# Assessment of Reinforced Fill Products
# Submission Requirements

*The applicant of reinforced fill product assessment shall furnish the Head of the Geotechnical Engineering Office of the Civil Engineering and Development Department with 2 complete sets of submission documents in loose leaf binders, tabbed and arranged as follows (For laboratory test data, original copies or certified true copies (certified by the issuing laboratories) shall be submitted):*

## A General Information of the Reinforced Fill Products

Provide the general information of the reinforced fill products including:

(i) Grades or ranges of the products for this submission (provide samples of each product).

(ii) Name and address of company.

(iii) Name and address of product distributor(s).

(iv) Name and address of manufacturer(s).

(v) Method of product identification.

## B Technical Information of the Reinforced Fill Products

Provide the technical information of the reinforced fill products including:

(i) Typical plan and sectional views.

(ii) Material (e.g., polyethylene, polypropylene, polyester, etc.) with the following applicable items:

- (a) Polymer source(s)
- (b) For polyethylene: primary resin type, class, density, grade and category (ASTM D1248-16 [ASTM, 2016a]) (to be replaced by ISO when available)
- (c) For polypropylene: resin type, class, density range, grade and category (ASTM D4101-17e1 [ASTM, 2017]) (to be replaced by ISO when available)
- (d) For polyester: minimum intrinsic viscosity correlated to number average molecular weight (e.g. ASTM D4603-18 [ASTM, 2018a] in conjunction with GRI GG8) and maximum carboxyl end groups (GRI GG7 / ASTM D7409-15 [ASTM, 2015]) (to be replaced by ISO when available)
- (e) Characteristics and concentration of photo-oxidation stabilizers used
- (f) Polymers used for coatings, if present, and the coating process
- (g) Percent of reprocessed polymer (recycled content)
- (h) Post-consumer recycled material, if any

(iii) Geometry (e.g., grid, mesh, sheet, strip, bar, etc.).

(iv) Dimensions (e.g., thickness, width, aperture size, mesh opening size, bar diameter, etc.)

(v) Standard dimensions of production unit (e.g., roll length and width, coil length, etc.).

(vi) Mass per unit area.

(vii) Typical stress-strain curve or load-strain curve.

(viii) Manufacturing process.

## C History of Use

Provide a brief history of the reinforced fill products including:

(i) History of manufacturing with date of initial manufacture at current factory.

(ii) Date of first application in soil reinforcement system.

(iii) Tallest structure constructed with these products.

(iv) Types of facing systems used with these products.

(v) Usage and limitations.

(vi) Job references with details such as completion date, location, design method and maximum height.

(vii) Representative information from instrumented structures (if available).

## D Manufacturer Quality Control/Quality Assurance Programme

Provide the details of manufacturer(s) including:

(i) A copy of the ISO 9001 certificate of the manufacturer(s).

(ii) A copy of the quality plan for each factory used in the production and supply of the products indicating minimum test requirements, test methods used, and test frequency.

(iii) Method of product identification and traceability (i.e. labelling).

## E Design Tensile Strength of Reinforcement

According to Geoguide 6 – Guide to Reinforced Fill Structure and Slope Design (GEO, 2017), the design tensile strength, $T_D$, of reinforcement is:

$$T_D = \frac{T_{ult}}{\gamma_{cr}\gamma_{d}\gamma_{id}}$$

where

$T_{ult}$ = ultimate tensile strength of reinforcement, which is the 95% lower confidence limit or Minimum Average Roll Value (MARV) tensile strength at 20°C±2°C

$\gamma_{cr}$ = partial factor on reinforcement to allow for creep, which is based

on the ratio of the ultimate tensile strength at 20°C±2°C to the creep limit tensile strength at 30°C obtained from laboratory creep tests

$\gamma_d$ = partial factor on reinforcement to allow for durability

$\gamma_{id}$ = partial factor on reinforcement to allow for installation damage

Provide the supporting information for the design tensile strength of the reinforced fill products at 30°C for 60 and 120 years including:

(I) Ultimate tensile strength of reinforcement $T_{ult}$

(i) Representative stress-strain curves with tensile strength and elongation at break at temperatures of 20°C±2°C, 30°C, and 40°C determined in accordance with BS EN ISO 10319: 2015 (BSI, 2015) for each product submitted. The actual temperature adopted for each test and the accuracy of measurement shall be stated.

(ii) Mean and 95% lower confidence limit (or MARV) ultimate tensile strength and strain for each product at 20°C ±2°C.

(iii) Mean and 95% lower confidence limit (or MARV) Quality Control strength and strain, standard procedure (e.g. single rib, grid or strip tests) and standard used.

(II) Creep Data for Determination of $\gamma_{cr}$

(i) 10,000-hr creep data for at least one of the reinforced fill products submitted and 1,000-hr creep data for the remaining reinforced fill products submitted, based on creep tests in accordance with BS EN ISO 13431: 1999 (BSI, 1999), including:

(a) The ultimate tensile strength and peak strain of the reinforced fill product tested in accordance with BS EN ISO 10319: 2015 (BSI, 2015), at a strain rate of 10% per minute at 20°C ±2°C. The tensile test samples shall be of the same size as the creep test samples and their relationship (e.g., taken from the same roll or from another roll from the same production unit) shall be stated.

(b) Creep strain data from the creep tests at four different loads covering and exceeding the range of the anticipated creep rupture load at 10,000 hrs (1,000 hrs for 1,000-hr creep tests) at 30°C. Creep tests shall be conducted to 10,000 hrs (1,000 hrs for 1,000-hr creep tests), or rupture, whichever is earlier, and at a temperature of 30°C.

(c) Creep stress-rupture data from the creep tests performed at a temperature of 20°C±2°C plus two or more elevated temperatures separated by a minimum interval of 10°C (e.g., 30°C and 40°C). A minimum of 12 loads shall be applied at each test temperature and shall be evenly distributed over each log cycle of time, with at least one rupture point at 10,000 hrs (1,000 hrs for 1000-hr creep tests) or greater. The data shall be presented in tables showing rupture time for each load and temperature and in graphs showing load against log t or log load against log t with measured points individually shown. Elongation at break and photographs of ruptured specimens taken from tests at the highest and lowest loads shall also be provided.

(ii) Additional creep data based on creep tests in accordance with BS EN ISO 13431: 1999 (BSI, 1999), if available, including,

(a) Creep strain and creep stress-rupture data for other products in the same product line based on a limited testing programme for at least 1,000 hrs until 10,000 hrs results are available.

(b) Creep strain and creep stress-rupture data from previous testing of similar products on earlier grades of the same geosynthetic type, or a similar product within the same product line until 10,000 hrs test results are available, if both of the following conditions are met: (i) the chemical and physical characteristics of tested products and proposed products are similar (see Note 1), and (ii) a limited testing programme is conducted on the new or similar product to at least 1,000 hrs.

(iii) Name(s) and location(s) of laboratory(ies) conducting the testing and evaluation. All test data shall be accompanied by a statement of accreditation of the measuring laboratory or proof of traceable calibration of the measuring equipment. For in-house testing, confirmation test results shall be provided for at least one product tested by both the in-house laboratory and an accredited independent laboratory for a creep period of 1,000 hrs using the same test procedures for the full range of temperatures and loads specified.

(iv) Photographs illustrating the creep testing equipment used.

(v) Records for the measured temperature and humidity over the test period including maximum fluctuations and the accuracy of the measurements. An isochronous diagram shall be drawn. (Isometric and Sherby-Dorn diagrams may also be presented, but are not required.)

(III) Durability Data for Determination of $\gamma_d$

(i) Durability data, for at least one of the reinforced fill products submitted, including:

(a) The ultimate tensile strength and peak strain of the reinforced fill product tested in accordance with BS EN ISO 10319: 2015 (BSI, 2015), at a strain rate used for the durability testing (i.e. the incubation testing). The tensile test samples shall be of the same size as the durability test samples and their relationship (i.e. taken from the same roll or from another roll from the same production unit) shall be stated.

(b) For polyester, durability test data from incubation tests consist of immersion in hot water and in a sodium hydroxide solution having a pH of 9 or greater, and at three or more temperatures separated by at least 10ºC intervals. A minimum of five specimens shall be incubated in each solution at each temperature and tested at even time intervals. Sufficient time shall be allowed until strength loss of at least 50% has occurred at each temperature. The following information shall be provided:

- A plot of tensile strength loss versus time.
- Molecular weight (ASTM D4603-18 [ASTM, 2018a] in conjunction with GRI-GG8) (to be replaced by ISO when available) and scanning electron micrographs of the virgin material and specimens taken from incubation chambers near the end of the immersion period.

- Measurements of pH and temperature over the incubation period including fluctuations and accuracy of measurements.

(c) For polyethylene and polypropylene, durability test data from incubation tests consist of oven ageing at three or more elevated temperatures separated by at least 10°C intervals. A minimum of five specimens shall be incubated at each temperature and tested at even time intervals. Sufficient time shall be allowed until strength loss of at least 50% has occurred at each temperature. The following information shall be provided:

- A plot of tensile strength and peak strain loss versus time.
- Scanning electron micrographs of the virgin material and specimens taken from incubation chambers near the end of incubation.

(ii) Additional durability test data, if available, from previous testing of similar products on earlier grades of the same geosynthetic type, or a similar product within the same product line until incubation test results are available if the chemical and physical characteristics of tested products and proposed products are shown to be similar (see Note 1).

(iii) Ultraviolet light degradation test data for the reinforced fill product having the lightest mass per unit area amongst those submitted products. Ultraviolet light degradation tests shall be in accordance with either ASTM D5970 / D5970M-16 (ASTM, 2016b) for outdoor testing or ASTM D4355 / D4355M-14 (ASTM, 2018) (to be replaced by ISO when available) for laboratory testing. The tests shall investigate strength loss after a total UV radiation exposure of 40 MJ/m2. The UV radiation (i.e., less than 400 nm) at the specimen must be monitored during the exposure. Additional information may be provided for other submitted products to substantiate their better performance.

(iv) Name(s) and location(s) of laboratory(ies) conducting the testing and evaluation. All data shall be accompanied by a statement of accreditation of the measuring laboratory or proof of traceable calibration of the measuring equipment.

(v) Photographs and drawings illustrating the durability testing equipment and procedures used.

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Note 1

- To verify similarity of polyolefins, the molecular weight and structure of the main polymer (i.e., branched or cross linked, homopolymer or blend, and percent crystallinity), percentage of material reprocessed, tenacity of the fibres, processing history, and polymer additives used (i.e., presence of antioxidants, fillers, etc.), shall be provided.
- To verify similarity of polyesters, molecular weight or intrinsic viscosity of the main polymer, carboxyl end group content, percent crystallinity, tenacity of the fibres and processing history, percentage of material reprocessed, and polymer additives used, shall be provided.

(IV) Installation Damage Data for Determination of $\gamma_{id}$

(i) Installation damage test data, for the reinforced fill product having the lightest mass per unit area amongst those submitted products plus other representative samples from the product line, including:

(a) The ultimate tensile strength and peak strain of the reinforced fill products tested in accordance with BS EN ISO 10319: 2015 (BSI, 2015). The relationship of the tensile test samples and the installation damage test samples (i.e. taken from the same roll or from another roll from the same production unit) shall be stated.

(b) The tensile strength and strain of the damaged reinforced fill products, in accordance with BS EN ISO 10319: 2015 (BSI, 2015), after installation damage test. The installation damage test shall indicate the change in strength of the reinforcement following installation in and extraction from Type I and Type II fill as defined in Table A.1 in the Appendix A of Geogudie 6 – Guide to Reinforced Fill Structure and Slope Design (GEO, 2017), and granitic fill material with an angularity of "angular" as defined in BS 812: Part 102: 1989 (BSI, 1989). A minimum of 10 specimens of at least 200 mm wide shall be tested either in accordance with BS EN ISO 10722:2019 (BSI, 2019) for laboratory testing or ASTM D5818-11 (ASTM, 2018b) for field testing. The granular fill shall be placed below the reinforcement as a bedding layer and a 150 mm lift thickness shall be used as cover over the reinforcement. The specific procedures used for the selection of samples, compaction equipment, placement of lift, monitoring of lift thickness, nature and particle size distribution of the fill materials, method of compaction, etc. shall be stated.

(ii) Name(s) and location(s) of the independent laboratory(ies) conducting the testing and evaluation. All data shall be accompanied by a statement of accreditation of the measuring laboratory and proof of traceable calibration of the measuring equipment.

(iii) Photographs and a description of the type and extent of damage visually evident in the exhumed samples and specimens.

## F Fill-to-Reinforcement Interaction

Provide the supporting information for the fill-to-reinforcement interaction coefficients (i.e. direct sliding coefficient, $\alpha_{ds}$ and pullout coefficient, $\alpha_p$) of the reinforced fill products including:

(i) Shear test and pullout test data performed with soils of similar particle size distribution to the Type I and Type II fill as defined in Geoguide 6. The particle size distribution, density and moisture content of the fill materials as placed, and the method of compaction shall be stated.

(ii) Name(s) and location(s) of independent laboratory(ies) conducting the testing and evaluation. All test data shall be accompanied by a statement of accreditation of the measuring laboratory or proof of traceable calibration of the measuring equipment.

## G References


ASTM (2015). *Standard Test Method for Carboxyl End Group Content of Polyethylene Terephthalate (PET) Yarns (ASTM D7409-15).* ASTM International, West Conshohocken, PA

ASTM (2016a). *Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable (ASTM D1248-16).* ASTM International, West Conshohocken, PA

ASTM (2016b). *Standard Test Method for Deterioration of Geotextiles from Outdoor Exposure (ASTM D5970 / D5970M-16).* ASTM International, West Conshohocken, PA

ASTM (2017). *Standard Classification System and Basis for Specification for Polypropylene Injection and Extrusion Materials (ASTM D4101-17e1).* ASTM International, West Conshohocken, PA

ASTM (2018a). *Standard Test Method for Determining Inherent Viscosity of Poly(Ethylene Terephthalate) (PET) by Glass Capillary Viscometer (ASTM D-4603-18).* ASTM International, West Conshohocken, PA

ASTM (2018a). *Standard Practice for Exposure and Retrieval of Samples to Evaluate Installation Damage of Geosynthetics (ASTM D5818-11(2018)).* ASTM International, West Conshohocken, PA

ASTM (2018b). *Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc-Type Apparatus (ASTM D4355 / D4355M-14(2018)).* ASTM International, West Conshohocken, PA

BSI (1989). *Testing aggregate. Part 102. Methods for sampling (BS 812-102: 1989).* British Standard Institution, London

BSI (2015). *Geotextiles. Wide-width tensile test (BS EN ISO 10319: 2015).* British Standard Institution, London

BSI (2019). *Geosynthetics. Index test procedure for the evaluation of mechanical damage under repeated loading. Damage caused by granular material (Laboratory test method) (BS EN ISO 10722:2019).* British Standard Institution, London

GEO (2017). *Guide to Reinforced Fill Structure and Slope Design (Geoguide 6) (Continuously Updated E-Version released on 29 August 2017).* Geotechnical Engineering Office, Civil Engineering and Development Department, HKSAR Government

GRI, GG7. *Carboxyl End Group Content of Polyethylene Terephthalate (PET) Yarns (GG7).* Geosynthetic Research Institute, USA

GRI, GG8. *Determination of the Number Average Molecular Weight of Polyethylene Terephthalate (PET) Yarns Based on a Relative Viscosity Value (GG8).* Geosynthetic Research Institute, USA