



## The measurement of surface roughness to determine the suitability of different methods for stone cleaning

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In order to select the best bead blasting based method to clean the stone masonry of specific areas of the Cathedral of Segovia (Segovia, Spain), measurements of the roughness of the stone surface were performed, before and after cleaning processes. These types of methods can, besides removing soiling and surface deposits, leave a rougher surface, which could favour a rapid deposit accumulation and accelerate stone decay due to a specific surface increase; or, on the contrary, the cleaning method can be so aggressive that can smooth the surface due to an excessive material remotion.

The equipment used for this study is an optical surface roughnessmeter (TRACEiT, Innowep GMBH), which is a non-destructive and portable device, uses white light and is contactless. It allows 3D roughness topographic maps (at a micrometer scale) and obtains values for Ra, Rq and Rz roughness parameters according to DIN EN ISO 4287 standard.

Two main varieties of stone can be found at both study areas of the Cathedral: the Cloister and the area called "Enlosado" (paving area), this last one an outdoor area in front of the building, with walls and stairs built in stonemasonry: a yellow dolostone and a white dolomite-rich limestone. The soiling layer or surface deposit layer was measured and analysed by means of petrological and mineralogical techniques (X ray diffraction, polarizing optical microscopy, scanning electron microscopy): around 70-200  $\mu\text{m}$  thick, and mainly composed of quartz and gypsum, as well as organic matter.

With the aim of assessing the cleaning method suitability some field areas were selected, representative of the soiling degree of the stonemasonry, and considering both types of stone varieties. In each assessment area (square or rectangle areas of approx 20x20 cm<sup>2</sup> or 10x20cm<sup>2</sup>), a reference area was selected together with 6 other areas in which cleaning was performed varying the particle size (88-150  $\mu\text{m}$ ), the particle composition (glass microspheres and aluminium oxide) and blasting pressure (<1 atm and 1-3 atm). Roughness measurements were accompanied by colour analysis of the areas before and after cleaning (using a spectrophotometer). For this study, Rz was considered the roughness parameter most interesting for the assessment of the most suitable cleaning technique, as well as the 3D roughness images.

Differences in the values of Rz, before and after cleaning, range from +36 to -34. The criteria followed in this study was to exclude differences above 5 units, in absolute terms, considering media values, both in the X and Y axes.

As a conclusion, the cleaning methods recommended as the most suitable were, for the yellow stone variety in the cloister, the aluminium oxide blasting method (105  $\mu\text{m}$  particle size) at a pressure under 1 atm, followed by the same method with the same particle size, at a pressure between 1 and 3 atm. For the white stone variety, two other cleaning methods are suitable: first, the method based on glass microspheres (90-150  $\mu\text{m}$  particle size) under less than 1 atm pressure, followed by aluminium oxide particles blasting (105  $\mu\text{m}$ ) under 1 atm pressure. As both varieties are intertwined in the masonry, the best cleaning method for both of them could be aluminium oxide blasting (105  $\mu\text{m}$ ) under 1 atm pressure.

In the case of the paving area, the stone cleaning recommendation is glass blasting with particle size ranging from 90 to 150  $\mu\text{m}$  under a pressure of 1 atm, followed by aluminium oxide blasting as a second option (88  $\mu\text{m}$  particle size) applied at a pressure ranging from 1 to 3 atm pressure.

Finally, this study confirms the measurement of surface roughness as a reliable test to determine the suitability of stone cleaning methods. It is a non destructive technique (contactless), portable, easy to use, non-expensive measuring, which can rapidly help to select – together with other techniques- the most adequate, non aggressive and most suitable cleaning method.

The authors thank to the programs Geomateriales (S2009/MAT-1629) and CONSOLIDER-TCP (CSD2007-0058).

