Discussion on the use of TerraLite™ Geofoam for use as a Lightweight fill for Architectural Purposes.

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Abstract:
TerraLite is an ultra-light weight fill material manufactured by Licensees of GeoTech Systems Corporation, which can be successfully used as a structural fill material for a wide range of applications provided just a few key requirements for the design are met. The primary concern is that the material not be subject to a continuous load in excess of its elastic strain limit. This paper will provide the approach for conducting this analysis.

Background:
There is a trend in architectural design towards increased utilization of areas above structures such as parking garages, pedestrian decks, and “green areas” which are landscaped and vegetated. Since soil can weigh as much as 130 pounds per cubic foot, it is necessary to find a way to reduce the “dead load” on top of the structure, to eliminate the need for costly design analysis and construction methods associated with higher strength, load bearing structures.

Material Description:
TerraLite Geofoam is a durable, strong, and extremely light weight synthetic material that has been used extensively world wide for nearly 30 years for the construction of highway over very weak soils and as an alternative to employing techniques for strengthening the soil such as surcharging with wick drains or geogrids.

TerraLite is particularly suited for roof top landscaping applications. It is totally inert and easy to cut in the field to accommodate penetrations and other irregular features on the roof. It will also serve to insulate the structure and move the dew point to the outside of the surface it is resting upon, and it has the lowest density of any structural fill material available in the world.

TerraLite is unique among Geofoams because it contains a built in, non-toxic insect resistant borate which provides assurance that structural quality will not be compromised by termites or carpenter ants.

TerraLite is available in a range of densities, ranging from 0.75 pounds per cubic foot (12 kg/M^3) to 2 pounds per cubic foot (32 kg/m^3). The strength, defined as the elastic strain limit as determined by ASTM 1621, varies in proportion to the density. The unit cost also varies in proportion to the density, but for roof top garden type applications, the lowest density material can usually be employed.

TerraLite is manufactured in large blocks measuring approximately 16 ft x 3 ft x 4 ft. When used for highway construction, it is not uncommon for these blocks to be used uncut. For landscaping purposes, it often convenient to specify smaller sheets or blocks which can be easily handled and placed at the job site. Hot wire type cutting harps make the cutting of TerraLite very economical and fast on the job site.

The most important material property to be considered when designing roofing/landscaping systems that include TerraLite is the “elastic strain limit.” This is the pressure required to compress the material one percent. Below this pressure (and this level of deformation), the material will behave elastically - that is, it will not undergo permanent deformation, and will reliably rebound as soon as the load is removed. Higher pressures than the elastic strain limit will cause permanent deformation and creep. This will cause the material to gradually undergo significant levels of compression. The key, therefore, is to keep the stress (the pressure) below this elastic strain limit.

The elastic strain limit for TerraLite is as follows:

Type	Density	Elastic Strain Limit
XI	0.75pcf (12kg/m^3)	5 psi
I	1.00 pcf (15 kg/m^3)	7 psi
VIII	1.25 pcf (20 kg/m^3)	8.5 psi
II	1.50 pcf (25kg/m^3)	12 psi
IX	2.00 pcf (32kg/m^3)	16 psi

Calculation:

In order to estimate the pressure experienced by a volume of TerraLite, it is necessary to estimate two things:
1) Dead Load - that load experienced continuously when installed, which is a function of the density of the materials and their depth above the fill.
2) Live Load - the load on the fill which results from transient loads on the very surface of the structure. Examples would be pedestrian traffic and emergency or landscaping support vehicles

Of these two types of loads, the most important is the dead load calculation, since this is likely to result in long term deformation and loss of performance of the fill.

Live loads can generally be ignored in landscaping applications since they will be small or infrequent (such as pedestrian traffic or emergency vehicles). The estimation of the pressure transmitted from loads applied at the surface of the landscaping system down to the TerraLite fill is complex due to the spreading of that pressure through soil mechanics.

In general, for landscaping applications, the live loads from pedestrians and small vehicles can be ignored, provided one (or both) of two conditions are met:

a) There is a load distribution slab above the TerraLite fill
b) There is at least 10 inches of cover above the fill.

In order to calculate the dead load, the primary input is the density and depth of the material over the TerraLite

γ_{soil} density ($\frac{lb}{ft^3}$)

h_{soil} height of fill (feet)

σ_{foam} Stress at 1% compression (elastic strain limit)

SF Safety Factor

$$h_{soil} = \frac{\sigma_{foam} \cdot 144}{\gamma_{soil} \cdot SF}$$

This series of simple, linear equations illustrates the way to estimate the maximum height of fill over TerraLite.

For example, using a design margin of 1.5, utilizing type IX TerraLite geofoam, which has an elastic strain limit of 5psi, and soil that has a density of 100 pounds per cubic foot provides the following maximum height:

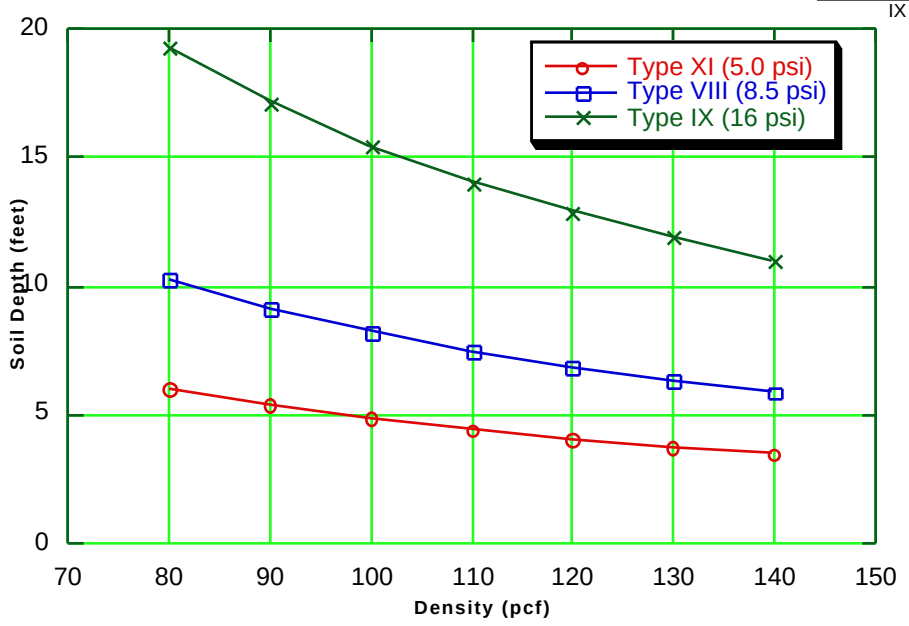
$$h := \frac{5 \cdot 144}{100 \cdot 1.5} \qquad h = 4.8 \text{ feet}$$

The maximum soil height in this example is 4.8 feet, with a design margin of 1.5. Practically speaking, this depth of soil would more than likely create problems for the underlying structure. If a depth of 4.8 feet was required, the designer would be wise to specify a greater thickness of TerraLite thereby using less fill for a given grade height.

Practically speaking, the height of soil over the TerraLite will usually be limited by the structural capacity of the roof to carry the load, long before the elastic strain limit of the EPS is approached.

The relationship between TerraLite density, soil density, and maximum soil height is illustrated in the following chart:

TerraLite	Density	Stress @ 1%
XI	.75 pcf	5 psi
I	1.0 pcf	7 psi
VIII	1.25 pcf	8.5 psi
II	1.5 pcf	12 psi
IX	2.0 pcf	16 psi



Other Considerations:

Planters
These generally will have greater weight than the grassy areas, and should be situated over structural columns within the building.

Buoyancy
TerraLite is so lightweight that it can develop significant uplift forces when totally submerged; however, this is almost never an issue in roof top landscaping since the vegetation itself requires a proper drainage system. In any case, there should always be some sort of system to drain water away from around the TerraLite fill.

Hydrocarbons
Petroleum and petroleum based solvents have an immediate and deleterious effect on TerraLite. When used in highway construction, this is avoided through the use of a geomembrane and/or a load distribution slab. In roof top landscaping, this should not be of concern, since few naturally occurring plants thrive when watered with gasoline.

Summary:

TerraLite Geofoam is uniquely qualified for use as an ultra-lightweight fill to be used in conjunction with soil and vegetation in roof top landscaping projects.

TerraLite will accommodate any design with any soil. As long as the dead load is below keep below the elastic strain limit (5psi for Type XI), the fill will perform as specified forever.