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Artículo

The timelessness of Thassos and Naxos heritage ornamental stones

La atemporalidad de las piedras ornamentales tradicionales de Thassos y Naxos

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Abstract: Heritage stones have been used since prehistoric times for a variety of purposes. The beauty of historic stone buildings that have endured over time testifies to the importance of heritage stones to the cultural heritage of societies. The aim of this paper is to study the timelessness of two ornamental stones from the islands of Thassos and Naxos. The marble of Thassos was originally extracted in the 7th century BC from the ancient quarry of Alykes, which produced a grey calcitic marble. This quarry had been in operation for over 1200 years and had become one of the most important sources of marble in ancient times. Today the ancient quarry is no longer in operation. The quarrying and exploitation of another calcitic marble began later, in modern times, in the central part of the island of Thassos. Laboratory tests carried out on this "new" marble have confirmed that its aesthetic and physical-mechanical properties are similar to those of the marble extracted from the ancient Alykes quarry. The white marble of Naxos was widely used even in prehistory and antiquity for religious purposes or for daily life objects and later for architectural purposes, in monuments and sculptures. Naxos quarry is still in operation, and the marble is used for various applications, due to its high quality characteristics. The mineralogical and physical-mechanical properties of these marbles have been determined in the Lithos Laboratory, in order to highlight their importance as heritage stones.

Keywords: Heritage ornamental stones; Thassos; Naxos; physical-mechanical properties; timelessness

Key points:

The timelessness of Thassos and Naxos ornamental stones due to their attractiveness and durability over time.

The importance of Thassos and Naxos marbles to the cultural heritage.

Laboratory tests carried out on Thassos and Naxos marbles for the determination of their characteristics.

Resumen: Las piedras patrimoniales se han utilizado desde la prehistoria para diversos fines. La belleza de los edificios históricos de piedra que han perdurado en el tiempo atestigua la importancia de las piedras patrimoniales para el patrimonio cultural de las sociedades. El objetivo de este artículo es estudiar la intemporalidad de dos piedras ornamentales de las islas de Tasos y Naxos. El mármol de Tasos se extrajo originalmente en el siglo VII a.C. de la antigua cantera de Alykes, que producía un mármol calcítico gris. Esta cantera llevaba en funcionamiento más de 1.200 años y se había convertido en una de las fuentes de mármol más importantes de la antigüedad. Hoy en *día, la* antigua cantera ya no está en funcionamiento. La extracción y explotación de otro mármol calcítico comenzó más tarde, en tiempos modernos, en la parte central de la isla de Tasos. Las pruebas de laboratorio realizadas con este «nuevo» mármol han confirmado que sus propiedades estéticas y físico-mecánicas son similares a las del mármol extraído de la antigua cantera de Alykes. El mármol blanco de Naxos fue ampliamente utilizado ya en la prehistoria y la antigüedad con fines religiosos o para objetos de la vida cotidiana y, más tarde, con fines arquitectónicos, en monumentos y esculturas. La cantera de Naxos sigue en funcionamiento, y el mármol se utiliza para diversas aplicaciones, debido a sus características de alta calidad. Las propiedades mineralógicas y físico-mecánicas de estos mármoles se han determinado en el Laboratorio Lithos, con el fin de destacar su importancia como piedras patrimoniales.

Palabras clave: Patrimonio piedras ornamentales; Tasos; Naxos; propiedades físico-mecánicas; intemporalidad.

Puntos clave:

La atemporalidad de las piedras ornamentales de Tasos y Naxos por su atractivo y durabilidad en el tiempo.

La importancia de los mármoles de Tasos y Naxos para el patrimonio cultural.

Pruebas de laboratorio realizadas sobre los mármoles de Tasos y Naxos para la determinación de sus características.

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Supplementary information ↓

1. INTRODUCTION

Heritage Stone has been used since prehistoric times as a building material for a variety of purposes, from the manufacture of hunting tools to the construction of magnificent monuments over the centuries. The beauty of historic stone buildings which have survived the test of time is evidence of the importance of heritage stones to the cultural heritage of societies. A historical synopsis of the main events that marked the history of the use of heritage stones is presented by Freire-Lista (2021). According to Freire-Lista (2021), at the time of their historical use, stones were simply stones used for a particular purpose. Some stones were transported long distances and traded for their rarity and durability, and some prehistoric quarries have survived to the present day. The use of these stones has been widespread, and they have been the building material for some of the most important structures that have had an impact on the history of mankind.

This paper examines the timelessness and significance of two important cultural stones quarried on the Greek islands of Thassos and Naxos, focusing on the determination of their physical-mechanical and mineralogical characteristics. The mineralogical and physical-mechanical properties of these stones have been determined in the ornamental stones quality control laboratory of the Hellenic Survey of Geology and Mineral Exploration (HSGME), called "Lithos" Laboratory.

The natural properties of an ornamental stone are divided into those that characterise the material, such as apparent density, open porosity, water absorption, etc., and those that determine the suitability of the stone for various specific uses, such as uniaxial compressive strength, flexural strength, the effect of thermal and/or freeze-thaw cycles on its strength, abrasion resistance, etc., while its aesthetics are related to its mineralogical composition.

2. MATERIALS AND METHODS

2.1. Materials tested

The marble of Thassos was originally extracted in the 7th century BC from the ancient quarry of Alykes, located on the southeastern side of the island, which produced a grey calcitic marble. Thanks to its proximity to the sea, the transport of the extracted marble to the Mediterranean was very easy. Architectural marble decoration in various places in the Mediterranean has been attributed to the quarry of Alykes on the basis of traditional art historical methods (Herrmann & Barbin, 1993). This quarry had been in operation for over 1200 years and had become one of the most important sources of marble in ancient times. Thassos marble was used throughout Greece and Asia Minor in the construction and decoration of temples and other important buildings. Marble from the Alykes quarry was used to build the tomb enclosure in the Kasta tumulus at Amphipolis (Source: WIKIPEDIA). Two and a half thousand cubic metres of marble blocks were needed to enclose the Macedonian tomb. Excavations at Amphipolis revealed marble doors of Macedonian tombs made of Alyki marble, as well as the wall cladding in all areas of the monument with the same marble. (Source: xrysoselladas.gr). In Roman and early Christian times, marble from the Alykes quarry reached Rome, where it was used in public buildings, temples, monuments and private residences. It was also used in the construction of extraordinary buildings in the Byzantine Empire, including parts of Aghia Sofia in Istanbul. Today the ancient quarry of Alykes is no longer in operation. A picture of the ancient quarry is illustrated in Figure 1. On the Alykes peninsula, there are the ruins of the quarry, partly submerged in the sea. Semi-finished sculptures, huge blocks of marble and columns bear witness to the ancient mining activity, as shown in Figure 2. Later, in the central part of the island, the quarrying and exploitation of another calcitic marble" began, known under the commercial name *"Thassos Crystallina"*, according to the European Standard EN 12440:2017, which refers to the Denomination Criteria. Laboratory tests have shown that this marble has technical characteristics similar to those of the "old" marble extracted from the ancient quarry, making it suitable for a wide range of applications in architectural projects.

Figure 1. An overview of the ancient quarry of Alykes.

Figura 1. Vista general de la antigua cantera de Alykes.

Figure 2. Ruins of the ancient Alykes quarry.
Figura 2. Ruinas de la antigua cantera de Alykes.

It is also important to highlight the use of *Naxian marble* already in prehistory and its various applications in antiquity. The Cycladic civilization has numerous archaeological finds, which prove the extensive use of this marble, such as for religious purposes or for objects of daily use and later in architecture. The white marble of Naxos was widely used in the monuments and sculptures of the sacred sites of Delos and Delphi. The temple of Apollo, called “Portara” (Figure 3), is a huge gate made of Naxian marble. It is the only remaining part of the unfinished temple on the island of Naxos, dating from 530 BC. The “Kouros of Apollonas”, also known as the “Colossus of Dionysus”, is a large unfinished statue of Naxian marble weighing around 80 tonnes, as shown in Figure 4. It is located in an ancient quarry near Apollonas, a small town in the northern part of Naxos. The “Kouroi of Melanes” (“Faranghi” and “Flerio”) are two oversized but incomplete freestanding figures of unclothed young men in Naxian marble, dating from the early 6th century BC. A great part of the island’s growth from the past until today is due to the rich marble deposits. The ancient marble quarry is no longer in operation, but there are new quarries operating a few kilometres from the old one in the same village of Kynidaros. A photograph taken from an active quarry in Naxos, is shown in Figure 5. The use of local marble in local building projects has been a major contributor to the sustainable architecture of the island. Naxos marble, known under the trade name *“Naxos Crystallina”*, according to the Denomination Criteria given in the European Standard EN 12440:2017, is used today for various interior and exterior decorative purposes, as well as for the restoration of many archaeological monuments, such as the Ancient Sanctuary of Apollo and Demeter at Gyroulas in Sagri (Naxos), as depicted in Figure 6.

Figure 3. Image of The Temple of Apollo on the island of Naxos.
Figura 3. Imagen del Templo de Apolo en la isla de Naxos.

Figure 4. The “Kouros of Apollonas”, located in an ancient quarry in Naxos.
Figura 4. El “Kouros de Apollonas”, ubicado en una antigua cantera en Naxos.

Figure 5. Picture taken from an active quarry in the island of Naxos.
Figura 5. Fotografía tomada desde una cantera en funcionamiento en la isla de Naxos.

Figure 6. Restoration of the Ancient Sanctuary of Apollo and Demeter at Gyroulas in Sagri (Naxos).
Figura 6. Restauración del antiguo santuario de Apolo y Deméter en Gyroulas, Sagri (Naxos).

2.2. Physical – mechanical properties

The accredited Ornamental Stones Quality Control Laboratory of the Hellenic Survey of Geology and Mineral Exploration (HSGME), called “LITHOS”, carried out a significant number of laboratory tests to highlight the quality and timelessness of the two heritage marbles quarried on the islands of Thassos and Naxos. The laboratory tests performed for determining physical-mechanical properties of the stones included apparent density, open porosity, water absorption, flexural strength under concentrated load, uniaxial compressive strength, abrasion resistance, rupture energy, freeze-thaw cycles, and breaking load at dowel hole. The mineralogical and petrographical characteristics were determined by macroscopic and microscopic examination. All laboratory tests described below, were carried out according to the European standards (EN Standards).

Apparent density and open porosity: The test procedures were conducted on 6 specimens from each stone according to EN 1936:2006. Apparent density, expressed as kg/m^3, is the ratio between the mass of the dry specimen and its apparent volume. Open porosity is the ratio (as a percentage) between the volume of the open pores and the apparent volume of the specimen.

Water absorption at atmospheric pressure: It is expressed as a percentage, by the ratio of the mass of the saturated specimen to the mass of the dry specimen, as described in EN 13755:2008, performed for 6 specimens of each stone.

Flexural strength under concentrated load: A 10-specimen set from each stone was prepared to undergo the test whose experimental procedure is described in EN 12372:2022. The average value of each set was calculated, expressed in MPa.

Uniaxial compressive strength: It is expressed by the ratio of the failure load of the specimen and its cross-sectional area before testing (in MPa). The procedure was carried out for 10 specimens of each stone according to EN 1926:2006.

Abrasion resistance: The test was performed according to EN 14157:2017 – Method B – Böhme abrasion test. The abrasive wear was determined as the loss in specimen volume, expressed in $cm^3/50cm^2$, for 3 specimens of each stone.

Rupture energy: It was determined for six specimens (in joules) of each marble, by the dropping of a spherical steel ball from given increasing heights until specimens broke, as described in EN 14158:2004.

Freeze-thaw cycles: 10-specimen sets from each marble started their freeze–thaw cycling tests in a saturated condition according to EN 12371:2010. Each cycle consisted of a 6h freezing period in air from +17 °C to −12 °C, followed by a 6h thawing period in water from −12 °C to +17 °C. Specimens were subjected to 48 cycles. After completion of the cycles, visual inspection was carried out to score their behaviour and then flexural strength was determined in compliance with EN 12372:2022. The strength obtained was compared to that corresponding to specimens having not undergone freeze-thaw cycles.

Breaking load at dowel hole: It was conducted for ten specimens of both marbles, consists of applying a force in a direction perpendicular to the face of a specimen through a dowel previously placed in a hole drilled in one of its sides and measuring the breaking load of the specimen (expressed in N), as defined in EN 13364:2002.

Petrographic examination: It was carried out according to EN 12407:2019, in thin sections prepared for samples of both marbles. Macroscopic description included the general colour, the rock structure, the grain size, macroscopic cracks, pores or cavities, evidence of weathering or alteration, etc. Microscopic description depicted the constituents of the marbles, such as percentage of minerals and grains, groundmass, discontinuities.

3. PRESENTATION OF THE RESULTS

The calculated average values of the results from the physical – mechanical tests are presented in Table 1. Apparent density is related to the weight of the structure and provides information on the compactness of the material, while open porosity and water absorption are mainly related to the external use of the material in wet conditions and also provide information on its strength, toughness and compactness. The determination of flexural strength provides evidence of its resistance to mechanical stress and helps in the selection of a stone suitable for use in cladding, roofing, stairs and paving. The determination of flexural strength after freeze-thaw cycles, which simulate the ageing of the material, is important in determining its behaviour for external applications in humid and cold climates. Abrasion resistance is related to differential wear and the ability of the material to be machined, and is critical in the selection of a stone suitable for paving and stairs. The breaking load at dowelhole test should be carried out in cases where natural stone is to be used for cladding or lining in buildings.

Table 1. Average values determined for the physical – mechanical properties of Thassos and Naxos marbles.

Tabla 1. Valores promedio determinados para las propiedades físico-mecánicas de los mármoles de Thassos y Naxos.

Physical - mechanical properties	Marbles	
	“Thassos Crystallina”	“Naxos Crystallina”
Apparent density (kg/m^3)	2710	2710
Open porosity (%vol)	0.2	0.3
Water absorption at atmospheric pressure (%wt)	0.2	0.1
Flexural strength under concentrated load (MPa)	11	10
Uniaxial compressive strength (MPa)	71	55
Abrasion resistance ($cm^3/50cm^2$)	20	23
Rupture energy (joule)	5	4
Strength after 48 Freeze-thaw cycles (MPa)	8	8.3
Breaking load at dowel hole (N)	1400	1500

Measurements of the physical-mechanical properties of “Thassos Crystallina” marble can confirm its durability over time. The low abrasion resistance, the relatively high flexural and compressive strength and the high rupture energy are such indicators. The absence of any deterioration or change in the specimens subjected to 48 cycles of freezing and thawing can be attributed to the low water absorption and low open porosity. These characteristics make “Thassos Crystallina” marble suitable for any type of application, even under the most varied climatic conditions. It reflects sunlight well and maintains a cool temperature, making it ideal for cladding in warmer regions. Khwayyir et al. (2022) investigated the unique characteristics of Thassos marble in terms of thermal properties in order to increase knowledge of the importance and ability of this marble to dissipate heat, especially in hot climates. According to the petrographic examination, this marble is light grey in colour, it is mainly composed of calcite, almost homogeneous and with a granoblastic texture, often forming triple points, polysynthetic twinning and rhombohedral cleavage. “Thassos Clystallina” marble is a metamorphic rock belonging to the carbonate marbles of the Rhodope Mountains, which are part of the region of Eastern Macedonia and Thrace (Source: Geological Map of Greece 1:50000, Thassos sheet).

The diachronic nature of “Naxos Crystallina” marble is confirmed and justified by both its physical-mechanical characteristics and its aesthetic image. The values determined for the above characteristics are very close to those measured for “Thassos Crystallina” marble, as shown in Table 1. It is a marble with high strength properties. It is suitable for interior and exterior use, wall cladding, flooring, stairs and any other design project. According to petrographic analysis, “Naxos Crystallina” is a white calcitic marble consisting almost entirely of calcite (100% calcite). Its texture is granoblastic to inequigranular and has a compact to irregular texture. The matrix of the rock consists of coarse-grained and anhedral calcite crystals, ranging in size from 0.25 mm to 6.50 mm. The rock has undergone intense tectonism, resulting in features such as wavy extinction of the calcite crystals, twinning, and bending and transposition of the twinning planes. A representative micrograph of a thin section of this material is shown in Figure 7. “Naxos Crystallina” marble belongs to the marbles of metamorphic complex, coarsely crystalline and white, containing intercalations of carbonate schists, amphibolites and biotite-hornblende gneisses (Source: Geological Map of Greece 1:50000, Island Naxos).

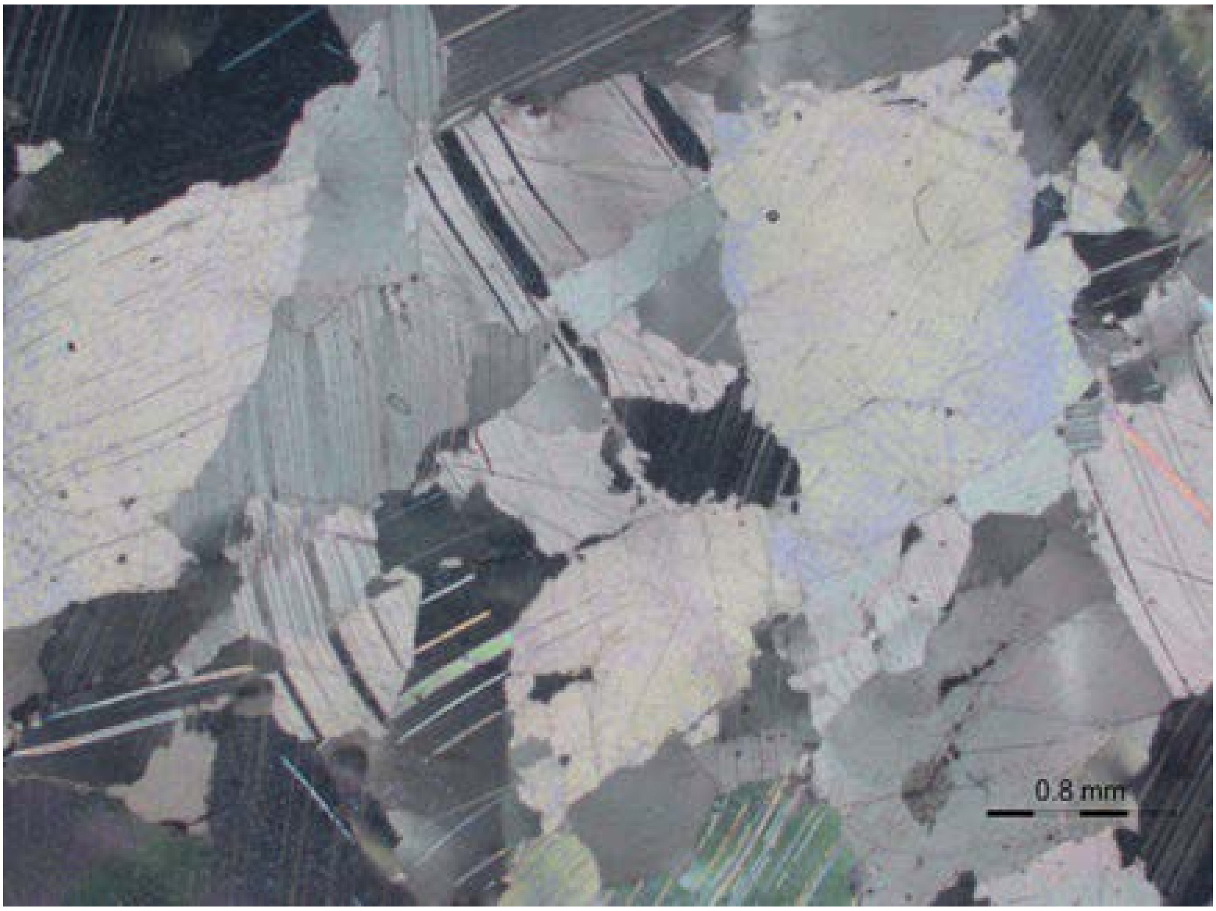

Figure 7. Representative micrograph of a thin section of “Naxos Crystallina” marble.

Figura 7. Micrografía representativa de una lámina delgada de mármol “Naxos Crystallina”.

4. CONCLUSIONS

Heritage stone has long been a material of choice for a wide range of purposes such as monuments, temples, buildings, bridges and other structures of cultural heritage importance. Throughout the centuries, heritage stones have played an important role in human culture, history, civilisation, architectural heritage restoration and geoheritage in general. The paper overviews the significance of two Greek heritage stones, known by their commercial names ‘Thassos Crystallina’ and ‘Naxos Crystallina’ marbles. The islands of Thassos and Naxos were the most important centres of marble production in Greece in ancient times. Since prehistoric times, the marbles producted from these islands, have been used in all kinds of applications, both in local communities and throughout the Mediterranean region. The physical - mechanical characteristics of these two marbles, which determine their behaviour, have been studied in the LITHOS laboratory. Their characteristics, on which their resistance to time and mechanical stress depends, as well as their aesthetics, which derive from their mineralogical composition, make them attractive structural ornamental stones. These results have shown that both types of marble are of very good quality and the microscopic study has revealed a good homogeneity in all their petrographic features. They are still used today in a wide range of applications and this confirms and justifies their timeless use.

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Konstantinos Laskaridis: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft, Photographs, Image editing, Writing – review & editing.

Angeliki Arapakou: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft, Photographs, Image editing, Writing – review & editing.

Michael Patronis; Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft, Photographs, Image editing, Writing – review & editing.

Competing interests

The authors of this article declare that they have no financial, professional, or personal conflicts of interest that could have inappropriately influenced this work

Statement on the use of Artificial Intelligence

Not applicable.

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