

# A Primer on Cellular Geosynthetics

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Materials with either an open or closed cellular structure, whether occurring naturally or manufactured, are noteworthy for a variety of reasons. They make very efficient use of relatively small amounts of solid material arranged in the form of numerous, thin cell walls yet the overall material has surprising stiffness and strength. Because there is so little solid material per unit volume the overall material has a relatively low density. In addition, the significant void space can sometimes be used productively to store liquids. Manufactured cellular materials with a solid fraction as low as 2% by volume (a porosity of 98% or void ratio of 4900% in geotechnical engineering terms) have been available since the 1950s and are now recognized as cellular geosynthetics which includes geocells, geocombs, and geofoams. This article focuses on the latter two materials and products made from them.

## Geofoams: Materials and Products

The use of geofoams increased dramatically worldwide during the 1990s and this continues to the present. As a result, most involved in engineered construction are now at least somewhat familiar with the more common geofoam materials and their now-routine use as lightweight fill, especially for roads. However, geofoams offer many more geosynthetic functions and potential applications for both transportation and building applications. To begin with, there are still misconceptions about the term "geofoam". Since the early 1990s, this has been the generic term for any synthetic geomaterial created in an expansion process using a gas called a blowing agent and resulting in a texture of numerous closed cells.

Therefore, geofoam is actually a very diverse family of many different kinds of materials:

- polymeric (plastic),
- cementitious (typically using Portland cement), and
- cellular glass.

The polymeric category is further subdivided depending on the polymer chemistry and specific manufacturing process used:

- rigid cellular polystyrene (RCPS), which can be either expanded polystyrene (EPS) or extruded polystyrene (XPS);
- polyethylene (PE); and
- polyurethane (PUR).

Despite the relatively large number and variety of geofoam materials, as a result of in-ground use and experience since the early 1960s EPS in its generic block-shaped form has emerged worldwide as the material and product of choice in most applications.

## Geofoams: Functions and Applications

Design by function is now recognized as the correct way to use any geosynthetic. In this context, "function" means what technical role is provided by the geosynthetic. One of the reasons EPS is the predominant geofoam material is that it can provide many functions simultaneously which enhances its cost effectiveness. It is worth noting that most of the functions provided by EPS-geofoam are unique and cannot be provided by any other type of geosynthetic.

Although not the oldest geofoam function, lightweight fill using EPS blocks, which dates back to at least the early 1970s, is perhaps the most intuitive because EPS has a density that is only about 1% of the density of normal earth materials (soil and rock) yet can support motor vehicles, aircraft, trains, and even small buildings and bridges. Lightweight fill is also the most widely known and commonly used function, especially for road construction as typified by an ongoing project shown in Figure 1.

Recent activities related to the use of EPS-geofoam as lightweight fill include:

- development and publication of detailed design manuals for roads on soft ground as well as for slope stabilization;
- broader applications beyond the well known and widely used road, airfield, and railway earthworks that include supporting shallow foundations for relatively lightly loaded buildings and small bridges directly on EPS blocks, and as backfills and fills behind earth retaining structures to reduce lateral earth pressures acting on the structures under both gravity and seismic loads; and
- development of 'anti-buoyancy' EPS blocks that allow groundwater infiltration during times of flooding so that block flotation is less of a problem (Figure 2).

Thermal insulation is the first known geofoam functional application, dating back to at least the early 1960s. A wide



Figure 1. EPS Blocks Used for Road-Widening Project on Soft Ground in U.S.A

variety of polymeric materials as well as cellular glass have been used successfully as thermal insulation although EPS and XPS now predominate. Some of the more interesting applications of this function are:

- above the roof slab of shallow buried structures such as cut-and-cover tunnels and parking garages to limit seasonal thermal changes and concomitant thermal expansion and contraction of the roof which can cause structural problems;
- with shallow foundations to allow shallower embedment (referred to in the literature as the frost-protected shallow foundation concept);
- beneath pavements and railway track to prevent or at least limit subgrade freezing and concomitant frost heave (and the problems that eventual thawing creates such as potholes);

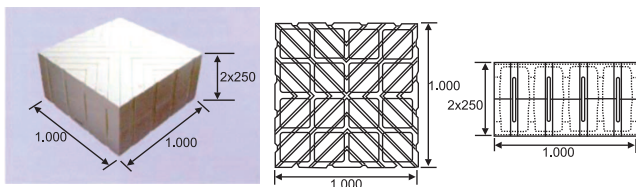


Figure 2. EPS-Geofoam 'Anti-Buoyancy' Blocks (all dimensions in millimetres)

- behind earth retaining structures, including soil-nailed walls, to prevent freezing of the drainage systems and/or retained soil;
- above liquid-bearing utility lines to allow shallower embedment while preventing freezing of the contents (referred to in the literature as frost shielding);
- beneath the inverts of open culverts to prevent frost jacking; and

- beneath the lining of mined tunnels to prevent freezing of their groundwater drainage systems.

Note that some of these applications are appropriate to all climates. Thus thermal insulation using geofoams is not just a 'cold-climate' geotechnology as many believe.

Drainage (fluid transmission) is a geofoam function that has been relatively little used to date although it was identified at least as far back as the 1970s as there are other geosynthetics such as sheetdrains and geonets that can provide this at a lower cost compared to a geofoam-based product. However, geofoam drainage products have a distinct advantage over other types of geosynthetic drainage products in that they can be multifunctional depending on the specific material and product used. Thus designers can make use of the fact that a geofoam drainage product can simultaneously provide other functions such as thermal insulation and compressible inclusion (defined subsequently) and thus be very cost effective.

The function of noise and vibration damping (the vibrations considered here are limited to small-amplitude motions) is another little-used geofoam function that dates back at least to the 1980s. Polymeric geofoams have proven to be useful in applications such as attenuating ground-borne vibrations from motor vehicles and trains as well as noise from trains.

Compressible inclusion is the name of one of the newer geofoam functions (since 1980s) and it has the potential to be the most widely used of all because of the number of potential applications, especially those involving earth retaining structures where there is potential to revolutionize construction. In simple terms, when a geofoam material is used as a compressible inclusion either behind an earth retaining structure or beneath a structure such as a building the geofoam is designed to be highly compressible and act essentially as a sacrificial, crushable layer to allow the adjacent soil to expand. By doing so, the horizontal or vertical earth pressures acting on a structure can be reduced, often significantly. The potential applications for geofoam compressible inclusions include:

- allowing shear-strength mobilization of soil adjacent to rigid and/or non-yielding earth retaining structures to reduce lateral earth pressures acting on these structures under both gravity and seismic loading (referred to nowadays as a seismic buffer);
- accommodating the volume change of expansive (swelling) soil or rock adjacent to an earth retaining structure; and
- accommodating structure movement such as that which occurs with integral-abutment and other types of jointless bridges. An example of a project application for this is shown in Figure 3.

The final functional category for geofoams is termed structural and includes a collection of applications, mostly using various types of polymeric foams:

- permanent insulated wall forms for cast-in-place (CIP) Portland-cement concrete (PCC);
- lightweight facing panels for mechanically stabilized earth walls (MSEW);
- void formers for CIP PCC construction;
- crash barriers for motor vehicles and aircraft;
- impact cushioning for rock sheds in mountainous regions; and
- void filling and foundation remediation using foam grouts.

### Geocombs: Materials and Products

Geocombs are the newest cellular geosynthetic to be



Figure 3. Geofabric Compressible Inclusion Used on a Bridge Project in the U.S.A

identified. This term was coined only in 1999 although these materials have been used in France and its territorial affiliates since the 1980s.

A geocomb is any open-cell polymeric material with a honeycomb-like cross-section that is created in an extrusion process. It is essentially a fused bundle of open-end tubes (Figure 4). Each tube is of the order of 25 mm wide and the overall material is approximately 96% voids (a porosity of 96% or void ratio of 2400%). Two different polymers are known to have been used for geocombs to date: a translucent polypropylene (PP) that appears white in color in Figure 4 and black polyvinylchloride (PVC). The PP product line is predominant in terms of past and current use.

The extruded honeycomb material is typically factory cut into panel- or block-shaped pieces that are the final product. In most cases, the final geocomb product has a non-woven geotextile that is factory bonded to one or both open ends of the tubes to prevent solid particles from entering them once the blocks are in place. The panels or blocks are placed with the tubes oriented vertically as the overall product is significantly stiffer when loaded in a direction parallel to the tube axes as opposed to perpendicular to them.

### Geocombs: Functions and Applications

Lightweight fill appears to be the predominant geocomb functional use to date. PP-geocomb blocks are broadly comparable to EPS-geofoam blocks in terms of load-carrying capability when used as lightweight fill for roads (Figure 5). Although PP-geocomb tends to cost more than EPS-geofoam per unit volume and has an overall dry density approximately twice that of EPS, geocombs have the distinct advantage of having virtually no buoyancy upon submergence as their open-cell structure allows water to fill the void spaces. This can be an advantage that makes geocomb the lightweight fill material of choice in applications where permanent or potential submergence is an important design consideration.

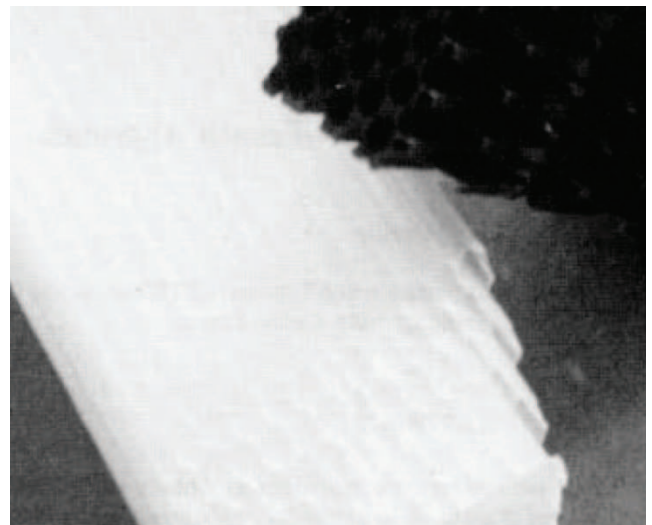


Figure 4. Sections of Geocomb Blocks Illustrating Open-Cell Structure

Drainage (fluid storage and transmission) is geocomb function that appears to be of growing interest in applications where fluid handling, primarily of water, is the primary need. Not only do geocombs readily transmit water but they can also be used to store water for some indefinite period of time. The primary application for this appears to be on projects where temporary storage followed by subterranean disposition of stormwater runoff is a benefit. For example, what amounts to a subterranean reservoir with



Figure 5. PP-Geocomb Blocks Used as Lightweight Fill on a Bridge Project in France.

a very efficient 96% voids per unit volume can be constructed without limit beneath parking lots and similar paved or even building areas.

### Closing Comments

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This article is a revised and updated version of a paper presented by Prof. Horvath in 2004 at the American Society of Civil Engineers (ASCE) Geo-Trans 2004 technical conference that was held in Los Angeles, California, U.S.A. Additional technical papers and research reports by Prof. Horvath can be accessed and downloaded at his personal website, [www.jshce.com](http://www.jshce.com). □