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A Study of nozzle angle in stone surface treatment with water jets

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ABSTRACT

The stone surface treatment with water jet is a recently introduced method. It is used to increase the roughness to improve its antislip properties while preserving esthetic appearance of the stone without having thermal shock, mechanical stress and the production of fumes and dust. Nozzle angle is one of the important parameters affecting treatment of surface. This study is an attempt to assess the effect of nozzle angle on surface treatment quality with water jet and to determine the most suitable nozzle angle value. For this purpose, surfaces of Sardinian Basalt samples are treated with pure water jet in six different nozzle angles (15°, 30°, 45°, 60°, 75° and 90°). The roughness is measured on all the treated surfaces by various roughness parameters. The experimental studies showed that treatment with nozzle angle between 30° and 75° gives the surfaces with similar regular variation.

1. Introduction

Contemporary stone architecture philosophies have definitively consolidated the use of ornamental stones with treated surface, especially rough surfaces, for cladding/facing, paving/flooring and more and more frequently for urban fixtures and in design [1]. Surface treatment is a set of operations performed on the surface, outside borders and edges of stone elements to give a certain appearance and also to provide housing for anchorage devices [2].

There are a number of methods of stone surface processing and finishing such as chiseling, bushhamering, sandblasting, scratching, flaming, grinding, water treatment. The choice of the method depends on the type and the conditions of the material, the esthetic effect, economics of the working, tradition and also market trends [3–5]. This study is concerned with water jet treatment.

Surface treatment methods based on mechanical tools, sand blasting and flaming lead to undesirable features such as chromatic modifications, production of micro-cracks, mechanical alterations. 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 and water jet treated stone surfaces are of higher level of esthetical appearance than the other methods [4,6–9].

Researchers [4,7–11] have experimentally treated the surfaces with water jet machine. In these studies, the surfaces were evaluated esthetically and compared by other surface treatment methods as flaming, bushhammering, sandblasting. In particular, Bortolussi et al. [10] worked on surface finishing marble with abrasive water jet. Careddu et al. [7] and [9] investigated how the water-jet is suited to treating the surfaces of many non-flammable rocks, with considerable esthetic and economic advantages. Costa [8] worked on superficial surface finishing with water jet technology and analyzed the results esthetically. Gürsel [11] investigated relationships between operating and performance parameters such as specific energy, excavation rate (material removal rate), roughness, luminance on different types of marbles for surface treatment operation with water jet. Careddu [4] showed the technical economic and esthetic results obtained with a new water jet treatment and compared it with competing technologies.

In all these studies, the nozzle angle 30° is considered only and the surface quality is assessed from the esthetic point of view. The purpose of this study is to investigate the effect of the nozzle angle in the range of 15–90° on the surface treatment and also to determine the most suitable nozzle angle. For this purpose, surface treatment operations with pure water jet are performed in six different nozzle angle values (15°, 30°, 45°, 60°, 75° and 90°) on Sardinian Basalt sample. The roughness measurements are performed in two perpendicular directions on all the treated surfaces and the surfaces are assessed by considering statistical and geostatistical criteria.

2. Material and method

Two main machines were used in this study; water-jet plant for the surface treatment operations and roughness measurement system to evaluate roughness of the treated surfaces.

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

2.1. Water-jet plant

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

- 37 kW pressure intensifier with three parallel pressure-multiplying pumps, supplying maximum water pressure of a 390 MPa with a 7 l/min capacity.
- Nozzle-bearing head equipped with a slope-regulating device, carrying a convergent-section sapphire orifice 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 $2 \times 1.6\ m^2$). 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 to collect cuttings and lessen water jet power.

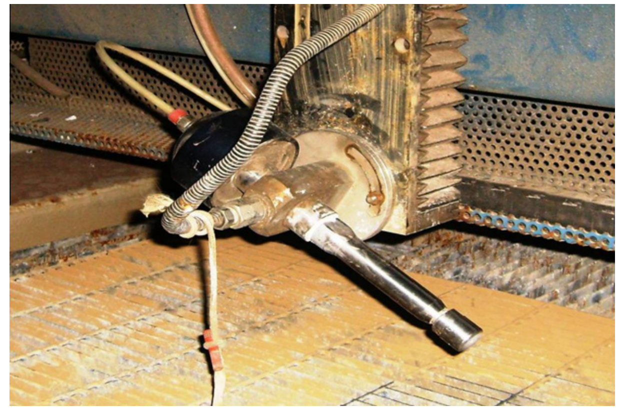

Fig. 2. Angled nozzle of the water jet.

- A programmable unit to which setting and automatic controls of all the functions are committed. It is interfaced with the working table by a CAD–CAM programming system [7].

For surface treatment operations, six different nozzle angles (jet inclination angle) are used (Fig. 2). These are 15°, 30°, 45°, 60°, 75° and 90°. Some of the parameters such as distance between water jet scanning lines (parallel-pass pattern), stand-off distance, jet pressure and cutting-head translation speed (traverse velocity) were kept constant during surface treatment operations.

2.2. Surface roughness measurement system

Surftest SJ-400 portable surface roughness tester system is used for the measurement of roughness values. The system has a recordable pin (stylus) which goes along a straight line on a flat surface and it moves up and down depending on the surface regularity. These vibrations are magnified 10–100,000 times and recorded. Thus roughness profile of the surface is obtained in micron level. The Surftest SJ-400 can evaluate 36 kinds of roughness parameters conforming to the standards such as ISO, DIN standards. The SJ-400 detector uses interchangeable nosepieces to allow skid or skidless measurements depending on the type of measurement required [12]. Roughness measurements can be print out and seen on the monitor.

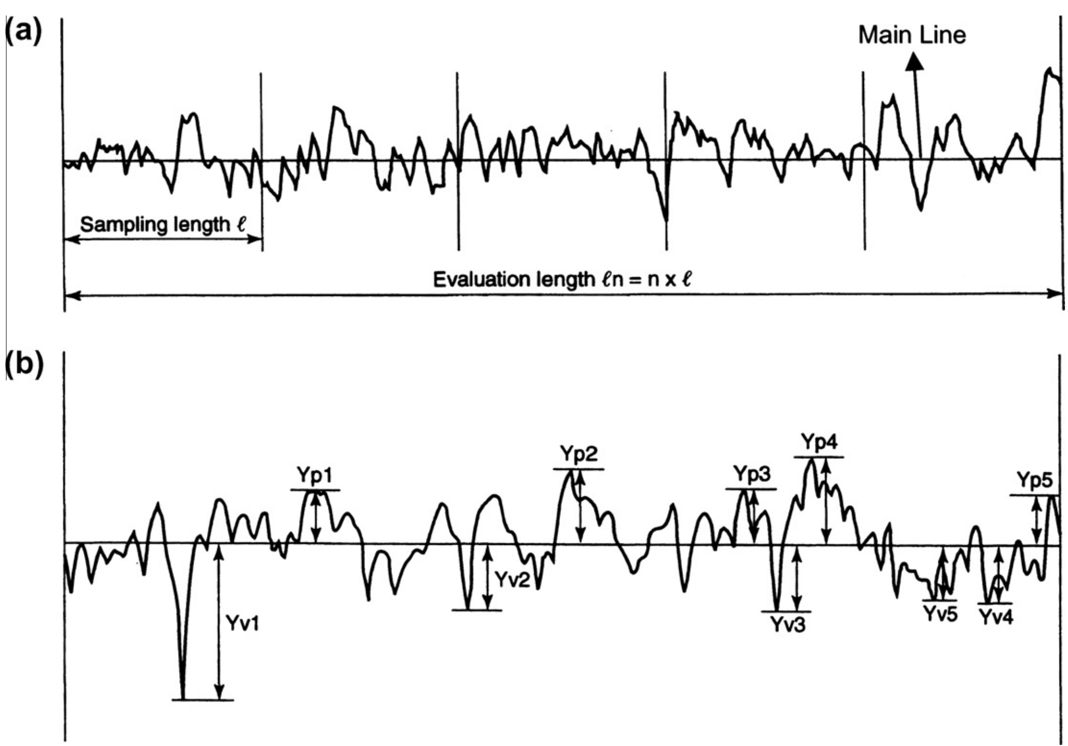

Fig. 3. A typical example of roughness profile, (a) and the deepest (*Yv*) and highest (*Yp*) peak values of the surface and (b) (Sile, 2007).