EXPANDED POLYSTYRENE (EPS) GEOFOAM CAN QUITE LITERALLY BE THE ESSENTIAL BUILDING BLOCKS FOR CONSTRUCTION PROJECTS REQUIRING EMBANKMENT FILL.

Often available in 1 x 1.2 x 2.4 to 5-m (3 x 4 x 8 to 16-ft) blocks, the material can be used to reduce loads on underlying soils, or to build highways quickly without staged construction. It has been employed to repair slope failures, lower lateral loads behind retaining structures, reduce vertical pressure on below-grade structures, accelerate construction, and minimize differential settlement at bridge abutments.

To this end, the Federal Highway Administration (FHA) has issued a National Deployment Statement urging all states to consider using alternative fills such as geofoam when planning fill and embankment projects. (The traditional fill method involves soil; piles are packed down and left to settle on their own—sometimes for years.)

FHA’s National Deployment Goal, posted on the agency’s Web site, says that by October of this year, the material will be a routinely used lightweight alternative for state Departments of Transportation (DOTs) on embankment projects where the construction schedule is of concern. The FHA also expects all state governments to have evaluated geofoam’s use by October 2011.

The material’s most significant advantage is its weight per volume. Geofoam is only 16 to 48 kg/m³ (1 to 3 lb/cf)—about 100 times lighter than soil and 20 to 30 times less than other alternative lightweight fill materials, such as cellular concrete, scoria (i.e. lava rock), or wood chips. Therefore, large earthmoving equipment is not required for construction.

After the blocks are delivered to the construction site, they can easily be trimmed to size and shape, and then placed by hand. In areas where right-of-way is limited, the material can be constructed vertically and faced, unlike
Example: Highway Frost Heave Damage

**Step 1.** Frost advances into subgrade and freezes soil around stone or culvert.

**Step 2.** As the ground freezes, the rock and culvert are raised upward with the frozen soil, leaving a void beneath. Frost susceptible soil rushes in to fill the voids where ice lenses form, causing upward pressure. A suction develops that draws more moisture from the water table below, creating thicker ice lenses and even more upward pressure.

**Step 3.** When thawing occurs, the smaller grained soils slide into the voids preventing the rock and culvert from returning to their original position. They thus move upward, resulting in frost heave damage to the roadway.

**Step 4.** Placing polystyrene below the roadway reduces frost penetration and freezing of subgrade, frost-susceptible soils and creates flat, even heat flow.

Strategic use of extruded polystyrene (XPS) can help reduce frost heave road damage.
The first uses of polystyrene geofoam in transportation applications were in the amelioration of frost heaves in the 1970s. Placing XPS below the roadway prevented freeze-thaw cycling, reducing frost heave road damage.

most other lightweight fill alternatives. It is also unaffected by adverse weather conditions. Geofoam has been used in myriad applications in diverse projects. Examples include:

- landscape fill for Millennium Park (Chicago, Illinois);
- green roof and landscape fill for the California Academy of Sciences (San Francisco);
- green roof fill for the Fidelity Tower Condos (Kansas City, Missouri);
- erosion-control material for the Hanging Lake Tunnel (Garfield County, Colorado);
- compressible inclusion to protect underground utilities (Weber Canyon, Utah);
- slope stabilization material for retaining walls (Dubuque, Iowa); and
- stadium seating fill for theaters and auditoriums throughout the country.

This article focuses on transportation infrastructure.

**Frost heave and embankment stabilization**

The first uses of polystyrene in transportation applications were in the amelioration of frost heaves in the 1970s. Placing extruded polystyrene (XPS) insulation below the roadway prevents freeze-thaw cycling, thereby reducing frost-heave road damage (Figure 1). The success of this use gave birth to the idea of employing much thicker EPS foam layers to reduce vertical pressure on soft sub-soils for eliminating settlement concerns.

Embankment stabilization is another application. Generally speaking, there are two options for stabilization:

- hold back the driving force causing instability through the use of retaining walls, soil nails, or mechanically stabilized earth; or
- reduce weight and therefore eliminate the driving force causing the instability.
Figure 2 compares two embankments: one showing traditional soil as fill, and the other with geofoam.

As blocks are installed below-grade, EPS greatly reduces vertical pressure by a 120:1 ratio. In effect, the embankments were designed to produce zero net load on the foundation soils. This is done by removing a volume equal to weight added by new construction. Geofoam also exerts no horizontal forces on the bridge abutment, retaining wall, foundation, or supporting walls (as do other traditional fills).

Figure 3 shows EPS geofoam significantly reduces axial loads on weaker sub-soils while concurrently reducing or eliminating lateral loads on abutments and foundations. For example, with a foundation wall going 9 m (30 ft) below-grade, the compacted soil will create 1700 kg (3750 lb) per square foot of vertical pressure at the wall base and 567 kg (1250 lb) per square foot of lateral pressure at the base of the foundation wall. This lateral pressure can be completely eliminated by using geofoam.

Throughout the United States, geofoam has been specified for large and small highway projects. Figure 4 shows the country’s first use of EPS in this regard—a highway between Durango and Mancos Hill in southwest Colorado in 1989.

The left half of the figure illustrates block placement to stabilize the slope.

Utah’s I-15 project
About 100,000 m$^3$ (3.53 million cf) of EPS—in accordance with ASTM D 6817, Standard Specification for Rigid Cellular Polystyrene Geofoam—was used in Utah for what is believed to be the country’s largest geofoam project. Blocks that were 820 mm (32 in.) thick, with a small quantity of 406-mm (16-in.) material, were employed as embankment fill and utility protection in the reconstruction of 27 km (17 mi) of I-15 in Utah from May 1997 to July 2001.

Wasatch Constructors, the engineer and contractor on the project, used the alternative fill for multiple reasons. “Conventional settlement solutions for I-15 would have been costly, timely, and would have interrupted utility services,” the firm’s Mark Kimble explained. “Geofoam was used to reduce settlement on buried utilities, improve the slope stability of embankments, and allow rapid installation in time-critical areas.”

Settlement under soil embankments affects not only the ground below, but also neighboring structures (Figure 5). If one were to build a conventional embankment on soft soil that is 6 m (20 ft) in height, the area of settlement can be up to 12 m (40 ft) away—twice the height of the embankment itself.

If soil had been used for the embankment pictured in Figure 6 (next page), this utility pole would have had to be relocated at a cost of more than $100,000 per pole. Since the entire alignment (i.e., four or five poles, rather than a single one) needed to be moved, the cost would have been roughly $450,000.

In Figure 7 (next page), geofoam was stepped into the existing soil-filled embankment at a 1:5:1 slope, eliminating horizontal pressure.

The diagram in Figure 8 (next page) shows methods to speed up construction. Wick drain installation and surcharging speeds up the soil’s consolidation by driving the water and air pockets out faster. Instead of taking three years, it may only take a year for the subsoil to fully settle.

Making TRAX
In June 2008, the Utah Transit Authority (UTA) started construction on a line to a new West Valley city hub for its TRAX light rail transit (LRT) system. The project is projected to cost $200 million and will span 8.2 km (5.1 mi). The West Valley line is expected to open next year for 3500 daily commuters.
Geofoam’s most significant advantage is its weight per volume. About 100 times lighter than soil, it is 20 to 30 times less than other lightweight fill materials.

TRAX used an estimated 60,350 m$^3$ (2.13 million cf), or about 639 truckloads, of EPS geofoam. The first shipments arrived in February 2009, and installation was completed in January 2010. The project manager from Stacy and Witbeck/Kiewit Western, Ryan Snow, explained there were a few conditions indicating this material would be the most advantageous solution.

“TRAX required construction of embankments up to [12 m] 40 feet high. The problem was caused by the Lake Bonneville deposits in the area, which are subject to settlement,” he said. “The geotechnical reports stated that in the construction areas, the existing soil could have settled up to [1.5 m] 5 ft and that would have taken up to three years. We didn’t have that much time. The existing soil conditions dictated geofoam would be the most appropriate fill material.”

Snow estimates the 12-month geofoam installation for TRAX would have taken about three years with traditional fill.

“We saved potentially two years. If we had used soil, we would have waited for settlement, or maybe filled partially and then waited some more, and then finished construction later,” he said. “There are geotechnical methods to expedite settlements, such as soil stabilization and wick drains, but those would also add costs.

In the end, geofoam proved to be the most economical choice. Additionally, the use of the material enabled the fills to take place over existing utilities and adjacent nearby structures without causing damage from nearby settlement.”

Accordingly, the future UTA transportation projects using geofoam include other light rail and transit projects with embankments in 2015 program. It will provide the state with 112 km (70 mi) of rail in seven years.

Manufacturing geofoam
EPS geofoam is manufactured throughout the United States. The process starts with resin beads expanded to 50 times their size. This material is then aged and cooled 12 to 48 hours, before being molded into blocks then heated to stabilize the material (i.e. cured). Once the blocks have taken their familiar form, they are then cured and ready for fabrication or shipment to the jobsite.

Geofoam is manufactured in seven engineered grades that conform to ASTM D 6817 to provide adequate strength.
EPS embankments are designed to produce zero net load on the foundation soils. This is accomplished by removing a volume equal to the weight added by new construction.

for intended applications. All material is evaluated under stringent third-party quality control and certified by independent quality assurance agencies such as Underwriters Laboratories (UL).

The material generally costs $45 to $88 per cubic yard (i.e. 0.77 m³) depending on the density. Still, the products provide significant cost savings for many projects.

For example, Todd Jensen, Utah Department of Transportation (UDOT) civil engineer and project manager for the Legacy Parkway, estimates covering sewer lines buried under cross-street 1200 North in the city of Bountiful saved $3 to 5 million dollars—the amount it would have cost to relocate the lines. Jensen also said that using the material allows highways to be built at a much accelerated pace because settlement is nearly non-existent.

Digging the future of geofoam

Professionals are able to work with the technical information provided by the geofoam manufacturer to determine which material is suitable for a specific project. (Specialized consultants are also available.) Certain design considerations need to be factored into each project; these may include:

• buoyancy concerns;
• chemical protection;
• differential icing; and
• compressive resistance.

EPS is inert in long-term burial conditions and contains no leachates.

Due to various attributes, the use of geofoam has grown immensely over the last 12 years. It is now widely accepted throughout the United States and many other parts of the world by the geotechnical community, not only for the transportation infrastructure projects highlighted here, but also a long list of applications, ranging from landscape fill to green roofing. CS

ADDITIONAL INFORMATION

Author
Terry Meier is ACH Foam Technologies’ expanded polystyrene (EPS) representative, specializing in geofoam. He was a participant in the Geofoam Task Force for the I-15 project (the largest such project in the world) and helped introduce the material to Taiwan and the Philippines over the last decade. Meier has been a guest speaker at the Geofoam Research Center at Syracuse University, the North American Geosynthetics Society Seminar, and EPS EXPO Conventions. He can be contacted via e-mail at tmeier@achfoam.com.

Abstract
Expanded polystyrene (EPS) geofoam can be used as an embankment fill to reduce loads on underlying soils, or to build highways quickly without staged construction. It has been employed to repair slope failures, reduce lateral loads behind retaining structures, accelerate construction on fill for approach embankments, and minimize differential settlement at bridge abutments. Using transportation-related case studies, this article examines the material’s density qualities and its uses.

MasterFormat No.
31 23 23.43–Geofoam

UniFormat No.
G10–Site Preparation
G20–Site Improvements

Key Words
Division 31  Expanded polystyrene
Earthwork  Geofoam
Embankment fill  Highway construction
Plant Locations

**Colorado (Corporate Office)**
5250 North Sherman Street  
Denver, CO 80216  
303.297.3844 p  
303.292.2613 f  
800.525.8697 toll free

**Georgia**
2731 White Sulphur Rd  
Gainesville, GA 30501  
770.536.7900 p  
770.532.8123 f  
800.533.2613

**Kansas**
4001 Kaw Drive  
Kansas City, KS 66102  
913.321.4114 p  
913.321.8063 f  
800.638.3626 toll free

1400 N. 3rd Street  
Kansas City, KS 66101  
913.321.4114 p  
913.321.8063 f  
800.638.3626 toll free

1418 Cow Palace Road  
Newton, KS 67114  
316.283.1100 p  
316.283.3732 f  
800.835.2161 toll free

**Iowa**
809 E. 15th Street  
Washington, IA 52353  
319.653.6216 p  
319.653.6837 f  
888.633.6033 toll free

**Nevada**
775 Waltham Way, Suite 105  
McCarren, NV 89434  
775.343.3400 p  
775.343.3407 f  
800.444.9290 toll free

**Utah**
111 W. Fireclay Ave  
Murray, UT 84107  
801.265.3465 p  
801.265.3542 f  
877.775.8847 toll free

**Wisconsin**
90 Trowbridge Drive  
P.O. Box 669  
Fond du Lac, WI 54936  
920.924.4050 p  
920.924.4042 f  
800.236.5377 toll free

www.achfoam.com / info@achfoam.com