Geofoam – A Light Weight Fill Alternative

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Abstract

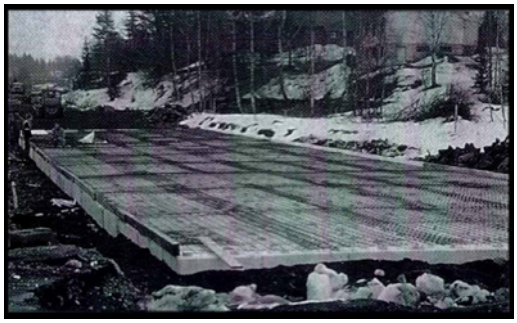
This paper demonstrates that EPS Geofoam is one of the very few engineered fill materials that has predictable and consistent physical properties. Geofoam exhibits the highest strength to weight ratio of any fill material. It a simple and -effective solution for five major geotechnical challenges that engineers, architects and contractors encounter on a regular basis:

1. How to eliminate or reduce of lateral loads upon structures with geofoam.
2. How to use geofoam to lighten up the driving block of a landslide.
3. How geofoam is used to reduce dead and live loads over existing buried utilities.
4. How to create a zero loading factor for soft soil remediation.
5. How geofoam is routinely used as a structural void fill for various concrete applications.

Geofoam has been successfully utilized for decades all over the world (Norway, Netherlands, United States of America, Japan, Germany, Trinidad & Tobago, Malaysia. to name some). It has been proven successful for commercial, residential and infrastructure projects. Regions around the United States and Canada have seen a dramatic growth in Geofoam usage in recent years.

Introduction

Geofoam is a rigid, engineered, lightweight fill material typically made of expanded polystyrene (EPS). As a fill material, a key advantage of EPS Geofoam is its weightlessness; it is approximately 100 times lighter than soil. Specifically, Geofoam is approximately 1 to 2 percent the weight of soil and 10 percent the weight of water. Typical densities for EPS fill are between 12-46 kg/m³ (0.7-2.85 ft³), therefore maintaining a predictable compressive strength that is suitable for many structural applications.



The history of Geofoam dates to the early 1930's, where scientists developed a way to commercially manufacture polystyrene. A German company called I. G. Farben is often cited as the developer of polystyrene.

The world's first known geotechnical application of EPS Geofoam was on a project in Norway in 1965, to prevent frost heaves from occurring on a large freeway (photo at right).

The first documented geotechnical project in North America was the installation of the Trans Alaska Pipeline, where geofoam was used for both utility protection and utility insulation simultaneously (pictured right).

Decades later, the 14th Green at Coeur d'Alene Resort in Idaho took the product even further and used the EPS fill to install a floating green in their lakeshore golf course. The novelty of this success is for this golf hole is how each golfer tees off on solid ground and then takes the boat out to putt on the floating green. Just imagine how many golf balls are lost and how management can change the distance to the hole to keep players challenged (pictured left).

In 2001, the first North American bridge approaches constructed with EPS fill, namely the Buffalo Road Bridge in Warsaw-NY and the I-15 highway project in Salt Lake City-UT, were both successfully completed. The Salt Lake City project is still the largest documented geofoam project in the United States, using approximately 120,000 cubic yards of EPS geofoam.

In 2005, the building industry released the ASTM D6817 standard. This standard, specific to geofoam, is substantially different to ASTM C578, which is the standard for rigid polystyrene insulation.

In 2006, the Federal Highway Administration designated geofoam as a priority, market-ready technology, with a deployment goal that EPS Geofoam will be a routinely used lightweight-fill alternative on projects where construction timelines were of concern.

Today, geofoam is fully recognized and accepted as a lightweight fill alternative and has seen increased usage in both commercial and residential applications. Since the first installation of geofoam in 1965, there have been numerous projects around the world which have relied on EPS Geofoam to solve construction problems involving soft soil remediation, slope stabilization, and lateral load reduction on structures. In addition to

providing a solution to many of these challenges, geofoam has proven to be an easy-to-use, more consistent and lower-cost lightweight structural void fill option.

Given EPS Geofoam's low weight, strength, and ease of use, more project teams are using it to solve regular construction challenges in five basic applications:

1. Eliminate or at least reduce lateral loads on structures
2. Create a zero loading factor for soft soil remediation
3. Lighten the driving block of a landslide for slope stabilization issues
4. Reduce lateral and dead loads over existing or newly buried utilities
5. Use as lightweight structural void-fill for a multitude of concrete and landscaping applications

Lateral load reduction on structures

EPS Geofoam significantly reduces lateral loads on retaining walls and building foundations. The material has an extremely low poisson's ratio (.05) and high coefficient of friction (.6), which helps enable placement of blocks in a way that replaces the sliding soil wedge above the angle of repose. By replacing the active wedge with EPS Geofoam, which can be completely free standing and self-supporting, project teams can save up to 75% of total project costs compared to traditional concrete walls designed to retain soil.

Using EPS Geofoam also reduces labor and material costs without the need for over excavation, and requires much less robust forming, reduced structural steel and concrete wall thickness, and fewer footings. The material can also reduce or eliminate the need for geo-grids and/or mechanical tiebacks. Project teams are able to construct a retaining wall with EPS Geofoam paired with a lower-cost fascia (which acts more like a fence).

EPS Geofoam blocks create retaining wall for bridge widening project in Omaha, NE

Another key advantage of using EPS Geofoam in retaining wall applications is the allowance for taller walls in narrower rights-of-way. This reduces time and cost spent on property acquisition. It also minimizes lane closures and reduces encroachment into wetlands or neighboring properties.

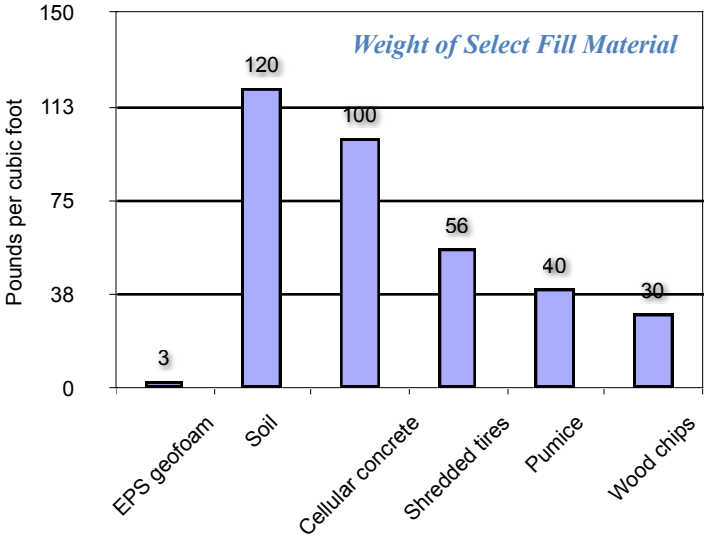
An abutment project example is the widening of the Pacific Street Bridge over I-680 (pictured right) in Omaha, Nebraska. Typically, crews would have removed and replaced the existing abutment walls since these walls were not designed to withstand increased lateral loads induced by fill for additional lanes. To avoid the cost and effort associated with this approach, the project team, from Hawkins Construction, instead excavated the soil between the existing abutment wall and soldier piles. The project team then simply

formed and extended the wall, using approximately 2,000 cubic yards of EPS Geofoam as lightweight back fill for the bridge approach.

EPS Geofoam blocks provide zero lateral load back fill on the KBS hospital in Dixon, IL

At the KBS Hospital (pictured left) in Dixon, Illinois, Bill Brown Construction used geofoam to simplify construction of the building's foundation walls creating a zero lateral load back fill, using only four truckloads of geofoam in place of 50 truckloads of gravel. This saved on hauling costs and greatly reduced construction traffic and truck staging.

EPS Geofoam can successfully create a zero or reduced lateral loads as a backfill on structures and foundations for many projects.



Soft soil remediation

Ground with soft soils or soft clay makes construction difficult. These soft surfaces are notoriously poor foundations for many projects, and may require extensive remediation. Instead of choosing costly (surcharging) and time-consuming remediation of soft soils, projects of all sizes can install EPS Geofoam, which provides high load-support while maintaining a low weight.

One such project was the renovation of the Renton City Hall in Renton, Washington. To meet building codes, new handicap ramps were required. The building is surrounded by extremely soft soils, so the ramps needed a very lightweight foundation to avoid post-construction settlement. After evaluating various traditional fills, the city chose EPS Geofoam. Merlino Construction installed 5,000 cubic yards of EPS Geofoam, which played a role in helping the project be completed two months ahead of schedule and nearly $600,000 under budget.

Geofoam blocks aid the widening of the I-80 / I-65 interchanges in Gary, Indiana

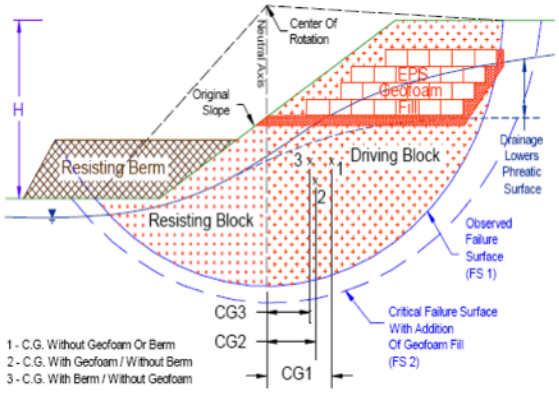
Another example was the widening of the I-80/ I-65 interchange in Gary, Indiana. At the south end of Lake Michigan, the project site had soft glacial soils. The Federal Highway Administration

(FHWA) recommended a net-zero load calculation of the roadbed to prevent post-construction settlement. To enable a shallow over excavation of the high-organic content soils, Walsh Construction used EPS Geofoam blocks as fill. In addition to providing a solid foundation for the roadway, using EPS Geofoam reduced construction truck traffic on a very congested set of roads. Transporting the EPS Geofoam only required 32 flatbed truckloads, which was equivalent to more than 400 dump truck loads of traditional earthen fill. A six-member crew was able to install 700 cubic yards of EPS Geofoam in only one week, working four- to five-hour days. “There’s really no comparison to using traditional fill,” said Gary Walsh, Walsh Construction Site Supervisor. “There are no lifts needed, we just unloaded the blocks and it installed fast.”

The very first levee application in North America was done in Suisun, CA by Steelhead Constructors out of Palo Cedro, CA. The project owned by the California department of water resources had noted that adding more traditional fill to bring the levee back to its original grade resulted in additional and unacceptable settlements over the years. The inclusion of geofoam in 1999 resulted in being able to bring the levee to its desired grade without adding any additional weight and the completed project was done in four weeks.

Slope stabilization

In addition to its use for soft soil remediation, EPS Geofoam’s low weight makes it an excellent option for stabilizing steep slopes, without the need to change the final slope geometry. As the material is much lighter than other fills, it greatly reduces the weight of a slope’s driving block and lowers the risk of costly and dangerous slope failures (figure below). Additionally, since slope stabilization generally happens on steep and uneven terrain, using EPS Geofoam simplifies construction since crews can move and place it without heavy earth moving and compaction equipment, drastically speeding up the construction schedule.



EPS Geofoam used for slope stabilization on the US 50 in CO.

The first geofoam slope stabilization project in North America was designed by Yeh and Associates and completed in 1989, where a section of US160 near Durango, CO had failed causing a lane closure. Approximately 850 cubic yards of geofoam was used and installed in a very short period of time allowing the road to be opened to traffic once again.

Among some of the slope stabilization projects that used EPS Geofoam for slope repair are:

- U.S. 101 near Willets, California
- U.S. 50 near Montrose, Colorado
- Window Rock Highway, Arizona
- State Highway 12 near White Pass, Washington

Another slope stabilization project was part of ongoing efforts to keep the low-lying New Orleans metro area dry, the U.S. Army Corps of Engineers completed improvements to a pumping station that drains the town of Avondale to Lake Cataouatche. The project included construction of a vehicle bridge over the station's above-ground, large diameter pipes. The bridge abutments are over extremely soft soil (compressible peat). The challenge facing the project engineers was that a traditional soil embankment would add substantial load to the underlying soils. That in turn, could cause slope stability problems on a canal parallel to the bridge, potentially leading to the collapse of the canal bank.

EPS19 was installed on both the East and West abutments of the USACE Lake Cataouatche Pump Station in Avondale, LA

The contractor, Merrick Construction (Cottonport, La.) installed 1,365 yd³ of EPS19 geofoam on the bridge's east and west abutments. Kenneth Lamoine, Project Manager with Merrick Construction commented that he was impressed with how fast geofoam installs versus traditional fills. “There's a huge schedule advantage to being able to avoid the traditional overburden scenario, in which placed fills sit around for months at a time before construction can continue.”

Reducing lateral and dead loads over buried utilities

Throughout the world, we have a tremendous amount of existing buried utilities. Often, we want to build new structures over them, but those utilities were never designed or intended to have additional loads placed upon them. In these situations, the utilities either have to be moved or upgraded at high expense. For such applications, geofoam can be an ideal option to reduce dead and lateral loads on those underground pipes, culverts and tunnels, while at the same time providing high thermal insulation values that protect against temperature fluctuations.

Utility protection & bridge approach support for Seattle’s SR-519

In Seattle, WA, geofoam was used to protect existing utilities, some over 100 years old, by reducing the load placed upon them. Poor current soil conditions were partially due

to the native soils that were placed in the area by the Denny Hill re-grade as well as an extremely high water table beneath the existing roadway. Geofoam allowed Kiewit engineers to successfully design the SR 519 project and the West and East approaches to the Royal Brougham Way Bridge (pictured right).

Whenever utilizing geofoam with new underground utilities, geofoam allows designers to specify less expensive structural utilities such as box culverts or pipes and at the same time reducing the lateral loads and dead loads prolonging the life of the structure. Another advantage seen is that geofoam can protect utilities during seismic activity by reducing in-situ vertical/lateral stresses and in other cases might assist in eliminating right-of-way or eminent domain claims.

Lightweight structural void fill

Given its low weight, EPS Geofoam is also well suited as a structural void fill in concrete forming operations. Crews can easily fabricate virtually any shape or slope, and the material eliminates separate concrete pours for vertical wall sections and topping slabs. Applications include bridge column formwork, stadium seating in auditoriums and sports arenas, stairways, podiums, loading docks and rooftop pool decks.

A project example is construction of water channel walls in the Fairfield-Suisun Sewer District (California) water treatment plant (pictured at right). Typical construction of such walls involves two-sided forming then filling the void with soil, sand or concrete slurry and completing a second concrete pour for a topping slab. To simplify and speed the work, the contractor instead used 90 cubic yards of EPS Geofoam. The geofoam blocks constituted half of the form, which simultaneously filled the void, plus easily bore the weight of the concrete topping slab. This enabled a monolithic pour of the channel tops and walls at the same time, which significantly reduced forming labor, material costs and accelerated the concrete pouring schedule.

EPS Geofoam provides a fast and simple way to form concrete walls as seen in these water channels in a California water treatment plant.

EPS Geofoam can be manufactured into custom-cut blocks in various shapes and sizes to enable contractors to quickly build up these and other similar features.

In garden roofs, geofoam can provide the elevation changes and at the same time provide a lightweight, water-resistant, supportive base for liners, soil, irrigation systems and plants.

Key attributes of Geofoam

A key benefit of EPS Geofoam is its predictable engineered values, which simplifies design and construction. EPS Geofoam is commonly available with compressive resistance values ranging from 316 to 2,678 psf at 1% deformation (the conservative elastic limit stress). As long as combined dead/live loads are under this strain threshold, the material will not creep or experience plastic yield. Because geofoam has a closed-cell structure, the material does not readily absorb water, making it suitable for below-grade applications.

EPS Geofoam is durable and doesn't require maintenance under normal conditions throughout its service life. The material is inert and highly stable – it will not decompose or produce undesirable gases or leachates. It is not affected by freeze-thaw cycles, moisture and road salts so is suitable for use in demanding environmental conditions. EPS Geofoam is recyclable, and project teams can order the material with recycled content. When a geofoam project has reached the project life span, the EPS Geofoam can be re-used in other projects such as the case with the re-construction of the Millennium Park in Chicago and the Maggie Daley Park where some 1,100 cubic yards of Geofoam will be reused during the re-construction of the area.

In areas of high seismicity, EPS Geofoam assemblies are being designed for those potential seismic accelerations as engineers are recognizing the advantages of using geofoam verses traditional fills in those areas. Studies from the University of Utah have shown that utilities such as natural gas pipelines buried underground and covered with geofoam can be a compressible, protective cover during seismic conditions. A significant amount of research has been performed in Japan for seismic loading application and has shown huge advantages of the use of geofoam over traditional fills.

Design Considerations for Geofoam

As with any construction material, there are also special design considerations that must be acknowledged where geofoam is used in design:

- Geofoam is subject to damage when exposed to certain hydrocarbon chemicals or solvents. The presence of these items should be considered during construction and if needed, the Geofoam can be blanketed with hydrocarbon resistant geo-membranes for protection.
- Geofoam is treated with a fire retardant to avoid the rapid spread of fire. However, EPS, which is used to manufacture Geofoam, is combustible at high temperatures. Care should be taken when working with open flames and/or high-heat equipment like welders, around geofoam.

- Geofoam exposed to sunlight for extended periods of time is susceptible to degradation from ultra-violet light although the degradation does not tend to hinder the product's integrity. Superficial discoloration generally occurs and can be removed by brooming it off or giving a very light pressure-washing.
- Given the lightweight nature of the geofoam blocks, care should be taken when stockpiling the material on job sites where windy conditions exist. The block stockpiles can be weighted or tied down as necessary.
- If hydrostatic pressures are a potential concern, drainage around a geofoam assembly might need to be addressed. At times, drainage blankets such as Carlisle MiraDrain™, pea gravel or #57 stone is used.

Construction & jobsite considerations for Geofoam

EPS Geofoam changes the traditional soil compaction phasing method in which contractors mechanically compact soil to a percentage of dry density and pay for multiple samples and laboratory tests. Unlike other lightweight fills such as shredded tires or wood chips, EPS Geofoam is homogenous, which provides uniform load transfer and eliminates differential settlement. Recent cost estimates of geofoam vary from $55 to $100 per cubic yard depending on the required physical properties needed for each specific project.

Although geofoam can be manufactured in many sizes and shapes, a standard block is typically 4 feet wide by 8 feet long, and of varying thickness. Once on site, contractors can be easily trim geofoam to the required dimensions by using a hot wire cutter. Some contractors use a handsaw or a chainsaw. When placing geofoam, the blocks are staggered so their joints are not located on the same vertical plane. At times, the blocks are interconnected with either barbed InsulGrip® plates or polyurethane adhesive such as Flexible Fast™.

Due to the low density of geofoam, the blocks can be maneuvered by hand or placed with small mechanical equipment. Geofoam is typically placed on level ground with the first course sitting on some sand, pea gravel or any locally available permeable leveling course material. Crews also can easily place EPS Geofoam by hand since one or two crewmembers can carry the blocks. This helps simplify construction on tight job sites, steep slopes or other hard-to-reach places.

Geofoam's construction cost saving advantages

Using geofoam as an alternative, to traditional soil fill or forms in construction, has many benefits that lead to overall project cost savings. The following are some of the added benefits of utilizing Geofoam verses traditional fills:

- Geofoam is easily installed and the lightweight nature of geofoam allows it to be maneuvered by hand and used on projects with tight construction access where the use of larger mechanical equipment may not be feasible.
- Shotcrete, Gunite, or soil can be placed directly against geofoam eliminating the need for expensive forming.
- Construction traffic and import costs are minimized, as 1 flatbed truck of geofoam is equivalent to approximately 12 dump truck loads of traditional fill.
- Congestion on the roads or road closures leading in and out of a project site is minimized.
- The construction time of a project is reduced as several feet of geofoam can be placed in a fraction of the time that it would take to place and compact traditional soil fill in the required 8- to 12-inch lifts. As an added incentive, geofoam does not require compaction testing like traditional fill.
- Decreased maintenance costs as a result of less settlement issues from the low density geofoam
- Tight construction scheduling can easily be maintained using geofoam as it can be installed during any type of weather or site conditions.
- Geofoam is extremely eco-friendly and geofoam blocks can be re-used in other projects or be recycled.

Shotcrete being applied on the vertical facia walls of the Topaz Bridge in McCammon, ID

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