An Ultrasound Based Technique for the Detection and Classification of Flaws Inside Large Sizes Marble or Stone Structural elements

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ABSTRACT

There is a growing interest in using ultrasound diagnostic techniques for non-destructive testing of marble/stone blocks or structural elements with large sizes, in order to detect internal flaws such as cracks or fissures. Here a specific diagnostic procedure, based on ultrasound transmission measurements, is proposed. A prototype of a measuring set-up, suitable for an in-field use, is described and the experimental results reported.

KEYWORDS: Non-Destructive Evaluation, Ultrasound Testing, Marble/Stone Quality Control

INTRODUCTION

The presence of faults, such as fissures and cracks, inside large sizes structural elements of stone or marble is a real risk factor. Non-destructive ultrasound based diagnostic techniques for the quality control of materials have been studied since many years and several dedicated tools are now available [1]. Most of the currently used ultrasound techniques appears quite suitable for the above types of materials as well. Diagnostic methods based on acoustic waves are already used to assess physical characteristic of underground rocks [2,3], and ultrasound techniques are applied to detect flaws inside concrete and masonry structures [4,5]. Thereore, the development of non-destructive diagnostic procedures for detecting faulty regions inside marble elements up to four meters in length seems be possible and of great interest. A procedure and a prototype tool, specifically designed for in-field use, is here described. Finally, some experimental results are presented and discussed.

THE PROPOSED PROCEDURE

On the basis of propagation experiments of ultrasound bursts through marble blocks of various types and with different internal flaws [6], the following remarks can be made:

i) The value measured for the propagation attenuation and its dependence vs. frequency suggests the use of ultrasonic burst with frequency within 50 -500 kHz range.
ii) The flaws most commonly encountered inside marble blocks are: low level flaws, tipically cracks; medium level flaws, tipically non homogeneous regions due to "filled fault"; high level flaws, tipically empty zones. The presence of flaws of the above said types, affect the propagation attenuation in relation to the frequency of the test signal: generally, the lower the frequency value, the lower the increase in the attenuation caused by a flaw of an assigned type.

On this basis the following test procedure was designed.

A region of the element under test is located, certainly free of flaws, and the propagation attenuation in that region is measured at 500, 100 and 50 kHz, for example, thus obtaining a reference set of values. We shall indicate these values as α^*_{500}, α^*_{100}, α^*_{50}, respectively.

With some guesswork and taking into account the characteristics of the particular element under test, a number of propagation paths are then chosen and the attenuation values (α_{i500}), along these paths, are measured for a burst frequency of 500 kHz .The regions with propagation attenuation values α_{i500} "near" (not greater than about 6 dB, for example) to the reference value α^*_{500} should be considered flaw-free. The paths are then considered with $\alpha_{i500} >> \alpha^*_{500}$ and a subsequent measure of attenuation is made at a frequency of 100 kHz. In the regions where α_{i100} result "near" α^*_{100}, a low level flaw is present, such as a crack. The paths are then considered with $\alpha_{i100} >> \alpha^*_{100}$ and an attenuation measurement at the frequency of 50 kHz is made. If α_{i50} results "near" to α^*_{50} a medium level flaw, such as a filled fault is to be expected. Where $\alpha_{i50} >> \alpha^*_{50}$, a high level flaw, such as void, is present

EXPERIMENTAL RESULTS

Laboratory experiments were first accomplished to determine the variations in the propagation attenuation due to the presence of flaws with different tipology, for the frequency range reported above. In these experiments marble blocks with sizes smaller than those of interest in real cases were used. Flaws of the type described were considered. In some cases, they were artificially created inside the material. On this basis the *attenuation threshold* levels used for declaring the presence of flaws were derived. Such levels resulted sufficiently indipendent from the type of marble or stone, except for particular cases, *Pietra Serena* for example. A prototype tool for in-field measurements was implemented according to the schematic diagram in Fig. 1. The station is based on the Panametrics high voltage pulser-receiver Model 5058PR. The output pulse is directly applied to the transmitting transducer, while the receiving transducer is connected to the receiver section of the instrument itself. Both the transducers are matched to the element under test by a specifically designed water based matching system. Here, for example, we report the results obtained in testing a *Bianco P* marble block with a width of 1.32 m, a height of 1.50 m and a length of 3.20 m. The test was accomplished by transmitting ultrasound pulses along an array of propagation paths, parallel to the direction of the width, as schematically shown in Fig. 2.

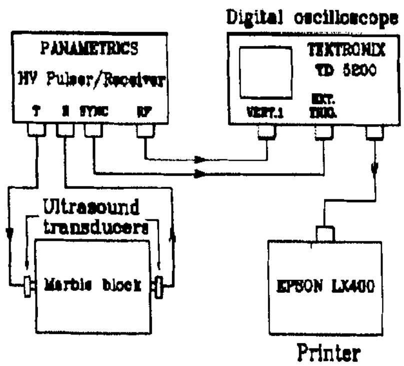

Figure 1: Measurement equipment used in in-field testing

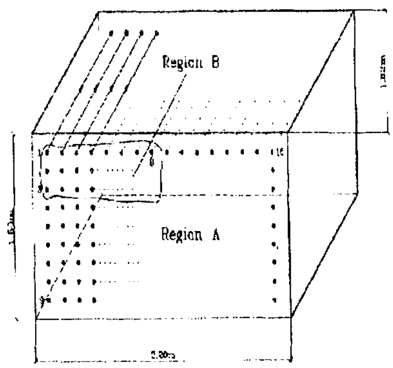

Figure 2: Propagation paths used to test the block

First transmission measurements at a frequency of 500 kHz were made. The propagation conditions were found to be good and sufficiently uniform for all the paths in the region A; on the contrary, for the paths located in the region B no propagation resulted. Then transmission measurements at frequencies of 100 kHz and 50 kHz were made and the results relative to the paths of region A (flaw free region) and region B were

On the other hand, a comparison of the signals in Figures 4 and 6 shows that the increase in the corresponding attenuation values is limited to 6 dB.

We can thus conclude that region B contains a medium level flaw.

A subsequent direct invasive inspection

compared. An example of the typical signals received at 100 KHz and 50 kHz for paths in region A are shown in Figs. 3 and 4, while the corresponding typical signals for paths in region B are shown in Figs. 5 and 6.

A comparison of the signals in Figures 3 and 5 highlights that the propagation attenuation relative to region B is about 37.3 dB greater than the attenuation relative to the region A.

of the block, which was allowed in this case, really showed the presence of a "filled fault".

CONCLUSIONS
In the technical literature we have found no proposals for the use of ultrasound techniques in non-destructive testing of stone or marble elements. We here proposed a procedure which uses ultrasound pulses within 50 kHz - 500 kHz frequency range for this application. On the basis of propagation tests, the procedure allows one to detect the presence of internal flaws and also to estimate, by comparing propagation measurements at different frequencies, the type of flaw itself.

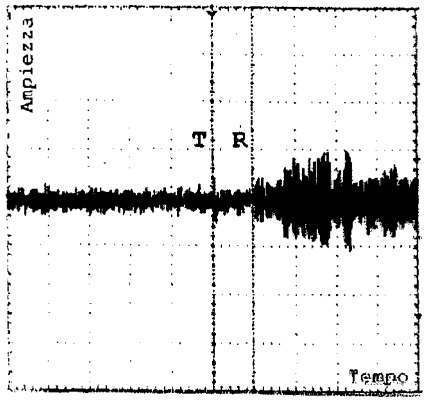

Figure 3: Transmission measures at 100 KHz in region B (medium level flaw)

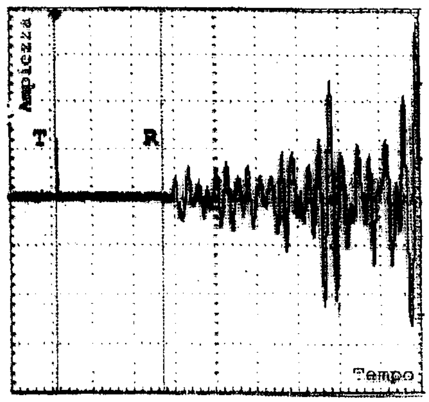

Figure 4: Transmission measures at 50 KHz in region B (medium level flaw)

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