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Assessment of the physical and mechanical variations of some travertines depend on the bedding plane orientation under physical weathering conditions

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HIGHLIGHTS

- Travertine is one of the most commonly used in construction projects.
- F-T cycles cause more change in UCS value than T-S cycles for travertine.
- Travertine strength is more affected by perpendicular than parallel loading.
- Bedding direction controls the durability of travertine under F-T and T-S cycles.

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ABSTRACT

Travertine has long been a popular material for stone tile flooring in many stages of construction projects due to having unique surface properties characterized by honeycomb structure. Significant differences may be observed in terms of both visual appearances on the rock surface and physical and mechanical behavior in the using area depending on the cutting direction.

In this study, different cutting directions were applied to travertine blocks and the effects of freezing–thawing and thermal shock cycles on the rock structure were experimentally investigated. The changes in the physical and mechanical properties of three different travertine types, such as uniaxial compressive strength, flexural strength, Bohme abrasion resistance, capillary water absorption and *P*-wave velocity values depending on the bedding direction were evaluated under the effect of freezing–thawing and thermal shock tests for 10, 20, 30, and 40 cycles. Qualitative results show that the freezing–thawing cycles have a more destructive effect on the mechanical properties in comparison to thermal-shock cycles through perpendicular loading conditions to the bedding planes in travertines.

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1. Introduction

Travertine has been an important building material for monuments and civil constructions from ancient times until present all over the world. It has been used as structural stone and also in ornamental elements such as sculptures. Travertine is commonly seen in different sizes as façade material, wall cladding, and flooring tiles [1]. Although travertine has high porosity and is composed of different sizes of pores in its structure, it has a wide usage area in the construction and facing stone industry [2] since they are found abundantly, easily processable and have distinctive decorative characteristics [3].

Travertine is being cut parallel or perpendicular to the bedding planes since it exhibits considerable visual variations depending on the cutting direction [3]. It may be cut perpendicular to its natural veins (vein-cut) to expose its natural cavities, open channels, and veins, or can be cut parallel to its natural veins (cross-cut) to conceal these natural properties [4]. Both types have different commercial values and the using preferences generally depend on the architectural design. Due to natural cavities, open channels, and veins that were developed during its formation, travertine has a strong directional veined appearance and corresponding variation in the rock properties [5].

In most engineering structures with rock materials, temperature variation, water content, and fluid permeability are primarily responsible for rock deterioration. They may affect the microstructure properties of the rock by inducing new microcracks and cause some mineralogical changes in the material and so affect its

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physical and mechanical properties [6]. The use of natural stone for outdoor applications generally exposed them to physical weathering conditions such as freezing–thawing (F-T) and thermal shock (T-S) action depending on the regional climate. The F-T test attempts to reproduce the stresses that may arise inside the rock when ice crystals are formed. These effects are generally obtained by varying the temperature below and above 0 °C in samples containing water. T-S refers to the stress that a stone tile undergoes when it is subjected to abrupt temperature changes, inside as well as outside. In cases of outside uses, a rapid temperature change, for example, sun followed by rain, can cause damage to the stones. When a natural stone is heated, all the composing minerals will expand depending on their thermal expansion coefficient. A rapid decrease in temperature will cause shrinkage of the outer minerals and a stress will be caused between the inner expanded hot body and the outer cold part. This process results in intergranular decohesion of the stone [7].

Material characteristics and engineering properties of travertines were investigated by a number of researchers [8–13]. Some researchers studied the effects of cutting direction on the physical and mechanical properties of the rocks. Ozcelik and Yilmazkaya [14] implied that the strong anisotropic characteristics are observed generally on the metamorphic and sedimentary rocks because of the existence of cleavage, foliation, schistosity, joints, bedding planes, lamination, and micro cracks. Cobanoglu and Celik [5] found that the uniaxial compressive strength values under parallel loading to lamination are 1.44 times higher than the perpendicular loading condition. Gokce [3] stated that, when the travertine is used without enough attention paid to the cutting directions, it may easily wear off in locations where pedestrian traffic is heavy and may cause some unexpected results in practice. For this reason, he studied the effects of cutting directions on Bohme abrasion values of 6 types of widely used anisotropic travertine rocks and he found that the values of Bohme abrasion loss values of the surfaces for cut parallel to the bedding planes were greater than those of the surfaces cut perpendicular.

García-del-Cura [15] analyzed the rock strength and elasticity modulus depending on two different bedding orientations and the strongest behavior is found for perpendicular to lamination in low-porous and for parallel to lamination in high porous rocks.

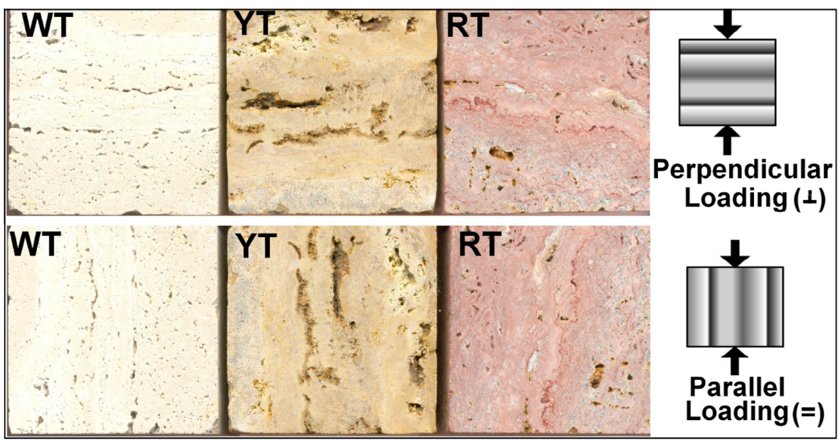
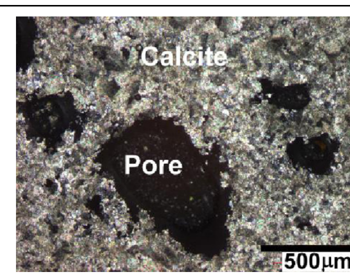
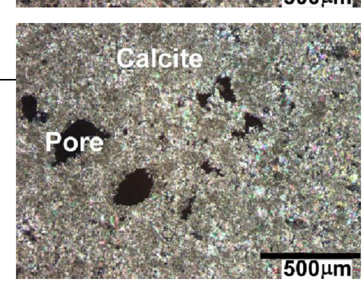


Fig. 1. Tested rocks, bedding planes, and loading conditions.

Table 1
Mineralogical and petrographical features of WT.

WT (perp.)	Mineral (%)	Texture	Pore degree (%)	Crystal shape	Particle width (μm)			
					Min.	Max.	Av.	
Calcite	99.0	Microcrystalline	12.3	Anhedral	4.8	194.5	36.7	
Opaque	<1			–	–	–	–	
Fracture and cracked systems	It was not observed							
Fossil content	It was not observed							
WT (parallel)	Mineral (%)	Texture	Pore degree (%)	Crystal shape	Particle width (μm)			
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