GUIDELINES FOR DESIGN AND CONSTRUCTION OF EXPANDED POLYSTYRENE FILL AS A LIGHTWEIGHT SOIL REPLACEMENT

GEOTECHNICAL ENGINEERING MANUAL
GEM-24
Revision #1

AUGUST 2015
GEOTECHNICAL ENGINEERING MANUAL:
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EXPANDED POLYSTYRENE FILL AS A LIGHTWEIGHT SOIL REPLACEMENT

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STATE OF NEW YORK
DEPARTMENT OF TRANSPORTATION
GEOTECHNICAL ENGINEERING BUREAU

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1. INTRODUCTION

The Geotechnical Engineering Bureau (GEB) provides earthwork and foundation engineering services for the design and construction of Departmental projects statewide. When subsurface explorations reveal that a project’s underlying soils are soft or unstable, the GEB may utilize specialized treatment options to allow completion of the desired final product.

Expanded Polystyrene Fill (EPS) is one such option. It is a lightweight fill used to reduce vertical stresses beneath embankments, or to reduce lateral stresses on retaining walls, abutments or foundations. EPS has been used in highway construction in Europe since the early 1970’s and was first used in New York in 1996. Advantages to using EPS include:

- EPS has a density that is less than 1% of typical soil fills. By using this extremely lightweight material in an embankment section over a deep, soft organic or clay soil deposit, significant time and cost savings may be achieved as compared to other foundation stabilization and settlement mitigation techniques.
- When properly designed as backfill, EPS blocks exert little to no lateral load on retaining structures.
- A typical block measuring 2 ft x 4 ft x 8 ft (0.6m x 1.2m x 2.4m) at a density of 1.25 pcf (0.2 kN/m$^3$) weighs 80 lbs (36 kg). On site, EPS blocks may be easily unloaded by two laborers and placed into position.
- The composition of an EPS block allows field cutting and trimming by a hand-held “hot wire” apparatus, hand or power saws to produce desired shapes.

This manual provides personnel in design and construction general information on EPS material and proper installation techniques.
2. DEFINITIONS

- **Expanded Polystyrene Fill (EPS):** also commonly called “geofoam”. This generic term is used to describe expanded polystyrene formed into low-density cellular plastic blocks to be used as lightweight, stable, inert, environmentally safe fill. The manufacturing process begins by exposing polystyrene resin beads, containing a hydrocarbon blowing agent, to steam. The polymer softens and the blowing agent expands the beads to form “pre-puff”. These pre-expanded beads are then placed in large rectangular-block molds. Steam is injected into the molds, where the beads expand further and fuse together to form the final product.

- **Subsurface Drainage:** a design aspect to be examined which will aid in the lowering of the groundwater table and/or maintain a positive drainage path in the vicinity of the EPS fill. Typically, a subsurface drainage system includes the installation of a layer of graded crushed stone placed behind and below the EPS fill, connected to a positive outlet. The graded crushed stone may also include a network of perforated drainage pipes.

- **Protective Cap:** a design aspect to be examined which will protect the EPS from accidental petroleum spills and concentrated loads. EPS will dissolve upon encountering petroleum products such as gasoline or diesel fuel. The protective cap may be either a geomembrane or concrete (typically at least 4 in. (100 mm) thick). When concrete is utilized, the protective cap may also serve to enhance the overall performance by aiding in the distribution of live and dead loads.
3. DESIGN

Upon request, the Geotechnical Engineering Bureau will provide project specific recommendations or contract ready drawings for EPS fills. Detailed design guidance is contained in NCHRP Report 529, Guideline and Recommended Standard for Geofoam Applications in Highway Embankments.

Some important project selection and design considerations:

- Final grade should be sufficient to allow 4 ft. (1.2 m) cover over EPS: Beneath a roadway, an EPS mass will act as an insulator and cause ice to form on the pavement at a higher ambient temperature than on the normal embankment sections. This could potentially create a differential icing condition similar to the “Bridge Freezes Before Roadway” phenomenon. A minimum of 4 ft. (1.2 m) of total cover between the top of the EPS and the riding surface has been shown to be effective in preventing this problem. The extra cover also aids in distributing live loads onto the EPS.

- Minimum soil cover over side areas (not under the pavement) is typically a nominal distance of 2 ft. (0.6 m).

- A protective cap should be included over critical areas of the EPS fill if there is a reasonable possibility of accidental contact with petroleum. This is typically a lightly reinforced 4 in. (100 mm) thick concrete slab and/or a geomembrane.

- Vertical load acting on the EPS should not be greater than the compressive strength at 1% strain (typically 5.8 psi (40 kPa) by specification) to avoid long-term creep deformation.

- Typically, normal groundwater elevation is below the bottom of the EPS fill: Buoyancy forces will cause the EPS blocks to float. If EPS blocks are placed below groundwater, additional analysis and construction techniques may be employed such as:
  - An analysis to balance buoyancy forces with sufficient overburden to achieve a suitable factor of safety against uplift.
  - An analysis of the nature and concentration of any contaminants in the groundwater that may affect the durability of the EPS.
  - The Contractor will need to utilize dewatering techniques during installation. The Contractor may also need to temporarily weigh the blocks down if the area is prone to flooding during storm events.

- Utilities (or likely future utility work) should not interfere with the EPS.
3.1 Instrumentation and Monitoring
EPS fills may be monitored during and after construction to verify the performance of the foundation soils and/or the EPS mass itself. The Geotechnical Engineering Bureau will determine what types of monitoring equipment (e.g. settlement platforms, tilt plates, vertical or horizontal extensometers) should be provided and installed as part of the construction contract.
4. QUALITY CONTROL AND QUALITY ASSURANCE

4.1 Preconstruction Stage Quality Control
The manufacturer/supplier shall have in place a Quality Control (QC) program and assume responsibilities to provide EPS fill material meeting the requirements of the specification. The QC program shall be monitored and certified by an independent third-party testing organization.

A minimum of 20 business days prior to beginning work, the contractor’s supplier should submit two copies of certified third-party test reports on two EPS blocks which have been manufactured no more than 6 months prior. Test specimen selection and preparation shall be done in accordance with the relevant ASTM standard and the most recent version of GTP-7 “Expanded Polystyrene Fill Sampling and Specimen Preparation Procedure”. The publication is available upon request to the Director of the Geotechnical Engineering Bureau. The submittal should also include detailed manufacturing records for the tested blocks.

4.2 Construction Stage Quality Assurance
The Engineer will perform on-site density tests by weighing and measuring an EPS block randomly chosen from each truck load or 2500± ft³ (75 m³) of EPS delivered to the project site. The Contractor shall provide a calibrated scale accurate to within 0.1 lbs (0.05 kg) and with sufficient capacity for this purpose. (In the past, two side-by-side platform scales or a hanging scale have been used.)

All EPS blocks should be clearly labeled with the manufacturer’s name, product type, density (as measured after seasoning and trimming), resin source, lot number, and date of manufacture. The Engineer may use this information for selecting blocks to be tested on-site and to compare measured densities. The Engineer may request copies of manufacturing records for any block.

It is suggested that the manufacturer/supplier have a representative present to observe the on-site density tests, as well as the handling and placement of blocks, at the start of delivery.

The Department reserves the right to take random samples from the project site for additional quality assurance testing. The GEB will make arrangements with the Engineer for this testing. If testing yields unsatisfactory results the Contractor may be directed to remove and replace potentially defective EPS blocks at no additional cost to the State.
5. CONSTRUCTION GUIDELINES

5.1 Contract Documents
A special specification has been developed for the use of EPS. The general requirements for EPS fill that have been included in the specification are shown in Section 6 Acceptance/Rejection Criteria. Depending on the application, a site specific design must be performed and any additional special requirements, as described in Section 3 Design, shall be included in the contract documents.

5.2 Construction Guidelines
In general, EPS fills should be constructed so that blocks fit together tightly and in such a way to avoid continuous vertical discontinuities by offsetting the joints between overlying blocks. Placing blocks in a “running bond” and rotating the pattern by 90 degrees in each successive layer is recommended to accomplish this. In cases where this is not possible due to physical obstructions, the contractor should submit a placement plan acceptable to the Engineer.

If irregular shapes are required, the EPS blocks may be trimmed in the field by a method approved by the Engineer. A “hot-wire” cutting device (a NiCr wire held between insulated handles and connected to a power source by a rheostat) is recommended.

To avoid damage, only small, rubber-tired equipment should operate directly on the EPS.
6. ACCEPTANCE / REJECTION CRITERIA

6.1 Manufactured Material
The manufactured EPS blocks shall meet the following physical requirements:

<table>
<thead>
<tr>
<th>MINIMUM PHYSICAL PROPERTIES</th>
<th>Density</th>
<th>Compressive Strength:</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM D 1622</td>
<td>1.25 pcf (0.2 kN/m³)</td>
<td></td>
</tr>
<tr>
<td>at 1% deformation</td>
<td>5.8 psi (40 kPa)</td>
<td></td>
</tr>
<tr>
<td>at 10% deformation</td>
<td>16.0 psi (110 kPa)</td>
<td></td>
</tr>
<tr>
<td>ASTM C 203</td>
<td>Flexural Strength</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30.0 psi (207 kPa)</td>
<td></td>
</tr>
<tr>
<td>ASTM D 2863</td>
<td>Flammability (Oxygen Index)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>24.0 %</td>
<td></td>
</tr>
</tbody>
</table>

The following reference standards shall apply in whole or in part to material supplied under the specification and as directed by the Engineer:

<table>
<thead>
<tr>
<th>APPLICABLE STANDARDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM D 6817</td>
</tr>
<tr>
<td>Standard Specification for Rigid Cellular Polystyrene Geofoam</td>
</tr>
<tr>
<td>ASTM C 390</td>
</tr>
<tr>
<td>Criteria for Sampling and Acceptance of Preformed Thermal Insulation Lots</td>
</tr>
</tbody>
</table>

6.2 Delivered Material
The delivered EPS fill material shall meet the dimensions shown on the plans or as approved by the Engineer. EPS comes in a variety of sizes, however is typically supplied as right rectangular prismatic blocks with nominal dimensions of 2 ft x 4 ft x 8 ft (0.6 m x 1.2 m x 2.4 m).

Blocks should be smooth and flat on all surfaces and have a dimensional tolerance of ±0.5%. Blocks with surface damage of 20% or more to a side area, or volume damage of 1% or more should be rejected.
REFERENCES


