product watch

Lighten Your Load...

Using Geofoams to Reduce Structural Design Loads from the Ground

By John S. Horvath, Ph.D., P.E.

How would you like to reduce the loads your structures must resist from the ground by a factor of 100 in some cases? It's easier than you may think using well-proven materials and concepts that have been around since the 1960s but only now are engineers exploiting to their full potential. By the end of this article you could be well on your way to having your structures and clients benefit from these new additions to your design toolbox.

Geofoams... The Design Alternative

The visionary Richard Buckminster 'Bucky' Fuller once suggested "Don't oppose forces; use them". He recognized that there are times when it is better to 'go with the flow' and work with the forces of nature rather than fight them with structural mass and stiffness. Geotechnical engineers are increasingly putting his advice to good use by designing with geosynthetic materials called *geofoams* to significantly reduce the forces caused by or applied to the ground in a wide variety of applications. Many of these innovative, cost-saving uses involve direct interaction with structures so structural engineers can also benefit from knowing what can be achieved using geofoams.

Geofoams...What Are They?

Geofoam is the generic term for any type of synthetic, closed-cell foam material that is used on or in the ground. There are numerous polymeric (plastic), glass and cementitious geofoam materials and products that have been tried since at least the early 1960's, but the most commonly used by far is a type of plastic that is generically called *expanded polystyrene* (EPS). EPS is the familiar, ubiquitous white foam that is available worldwide and does everything from containing your morning coffee to protecting your new TV or stereo. Many structural engineers are already familiar with the above-ground construction applications of EPS as a wall- and roof-insulation material. You can now add to these myriad consumer and structural uses the fact that EPS can be molded into large blocks or panels with the quality, durability and environmental friendliness that has proven to be sufficient for permanent in-ground use.

Why Use Geofoams?

Engineered construction always involves the dual considerations of technical performance and cost. Although geofoam materials such as EPS generally cost more than soil on a strictly volumetric basis, experience indicates that the net savings in structural materials and construction time for design alternatives formulated around the use of geofoams more than offsets the incremental cost of the geofoam material. This overall construction cost saving (not to mention the fact that structures utilizing geofoams often have life-cycle savings in maintenance and/or operation) has proven to be true on projects of all sizes, in all types of ground conditions, and for both gravity and seismic loads. Perhaps most importantly, EPS geofoam has proven to be cost effective for both new construction as well as in the rehabilitation, upgrading or renovation of existing structures, especially when there are site constraints that make material handling a challenge.

Design by Function

The key to using any geofoam material in engineered construction is to first define the *function* or role the geofoam product must provide. Only then can the necessary properties of the geofoam product be identified and specified.

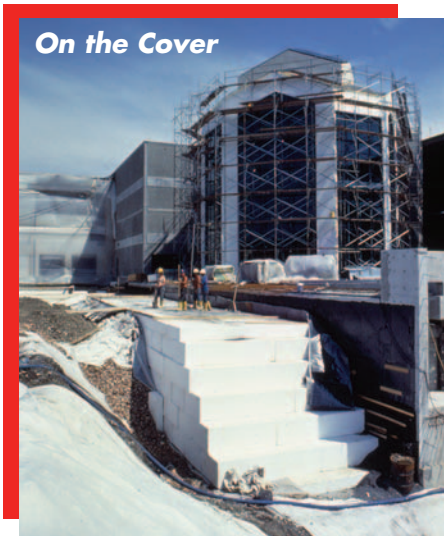
EPS geofoam is particularly versatile and can be formulated to provide a range of engineering properties that can be matched to the intended application. On many projects, multiple functions (typically thermal insulation plus one or more others) can be obtained from one geofoam product which enhances the cost-effectiveness of using EPS geofoam.

Lightweight-Fill Functional Applications

Although EPS was invented ca. 1950 for use as thermal insulation (which remains an important function in both above- and below-ground construction applications), its widest and perhaps most-intuitive functional use as a geofoam material is as *lightweight fill*. This is because EPS has a density that is only about 1% of that of soil and rock. That's right, it weighs only about 1 to 2 pounds per cubic foot (15 to 30 kilograms per cubic metre). Newton's second law of physics reminds us that force and mass are directly proportional, so it is possible to reduce earth loads under both gravity and seismic loading by a factor of about 100 when EPS geofoam is used to replace normal earth materials as backfill and fill. Of course, low density alone would mean nothing in engineered construction if a material were incapable of supporting reasonable loads. Credit the naturally efficient cellular structure of EPS with its being able to support motor vehicles, trains, aircraft and even lightly loaded structures even though it is approximately 98% air by volume.

There are many different ways in which the lightweight-fill function of EPS geofoam can be used to advantage by structural engineers. Some of the more common ones include:

On the Cover



Graphic 1: EPS-geofoam blocks surround an entire mat-supported mall building in Syracuse, NY [credit: Heinrich Photographs, Buffalo, NY; courtesy of BASF].

Graphic 2: EPS-geofoam blocks were used in a cramped urban site for a pile-supported hotel in Honolulu, HI [credit: Pacific Allied Products, Ltd.].

• Use as backfill or fill behind basement and retaining walls – This drastically reduces the lateral 'earth' pressures acting on the walls as well as the vertical stresses on the adjacent ground (an important consideration for soft-ground sites when settlements are a design issue);

• As backfill and fill over the roof slabs of below-ground structures (parking garages, etc.) or elevated exterior slabs – This significantly reduces the loads for which these slabs must be designed;

• As backfill or fill under shallow foundations (footings, mats, slabs-on-grade) supporting lightly loaded buildings and even small bridges – On sites where the underlying soils are soft and compressible, it is possible to design a compensated or 'floating' foundation for a structure by replacing soil with EPS-geofoam blocks and constructing the foundation directly on or above the geofoam layer.

Engineers continue to find new applications for geofoams as lightweight fill. In recent years, the use of EPS blocks has migrated inside existing structures and been used to fill basements for various purposes and create 'stadium' seating for movie theaters.

Graphic 3: Below-ground parking structure in Chicago, IL being backfilled with EPS-geofoam blocks on its roof slab [credit: AFM].

Compressible-Inclusion Functional Applications

One of the newer functional applications of EPS geofoam is *compressible inclusion*. This is the economical use of only a relatively thin (of the order of 6 inches (150 mm)) layer of crushable geofoam material between a structure and the adjacent ground. Conceptually, compressible-inclusion applications can be visualized as the way in which a foam egg carton cushions and protects eggs.

There are two primary ways in which the use of geofoam compressible inclusions has proven useful and cost effective in practice:

• Beneath structural slabs underlain by potentially expansive soils and rock – Although cardboard 'void formers' have been used in such applications, the use of EPS-geofoam products has become the preferred alternative in recent years because EPS is unaffected by wet ground or weather and will not decompose after construction (which can create a methane-gas explosion hazard as was experienced on at least one project in the U.K.);

Graphic 4: EPS-geofoam blocks used as both spread-footing foundation support and retaining wall fill for a low-rise commercial building in Chicago, IL [credit: Polyfoam Packers].

Graphic 5: Filling with blocks of EPS geofoam inside an existing building basement in Chicago, IL [credit: Polyfoam Packers].

Graphic 6: Placing an EPS-geofoam compressible inclusion (void former) on a building project in Winnipeg, Manitoba, Canada [credit: PFB Corporation/Plasti-Fab Division].

Graphic 7: Use of a multifunctional geofoam compressible inclusion for a deep building basement in Kansas City, MO [credit: GeoTech Systems Corporation].

Graphic 8: Close-up of the geofoam product providing the functions of compressible inclusion, groundwater drainage, and thermal insulation in Kansas City [credit: GeoTech Systems Corporation].

• Behind basement and retaining walls – This is a lower-cost alternative to using EPS blocks as a lightweight fill as described above ,and is useful on projects where only a modest reduction in lateral earth pressures is desired or cost effective. In such applications the geofoam product is usually designed to be multifunctional, and provide drainage and thermal insulation in addition to serving as a compressible inclusion.

Getting Started with Geofoams

Additional information about geofoams can be found at the Manhattan College Center for Geotechnology (CGT) website at www.engineering.manhattan.edu/civil/CGT.html. One of the goals of the CGT is to foster greater interaction between structural and geotechnical engineers in practice. To that end, the CGT maintains a special webpage to keep structural engineers apprised of new developments in geotechnical engineering. This page can be accessed directly at www.engineering.manhattan.edu/civil/CGT/T2structural.html. Please pay us a visit and lighten up!▪

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