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The Effects of Specimen Volume, Temperature and Water Content on Shore Hardness

R.Altındağ
Department of Mining Engineering, Süleyman Demirel University, İsparta, Turkey

ABSTRACT: In this study, the effect of specimen size, temperature and water content on Shore hardness is investigated. With this objective, core samples of different sizes were prepared from nine different types of rocks. Firstly, Shore hardness (SH) tests on these samples were conducted and hardness values were determined using Shore scleroscope apparatus. Secondly, the same specimens were conditioned in a drying-out cupboard at different temperatures. Then, the Shore hardness values of the saturated specimens were obtained according to specimen volume. In order to determine die SH values of the rocks, the minimum test specimen volume required is suggested.

1 INTRODUCTION

Shore hardness (SH) value, one of the main physical properties of rocks, is essentially influenced by rock mineralogy, elasticity and cementation. The physical and mechanical properties of rocks are used for drillability analyses in laboratory and field studies. The SH values of rocks are used for various purposes. SH value is used in empirical equations in the literature with regard to drillability (Rabia & Brook, 1981), the efficiency of roadheaders and wearing of drilling tools. The SH value is also used to determine the uniaxial compressive strength of rocks (Wijk, 1980; Atkinson, 1993; Holmgeirsdottir & Thomas, 1998; Onargan et al. 1997).

Therefore, a reliable determination of the SH value of rocks is very important. The differences in the size of the specimens affect the Shore hardness value (Rabia & Brook, 1979; Misra, 1972; ISRM, 1978). Thus, it is impossible to compare test results presented in literature.

2 PREVIOUS WORK

Misra (1972) suggested that a specimen should have a diameter of 25 mm (surface area of 4.91 cm^2) and thickness of 5 cm for determining its Shore hardness value (Rabia & Brook, 1978).

According to the method proposed by the International Society for Rock Mechanics (ISRM, 1978), a test specimen with a minimum surface area of 10 cm^2 and a minimum thickness of 1 cm should be used.

Rabia & Brook (1978) suggested that die minimum specimen volume should be 40 cm^3 for determination of the Shore hardness of a specimen. They proposed that a minimum of 50 measurements should be made on 5 specimens and the arithmetical average of these measurements should be used for the determination of the SH value of a specimen.

3 THE EFFECT OF SPECIMEN VOLUME

In Üiis study, cores were drilled from nine different rocks at 54 mm in diameter. For each rock, approximately 7-8 specimens were prepared. Firstly, the SH values were measured for each rock of different volume. Then, the specimens were conditioned in a dry-out cupboard at temperatures of 20°C, 60°C and 120°C. The Shore hardness values of the specimens were measured for each temperature.

For the SH measurement, about 3500 readings were made using a C-2-type Shore scleroscope according to the suggested methods of the International Society for Rock Mechanics {ISRM, 1978).

The relationships between specimen volume and Shore hardness are illustrated in Figures 1-7. The Shore hardness values of the specimens were found to increase depending on the specimen volume up to the critical volume. Specimens with volume greater than 80 cm^3 did not show significant variations in SH value.

The arithmetical average of the SH values, which were measurements at the horizontal level of the

curve, was taken as the Shore hardness value of die specimen. The specimen volume curve at dus point, where it begins to extend horizontally, İs the volume for determining the SH value of the specimen. This point shows the necessary minimum specimen volume for determining SH. It was determined that the minimum specimen volume was 80 cm^3 in all the tests for nine different rocks. Therefore, it is suggested that die minimum specimen volume should be 80 cm^3 for the determination of the SH of a specimen. This finding is different from the specimen volume values suggested by previous workers.

Finally, the effects of the specimen volume and temperature on Shore hardness were investigated.

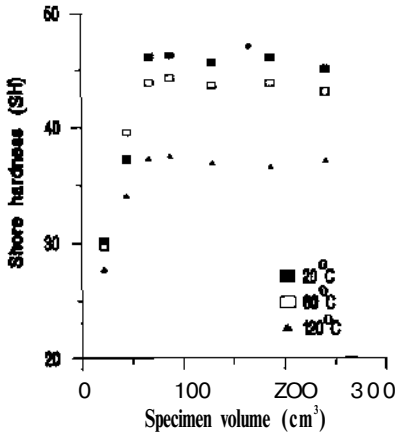

Figure 1. The relationship between specimen volume and Shore hardness value of the 1 st rock type

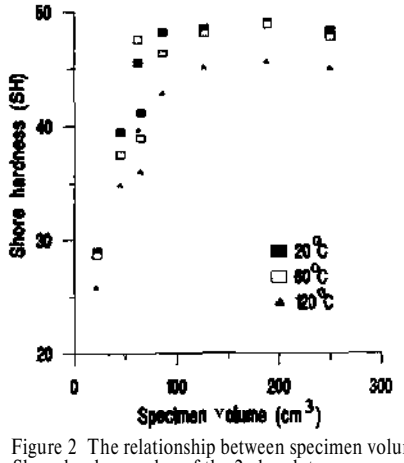

Figure 2 The relationship between specimen volume and Shore hardness value of the 2nd rock type

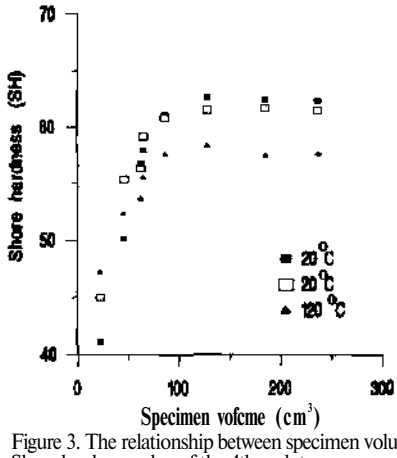

Figure 3. The relationship between specimen volume and Shore hardness value of the 4th rock type.

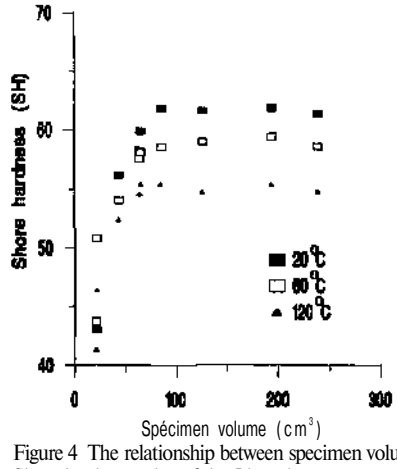

Figure 4 The relationship between specimen volume and Shore hardness value of the 5th rock type.

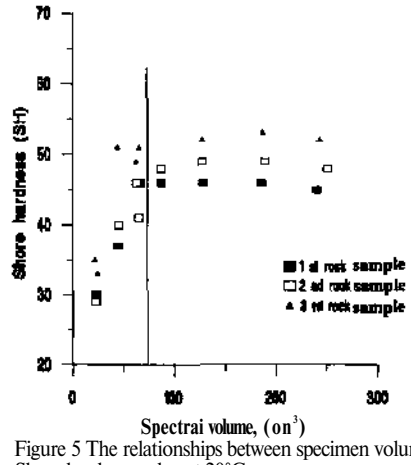

Figure 5 The relationships between specimen volume and Shore hardness value at 20°C

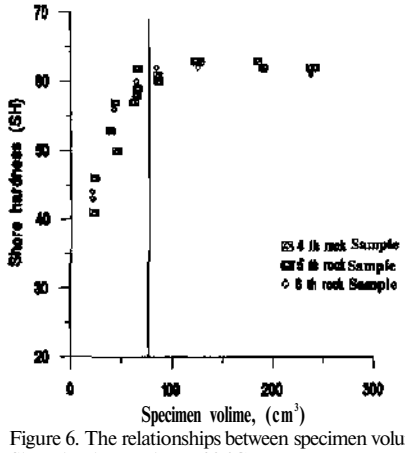

Figure 6. The relationships between specimen volume and Shore hardness value at 20 °C

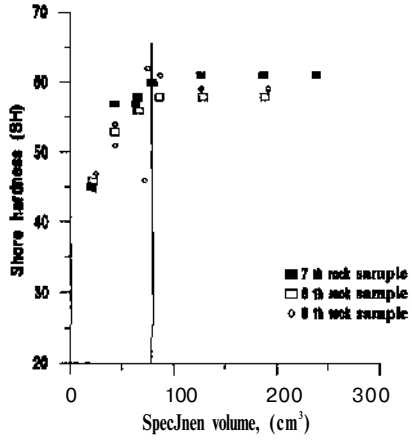

Figure 7 The relationships between specimen volume and Shore hardness value at 20 °C

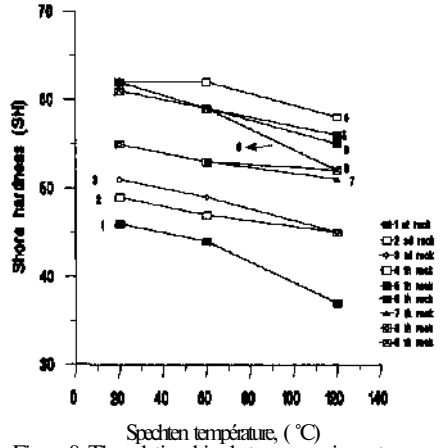

Figure 8. The relationships between specimen temperature and Shore hardness value (with 80 cm^3 volume)

It is not possible to compare the Shore hardness values obtained from previous methods suggested by various researchers. Therefore, the author believes that the standard test method suggested by the ISRM should be reviewed.

4 THE EFFECT OF SPECIMEN TEMPERATURE

In a previous study, it was observed that the mechanical parameters of the heated rocks decrease with temperature (Mahmutoğlu, 1998).

The relationships between SH and specimen volume at 20 °C are given in Figures 5-7.

The SH values of each rock were taken as the arithmetical average values of measurements which were made on volumes greater than 80 cm^3.

In this study, specimens of different volumes prepared from each rock were conditioned in a drying-out cupboard at 20°C, 60°C and 120°C in order to determine the effects of specimen temperature on Shore hardness. The relations of specimen volume vs. SH values were given in Figures 1-4 for some rock types.

It can be seen that the Shore hardness value decreases with increasing specimen temperature. Therefore, when the temperature increased in the specimens, the SH decreased. At each temperature, the Shore hardness values of the rocks did not exhibit significant differences at volumes higher than 80 cm^3. It can be seen that the minimum volume of specimens was found to be 80 cm^3.

The relationships between SH values and specimen temperatures with a volume of 80 cm^3 are illustrated in Figure 8. This figure shows that the SH value decreases with increasing specimen volume. Therefore, the SH values fall with increasing rock temperature.

The Shore hardness values of the rocks tested at different temperatures are given in Table 1.

Table 1. Average Shore hardness values of rocks at different temperatures (with 80 cm^3 volume)

Rock Number	Rock Sample	20°C	60°C	120°C
1	Marble	46	44	37
2	Marble	49	47	45
3	Marble	51	49	45
4	Limestone	62	62	58
5	Limestone	62	59	56
6	Limestone	61	59	55
7	Limestone*	55	53	51
8	Limestone**	55	53	52
9	Sandstone	61	59	52

* SH values of each test is given in the Appendix (Table A1)
** SH values of each test is given m the Appendix (Table A2).

5 THE EFFECT OF WATER CONTENT

During this stage of the investigations all the specimens were saturated by being kept in water for 72 hours. The Shore hardness values of all the specimens were determined by a Shore sclerescope as in the other tests. The relationships between the Shore hardness values of the saturated specimens and their varying values were examined graphically (Figure 9). Figure 9 shows that the Shore hardness values of specimens greater than approximately 80 cm^3 do not *have* recordable changes. According to this graph, the critical volume for saturated specimens can be taken as 80 cm^1.

However, the Shore hardness values of the saturated specimens were found to be lower than the original specimen values. Therefore, water content has a negative effect on the Shore hardness of specimens.

The Shore hardness values of saturated specimens, obtained nine different rock types, tested during this study are presented in Table 2.

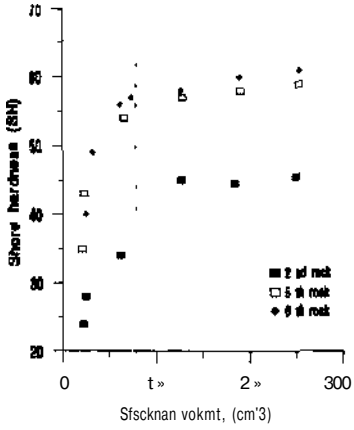

Figure 9. The relationship between specimen volume and Shore hardness value of some saturated rocks.

Table 2. Average Shore hardness values of saturated rocks (with 80 cm^3 volume)

Rock Number	Rock Type	Shore Hardness
1	Marble	42
2	ManMe	45
3	Marble	45
4	Limestone	58
5	Limestone	59
6	Limestone	60
7	Limestone	53
8	Limestone	53
9	Sandstone	58

6 RESULTS AND DISCUSSION

1. A minimum volume of 80 cm^3 is suggested in order to obtain a consistent Shore hardness value of a rock.

2. No significant variations were recorded with volumes larger than the suggested volume. The mean of readings taken from 5 specimens can men be taken as the Shore hardness of a rock.

3. An increase in the temperature of a specimen causes the Shore hardness value of the specimen to decrease. Therefore, increasing temperature has a negative effect on the SH values of rocks.

4. The Shore hardness values of saturated specimens are lower than original specimen values. For saturated rocks, Shore hardness tests should be conducted with a minimum specimen volume of 80 cm^3.

5. The method suggested by the International Society for Rock Mechanics should he rewieved.

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APPENDIX

Table AI Shore hardness values of Fethiye Bej (limestone)

	Shore Hardness Values		
V fem^3)	20JÇ	60JÇ	120 *C
85 63	57 71	55 90	54 45
66 23	56 20	52 40	5160
42 50	53 15	50 00	48 25
21 17	46 24	40 35	43 95
188 03	58 43	58 00	54 40
127 5	58 14	56 30	55 70
64 54	5552	5565	48 75
Average	55 06	52 66	5101

Table A2 Shore hardness values of Kennt (limestone)

	Shore Hardness Values		
V fem*)	20 °C	60 ^{D}C	120°C
19181	58 55	56 55	55 55
12649	5929	5841	5660
7195	4620	47 10	47 45
86 68	6120	59 10	58 20
74 48	62 10	57 55	57 70
44 06	54 40	54 05	53 80
25 19	46 70	45 20	45 60
4443	50 60	46 25	46 90
Average	54 87	53 01	52 73