Series 600 EARTHWORKS

Appendix 6/1: Requirements for Acceptability and Testing etc. of Earthworks Materials

1 Acceptability Limits for Fills

Inert Arisings

Inert arisings shall comprise material from the following formations:

- Subsoil and superficial soils – Glacial Till; and
- Sandstone, siltstone and mudstone from Ravenscar Group and Staithes Sandstone Formation.

The maximum particle size for inert spoil to be incorporated in the screening mounds shall be 500mm.

For cohesive arisings the minimum undrained shear strength of material to be incorporated in the mounds is 50kN/m^2.

Liquid waste/slurry shall not be deposited within the spoil mounds.

Inert spoil placed within the spoil mounds shall comply with the requirements of table 6/1A overleaf

Clay Liner

The clay liner shall be constructed from material complying with the requirements for Class 2A, Wet Cohesive Material and the specific limits in table 6/1A overleaf. The method compaction requirements of table 6/1 are deleted and replaced with end product requirements defined in table 6/1A overleaf.

TABLE 6/1A - Acceptable Earthworks Materials : Classification and Compaction Requirements								
CLASS	**GENERAL MATERIAL DESCRIPTION**	**USE**	**PERMITTED CONSTITUENTS (All subject to the requirements of Clause 601 of Materials and Workmanship Specification)**	**MATERIAL PROPERTIES**				**COMPACTION REQUIREMENTS**
				PROPERTY	**TEST**	**LIMITS**		
						LOWER	**UPPER**	
4A	Coarse grained spoil	General Fill	Subsoil and superficial soils – Glacial Till (sand and gravel), arenceous rocks (Sandstone and gritstone) from Ravenscar Group and Staithes Sandstone Formation	Grading	BS 1377: Part 2	-	500mm	6 passes of a vibratory roller with a mass per metre width of roll not less than 3500kg in layers not exceeding 500mm thick[3]
4B	Fine grained spoil	General Fill	Subsoil and superficial soils – Glacial Till (silt and clay), argillceous rocks (siltstone and mudstone) from Ravenscar Group and Staithes Sandstone Formation	Grading	BS 1377: Part 2	-	500mm	6 passes of a vibratory roller with a mass per metre width of roll not less than 3500kg in layers not exceeding 300mm thick[3]
				Undrained shear strength of remoulded material	Clause 633	50kPa	-	
2A	Wet cohesive material	Clay Liner	Any material or combination of materials other than chalk	Grading	BS 1377: Part 2	Table 6/2	Table 6/2	End product. ≥95% of MDD from 2.5kg rammer test and ≤5% air voids.
				Grading	BS 1377: Part 2	≥ 20 % passing 63μm and a minimum clay content (particles < 2 μm) of 8 %.		
				Moisture Content	BS 1377: Part 2	see note 1	see note 1	
				Plastic Limit (PL)	BS 1377: Part 2	-	-	
				Liquid Limit (LL)	BS 1377: Part 2		90	
				Plasticity Index	BS 1377: Part 2	10	65	
				MCV	Clause 632	-	-	
				Undrained shear strength of remoulded material	Clause 633	50kPa	-	
				Remoulded Permeability	BS 1377: Part 6 method 6		1×10^{-9}m/s	

Footnotes to Table 6/1A

1. The acceptable range of moisture content shall be determined from dry density vs moisture content tests to achieve the required compaction requirements
2. Where BS 1377: Part 2 is specified for mc, this shall mean BS 1377: Part 2 or BS EN 1097-5 as appropriate.

Groundwater Drainage Blanket

The groundwater drainage blankets beneath the eastern spoil mound shall be constructed from Type B drainage material in accordance with table 6/1B below compacted in accordance with table 6/4 method 3.

Table 6/1B Requirements for Type B Drainage	
	Type B
Standard	BS EN 13242
Size, mm	20/40
Grading and oversize categories	G_C80-20
Oversize category	-
Category for tolerances at mid-size sieves	GT_{NR} (no requirement)
Category for maximum fines content	f_{NR} (no requirement)
Summary grading requirements	
Sieve size, mm	% passing by mass
80	100
63	98 - 100
40	80 - 99
20	0 - 20
10	0 - 5
4	-
2	-
0.500	-
0.125	-
0.063	-

All site won materials for re-use shall comply with the relevant classes in Table 6/1. Processed material shall be tested for compliance in accordance with Table 1/5 and Table 6/1.

2. Requirements for Determining Acceptability

The Contractor shall be responsible for the classification and determination of acceptability of all earthwork materials.

For site won materials, classification shall be carried out at source.

For imported materials, testing shall be carried out at the point of deposition with the exception of chemical testing which should be undertaken before material is deposited on site. Testing frequencies are given in Table 1/5.

Where materials are to be stockpiled for longer than 14 calendar days, the Contractor shall carry out repeat classification and acceptability testing in accordance with Table 1/5 not more than 3 calendar days prior to their use within the permanent works.

Prior to the excavation and/or placement of materials the Contractor shall provide the Employer's Representative with a copy of the test results relevant to the material that he intends to use and his proposed classification of the material. These results, together with exploratory hole records where relevant, shall be submitted to the Employer's Representative two days prior to excavation / placement. Testing for each material shall be of the frequency stated in Table 1/5. These results shall be submitted together with an updated plan at 1:500 scale showing samples and in-situ test locations.

The Contractor shall keep an updated schedule of both laboratory and in-situ testing. This schedule shall record the following:

a. Sample or test number (a unique reference number);
b. Sample or test location (co-ordinated reference point and reduced level);
c. Description of the material tested;
d. Date sampled;
e. Description of tests to be carried out;
f. Date sample dispatched for testing;
g. Date test result received;
h. Classification of soil in terms of Table 6/1.

This schedule shall be submitted together with an updated plan at 1:500 scale showing the sample and in-situ test locations.

Site Trials for Low Permeability Clay Liner

A site trial shall be performed for the Low Permeability Clay Liner on a part of the site to be agreed with the Employer's Representative, which shall comprise a minimum of two layers over an area of at least 150m^2.

The site trial shall demonstrate to the Employer's Representative satisfaction that:

- the completed section complies with all the requirements of this specification;
- the in-situ testing requirements of can be achieved;
- the testing procedure is adequate;
- the acceptability limits are appropriate;
- the method of backfilling holes created by the testing is adequate;
- the plant is suitable, reliable and of ample production capacity to meet the programme; and
- interlayer bonding is adequate.

Should the Employer's Representative consider that any aspect of the site trial does not comply with the Specification he shall inform the Contractor, who shall

immediately take such steps as shall be required to rectify the situation. The Contractor shall not proceed with the construction of the Low Permeability Liner until the Employer's Representative has given his consent.

During the site trial all the tests shall be performed as for main earthwork construction (Table 1/5A). A minimum of 3 in-situ density (NDG) and on-site moisture content tests and two permeability tests shall be required to demonstrate that the trial pad has achieved the requirements of the Specification. Core cutter samples for permeability testing and verification of in-situ density shall be taken after removal of the top 75mm of the compacted layer. The Employer's Representative shall decide on the additional frequency and number of tests if necessary. All tests made during the site trail shall be exactly as are proposed for quality control testing, or as specified, and the tools and equipment used in testing shall be those to be used for quality control testing.

Any materials placed during the site trial which, in the opinion of the Employer's Representative, do not meet the requirements of the Specification, shall be removed from the area of the liner, and the unsuitable materials shall be replaced by approved suitable material.

A report on the site trial shall be submitted to the Employer's Representative on conclusion of the trial. The report shall state the equipment to be used for placement of the liner fill, the maximum thickness of each layer and the minimum number of passes per layer.

Surveys

Immediately prior to commencing construction of any section of the Clay Liner, the Contractor shall undertake a survey of the formation for the Clay Liner on a 5m x 5m grid.

A further survey shall be carried out "point on point" on the same 5m grid on completion of the final layer of the clay liner in each section.

Validation of Clay Liner

Validation testing shall be carried out by the Contractor in accordance with Table 1/5. The laboratory undertaking testing shall hold current UKAS accreditation for all of the tests being performed.

All tests and samples are to be given a unique reference that allows the sample/test type, the location of the sample or test and the layer number sampled or tested to be identified. The format of sample/test reference numbers is to be agreed with the Employers Representative.

The following meta-data is to be included in the testing report:

- Sample/test reference number
- Sampling/testing date
- Sample/test type
- Sample location to national grid coordinates to 0.1m
- Layer number sampled/tested
- Test type

In the event that any test or inspection reveals that the element tested or inspected does not meet the requirements of the Specification, the following action shall be implemented.

Further tests shall be undertaken to determine the extent of the non-conformance.

If the reason for the non-conformance is low in-situ density, the material shall be compacted by further passes of the roller and retested. If the re-tests meet the required density, the material shall be considered acceptable. If the re-tests fail to achieve the required density the non-conforming material shall be removed, replaced and retested.

If the reason for the failure is the use of unsuitable material, the unsuitable material shall be removed, replaced with suitable material and re-tested.

The reference number of repeat tests is to be suffixed "R" to clearly identify that it is a repeat.

The location and nature of the non-conformance shall be recorded.

Validation Records and Report

The results from in-situ density and moisture content testing shall be submitted to the Employer's Representative daily on the day testing is undertaken.

The results from laboratory tests, with the exception of permeability test results, shall be submitted to the Employer's Representative within 1 week of sampling.

The results from laboratory permeability tests shall be submitted to the Employer's Representative within 3 weeks of sampling.

The results from all tests are to be reported in an Excel spreadsheet that includes all of the meta-data listed above together with the test result. The spreadsheet is to be coded to highlight any test result that exceed the acceptance criteria in Table 6/1A and any test results that are over-due.

The spreadsheet is to be updated by the Contractor on a weekly basis to include the meta-data of all tests and samples taken that week, together with the results of tests completed that week, and is to be submitted to the Employer's Representative on a weekly basis.

The format of the spreadsheet is to be agreed with the Employer's Representative.

The Contractor is to produce a validation report for each section of the clay liner completed incorporating the records from all tests undertaken on the clay liner.

The records shall comprise as a minimum the following:

a. Sources of fill materials
b. Results of earthworks compliance testing.
c. Photographic record of key elements of the works.
d. Details of any non-conformances and details of the remediation procedures and repeat testing results for rectification of the non-conformance.
e. Surveys of formation level and finished liner level on a 5m grid "point on point"

f. Isopachyte drawing(s) showing the thickness of the clay liner.

g. As built drawings of drains and attenuation ponds

The Employer's Representative will be responsible for preparing a detailed Construction Quality Assurance (CQA) report for each stage of the clay liner for submission to the Environment Agency in accordance with the requirements of the site's Environmental Permit.

No non-inert non-hazardous material is to be deposited on top of the clay liner until the CQA report has been approved by the Environment Agency.

3. Designation of Material as Class 3

Not used

4. Requirements for processing to render unacceptable material acceptable

i) U1A unacceptable material requiring processing

Site won materials, including the inert and non-inert arisings for incorporation in the mounds, may be classed as unacceptable due to having natural moisture content too high or undrained shear strength too low to meet the requirements of the Specification, or due to the presence of particles >500mm.

The Contractor shall improve soft or wet material, by processing/sorting, stockpiling and/or lime/lime-cement treatment. Any treatment of class U1 material requiring additives such as lime or cement shall be agreed in advance with the Employer's Representative.

Materials containing particles >500mm shall be processed to reduce the particle size to below 500mm.

If any material cannot be processed to meet the classification of allowed materials then the contractor shall clarify the performance requirements of each earthworks zone with the designer. They may then propose an earthworks trial in order to determine a method to process or place the material in accordance with the design requirements.

The Contractor shall set out proposals of the proposed conditioning processes and provide information to the Employer's Representative to demonstrate the conditioned material meets the requirements of Table 6/1A and Appendix 6/1.

ii) U1B unacceptable material requiring processing

It is not envisaged that U1B materials will be encountered. If visual or olfactory evidence of contamination is observed during the earthworks the procedure outlined in Appendix 6/2 should be followed.

5. Requirements for Groundwater Lowering

Groundwater lowering is not required, however the Contractors attention is drawn to the requirement to construct groundwater drainage blankets beneath parts of the eastern mound due to the presence of springs and seepages. There are no specific

requirements for dewatering other than sump pumping to maintain suitably drained excavations.

The Contractor shall refer to the FWS Consultants Ltd Hydrogeological Baseline Report (May 2016) for information on groundwater levels at the site.

Allow for seasonal variations from recorded levels. Notify the Employer's Representative if the levels encountered vary significantly.

All reasonable measures shall be taken to ensure construction areas shall be kept free of groundwater infiltration and the effects of weather, and that the sub-grade is protected.

6. Lime stabilised Class 9D material

Not used.

7. Acceptability and testing of unburnt colliery spoil

Not used

8. Permitted use of rapid assessment procedure for material acceptability

Where moisture content is specified as the method of material classification and control, the Contractor may use a "rapid" method as an alternative to BS1377: Part 2 method provided that such "rapid" methods are weekly calibrated against conventional BS methods using drying ovens. The Contractor shall submit details of the proposed calibration method to the Employer's Representative for review prior to the start of the earthworks.

9. Requirements for removal off site of excavated material requiring processing or retention of surplus material on site

Material shall not be removed off site for processing.

10. Permitted use of material required to be processed for purposes other than for general fill

Not used.

11. Requirements for In Situ Resistivity Tests

Not used.

12. Requirements for In Situ Redox Potential Tests

Not used.

13. Bearing Ratio Requirements for Class 6R and 7I material

Not used

14. Requirements for the assessment of the effects of water soluble sulphate, oxidisable sulphides and total potential sulphate in accordance with TRL Report 447

Not Used

15. Requirements for the Magnesium Sulphate (MS) Soundness test

Not used.

Appendix 6/2: Requirements for Dealing with Class U2 Unacceptable Material

1. Excavation and disposal unknown Class U1B and U2 material

The ground investigation works have not indicated any areas of potential contamination within the scope of the Site Preparation phase.

On-site soils are considered to be appropriate for re-use on-site without testing provided that they display no visual or olfactory evidence of contamination.

If visual or olfactory evidence of soil or groundwater contamination is encountered as part of the earthworks, the Contractor is to prevent further disturbance of the potentially contaminated area and stockpile any excavated material separately on a clean plastic bunded sheet to prevent surface water run-off. The Contractor shall also inform the Employer's Representative immediately for instructions on how to proceed in this area.

Draw to the attention of all personnel working on the site the nature of possible contamination and the need to take any precautionary measures in handling the material from the ground.

Any material displaying visual or olfactory evidence of contamination will require sampling and testing (at a frequency of 1 sample per $50m^3$) to determine whether the material can be re-used on the site or requires off-site disposal. Following testing, the Contractor shall submit to the Employer's Representative for review proposals for treatment and/ or disposal of contaminated material.

2. Pre-agreed requirements of Environmental Health Officer etc. for disposal including specific sites

Not used.

3. List of known hazardous materials likely to be encountered

The ground investigations have not identified any hazardous materials

4. Methods of excavation, precautions and requirements for handling

If material is suspected of being contaminated material, then it shall be left in place while classification is being carried out i.e. following sampling and testing.

A method statement shall be submitted by the Contractor to the Employer's Representative for review detailing how any contaminated material will be dealt with, including Health and Safety Requirements when dealing with potentially contaminated material.

It is recommended that the risks to construction workers are controlled during construction through use of the following health and safety procedures:

a. Use of protective clothing and equipment;

b. Provision of decontamination facilities;

c. Dust suppression measures during the works;

d. Health and safety training, guidance notes and signs.

Implement appropriate health and safety measures as considered necessary and communicate the need for vigilance to all site staff.

Appropriate PPE should be worn at all times, and a no smoking and a no hand-to-mouth policy should be implemented during the main construction works.

The Contractor should remain vigilant for evidence of asbestos, in particular around existing buildings where cement bonded asbestos has been identified, and should inform the Employer's Representative immediately if asbestos is encountered.

In the event that any possible contamination is identified, draw to the attention of all personnel working on the site its nature and the need to take any precautionary measures in handling the material from the ground. Report and investigate any unusual findings.

5. Special Requirements for dealing with leachate and contaminated water

Groundwater / leachate from any contaminated areas shall not be discharged to public or private surface water or foul sewers, or to watercourses without prior approval from the relevant Authority. Should groundwater or leachate be found in contaminated areas, it shall be contained to prevent contamination of uncontaminated ground, and the sampled and tested prior to disposal subject to the approval of the relevant authority.

6. Requirements for special drainage and for sealing exposed surfaces of contaminated materials

The Contractor shall take appropriate temporary measures to prevent infiltration of gas and leachate into any drainage system, underground services or conduits (natural or built), whether on or off site. The Employer's Representative shall be immediately informed such that appropriate measures can be included within the permanent design.

Appendix 6/3: Requirements for Excavation, Deposition, Compaction (other than dynamic compaction)

1. Earthworks drawings and reports

For earthworks drawings refer to the main contract specification.

Reports

Report Title	Report Reference
FWS Consultants Ltd. Factual Geotechnical Report for the shafts at the Dove's Nest Minehead, North Yorkshire	FINAL DRAFT 1433-01/January 2014
FWS Consultants Ltd. Hydrogeological Baseline Report for the Dove's Nest Minesite, North Yorkshire. 2012 to 2016.	1975OR01Rev.1/May 2016
Factual Report on Trial Pitting Investigations at Doves Nest Minesite	1433/November 2013
Fugro Engineering Services. Dove's Nest Phase 2 Groundwater Monitoring Wells Stage 1 and 2. Factual Report on Ground Investigation.	G131087U September 2014
Fugro Engineering Services Doves Nest Phase 3 Ground Investigation Report On Ground Investigation Without Geotechnical Evaluation	G141038U September 2014
FWS York Potash Ltd. Discharge of Planning Conditions for Planning Application NYM/2014/0676/MEIA, The York Potash Project. Soil Management Plan Rev 5	1433DevOR162Rev5/ December 2016
Dunelm Geotechnical and Environmental Factual Report on Site Investigation for Land at Phase 4 – Stage 1, Dove's Nest Mine Site and Additional MTS Monitoring Boreholes	Final: D6884-1 December 2016.
Arup factual report on ground investigation for Land at Dove's Nest Farm access road cement stabilisation feasibility ground investigation.	Draft: REP-P10-DNF-CG-001

2. Blasting for excavation

Not used.

3. Cutting faces

Not used

4. Watercourses (ditches, filter drains, existing ponds and streams)

The Contractor shall provide adequate drainage for all earthworks.

The Contractors particular attention is drawn to the potential for encountering natural springs within the eastern area of the site. Where springs or seepages are encountered, granular drainage blankets are to be provided in accordance with the contract drawings.

No unauthorised discharge shall be made to any watercourse on or adjacent to the site. Discharge of temporary drainage shall be controlled to meet environmental standards.

5. Embankment construction

The Contractor's particular attention is drawn to Clause 608 (Construction of Fills) of the Specification for Highway Works. The works shall be protected against weather in accordance with the relevant sub-clauses.

Embankments shall be constructed with the slopes shown on the drawings. Temporary slopes shall not be constructed with steeper gradients than 1:3 (v:h), except in those cases detailed in Clause 608.5 or the contract drawings.

Haulage of fill material shall proceed only when sufficient spreading and compaction plant is operating at the place of deposition to ensure compliance with the requirements of this specification.

Embankments – Deposition of Inert Arisings

Inert arisings shall be deposited and compacted in layers to the requirements of table 6/1A.

Adequate means shall be provided for control of water shed onto the embankment layers. This shall include:

- forming slopes with appropriate falls, gradient and sealed surfaces;
- providing, where necessary, temporary watercourses, drains, pumping and the like;
- providing adequate means for preventing silt discharge into watercourses.

At the end of each working day, the surface of the layer shall be rolled to achieve a smooth, sealed surface.

The final surface of the inert material shall be scarified prior to replacing subsoil and topsoil.

Construction of Clay Liner

A clay liner shall be constructed in the areas indicated on the contract drawings to a minimum thickness of 1m + 2x the tolerance of the survey equipment being used to survey the formation and top of liner levels (for example, if the accuracy of the survey equipment is +/- 15mm, the minimum thickness of the liner shall be 1030mm).

All material to be used in construction of the clay liner shall be Class 2A material, with a minimum undrained shear strength Cu=50kPa (Table 6/1A).

The liner shall be constructed by spreading and compacting suitable material in layers. The thickness of layers and the number of passes of the compaction plant shall be determined from the site trial.

Compaction of the clay liner shall be carried out using the same compaction plant used in the site trial. Should the Contractor wish to use alternative plant the site trial shall be repeated.

Prior to placing successive layers of clay, the surface of the preceding layer shall be inspected by the Employer's Representative. Watering and/or scarified shall then be undertaken as necessary to ensure a homogeneous seal without incorporating dry or desiccated layers.

If the material to be placed is in, or reaches a condition such that it cannot be compacted in accordance with this specification, the Contractor shall do one of the following:

- Make good by removing the material either to tip or elsewhere until it is in a suitable condition for re-use and replacing it with suitable material;
- Make good the material by wetting or drying;
- Cease work on the material until its physical condition is such that it can again be compacted in accordance with the agreed procedure.

Groundwater Drainage Blankets

The drainage blanket layout should be as shown on the contract drawings listed in Appendix 6/5.

The drainage blankets shall be constructed from Type B Filter Material in accordance with SHW, Clause 505, Table 5/5 (reproduced herein as Table 6/1B), placed and compacted in layers.

6. Compaction

The Contractor's particular attention is drawn to Clause 612 (Compaction of Fills) of the Specification for Highway Works.

Where Class U1A material has been rendered suitable for use, and reclassified, the method of compaction shall be as set out in Table 6/1A based upon the revised material classification.

Inert Arisings

Inert spoil that is granular in nature is to be spread in layers not exceeding 500mm thick and compacted by not less than 6 passes of a vibratory roller with a mass per metre width of roll not less than 3500kg.

Inert spoil that is cohesive in nature shall be placed in layers not exceeding 300mm thick, compacted as above.

The final surface of the inert material shall be scarified prior to replacing subsoil and topsoil.

Low Permeability Clay Liner

Compaction requirements shall be confirmed following field compaction trials.

The low permeability basal layer shall be compacted to achieve a dry density of ≥95% of the maximum dry density (2.5kg rammer test) with air voids of ≤5% and permeability ≤ 1 x 10^{-9}m/s.

Non-Inert Non-Hazardous Arisings with low polluting potential

Spoil that is granular in nature is to be spread in layers not exceeding 500mm thick and compacted by not less than 6 passes of a vibratory roller with a mass per metre width of roll not less than 3500kg.

Spoil that is cohesive in nature shall be placed in layers not exceeding 300mm thick, compacted as above.

The material placed in the final 1m shall be classified by the Contractor as Class 1A, 1B, 1C, 2A, 2B or 2C based on its grading in accordance with Table 6/1, and compacted in accordance with Table 6/4 for the relevant class of material.

Drainage Blanket

The drainage material shall be placed and compacted in accordance with method 3 of table 6/4.

7. Excavation

Topsoil is to be stripped from beneath all permanent and temporary spoil bunds. All topsoil shall be stockpiled on site for re-use prior to further earthworks operations. Refer to the Soil Management Plan (FWS Consultants, 2017, Ref. 1433DevOR162).

Subsoil is to be stripped from beneath the working platforms, access road and beneath permanent bunds. Where subsoil is stripped, the depth of subsoil to be removed shall be not less than 500mm. Upper subsoil (true subsoil comprising weathered material found directly beneath topsoil) shall be stripped and stockpiled separately from lower subsoil (un-weathered glacial soils).

All subsoil shall be stockpiled on site for re-use in restoration of the spoil mounds and screening bunds. Refer to the Soil Management Plan.

Excavation of topsoil and subsoil is to be carried out in accordance with the Archaeological Written Scheme of Investigation (Cotswold Archaeology 2016,Ref. 660829/D).

8. Limiting distance for deposition of materials

Not used.

9. Excavations to be battered and requirements for benching

If, during filling the difference in level between adjacent areas of filling exceeds 500mm, cut into edge of higher filling to form benches 500mm minimum width and height equivalent to depth of a layer of compacted filling.

Spread and compact fill to ensure maximum continuity with previous filling.

10. Excavation supports

Excavation supports are not required for the permanent works, although the Contractor must comply with the requirements of the Health and Safety Executive when excavating trenches or openings, and such excavations must be supported.

11. Benching and shaping of slopes

Before placing material on sloping ground with a gradient in steeper than 20% benches shall be cut into existing slopes with a minimum depth of 500mm in order to provide a key for the overlying material.

12. Fill levels for corrugated steel buried structures

Not used.

13. Protection layers over corrugated steel buried structures

Not used.

14. Mixing of acceptable and unacceptable materials

Unacceptable and acceptable materials shall be excavated and stored separately.

15. Fill where ST1 concrete is not required

Not used.

16. Additional requirements for corrugated steel buried structures

Not used.

Appendix 6/5: Geotextiles used to separate earthworks materials

1. Drawing references for location where geotextiles are to be used in separation layers

Geotextile separator layers are to be placed above and below the groundwater drainage layers as shown on drawing 40-ARI-WS-71-CI-DR-1080 in the locations shown in the contract drawings.

2. Whether the geotextiles are to be of synthetic or other fibres

Geotextile Separators

Geotextile separator layers are required above and below the drainage blankets at the base of the spoil mounds.

The geotextile separator layers shall comprise non-woven geotextiles manufactured from prime quality virgin polypropylene or polyethylene fibres.

Geotextiles may be needle punched or thermally bonded and shall be CE certified for a design life in excess of 100 years.

Geotextiles shall be manufactured under factory production control in accordance with EN 13257.

Geotextiles shall have the following properties:

Material Property	Test Method	Units	Minimum Value	Allowable tolerance
Burst Resistance	EN ISO 13433	kPa	500	-10%
Tensile Strength	EN ISO 10319:2008	kPa	250	- 10%
Puncture Resistance	EN ISO 12236	N	75	- 10%
Transverse Permeability	EN ISO 11058	$l/m^2/s$	100	- 10%
Durability				
Resistance to Oxidation (150 Years)	EN 12225	Retained Strength after 84 days		>80%
Microbiological Resistance	EN ISO 12225	Retained Strength		>80%

General

The geotextile manufacturers shall supply production test certificates on mechanical properties at a frequency not less than one set of tests per $5000m^3$ delivered.

Test certificates that demonstrate the durability requirements are satisfied for the materials supplied are to be supplied prior to the materials being incorporated into the works.

Test methods shall be as per the above specification and the testing laboratory must be UKAS accredited to carry out the tests. Test certificates are to be supplied to the Engineer prior to materials being incorporated in the works.

Details of proposed geotextiles are to be supplied to the Employer's Representative for approval prior to incorporation in the Works.

3. Handling and Deployment of Geotextiles

Geotextiles shall be delivered in packaging that protects the material from UV light and shall be kept in packaging until required for installation. The packaging and geotextile shall be clearly marked with the product name in accordance with EN 150 10320.

The rolls of geotextiles shall be stored on level ground and stacked not more than four rolls high and no other materials shall be stacked on top of the geotextiles.

Roll dimensions and weights will vary with the dimensions of the product ordered. It is necessary to support this weight during transport across the site using an appropriate core pipe. Lifting chains or straps appropriately rated to the weight of the geotextile roll shall be used in combination with a spreader bar. A front end loader, backhoe, dozer, or other equipment can be utilised with the spreader bar and core pipe or slings. Alternatively a forklift with a "stinger" attachment may be used for on-site handling. A forklift without a stinger attachment shall not be used to lift or handle the geotextile rolls.

The geotextiles shall be laid in continuous contact with the underlying layer and shall not be stretched or bridged over hollows or humps. The surface onto which geotextiles are placed shall be free from stones sharp objects or other deleterious material that could damage the geotextile. All protrusions extending more than 12mm from the subgrade surface shall be removed, crushed, or pushed into the surface with a smooth drum compactor. Joints shall be formed by overlapping in accordance with manufacturer's instructions, a copy of which shall be supplied to the Employer's Representative prior to deployment.

Geotextile rolls shall be taken to the work area of the site in their original packaging. The orientation of the geotextile (i.e. which side faces up) may be important if the geotextile is a composite of different materials or types of geotextile. Geotextiles shall be laid and installed in the positions and to the line and levels described on the drawings. Construction plant must not operate directly on the geotextiles. Equipment which could damage the geotextile shall not be allowed to travel directly on it. When placing material on top of geotextiles, delivery and excavation plant shall operate on a minimum layer of 1m of cover.

Only as much geotextile as can as can be covered at the end of the working day shall be deployed. The geotextile shall not be left uncovered overnight.

Appendix 6/7: Sub-formation and Capping and Preparation and Surface Treatment of Formation

1. Drawing references for capping

Not used

2. Surface level tolerance

Preparation and surface treatment of sub-formation, including tolerances, shall be in accordance with Clause 616.1 as for formation.

3. Permitted classes of capping singly and in combination

Not used

4. Cuttings and embankment – procedures for construction of capping

Reference Clause 613.11 and 613.12

5. Demonstration Areas

Not used.

6. Drawing references for sub-formation requirements

Reference Clause 613.8

7. Lime stabilisation

Not used.

8. Treatment of formation

Formation to Spoil Mounds

The final excavation to formation level shall be carried out immediately before placing any fill to prevent weathering of the contact surface.

The formation shall be proof rolled tested and inspected for evidence of soft spots. Proof rolling of formation shall be carried out with a vibratory roller of minimum mass per metre length of vibratory roll of 1800kg.

The minimum undrained shear strength at formation level to the mounds shall be 50kN/m^2.

Hand shear vane testing is to be carried out (test carried out in general accordance with BS1377-9) at formation level on a 10m x 10m grid to verify that the design formation strength is achieved and the results of the tests are to be submitted to the Employer's Representative prior to the formation being covered.

Any soft materials with undrained strength below 50kN/m^2 are to be excavated until material with the required strength is reached.

These materials shall be deposited in a stockpile(s) away from any acceptable material to be used for engineering fill.

Following completion of surface preparation, a visual inspection shall be undertaken by the Employer's Representative to confirm the overall suitability of the formation.

Once the formation has been exposed, the Contractor shall be responsible for maintaining it in the condition in which it was approved by the Employer's Representative. Exposed areas of formation should be kept to a minimum and should be covered quickly to avoid deterioration from adverse weather. If at any time the formation becomes softened due to precipitation, it shall be stripped by at least 50 mm to expose a competent formation that shall be re-compacted.

Formation acceptance will be withdrawn by the Employer's Representative should deterioration occur subsequent to the initial acceptance.

It shall be the responsibility of the Contractor to rectify any deterioration of the formation which occurs, and construction of the next layer shall not commence until the remediated formation has been re-inspected and accepted by the Employer's Representative.

Where required, further cut or fill shall take place to achieve the levels shown on the Contract Drawings.

Formation to Clay Liner

Prior to construction of the clay liner, the formation beneath the liner shall be firm, smooth and free from water, slurry cracks, voids debris and stones or any other deleterious material.

The minimum undrained shear strength at formation level to the clay liner shall be $50kN/m^2$.

Hand vane testing is to be carried out at formation level on a 10m x 10m grid to verify that the design formation strength is achieved and re results of the tests are to be submitted to the Employer's Representative prior to the formation being covered.

Any areas where the undrained strength is below $50kN/m^2$ are to be excavated and replaced with class 2A material in accordance with the requirements for the clay liner.

Where the formation is below original ground level, the final excavation to formation level shall be carried out immediately before placing any fill to prevent weathering of the contact surface.

The formation shall be proof rolled tested and inspected for evidence of soft spots. Proof rolling of formation shall be carried out with a vibratory roller of minimum mass per metre length of vibratory roll of 1800kg.

Following completion of surface preparation, a visual inspection shall be undertaken by the Employer's Representative to confirm the overall suitability of the formation.

Once the formation has been exposed, the Contractor shall be responsible for maintaining it in the condition in which it was approved by the Employer's

Representative. Exposed areas of formation should be kept to a minimum and should be covered quickly to avoid deterioration from adverse weather. If at any time the formation becomes softened due to precipitation, it shall be stripped by at least 50 mm to expose a competent formation that shall be re-compacted.

Formation acceptance will be withdrawn by the Employer's should deterioration occur subsequent to the initial acceptance.

It shall be the responsibility of the Contractor to rectify any deterioration of the formation which occurs, and construction of the next layer shall not commence until the remediated formation has been re-inspected and accepted by the Employer's Representative.

9. Testing for rate of spread of lime

Not used.

10. Chemical analysis reports

If lime is to be used, chemical analysis reports should be prepared in accordance with Clause 615.4 of the Specification.

11. Preparation of formation on existing sub-base material

Not used.

12. Requirement for Cement type in lime cement stabilisation

Clause 643.5 shall apply if to be used.

13. Requirements for alternative thickness of layers to be stabilised

Not used.

14. Alternative treatment requirements for layers to be stabilised

Not used.

Appendix 6/8: Topsoiling

1. Drawings references for topsoiling

Topsoiling and subsoiling is required on all spoil mounds shown on drawing shown on the contract drawings.

2. Height limits of topsoil stockpiles

Topsoil stockpiles shall not exceed 3m high. Subsoil stockpiles shall not exceed 7m high.

3. Period of time for topsoil stockpiles

Refer to clause 602.10.

Temporary stockpiles that are to be in place for more than 3 months are to be grass seeded.

The Contractors particular attention is drawn to restrictions on the timing of soil stripping, soil placement and landscaping stipulated in the Environmental Statement and by any Planning Conditions.

4. Handling Topsoil and Subsoil

Topsoil and subsoil shall be stripped, handled, stored and replaced in accordance with the Good Practice Guide for Handling Soils (MAFF April 2000) and the Construction Code of Practice for the Sustainable Use of Soils on Construction Sites (Defra 2009).

Topsoil, upper sub-soil (weathered material found directly below topsoil) and lower subsoil (unweathered glacial soils) shall be stripped and stockpiled separately.

Restoration soil thicknesses shall be as follows:

- Woodland areas over inert fill where no geo-composite drainage layer is required: 300mm topsoil over 400mm upper subsoil over 500mm lower subsoils, to form a total rootable depth of 1200mm. The surface of underlying substrate to be scarified to 200mm depth prior to subsoil spreading, to provide a key and reduce potential for a root pan to form;
- Woodland areas over non-hazardous non-inert material: 300mm topsoil over 400mm upper subsoil on 1300mm lower subsoils, to form a total rootable depth of 2000mm. The proportionate depth of upper and lower subsoils may be varied depending on availability of each type of subsoil but the overall 2000mm rootable depth would be maintained;
- Mixed scrub/ grassland areas – 300mm upper subsoil over 300mm lower subsoil, with a mosaic of 50% cover of topsoiled (average 300mm deep) and non-topsoiled areas

Species-rich grassland areas – 300mm topsoil over 200mm upper subsoil, to form a total rootable depth of 500mm.

Appendix 6/9: Earthwork Environmental Bunds, Landscape Areas, Strengthened Embankments

1. Earthwork Environmental Mounds

The locations of earthworks bunds are shown on the contract drawings. The noise bunds are to be constructed using acceptable materials in accordance with Appendix 6/1 placed and compacted in accordance with Appendix 6/3.

2. Landscape Areas

The Contractor should refer to the contract drawings.

3. Strengthened Embankments

Not used

Appendix 6/14: Groundwater Drainage Pipes

All pipe work shall comprise 225mm OD SDR 11 PE80 HDPE to the detail shown on the contract drawings. Perforated pipe work should be perforated with not less than 200mm² of perforations per metre length of pipe. Perforations shall not reduce the pipe stiffness by more than 5%. Pipes should be laid on sand bedding.

All HDPE perforated and plain pipe work shall be butt fusion welded or coupled using electrofusion couplers. All butt-welded HDPE pipes are to be welded using the correct equipment and procedures and conforming to the requirements of DVS 2207 and DVS 2208, under environmental conditions compatible with producing satisfactory joints.

If the Contractor considers that the position of any site welded joint prevents difficulties such that the quality of the weld is likely to be impaired he shall notify the Employer's Representative. Where practicable, the position of the joint shall be modified, e.g. by cutting the pipes and introducing a short section of pipe so that access to the new joints is adequate, or by temporary removal of pipe supports or other items. Any such modification shall be agreed.

The welding area shall be protected from inclement weather conditions.

All welding machines shall be capable of rigidly clamping and aligning pipe and/or fittings, in situ machining surfaces to be welded and applying appropriate end loads during welding without damage to or distortion of the work.

Except when otherwise agreed, on the evidence of prior satisfactory work, the Contractor shall make suitable test pieces simulating shop and site weld procedures using the welding equipment and power supplies to be used in the contract. All tests shall be made in the presence of the Employer's Representative. Test welds for pipe butt welds shall be made between lengths of pipe not less than 200mm long.

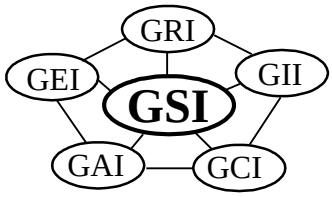
All test pieces shall be submitted to the Employer's Representative for visual examination, and if acceptable the Contractor shall arrange for destructive testing. This shall include, as appropriate, pressure testing, tensile testing, sectioning and polishing and ultrasonic examination. When required by the Employer's Representative the Contractor shall provide test certificates from an independent test laboratory showing that the performance of the welded pipe complies with the requirements of DIN 16963:Part 2.

All welders shall be experienced in carrying out the type of work involved in the Contract. Representative test pieces are required to prove the competence of each welder unless evidence of prior satisfactory work is accepted by the Employer's Representative.

APPENDIX 6

HDPE STANDARD GRI GM13

Geosynthetic Institute
475 Kedron Avenue
Folsom, PA 19033-1208 USA



Revision 14: January 6, 2016
Revision schedule on pg. 11

GRI Test Method GM13*

Standard Specification for

"Test Methods, Test Properties and Testing Frequency for
High Density Polyethylene (HDPE) Smooth and Textured Geomembranes"

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

1.1 This specification covers high density polyethylene (HDPE) geomembranes with a formulated sheet density of 0.940 g/ml, or higher, in the thickness range of 0.75 mm (30 mils) to 3.0 mm (120 mils). Both smooth and textured geomembrane surfaces are included.

1.2 This specification sets forth a set of minimum, physical, mechanical and chemical properties that must be met, or exceeded by the geomembrane being manufactured. In a few cases a range is specified.

1.3 In the context of quality systems and management, this specification represents manufacturing quality control (MQC).

Note 1: Manufacturing quality control represents those actions taken by a manufacturer to ensure that the product represents the stated objective and properties set forth in this specification.

1.4 This standard specification is intended to ensure good quality and performance of HDPE geomembranes in general applications, but is possibly not adequate for the complete specification in a specific situation. Additional tests, or more restrictive

*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

values for test indicated, may be necessary under conditions of a particular application.

Note 2: For information on installation techniques, users of this standard are referred to the geosynthetics literature, which is abundant on the subject.

2. Referenced Documents

2.1 ASTM Standards

D 792 Specific Gravity (Relative Density) and Density of Plastics by Displacement
D 1004 Test Method for Initial Tear Resistance of Plastics Film and Sheeting
D 1238 Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
D 1505 Test Method for Density of Plastics by the Density-Gradient Technique
D 1603 Test Method for Carbon Black in Olefin Plastics
D 3895 Test Method for Oxidative Induction Time of Polyolefins by Thermal Analysis
D 4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
D 4833 Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products
D 5199 Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes
D 5397 Procedure to Perform a Single Point Notched Constant Tensile Load – (SP-NCTL) Test: Appendix
D 5596 Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
D 5721 Practice for Air-Oven Aging of Polyolefin Geomembranes
D 5885 Test method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Calorimetry
D 5994 Test Method for Measuring the Core Thickness of Textured Geomembranes
D 6370 Standard Test Method for Rubber-Compositional Analysis by Thermogravimetry (TGA)
D 6693 Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes
D 7238 Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus
D 7466 Test Method for Measuring the Asperity Height of Textured Geomembranes

2.2 GRI Standards

GM10 Specification for the Stress Crack Resistance of Geomembrane Sheet

2.3 U. S. Environmental Protection Agency Technical Guidance Document "Quality Control Assurance and Quality Control for Waste Containment Facilities," EPA/600/R-93/182, September 1993, 305 pgs.

3. Definitions

Manufacturing Quality Control (MQC) - A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract specifications.
ref. EPA/600/R-93/182

Manufacturing Quality Assurance (MQA) - A planned system of activities that provides assurance that the materials were constructed as specified in the certification documents and contract specifications. MQA includes manufacturing facility inspections, verifications, audits and evaluation of the raw materials (resins and additives) and geosynthetic products to assess the quality of the manufactured materials. MQA refers to measures taken by the MQA organization to determine if the manufacturer is in compliance with the product certification and contract specifications for the project.
ref. EPA/600/R-93/182

Formulation, n - The mixture of a unique combination of ingredients identified by type, properties and quantity. For HDPE polyethylene geomembranes, a formulation is defined as the exact percentages and types of resin(s), additives and carbon black.

4. Material Classification and Formulation

4.1 This specification covers high density polyethylene geomembranes with a formulated sheet density of 0.940 g/ml, or higher. Density can be measured by ASTM D1505 or ASTM D792. If the latter, Method B is recommended.

4.2 The polyethylene resin from which the geomembrane is made will generally be in the density range of 0.932 g/ml or higher, and have a melt index value per ASTM D1238 of less than 1.0 g/10 min.

4.3 The resin shall be virgin material with no more than 10% rework. If rework is used, it must be a similar HDPE as the parent material.

4.4 No post consumer resin (PCR) of any type shall be added to the formulation.

5. Physical, Mechanical and Chemical Property Requirements

5.1 The geomembrane shall conform to the test property requirements prescribed in Tables 1 and 2. Table 1 is for smooth HDPE geomembranes and Table 2 is for single and double sided textured HDPE geomembranes. Each of the tables are given in English and SI (metric) units. The conversion from English to SI (metric) is soft.

Note 3: The tensile strength properties in this specification were originally based on ASTM D 638 which uses a laboratory testing temperature of 23°C ± 2°C. Since ASTM Committee D35 on Geosynthetics adopted ASTM D 6693 (in place of D 638), this GRI Specification followed accordingly. The difference is that D 6693 uses a testing temperature of 21°C ± 2°C. The numeric values of strength and elongation were not changed in this specification. If a dispute arises in this regard, the original temperature of 23°C ± 2°C should be utilized for testing purposes.

Note 4: There are several tests often included in other HDPE specifications which are omitted from this standard because they are outdated, irrelevant or generate information that is not necessary to evaluate on a routine MQC basis. The following tests have been purposely omitted:

- Volatile Loss
- Dimensional Stability
- Coeff. of Linear Expansion
- Resistance to Soil Burial
- Low Temperature Impact
- ESCR Test (D 1693)
- Wide Width Tensile
- Water Vapor Transmission
- Water Absorption
- Ozone Resistance
- Modulus of Elasticity
- Hydrostatic Resistance
- Tensile Impact
- Field Seam Strength
- Multi-Axial Burst
- Various Toxicity Tests

Note 5: There are several tests which are included in this standard (that are not customarily required in other HDPE specifications) because they are relevant and important in the context of current manufacturing processes. The following tests have been purposely added:

- Oxidative Induction Time
- Oven Aging
- Ultraviolet Resistance
- Asperity Height of Textured Sheet (see Note 6)

Note 6: The minimum average value of asperity height does not represent an expected value of interface shear strength. Shear strength associated with geomembranes is both site-specific and product-specific and should be determined by direct shear testing using ASTM D5321/ASTM D6243 as prescribed. This testing should be included in the particular site's CQA conformance testing protocol for the geosynthetic materials involved, or formally waived by the Design Engineer, with concurrence from the Owner prior to the deployment of the geosynthetic materials.

Note 7: There are other tests in this standard, focused on a particular property, which are updated to current standards. The following are in this category:

- Thickness of Textured Sheet
- Puncture Resistance
- Stress Crack Resistance
- Carbon Black Dispersion (In the viewing and subsequent quantitative interpretation of ASTM D 5596 only near spherical agglomerates shall be included in the assessment).

5.2 The values listed in the tables of this specification are to be interpreted according to the designated test method. In this respect they are neither minimum average roll values (MARV) nor maximum average roll values (MaxARV).

5.3 The properties of the HDPE geomembrane shall be tested at the minimum frequencies shown in Tables 1 and 2. If the specific manufacturer's quality control guide is more stringent and is certified accordingly, it must be followed in like manner.

Note 8: This specification is focused on manufacturing quality control (MQC). Conformance testing and manufacturing quality assurance (MQA) testing are at the discretion of the purchaser and/or quality assurance engineer, respectively.

6. Workmanship and Appearance

6.1 Smooth geomembrane shall have good appearance qualities. It shall be free from such defects that would affect the specified properties of the geomembrane.

6.2 Textured geomembrane shall generally have uniform texturing appearance. It shall be free from agglomerated texturing material and such defects that would affect the specified properties of the geomembrane.

6.3 General manufacturing procedures shall be performed in accordance with the manufacturer's internal quality control guide and/or documents.

7. MQC Sampling

7.1 Sampling shall be in accordance with the specific test methods listed in Tables 1 and 2. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width.

7.2 The number of tests shall be in accordance with the appropriate test methods listed in Tables 1 and 2.

7.3 The average of the test results should be calculated per the particular standard cited and compared to the minimum value listed in these tables, hence the values listed are the minimum average values and are designated as "min. ave."

8. MQC Retest and Rejection

8.1 If the results of any test do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

9. Packaging and Marketing

9.1 The geomembrane shall be rolled onto a substantial core or core segments and held firm by dedicated straps/slings, or other suitable means. The rolls must be adequate for safe transportation to the point of delivery, unless otherwise specified in the contract or order.

10. Certification

10.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

ENGLISH UNITS

Table 1(a) – High Density Polyethylene (HDPE) Geomembrane -Smooth

Properties	Test Method	Test Value							Testing Frequency (minimum)
		30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness (min. ave.)	D5199	nom.	nom.	nom.	nom.	nom.	nom.	nom.	Per roll
• lowest individual of 10 values		-10%	-10%	-10%	-10%	-10%	-10%	-10%	
Formulated Density mg/l (min.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	200,000 lb
Tensile Properties *(1)* (min. ave.)	D 6693								20,000 lb
• yield strength	Type IV	63 lb/in.	84 lb/in.	105 lb/in.	126 lb/in.	168 lb/in.	210 lb/in.	252 lb/in.	
• break strength		114 lb/in.	152 lb/in.	190 lb/in.	228 lb/in.	304 lb/in.	380 lb/in.	456 lb/in.	
• yield elongation		12%	12%	12%	12%	12%	12%	12%	
• break elongation		700%	700%	700%	700%	700%	700%	700%	
Tear Resistance (min. ave.)	D 1004	21 lb	28 lb	35 lb	42 lb	56 lb	70 lb	84 lb	45,000 lb
Puncture Resistance (min. ave.)	D 4833	54 lb	72 lb	90 lb	108 lb	144 lb	180 lb	216 lb	45,000 lb
Stress Crack Resistance *(2)*	D5397 (App.)	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	per GRI-GM10
Carbon Black Content (range)	D 4218 *(3)*	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	20,000 lb
Carbon Black Dispersion	D 5596	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(5)*									200,000 lb
(a) Standard OIT	D 3895	100 min.	100 min.	100 min.	100 min.	100 min.	100 min.	100 min.	
— or —									
(b) High Pressure OIT	D 5885	400 min.	400 min.	400 min.	400 min.	400 min.	400 min.	400 min.	
Oven Aging at 85°C *(5), (6)*	D 5721								
(a) Standard OIT (min. ave.) - % retained after 90 days	D 3895	55%	55%	55%	55%	55%	55%	55%	per each formulation
— or —									
(b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5885	80%	80%	80%	80%	80%	80%	80%	
UV Resistance *(7)*	D 7238								
(a) Standard OIT (min. ave.)	D 3895	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	per each formulation
— or —									
(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(9)*	D 5885	50%	50%	50%	50%	50%	50%	50%	

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 1.3 inches
Break elongation is calculated using a gage length of 2.0 in.

(2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(3) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

SI (METRIC) UNITS

Table 1(b) – High Density Polyethylene (HPDE) Geomembrane - Smooth

Properties	Test Method	Test Value							Testing Frequency (minimum)
		0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	
Thickness - mils (min. ave.) • lowest individual of 10 values	D5199	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	per roll
Formulated Density (min.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	90,000 kg
Tensile Properties *(1)* (min. ave.) • yield strength • break strength • yield elongation • break elongation	D 6693 Type IV	 11 kN/m 20 kN/m 12% 700%	 15 kN/m 27 kN/m 12% 700%	 18 kN/m 33 kN/m 12% 700%	 22 kN/m 40 kN/m 12% 700%	 29 kN/m 53 kN/m 12% 700%	 37 kN/m 67 kN/m 12% 700%	 44 kN/m 80 kN/m 12% 700%	9,000 kg
Tear Resistance (min. ave.)	D 1004	93 N	125 N	156 N	187 N	249 N	311 N	374 N	20,000 kg
Puncture Resistance (min. ave.)	D 4833	240 N	320 N	400 N	480 N	640 N	800 N	960 N	20,000 kg
Stress Crack Resistance *(2)*	D 5397 (App.)	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	per GRI GM-10
Carbon Black Content - %	D 4218 *(3)*	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	9,000 kg
Carbon Black Dispersion	D 5596	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) *(5)* (a) Standard OIT — or — (b) High Pressure OIT	 D 3895 D 5885	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	90,000 kg
Oven Aging at 85°C *(5), (6)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	per each formulation
UV Resistance *(7)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(9)*	D 7238 D 3895 D 5885	 N. R. *(8)* 50%	 N.R. *(8)* 50%	 N.R. *(8)* 50%	 N.R. *(8)* 50%	 N.R. *(8)* 50%	 N.R. *(8)* 50%	 N.R. *(8)* 50%	per each formulation

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction
Yield elongation is calculated using a gage length of 33 mm
Break elongation is calculated using a gage length of 50 mm

(2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(3) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

ENGLISH UNITS

Table 2(a) – High Density Polyethylene (HDPE) Geomembrane - Textured

Properties	Test Method	Test Value							Testing Frequency (minimum)
		30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness mils (min. ave.) • lowest individual for 8 out of 10 values • lowest individual for any of the 10 values	D 5994	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	per roll
Asperity Height mils (min. ave.)	D 7466	16 mil	16 mil	16 mil	16 mil	16 mil	16 mil	16 mil	every 2nd roll *(1)*
Formulated Density (min. ave.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	200,000 lb
Tensile Properties (min. ave.) *(2)* • yield strength • break strength • yield elongation • break elongation	D 6693 Type IV	 63 lb/in. 45 lb/in. 12% 100%	 84 lb/in. 60 lb/in. 12% 100%	 105 lb/in. 75 lb/in. 12% 100%	 126 lb/in. 90 lb/in. 12% 100%	 168 lb/in. 120 lb/in. 12% 100%	 210 lb/in. 150 lb/in. 12% 100%	 252 lb/in. 180 lb/in. 12% 100%	20,000 lb
Tear Resistance (min. ave.)	D 1004	21 lb	28 lb	35 lb	42 lb	56 lb	70 lb	84 lb	45,000 lb
Puncture Resistance (min. ave.)	D 4833	45 lb	60 lb	75 lb	90 lb	120 lb	150 lb	180 lb	45,000 lb
Stress Crack Resistance *(3)*	D 5397 (App.)	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	per GRI GM10
Carbon Black Content (range)	D 4218 *(4)*	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	20,000 lb
Carbon Black Dispersion	D 5596	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(6)* (a) Standard OIT — or — (b) High Pressure OIT	 D 3895 D 5885	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	200,000 lb
Oven Aging at 85°C *(6), (7)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	per each formulation
UV Resistance *(8)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(10)*	D 7238 D 3895 D 5885	 N.R. *(9)* 50%	 N.R. *(9)* 50%	 N.R. *(9)* 50%	 N.R. *(9)* 50%	 N.R. *(9)* 50%	 N.R. *(9)* 50%	 N.R. *(9)* 50%	per each formulation

(1) Alternate the measurement side for double sided textured sheet

(2) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 1.3 inches
Break elongation is calculated using a gage length of 2.0 inches

(3) P-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.
The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(4) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(8) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(9) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(10) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Table 2(b) – High Density Polyethylene (HDPE) Geomembrane - Textured

Properties	Test Method	Test Value							Testing Frequency (minimum)
		0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	
Thickness mils (min. ave.) • lowest individual for 8 out of 10 values • lowest individual for any of the 10 values	D 5994	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	per roll
Asperity Height mils (min. ave.)	D 7466	0.40 mm	0.40 mm	0.40 mm	0.40 mm	0.40 mm	0.40 mm	0.40 mm	every 2nd roll *(1)*
Formulated Density (min. ave.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	90,000 kg
Tensile Properties (min. ave.) *(2)* • yield strength • break strength • yield elongation • break elongation	D 6693 Type IV	 11 kN/m 8 kN/m 12% 100%	 15 kN/m 10 kN/m 12% 100%	 18 kN/m 13 kN/m 12% 100%	 22 kN/m 16 kN/m 12% 100%	 29 kN/m 21 kN/m 12% 100%	 37 kN/m 26 kN/m 12% 100%	 44 kN/m 32 kN/m 12% 100%	9,000 kg
Tear Resistance (min. ave.)	D 1004	93 N	125 N	156 N	187 N	249 N	311 N	374 N	20,000 kg
Puncture Resistance (min. ave.)	D 4833	200N	267 N	333 N	400 N	534 N	667 N	800 N	20,000 kg
Stress Crack Resistance *(3)*	D 5397 (App.)	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	per GRI GM10
Carbon Black Content (range)	D 4218 *(4)*	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	9,000 kg
Carbon Black Dispersion	D 5596	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) *(6)* (a) Standard OIT — or — (b) High Pressure OIT	 D 3895 D 5885	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	90,000 kg
Oven Aging at 85°C *(6), (7)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	per each formulation
UV Resistance *(8)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(10)*	D 7238 D 3895 D 5885	 N.R. *(9)* 50%	 N.R. *(9)* 50%	 N.R. *(9)* 50%	 N.R. *(9)* 50%	 N.R. *(9)* 50%	 N.R. *(9)* 50%	 N.R. *(9)* 50%	per each formulation

(1) Alternate the measurement side for double sided textured sheet

(2) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 33 mm
Break elongation is calculated using a gage length of 50 mm

(3) The SP-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.
The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(4) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(8) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(9) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(10) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Adoption and Revision Schedule
for
HDPE Specification per GRI-GM13

"Test Methods, Test Properties, Testing Frequency for
High Density Polyethylene (HDPE) Smooth and Textured Geomembranes"

Adopted:	June 17, 1997
Revision 1:	November 20, 1998; changed CB dispersion from allowing 2 views to be in Category 3 to requiring all 10 views to be in Category 1 or 2. Also reduced UV percent retained from 60% to 50%.
Revision 2:	April 29, 1999: added to Note 5 after the listing of Carbon Black Dispersion the following: "(In the viewing and subsequent quantitative interpretation of ASTM D5596 only near spherical agglomerates shall be included in the assessment)" and to Note (4) in the property tables.
Revision 3:	June 28, 2000: added a new Section 5.2 that the numeric table values are neither MARV or MaxARV. They are to be interpreted per the the designated test method.
Revision 4:	December 13, 2000: added one Category 3 is allowed for carbon black dispersion. Also, unified terminology to "strength" and "elongation".
Revision 5:	May 15, 2003: Increased minimum acceptable stress crack resistance time from 200 hrs to 300 hrs.
Revision 6:	June 23, 2003: Adopted ASTM D 6693, in place of ASTM D 638, for tensile strength testing. Also, added Note 2.
Revision 7:	February 20, 2006: Added Note 6 on Asperity Height clarification with respect to shear strength.
Revision 8:	Removed recommended warranty from specification.
Revision 9:	June 1, 2009: Replaced GRI-GM12 test for asperity height of textured geomembranes with ASTM D 7466.
Revision 10	April 11, 2011: Added alternative carbon black content test methods
Revision 11	December 13, 2012: Replaced GRI-GM11 with the equivalent ASTM D 7238.
Revision 12	November 14, 2014: Increased minimum acceptable stress crack resistance time from 300 to 500 hours. Also, increased asperity height of textured sheet from 10 to 16 mils (0.25 to 0.40 mm).
Revision 13	November 4, 2015: Removed Footnote (1) on asperity height from tables.
Revision 14	January 6, 2016: Removed Trouser Tear from Note 5.