New Replacement Formations on Expansive Soils Using Recycled EPS Beads

Remplacement sur les sols expansifs en utilisant des perles EPS

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ABSTRACT: One of the main problems encountered in constructing foundations on clays is volume change independent of loading caused by swelling of the soil. When the swelling is obstructed, large swelling pressures arise and that can cause damage to structures. This study examines the role of recycled expanded polystyrene (EPS) beads which is mixing with replaced soil in accommodating soil expansion and hence reducing swelling pressures on structures foundation. Laboratory tests are presented on the formation of expansive soil using Bentonite clay. Laboratory model was used to measure the decrease of the swelling, using replacement material which formed of blending sandy soil with recycled (Expanded Poly-Styrene) EPS-beads. The effect of different compositions and different ratios between EPS-beads, and sand as a replacement soil on the expansive soil (Bentonite powder, PI=95.4%, and G_s=2.55) which had free swell equal to 96.7% were studied. Results so far show that the EPS beads mixed with sand significantly reduces the volumetric change of the expansive soils. The parametric study showed that increasing EPS beads percentage in the replacement soil decreases bearing capacity and dry density γ_d, and increases OMC while for the Bentonite free swell decreases and settlement increases. Increasing footing breadth increases swelling and settlement. With increasing replacement layer thickness and beads density, the swelling and settlement decrease.

RÉSUMÉ : Un des principaux problèmes rencontrés dans la construction des fondations sur des argiles est le changement de volume indépendant de chargement provoqué par le gonflement du sol. Lorsque le gonflement est obstrué, les grandes pressions de gonflement surviennent et peuvent causer des dommages aux structures. Cette étude examine le rôle du polystyrène expansé recyclé (EPS) des perles qui est le mélange avec le sol remplacé en accueillant l'expansion du sol et donc la réduction des pressions sur le gonflement de fondation des structures. Des essais en laboratoire sont présentés sur la formation des sols expansifs avec de l'argile bentonite. Modèle de laboratoire a été utilisé pour mesurer la diminution de l'enflure, l'utilisation du matériel de remplacement qui a formé de l'assemblage avec des sols sablonneux recyclés (Expanded Poly-Styrène) EPS-perles. L'effet de différentes compositions et différents ratios entre les EPS-perles, et le sable du sol comme un remplacement sur le sol expansive (bentonite en poudre, PI = 95,4%, et GS = 2,55), qui avait sans égale gonfler à 96,7% ont été étudiés. Les résultats obtenus jusqu'ici montrent que les perles EPS mélangés avec du sable réduit considérablement le changement volumétrique des sols gonflants. L'étude paramétrique a montré que l'augmentation des EPS perles de pourcentage dans le sol de remplacement diminue la capacité portante et la densité sèche γd, et augmente OMC alors que pour la bentonite diminue la houle libres et augmente de règlement. L'augmentation de la largeur de fondation augmente l'enflure et de règlement. Avec une épaisseur de remplacement couche augmente et la densité des perles, l'enflure et la diminution de règlement.

KEYWORDS: Recycled expanded polystyrene, beads, expansive soils, swelling, sand, Bentonite.

1 INTRODUCTION

Problems related to expansive soils exist worldwide. Many buildings, light structures, highways, railways, airport slabs, water channels, pipelines, earth retaining walls, dams and bridges are damaged by expansive soils. One of the main problems encountered in constructing foundations on clays is volume change independent of loading caused by swelling and shrinkage of the soil. When the swelling is obstructed, large swelling pressures arise and that can cause damage to structures. There are many conventional treatments available for control of these problems. These include soil replacement with compaction control, moisture control, surcharge loading and thermal methods (Chen, 1988; Nelson and Miller, 1992). However, these methods have their own limitations with regards to their effectiveness and costs.

Expanded polystyrene (EPS) is a cellular polymeric material commonly used as a packaging medium for a variety of consumer appliances and electronic equipment. It is a lightweight material with a very low density (0.10 -0.20 kN/m^3) .Due to its convenience and low cost, EPS usage is increasing in the consumer market. That in turn results in a continuing increase in the availability of waste EPS products. Because of their lightweight and bulk nature, the waste EPS products occupy a substantial area of the landfill. Unlike other organic materials, EPS is not decomposable or biodegradable. Because of these problems, the European Union has restricted the disposal of EPS into landfills and set recycling targets (PPW Directive, 2005; UNEP, 2000). These impositions have forced manufactures to look for alternative reuse and recycle options. There are many recycling options available like thermal and compression methods. However, possible contamination of the products while in transportation and their limited usage make some of the products unsuitable for recycling. Hence there is a need to try other innovative applications for the bulk utilisation of waste EPS.

Since its inception, EPS composite soil has attracted the interests of many researchers. A few papers have been published regarding using EPS composite soil in reducing swelling pressures on structures foundation and behind retaining walls. Illuri & Nataatmadja (2007) and Illuri (2007) investigated the use of recycled EPS as a partial soil replacement and swell modifier for expansive soils. Artificially prepared expansive soils were manufactured in the laboratory by mixing fine sand with sodium bentonite of various proportions. Recycled EPS beads were mixed with these soils and the effects of varying the amount were investigated. The proposed soil improvement technique is thus showing great promise in sustainable construction. Nataatmadja and Illuri (2009) prepared an artificially reconstituted soils of different plasticity values by mixing fine sand and sodium bentonite. It has been found that the addition of EPS granules into these soils results in light-weight backfill materials, suitable for reducing swelling pressure behind domestic retaining walls.

The current research was conducted to investigate the recyclability of EPS packaging products in reducing swelling pressures on structures foundation by using recycled EPS beads as a mechanical admixer in replaced soils at their optimum-moisture contents. Mixing recycled EPS beads with soil replacement is introduced an environment-friendly geomaterials. The applications of recycled EPS as a swell shrink modifier as well as desiccation controller of expansive soils were considered in this study. The quantitative evaluation also whether recycled EPS beads provides significant benefits for use in soil replacement to reduce swelling pressures was done through an extensive experimental program.

2 MATERIALS

2.1 *Replacement Soil*

The replacement soil was sub-angular silica sand and classified according to the unified soil classification (USCS) system as a poorly-graded clean medium to fine sand (SP) with coefficient of curvature (C_c)= 1.73, coefficient of uniformity (C_u)=3.6 , max dry density (γ_{dmax}=19.2kN/m^3) and optimum moisture content (OMC)= 9%.

2.2 *Expansive Soil*

The expansive soil was a sodium Bentonite. The physical properties for the used Bentonite are summarized in Table 1.

Table 1. Physical properties of the used Bentonite

Liquid Limit (LL) %	143
Plastic Limit (PL)%	47.6
Plasticity Index (PI) %	95.4
Free Swell (FS)%	96.7
Specific Gravity (Gs)	2.55
Max Dry Density (γ_{dmax}) kN/m^3	14
Optimum Moisture Content (OMC) %	24

2.3 *Recycled EPS Beads*

For the present study, waste EPS beads were collected with three different beads densities and particle sizes. Photo 1 shows the beads's size compared to sand particles. The beads densities and particle sizes are summarized in Table 2.

Table 2. Properties of EPS Beads

EPS Beads	400	500	600
Density (KN/m^3)	0.10	0.16	0.20
Particle Size (mm)	5-6	4-5	1-3

3 COMPACTION CHARACTERISTICS OF SAND EPS MIX

To study the compaction characteristics, standard Proctor compaction tests were performed on a number of sand EPS mixes. With the addition of EPS beads, the density of the resulting composite is much lower than the original soils.

The EPS beads were added to the moist soil at a certain percentage of the soil's dry mass. Compaction tests of the sand with EPS (SWEPS) composite were subsequently carried out immediately after mixing the sand and EPS.

Compaction curves for mixes of sand with different percentages of EPS beads are shown in Figure 1. From this figure, it can be observed that with the addition of EPS beads the dry density of the resulting mix varies considerably, it decrease with increasing the beads content but there is no significant variation in the optimum moisture content. This can be attributed to the low bulk density and very low moisture absorbency of the EPS beads. Since the beads are bulk in volume but very low in mass, the mass of the soil-EPS composite is generally controlled by the mass of the soil in the mix. Furthermore, as the moisture is held within the soil particles, the optimum moisture content of the mix is controlled by the optimum moisture content of the sand. From previous stud it is found that the increase of EPS-beads density increases the maximum dry density at the same beads ratio, Abdelrahman,(2009)

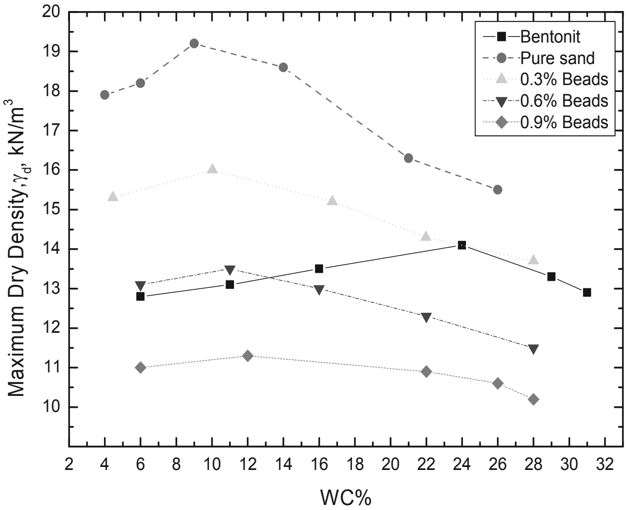

Figure 1. Compaction curves for mixes with sand and EPS contents at density of t EPS beads = 0.16kN/m^3

4 EXPERIMENTAL WORK

4.1 *Test Model*

Experimental model consists of cylindrical soil sample container with diameter is 15 cm and height = 18cm , two vertical dial gages to measure the settlement and swelling , circular footing with different diameters. Vertical stress equal to 30 kN/m^2 was applied on the footing which represented the applied stress of three stories building.

4.2 *Test Program*

A series of tests were performed on circular footing with different diameters rested on sand EPS mix replacement layer with different ratios of EPS beads and layer thickness above Bentonite layer both sand EPS mix replacement layer and Bentonite layer were compacted at their optimum moisture content (OMC). Mixing EPS beads with sand replacement layer leads to settlement under loading condition before adding water to the swelling layer cause EPS beads are compressible material and this explain why swelling and settlement are discussed together in the test results. The studied parameters are summarized in Table 3.

Table 3. The studied parameters

Diameter of footing (d) cm	5, 7, 10, and 12
Beads Density (γ_B) kN/m^3	0.1, 0.16 and 0.2
Beads Content (B) %	0, 0.3, 0.6, 0.9, and 1.2
Normalized Replacement Thickness (t_r/t_s) %	0, 12.5, 20, 25 and 33

4.3 Test Results and Analysis

4.3.1 Test results presentation

Swelling and settlement on surface soil and circular footing are presented in a set of curves with the different studied parameters.

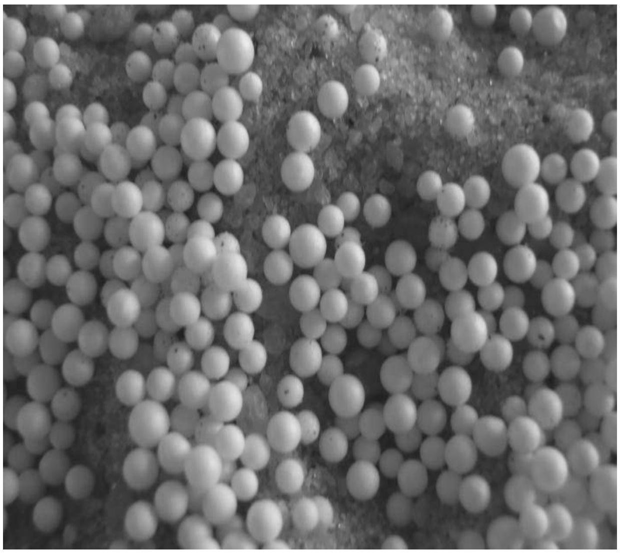

Photo 1. EPS beads mixed with sand

4.3.2 Effect of footing diameter (d) cm

Increasing rigid footing breadth causes increasing in settlement in soil. In case of swelling soil increasing footing breadth also causes increasing in swelling deformation even with existing of beads. But EPS beads may be leads to decrease the percent of the swelling and the settlement deformation as shown in Figure 2.

4.3.3 Effect of beads density (γ_B) kN/m^3

EPS density appears to be the main parameter that correlates with most of its mechanical properties. Compression strength, shear strength, tension strength, flexural strength, stiffness, creep behavior and other mechanical properties depend on the density. Higher density leads to improve its effect. As shown in Figure 3 increase beads density (γ_B) kN/m^3 leads to decrease each of the swelling and settlement on surface soil and circular footing.

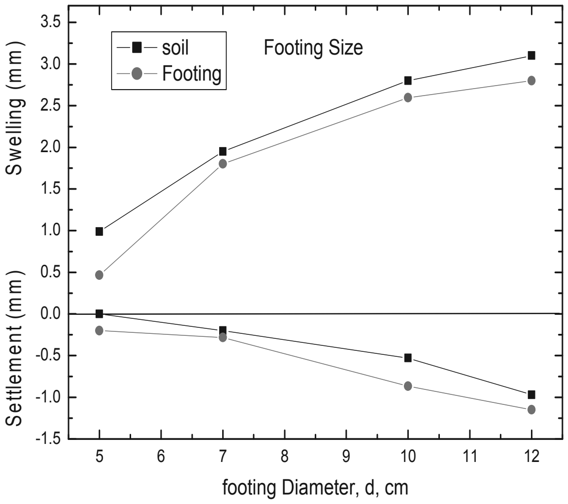

Figure 2.Relationship between increasing footing diameter (d) cm on settlement and swelling for soil and footing

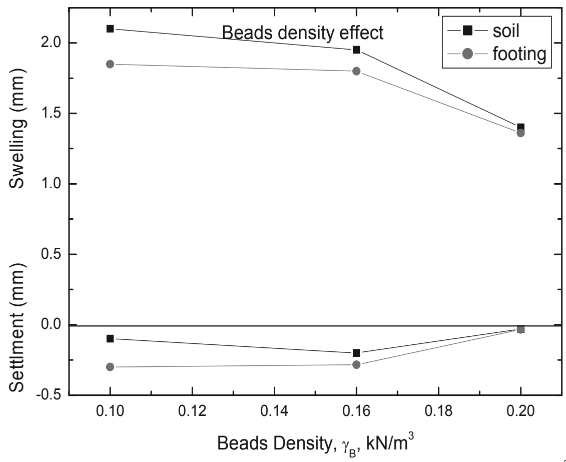

Figure 3.Relationship between increasing beads density (γ_B) kN/m^{3}on settlement and swelling for soil and footing

4.3.4 Effect of beads content (B) %

The EPS beads are highly compressible, with soft elastic nature, having only about 1% of the density of a typical soil.

As shown in Figure 4 increase beads content (B) % leads to decrease swelling pressure on the footing and decreases also the swelling settlement. EPS beads particles swelling energy absorption because of its compressible nature.

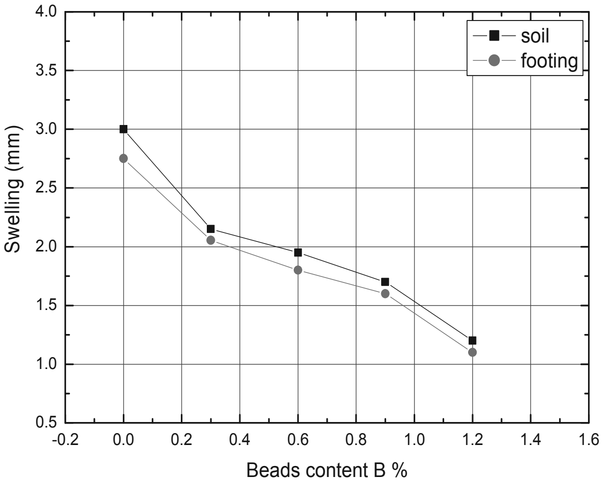

Figure 4.Relationship between increasing beads content (B) % on swelling for soil and footing

4.3.5 Effect of normalized replacement thickness (t_r/t_s) %

Replacement layer thinness t_r was chosen as a percentage of soil layer thickness t_s .As shown in Figure 5 increasing the replaced layer improve the resistance to the swelling pressure and decrease the swelling deformation. But economic point of view also is important taking in to account the swelling layer thickness. Increasing the normalized replacement thickness (t_r/t_s) % leads to decrease each of the swelling and settlement on surface soil and circular footing.

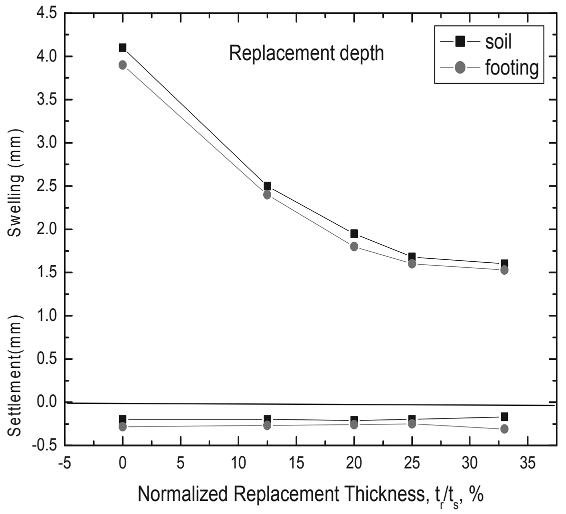

Figure 5.Relationship between increasing normalized replacement thickness (t_r/t_s) % on settlement and swelling for soil and footing

4.3.6 Effect of normalized replacement thickness (t_r/t_s) % at beads content (B) = 0.6%, footing diameter (d) = 7cm and of beads density (γ_B) = 0.16 kN/m^3

Figure 6 shows the detailed measurments for footing and replaced soil surrounded the footing during 24 hours. It obvious that at replaced soil with sand and EPS beads decreased the swilling more than 60% , also no big difference in settlement before adding water between different replacement ratios. Adding water after one hour to the model to saturate the soil caused swelling which increases with time. Increasing replacement layer thickness decreases the swelling.

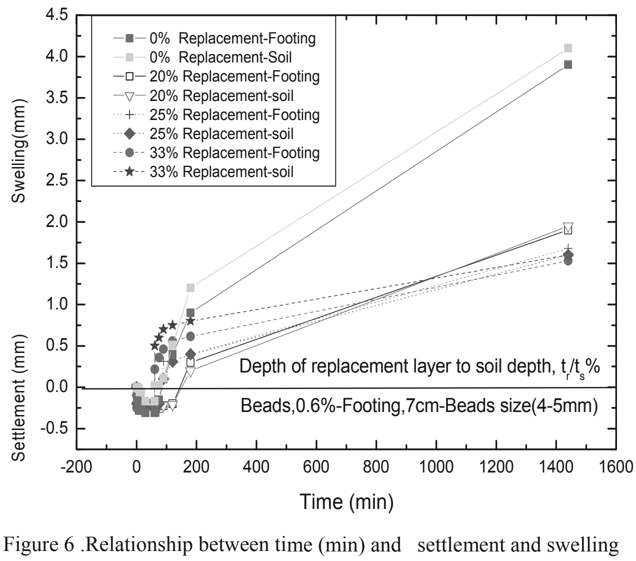

Figure 6 .Relationship between time (min) and settlement and swelling in (mm) for different normalized replacement thickness (t_r/t_s) % at beads content (B) = 0.6%, footing diameter (d) = 7cm and of beads density (γ_B) = 0.16 kN/m^3

5 CONCLUSIONS

The results of a study on the potential use of sand –EPS mix as soil replacement layer to reduce swelling of expansive soils below structure foundation have been presented. Different parameters affecting the swelling of structure foundation have been studied.

These parameters included the effect of footing diameter (d) cm where increasing rigid footing breadth caused increasing in settlement in soil but the presence of EPS beads lead to decrease the percent of the swelling and the settlement deformation. The second parameter was the effect of beads density (γ_B) kN/m^3 where increase beads density lead to decrease each of the swelling and settlement on surface soil and circular footing. The third parameter the effect of beads content in the sand replacement layer (B)% which was the most important parameter in this study where increasing this content lead to significant decrease in swelling. The fourth parameter was the effect of normalized replacement thickness (t_r/t_s) % where increasing the replaced layer improved the resistance to the swelling pressure and decrease the swelling deformation.

The innovative application of the recycled EPS beads mixed with sand replacement layer at optimum moisture content, so as to make a beneficial use of the waste EPS products, will offer a sustainable solution for both the housing and EPS industries.

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