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# Technical Note

# Effects of Specimen Volume and Temperature on Measurements of Shore Hardness

By

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## 1. Introduction

The Shore Hardness (SH) value, one of the main physical properties of rocks, is essentially influenced by rock mineralogy, elasticity and cementation. Both drillability analysis in laboratory and field studies are applied as physical and mechanical properties of rocks. The SH values of rocks are used for various purposes. The SH value is used in empirical equations concerning drillability (Rabia and Brook, 1981), efficiency of roadheaders and wearing of drill tools. The SH value was also used to determine the uniaxial compressive strength of marbles (Atkinson, 1993; Onargan et al., 1997).

A reliable determination of the SH value of rocks is very important. The size of the specimens influences this value (Rabia and Brook, 1978) and the results of the proposed test methods presently available (ISRM, 1978) do not give consistent values.

## 2. Previous Work

Misra (1972) suggested that a specimen should have 25 mm diameter (surface area of 4.91 $cm^2$) and length of 5 cm for the determination of shore hardness (Rabia and Brook, 1978).

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

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

## 3. The Effect of the Specimen Volume

The cores were drilled from seven different rocks by 54 mm in diameter. For each rock, seven or eight specimens were prepared. At the beginning, SH values were measured for each rock in different volume. After that, the specimens were conditioned in a dryer at 20 °C, 60 °C and 120 °C temperature during 24 hours. Later, the SH values of the specimens were measured at each temperature. The SH measurements, about 3250 readings, were made by using C-2 type Shore Scleroscope.

The relationship between specimen volume and SH values of rocks is illustrated in Figs. 1 and 2. The rocks in this study are marble, limestone and sandstone. The SH values of the specimens increase with volume until a critical specimen volume is attained. After this critical specimen volume, 80 $cm^3$, the SH values do not show significant changes. They are close to each other at the same rock temperature.

The values of SH are approximately the same at each temperature after the critical value of the specimen volume. The SH values follow a horizontal line. This critical specimen volume separates two regions. The SH values of these regions are different values. Therefore, this critical specimen volume is found for all rocks.

Finally, the effect of the specimen volume and temperature on SH values was investigated. At 20 °C, the relationship between SH and specimen volume is given in Fig. 3. In this figure, the critical specimen volume separates two regions. Region I is from 0 to 80 $cm^3$. Region II is from 80 to 250 $cm^3$.

In this experiment, the SH values of each rock were taken as arithmetical average values. The SH values of rocks at different temperatures are presented in Table 1. In this study, the critical volume value is accepted as 80 $cm^3$. The SH values of all rocks do not change with specimen volume after that critical volume.

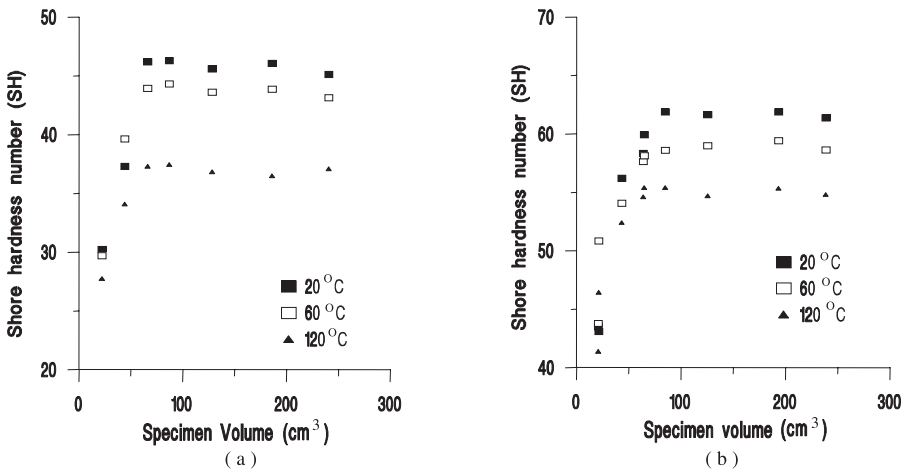


**Fig. 1a,b.** The relationship between specimen volume and shore hardness value of rocks **a**: for the 1st rock (marble), **b**: for the 5th rock (limestone)

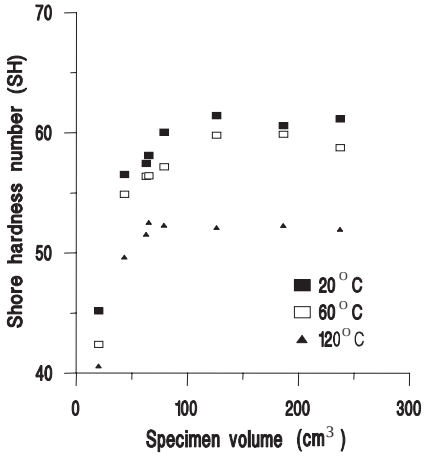


**Fig. 2.** The relationship between specimen volume and shore hardness value of the 7 th rock (sandstone)

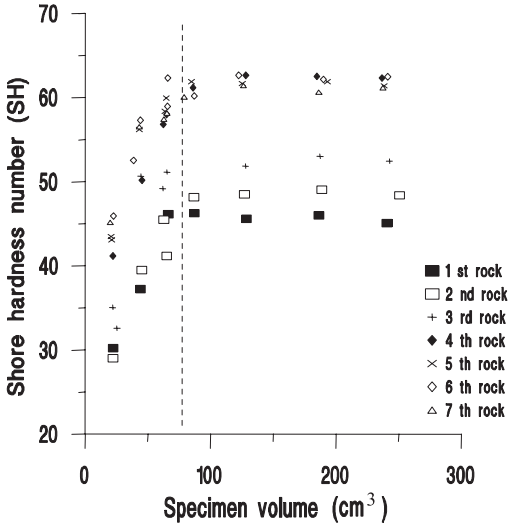


**Fig. 3.** The relationships between specimen volume and shore hardness value at 20 °C

**Table 1.** Shore hardness values of rocks at different temperatures (considering 80 $cm^3$ volume)

| | Rock type | 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 | Sandstone | 61 | 59 | 52 |

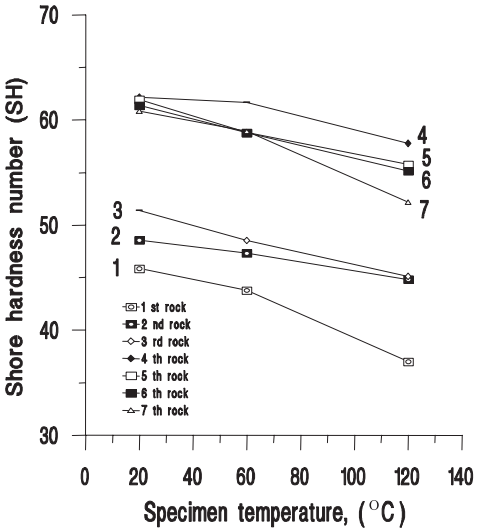


**Fig. 4.** The relationships between specimen temperature and shore hardness value (considering 80 $cm^3$ volume)

The results obtained for SH do not compare well with the values given by previous researchers. Therefore, the author believes that the standard test methods suggested by ISRM should be revised.

## 4. The Effect of the Specimen Temperature

In a previous study, it was observed that the mechanical parameters of the heated rocks decreased with increasing temperature. Therefore, the increasing deformation verifies the closing of grain boundaries loosened by cyclical heating (Mahmutoglu, 1998). Also, in this study, the SH values of heated rocks decrease due to thermal expansion of mineral components.

In order to determine the effects of specimen temperature on measurements of SH, the different volume specimens were prepared from each rock and were heated in a dryer at 20 °C, 60 °C and 120 °C. All measurements were done on these heated specimens within few minutes. The relations of specimen volume and the SH values are shown in Figs. 1 and 2 for marble, limestone and sandstone.

It is shown that the SH values for each rock decrease with increasing specimen temperature. The SH values of all rock specimens do not change significantly at different temperature in bigger than 80 $cm^3$ specimen volume (Figs. 1 and 2). The SH exact values of all rocks are given in Table 1.

Fig. 4 shows the relationships between the SH values and specimen temperatures at 80 $cm^3$ volume value. The SH values are decreasing with increasing temperature for these rocks.

## 5. Conclusions

1. A minimum volume of 80 $cm^3$ is suggested to obtain consistent Shore Hardness values of a rock.
2. The mean of readings made on 5 specimens can then be taken as the shore hardness of a rock.
3. The suggested method by the International Society for Rock Mechanics should be revised.
4. The Shore Hardness value of rock decreases with increasing temperature.

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