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GeoFoam
by
John S. Horvath, Ph.D., P.E.

Lecture Notes

Slide No	Text
1	Introduction
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3	**Definition of Geofoam** **Geofoam materials.** Geofoam materials fall into two broad categories: 1. polymeric (plastic) and 2. inorganic. Polymeric materials include: . polyethylene . polyisocyanurate . polystyrene (called polystyrol in some countries) . polyurethane . other (e.g. polystyrene/polyethylene copolymer blends). Inorganic materials include: . cellular glass . cementitious materials (e.g. foamed Portland cement concrete). While each of these materials can have a cost-effective geofoam application, polystyrene foam has always and continues to dominate the geofoam market worldwide. **Polystyrene foam.** There are two distinctly different manufacturing processes for polystyrene foam. The different processes result in materials with different textures and, more importantly, significantly different geotechnically relevant properties. The two types of polystyrene foam are generally referred to worldwide as: . expanded polystyrene (EPS) and . extruded polystyrene (XPS).
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5	**Full-size EPS Block in Temporary Storage after Molding**Both are manufactured in fixed plants and were invented circa 1950 so the basic materials are generic and available worldwide. However, it is common for both Geofoam and non-Geofoam products manufactured from EPS and XPS to be marketed using trade names. In addition, certain Geofoam products manufactured in whole or in part from EPS and XPS are proprietary. It is easy to distinguish visually between EPS and XPS as the former consists of individual beads of cellular polystyrene that are permanently fused together. This is the reason that EPS is sometimes referred to colloquially as “beadboard” although this term should not be used. On the other hand, XPS has a uniform cellular texture. Color can also be a useful distinguishing feature between EPS and XPS although care is required. EPS is inherently white in color and is typically sold as such whereas XPS is generally colored for product identification and marketing purposes. However, exceptions abound, especially when viewing things

	globally. In some countries (Canada and the United Kingdom are noteworthy examples) EPS is sometimes colored for Geofoam marketing purposes. However, the colors used can conflict with practice in other countries. For example, pink is used in the U.K. for a particular EPS product that is sold exclusively for Geofoam applications whereas in the U.S.A. the same color is used for a brand of XPS products used for both Geofoam and non Geofoam purposes. Therefore, texture, not color, should always be used as the primary distinguishing feature between EPS and XPS.
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8	**Geosynthetic Functions of GeofoamGeofoam functionsIntroduction.** Design by function is recognized as the appropriate design philosophy for any type of geosynthetic so understanding the functions that geofoams can provide is the first step in designing with geofoam. One of the reasons EPS is the geofoam material of choice worldwide is that it is the only geofoam material that can technically and economically provide any and all of the geosynthetic functions that have been identified to date for geofoam. XPS (and other geofoam materials) have much more limited application where they are cost effective. In addition, EPS is a relatively simple material to manufacture and is available worldwide which adds to its position as the predominant geofoam material. The following are the geofoam functions provided by EPS organized by chronological usage and approximate date of initial use.Where appropriate, the alternative use of XPS (the most commonly used geofoam material after EPS) to provide that function is also noted. **Thermal Insulation (1960s).** This is the one function where both EPS and XPS are often competitive in practice. The large relative volume approximately 98%) of gas enclosed in the cells of EPS and XPS provides a significant thermal-insulative value and is the reason these materials were developed in the first place circa 1950. **Lightweight Fill (1970s).** EPS can have a density as low as ~10 kg/m3 which is less than 1% of that of normal earth materials (soil and rock). For this reason, this function is sometimes referred to as *ultralightweight fill*. Despite its low density, the stiffness and strength of EPS can be sufficient to support motor vehicles, trains, airplanes, and even lightly loaded buildings. Thus EPS geofoam is useful as a lightweight fill material. **Fluid Transmission (1970s).** This is the one geofoam function that duplicates a common function of other types of geosynthetics. The geofoam material can either be inherently highly permeable (most geofoam materials, including EPS and XPS, are not) or, more commonly, the final EPS or XPS geofoam product can be shaped or cut so as to contain voids or channels for the fluid to flow through. **Vibration Damping (1980s).** The relatively high stiffness to density ratio of EPS geofoam materials makes it relatively efficient at damping the small-amplitude ground vibrations and even air-borne noise from motor vehicles and trains. **Compressible Inclusion (1980s).** EPS can be formulated to be highly compressible and thus efficient for use behind or above rigid/non-yielding structures. This allows what is called *controlled yielding* (movement) of the adjacent soil or rock which in turn reduces the load on the structure. The classical soil mechanics phenomenon of arching is one type of yielding that can be induced using a compressible inclusion as is the development of the active earth pressure state behind an otherwise non-yielding wall. **Structural (1990s).** This function relates to some of the newest and still emerging (as of 1998) uses of geofoam such as panels of EPS as facing for mechanically stabilized earth walls (MSEW) and a variety of EPS and XPS products used as formwork for poured-in place reinforced concrete walls. **Overall analytical approach** One of the factors that often inhibits the use of geosynthetics by those unfamiliar with them is uncertainty over how to analytically deal with the

	geosynthetic. In this context it is useful to point out that designing with Geofoam is best approached by considering the geofoam to be an equivalent earth material with engineering properties and parameters such as density, Young's modulus, Poisson's ratio, and coefficient of thermal conductivity that are conceptually identical, although numerically different, than earth materials with which the design professional is more familiar. As a result, normal geotechnical engineering analytical methodologies for settlement, slope stability, and heat flow (to name but a few) can generally be applied with little or no modification to problems that incorporate geofoam. In fact, because many geofoam materials are both more predictable as well as simpler in their behavior compared to normal earth materials designing with geofoam easier than designing with soil and rock.
9	*Hidden Slide*
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12	**Geofoam Insulated Road Pavement under Construction in Norway**Because geofoam can be constructed with a vertical side slope, a geofoam fill requires less area or right of way for the finished structure. This reduces the cost as well as the social/political and environmental impact of land acquisition for a project. . Use of geofoam usually allows other parts or components of the overall structure to be reduced in cost or even eliminated. This is because geofoam imposes much smaller loads on an adjacent structure. . Use of geofoam generally does not require ancillary ground improvement strategies (e.g. wick drains and preloading on soft soil). A geofoam alternative achieves additional constructability cost reductions because it: . proceeds faster due to the very low density of geofoam and concomitant ease of placement, . does not require highly skilled and expensive labor for construction, . generally requires minimal heavy equipment, and . is significantly less affected by weather compared to traditional earthwork. Finally, when life-cycle (operational) and other post-construction costs (e.g. future maintenance) are considered as they should always be, the geofoam alternative further reduces costs because of: . typically reduced maintenance requirements, . lower energy consumption for operation (where relevant), and . generally superior overall performance of the final structure. The need to consider all costs of a design alternative is very important. An excellent example of how this concept was applied to a problem involving insulated road pavements can be found in the paper by Doré et al. (1995).
13	**Existing Railroad Track being thermally insulated with Geofoam in Norway** **EXAMPLES OF GEOFOAM APPLICATIONS** **Thermal insulation** Thermal insulation is useful in any application where it is desired to restrict the flow of heat. This may be either for conservation of energy consumption during operation of the structure, construction-cost savings, or for improved geotechnical performance of the structure. Contrary to many perceptions, geofoam thermal insulation can be used cost effectively in any climate and not just those subjected to seasonal or permanent cold weather. Examples of types of structures where geofoam thermal insulation has been used include: . building basements (all climates), . refrigerated buildings (all climates), . cold-liquid storage tanks (all climates), . clay liners of landfills (all climates), Road/airfield pavements and railways (cold climates) *(See Slide)*

14	•Building foundations (cold climates) •Sewage/water-supply/oil pipelines (cold climates) Most thermal insulation applications use relatively thin (50 to 100 mm thick) panels of geofoam. The products used tend to be either panels of EPS of desired thickness that are factory cut from full-size blocks or XPS panels manufactured directly to the desired thickness. **Lightweight fill**Geofoam can be useful as a lightweight fill material in any application where the very low density can be advantageous. This includes under normal gravity stresses but particularly under dynamic loading such as seismic. Typical applications to date include:
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17	**Rebuilding a Failed Road Embankment with EPS-block Geofoam in Winter in the U.S.A** **Fluid transmission** Because fluid transmission is the one geofoam function that duplicates a function available with other types of geosynthetics such as sheet drains and geonets, the applications where geofoam can be cost effective as a drainage product are generally limited to where one or more additional geofoam function such as thermal insulation and/or compressible inclusion can be used beneficially. Examples of where geofoam, either alone or together with geotextiles as part of a drainage geocomposite, have proven to be cost effective include as part of a system for the collection and disposal of: . ground water around: . building basements and . earth retaining structures; and ground-borne gases (methane, radon) around basements of buildings. Geofoam products used include shape-molded EPS specific to an application as well as panels of EPS block and XPS factory cut with grooves or channels. There is also a material called *porous polystyrene block* that is made using the same raw material as EPS and used for drainage applications because of its unique (for geofoam) inherent permeability.
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23	**Vibration damping** Examples where geofoam has been used to provide this function include: . attenuation of ground-borne vibrations from: . motor vehicles and . trains, and . attenuation of noise from trains, especially surface light rail (trams) in urban environments. Geofoam products used typically consist either of full-size blocks of EPS or panels cut from a block of EPS.
24	**Compressible Inclusion** Applications involving the use of geofoam as a compressible inclusion have shown significant diversity even in just the relatively few years that this function has been exploited. To date, applications have been in three categories: **1.** with earth retaining structures to . reduce lateral earth pressures acting on the structure by: . allowing strain and concomitant shear-strength mobilization within the retained soil, . accommodating volume change of earth materials such as expansive soil or rock or freezing soil, and

	. accommodating structure movement such as occurs with integral-abutment bridges; and . reduce settlements behind the structure; **2.** beneath and adjacent to foundation elements to reduce stresses from expansive soil or rock; and **3.** above or below pipes, culverts, and small-diameter tunnels to reduce vertical stresses by inducing arching within the soil. Geofoam products used are typically low-density (~10 kg/m^3) EPS and, more recently, *elasticized EPS*. The latter is normal EPS that has been subjected to an additional manufacturing step to permanently modify its stress-strain characteristics to enhance its compressibility under stress magnitudes encountered is most geotechnical applications. (See Slides 23 - 28 for examples)
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29	**Structural** Applications involving the structural function are still evolving. Some that have been identified and used to date include: . wall forms for cast-in-place Portland cement concrete (PCC), . facing panels for mechanically stabilized earth walls (MSEW), . void formers for cast-in-place PCC, and . foundation remediation and other ground-stabilization activity by grouting. Geofoam products used primarily are a variety of EPS block and EPS shape as well as XPS and other geofoam materials for certain applications (e.g. polyurethane grout).
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