A new scientific approach to determine the stone workability

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Lorena Zichella, Rossana Bellopede, Fiorenza Baudana, Paola Marini

Synopsis

The prediction of stone - diamond wire interaction is important for the extractive sector, both to improve the productivity and efficiency of quarry work and to avoid dangerous and expensive endeavours of cutting when an unknown stone has to be introduced in the plant. Combining two simple test as the measurement of ultrasonic pulse velocity of the stone and the Knoop micro hardness, a scientific classification of workability have been found. In particular, in this work the application of this scientific classification methodology to the stone plant has been studied, performing UPV measurements on stone block before their cutting The correlation of ultrasonic measurements by indirect method with the index HK25 allowed to order the stones in classes of workability that correspond to what the owners of the plant used to give to such stones. Moreover the correspondence with the in situ cutting parameters has confirmed the reliability of this scientific methodology.

Keywords

Stone workability, diamond wires, ultrasonic pulse velocity, cutting technique.

Introduction

The concept of workability and stone machining has been, for the past thirty years, one of the main area of investigation in national and international researches. Moreover, nowadays this topic has not only a great importance for the conventional economy but also a strategic importance for the Circular Economy.

The prediction of stone - diamond wire interaction is crucial for the extractive sector, both to improve the productivity and efficiency of quarry work and to avoid dangerous and expensive endeavours of cutting when an unknown stone has to be introduced in the plant. The diamond wire users themselves determined an empirical classification of the stone (Industrial Workability Classification) mainly taking into account the greater or lesser ease of cutting. However the new classification suggested by Bellopede et al. (2014) has been obtained by means of a scientific approach with easy and expeditious test methods. In particular, while the IWC is characterized by 9 classes, with the new technical classification the classes decrease to 7, thus reducing the case of overlapping and uncertainty due to the intrinsic variability of the materials.

Diamond-wire cutting operations are affected essentially by two different kinds of parameters: partially controlled and non-controlled. The partially controlled ones refer to the properties of the cutting tools and equipment, such as the cutting speed (peripheral speed of the diamond-wire – m/s), the feed rate (cm/h), and the machine absorption (ampere/m). Instead, the non-controlled parameters refer to the stone properties, such as the petrographic and mineralogical composition, grain size, water content, weathering, discontinuities/anisotropy and hardness.

Previous studies (Bellopede et al 2014, Amaral et al 2000, Ersoy et al 2005, Gokhan at al 2013) demonstrated that the uncontrolled parameters can be measured indirectly by different techniques but the Knoop micro-hardness and the Ultrasonic Pulse Velocity (UPV) measures best correlate with workability and are therefore more significant . From 1982 Mancini and Morandini and more recently, in 2003, Beste and Jacobson have underlined the importance of the micro-hardness measurement to study the tool wear. However, in literature, the relationship between petrographic characteristics and the industrial process involved in cutting and finishing stones is noticeably unknown, as pointed out by Riberiro et al (2007). UPV measures can be considered an expedite and reliable testing of the mechanical properties of a rock (quarry face or block), and gives also available information on the stone slab quality (Bellopede et al 2005, Vasconcelos et al 2008).

The aim of the present work is to evaluate the applicability of this scientific classification methodology to the stone plant.

Materials and Methods

The following siliceous stones with industrial index of workability (IWC) between 3-4 have been tested:

-a diorite (DIO), with IWC 3 composed by 65% of plagioclase, 30% of hornblende and biotite and 5% of opaque minerals; the grain size distribution is from 0,01 to 2 mm;

-a sienite (SIE), with IWC 3 composed by 50% of feldspar, 25% of biotite and hornblenda, 15% of quartz; the grain size distribution is from 0,03 to 2 mm;

- a granite (RBE), with IWC 3-4 composed by 60% of plagioclase and K- feldspar, and 30% of quartz; 10% of biotite; the grain size distribution is from 0,05 to 12 mm;

- a granite (GRP), with IWC 4 composed by 65% of K- feldspar and plagioclase, 30% of quartz, 5% of biotite and pyroxene; the grain size distribution is from 0,1 to 12 mm.

Indirect and direct UPV measurements have been performed in situ on stone block. The same slabs has been additionally tested in laboratory by means UPV in indirect method and Knoop hardness measurements. Knoop hardness measurements are conducted with a load of 1,96 [N], with a sequence of number of identifications per sample of 40 points. The HK25 has been chosen as the index of correlation with the UPVs, as it represents the least hard minerals and the micro-fractures or voids, therefore HK25 better represents the anisotropy and the weaknesses of the stone investigated. The ultrasonic pulse velocity (UPV) was determined using a PUNDIT–CRO instrumentation connected to oscilloscope software for a lap-top, with conic 33 kHz frequency transducers. Measurements were made indirectly by placing the transmitter transducer on a fixed point and the receiver at progressive distances (each 25 mm: from 25 mm to 175 mm) on the same specimen surface (specimen dimensions 200mm x 200mm x 20 mm). For the direct methods the receiver was placed on the opposite surface respect the transmitter.

Results

In the Tab. 1 the results of ultrasonic and microhardness measurements of the different 4 rock tested are reported. In the same table with the data of feed rate and machine absorption [A] taken during the cutting process are shown.

As it is possible to note from the figure 1, where also other rocks of different petrographic nature are reported in red, the scientific classification based on the indirect UPV and HK25 measurements match with the IWC of the four stone tested. In the figure 2 the well correlation between the machine absorption and the quartz content is shown. However, the cutting parameters weren't measured for all the stones, consequently it not possible to demonstrate the full correlation with quartz content. The correlation among machine absorption [A] and HK25/UPVind (as mean values of UPV performed by indirect method on the block) is reported. The exponential regression has a correlation coefficient of 0.91. The correlation between HK25, UPV and workability class demonstrated in the previous research (Bellopede et al, 2014) has been confirmed here.

Table 1 Rock tested, cutting parameters, ultrasonic (mean value of 10 measurements) and micro hardness (HK25) measurements.

Rock type	Acronym	Feed rate (cm/h)	Machine absorption (A/wire)	UPV indirect method on block perpendicular direction (m/s)	UPV indirect method on block parallel direction (m/s)	UPV indirect method on slab perpendicular direction (m/s)	UPV indirect method on slab parallel direction (m/s)	UPV direct method on block (m/s)	HK25 – MPa-
Diorite	DIOs	16.5	1.43	2287	2352	2708	2443	5450	2789
Sienite	SIE	24.4	1.65	2482	2172	2449	2299	4730	3602
Granite	RGB	25.00	2.78	2387	2310	2754	2430	3530	4049
Granite	GRP	23.8	2.83	2601	2510	2785	2780	4500	5234

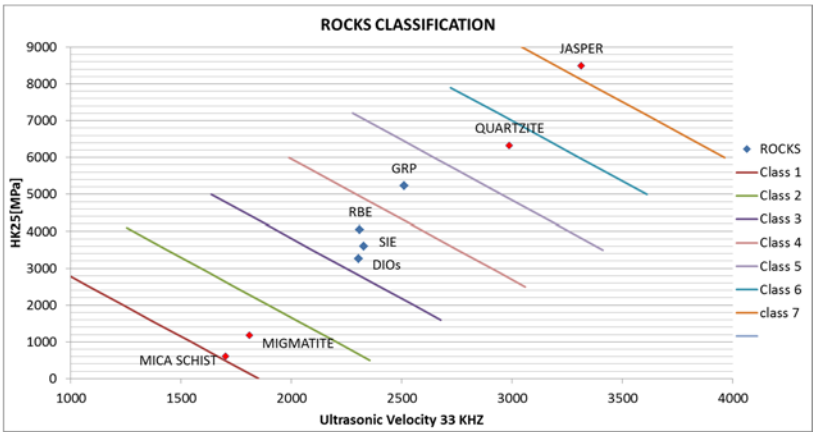

Fig. 1 Scientific classification of tested stone

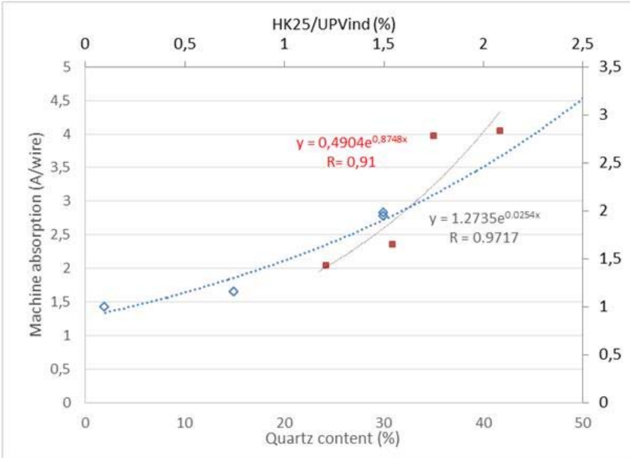

Fig. 2 Machine absorption vs H25/UPVind and vs quartz content for RBE, SIE, DIOs and GRP

Discussion and conclusions

The in situ measurements on blocks on different types of siliceous stone allowed to verify the reliability of the different measurement techniques used and to validate a new scientific classification for the workability of natural stones.

The ultrasonic measurements on blocks are well correlated with those performed on the slabs on the same stone. Moreover indirect UPV measurements can be considered reliable as they match with data resulting from direct method.

The correlation of ultrasonic measurements by indirect method with the index HK25 allowed to order the stones in classes of workability that correspond to what the owners of the plant used to give to such stones. The correspondence with the in situ cutting parameters has confirmed the reliability of this scientific methodology. This proposed scientific classification help the choice of the cutting parameter (feed rate, cutting speed) to achieve technical and economic enhancement in plant.

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