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Improving the characteristics of expansive soils by using geofoam technique

Améliorer les caractéristiques des sols gonflants en utilisant la technique de Geofoam

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ABSTRACT: Structures constructed on swelling soil may encounter many engineering problems due to high swelling pressure. This study is dedicated to investigate the effect of using XPS- Geofoam sheets on Swelling Soil. To improve the swelling pressure, oedometer tests were carried out. The Geofoam added was 10, 20, and 30% of the soil sample thickness when tested in the big ring while in the small ring tests were carried out with 20% Sand, 20% XPS- Geofoam, 5% Sand + 5% XPS and 10% Sand + 10% XPS of the soil sample thickness). Bentonite was used to represent the swelling soil in the area of Tamiya in Fayoum city, Egypt. The results obtained from using XPS, showed that adding 30% XPS decreased swelling pressure by 57%. On the other hand, using XPS sheets with a sand layer, showed that adding 10% XPS and 10% sand decreased significantly the swelling pressure by 76%. It was then concluded that 10% XPS and 10% sand is the best addition to improve the ratio of swelling pressure of swelling soils. The results from this study may help to further improve other properties of swelling soil.

RÉSUMÉ : Les structures construites sur un sol gonflant peuvent rencontrer de nombreux problèmes techniques tels qu'une pression de gonflement élevée. Cette étude est consacrée à étudier l'effet de l'utilisation de Geofoam sur le sol gonflant. Pour améliorer la pression de gonflement, des essais œdométriques ont été abordés. L'ajout de Geofoam correspond aux pourcentages proportionnels de 10, 20 et 30% de l'épaisseur du sol dans un grand anneau tandis que l'ajout dans le petit anneau est de (20% sable, 20% XPS, 5% sable + 5% XPS et 10% sable + 10% XPS par épaisseur du sol). La bentonite est la représentative de sol gonflant préparée dans la région de Tamiya dans la ville de Fayoum en Égypte. Pour XPS, les résultats ont montré que l'ajout de 30% de XPS diminuait la pression de gonflement de 57%. Pour XPS & Sable, les résultats ont montré que l'ajout de 10% de XPS et de 10% de sable diminuait considérablement la pression de gonflement de 76%, 10% de XPS et 10% de sable était le meilleur ajout pour améliorer le rapport de pression de gonflement du sol gonflant. Les résultats de cette étude peuvent aider les chercheurs à améliorer d'avantage les propriétés de sol gonflant.

KEYWORDS: swelling soil, bentonite, swelling pressure, XPS Geofoam, oedometer.

1 INTRODUCTION.

Expansive soils in many parts of Fayoum Oasis pose a significant hazard to foundations of light buildings. This is well presented in Tamiya area, where the design structures on swelling soil cause many problems due to high swelling pressure. Expansive soils are unsaturated soils that exhibit vertical swelling pressures and strains upon inundation with water. These volumetric changes cause severe damage to structures constructed on them and economic losses which represents a challenge.

Potentially expansive soils can typically be recognized in the laboratory by their plastic properties. Inorganic clays of high plasticity, generally are those with liquid limits exceeding 70 percent and plasticity index over 30 (Abdelrahman, G. E, 2004), usually have a high swelling capacity.

Geofoam is either the 1950 BASF expanded polystyrene, EPS, or extruded polystyrene, XPS. It is a lightweight material having high strength and stiffness to weight ratio (Refsdal; Duskov; Skuggedal and Aaboe; Frydenlund; and McDonald and Brown). Frydenlund suggested the 1972 EPS geofoam's was initially used to control settlement as a corrective measure for the Flom Bridge in Norway. Hillmann assumed Geofoam's first usage in Germany in 1995 was to reduce the differential settlement of a bridge. Malaysia's first application of EPS as lightweight fill material was in 1992, by Mohamad, E.

The paper in hand is to examine the effect of the addition of XPS Geofoam on the mechanical behavior of the swelling soil so as to obtain its swelling pressure reduction, S.P.R.

2 MATERIALS AND TESTING METHOD

This part includes the properties of the swelling soil (bentonite), the XPS- Geofoam's used as a sheet layer to improve the swelling soil and the sand soil as percentage of the Geofoam thickness. The tests were performed on the swelling soil before and after adding Geofoam with and without sand layer in order to measure their effect on the swelling pressure.

2.1 *Materials:*

A detailed description is given of the properties of the materials used in this study i.e. the swelling soil (bentonite), the sand and the XPS- Geofoam.

2.1.1 *Bentonite:*

To simulate Tamiya soil located at Fayoum city, which consists of extended hard swelling soil, bentonite yellow powder was used as the swelling soil due to its similar properties. In order to obtain the sample, powder was mixed with 20% water content. The oedometer apparatus was used to measure the swelling pressure. Atterberg limit tests, compaction test, specific gravity test and free swell test, were conducted. Table 1 presents a summary of the physical properties of the bentonite sample.

Table-1. Physical properties of bentonite sample

Properties	Values
Liquid Limit, L.L (%)	366
Plastic Limit, P.L (%)	66
Plasticity Index (%)	300
Specific Gravity (Gs)	2.63
Free Swelling (%)	660
Water Content, W.C (%)	20

2.1.2 *Geofoam:*

Geofoam is defined as a block or of planar rigid cellular foamed polymeric material used in geotechnical engineering applications. Referring to ASTM (C 578) the Geofoam is classified into 12 types having variable physical properties. Their densities range from 12 kg/m^3 to 48 kg/m^3. The geofoam represents about 1% of the soil density for the lower geofoam densities. There are two types of Geofoam: expanded polystyrene EPS Geofoam and extruded polystyrene XPS Geofoam depending on the manufacturing process. XPS Geofoam sheet was used in this study with density 32kg/m^3 and compressive strength 3kg/cm^2.

2.1.3 *Sand:*

Fine sand (0.075 – 0.425 mm) to medium sand (0.425 – 2.36 mm) was used as a sand layer with Geofoam. Sand properties were determined by performing some tests in the laboratory such as sieve analysis test, compaction test and specific gravity test. The summary of the sand properties is shown in Table 2.

Table 2. Physical properties of the sand sample

Properties	Values
Specific Gravity (Gs)	2.65
Max Dry Density (t/m^3)	1.89
O.M.C (%)	11.75
Voids ratio at the maximum dry density	0.40
Degree of saturation at maximum dry density (%)	78
Air content at maximum dry density (%)	6.29
The effective diameter (mm)	0.30
Uniformity Coefficient (CU)	2.67
Coefficient of Curvature (CC)	1.13
Fine in a sample (%)	1.04

2.2 *Testing Method:*

This part presents a detailed description of tests curried out in the laboratory on swelling soil before and after adding Geofoam.

2.2.1 *Mechanical properties tests:*

In order to determine the swelling properties of the soil with and without Geofoam, the oedometer with modified ring is used. The ring has been used with a diameter 100 mm and a height of 60 mm. The change in the dimension of the ring aims at studying the effect of increasing the surface area of the swelling clay. Figure 1 shows the modified oedometer and Figure 2 shows the sketch of specimen in modified Oedometer when using swelling soil with Geofoam.

Figure 1. Modified Oedometer

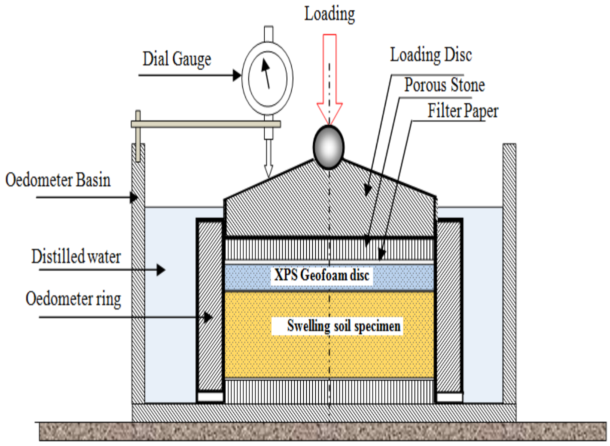

Figure 2. sketch of specimen in Oedometer

2.2 *Preparing Oedometer Samples with Different sizes:*

Oedometer tests are performed by applying different loads to a soil sample and measuring the deformation response. The results from these tests are used to control the swelling pressure.

The loading frame is modified to fit the ring dimensions. The change in the dimension of the ring aims to study the effect of size on the swelling characteristics of soil.

Table 3 shows the present dimensions of the oedometer ring.

Table 3. presents different dimensions of the ring of the Oedometer test.

Dimensions	Values	units
Oedometer Internal Ring Diameter	100	mm
Oedometer Ring Height	100	mm
Prepared sample diameter	100	mm
Prepared sample Height	60	mm

3 RESULTS AND DISCUSSION

3.1 *Testing using XPS Geofoam:*

In order to reduce the swelling pressure using XPS Geofoam, test results showed that increasing Geofoam layer thickness as a percentage of soil layer decreases the swelling pressure as shown in Figure 3. Table 4 presents a summary of all of the swelling pressure results and percent of reduction.

Table 4. Presents of Swelling Pressure results for modified Sample Diameter when using geofoam

Sample composition	Swelling Pressure (kg/cm^2)
Natural Soil "Swelling Soil"	1.72
Swelling Soil + 10% XPS	1.44
Swelling Soil + 20% XPS	1.10
Swelling Soil + 30% XPS	0.58

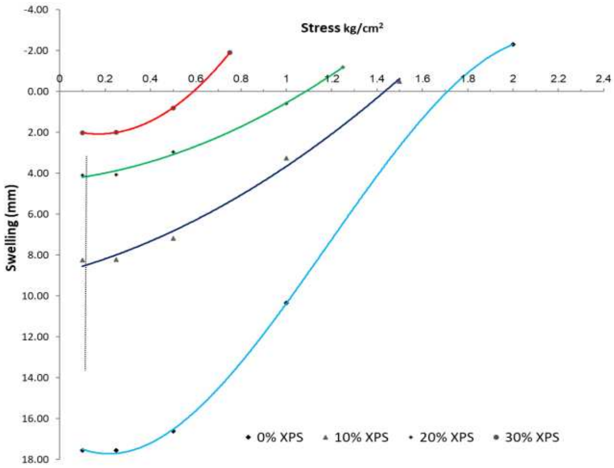

Figure 3. Effect of adding different percentages of Geofoam (XPS) on Swelling Pressure

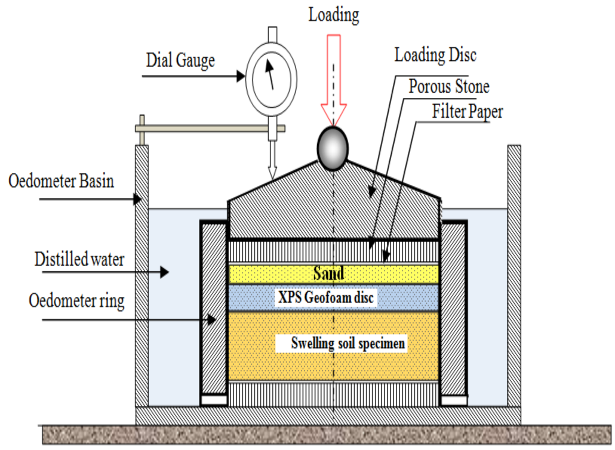

Figure 4. sketch of the specimen in modified Oedometer when using geofoam and sand

Adding XPS Geofoam layer on swelling soil decreases the axial heave and axial free swell as shown in table 5.

Table 5. Present axial free swell when using geofoam

Prepared Sample	Axial Heave (mm)	Axial Free Swell (%)
Natural Soil "Swelling Soil"	17	28.33
Swelling Soil + 10% XPS	8.50	14.17
Swelling Soil + 20% XPS	4.00	6.67
Swelling Soil + 30% XPS	2.00	3.33

From the results, it can be noticed that the maximum axial heave is 17mm when using natural soil. Thus, the minimum heave was 2mm when using swelling soil with 30% geofoam. Besides, the heave for 10% and 20% geofoam were 8.50mm and 4.00mm, respectively. In addition, it was concluded that the rate of percentage reduction of heave decreases with the increase of Geofoam thickness.

3.1 *Testing using XPS Geofoam and Sand layer:*

Figure 4 shows the sketch of the specimen in a modified Oedometer ring when using swelling soil with geofoam and sand. In this case, a layer of sand was used in addition to the Geofoam layer to study the extent of the effect on soil swelling pressure.

The test results for adding a sand layer on Geofoam (XPS), over the swelling soil in a modified oedometer diameter is shown in Figure 5.

Meanwhile, Table 6 presents a summary of all of the swelling pressure results and percent of reduction. Table 7 presents axial heave and axial free swell.

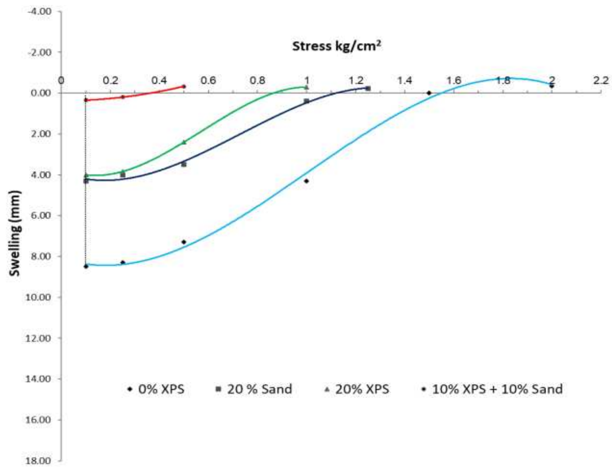

Figure 5. Effect of adding different percentages of Geofoam (XPS) and sand on Swelling Pressure

Table 6. Presents of Swelling Pressure Results for modified Oedometer Diameter when using geofoam and sand

Sample composition	Swelling Pressure (kg/cm^2)
Natural Soil "Swelling Soil"	1.55
Swelling Soil + 20% Sand	1.11
Swelling Soil + 20% Geofoam	0.88
Swelling Soil + 10% Geofoam + 10% Sand	0.37

Table 7. Present axial free swell when using geofoam and sand

Prepared Sample	Axial Heave (mm)	Axial Free Swell (%)
Natural Soil "Swelling Soil"	8.50	28.33
Swelling Soil + 20% Sand	4.40	14.17
Swelling Soil + 20% Geofoam	4.00	13.33
Swelling Soil + 10% Geofoam + 10% Sand	0.40	1.33

From Figure 5 and Table 7 it can be noticed that the maximum axial heave is 8.50mm when using swelling soil. But, the minimum heave was 0.40mm when using swelling soil with 10% geofoam and 10% sand. Whereas, the heave for 20% sand and 20% geofoam were 4.40mm and 4.00mm, respectively.

Table 8 and Figure 6 present swelling pressure reduction (S.P.R) of swelling soil in a modified diameter oedometer ring when using geofoam only.

Table 8. Presents of Swelling Pressure Reduction for modified Diameter Oedometer Ring when using geofoam only

Sample composition	S.P.R(%)
Natural Soil "Swelling Soil"	------
Swelling Soil + 10% XPS	16.28
Swelling Soil + 20% XPS	36.05
Swelling Soil + 30% XPS	66.28

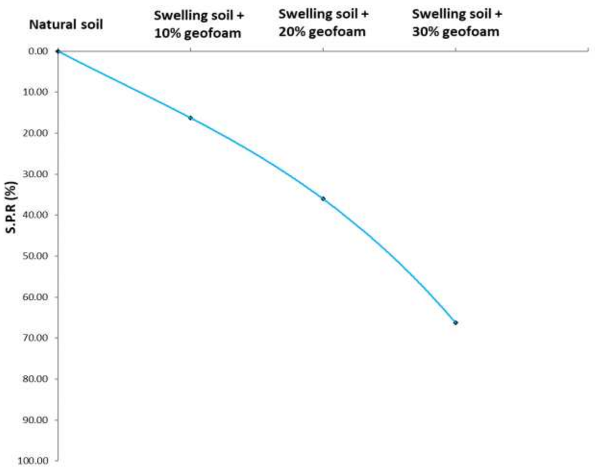

Figure 6. Presents Swelling Pressure Reduction (S.P.R) of swelling soil in the modified Diameter Oedometer Ring when using geofoam only

It was found that 30% Geofoam is the best material to improve the Swelling Pressure of swelling soil for in large diameter oedometer ring.

Table 9 and Figure 7 present swelling pressure reduction (S.P.R) of swelling soil for in a modified diameter oedometer ring when using geofoam and sand.

Table 9. Presents of swelling pressure reduction for modified diameter oedometer ring when using geofoam and sand

Sample composition	S.P.R(%)
Natural Soil "Swelling Soil"	------
Swelling Soil + 20% Sand	28.39
Swelling Soil + 20% Geofoam	43.23
Swelling Soil + 10% Geofoam + 10% Sand	76.13

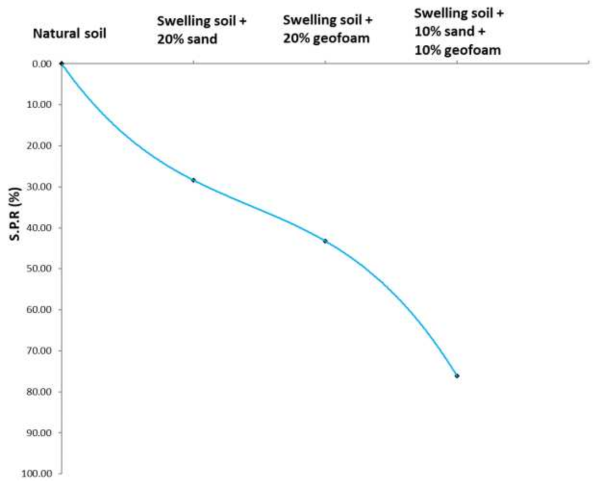

Figure 7. Present Swelling Pressure Reduction (S.P.R) of swelling soil for in modified diameter oedometer ring when using geofoam and sand

It was found that 10% Geofoam + 10% Sand give the best results to minimize the swelling pressure in case of testing the swelling soil using the oedometer conventional sample diameter.

Preferably using 10% Geofoam + 10% Sand to improve the swelling pressure besides it is more economic than using 20% or 30% Geofoam.

4 CONCLUSIONS

In order to mitigate the vertical swelling, extruded polystyrene XPS geofoam and sand were added on swelling soil by using a modified ring. The percentage in Case 1 (10% XPS, 20% XPS, and 30% XPS of the thickness of soil) and in Case 2 (20% XPS, 20% Sand, 5% XPS & 5% Sand, and 10% XPS & 10% Sand of the thickness of soil) were used in the aim to reduce the ratio of swelling pressure.
The following results can be concluded:

- Using Geofoam Material as a sheet is effective to decrease swelling pressure, and the free swell of swelling soil.
- Increasing Geofoam thickness shows more improvement in swelling soil properties.
- XPS Geofoam with 20% of soil height has reduced the swelling pressure by about 43%, while the sand with the same percentage has minimized the swelling pressure by only 28%.
- 10% XPS Geofoam + 10% Sand is the most effective and economical inclusion to minimize the swelling potential of expansive soil, the swelling pressure reduced by about 76 %.
- In the field, the thickness of XPS Geofoam should be related to the expected thickness of the expansive soil active zone.
- Using XPS Geofoam has the advantage over Sand to act as a barrier for seepage of water to the expansive soil.

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