Scale Effect on the Tensile Strength in the Brazilian Test

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Extended Abstract

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Introduction

Determination of the mechanical properties of rock materials has been remained as a challenge for engineering geologists. In-situ tests are rarely used to determine the mechanical properties of rocks due to difficulties in sample preparation, performing and interpretation of the results, high costs as well as the required long time for doing the experiments. The common approach to determine the mechanical properties of rock materials is through conducting laboratory experiments and estimation the in-situ properties based on these laboratory results. This approximation, which is called scale effect, has been remained as a challenge for engineering geologists and practical rock engineers for decades.

One of the important mechanical properties of rocks is the tensile strength which is usually measured by indirect Brazilian tensile test. Studies on the effect of scale on the Brazilian tensile strength of rocks have been very limited and most of previous studies have been focused on concrete. Results of forgoing studies on the effect of sample size on the tensile strength are inconclusive. Some studies show that as the diameter of sample increases, the tensile strength decreases while other studies express no scale effect or the increase of tensile strength. Furthermore, most of these studies were carried out on a limited range of sample diameters and a unified and widely accepted tensile scale effect model cannot be found. To overcome these shortcomings, experimental studies were undertaken on a typical sandstone at a wide range of sample diameters and then models are proposed to estimate the tensile strength of rocks at different sample sizes using the non-linear regression analysis.

Material and Methods

Hawkesbury sandstone was used for this study. Hawkesbury sandstone dominates the bedrock of Sydney, Australia, sedimentary domain and many civil and mining structures has been constructed in/on this rock. Blocks of rock having 600 mm length and 300 mm width and height were prepared from Gosford Quarry mine. These blocks were cored using metalmaster drilling machine RD-900 Hafco and samples with diameter in the range of 19 to 145 mm. All samples were then cut with thickness to diameter ratio of 0.5. Brazilian experiments were undertaken using MTS 815 Servo-control machine and followed by ASTM standard.

Results and Discussion

Results of the experiments are presented in Table 1. An essential step before interpreting the results of Brazilian tests, is the investigation of failure mechanism which shows the validity of the results. In Brazilian test, it is assumed that the tensile crack initiates from the center of disk and then propagates. As shown in Figure 1, at diameter of 145 mm, cracks were initiated under the loading platen and then samples were failed while at other diameters, generation of tensile cracks at the center of specimens resulted in the failure of specimens. Therefore, results of experiments on samples with diameter of 145 mm were removed from the analysis.

Table 1. Results of Brazilian experiments at different diameters

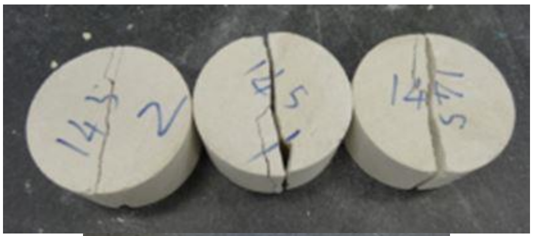
Diameter (mm)	Tensile Strength (MPa)	Standard Deviation	Coefficient of variation (%)
19	3.40	0.41	12.08
25	3.75	0.43	11.35
38	3.15	0.26	8.16
50	3.09	0.13	4.33
66	2.83	0.38	13.52
96	2.47	0.19	7.54
118	2.47	0.25	9.98
145	3.43	0.13	3.92

Effect of sample diameter on tensile strength is illustrated in Figure 2 which shows that as the sample diameter increases, tensile strength decreases. New models were developed to estimate tensile strength at different sizes using non-linear regression analysis and Hoek and Brown model (Eq. 1), size effect law (SEL) (Eq. 2) and multifractal scaling law (MFSL) (Eq. 3). These models are as follow:

$$\sigma_t = \sigma_{t50}(50/d)^{0.236} \quad R^2 = 0.835 \tag{1}$$

$$\sigma_t = \frac{4.19}{\sqrt{1+(d/58.46)}} \quad R^2 = 0.928 \tag{2}$$

$$\sigma_t = 2.18\sqrt{1+(42.09/d)} \quad R^2 = 0.795 \tag{3}$$



a

b

Figure 1. Failure mechanisms of Brazilian disks. a) Specimens having 145 mm diameter and b) Two specimens with diameter of 38 mm and 50 mm.

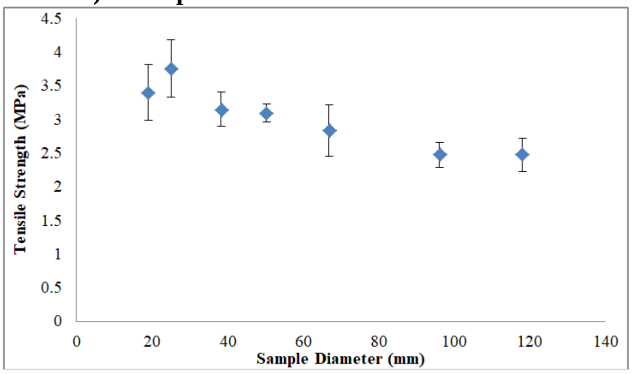


Figure 2. Effect of sample diameter on tensile strength

These models are shown in Figure 3. The models were compared against experimental tests and it was found that the SEL model can provide a better estimation of tensile strength at different sizes.

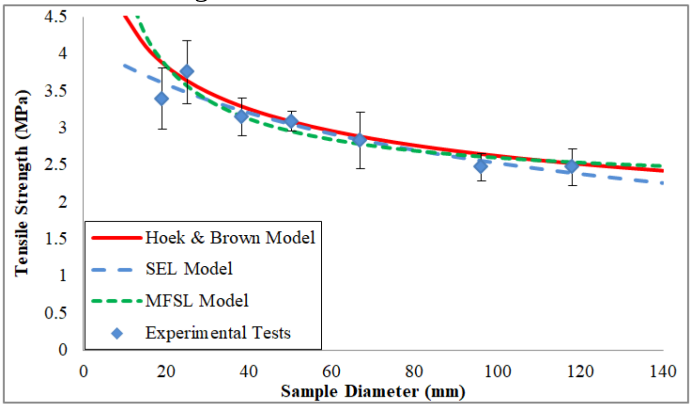


Figure 3. Comparison of experimental tests against Hoek and Brown, SEL and MFSL models

Conclusion

In this paper, the effect of specimen size on tensile strength was investigated. Brazilian tensile tests on samples having diameter in the range of 19 to 145 mm were carried out. It was found that as the sample diameter increase, the tensile strength decreases. Based on the non-linear regression analysis, scale effect models were proposed using the Hoek and Brown, SEL fracture energy and MFSL multifractal models. It was found that the SEL model can provide a better estimation of tensile strength at different diameters.

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