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Geotechnical Engineering in Multidisciplinary Research: from Microscale to Regional Scale,
CNRIG2016Evolution of grain-size distribution of pumice sands in 1-D
compressionMaurizio Ziccarelli^{a,*}^aDICAM – Dipartimento di Ingegneria Civile, Ambientale, Aerospaziale, dei Materiali – Università degli Studi di Palermo, Palermo 90128, Italy

Abstract

Crushing is one of the micromechanisms that govern the mechanical behaviour of sands at medium-high stresses. It depends on mineralogy, form and strength of single particle, mean stress level, coordination number, time, etc.. It causes changes of grain-size distribution, porosity, number and type of grain contacts, fabric, structure of the material, etc.. Results of an experimental research on the crushing of pumice sands compressed under 1-D conditions to vertical effective stresses σ'_v up to 100 MPa are reported here. They show marked crushing already at σ'_v of about 200 kPa. The evolution of the grain-size distribution can be represented by $\Delta D_i = h/(K(1+C \exp(-hlg\sigma'_v)))$ in which ΔD_i is the decrement of the generic characteristic diameter. C , h , K are positive parameters depending on the sand's nature and initial state. This relation properly accounts for the existence of an upper limit to ΔD_i (or the existence of a limit grading). It is able also to describe the evolution of the global relative breakage indexes.

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1. Introduction

Granular materials are multi-scale and complex systems and their mechanical behaviour depends on the micro, meso and macro scale. The macro response of this type of materials, and in particular the deformation mechanisms, are governed essentially by the relative particle to particle sliding, rolling and breakage (or crushing) of grains, and in

*Corresponding author. Tel.: +3909123896762; fax: +391782736838.

E-mail address: maurizio.ziccarelli@unipa.it

minor measure of fractures, abrasion and elastic deformations of the single particles. It is well known that grain crushing plays a fundamental role in the mechanical behaviour of particulate materials, being one of the main deformation mechanisms at medium-high stresses. As crushing progresses, for effect of increasing applied stresses, the grain-size distribution undergoes modifications, causing changes in the porosity, grain-to-grain contacts, density, packing density, and in the complex process of generation and fragmentation of particles. Grain crushing influences the permeability, shear strength, deformability, critical state of granular materials. It interests, at “normal” stress level and strain conditions, particles such as weak rock, carbonate sands, expansive clay pellets, pyroclastic soils, and, at high or very high stresses, also materials consisting of very hard particles such as quartz sands. It has relevance in many practical problems such as high earth dams, deep wells and tunnels, driven piles, explosions, impact of projectiles, rock avalanche, “sturzsstroms”, etc.. Breakage of grains has been object of many experimental, theoretical and numerical studies regarding sand type, stress-path, effective stress level, etc. [e.g. 1-9]. However, some aspects are still not fully understood, in particular with reference to the evolution of characteristic diameters, the mean stress level at which the evolution of grading is self-similar or fractal. This paper reports the results of an experimental research, relative to a very high interval of stresses ($\sigma'_{vmax} = 100$ MPa), on a pumice sand that is particularly crushable even at relatively low mean stress levels.

2. Material and test procedure

The tests was performed on pumice sands artificially obtained, from fragmentation, of rock fragments commercially available, of 10-15 mm. The sands used in the experimentation have diameter ranging from 0.18mm to 2 mm, and are almost monogranular, Figure 1. The uniformity coefficient C_u of tested sands ranges from 1.18 to 1.29 (sands 1-6) and from 1.38 to 1.66 (sands 7-8). The sands 7 and 8 are obtained as mixtures of sands 3, 4 and 5 and sands 4 and 5 respectively. The initial void ratio e_0 ranges from 3.03 to 3.6 for sands 1-6 and from 2.93 to 3.01 for sands 7 and 8. The sand grains have irregular shape, are generally at sharp corners and have a system of intragranular voids. One-dimensional compression tests have been carried out in a specially built oedometer capable of withstanding high stresses up to 120 MPa [4]. The diameter and the height of the specimens were 73mm and 20 mm respectively. The sand has been placed dry in the oedometer and then gently tamped. The vertical load was applied by means of a hydraulic press at constant rate of axial deformation of 0.5mm/min; the tests duration ranging from 5 to 10 min. The tests axial deformation and the duration of tests are such that the influence of creep on grain crushing is negligible. Overall 200 tests have been performed. Tests were performed on dry sands. After testing the specimens were sieved with the aim of studying the evolution of breakage of particles process.

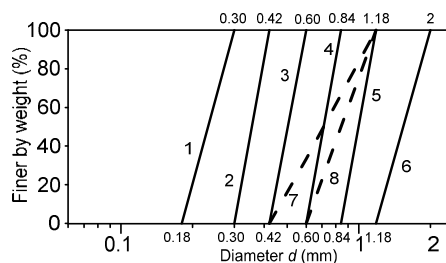


Fig. 1. Initial grading of the sands utilised in the experimentation.

3. Experimental results

Figure 2 shows some photos (obtained by using the optical microscope at different magnifications) after sieving, of some particles of the material of different sizes of a specimen subjected to $\sigma'_v = 15$ MPa. There are sand particles of the same sizes of the initial sand ($0.42 < d < 0.60$ mm); this means that not all the grains are crushed at the end of the test. The deformation process consequent to the load application produces particles of various sizes, all with very sharp corners, including those with very small sizes ($d \leq 0.074$ mm). These observations demonstrate that also the smaller particles are still potentially crushable, having a small coordination number, C.N. (number of contacts with its neighbor

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