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Procedia Earth and Planetary Science 15 (2015) 249 – 256

Procedia
Earth and Planetary Science

World Multidisciplinary Earth Sciences Symposium, WMESS 2015

Marble Characterization by ultrasonic methods

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Abstract

Ultrasonic techniques are increasingly being used in various fields such as mining, geotechnical, civil engineering, because they are non-destructive and easy to apply. These techniques are usually employed both in situ and in laboratory to characterize and determine the dynamic and physical properties of rocks. In cultural heritage, the characterization of marble statue by acoustic wave is a well-known non-destructive method. This paper undertakes a study of the Carrara marble that composes the statues exposed in the Château de Versailles gardens, in order to better understand the processes of deterioration affecting them. For this, 10 cm side square plates of Carrara marble are artificially aged through heating/cooling thermal cycles performed on one face of the samples. Acoustic waves such as compressive, shear and Rayleigh are generated by 1 MHz central frequency contact transducers exited by a voltage pulse generator. A laser vibrometry detection method is used in the case of Rayleigh wave detection. The transmission measurements point out a strong decrease of the wave speed as well as a dramatic decrease of the maximum frequency transmitted in conjunction with the weathering. The velocity of ultrasonic waves depends on the physical and mechanical properties of the stone (such as density, porosity, elastic constants, and structure), Therefore, correlating the changes in these properties with the measured ultrasonic velocity helps to provide classification schemes for evaluating the degree of stone deterioration Köhler (1991). Some classical tests such as drilling resistance and water absorption (contact sponge method and water drop test) were also performed in order to complete the results obtained by ultrasonic velocity method.

Peer-review under responsibilty of the Organizing Commitee of WMESS 2015.

Keywords: marble characterization, Rayleigh wave, vibrometry laser, drilling resistance, water absorption.

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Peer-review under responsibilty of the Organizing Commitee of WMESS 2015.
doi:10.1016/j.proeps.2015.08.061

1. Introduction

Natural stone has been an important building material for thousands of years. A significant part of the world's cultural heritage is built of stone. In order to get the required knowledge for the preservation and conservation of stone, various investigation methods are applied. The traditional techniques already in use for the investigation of natural stone are generally destructive: uniaxial compression (L.N.Y. Wong and H.H. Einstein, 2009), triaxial deformation (MR. Ayling et al, 1994) and strength test (Mingqing You, 2011), etc. Among the non-destructive methods with most acceptance and applications in the study of the structural characteristics and state of conservation of stone materials in historic and artistic buildings is by determination of the propagation velocity of ultrasonic waves (Saez-Perez and Rodriguez-Gordillo, 2008). This research focused on the use of non-destructive ultrasonic technique as validated by traditional methods for the study of the degree of weathering of marble. For this, some aged samples were prepared artificially by a thaw-freeze cycles. Ultrasonic velocity seemed to correlate well with the degree of weathering in the marble.

2. Methods and equipment

2.1. Materials

Tow samples of Carrara marble are tested I1 and G1 (10*10*3 cm). In order to simulate degradations encountered in Carrara marble statue in Chateau de Versailles, an ageing artificially protocol was developed and applied on the sample G1 (Fig. 1). The protocol consists in a 25 thaw-freeze cycles for different temperatures (100°C, 200°C, 300°C and 400°C). In this experiment the temperature cycles are exposed to one side of the sample. A ceramic hot plate (450°C max) and a recipient with ice cube are used.

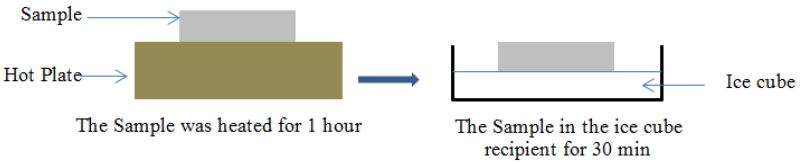

Fig. 1. Illustration of the thaw-freeze protocol.

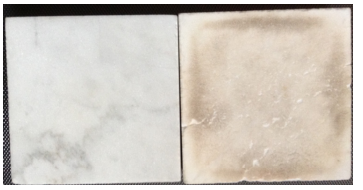

Fig. 2. Non-degraded sample I1 (left), artificial aged sample G1 (right).

2.2. Ultrasonic test

Ultrasonic method consists of propagating ultrasound waves through a material to measure the travel time and any change of intensity of the wave for a given distance. In the transmission method (the method that we use in this study), the ultrasonic transmitter and receiver are placed opposite to each other on either side of the marble sample and the time needed for the wave to travel along the distance between them is measured. The time of flight (TOF) allows calculating the shear and longitudinal wave velocities through sample. Acoustic waves such as compressive, shear and Rayleigh are generated by 1 MHz central frequency contact transducers exited by a voltage pulse generator. A vibrometry method is used in the case of Rayleigh wave detection. A coupling media, to improve the acoustic contact between the sample and the transducers was used (Fig. 3 and 4).