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Experimental study on the determination of small strain-shear modulus of loess soil

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KEYWORDS

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Abstract The primary aim of this study was to investigate the collapse potential of loess soil in Egypt, the factors affecting the dynamic properties of this soil and establish relationships between them. Whether engineered or natural, may exist in seismic zones; or may be subjected to small strain vibrations, therefore, there is a need to assess the wetting dynamic properties of collapsible soils.

A series of oedoemeter and resonant column tests were conducted to study the effect of applied pressure, void ratio, water content and silt content on the collapse potential (C_p), maximum shear modulus (G_{max}) and damping ratio (D_T) of the tested samples. The results indicate significant increase in the collapse potential and reduction in (G_{max}) with the increase of silt content. The results, also, indicate that the (C_p) is less for sample with higher initial relative densities and initial water content.

Test results also show that (G_{max}) increases with the increase of confining pressure and relative density. The change in damping properties is not significant under the effect of silt content and water content, and it reduces slightly with the increase of confining pressure and relative density. Empirical equations based on the results of the experimental work were proposed to predict (G_{max}) with respect to (C_p), voids ratio and applied pressure.

Introduction

Loess soils can be defined as the soil which can exhibit a large settlement with or without increase in the applied stress upon wetting. This volume change is usually associated with change in soil structure. Loess soil covers approximately 10% of the Earth's land mass [1].

In Egypt, recent extensions of urban communities towards the desert have exposed Egyptian geotechnical engineers to relatively new challenges, among which is dealing with loess soil.

Abbreviations: G_{max}, maximum shear modulus; D_T, damping ratio; C_p, collapse potential; τ_d, shear stress; σ_{vo}, normal stress; G_s, specific gravity; R_D, relative density; w_c; water content.

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Loess soils are observed in many areas in Egypt. Most of these areas are situated in the western desert which covers about 65% of the area of Egypt. From the previous studies, it can be concluded that most of the loess soils in Egypt were deposited in shallow water depths in a loose structure of high void ratio. Rivers, flood streams and rainfalls are responsible for these formations.

Detecting the dynamic settlement potential of this soil is misleading during site investigation due to cementation and negative pore pressures which causes high strength. The extent of the problem could be significant in regions where loess soils are widespread and the seismic activity is great and especially where the collapse has been triggered by rising ground water table.

Gibbs and Bara [2] studied a collapsible potential of loess soil which subjected to cyclic loading and their results show that 10% reduction in shear strength parameters (c and ϕ) is observed due to cyclic loading equivalent to a 0.39 g. Parkash and Puri [3] tested undisturbed samples of loess from Memphis (USA) under cyclic triaxial conditions. They observed that in these types of soils the development of large axial strain and pore pressure build-up go together. They also found that the number of cycles of loading required to induce liquefaction was large for the loessial silt soils compared to clean sands. This was explained by the presence of cohesion in the loessial soils which delayed the build-up of pore water pressures.

Bahatia and Quasts [4] performed a series of static and cyclic triaxial tests on fabricated and undisturbed samples under natural moisture content and saturated conditions to study the effect of soil structure on the static and cyclic behaviour of soils. The most recent material to be deposited in this area is the alluvium; these deposits then dried out and never again become saturated. They observed that the structure of collapsible soil helped to increase the resistance to deformations under both static and cyclic loading as long as the soil was tested under the natural moisture content. If the soil was saturated, the collapsible soil structure was broken down and the soil did not show any increased resistance to deformation but behave like any loose soil. It is also noticed that the fabricated samples experienced larger strains than undisturbed samples for the same deviatoric stress.

Ishihara and Harada [5] conducted a series of cyclic simple shear tests on local Japanese soils to examine the influence of collapse on liquefaction or cyclic softening characteristics of reconstituted partially saturated samples with different histories of collapse. They found that the cyclic stress ratio (τ_d/σ'_{vo}) needed to induce a state of cyclic softening under a given number of cycles depends on the collapse potential experienced by the samples prior to the application of cyclic load especially at relatively low number of cycles (<10). In other words, the greater the collapse potential, the smaller the cyclic stress ratio required to causing cyclic softening.

Laboratory testing programme

Materials

Samples used in this research were obtained from the site of the underground metro – fourth stage – 6 October City at the link between the Ring road and Wahat road. Figs. 1 and 2 show the location of the study area by Google Earth and a cross sections in the natural soil of the study area.

Some of the natural samples obtained for this research were washed on No. 200 sieve in order to separate the fines from the sand to be able to use different portions out of fines in the study. Four mixtures of samples were prepared with fines contents of 0%, 10%, 20%, and 30%. Other samples were left for undisturbed testing.

The physical properties of the tested soil were determined according to ASTM standards. Test results are summarized in Table 1 and Figs. 3 and 4.

Testing techniques

Oedometer tests

In order to study the collapse potential and the stress strain behaviour of tested soils, laboratory tests were carried out by means of conventional oedometer device using remoulded samples. Samples were of 6.0 cm diameter and 2.4 cm height. The tested soil mixture was placed in the oedometer ring in 4 layers each of 5 to 6 mm and compacted using wooden dolly, in order to achieve the desired relative density. The moisture content varies according to the testing programme. Several attempts were carried out for the target relative density to be reached.

Resonant column test

The resonant column test is used for measuring the low-strain dynamic properties of soils by vibrating a cylindrical soil specimen in a fundamental mode of vibration, in torsion or flexure [6]. Once the fundamental mode is established, the resonant frequency and amplitude of vibration are measured. This fixed-free configuration system is capable of testing a cylindrical specimen in torsion at its fundamental frequency by a drive system. From measuring the motion of the free end, and the velocity of the propagating wave, the degree of material damping can be derived. The shear modulus is then obtained from the derived velocity and the density of the sample. Figs. 5

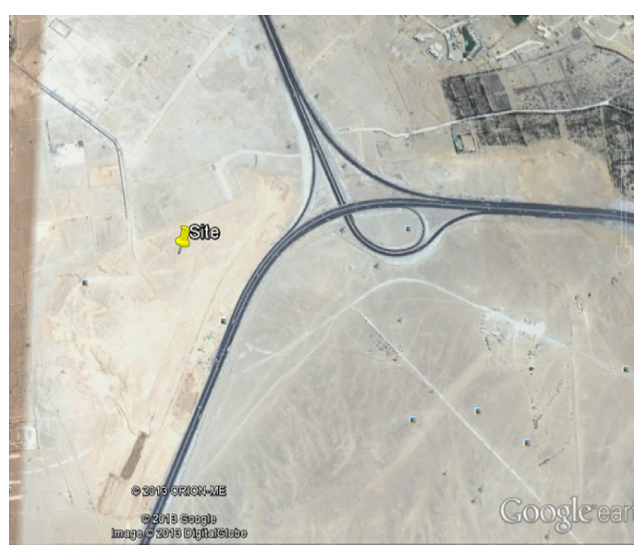

Figure 1 Study area by Google earth.