

Geofoam Fills and the Non-Issue of Buoyancy

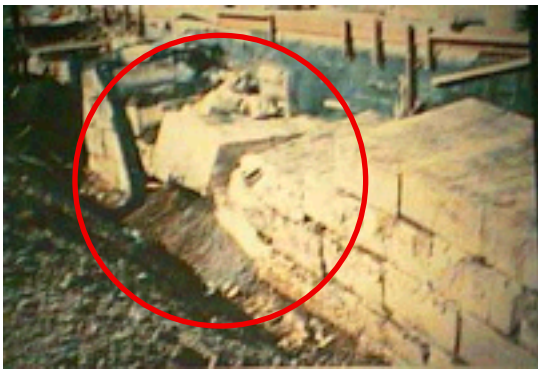
Reference: Lessons Learned from Failures Involving Geofoam in Roads and Embankments, John S. Horvath, Ph.D., P.E. Professor of Civil Engineering Manhattan College, April 1999

Introduction:

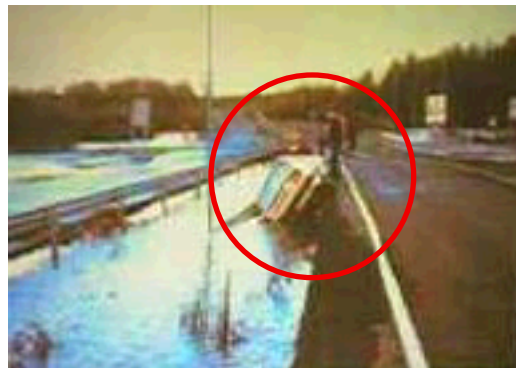
Geofoams are usually called for in those areas where the soils are too weak to support the weight of planned construction, whether it be earthen embankments or rigid structures such as building foundations. It is no coincidence, therefore, that Geofoams are utilized frequently in low lying, swampy areas.

Accidents & Freaks of Nature:

Since Geofoam has such a low density, there can be concern about the forces



**Carousel Mall,
Syracuse NY**



**Scene in Norway 1987,
Extreme flood event**

developed by buoyancy in those situations where the blocks become partially or totally submerged due to flooding, water main breaks, or heavy rains.

Two examples of this are shown below. In the Case of the Carousel Mall in Syracuse New York, the fill was under construction when a water main was damaged, filling the area surrounding the EPS with water.

The second example shown is from a roadway in Norway during an unusually high flood. The extreme movement of the foam can be observed from the position of the car which was parked on the curb before the flood. This incident was described in the referenced document, in case "L-4." The flood levels were 850 mm higher than those assumed in the original design.

Proper Design:

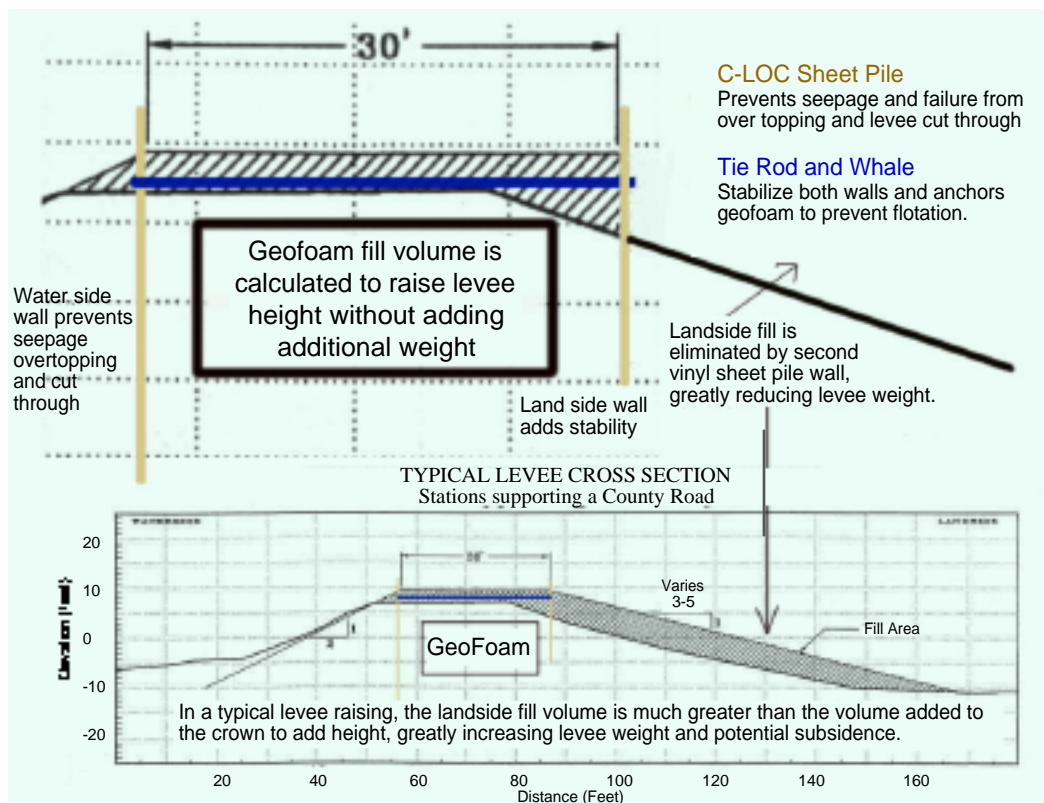
The buoyant properties of Geofoam are perfectly understood, and an engineer can

anticipate what the uplift forces on the fill are likely to be. Through proper design, an engineer can maintain adequate design margins against flotation.

There are three simple ways to manage the uplift forces developed as Geofoam is submerged:

- 1) Design the fill such that there is adequate weight of fill over the foam to hold it down during periods of high water levels.
- 2) Employ Helical Soil Anchors to resist the uplift forces and restrain the EPS Geofoam during periods of high water levels.
- 3) Reduce the potentially buoyant volume by utilizing a heavier “light weight fill” beneath the EPS geofoam, or by installing a floodable light weight composite such as “geocomb” or an array of PVC pipes.

It is illustrative to consider the example of a flood control levee. In this application, the fill is designed for partial immersion but must retain enough downward force on the fill to prevent it from sliding due to the differential pressure arising from the high water level on only one side, yet not be so heavy as to exceed the native soil’s bearing capacity.



Design Details of Roaring Slough levee in California

The following discussion will rigorously step through the design considerations to make an embankment that will resist flotation utilizing the weight of the soil only. All assumptions are stated and relevant calculations provided:

Assumptions:

Reference McCarthy page 436-436 on Foundations and Bearing Capacity Equations

$\phi_{\min} := 26 \cdot \text{deg}$ See page 376 for table of these values. These are the range for a silt (non plastic).

$\phi_{\max} := 35 \cdot \text{deg}$

To estimate soil strength utilizing bearing capacity equation:

$N_q(\phi) := e^{\pi \cdot \tan(\phi)} \cdot \tan\left(\frac{\phi}{2} + \frac{\pi}{4}\right)^2$ for cohesion, also see McCarthy p 393

$N_c(\phi) := (N_q(\phi) - 1) \cdot \cot(\phi)$ $c' := 100 \cdot \frac{\text{lbf}}{\text{ft}^2}$ p710 of CE handbook for normally consolidated, noncemented clays with a low preconsolidation stress (ranges from 100-500 psf)

$N_\gamma(\phi) := 2 \cdot (N_q(\phi) + 1) \cdot \tan(\phi)$

$q_{\text{ult}}(\phi, c, \gamma, B) := c \cdot N_c(\phi) + \frac{1}{2} \cdot B \cdot \gamma \cdot N_\gamma(\phi)$ Bearing Capacity Equation

$q_{\text{ult}} \text{ 15 deg, } c', 120 \cdot \frac{\text{lbf}}{\text{ft}^3}, 16 \cdot \text{ft} = 3.64 \cdot 10^3 \cdot \frac{\text{lbf}}{\text{ft}^2}$

$\text{Soil_Strength} := q_{\text{ult}} \text{ 15 deg, } c', 120 \cdot \frac{\text{lbf}}{\text{ft}^3}, 16 \cdot \text{ft}$

To estimate the maximum soil height before settlement becomes a problem, assuming a safety factor of 3:

Safety_Factor := 3

$\text{Max_Soil_Height} := \frac{\text{Soil_Strength}}{\text{Safety_Factor} \cdot \text{Soil_Density} \cdot g}$

Max_Soil_Height = 10.11 *ft

This is the maximum height the embankment can be, before it's mass becomes too great for the strength of the soil on which it is being built.

If the dead weight is to hold the foam down, then the max height of foam will be:

$$\text{Max_Foam_Height} := \frac{\text{Max_Soil_Height}}{\text{Safety_Factor}} \cdot \frac{\text{Soil_Density}}{\gamma_{H2O}}$$

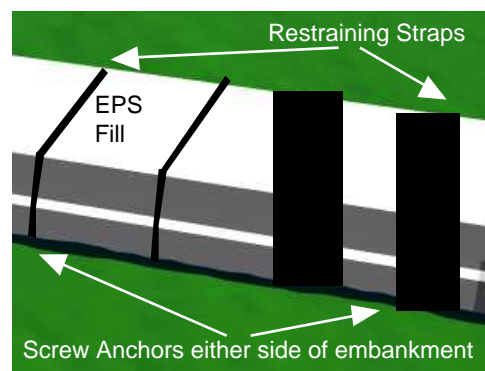
$$\text{Max_Foam_Height} = 6.478 \text{ *ft}$$

From the simple preceding example, it has been shown that in this case a very conservatively designed Geofoam filled embankment....

- Can be at least eight feet higher than what would normally be possible,
 - + With a design margin of 3 against settlements,
 - + With a design margin of 3 against block flotation,
even if the Geofoam is completely submerged!

In order to improve these design margins, and to protect against sliding, helical soil anchors can be employed.

These devices are quickly installed, with a holding ability directly proportional to their installation torque. In the diagram to the right, they are installed in pairs, either side of the EPS fill, and connected with a strap running over the fill or tied into the load distribution slab over the EPS fill, if there is one.



Use of Screw Anchors over fill illustrated



Types of Screw Anchors

In marshy soil, a typical pair of anchors are capable of resisting a buoyant force of 32,000 lbf.

The required anchor spacing can be easily derived from the cross sectional area of the fill which can provide the lift per lineal foot from buoyancy.

Over 100,000 of these anchors have been installed, often in submarine applications where they are continuously exposed to seawater. The estimated life of the anchors is on the order of 100 or more years.

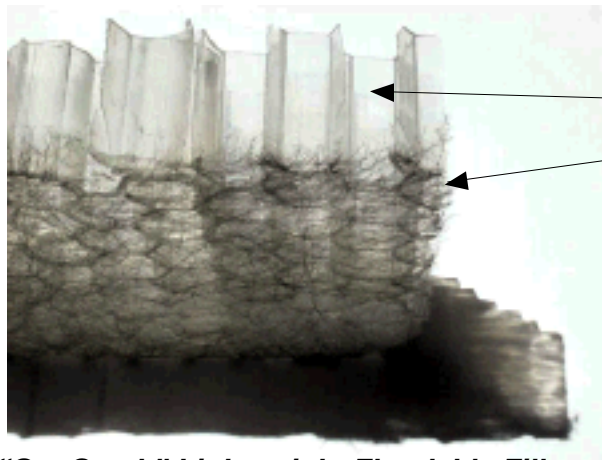
Only the ground protruding elements (or those in a splash zone) show the effects of corrosion, which can be mitigated with galvanization and/or the use of sacrificial anodes. The service life of soil anchors should be adequate for any highway or other EPS fill application.



Installation of Screw Anchors

Another approach for addressing the issue of buoyancy is to eliminate buoyant volume low in the fill. Depending on the project conditions and requirements, there are two ways to accomplish this:

- 1) Use of a heavier “light weight” fill beneath the EPS Geof foam, such as fly ash, which has a density slightly greater than water but less than 1440 kilograms per cubic meter.
- 2) Use of a lightweight, porous assembly that has a large floodable volume resulting in minimal buoyant forces. This could be comprised of something as ordinary as



Hollow plastic prisms
Geotextile

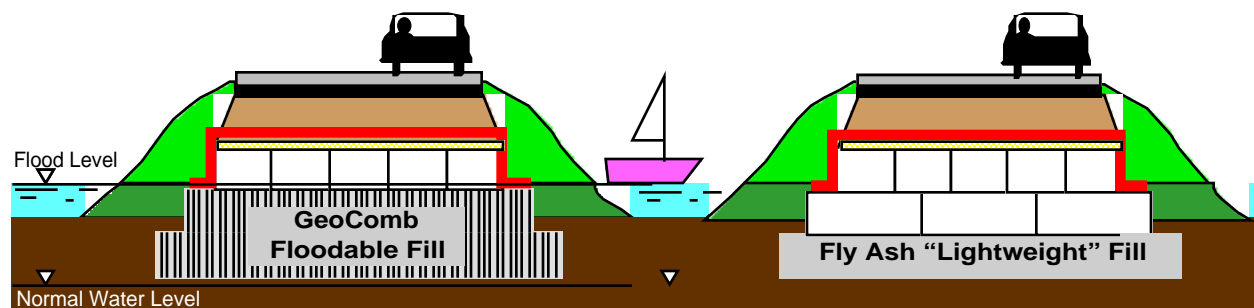
Property	Value
Density (dry)	40 kg/m ³
Density (flooded)	980 kg/m ³
Strength	400 kPa at failure
Block Size	1m x 2m x 480mm

“GeoComb” Lightweight Floodable Fill

stacked PVC Piping (of suitable strength) or a new geocomposite such as “geocomb.”

Geocomb is a plastic assembly comprised of hollow hexagons arranged in a honeycomb like structure and covered with a loosely woven geotextile. This product is illustrated below:

These two approaches are illustrated below:



These illustrations show the cross section of an embankment built over poor soil utilizing EPS geof foam during a flood event. The uplift forces are minimized by the weight of the road subgrade plus the use of non-bouyant materials below the expected flood line.

Summary:

Although Geofoam is a very buoyant material there have been very few instances in the past of embankment failures due to the buoyancy of geofoam fills floating despite the fact that the use of this technique for road building has been used in thousands of projects world wide in low lying areas which are susceptible to flooding.

In addition, it is very easy to estimate the effect of flooding on the integrity of EPS fills, and there are a number of design options which can be exercised to make an EPS Geofoam embankment failure a virtual impossibility, all the while retaining the unique advantages an ultra light weight geofoam structure has over other techniques for building over soft soils.

For Further Information on TerraLite EPS Geofoam or Induplast Geocomb, contact:

GeoTech Systems Corporation
9912 Georgetown Pike Suite D-2
Great Falls, VA 22066

(v) 703 759 0300
(f) 703 757 0119

geosyscorp@aol.com

or visit our web site

www.geosyscorp.com

