



Research on the Physical Properties of the Building Stones in East Black Sea Region

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ABSTRACT

This study investigates the physical properties of Ünye stone (Ordu), Harşit granites (Giresun), and Trabzon gray stone (Trabzon) used as building materials in the Eastern Black Sea Region. Chemical components, thermal conductivity, compressive stress, water absorption, and abrasion percentages of selected stones were determined. Ünye stone has small thermal conductivity coefficient value as 0.67 W/mK, indicating that it can be used for thermal insulation and decorative purposes as briquettes, bricks, or wall cladding materials. Harşit granites have compressive strength and abrasion ratio values of 113 MPa and 1.05%, respectively. Trabzon gray stone has compressive strength and abrasion ratio of 125 MPa and 1.13%, respectively. These results indicate that Harşit granite and Trabzon gray stone can be used as wall cladding materials and wear-resistant floor coverings. These three stones are widely used since they are cheap and abundant.

Keywords: Ünye stone, Harşit granites, Trabzon gray, building material

1. Introduction

Natural stones are the most common materials extracted from the ground and used for construction. Stones symbolize civilization, as people have used them for accommodation and artistic purposes for centuries. Stones have allowed us to build durable structures, solid works of art, arches, bridges, and inns. We can use natural stones for construction purposes because they contain precious minerals. Today, people have different demands on building materials. In the past, people used natural building stones due to architectural limitations. However, today, those natural building stones are used for aesthetic purposes in modern architecture and for different purposes (interior and exterior decoration, paving, siding, etc.). Therefore, people demand natural stones more and more, making them one of the attractive sectors.

Türkiye is a favorable country in terms of natural stone, with a total reserve of 5.167 billion m³. The Aegean Region ranks first with 3.5 billion m³ of reserves. The Eastern Black Sea Region also has a high potential with its granite reserves. The region has total reserves of 250 million m³ (435 million tons) of natural stone [1].

There is a significant number of research on structural stones in the literature. These studies can be grouped into two categories. The first group of studies introduces building stones. For example, Çapık investigated the usability of Harşit granites as marble [2]. Çapık and Yılmaz investigated the physico-mechanical properties of

Harşit granites [3]. Bak et al., focused on the formation and usage areas of Trabzon gray stone [4]. Avsaroglu addressed the physical properties of Ünye stone and gave examples of its usage areas [5].

The second group of studies addresses building stones' formation, usage areas, and thermal and mechanical properties. For example, Pivko focused on the formation of stones [6], while Kazancı and Gürbüz studied the geological formation of natural stones in Türkiye [7]. Dinçer et al, investigated the water absorption ratios of ignimbrites [8]. Gürdal investigated why natural stones deteriorate and how to protect them [9]. Bakış et al. examined the usability of Ahlat stone in the construction sector [10]. Biçer conducted studies on the thermal and mechanical properties of Ahlat and Malazgirt stones [11] used as building materials in many provinces and districts of the Euphrates basin [11, 12], Aegean [13], Marmara [14] and Mediterranean Regions [15]. Külekci and Yılmaz, investigated physical properties of the Late Jurassic-Early Cretaceous volcanics, which are widely spreading around Trabzon usability of building rubble as road underfill [16, 17]. Aliyazicioğlu and Külekçi, some physical and mechanical experiments of basalt and limestone type rocks were implemented and interpreted [18]. Külekci et al, investigated of usability of construction waste as aggregate [19].

In order to use natural stones as building materials, it is essential to know their physico-mechanical properties well. Ünye stone, Harşit granites, and Trabzon gray stone are widely used in the Eastern Black Sea Region.

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This study investigated their thermal and mechanical properties. Those stones have been used in many buildings and floor coverings for centuries. This study applied specific tests to determine what kind of properties those stones have and to explain why they are widely used in the Eastern Black Sea Region.

2. Materials and Methods

2.1. Materials

Ünye Stone

Ünye stone is red, yellow, white, or gray and has thermal insulation properties. It is limestone, which is a sedimentary rock and is mainly used on the exterior of buildings. It is easy to process and gains hardness and durability after contact with air (Ünye stone has a hardness of 4-5 Mohs). It is also a fire-resistant building material because it is resistant to high temperatures. It does not contain any harmful substances because it is ecological. Buildings with Ünye stone are warm in winter and cool in summer. It is a landscape and interior decoration material with high strength and resistance to pressure and slope. It is used in many parts of the world, such as the National Museum in Turkmenistan (Fig 1-a), the headquarters of Fortis Bank in Belgium, the seven-star Burj al-Arab in Dubai, etc. The Yeditepe University in Türkiye is covered with Ünye stone (Fig 1-b). Ünye stone in different colors was used for cladding and ornamental purposes on the exterior and interior surfaces of Çamlıca Mosque. It was also used in hundreds of buildings, such as the Palace of Justice in Konya and the Palace of Justice in Kastamonu.



a)



b)

Figure 1. a) Turkmenistan National Museum [20], b) Yeditepe University [21]

Harsit Granites

Harsit granite quarries are located in the Harsit valley, 10 km south of the center of the Doğan kent district of

Giresun province. It is gray and has a specific gravity of 2.76 g/cm³ and high strength. It is used as a building stone for paving, kitchen countertops, stair steps, and flooring (Fig 2). This stone is basalt-type and it has a hardness of 6-7 Mohs.



a)



b)



c)

Figure 2. Harsit granites applications a) kitchen countertops [22], b, c) cobblestone [23, 24]

Trabzon Gray Stone

Trabzon gray quarries are located around Gözaçan village on the Trabzon-Erzurum highway, 10 km from Trabzon. Stone and wood are traditional building materials in Trabzon. Trabzon gray stone allows developers to construct buildings of different architectural types, such as Trabzon Kostaki Mansion (Trabzon Museum) (Fig 3-a) and Akçaabat-Ortamahalle Kagir Houses (Fig 3-b). Trabzon gray stone is a hard rock used as exterior cladding, curbs, paving stones, and road pavement (Fig 3-c). Until recently, Trabzon Gray stone had been exported abroad (Russia). This stone is basalt-type and it has a specific gravity of 2.53 g/cm³, hardness of 6-7 Mohs (Table 1). While the calcium carbonate ratio is very high in ünye stone, the silica content is high in the others.



a)



b)

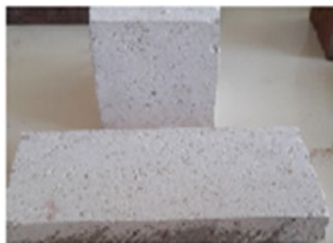


c)

Figure 3. Trabzon gray stone applications a) Trabzon museum, b) Akcaabat masonry houses [25], c) cobblestone [26]

2.2. Methods

Samples from two quarries were prepared for thermal (150x60x20 mm) and pressure and abrasion tests (100x100x100 mm) (Fig 4). Table 1 shows the chemical compositions of the samples.



a)



b)



c)

Figure 4. Samples of; a) Ünye stone, b) Harşit granites, c) Trabzon stone

Table 1. The chemical composition of the samples, (%)

Component Materials	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	LI	Undef.
Ünye ston.	7.05	2.41	3.32	51.3	1.82	32.8	1.24
Harşit gra.	67.48	17.14	4.61	3.42	1.24	5.08	1.13
Trabzon gr	54.40	11.68	12.36	5.70	8.58	4.25	3.12

Thermal conductivity

Thermal conductivity was determined using a "Shotherm-QTM" device, which measures under the transient regime based on the hot wire method according to DIN 51046 standard (Fig 5-a). The device measures the coefficient of thermal conductivity in the range of 0.02-6 W/mK with an accuracy of 5% [27, 28]. Measurement results are given in Table 2.

Compressive strength and volume abrasion

Compressive strength and volume abrasion were determined using by "Ele" International device according to TS 699 standard (Fig 5-b) [29]. Table 2 shows the results of abrasion loss in volume for 88 cycles in the friction abrasion tests (Fig 5-c).



a)



b)



c)

Figure 5. Test units of a) thermal conductivity, b) compressive strength, c) volume abrasion

Water absorption

Water absorption is determined to investigate the existence of a dry volume in which ice crystals can expand during the freezing process of building materials in direct contact with water. The dry (W_k) and water-absorbed (W_d) weight of each sample were determined, and then the water absorption ratio was calculated using the equation below:

$$\text{Water absorption percent} = \left\{ \frac{W_d - W_k}{W_k} \right\} \cdot 100 \quad (1)$$

Specific weight

Dry weight was measured using a balance with a precision of 1%. The volumes of the samples were determined, and the densities were calculated.

3. Results and Discussions

The samples were compared with other building materials. Ünye stone has a thermal conductivity of 0.67 W/mK. Considering the heat transfer under both continuous and time-dependent regimes, we can state that Ünye stone is better than other building materials in terms of thermal insulation (Table 3). Ünye stone is a natural stone that is easy to process and gains hardness and durability by contact with air. Therefore, it can also be used as a decoration material. It has low abrasion (1.2 %) and high pressure (52.6 MPa), indicating robustness. Therefore, if used as an exterior cladding, it can both save energy and obtain images with aesthetic value. This is why it is widely used worldwide.

Harşit granites are not structurally preferable because they have a thermal conductivity of 1.42 W/mK. The tests performed according to TS 699 standard show that Harşit granites have a compressive strength of 2.69 g/cm³ and a volume abrasion of 1.05%. These results suggest they can be used as kitchen countertops in interior and exterior floorings.

Trabzon gray stone has a thermal conductivity of 1.18 W/mK. In other words, it is not a very promising stone but can be used for decorative purposes and exterior cladding as well as for thermal insulation. According to T.S.E. 1910 standard, a natural building stone should have a specific gravity greater than 2.55 g/cm³ to be used as a cladding material [30]. Trabzon gray stone has a specific gravity of 125 g/cm³, compressive strength of 125 MPa, and volume abrasion of 1.13 %, indicating that

it can be used for interior and exterior flooring and as a paving material.

Table 2. Thermal and mechanical properties

Materials	Specific weight (g/cm ³)	Thermal condu. (W/mK)	Compr. streng. (MPa)	Water absor. (%)	Volume abras. (%)
Ünye stone	1.85	0.67	52.6	1.52	1.2
Harşit grani.	2.69	1.42	113	0.35	1.05
Trabzon gr.	2.53	1.18	125	1.06	1.13

Ünye stone, Harşit granites, and Trabzon gray stone are in better condition than uniaxial compressive strength values (Table 3). They can be used as load-bearing walls and partition elements. The abrasion loss values show that they can also be used as building elements (stairs, parquet, etc.) that are exposed to excessive abrasion. They are cheap and abundant. Ünye stone, in particular, can be used as a decoration material. However, they can also be used as bricks and briquettes or wall cladding on exterior walls, both for load-bearing and energy-saving purposes.

Table 3. The physical properties of some building materials [31]

Materials	Density (kg/m ³)	Thermal conductivity (W/mK)	Compressive strength (MPa)
Concrete	1906	0.814	20
Granite	2643	1.73	120
Limestone	2483	1.16	35
Sandstone	2235	1.85	80
Marble	2603	2.77	50
Common brick	1602	0.692	16

The water absorption tests show that Ünye stone, Harşit granites, and Trabzon gray stone have less than 30% water absorption rates [32]. Therefore, they can be used in dry, saturated, and partially frost-affected environments. None of them are in danger of freezing at temperatures below 0° C. Figure 6 shows the time-dependent changes in the weight of the samples in the water absorption tests. Figure 7 shows the time-dependent changes in the weight of the samples during drying. Figure 8 shows the physical properties of the samples.

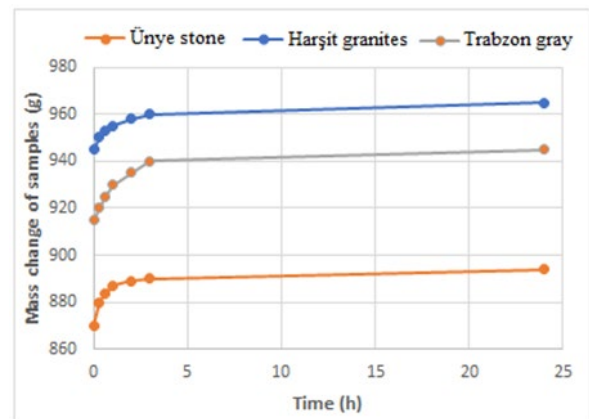


Figure 6. Time-dependent changes in the weight of the samples in the water absorption tests

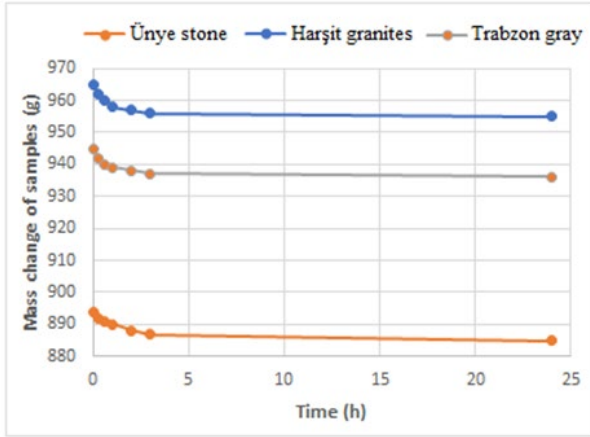


Figure 7. Time-dependent changes in the weight of the samples during drying

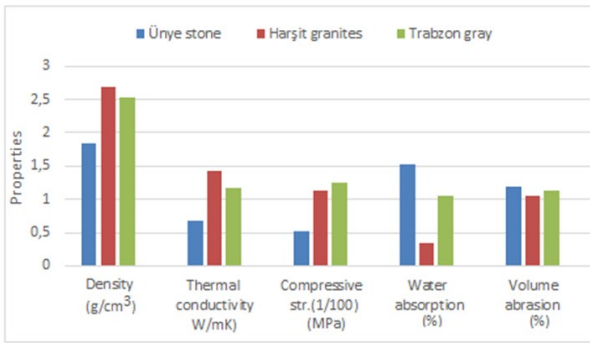


Figure 8. The physical properties of the samples

4. Conclusions

Ünye stone (Ordu), Harşit granites (Giresun), and Trabzon gray stone (Trabzon) are used as building materials in the Eastern Black Sea Region. This study experimentally determined their thermal and mechanical properties. The following findings were revealed:

- ✓ Ünye stone has a low thermal conductivity coefficient (0.67 W/mK). Therefore, if we use it as cladding (bricks, masonry, etc.) for the external walls of buildings, we can save energy and benefit from its advantages in terms of strength and comfort. Harşit granites and Trabzon gray stone have thermal properties that are not attractive in terms of the energy economy. On the other hand, Ünye stone is easy to process and can be found in different colors. Therefore, it is used for cladding purposes on exterior walls or as a decoration material.
- ✓ Harşit granites have compressive strength and abrasion ratio of 113 MPa and 1.05%, respectively. Trabzon gray stone has compressive stress and abrasion ratio of 125 MPa and 1.13%, respectively. Therefore, they can be used as wall cladding or wear-resistant floor covering materials.
- ✓ Ünye stone, Harşit granites, and Trabzon gray stone are cheap, abundant, and easy to process. Therefore, they can be used as building facades and floor coverings or for decorative purposes.

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