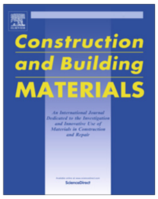
Construction and Building Materials 113 (2016) 773–782

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat



An investigation on the geotechnical properties of sand–EPS mixture using large oedometer apparatus

Reza Jamshidi Chenari [a,*], Mehran Karimpour Fard [b], Sabina Pourghaffar Maghfarati [c], Faranak Pishgar [d], Sandro Lemos Machado [e]

[a] *Department of Civil Engineering, Faculty of Engineering, The University of Guilan, P.O. 3756, Rasht, Guilan, Iran*
[b] *Department of Civil Engineering, Faculty of Engineering, The University of Guilan, Iran*
[c] *Azad University, Iran*
[d] *Islamic Azad University, Fouman and Shaft Branch, Fouman, Guilan, Iran*
[e] *Universidade Federal da Bahia, Brazil*

HIGHLIGHTS

- Deformation and constrained modulus of EPS–sand mixture was investigated.
- Permeability and hydraulic conductivity of EPS–sand mixture was obtained.
- A new fabricated large size oedometer apparatus was designed and tested.
- A K_0 coefficient measurement was designed through a ring pressure cell inside the large oedometer apparatus.
- Unconstrained deformation modulus to be back-calculated from oedometeric gauge readings was for the first time calculated.

ARTICLE INFO

Article history:
Received 16 July 2015
Received in revised form 1 March 2016
Accepted 17 March 2016
Available online 25 March 2016

Keywords:
Expanded poly styrene (EPS)
Permeability
Deformation and strength characteristics
Large scale oedometer

ABSTRACT

The applicability of Expanded PolyStyrene (EPS) beads mixed with sand in five different contents was investigated for use in geotechnical engineering applications utilizing a newly designed and fabricated large scale oedometer apparatus. Permeability, coefficient of earth pressure “at rest” and the volume compressibility coefficient were measured and calculated for different EPS beads contents. Consolidation and permeability tests were conducted under different overburden pressures. The main findings of major recent studies were compared with current study and verification of new results was undertaken. Permeability, coefficient of earth pressure “at rest” and the volume compression coefficient along with some important deformation and strength characteristics parameters namely, the internal friction angle, constraint modulus and the drained 3-D elasticity modulus were investigated. The Results revealed that permeability, internal friction angle, constraint modulus and 3-D Young modulus decreases with inclusion content. However, the volume compressibility coefficient and the K_0 coefficient showed opposite trends. Predictive models were submitted in forms of Multi Linear Regression, MLR simulations and their performances were evaluated.

1. Introduction

There have been growing interest in the use of non-conventional as lightweight geo-materials, and their introduction has presented both opportunities and challenges to researchers and engineers worldwide. Attention is specifically needed to be drawn to the consideration of both the cost and environmental implications when any new material is introduced into construction. In recent decades, a successful conversion from academic excellence to commercial viability has occurred.

Lightweight fill materials have a wide range of civil engineering applications around the world. They may be used as fill over soft clay sites to prevent excessive settlement; as backfill for retaining and basement walls to reduce the horizontal driving forces; as fill material to increase factor of safety for slopes by reducing driving forces; as seismic buffers to alleviate seismic forces, and so forth. Various types of lightweight fills, such as Expanded PolyStyrene (EPS)-block geofoam, EPS beads, tire waste products like shredded

---

* Corresponding author.
E-mail addresses: Jamshidi_reza@guilan.ac.ir (R. Jamshidi Chenari), mehranfard@gmail.com (M. Karimpour Fard), sabinapurghaffar@yahoo.com (S. Pourghaffar Maghfarati), faranakpishgar@yahoo.com (F. Pishgar), smachado@ufba.br (S. Lemos Machado).

http://dx.doi.org/10.1016/j.conbuildmat.2016.03.083
0950-0618/

tires, tire chips and tire crumbs have been reported. Using such materials not only provides lightweight fill solution for civil engineering projects, but also helps to save the environment by recycling these materials instead of stockpiling them.

EPS-block geofoam gained popularity due to its wide application areas such as compressible inclusions [14,15,22], reduction of swelling pressure caused by expansive sub-soils ([6,16], fill materials in highway embankments [28] and remediation of sandy slopes [1,24]. In order to overcome shortcomings of EPS-block geofoam namely transportation issue, lack of formability to fill irregular volumes and compatibility with on-site soil, lightweight fill material composed of a mixture of EPS beads with soil and alternative additives is recommended [29–31,20,32,9,10,21,26,11].

Miao et al. [21] mixed dredged sand with EPS-beads and Portland cement. They conducted different geotechnical tests to investigate their potential use for mitigation of settlement problems associated with bridge approach embankments over soft soil. Padade and Mandal [25] proposed a geomaterial by blending fly ash instead of soil with EPS-beads and cement. Using compression tests they showed that the compressive strength of EPGM (Expanded Polystyrene-bead Geo-Material) increases considerably if cement-to-fly ash ratios of 10%, 15% and 20% are used. Some researchers mixed EPS particulates with sand to create a lightweight fill and measured the stress–strain characteristics of the modified soils in the laboratory using direct shear and triaxial compression tests [20,32,9,10,21,11]. Deng and Xiao [9,10] studied the stress–strain behavior of EPS–sand for a single type of EPS bead–sand mixture. They showed a systematic decrease in drained strength with increasing EPS content.

So far previous studies for lightweight geo-materials are mainly about the mechanical behaviors. When used in practical engineering, lightweight soil may undergo various hydraulic and seepage loads; so it is necessary to investigate its hydraulic properties along with the mechanical and stress–strain behavior. The main aim of this study is to conduct some large Oedometer tests on fine grained sand mixed with EPS beads with different weight contents to investigate its effect on mechanical and hydraulic properties of the proposed lightweight geo-material.

2. Experimental study

2.1. Materials

The experiments are carried out on “Chamkhaleh Sand”, supplied from Chamkhaleh Beach adjacent to Chamkhaleh River, located on SW of Caspian Sea. The particles are quartz–based with gray color and uniform particle distribution as shown in Fig. 1. The index properties of the used host sand are given in Table 1. The specific gravity was determined according to ASTM D 854. Maximum and minimum dry unit weights were determined based on ASTM D 4253 [4] and ASTM D 854 [5], respectively. It had a specific gravity of 2.63, a maximum dry unit weight of 16.1 kN/m^3 (i.e., minimum void ratio of 0.63) and a minimum dry unit weight of 14.2 kN/m^3 (i.e., maximum void ratio of 0.85). The particle size distribution of the sand is given in Fig. 2. The sand had a coefficient of uniformity of 1.54, a coefficient of curvature of 0.95, and was classified under the Unified Soil Classification System as SP (poorly graded sand) and under the AASHTO Soil Classification System as A-3. The friction angle of the sand was 38° when its relative density Dr was 60%.

The EPS beads used in this study is super light polymer foam, pre-puffed from polystyrene resin, provided by a local EPS block moulding company which had been manufacturing EPS geofoam blocks. The beads were white, even, and spherical, sizing between 2–7 mm (Fig. 3). The relevant index properties of EPS bead are presented in Table 1.

Determination of the unit weight and specific gravity of the EPS beads were conducted employing a procedure modified from comparable standard test method for fine aggregates (i.e., ASTM C128 [3]). Beads were placed into a 1-L hydrometer until the volume of the hydrometer was apparently occupied. Beads were placed into the hydrometer without noticeable compaction effort so as to reach a moderate compaction state. Unit weight of the beads is then easily calculated by scaling the net weight of beads, used to fill the bottle. The unit weight obtained for EPS beads was 0.08 kN/m^3. Specific gravity (Gs) of beads was also calculated by filling the voids between EPS beads with distilled water and then to calculate the net volume of beads and determine the specific gravity of beads, which was 0.013.

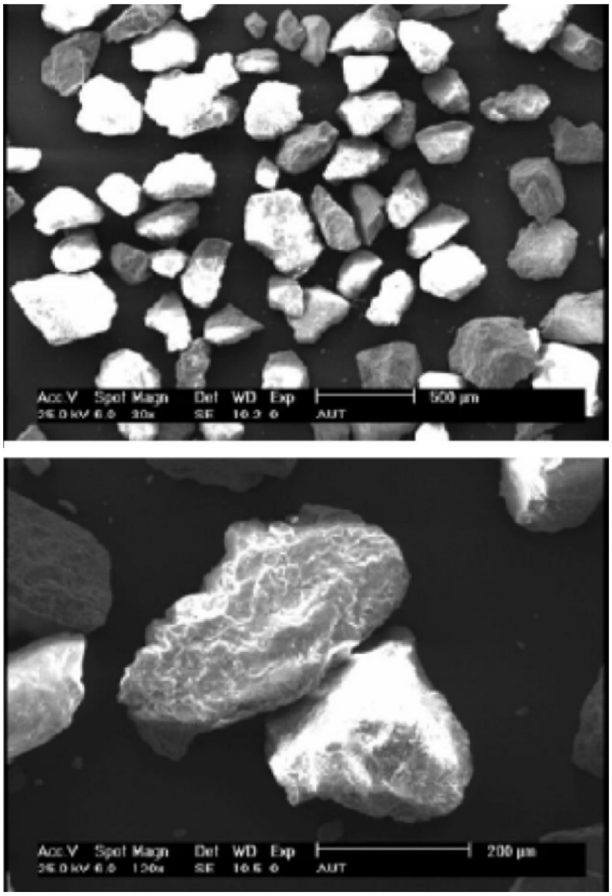


Fig. 1. Magnified photos of Chamkhaleh Sand [12].

2.2. Specimen preparation

EPS–sand specimens (Fig. 4) were formed by mixing EPS beads with sands at a dry mass ratio η of EPS beads over sands, which was thought as the most significant factor controlling the unit weight, mechanical and hydraulic behavior of the mixtures. Investigated ratios were 0.1%, 0.2%, 0.3%, 0.5% and 1% for EPS beads by weight. Sufficient water was added to the EPS–sand samples. The added water provided bonding between specifically the EPS beads and sand, which made it possible to mix without segregation. Initial water content was measured precisely to control the target dry density of prepared samples for test. For each designated mixing ratio, the mass-based proportions of sand, EPS bead were determined beforehand. The proportioned materials were mixed thoroughly until the mixtures were homogenous enough.

Material was molded into the chamber of oedometer apparatus at a designated weight and dry density of 14.6 kN/m^3. To reach the target dry density, a handy tamper was employed. It should be noted that the dry density was defined based on total solid constituents, namely EPS beads and sand particles. Some researchers try to maintain a constant skeletal or matrix dry density for sand portion [2], however authors believe that considering a constant skeletal relative density is a tricky situation which is strictly affected by compressibility of inclusions and needs precise estimate of sand portion volume. In real world applications, practitioners would rather to adopt a simple procedure based on either maintaining a constant total dry sand portion weight assumption [18] or adopting a constant overall bulk dry density which is the case in this study. Specifically, the target dry density of EPS–sand mixtures was achieved by quantifying the weight of proportioned EPS and sand to be placed within a volume (i.e., 57,000 cm^3). Compaction was completed in seven layers. A list of specimens and corresponding weight and volume ratios is provided in Table 2 for EPS beads mixed with sand. Totally 6 large Oedeometer tests were performed in this investigation. The first test was conducted on employed host sand. Each mixture was tested at three different overburden pressures, 160, 260 and 375 kPa. The volumetric ratio of EPS over the combination of EPS and sand in the mixture, χ, was calculated based on the mixing ratios and specific gravities of particles for each mixture, as presented in Eq. (1). If the EPS content increased above 1%, the EPS volumetric ratio exceeded 70%, which substantially led to reduced sand inter-particle interactions.

$$\chi = \frac{\frac{\eta}{G_{SEPS}}}{\frac{100}{G_{ss}} + \frac{\eta}{G_{sEPS}}} \tag{1}$$