Soil Dynamics and Earthquake Engineering 31 (2011) 1144–1153

Contents lists available at ScienceDirect

Soil Dynamics and Earthquake Engineering

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

A united deformation-strength framework for Lightweight Sand–EPS Beads Soil (LSES) under cyclic loading

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ARTICLE INFO

Article history:
Received 8 January 2009
Received in revised form
25 March 2011
Accepted 10 April 2011
Available online 30 April 2011

ABSTRACT

As a new artificial geo-material, lightweight soil is an ideal countermeasure to solve many geotechnical problems in soft ground by reducing upper load, and Lightweight Sand–EPS Beads Soil (briefly as LSES) is a typical representative. Generally used as backfill, which may bear earthquake loading or traffic loading, the behaviors of LSES under dynamic loading are worth to pay much attention on, though there are few relative studies about this at present. Based on laboratory cyclic triaxial test data presented in this study, a united framework is tried to set up, in which deformation and strength of LSES can be integrated by failure cycle number N_f that corresponds to the complete degradation of LSES structure. This framework describes both the development process of cyclic deformation and dynamic failure criteria in the state as the structure cannot afford further tension. Meanwhile, cyclic stress–strain relationships and Modulus Reduction Curves for LSES with different mixture ratios are also discussed. All distinct behaviors of LSES are considered to arise from its bond-dominated structure, which controls the two types of modulus reduction characteristics and brittle failure of LSES under cyclic loading.

1. Introduction

In the last decade, the infrastructure construction in China has made great advances; however, many kinds of geotechnical problems have turned up in coastal areas where various weak grounds spread widely, especially in projects such as highway, large bridge, giant dam, etc. These problems generally result from two reasons, which are overweight of upload and low bearing capacity of ground. While in practice engineers usually solve problems aiming at the latter. Due to the complexity and uncertainty, the efficiency of ground improving methods is doubtable. Lightweight geo-materials thus may be preferable choice. Expanded Polystyrene (EPS) blocks as the initiative lightweight geo-material are first successfully used in Norway, as backfill in an embankment on soft ground, effectively reducing the upload [1]. However, high price of EPS limits its extensive usage in engineering projects. Recently, a new type of lightweight geo-material has been developed, which is made by mixing some lightweight agents into artificially cemented soil. Two kinds of lightweight soil made by air foam and EPS beads are named foam-treated soil (FTS) and bead-treated soil (BTS), respectively [2]. In particular the geo-material mixed by EPS beads and artificially cemented sand is called lightweight sand–EPS beads soil (briefly as LSES). When made in field, the wet density of lightweight soil is in the range of 1.0–1.2 g/cm^3, while in laboratory, the corresponding range is wider, which is 0.7–1.3 g/cm^3. Therefore, the purpose of reduction of self-weight and applied forces induced by embankment on soft ground is easily achieved. Additionally, lightweight soil is also a good measure to deal with solid waste such as dredged slurry and used EPS package.

So far previous studies for lightweight geo-materials are mainly about the mechanical behaviors under static loading [3,4]. When used in practical engineering, lightweight soil may undergo various dynamic load induced by earthquake, vehicle, ocean wave, etc.; so it is necessary to investigate its behavior under cyclic loading. In general as for homogeneous soils such as sands or clays, it is well known that the deformation characteristics are nonlinear and shear modulus and damping ratio vary significantly with shear strain amplitude under cyclic loading [5–7]. However, lightweight soil is non-homogeneous, consisting of several mixtures with very different properties; so whether there are any differences in behavior of LSES under cyclic loading comparing to that of uniform sands or clays is worth to research. Based on laboratory test data, an effort is made to set up a united framework relating deformation to strength mechanics for LSES under cyclic loading in an experimental as well as mathematical way. Accordingly, factors affecting the model such as confining pressure, the proportion of cement and EPS beads, and failure criteria are also discussed.

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0267-7261/$ - see front matter
doi:10.1016/j.soildyn.2011.04.002