A Technical Note on

Effect of Saturation and Deformation Rate on Split Tensile Strength for Various Sedimentary Rocks

K.S. Pathania

Department of Civil Engg.
NIT, Kurukshetra, India

Email: pathaniaks@rediffmail.com

ABSTRACT

This technical note deals with the study of engineering properties determined in the laboratory for limestone and sandstone. The test results on equally dimensioned discs of the stone show a considerable variation in computed split tensile strength with varied rates of deformation. Hence the effect of strain rate on the tensile strength of sandstone and limestone under wet and dry conditions has been studied using the split tensile strength test technique. It has been observed that the tensile strength of these tested samples is dependent on the rate of deformation particularly in a dry state. On saturation the value of split tensile strength is observed to reduce significantly.

Keywords: Sedimentary rocks; Split tensile test; Deformation rate; Saturation rate; Sandstone; Limestone

1. INTRODUCTION

An accurate knowledge of the tensile strength of a rock mass is necessary in the design of underground openings; design of bolting systems, blasting and drilling processes, and in many other important engineering applications. Although the design procedure utilize the compressive strength of the rock as the basic property, it is no doubt true that even while a rock fails under a compressive load tensile cracks first develop and these are often the first failure phenomenon noted.

The most logical method of measuring the tensile strength is the straight pull out test, in which samples in the central section of the specimen is made of a small cross section i.e the samples are made in the form of a “dog-bone” or a “briquette type”. Alternatively epoxy resins have been used as adhesives to the samples and pulled through flexible cables (Fairhrust, 1961)

Indirect estimation of tensile strength has become necessary in view of the many difficulties which are encountered in conducting direct tensile tests. Diametral compression of solid discs or cylinders has been adopted with considerable success (Hondros, 1959; Hobbs, 1964). Colback (1966) and several others proposed the diametral compression of cylindrical discs with a small hole in the centre. Hobbs (1964) observed that the tensile strength as obtained from this type of 'Ring Test' is much higher than obtained with a solid discs or cylinder, as the central hole ensures crack propagation from the centre of the disc. Generally cracks start propagating from loading platens.

Another method used is to apply an internal radial pressure to a hollow cylinder. From the results presented by Hardy and Jayraman (1970) the ratio of tensile strength obtained by this method to that of the direct pull test varies from 1.13 to 1.84 for the different types of rocks tested by them.

Several investigators have used a 'point-load' test. This point load tensile strength is determined by applying compressive point loads to the curved surface of a cylindrical core specimen while the axis of the core is horizontal. The point load is applied in a testing machine through a hardened set of steel rollers or conical shaped pointed wedges at right angles to the axis of the specimens. The loading produces tensile stresses perpendicular to the axis of the loading.

McWilliams (1967) presented a method for estimation of tensile strength by subjecting 5cm diameter discs of rock to stress under two hemi-spherical indenters acting on the opposite surfaces of the disc at its center.

2. SPLIT TENSILE TEST

Brazilian test (indirect split tensile test)on solid disc has by far been adopted in a large number of testing programmers and research projects.This test has been used for the determination of elastic properties of concrete by Hondros (1959), the tensile strength of coal by Berenbaun and Brodie (1959) and of rocks by Hobbs (1964). Tensile strengths measured in this manner are very reproducible and are in reasonable agreement with values obtained in uniaxial tension. In some cases single diametral fractures are not found to occur but several fractures branching from the diametral points, some doubts have been raised about the mechanism of failure in this test and it has been suggested that the failure starts by shear failure in the region of high compressive stresses near the contacts.

The simplicity of sample preparation and case in testing is a great advantage of this test. In this test, according to the linear elastic theory there is a uniform tensile stress of $2F/\pi Dt$ across the diametral plane. Thus, the tensile strength is calculated as follows:

$$\sigma_t = \frac{2F}{\pi Dt} \tag{1}$$

Where,
F = failure load,
D = diameter of the specimen, and
t = thickness of the specimen.

Tests have been conducted for split tensile strength under different deformation rate for limestone and sandstone specimens. Table 1 shown variation of average split tensile strength for limestone under dry and saturated conditions. Data shown in Table 1 have been plotted in Figures 1 and 2 for dry and saturated conditions respectively. Similarly Table 2 and Figures 3 and 4 are for tests on sandstone specimens.

Table 1 - Brazilian test results for limestone

Deformation Rate (mm/min)	Average Split Tensile Strength	
	Oven dry specimen (kg/cm^2)	Saturated specimen (kg/cm^2)
1.0	40.0	27.7
0.5	36.1	26.1
0.4	35.4	25.5
0.2	32.8	24.9
0.1	31.0	24.6
0.05	29.4	24.2
0.04	29.0	24.0
0.02	28.6	23.8

Density = 2.6 t/m^3*; Saturated density = 2.7 t/m*^{3}

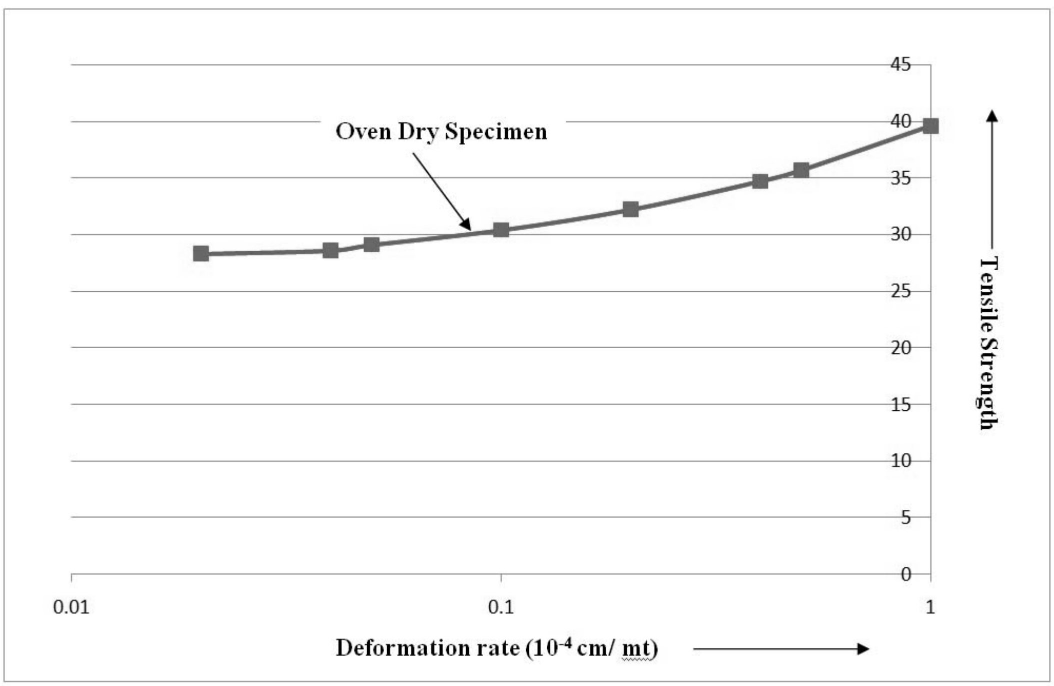

Fig. 1 – Effect of deformation rate on split tensile strength for limestone in dry condition

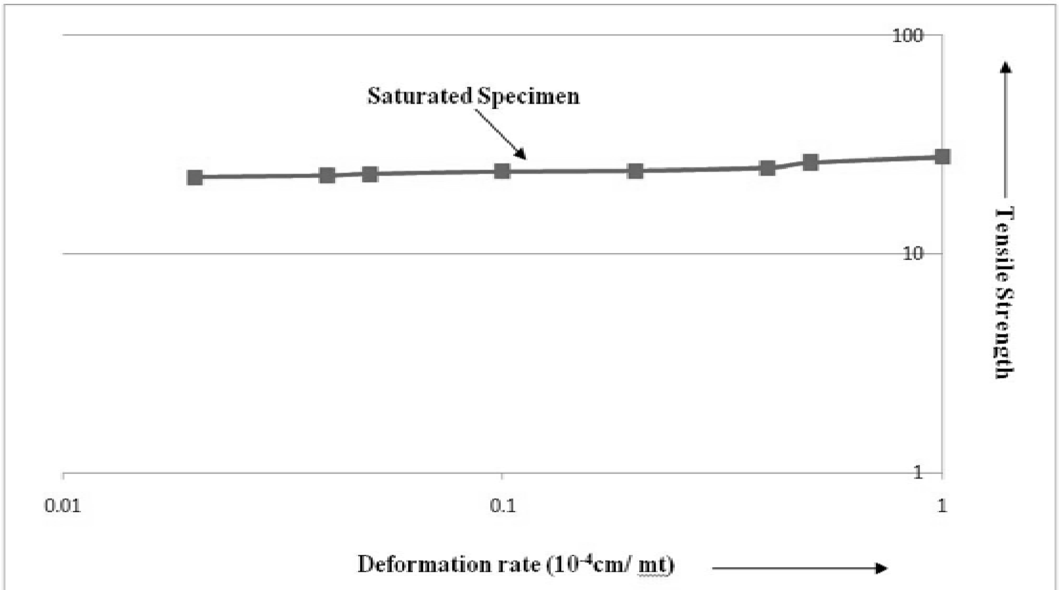

Fig. 2 – Effect of rate of deformation on split tensile strength for limestone in saturated condition

Table 2 - Brazilian test results for sandstone

Deformation Rate (mm/min)	Average Split Tensile Strength	
	Oven dry specimen (kg/cm^2)	Saturated specimen (kg/cm^2)
1.0	34.5	14.3
0.5	29.6	12.6
0.4	28.4	11.8
0.2	26.2	10.7
0.1	24.0	10.5
0.05	22.2	10.0
0.04	22.0	9.9
0.02	20.8	9.8

Density = 2.35 t/m^3; Saturated density = 2.55 t/m^3

3. DISCUSSION OF TEST RESULTS

The test results on equally dimensioned discs of lime stone and sand stone show a considerable variation in computed split tensile strength with varied rates of deformation (Figs. 1, 2, 3 and 4 and Tables 1 and 2).

The split tensile strength of oven dry samples of lime stone varied from 40.0 kg/cm^2 (4MPa) to 28.6 kg/cm^2 (2.86MPa) when rate of deformation was decreased from 1.0 mm/min to 0.02 mm/min and under saturation condition the split tensile strength varied from 27.7kg/ cm^2 (2.77MPa) to 23.8 kg/cm^2 (2.38MPa) within the same range.

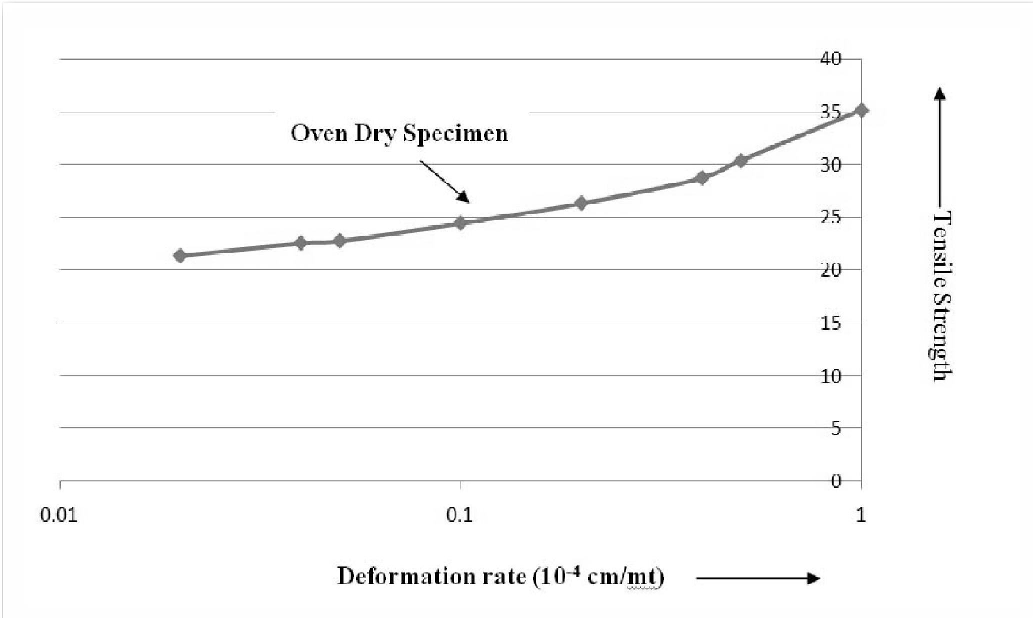

Fig. 3 – Effect of rate of deformation on split tensile strength for sandstone in dry condition

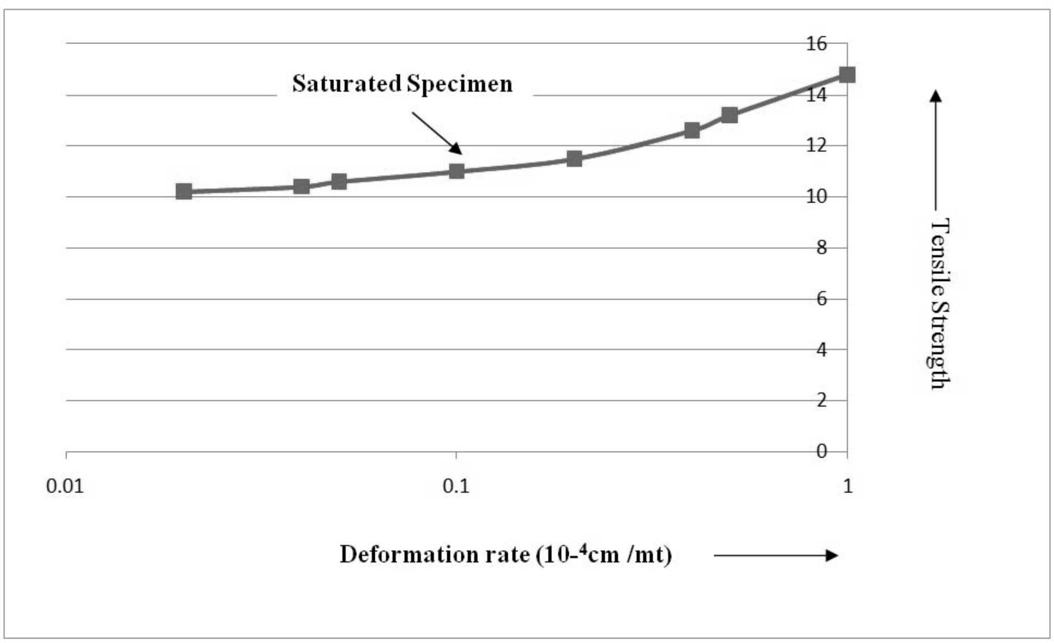

Fig. 4 – Effect of rate of deformation on split tensile strength for sandstone in saturated condition

A similar trend of variation was observed for sand stone in which split tensile strength of oven dry samples varied between 34.5 kg/cm^2 (3.45MPa)to 20.8 kg/cm^2 (2.08MPa) and under saturated condition from 14.3 kg/cm^2 (1.43MPa) to 9.8 kg/cm^2 (0.98MPa) within the same range of rates of deformation as in the case of lime stone.

Under saturated condition the split tensile strength reduced considerably. The average reduction in percentage of oven dry split tensile strength for lime stone is about 20% but for sand stone it is of the order of about 50%.

A relatively larger reduction in the split tensile strength of sandstone sample (Dry density = 2.35 t/m^3, Saturated density =2.55 t/m^3) can be attributed to its coarse grained structure and porosity which allowed a greater absorption of water i.e. about 8.5 percent by weight under saturated condition.

The fine grained limestone sample (Dry density = 2.6 t/m^3, Saturated density = 2.7 t/m^3) water absorption was only 3.8 percent by weight under saturated condition and thus reduction in split tensile strength was less pronounced.

4. CONCLUSIONS

The test results on equally dimensioned discs of lime stone and sand stone show a considerable variation in computed split tensile strength with varied rates from the experimental results obtained and foregoing discussion, following conclusion can be drawn

- The split tensile strength of rocks varies with the rate of deformation i.e. a higher value of split tensile strength at higher rate of deformation. Thus, the fracture propagation is a time-dependent phenomenon.
- Under saturation condition effect of variation in the split tensile strength with rate of deformation is similar but is less pronounced as compared to dry condition.
- Under saturated condition the split tensile strength of rocks reduces significantly and the extent of reduction in the quality and type of rocks.

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