepted by the Contractor before material is placed.

An example Formation Acceptance Sheet template is provided in Appendix D.

2.4 Maintenance of Records

The CQA Engineer is responsible for the control and storage of all records regarding the installation of the liner. The CQA Engineer will maintain the original copy of all records, with copies being held by the Contractor. The CQA Engineer shall maintain the original records until the CQA Report has been produced and accepted by the Environment Agency. A copy of any laboratory and field test results shall be kept along with the remaining project information.

The CQA Engineer is responsible for controlling the distribution of all documents pertaining to quality assurance. This will require him to set up procedures whereby:

(a) Each issue of each document has a unique identification;
(b) A record is kept of the distribution of each document;
(c) A record is kept of confirmation of receipt and confirmation of familiarity of important documents.

2.5 Survey of Levels

The Contractor shall provide grids of levels at 5 metre centres. These initial level surveys shall be carried out on completion and approval by the Engineer of the surface preparation for the following:

- Top of the subgrade formation; and
- Top of ECL.

2.6 Site Visits

It is anticipated that the Environment Agency will periodically visit the site during the construction works. During these visits, the CQA Engineer supervising the works shall make available all test results compiled up to that date.

2.7 Design Changes

Any significant design changes, required to ensure the suitability of the construction works, shall be referred to the Environment Agency for approval. The Engineer shall determine whether a design change is significant in nature to merit further approval from the Environment Agency.

2.8 Contamination testing of material

It is not anticipated that naturally occurring mineral materials will be imported to the Site for the purposes of providing an engineering layer for the Site. Should this assumption change, then contamination testing will be required at a frequency and to standards agreed by the CQA Engineer.

3 Earthworks

3.1 General

Earthworks shall be carried out in accordance with the Specification for Highways Works (SHW), Series 600 March 1998 (Volume 1), amended February 2016[1], published by Her Majesty's Stationery Office, as modified and supplemented by the additional particular requirements specified in this section. This document should be read in conjunction with Specification for Highways Works (SHW), Series NG 600 March 1998 (Volume 2), amended February 2016[2], Notes for Guidance on the Specification.

Insofar as any of the particular requirements may conflict or be inconsistent with any other provision of the Specification, the particular requirements shall always prevail. A copy of the Specification for Highway Works, Series 600 shall be kept on site at all times.

The above documents are referred to throughout this CQA Plan as the "Specification for Highway Works" or "SHW".

The Contractor shall provide a summary of the Contractor's Construction Quality Assurance procedures and any method statements.

3.2 Sourcing Material

The Contractor shall adopt a "green" purchasing policy to enable the environmental origin of imported materials to be considered during the selection process. It is accepted that the following is not required for materials already available on site, which includes the clay for the ECL.

In sourcing materials for the works, the Contractor shall endeavour to:

a) Agree environmental purchasing policy with Suttles;
b) Avoid purchasing materials from environmentally sensitive locations;
c) Purchase materials from sources that follow environmentally good practices, and comply with all relevant environmental legislation;
d) Seek the following information about materials when making product choices:
    - The embodied energy in the material (or associated carbon dioxide emissions);
    - The impacts associated with extraction of the source material;
    - The pollution associated with the manufacture of the product;
    - The sustainability of the resources from which it was derived;
    - The recycled content of the material;
    - Emissions affecting the wellbeing of users during and after construction; and
    - Problems arising from the disposal of materials after use.
e) Increase the use of recycled materials where possible;
f) Minimise waste and segregate and recycle;
g) Source materials locally to minimise transport costs;
h) Ensure that purchasing to avoid waste is explicitly targeted;
i) Ensure any environmental purchasing requirements are followed by any Sub-contractors.

[1] http://origin.standardsforhighways.co.uk/ha/standards/mchw/vol1/pdfs/600.pdf

[2] http://origin.standardsforhighways.co.uk/ha/standards/mchw/vol2/pdfs/MCHW%20NG600.pdf

3.3 Tolerances in Construction Thicknesses

The thickness of the compacted materials forming the lining shall be measured perpendicular to the line of the slope.

The subgrade formation and the thickness of the ECL shall be within a tolerance of +50mm to -0mm.

4 Preparation of the Subgrade Formation

4.1 General

Prior to the installation of basal lining system, the subgrade formation shall be prepared. The layer shall provide a uniform, smooth and firm surface on which to place the ECL. Any sharp objects shall be removed from the subgrade formation and the surface graded to a maximum of 1 (v) to 3 (h). The CQA Engineer together with the Contractor, shall approve the state of the subgrade prior to the installation of the lining system.

4.2 Preparation of the Subgrade Formation

The Contractor shall prepare the subgrade surface by clearing of vegetation, trimming and filling such that it is in a suitable condition to receive the lining system as detailed in Section 1.3. The surface shall be sufficiently firm to form a suitable working surface for the plant being operated. Any soft or loose material on the formation surface shall be removed and replaced with compacted acceptable material, Class 1A, IB, 2A, 2B or 2C, as defined by SHW. After preparing the formation surface and prior to placing the lining system, the Contractor shall inspect the surface and remove or roll into the subgrade any objects which exceed +/- 25mm under a 1000mm lath and no rounded irregularity should exceed +/-50mm under a 3000mm lath.

Prior to the installation of the ECL, the subgrade shall be prepared by regrading and compaction to ensure an even surface has been achieved free from any ruts, bumps or depressions that could result in ponding. The surface shall be rolled with, at least, 4 passes of a smooth wheeled roller having a mass per metre roll of 4400-6000kg, or equivalent method to be agreed in advance by the Engineer. When each area of the surface has been prepared, the Contractor shall notify the CQA Engineer so that an inspection can be made. The Contractor shall satisfy himself that the surface will not lead to damage of the ECL and shall complete a Formation Acceptance Sheet, which he shall provide to the Engineer and copy to the CQA Engineer. If the Contractor is concerned about the quality of the subgrade, he shall notify the CQA Engineer immediately. The CQA Engineer or his inspectors shall inspect the subgrade daily and identify any areas to the Contractor who should arrange for them to be remediated. Following approval, the formation surface shall be surveyed by the Contractor to provide a grid of levels at 5 metre centres. The surveyed levels shall be agreed with the CQA Engineer.

5 Engineered Clay Liner (ECL)

5.1 General

The ECL shall be constructed and should achieve a minimum thickness of 600mm and shall be protected at all times from any deterioration due to the effects of weather, plant or any other cause. The layer shall provide a uniform, smooth and firm layer. Any sharp objects shall be removed from the underlying formation. The inspection shall also consider any signs of seepage or instability. If the formation is deemed suitable for placement of the ECL, a Formation Acceptance Sheet will be completed for the specific area inspected and signed by both parties. No ECL placement should be undertaken until this acceptance has been obtained.

5.2 Source Material Evaluation

The proposed engineering clay will be the subject of a Source Evaluation Report (SER) and approval of the Environment Agency. The objective for sampling from source is to determine the acceptability criteria to be achieved during placement. The proposed material shall meet the requirements of the tests as described in Sections 5.2.1 to 5.2.7. The Contractor shall refer to the SER for details of any source-specific processing that is required to meet the Specification. In the event that there is inconsistency between this CQA Plan and the SER, the SER requirement shall prevail.

Additional source testing may be required by the CQA Engineer if visually, the clay appears to alter from the material previously used and tested.

Acceptable materials are those which meet the requirements of Clause 601 of the “Specification for Highways Works”[1], to the satisfaction of the Engineer.

The Contractor shall provide Method Statements to the Engineer prior to the compaction trials which shall detail the plant and methods he proposes to employ in satisfying the requirements of this CQA Plan.

In order to obtain approval to his proposed source of clay for the seal, the Contractor shall arrange for and submit to the CQA Engineer, test results to demonstrate that the proposed material will comply in all respects with the requirements of the CQA Plan. Tests shall be on representative samples from the actual volume of clay that is proposed for use. The samples shall be selected from a grid of sampling locations spaced evenly throughout the area and depth of the proposed source.

The minimum number of tests carried out on the source materials proposed for the clay seal in the liner, for the purpose of demonstrating acceptability is indicated in Table 5.1.

Table 5.1: Test Requirements

Test	Number of Tests
Moisture content (BS 1377-2:2022/BS EN ISO 17892-1:2014)	8
Liquid Limit (BS 1377-2:2022/BS EN ISO 17892-12:2018+A1:2021)	4
Plastic Limit (BS 1377-2:2022/BS EN ISO 17892-12:2018+A1:2021)	4
Particle size distribution by combined sieving and sedimentation to establish full grading curve (BS1377-2:2022/BS EN ISO 17892-4:2016+A1:2021)	4
Compaction test by 4.5 kg rammer (BS 1377-2:2022, clause 11.5)	4
Permeability in a triaxial cell (BS 1377-2:2022/BS EN ISO 17892-11)	4
Undrained shear strength on remoulded sample (BS 1377-2:2022/BS EN ISO 17892-2:2014)	4

Tests submitted for the purpose of approval shall be carried out by a laboratory independent from the Contractor which is UKAS accredited for such tests.

The Contractor shall demonstrate that material proposed for forming the clay seal is capable of being compacted (by the equipment to be used for its emplacement) to an extent which will achieve a permeability of not more than 1.0×10^{-9} m/sec. The Contractor shall establish the range of permeability which can be achieved in the field at varying moisture contents. The range of moisture contents at which samples are compacted for permeability testing shall relate to the optimum moisture content and the field moisture contents, and shall be agreed with the Engineer prior to testing.

Upon submission of test results to the Engineer, the Contractor shall state the minimum dry density, maximum air voids percentages, and maximum and minimum moisture contents with which he proposes to comply.

5.2.1 Moisture Content

This test is undertaken to determine whether the clay needs to be wetted or dried prior to placement in order to meet acceptance criteria. Testing shall be carried out to BS 1377-2:2022/BS EN ISO 17892-1:2014.

The minimum acceptable moisture content of the clay shall be the Optimum Moisture Content as determined under BS 1377-2:2022, clause 11.5 (4.5kg rammer). The maximum moisture content permissible shall be determined through testing and shall be equivalent to the moisture content corresponding to a minimum undrained shear strength of 75 kPa as determined by BS 1377-2:2022/BS EN ISO 17892-2:2014. The range of moisture content permissible at the site shall be determined through clay source evaluation tests and modified, if necessary, through field trials.

5.2.2 Atterberg Limits

The plastic and liquid limits and plasticity index are obtained using the test method in BS 1377-2:2022/BS EN ISO 17892-12:2018+A1:2021.

The plasticity index should be between 10% and 65%. Higher plasticity clay may be used, but will tend to form clods when dry of optimum and sticky when wet. Therefore, more care is required to reduce the larger clods of clay. Highly plastic soils are more likely to shrink and swell when wetted or dried and care will also be required to avoid alterations in moisture content after placement.

The liquid limit shall not exceed 90%.

5.2.3 Particle Size Distribution

Particle size distribution (PSD) will be determined using BS1377-2:2022/BS EN ISO 17892-4:2016+A1:2021 Tests 5.2 or 5.3 and 5.4.

Materials with high clay or clay and silt contents will have a lower permeability. The source clay shall have no less than 10% (by weight) of its particles with a particle size less than 2 microns.

The maximum particle size is to be 100mm in any dimension. Should particles greater than this dimension be found; they must be removed during placement or at source.

5.2.4 Compaction Tests

Compaction tests should be performed to BS 1377-2:2022, clause 11.5. The compaction tests will be used to obtain the optimum moisture content of the clay for varying compactive efforts and moisture of the material. The maximum dry density of the material is also obtained by this method.

From the compaction tests a 5% air voids line will be produced. The clay must be capable of being engineered to give a maximum of 5% air voids within the range of moistures specified within Section 5.2.1.

5.2.5 Undrained Shear Strength

The undrained shear strength of the recompacted materials is to be established from remoulded samples prepared at their natural moisture content and also at a range of moisture contents and dry densities, the results of which will be used to determine the relationship between the moisture content and dry density with the undrained shear strength.

The minimum permissible dry density will be related to the clay's ability to resist deformation under imposed loading during the construction and operational phases. The minimum acceptable undrained shear strength is 75 kPa. From the results, a minimum dry density and maximum moisture content can be established for the clay. The confining pressure during the test shall be 50 kPa.

Tests will be undertaken until the Contractor is confident of the minimum dry density at maximum moisture content, required to achieve the minimum acceptable shear strength. The procedure for undertaking the tests is described in BS 1377-2:2022/BS EN ISO 17892-2:2014.

5.2.6 Percentage Air Voids

The clay must be capable of being compacted to achieve a maximum of 5% air voids. A greater percentage of air voids up to a maximum of 8% may be accepted, providing that the undrained shear strength and permeability meet their respective requirements and the clay is placed in accordance with the methodology agreed during field trials.

5.2.7 Permeability

The source clay material should be capable of being placed to achieve permeability not greater than 1×10^{-9} m/s. The preparation of the samples and testing should be carried out using the Constant Head Method described in BS 1377-2:2022/BS EN ISO 17892-11.

The permeability should be determined at optimum moisture content -3%, optimum moisture content, optimum moisture content + 3%, optimum moisture content + 6%. The optimum moisture content should be determined from the samples prepared using a 4.5 kg rammer. Should any of the source material samples show that the permeability obtained exceeds the target level the source should be deemed to be unsuitable and alternative options should be discussed with Suttles and the CQA Engineer.

Where the specified requirements for permeability have not been achieved, the Contractor shall remove the non-complying material from site and replace it with acceptable material. Replacement material shall be subject to the same testing requirements as the original material. All additional testing costs shall be borne by the Contractor. Where non-compliance is due to poor compaction, the Contractor shall remove and recompact the material.

5.3 Clay Material Acceptance

The CQA Engineer shall assess the results of the tests undertaken and shall confirm to the Contractor his acceptance or rejection of the imported clay for incorporation into the works.

5.4 Clay Liner Field Trial

Prior to the commencement of the ECL construction, a compaction trial shall be carried out to prove that the proposed construction methodology will achieve the required Specification. The main objectives of the trial shall be to:

- Verify that the materials, methods of construction and plant used in the works will produce a compacted clay liner, which meets the hydraulic conductivity objectives defined for the project; and
- Verify that the proposed CQA procedures will result in a high-quality clay liner that will meet performance objectives.

In order to demonstrate that the proposed method of compaction will achieve the specified requirements, the Contractor shall carry out a compaction trial on a representative volume of the proposed seal material. The trial shall be a minimum of 10m wide x 20m long, and include at least two layers of the clay to a compacted maximum layer thickness of 200mm using a padfoot or other type of roller, as appropriate. The ECL shall be placed and compacted in accordance with the National Highways Specification for Highways Works (SHW), series 600[1].

The trial pad will be placed under controlled conditions. The methodology shall be varied to determine the most suitable procedure for placement and in particular adequate compaction of the clay fill. All placed layers with the exception of the initial layer will be tested and each variation in placement methodology investigated, with no less than one test per layer.

On completion of testing and sampling of the first layer, a second layer shall be placed, compacted and tested.

The Contractor shall only employ plant which is suitable for the soils to be handled. He shall not at any time use plant which damages the natural strength of the fill material, either in-situ or during its handling and placing, or in its final compacted state.

The layer shall be compacted with a range of passes of the compaction plant, as necessary, and tested for each compaction regime by the CQA Engineer (or Testing Laboratory) to determine the most effective method of achieving the required specification.

The Contractor may adopt alternative methods of compaction subject to the approval of the CQA Engineer. A compaction trial shall be carried out for each alternative method proposed.

The minimum number of tests carried out on the compaction trial materials proposed for the clay seal in the liner, is indicated in Table 5.2.

Table 5.2: Minimum number of tests per layer for the trial Engineered Clay Liner (ECL)

Test	Number of tests
In-situ Density (BS 1377-9:1990)	6
Moisture content (BS 1377-2:2022/BS EN ISO 17892-1:2014)	6
Liquid Limit (BS 1377-2:2022/BS EN ISO 17892-12:2018+A1:2021)	3
Plastic Limit (BS 1377-2:2022/BS EN ISO 17892-12:2018+A1:2021)	3
Particle size distribution by combined sieving and sedimentation to establish full grading curve (BS1377-2:2022/BS EN ISO 17892-4:2016+A1:2021)	3

The Contractor shall be aware that additional tests may be carried out at the same time by the Engineer.

Where the test results from the compaction trial do not comply with the specified requirements or the limits stated by the Contractor (minimum dry density, maximum air voids percentages, and maximum and minimum moisture contents), the Contractor shall at no cost to the Client either:

a) Modify the proposed compaction method and repeat the compaction trial and testing until compliance has been demonstrated, or
b) Propose an alternative source of clay for the seal and repeat material acceptability testing in accordance with Table 5.1 and the compaction trial and test until compliance has been demonstrated.

Where the results demonstrate that the methodology and plant used for the compaction trial achieve the required Specification as defined in Section 5.2, works may proceed with placement of the ECL. If the results of the trial prove unsuccessful, the placement methodology and/or compaction plant shall be changed and a further trial carried out to assess the revisions. This process shall continue until the CQA Engineer is satisfied that the proposed plant and methodology will produce satisfactory results. If the compaction trial is carried out within the ECL area, any non-conforming material shall be removed prior to ECL construction. The Contractor shall provide the CQA Engineer with a minimum of one week's notice that any field trial is to be undertaken.

Upon completion of the compaction trial and receipt of the test results, the Contractor shall submit to the CQA Engineer a method statement giving full details of the proposed method and sequence of placement, compaction and temporary protection for the seal and quality control procedures.

Placement of the clay seal shall not commence until the CQA Engineer has given his written approval to the method statement provided. The Engineer shall give his decision as to acceptance or otherwise of the Contractor's proposals within three full working days of receipt of all tests results, and the Contractor's method statement. Any importation of materials onto the site prior to the Engineers approval shall be at the Contractor's risk. All material which proves to be unacceptable shall be removed from the site at the Contractor's expense. The trial area may be incorporated into the permanent works providing it complies in all respects with the specified requirements for the seal.

Holes formed in the seal in the course of testing shall be backfilled with a 1:4 bentonite/sand mix compacted in thin layers by hand using a tamper. The alternative would be to remove the affected layer and replace with a freshly compacted clay to the standards determined by the field trial and included within the method statement.

Additional trial sections may be required during the earthworks, if site conditions change such that the CQA Engineer feels the liner construction may be compromised. A change in site conditions could be a different type of compaction plant, changes in the weather and changes in the nature of the clay, or/and other factors which could affect liner construction may also be considered.

Subject to a satisfactory outcome of the compaction trial and subject to the agreement of the Engineer the trial ECL can be incorporated into the permanent works. If not, the CQA Engineer shall agree with the Contractor any measures required to allow the trial area to be retained or the Engineer will instruct the Contractor to remove the section of the trial that does not meet specification.

5.5 Engineered Clay Liner Construction

On completion of the compaction trial, the ECL shall be constructed using the plant and methodology determined by the trial. The compaction method shall not be changed without further trials to demonstrate the suitability of the revised method.

All installation work shall be carried out under supervision up to and including project completion. The Contractor shall identify to the CQA Engineer the key personnel, their qualifications, experience, training and duties.

Directly upon completion of each layer in each panel of compaction, the Contractor shall notify the CQA Engineer so that an inspection and in-situ testing can be carried out. No layer shall be covered until the CQA Engineer has carried out an inspection.

If a smooth-drum roller is used to seal an intermediate layer surface against rainfall/ desiccation, the layer surface shall be scarified to a minimum depth of 25mm prior to the placement of any subsequent layer to ensure a competent key between layers. Any clay material that becomes excessively dry/wet shall be wetted/left to dry sufficiently or shall be removed from the works.

The Contractor shall determine the method of compaction, which shall achieve all of the specified requirements for the clay seal. The minimum requirements are as follows:

- Maximum permeability to be 1 x 10^{-9} m/sec;
- 90% of all results to have a maximum air voids of 5%, with an absolute maximum air voids permitted being the lesser of 8% or a value agreed following the source testing;
- Minimum amount of compaction to be as specified by Table 6/4 Method 1 in the SHW[1]. A greater number of passes or thinner layers may be necessary to ensure adequate compaction and that all discontinuities are removed, as agreed in the approved method statement;
- Minimum total ECL layer thickness to be 600mm.

Any unsuitable materials within the ECL shall be removed including any stones or clods larger than 100mm or excessively softened or wetted clay. Joints between sections of placed ECL shall be constructed with a stepped connection between successive layers to ensure the continuity of the seal.

The Contractor shall provide the CQA Engineer with a programme each day showing the estimated times when areas will become available for inspection and testing on the following two days.

The Contractor shall protect the surface from desiccation, flooding and freezing. Protection may be in the form of a temporary thin plastic cover to be removed prior to liner installation. Surfaces containing desiccation cracks exceeding 12mm deep or exhibiting swelling, heaving or other similar conditions shall be replaced or reworked by the Contractor.

The ECL shall be finished as necessary to produce an even and stable surface, without any significant bumps, hollows or areas that may collect standing water. Any large or sharp objects shall be removed from the surface to the satisfaction of the CQA Engineer. The surface of the formation shall have no sudden sharp or abrupt changes in grade. The surface shall be free of protrusions, hollows and soft materials.

Where the specified requirements or the limits stated by the Contractor (minimum dry density, maximum air voids percentages, and maximum and minimum moisture contents) have not been achieved, the Contractor shall at his own cost carry out in-situ permeability tests at those locations and laboratory permeability tests on representative samples, to enable the CQA Engineer to determine whether or not the specified requirements for permeability have been achieved. The Contractor shall arrange for testing to be carried out by an independent laboratory which is UKAS accredited for such tests. The alternative would be to agree an amount of material that has been rejected and should be removed, or for the layer to be recompacted and retested.

5.6 Clay Sampling Locations

Sampling shall be carried out to provide data on the whole of the ECL. In order to determine the extent of any areas of failure, the sample locations should be based on an alphanumeric grid system, with any further test requirements being determined by the CQA Engineer on a day-to-

day basis. Locations of test samples will be logged and indicated in the CQA Report, together with a copy of a sample location drawing.

5.7 Conformance Testing

The CQA Engineer shall verify that all aspects of ECL construction are carried out in accordance with this CQA Plan including conformance testing as detailed within this Section.

The CQA Engineer (or UKAS accredited Testing Laboratory) shall carry out a regime of field conformance testing (including nuclear density gauge (NDG) testing as described in Table 5.3) and sampling for laboratory testing in accordance with Table 5.3 to verify that the ECL meets the required specification and placement criteria. Testing shall be carried out on each layer placed. The CQA Engineer shall record the test location and result. NDG measurements and samples taken for testing shall be evenly distributed over the entire placed ECL.

Subsequent layers of ECL shall not be placed until the CQA Engineer has verified that the tested layer has achieved the required density/moisture content criteria. Any remedial works shall be carried out as determined by and to the satisfaction of the CQA Engineer.

The CQA Engineer and Contractor shall check the results of all laboratory conformance testing to verify that the ECL meets the required specification.

The Contractor shall increase the number of tests as necessary to take account of the nature and variability of the source material. The number and distribution of sample locations shall be agreed by the CQA Engineer prior to samples being taken. The Contractor shall record the locations of the testing and sampling points, and present the data to the CQA Engineer in a format to be agreed with the CQA Engineer.

Table 5.3: Specification and Conformance Testing Requirements for the Engineered Clay Liner (ECL)

Property	Test Method (BS 1377)	Required Value	Conformance Testing Frequency
Shear Strength	Hand shear vane In accordance with manufacturer's instructions	75 kPa	20m grid
Liquid Limit	BS 1377-2:2022/BS EN ISO 17892-12:2018+A1:2021	< 90%	Per 250 m^3 clay placed
Plasticity Index	BS 1377-2:2022/BS EN ISO 17892-12:2018+A1:2021	<65%, >10%	
Particle density	BS 1377-9:1990	-	
Moisture content	BS 1377-2:2022/BS EN ISO 17892-1:2014	-	
Particle Size Distribution	BS1377-2:2022/BS EN ISO 17892-4:2016+A1:2021	< 125 mm	Per 500 m^3 clay placed
Clay Content	BS1377-2:2022/BS EN ISO 17892-4:2016+A1:2021	> 10%	
Density/ Moisture Content Relationship	BS 1377-2:2022, clause 11.5	As per acceptability envelope – see Source evaluation report	40m linear grid per 0.25m lift, using a nuclear density gauge (NDG); one density core per 5 NDG's
Air Voids Content	BS 1377-2:2022, clause 11.5	<5%	

Property	Test Method (BS 1377)	Required Value	Conformance Testing Frequency
Permeability	BS 1377-2:2022/BS EN ISO 17892-11	< 1 x 10^{-9} m/s	Per 500 m^2

Note 1: Samples for conformance testing shall be taken from location evenly distributed throughout the ECL.

Note 2: Core samples shall be taken in duplicate, one of the duplicate core samples shall be sealed in hot wax to prevent moisture loss and stored in accordance with the laboratory procedure.

Tests should be carried out on all layers of placed clay to ensure that testing is undertaken throughout the full depth of liner.

The purpose of the tests carried out by the CQA Engineer is to provide evidence to the Environment Agency that the specified requirements have been complied with. The tests are not intended to provide a quality control mechanism to the Contractor. The results of tests carried out by the CQA Engineer will be made available to the Contractor. However, the Contractor should note that some of the test results will not be available until a number of days after sampling in the field. The Contractor shall allow any additional testing to be carried out on other quality control measures which he considers necessary in order to ensure that the specified requirements are being complied with. The results of any such additional tests shall be made available to the CQA Engineer.

5.8 Stockpiling Clay

The CQA Engineer shall examine the clay from the stockpiles on site. This shall include any further clay materials that are delivered to site and stockpiled prior to use, the CQA Engineer shall assess whether the material is suitable for construction or is adversely affected by weather conditions. Material may only be used if it can be placed in accordance with the acceptance criteria.

Clay must not become contaminated with any other materials whilst in the stockpile. Any contaminated material must be removed and not used in construction of the works.

The CQA Engineer shall keep written records of these inspections and provide a copy of these to the Contractor, if required.

5.9 Placing Clay Lifts

The CQA Engineer shall note the results of all clay testing and shall assess whether the placed material complies with this CQA Plan. The CQA Engineer shall keep records of the clay test reports.

The Contractor and/or the CQA Engineer should inspect the clay for any oversized materials (greater than 100mm in any linear dimension) and presence of vegetation. Should either of these be present they shall be removed by picking.

The surface of each clay lift is to be scarified to provide a key for subsequent lifts.

The CQA Engineer shall also check the general visual conformance of the clay and shall, at regular intervals, satisfy himself of the following:

- Visual homogeneity of the clay;
- Number of passes of compaction equipment;
- Maximum clod size;
- Inter-lift scarification; and
- Lift thickness.

If the CQA Engineer has any concerns relating to the above, he should immediately inform the Contractor and, if necessary, record his concerns on the Daily Summary Report or on the Corrective Measures Report.

5.10 Adverse Weather Conditions

Clay shall not be placed in adverse weather conditions such as heavy rain or frost as this will affect the moisture content. It is the responsibility of the CQA Engineer to determine whether the material is being adversely affected by the weather and identify this to the Contractor.

The CQA Engineer shall identify any significant drying or wetting in between lifts. If the clay has become too dry this may be remedied by wetting and scarifying the surface, or by removal of the dry material, until moist material is exposed prior to placement of the next clay lift. The CQA Engineer shall monitor such remedial processes and ascertain whether they meet the overall requirements of this CQA Plan.

5.11 Corrective Action

A sample is deemed acceptable if values of moisture content and dry density fall within the desired range determined by the clay source testing.

If the CQA Engineer is not satisfied that the clay is consistently being laid to the requirements of this CQA Plan, then the CQA Engineer, through the Engineer, may either request further testing to be undertaken prior to continuation of the works, or the removal of all material which is represented by the sample or samples. The CQA Engineer shall designate the extent of clay removal.

Corrective action, dependent on the reason for failure may comprise the following:

- If clay is too wet, turn over and allow to dry;
- If clay is too dry, turn over, wet and recompact;
- If oversize or vegetative material is present remove by hand; and
- If other material defects are found remove the lift and replace.

Should remedial works to minor surface desiccation, swelling or heaving be necessary, the Contractor shall scarify to the required depth and subsequently re-compact with suitable compaction plant in accordance with the Series 600 of the National Highway's "Specification for Highways Works" (SHW)[1]. Any remedial works carried out to the ECL shall be carried out to the full satisfaction of the CQA Engineer.

At locations where the results of the field-testing indicate failure to achieve the required acceptance criteria, the CQA Engineer on the basis of surrounding locations of compliant tests shall determine the extent of the non-compliant area.

Remedial works shall then be undertaken using one of the following procedures:

- Additional compaction of the area;
- Adjustment of the clay moisture content by the addition of water or by scarifying and/ or allowing drying until the required moisture content is obtained, followed by additional compaction as necessary; and
- Removal of the material and replacement with suitable material.

The CQA Engineer shall record all locations/areas of non-compliance together with remedial actions taken and shall not permit placement of a subsequent layer on the area until compliance is achieved.

The CQA Engineer shall inspect the remediated surface for suitability. Level surveys shall be repeated to confirm that the requisite design profile has been achieved.

5.12 Use of High Plasticity Clay

If the source material is of high plasticity, the Contractor must undertake particular care during placement and compaction of the clay. This type of material is prone to form clods which will require more effort to break down to a manageable size. The material may become sticky when wet and may dry out and crack due to hot weather. The CQA Engineer must be aware of the problems associated with the placement of a highly plasticity clay and must check for signs of the problems during inspections.

A. Confirmation of Familiarity with CQA Plan

All listed staff confirm their familiarity with the above Quality Management Document(s) by signing and dating this form against their names. The holder of this document shall also sign to confirm familiarity and to confirm that all appropriate staff responsible to the holder are aware of the document contents. The original signed form shall be retained with the document, and a copy returned to the Company Quality System Manager, for record purposes.

NAME	FUNCTION	SIGNATURE	DATE

B. Daily Summary Report

Date	Location	
Personnel Involved		
Weather Conditions (temp, cloud cover, rainfall)		
Summary of Meetings or Significant Discussions	Actions recommended / taken	
Location on site of Construction undertaken (see attached plan)		
Plant and Personnel being utilised		
Materials supplied to site: Description Quantity		
Details of work accomplished		
Records of observations[3]	Relevant visitors	Signature of CQA Engineer

[3] Observations include: calibrations or recalibrations of test equipment; descriptions of the adequacy of the work; decisions made regarding approval of work and corrective actions required

C. Corrective Measures Report

Identification No:

Date	
Location of Problem (see attached site plan)	
Reason for Failure	Probable Cause
How and when was problem discovered?	
Notes of any communication between Contractor and CQA Engineer about the problem	
Suggestive Corrective Action	Details of Corrective Action Undertaken
How can methodology be altered to prevent recurrence of this problem?	
Signature of CQA Engineer	

D. Formation Acceptance Sheets

Subgrade Formation Acceptance Certificate

<table>
<tr><td>Date:</td><td rowspan="2">Client:</td></tr>
<tr><td>Location:</td></tr>
<tr><td colspan="2">Partial/ Final Acceptance</td></tr>
<tr><td colspan="2">This is to certify that the area of prepared sub-grade on the quarry area indicated on the attached sketch number MM Sketch xxx was jointly inspected by the CQA Engineer, and the Contractor and is suitable for constructing and engineered clay layer.</td></tr>
<tr><td colspan="2">Signed for (Main Contractor)
…….....
Date:
…….

Signed for CQA Engineer
…….....

Date:
…….</td></tr>
<tr><td>Acceptance Number:</td><td>Area accepted: Numbers… to …</td></tr>
</table>