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Comparison of the water jet and some traditional stone surface treatment methods in different lithotypes

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ABSTRACT

Marble slabs with rough surface have captured a large share in the market of ornamental stones in recent years. There are many different methods of stone surface treatment currently used to improve the aesthetic appearance of the surface of the marble slab or tile or to increase the roughness. Traditional methods like bush hammering, polishing or flaming have various disadvantages that may reduce the market interest for particular applications. The aim of this study is to compare the water jet surface treatment method with traditional methods. For this purpose five different types of stones (granite, basalt, serpentine, limestone and marble) were treated with water jet and the results were compared with the results obtained from traditional methods. The results of the color, gloss, luminance and roughness analysis were used as the comparison parameters. Results so far achieved indicate that the application of water jets in surface treatment can reduce (or even eliminate) some disadvantages of traditional methods because it enables to obtain a surface with required roughness while preserving aesthetic appearance of the stone.

1. Introduction

Traditional methods of stone surface processing and finishing include different kinds of treatments applied to improve the aesthetic appearance of the surface and/or to increase its roughness (and thus increase the antiskid properties) [1]. The choice of the type of surface treatment depends on the type and the conditions of the material for dealing, the aesthetic effect, and the economics of the work, the tradition and also the market trends [2,3].

Contemporary stone architecture philosophies have definitively consolidated the use of ornamental stones with treated surfaces; especially rough surfaces, for cladding/facing, and paving/flooring and, more and more frequently for urban fixtures and in design [4]. Surface treatment is a set of operations performed on the surface, outside the borders and edges of stone elements to give a certain appearance and also to provide housing for anchorage devices [5].

Rustic treatments now account for approximately 30% of total surface treatments. The reasons for the success of this kind of workmanship can be related to fashion (newness, attractiveness and color) and also to technical and economical aspects (rough, no-slip surfaces). In addition, a rustic finish, while costing less than polishing, is generally sold at the same or even at a higher price.

There are a number of stone surface treatment methods in marble industry such as chiseling, bush hammering, sand blasting, scratching, flaming, grinding and water jetting. This study is concerned with bush hammering, polishing, flaming and water jet treatments.

Water jetting is a relatively new process of stone surface treatment based on the action of very high velocity water jets generated at constant pressure [6–10]. Water jet treated stone surfaces provide higher levels of aesthetical appearance.

Bush hammering is a rough impact treatment that can be obtained by "bush hammers" (a particular kind of hammer with a number of pyramidal picks). Bush hammering is used mainly in outdoor applications, such as sculptures, stairs, riddles, and pavements. It gives the surface a carved aspect, rough and in relief (called "orange skin") [11].

Flaming is a thermal process working by inflicting very high heat (more than 2000 °C) on the surface, which undergoes a thermal shock that dislodges and granulates a number of crystals, creating a typical kind of roughness. The process is aided by a polymineral (and silicate) stone composition, so that granites give the best results; carbonate rocks tend to crumble (calcination) although there are types of limestone that can be flamed with very good results because they contain magnesium and/or impurities of various kinds. Flaming is done with oxy-propane fuel even though, theoretically, it could be done with common gases (methane) if supplied at adequate pressure [12].

Polishing is the final stage in smoothing as well as its final refinement in the aesthetic and chromatic sense; all residual pores

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are occluded and the surface becomes shiny, reflective and mirroring. With this treatment, the material reaches a maximum definition of veining, pattern and grain, the greatest accentuation of chromatics (color and depth) and a high degree of protection against aggressions of various types; but polishing also highlights defects (uneven color, spotting, pattern variations, etc.). Like every other surface treatment, it too has its Achilles' heel: when wet, a polished surface is slippery and on softer materials the polish tends to turn opaque in highly trafficked areas [12].

All of the aforementioned technologies exhibit different disadvantages which may reduce the interest of the market for each of them. In case of surface finishing treatments based on the action of mechanical tools, sand blasting and flaming, the technological limits are due to the changes of the surface characteristics of the treated material. These changes can be produced by mechanical alterations (as a consequence of impacts or of heat shock actions) or chromatic modifications (as an effect of the production of micro-cracks) and by crystals melting (which generates a decrease of color brightness and some chromatic differences with an opaque effect on the material that is not desired by possible end users). In the case of polishing, for which the chromatic and aesthetic aspects are preserved, the surface has slippery features, which represents a significant disadvantage, especially in case of pavement applications.

Stone surface treatment by water jet technology overcomes some of these disadvantages with low productivity and high processing costs. The pressure used for stone surface treatment with water jets ranges between 200 and 400 MPa. The problems related to this technology are linked with the very high pressures and correspondingly low flow rates. As a result, the technology provides low productivity of surface treatment [11,13].

Researches [6–9,14,15] have experimentally treated surfaces with water jet machine. In these studies, surfaces evaluated aesthetically. In particular, Bortolussi et al. [14] worked on surface finishing marble with abrasive water jet. Careddu et al. [6,8,9] investigated how the water jet is suited to treating the surfaces of many non-flammable stones, with considerable aesthetic and economic advantages. Costa [7] worked on superficial surface finishing with water jet technology and analysed the results aesthetically. Gürsel [15] investigated relationships between operating and performance parameters, such as specific energy, excavation rate (material removal rate), roughness and luminance on different types of marbles for surface treatment operation with water jet.

However, the quality of the designed surfaces was not assessed by gloss and luminance analysis in any of these while comparisons in terms of the being aesthetic or not remained to be relative.

For this reason, in this study, surface treatments were made by means of using different methods (bush hammering, flaming, polishing, water jet) and the quality of the surfaces of basalt, serpentine, limestone, marble and granite types of stones were determined not only by color analysis and roughness methods but also by gloss and luminance measurements and comparisons between the methods were made based on the results obtained from these measurements. The roughness measurements were performed in two different axes (*X* and *Y*) and the assessments were done accordingly.

2. Machinery and equipment

Surface treatment operations have been performed by using water jet on different kind of stones such as Sardinian Basalt (basalt), Guetemala Green (serpentine), Orosei Marble (limestone), Carrara White (marble) and Pearl Grey (granite) having $7 \times 7 \times 2$ cm size. Color, luminance, gloss and roughness analyses have been performed on the surfaces treated by using water jet, bush hammering, polishing, flaming methods and also disc sawed surfaces.

2.1. Water jet plant

The equipment used in the experimental plan was a robot, numerically controlled on two axes, whose nozzle-bearing head was deliberately inclined to carry out the experiment (Fig. 1). The system consists of the following components:

- Thirty-seven kilowatt pressure intensifier with three parallel pressure-multiplying pumps, supplying maximum water pressure of 390 MPa with 7 l/min capacity.
- Nozzle-bearing head (Fig. 2) equipped with a slope-regulating system, carrying a convergent-section sapphire nozzle 0.3 mm in diameter. The head is mounted on a mobile bridge (robot) supported by a steel structure.
- Numerical control robot dedicated to moving the water jet on two controlled axes (*X* and *Y*) and a manual *Z*-axis, working on a bench (with a useful surface of 2×1.6 m^2). The axes are driven by electric servo-systems equipped with high resolution measurement systems. Maximum cutting-head speed is 24.5 m/min. Beneath the bench, there is a water tank in order to collect refuse and lessen water jet power.
- A programmable unit to which setting and automatic controls of all the functions are committed. It is interfaced with the plant by a CAD–CAM programming system [6].

Fig. 1. Water jet machine used in this study (waterline 1620).

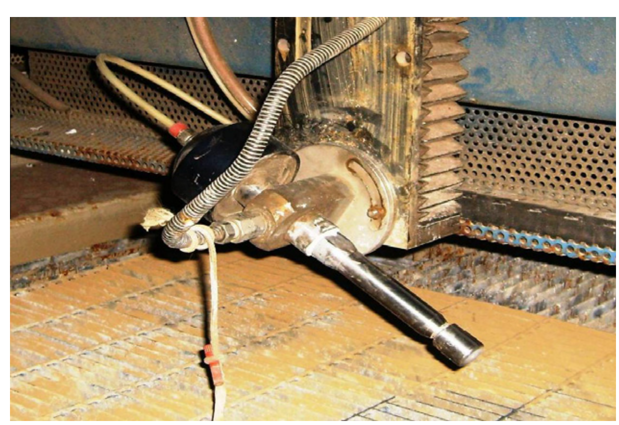

Fig. 2. Angled nozzle of the water jet.