ROUGHNESS MEASUREMENT APPLIED TO THE MONITORING AND THE FOLLOW-UP OF BUILDING CLEANING

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Abstract

The first aim of this paper is to present a new profilometry method, which has provided very good results in the roughness measurements on limestone of Neuchâtel (Switzerland) samples. This method is the optical profilometry based on chromatic confocal imaging. The measurements made on three samples cleaned with different techniques show that this optical method resolution is very well adapted to the evaluation of degradations due to building cleaning. As this technique is not easy to apply *in-situ*, the second aim is to propose an imprint moulding method, using dental products and silicon resin. This imprint moulding method will provide a good tool to estimate the loss of material caused by all building cleanings.

Keywords: roughness measurement, optical profilometry, imprints moulding, building stones

1. Introduction

In the last decade a variety of cleaning techniques for buildings was developed (high pressure cleaning, rubbing cleaning, poultice cleaning, laser…). All these methods are frequently implemented without control or scientific follow up. Motivated only by the visual improvement, the firms that execute the work often favour rapidity of the intervention instead of quality of the work and they use extreme conditions for the cleaning procedure such as too high pressure, too elevated chemical or solid components concentrations. The result for the buildings is a degradation of the surface. These modifications have not only a direct impact on the appearance of the buildings façades (colour, details of the sculptural relief…) but also on their durability (heightened sensibility of the materials to environmental attack…)

Apart from the simple visual observations no method exists which allows the measuring of the degree of degradation caused by the cleanings. That's why we have tested a profilometry method to quantify the degradation. This method was first tested on samples taken on buildings. As the results were significant and permitted to really quantify different cleaning methods, we now develop a method of moulding, with a high

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degree of confidence, which will allow quantifying the degradations caused by building cleanings without any sample taking.

2. Optical profilometry with chromatic aberration

2.1. Principle of the technique

The roughness measurements were performed with the Optical Profilometre of the "Institut National des Sciences Appliquées" in Strasbourg (France). This apparatus works according to the principle of the confocal imagery with extended field.

The first principle of this imagery technique is the principle of the confocal microscopy, partially explained in figure 1.

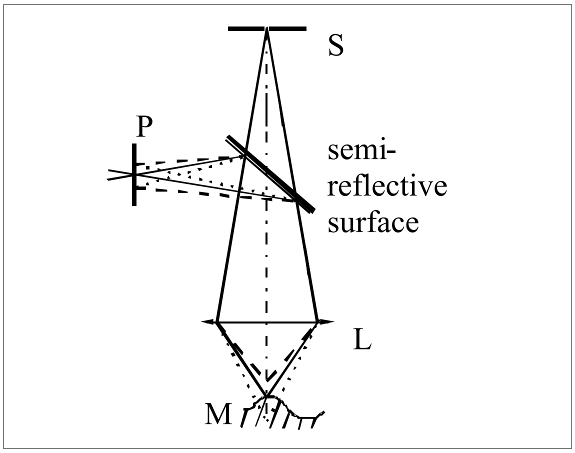

Figure 1. Principle of the confocal imagery (after COHEN-SABBAN, 1999)

The detection principle of the confocal microscopy uses a double spatial filtering which allows firstly to light only one point on the object, and secondly to detect the diffused and/or reflected light coming from this only point. The light coming from the source point S (first spatial filter) goes through the lens L and reaches the point M on the object. The reflected light coming from M goes through L and after a reflection on a semi-reflective surface, reaches the second spatial filter P. The light coming from a point situated above or below but on the same axis as M is filtered by P (figure 2).

The second principle of the employed method is based on the chromatic coding used by S.T.I.L. (Science et Technique Industriel de la Lumière, Aix-en-Provence, France, the company holder of the patent) in confocal microscopy. This technique allows working with an extended depth of focus: about ten microns to a few millimetres. The chromatic coding is obtained as follows: a polychromatic one-off source is broken down in a continuous range of monochromatic images uniformly divided on a straight-line segment. The length of this segment is equal to the required depth of focus. In this way, to each depth of focus corresponds only one wavelength (figure 2).

The spatial filtering selects the light coming from the measured points in order to preserve the chromatic coding. The wavelength value of the retro diffused and/or reflected light informs immediately about the altitude of the point. After the second filtering, the light signal is collected and the mean value of the wavelength is measured. The presence of an object in M gives a maximum light intensity for the wavelength λ_M. The measurement of the peak intensity allows taking photos according to a principle similar to the retro diffused electrons used in a scanning electron microscope (SEM), the present method, however, giving access to additional three-dimension planes than with an SEM.

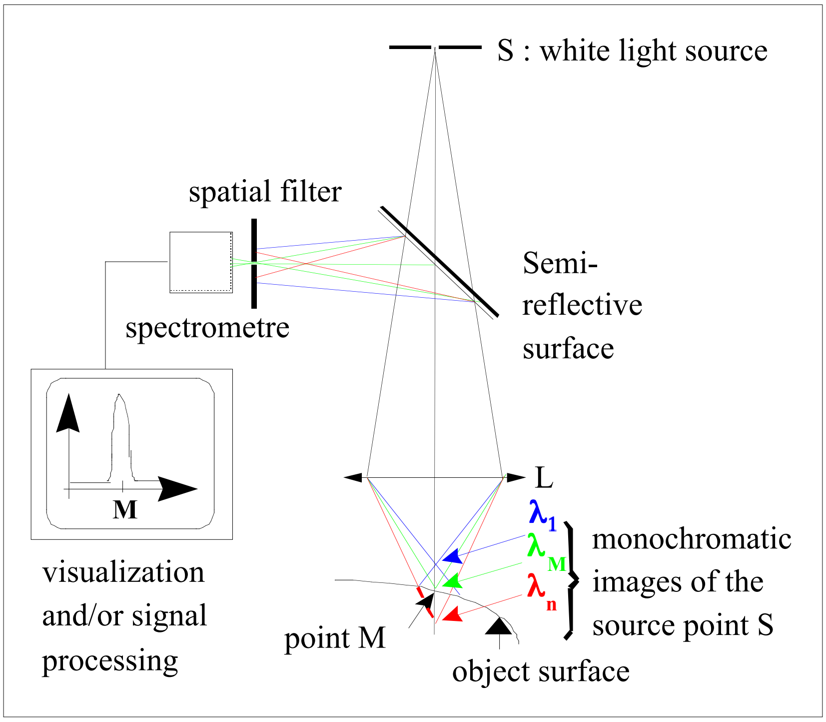

Figure 2. Principle of the extended field confocal microscopy (after Cohen-Sabban, 1999)

2.2. Apparatus

The acquisitions were performed with the "Micromeasure 3D - without contact station" of the Engineering Surfaces laboratory in the "Institut National des Sciences Appliquées" of Strasbourg (France). This apparatus allows measuring object profiles or surfaces with a nanometric resolution whatever surface dimensions are being studied.

The station is made up of X, Y and Z translation tables moved by means of step by step motors, high resolution optical sensor without contact and control software. The optical sensor itself is made up of a measurement probe that can be changed according to the roughness dimension we want to study, an optical fibre link and an optoelectronic case. The standard movement of the translation tables is 100 to 250 mm in X, Y and 50 mm in Z.

The probe characteristics used are as follows: 0 – 3000 µm depth of focus; 6 cm work distance; 8 mm focal distance; 0,01 µm Z resolution; 2 µm spot diameter; 300Hz frequency.

2.3. Advantages and limits

Apart from the fact that the studied material has to reflect the light, this method has only advantages. The sample has not to be prepared; the measurements are made without contact, i.e. without deformation of the sample; the light coming vertically on the sample can reach the hole back; only one scanning of the surface is necessary; if an artefact appeared during acquisitions, the software allows to correct them.

Then the large depth of focus of this apparatus allows to work on highly rough surfaces like building stones, whereas all the other profilometry techniques, like confocal microscopy, laser interferometry, or atomic force microscopy, can only measure micro or nanometric roughness.

2.4. Materials and experimental procedure

The Museum of Natural History in Neuchâtel (Switzerland) is made of the stratotype Hauterivian limestone called "pierre jaune de Neuchâtel". This building was cleaned in 2000 with a rubbing cleaning method. Three witness zones were left dirty on the façades. In the present study, only the witness zone of the north façade is being considered. This zone is sheltered under a sill window, without any important rain washing but where the relative humidity is often high due to the orientation towards north and the capillary rising from the building base made of "roc du Jura" a very dense and non-permeable limestone which stops the water drainage.

Figure 3. Localization of the studied sample on the façade of the Museum of Natural History in Neuchâtel

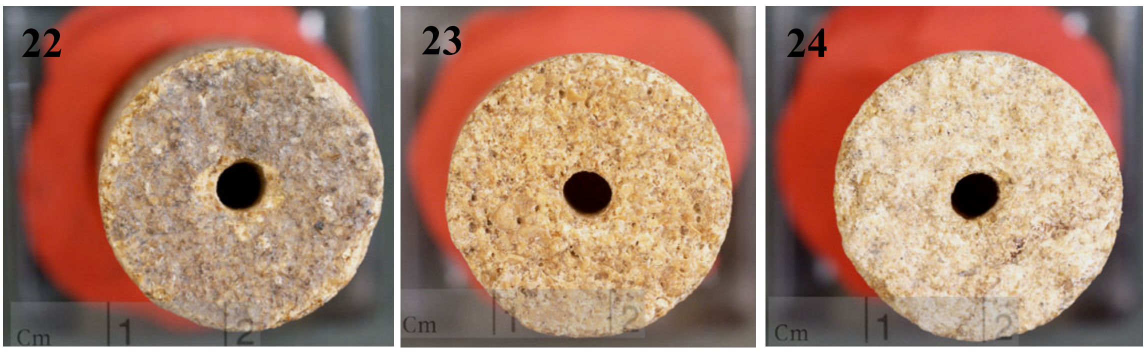

Figure 4. Surface of the three samples studied

The three samples studied were taken in a zone that was or still is covered with a thin brownish crust of nearly glassy aspect, formed by the trapped particles coming from the atmospheric pollution and dust. These particles stick to the humid façade and are never washed. In 2002 a part of the witness zone has been cleaned with a poultice method. The three samples have been taken from the same stone block as follows (figure 3):

- Sample 22 has been taken from the dirty zone;

- Sample 23 has been taken from the rubbing cleaned zone;
- Sample 24 has been taken from the poultice-cleaned zone.

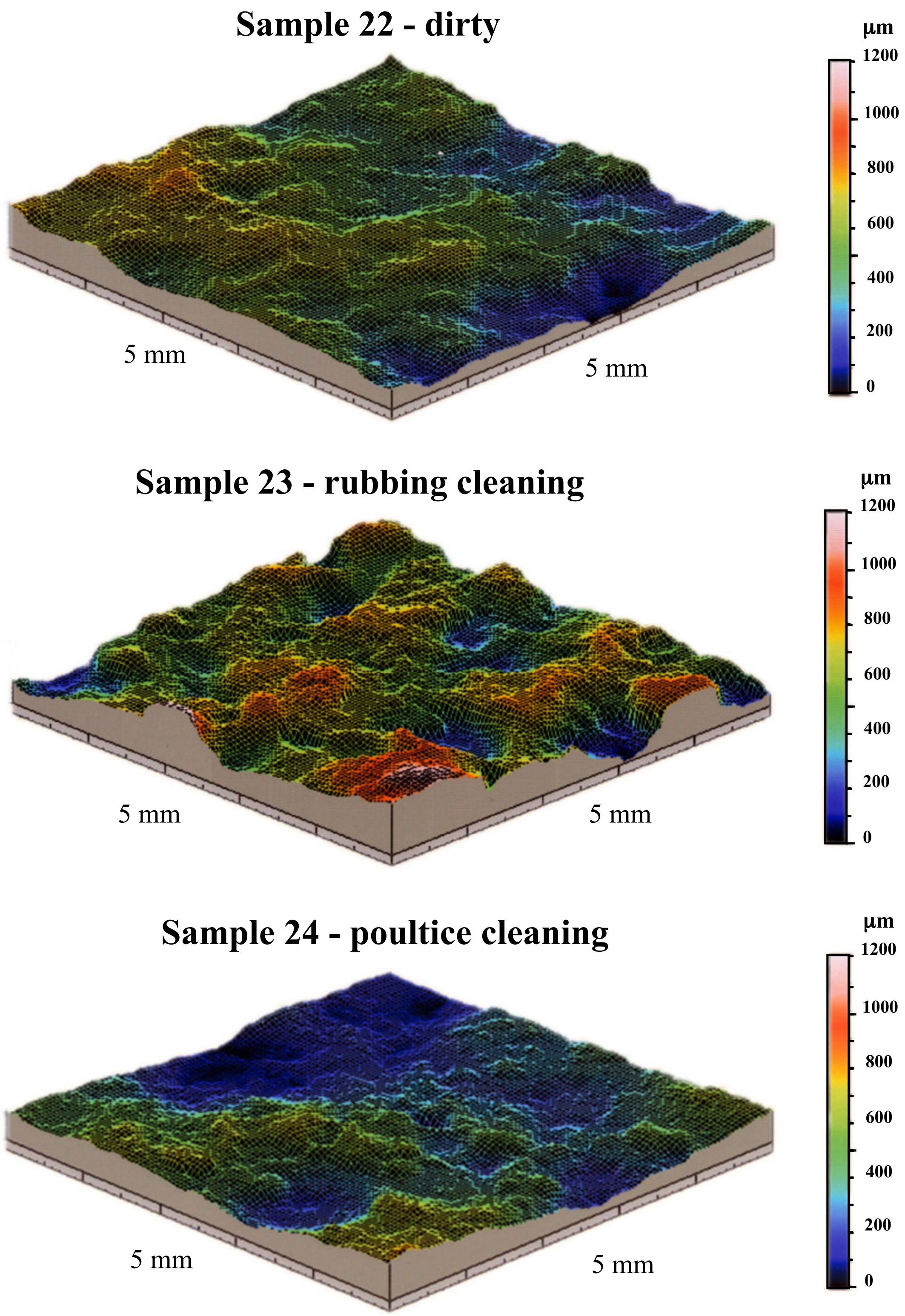

Figure 5. Surface 3d reconstructions of the studied samples.

Photos of the surface are shown in figure 4. The hole that can be observed in the middle of each surface sample has been used as a guideline at the beginning of the drilling. Without this guideline, the drill slips and destroys the sample surface. The measurements were performed on a 5x5 mm area with a 10µm step.

2.5. Results

The results are represented in the 3d surface reconstructions (figure 5). These reconstructions can be compared to the photos of the sampled zones (figure 6). On those photos, taken very closely to the surface with low-angled light, a first qualitative estimation of the roughness can be made. The values deducted from the optical profilometry measurements are shown in tab. 1.

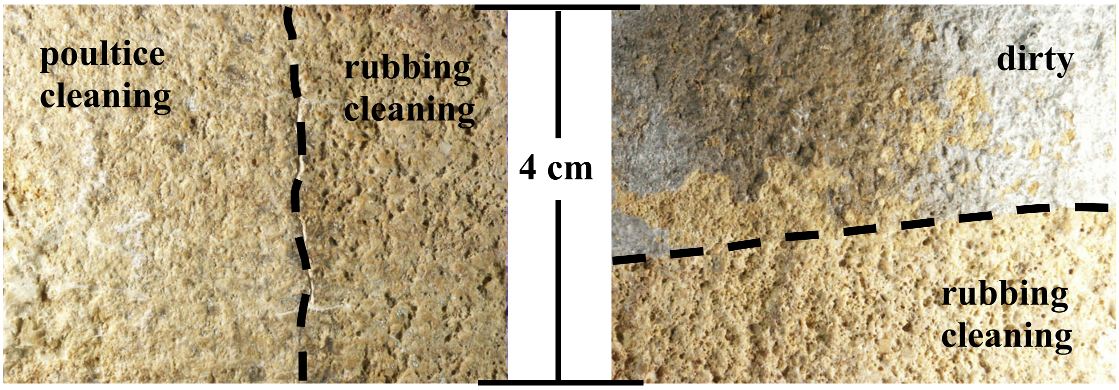

Figure 6. Photographies of the sampled zones taken with low-angled light – F. Girardet

In the three surface states studied the different degrees of roughness are easily visible by the naked eye: the dirty surface has a low roughness, the roughness of the poultice cleaned surface is close to the dirty one whereas the roughness of the rubbing cleaned surface is very high. These "macroscopic" observations are shown on figure 6. The results exposed in figure 5 and tab. 1 evidence that the profilometric method used allows to confirm these observations and to quantify them. The calculated complexity of the dirty surface (15.6%) is comparable to the complexity obtained on the poultice-cleaned surface (24.0%) whereas the complexity of the rubbing cleaned surface is clearly higher (60.8%).

Table 1. Experimental parameters and principal results of the profilometry

		Experimental parameters				Results		
Sample	Surface state	X (mm)	Y (mm)	Step (µm)	S-2d (mm^3)	S-3d (mm^3)	S-3d/S-2d	Complexity (%)
22	**Dirty**					28.9	1.16	15.6
23	**Rubbing cleaning**	5	5	10	25	40.2	1.61	60.8
24	**Poultice cleaning**					31	1.24	24.0

These results prove that the depth of field of this optical profilometric method is perfectly adapted to the quantification of building cleaning methods degradations. But this technique is not easily applicable *in-situ*. In the studied case,we have been allowed to sample the surface but this is an exception. In general, the sampling is not allowed. We have to develop an imprint moulding method in order to applie the profilometry on moulds with a high degree of confidence.

2.6. Moulding

In order to make the roughness measurement a non-destructive method, the "Expert-Center pour la conservation du patrimoine bâti" Lausanne laboratory is developing an imprint moulding technique. This development is based on F. Girardet’s work started a few years ago. F. Girardet had the idea to use dental products in order to make imprints and moulds.

The negative imprint on the building is made with an alginate that is normally used for dental imprints (Elastic impression cream – Produits dentaires SA, Vevey, Switzerland). Alginate has been chosen because it will not pollute the studied surface, which is not the case with silicone resins. The alginate, contrary to the silicon resins, does not pollute the studied surface. However, alginate not being stable in time after solidification, it is necessary to rapidly make a positive mould. For these moulds, different very thin plasters have been tested, such as dental plasters. Various problems have been encountered with the test-plasters: during the hardening process they tend to absorb the water of the alginate thus rapidly deforming it. The thinner plasters, giving the more precise moulds, are very fragile and a lot of precautions have to be taken before and during the measurement even if the optical profilometry method is used without any contact. Due to these reasons, we have also tested a silicon resin (Silicon rubber RTV-ME 622 – Wacker silicone) which up to now gives the best results: this resin does not absorb the water of the alginate, it is very tough and non-deformable after solidification despite its elasticity. However, its durability in the long run remains to be determined. Tests are going on and are really promising.

3. Conclusion and perspectives

The first results of roughness measurements obtained with the optical profilometry based on chromatic confocal imaging show that this technique is very well adapted to estimate the degradations provoked by building cleaning systems. The measurements made on samples taken from a limestone of Neuchâtel allow quantifying the roughness modifications caused by poultice and rubbing cleaning systems.

Nevertheless, a reliable imprint moulding method has still to be developed in order to make the necessary measurements without any building sampling. A comparison of measurements made exactly at the same place before and after a cleaning will be very useful. Such a method using dental products and silicon resins is going to be developed. After improvement of the material and the use of it, we consider completing the imprint moulding by the use of reference points on the building. For these marks, 2 mm Ø stainless steel nails will be hammered in the building façade before the cleaning. The first imprint will be made before the cleaning process, and the second one after it. The reference points will allow comparing the roughness of exactly the same sample surface before and after cleaning. The surface marks undamaged by any cleaning will serve as reference for the calculation of lost material: the optical profilometry based on chromatic confocal imaging will permit to calculate the material quantity removed by the cleaning process by simple image subtraction.

This imprint moulding method associated with the optical profilometry based on chromatic confocal imaging measurement will be a valuable if not an essential tool for all persons interested in the cleaning impact on all buildings.

4. Acknowledgements

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5. References

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