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# Determination of physical and mechanical properties of limestones used as marble in Tut-Adiyaman Region in Turkey

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Abstract:

This study aimed to reveal the petrography and physical-mechanical properties of limestones, which have an important reserve and are used as marble, in Tut district of Adıyaman province, which is one of the important cities of southeast Anatolia. As a result of petrographic analysis of the rock known commercially as Emprador, it was determined that it is bioclastic limestone with abundant nummulite fossils. Density, dry and saturated unit weight, water absorption, surface roughness, abrasion resistance and uniaxial compressive strength tests were applied to determine the physical and mechanical properties of the limestones. According to the test results obtained, the density of the limestones, dry unit weight, saturated unit weight, water absorption by weight, water absorption by volume, average surface roughness, ten points roughness average, maximum roughness value, Böhme abrasion resistance and uniaxial compressive strength values were determined as 2.486 gr/cm$^3$, 2.478 gr/cm$^3$, 2.52 gr/cm$^3$, 1.482%, 3.644%, 3.31 µm, 16.24 µm, 20.03 µm, 8.958 cm$^3$/50cm$^2$ and 1004.03 kgf/cm$^2$ respectively. The results show that the limestones in and around Tut (Adıyaman) county can be used in large areas for decorative purposes, with their physical and mechanical properties, as well as their colour tone and the texture formed as a result of the calcite veins being shaped like a natural pattern.

Keywords: natural stone, marble, limestone, physico-mechanical tests

## 1. Introduction

Located in the Alpine-Himalayan mountain belt, Turkey hosts many natural stone resources of different origins, in different colours and textures. In Turkey, which has proven its continuity in the natural stone industry and has more than 250 different resources released to the market, the reserves are spread over a wide region. Considering the distribution of known resources by regions, 32% of them are located in the Aegean region, 26% in the Marmara region, 11% in the Central Anatolia region and the remaining part in the Mediterranean, Black Sea and Eastern Anatolia regions (Çelik et al. 2021).

The oldest products used by human beings as building materials throughout history are known as natural stones. Marble, on the other hand, is a building product that has emerged as a result of the use of natural stones in the construction sector, especially in different areas, and has an important place in this field throughout the world. Today, the term marble is used in two different senses. Scientifically, it is defined as a metamorphic rock formed as a result of metamorphism of rocks with calcium carbonate composition; In commercial terms, it is used for natural stones that can give blocks, can be cut and processed and hold a good polish. Marbles, which provide a wide area of use in the field of construction, are required to have some physical and mechanical properties according to the area of their use. Today, marbles are widely used in kitchen work surfaces, stair steps, flooring, wall coverings and decorative purposes. As a result of the developing technology and methods, the marble sector has taken place of an industry branch that is growing day by day all over the world.

There are many studies in the literature on a determination of physical and mechanical properties of marbles, their extraction methods and positive and negative properties, as well as usability as raw materials. In this context, some researchers have carried out studies to determine the physical and mechanical properties of rocks of different origins and their usability as marble according to standards or to determine the properties of rocks currently used as marble [Erguvanlı et al. 1972; Onargan et al. 1995; Yavuz et al 2002; Çavumirza et al. 2003; Kılıç et al. 2003; Sümer et al. 2003; Tutuş and Kılıc 2007; Mutluhan and Özsan 2010; Kuşçu and Demiray 2015; Kılıç et al. 2018; Şimşek and Bilir 2022]. Some researchers have studied the usability of marble as a raw material in building materials such as artificial marble, concrete and gas concrete, and the usability of waste marble dust in similar building materials [Konak et al. 1999; Gülan et al.2016; Günaydın et al. 2016; Şimşek and Demir 2021]. Some researchers conducted studies on the performance analysis of marble cutting methods in quarries [Eleren and Ersoy 2007; Tolouei 2017; Çalışkan and Yavuz 2019; Dilmaç and Görgülü 2019].

Emprador type marbles (limestones) obtained from the marble quarry belonging to the Safvan Marble Enterprise located around the Tut district of Adıyaman province, used within the scope of the research, are included in the formation, which was first defined as the Hoya formation by Sungurlu (1974). The Hoya formation consists of limestone and dolomitic limestone units and is defined as gray-off-white coloured, abundant fossiliferous (abundant algae), angular fractures, clay-filled, medium-thick bedded karst formations. The Hoya Formation is Eocene aged and outcrops in an area of approximately 25 km in length and 7 km in the north of Adıyaman province (Yıldırım, 2013). In this study, it was aimed to investigate the mineralogical, physical and mechanical properties of limestones that can be used as marble in Tut district of Adıyaman province..

## 2. Materials and Methods

The marble samples, used within the scope of the study, were obtained from the Safvan Marble quarry in the Tut district of Adıyaman (Fig. 1a). The petrographic analysis, density, water absorption value, surface abrasion value, surface roughness and compressive strength values were investigated by sizing the samples in accordance with the test standards. In order to determine the petrographic analysis density, water absorption value, surface abrasion value, surface roughness and compressive strength values of the samples, they were cut in accordance with the standards (Fig. 1b).

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**Fig. 1** a) View of the study area, b) Samples sized for analysis

For petrography studies of the samples (limestone), thin sections were prepared in the thin section laboratory of the Mersin University, Faculty of Engineering, Department of Geological Engineering and analyzed under polarized microscope.

The density of the samples was determined by calculating the volume of the samples obtained from the field and not subjected to any treatment by water overflow method. In order to determine the dry and saturated unit weight and water absorption values, the dry weights of the samples were calculated by keeping them in an oven at 105°C until the maximum dryness was reached. Then, the same samples were kept in a container filled with water until they were completely saturated, and their saturation weights were calculated. As a result of substituting the obtained data in the relevant formulas, unit volume weight and water absorption values were determined (Fig. 2).

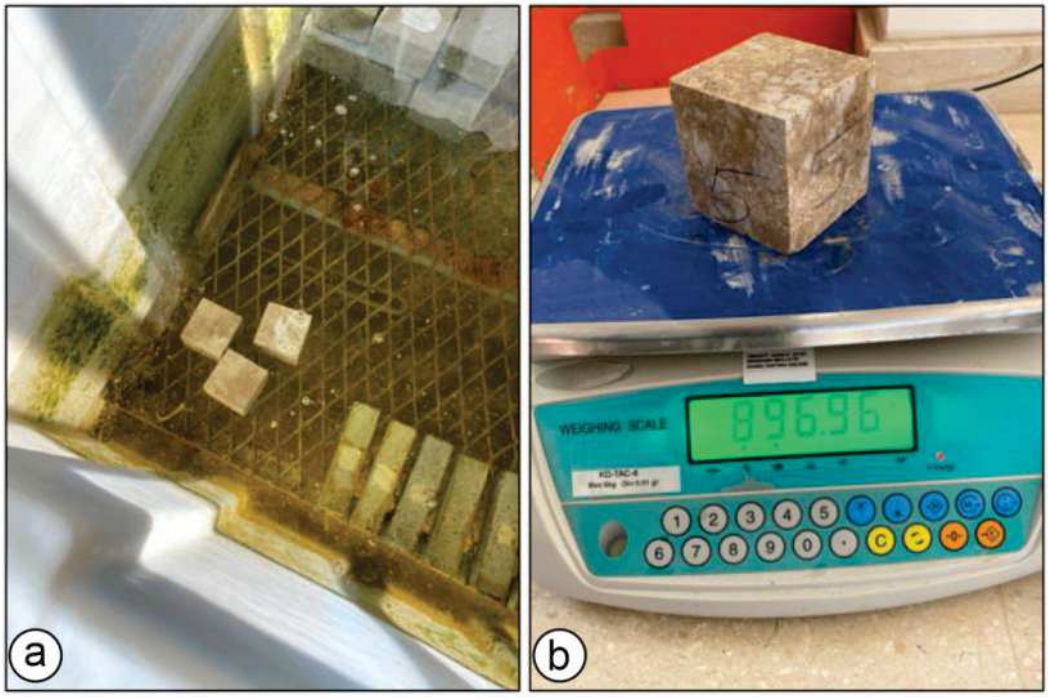


**Fig. 2.** Water absorption and dry-saturated unit weight measurement:
a) water tank, b) weight measurement

Marsurf M 300 diamond needle scanning surface roughness measuring device was used to determine the surface roughness of the marbles (Fig. 3). These measurements were applied taking into account the issues specified in the relevant standard. At least 5 different readings were made on each test sample and the average value was given. This measurement was related to the indentations and

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protrusions on the sample surface as a result of the up and down movement of the 5 μm diameter diamond needle tip on the sample surface.


**Fig. 3.** Determination of surface roughness

In order to determine the compressive strength of the marbles, the samples cut to size in accordance with the marble standard were subjected to uniaxial compressive strength (Fig. 4). In order to determine the strength, measurements were made on 5 different samples and the average value was given.


**Fig. 4.** Determination of compressive strength: a) test application b) broken sample

Böhme abrasion test was used to determine the wear value on the surfaces of the marble samples (Fig. 5). For this test, the edge lengths of the samples were cut to 71±1.5 mm and applied to the surface of each sample with 4 cycles and 88 cycles. The test was performed at least 3 times for each sample and the average of these values was given as volumetric loss.

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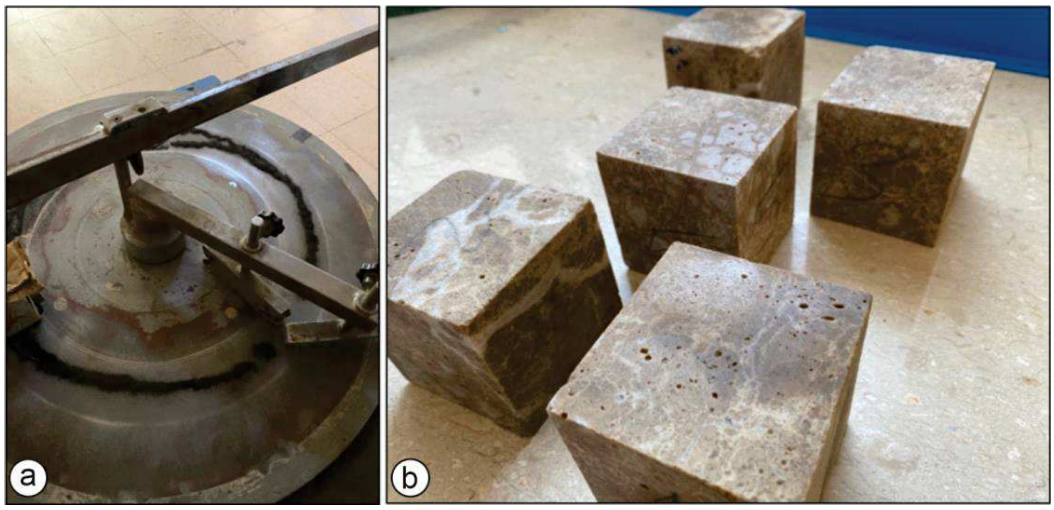


**Fig. 5.** Determination of Böhme abrasion resistance:
a) Böhme abrasion test instrument b) test samples

## 3. Results and discussion

Within the scope of the study, marble (limestone), known as Emprador in the marble sector, has been mined industrially in the region in recent years, making a great contribution to the regional economy. The produced marbles have various commercial names (Dark-Emprador, Adıyaman Emprador etc.). In the petrography study, carried out on limestones (Emprador marble) taken within the study area, according to the limestone classification made with the Folk (1965) classification; It was defined as bioclastic limestone and fossils and shell fragments of nummulites were observed in it (Fig. 6 b). It is known that the nummulites represent Eocene age, and the limestones sampled from the study area were found to be of Eocene age.

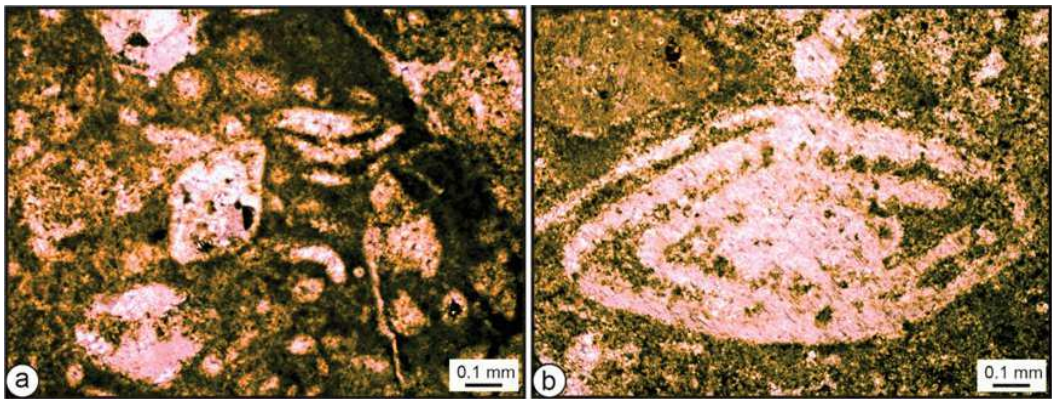


**Fig. 6.** Thin section images of Adıyaman (Emprador) limestone (Crossed Polorized Light):
a) Bioclastic limestone with nummulite fossils and various shell fragments,
b) Nummulite fossil thin section view

Density, dry-saturated unit weight, water absorption, uniaxial compressive strength, surface roughness and Böhme abrasion resistance tests were repeated at least 5 times for each test in order to determine the physical and mechanical properties of marbles within the scope of the tests presented as the mean of the data.

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**Table 1.** Analysis Results of Marbles

| Uygulanan Analiz | Ortalama Değer |
|---|---|
| Density (gr/cm$^3$) | 2.486 |
| Dry Unit Volume Weight (gr/cm$^3$) | 2.478 |
| Saturated Unit Volume Weight (gr/cm$^3$) | 2.52 |
| Water absorption by weight (%) | 1.482 |
| Water absorption by volume(%) | 3.644 |
| Böhme Abrasion Resistance (cm$^3$/50cm$^2$) | 8.958 |
| Uniaxial Compressive Strength (kgf/cm$^2$) | 1004.03 |
| Average Surface Roughness (μm) | 3.31 |
| Ten Points Surface Roughness (μm) | 16.24 |
| Biggest Roughness Value (μm) | 20.03 |

The density of the marbles used in the study was determined as 2.486 gr/cm$^3$. According to TS 1910, the density of natural stone used as paving stone in buildings should be at least 2.55 gr/cm$^3$ (TSE 1977a). The dry and saturated unit weights of the marbles were calculated as 2.478 and 2.52 gr/cm$^3$, respectively.

The lower the water absorption value of the natural stone to be used in exterior cladding, the more ideal it is. The water absorption values of the rocks used in the study were determined as 1.482% and 3.644% by weight and volume, respectively. According to TS 1910, the water absorption value of natural stone should be at most 0.75% under atmospheric factors. According to TS 2513, the weight water absorption rate of natural building blocks should not be greater than 1.8% (TSE 1977b). According to TS 10449, the water absorption of marbles at atmospheric pressure should be less than 0.4% (TSE 2004). According to the results obtained, it is seen that Adıyaman limestones are suitable for use according to TS 2513.

According to TS 10449, the compressive strength of the marbles should be greater than 50 MPa for the marbles to be used in flooring, stair steps and flooring, and more than 30 MPa for the marbles to be used for wall covering. According to the results obtained, this value was determined as 1004.03 kgf/cm (98.462 MPa) in Adıyaman limestones. Therefore, the test samples are suitable to be used according to the relevant standards. When the Böhme abrasion resistance was examined, the abrasion of the limestone sample was found to be 8.958 (cm$^3$/50cm$^2$). According to TS 10499, this value is required to be less than 25 for natural stone used as paving stone and less than 15 for natural stone to be used in flooring. It is seen that the limestones used in the study meet both standard values.

## 4. Conclusions

As conclusions,

- Emprador marble (limestone) taken from the quarry of the Safvan Marble Enterprise in the Tut district of Adıyaman within the study area was determined to be bioclastic limestone containing abundant nummulite fossils as a result of the petrographic study.
- As a result, considering the tests performed on the limestones used in the study and the values required in the relevant standards, the density and unit volume weight values cannot meet the desired values in the relevant standards; uniaxial compressive strength, water absorption and Böhme abrasion resistance values were found to be above the required values.
- When all these tests are evaluated in general, it can be concluded that the examined limestones meet the building stone standards and are suitable for use.

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