Geofoam Construction and Application to Industry

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Abstract— 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 1in 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.

Index Terms— Geofoam, EPS, XPS.

I. INTRODUCTION

During the last few years, geotechnical engineering professionals and academics have become increasingly aware and familiar with the application of geofoam materials. The generic name "geofoam" was proposed by Horvath (1992) to describe all rigid plastic foam that's used in geotechnical applications. Later, the definition of geofoam was broadened to include any cellular material or product created by an expansion process .These synthetic materials are now recognized as a category of geosynthetics, as proposed by Horvath.

Although several materials have been used as geofoams, the majority of applications, involve the use of EPS.EPS is manufactured by first heating expandable polystyrene solid beads to produce a bulk of cellular spheres containing numerous closed cells and having a diameter of three to four times the diameter of the initial solid beads.

The analysis and design of geotechnical application, using the functions of geofoam mentioned above, require the knowledge of the mechanical properties of geofoam in both the static and dynamic loading range. Although a considerable amount of data pertaining to the mechanical behavior of EPS under static loading conditions have been reported in the geotechnical literature in the last few years.

II. BACKGROUND

The manufacture of rigid plastic foams dates back to the 1950s, with adaptation for geotechnical use occurring in the early 1960s. In 1992,the category of "GeoFoam" was proposed as an addition to the variety of geosynthetics already in existence. The most commonly used GeoFoam material is a polymeric form called expanded polystyrene (EPS), also known as expanded polystyrol outside of the United States. Such widespread use can be attributed to global availability, significantly lower cost than other materials, and the absence of postproduction long-term release of gases such as formaldehyde or CFC, a behavior observed with other polymeric forms (Horvath 2004).

The most common method of producing EPS GeoFoam is block molding, in which a mold is used to create a prismatic rectangular block. Depending upon the application, other mold shapes can be used, however it is more common to shape the blocks post-production (Horvath 1994).

The raw material used to create GeoFoam is referred to as expandable polystyrene, or often resin, and is composed of small beads with diameters similar to medium to coarse sand (0.2 to 3 mm). The bead size chosen will not ultimately affect the engineering properties of the completed block (Horvath 1994). The beads are composed of polystyrene and a dissolved petroleum hydrocarbon, usually pentane or rarely butane, which acts as the blowing agent. The beads may also contain other additives to affect certain properties of the completed block (flammability, etc.), however this is dependent upon the application in a similar fashion to the addition of admixtures in concrete (Stark et al. 2004).

The density of EPS GeoFoam is controlled primarily through regulation of the manufacturing. It has been found that even with a well-controlled manufacturing process, there will still be variability in density between blocks from the same production run, as well as a density gradient within each block. This can affect the geotechnical properties of the material, as density has been found to be a controlling factor in the performance of the GeoFoam (Horvath 1994). The actual range of densities that EPS blocks can be manufactured is between approximately 10 kg/m3 (0.6 lb/ft3) and 100 kg/m3 (6 lb/ft3) (Stark et al. 2004). The low density of EPS GeoFoam results in the development of uplift forces when submerged in water, and therefore for many design situations an anchor system or adequate surcharge load (e.g. soil cover) is required (Negussey 1997).

The dimensions of GeoFoam blocks affect only cost and construction layout, and not the engineering properties of the blocks. There are no standard sizes for EPS block molds and given the numerous applications of GeoFoam blocks and abundant manufacturers (over 100 in the United States), there is much variability in dimensions of raw GeoFoam blocks. Typically designers attempt to use full-sized blocks and when necessary blocks can be cut to shapes in-situ with a hot wire or, less effectively, a chainsaw. An alternative to in situ shaping of the blocks is custom manufacture of the block mass, in which the EPS producer uses the construction plans to develop an efficient layout for the block mass, however this is usually reserved for complex projects due to the associated increases in cost (Stark et al. 2004).

EPS GeoFoam has proven to be quite durable when exposed to common natural elements. Polystyrene is non-biodegradable, and is inert in both soil and water (Horvath 1994). Exposure to ultraviolet (UV) radiation from sunlight causes only cosmetic discolorations, and only after an extended period of time, allowing for a window of exposure time during the construction period .Exposure to water may result in a small amount of absorption, the magnitude of which is inversely proportional to the density of the geoFoam and is dependent upon numerous factors such as GeoFoam block thickness, surrounding hydraulic gradients, and the phase of the water. Water absorption does not affect the volume of the EPS, and there is no effect on mechanical properties (Horvath 1994).

Exposure to certain substances and conditions can result in damage to the polystyrene. The use of polystyrene in transportation projects risks the material coming into contact with common fuels, which polystyrene will readily dissolve in, or road salts, however this risk is usually eliminated through the proper installation of a barrier such as an impermeable membrane (Horvath 1994). Polystyrene can be flammable when exposed to an ignition source, as is the blowing agent used in production. An additive, usually consisting of a bromine-based chemical, added to the expandable polystyrene causes the material to become flame retardant. The issue of ignition of the flammable blowing agent is resolved by allowing adequate seasoning time of the EPS block in order to allow out gassing to occur. Flame retardant EPS can still melt when exposed to extreme temperatures between approximately 150 and 260°C, however maximum exposure temperatures for design conditions are usually considerably lower (Stark et. al. 2004). The thermal conductivity of dry EPS GeoFoam is affected by the density of the material, which can be controlled during the manufacturing stage, and the ambient temperature. Generally, the thermal conductivity of dry EPS GeoFoam is approximately 30 to 40 times less than that of soil, making it a very efficient insulator. The effect of absorbed water upon thermal conductivity is more difficult to quantify, given the numerous factors affecting the volume of water uptake (Stark et. al. 2004). As water has a higher thermal conductivity than dry EPS GeoFoam, moisture absorption is expected to result in an increase in thermal conductivity. Even under extreme cases of moisture absorption, EPS GeoFoam serves as a better insulator than soil.

III. PROPERTIES OF GEO FOAM

A. Expanded Polystyrene (EPS):

There are two primary methods for molding EPS:

1)Block molding:

which produces finished prismatic blocks that are typically 500 mm to 600 mm high, 1000 mm to 1200 mm wide, and 2000 mm to 5000 mm long. These blocks can be cut into panels or pieces of various shapes for specific applications where There is significant potential for using geofoam panels as facing for thin retaining walls (in the way that precast concrete panels are used now) and as blocks in Segmental Retaining Walls (SRWs) in a way that concrete blocks are used . The full-size blocks are neither required nor desired. Products that result are called "EPS-block geofoam." This is the predominant type of EPS geofoam and predominant geofoam product overall worldwide.

2) Custom shape molding**:**

Produces pieces with specific shapes. In non-geofoam applications common examples include the white foam coffee cup and the cushion packaging used around consumer electronics and appliances. Shape-molded EPS products for geofoam applications (called "EPS-shape geofoam") were rare until the last few years. There is a variation on block molding called slab molding in which relatively thin panels are produced directly, with a custom shape so that it is actually a slab-shape hybrid. Such products for geofoam applications are relatively rare because of the highly specialized molding equipment required. In addition, there are other niche geofoam materials such as glued or molded polystyrene porous block and elasticized EPS block

Geo composite products that utilize EPS as a component are becoming increasingly common. One example is the Geo inclusion, which is available in North America. This product uses a panel of elasticized-EPS-block geofoam as its primary component plus a drainage geo composite that is factory laminated to one face of the panel.

B. Extruded Polystyrene (XPS)

XPS is produced primarily in plank-shaped pieces. It is possible to custom-extrude a particular shape but the distinction between plank and shapes in geofoam terminology is not done (at least to date) as it is for EPS.

1. Durability:

Durability of geosynthetics in general has been a subject of great interest in recent years. Overall, the durability of EPS and XPS geofoams is excellent. . Typically, the only concern with EPS and XPS geofoams is that they be protected from gasoline and similar petroleum-hydrocarbon liquids with a geomembrane or similar barrier in applications where there is a potential for a fuel spill (e.g., road embankments).

In addition, in some applications (thermal insulation around the below-ground space of buildings is one in particular) there have been problems with infestation by certain burrowing insects (termites, carpenter ants). It appears that an effective passive treatment against potential insect infestation has been developed for EPS-block but not XPS.

2. Thermal Insulation:

EPS and XPS were invented circa 1950 primarily to provide thermal insulation. Foams are very efficient thermal insulators because they are approximately 98% to 99% gas by volume and gases are typically very efficient thermal insulators. Therefore, it is the first known application call geofoam was as thermal insulation of roads, railways, and airfield pavements (to prevent or at least reduce seasonal frost heaving or retard thawing in permafrost areas); the below-ground portions of buildings (to reduce seasonal heating requirements); and beneath on-grade storage tanks containing cold liquids (one of the few applications where glass foam is used almost exclusively).

Pavement construction cost as reflected in the protection offered against frost heaving. When insulated pavements were first used, they were designed to provide full protection against frost penetration into the sub grade beneath the geofoam and concomitant frost heaving. Some later designs allowed partial frost penetration of the sub grade, primarily as an economy measure. All geofoam materials absorb ground water with time and this reduces their thermal resistivity so should be accounted for in design.

3. Lightweight Fill:

Geofoams, especially polymeric ones, are unique materials they have a density only about 1% to 2% of the density of soil and rock are sufficiently strong to support many types of loads encountered in geotechnical applications. The earliest function of geofoam that was developed was its use as a lightweight fill material in a wide variety of "earthworks." The benefit of using geofoam as opposed to other materials in earthworks is the significantly reduced stresses on the underlying subgrade. This can have multiple benefits in terms of reduced settlements, increased stability, and lightweight fill material under highway. Useful index property in the same way that particle size of granular soils or Atterberg Limits of plastic soils are useful index properties of soils .Applications fall into two broad categories:

Earth retaining structures where horizontal arching is involved. Pipes, culverts, and similar structures where vertical arching is involved e.g. Geofoam in landscaping.

4. Compressible Inclusions:

Geofoam 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. trains.

One of the very useful aspects of EPS-block geofoam is that it can be manufactured over a range in densities. This is relevant because if EPS block is manufactured to certain quality standards then (and only then) can density be a useful index property in the same way that particle size of granular soils or Atterberg Limits of plastic soils are useful index properties of soils. Applications fall into two broad categories Earth retaining structures where horizontal arching is involved. Pipes, culverts, and similar structures where vertical arching is involved e.g. Geofoam in landscaping.

5.Drainage:

Geofoam materials have very low permeability for fluids (both gases and liquids). However, both EPS and XPS geofoam products can be factory cut or purposely shape molded to have geometry such that they readily transmit fluids (especially ground water) along one face or side of the product. This has been extended to EPS-shape products intended to readily transmit ground-borne gases such as methane and radon.

There are geofoam materials that have an inherent permeability throughout their entire thickness. The most-common example is glued polystyrene porous block. This panel-shaped product uses expanded spheres of polystyrene that are glued into an open matrix. One face of the panel is typically covered with a geotextile which provides separation and filtration functions. In general, geofoam products are not cost effective compared to other drainage geocomposites when only drainage is required.

6.Water Absorption:

Any water absorbed into a geofoam product will, as a minimum, increase the coefficient of thermal conductivity of the geofoam and thus reduce its thermal efficiency. This should be considered during the thermal design of geofoam used as thermal insulation. In addition, some geofoam materials (but not EPS or XPS) can have their mechanical (stress-strain) behavior negatively affected by absorbed water. Volume change (increase or decrease) of some geofoam materials (but not EPS or XPS) can also result from water absorption.

Geotechnical engineers should be aware of the fact that absorbed water in foam materials is always reported as percent on an absolute volume basis, i.e. volume of water as a percent of the total volume of the geofoam product. This is fundamentally and significantly different from how water content of earth materials is expressed which is on a relative weight basis (weight of water divided by weight of dry soil or rock). It appears that the reason water content of foams is expressed this way is because water is on the order of 50 times denser than most foam materials so a water content expressed on a weight basis would be a relatively large number (several hundred percent). While there is nothing inherently wrong with this, it does present a nuisance (writing large numbers) as well as has psychological and marketing impacts (large numbers imply large problems, which is not necessarily the case).

IV. TEST'S AND RESULT

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.

Table1:ASTM D6817 Physical Property Requirements of EPS Geofoam.

Type	EPS12	EPS15	EPS19	EPS22	EPS29	EPS39	E
Density, min., kg/m3(lb/ft3)	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)	103 (15.0)	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

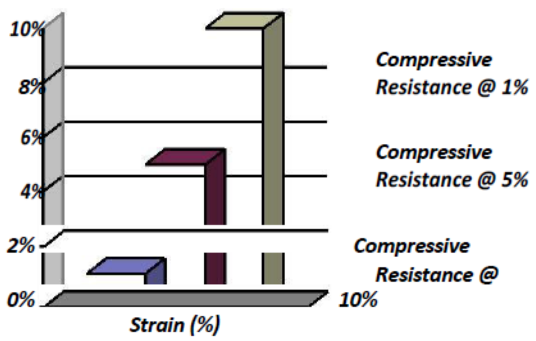

Figure1: Stress-strain relationship for EPS geofoam

A. 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.

B. 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.

C. 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.
D. 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
Table2.Chemical Resistance of EPS Geofoam:

EPS is resistant to:	Chemicals that may damage EPS:
Alkalis	Hydrocarbons
Dilute inorganic acids	Chlorinated hydrocarbons
Gypsum plaster	Organic solvents
Most alcohols	Ketones
Portland cement	Ethers
Silicone oil	Esters
Solvent-free bitumen	Diesel and Gasoline
	Concentrated acids
	Vegetable Oils
	Paraffin
	Animal Fats and Oils

V. LIMITATIONS OF GEOFOAM

A. Advantages:

1. Low density/high strength: Geofoam is 1% to 2% thedensity of soil with equal strength.

2. Predictable behavior: Geofoam allows engineers to be much more specific in the design criteria. This is very different than other lightweight fillers, such as soil, that can be very variable in composition.

3. Inert: Geofoam will not break down, so it will not spread into surrounding soils. This means that geofoam will not pollute the surrounding soil.

4. Geofoam can also be dug up and reused.

5. Limited labor required for construction: Geofoam can be installed by hand using simple hand tools. This eliminates the investment and operating cost of heavy machinery.

6. Decreases construction time: Geofoam is quick to install and can be installed during any type of weather, day or night, resulting in faster installation time.

B. Disadvantages:

1. Fire hazards: Untreated geofoam is a fire hazard.

2. Vulnerable to petroleum solvents: If geofoam comes in contact with a petroleum solvent, it will immediately turn into a glue-type substance, making it unable to support any load.

3. Buoyancy: Forces developed because of buoyancy can result in a dangerous uplift force.

4. Susceptible to insect damage: Geofoam should be treated to resist insect infestation. If it is not, insects such as ants can burrow into the geofoam, weakening the material.

VI. FUTURE SCOPE IN INDIA

Due to the development of construction industry in India and a demand for environmental friendly and economical construction material there is a great demand for application of geofoam in various construction activities such as road stabilization ,abutment ,backfilling ,gardening, decorative purpose, road construction over poor soil, road widening, culverts, pipeline and buried structures, compensating foundation, rail embankment, landscaping and vegetative green roofs, retaining and buried wall backfill, slope stabilization, stadium and theater seating, airport ways, taxi ways,

VII. CONCLUSION

1. It is a light weight material and the best available replacement for soil in road stabilization process.

2. Due to its chemical resistance properties it can be used in construction of impact resistance floors.

3. Due to it light weight and easy to handle property it can be used in aesthetic enhance of the building structure.

4. Geo foam has a widespread application in the field of landscaping.

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