Guide to the Specification of Geosynthetics

Foreword

This is the first edition of the Guide to the Specification of Geosynthetics and as such represents the recommendations of the IGS Technical Committee. This edition will also be placed on the IGS Web Site to provide IGS members with ready access to the guide to the specification of geosynthetics.

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1 Introduction

This Guide to Specification has been prepared by the Technical Committee of the International Geosynthetics Society.

The objective of this document is to be a generic guide to those writing specifications.

The guide will provide information which is useful to those who use specifications, buyers of geosynthetics and installers.

Definitions and usage of specialist terms used in this guide are consistent with the IGS publication ‘Recommended Descriptions of Geosynthetics Functions, Geosynthetics Terminology, Mathematical and Graphical Symbols.

Example Model Specifications are given in Annexes to this document, these may be used as a basis for writing project specifications and the user is responsible for ensuring that any values used are correct and appropriate for the application and materials.
2 Philosophy and Compatibility with National Specifications

Philosophy

The philosophy used in drafting this guide is that a good specification is one which embodies the following aspects:

- The specification should be concise,
- The specification for each class of product should be based on a minimum number of properties relevant to the conditions of use,
- The specification should be based on the results of an engineering design.

National Specifications

In preparing this guide various national and other standards which pre-exist have been considered and where possible aspects of those documents have been included in the preparation of this guide.

References

Geosynthetic properties are measured using a number of test procedures published by standardisation organisations on an international, regional or national basis

- International Standards Organisation (ISO): used in many countries world wide, often issued as dual numbered standards with European Norms
- Europe – European Norms (ENs), standards published in English, German and French as official versions, other language editions also exist as prepared by individual countries and registered with CEN.
- North America – ASTM International, used extensively in North America and other parts of world where USA has a strong influence
- Australia – standards used in Australia and some Pacific areas.
- China and Korea – national standards based on ASTM standards

For typical values of properties of geosynthetic products useful directories are published by Geosynthetic Fabrics Report (GFR) and the Italian Geosynthetics Society
3 Applications

The applications will be considered by product types;

- Geotextiles
- Geogrids
- Geomembranes and GCLs
- Geomats and Erosion control products

The descriptions of each application and function are described in one of the IGS Education Committee brochures. The brochures can be downloaded from the IGS web site at http://www.geosyntheticssociety.org/. The brochures available include:

- Geosynthetics Types
- Geosynthetics Functions
- Geosynthetics in Filtration and Drainage
- Geosynthetics in Embankments on Soft ground
- Geosynthetics in Erosion Control
- Geosynthetics in Road Engineering
- Geosynthetics in Waste Disposal
- Geosynthetics in Unpaved Roads
- Geosynthetics in Reinforced Slopes
- Geosynthetics in Reinforced Roads
- Geosynthetics in Tunnelling and Underground Structures
- Geosynthetics in Waste Water
- Geosynthetics in Coastal Protection
- Geosynthetics in Channels and Waterways
- Geosynthetics in Railways
4 Functions

The functions of each type of geosynthetic considered for each section of the specification are those functions which are commonly ascribed to these products; other special functions can be satisfied by the use of some products or combinations thereof. These special functions can be described by the specifier by using application specific clauses.

The normal functions used in specifications and standards are:

- Separation: the prevention from intermixing of adjacent dissimilar soils and or materials
- Filtration: the retaining of soil or other particles subject to hydrodynamic forces while allowing the passage of fluids into or through the geosynthetic.
- Drainage: the collecting and transmitting of precipitation, ground water and or other fluids in the plane of the geosynthetic.
- Reinforcement: the use of the tensile properties of a geosynthetic to improve the mechanical properties of soil or other construction materials.
- Barrier: the prevention of the movement of any fluid through a construction by the use of a geosynthetic barrier.
- Protection: the use of a geosynthetic material as a localised stress reduction layer to prevent or reduce damage to a given surface or layer.
- Surface erosion control: the use of a geosynthetic to prevent soil or other particle movements on the surface of a slope.

If the functions are assigned to the products the normal functions for each type of geosynthetic are:

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Geogrids

- Reinforcement
- Separation

Geomembranes and Geomembranes and Geocomposite Clay Liners

- Separation
- Barrier
Geocomposites may be formed that have multiple functions.
5 Geotextile Functions: separation, filtration, reinforcement, protection & drainage

5.1 Separation

This function is rarely used in isolation; it is normally combined with one or more of the other functions, filtration and reinforcement being most usual. One of the only pure uses of a geosynthetic as a separator is at the base of fill for a temporary haul road, but even there, in most situations the geotextile also acts as reinforcement. The design of the geotextile will be based on a tensile strength requirement, the puncture resistance (CBR or Cone Drop resistance) and durability tests to determine the survivability in the service environment.

5.2 Filtration

A well established function, where there are economic advantages, as geosynthetics act as a direct replacement for selected, graded granular filters. Drainage geosynthetics are commonplace in highway drainage systems, beneath revetments, sea defence groynes, sludge dewatering systems and can be used in the drainage systems of dams. The application of geotextiles in dams has taken some time to be accepted by engineers responsible for dam safety because the consequences of a failure of the drainage / filter systems in a dam structure need to be avoided. The design of filters is by relating the laboratory measured effective opening size (usually the O₉₀ or O₉₅), the method of manufacture of the geotextile (woven or non-woven) to one or more of the soil grading characteristics (d₁₀, d₅₀ or d₉₀) and the soil plasticity with an empirical factor from one of the many texts or papers. Checks are required to ensure that the geotextile acts:

- As a filter - to stop the loss of fine particles from the protected soil
- To allow water to pass through at a rate not less than the permeability of the soil allows water to reach the surface of the geotextile
- Such that the fine soil particles do not clog the apertures in the geotextile – clogging needs to be avoided when using thick non-woven geotextiles.

Factors to be included in specifications may include:

- Pore size of openings (O₉₀ or O₉₅)
- Installation damage resistance (CBR, Drop Cone or Abrasion – normally one or two properties only)
- Tensile strength
- Water permeability normal to the plane
- Durability
  - Resistance to weathering (UV resistance during installation)
  - Micro biological degradation resistance
  - Resistance to chemical attack

5.3 Reinforcement
Geosynthetics used as reinforcement are normally high strength woven geotextiles or Geogrids. In some designs non-woven geotextiles are used, in particular in Japan where the use of high strain non-woven geotextiles has been shown to perform well in seismic events. The reinforcement products are subject to more analytical design than for any other function. There are numerous programs now available to allow engineers to design the reinforcements for over-steep slopes, basal reinforcements for embankments on soft ground, and reinforcements to voids and piled foundations.

Some specialised geotextiles are used to reinforce asphaltic road pavements. The products used in this application include woven glass fibre, geotextiles and geogrids.

The specification for reinforcements may include both the short term tensile strength and the creep limited tensile strength depending on the nature and the length if time the geotextile will be under load.

Factors to be included in specifications may include:

- Short term tensile strength
- Long term or creep limited tensile strength
- Strain or elongation at design stress.
- Puncture resistance (CBR or Cone Drop)
- Coefficients of friction or interaction between the geotextile and the soils
- Durability
  - Chemical – especially when in waste containment
  - Resistance to weathering (UV if to be left exposed during installation or in service).

Geogrids exposed on wrap around facings will require additional specification items as:

- Chemical resistance for contact with soil or backfill materials, especially if demolition or recycled material is used as fill.
- Damage resistance during installation.
- Fire resistance

5.3.1 Reinforcement: Load Transfer Platforms (Geotextiles and Geogrids)

Load Transfer Platforms are used to distribute the loads from fills or other foundations into piles, vibro-concrete columns, or vibro-replacement stone columns installed through soft soils which would consolidate under the applied loading. Load transfer platforms are designed to support the fill which is not supported directly on the piles or other ground treatment taking into account arching in the fill. Where there is insufficient thickness of fill for the development of arching the forces in the geotextile or geogrid may be very high. The design of load transfer platforms needs careful consideration.

The output from the design for the specification may include:

- Short term tensile strength
- Elongation or strain at design load.
- Long term strain limited tensile strength for the long term loading.
- Strain at long term loading
- Installation damage resistance (CBR, Cone Drop or Abrasion)
- Coefficients of friction or interaction between geotextiles and soils
5.3.2 Reinforcement: Asphalt

Geotextiles and geogrids used to reinforce asphalt paving layers must provide increased tensile strength at a very low deformation. They must be compatible with the asphalt to provide a strong internal bond within the asphalt matrix. They must be thermally stable and physically durable to withstand the rigours of the paving operation, for long term performance they must not exhibit creep deformation or chemical breakdown over time.

To maximise performance asphalt reinforcement should be placed between two bituminous layers, this enables the aggregate particles of the asphalt to become mechanically interlocked with the reinforcement, this confinement impedes particle movement and ensures better compaction, greater bearing capacity and increased load transfer with less deformation.

Design methods are normally empirical but with the advent of analytical methods for pavement design the realistic estimates of service strains and stresses, specific stress strain relationships for asphalt reinforcement can be calculated and hence specified.

Factors to be included in specifications for asphalt reinforcement may include:

- Tensile Strength
- Modulus of Elasticity
- Elongation at Break
- Melting Point
- Mass/Unit Area

5.4 Protection

Geotextiles with a protection function are intended to minimise damage to other materials, for example Geomembranes due to contact with fills or the underlying subgrade and asphalt overlays due to cracks in the old pavement.

5.4.1 Protection: Geomembranes

The protection is normally achieved by using thicker non-woven geotextiles, geocomposite clay liners may also be used as protection layers, design is by carrying out site trials or laboratory tests.

Factors to be included in specifications may include:

- Protection Efficiency Test (Cylinder test or Pyramid Puncture test)
- Puncture resistance (CBR or Cone Drop),
• Damage during installation (Abrasion)
• Durability
  o Chemical – especially when in waste containment
  o Resistance to weathering (UV if to be left exposed during installation or in service).

### 5.4.2 Protection: Asphalt Overlays

Geotextiles may also be used to provide protection for Asphalt Overlays. Geotextiles, typically nonwovens, are placed between pavement layers to providing stress relief at the old asphalt and new asphalt interface, which retards the development and growth of reflection cracks. To provide bonding between the layers, paving geotextiles are saturated with asphalt cement, which waterproof the geotextile and creates a barrier for water infiltration into the pavement section.

### 5.5 Drainage

Drainage using geosynthetics is often accomplished using geonets. Other drainage products include deformed sheets, (cuspated), mini pipes or other voided polymeric structures with a geotextile filter or barrier on one or both sides as required by the service situation. Very thick needle-punched products can be used as both filters and drainage carrier layers.

Typically geosynthetic drains are used in the following applications:

- highway edge drains to drain the pavement construction layers,
- drains in earthworks, (slope drains on cut slopes to collect ground water seepage),
- drains behind retaining walls, to prevent the build up of water pressures which could destabilise the structure,
- dissipation layers to reduce excess pore pressures in cohesive fills,
- drainage layers within landfill lining systems,
- venting layers below impermeable landfill capping layers to allow gasses produced in landfills to escape to the atmosphere or a gas collection system.

Design methods are based upon standard tests with large factors of safety to allow for in service ‘unknowns’ such as clogging and bacterial growth.

Factors to be included in specifications include:

**Core**
- In-plane flow capacity under load and with geotextile obstruction of the core between the supporting elements.
- Compressive creep behaviour of the core under vertical and inclined load.
- Durability
  o Chemical – especially when in waste containment
  o Resistance to weathering (UV if to be left exposed during installation or in service).

Geotextile – as for filters & durability

Geomembrane (if used) – as for barriers in Section 7
6 Geogrid Function: Reinforcement

Geogrids have a single prime function which is to act as strengthening elements in soil, in some applications, basal reinforcement for unpaved roads on soft sub-grades, geogrids can also provide some separation of materials.

Geogrids are planar, polymeric structures consisting of regular open networks of integrally connected tensile elements, which may be linked by extrusion, bonding or interlacing, whose openings are larger than the constituents, used in contact with soil/rock and/or any other geotechnical material in civil engineering applications. Geogrids can be manufactured from PET, HDPE, PP, AR and PVA using a variety of different methods which include:

- Punched and drawn sheet, either uniaxial drawn or biaxial drawn
- Strips of polymer welded at nodes or crossing points*
- Knitting / weaving of strands or fibre bundles*

Note: * It is possible to produce very high strength geogrids (>200 kN/m width)

6.1 Slopes and Walls

The strengthening of slopes is normally considered in three groups:

- Slopes with a face angle up to 45 degrees to the horizontal – reinforcement normally stopped of close to or at the face, topsoil cover supported using erosion control matting
- Slopes with a face angle of between 45 and 70 degrees to the horizontal – normal to provide a wrap around facing with the main reinforcement on the face and tucked into the fill at the top of the layer, steel mesh facing can also be used to support the face – topsoil or other growing medium retained behind the facing.
- Slopes with a face angle steeper than 70 degrees to the horizontal to vertical (Walls)– these slopes are often provided with a hard or semi-hard facing system, precast concrete panels, concrete modular blocks, king post and infill planks, flexible steel units.

The design of reinforced soil slopes involves considering the internal stability of the reinforced soil mass to determine the geometric arrangement of the geogrids and the tensile strength required to maintain stability. The overall stability of the reinforced soil block is also considered to ensure that failure by sliding, overturning or foundation bearing capacity is avoided.

The design of slopes up to and including 70 degrees inclination should include details of repair methods which can be used in the event of a loss of face support e.g. by fire to covering vegetation, mechanical damage or vandalism.

The output from the design for the specification may include:

- Short term tensile strength
- Long term or creep limited tensile strength
- Strain at design stress.
• Pull out resistance
• Interaction or Friction coefficients between fill and geogrids
• Connection strengths when connected to facing systems.
• Durability considerations
  o  UV resistance for geogrids exposed on wrap around facings
  o  Chemical resistance for contact with soil or backfill materials, especially if demolition or recycled material is used as fill.

6.2 Basal Reinforcement (Geogrids and Geotextiles)

Basal reinforcement of embankments is designed to prevent lateral spreading of the embankment and to reduce the strains in the underlying foundation soils. The design of basal reinforcement is normally undertaken using standard slope stability methods modified to allow for the tensile resistance acting at the base of the embankment. In most approaches the peak tensile resistance from the reinforcement is needed during of construction, as the foundation soils consolidate and increase in strength the force required from the reinforcement to maintain stability will / should reduce.

The output from the design for the specification may include:

• Short term tensile strength
• Elongation or strain at design load.
• Long term strain limited tensile strength for the long term loading.
• Strain at long term loading
• Coefficients of friction or interaction between the geogrids and soils
• Installation damage resistance (CBR, Cone Drop - geotextiles or Abrasion – geotextile or geogrid)
• Durability –
  o  UV or Weathering Resistance during installation
  o  Chemical durability in contact with soils and or ground water

6.3 Mattresses

Geogrid mattresses are a special basal reinforcement which due to the inherent bending stiffness will redistribute the settlement of the embankment – the normal ‘dishing’ with the maximum settlement at the centre of the fill will be reduced. The bearing capacity of the foundation soils becomes one of the major design considerations.

The output from the design for the specification may include:

• Short term tensile strength
• Elongation or strain at design load.
• Long term strain limited tensile strength for the long term loading.
• Strain at long term loading
• Installation damage resistance
• Durability –
  o  UV or Weathering Resistance during installation
  o  Chemical durability in contact with soils and or ground water
6.4 Load Transfer Platforms (Geogrids and Geotextiles)

See Section 5.6 for details.

6.5 Void Spanning

Void spanning in areas of old mine workings or over soils or rocks with a potential to develop solution features, can be considered as a special case of a load transfer platform design. In the void spanning case the geogrid may be required to remain in place for many years without any loading, the loading will only be applied when a void propagates to the level at which the geogrid sits in the construction. The geogrid is normally installed to provide a short term capacity to prevent a total collapse of the construction into the void, such that there is time to stabilise the void.

The output from the design for the specification may include:

- Short term tensile strength
- Elongation or strain at design load.
- Long term strain limited tensile strength for the long term loading.
- Strain at long term loading
- Installation damage resistance
- Coefficients of friction and interaction between geogrids and soils
- Durability –
  - UV or Weathering Resistance during installation
  - Chemical durability in contact with soils and or ground water.
7 Geomembrane and GCL Function: Barrier

The barrier function is the primary purpose for any geomembrane and GCL. This section includes geomembranes manufactured from polymeric, bituminous and geocomposite clay liners (GCL). They are used to prevent the escape of liquids from containments or to prevent or reduce the flow of liquids through soils or other parts of construction works.

The design should minimise the tensile forces in the membrane layer, the use of smooth and rough faced materials can help control the tensile and shear forces in the layer.

The output from the design for the specification may include:

- Type of material (polymer, rubber, bitumen, or clay)
- Formulation mixing and processing (for polymer, rubber and bitumen)
- Thickness (at 2kPa)
- Gas and water permeability
- Tensile strength (Uniaxial or axisymetric)
  - Strength
  - Strain
- Puncture Resistance
- Burst strength
- Tear Resistance
- Interface shear
- Internal shear (Bitumen, GCL and geocomposite)
- Clay mass, free swell, peel strength, moisture content and fluid loss (for GCLs)
- Durability, performance
  - UV Exposure requirements
  - Oven Aging (not GCL’s)
  - Liquid immersion tests – full product testing
    - Stress crack resistance (only polymeric HDPE)
- Seaming processes and controls
- Testing of site works (seams, when mechanically jointed)
8 Functions of Geomats, Geoblankets and Erosion Control Products

8.1 Geomats and Geoblankets
The Geomats and Geoblankets are used for surface erosion control, to prevent or reduce the transport of soil by erosion agencies (water or wind). Some products may be intended to be permanent application while others may only be designed for a short term life to prevent erosion until vegetation becomes established.

The output from the design for the specification of Geomats and Geoblankets as erosion control products may include:

- Soil containment
- Shear strength
- Bio degradability for temporary applications
- UV Resistance for permanent applications
- Tensile strength (secondary)
- Fixing of the product to the slope, pegging and anchor trenches

8.2 Geocells
When used to provide control of erosion laid on the surface of slopes, Geocells are used to physically prevent the down slope migration of soil under the action of erosion agencies.

The output from the design for the specification of Geocells, as erosion control products may include:

- Dimensions
- Strength of joints/nodes
- Bio degradability for temporary applications
- UV Resistance for permanent applications
- Tensile strength (secondary)
- Permeability of cell materials
- Physical dimensions of cells (Length, breadth and height)
- Dimensional stability during filling
- Fixing and anchoring

Geocells can be used for the construction of steep reinforced soil slopes, the Geocells are laid horizontally in layers each layer being filled with soil.

Geocells can be used to strengthen or reinforce unpaved roads over poor sub-grades

The output from the design for the specification of Geocells, as products to reinforce unpaved roads may include:

- Strength of joints / nodes
- UV Resistance for permanent applications
- Tensile strength
- Physical dimensions of cells (Length, breadth and height)
Dimensional stability during filling

The output from the design for the specification of Geocells, for use as steep slope reinforcement may include:

- Strength of joints / nodes
- UV Resistance for permanent applications
- Tensile strength
- Physical dimensions of cells (Length, breadth and height)
- Dimensional stability during filling
9 Site control of geosynthetic products delivered to the works

All products delivered to sites for incorporation into works should have the properties described in the specification verified. The verification of these properties can be carried out by one of the following procedures:

- Prior to delivery with certificates or declaration of conformity or actual test results provided to the purchaser e.g. CE marking, NTPEP (USA state agency approval),
- Type approval, agency for national, state or other client bodies,
- Testing of samples taken from products to be or delivered to the works – tests to be completed prior to building in to the works,
- Simple measurements on site – thickness or mass per unit area.

Checks need to be carried out to ensure that installation instructions are followed as described in the project specification are followed explicitly, that is:

- The formation or substrate is prepared properly, line and level,
- Rolls are laid in the correct directions,
- Laps are set as described,
- Seams are made as required,
- Cover soils are placed such that damage beyond that allowed for in the design does not occur and to required density or strength.
- Supervision - A suitably qualified and experienced person shall be responsible for checking that the construction complies with the design and all other contract documents.
- Monitoring - Monitoring of all works connected with the execution of various stages of construction shall be in accordance with the method statement made to fulfil the design and the project specification.
- Testing - The testing shall be in accordance with the specifications of the design. The records of any testing shall provide the test method and procedure, test results and the conclusions and relevance.
- The level of supervision, monitoring and testing should be in accordance with the specification.
- The type, extent and accuracy of monitoring and testing requirements on and off site should be clearly shown in the specification and organised before work commences on site.
- Unless specified in the Design, supervision should relate to site preparation topography, geotechnical data, set-up, geometry of excavations, foundation pad (if applicable); fills : conformity with design: characteristics, placing and compaction, monitoring and testing when necessary; reinforcement : conformity with design, reception, handling, storage, placing, damage during installation, prestressing of reinforcement (if applicable), monitoring and testing when necessary; facing materials : conformity with design, installation of facing elements, alignments and displacements, finishing, monitoring and testing when necessary; drainage : base / foundation, back slope, layer drainage during installation, other drainage systems needed.
Annexes Model Specifications

Disclaimer

The model specifications which are included in the following Annexes are provided as a guide to designers and others preparing specifications for the use of geosynthetic products in civil engineering and building works.

When using these model specifications DO NOT mix and match between different model documents. Aspects of a particular Annex should be used only be used with other aspects or parts of the same Annex

The IGS does not warrant that the use of these model specifications will avoid contractual disputes and it is the responsibility of the user to ensure that the contract documents are mutually compatible.

Where values of characteristics are given in the Guide these are NOT given as definitive values to be used in any project. The designer or person preparing the specification MUST check and insert values which have been based on a project specific analysis.

The European specifications may use terminology which does not comply with the IGS Guidelines as the terminology is required to comply with ENISO 10318.
Annex 1: UK Specification for Geosynthetics in a general civil engineering project– based on CE marking and declared values (Date of document September 2005)

A1.1 Materials for Geotextiles, Separation, Drainage Composites, Barriers and Geosynthetic Reinforcement.

Geotextiles for separation, filtration shall be manufactured from any of the following polymers: polyester, polyamide, polypropylene or polyethylene, the fibres may be either woven, heat bonded or needle punched.

Geocomposite Drainage layers shall be constructed using a core manufactured from polyethylene, polypropylene or polyamide, with a layer of geotextile separator on both sides with the properties given in Section A2.

Geosynthetics for the core of drainage geocomposite products may be manufactured from polyester, polyamide, polypropylene or polyethylene. The polymer products may be in the form of a deformed sheet, random fibres or a regular net with elements joined at intersections. The geotextile filter separator must be securely fixed to the core at regular intervals by gluing, heat bonding or mechanical fixings.

All Geosynthetic products delivered to site shall be marked in accordance with BS EN 10320.

Geotextiles for protection shall be manufactured from any of the following polymers: polyester, polyamide, polypropylene or polyethylene using a process of needle punching to entangle the fibres. No re-cycled or post consumer polymer may in incorporated into the protection geotextiles.

Geogrids may be manufactured using one or a combination of the following processes:

- from high density polyethylene sheet oriented in one or both directions so that the resulting ribs have a high degree of molecular orientation which is continued through the integral transverse ribs.
- from polyester yarns which are knitted into an open structure coated with PVC or other protective materials
- from polyester yarns in bundles which are coated with PVC or other protective coatings in the form of strips which are spaced and joined with strips of lighter or equal strength, the cross strips being welded to the main strips at each intersection.
- From high modulus PVA or other high tenacity polymer strips which are joined in grid arrangement by welding at each intersection.

Geosynthetic barriers shall be manufactured from high density polyethylene with additives to provide the durability and properties specified in Section A6.

A1.2 Geotextiles to Separate Earthworks and Filter Water Flows

(Note: all [highlighted] figures are contract specific and MUST be reviewed after designs are completed)

All geotextiles for separation and filtration shall be delivered to site marked with a CE mark.
and accompanying documentation to EN 13249 Characteristics required for use in the construction of roads and other trafficked areas.

All geotextiles for use as separators and filters in drainage systems shall be delivered to site marked with a CE mark and accompanying documentation to EN 13249.

The durability of geotextile separators and filters shall be evaluated in accordance with Annex B of EN 13249.

*Note: For other applications the appropriate EN standards must be used to determine which harmonised tests must be reported on the CE labels and documents*

The minimum tensile strength of the geotextile separator / filter layer shall be \( 12 \, \text{kN/m} \) width when measured in accordance with ENISO 10319, expressed as the mean value given by the manufacturer in the accompanying documentation, minus the quoted tolerance.

The minimum Permeability Normal to the plane of the geotextile separator / filter layer shall be \( 85 \, \text{l/m}^2/\text{sec} \) when measured in accordance with EN ISO 11058, expressed as the mean value given by the manufacturer in the accompanying documentation, minus the quoted tolerance.

The Characteristic Opening Size of the pores in the geotextile shall lie in the range \( 0.050 \) mm to \( 0.200 \) mm when tested in accordance with ENISO 12956. The Characteristic Opening Size value shall be determined as: the minimum value will be the mean value quoted minus the quoted negative tolerance and the maximum value shall be the mean value quoted plus the quoted positive tolerance.

The minimum static puncture strength of the geotextile protection layer shall be \( 1800 \, \text{N} \), expressed as the mean value given by the manufacturer in the accompanying documentation, minus the quoted tolerance. Reference test method EN ISO 12236.

The maximum cone drop hole size, of the geotextile protection layer shall be \( 20 \, \text{mm} \), expressed as the mean value given by the manufacturer in the accompanying documentation, plus the quoted tolerance. Reference test method EN 918.

All quoted values being taken from the accompanying documents provided with the materials in support of the CE Marking.

**A1.3 Geotextiles as Protection Layers**

All geotextiles for Protection Layers shall be delivered to site marked with a CE mark and accompanying documentation as described in BS EN 13265 Characteristics required for use in liquid waste containment projects.

The durability of geotextile protection layers shall be evaluated in accordance with Annex B of BS EN 13265. *(Note: include other standards as necessary)*

The minimum tensile strength of the geotextile protection layer shall be \( 25 \, \text{kN/m} \) width, expressed as the mean value given by the manufacturer in the accompanying documentation, minus the quoted tolerance. Reference test method BS EN ISO 10319.

The minimum static puncture strength of the geotextile protection layer shall be \( 4500 \, \text{N} \), expressed as the mean value given by the manufacturer in the accompanying documentation, minus the quoted tolerance. Reference test method BS EN ISO 12236.
The nominal thickness of the geotextile protection layer is to be not less than (4.5) mm, no tolerances. Reference test method BS EN 964-1.

All quoted values being taken from the accompanying documents provided with the materials in support of the CE Marking

A1.4 Geosynthetic Drainage Composites

All geosynthetics for use as Drainage layers shall be delivered to site marked with a CE mark and accompanying documentation as described in BS EN 13252 Characteristics for use in Drainage Systems.

The durability of geosynthetic drainage layer layers shall be evaluated in accordance with Annex B of BS EN 13252. *(Note: include other standards as necessary)*

The properties of the geotextile filter layers shall be as set out in Annex A3 for geotextile separator / filter products.

The nominal thickness of the geosynthetic drainage layer is to be not less than (4.5) mm, no tolerances. Reference test method BS EN 964-1.

The In-plane Water Flow the geosynthetic drainage layer is to be not less than (0.30) l/m/sec (measured between one hard and one soft contact surface with a hydraulic gradient of 0.5), expressed as the mean value given by the manufacturer in the accompanying documentation, minus the quoted tolerance. Reference test method BS EN ISO 12958.

All quoted values being taken from the accompanying documents provided with the materials in support of the CE Marking

A1.5 Geosynthetic Barrier Layer

The Geosynthetic Barrier Layer shall be manufactured from High Density Polyethylene in the form of a sheet.

The BS EN standards for the required characteristics of geosynthetic barriers have not yet been published and therefore there is no requirement to CE mark these products or provide supporting information.

The properties of the HDPE Barrier shall be:

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>UNITS</th>
<th>Minimum Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>BS EN 1849-2</td>
<td>mm</td>
<td>(1.9)</td>
</tr>
<tr>
<td>Tensile Strength at Yield</td>
<td>ISO 527 (Modified)</td>
<td>kN/m</td>
<td>(30)</td>
</tr>
<tr>
<td>Tensile Strength at Break</td>
<td></td>
<td>kN/m</td>
<td>(33)</td>
</tr>
<tr>
<td>Elongation at Yield</td>
<td></td>
<td>%</td>
<td>(12)</td>
</tr>
<tr>
<td>Elongation at Break</td>
<td></td>
<td>%</td>
<td>(40)</td>
</tr>
<tr>
<td>Stress Crack Resistance</td>
<td>EN 14576</td>
<td>hrs</td>
<td>(&gt;300)</td>
</tr>
</tbody>
</table>
Where pipes or other entries are required to penetrate the barrier layer a purpose made collar shall be used to seal the pipe to the barrier layer. The collar shall be fabricated from HDPE have properties equal to those specified for the main barrier layer. The collar shall be welded to the barrier using an extrusion weld and sealed to the pipe or duct with a clamping system as shown on the drawings for the specific location.

Prior to laying the geosynthetic barrier the Contractor shall provide to the Engineer a plan showing the intended layout of the panels and the seams/joints to be made. The layout plan shall be submitted not less than 7 days before the commencement of the work. The Contractor shall on a daily basis record the panels laid and the actual seams made, this daily record shall be sent to the Engineer not more than 24 hours after the work recorded is completed. The daily record shall include the position of any tests made on the work or samples taken for off-site testing.

**A1.6 Geogrid (HDPE drawn type)**

All geosynthetics for use for soil reinforcement shall be delivered to site marked with a CE mark and accompanying documentation as described in BS EN 13251 Characteristics for use in earthworks, foundations and retaining structures.

Geogrid manufactured from high density polyethylene sheet oriented in one direction so that the resulting ribs have a high degree of molecular orientation which is continued through the integral transverse ribs.

The creep limited tensile strength, for a design life of 120 years shall be (25.5) kN/m at a mean temperature of 20 degrees C. This shall be determined by application of standard extrapolation techniques to creep data obtained in accordance with BNS EN ISO 13431 and shall be the lower bound value.

The short term tensile strength, measured in accordance with BS EN ISO 10319 shall be not less than (80) kN/m, expressed as the mean value minus the negative tolerance, declared for CE marking in accordance with BS EN 13252.

All quoted values being taken from the accompanying documents provided with the materials in support of the CE Marking.

**A1.7 Geogrid (Polyester strip type)**

All geosynthetics for use for soil reinforcement shall be delivered to site marked with a CE mark and accompanying documentation as described in BS EN 13251 Characteristics for use in earthworks, foundations and retaining structures.

Geogrid manufactured from bundles of polyester yarns encapsulated in a PVC sheath to form strips. The strips shall be spaced by transverse strips which shall be joined to the main strips at each intersection by a weld or other permanent connection.

The short term tensile strength in the main roll direction, measured in accordance with BS EN ISO 10319 shall be not less than (80) kN/m, expressed as the mean value minus the negative tolerance, declared for CE marking in accordance with BS EN 13252.

All quoted values being taken from the accompanying documents provided with the materials in support of the CE Marking.
A1.8 Testing and Certification

No additional testing is required for geosynthetic products delivered to site with a CE Mark and the correct accompanying documentation.

In cases where there is no accompanying documentation samples shall be taken from the delivered or to be delivered materials at a rate of (1 sample from each batch of 10 rolls or 1 sample from every 5,000 rolls). The samples shall be taken in accordance with the provisions of BS EN 963 Sampling and Preparation of Test Specimens in agreement with the Engineer’s Representative or his nominee.

The samples shall be subjected to the tests described in the relevant clause in this specification at an independent laboratory with UKAS accreditation for the tests to be carried out.

The various tests cover the procedures to be followed to determine the resistance of the barrier and joints to water and weathering and their ability to recover without shape loss after tension. All tests described shall be carried out by the Contractor and deemed to be included in the Contract Price.

The HDPE Barrier layer shall be delivered to site with certificates from an independent UKAS accredited laboratory to show that the properties of the material delivered to site complies with this specification. If such certificates are not available then samples shall be taken for testing as described for the other geosynthetic materials.

The results of all independent off site testing must be available to the ER before the geosynthetic material is covered in the works.

A1.9 Installation

Waterproof barrier systems shall be installed by personnel approved by the Engineer. All personnel installing the barrier system shall be third party accredited in accordance with the Environment Agency Directives for the Landfill Lining Industry. Approval of a lining Contractor shall also be subject to relevant experience and performance.

Prior to the laying of the geosynthetic products barriers, the excavated face or fill surface shall be “hand-picked” to ensure that no stones greater than (20) mm in size, or any sharp protruding edges exist on the face of the excavation. A 150mm layer of fine graded soil may be laid to provide a surface free from stones.

The geosynthetics shall be laid such that they are laid smooth without wrinkles and folds and are in intimate contact with the underlying surface or material.

Filters, separating and protection geotextiles shall be laid with a minimum lap of (0.3) m between the edges of adjacent rolls and if lapped along the roll the minimum lap in the roll direction shall be (1.0) m.

The Geosynthetic Drainage geocomposite material shall be laid with the core butted to adjacent rolls and the geotextile filter/separating cover shall be lapped as described in the preceding paragraph.
When laying soils over any geosynthetic layer, geotextiles or barriers, the fill shall NOT be tipped directly onto the geosynthetic layer. Fill shall be tipped adjacent to the final position and shall be pushed into place by a small light weight dozer or the fill shall be placed using a grab. When a grab is use the fill shall not be dropped from a height which exceeds 1.0m. When pushing fill into place using a dozer or other bladed piece of plant which could be wheel or track mounted plant the plant shall not be allowed to run on the geosynthetic layers unless there is a minimum thickness of (400) mm of covering soil or other material.

Prior to seaming of the barrier each day, trial seams shall be carried out to confirm the set up of the seaming equipment for the ambient conditions and that the equipment is working satisfactorily. Trial seams shall be produced under the same conditions as the installation seams and shall be performed with the barrier in contact with the same sub-grade type.

A trial seam shall be carried out for each piece of seaming equipment proposed for use at the beginning of each seaming period and following a prolonged period of shut down. All trial seams shall be carried out in the presence of the Engineer.

From each trial seam, five tab samples of length 200mm by 25mm shall be extracted at random from the length of the seam. The tabs shall be examined by the Engineer to confirm that the seam exhibits a homogenous fusing of the two sheets with no definable boundary or layer. The tabs shall be tested by the Contractor for peel failure using a field tensiometer in the presence of the Engineer. The mode of failure shall be yield of the sheet material outside the seam. No more than one of the five samples shall fail in the seam.

If the field testing of the trial seams proves unsatisfactory further trial seams shall be performed and the procedure repeated until the site engineer or CQA Inspector is satisfied with the set up of the particular item of seaming equipment. The site engineer or CQA Inspector will not allow seaming of the barrier to commence until successful trial seams are achieved.

The ER will require that each seam undergoes non-destructive testing in accordance with the following procedures and shall record the results of the testing.

Air Pressure Testing

All twin wedge fusion seams shall be pneumatically tested. The air channel shall be inflated to a minimum pressure of (2) bar (30 psi, 200 kPa) and maintained, following removal of the pressure source, to meet the following requirements:

<table>
<thead>
<tr>
<th>Period of Time</th>
<th>Limit of Allowable Pressure Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 minute</td>
<td>None</td>
</tr>
<tr>
<td>5 minutes</td>
<td>10%</td>
</tr>
</tbody>
</table>

On completion of the test, the channel shall be deflated from its farthest extent to confirm that the full length of seam had been tested.

If a seam fails air pressure testing or indicates a channel blockage, the test length shall be incrementally reduced until the failure area has been clearly identified. In the case of identifiable points of failure, the seam shall be repaired. If specific points of failure cannot be identified or if the site engineer or CQA Inspector is not satisfied with the integrity of the seam, the seam shall be repaired by replacement or capping.

Spark Testing
All extrusion seams shall be tested over their entire length using a high frequency continuous coil spark tester. The equipment shall be adjustable in voltage between 15kV and 30 kV and shall generally be operated at a voltage of 10kV per mm of membrane thickness. The spark tester shall be passed slowly in close proximity to the weld to test all points on the weld. Any anomalies in the seam will be identified by the presence of a spark. The location of any sparks shall be marked and the seam repaired and re-tested to the satisfaction of the Engineer.

Alternatively extrusion welds shall be tested using the vacuum box method.

**Destructive Testing**

Destructive seam testing may be carried out at seam overruns at each weld at the discretion of the site engineer or the CQA Inspector, to avoid patches in the new liner. The samples shall be taken at a minimum frequency of one per (200)m length of seam. However, the site engineer or the CQA Inspector may increase this frequency if test results indicate problems or poor workmanship.

The samples shall be a minimum of 0.3m wide by 1.0m long with the seam centred lengthways. One 25mm wide strip shall be cut from each end of the sample and shall be tested in the field for peel adhesion and shear failure. The seam shall not fail in the seam. If the field tests are acceptable the remainder of the sample shall be bisected, one for the Contractor for archive storage and one for the site engineer or the CQA Inspector. The site engineer or the CQA Inspector shall review the results at the earliest opportunity to assess compliance.

The Contractor shall undertake field destructive testing of all fusion seaming. On completion each fusion seam, a tab sample shall be taken from each end of the seam and tested for peel adhesion failure. The sample shall not fail in the seam.

The Contractor shall maintain full records of all destructive testing which shall be provided to the site engineer or the CQA Inspector on a regular basis.

**Action in the event of Failed Tests**

In the event of a failed destructive test the Contractor will have the following options:

a) Replace or cap the entire seam i.e. remove the seam and re-seam or extrusion weld a strip of additional barrier over the seam.

b) Extract further samples for destructive testing from the proximity of the failed location, a minimum of 3m from the location of the failed test in both directions (if applicable). If these samples pass destructive testing, the seam shall be reconstructed between these locations by capping as detailed in Section a) above.

At the completion of the lining works the drainage layer shall be placed and the barrier system shall be subjected to an electrical leak detection survey to confirm that there are no detectable holes through the HDPE Barrier layer.
A1.10 Test Certificates

The Contractor shall submit test certificates for the properties defined in Clause 2.1.05 for the supplied liners before laying. The test certificates shall be from an accredited laboratory confirming the condition of the liner.

A1.11 Additional Tests on Materials

The Contractor shall make the necessary arrangements as required for check tests to be made on any of the materials specified for compliance with the requirements of the appropriate Clause and the Standard tests applicable to the Clause, if called upon to do so by the site engineer or the CQA Inspector, either before installation of the liner or at any time throughout the work.

The Contractor shall allow within the Contract Sum (or such other arrangements as may be appropriate) for undertaking additional testing of the materials where there has been a failure test.

A1.12 Certificates for Compliance with the Specification

The Contractor shall submit certificates throughout the course of the work for all consignments of liner and consumables to be used in the formation of the liner in advance of laying for approval by the site engineer or the CQA Inspector, to ensure that all materials comply with the relevant Clauses in the Specification. Records of lots or locations are to be made and provided to the site engineer or the CQA Inspector.
ANNEX 2: Specification for Geotextiles used as Separation and Basal Reinforcement (not Europe) (Date of document September 2005)

The specification for two classes of geotextile, to be used as a stand-alone document. The two classes of geotextile described are to be used in conjunction with the construction of an earth fill embankment 3 m to 4 m high constructed on estuarine alluvium. The Class A geotextile is a separation layer beneath a 1 m thick layer of rock fill. The Class B geotextile is a filter layer to be placed beneath a hand pitched stone revetment.

Specification for Geotextiles for Separation and Basal Reinforcement

1. Geotextiles shall be of woven or non woven construction using polypropylene, polyester fibres, incorporating additives to reduce the rate of degradation from ultra violet light.

2. Geotextiles shall be protected at all times against mechanical or chemical damage. Geotextiles shall be stored on site in the wrappings provided by the manufacturer until required for use in the works. The geotextile shall not be exposed to sunlight for more than seven days before being covered with fill materials. The rolls shall be stored on level ground and stacked not more than five rolls high. No other materials shall be stacked on top of the Geotextiles.

3. The layer of material on which the geotextile is to be placed shall not have protrusions or sharp projections, which are likely to damage the geotextile during installation or in service. The method of installation shall ensure that the geotextile is in continuous contact with the surface on which it is to be placed and the geotextile shall not be stretched or bridged over hollows or humps. Operation of construction plant directly on the installed geotextile will not be permitted and its covering with fill material shall take place immediately after it has been laid.

4. The geotextile shall be laid and lapped as described on the drawings. Where lapping is employed, the adjacent sheets or strips shall be overlapped by at least the value specified for the class of the geotextile in Table 1.

5. The Contractor shall supply certification, from a laboratory approved by the Engineer, that the properties of the Geotextiles comply with the requirements of the specification. The certification shall be provided before any geotextile is incorporated in the works. All Geotextiles delivered to site shall be marked in accordance with BS EN 10320 ‘Geotextiles - Identification on Site’.

6. The Geotextiles required for the works shall have the properties stated in Table 1. The following definitions shall apply when considering the results of any tests carried out on the Geotextiles.

7. Characteristic strength: the strength of the geotextile below, which not more than 5% of the test results, may be expected to fall. This represents the strength at 1.64 standard deviations below the mean strength.

8. Mean value: The mean value for any set of test results shall be the ‘arithmetic mean’ for that set of tests.
9. Set of tests: A set of tests shall be the tests carried out on specimens cut from one sample. The number of specimens shall be as defined in the particular test standard.

10. The classes of Geotextiles are to be used in the works as follows:

   Class A: Geotextile separation layer beneath rock fill.
   Class B: Geotextile filter beneath revetment (Note: geotextile Class A can be used to replace Class B material).

### Table 1: Properties of Geotextiles

<table>
<thead>
<tr>
<th>Property</th>
<th>Class A</th>
<th>Class B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristic Tensile Strength, warp. kN/m (mean minus the negative tolerance) BSEN ISO 10319</td>
<td>35</td>
<td>13</td>
</tr>
<tr>
<td>Characteristic Tensile Strength, weft, kN/m (mean minus the negative tolerance) BSEN ISO 10319</td>
<td>26</td>
<td>9.5</td>
</tr>
<tr>
<td>Characteristic Dynamic Perforation value, (mean plus the positive tolerance, max. hole dia.),mm, (Cone Drop Test) BSEN 918</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>Characteristic Static Puncture Resistance, (mean minus the negative tolerance) N, (CBR Test), BSEN ISO 12236</td>
<td>3500</td>
<td>1500</td>
</tr>
<tr>
<td>Water flow normal to plane, (mean minus the negative tolerance) l/m²/sec, BSEN ISO 12958</td>
<td>40</td>
<td>15</td>
</tr>
<tr>
<td>Characteristic Apparent Opening Size, (O_{90}), (mean value max positive and negative tolerances), mm, BSENISO 12956</td>
<td>0.40 ± 0.15</td>
<td>0.40 ± 0.15</td>
</tr>
<tr>
<td>Minimum lap when laid, m.</td>
<td>0.50</td>
<td>0.30</td>
</tr>
</tbody>
</table>

11. Geotextiles to be incorporated in the works shall be subjected to Quality Assurance tests. The tests shall be carried out in a laboratory approved by the Engineer. Samples shall be taken from the Geotextiles delivered to site or to be delivered to site in accordance with the provisions of BSEN 963 ‘Geotextiles - Sampling and Preparation of Test Specimens’. Samples shall be taken at a frequency of not less than one sample for each 10,000 m² of geotextile to be incorporated in the works. The tests to be carried out on both classes of geotextile shall be:

   - Characteristic Tensile Strength (wide width tensile test)
   - Static Puncture Test (CBR) or Dynamic Puncture Test (Drop Cone)
   - Water flow normal to the plane
   - Effective opening size

12. The results of the tests shall be presented to the Engineer’s representative not less than 21 days after the samples have been taken and in no case prior to the geotextile represented by the samples being incorporated into the works.

APPENDIX 5/4 FOR A UK TRUNK ROAD, SHW 1991
Series 500 Drainage and Service Ducts
Appendix 5/4: Fin Drains and Narrow Filter Drains (note drawing numbers and values quoted for properties are project specific)

1. The requirements for Fin Drains and Narrow Filter Drains are indicated on the Drawings No. 88326/T/1050 to 1078 Roadworks, Fencing and Drainage and the schedule contained in Volume 9, Drainage Schedules. Construction requirements are given in the Highway Construction Details, Series B and F and Volume 6, Special Construction Details, together with additional detailed requirements contained in this Appendix.

2. The Fin/Narrow Filter Drain to be used shall be Drain Type 5, 6, 7 or 9 as shown on Drawing No. F18, of the Highway Construction Details.

3. The mean apparent opening size of the geotextile (O90) shall lie in the range 0.10 to 0.40 mm.

4. The geotextile shall allow water to flow through it normal to the principal surface at a rate of not less than 30 litres/sec/m², expressed as the mean value minus the negative tolerance value given by the manufacturer.

5. The pipe diameter for fin drains types 6 and 7 shall be not less than 100mm.

6. All exposed edges must be covered before delivery to site or immediately on laying.

7. The minimum long term in plane flow rates required for the fin drains, measured using BSEN ISO 12958, as the mean values minus the manufacturers quoted negative tolerance, shall be:

<table>
<thead>
<tr>
<th>Fin Drain Type</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Stress (kPa)</td>
<td>200</td>
<td>100</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>Hydraulic gradient</td>
<td>0.1</td>
<td>1.0</td>
<td>1.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Minimum In-plane Flow (Mean minus the negative tolerance) (l/m/sec)</td>
<td>0.5</td>
<td>15.0</td>
<td>0.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>

8. The permeability of the granular backfill material to be used for Narrow Filter Drains Type 9 shall be not less than $1 \times 10^{-5}$ m/sec when tested in accordance with BS 1377 Part 5. Geotextiles used to wrap the drains shall be tested in accordance with the procedures and at the rates stated in Appendix 6/5.

9. Certification

   All geotextile fin drains delivered to site shall be CE Marked in accordance with BSEN 13252 and other if appropriate and delivered with the Accompanying Documents showing the values of all specified characteristics and marked in accordance with BS EN 10320 ‘Geotextiles - Identification on Site’.
Annex 4 Specifications for Geosynthetics in Pollution Control Channels for a UK Highway. (Date of Document September 2005).

Annex 4 is a special Appendix to the SHW 1991 (Ref. 1) for the specification of the lining components of pollution control channels to be constructed within the highway drainage system. The intention of the pollution control channels is that in normal service the surface and ground water collected by the highway drains is discharged to a watercourse without containment in the event of a spillage on the highway the emergency services close the outlet of the pollution control channel to prevent the pollutant reaching the watercourse. The impermeable lining of the pollution control channel is designed to prevent seepage of the pollutant into the ground.

**SPECIAL APPENDIX 5/70 - GEOMEMBRANES AND PROTECTION GEOTEXTILES**

**Pollution Control Channels: Lining Systems Impermeable Membrane**

1. Geosynthetics and revetment systems are required for lining the pollution control ditch as shown on the contract drawings *(Note: list numbers if possible)*.

2. The pollution control channels shall be lined with a geosynthetic barrier with the following characteristics:

   **Geosynthetic Barrier: Class C**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Permitted values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials:</td>
<td>Linear Low Density Polyethylene (LLDPE)</td>
</tr>
<tr>
<td></td>
<td>Plasticized Polyvinyl Chloride (PVC)</td>
</tr>
<tr>
<td></td>
<td>High Density Polyethylene (HDPE)</td>
</tr>
<tr>
<td></td>
<td>Flexible Polypropylene (FPP)</td>
</tr>
<tr>
<td>Thickness (minimum) : (EN 1849-2)</td>
<td>1.0 mm</td>
</tr>
<tr>
<td>Tensile Strength (minimum) (ISO 527)</td>
<td>(HDPE)</td>
</tr>
<tr>
<td></td>
<td>(LLDPE)</td>
</tr>
<tr>
<td></td>
<td>(PVC)</td>
</tr>
<tr>
<td></td>
<td>(FPP)</td>
</tr>
<tr>
<td></td>
<td>28 N/mm²</td>
</tr>
<tr>
<td></td>
<td>18 N/mm²</td>
</tr>
<tr>
<td></td>
<td>15 N/mm²</td>
</tr>
<tr>
<td></td>
<td>15 N/mm²</td>
</tr>
<tr>
<td>Tear Resistance (Minimum) (ISO 34)</td>
<td>125 N/mm (HDPE)</td>
</tr>
<tr>
<td></td>
<td>60 N/mm (LLDPE)</td>
</tr>
<tr>
<td></td>
<td>44 N/mm (PVC)</td>
</tr>
<tr>
<td></td>
<td>60 N/mm (FPP)</td>
</tr>
<tr>
<td>Burst Resistance <em>(ASTM D 5617)</em></td>
<td>10 N/mm² (HDPE)</td>
</tr>
<tr>
<td></td>
<td>4 N/mm² (all others)</td>
</tr>
<tr>
<td>Puncture Resistance (Min) (CBR test BSENISO 12236)</td>
<td>1500 N (all materials)</td>
</tr>
</tbody>
</table>

**Frequency of testing**

Geosynthetic barriers to be incorporated in the works shall be subjected to Quality Assurance tests. The tests shall be carried out in a laboratory approved by the Engineer.
Samples shall be taken from the geosynthetic barriers delivered to site or to be delivered to site in accordance with the provisions of BSEN 963 'Geotextiles - Sampling and Preparation of Test Specimens'. Samples shall be taken at a frequency of not less than one sample for each 10,000 m² of geosynthetic barrier to be incorporated in the works. The tests to be carried out on of geosynthetic barrier shall be:

- Tensile Strength
- Tear Resistance
- Puncture Resistance
- Burst Resistance

The results of the tests shall be presented to the Engineer's representative not less than 21 days after the samples have been taken and in no case prior to the geosynthetic barrier represented by the samples being incorporated into the works.

**Jointing**

Site jointing or factory jointing will be permitted. All joints shall be double seemed to allow an air pressure test on completion of each joint. Joints shall exhibit not less than 75% of the tensile strength of the parent material. The method of tensile testing shall be proposed by the Contractor for agreement by the Engineer before any tests are carried out. Site joints shall be formed by fusion welding techniques appropriate to the materials being used. Prior to any site jointing work a trial joint shall be formed. The trial joint shall be not less than 8 metres long and shall be formed using equipment to be used on the Works and by the operatives to be employed on the work. The trial joint will be visually inspected air pressure tested and samples cut from the weld for a Shear Test (ASTM D3083) and a Peel Test (ASTM D413) the results of the trial test pieces will be the 'reference' values. During the work samples will be cut from the overrun at the ends of production joints at a rate of not less than one for each 800 lin. metres of joint formed. The samples will be tested alternately in shear and peel and no joint will be accepted if the result of the test on the production samples is less than 90% of the reference value. Any joint, which allows any loss of air during the air pressure test, shall be re-welded and re-tested.

**Pipes etc:** At inlets or outlets where it is necessary to make an opening in the membrane a special collar shall be used which shall be joined to the geosynthetic barrier as a field joint.

**Laying on site**

All geosynthetic barriers shall be laid upon a protection geotextile. The geosynthetic barrier shall not be bent around any sharp corners or bent through a radius of less than 1000mm.

The level of any point on the surface shall not vary from the specified level by more than +50mm to -75mm. There shall be no abrupt irregularities in the surface exceeding 10mm.

The surface upon which the protection geotextile is laid shall be free from all loose stones larger than 20mm, if rounded particles (river or beach gravels) or 10mm, if sub angular or angular (crushed rock). The protection geotextile shall not span any hollows in the surface and must be laid to be in constant contact with the surface.

All geosynthetic barriers delivered to site shall be CE Marked in accordance with EN 13491, EN13492, EN13361, EN13362 or EN13493 as appropriate and delivered with the Accompanying Documents showing the values of all specified characteristics and
Protection Geotextile

3. Geosynthetic barriers shall be laid on a protection geotextile with the following characteristics.

- Tensile Strength Warp 10 kN/m (Mean minus the negative tolerance) (BSEN ISO 10319)
- CBR Push Through Force 5000 N (Mean minus the negative tolerance) (BSEN ISO 12236)
- Minimum Mass Per Unit Area 400 gm/m² (Mean minus the negative tolerance) (BS EN 965)
- Minimum Thickness under 2 kPa 6 mm (Mean minus the negative tolerance) (BSEN 964-1)

All other aspects of the geotextile, durability, life expectancy, laying and testing shall be as described in Clause 609 (SHW) and Appendix 6/5.

All Geotextiles delivered to site shall be CE Marked in accordance with the provisions of BSEN 13257, 13256, 13253, 13254 or 13255 as appropriate and delivered with the Accompanying Documents showing the values of all specified characteristics and marked in accordance with BS EN 10320 'Geotextiles - Identification on Site'.

Samples for testing shall be taken at a rate of not less than one sample (sufficient for all tests required) for each 5000 m² of protection geotextile delivered to site. Test samples shall be taken in accordance with BSEN 963, the sampling report shall be sent to the laboratory accredited for the tests required, with the samples and a copy of the report sent to the Engineer within 24 hours of the samples being taken. The results of tests are to be delivered to the Engineer within 21 days of sampling.

Concrete Block Revetment

3. Where shown on the drawings the geosynthetic barrier shall be covered with a precast cellular concrete block revetment system. The individual blocks shall have a thickness of not less than 80 mm, an open area of not less than 15%. The blocks shall be interlinked with each other using polyester or galvanised wire cables, the voids in the blocks shall be filled with Type C drainage media.

The individual blocks shall be tapered to ensure that a mechanical interlock can develop between the blocks and the Type C in-fill.

4. Where concrete block revetments are used, a second layer of protection geotextile shall be laid on the geosynthetic barrier prior to laying the concrete blocks.

Soil Containment System

5. Where shown on the drawings the geosynthetic barrier shall be covered with a
A ‘honeycomb' soil containment system manufactured from a permeable geotextile.
The properties of the soil containment system shall be:

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of cells</td>
<td>300 mm minimum across any diagonal</td>
</tr>
<tr>
<td>Depth of cells</td>
<td>100 mm</td>
</tr>
<tr>
<td>Construction</td>
<td>Thermal bonding</td>
</tr>
<tr>
<td>Permeability</td>
<td>10 litres/m²/sec (Min Normal to face of cell walls BSEN ISO 11058)</td>
</tr>
</tbody>
</table>

No testing is required; a certificate of compliance is to be delivered to the Engineer before any of the Soil Containment System is incorporated on the Works.

All soil containment Geotextiles delivered to site shall be CE Marked in accordance with the provisions of BSEN 13253 and other standards appropriate to the application of the product and delivered with the Accompanying Documents showing the values of all specified characteristics and marked in accordance with BS EN 10320 ‘Geotextiles - Identification on Site’.

6. The soil containment system shall be fixed to the ground at the top of the slope as shown on the drawings and filled with topsoil. The topsoil shall be placed carefully from the bottom of the slope to the crest.

Topsoil shall be seeded as described in Clause 618 except that the surface shall not be harrowed as in Clause 618.5.

APPENDIX 6/5 FOR UK TRUNK ROAD, SHW 1991: Series 600 Earthworks
Appendix 6/5: Geotextiles Used to Separate Earthworks Materials

1. The locations at which Geotextiles are required for the purposes of separating earthworks materials are shown on Drawing No. 88326/T/1036 (Note: Geotextiles which are required to strengthen embankments are detailed in Appendix 6/9).

2. Geotextiles shall be laid as shown on the drawings and shall be lapped at sheet edges by not less than 0.3m or shall be joined with sewn seams or bonded or glued to adjacent sheets as recommended by the manufacturer or supplier.

2. Geotextiles for separation shall be manufactured from any of the following polymers: polyester, Polyamide, polypropylene or polyethylene. All Geotextiles delivered to site shall be CE Marked in accordance with BSEN 13249 and other if appropriate to the conditions of use and delivered with the Accompanying Documents showing the values of all specified characteristics and marked in accordance with BS EN 10320 `Geotextiles - Identification on Site'.

3. The Geotextiles shall, when exposed to UV light in an accelerated weathering test BSDD ENV 12224, carried out and interpreted in accordance with the procedures described in the CEN Report CR ISO 13434, have a resistance to UV light and weathering, such that the time to reduce the characteristic tensile strength by 50% exceeds 3 months. The Geotextiles shall have a resistance to chemical degradation and biological degradation, such that when tested in accordance with the index test methods described in BSEN 12226, the reduction in characteristic tensile strength does not exceed 25% of the original value.

4. The minimum expressed as the mean value minus the negative tolerance, tensile strength of the geotextile separator shall be 6 kN/m width when measured in accordance with BSEN ISO 10319.

5. All Geotextiles delivered to the site shall be marked in accordance with BSEN 10320. Samples for testing in accordance with Clause 609 shall be taken in accordance with the prescriptions of BSEN 963 `Geotextiles - Sampling and Preparation of Test Specimens'. The sampling report shall be sent with the samples to the test laboratory and a copy shall be delivered to the Engineer within 24 hours of the sampling.

6. Samples shall be taken on site or with the agreement of the Engineer at the Manufacturers works or stores. Samples shall be taken at a rate of not less than one sample for each 10,000 square metres of each produced used in the Works. Each sample shall be sufficiently large for all the specimens required for the tests to be cut from the one sample.

7. All tests shall be carried out in an accredited laboratory for the tests. The results of the tests shall be delivered to the Engineer within 21 days of the samples being taken on site and in any case before any material is used in the Works.
Annex 6: Specification for Geosynthetics to be used in soil reinforcement associated with a UK Highway (Date of Document September 2005)

APPENDIX 6/9 FOR UK TRUNK ROAD, SHW 1991: Series 600 Earthworks

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

1. Landscape Areas – not used

2. Geosynthetics for Basal Reinforcement of Strengthened Embankments

   (i) The locations at which reinforcing Geosynthetics are to be laid are shown on the Drawing No. **88326/T/1036**.

   (ii) The Geosynthetics shall be stored and laid in accordance with the appropriate paragraphs of Clause 609 with the exception that for Type A materials the minimum overlap shall be **500 mm** and not as specified in Clause 609.5. All Geosynthetics delivered to site shall be CE Marked in accordance with the provisions of BSEN 13251 and other standards appropriate to the application of the product and delivered with the Accompanying Documents showing the values of all specified characteristics and marked in accordance with BS EN 10320.

   (iii) The Geosynthetics to be used shall be:-
   Type A - Woven using polyester filaments
   Type B - Any construction method using polyethylene, polypropylene or polyester polymers

   These materials shall have the following properties, and be as specified in Clause 609.

<table>
<thead>
<tr>
<th>Test Method</th>
<th>Type A</th>
<th>Type B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristic Tensile Strength, warp. kN/m (mean minus the negative tolerance) BSEN ISO 10319</td>
<td>180</td>
<td>27</td>
</tr>
<tr>
<td>Characteristic Tensile Strength, weft. kN/m (mean minus the negative tolerance) BSEN ISO 10319</td>
<td>35</td>
<td>N/A</td>
</tr>
<tr>
<td>Tensile Strain, warp. %, (mean minus the negative tolerance) BSEN ISO 10319</td>
<td>9.5</td>
<td>N/A</td>
</tr>
<tr>
<td>Water flow normal to the plane (mean minus the negative tolerance), l/m²/sec (BSEN ISO 11058)</td>
<td>8.5</td>
<td>27</td>
</tr>
<tr>
<td>Static Puncture Resistance, N, (mean minus the negative tolerance) (BSEN ISO 12236)</td>
<td>N/A</td>
<td>2700</td>
</tr>
</tbody>
</table>
(iv) All tests shall be carried out as described in the appropriate sub-clauses of Clause 609. Material samples shall be taken from fabric to be incorporated in the earthworks as described in Appendix 6/5 para. 4. The number of samples to be taken for testing shall be one sample set per 10,000 square metres of fabric.

(v) The Contractor shall provide evidence to the Engineer that the geosynthetic has the durability properties described in Appendix 6/5 para. 3.

(vi) Reinforcement shall be laid in one continuous sheet from the outer face of the embankment to the inner edge, with the warp direction as shown on the drawings. Adjacent sheets shall be overlapped by 500 mm, or stitched to maintain 60% of the weft strength. The strength of sewn joints shall be demonstrated using the test procedures in BSEN 10321. One set of tests shall be carried out on specimens cut from a 10 m long trial sample produced using the same machinery and methods proposed for the main works. Samples for checking the quality of the works shall be taken at a rate of one sample for each 1000 metres of seam. The works samples shall be tested in accordance with BSEN 10321 and all procedures for sampling and reporting shall be as described in Appendix 6/5 paras. 4, 5 and 6.

(vii) Reinforcement shall be placed as specified for Geosynthetics in Clause 609.6. Any excess reinforcement protruding from outer faces receiving topsoil shall be trimmed off before placement of topsoil.

(viii) Fill materials shall be as described in Appendix 6/1. The Contractor shall ensure that Geosynthetics supplied for inclusion in the permanent works are compatible with fill material to be used. When using polyester based Geosynthetics lime shall not be used to modify the properties of in-situ soils or fill materials.

3. Geogrids for Reinforcement of Over-steep Embankments (Face Angle 45° to 70° to Horizontal)

i) The locations at which reinforcing Geogrids are to be laid are shown on Drawing No. 888320/T/1040.

ii) The Geogrids shall be stored in accordance with the appropriate paragraphs of Clause 609.

iii) The Geogrids shall be laid as indicated on the drawings. The Geogrids shall be pulled tight so that there is no visible slack in the material as fill is laid. Fill shall be placed into the geogrid in such a manner that lateral displacement of the geogrid is avoided.

iv) All Geogrids delivered to site shall be CE Marked in accordance with the provisions of BSEN 13251 and other standards appropriate to the application of the product and delivered with the Accompanying Documents showing the values of all specified characteristics and marked in accordance with BS EN 10320.

v) The Geogrids to be used shall be:
   - Type A: Drawn high density polyethylene or polypropylene
   - Type B: PVC covered interwoven polyester

<table>
<thead>
<tr>
<th>Characteristic Tensile Strength, kN/m (mean minus the negative tolerance) BSEN ISO 10319 (machine or warp direction)</th>
<th>Type A</th>
<th>Type B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type A1</td>
<td>Type A2</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>50</td>
</tr>
</tbody>
</table>

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vi) Products, which are not covered by a current independent certificate for this application, will only be considered when a test certificate from an independent accredited laboratory is supplied to the Engineer. The test certificate shall be not more than 4 months old.

In addition, Geogrids not covered by a current independent certificate scheme shall be subjected to regular testing of samples taken from materials delivered to site. Samples for testing shall be taken at a frequency of one sample for every 5,000 square metres of each type of geogrid in accordance with the prescriptions of BSEN ISO 10320 `Geotextiles - Sampling and Preparation of Test Specimens'. The sampling report shall be sent with the samples to an accredited laboratory for testing, a copy of the sampling report shall be delivered to the Engineer within 24 hours of the sampling. The results of the tests shall be delivered to the Engineer within 21 days of the sampling and before the material represented by the sample is incorporated into the Works.
Annex 7 Specifications from GRI (Document dated April 2005)
(http://www.geosynthetic-institute.org/specs.htm)

Annex 7.1 – Separation

GRI GT13 - Standard Specification for “Test Methods and Properties for Geotextiles Used as Separation between Subgrade Soil and Aggregate

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 geotextile test methods properties for subsequent use as separation between subgrade soil and aggregate predominantly in pavement systems.

Note 1: While separation occurs in every geotextile application, this pavement related specification focuses on subgrade soils being “firm” as indicated by CBR values higher than 3.0 (soaked) or 8.0 (unsoaked).

1.2 This specification sets forth a set of physical, mechanical and endurance properties that must be met, or exceeded, by the geotextile being manufactured.
1.3 In the context of quality systems and management, this specification represents a manufacturing quality control (MQC) document. However, its general use is essentially as a recommended design document.
1.4 This specification is intended to assure both good quality and performance of fabrics used as geotextile separators but is possibly not adequate for the complete specification in a specific situation. Additional tests, or more restrictive values for the tests indicated, may be necessary under conditions of a particular application.
1.5 This standard specification does not address installation practice. This item is addressed in the geosynthetics literature dealing with this particular application and under unique situations might require modifications, e.g., higher values and/or additional test properties.

2. Referenced Documents
2.1 ASTM Standards
D 4354 Practice for Sampling of Geosynthetics for Testing
D 4355 Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus)
D 4533 Test Method for Trapezoidal Tearing Strength of Geotextiles
D 4632 Test Method for Grab Breaking Load and Elongation of Geotextiles
D 4759 Practice for Determining the Specification Conformance of Geosynthetics
D 4873 Guide for Identification, Storage and Handling of Geotextiles
D 5261 Test Method for Measuring Mass per Unit Area of Geotextiles
D 6241 Test Method for Static Puncture Strength of Geotextiles and Geotextile Related Product Using a 50-mm Probe

2.2 AASHTO Specification
M288-00 Geotextile Specification for Highway Applications
3. Definitions
3.1 Formulation - The mixture of a unique combination of ingredients identified by type, properties and quantity. For nonwoven geotextiles, a formulation is defined as the exact percentages and types of resin(s), additives and/or carbon black.
3.2 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].

Minimum Average Roll Value (MARV) – For geosynthetics, a manufacturing quality control tool used to allow manufacturers to establish published values such that the user/purchaser will have a 97.7% confidence that the property in question will meet published values. For normally distributed data, “MARV” is calculated as the typical value minus two (2) standard deviations from documented quality control test results for a defined population from one specific test method associated with one specific property.

3.4 Minimum Value – The lowest sample value from documented manufacturing quality control test results for a defined population from one test method associated with one specific property.
3.5 Maximum Value – The highest sample value from documented manufacturing quality control test results for a defined population from one test method associated with one specific property.
3.6 Separation – The placement of a flexible porous geosynthetic between dissimilar materials so the integrity and functioning of both materials can remain intact or be improved.

Note 2: For separation of stone base courses overlying soil subgrades this primary function simultaneously prevents the stone from intruding down into the soil and the soil from pumping up into the stone.

4. Material Classification and Formulation
4.1 This specification covers geotextiles used as separation materials.
4.2 The polymer types are usually polypropylene, polyester or polyethylene, but other polymers are also possible in this regard.
4.3 The type of geotextile style is not designated. However a distinction can be made based on the elongation criteria of 50%.

Note 3: It is assumed that nonwoven fabrics break at elongations higher than 50%. Woven fabrics always break at elongations significantly lower than 50%.

5. Specification Requirements
5.1 The geotextiles for use as separator shall conform to Tables 1 or 2. Table 1 is given in English units and Table 2 is in SI (Metric) units. The conversion from English to SI units is “soft”.
5.2 The required values for most properties in Tables 1 and 2 are to be minimum average roll values (MARV) except UV resistance which is a minimum value and AOS which is a maximum value.
5.3 The required class is determined by the severity of installation conditions (i.e., size of equipment, condition of subgrade, thickness of covering lift, etc.). Table 3 gives guidance in this respect.
6. Workmanship and Appearance
6.1 The finished geotextile shall have good appearance qualities. It shall be free from such defects that would affect the specific properties of the geotextile, or its proper functioning.
6.2 General manufacturing procedures shall be performed in accordance with the manufacturer’s internal quality control guide and/or documents.

7. MQC Sampling, Testing, and Acceptance
7.1 Geotextiles shall be subject to sampling and testing to verify conformance with this specification. Sampling shall be in accordance with the most current modification of ASTM Standard D 4354, using the section titled, “Procedure for Sampling for Purchaser’s Specification Conformance Testing.” In the absence of purchaser’s testing, verification may be based on manufacturer’s certifications as a result of testing by the manufacturer of quality assurance samples obtained using the procedure for Sampling for Manufacturer’s Quality Assurance (MQA) Testing. A lot size shall be considered to be the shipment quantity of the given product or a truckload of the given product, whichever is smaller.
7.2 Testing shall be performed in accordance with the method referenced in this specification for the indicated application. The number of specimens to test per sample is specified by each test method. Geotextile product acceptance shall be based on ASTM D4759. Product acceptance is determined by comparing the average test results of all specimens within a given sample to the specification MARV. Refer to ASTM D 4759 for more details regarding geotextile acceptance procedures.

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. Shipment and Storage
9.1 Geotextile labelling, shipment, and storage shall follow ASTM D 4873. Product labels shall clearly show the manufacturer or supplier name, style, and roll number. Each shipping document shall include a notation certifying that the material is in accordance with the manufacturer’s certificate.
9.2 Each geotextile roll shall be wrapped with a material that will protect the geotextile, including the ends of the roll, from damage due to shipment, water, sunlight and contaminants. The protective wrapping shall be maintained during periods of shipment and storage.

Note 4: The project specification shall be very explicit as to the maximum exposure time between the geotextile being removed from the wrapper and being backfilled with soil or covered with another geosynthetic.

9.3 During storage, geotextile rolls shall be elevated off the ground and adequately covered to protect them from the following: site construction damage, precipitation, extended ultraviolet radiation including sunlight, chemicals that are strong acids or strong bases, flames including welding sparks, temperatures in excess of 160°F (71°C), and any other environmental condition that may damage the property values of the geotextile.

10. Certification
10.1 The contractor shall provide to the engineer a certificate stating the name of the manufacturer, product name, style number, chemical composition of the filaments or yarns, and other pertinent information to fully describe the geotextile.
10.2 The manufacturer is responsible for establishing and maintaining a quality control program to assure compliance with the requirements of the specification. Documentation describing the quality control program shall be made available upon request.
10.3 The manufacturer’s certificate shall state that the finished geotextile meets the requirements of the specification as evaluated under the manufacturer’s quality control program. A person having legal authority to bind the manufacturer shall attest to the certificate.
10.4 Either mislabelling or misrepresentation of materials shall be reason to reject those geotextile products.

Tables included in the GRI document are not included in this guide go to http://www.geosynthetic-institute.org/specs.htm for the full document.
Annex 7.2 Specifications for HDPE Membranes (Document dated April 2005)

GRI Test Method GM13*

Standard Specification for "Test Properties, Testing Frequency and Recommended Warranty 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 values for test indicated, may be necessary under conditions of a particular application.

1.5 This specification also presents a recommended warrant which is focused on the geomembrane material itself.

1.6 The recommended warrant attached to this specification does not cover installation considerations which is independent of the manufacturing of the geomembrane.

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 6693 Test Method for Determining Tensile Properties of Non-reinforced Polyethylene and Non-reinforced Flexible Polypropylene Geomembranes
2.2 GRI Standards
GM10 Specification for the Stress Crack Resistance of Geomembrane Sheet
GM 11 Accelerated Weathering of Geomembranes using a Fluorescent UVA Condensation Exposure Device
GM 12 Measurement of the Asperity Height of Textured Geomembranes Using a Depth Gage

3. Definitions

3.1 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

3.2 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
- Water Absorption
- Dimensional Stability
- Ozone Resistance
- Coeff. of Linear Expansion
- Modulus of Elasticity
- Resistance to Soil Burial
- Hydrostatic Resistance
- Low Temperature Impact
- Tensile Impact
- ESCR Test (D 1693)
- Field Seam Strength
- Wide Width Tensile
- Multi-Axial Burst
- Water Vapour Transmission
- Various Toxicity Tests

Note 5: There are several tests which are included in these standards (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

Note 6: 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).

Note 7: There are several GRI tests currently included in this standard. Since these topics are not covered in ASTM standards, this is necessary. They are the following:
• UV Fluorescent Light Exposure
• Asperity Height Measurement

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

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.

11. Warranty

11.1 Upon request of the purchaser in the contract or order, a manufacturer's warrant of the quality of the material shall be furnished at the completion of the terms of the contract.

11.2 A recommended warranty for smooth and textured HDPE geomembranes manufactured and tested in accordance with this specification is given in Appendix A.

11.3 The warranty in Appendix A is for the geomembrane itself. It does not cover subgrade preparation, installation, seaming, or backfilling. These are separate operations that are often beyond the control, or sphere of influence, of the geomembrane manufacturer.

Note 9: If a warrant is required for installation, it is to be developed between the installation contractor and the party requesting such a document.

Tables included in the GRI document are not included in this guide go to http://www.geosynthetic-institute.org/specs.htm
For the full document.

STANDARD SPECIFICATION FOR ROLLED EROSION CONTROL PRODUCTS

This specification was prepared by the Erosion Control Technology Council and the original may be downloaded from their web site at www.ectc.org. Imperial units are from the original document, metric units are given for information.

This work consists of constructing temporary and permanent installations to control erosion, enhance vegetation establishment, and survivability on slopes, channels, and includes installing rolled erosion control products.

Temporary Rolled Erosion Control Products
For applications where natural vegetation alone will provide sufficient permanent erosion protection, furnish a temporary rolled erosion control product with the necessary longevity and performance properties to effectively control erosion and assist in the establishment of vegetation under the anticipated immediate site conditions. The temporary rolled erosion control product shall conform to one of the following specifications and corresponding properties found in Table 1.

Permanent Rolled Erosion Control Products
For applications where natural vegetation alone will not sustain expected flow conditions and/or provide sufficient long-term erosion protection, furnish a permanent rolled erosion control product with the necessary performance properties to effectively control erosion and reinforce vegetation under the expected long-term site conditions. The permanent erosion control product shall conform to one of the specifications and corresponding properties found in Table 2.

Rolled erosion control products are designated as follows:

(a) Mulch control netting. A planar woven natural fibre or extruded geosynthetic mesh used as a temporary degradable rolled erosion control product to anchor loose fiber mulches.

(b) Open weave textile. A temporary degradable rolled erosion control product composed of processed natural or polymer yarns woven into a matrix, used to provide erosion control and facilitate vegetation establishment.

(c) Erosion control blanket. A temporary degradable rolled erosion control product composed of processed natural or polymer fibres mechanically, structurally or chemically bound together to form a continuous matrix to provide erosion control and facilitate vegetation establishment.

(d) Turf reinforcement mat. A rolled erosion control product composed of non-degradable synthetic fibres, filaments, nets, wire mesh and/or other elements, processed into a permanent, three-dimensional matrix of sufficient thickness. TRMs, which may be supplemented with degradable components, are designed to impart immediate erosion protection, enhance vegetation establishment and provide long-term functionality by permanently reinforcing vegetation during and after maturation. Note: TRMs are typically used in hydraulic applications, such as high flow ditches and channels, steep slopes, stream banks, and shorelines, where erosive forces may exceed the limits of natural, unreinforced vegetation or in areas where limited vegetation establishment is anticipated.
Construction Requirements for Erosion Control Blankets, Open Weave Textiles, and Turf Reinforcement Mats

General. Make the soil surface stable, firm, and free of rocks and other obstructions. Install rolled erosion control products according to the manufacturer’s published installation recommendations or the following minimum guidelines. In areas to be mowed soon after installation, use ultra-short term temporary RECPs that utilize (or consist of) rapidly degrading nettings having a maximum service life of 3 months or less. Install rolled erosion control products after application of seed, fertilizer and other necessary soil amendments, unless soil in-filling of the rolled erosion control product is required. If soil in-filling is required, install roller erosion control product, apply seed, and lightly brush or rake (0.3 to 0.7 in / 8 to 18 mm) of topsoil into the voids in the rolled erosion control products to fill the product thickness. Mulch Control Netting (Type 1.A., 2.A., 3.A.) immediately after dry mulch application install mulch control netting.

Stakes or staples for securing rolled erosion control products to the soil must be at least (6 in / 150 mm) long. Longer anchors may be necessary in sandy, loose, or wet soils. Unroll the rolled erosion control product parallel to the primary direction of flow and place it in direct contact with soil surface. Do not stretch or allow material to bridge over surface inconsistencies. Overlap edges of adjacent rolled erosion control products by (2 to 6 in / 50 to 100 mm). Use a sufficient number of stakes or staples to prevent seam separation. Overlap roll ends of joining rolled erosion control products (2 to 6 in / 50 to 150 mm) in the direction of flow.

(a) Slope Installations. At the top of slope, anchor the rolled erosion control product by one of the following methods:

(1) Staples. Install the rolled erosion control product (3 ft / 900 mm) over the shoulder of the slope onto flat final grade. Secure with a single row of stakes or staples on (1 ft / 300-mm) centres.

(2) Anchor trench. Construct a (6 in by 6 in / 150 mm by 150 mm) anchor trench. Extend the upslope terminal end of the rolled erosion control product (3 ft / 900 mm) past the anchor trench. Use stakes or staples to fasten the product into the anchor trench on (1 ft / 300 mm) centres. Backfill the trench and compact the soil. Apply seed and any necessary soil amendments to the compacted soil and cover with remaining (1 ft / 300 mm) terminal end of the rolled erosion control product. Secure terminal end with a single row of stakes or staples on (1 ft / 300 mm) centres.

(3) Check slot. Construct a stake or staple check slot along the top edge of the rolled erosion control product by installing two rows of stakes or staples (4 in / 100 mm) apart on (4 in / 100 mm) centres. Drive all stake and staple heads flush with soil surface. Securely fasten all rolled erosion control products to the soil by installing stakes or staples at a minimum rate of (1.3 yd² / 1.5/ m²).

(b) Channel Installations. Construct an anchor trench at the beginning of the channel across its entire width according to paragraph (a)(2) above. Follow the manufacturer’s installation guidelines in constructing additional anchor trenches or check slots at intervals along the channel reach and at the terminal end of the channel, according to paragraph (a)(2) or (a)(3) above respectively. Securely fasten all rolled erosion control products to the soil by installing stakes or staples at a minimum rate of (1.7 yd² / 1.5/ m²). Significantly higher anchor rates may be necessary in sandy, loose, or wet soils and I in severe applications. Repair any damaged areas immediately by restoring soil to finished grade, re-applying soil amendments and seed, and replacing the rolled erosion control product.
Table 1. ECTC Standard Specification for Temporary Rolled Erosion Control Products
For use where natural vegetation alone will provide permanent erosion protection

<table>
<thead>
<tr>
<th>Type Product Description Material Composition</th>
<th>Slope Applications*</th>
<th>Channel Applications*</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum Gradient C Factor2, 5</td>
<td>Max. Shear Stress3, 4, 6</td>
<td>Tensile Strength1</td>
</tr>
<tr>
<td>1.A Mulch Control Nets A photodegradable synthetic mesh or woven biodegradable natural fiber netting.</td>
<td>5:1 (H:V) &lt; 0.10 @ 5:1</td>
<td>0.25 lbs/ft2 (12 Pa)</td>
<td>5 lbs/ft (0.073 kN/m)</td>
</tr>
<tr>
<td>1.B Netless Rolled Erosion Control Blankets Natural and/or polymer fibres mechanically interlocked and/or chemically adhered together to form a RECP.</td>
<td>4:1 (H:V) &lt; 0.10 @ 4:1</td>
<td>0.5 lbs/ft2 (24 Pa)</td>
<td>5 lbs/ft (0.073 kN/m)</td>
</tr>
<tr>
<td>1.C Single-net Erosion Control Processed degradable natural and/or polymer fibres mechanically bound together by a single Blankets &amp; Open Weave rapidly degrading, synthetic or natural fiber netting or an open weave textile of processed rapidly Textiles degrading natural or polymer yarns or twines woven into a continuous matrix</td>
<td>3:1 (H:V) &lt; 0.15 @ 3:1</td>
<td>1.5 lbs/ft2 (72 Pa)</td>
<td>50 lbs/ft (0.73 kN/m)</td>
</tr>
<tr>
<td>1.D Double-net Erosion Control Blankets Processed degradable natural and/or polymer fibres mechanically bound together between two rapidly degrading, synthetic or natural fiber nettings.</td>
<td>2:1 (H:V) &lt; 0.20 @ 2:1</td>
<td>1.75 lbs/ft2 (84 Pa)</td>
<td>75 lbs/ft (1.09 kN/m)</td>
</tr>
</tbody>
</table>

1. “C” factor and shear stress for Types 1.A., 2.A. and 3.A mulch control nettings must be obtained with netting used in conjunction with pre-applied mulch material.


3. “C” Factor calculated as ratio of soil loss from RECP protected slope (tested at specified or greater gradient, h:v) to ratio of soil loss from unprotected (control) plot in large-scale testing. These performance test values should be supported by periodic bench scale testing under similar test conditions using Erosion Control Technology Council (ECTC) Test Method # 2.

4. Erosion Control Blankets & Open Weave Textiles An erosion control blanket composed of processed slow degrading natural or polymer fibres mechanically bound together between two slow degrading synthetic or natural fiber nettings to form a continuous matrix or an open weave textile composed of processed slow degrading natural or polymer yarns or twines woven into a continuous matrix.

LONG-TERM - Typical 36 month functional longevity.

<table>
<thead>
<tr>
<th>Type Product Description Material Composition</th>
<th>Slope Applications*</th>
<th>Channel Applications*</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum Gradient C Factor2, 5</td>
<td>Max. Shear Stress3, 4, 6</td>
<td>Tensile Strength1</td>
</tr>
<tr>
<td>3.A Mulch Control Nets A slow degrading synthetic mesh or woven natural fiber netting.</td>
<td>5:1 (H:V) &lt; 0.10 @ 5:1</td>
<td>0.25 lbs/ft2 (12 Pa)</td>
<td>25 lbs/ft (0.36 kN/m)</td>
</tr>
<tr>
<td>3.B Erosion Control Blankets &amp; Open Weave Textiles An erosion control blanket composed of processed slow degrading natural or polymer fibres mechanically bound together between two slow degrading synthetic or natural fiber nettings to form a continuous matrix or an open weave textile composed of processed slow degrading natural or polymer yarns or twines woven into a continuous matrix.</td>
<td>1.5:1 (H:V) &lt; 0.25 @ 1.5:1</td>
<td>2.50 lbs/ft2 (96 Pa)</td>
<td>100 lbs/ft (1.45 kN/m)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type Product Description Material Composition</th>
<th>Slope Applications*</th>
<th>Channel Applications*</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum Gradient C Factor2, 5</td>
<td>Max. Shear Stress3, 4, 6</td>
<td>Tensile Strength1</td>
</tr>
<tr>
<td>4 Erosion Control Blankets &amp; Open Weave Textiles An erosion control blanket composed of processed slow degrading natural or polymer fibres mechanically bound together between two slow degrading synthetic or natural fiber nettings to form a continuous matrix or an open weave textile composed of processed slow degrading natural or polymer yarns or twines woven into a continuous matrix.</td>
<td>1:1 (H:V) &lt; 0.25 @ 1:1</td>
<td>2.25 lbs/ft2 (108 Pa)</td>
<td>125 lbs/ft (1.82 kN/m)</td>
</tr>
</tbody>
</table>
4. Required minimum shear stress RECP (unvegetated) can sustain without physical damage or excess erosion (> 12.7 mm (0.5 in) soil loss) during a 30-minute flow event in large-scale testing. These performance test values should be supported by periodic bench scale testing under similar test conditions and failure criteria using Erosion Control Technology Council (ECTC) Test Method #3.

5. The permissible shear stress levels established for each performance category are based on historical experience with products characterized by Manning's roughness coefficients in the range of 0.01 - 0.05.

6. Acceptable large-scale test methods may include ASTM D6459, Erosion Control Technology Council (ECTC) Test Method #2, or other independent testing deemed acceptable by the engineer.

7. Per the engineer's discretion, Recommended acceptable large-scale testing protocol may include ASTM D6460, Erosion Control Technology Council (ECTC) Test Method #3 or other independent testing deemed acceptable by the engineer.
Table 2. ECTC Standard Specification For Permanent Rolled Erosion Control Products

For applications where vegetation alone will not sustain expected flow conditions and/or provide sufficient long-term erosion protection.

**Permanent 1** - All categories of TRMs must have a minimum thickness of 0.25 inches (6.35 mm) per ASTM D 6525 and U.V. stability of 80% per ASTM D 4355 (500 hours exposure).

<table>
<thead>
<tr>
<th>Type</th>
<th>Product Description</th>
<th>Material Composition</th>
<th>Slope Applications Maximum Gradient</th>
<th>Channel Applications Maximum Shear Stress4, 5</th>
<th>Minimum Tensile Strength2,3</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.A</td>
<td>Turf Reinforcement Mat</td>
<td>Turf Reinforcement Mat (TRM) – A rolled erosion control product composed of non-degradable synthetic fibres, filaments, nets, wire mesh and/or other elements, processed into a permanent, three-dimensional matrix of sufficient thickness. TRMs, which may be supplemented with degradable components, are designed to impart immediate erosion protection, enhance vegetation establishment and provide long-term functionality by permanently reinforcing vegetation during and after maturation. Note: TRMs are typically used in hydraulic applications, such as high flow ditches and channels, steep slopes, stream banks, and shorelines, where erosive forces may exceed the limits of natural, unreinforced vegetation or in areas where limited vegetation establishment is anticipated.</td>
<td>0.5:1 (H:V)</td>
<td>(288 Pa)</td>
<td>(1.82 kN/m)</td>
</tr>
<tr>
<td>5.B</td>
<td>Turf Reinforcement Mat</td>
<td></td>
<td>0.5:1 (H:V)</td>
<td>(384 Pa)</td>
<td>(2.19 kN/m)</td>
</tr>
<tr>
<td>5.C</td>
<td>Turf Reinforcement Mat</td>
<td></td>
<td>0.5:1 (H:V)</td>
<td>(480 Pa)</td>
<td>(2.55 kN/m)</td>
</tr>
</tbody>
</table>

1 For TRMs containing degradable components, all property values must be obtained on the non-degradable portion of the matting alone.

2 Minimum Average Roll Values, machine direction only for tensile strength determination using ASTM D 6818 (Supersedes Mod. ASTM D5035 for RECPs)

3 Field conditions with high loading and/or high survivability requirements may warrant the use of a TRM with a tensile strength of 44 kN/m or greater.

4 Required minimum shear stress TRM (fully vegetated) can sustain without physical damage or excess erosion (> 12.7 mm soil loss) during a 30-minute flow event in large scale testing. These performance test values should be supported by periodic bench scale testing under similar test conditions and failure criteria using Erosion Control Technology Council (ECTC) Test Method #3.

5 Acceptable large-scale testing protocol may include ASTM D6460, Erosion Control Technology Council (ECTC) Test Method #3, or other independent testing deemed acceptable by the engineer.
Annex 9 Specifications for the use of cellular confinement products in slope protection – Geocells (Geoweb™) (Document dated April 2005)

Description
The work covered by this section includes the furnishing of all labour, materials, equipment and incidentals for construction and installation of the Geocell Slope Protection System as shown on the Construction Drawings and described by the Contract Specifications.

References
The American Society of Testing and Materials (ASTM)
American Association of State Highway and Transportation Officials (AASHTO)
Construction Specifications Institute (CSI) format specifications

Submittals
Submit current product quality assurance test data and independent laboratory test results indicating compliance with specified performance. No material will be considered as an equivalent to the geocell material unless it meets all areas of this section without exception. Manufacturers seeking to supply what they call equivalent material must submit records, data, independent test results, samples, certifications, and documentation deemed necessary by the Engineer to prove equivalency. The Engineer will approve or disapprove other manufacturers’ materials within 60 days after all submitted information is studied and tested.

Quality Assurance and Certification
Product manufacturers shall provide certification of compliance with all applicable testing procedures and related specifications upon written request. Request for certification shall be submitted by the purchasing agency no later than the date of order placement.

On-site Manufacturer’s Representative
The manufacturer shall provide a qualified representative on site at the start of construction to ensure that the contractor installs the geocell system in accordance with the contract drawings and specifications. The representative shall have at least 5 years experience installing geocell slope protection systems and have installed a minimum of 500,000 ft² / 50,000 m² of geocell material.

ISO Certification
The manufacturer shall have earned a certificate of registration, which demonstrates that its quality-management system for its geocell cellular confinement system is currently registered to the ISO 9001:2000 quality standards.

The scope of ISO 9001:2000 registration shall be for the entire geocell product manufacturing process from incoming raw materials (resin) to finished product. Earned
registration shall be verifiable by providing a copy of the current continuous registration certificate upon the customer's written request.

Under the scope of the ISO quality standard, the manufacturer shall compile, keep record of, and provide for each customer order or production lot, actual and certified values for the following:

1. Resin Lot Number
2. Resin Density
3. Carbon Black content (where applicable)
4. Sheet Thickness
5. Short-term Seam Peel Strength
6. Long-term Seam Peel Strength - 7-day hot box method

**10,000-hour Seam Peel Strength Certification**

The manufacturer shall provide data showing that the high-density polyethylene resin used to produce the geocell sections has been tested using an appropriate number of seam samples and varying loads to generate data indicating that the seam peel strength shall survive a loading of at least 209 lbf/95 kg for a minimum of 10,000 hours.

**Materials Handling and Storage**

The contractor shall check all materials delivered to the site to ensure that the correct materials have been received.

Materials shall be stored on site in a manner that ensures that no damage occurs to any of the materials. Damaged materials shall be replaced at the Contractor's expense.

**Part 2 Materials**

**Geocell Cellular Confinement System**

The geocell system consists of an assembly of HDPE sheet strips connected in series, using full-depth ultrasonic spot-welded seams, aligned perpendicular to the longitudinal axis of the strips. When expanded, the interconnected strips form the walls of a flexible, three-dimensional cellular confinement structure into which the specified infill materials can be placed. The system shall include:

- Geocells
- Integral Polymer Tendons
- Restraint Pins
- Steel J-Hook Stakes
- Geosynthetic Layer
- Cell Infill Material: Topsoil/Vegetation
Geocell Materials - Composition and Properties

Geocell Base Material

Polyethylene used to make strips for geocell sections shall have a density of 0.935 - 0.965 g/cm³ (58.4 - 60.2 lb/cu.ft) tested per ASTM D1505.

Polyethylene used to make strips for geocell sections shall have an Environmental Stress Crack Resistance (ESCR) of 3000 hour tested per ASTM D1693.

The resin manufacturer's certification of polyethylene density and ESCR shall be available upon request from the manufacturer.

Carbon black shall be used for ultra-violet light stabilization. Carbon black content shall be 1.5% - 2% by weight through the addition of a carrier with a certified carbon black content. The carbon black shall be homogeneously distributed throughout the material.

Strip Properties

Strips used to make geocell sections shall have a sheet thickness, of 1.27 mm -5% +10% (50 mil -5% +10%) tested per ASTM D5199. Thickness shall be determined in the flat, before any surface texturing or other surface disruption.

Perforations shall be such that the peak friction angle between the surface of the perforated plastic and a #40 silica sand at 100% relative density shall be no less than 85% of the peak friction angle of the silica sand in isolation when tested by the direct shear method per ASTM D 5321. The quantity of perforations shall remove 19.6% ± 3% of the cell wall area.

Cell Seam Peel Strength Tests

Cell seam strength shall be uniform over the full depth of the cell. Minimum seam peel strengths shall be: 640 lbf / 2840 N for the 8.0 in / 200 mm depth cell, 480 lbf / 2130 N for the 6 in / 150 mm depth cell, 320 lbf / 1420 N for the 4 in / 100 mm depth cell, 240 lbf / 1060 N for the 3 in / 75 mm depth cell. Short-term peel strength shall be tested per Appendix A.

Long-term seam peel-strength test shall be performed on all resin or pre-manufactured sheet or strips. A 4 in / 100 mm wide seam sample shall support a 160 lbf / 72.5 kg load for a period of 168 hours (7 days) minimum in a temperature-controlled environment undergoing a temperature change on a 1-hour cycle from ambient room to 130°F / 54°C. Ambient room temperature is per ASTM E41. Long-term peel strength shall be tested per Appendix B.

Geocell Dimensions

The geocell sections shall be fabricated using strips of sheet polyethylene each having a length of 11.8 ft / 3.61 m. Polyethylene strips shall be connected using full-depth, ultrasonic spot-welds aligned perpendicular to the longitudinal axis of the strip. The ultrasonic weld melt-pool width shall not exceed 1 in / 25 mm.

The number of expanded cells per unit area shall be 18.2/yard² / 21.7/m².

Geocell sections for slope construction shall have the following ranges of expanded dimensions.

<table>
<thead>
<tr>
<th>Sections</th>
<th>Expanded Dimensions</th>
</tr>
</thead>
</table>
**Tendoned Geocell Sections**

Geocell sections shall be provided with a series of aligned holes through the cell walls for the insertion of tendons in the expanded direction of the section. Tendons are inserted in the field such that they pass through the geocell section in the direction of expansion. Hole diameter shall be **13 mm**.

The polyester tendon shall be manufactured from bright, high-tenacity, industrial continuous-filament polyester yarn woven into a braided strap. Elongation shall be 9-15% at break. The tendon shall have a minimum break strength of **6.7 kN** and minimum diameter/width of **19 mm**.

The tendon material shall be TP 67.

**Steel J-Hook Stake Anchors Engaged to Tendons**

Tendoned geocell sections shall be anchored with rows of J-hook stake anchors which shall engage and hold the integral tendons against the foundation soil.

Steel J-hook stakes shall be fabricated from mild steel or reinforcing steel rod. Each stake shall have a minimum-radius, 180-degree return at one end. When specified, galvanizing shall be per AASHTO M-218.

The minimum stake length shall be **0.9m**. The minimum stake diameter shall be **10mm**.

**Restraint Pins Tied to Tendon**

Restraint pins shall be used as a load transfer pins with the tendoned anchor system. Restraint pins shall transfer load from the infilled geocell cells to the tendon.

**Geosynthetic Components**

**Geosynthetic Layer(s)**

The bottom geosynthetic layer shall consist of a geotextile separator / filter with a minimum tensile strength of **10 kN/m** and a drop cone maximum hole size of **3mm**.

**Geo-composite Drainage Systems**

Geo-composite drainage systems, including geotextile wrapped perforated pipes and sheet drainage cores, may be incorporated as sub-drains and interceptor drains. Product selection and application shall be determined by the design Engineer.

**Topsoil Infill**

The topsoil shall consist of fine sandy material

The vegetation shall consist of seed mix to be agreed with the designer's representative

The specified topsoil infill material shall be topsoil free of foreign material that could prevent complete uniform filling of the cells. The specified vegetation shall be applied immediately following placement of the topsoil infill.
**Crest Anchor System**

The crest anchor system shall be driven ground anchors of the Duckbill or Platypus type, driven to give a minimum pull out resistance of 4 tonne per anchor.

**Part 3 Construction**

**Examination**

Verify that site conditions are as indicated on the Construction Drawings.

Verify that layout of the proposed work is in accordance with the Construction Drawings.

Verify that all required materials delivered to the site comply with the Contract Specifications.

**Foundation Soil Preparation**

Carry out approved sediment control works with coordinated stream diversion and dewatering operations.

Following bulk excavation and fill placement operations, shape the subgrade soils to the grades and dimensions shown on the Construction Drawings. Depressions in the subgrade may be infilled with suitable native soils. Soils which are highly saturated, highly compressible, or unstable shall not be used as fill.

Proof roll and examine the foundation soil to ensure that it meets minimum strength requirements assumed for design. Remove unacceptable materials and replace with approved compacted fill. If on-site fill material is deemed unsuitable by the engineer, select material shall be imported for filling and shaping the slope foundation.

**Placement of Geosynthetic Layer(s)**

The geosynthetic layers shall be placed at the locations designated on the Construction Drawings. Overlaps between adjacent sections of geosynthetic shall be a minimum of 12 in/300 mm or as directed by the engineer. The outer edge of the geosynthetic shall be buried a minimum of 6 in/150 mm below finished subgrade throughout the entire perimeter of the designated area in order to prevent the uncontrolled flow of surface runoff below the geosynthetic.

**Placement and Anchoring of Geocell Sections**

**Tendoned Geocell Sections**

Pre-cut lengths of tendon material shall be fed through the aligned holes in the cell walls of the geocell strips prior to expanding individual sections into position.

Geocell sections shall be expanded uniformly into position over the geosynthetic or foundation soil as shown on the Construction Drawings. The orientation of expanded sections shall be as indicated on the Construction Drawings. Accommodation of non-linear alignments may require non-uniform expansion of individual geocell sections in order to form tapered or curved elements. When properly expanded, the individual cells of each geocell section shall measure between 11.3 in/287 mm long by 12.6 in/320 mm wide (nominal ± 10%).
The edges of adjacent sections of geocell shall be inter-leafed or butt-jointed according to which side-wall profiles abut. In all cases, the upper surfaces of adjoining geocell sections shall be flush at the joint. Inter-leaf side connections between expanded geocell sections. Welded edge seams should be overlapped and aligned when stapling. Abut end connections between geocell sections. The longitudinal centre-lines of abutting external cells should be aligned and stapled at the cell wall contact point.

Adjoining sections shall be stapled together using a pneumatic stapler using 1/2in/13mm wire staples.

Refer to the manufacturer’s standard drawings for additional details regarding panel connections.

Crest Anchorage
The geocell system shall be anchored at the crest of the slope and expanded down the slope surface.

Where tendons are required through end connections (inter-leafed only), the tendons shall be fed through the holes of adjoining sections after the geocell sections have been expanded into position.

Crest Anchor System
With the sections collapsed, thread pre-cut tendons through the predrilled holes. Secure the tendons to the specified anchor system. Fully expand the section down the slope, repeating the process for subsequent sections. After expanding, sections can be held in the expanded position with the specified anchor stakes or other suitable methods.

Anchor System

J-Hook Stakes Engaged to Tendons
The geocell sections shall be permanently anchored with the specified J-Hook stake anchors in the prescribed pattern. At each anchor location, use the prescribed knot to tie the tendon around the stake and drive the J-hook stake flush with the ground surface. The tendon and stake anchor layout shall be as shown on the Construction Drawings.

Restraint Pins Tied to Tendons
The geocell sections shall be permanently anchored with the specified restraint pins in the prescribed manner. At each tendon restraint location, engage the restraint pin to the tendon using the prescribed knot and pull the tendon toward the top of the slope to ensure that the restraint pin bears against the cell wall. The tendon and restraint pin layout shall be as shown on the Construction Drawings.

Placement of Infill
Infilling of geocell sections can begin when anchoring work is complete. Infill from the crest of the slope to the toe, limiting drop-height of infill material to 3 ft/1 m maximum.
Topsoil Infill
Overfill the specified topsoil between 1 in and 2 in / 25 mm and 50 mm and lightly tamp or roll to leave the soil flush with the top edge of the cell walls. The slope shall be vegetated as specified.

Placement of Vegetation
The specified vegetation shall be placed according to standard construction methods.

Part 4 Measurement
Measurement for the geocell slope protection system shall be based on the contract unit price per square meter (square yard) of protected slope surface area measured perpendicular to the surface. The contract unit price shall include the cost of all labour, materials, and equipment to install the geotextile under layer(s), geocell system, polymer tendons, anchor stakes, restraint clips, infill material, trench backfill materials and surface treatments (if specified).

Appendix A
Short-Term Seam Strength Test Procedure

Frequency of Test
The short-term seam peel strength test (referred to as the 'test' in this section) shall be performed on a geocell section randomly taken directly from the production line each two hours.

Test Sample Preparation
Randomly select 10 welds within the geocell section to be tested. Cut the strips defining those welds from the section such that the cut is 4 in / 10 cm on both sides of the weld and perpendicular to the weld. End and internal welds require 4 cuts. Edge welds require 2 cuts. Prior to testing, the test samples shall have air cool for a minimum of 30 minutes from the time the selected geocell section was manufactured.

Short-term Seam Peel Strength Test
The apparatus used for testing the short-term seam peel strength shall be of such configuration that the jaws of the clamp shall not over stress the sample during the test period. The sample to be tested shall be loaded such that the load applied shall produce a peeling action on the seam. Load shall be applied at a rate of 12 in / 300 mm per minute and be applied for adequate time to determine the maximum load. The date, time and load shall be recorded.

Short-term seam peel strength shall be defined as the maximum load applied to the test sample. Minimum required short-term seam peel strength shall be:

- 640 lbf for the 8 in depth / 2840 N for the 200 mm depth cell,
- 480 lbf for the 6 in depth / 2130 N for the 150 mm depth cell,
- 320 lbf for the 4 in depth / 1420 N for the 100 mm depth cell.
240 lbf for the 3 in depth / 1060 N for the 75 mm depth cell.

Definition of Pass / Failure

Two methods shall be used to determine acceptability of the manufactured geocell sections. The successful passing of the short-term seam peel test shall not be used to determine acceptable of the polyethylene for use in manufacturing of the geocell sections. Acceptability of the polyethylene shall be determined through tests conducted in Appendix B.

The Tested Value

If more than one of the tested seam samples fails to meet the minimum peel strength, all sections manufactured after the previously successful test shall be rejected.

If all tested seam samples meet the minimum peel strength, all geocell sections manufactured since the last successful test shall be considered to have passed the test.

When one of the tested seam samples fails to meet the minimum peel strength, another 10 samples shall be randomly selected and cut from the previously selected section. If more than one of these samples fails, all sections manufactured after the previously successful test shall be rejected. Otherwise, all geocell sections manufactured since the last successful test shall be considered to have passed the test.

Visual Failure Mode

After each sample is tested, the seam shall be examined to determine the failure mode. Two failure modes are possible.

- Material failure within and adjacent to the weld indicated by material strain and
- Weld failure resulting in complete separation of the seam and shows little or no material strain.

Upon examination, when the failure mode results in complete separation of the seam and indicates little or no material strain, product manufactured shall be rejected.

Appendix B

Long-Term Seam Strength Test Procedure

Frequency of Test

The long-term seam peel-strength test (referred to as the ‘test’ in this section) shall be performed:

1. on each new resin lot number if the geocell manufacturer extrudes the sheet or strip used to produce the geocell material.
2. on each new order of sheet and/or strip if the geocell manufacturer does not extrude the sheet and/or strip used to produce the geocell material.
Test Sample Preparation

A test sample shall be made using four of the strips meeting all aspects of the material portion of this specification. The four strips are to be welded together using a warm welder producing a 2-cell long section of geocell product. The 2-cell section of geocell shall have 3 rows of welds connecting the four strips. The rows of welds are to be labelled A, B and C. The individual welds within each row shall be numbered consecutively from left to right starting with the number 1 (one). The test sample shall air cool for a minimum of 30 minutes.

Randomly select 10 welds from within the test sample. Cut the strips defining those welds such that the cut is 4 in / 10 cm on both sides of the weld and perpendicular to the weld. End and internal welds require 4 cuts. Edge welds require 2 cuts. These samples shall be cut to a width of 4 in / 10 cm. Properly identify each weld using the row letter and weld number.

These samples are now ready to be tested.

Long-term Seam Peel Strength Test

The long-term seam peel-strength test shall take place within an environmentally controlled chamber that undergoes temperature change on a 1-hour cycle from room temperature to 54°C (130°F). Room temperature shall be defined per ASTM E41.

Within the environmentally controlled chamber, one of the ends of the samples (10 samples in total) shall be secured to a stationary upper clamp. The jaws of the clamp shall be of such configuration that the grip does not over stress the sample during the test period. The sample shall be secured so that its axis is vertical and the welds being tested are horizontal as the sample hangs within the environmentally controlled chamber. The sample to be tested shall be loaded such that the load applied shall produce a peeling action on the seam.

A weight of 160 lb / 72.5 kg shall be lifted via a hoist or lift platform and attached to the free lower end, of the sample. The weight shall be lowered in a way so that no impact load occurs on the sample being tested. The weight shall be sufficient distance from the floor of the chamber so that the weight will not touch the floor of the chamber as the sample undergoes creep during the test period. The date and hour the weight is applied shall be recorded.

The temperature cycle shall commence immediately within the environmentally controlled chamber. The test period for the applied load shall be 168 hours.

Definition of Pass / Failure

If any of the 10 seams fail prior to the end of the 168-hour (7-day) period, the date and hour of the failure shall be recorded and the polyethylene resin and strip material shall be considered unsuitable for geocell manufacturing.

Part 1 General

Description
The work covered by this section includes the furnishing of all labour, materials, equipment and incidentals for construction and installation of the Geocell Load Support System, as shown on the Construction Drawings and described by the Contract documents.

References
The American Society of Testing and Materials (ASTM)
American Association of State Highway and Transportation Officials (AASHTO)
Construction Specifications Institute (CSI) format specifications

Submittals
Submit shop drawings.
Submit product data, drawings and samples.
Submit current product quality assurance test data and independent laboratory test results indicating compliance with specified performance. No material will be considered as an equivalent to the geocell material unless it meets all areas of this section without exception. Manufacturers seeking to supply what they call equivalent material must submit records, data, independent test results, samples, certifications, and documentation deemed necessary by the Engineer to prove equivalency. The Engineer will approve or disapprove other manufacturers materials within 60 days after all submitted information is studied and tested.

Quality Assurance and Certification
Product manufacturers shall provide certification of compliance with all applicable testing procedures and related specifications upon written request. Request for certification shall be submitted by the purchasing agency no later than the date of order placement.

On-site Manufacturer’s Representative
The manufacturer shall provide a qualified representative on site at the start of construction to ensure that the contractor installs the geocell system in accordance with the contract drawings and specifications. The representative shall have at least 5 years experience installing geocell load support systems and have installed a minimum of 50,000 m² (500,000 ft²) of geocell material.

ISO Certification
The manufacturer shall have earned a certificate of registration, which demonstrates that its quality-management system for its geocell cellular confinement system is currently registered to the ISO 9001:2000 quality standards.
The scope of ISO 9001:2000 registration shall be for the entire geocell product manufacturing process from incoming raw materials (resin) to finished product. Earned registration shall be verifiable by providing a copy of the current continuous registration certificate upon the customer’s written request.

Under the scope of the ISO quality standard, the manufacturer shall compile, keep record of, and provide for each customer order or production lot, actual and certified values for the following:

- Resin Lot Number
- Resin Density
- Carbon Black content (where applicable)
- Sheet Thickness
- Short-term Seam Peel Strength
- Long-term Seam Peel Strength - 7-day hot box method

10,000-hour Seam Peel Strength Certification
The manufacturer shall provide data showing that the high-density polyethylene resin used to produce the geocell sections has been tested using an appropriate number of seam samples and varying loads to generate data indicating that the seam peel strength shall survive a loading of at least 95 kg (209 lbf) for a minimum of 10,000 hours.

Materials Handling and Storage
The contractor shall check all materials delivered to the site to ensure that the correct materials have been received.

Materials shall be stored on site in a manner that ensures that no damage occurs to any of the materials. Damaged materials shall be replaced at the Contractor's expense.

Substitutions
No material will be considered as an equivalent to the geocell material specified herein unless it meets all areas of this specification without exception. Manufacturers seeking to supply what they represent as equivalent material must submit records, data, independent test results, samples, certifications, and documentation deemed necessary by the Engineer to prove equivalency. The Engineer shall approve or disapprove other manufacturers materials within 60 days after all submitted information is studied and tested.

Part 2 Materials
Geocell Cellular Confinement System
The geocell system consists of an assembly of fully surface-textured HDPE sheet strips connected in series, using full-depth ultrasonic spot-welded seams, aligned perpendicular to the longitudinal axis of the strips. When expanded, the interconnected strips form the walls of a flexible, three-dimensional cellular confinement structure into which the specified infill materials can be placed. The system can include:
- Geocells
- Temporary Stake Anchors
- Composite Sub-drains
- Cell Infill Material
- Pavement Surface Materials
- Pavement Sub base Material

**Geocell Materials - Composition and Properties**

**Geocell Base Material**

Polyethylene used to make strips for geocell sections shall have a density of 0.935 - 0.965 g/cm³ (58.4 - 60.2 lb/cu.ft) tested per ASTM D1505.

Polyethylene used to make strips for geocell sections shall have an Environmental Stress Crack Resistance (ESCR) of 3000 hour tested per ASTM D1693.

The resin manufacturer's certification of polyethylene density and ESCR shall be available upon request from the manufacturer.

Carbon black shall be used for ultra-violet light stabilization. Carbon black content shall be 1.5% - 2% by weight through the addition of a carrier with certified carbon black content. The carbon black shall be homogeneously distributed throughout the material.

The manufacturer shall certify the percentage of carbon black.

**Strip Properties**

Strips used to make geocell sections shall have a sheet thickness, of 1.27 mm -5% +10% (50 mil -5% +10%) tested per ASTM D5199. Thickness shall be determined in the flat, before any surface texturing or other surface disruption.

Perforations shall be such that the peak friction angle between the surface of the perforated plastic and #40 silica sand at 100% relative density shall be no less than 85% of the peak friction angle of the silica sand in isolation when tested by the direct shear method per ASTM D 5321. The quantity of perforations shall remove 19.6% ± 3% of the cell wall area.

**Cell Seam Peel Strength Test**

Cell seam strength shall be uniform over the full depth of the cell. Minimum seam peel strengths shall be: 2840 N (640 lbf) for the 200 mm (8.0 in) depth cell, 2130 N (480 lbf) for the 150 mm (6.0 in) depth cell, 1420 N (320 lbf) for the 100 mm (4.0 in) depth cell, 1060 N (240 lbf) for the 75 mm (3.0 in) depth cell. Short-term peel strength shall be tested per Appendix A.

Seam hang-strength test shall be performed on all resin or pre-manufactured sheet or strips for a period of 168 hours (7 days) minimum in a temperature-controlled environment that undergoes change on a 1-hour cycle from room temperature to 54°C (130°F). Room temperature is defined in ASTM E41. Long-term peel strength shall be tested per Appendix B.
Geocell Dimensions

The geocell sections shall be fabricated using strips of sheet polyethylene each having a length of 3.61 m (11.8 ft). Polyethylene strips shall be connected using full-depth, ultrasonic spot-welds aligned perpendicular to the longitudinal axis of the strip. Weld spacing shall be 445 mm ± 2.5 mm (17.5 in ± 0.10 in). The ultrasonic weld melt-pool width shall not exceed 25 mm (1.0 in).

The area of expanded cells shall be 460 sq. cm (71.3 sq. in).

Geocell sections for load support construction shall have the following ranges of expanded dimensions.

Geosynthetic Components

The bottom geosynthetic layer shall consist of a separation geotextile with characteristics to be agreed with the Designers Representative.

Geo-composite Drainage Systems

Geo-composite drainage systems, including geotextile-wrapped perforated pipes and sheet drainage cores, may be incorporated as sub-drains and interceptor drains. Product selection and application shall be determined by the design Engineer.

Stake Anchors

Geocell sections may be temporarily anchored with ATRA® anchors or J-hook stakes prior to placing the infill material. The stake layout shall be as required to shape the geocell sections to the specified dimensions. The stake diameter and length shall be suitable to hold the geocell sections in tension for the given foundation soil conditions.

Sub base Aggregate (if required)

The sub base aggregate shall be well graded crushed stone or gravel with a maximum particle size of 37.5 mm (1 1/2 in) and no greater than 10% passing the #200 sieve. The coarse fraction of the base aggregate shall have a Los Angeles Abrasion test wear of no greater than 50%. The fines fraction (i.e. passing the #200 sieve) shall not be greater than two-thirds of the fraction passing the #40 sieve and the fraction passing the #40 sieve shall have a liquid limit no greater than 25% and a plasticity index not greater than 6%.

Infill Material

Aggregate

The aggregate shall consist of a well grade crushed rock, crushed concrete or other waste or recycled material with a maximum particle size of 20mm.

Part 3 Construction

Examination

Verify that site conditions are as indicated on the Construction Drawings.

Verify that layout of the proposed work is in accordance with the Construction Drawings.
Verify that all required materials delivered to the site comply with the Contract Specifications.

Site Preparation

The subgrade shall be grubbed and cleared of all trees, brush and root matter. Subgrade soils shall be excavated or graded to the lines and grades shown on the Construction Drawings. The upper 0.3 m (1 ft) of the subgrade shall be compacted to a minimum of 95% Standard Proctor Dry Density (SPDD) or as specified by the Engineer.

Where subgrade soils are encountered that are weaker than the assumed design strength, the contractor shall excavate the affected areas and replace the excavated material with suitable fill under the direction of the Engineer.

Geosynthetic Installation

The geosynthetic shall be installed per the manufacturer and/or engineer’s recommendations and/or specifications.

Placement of Pavement Sub base

Sub base aggregate shall be placed in lifts not exceeding 200 mm (8 in) and compacted to a minimum of 95% Standard Proctor Dry Density (SPDD) or as specified by the Engineer. The thickness of sub base and base aggregate layers, after compaction, shall be as indicated on the Construction Drawings.

Geocell Installation

The geocell sections shall be placed directly on the prepared subgrade or sub base and infilled with the specified infill material. The geocell section thickness shall be as indicated on the Construction Drawings.

The geocell sections shall be expanded into position at the grades and lines shown on the Construction Drawings. The orientation of expanded sections shall be as indicated on the Construction Drawings. Individual geocell sections can be held in their expanded positions with steel stakes driven inside selected outer cell walls prior to filling or other suitable methods. Stretcher frames may be used when dimensional tolerances are required. When properly expanded, the typical plan dimensions of individual cells should measure between 287 mm (11.3 in) long by 320 mm (12.6 in) wide (nominal ± 10%).

The edges of adjacent geocell sections shall be inter-leafed or butt-jointed according to which side-wall profiles abut. In all cases, the upper surfaces of adjoining geocell sections shall be flush at the joint. Inter-leaf side connections between expanded geocell sections. Welded edge seams should be overlapped and aligned when stapling. Abut end connections between geocell sections. The longitudinal centrelines of abutting external cells should be aligned and stapled at the cell wall contact point.

Adjoining sections shall be stapled together using a pneumatic stapler using 1/2 inch wire staples.

Refer to the manufacturer’s standard drawings for additional details regarding panel connections.

The geocell sections shall be anchored in position prior to placing infill material by using either temporary stakes, by hand placement of infill material into the corner cells, or by other suitable methods.
At catch basins, utilities, or other obstructions, the geocell sections shall be stretched into position and cut around the perimeter of the obstruction to allow the geocell sections to slip over the obstruction and placed flat on the prepared surface.

**Placement of Infill Soil**

The specified infill material shall be placed into the expanded cells with equipment appropriate for the site conditions such as a backhoe or a front-end loader. The maximum drop height into the cells shall be limited to a maximum of 1 m (3 ft) to avoid damage or displacement of the cell walls.

**Aggregate Infill**

Overfill the cells and level to a minimum 50 mm (2 in) above the top of the cell walls. A front-end loader may be used to place the infill provided that it only traffics above geocell sections that have been filled and covered with the minimum 50 mm (2 in) of additional material. The infill material shall be compacted to a minimum density of 95% Standard Proctor Dry Density (SPDD) or as specified by the Engineer. The surface shall be graded to the minimum specified height of compacted overfill material. This may be accomplished by back-blading with a straight edged loader bucket. A tolerance of plus or minus 12.5 mm (1/2 in) is acceptable.

**Placement of Aggregate Wearing Course (if required)**

The specified aggregate base material shall be placed and compacted to the lines and grades shown on the Construction Drawings. The surface aggregate shall be compacted to a minimum density of 95% SPDD.

**Part 4 Measurement**

Measurement for the geocell load support system will be based on the contract unit price per square meter (yard) of geocell material. The contract unit price shall include the cost of all labour, materials, and equipment to install the geotextile under layer(s), the geocell system, place and compact the sub-base, base material(s) and surface materials and site clean up.

**Appendix A**

**Short-Term Seam Strength Test Procedure**

**Frequency of Test**

The short-term seam peel strength test (referred to as the ‘test’ in this section) shall be performed on a geocell section randomly taken directly from the production line each two hours.

**Test Sample Preparation**

Randomly select 10 welds within the geocell section to be tested. Cut the strips defining those welds from the section such that the cut is 10 cm (4 in) on both sides of the weld and perpendicular to the weld. End and internal welds require 4 cuts. Edge welds require 2 cuts. Prior to testing, the test samples shall have air cool for a minimum of 30 minutes from the time the selected geocell section was manufactured.
**Short-term Seam Peel Strength Test**

The apparatus used for testing the short-term seam peel strength shall be of such configuration that the jaws of the clamp shall not over stress the sample during the test period. The sample to be tested shall be loaded such that the load applied shall produce a peeling action on the seam. Load shall be applied at a rate of 300 mm (12 in) per minute and be applied for adequate time to determine the maximum load. The date, time and load shall be recorded.

Short-term seam peel strength shall be defined as the maximum load applied to the test sample. Minimum required short-term seam peel strength shall be:

- 2840 N (640 lbf) for the 200 mm (8 in) depth cell.
- 2130 N (480 lbf) for the 150 mm (6 in) depth cell.
- 1420 N (320 lbf) for the 100 mm (4 in) depth cell.
- 1060 N (240 lbf) for the 75 mm (3 in) depth cell.

**Definition of Pass / Failure**

Two methods shall be used to determine acceptability of the manufactured geocell sections. The successful passing of the short-term seam peel test shall not be used to determine acceptable of the polyethylene for use in manufacturing of the geocell sections. Acceptability of the polyethylene shall be determined through tests conducted in Appendix B.

**The Tested Value**

If more than one of the tested seam samples fails to meet the minimum peel strength, all sections manufactured after the previously successful test shall be rejected. If all tested seam samples meet the minimum peel strength, all geocell sections manufactured since the last successful test shall be considered to have passed the test. When one of the tested seam samples fails to meet the minimum peel strength, another 10 samples shall be randomly selected and cut from the previously selected section. If more than one of these samples fails, all sections manufactured after the previously successful test shall be rejected. Otherwise, all geocell sections manufactured since the last successful test shall be considered to have passed the test.

**Visual Failure Mode**

After each sample is tested, the seam shall be examined to determine the failure mode. Two failure modes are possible:

- Material failure within and adjacent to the weld indicated by material strain and
- Weld failure resulting in complete separation of the seam and shows little or no material strain.

Upon examination, when the failure mode results in complete separation of the seam and indicates little or no material strain, product manufactured shall be rejected.
Appendix B

Long-Term Seam Strength Test Procedure

Frequency of Test
The long-term seam peel-strength test (referred to as the ‘test’ in this section) shall be performed:

- on each new resin lot number if the geocell manufacturer extrudes the sheet or strip used to produce the geocell material.
- on each new order of sheet and/or strip if the geocell manufacturer does not extrude the sheet and/or strip used to produce the geocell material.

Test Sample Preparation
A test sample shall be made using four of the strips meeting all aspects of the material portion of this specification. The four strips are to be welded together using a warm welder producing a 2-cell long section of geocell product. The 2-cell section of geocell shall have 3 rows of welds connecting the four strips. The rows of welds are to be labelled A, B and C. The individual welds within each row shall be numbered consecutively from left to right starting with the number 1 (one). The test sample shall air cool for a minimum of 30 minutes.

Randomly select 10 welds from within the test sample. Cut the strips defining those welds such that the cut is 10 cm (4 in) on both sides of the weld and perpendicular to the weld. End and internal welds require 4 cuts. Edge welds require 2 cuts. These samples shall be cut to a width of 10 cm (4 in). Properly identify each weld using the row letter and weld number.

These samples are now ready to be tested.

Long-term Seam Peel Strength Test
The long-term seam peel-strength test shall take place within an environmentally controlled chamber that undergoes temperature change on a 1-hour cycle from room temperature to 54°C (130°F). Room temperature shall be defined per ASTM E41.

Within the environmentally controlled chamber, one of the ends of the samples (10 samples in total) shall be secured to a stationary upper clamp. The jaws of the clamp shall be of such configuration that the grip does not over stress the sample during the test period. The sample shall be secured so that its axis is vertical and the welds being tested are horizontal as the sample hangs within the environmentally controlled chamber. The sample to be tested shall be loaded such that the load applied shall produce a peeling action on the seam.

A weight of 72.5 kg (160 lb) shall be lifted via a hoist or lift platform and attached to the free lower end, of the sample. The weight shall be lowered in a way so that no impact load occurs on the sample being tested. The weight shall be sufficient distance from the floor of the chamber so that the weight will not touch the floor of the chamber as the sample undergoes creep during the test period. The date and hour the weight is applied shall be recorded.
The temperature cycle shall commence immediately within the environmentally controlled chamber. The test period for the applied load shall be 168 hours.

Definition of Pass / Failure

If any of the 10 seams fail prior to the end of the 168-hour (7-day) period, the date and hour of the failure shall be recorded and the polyethylene resin and strip material shall be considered unsuitable for geocell manufacturing.


1. SCOPE

1.1. This is a materials specification covering geotextile fabrics for use in subsurface drainage; separation; stabilization; erosion control; temporary silt fence; and paving fabrics. This is a material purchasing specification and design review of use is recommended.

1.2. This specification sets forth a set of physical, mechanical and endurance properties that must be met, or exceeded, by the geotextile being manufactured.

1.3. In the context of quality systems and management, this specification represents a manufacturing quality control (MQC) document. However, its general use is essentially as a recommended design document.

1.4. This specification is intended to assure both good quality and performance of geotextiles used as listed in Section 1.1, but is possibly not adequate for the complete specification in a specific situation. Additional tests, or more restrictive values for the tests indicated, may be necessary under conditions of a particular application.

1.5. This is not a construction or design specification. This specification is based on geotextile survivability from installation stresses. Refer to Appendix A of this specification for geotextile construction guidelines.

2. REFERENCED DOCUMENTS

2.1. AASHTO Standards:

- T 88, Particle Size Analysis of Soils
- T 90, Determining the Plastic Limit and Plasticity Index of Soils
- T 99, Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in.) Drop

2.2. ASTM Standards:

- D 123, Standard Terminology Relating to Textiles
- D 276, Test Methods for Identification of Fibers in Textiles
- D 4354, Practice for Sampling of Geosynthetics for Testing
- D 4355, Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus)
- D 4439, Terminology for Geosynthetics
- D 4491, Test Methods for Water Permeability of Geotextiles by Permittivity
- D 4533, Test Method for Trapezoid Tearing Strength of Geotextiles
- D 4632, Test Method for Grab Breaking Load and Elongation of Geotextiles
- D 4751, Test Method for Determining Apparent Opening Size of a Geotextile
• D 4759, Practice for Determining the Specification Conformance of Geosynthetics
• D 4833, Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products
• D 4873, Guide for Identification, Storage, and Handling of Geotextiles
• D 5141, Test Method for Determining Filtering Efficiency and Flow Rate for Silt Fence Application of a Geotextile Using Site Specific Soils
• D 5261, Test Method for Measuring Mass per Unit Area of Geotextiles
• D 6140, Test Method for Determining the Asphalt Retention of Paving Fabrics
• D 6241, Test Method for Static Puncture Strength of Geotextiles and Geotextile Related Products Using a 50-mm Probe

\[1\] Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

3 CERTIFICATION

3.1 The contractor shall provide to the Engineer, a certificate stating the name of the manufacturer, product name, style number, chemical composition of the filaments or yarns and antler pertinent information to fully describe the geotextile.

3.2 The Manufacturer is responsible for establishing and maintaining a quality control procedure to assure compliance with the requirements of the specification. Documentation describing the quality control program shall be made available upon request.

3.3 The Manufacturer's certificate shall state that the furnished geotextile meets MARV requirements of the specification as evaluated under the Manufacturer's quality control procedure. The certificate shall be attested to by a person having legal authority to bind the manufacture

3.4 Either mislabelling or misrepresentation of materials shall be reason to reject those products.

4. SAMPLING, TESTING, AND ACCEPTANCE

4.1 Geotextiles shall be subject to sampling and testing to verify conformance with this specification. Sampling for testing shall be in accordance with ASTM D 4354. Acceptance shall be based on testing of either conformance samples obtained using Procedure A of ASTM 3 -1354, or based on manufacturer's certifications and testing of quality assurance samples obtained using Procedure B of ASTM D 4354. A lot size for conformance or quality assurance sampling shall be considered to be the shipment quantity of the given product or a truckload of the given product, whichever is smaller.

4.2 Testing shall be performed in accordance with the methods referenced in this specification for the indicated application. The number of specimens to test per sample is specified by
each test method. Geotextile product acceptance shall be based on ASTM D 4759. Product acceptance is determined by comparing the average test results of all specimens within a given sample to the specification MARV. Refer to ASTM D 4759 for more detail regarding geotextile acceptance procedures.

5. SHIPMENT AND STORAGE

5.1 Geotextiles labelling, shipment, and storage shall follow ASTM D 4873. Product labels shall clearly show the manufacturer or supplier name, style name, and roll number. Each shipping document shall include a notation certifying that the material is in accordance with the manufacturer's certificate.

5.2 Each geotextile roll shall be wrapped with a material that will protect the geotextile from damage due to shipment, water, sunlight, and contaminants. The protective wrapping shall be maintained during periods of shipment and storage.

5.3 During storage, geotextile rolls shall be elevated off the ground and adequately covered to protect them from the following: site construction damage, precipitation, extended ultraviolet radiation including sunlight, chemicals that are strong acids or strong bases, flames including welding sparks, temperatures in excess of 71 °C (160°F), and any other environmental condition that may damage the physical property values of the geotextile.

6. GEOTEXTILE PROPERTY REQUIREMENTS FOR SUBSURFACE DRAINAGE, SEPARATION, STABILIZATION, AND PERMANENT EROSION CONTROL

6.1 General Requirements

6.1.1 Table 1 provides strength properties for three geotextile classes. The geotextile shall conform to the properties of Table 1 (not included) based on the geotextile class required in Table 2, 3, 4, or 5 (not included) for the indicated application.

6.1.2 All numeric values in Table 1 (not included) represent MARV in the weaker principal direction. The geotextile properties required for each class are dependent upon geotextile elongation. When sewn seams are required, the seam strength, as measured in accordance with ASTM D 4632, shall be equal to or greater than 90 percent of the specified grab strength.

6.2 Subsurface Drainage Requirements
6.2.1 Description. This specification is applicable to placing a geotextile against a soil to allow for long-term passage of water into a subsurface drain system retaining the in-situ soil. The primary function of the geotextile in subsurface drainage applications is filtration. Geotextile filtration properties are a function of the in-situ soil gradation, plasticity, and hydraulic conditions.

6.2.2 Geotextile Requirements. The geotextile shall meet the requirements of Table 2 (not included). Woven slit film geotextiles (i.e., geotextiles made from yarns of a flat, tape-like character) will not be allowed. All numeric values in Table 2 (not included), except AOS represent MARV in the weaker principal direction. Values of AOS represent maximum average roll values.

6.2.3 The property values in Table 2 (not included) represent default values which provide sufficient geotextile survivability under most construction conditions. Note 2 of Table 2 (not included) provides for a reduction in the minimum property requirements when sufficient survivability information is available. The Engineer may also specify properties different from those listed in Table 2 (not included) based on engineering design experience.

6.3 Separation Requirements

6.3.1 Description. This specification is applicable to the use of a geotextile to prevent mixing of a subgrade soil and an aggregate cover material (sub base, base, select embankment, etc.). This specification may also apply to situations other than beneath pavements where separation of two dissimilar materials is required but where water seepage through the geotextile is not a critical function.

6.3.2 The separation application is appropriate for pavement structures constructed over soils with a California Bearing Ratio equal to or greater than 3 (CBR > 3) (shear strength greater than approximately 90 kPa). It is appropriate for unsaturated subgrade soils. The primary function of a geotextile in this application is separation.

6.3.3 Geotextile Requirements. The geotextile shall meet the requirements of Table 3 (not included). All numeric values in Table 3 (not included) except AOS represent MARV in the weakest principal direction. Values for AOS represent maximum average roll values.

6.3.4 The property values in Table 3 (not included) represent default values which provide for sufficient geotextile survivability under most construction conditions. Note 1 of Table 3 (not included) provides for a reduction in the minimum property requirements when sufficient survivability information is available. The Engineer may also specify properties different from those listed in Table 3 (not included) based on engineering design and experience.

6.4 Stabilization Requirements

6.4.1 Description. This specification is applicable to the use of a geotextile in wet, saturated conditions to provide the coincident functions of separation and filtration. In some installations, the geotextile can also provide the function of reinforcement. Stabilization is applicable to pavement structures constructed over soils with a California Bearing Ratio between one and three (1<CBR<3) (shear strength between approximately 30 kPa and 90 kPa).
6.4.2 The stabilization application is appropriate for subgrade soils which are saturated due to a high groundwater table or due to prolonged periods of wet weather. This specification is not appropriate for embankment reinforcement where stress conditions may cause global subgrade foundation or stability failure. Reinforcement of the pavement section is a site specific design issue.

6.4.3 Geotextile Requirements. The geotextile shall meet the requirements of Table 4 (not included). All numeric values in Table 4 (not included) except AOS represent MARV in the weakest principal direction. Values for AOS represent maximum average roll values.

6.4.4 The property values in Table 4 (not included) represent default values which provide (not included) for sufficient geotextile survivability under most construction conditions. Note 1 of Table 4 provides for a reduction in the minimum property requirements when sufficient survivability information is available. The Engineer may also specify properties different from those listed in Table 3 (not included) based on engineering design and experience.

6.5 Permanent Erosion Control

6.5.1 Description. This specification is applicable to the use of a geotextile between energy absorbing armour systems and in the in-situ soil to prevent soil loss resulting in excessive scour and to prevent hydraulic uplift pressures causing instability of the permanent erosion control system. This specification does not apply to other types of geosynthetic soil erosion control materials such as turf reinforcement mats.

6.5.2 The primary function the geotextile serves in permanent erosion control applications is filtration. Geotextile filtration properties are a function of hydraulic conditions, and in-situ soil gradation, density and plasticity.

6.5.3 Geotextile Requirements. The geotextile shall meet the requirements of Table 5 (not included). Woven slit film geotextiles (i.e., geotextiles made from yams of flat, tape-like character) will not be allowed. All numeric values in Table 5 except AOS represent MARV in the weaker principal direction. Values for AOS represent maximum average roll values.

6.5.4 The property values in Table 5 (not included) represent default values which provide for sufficient geotextile survivability under conditions similar to or less severe than those described under Note 2 of Table 5 (not included). Note 3 of Table 5 (not included) provides for a reduction in the minimum property requirements when sufficient survivability information is available or when the potential for construction damage is reduced. The Engineer may also specify properties different from those listed in Table 5 (not included) based on engineering design and experience.

6.6 TEMPORARY SILT FENCE REQUIREMENTS

6.6.1 Description. This specification is applicable to the use of a geotextile as a vertical, permeable interceptor designed to remove suspended soil from overland water flow. The function of a temporary silt fence is to filter and allow settlement of soil particles from sediment laden water. The purpose is to prevent the eroded soil from being transported off the construction site by water runoff.

6.6.2 Geotextile Requirements. The geotextile used for temporary silt fence may or may not be supported between posts with wire or polymeric mesh. The temporary silt fence geotextile shall meet the requirements of Table 6. All numeric values in Table 6 (not included) except AOS represent MARV. Values for AOS represent maximum average roll values.
6.6.3 Field monitoring shall be performed to verify that the armour system placement does not
damage the geotextile. The minimum height above ground for all silt fence shall be 760 mm.
Minimum embedment depth shall be 150 mm. Refer to Appendix for more detailed
installation requirements.

6.7 PAVING FABRIC REQUIREMENTS

6.7.1 Description. This specification is applicable to the use of a paving fabric, saturated with asphalt
cement, between pavement layers. The function of the paving fabric is to act as a
waterproofing and stress relieving membrane within the pavement structure. This specification
is not intended to describe fabric membrane systems specifically designed for pavement joints
and localized (spot) repairs.

6.7.2 Paving Fabric Requirements. The paving fabric shall meet the requirements of Table 7 (not
included). All numeric values in Table 7 (not included) represent MARV in the weaker
principal direction.

CONSTRUCTION INSTALLATION GUIDELINES

A.1 GENERAL

A.1.1 This Appendix is intended for use in conjunction with AASHTO Specification M 288-96 for
Geotextiles. The Specification details materials properties for geotextiles used in drainage,
erosion control, separation/stabilization, silt fences, and pavement overlay application. The
material properties are only one factor in a successful installation involving geotextiles. Proper
construction and installation techniques are essential in order to ensure that the intended function
of the geotextile is fulfilled.

A.1.2 Geotextile Identification, Packaging, and Storage

A.1.3 Geotextile Exposure Following Placement

A.3.1 Atmospheric exposure of geotextiles to the elements following lay down shall be a
maximum of 14 days to minimize damage potential.

A.4.1 Seaming

A.4.1.1 If a sewn seam is to be used for the seaming of the geotextile, the thread used shall
consist of high strength polypropylene, or polyester. Nylon thread shall not be used. For erosion
control applications, the thread shall also be resistant to ultraviolet radiation. The thread shall be
of contrasting colour to that of the geotextile itself.

A.4.2.2 For seams which are sewn in the field, the Contractor shall provide at least a 2 meter
length of sewn seam for sampling by the Engineer before the geotextile is installed. For seams
which are sewn in the factory, the Engineer shall obtain samples of the factory seams at random
form any roll of geotextile which is used on the project.

A.4.2.2.1 For seams that are field sewn, the seams sewn for sampling shall be sewn using
the same equipment and procedures as will be used for the production seams. If seams are
sewn in both the machine are cross machine direction, samples of seams from both directions
shall be provided.

A.4.2.2.2 The seam assembly description shall be submitted by the Contractor along with the
sample of the seam. The description shall include the seam type, stitch type, sewing thread, and
stitch density.
A.2 DRAINAGE GEOTEXTILES3 (See Specification Sections 7.1 & 7.2)

A2.1 Construction

A2.1.1 Trench excavation shall be done in accordance with details of the project plans. In all instances excavation shall be done in such a way so as to prevent large voids from occurring in the sides and bottom of the trench. The graded surface shall be smooth and free of debris.

A2.1.2 In the placement of the geotextile for drainage applications, the geotextile shall be placed loosely with no wrinkles or folds, and with no void spaces between the geotextile and geotextiles used as sheet drains are not included in the discussions in this section. Successive sheets of geotextiles shall be overlapped a minimum of 300 mm, with the upstream sheet overlapping the downstream sheet.

A2.1.2.1 In trenches equal to or greater than 300 mm in width, after placing the drainage aggregate the geotextile shall be folded over the top of the backfill material in a manner to produce a minimum overlap of 300 mm. In trenches less than 300 mm but greater than 100 mm wide, the overlap shall be equal to the width of the trench. Where the trench is less than 100 mm the geotextile overlap shall be sewn or otherwise bonded. All seams shall be subject to the approval of the Engineer.

A2.1.2.2 Should the geotextile be damaged during installation or drainage aggregate placement, a geotextile patch shall be placed over the damaged area extending beyond the damaged area a distance of 300 mm, or the specified seam overlap, whichever is greater.

A2.1.3 Placement of drainage aggregate should proceed immediately following placement of the geotextile. The geotextile should be covered with a minimum of 300 mm of loosely placed aggregate prior to compaction. If a perforated collection pipe is to be installed in the trench, a bedding layer of drainage aggregate should be placed below the pipe, with the remainder of the aggregate placed to the minimum required construction depth.

A2.1.5.1 The aggregate should be compacted with vibratory equipment to a minimum of 95 percent Standard AASHTO density unless the trench is required for structural support. If higher compactive effort is required, a Class 1 geotextile as per Table 1 of M 288 Specification is needed.

A2.1.4 Figures A1 through A3 illustrate various geotextile drainage application details.

A.3 SEPARATION/ STABILIZATION GEOTEXTILES (See Specification Sections 7.1, 7.3 and 7.4)

A3.1 Construction

A3.1.1 The installation site shall be prepared by clearing, grubbing, and excavation or filling the area to the design grade. This includes removal of top soil and vegetation.

NOTE 1—Soft spots and unsuitable areas will be identified during site preparation or subsequent proof rolling. These areas shall be excavated and backfilled with select material and compacted using normal procedures.

A3.1.2 The geotextile shall be laid smooth without wrinkles or folds on the prepared subgrade in the direction of construction traffic. Adjacent geotextile rolls shall be overlapped, sewn or joined as required in the plans. Overlaps shall be in the direction as shown on the plans. See Table A1 for overlap requirements.

TABLE A1
### A3.1.2.1
On curves the geotextile may be folded or cut to conform to the curves. The fold or overlap shall be in the direction of construction and held in place by pins, staples, or piles of fill or rock.

### A3.1.2.2
Prior to covering, the geotextile shall be inspected by a certified inspector of the Engineer to ensure that the geotextile has not been damaged (i.e., holes, tears, rips) during installation. Damaged geotextiles, as identified by the Engineer, shall be repaired immediately. Cover the damaged area with a geotextile patch which extends an amount equal to the required overlap beyond the damaged area.

### A3.1.3
The sub base shall be placed by end dumping onto the geotextile from the edge of the geotextile, or over previously placed sub base aggregate. Construction vehicles shall not be allowed directly on the geotextile. The sub base shall be placed such that at least the minimum specified lift thickness shall be between the geotextile and equipment tires or tracks at all times. Turning of vehicles shall not be permitted on the first lift above the geotextile.

#### NOTE 2 — On subgrades having a CBR value of less than 1, the sub base aggregate should be spread in its full thickness as soon as possible after dumping to minimize the potential of localized subgrade failure due to overloading of the subgrade.

#### A3.1.3.1
Any ruts occurring during construction shall be filled with additional sub base material, and compacted to the specified density.

#### A3.1.3.2
If placement of the backfill material causes damage to the geotextile, the damaged area shall be repaired as previously described in section A2.1.3.1. The placement procedures shall be then be modified to eliminate further damage from taking place (i.e., increase initial lift thickness, decrease equipment loads, etc.).

#### NOTE 3 — In stabilization applications, the use of vibratory compaction equipment is not recommended with the initial lift of sub base material, as it may cause damage to the geotextile.

### A4. EROSION CONTROL GEOTEXTILES (See Specification Section 7.5.)

#### A4.1 Construction

##### A4.1.1
The geotextile shall be placed in intimate contact with the soils without wrinkles or folds and anchored on a smooth graded surface approved by the Engineer. The geotextile shall be placed in such a manner that placement of the overlying materials will not excessively stretch so as to tear the geotextile. Anchoring of the terminal ends of the geotextile shall be accomplished through the use of key trenches or aprons at the crest and toe of slope. Refer to Figures A4 through A7 for construction details.
NOTE 1 — In certain applications to expedite construction, 450 mm anchoring pins placed on 600 to 1800 mm centres, depending on the slope of the covered area, have been used successfully.

A4.1.1.1 The geotextile shall be placed with the machine direction parallel to the direction of water flow which is normally parallel to the slope for erosion control runoff and wave action (see Figure A4), and parallel to the stream or channel in the case of stream bank and channel protection (see Figure A6). Adjacent geotextile sheets shall be joined by either sewing or overlapping. Overlapped seams of roll ends shall be a minimum of 300 mm except where placed under water. In such instances the overlap shall be a minimum of 1 m. Overlaps of adjacent rolls shall be a minimum of 300 mm in all instances.

NOTE 2 — When overlapping, successive sheets of the geotextile shall be overlapped upstream over downstream, and/or upslope over down slope. In cases where wave action or multidirectional flow is anticipated, all seams perpendicular to the direction of flow shall be sewn.

A4.1.1.2 Care shall be taken during installation so as to avoid damage occurring to the geotextile as a result of the installation process. Should the geotextile be damaged during installation, a geotextile patch shall be placed over the damaged area extending 1 m beyond the perimeter of the damage.

A4.1.2 The armour system placement shall begin at the toe and proceed up the slope. Placement shall take place so as to avoid stretching and subsequent tearing of the geotextile. Riprap and heavy stone filling shall not be dropped from a height of more than 300 mm. Stone with a mass of more than 100 kg shall not be allowed to roll down the slope.

A4.1.2.1 Slope protection and smaller sized of stone filling shall not be dropped from a height exceeding 1 m, or a demonstration provided showing that the placement procedures will not damage the geotextile. In underwater applications, the geotextile and backfill material shall be placed the same day. All void spaces in the armour stone shall be backfilled with small stone to ensure full coverage.

A4.1.2.2 Following placement of the armour stone, grading of the slope shall not be permitted if the grading results in movement of the stone directly above the geotextile.

A4.1.3 - Field monitoring shall be performed to verify that the armour system placement does not damage the geotextile.

A4.1.3.1 Any geotextile damaged during backfill placement shall be replaced as directed by the Engineer, at the contractor's expense.

A5. SILT FENCE GEOTEXTILES (See Specification Section 8.)

A5.1 Related Material Requirements

A5.1.1 Wood, steel, or synthetic support posts having a minimum length of 1 m plus the burial depth may be used. They shall be of sufficient strength to resist damage during installation and to the support applied loads due to material build up behind the silt fence.

NOTE 1 — It has been found that hardwood post having dimensions of at least 30 mm x 30 mm, No. 2 Southern Pine at least 65 mm x 65 mm or steel posts of U, T, L, or C shape, weighing 600 g per 300 mm have performed satisfactorily.


A5.1.2 Wire or polymer support fence shall be at least 750 mm high and strong enough to support applied loads. Polymer support fences shall meet the same ultraviolet degradation requirements as the geotextile.

NOTE 2 — Wire support fences having at least 6 horizontal wires, and being at least 14 gauge wire have performed satisfactorily. Vertical wires should be a maximum of 150 mm apart.

A5.2 Construction

A5.2.1 The geotextile at the bottom of the fence shall be buried in a "J" configuration to a minimum depth of 150 mm in a trench so that no flow can pass under the silt fence. The trench shall be backfilled and the soil compacted over the geotextile.

A5.2.1.1 The geotextile shall be spliced together with a sewn seam only at a support post, or two sections of fence may be overlapped instead.

A5.2.1.2 The Contractor must demonstrate to the satisfaction of the Engineer that the geotextile can withstand the anticipated sediment loading.

A5.2.1.3 See Figure A8 for details.

A5.2.2 The posts shall be placed at a spacing as shown on the project plans. Posts should be driven or placed a minimum of 500 mm into the ground. Depth shall be increased to 600 mm if fence is placed on a slope of 3:1 or greater.

NOTE 3 — Where 500 mm depth is impossible to attain, the posts should be adequately secured to prevent overturning of the fence due to sediment loading.

A5.2.3 The support fence shall be fastened securely to the upslope side of the fence post. The support fence shall extend from the ground surface to the top of the geotextile.

A5.2.4 When self-supported fence is used, the geotextile shall be securely fastened to fence posts.

A5.2.5 Silt fences should be continuous and transverse to the flow. The silt fence should follow the contours of the site as closely as possible. The fence shall also be placed such that the water cannot runoff around the end of the fence.

A5.2.5.1 The silt fence should be limited to handle an area equivalent to 90 square meters per 3 meters of fence. Caution should be used where the site slope is greater than 1:1, and water flow rates exceed 3 litres per second per 3 meters of fence.

A5.3 Maintenance

A5.3.1 The Contractor shall inspect all temporary silt fences immediately after each rainfall, and at least daily during prolonged rainfall. Any deficiencies shall be immediately corrected by the Contractor.

A5.3.1.1 The Contractor shall also make a daily review of the location of silt fences in areas where construction activities have altered the natural contour and drainage runoff to ensure that the silt fences are properly located for effectiveness. Where deficiencies exist as determined by the Engineer, additional silt fence shall be installed as directed by the Engineer.

A5.3.1.2 Damaged or otherwise ineffective silt fences shall be repaired or replaced promptly.

A5.3.2 Sediment deposits shall either be removed when the deposit reaches half the height of the fence, or a second silt fence shall be installed as directed by the Engineer.

A5.3.3 The silt fence shall remain in place until the Engineer directs it be removed. Upon removal, the Contractor shall remove and dispose of any excess sediment accumulations, dress the area to give it a pleasing appearance, and vegetate all bare areas in accordance with contract requirements.

A5.3.3.1 Removed silt fence may be used at other locations provided the geotextile and other material requirements continue to be met to the satisfaction of the Engineer.
A6. PAVING GEOTEXTILES (See Specification Section 9.)

A6.1 Materials

A6.1.1 The sealant material used to impregnate and seal the geotextile, as well as bond it to both the base pavement and overlay, shall be a paving grade asphalt recommended by the geotextile manufacturer, and approved by the Engineer.

A6.1.1.1 Uncut asphalt cements are the preferred sealants; however, cationic and anionic emulsions may be used provided the precautions outlined in Section A6.3.3 are followed. Cutbacks and emulsions which contain solvents shall not be used.

A6.1.1.2 The grade of asphalt cement specified for hot-mix design in each geographic location is generally the most acceptable material.

A6.1.2 Washed concrete sand may be spread over an asphalt saturated geotextile to facilitate movement of equipment during construction or to prevent tearing or delamination of the geotextile. Hot-mix broadcast in front of construction vehicle tires may also be used to serve this purpose. If sand applied, excess quantities shall be removed from the geotextile prior to placing the surface course.

A6.1.2.1 Sand is not usually required. However, ambient temperatures are occasionally sufficiently high to cause bleed-through of the asphalt sealant resulting in undesirable geotextile adhesion to construction vehicle tires.

A6.2 Equipment

A6.2.1 The asphalt distributor shall be capable of spraying the asphalt sealant at the prescribed uniform application rate. No streaking, skipping, or dripping will be permitted. The distributor shall also be equipped with a hand spray having a single nozzle and positive shut-off valve.

A6.2.2 Mechanical or manual lay down equipment shall be capable of laying the geotextile smoothly.

A6.2.3 The following miscellaneous equipment shall be provided: stiff bristle brooms or squeegees to smooth the geotextile; scissors or blades to cut the geotextile; brushes for applying asphalt sealant to geotextile overlaps.

A6.2.4 Pneumatic rolling equipment to smooth the geotextile into the sealant, and sanding equipment may be required for certain jobs. Rolling is especially required on jobs where thin lifts or chip seals are being placed. Rolling helps ensure geotextile bond to the adjoining pavement layers in the absence of heat and weight associated with thicker lifts of asphaltic pavement.

A6.3 Construction

A6.3.1 Neither the asphalt sealant nor the geotextile shall be placed when weather conditions, in the opinion of the Engineer, are not suitable. Air and pavement temperatures shall be sufficient to allow the asphalt sealant to hold the geotextile in place. For asphalt cements, air temperature shall be 10°C and rising. For asphalt emulsions, air temperature shall be 15°C and rising.

A6.3.2 The surface on which the geotextile is to be placed shall be reasonably free of dirt, water, vegetation, or other debris. Cracks exceeding 3 mm in width shall be filled with a suitable crack filler. Potholes shall be properly repaired as directed by the Engineer. Fillers shall be allowed to cure prior to geotextile placement.

A6.3.3 The specified rate of asphalt sealant application must be sufficient to satisfy the asphalt retention properties of the geotextile, and bond the geotextile and overlay to the old pavement.

NOTE 1 —When emulsions are used, the application rate must be increased to offset water content of the emulsion.
A6.3.3.1 Application of the sealant shall be by distributor spray bar, with hand spraying kept to a minimum. Temperature of the asphalt sealant shall be sufficiently high to permit uniform spray pattern. For asphalt cements the minimum temperature shall be 145°C. To avoid damage to the geotextile, however, the distributor tank temperature shall not exceed 160°C.

A6.3.3.2 Spray patterns for asphalt emulsion are improved by heating. Temperatures in the 55 °C to 70 °C range are desirable. A temperature of 70 °C shall not be exceeded since higher temperatures may break the emulsion.

A6.3.3.3 The target width of asphalt sealant applications shall be the geotextile width plus 150 mm. The asphalt sealant shall not be applied any farther in advance of geotextile placement than the distance the contractor can maintain free of traffic.

A6.3.3.4 Asphalt spills shall be cleaned from the road surface to avoid flushing and geotextile movement.

A6.3.3.5 When asphalt emulsions are used, the emulsion shall be cured prior to placing the geotextile and final wearing surface. This means essentially no moisture remaining.

A6.3.4 The geotextile shall be placed onto the asphalt sealant with minimum wrinkling prior to the time the asphalt has cooled and lost tackiness. As directed by the engineer, wrinkles or folds in excess of 25 mm shall be slit and laid flat.

A6.3.4.1 Brooming and/or pneumatic rolling will be required to maximize geotextile contact with the pavement surface.

A6.3.4.2 Overlap of geotextile joints shall be sufficient to ensure full closure of the joint, but should not exceed 150 mm. Transverse joints shall be lapped in the direction of paving to prevent edge pickup by the paver. A second application of asphalt sealant to the geotextile overlaps will be required if in the judgement of the Engineer additional asphalt sealant is needed to ensure proper bonding of the double geotextile layer.

A6.3.4.3 Removal and replacement of geotextile that is damaged will be the responsibility of the contractor.

NOTE 2 — The problems associated with wrinkles are related to thickness of the asphalt lift being placed over the geotextile. When wrinkles are large enough to be folded over, there usually is not enough asphalt available from the tack coat to satisfy the requirement of multiple layers of geotextiles. Therefore, wrinkles should be slit and laid flat. Sufficient asphalt sealant should be sprayed on the top of the geotextile to satisfy the requirement of the lapped geotextile.

NOTE 3 — In overlapping adjacent rolls of geotextile it is desirable to keep the lapped dimension as small as possible and still provide a positive overlap. If the lapped dimension becomes too large, the problem of inadequate tack to satisfy the two lifts of geotextile and the old pavement may occur. If this problem does occur then additional asphaltic sealant should be added to the lapped areas. In the application of the additional sealant, care should be taken not to apply too much since an excess will cause flushing.

A6.3.4.4 Trafficking the geotextile will be permitted for emergency and construction vehicles only.

A6.3.5 Placement of the hot-mix overlay should closely follow geotextile laydown. The temperature of the mix shall not exceed 160°C. In the event asphalt bleeds through the geotextile causing construction problems before the overlay is placed, the affected areas shall be blotted by spreading sand. To avoid movement of, or damage to the seal-coat saturated geotextile, turning of the paver and other vehicles shall be gradual and kept to a minimum.
A6.3.6 Prior to placing a seal coat (or thin overlay such as an open-graded friction course), lightly sand the geotextile at a spread rate of 0.65 to 1 kg per m, and pneumatically roll the geotextile tightly into the sealant.

ADVISORY

It is recommended that for safety considerations, trafficking of the geotextile should not be allowed. However, if the contracting agency elects to allow trafficking, the following verbiage is recommended:
"If approved by the Engineer, the seal coat saturated geotextile may be opened to traffic for 24 to 48 hours prior to installing the surface course. Warning signs shall be placed which advise the motorist that the surface may be slippery when wet. The signs shall also post the appropriate safe speed. Excess sand shall be broomed from the surface prior to placing the overlay. If, in the judgement of the Engineer, the fabric surface appears dry, and lacks tackiness following exposure to traffic, a light tack coat shall be applied prior to the overlay."

**NorGeoSpec**

A Nordic system for specification and control of geotextiles in roads and other trafficked areas

NorGeoSpec is the result of a Nordisk Industrifond project with financial support from the road authorities in Finland, Sweden and Norway and a group of geotextile producers and distributors. The project work is done by VTT and SINTEF and with an advisory group consisting of:

Øystein Myhre and Arne Sørlie, The Norwegian Public Roads Administration, Norway

Pentti Salo, The Finnish Road Administration, Finland

Lovisa Moritz and Ingrid Sødergren, The Swedish National Road Administration, Sweden

Oddur Sigurdsson, VSO Consulting, Island

The project has resulted in a common Nordic system for specification and control of geotextiles which is likely to have a strong beneficial effect both economically and technically. We would like to thank the participants in the project and especially the road authorities for the good contribution to the project.

We would also like to give our appreciation to Nordisk Industrifond for the financial support.

The first revision of the NorGeoSpec system is issued 2004.06.30.

Download the NorGeoSpec 2002 revision 1 report [here](#).
A NorGeoSpec Technical Committee (NTC) with representatives from road authorities in the Nordic countries, VTT and SINTEF Civil and Environmental Engineering is established.

SINTEF is mandated to be the NorGeoSpec Certification Body (NCB) by the NTC. SINTEF is a Notified Body related to directive 89/106/EEC (ID 1278) for geotextiles and geotextile related products.

SINTEF issues NorGeoSpec certificates stating the compliance with the NorGeoSpec requirements.

The compliance with the NorGeoSpec requirements can be verified by two different procedures:

- **Quality Conformity Attestation (QCA)**
- **Independent Product Attestation (IPA)**

**QCA:** The NCB can issue a QCA certificate according to the following requirements:

- The manufacturer shall provide nominal values and tolerances for the characteristics according to Table 5.1 in the NorGeoSpec report.
- The values corresponding to 95% confidence limits (nominal value +/- the tolerances) shall meet the requirements in Table 5.2 in the NorGeoSpec report.
- The data provided by the manufacturer must be the same as given on the CE-mark accompanying document.
- Initial type testing must be performed at all products and for all characteristics. The testing must be performed at an external laboratory, recognised by the NCB. The initial type testing results must fulfil the NorGeoSpec requirements.
- Evaluation of internal FPC, both system of quality control and the results. The results must comply with the NorGeoSpec requirements.
- The manufacturer must have a contract with the NCB, which will be responsible for this evaluation and for running continuous surveillance. This involves unannounced sampling at production site and at store and surveillance of internal FPC, both system and results. There will be minimum two random samplings every year.

**IPA:** The NCB can issue an IPA certificate according to the following requirements:
• The manufacturer shall provide nominal values and tolerances for the characteristics according to Table 5.1 in the NorGeoSpec report.
• The values corresponding to 95% confidence limits (nominal value +/- the tolerances) shall meet the requirements in Table 5.2 in the NorGeoSpec report.
• The data provided by the manufacturer must be the same as given on the CE-mark accompanying document.
• Mean values from accredited tests at an independent laboratory shall be within the 95% confidence limits. The results from the independent laboratory shall not be older than 3 months at the time of requesting certification.
• Documentation of the FPC.

APPLICATION PROFILE TEST

A test page where applicants can evaluate the application profile of their geotextiles can be found here.

Please note that the application profile test is developed for manufacturers and distributors planning to introduce their products on the Nordic market. This test evaluates only product characteristics. Passing the test is therefore not a guarantee that the product will achieve a specific specification profile or that the product will be certified.

Questing regarding certification can be directed to e-mail: post@norgeospec.org
NorGeoSpec 2002
A Nordic system for specification and control of geotextiles in roads and other trafficked areas (Document from http://www.norgeospec.org/ dated May 2006)

Preface
NorGeoSpec 2002 is the result of a Nordisk Industrifond project with financial support from the road authorities in Finland, Sweden and Norway and a group of geotextile producers and distributors.

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1 Introduction
The NorGeoSpec 2002 system is prepared as a common Nordic system for specification and control of geotextiles for separation and filtration in roads. In Finland, Sweden and Norway a common classification system for this application was developed in 1979. This system has been revised in the different countries over the years and a number of standardised test methods have been prepared at a European level by CEN TC 189. The intention of the NorGeoSpec was to develop a new system for specification and control based on the required characteristics and test methods standardised by CEN.
The NorGeoSpec is based on the experiences from the previous classification systems in Finland, Sweden and Norway and a research project involving laboratory and field testing of geotextiles.
The specification is based on the required documentation of product characteristics and test methods as given in the relevant application standard EN 13 249.
The NorGeoSpec includes: -general requirements for the geotextiles
  -requirements on which characteristics for the geotextiles shall be declared by the manufacturer
  -specific requirements related to specification profiles
  -guidelines for selection of relevant specification profile
  -system for control of geotextiles delivered on site
The specification system **NorGeoSpec 2002** as such is implemented as a complete system. This is a revised version of the NorGeoSpec dated 2004-06-30. The rules of NorGeoSpec and responsibilities of the parties involved are described in detail in Appendix A.

### 1.1 Scope
This document presents a Nordic system for specification and control of geotextiles (NorGeoSpec) used for separation and filtration in roads and other traffic areas. The separation function is always used in conjunction with filtration; accordingly the separation will never be specified alone.

The NorGeoSpec defines product requirements related to specification profiles, a system for certification and control of geotextiles and guidelines for selection of relevant specification profiles.

This specification should not be applied in cases where large water flow is expected, like in ditches. In such cases other specifications based on a site specific design should be used.

### 2 Normative references
This specification also contains provisions from other publications, such as dated or undated references. These normative references are cited at the relevant places in the text, and publications are listed in the following. If dated references are changed or revised, the changes or revision will not be valid in the NorGeoSpec system. They will only become valid through the publication of an amendment or a revised edition of NorGeoSpec. For undated references, the latest edition of the cited publication is valid.

- EN 918 Geotextiles and geotextile-related products - Dynamic perforation test (cone drop test)
- prEN ISO 9862 Geotextiles and geotextile-related products - Sampling and preparation of test specimens.
- EN ISO 9002 Quality systems - Model for quality assurance in production and installation
- EN ISO 10318 Geotextiles - Vocabulary
- EN ISO 10319 Geotextiles - Wide width tensile test (ISO 10319:1993)
- EN ISO 10320 Geotextiles and geotextile-related products- Identification on site
- EN ISO 11058 Geotextiles and geotextile-related products - Determination of water permeability normal to their plane without load
- EN ISO 12236 Geotextiles and geotextile-related products - Static puncture test (CBR-test)
- EN ISO 12956 Geotextiles and geotextile-related products - Determination of the characteristic opening size
- EN 13249 Geotextile and geotextile related products- “Required characteristics for use in the construction of roads and other trafficked areas.”

### 3 Terms, definitions and abbreviations
In general all terms are referred to EN ISO 10318 Geotextiles - Vocabulary.

In the specific requirements the following terms are used:
- **Nominal value** The value of a characteristic stated by the manufacturer. The nominal value is considered to correspond to the mean value of a large number of samples.
- **Tolerance** The tolerance for a characteristic is to be stated by the manufacturer. The tolerances are used to define the one sided 95% confidence limit for the characteristic.
- **Average values** The average of the properties in machine and cross machine direction.
- **Uniformity requirement**: Some products may have a large difference in strength and strain between machine and cross machine direction. A uniformity requirement of 1.5 is included to not give credit for strain at failure.
higher than 1.5 times the direction with the smallest value. 95% confidence limit. The nominal value subtracted or added the tolerance is defined as the one sided 95% confidence limit.

Sample In the delivery control a sample consists of tests on several single specimens. The number of tests on single specimens for a specific characteristic is specified in the test standards.

Test result: The average value of the tests on single specimens in the sample.

F Maximum tensile strength (kN/m)
ε Strain at maximum tensile strength
R Strain energy index, $R = \frac{1}{2}F^*\varepsilon$
T; The tolerance of the characteristic in engineering units
U Uniformity requirement.

The following subscripts are used in combination with F, ε and T:
MD Machine Direction
CMD Cross Machine Direction
a Average of machine and cross machine direction
95% confidence limit
F , ε Tolerance for strength and strain properties respectively.

TC NorGeoSpec Technical Committee, with representatives from national road authorities in the countries where the NorGeoSpec is applied, VTT and SINTEF.
NCB NorGeoSpec Certification Body, mandated and nominated by the Technical Committee appointed by the National Roads Administrations of the countries where the NorGeoSpec is applied.
QC Quality Certificate
IPA Independent Product Attestation

4 General requirements
Identification of the geotextile products according to EN ISO 10320 “Geotextiles and geotextile related products – Identification on site” shall be enabled.
The geotextiles have to comply with the general requirements as set down in EN 13249 “Geotextiles and geotextile related products – Characteristics required for use in the construction of roads and other trafficked areas (excluding railways and asphalt inclusion)”. The characteristics, their relevancy to the conditions of use, and the test methods to be used are given in Table 1 in EN 13249. The geotextile products have to fulfil all the conditions and requirements set in EN 13249 for CE-marking and FPC (factory production control) and have to be assigned durable > 25 years (according to Appendix A in EN 13249).

5 Specific requirements
The specific requirements in NorGeoSpec are related to the five different specification profiles.
Guidelines for evaluation of relevant specification profile dependent on the application are given in Chapter 7. These specification profiles give requirements to the characteristics and test methods in Table 5.1. (Not included – see the web site at http://www.norgeospec.org/ for current values)
The specific requirements have to be fulfilled for both Independent Product Attestation and Quality Certification.
The required values for each characteristic and corresponding maximum tolerance limits are given in Table 5.2. (Not included – see the web site at http://www.norgeospec.org/ for current values)

6 Product Attestation, Quality Certification and Product Control
Compliance with the NorGeoSpec requirements is declared by the NorGeoSpec mandated Certification Body (NCB).
Compliance with the requirements can be achieved by two different procedures:
- Independent Product Attestation (IPA)
- Quality Certification (QC)
The NCB is a Notified Body according to the EC-mandate 102 for geotextiles and geotextile related products, is for NorGeoSpec purposes mandated and nominated by the Technical Committee (TC) appointed by the National Roads Administrations of the countries where the NorGeoSpec is applied. The TC represents partners involved in the NorGeoSpec certification, including representatives from the National Roads Administrations in the NorGeoSpec countries, VTT and SINTEF.
The NCB is the prime contact of the manufacturer. The NCB handles the procedures of both Independent Product Attestation (IPA) and Quality Certification (QC), with the support of the NorGeoSpec accredited laboratory and is advised by the Technical Committee in its decisions.
The rules to issue NorGeoSpec Quality Certificates and Independent Product Attestation for geotextile products are described in the NorGeoSpec report and its Appendix A. This document is regularly revised and updated by the Technical Committee (TC) and published on the website http://www.norgeospec.org.

6.1 Compliance with the NorGeoSpec specification
Compliance with the NorGeoSpec requirements are declared by the NCB to any manufacturer, or the manufacturer’s authorised representative, who applies for it, on condition that the concerned product satisfies the present rules published on the website http://www.norgeospec.org. Declared compliance can only be stated for a product with the same name as on its CE-mark accompanying document.
The manufacturer or the manufacturers authorized representative applying for compliance with the NorGeoSpec rules must:
- accept all the conditions stated in the current issue of the NorGeoSpec and its annexes
- publish the same average value for each required characteristic for the CE-mark and for the NorGeoSpec
- inform the NCB of essential modifications that occur in the production
- facilitate the assignments of the auditor described in the present rules
- conform without any restriction to decisions taken in accordance with the present rules
- forward at the request of the NCB all commercial and promotional documents (incl. electronic format) where the NorGeoSpec is referenced
- inform the NCB in case of stop in manufacturing or in the manufacturing control process
- inform the NCB of all production places and stock locations operated by the manufacturer for the products the manufacturer applies for the certification
- accept publication of list of its certified or attested products and their quality certificate(s) or their product attestations or http://www.norgeospec.org.
Compliance with the NorGeoSpec requirements can be verified by two different procedures:
- Quality Certificate (QC)
- Independent Product Attestation (IPA)

**QC:** The NCB can issue a Quality Certificate (QC) according to the following requirements:
- The manufacturer shall provide nominal values and tolerances for the characteristics according to Table 5.1.
- The values corresponding to 95% confidence limits (nominal value +/- the tolerances) shall meet the requirements in Table 5.2.
- The data provided by the manufacturer must be the same as given on the CE-mark accompanying document.
- When requesting certification, initial testing must be performed at all products and for all characteristics according to Table 5.2. The testing must be performed at an external laboratory and the sampling must be done by an independent auditor, recognised by the NCB. The sampling and testing must be organised by the NCB. The initial type testing results must comply with the NorGeoSpec requirements.
- The manufacturer must have a contract with the NCB, which will be responsible for running continuous surveillance. This involves unannounced sampling at production sites, at stock and at construction sites. There will be minimum two and maximum four random samplings every year.

**IPA:** The NCB can issue an Independent Product Attestation according to the following requirements:
- The manufacturer shall provide nominal values and tolerances for the characteristics according to Table 5.1.
- The values corresponding to 95% confidence limits (nominal value +/- the tolerances) shall meet the requirements in Table 5.2.
- The data provided by the manufacturer must be the same as given on the CE-mark accompanying document.
- Mean values from accredited tests at an independent laboratory shall be within the 95% confidence limits. The results from the independent laboratory shall not be older than 3 months at the time of the request.

### 6.2 Delivery control

The frequency of delivery control shall be:

**For products with Quality Certificates:**
- 1 every 50,000 m² minimum but 1 identification control above 10,000 m²

For products with Quality Certificates, only identification control according to EN 10320 are required. If a product fails in the delivery control it is to be decided by the client, whether additional tests for attestation of conformity with specification are to be made or if the lot is to be rejected.

**For products with Independent Product Attestation:**
- 1 every 10,000 m², but minimum 1 test above 1,000 m²

For products with Independent Product Attestation, the delivery control can be performed according to a Simplified Procedure (SP) or, if required by any of the parties, an Extended Delivery Control (EDC). If the product is not accepted as complying with the requirements according to the SP any of the parties may require that the delivery control be performed according to EDC.

### 6.3 Procedures for delivery control

**Simplified Procedure (SP):**
- The marking and labelling of the rolls and of the products shall be checked. The marking of the products shall be according to EN ISO 10320.
• The compliance of characteristics with the values defined by the manufacturer shall be made on tests made on two representative samples (A and B) taken from different rolls. Sampling shall be made according to prEN ISO 9862.
• The characteristics to be controlled on sample A in the simplified procedure are:
  - mass per unit area, in field quality control the sample size shall be 500x500 mm
  - tensile strength or static puncture force from the CBR test.
The tensile strength can be checked by wide width tensile test according EN ISO 10319, static puncture test EN ISO 12236 (CBR) or by a simplified test method if a correlation between the test results from tests performed according to EN ISO 10319 and the simplified method is established.
For the CBR test the nominal value and the tolerance are to be provided by the manufacturer. The test result from the CBR test is therefore compared with 95% confidence limit for static puncture strength.

**Decision procedure for SP (presented as flow chart in Appendix B):**
1. If the test results for one or more of the particular characteristics are within the tolerance values given by the manufacturer the product is accepted.
2. If the test results for one or more of the particular characteristics are outside 1.5 times the tolerance values provided by the manufacturer the product does not comply with respect to the requirements. Any of the parties may then require delivery control according to EDC.
3. If the test results for one or more of the particular characteristics are within 1 and 1.5 times the tolerance values given by the manufacturer sample B shall be tested.
4. If the test results of the sample B of one or more for the same particular characteristics are within the tolerance values provided by the manufacturer the product is accepted as complying with respect to that characteristic.
5. If the test results of the sample B for one or more of the same particular characteristics are outside the tolerance values given by the manufacturer the product does not comply with respect to the characteristics. Any of the parties may then require delivery control according to EDC.

**Extended Delivery Control (EDC):**
• The delivery control according to EDC may be required by any of the parties. The EDC is to be based on accredited tests at an independent laboratory.
• The marking and labelling of the rolls and of the products shall be checked. The marking of the products shall be according to EN ISO 10320.
• The compliance of characteristics with the values defined by the manufacturer shall be made on tests on two representative samples (A and B) taken from different rolls. Sampling shall be made according to prEN ISO 9862.
• The characteristics to be controlled on sample A in the EDC are:
  - mass per unit area, EN 965
  - tensile strength, EN 10319
  - tensile strain, EN 10319
  - dynamic perforation resistance, EN 918.

**Decision procedure for EDC (presented as flow chart in Appendix B):**
If the test result(s) (average of the tested sample) for the particular characteristics is (are) within the 95% confidence limits the product is accepted.
1. If the test results for one or more of the particular characteristics are within the tolerance values given by the manufacturer the product is accepted.
2. If the test results for one or more of the particular characteristics are outside 1.5 times the tolerance values provided by the manufacturer the product does not comply with respect to
the requirements.

3 If the test results for one or more of the particular characteristics are within 1 and 1.5 times the tolerance values given by the manufacturer sample B shall be tested.

4 If the test results of the sample B of one or more for the same particular characteristics are within the tolerance values provided by the manufacturer the product is accepted as complying with respect to that characteristic.

5 If the test results of the sample B for one or more of the same particular characteristics are outside the tolerance values given by the manufacturer the product does not comply with respect to the characteristics.

7 Guidelines for selection of specification profile

The selection of specification profile may be based on subsoil conditions, fill material grain size and a combination of construction conditions and quality requirements for the road. For conditions not covered by these guidelines, a special evaluation of required specification profile should be done.

The construction conditions and road quality requirements are combined into traffic classes Normal and High according to the following:

Subsoil:
The subsoil is divided into two groups, Soft and Firm. Evaluation of type of subsoil can be done according to the remarks.

- Soft - soft clay with undrained shear strength $\leq 25$ kPa, and peat
- Firm - Medium - and stiff clay with undrained shear strength $> 25$ kPa, and sand and gravel

Construction conditions:

- Normal: Two or more of the following conditions: Heavy construction traffic, angular and sharp fill material, compaction with heavy and vibrating equipment, construction traffic on fill layers with thickness less than 300 mm
- Favourable: For fill material with maximum stone size $< 200$ mm and layer thickness $> 1.5 \times$ max. stone size.

Traffic:

- High - Medium and high volume roads ($> 500$ vehicles per day)
- Normal - Access roads, small roads ($< 500$ vehicles per day)

Based on these input parameters the selection of relevant specification profile can be done according to Table 7.1. (Not included – see the web site at http://www.norgeospec.org/ for current values)

Annex A and following requirements for attestation in accordance with the NorGeoSpec are not include see the web site at see the web site at http://www.norgeospec.org/ for details.