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Predicting the noise level during sawing of carbonate rocks from the P-wave velocity

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ABSTRACT

Noise affects humans both physically and psychologically, whose impacts vary from person to person. Block cutting machine is one of the most important noise sources in the stone processing plants. This study investigates the predictability of the noise level generated during sawing of carbonate rocks from the P-wave velocity. First, the P-wave velocities of rock samples were measured in the laboratory. Then, the core samples were cut by an automatic cutting machine with diamond saw in the laboratory and noise levels were measured. A strong linear correlation was found between the noise levels and the P-wave velocity. After including the densities of the samples to the analysis, the correlation coefficient was increased significantly. It is concluded that the noise level of carbonate rocks can be estimated using the derived equations from the P-wave velocity. The laboratory noise level can be converted to the site noise level using a conversion factor.

Keywords: Rock sawing, Noise, P-wave velocity

1. INTRODUCTION

About 20 % of European labors are exposed to noise so loud that they would have to raise their voice to talk to other people. Exposure to noise is especially common in the construction and manufacturing sectors (1). There are both physical and psychological effect of noise on humans. Exposure to excessive noise for a short time can cause temporary hearing loss, while long-term exposure to loud noise, or short exposures to very loud noises, can cause permanent hearing loss. In addition to hearing loss, exposure to noise in the workplace can cause a variety of other problems, including chronic health problems (2):

- Exposure to noise over a long period of time decreases coordination and concentration. This increases the chance of accidents happening.
- Noise increases stress, which can lead to a number of health problems, including heart, stomach and nervous disorders. Noise is suspected of being one of the causes of heart disease and stomach ulcers.
- Workers exposed to noise may complain of nervousness, sleeping problems and fatigue (feeling tired all the time).
- Excessive exposure to noise can also reduce job performance and may cause high rates of absenteeism.

There are limited studies in the literature on the relation between the rock properties and the sound level during cutting rock by diamond saw. Karakurt et al. (3) carried out a study on the noise level generated during the sawing of granites using circular diamond sawblades. They showed that increasing of peripheral speed, traverse speed and cutting depth increased noise levels. They derived relations having moderate correlation coefficients between the noise level and both compressive strength and density. They also developed multiple regression models for the prediction of noise level

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by including the operating variables and rock properties. We (4) studied the assessability of the noise from sawing rock by diamond saw using the P-wave velocity. The noise level measurement and P-wave velocity tests were performed on 36 different rock types. The evaluation of the results showed that there was a strong power relation between the noise level and the P-wave velocity. It was concluded that the noise level from the diamond sawing could be assessed using the P-wave velocity. We (5) also investigated the predictability of the Los Angeles abrasion loss from the noise level in cutting rocks by diamond saw and developed a prediction equation. In this study, the Los Angeles abrasion, noise level measurement, density, and porosity tests were carried out on 27 different rock types such as igneous, metamorphic, and sedimentary. A good relation between the Los Angeles abrasion loss and noise level was found. The multiple regression analysis was also performed by also including density and porosity values in order to check the possibility of obtaining the more significant relations. However, it was seen that the correlation coefficients of the multiple regression equations were slightly higher than that of the simple regression equation. In another study (6), we evaluated the predictability of the physico-mechanical properties of rocks from the noise level in cutting rock by diamond saw in the laboratory and derived some correlations. The noise measurement, uniaxial compressive strength, Brazilian tensile strength, point load strength, density, and porosity test were carried out on 54 different rock types in the study. Significant correlations were found between the noise level and the rock properties. In our recent study (7), we studied the predictability of the noise from the block cutting machines using the physico-mechanical and mineralogical properties of rocks during sawing igneous rocks. The strong correlations were derived between the noise level and the rock properties using the physico-mechanical and mineralogical properties.

The level of noise allowed by most countries' noise standards is generally 85-90 dB over an eight-hour workday (2). Block cutting machines have been extensively used for the slab production and are the most important noise sources in the stone processing plants. The noise levels of these machines during cutting the rock are generally higher than the allowable level of noise. Predicting the noise level of the block cutting machine during the sawing of a new rock type is useful for the noise management. In this study, the predictability of the noise from the block cutting machines was investigated using the P-wave velocity for carbonate rocks.

2. SAMPLING

Rock blocks were collected from the stone and marble quarries, and stone processing plants in Nigde, Kayseri, Konya, Antalya and Afyon areas of Turkey for the laboratory testing. In order to provide the test specimens free from fractures, partings or alteration zones, block samples were inspected for macroscopic defects. A total of 17 different rock types were sampled, 5 of which were limestone, 7 of which were travertine, and 5 of which were marble. The locations and the types of the rocks sampled are given in Table 1.

Table 1 – The rock types and the locations of the tested rocks.

Rock code	Location	Rock type (Trade mark)
1	Sogutalan/Bursa	Limestone (Bursa beige)
2	Korkuteli/Antalya	Limestone(Korkuteli beige)
3	Fethiye/Mugla	Limestone(Aegean brown)
4	Bunyan/Kayseri	Limestone (Bunyan rosa)
5	Yahyali/Kayseri	Dolomitic Limestone
6	Mut/Icel	Travertine
7	Finike/Antalya	Travertine (Limra)
8	Karaman	Travertine
9	Godene/Konya	Travertine
10	Demre/Antalya	Travertine(Demre stone)
11	Bucak/Burdur	Travertine (Limra)
12	Sivas/Yildizeli	Travertine
13	Uckapili/Nigde	Marble
14	Iscehisar/Afyon	Marble (Tiger skin)
15	Kemalpasa/Bursa	Marble
16	Iscehisar/Afyon	Marble (Afyon sugar)
17	Gumusler/Nigde	Marble

3. LABORATORY STUDIES

3.1 Ultrasonic velocity test

The P-wave velocities were measured on the samples having a diameter of 54.7 mm and a length of 110 mm. End surfaces of the core samples were polished sufficiently smooth plane to provide good coupling. In the tests, PUNDIT 6 instrument and two transducers (a transmitter and a receiver) having a frequency of 1 MHz were used. A good acoustic coupling between the transducer face and the rock surface is necessary for the accuracy of transit time measurement. Stiffer grease was used as a coupling agent in this study. Transducers were pressed to either end of the sample and the pulse transit time was recorded (Figure 1). The tests were repeated three times for each rock type and average value was taken as the P-wave velocity value (Table 2).

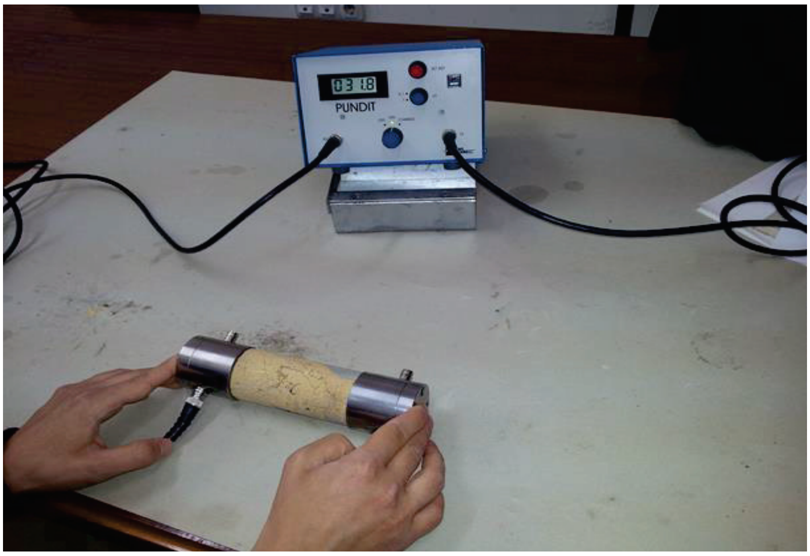

Figure 1 – P-wave velocity measurement.

3.2 Noise level measurement tests

The core samples with a diameter of 54.7 mm were cut using an automatic cutting machine with a diamond saw of 300 mm (Figure 2). The rotational speed of the saw was 2750 rpm and the advancing rate of the saw was 10 mm/min. The noise level was continuously measured by a sound level meter during cutting of the core sample. The measurements were generally repeated three times and the results were averaged for each rock type (Table 2).

Figure 2 – The automatic cutting machine used in the noise level measurement tests.

3.3 Density test

The smooth-cut core samples were used in the determination of the dry density. The specimen volume was calculated from the average of several calliper readings. The mass of the specimen was determined by a balance, capable of weighing to an accuracy of 0.01 of the sample weights. The density values were obtained from the ratio of the specimen mass to the specimen volume. The density tests were repeated three times for each rock type and the average value was recorded as the density value (Table 2).

Table 2 – Average test results.

Rock code	Noise level (dB)	P-wave velocity (km/s)	Density (g/cm^3)
1	86.6	6.1	2.61
2	87.9	6.2	2.61
3	83.6	6.1	2.57
4	83.4	6.0	2.62
5	84.1	6.1	2.63
6	80.4	4.0	1.97
7	81.5	4.3	2.35
8	83.1	5.4	2.33
9	81.7	5.4	2.36
10	83.1	5.5	2.39
11	78.8	3.7	2.17
12	84.1	5.4	2.43
13	85.2	5.7	2.69
14	82.6	4.1	2.59
15	83.6	4.6	2.64
16	84.0	5.1	2.62
17	83.7	5.3	2.68

4. EVALUATION OF THE RESULTS

The test results given in Table 2 were evaluated using the regression analysis. The noise levels were correlated to the P-wave velocity values in order to develop an estimation equation. A linear relation with a good correlation coefficient (r) of 0.78 was found between the noise level and the P-wave velocity (Figure 3). Increasing P-wave velocity increases the noise level. The equation of the line is:

$$NL = 2.04V_p + 72.68 \tag{1}$$

where, NL is the noise level (dB) and V_P is the P-wave velocity (km/s).

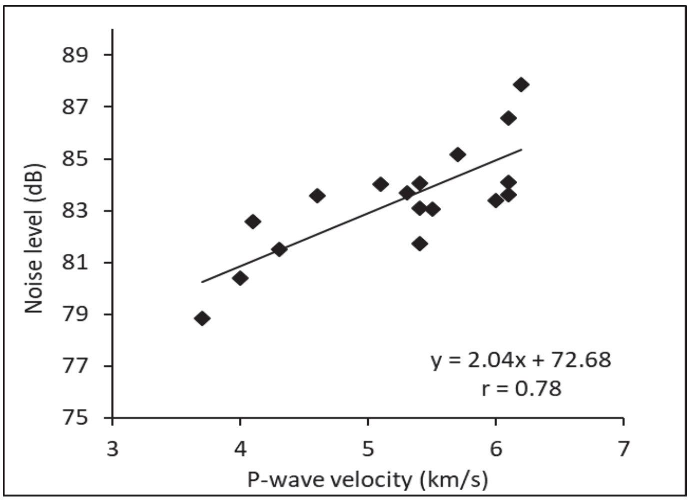

Figure 3 – The correlation between the noise level and the P-wave velocity.

The P-wave velocity values were also correlated to the density values. As shown in Fig. 4, there is a linear relation between the P-wave velocity and the density values. Increasing density increases the P-wave velocity values. The relation has a good correlation coefficient (0.74). The equation of the line is:

$$NL = 7.75\gamma + 64.09 \quad (2)$$

where, NL is the noise level (dB) and γ is the density (g/cm^3).

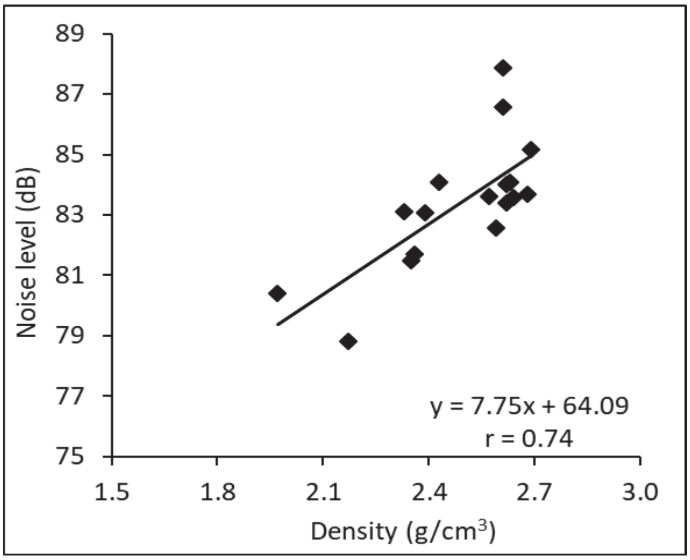

Figure 4 – The correlation between the noise level and the density.

The multiple linear regression analysis was performed by including both the P-wave velocity and the density values to the analysis for the expectation of obtaining stronger model than Equation 1. The correlation coefficient of the derived model is 0.85, higher than that of Equation 1. The derived multiple regression model is as follows:

$$NL = 1.4V_p + 4.4\gamma + 65.22 \quad (2)$$

where, NL is the noise level (dB), V_P is the P-wave velocity (km/s), and γ is the density (g/cm^3).

The measured and estimated noise levels in this study are the laboratory noise levels. These noise levels should be converted to the field noise levels for the practical use. It was shown (7) that the laboratory noise levels can be converted to the field noise level by multiplying a conversion factor of 1.16 for the block cutting machines. Thus, the conversion factor can be used for converting the estimated noise levels using the equations derived in this study to the field noise level.

5. CONCLUSIONS

The noise level measurements were performed in the laboratory during cutting seventeen carbonate rocks such as limestone, travertine and marbles in order to evaluate the noise from the block cutting machines in the stone processing factories using the P-wave velocity of rocks. The statistical analysis of the results showed that there was a strong linear correlation between the noise levels and the P-wave velocity. Multiple regression analysis was also performed by including both the P-wave velocity and the densities of the samples to the analysis and a stronger model was derived than that of the simple regression analysis.

Concluding remark is that the laboratory noise level for a new rock type to be cut can be estimated using the derived relations, and then, the it can be converted to the site noise level using the conversion factor.

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