EPS Industry Alliance
Geofoam Civil Engineering

Expanded Polystyrene (EPS)
Geofoam Applications & Technical Data

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Expanded Polystyrene (EPS) Geofoam Applications & Technical Data

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product overview

1.1 Description

Expanded polystyrene (EPS) geofoam has been used as a geotechnical material since the 1960s. EPS geofoam is approximately 1% the weight of soil and less than 10% the weight of other lightweight fill alternatives. As a lightweight fill, EPS geofoam reduces the loads imposed on adjacent and underlying soils and structures.

EPS geofoam is not a general soil fill replacement material but is intended to solve engineering challenges. The use of EPS typically translates into benefits to construction schedules and lowers the overall cost of construction because it is easy to handle during construction, often without the need for special equipment, and is unaffected by occurring weather conditions. In addition, EPS geofoam can be easily cut and shaped on a project site, which further reduces jobsite challenges. EPS geofoam is available in numerous material types that can be chosen by the designer for a specific application. Its service life is comparable to other construction materials and it will retain its physical properties under engineered conditions of use.

There are numerous manufacturers and suppliers of EPS geofoam in North America. Expanded polystyrene is created in a two-stage, molded bead process. EPS geofoam is produced in blocks that can be cut into various shapes and sizes - and a range of compressive resistances - to suit specific project needs. As an engineered product, it can be produced to obtain the required compressive resistance. EPS geofoam density, only about 1% that of soil and rock, is controlled during the manufacturing process, making it a superior, ultra-lightweight fill material that significantly reduces the stress on underlying subgrades. The lighter load can reduce settlements and can improve stability against bearing and slope failures.

ASTM International provides a specification for the minimum properties of EPS geofoam. The relevant ASTM specification for EPS geofoam is **ASTM D6817 Standard Specification for Rigid Cellular Polystyrene Geofoam**. Other ASTM standards are **D7180 Standard Guide for the Use of EPS Geofoam in Geotechnical Projects** and **D7557 Standard Practice for Sampling of EPS Geofoam Specimens**. Thorough knowledge and understanding of the standard being used on a EPS geofoam project is essential.

ASTM D6817 Physical Property Requirements of EPS Geofoam

Type	EPS12	EPS15	EPS19	EPS22	EPS29	EPS39	EPS46
Density, min., kg/m^3(lb/ft^3)	11.2 (0.70)	14.4 (0.90)	18.4 (1.15)	21.6 (1.35)	28.8 (1.80)	38.4 (2.40)	45.7 (2.85)
Compressive Resistance, min., kPa (psi) at 1 %	15 (2.2)	25 (3.6)	40 (5.8)	50 (7.3)	75 (10.9)	103 (15.0)	128 (18.6)
Compressive Resistance, min., kPa (psi) at 5 %	35 (5.1)	55 (8.0)	90 (13.1)	115 (16.7)	170 (24.7)	241 (35.0)	300 (43.5)
Compressive Resistance, min., kPa (psi) at 10 %[A]	40 (5.8)	70 (10.2)	110 (16.0)	135 (19.6)	200 (29.0)	276 (40.0)	345 (50.0)
Flexural Strength, min., kPa (psi)	69 (10.0)	172 (25.0)	207 (30.0)	240 (35.0)	345 (50.0)	414 (60.0)	517 (75.0)
Oxygen index, min., volume %	24.0	24.0	24.0	24.0	24.0	24.0	24.0

The typical design load limit for EPS Geofoam is the compressive resistance at 1%. Please refer to section 4.2 for additional information.

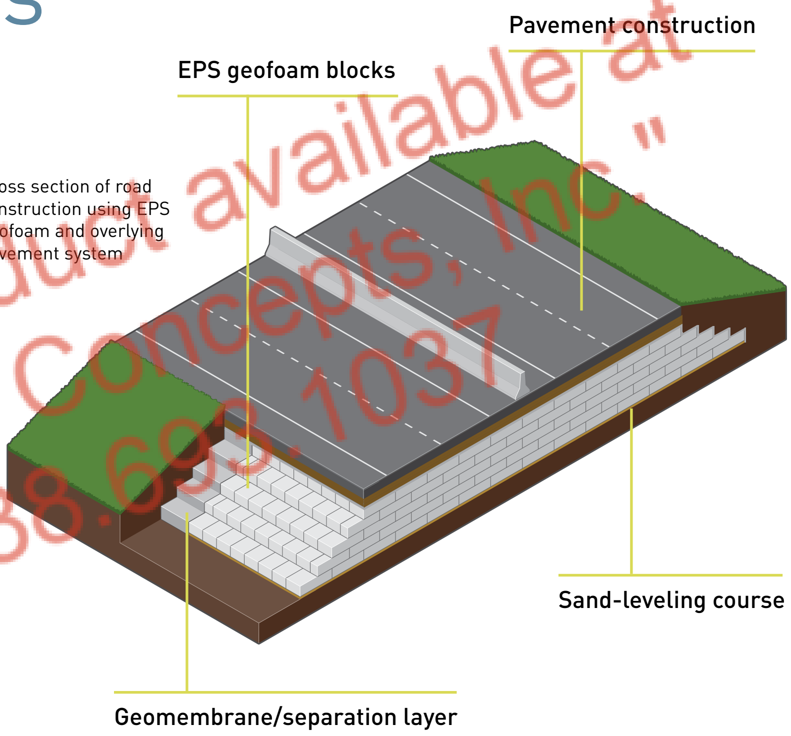
1.2 Applications & use

EPS geofoam is inherently multi-functional, which makes it effective to use in a wide variety of applications. It offers special advantages for construction on soft ground, slope stabilization and retaining walls. EPS geofoam has been used in road and airfield pavements and railway track systems, beneath refrigerated storage buildings, sports arenas and storage tanks to prevent ground freezing and heaving and in below-ground building segments to reduce seasonal heating and cooling requirements. EPS geofoam enables engineers, architects, and builders to design for key geosynthetic functions and select the best combination of products to achieve project goals. With unprecedented strength and flexibility, EPS geofoam also offers innovative solutions to a range of problems, including protection from earthquake shock and noise and vibration dampening.

02

eps geofoam applications

Road construction over poor soils



Cross section of road construction using EPS geofoam and overlying pavement system

2.1

The growing need for new roads may, in many cases, require construction over soft or loose soils that are incapable of supporting additional loads. Designers must identify innovative materials and construction techniques to address the problem of building on soft soils or where sensitive existing utilities or wetlands are present while, at the same time, accelerating project schedules. EPS geofoam can be used to replace compressible soils or in place of heavy fill materials to prevent unacceptable loading on underlying soils and adjacent structures. The high compressive resistance of EPS geofoam makes it able to adequately support traffic loadings associated with secondary and interstate highways. Construction with EPS geofoam also saves time because EPS geofoam is easy to handle without the need for special equipment. Because EPS geofoam is an engineered product it arrives on site already having undergone rigorous Q&A testing, unlike other fill materials that require time consuming QA/QC testing.

A description of a typical road construction, from bottom to top, is as follows: compact a layer of sand at the base of the roadway excavation to provide a level and free draining construction surface. Place the EPS geofoam to the desired height, staggering the vertical joints in each course so as not to create continuous vertical seams.

If required, a separation layer may be placed between the top of the EPS geofoam and the overlying pavement system. A separation layer can have two functions: to enhance the overall performance and life of the pavement system by providing reinforcement, separation and/or filtration and to enhance the durability of the EPS geofoam both during and after construction. Choices for the separation layer include geotextile, hydrocarbon resistant geomembrane, geogrid, geocell with soil fill, soil cement, pozzolanic stabilized materials or a reinforced concrete slab. For example, if protection against fuel spills is desired, a hydrocarbon resistant geomembrane cover can be placed over the uppermost EPS block course to protect from possible hydrocarbon attack. Alternately, a reinforced concrete load distribution slab can be used to protect the EPS geofoam from hydrocarbon attack and from potential overstressing resulting from heavy traffic loads. Other structural features (i.e., tilt-up panel walls, impact barriers, light and power poles, etc.) can be anchored to the load distribution slab.

The pavement system, which generally consists of select fill, roadbase gravel and an asphalt or concrete pavement driving surface, is subsequently constructed atop the separation layer.

Prevention of differential icing is a consideration when using EPS geofoam in roadway construction in cold climates. Differential icing is defined as the formation of ice on the surface of an insulated pavement, when the adjacent, non-insulated pavement remains ice-free. When constructed next to existing roadways, sections of pavement constructed over EPS geofoam can form ice prior to adjoining areas because EPS geofoam is an excellent insulator, which prevents heat from reaching the pavement from the underlying soil. One way to address this concern is to keep the top level of the EPS geofoam at or below the appropriate frost line for the region. For example, for a frost line of 3 feet (0.9 meters), a minimum separation layer and pavement system material thickness of 3 feet (0.9 meters) should be provided over the EPS geofoam.

The Indiana Department of Transportation specified EPS geofoam for the reconstruction of the Borman Expressway near Gary, Indiana. This area is underlain by extremely soft native soils due to its proximity to Lake Michigan. Thirty-two truckloads of EPS geofoam blocks were used for this project, which is equivalent to 400 dump truck loads of traditional soil fill. Thus, the use of EPS geofoam reduced the loading on the existing soft native soils while saving project time, testing, fuel and cost.

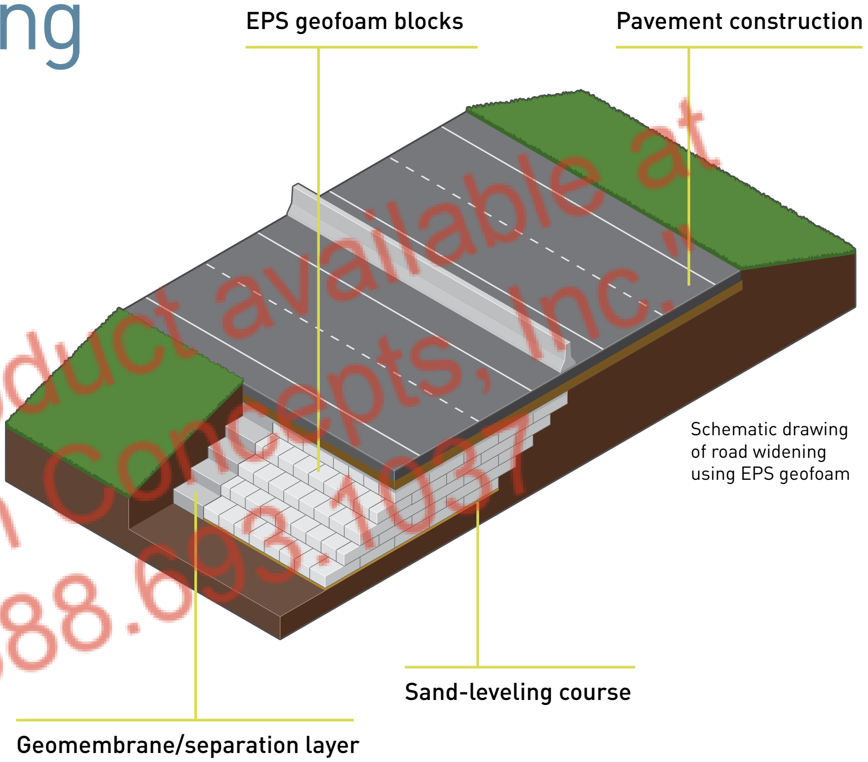
EPS geofoam was used to solve two problems for a planned housing development in the coastal area of Great Yarmouth in the United Kingdom. A flood risk assessment recommended that the ground level be raised above sea level. Another challenge for the developers was that existing soils in the area were soft alluvial clays and peat. EPS geofoam was used for the dual purposes of raising the ground level and addressing the problem of potential settlement, which would have recreated the flood hazard.

- Reconstruction of the Borman Expressway using EPS geofoam fill near Gary, Indiana.

- EPS geofoam used over unstable tide flats to stabilize the Alaska Way Viaduct in Seattle, Washington. WSDOT chose EPS geofoam because the weight of fill dirt would cause the surface to sink as much as 8 inches, which would result in de-stabalizing the entire viaduct.

Road widening

2.2 Roadways often have to be widened to reduce congestion. This situation results in additional fill being required for the roadway to be widened. This can be an expensive and time-consuming process if the soils adjacent to the existing roadway are not adequate to support the traffic loads because the resulting settlement can impact the existing roadway. In traditional construction, soil embankments are built in thin lifts, each of which must be compacted before the next lift is placed. Using EPS geofoam eliminates the need for compaction and fill testing, reduces the construction time and minimizes impact to the existing roadway and adjacent structures and/or buried utilities. The high compressive resistance of EPS geofoam makes it able to withstand the induced traffic forces without causing unacceptable loading of the underlying soils or adjacent fill. In addition, it may be possible to build steeper slopes using EPS geofoam than soil, which can reduce the amount of additional right-of-way that needs to be acquired.



Schematic drawing of road widening using EPS geofoam

The largest EPS project in the United States was the widening of I-15 in Salt Lake City, Utah where, from 1997 to 2001, approximately 130,800 cubic yards (100,000 cubic meters) of EPS geofoam was used to reconstruct parts of the interstate to facilitate the 2002 Winter Olympics.

In some locales, numerous pre-existing buried utility lines traversed or paralleled the interstate in the widened areas. These utilities consisted of high pressure gas lines, water mains and communication cables, all of which needed to remain in-service during construction. However, placement of conventional soil for the embankments in the widened areas would have produced as much as 3.3 to 4.9 feet (1 to 1.5 meters) of settlement, thus exceeding the strain tolerances of the buried utilities. The use of EPS geofoam in the utility areas essentially eliminated these large and damaging settlements and allowed construction to proceed rapidly without expensive interruption, replacement or relocation of the utilities.

The I-15 Reconstruction Project received the 2002 American Society of Civil Engineers (ASCE) Outstanding Civil Engineering Achievement Award. In announcing the selection of the I-15 project, the selection jury noted that the project had been completed in just four years, half the time that would have been required using traditional approaches, and the project came in $32 million under budget. The ASCE selection jurors also noted the innovative use of materials, such as lightweight EPS geofoam fill for embankments in making their selection of this project.

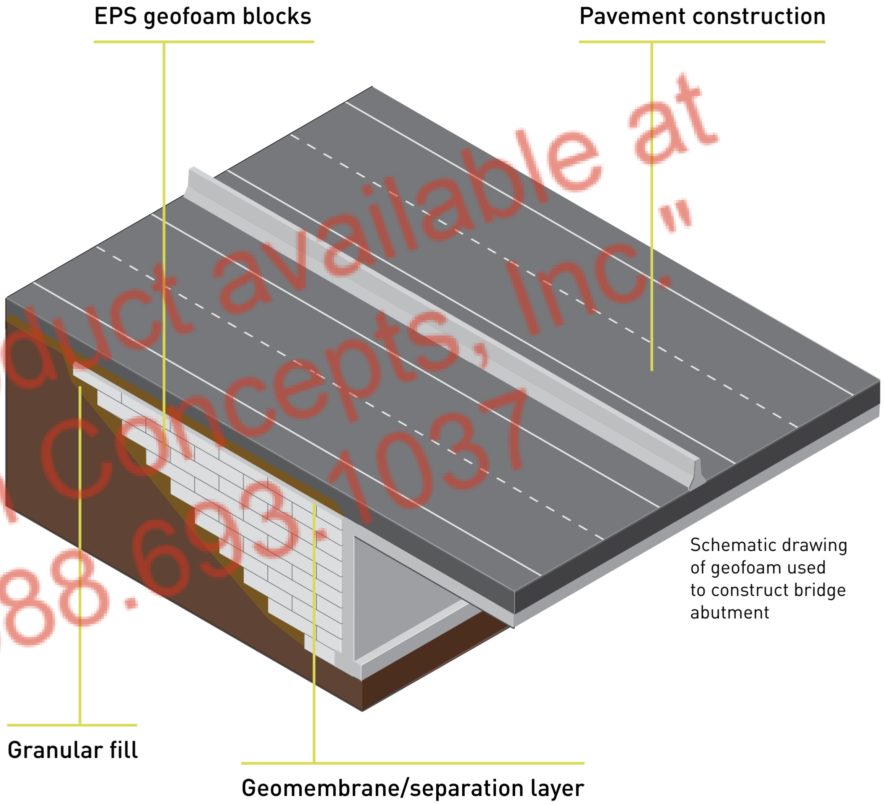
The Idaho Transportation Department chose EPS geofoam to construct the Topaz Bridge replacement and widening of Highway US 30 located in southeastern Idaho. To widen and elevate the bridge approach, EPS geofoam was used to create a zero net load condition on the underlying soft, alluvial soils. A zero net load condition means the subsurface soils experience no increase in applied pressure due to the widened and elevated approach, which prevents any significant post-construction settlement or bearing capacity problems. It is accomplished by excavating the existing foundation soils and replacing them with EPS geofoam to a depth sufficient to compensate for the new loads added by the overlying pavement section.

The EPS geofoam embankment has a 34.5-foot (10.5 meter)-high vertical face covered with a 2-inch (5 cm)-thick shotcrete facing.

- EPS geofoam used in road widening and bridge replacement project, Gary, Indiana.

Bridge abutment

2.3 There are several advantages to using EPS geofoam to construct approach fills for bridge abutments. Because of its high compressive resistance, EPS geofoam can safely support highway loading without over-stressing the underlying soils. This usually results in less differential movement at the bridge/approach fill interface, which reduces the construction cost of the approach slab and its long-term maintenance. In addition, when compared to traditional embankment fills, EPS geofoam imparts significantly reduced lateral forces on abutment walls, foundations and other retaining structures, because the transmitted lateral force is proportional to the weight of the backfill. If this weight is substantially reduced, as with the case of EPS geofoam backfill, this leads to savings in the design of bridge abutment and other walls, which are no longer required to resist large horizontal static and dynamic forces.



Schematic drawing of geofoam used to construct bridge abutment

The King County Road Services Division in Washington State undertook a project to reconstruct the York Bridge over the Sammamish River. One of the design challenges was the presence of deep, compressible peat and clay soils on the west side of the river. There was also an existing sanitary sewer line running along the west bank of the river. EPS geofoam was chosen as the preferred alternative to construct the west approach to the bridge. The designers were able to achieve a zero net load by replacing existing foundation soils with lightweight EPS geofoam, eliminating potential settlement at the bridge approach as well as potential damage to the existing sewer.

The EPS geofoam blocks were faced with precast concrete panel walls. A 6-inch (15 cm)-thick, reinforced concrete slab was placed on top of the EPS geofoam to distribute the traffic loads, protect against possible fuel spillage and provide lateral support to the exterior concrete panels. Lastly, the overlying roadway subgrade and pavement were constructed atop the load distribution slab.

EPS geofoam was also used in a project in Bellevue, Washington to construct a bridge approach between two existing buildings. At this location, there was a narrow gap of only a few feet between the existing structures and the planned bridge approach. In addition, design calculations suggested that the foundations of the existing structures could not withstand additional loading or settlement caused by placement of conventional fill. After calculating the loads induced by the new roadway, an equivalent amount of existing soil was removed and replaced with EPS geofoam fill, resulting in a zero net loading on the existing building foundations.

Bridge underfill

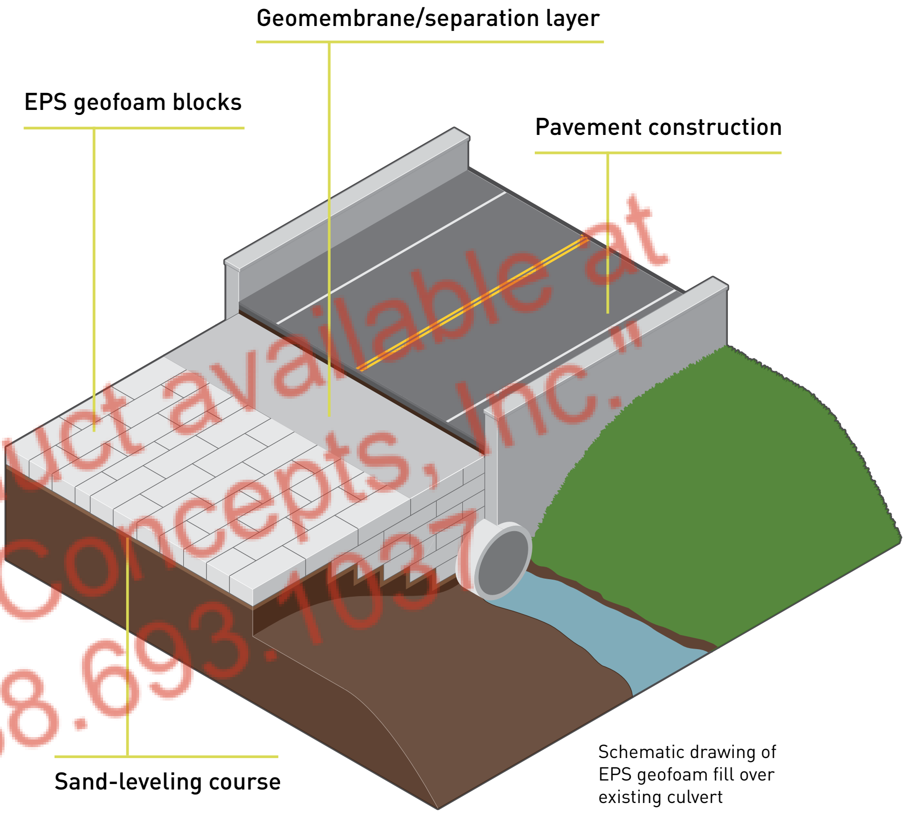
2.4 EPS geofoam can be used to support bridges when properly designed. EPS geofoam's light weight adds little additional load to the underlying ground. In cases where the existing bridge is no longer structurally capable of carrying the required traffic loads, EPS geofoam infill can help support the span and transfer the traffic load safely to the foundation or underlying soil.

An infill project was completed in St. Louis, Missouri under an active bridge along Tucker Boulevard. About 24,000 cubic yards of EPS geofoam was used to fill the void created when the 80-year-old tunnel used by the Illinois Terminal Railroad was removed. One reason the City of St. Louis used EPS geofoam was the masonry wall of an adjacent building could not support the weight of traditional earth fill.

Pitt River Bridge in British Columbia.

Culverts, pipelines & buried structures

2.5 Engineering plans often call for the placement of new fill over existing underground structures that were not designed to support the increased loads. Rather than removing or strengthening the existing underground structures, the new fill load can be reduced to a tolerable level by using EPS geofoam instead of heavier traditional fills.



Schematic drawing of EPS geofoam fill over existing culvert

EPS geofoam placement atop concrete culvert during construction of embankment widening.

Compensating foundation

2.6

EPS geofoam can be used as a compensating foundation to reduce the load on underlying compressible soils and minimize building settlement along with potential bearing capacity problems. Existing soil is excavated to reduce the net applied load to the soil by the new structure. If the amount of soil excavated equals the full weight or stress applied by the new structure, the foundation is called "floating" or "fullycompensating."

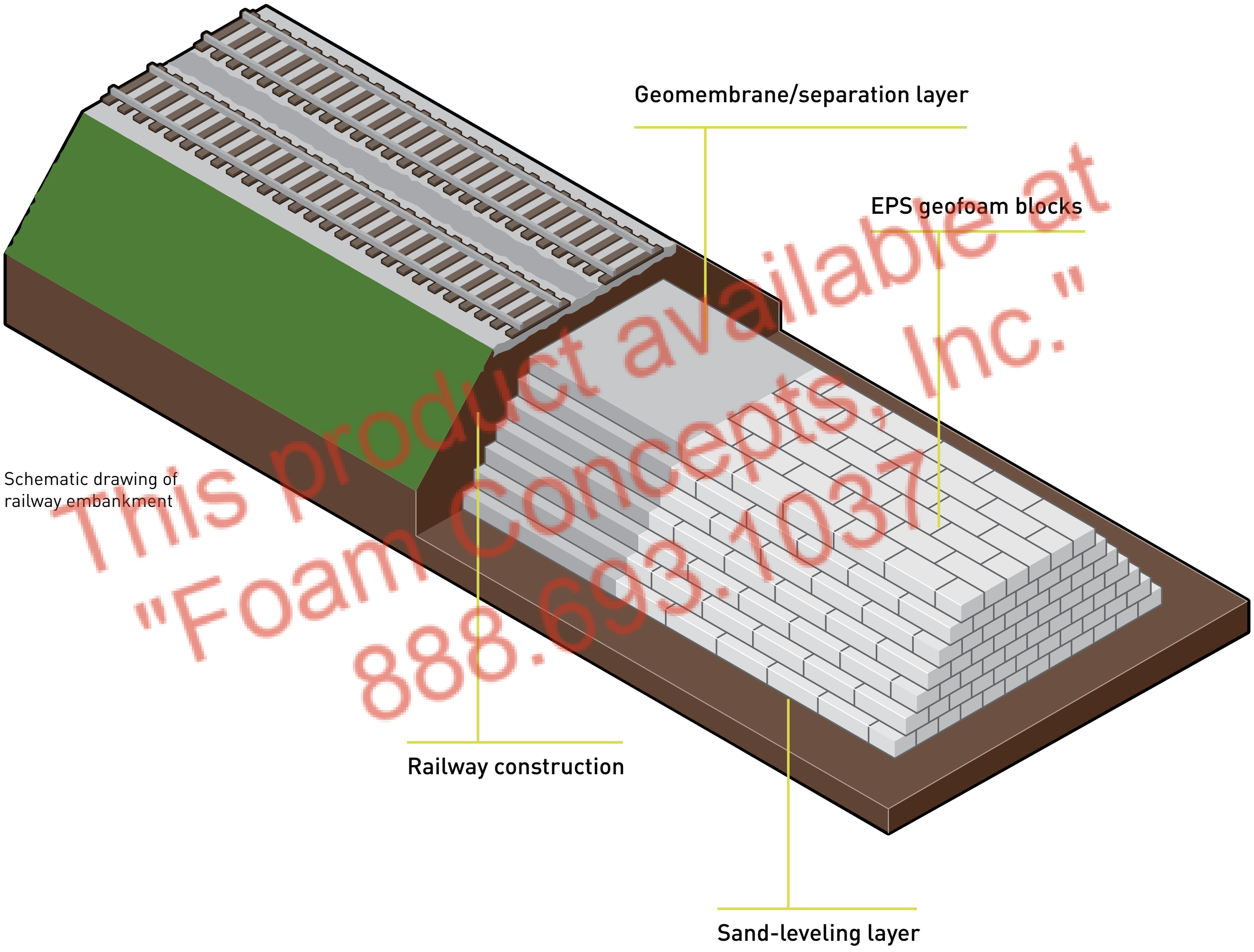
Rail embankment

2.7

The U.S. Federal Highway Administration has urged all states to consider alternate materials when planning fill and embankment projects. EPS geofoam can be used to construct railway embankments that do not overload the existing soils. As a fill material, EPS geofoam is strong enough to support railway loads.

EPS geofoam was used in the expansion of the Utah Transit Authority (UTA) TRAX light-rail system and Frontrunner Commuter rail system in and near Salt Lake City, Utah. The primary design consideration for the TRAX project was to avoid settlement of adjacent bridges and utilities resulting from settlement of underlying lake deposits.

In one area, near the I-15 alignment, the new TRAX approach embankments needed to be as much as 40 feet (12.2 meters) high so the new bridge structures could cross over an existing and operational railroad yard (Roper Yard). Geotechnical reports estimated that settlements in the existing soils could be as large as 5 feet (1.5 meters) if traditionally built embankments were constructed. In addition, conventional techniques used to strengthen the foundation soils and reduce settlements would have added time and cost to the project. EPS geofoam was chosen as the most appropriate fill material based on project time and cost constraints.

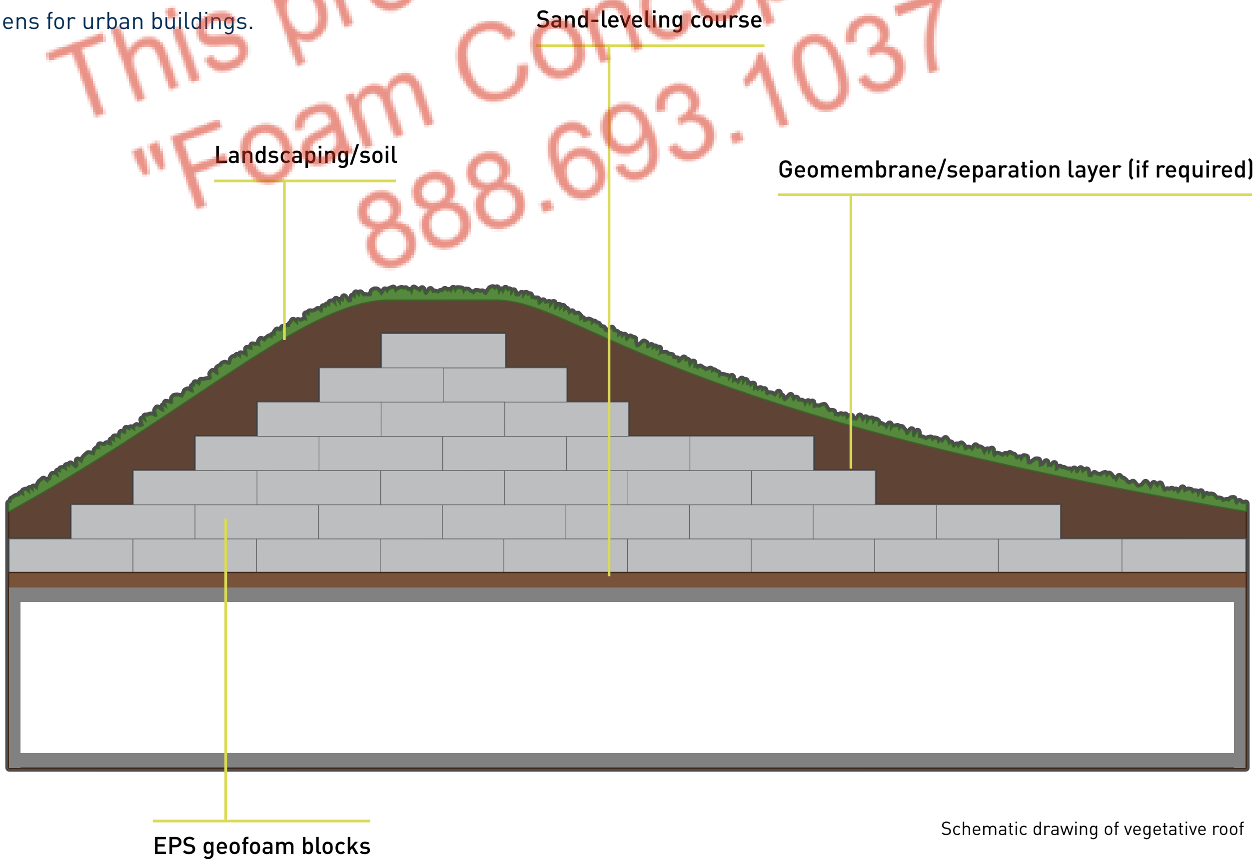


Schematic drawing of railway embankment

- EPS geofoam used to construct rail embankment.

Landscaping & vegetative green roofs

2.8 EPS geofoam can be used to create topography without adding significant load to underlying structures and services. Some examples of this application include creating roof gardens for urban buildings.



Schematic drawing of vegetative roof

Vegetative roofs provide many benefits to a building, especially in urban areas. They reduce runoff by managing rainwater, improve air quality and reduce air temperatures. EPS geofoam is ideal for this application because it can be cut or trimmed to fit odd geometries, can be installed on the roof without special equipment and does not add any appreciable load to the roof structure. EPS geofoam can be cut and shaped on site to create interesting architectural and landscape profiles. An added benefit of using EPS geofoam for a vegetative roof is the additional insulation value it provides.

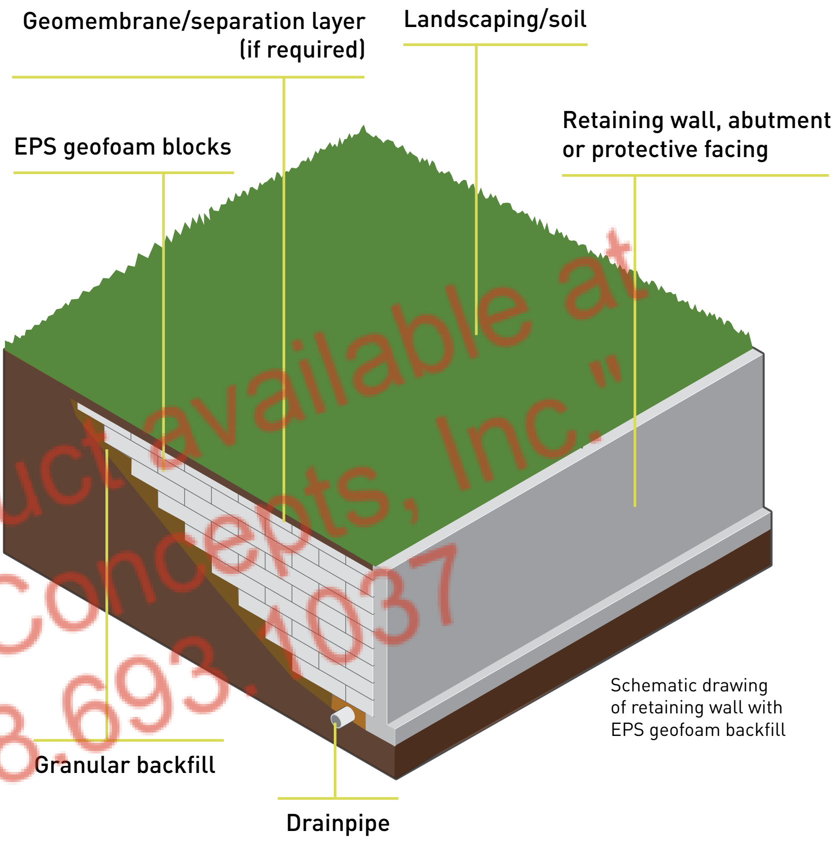
EPS geofoam was used to shape vegetative roof installations at the Scottish Parliament building in Edinburgh, Scotland and the conference center at Temple Square in Salt Lake City, Utah. A series of interesting geometric shapes was created with little additional load added to the underlying structures.

EPS geofoam was used on an underground parking garage as part of the renovation of the Calgary Court of Queens Bench building. The load induced on the underground parking structure due to surface landscaping needed be reduced. A portion of the fill material above the garage was replaced with EPS geofoam lightweight fill material and the landscaping was completed.

Retaining & buried wall backfill

2.9 EPS geofoam can be used as backfill behind retaining and buried structures to greatly reduce lateral pressures on the structure. Because the horizontal pressure acting on a retaining wall is proportional to the weight of the backfill, a less robust retaining structure is needed if the backfill soil in the active zone behind the retaining wall is replaced with EPS geofoam.

Likewise, the use of EPS geofoam backfill behind retaining and buried structures also limits the horizontal forces that can develop during earthquakes. In retaining wall applications, adequate drains should be provided to prevent the development of hydrostatic pressure and uplift due to buoyancy for sites with shallow groundwater and loose soils.

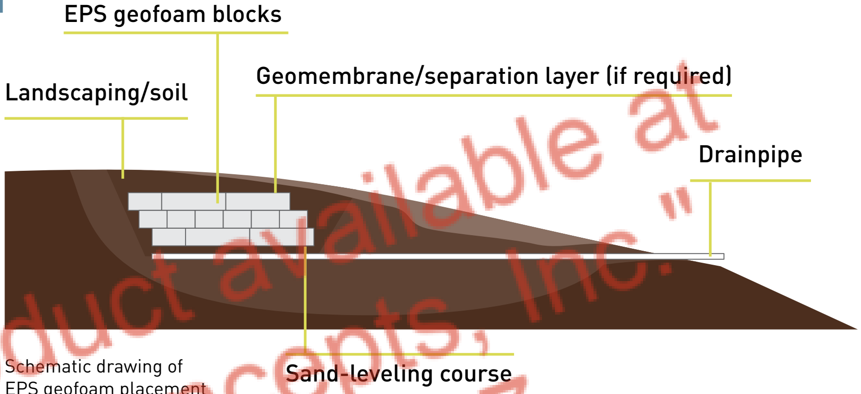


Schematic drawing of retaining wall with EPS geofoam backfill

EPS geofoam was used as backfill behind a retaining wall for a student housing project at West Virginia University in Morgantown, West Virginia. Shown in the photo below, the wall is 31 feet high. Originally designed to retain soil backfill, the wall was 3 feet wide at the bottom, tapering to 12 inches wide at the top. By replacing the soil backfill with EPS geofoam, engineers redesigned and constructed the wall 12 inches thick from top to bottom, saving a tremendous amount of cost, time and labor.

EPS geofoam retaining wall backfill for West Virginia University student housing project, Morgantown, West Virginia.

Slope stabilization



Schematic drawing of EPS geofoam placement in a slide area

2.10 Unstable slopes can be remediated by removing a portion of the existing soil and replacing it with lightweight EPS geofoam, thus unloading the head or top of the landslide and improving its stability. With this method, the entire slide mass may not need to be excavated and replaced to achieve the desired factor of safety against future sliding, which can lead to significant time and cost savings. EPS geofoam can be used for slope stabilization and repair in both soil and rock slopes.

This solution was used to repair unstable slopes along County Highway A in Wisconsin and Highway #1 in Duncan, British Columbia.

A slow moving landslide along a section of County Highway A in northern Wisconsin necessitated continuous patching of the overlying pavement. The sliding surface of the landslide was found to be below the groundwater surface. This meant that the traditional solution of removing the entire slide mass and sliding surface and replacing it with strong compacted fill would require extensive groundwater control and closing the highway, both of which were highly undesirable. Slope stability analyses were performed to determine the volume of EPS geofoam needed to replace the existing soil that would lead to an overall factor of safety against future sliding.

The designers were also careful to address differential icing and buoyancy concerns because of the nearby groundwater surface. A stable slope was created without having to close the highway during repair using EPS geofoam.

A section of Highway #1 near Duncan, British Columbia (BC) on Vancouver Island had been subject to periodic side slope failure. This roadway is in close proximity to Dougan Lake, which increased the likelihood of ongoing slope stability problems. The Province of BC, Ministry of Transportation and Highways, Nanaimo Office, sought a long-term performance solution. The corrective measure taken was to excavate the section of road down to hardpan and to replace a portion of the failed soil embankment with lightweight EPS geofoam. This allowed the current grade of the highway to be re-established while reducing the applied load.

- The Pennsylvania Department of Transportation selected EPS geofoam to repair a 400-foot section of road prone to recurrent landslides, Pine Township, Pennsylvania.

Stadium & theater seating

2.11 EPS geofoam can be used to form tiered seating in locations such as auditoriums, movie theaters, gymnasiums and churches. The high compressive resistance and light weight of EPS geofoam make it well suited to both new construction and renovation projects.

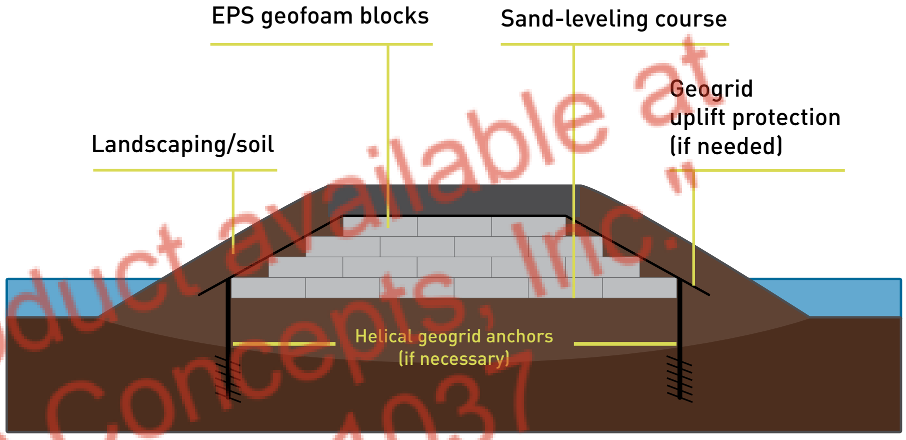
For these projects, the EPS geofoam blocks are fabricated and then stacked to create the desired profile. Fascia riser screeds are attached to the front of the blocks and provide formwork for the placement of finished concrete treads. Seats, bleachers and other attachments and finishes are then added to complete the project.

- Stacked EPS geofoam blocks used to create tiered seating in a theater.

Levees

2.12

Levees are frequently built on compressible alluvial soils along rivers because of river depositional patterns. These compressible and saturated soils settle over time due to primary and secondary compression. This continued settlement results in the levee having to be repeatedly raised to provide the desired flood protection. Levees are usually raised with conventional soil fill to return the levee to its original level. The extra weight from the levee raising causes additional settlement and the cycle of settlement and raising continues.



Schematic drawing of levee repair using EPS geofoam

EPS geofoam can be easily installed to provide the volume needed to return the levee to its original configuration. And with approximately 1% of the weight of traditional soil fills, the use of EPS as fill reduces/eliminates additional stress and the cycle of settlement and levee raising. Of course, sufficient protective soil cover must be placed above the EPS geofoam. EPS geofoam can be easily handled at sites that have difficult accessibility and, if needed, EPS geofoam can be transported by barge.

To allow placement of the EPS geofoam, a portion of the existing levee is removed and stockpiled for reuse as soil cover for the EPS geofoam. A geotextile is used on the exposed subgrade to provide separation and improved stability.

EPS geofoam blocks are placed on a sand-leveling bed and a geomembrane cover is used to encapsulate the blocks. A geotextile is placed over the geomembrane and the excavated soil is compacted over the EPS geofoam to bring the levee to its design elevation. These same principles can be applied to the construction of a new levee.

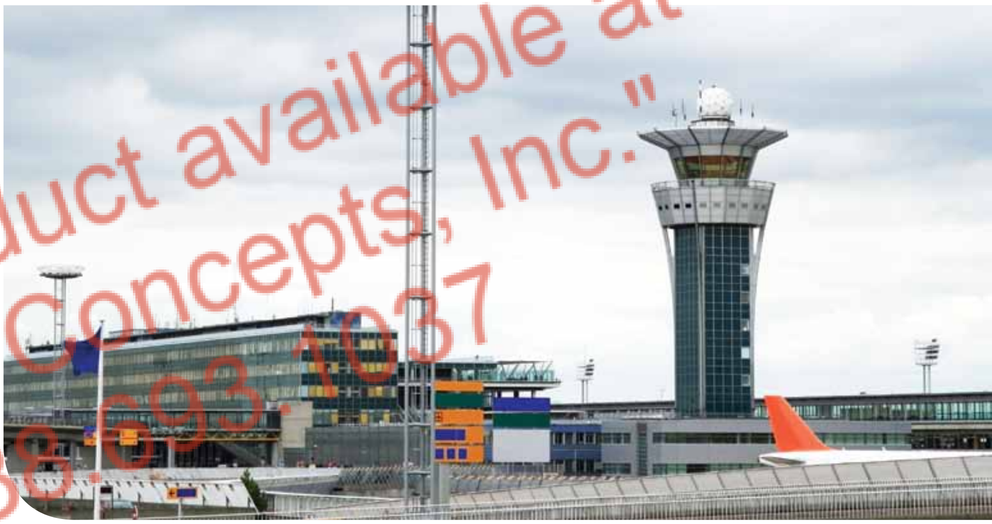
EPS geofoam used for North Creek levee, Bothell, Washington.

Airport runway/taxiway

2.13

Similar to road construction, EPS geofoam can be used under airport runways to replace unsuitable soils without overloading the underlying subgrade materials.

The New Orleans Airport East/West runway rehabilitation project included the removal of existing damaged pavement and the construction of new taxiways. EPS geofoam was used under the new pavements to control settlement on the highly compressible and saturated soils and to prevent differential settlements at the intersection of new and existing pavements.



Foundations for lightweight structures

2.14

An innovative use of EPS geofoam is to replace traditional agricultural pile footings on peat soils. The advantages of using EPS geofoam for the footings are light weight, cost savings, ease of construction and transportability for reuse.

In the photo to the right, EPS geofoam footings were designed to impart a net zero load on the underlying and highly compressible peat soils. The total load, which is contributed by the footing and structure self-weights, the lateral wind load and a safety factor, was translated into the volume of soil that had to be removed to produce a net zero load, and the footing was sized to accommodate this removal volume.

EPS geofoam is a viable choice for footings for these types of lightweight structures built on compressible peat or clayey soils since there is little or no settlement of the footings.

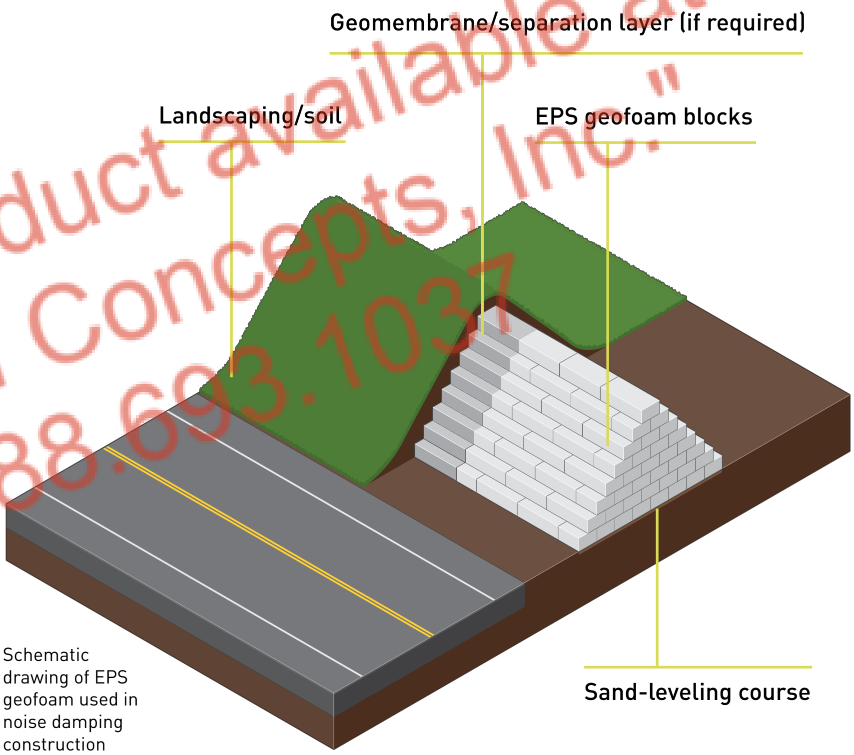
Special applications

2.15

This section describes some of the more unique applications of EPS geofoam in construction activities in North America. Some of these special applications include noise or visual barriers, expansive soils, earthquake mitigation, permafrost and rockfall protection.

2.15.1 Noise and vibration damping

EPS geofoam can be used to build free-standing walls or embankments to reduce noise from highways. They can also be used to reduce the transmission of ground borne vibrations, for example, under railways or pavements, as part of the foundation of adjacent structures or as a cutoff wall between the railways or pavements and the adjacent structures.



Schematic drawing of EPS geofoam used in noise damping construction

2.15.2 Compressible application

EPS geofoam is available in a wide range of compressive resistances. Compressible applications utilize the compressibility of EPS geofoam to accommodate ground movements. In contrast to most applications where EPS geofoam is designed for loading below the compressive resistance at 1% of the EPS geofoam, compressible applications are designed for strains beyond 1%.

When properly designed, EPS geofoam, when in contact with expansive soils, deforms and reduces the stresses transmitted to the relatively stiff structures by allowing the soils to expand, compress the EPS geofoam and not impact the structure. This means that the retaining structure or floor slab, built adjacent to or on expansive soil, only has to be designed for a small percentage of the forces that would be expected due to swelling or heaving of the expansive soil.

2.15.3 Seismic application

EPS has two primary advantages that make it attractive for seismic design: its light weight and its compressibility. The low weight of EPS geofoam provides a significant reduction in the seismic forces imposed on buried structures, retaining walls, pipelines, etc., because the magnitude of the seismic force is proportional to the mass of the system, i.e., force equals mass times acceleration. Because EPS geofoam is moderately to highly compressible it can deform and act as a "buffer" to reduce the seismic energy imparted to the system. Numerical modeling of these buffer systems suggests that the horizontal seismic forces imparted to retaining walls and other buried structures can be reduced about 20 to 50%, depending on the thickness and compressive resistance of the EPS geofoam.

EPS geofoam embankments are stable during earthquakes based on post-earthquake performance observations from Japanese researchers. Other U.S. studies show that EPS geofoam embankments are inherently stable for small to moderate-size earthquakes.

EPS geofoam has also been used atop and around buried steel pipelines to protect them from potential rupture during fault offset from a seismic event or other types of permanent ground displacement.

2.15.4 Permafrost embankments

Roadways constructed over permafrost are susceptible to thaw settlement, which results in high maintenance costs and poor ride quality. The thaw settlement is caused by the permafrost thawing. The shoulders of the roadway tend to be the most problematic areas because there is less fill over the shoulders, which means less insulating material to prevent the heat from reaching the permafrost and causing thawing. Constructing an EPS geofoam embankment over the permafrost takes advantage of the insulating quality of EPS. The primary purpose of the EPS geofoam is to sufficiently insulate the underlying permafrost to minimize/prevent heat transfer into the frozen ground, which reduces thawing and thaw-consolidation of ice-rich permafrost soils to an acceptable level.

The light weight of EPS geofoam also induces little settlement due to increased stress even if the insulation effect of EPS geofoam does not keep the permafrost frozen. Finally, the ability to construct an embankment quickly and under adverse winter conditions is of great benefit in a climate with a short and unpredictable construction season.

2.15.5 Rockfall/impact protection

Development in mountainous regions sometimes occurs where there is a high probability of rockfall. Structures, roads and railways built in the trajectory of the rock need to be protected. Protection galleries can be a good choice when the area to be protected is relatively narrow and limited, like roads and railways, and safety in the area below the protected area can be neglected. Traditionally, rockfall protection galleries are constructed with a soil layer over their cover, which provides limited energy absorption. Adding a layer of EPS geofoam under the soil cover could greatly improve the performance of the protection gallery due to the high energy absorption capacity shown by EPS geofoam as it strains during impact.

EPS geofoam used for road widening project over seismically active area on I580-US 101, San Rafael, CA.

03

design considerations

Design considerations

There are numerous design considerations for EPS geofoam applications. These considerations include engineering properties and construction factors. This section presents some of the advantages and unique features of building with EPS geofoam, as well as precautions that must be followed.

3.1 Lightweight

EPS geofoam is manufactured in various unit weights that typically range from about 0.7 to 2.85 pounds per cubic foot (11.2 to 45.7 kilograms per cubic meter). As a result, they impart small dead load or stress to underlying soils, structures and utilities. This is especially advantageous where the existing soils are poorly suited to support additional loading (e.g., compressible clay, peats, etc.). In fact, existing loads can be significantly reduced by excavating and replacing native soils, which commonly weigh about 100 pounds per cubic foot (1,602 kilograms per cubic meter), with EPS geofoam. This can eliminate the need for specialized foundations or site preloading to reduce settlement and improve bearing capacity. The use of EPS geofoam over existing utilities can eliminate the need for utility relocation. The use of EPS geofoam behind earth retaining structures, such as bridge abutments, can reduce lateral stresses.

3.2 Strength

EPS geofoam is available in a range of compressive resistances. A project designer can choose the specific type of EPS required to support the design loading while minimizing cost. Several different types of EPS geofoam can be specified on a single project to maximize savings. For example, higher strength EPS geofoam can be used in high applied stress areas while lower strength blocks are used in areas where the applied stresses are lower.

EPS geofoam design loads are recommended to not exceed the compressive resistance at 1% capacity. This limit controls the amount of long-term deflection, or creep, resulting from permanent sustained loads.

Note: Adequate soil cover, or a load distribution slab, may be needed to distribute heavy concentrated loads.

3.3 Ease of handling

No special equipment is required when building with EPS geofoam. Blocks can often be carried and set in place by laborers or easily handled with mechanized equipment. This is an important consideration when the construction site is congested or does not have the clearances required for traditional placement or compaction equipment. EPS geofoam can be field cut using a hot-wire cutter, hand saw or chain saw. The EPS geofoam can be trimmed on site to accommodate the shapes of existing underground utilities and services.

3.4 Construction time

EPS geofoam helps projects maintain extremely tight construction schedules. The ease and speed with which EPS geofoam can be constructed results in shorter construction time because of faster placement rates, reduced utility relocation and less disruption of traffic in urban areas. Additionally, adverse weather conditions typically do not affect placement rates of EPS geofoam.

3.5 Construction cost

In addition to other project costs, using EPS geofoam reduces the loading on adjacent supporting structures. Adjacent structures can be designed to be less robust and therefore less expensive. This is particularly important for underground utilities. Typically the higher cost of some types of lightweight fill materials is usually offset by savings when all of the project costs are considered, such as lower installation costs and lower maintenance. Available in a range of compressive resistances, EPS geofoam allows for economical project design.

3.6 Stability

EPS geofoam is considered a permanent material when correctly specified and installed.

3.7 Insulation

EPS is an efficient thermal insulator. EPS has been used for many years as insulation for various building applications. Although some applications may not directly utilize the insulation value of EPS geofoam, this aspect should be considered in all designs.

3.8 Protection

Chemical Exposure

EPS geofoam can be damaged when exposed to certain hydrocarbon chemical and may need protection.

There are a number of hydrocarbon resistant geomembranes that are suitable for protection of EPS geofoam. Make sure that the geomembranes used are compatible with EPS. For example, polypropylene, polyethylene, chlorosulphonated polythylene (CSPE) and Ethylene Interpolymer Alloys (EIAs) are compatible geomembranes. If using EPS geofoam in a location with contaminated soils, laboratory testing should be performed to determine the nature of the contaminants and their possible effects.

Fire

Like many construction materials, EPS is combustible. EPS geofoam is manufactured with a flame retardant in North America. Appropriate precautions should be implemented at project sites if open flame procedures, such as welding, will be performed. In geotechnical finished applications EPS geofoam is protected from exposure by soil, concrete or other cover materials. When used within buildings, gypsum board or concrete should be used for protection.

- EPS is combustible.
- A flame retardant is part of EPS geofoam. This retardant inhibits the early stages of fire development.

UV Light

EPS is susceptible to ultra violet degradation if exposed to sunlight for long periods of time. Degradation caused by prolonged exposure to sunlight is generally surficial (yellow colored dust) and does not cause detrimental property changes of practical importance. This discoloring can be removed by power washing or a grinder, if desired.

Wind

Wind speeds should be monitored during construction to determine if overburden weight restraints such as sandbags should be placed on top of the EPS geofoam to prevent the blocks from shifting.

3.9 Buoyancy

Because of its closed-cell structure and light weight, EPS geofoam is buoyant. Care must be taken during design, construction and post-construction to ensure that the potential flotation forces are accounted for within the hydrological conditions of the site. Adequate surcharge, i.e., soil or pavement cover, or an alternate means of passive restraint must be provided against uplift. Alternately, the material can be installed above the water table or the water table can be lowered using suitable drains or other dewatering systems.

Drainage (generally a sand or gravel layer) can be provided between the EPS geofoam fill and the natural soils to reduce potential uplift forces. Providing for adequate drainage of groundwater and/or surficial waters below the EPS geofoam prevents water from infiltration and reduces the development of uplift forces.

3.10 Water absorption

EPS has a closed-cell structure that limit water absorption. When used in well-drained conditions, no change in EPS geofoam weight is expected over time. A slight increase in the weight of EPS geofoam can be expected over time due to water absorption if installed in a submerged application.

3.11 Sustainability

EPS geofoam can be reground, recycled and reused in many composite applications such as lightweight concrete, plastic lumber, weather resistant outdoor decks, fencing, drain field aggregate, etc.

Compared with traditional fill materials, fewer trucks with lighter loads are required to deliver EPS geofoam to a project site. This means less pollution from fuel emissions and less wear and tear on the nation's roadways and infrastructure.

Traditional soil fills are constructed in thin lifts with repeated compaction. This requires considerable time, construction equipment, fuel to operate the equipment and testing to ensure adequate compaction. For soft soil conditions, significant waiting time is required after fill placement while the underlying foundation soil consolidates and settles. In contrast, EPS geofoam can be quickly placed with no need for compaction or waiting for consolidation to occur. Because each block is equivalent to the height of several soil lifts, construction proceeds more rapidly. In addition, EPS geofoam is unaffected by the normal range of climate and moisture conditions so construction can proceed without regard to weather. Traditional soil fills have to be constructed and compacted within relatively narrow soil moisture conditions to achieve the desired dry unit weight. In addition, because gravity loads and the lateral forces that develop under static and seismic loads are proportional to backfill material density, i.e., the greater the backfill density, the greater these loads. The use of lightweight EPS geofoam significantly reduces these loads.

04

technical data

Technical data

4.1 EPS geofoam types

EPS geofoam is available in different material types. Thorough knowledge and understanding of the type being used on a EPS geofoam project is essential.

ASTM International has three standards pertaining to EPS geofoam.

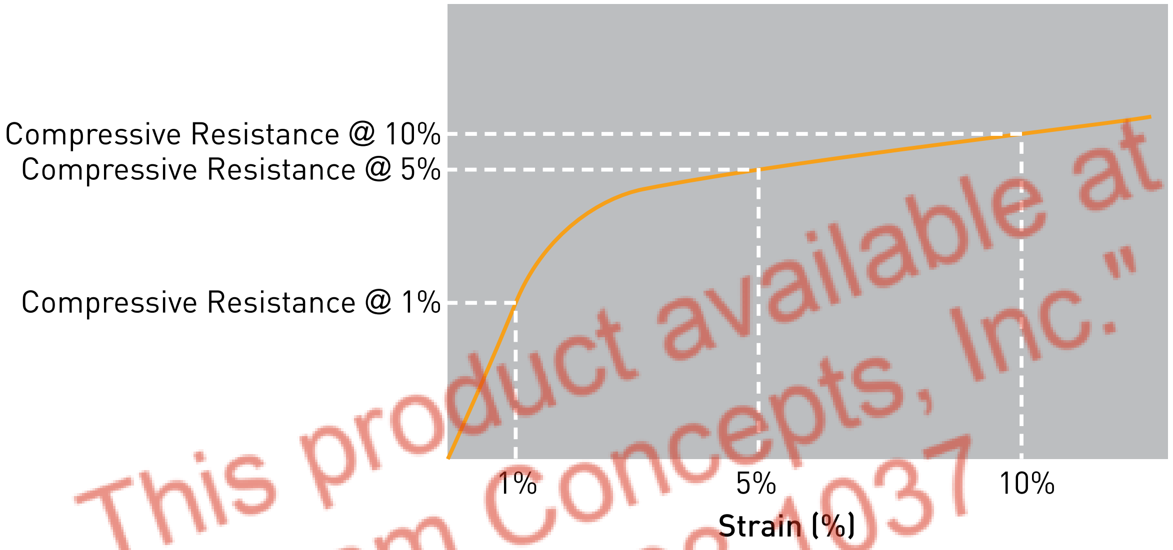
- **ASTM D6817 Standard Specification for Rigid Cellular Polystyrene Geofoam** provides information on the physical properties and dimensions of expanded polystyrene intended for use as geofoam.
- **ASTM D7180 Standard Guide for use of Expanded Polystyrene (EPS) Geofoam in Geotechnical Projects** covers design considerations for the use of EPS in geotechnical applications.
- **ASTM D7557 Standard Practice for Sampling of EPS Geofoam Specimens** can be used for quality assurance.

ASTM D6817 Physical Property Requirements of EPS Geofoam

Type	EPS12	EPS15	EPS19	EPS22	EPS29	EPS39	EPS46
Density, min., kg/m^3(lb/ft^3)	11.2 (0.70)	14.4 (0.90)	18.4 (1.15)	21.6 (1.35)	28.8 (1.80)	38.4 (2.40)	45.7 (2.85)
Compressive Resistance, min., kPa (psi) at 1 %	15 (2.2)	25 (3.6)	40 (5.8)	50 (7.3)	75 (10.9)	103 (15.0)	128 (18.6)
Compressive Resistance, min., kPa (psi) at 5 %	35 (5.1)	55 (8.0)	90 (13.1)	115 (16.7)	170 (24.7)	241 (35.0)	300 (43.5)
Compressive Resistance, min., kPa (psi) at 10 % ^{A}	40 (5.8)	70 (10.2)	110 (16.0)	135 (19.6)	200 (29.0)	276 (40.0)	345 (50.0)
Flexural Strength, min., kPa (psi)	69 (10.0)	172 (25.0)	207 (30.0)	240 (35.0)	345 (50.0)	414 (60.0)	517 (75.0)
Oxygen index, min., volume %	24.0	24.0	24.0	24.0	24.0	24.0	24.0

The typical design load limit for EPS Geofoam is the compressive resistance at 1%. Please refer to section 4.2 for additional information.

Stress-strain relationship for EPS geofoam



4.2 Compressive resistance

EPS behaves as a linear elastic material up to a strain of about 1% as shown in the figure above that depict the stress-strain response of EPS. As a result, the design recommendation for EPS geofoam is to limit loading to the compressive resistance at 1% strain. The stress at a compressive strain of 1% is called the elastic limit stress and is measured in a standard rapid-loading compression test. Except for special compressible applications, higher compressive strain, e.g., 5 or 10%, is not used to estimate the EPS strength because these strains are past the yield strength of the EPS and this may lead to undesirable permanent strains.

4.3 Creep

Creep behavior of EPS is minimal at strain levels below 1%, which is another reason for using a compressive resistance at 1% strain for design of EPS geofoam. Creep effects increase significantly at higher strains, e.g., 5 and 10%. In summary, a compressive resistance at 1% ensures adequate performance and acceptable creep behavior in EPS geofoam applications.

4.4 Load distribution

Poisson's ratio for EPS is approximately value of 0.12 within the elastic range.

4.5 Coefficient of friction

The coefficient of friction, μ, between EPS geofoam is 0.5 along molded faces. It is higher along cut faces where there is increased roughness. The coefficient of friction for a wire cut face can be assumed to be the same as a molded face or 0.5. If yellowing of the block surface occurs due to UV exposure, the block should be brushed to remove the residue and a coefficient of friction of 0.5 can be used.

4.6 R-value

EPS is an efficient thermal insulator. For construction applications the polystyrene foam industry has developed test data as reported in ASTM C 578 Standard Specification for Rigid Cellular Polystyrene Thermal Insulation. Although some EPS geofoam applications may not directly utilize the insulation value of EPS geofoam, this aspect should be considered in all designs.

4.7 Water absorption

EPS has a closed-cell structure that limits water absorption. An increase in density of EPS geofoam can be expected over time due to water absorption if the blocks are installed in a submerged application.

4.8 Stability

EPS is resistant to fungi and mold and offers no nutritional value to insects. Protection methods for termites include adding a termiticide during the manufacturing process or placing a physical barrier, such as a geomembrane, around the EPS geofoam.

4.9 Chemical resistance

EPS is not soluble in water.

EPS is resistant, at ambient temperature, to:

- alkalis
- dilute inorganic acids
- gypsum plaster
- most alcohols
- portland cement
- silicone oil
- solvent-free bitumen

EPS can be damaged by, and should not come in contact with the materials below. Protect EPS geofoam from contact with these materials both during construction and after project completion using an appropriate hydrocarbon-resistant geomembrane or other physical barrier:

- hydrocarbons
- chlorinated hydrocarbons
- organic solvents
- ketones
- ethers
- esters
- diesel and gasoline
- concentrated acids
- vegetable oils
- animal fats and oils
- paraffin

If using EPS geofoam in a location of contaminated soils, laboratory testing should be performed to determine the nature of the contaminants, e.g. methane, and their possible impact on the EPS geofoam.

Chemical Resistance of EPS Geofoam

EPS is resistant to:	**Chemicals that may damage EPS:**	
• alkalis	• hydrocarbons	• concentrated acids
• dilute inorganic acids	• chlorinated hydrocarbons	• vegetable oils
• gypsum plaster	• organic solvents	• paraffin
• most alcohols	• ketones	• animal fats and oils
• portland cement	• ethers	
• silicone oil	• esters	
• solvent-free bitumen	• diesel and gasoline	

This table provides general guidance but should not be relied upon solely when EPS geofoam could be exposed to chemicals.

Contributing members

ACH Foam Technologies
www.achfoam.com

AFM Corporation
www.afmcorporation.com

Atlas EPS
www.atlaseps.com

BASF Corporation
iwww.plasticsportal.com/products/styropor.html

Beaver Plastics Ltd.
www.beaverplastics.com

Cellofoam North America Inc
www.cellofoam.com

Drew Foam Companies, Inc.
www.drewfoam.com

Flint Hills Resources, LP
www.fhr.com/chemicals/intermediates/eps.aspx

FMI-EPS, LLC
www.fmi-eps.com

Georgia Foam, Inc. & Mid-Atlantic Foam
www.gafoam.com

Houston Foam Plastics
www.houstonfoam.com

Insulation Corporation of America
www.insulationcorp.com

Insulfoam, a division of Carlisle Construction Materials
www.insulfoam.com

Le Groupe LegerLite, Inc.
www.legerlite.ca

Mansonville Plastics Ltd.
www.mansonvilleplastics.com

NOVA Chemicals, Inc.
www.novachemicals.com/EPS/index.cfm

OPCO, Inc.
www.opcodirect.com

Plasti-Fab Ltd.
www.plastifab.com

Versa Tech Inc.
www.versatechinc.net

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NOVA Chemicals	Cover, 2.10, 3.10
Plasti-Fab Ltd.	2.5, 3.1

All illustrations are for reference only and are not actual representations of EPS geofoam design.

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STARK CONSULTANTS, Inc.

Stark Consultants, Inc., a woman-owned small business, has been providing geotechnical and structural engineering consulting services since its inception in 1997. Our clients include federal, state and local government agencies, private research agencies, utilities, attorneys, engineers and consultants, among others.

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Dr. Timothy D. Stark is a professor of civil and environmental engineering at the University of Illinois at Urbana-Champaign with an expertise in geotechnical engineering. Dr. Stark has been conducting research and teaching on geosynthetics and geofoam for over fifteen years. Dr. Stark has received a number of awards for his research and teaching activities including the elected R.S. Ladd Standard Development Award from the ASTM (2011), Fellow, American Society of Civil Engineers (ASCE) (2005), R.M. Quigley Award from the Canadian Geotechnical Society (2003), Standard Development Award from the ASTM (2002), Walter L. Huber Research Prize from the ASCE (1999), University Scholar Award from the University of Illinois (1998) and the Thomas A. Middlebrooks Award from the ASCE (1998). Dr. Stark is also a licensed professional engineer in Illinois. Dr. Stark was the principal investigator for the NCHRP Project 24-11(01) titled "Guidelines for Geofoam Applications in Embankment Projects" and is currently the co-principal investigator for NCHRP Project 24-11(02) titled "Guidelines for Geofoam Applications in Slope Stability Projects." Other current geosynthetics research topics include being the technical director of the industry-sponsored Fabricated Geomembrane Institute (www.fabricatedgeomembrane.com).

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His specialty areas are in geotechnical earthquake engineering, design and construction of lightweight embankments (i.e., geofoam), soil stabilization, geotechnical instrumentation and assessment and mapping of liquefaction-induced ground failure. He has worked on projects that include highways, dams, building foundations, tailings impoundments, pipelines and hazardous and radioactive waste facilities.

Dr. David Arellano

Dr. David Arellano has been an assistant professor of civil engineering at the University of Memphis since August 2005. Previously, he worked in private practice for nearly 10 years for several geotechnical engineering consulting firms. In addition to private practice, he was an officer in the Corps of Engineers in the U.S. Army Reserve for nearly 23 years. He obtained both his undergraduate and graduate degrees from the University of Illinois in Champaign. Dr. Arellano is a licensed Professional Engineer in Wisconsin.

Dr. Arellano was involved with the NCHRP Project 24-11(01) titled "Guidelines for Geofoam Applications in Embankment Projects." He is currently the lead Co-PI for NCHRP Project 24-11(02) titled "Guidelines for Geofoam Applications in Slope Stability Projects." Other current research topics include use of expanded recycled polystyrene in drainage applications and engineering behavior of loess soils.

Contacts & resources

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