Design of EPS Geofoam as a Pavement Block

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Abstract- Expanded polystyrene Geofoam (EPS) has offered solutions to many civil engineering problems associated with pavement construction. Issues, such as the construction of pavements on low bearing capacity subgrade soils (such as peats and clays), or in regions with severe winters, and the construction of pavements over underground services, these all have been overcome with the use of EPS geofoam. From this paper it is concluded that this material is used for many pavement applications and these include the use of EPS geofoam as a lightweight fill, as a thermal insulator, a vibration dampener, and for the protection of underground services. But, there are a number of barriers that are stopping the use of EPS geofoam from becoming standard worldwide. Thus is requires a development and proliferate technical knowledge to avoid the inefficient, and even the incorrect use of EPS geofoam and there is also room for research in the development of latest and innovative applications for the use of EPS geofoam, and for the development of updated standards and test procedures. To facilitate research in these areas, this review paper discusses the design considerations.

Keywords: - Expanded polystyrene, densities of geofoam, design consideration.

I. INTRODUCTION

Expanded polystyrene (EPS) is a polymeric geosynthetic material with a cellular closed cell structure. Its manufacture involves the heating of expandable beads of polystyrene with steam, and the placement of these heated expanded polystyrene beads into moulds to create prismatic blocks of EPS[1]. These blocks are manufactured for use in a variety of civil engineering applications. One of its primary applications is in pavement construction to counter the issue of low bearing capacity subgrade soils, an application that has been very successful, and, consequently, has been widely adopted and utilized for more than four decades[2]. Other applications of EPS include thermal insulation, compressible inclusion, slope stability, bridge abutment construction, stadium seating construction, and even noise/vibration dampening[3-5] .There are a number of attributes that make expanded polystyrene a suitable material for pavement construction. Firstly, EPS is an ultra-lightweight material that has a density of approximately 1/100th of other conventional fill materials (see Table 1). This means that EPS can be used in a lightweight fill application, where it is used in the place of low bearing capacity foundation soils or heavy fill materials, to prevent the associated issue of unacceptable rates of settlement. Also, EPS has a small Poisson's ratio, and a high self-sustaining character, resulting in reduced lateral pressure when used as a backfill material for structures like retaining walls. Other benefits include the savings that can be made in cost and time during construction. The cost savings can also be made from the decreased in maintenance costs due to the low settlement associated with EPS geofoam block, since the volume of soft soil that needs to be removed can be reduced (some scenarios), and since the costly task of utility relocation can be avoided entirely (construction can be done over utilities). In addition, savings in construction times can be made since construction can continue during adverse weather conditions, since the time needed for underlying soils to consolidate is eliminated, and since the installation is rapid [6-8]

Table 1

Ranges in densities of typical lightweight fills

Lightweight Fill Type	Range in Density
Geofoam(EPS)	12-35
Foamed Concrete	335-770
Wood Fibre	550-960
Shredded Tyres	600-900
Expanded shale and Clay	600-1040
Fly-ash	1120-1440
Boiler Slag	1000-1750
Air cooled slag	1100-1500

II. LITERATURE REVIEW

A. H. Padade and J. N. Mandal (2014) showed in their paper that, the interface strength behavior of EPS geofoam was not significantly influenced by its density, also the failure envelopes for all the interfaces were found to be almost linear and the behavior of EPS geofoam to geofoam interface exhibits peak and residual trends in shear strength. However, no peak and residual shear strengths were observed in all other interface behaviors. For all densities of EPS geofoam, it was observed that no significant variation was found in interface friction angle values. However, increasing the density of EPS geofoam showed slightly increased adhesion.

Dawit Negussey and Xiaoodng Huang (2011) had found that to design pavement structures with geofoam as subgrade according to the AASHTO and other pavement design guides, the resilient modulus, California Bearing Ratio (CBR), and modulus of subgrade reaction of geofoam need to be determined also CBR values interpreted by a modified method yielded higher values than conventional methods but still less than acceptable soils.

Matthew Ashdown (2017) says that expanded polystyrene appears to be a versatile material that can be used in a myriad of geotechnical engineering applications, particularly in pavement construction. This is possible due to the interesting mechanical properties of EPS geofoam such as- Lightweight character, which allows it to be an excellent fill material, low thermal conductivity, which makes it a suitable pavement insulator in cold climates, Compressibility, which facilitates its application in the protection of underground services, vibration dampening qualities that makes it a potential vibration dampener.

Y. Zou, J.C. Small and C.J. Leo (2000) found that

Plastic deformation occurs even at small stress levels, the magnitude of cumulative permanent deformation increases nonlinearly with loading and test results showed that block size and lateral restraint did not affect the performance of the EPS geofoam blocks. These findings will give design engineers added flexibility in design.

III. DESIGN CONSIDERATION

This section addresses the considerations that the designer must appreciate when designing pavement structures with EPS. This section also discusses some of the important geotechnical parameters that must be calculated for the design of pavements using EPS. For a more detailed design procedure, the designer should see the NCHRP Report 529.

3.1. Bearing capacity

The bearing capacity of the EPS geofoam is an important parameter that must be calculated when designing pavement structures, as the EPS geofoam can fail in bearing, potentially causing excessive vertical settlements in the pavement system, and even damage to adjacent properties. The ultimate bearing capacity of EPS can be calculated using Eq. which is presented below:

$$q_{ult} = cN_c + {}^{\gamma}D_f N_q + {}^{\gamma}B_w N_{\gamma}$$

where, c = Mohr-Coulomb shear strength parameter termed cohesion, KN/m^2,

Nc, N^{γ}, Nq = Terzaghi's bearing capacity factors,

$^{\gamma}$ = Unit weight of soil, KN/m^3,

B_w = Bottom width of embankment (m) and

D_f = Depth of embedment (m)

3.2. Buoyancy and seismic loading

The potential effects of groundwater on the EPS blocks must be considered during design, since EPS geofoam is extremely lightweight and has a closed cell structure, making it susceptible to buoyancy when in the presence of water. Interestingly, this buoyancy is not reduced significantly by the absorption of water by the EPS blocks over time. To counter this issue, sufficient dead load stresses must be applied on the EPS blocks to counteract the potential uplift forces. Seismic loading must be considered during the design of pavement systems to avoid geotechnical problems, such as seismic settling and seismic liquefaction. This is of significance since seismic loadings can affect both the internal and external stability of road embankments. Interestingly, the considerations made for seismic loading during the design of EPS embankments, are much the same as the considerations made for seismic loadings induced on embankments constructed from other earth materials. It has also been discovered that the risk of seismic loading depends on the site, and the nature and the thickness of the natural soil atop the bedrock, rather than the material in use (EPS geofoam).

3.3. Settlement

Settlement is another important factor that must be considered during the design of pavement structures using EPS geofoam. The settlement that occurs as a result of immediate settlement, primary consolidation of the fill material, secondary consolidation of the fill material, and the long-term creep of the fill material, must be accounted for during design. Generally, settlement that occurs as a result of the lateral deformation of subgrade soils at the edge of an embankment is typically not considered, because, provided the factor of safety for external instability is greater than 1.4, it is negligible in comparison to the other previously mentioned modes of settlement. Lateral creep deformation, however, needs to be accounted for during design if the embankment is to be constructed atop underground utilities.

3.4. Pavement composition considerations

An EPS geofoam embankment consists primarily of three components that can be observed in Fig. 1.

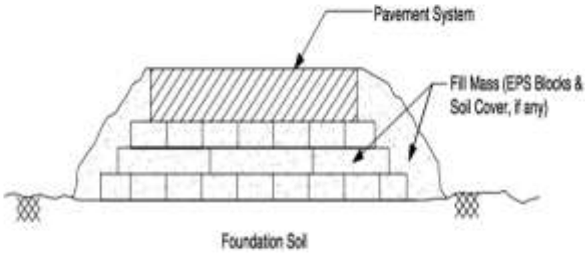

Fig.1 Major components of an EPS block embankment

These include the foundation soil, proposed fill mass, and the pavement system. The foundation soil is placed prior to the fill mass, and can be subject to ground improvement techniques. The proposed fill mass consists of EPS blocks, and, sometimes, it also consists of a layer of soil cover that sits between the bottom of the EPS blocks and the foundation soil. This soil may also be placed at the sides of the embankment depending on whether the embankment is trapezoidal or vertical. Finally, the pavement system is constructed atop the EPS mass.

A Load Distribution Slab can be constructed as part of the subgrade to reduce the stresses induced by vehicles to acceptable levels, or to reduce the thickness of the embankment, and, consequently, the cost of the pavement structure. It is typically used in the construction of high-volume traffic highways, and the construction of highways typically trafficked by heavy vehicles. Its use is dictated by certain factors; these include cost, which typically accounts for 20–30% of the project cost; the risks associated with sliding during seismic events; the ponding of water on the slab inside the pavement system; and the increased risk of differential icing and solar heating. There are several recommendations that should be followed during the design of a pavement with regards to its composition

Firstly, a minimum of two layers of EPS blocks should be provided so that blocks do not move during service, a scenario in which the pavement could fail, and, secondly, the overall minimum depth of the EPS fill mass should be 1.2 m so that the risk of differential icing is minimized.

IV. CONCLUSIONS

1. The extremely minor settlement leads to low maintenance costs.

2. The EPS is an elasto-plastic hardening material which also softens stiffness wise under increasing confining pressure.

3. As the cost of the Geo-foam is less as compared to soil and also it is 100 times lighter than soil therefore Geo-foam is widely used in the world.

4. Also it is much lighter than the soil or subgrade materials it is accepted worldwide.

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