Investigation on the mechanical attitude of basaltic rocks from Mount Etna through InfraRed Thermography and laboratory tests

G. Pappalardo a, S. Mineo b,*

a Università degli Studi di Catania, Corso Italia 57, 95129 Catania, Italy
b Università degli Studi di Napoli Federico II, Largo San Marcellino 10, 80138 Napoli, Italy

ABSTRACT

The laboratory characterization of basaltic rocks from Mount Etna (eastern Sicily) is presented herein, with the aim of investigating on the mechanical attitude of such rock, widely employed as construction and decorative material. The analysis was carried out following both traditional and innovative approaches, through laboratory tests and InfraRed Thermography prospecting. In particular, the rocks underwent a geotechnical characterization aimed at assessing their main physical and mechanical properties, while Thermography was employed for the infrared analysis of specimens, to highlight differences and peculiar features related to their structure. Achieved results show that such rock type, renowned worldwide for its importance, cannot be represented by standard engineering geological parameters, because its properties are affected by a great statistical variability, which could condition its use as construction or decorative material.

Furthermore, the innovative methodological approach followed herein proved very worthwhile in the laboratory characterization of a rock and lays the foundations for future studies focusing on the utility of new technologies in this field.

Keywords: Basalt, Porosity, InfraRed Thermography, UCS, Etna, Persistence

1. Introduction

Mount Etna, located along the Ionian coast of Sicily, is one of the most famous basaltic volcanoes in the world, thanks to its almost continuous eruptions since at least Ancient-Greek times [38,8]. It is renowned for its exceptional level of volcanic activity, and according to UNESCO, who in 2013 inscribed it on the World Heritage List as an Outstanding Universal Value, its scientific importance and cultural values are of global significance.

Quarried volcanic rocks are among the most employed stones in southern Italy for construction and decorative purposes, thanks to their abundance (lava flows cover about 1260 km²) and good mechanical properties. Several monuments of the Italian cultural heritage, along with most of the historical Baroque buildings and churches of Etnian area, hold such rocks in their bearing elements and all the historical streets of villages and towns of this area are paved with strong and heavy basaltic tiles. At first, such rocks were used only for road pavement and load-bearing elements of local constructions, and then their usage was extended to internal and external paving, sculptures and coating for architectural elements. Furthermore, several quarries produce also aggregates for bituminous conglomerate and strong, fine concrete by crushing the rock. The good mechanical strength of basalts is acknowledged worldwide (e.g. [29,15,41]. Nevertheless, due to the genesis of such rocks, there is a feature playing a key role in their mechanical behavior: it is the porosity, represented by vesicles within the rock texture [2]. These typical voids are frozen relics of gas evolution and bubble growths, with variable size [36], which affect a cooled lava flow with a non-uniform distribution. It is well known that...
porosity varies widely in basalts also due to the heterogeneities occurring between and within lava flows (e.g. [37,12,23]). International researchers agree that the presence of voids in a rock usually causes great variations in its engineering geological properties (e.g. [42,30] and references therein), leading to relevant strength reductions, thus to a worsening of the mechanical attitude.

Based on such feature, basaltic rocks from Etna can be grouped into two categories: massive (MR) and vesicular (VR) rocks. In particular, MR are represented by rocks showing a compact texture, with the almost absolute absence of macroscopic voids, while VR are characterized by the presence of pores at a hand-scale analysis. In this light, this paper aims at investigating on the physical and mechanical behavior offered by 62 basaltic rocks with different degree of vesiculation, by analyzing the outcomes of InfraRed Thermography (IRT) and laboratory tests. In particular, IRT was employed for the infrared macroscopic analysis of specimens and for the study of their porosity condition.

On the other hand, the physical and mechanical characterization of rocks was carried out in laboratory through the estimation of bulk and real density ($\gamma_b$, $\gamma_r$), total and effective porosity ($n$, $n'$), Uniaxial Compressive Strength (UCS), Young modulus ($E$). Furthermore, data were statistically processed aiming at correlating the main properties to highlight their mutual dependence and to investigate on the influence of vesicles on the strength of such rock type. Achieved results represent a statistically relevant dataset, providing interesting information on the mechanical behavior of basaltic rocks, which can have practical implication in not only the construction and decorative fields, but also in the restoration of historical buildings and monuments.

Moreover, the characterization presented herein can be taken into account for further researches both on basalts belonging to different countries, to highlight differences and similarities, and on other rock types.

2. Historical and geological background of Mount Etna

From a geodynamic point of view, Mount Etna is located between two important structures of eastern Sicily: the Gela-Catania foredeep on one hand and the front of the orogenic belt overlapping the African continental plate margin, named Hyblean Foreland, on the other [22]. Its volcanic activity started with eruptions of tholeiitic lavas in the late-Pleistocene and evolved into Na-alkaline products, with a constant increase during the last 200 ky [33,16]. Records of eruptions became reasonably complete from the beginning of the fifteenth century [10] and, among the strongest eruptive events, the 1669 eruption is known as the largest ever occurred during the past 400 years [40]. In this occasion, the widest and longest lava field was produced, destroying numerous settlements and most of Catania city [8]. Nowadays Etna is the result of a complex evolutionary history, driven by the superimposition of at least two main eruptive centers in time and space (Branca et al. [7] and references therein) (Fig. 1). Along with the eruptive activity, the volcano has a rich history of both aseismic and seismic deformations, which concurred to the widespread instability affecting the rock slopes of the study area [6].

From a petrographic point of view, Etna lavas can be classified as trachibasalts and trachiiandesites (e.g. [20,21,39]) with a porphyritic texture and a mineral suite usually represented by plagioclase, pyroxene and olivine in a crystallized groundmass (Fig. 2a), rarely vitrophyric, sometimes showing macro and micro vesicles (Fig. 2b).

3. Contribution of InfraRed Thermography in rock mechanics

InfraRed Thermography is a non-destructive technique, which allows assessing the surface temperature of an object by capturing...
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