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14764 - Diamond wire cutting – Sense of Rock Strength

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INTRODUCTION

Extraction methods of natural stones have become faster and more resource-saving according technical improvements in recent decades. For example durable diamond wires with sintered beads have given a huge leap for the economic profitability of wire sawing, especially for the efficient quarrying of hard stones. Rock mechanics, like hardness and strength set however limits to the speed of extraction and consequently also to the economic base for the each quarry. This research compares performance of wire sawing and technical properties of three black stones. Testing was a part of the project “Resource efficiency development of natural stone production” carried out by Geological Survey of Finland in the years 2015-2018. Project got financing from the European Regional Development Fund (ERDF).

Figure 1. A wire cutting test of gabbro at Oulainen quarry in western Finland. 1. saw unit, 2. flywheel, 3. pulley, 4. tracks, 5. flushing water, 6. access holes 2. for the wire, 7. diamond wire loop.

METHODOLOGY

The probable relationship between the speed of a diamond wire cut and the rock strength was aimed to find out by sawing and technical tests. Wire cutting was done at two black stone quarries, Kivilahti and Oulainen in Finland. Reference data was get from PG Black quarry located in Varpaisjärvi. Technical properties according EN-standards were already available. The wire loop was as longest 80 meters in both tests. The water consumption for flushing the wire was 1.2-1.8 m^3 per hour. The peripheral speed of the wire (m/s) and the applied tension (ampere, A) were written up from the control panel. The cutting performance (m^2/h) was calculated by multiplying the bench height (m) and the speed of the backward movement of the saw unit on tracks (m/h). The bench height for the primary cut was about 6 m at Kivilahti and 4.2 m at Oulainen. The wire was Tyrolit rubber assembly GSF 5 with the specification of a hard granite. The number of sintered diamond beads was 40 per one meter, diameter 11.3 mm. Power of the saw unit was 55 kw.

RESULTS

Measured cutting speeds of the studied rock types displayed remarkable difference. Oulainen gabbro appeared relatively soft, the sawing rate 20.6 m^2/h, while Kivilahti diabase hard 7.9. Reference data from Varpaisjärvi quarry was 9.0 m^2/h. The sawing test of Kivilahti diabase was done by an optimal wire speed 30 m/s and the tension 75-90 amperes (A). At Oulainen quarry the applied wire speed was slight lower 27-30 m/s also the force by which the wire was pulled, 73-82 A.

Strength of studied rock types has a positive correlation to measured maximum cutting speeds. Kivilahti black has a highest flexural strength 32.7 MPa and Oulainen lowest 18.4 among here studied rock types. Reference, BG Black is 26.1 MPa in flexural strength. Abrasion resistance (Wide wheel, EN 14157) of Kivilahti is 12 millimeter, the value of PG Black 16 closer to that of Oulainen 15. lowest 18.4 among here studied rock types. Reference, BG Black is 26.1 MPa in flexural strength. Abrasion resistance (Wide wheel, EN 14157) of Kivilahti is 12 millimeter, the value of PG Black 16 closer to that of Oulainen 15.

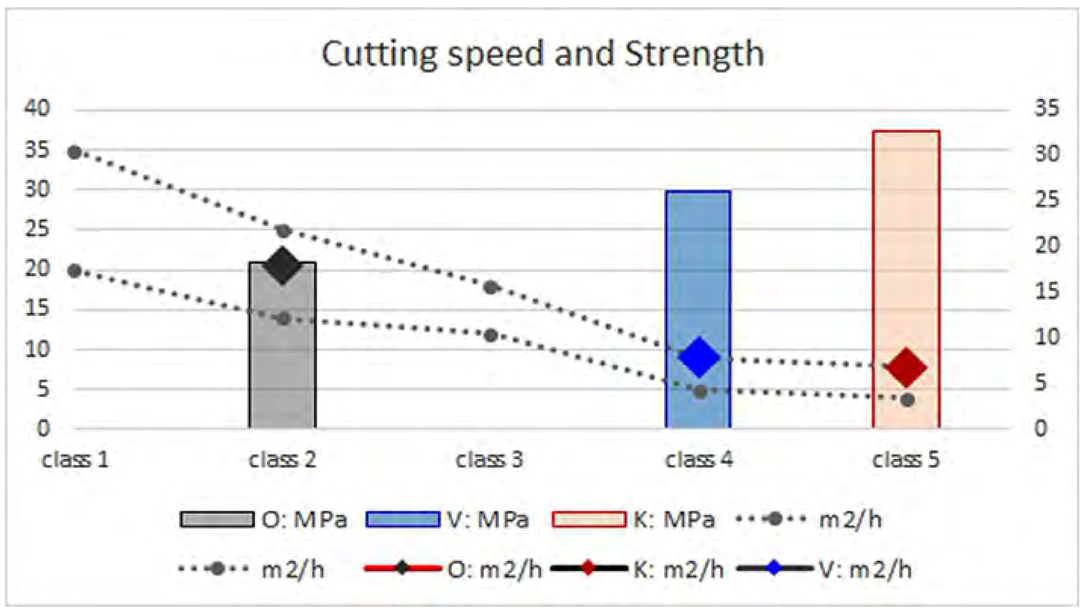

Figure 3. The speed of diamond wire cutting on left axes (m^2/h) and the flexural strength on right, according standard EN 12372 (MPa). The cutting rate of the soft Oulainen gabbro (black diamond) relates to that of class 2 granites, the hard diabase at Varpaisjärvi to class 4 (blue) and that of Kivilahti class 5 (red). Upper and lower values of average cutting speeds among granites are by dashed lines.

Table 1. Technical properties of black stones: Kivilahti, Oulainen and PG Black.

Standard	Property	Unit	Kivilahti	Oulainen	PG Black
EN 13755	Water absorption	%	0.03	0.09	0.09
EN 1936	Real density and apparent density	kg/m^3	3060	2900	3080
EN 1936	Total and open porosity	%	0.10	0.29	0.29
EN 12372	Flexural strength	MPa	32.7	18.4	26
EN 1926	Uniaxial compressive strength	MPa	293	210	311
EN 14157	Wide wheel abrasion resistance	mm	12	15	16

CONCLUSION

According the results of this research the high cutting speed of Oulainen gabbro 20.6 m^2/h relates to low flexural strength 18.4 MPa, while 2.6-fold lower speed Kivilahti to high strength 32.7. BG Black is diabase as well Kivilahti displaying the same level of cutting speed 9 m^2/h and flexural strength 26.1. Oulainen gabbro is able also to consider as soft stone, Mohs hardness 5.54 and wide wheel abrasion 16 mm, these of Kivilahti 5.90 and 12. The importance of hardness has also to be taken account when calculating economic profitability of quarrying by the cutting speed data. Combining the both strength and the hardness of a rock leads to better estimation of the durability of a wire. Beyond the values of a single cut, the real productivity of wire sawing is about 1-5 m^2/h, when extraction, block cutting and shaping phases are included. Produced square meters and wire-life are in any case primarily related to physical parameters of the rock, like the sense of strength.

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