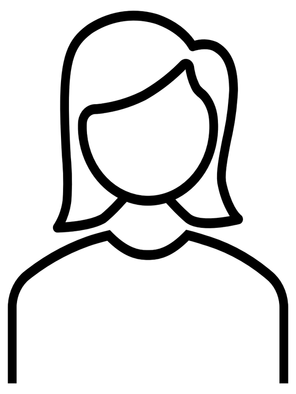
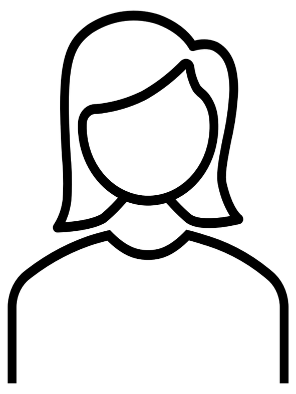
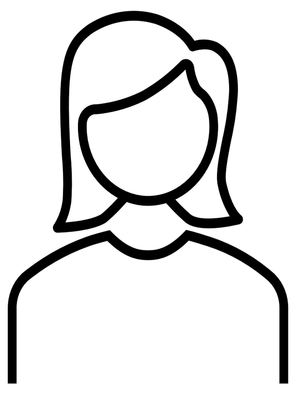
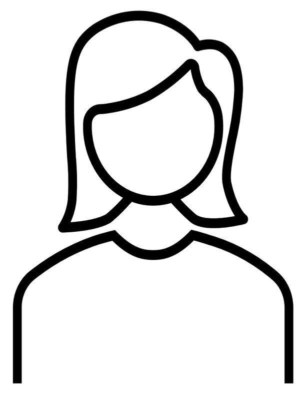
Analyzing tensile strength and deformability as a function of anisotropy

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Introduction

Anisotropy is a very common condition in rock mass; it can be due to different factors and directly affects the failure mechanism of the rock mass. There are many studies about the variation of compressive resistance in the function of anisotropy. However, there is a lot less about the tensile behavior in a transversely isotropic rock. In addition, tensile strength studies, due to simple sample preparation and cost, typically do not perform Direct Tensile Test, only the Brazilian test which is an indirect tensile test.

The present study is focused on the determination of the deformability, compressive and tensile strength of anisotropic rocks. Being remarkable that the mechanical behavior of the anisotropic rock mass is dependent on the inclination of the foliation planes. Considering a parallel plane of weakness, suppose that the two extremes of tensile strength are 0°(horizontal) and 90° (vertical). (fig. 1).

The variation of strength and deformability as a function of anisotropy is analyzed, as well as the variation of elastic behavior in tensile and compressive.

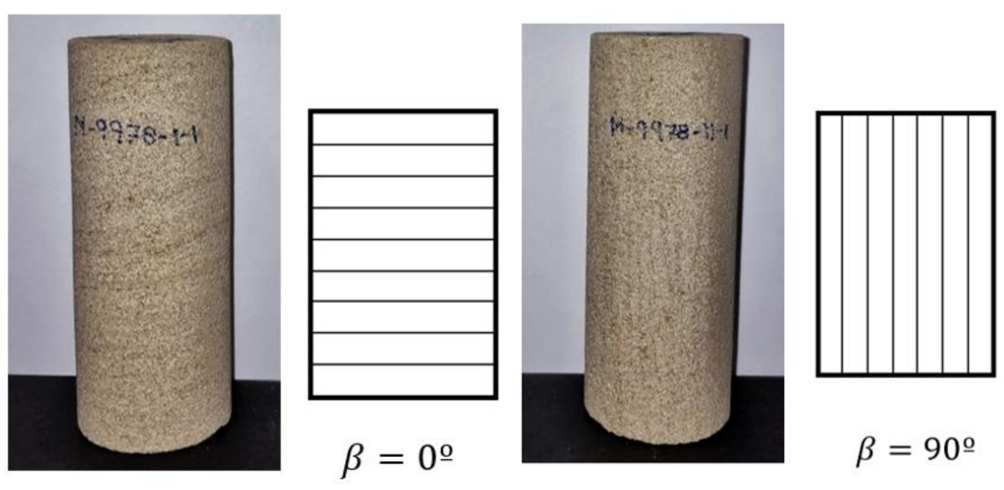

Figure 1. Inclination of the discontinuity.

Methodology

A series of laboratory tests has been done in anisotropic sandstone (lithic arkose), from Burgos, Spain, including uniaxial compressive strength tests (UCT), direct tensile strength tests (DTT), and diametric compression (Brazilian tests, BrT). The tests were carried out with strain gauges that allowed estimating the elastic modulus. To determine the anisotropic direction, ultrasonic pulse wave velocity tests were also performed.

Based on the anisotropy classification according to ultrasonic wave velocity [1], the rock is considered highly anisotropic, VA = 21%. Table 2 presents the values of Pwave obtained in the three directions.

Table 1: Summary of laboratory tests carried out.

Test		Numbers of test
UCT	β = 0º	7
	β = 90º	9
DTT	β = 0º	7
	β = 90º	3
BrT	β = 0º	19
	β = 90º	8

Table 2: Pwave results.

Direction	Pwave (m/s)
X (β = 90º)	1469 (1375-1748)
Y (β = 90º)	1551 (1462-1764)
Z (β = 0º)	1240 (1195-1346)

Most of the tests are performed with samples of 49 mm diameter. The DTT was realized in samples with a thickness of 1 - 2.5 the diameter based on [2] recommendation.

The BrT is carried out in two ways, with force control, and with displacement control, the results are presented in two different graphics.

Results

The following graphs present the results obtained:

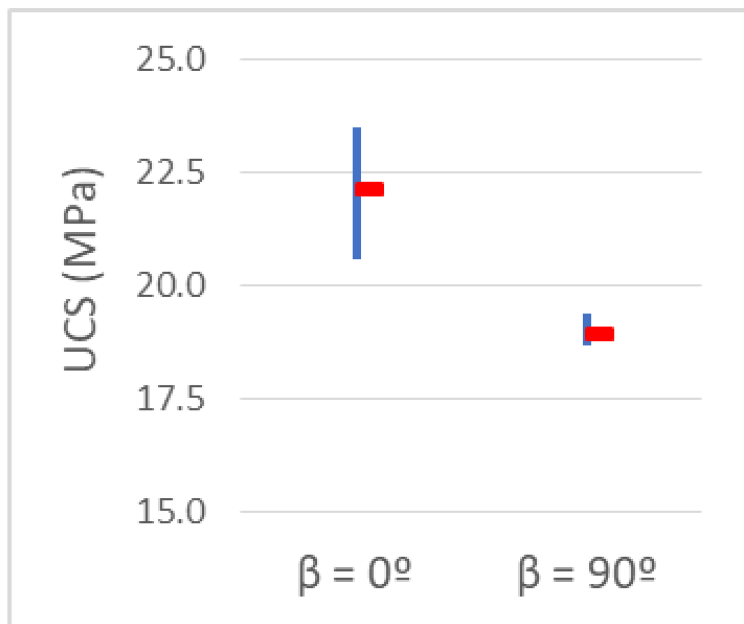

Figure 2. Uniaxial compression test results.

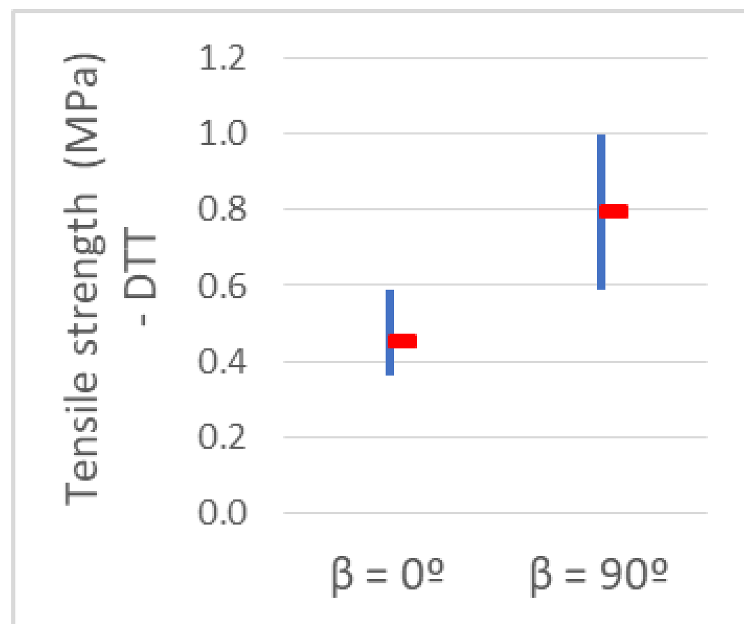

Figure 3. Direct tensile test results.

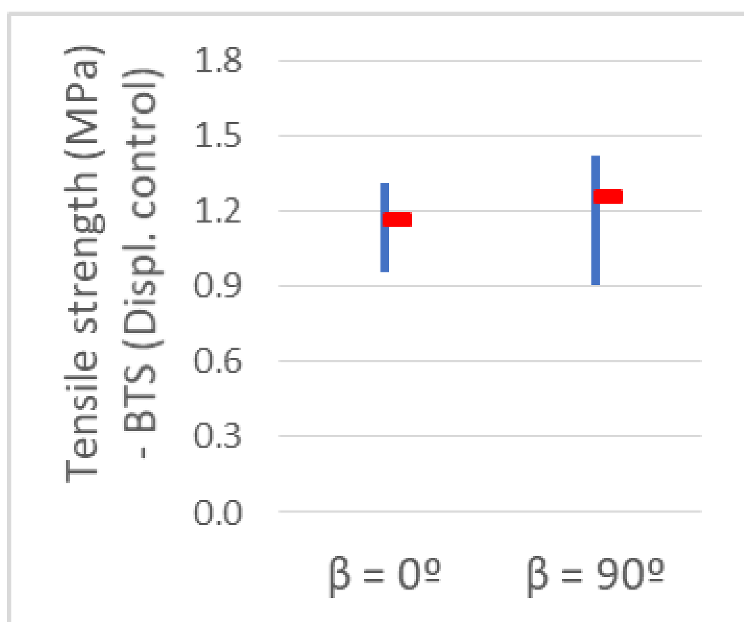

Figure 4. Brazilian test results – Displacement control.

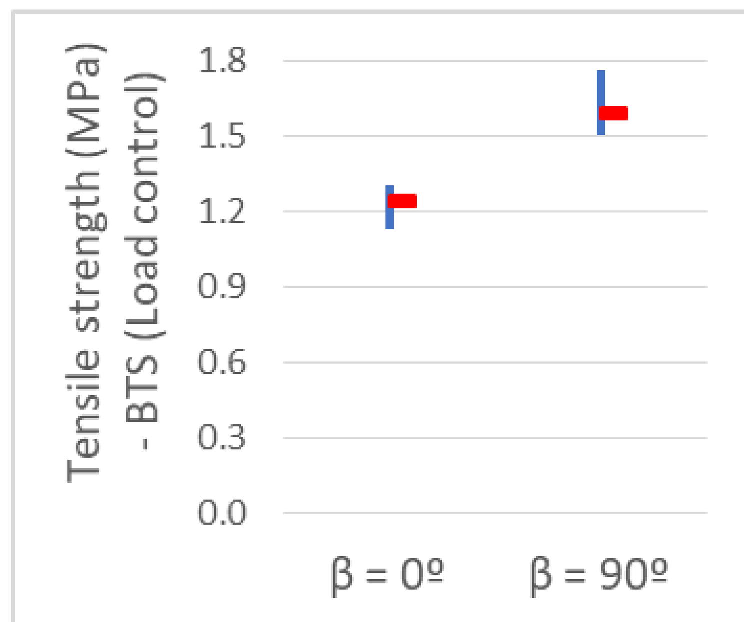

Figure 5. Brazilian test results – Load control.

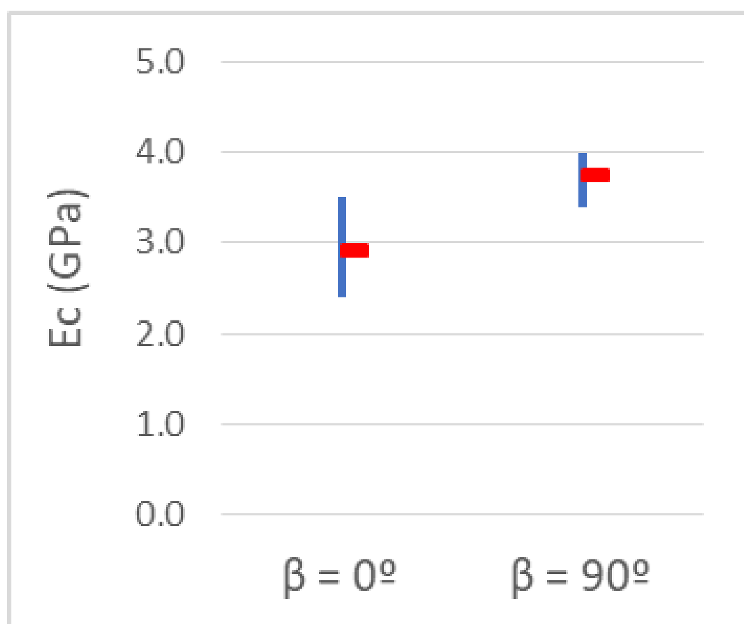

Figure 6. Compression elastic modulus.

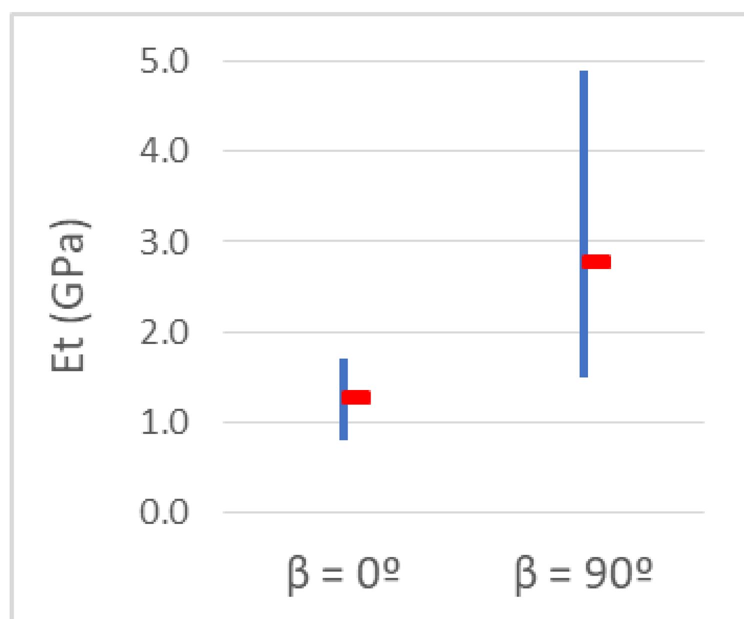

Figure 7. Tensile elastic modulus.

Conclusion

The highest tensile strength is obtained with the vertical discontinuities (β = 90º), while the maximum value of the UCS is obtained with the horizontal discontinuities (β = 0º).

The value of the estimated tensile strength with the BrT (by both methods) is higher than that obtained by the DTT. Using displacement control the results are less than applying load control.

It is highlighted that the elasticity modulus varies in compression and tensile, being higher in compression. Also, it is dependent on the discontinuity orientation.

Acknowledgments

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References

[1] K. Tsidzi, *Propagation characteristics of ultrasonic waves in foliated Rocks*. Bull. Int. Association of Eng. Geology, **1997**, Vol. 56 (pp. 103–113)

[2] Mauro Muñiz-Menéndez, Ignacio Pérez-Rey, *Influence of the specimen slenderness on the direct tensile strength of rocks*. 15th ISRM Congress, Salzburgo (Austria) October 2023.