Performance evaluation of geomat drainage geocomposites and case histories

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ABSTRACT: Planar drainage geocomposites have core configurations in the form of geonets, geomats, and geospacers, made of various polymers. Their hydraulic performance is dependent upon the applied loads, field boundary and environmental conditions. A 5mm thick geomat with regular wave like polypropylene profile was evaluated in this paper to demonstrate its performance and suitability for engineering applications. Results from conventional compressive creep and Stepped Isothermal Method (SIM) methods, and creep tests under combined normal and shear loads, show the long-term structural stability under low to medium loads. Long-term transmissivity results demonstrate a stable flow over time. Two case histories of successfully installed projects with this particular geomat illustrate the effectiveness in draining pore water in a high-profile dredging project, and in dissipating seepage water behind a Mechanically Stabilized Earth (MSE) wall structure.

Keywords: Geomat, geonets, geocomposites, drainage, performance, case histories, MSE wall, dredging

1 INTRODUCTION

A drainage geocomposite is composed of a polymeric core with a nonwoven geotextile bonded to one or both sides. The geotextile facing soil is used to filter out soil particles while allow passage of fluids, while the geotextile against an impervious geomembrane (when present) increases the interface friction and provide cushion protection. Drainage cores have a variety of configurations, as shown in Figure 1, but can be grouped by geonets, geomats, and geospacers (geomats and geospacers are also called sheet drains). ISO 10318 provides the following definition for these products:

- Geonet (GNT): geosynthetic consisting of parallel sets of ribs overlying and integrally connected with similar sets at various angles
- Geomat (GMA): three-dimensional, permeable structure, made of polymeric monofilaments, and/or other elements (synthetic or natural), mechanically, and/or thermally, and/or chemically, and/or otherwise bonded
- Geospacer (GSP): three-dimensional polymeric structure designed to create an air space in soil and/or other materials in geotechnical and civil engineering applications

The primary function of a drainage geocomposite is DRAINAGE. They are extensively used in large planar areas, including but not limited to surface water drainage and landfill gas collection layers in landfill closures, leachate collection, detection layers in landfill base liner systems, as well as, behind retaining walls, against soil slopes with seeping water, beneath surcharge fills, pavement subsurface drainage, and as horizontal or vertical drainage inceptors. This drainage function must be preserved over the duration of its service life. Important engineering properties of a drainage geocomposite drain include: filtration characteristics of the geotextile adjacent to soil, structural stability under loads, adequate in-plane flow rate (or transmissivity) under field conditions, and interface strength with adjacent soil and/or other 'geo' layers.

Nonwoven geotextiles are commonly manufactured with polypropylene or polyester; geonets are almost exclusively extruded with high density polyethylene (HDPE); and geomats or geospeacers use different polymers such as polypropylene and polyamide. The focus of the paper is on performance of drainage geomats and application histories. The next section presents important behaviors of a 5 mm thick drainage geomat: long-term compressive creep under vertical loads, under combined vertical and shear loads; and long-term in-plane flow capacity (transmissivity). The following sections describe two case histories with this geomat for draining pore water in a high-profile dredging project, and for dissipating seepage waters behind and beneath a MSEW structure, and the paper finishes with a conclusion.

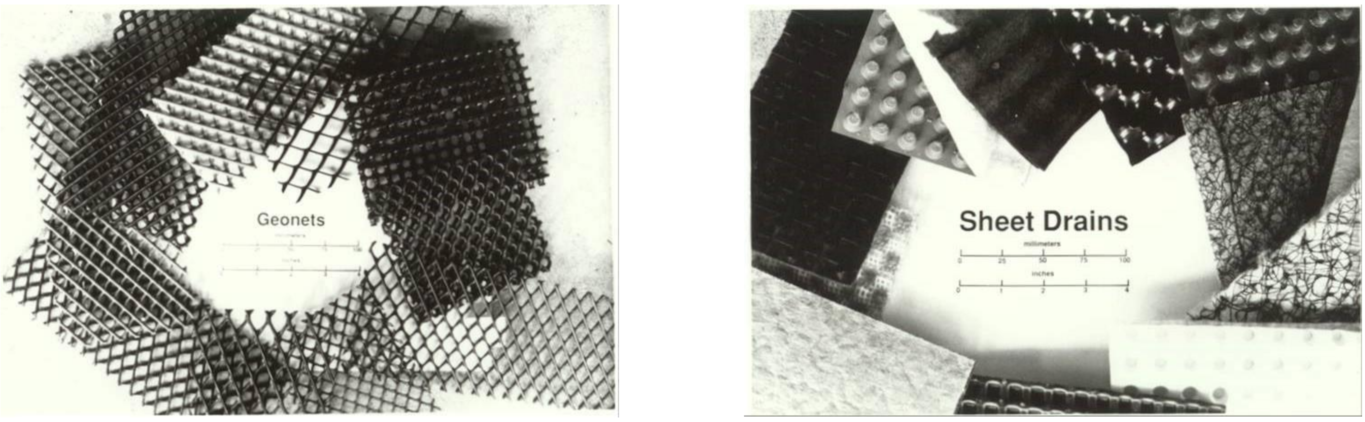

Figure 1. Photographs of planar geocomposite drains (from GRI Report #25).

2 PERFORMANCE EVALUATION

Performance evaluation was conducted on a drainage geocomposite manufactured by thermobonding a geomat core with two nonwoven geotextiles. The geomat geocomposite has a thickness of 5 mm, the core is made of polypropylene, with regular wave like profile along the length direction, as shown in Figure 2. Long-term performance evaluation included compressive creep tests with conventional and SIM method, compressive creep tests under combined normal and shear loads, and long-term transmissivity tests. All tests were performed by a third-party laboratory in USA.

Figure 2. Polypropylene geomat with regular wave like profile (longitudinal channel shape)

2.1 *Conventional Compressive Creep testing*

Conventional Compressive Creep testing was performed in general accordance with ISO 25619-1:2008, Geosynthetics -- Determination of compression behavior – Part 1: Compressive creep properties. Test specimens measured 150 mm square. Specimens were maintained at 20°+/-0.5°C degrees for up to 10,000 hours. Two specimens have been tested at each load level for repeatability. Figure 3 (left) shows the setup of a conventional compressive creep test, with longitudinal channels of the specimen placed down the slope direction, to simulate creep behaviors under combined normal and shear loads.

2.2 *Accelerated Compressive Creep testing*

Accelerated compressive creep testing was performed using ASTM D7361-07(2012), Accelerated Compressive Creep of Geosynthetic Materials Based on Time-Temperature Superposition using SIM. Test specimens measured 150 mm square. The temperature region employed used a ramp from 20°C to 76°C degrees via 10,000-second steps of 7°C degrees each. All shifting was performed in accordance with ASTM D7361. Figure 3 (right) is a photograph of the SIM test device.

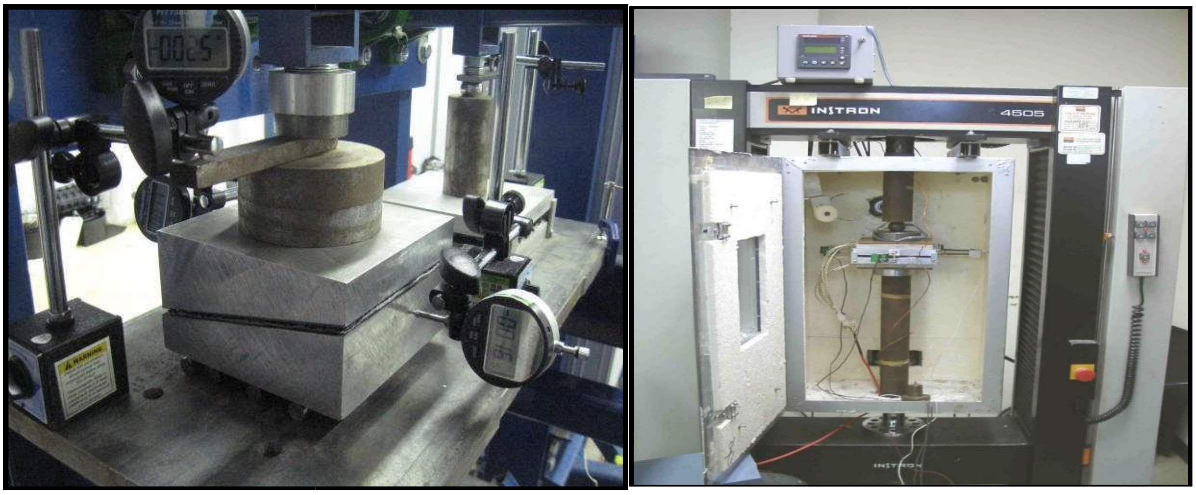

Figure 3. Photos of a conventional compressive creep test with shear and SIM test apparatus

Table 1 summarizes compressive creep results in terms of retained thickness after 100, 1,000, and 10,000 hours of loading and the creep reduction factor for a 50-year design life, and flow rate reduction factor based on transmissivity tests at pre-determined thickness from the compressive creep tests (Scott et al, 2015). Under a 100 kPa load, the geomat retained 82% (averaging from the conventional and SIM methods) of its initial thickness after 10,000 hours of loading, corresponding to a reduction factor 1.14 for a 50-year design life. The geomat structure experienced an average 4.5% reduction in thickness from 100 hours to 10,000 hours of loading, indicating stable structure after an initial reduction in thickness when the load was applied. Under a 200 kPa load, the geomat retained an average 69.5% of the initial thickness after 10,000 hours of loading, corresponding to a reduction factor 1.41 for a 50-year design life. The geomat structure experienced an average 12.5% reduction in thickness from 100 hours to 10,000 hours of loading, indicating stable structure after an initial reduction in thickness when the load was applied. In addition, results from the conventional creep and SIM methods are similar, with an average 1.3% difference in thickness retained.

Table 1. Compressive creep test results

Compressive loads	Test methods	Retained thickness @100 hours	thickness @1000 hours	Retained thickness @10,000 hours	Creep Reduction Factor
kPa	ISO25619 - Conventional ASTM D7361 -SIM	%	%	%	50 years
100	Conventional	86.35	85.23	82.7	1.143
	SIM	85.64	83.78	81.49	
200	Conventional	79.19	76.95	70.17	1.409
	SIM	79.42	75.42	68.72	

Figure 4 shows the 10,000 hour compressive creep curve for the geomat tested under combined normal and shear loads. The normal load applied was 50 kPa, with a shear load of 20% of the normal load in accordance with ISO 25619 standard. The geomat retained 82.8% of the initial thickness after 10,000 hours of combined normal and shear loading. The geomat structure experienced a 3.5% reduction in thickness from 100 hours to 10,000 hours of loading, indicating stable structure after an initial reduction in thickness when the combined normal and shear loads were applied.

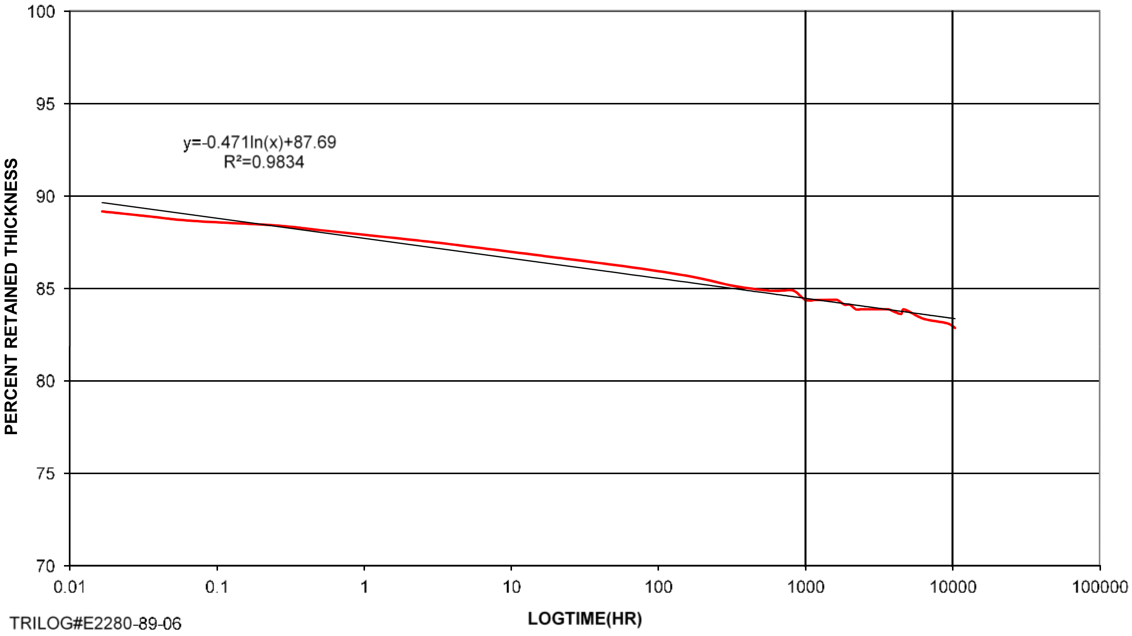

Figure 4. Compressive creep with shear test results under a 50 kPa normal load

2.3 *Long-term in plane flow rate tests*

To evaluate the long-term water flow rate (transmissivity) of the geomat geocomposite, specimens were subjected to air pressure loading for a period of 24 months. The geomat specimens were installed in a specially designed compressive creep test box, and loaded 50 kPa by means of pressure bags placed on the of top and below the box. The air pressure on the top and bottom side of the box was monitored using manometers. The water flow capacity was measured according to ASTM D4716, or EN ISO 12958. The specimens were tested in condition as delivered, after 2 weeks, 1 month, 4 months, 8 months, 14 months and 24 months loading in the compressive creep test box. The specimens were installed back into the creep test box after testing the water flow rate at each interval.

Figure 5 reports the measured long-term flow rate of the geomat under a 50 kPa load, 1.0 hydraulic gradient, tested along its length direction and with rigid/soft boundary conditions, typical of landfill capping applications where a drainage geocomposite is typically placed on top of a geomembrane liner. The geomat has an initial water flow rate 0.81 l/(m.s), 0.753 l/(m.s) after two weeks, 0.71 l/(m.s) after 14 months and retained water flow rate 0.717 l/(m.s) after two months of loading. The geomat experienced a 13% reduction in flow rate from initial flow rate to 24 weeks of loading; however, the flow rate reduction is less than 1% from 14 months to 24, indicating stable flow rate after an initial reduction.

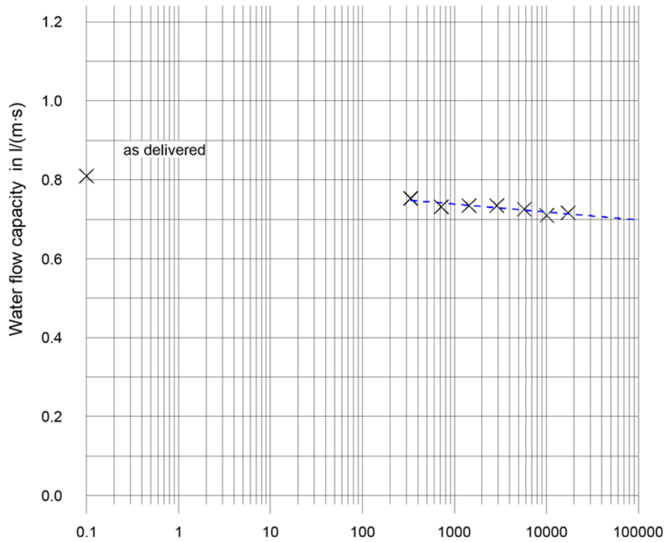

Figure 5. Long-term in plane flow rate under a 50 kPa normal load

3 CASE HISTORY 1: DRAINAGE OF DREDGED FILL AT PORT OF GAETA, ITALY

The expansion of the Port of Gaeta (Italy) included 60,000 square meters of diked containment area to be reclaimed and developed into a container depot using fine-grained materials dredged from the gulf (de Lillis et al., 2017), as shown in Figure 6 a photo of bird eye view of the construction site and the cross-section. Prefabricated vertical drains (spacing 2 m) were installed to speed up the consolidation of the foundation soils. The consolidation of the dredged mud is accelerated through three horizontal drainage layers, installed from floating platforms. The first layer is a geomat geocomposite drain, placed on top of the foundation soils and hydraulically connected to the vertical drains; the second and the third layers are made of micro-fissured drainage pipes, placed parallel to the short side of the containment area and spaced 4 meters. The geomat has 5 mm thickness, AASHTO Class II nonwoven geotextile thermally bonded to both sides, 25 kN/m tensile strength, and in plane flow capacity 1.0 l/(m.s) at 20 kPa load, 1.0 gradient, and soft/soft boundary conditions. Figure 7 shows photos of the installation of the geomat geo-composite from a floating platform and a close look at the geomat on the site. The installation of these drainage systems reduces the drainage path to an average of about 1 m, thus significantly reducing the consolidation time. The two upper drainage layers are connected to a vacuum pump circuit that reduces the pressure inside the pipes below the atmospheric pressure (-60 kPa), hence enhancing water flow due to higher hydraulic gradient.

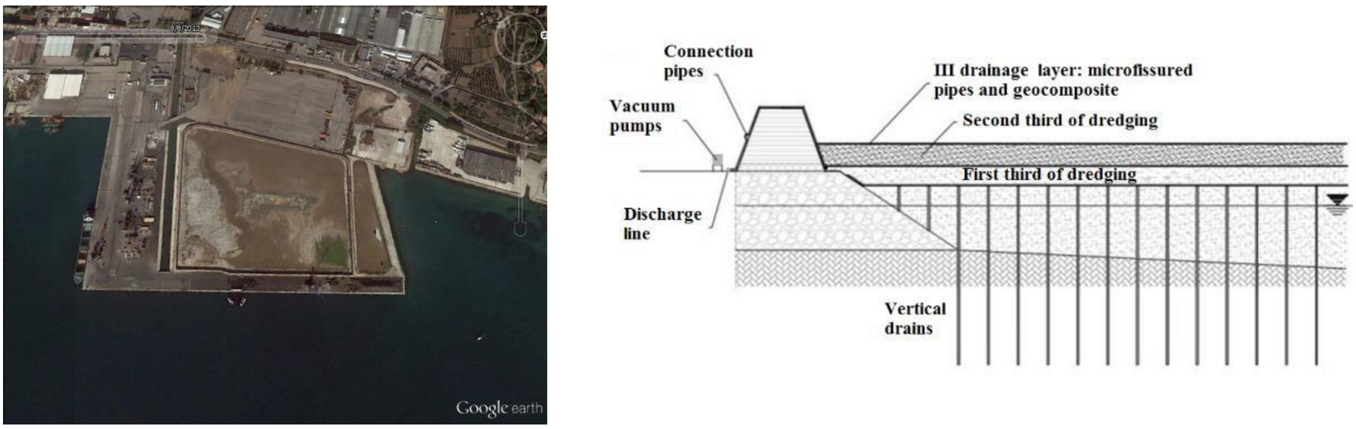

Figure 6. Bird eye view of the site and the cross-section

Figure 7. Installation of the horizontal geomat geocomposite from a floating platform

After three phases of filling 122,000 cubic meters each of the dredging operations, consolidation and surface water drainage have progressed significantly over a four-month period, as shown in dated photos in Figure 8. The geomat geocomposites were effective in draining pore waters from the prefabricated vertical drains, and the water into and within the dredged fills, as a result, allowing the creation of a working platform for further surcharge preloading and eventually meeting design loads of 40 kPa for the container depot. Further details regarding the geotechnical aspects of the design of the containment area of the port of Gaeta are reported by de Lillis and Miliziano (2016).

Figure 8. Construction site photos showing the progress of the drainage and consolidation

4 CASE HISTORY 2: DRAINAGE BEHIND CRUSHER MSE WALL, BIRDSBORO, PA, USA

Crusher walls (Mine Dump Walls) are used to support vertical or near vertical grade changes to minimize the footprint of the facility. Hoppers or crushers can be installed within these walls. Mined material is hauled to the upper terrace and unloaded into the hopper/crusher. A new primary crusher unit was being added to the Dyer Quarry in Birdsboro, PA in 2014. The terrain at the design location for the new crusher was challenging, a retaining wall was necessary to create a safe platform for unloading trucks. A MSE wall system was the chosen to build around the crusher to minimize the lateral earth pressure on the crusher, and to support the live load of the haul truck “CAT D773” used in this facility, which has a payload of 99,342 kg. The maximum exposed height of the wall is 21 meters with approximate wall fascia area of 1,858 sq. meters. The geogrid reinforcement for the wall is manufactured from high tenacity, multifilament polyester yarns aligned and co-extruded with polyethylene to create polymeric strips. These strips are laid flat in the length direction with a secondary strip laid and welded across the full width in the cross direction. Geogrid tensile strength for the project varies from 65 to 200kN/m, and intermittent tensile strength of 100, 120 and 150 kN/m were used in the intermediate course to optimize the cost of the MSE wall.

Extensive research and database on failed MSE walls by Geosynthetic Institute concluded that 63% of those failures were caused in whole or part by water within, or adjacent to, the reinforced soil zone (Koerner and Koerner, 2009, GSI Newsletter/Report June 2017). The geomat drainage geocomposite designed and installed behind the MSEW has a 5 mm thickness, AASHTO Class III nonwoven geotextiles boned on both sides of the core, 17 kN/m tensile strength, and 0.6 l/(m.s) in plane flow capacity under 200 kPa load and 1.0 gradient.

The construction drawing is shown in Figure 9. A portable laser tracker was installed on the wall face to measure and document potential movement during the quarry operation. A photo of almost completed MSE wall is shown in Figure 10.

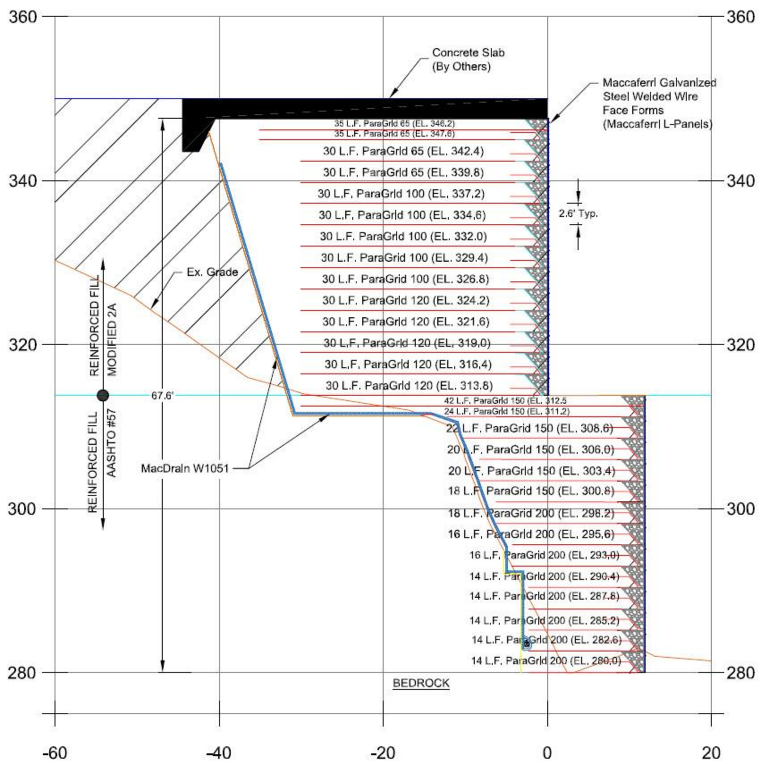

Figure 9. Cross-section of the MSEW with drainage geocomposites and geogrids

Figure 10. MSEW close to completion

5 CONCLUSIONS

Product evaluation and selection should be based on long-term drainage performance under field conditions, not the polymer type or configurations of the drainage core. After assessing a 5 mm thick polypropylene geomat with regular wave like profile by a third-party laboratory, results indicated its performance and suitability for engineering applications. Results from the geomat assessment of conventional compressive creep and SIM methods show the long-term structural stability under normal loads, as well as under combined normal and shear loads. Long-term transmissivity tests demonstrate stable flow under a load typical of a landfill closure. Two case histories of projects with this geomat installed illustrate the successful utilization of this geomat in draining pore water for application in a dredging project and in dissipating seepage water behind an MSE wall structures.

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