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A NEW NON INVASIVE METHOD TO EVALUATE THE DETACHMENTS OF PLASTERS. FIRST RESULTS

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Abstract

The conservation of the historical finishes represents a difficult issue, due to their aesthetical and functional roles. In particular, the investigation on surfaces (external o internal) with wall paintings represent a typical case where researchers has some difficulties to apply non invasive diagnostic technique about the detachment of these surfaces. The method here described is aimed at the definition of a scientific method for the evaluation of the adhesion between the fresco and the wall. To this end a proper measuring instrument, based essentially on the principle of stationary waves and suitable for easy use in situ, has been designed and realized. To better understand the range of reliability of the instrument and its limits, a set of measurements were carried out on a testing masonry. On this wall two layers of lime plaster were applied and different typologies of detachments were artificially created.

Keywords: *Non invasive diagnostic technique; Detachment detection; Acoustical method; Decorated surfaces preservation.*

Introduction

The plasters are one of the main expressive elements which strongly contributes to define the image of the architectures. Nevertheless, their conservation is not only an aesthetic need, but it is necessary for the correct maintenance of structure building and to hand down the architectural heritage. The detachment of plaster is even more serious if the surface is decorated with frescos or graffiti. Different physical, chemical and biological factors, like structure displacements, vibrations, temperature changes, humidity, pollution and biological colonization, which frequently acts in synergy, are responsible of the degradation of the plaster.

The detachments are often located between the support and the *arriccio* so some non-destructive test should be performed to detect them. For sure, an early identification of the voids and detachments permits to plan an accurate conservative intervention, maximizing the preservation of historical materials and optimizing costs [1-3].

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The non destructive techniques status of the art for wall paintings diagnostic techniques offers many solutions that too often require expensive and or impractical instrumentation, and this contrasts with the needs of cultural heritage curators. To date, the traditional empirical method of knocking the surface to detect the hidden voids is still used even if some non destructive techniques based on the acoustical method has been applied recently [4-7].

The goal of this research is the setting of a new non destructive technique based on acoustic measures able to detect the detachment of the layers of plasters and frescos. The described method is based on the measurement of wall impedance by means of specially adapted standing wave tube. The apparatus for detecting detachments has been designed and built in the INRIM institute, in the framework of the regional project Re-Frescos. Previous experiments were performed whit this instruments both in laboratory and in situ and contradictory results were achieved [8-9]. For these reasons, a testing masonry was built creating controlled detachment of the *arriccio* and/or of the finishing layer in order to verify the influence of different characteristics (such as depth of detachment, kind of finishing, thickness of plaster) on the reliability of the measures.

Materials and methods

The experimental apparatus

The experimental apparatus is schematically represented in figure 1a. The instrument measures the value of sound absorption coefficient and acoustic impedance in the portion of fresco where it lays. The adopted method is based on the evaluation of a transfer function between the two microphones inserted in the tube, as stated in the Standard ISO 10534-2 [10].

The tube lays on the fresco with a special head made by a 5mm thick synthetic material layer, whose deformability allows adaptation to the wall surface without damaging it. In order to lighten the instrument, loudspeaker and tube have been decoupled then connected through a flexible tube. It was demonstrated that the modified set up is compatible with the whole measurement process.

The tube is made of Plexiglas with 30 mm internal diameter and 360mm length. In the current setup the microphones spacing is fixed at 16mm, thereby the absorption coefficient $\alpha(\omega)$ is limited at the precautionary frequency range 2000Hz - 5000Hz. Microphones can rotate of 180° as required in [10] for the instrument calibration.

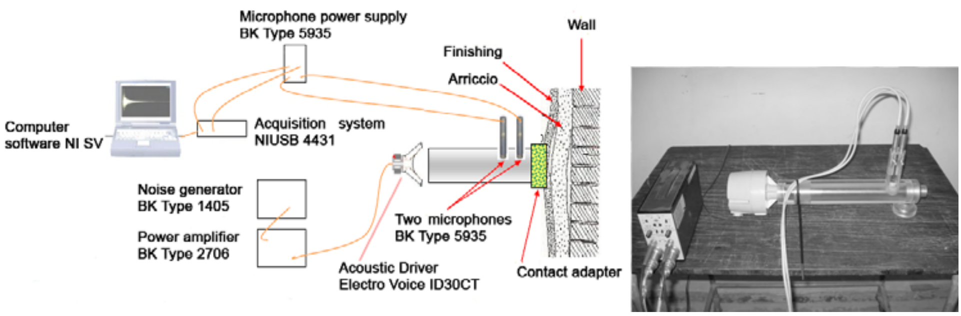

Fig. 1. Diagram of the tube lying on the fresco **(a)** and the "Re-fresco Tube" **(b)**.

This measuring technique is based on the assumption that the stuck air contained under the surface of a detached fresco can varies the properties of the wall portion and these features can be measured in the form of sound absorption. The assumption was verified in [9] by means of a specific extension of the standing wave tube where in several air cavities systems (air layer among clamped plate and movable piston surface) were inspected in terms of acoustical absorption. The system formed by the plate and the cavity acts as a resonator whose resonance frequencies depends by the geometrical and physical properties of both the plate and the cavity.

In the eyes of the air cavity resonance frequencies are inversely related to the cavity depth, whereas they are in proportion to the plate thickness.

The testing masonry

A testing masonry was built in order to validate the acoustical method and to better understand the limits which currently affects this technique. The wall is 150cm and, in this first step of the work, the plaster was applied only in the lower portion as shown in figure 2.

The masonry was realized in stone ashlar (gneiss) and hydraulic lime joints to respect the historical constructive techniques. The surface of the stone was not roughen before the application of the first layer of plaster. For this reason, the *arriccio* appeared irregular, with lacunae and it was non well sticked to the support in some points. All these defects were mapped. In order to simulate the presence of a non visible detachment of the *arriccio* from the stone masonry, the lacunae were filled with felt tissue and a thin layer of plaster was applied above it as reported in Fig. 2a and b. To increase the records of the defects, a thin finishing was then applied. In some case this layer is adherent to the *arriccio*, in other it was detached from the *arriccio* thanks to the interposition of the tissue, which was removed once the plaster was hardened (Fig. 2c).

In this way, different typologies of surfaces were realized, as summarized in Table 1.

Fig. 2. Lacunae in the *arriccio* of the testing masonry. The plaster was applied only in the lower portion of the wall **(a)**. After the mapping**,** the lacunae were covered with a thin layer of plaster sustained by a tissue **(b)**. Detachment of the finishing layer **(c).**

Results and Discussion

The Re-Fresco tube was placed in contact with the selected surface. Particular attention was paid to the adherence of the tube's head to the wall surface, in order to prevent any air leaks. Using LabView grafical interface, it was possible to monitor the whole measurement process; in particular the coherence function calculated between the two microphones signals was monitored as indicator of the rightness of the measure.

The measures were performed on different points of the wall where no detachment or detachment of one or two layers of plaster is present, as reported in figure 3 and in Table 1.

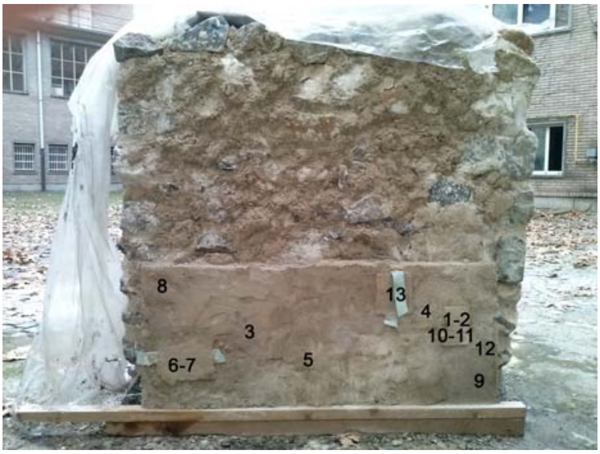

Fig. 3. Position of the measured points on the testing wall.

Table 1. Schematization of the measured points.

	SAMPLES: MEASURING POINTS												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Arriccio: No detachment													
Arriccio: Detachment													
Finishing: Detachment Arriccio: No detachment													
Finishing: Detachment Arriccio: Detachment													

In figure 4a results on non-detached *arriccio* are reported. Absorption lines were rather uniform and did not show any peak. The absolute alpha-value, e.g. the vertical translation of the absortpion lines in the graph, should be related to the variable roughness of the surface and to the relative scattering of sound waves. Investigations for this aim are in progress.

Detached *arriccio* responses are reported in figure 4b. Absorption lines were still rather uniform, save for the sample number 4, which shows two weak prominences approximately at 2750Hz and 3250Hz. However, these data could not be considered sufficient to recognize a healthy or defective *arriccio*.

Cavity resonances were detected in the case of finishing detachment, as shown in figure 5a. Several absorption peaks appeared on the graph, each of which was related to the acoustical capacitance of the air cavities hidden behind the detached finishing.

Surprisingly, in the case of detachment of both the layers reported in figure 5b, absorption lines did not present authentic peaks even if they were more pleated. However a little peak approximately at 2750Hz, similar to the instance of sample 4 in figure 4b was detected.

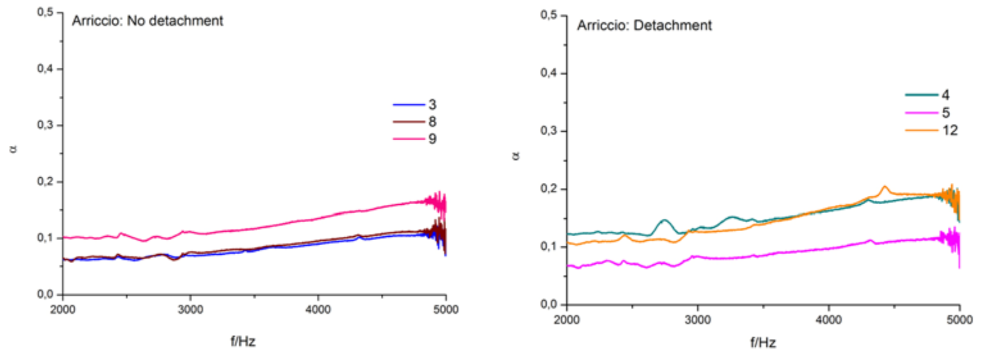

Fig. 4. Measures performed on the undetached plaster **(a)** and on the detached arriccio layer **(b)**.

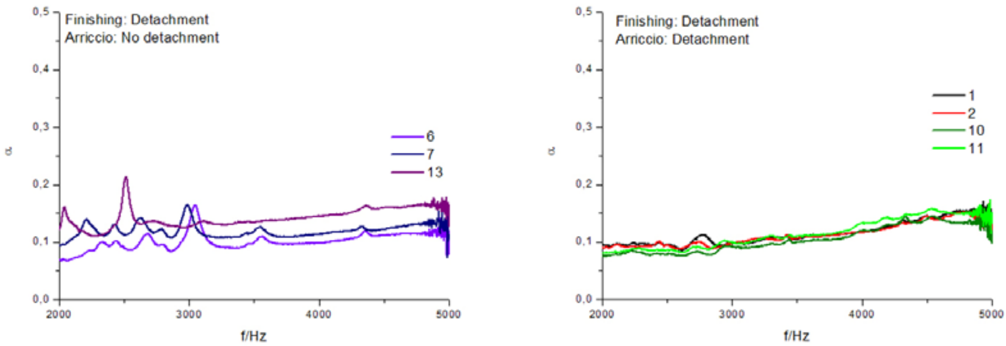

Fig. 5. Measures performed on the non detached plaster **(a)** and on the detached arriccio layer **(b)**.

Conclusions

A dedicated impedance tube was used to measure the sound absorption of wall portions, in order to detect contingent detachments. The examined frequency range was included between 2 kHz and 5 kHz due to the utilized measuring setup.

Only finishing detachments were located by the instrument, in the form of sound absorption peaks. For healty samples $\alpha(\omega)$ is uniform, as it should be, but significant differences from this case were not found for both *arriccio* and *arriccio* plus finishing detachments.

The usable frequency range was too narrow and it should be extended towards lower frequencies, by increasing the microphones spacing. Especially for *arriccio* detachments analysis at lower frequencies could show tell-tales absorption peaks.

The sound absorption revealed by this technique is due to an event of air cavity resonance: the air trapped into the cavity is stressed by the vibration of the detached surface, and it acts as a gas-spring able to absorb sound energy. If the thickness of the detached surface is high, then it is scarcely moved by the sound within the tube and no resonances are detected. From this point of view an additional intrinsic problem of the method is that the tube has to be endorsed with a certain force to the wall and this reduces its motion.

The finishing properties (roughness and porosity) do influence sound absorption measures and it is essential to know how. A study about this topic, the extension of the analysis toward lower frequencies and the comparison of the incoming results with other non destructive techniques, could represent the future steps of this research.

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