Investigation of the artifical vibration wave motions formed on the dry and saturated rock samples

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Abstract: *Blast-induced vibration waves can expand far away from its resource. According to its strength it has a capacity to damage civil structures. It is therefore critical that wave propagation mechanism of each mine site should be well presented and its neutralization facts are described. In this study, vibration wave result from blasting of mining and tunnel excavation site were simulated in laboratory by impact wave initiator. Vibration propagation based on the change of peak particle velocity in dry and saturated rock samples were then determined to compare. Vibration monitoring seismograph were used to measure and record the waves form (transverse, longitudinal, vertical and peak vector sum) at the predetermined point on rock samples. Under constant distance between vibration wave initiator and vibration measuring device, differences in waves were evaluated by the rock porosity and water content.*

Introduction

Conventional excavation techniques based on drilling and blasting are the most widely adopted techniques for mining and civil engineering projects. Rock blasting produces ground shock and vibration as a side effect of rock fragmentation which may cause damage to surrounding civil structures such as, houses, buildings, bridges, dams, tunnels and monuments. Due to expansion of land using for housing and other civil engineering structures, distances between these structures and excavation sites getting closer gradually in Turkey each year. That means, blast induced ground vibration and their propagation in rock masses have been drawing more and more attention as a research subjects.

Knowledge of vibration waves and their propagation mechanisms, rock mass mechanical properties and rock structural features are important to analyze rock vibration due to blasting operations. The results obtained here will be the optimum rock blasting conditions. Properties of rock masses between blasting site and targeted civil constructions such as; elastic modulus, water content (humidity), permeability and porosity are influencing factors on blast induced vibration propagation. Besides these properties, vibration wave propagation are also strongly related with the rock mass lithelogy. Different rock masses types and structures have diverse characteristics when the vibration wave propagation through them is considered.

Bahloli [2] is one of the noticeable researchers who mentioned the rock mass and rock material properties for blasting design. Howkins[3] argued earlier that seismic velocity is effected by discontinuities in the rock masses. Similarly Cook [4] later on mentioned that there are lots of discontinuities and fractures in the rock masses which definitely modify the properties of rock masses and their seismic reactions.

Aldas [1] was performed a study in open pit lignite mine and remarked once more on a subject which is formerly argued by Bollinger, concluding remark on this subject is; "strength, density and porosity properties of rock masses influence shock wave propagation velocity travelling in them". Bollinger [5] wrote also that, vibration waves due to blasting are effective (stronger) in soft rocks and soil when it is compared to strengthened rock. Blair and Spathis [6] had theoretical and practical researches about the effects of rock properties on vibration wave propagations. Later, Olofsson [7] explained the effects on vibration characteristics of soil based on vibration wave velocity, soil type, underground water level, humidity and topography. Wu et.al. [8] wrote that propagations of vibration and ground shocks are remarkable design parameters that can cause damage on dam, tunnel construction bridges and buildings. They researched on if there is a relation between wave propagation velocities and the rock masses encountered in their blasting test sites. All these works create new questions in mind if the humidity condition of rock masses has been differentiated how the vibration wave propagation is affected.

The study reporting here is part of the research performed by Kekec [9] and purposely researching about this condition in laboratory. During the laboratory tests, peak particle velocity created by standard sources in the rock samples were measured from laboratory specimens in different humidity conditions. In order to test the humidity affects on vibration propagation, 9 different rock samples (each of it was prepared in different manner) were used. Layout of tests carried out during this study is given in Figure 1. Particle motion formed purposely by artificial vibration source were measured and saved as transverse (PVT), longitudinal (PVL), vertical (PVV) and peak vector sum (PVS) by the help of *Instantel Minimate Plus* instrument.

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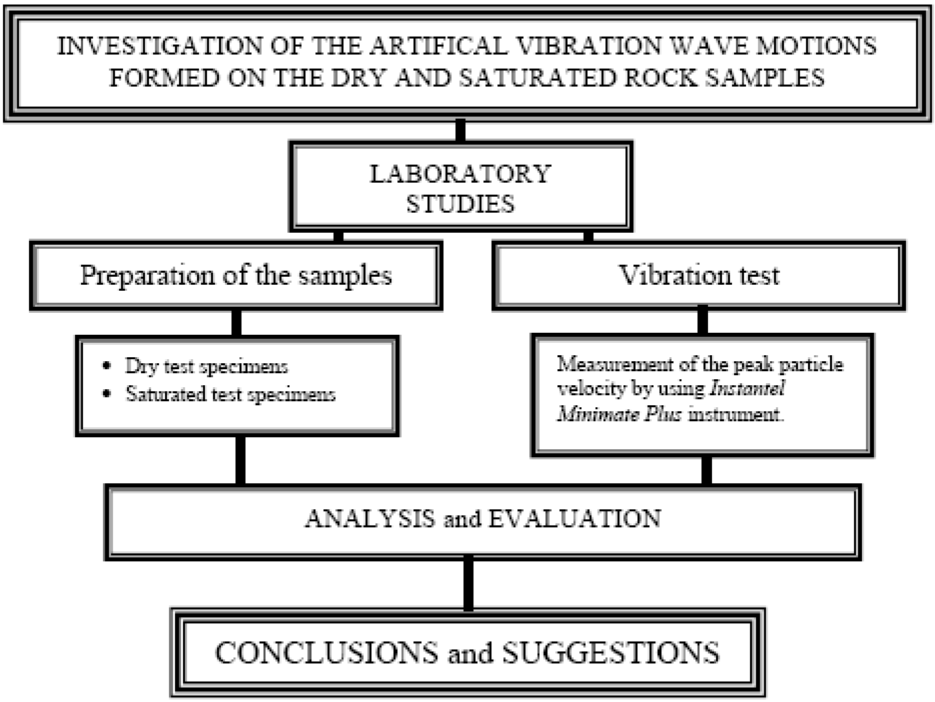

Fig. 1. Layout of the research study.

Preparation of test samples

In this research, 9 different test samples were prepared from ignimbrite, travertine, and basalt rocks. Before the tests, rock blocks (50x50x25 cm in dimension) obtained from 3 different rock quarries were carefully carried to the rock mechanic laboratory of Selcuk University. Then they were cut into prism with 50x15x10 cm in dimension to form required test samples. It is important here in this research to have exactly the same test samples' dimension as given before. Dry test samples were kept in oven, adjusted to 105 ^{o}C, for 24 hours to eliminate water content of original rock samples. Then these samples were stored in a laboratory room (20 ^{o}C) until the tests were performed. Saturated samples on the other hand kept in water in laboratory room (20 ^{o}C) for 48 hours (Figure 2) to get full saturated rock condition. These test samples were then tested when they were taken out of the water (after rinsing the surface wetness of samples) without waiting to eliminate drying action.

Fig. 2. Rock samples prepared in given dimensions had been kept in water for 48 hour to obtain saturated rock sample condition.

Vibration source during the tests

Vibration wave propagation differences in dry and saturated rock samples were recorded in this study. During the tests, same rock samples were tested for their dry and saturated conditions. In order to supply exactly same vibration force to the test samples, simple but effective instrument was designed to manufacture. It was made up from stainless pipe and wooden carrying structure (Figure 3). Stainless pipe's inner diameter is 50 mm which is enough to permit a steel ball (20 mm in diameter and 68 gram in weight) roll down. When this instrument located over any test samples on massive concrete laboratory bench (or on concrete floor) as seen in Figure 4, the test are almost ready to start. After locating the vibration measuring device's sensor (geophone) on the samples the test can be performed. Vibration impact point and geophone locations were measured and signed for each rock samples before the tests to ensure to obtain similar test conditions (Figure 4).

Vibration in this study was obtained by the impact of the stainless steel ball impact on the sample. Energy level of impact obtained by free fall of 68 gram stainless steel ball was fulfilled the vibration wave creation activity in this research. Energy level holes had been drilled on steel pipe to know the exact position of the steel ball before falling down to create required vibration in the rock samples. These holes (5 energy levels) can be seen in Figure 3.

Fig. 3. Vibration wave was generated with especially designed simple but effective instruments shown here. The photo on the right hand site shows the test sample and apparatus just before the test.

During the tests steel ball put into the specially designed instrument's pipe at the required level of energy. Then the instruments and geophone were located to their predetermined position. Geophone was started to record background vibration in the laboratory building. Then the *Instantell Minimate* was adjusted to eliminate these background vibrations. After checking the steel ball position in the instrument's pipe (potential energy level), pin holding the steel ball was moved out. Then steel ball fall freely and hit the rock sample at the targeted position. The impact of this hit depends on the weight of steel ball and its speed at the impact time. That means energy of impact depends on the height of the freefalling in this instrument. That was predetermined as 5 levels for the designed instrument and drilled on its steel pipe.

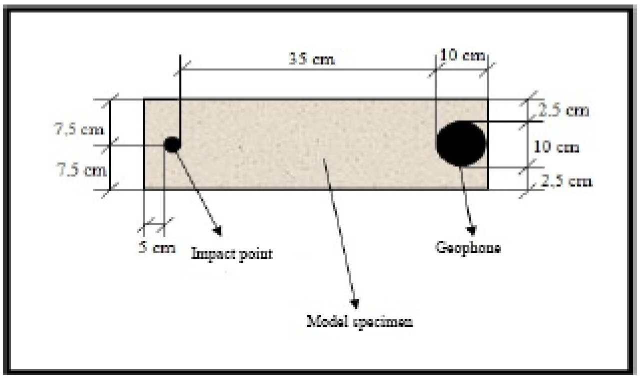

Fig. 4. Upper face of each rock sample was measured before the tests to point the impact point and geophone position. This marking action was done for each rock sample to ensure the testing condition was exactly similar to each other.

Measurement of the peak particle velocity (PPV) occurred at rock samples "geophone" position then recorded during the tests to evaluate any differences among themselves. When the pre-test conditions were all same, the resultant differences in PPV depend only on rock sample properties. Pre-test conditions adjusted during this research were; impact energy level, impact point position, geophone position, (consequently the distance between them), rock sample dimension, room temperature, silent (non vibrating) laboratory room condition. Tests then were performed without causing any additional vibration besides the falling of the test ball through the designed instrument pipe. After recording and saving the rock sample vibration due to the impact, *Instantel Minimate Plus* data were transferred to PC software program, *Blastware Rev-8.12*, to evaluate the vibrations obtained.

In this research, vibration tests were performed separately for each dry rock samples. Then the same samples were water saturated for 48 hours to continue the vibration tests for their saturated conditions. During the tests, vibration records were saved for 10 repeated impacts (with the same energy level). Then these values were averaged to point characterized PPV values for the tested rock sample (Table 1). Averaged values for dry and saturated rock samples demonstrate that PPV values were decreased when the same samples were saturated. Table 1 shows also this decrease in terms of percentage taking the dry samples' PPV values as a reference point. During the vibration tests, 3th level (potential energy level) was used to create impact hit on the samples. There were mainly 3 types of massive rocks (basalt, ignimbrite and travertine) in this research. However due to the mining site differences, rock samples tested in this research were named accordingly as shown in Table 1.

Tab. 1. Resultant peak particle velocity (PPV) values and water weight in sample.

Sample name	**Peak Particle Velocity (PPV)** [mm/s]			**Water weight in sample** [gr]
	Dry samples	**Saturated samples**	**Decrease** [%]	
Basalt	31.48	22.80	27.57	2.61
Ignimbrite-G2	35.80	21.47	40.03	15.95
Ignimbrite-G1	47.65	26.75	43.86	17.39
Ignimbrite-P	57.39	26.17	54.40	24.19
Ignimbrite-B	49.30	21.48	56.43	28.39
Travertine-G	33.41	21.59	35.38	2.42
Travertine-K	18.69	12.86	31.19	1.80
Travertine-P	24.41	18.56	23.97	5.58

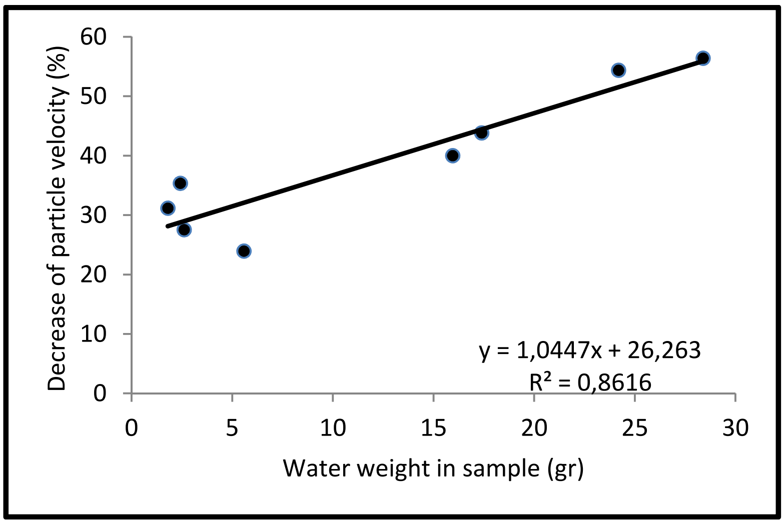

Fig. 5. The relation graphs between decrease of particle velocity and water weight in samples.

Conclusion

It is know already that vibration created in/on the rock masses propagates through them as different wave forms. Their original energy levels depend on the energy of the action which create them. Then these energy levels are decreased while they propagate in the rock masses. So it can be meaningful to say teht, they spent different energy potentials while they are passing through different types of rock masses. In this research, it is aimed to clarify the influence of water saturation on vibration propagation. In order to measure determine this fact, dry and water saturated massive rock samples were tested for their vibration wave propagation differences. Peak particle velocity (PPV) values measured from the test samples were measured for exactly the same test conditions.

In this research it is determined that water saturation condition has negative affect on PPV values determined from the rock samples. When the Table 1 is examined, PPV values obtained from the rock samples (8 of them) were all decreased for their saturated conditions. That means water in rock masses has decreasing affect on PPV values. Maximum decrease in percentage happens for Ignimbrite-B sample while minimum decrease in percentage was determined for Travertine-P sample. The differences in the PPV value decrease can be water content related or rock minerals related. In order to evaluate the affects of water on PPV values in this research tests, water content of the rock samples are taken into consideration. Table 1 shows each rock samples' water content in weight. It is seen that there is a relation between PPV value decrease and water weight in samples (Figure 5.). This shows that vibration waves can pass through dry rock masses with loosing less energy than saturated rock masses. Water in the rock masses then cause energy lost for travelling vibration wave.

It is important to know this fact for mining engineers that, if they have saturated rock masses to be blasted, the effectiveness of the vibration wave in this saturated rock mass is lower with respect to the dry part of the same rock mass in the same mining site. This can be negative effect on the performance of the saturated rock blasting. But it is good for the wave propagation point of view. That is vibration waves created from the mine site blasting can not be travelled long enough in saturated rock masses. So they cause less disturbance on surrounding area, that means mining operation come accross less problem, originated from surrounding civil engineering works and people.

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References

[1] Aldas G. G.: Effect of some rock mass properties on blasting induced ground vibration wave characteristics at Orhaneli surface coal mine, *PhD Thesis, METU, p113, 2002*.

[2] Bohloli B.: Effect of the geological parameters on rock blasting using the Hopkinson Split Bar, *Int. J. Rock. Mech. Min. Sci., V34, p321, 1997*.

[3] Howkins L.V.: The reciprocal method of routine shallow seismic refraction investigations, *Geophysics, V26, pp809-819, 1961*.

[4] Cook N. G. W.: Natural joints in rock: mechanical, hydraulic and seismic behavior and properties under normal stress. *Int. J. Rock. Mech. Min. Sci. & Geomech. Abst., V29, p.198, 1992*.

[5] Bollinger G.A.: Blast Vibration Analysis, *Southern Illinois Univ., Press, p132, 1971*.

[6] Blair D. P., Spathis A. T. : Attenuation of explosion generated pulse on rock masses, *J. Geophys. Res., V87, pp3885-3892, 1982*.

[7] Olofsson O.S.: Applied explosives technology for construction and mining, *Sweden, p303, 1990*.

[8] Wu Y.K, Hao H., Zhou Y.X., Chong K.: Propagation characteristics of blast-induced shock waves in a jointed rock mass, *Soil Dynamics and Earthquake Engineering, pp407-412, 1998*.

[9] Kekec B.: Blasting induced ground vibration determination according to the some rock materials and rock mass properties, *PhD Thesis, Selcuk University, p213, 2010*.