Brazilian and ring tests in assessing indirect tensile strength of sandstone

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Abstract

This paper presents a comparative evaluation of Brazilian and ring tests in assessing indirect tensile strength of sandstone from Korba Coal Field, Chhattisgarh. Laboratory investigations and subsequent analysis of test results revealed that Brazilian tensile strength (BTS) and ring tensile strength (RTS) are linearly correlated where BTS is found to be of higher magnitude than RTS for majority of the specimens. However, ring test produces more consistent test results than Brazilian test. It was also found that RTS provides a better indication of applied energy than BTS. Moreover, micro structural studies depicted that RTS is more representative of the inherent/initial micro cracks within the concerned rock than BTS. As RTS value is generally less than corresponding BTS value, it is also more advantageous than BTS in an engineering environment from safety point of view. It is concluded that the use of ring test to characterize indirect tensile strength of rock materials, which has not gained much attention unlike Brazilian test, should be explored further considering different rock types from different areas with specific geology in order to ascertain applicability of this test in routine rock engineering environments.

1. Introduction:

Rock materials are much weaker in tension than in compression and therefore, characterization of tensile strength is an important issue in rock engineering. Uniaxial tensile test is, however, difficult to perform because of practical problems in gripping rock specimens, aligning the specimen and applying a tensile load directly parallel to the specimen axis. On the other hand, Brazilian test requires thin disc specimens that are easy to prepare and the test procedure involves diametral compression of a disc where specimen failure is caused by an induced tensile stress (or indirect tensile stress). In this test, the induced tensile stress remains almost uniform about the loaded diameter. Compression-induced extensional fracturing generated in this test is also representative of the in situ loading and failure of rocks (Aydin and Basu, 2006). Although Brazilian test is widely used for evaluation of rock tensile strength, some researchers pointed out that not only tensile stresses are developed in the disc but also high shear stresses are produced close to the loading platens (Vutukuri et al., 1974). To limit the shearing stresses developed in the diametrically compressed disc in a Brazilian test, the method of ring test was developed where a disc with a central hole is subjected to diametral compression. Nevertheless, ring test has not gained much attention in routine rock engineering environments. This paper presents a comparison between Brazilian and ring tests in assessing indirect tensile strength of sandstone from Korba Coal Field, Chhattisgarh.

2. Samples and Laboratory Investigations:

Sandstone core samples of diameter 47mm were collected from Korba Coal Field, Chhattisgarh. In order to ascertain uniformity and intactness of the samples, attention was given to avoid any intercalation and visible fractures. The collected cores were from different boreholes with their depth of occurrence varying from 150m to 300m. Geologically and Stratigraphically, the sandstone belongs to the Lower Barakar Formation of the Gondwana sequence where the Barakar Formation is underlain by the Talchir formation and overlain by the Barren Measures Formation (Vaidyanadhan and Ramakrishnan, 2010).

According to the stipulations by ASTM D3967 (2001), the specimen thickness to diameter ratio for Brazilian test should be within the range of 0.2-0.75. In this investigation, the said specification was complied for both Brazilian and ring test specimens. A total of 28 disc specimens (14 specimens for each test) were prepared from the collected core samples. It should be noted that each of the Brazilian test specimens had its equivalent ring test specimen and this equivalence was maintained by saw-cutting the same core sample. A circular hole of diameter 4mm perpendicular to the disc-face was drilled through the center of ring test specimens. Specimens prepared for both Brazilian and ring tests are shown in Picture 1.

In this study, a Brazilian test frame fitted within the GCTS© point load system (PLT-100) of 100 kN load capacity was used (Picture 2). The test procedures were kept consistent for all disc specimens that were in accordance with ASTM D3967 (2001). Each of the specimens was loaded between the curved jaws of the Brazilian test frame until it failed. Applied load and corresponding vertical deformation were continuously recorded by a load cell and a deformation sensor (LVDT) installed within the system respectively. Brazilian tensile strength (BTS) was calculated from the following equation (ASTM D3967, 2001):

$$BTS = 2P/(\pi td) \quad (1)$$

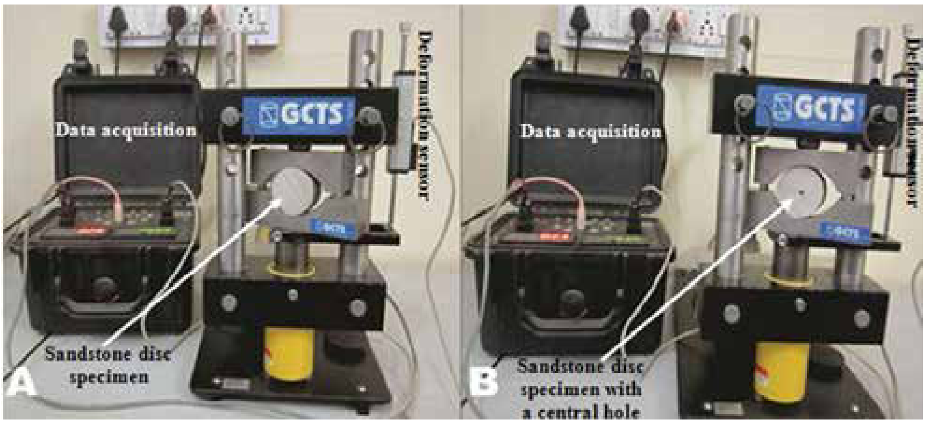
Where P is the 'peak load'; and t and d are thickness and diameter of the disc respectively. Ring tensile strength (RTS) was calculated as per Hobbs (1964):

$$RTS = P(6+38\rho^2)/(\pi r_o t) \quad (2)$$

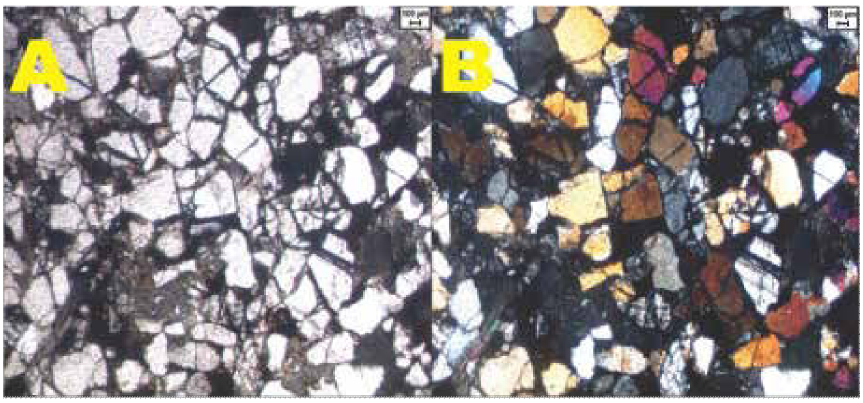
Where P is the 'peak load'; ρ is the ratio between the internal radius (hole) r_i and the external/outer radius (disc) r_o; and t is the thickness of the disc.

A total of four thin sections were prepared from core samples numbered as 2, 3, 6 and 12. Each thin section was perpendicular to core axis of the corresponding sample. Five random but non-overlapping frames from each section were considered to examine relative orientation of micro cracks. The software LEICA© was used for this analysis. A general photomicrograph of the investigated sandstone is given in Picture 3.

Picture 1 Discs without and with holes at the centre prepared from sandstone cores for Brazilian and ring tests respectively



Picture 2 Laboratory setups for (A) Brazilian and (B) ring tests



Picture 3 General photomicrograph of the investigated sandstone

3. Test Results and Analysis:

The complete test results obtained from Brazilian and ring tests are summarized in Table 1. When BTS was plotted against RTS, a linear correlation emerged (Figure 1). When RTS and BTS values were plotted together against corresponding number of the sample, BTS was found to be of higher magnitude than RTS for majority of the samples (Figure 2). For samples 3 and 6, the situation was, however, opposite. When standard deviation (s.d.) was calculated for BTS and RTS, it was found to be more in case of BTS than in case of RTS (Figure 2).

For every specimen under each of Brazilian and ring test conditions, energy required to break the specimen was calculated as peak load and vertical deformation were known. When this energy was plotted against corresponding BTS, a linear positive correlation with $R^2 = 0.61$ was obtained (Figure 3a). On the other hand, a linear positive correlation with $R^2 = 0.69$ became apparent when calculated energy was plotted against corresponding RTS (Figure 3b). It should be noted that no correlation equation is shown in Figures 3a and b because of the mismatch in dimension on both sides of the equation. In other words, Figures 3a and b are presented purely based on statistical relations between two sets of variables (dependent and independent) without any physical connotation to the related correlation equations.

Although a linear correlation exists between BTS and RTS (Figure 1), s.d. for BTS values is higher than that for RTS values (Figure 2). This implies that RTS provides more consistent results than BTS for the investigated sandstone. The correlation between applied energy and RTS is also better than that between applied energy and BTS (Figures 3a and b), which signifies that RTS provides a better indication of applied energy than BTS. As RTS value is generally less than the corresponding BTS value (Figure 2), RTS value seems to be more advantageous than BTS value in an engineering environment from safety point of view as far as indirect tensile strength of rocks is concerned.

As micro cracks play a dominant role in governing rock mechanical behavior, micro crack orientations with respect to Y-axis of the microscope stage were determined and the standard deviations of relative orientations of micro cracks from the selected thin sections were calculated. When BTS and RTS were plotted against corresponding standard deviation, RTS depicted significantly better correlation coefficient than BTS (Figure 4). It should be noted that strength of a specimen is likely to decrease if standard deviation of relative crack orientations decreases as it reflects degree of preferential crack orientations. It is apparent from Figure 4 that the indicated hypothesis holds better in case of RTS than in case of BTS. Therefore, analysis of crack orientation supports better representation of inherent/initial micro cracks within specimens by RTS than by BTS.

Table 1
Brazilian and Ring Test Results

Specimen No.	BTS (MPa)	Specimen No.	RTS (MPa)
1E	3.12	1F	2.30
2E	2.03	2F	1.89
3E	3.29	3F	3.89
4E	2.08	4F	1.74
5E	6.25	5F	5.25
6E	2.02	6F	2.30
7E	4.12	7F	2.41
8E	2.13	8F	1.55
9E	Specimen broken during preparation	9F	Specimen broken during preparation
10E	2.30	10F	1.96
11E	2.03	11F	1.46
12E	6.13	12F	3.24
13E	2.04	13F	1.58
14E	2.02	14F	1.61
15E	4.68	15F	2.88

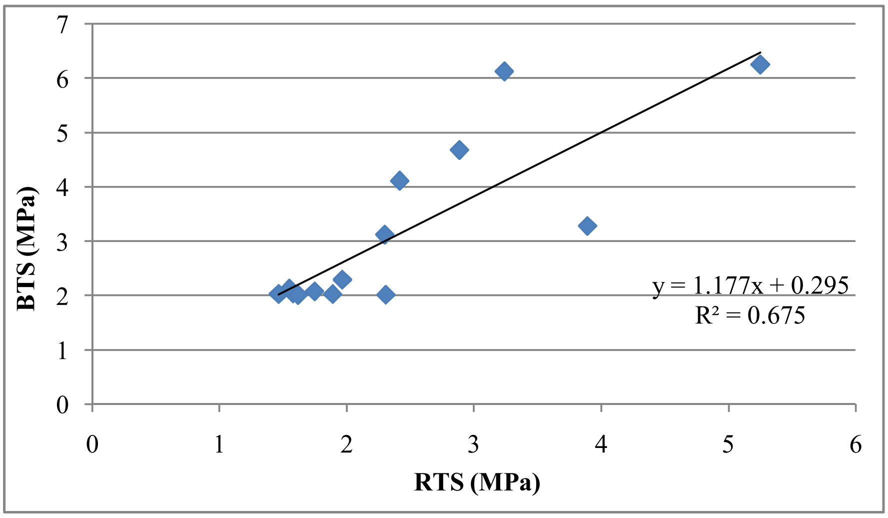


Figure 1 BTS plotted against corresponding RTS

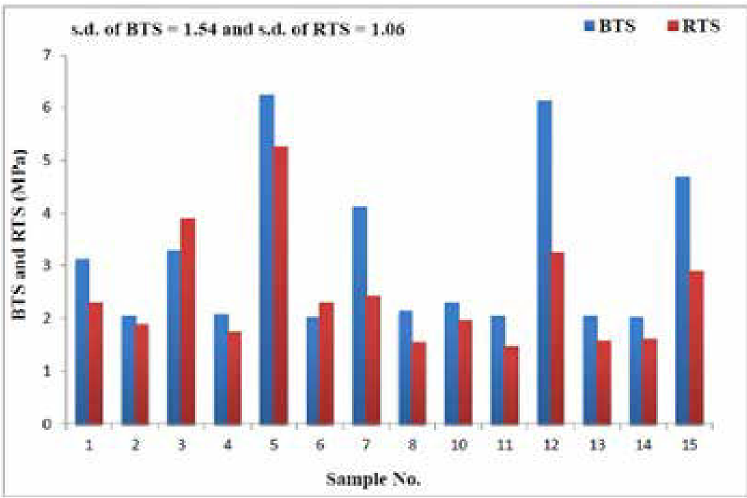
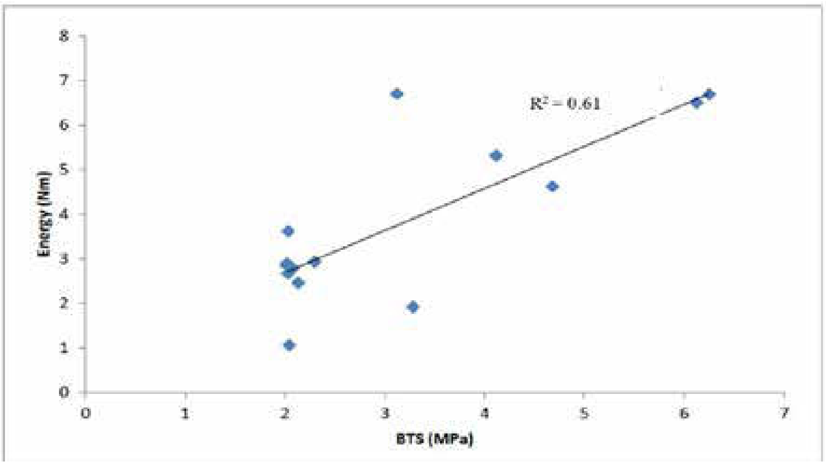


Figure 2 BTS and RTS plotted against corresponding sample no.

(a)



(b)

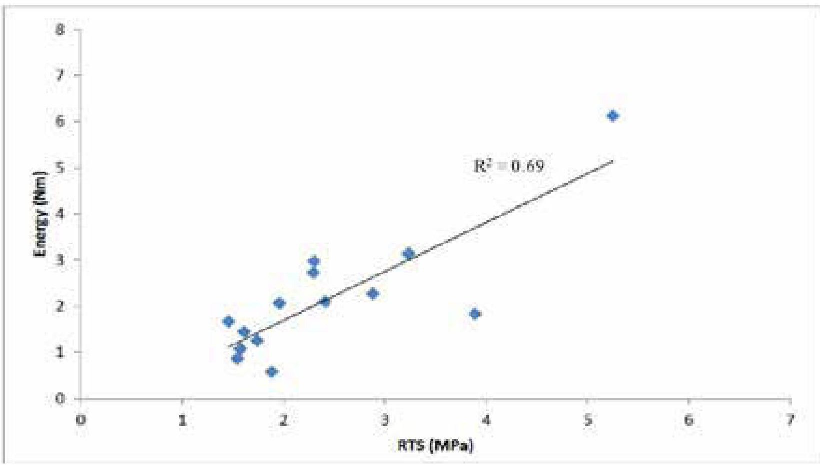


Figure 3 Applied energy plotted against (a) BTS and (b) RTS.

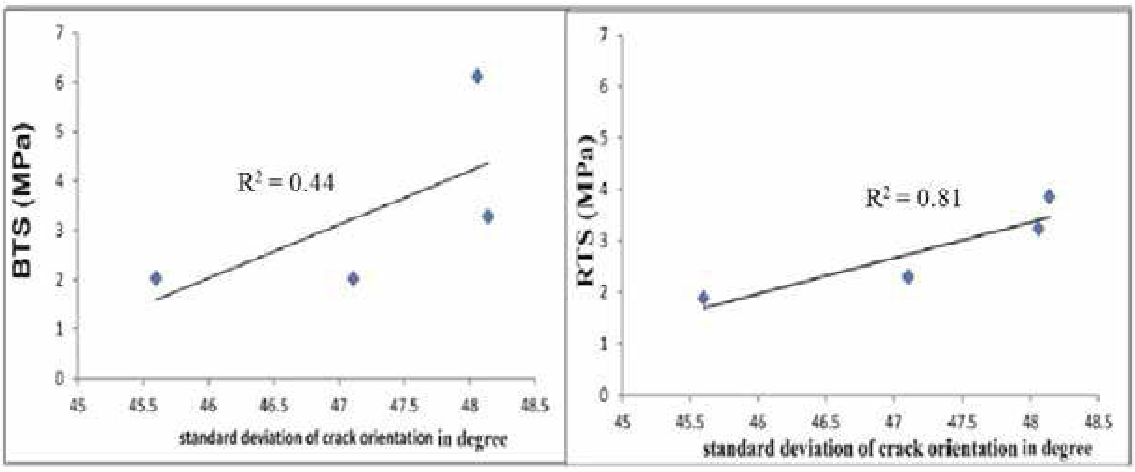


Figure 4 BTS and RTS plotted against standard deviation of relative orientations of micro cracks

4. Conclusions:

On the basis of the present investigation, the following conclusions are drawn:

RTS appears to be more meaningful than BTS in characterizing indirect tensile strength of the investigated sandstone.

The use of ring test, which has not gained much attention unlike Brazilian test, needs to be explored further considering different rock types from different areas with specific geology in order to ascertain applicability of this test in routine rock engineering environments.

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