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Particular features of the physical and mechanical characteristics of certain Phlegraean pyroclastic soils

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ABSTRACT

This paper deals with the mechanical properties of a number of pyroclastic soils derived from volcanic eruptions (pozzolan and pumice) in the Campanian region of central Italy. Although the analyzed samples come from the Phlegraean and Vesuvian areas, the conclusions and observations on their mechanical properties can be considered similar for most volcanic soils. The behavior of this kind of material is somewhat peculiar and indicates that pozzolan can be considered as an intermediate soil with technical characteristics between granular and cohesive soils. Pumice, one component of pozzolan, undergoes the process of grain crushing even at low stress levels, which influences the shear strength of this material. The failure envelope determined for dry and saturated specimens is non linear, such as the strength parameter (φ') that is a function of the confining pressure or consolidation pressure. In addition, some surprising findings have emerged from the experimental results, such as the tendency of the pozzolan to swell in the absence of the pumice, high compressibility and high shear strength, high porosity beside low hydraulic conductivity, high values of the angle of friction of pumice, at constant volume, for both the "mixed grain size" and for each granulometric class fraction.
Finally it is worth stressing that the study discussed in this article aims to provide a further contribution to the identification of those factors related to the alteration of the physical and mechanical characteristics of these types of soils which could trigger instability phenomena, especially during rainfall, affecting areas of the world where there is a presence of volcanoes.

1. Introduction

Some of the aims of this paper are to introduce further insight concerning the behavior of pyroclastic materials, through specific tests carried out both in situ and in laboratory. The selected soils sampled in the Phlegraean area, show similar characteristics of materials that have erupted from several volcanoes around the world. A perfect example of a Plinian eruption must certainly be that of the Mt. St. Helens Volcano in the state of Washington that occurred on May 18, 1980 at 8:32. In particular, we analyzed a number of pozzolan soils with specific attention to the pumice constituents. Pozzolan shares many characteristics with fly ash that has undergone a partial "zeolitizzazione" (Fourie et al., 1999). The granulometric distribution of pozzolan soils is widespread, from fine ash (silt) to coarse ash (sand) including lapilli (pebble) and the pumice that thus represents one of the main coarse size component (Schmidt, 1981). These kinds of soils are widely studied for their importance in many hazardous situations in particular related to instability phenomena. Thus a thorough knowledge of their physical and mechanical behavior is necessary.

The name "pozzolan" comes from the ancient Latin words "pulvis puteolanus" (Marcus Vitruvius Pollio's De Architecture, Book II, chapter 6) and is also used as a commercial term. From a geological point of view, the selected pozzolan is attributed to the eruption of the Yellow Neapolitan Tuff (Cole and Scarpati, 1993). This kind of loose pozzolanic cover still maintains the original characteristics associated with the different mechanisms of deposition. There are several studies concerning the physical and mechanical characteristics of pozzolanic soils, including that of Pellegrino (1967), Aversa and Evangelista (1998), Esposito and Guadagno (1998), Cecconi et al. (1998), Pasculli et al. (2000), De Vita et al. (2008). Prior to the mudslides of Pozzano in January 1997 and the catastrophic event of Pizzo D'Alvano, May 1998 (Celico and Guadagno, 1998; De Vita, 2000; Del Prete et al., 1998; Guadagno, 1991), a systematic study to determine the characteristics of pumice deposits, especially their physical characteristics, was published by Whitam and Sparks (1986).

The present study examines both the peculiar physical and mechanical proprieties of these pyroclastic soils versus different grain size distribution (with different pumice content) and the mechanical characteristics of the pumice itself.

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Furthermore after the events of 5th and 6th May 1998, a number of samples of pumice were taken in Pizzo D'Alvano, marked PA2 and PA3. Some physical characteristics of these samples, described in the following sections, were determined both on site and through laboratory tests.

2. Geology materials and selected soils

The samples analyzed come from an area located in the Phlegraean Fields in the district of Naples (Fig. 1).

The geological features are characterized by the Pizzo D'Alvano ridge. This is composed essentially of powerful successions of Mesozoic carbonate platform (Unit Alburno–Cervati, D'Argenio et al., 1973) and appears transversely dissected by valleys in generally deep and variously oriented structures. The cretaceous limestone that forms the backbone of this group is often covered with late Quaternary pyroclastic layering, acquiring more power in the shelves summit and at the base of the slopes that are connected, the Campanian Plain, the Vallo di Lauro and basins Siano and Bracigliano, by means of a depositional glacis that consists essentially of alluvial fans referable to multiple overlapping generations. The oldest conoids (Upper Pleistocene) are located in the upper area of the depositional fitting and are constituted by layered bodies of limestone gravel and sub rounded elements, often cemented, to follow these similar conglomeratic series, but with the presence of matrix and interbedded pyroclastic which gradually become more important. The alluvial series hinder intermittently, a series of volcanic rocks assume a primary position among which stand out: cineritic deposits from flow Ignimbrite bell associated with the basal pumice fall series (mean age: 32 ka bp); lapilli and cineritic Vesuvian eruptions called "the Codola" (age: 25 ka bp; Alessio et al., 1974), "Sarno" (age: 17 ka bp; Rolandi, 1997), "Octavian" (age 8 ka bp; Rolandi et al., 1993a,b), "Avellino" (age: 3.6 ka bp; Delibrias et al., 1979).

Finally, in order to provide a summary of the sampling locations, already visualized in Fig. 1, the main material of which the samples are composed and the tests type to which each sample was subjected, Table 1 has been introduced.

The tests were performed in different years and seasons, but we believe that there are no problems in this regard.

3. Pozzolanic soil characterization

The determination of physical and mechanical parameters of sampled pozzolanic soils was carried out with both laboratory tests and with in situ measurements.

The sampled pozzolanic soils are cineritic deposits, derived from the third period of activity of the Phlegraean Fields. Because of their partial saturation, these materials show a certain degree of cohesion. This occurrence allows the provision of undisturbed sampling using classic techniques. In the specific case, a metal cubic box measuring 0.30 m per side was used. One of the faces of the cube is formed by a removable cap and the edges of the remaining faces are shaped so as to be able to penetrate into the ground allowing greater mass removal compared with the size of a sample extracted by a "Shelby" sampler.

The results obtained for the pozzolan soil were surprising as they had a tendency to swell in the oedometer tests. Analysis of the behavior of the pozzolan was extended by in situ tests (Di Clemente et al., 2001) for the determination of natural unit weight (γn) and the coefficient of hydraulic conductivity (K).

The pozzolan used in the laboratory tests came from a quarry owned by "Pozzolan Flegrea Ltd", in the Giuliano area of Naples. Four specimens (P1, P2, AP3 and AP4) were sampled. A detailed lithostratigraphic study of the area (de Gennaro et al., 2000) evidenced the presence of two distinct units, A and B. Unit-A consists of six layers of volcanic ash with pumice bands while in Unit-B there are coarse particles in the fine matrix. The materials, of variable composition passing from trachyte to phonolite, are probably the result of an eruption from a zoned magma chamber. The laboratory tests were aimed at determining the parameters of resistance and compressibility, paying particular attention to the swelling tendency of such soils. In particular tensiometer tests were carried out by a Hydrocon oedometer, equipped with special instrumentation to detect pore suction pressures. On the other hand, density and infiltration tests

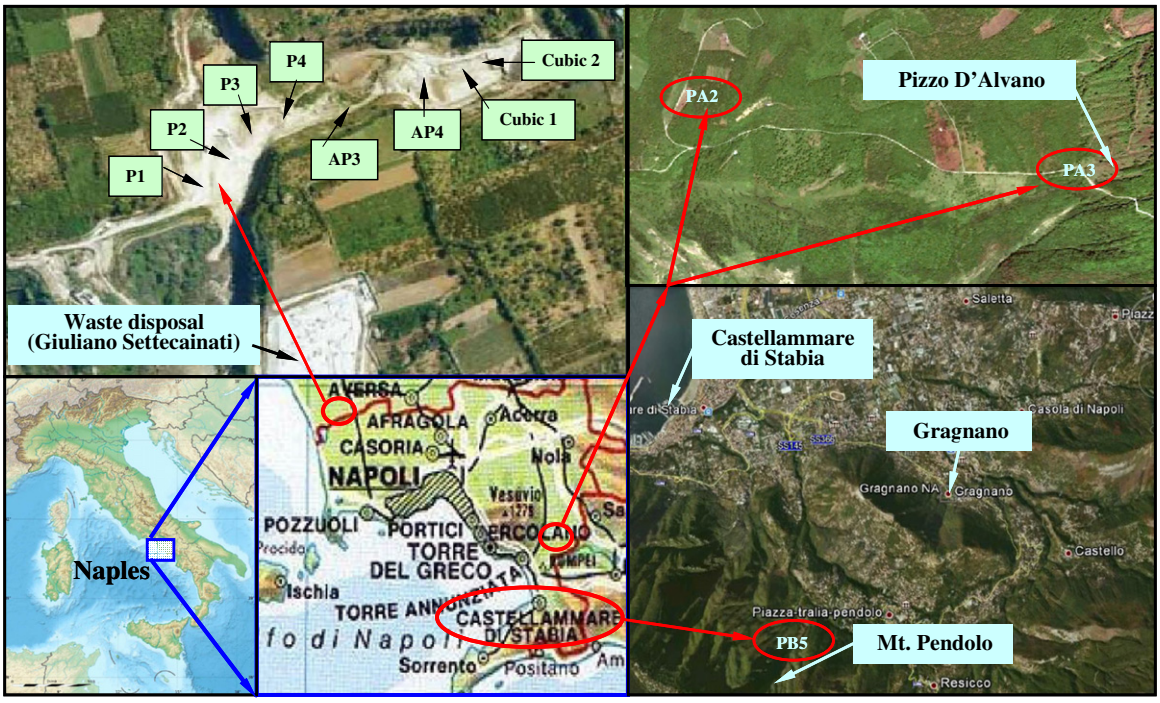

Fig. 1. Phlegraean area.