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SOME PHYSICAL PROPERTIES OF THE BUILDING STONES FROM SOUTHEASTERN ANATOLIA REGION

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Abstract

In this study, some of the physical properties of the Karacadag stone from Diyarbakir, Sanliurfa stone from Sanliurfa, Mardin and Midyat stones from Mardin and Hasankeyf stone from Batman which have been used extensively as a building material in Southeastern Anatolia Region were investigated. The stones having different features have been used as building materials in every places all over the region for ages. Heat and mechanical properties of these stones have not been searched yet. The aim of this work is to find out how suitable these rocks are as structural materials. For this aim, two specimens from different sources for each stone chosen from various places in Southeastern Anatolia Region, have been taken. After chemical analysis, the experiments for determining the heat conductivity and heat capacity, water absorption and mechanical strength were carried out. The results are compared with the other building materials especially in the aspects of energy saving, strength and natural comfort conditions.

Key words: Andesite tuff, building stones, building materials, physical materials

1. Introduction

Price increases in the construction materials due to energy costs, along with the demand growth in buying house, bear the potential to bring forward the use of natural stone as load-bearing and filling material depending on the geological structure of every region. Stones are mainly used as carriers, while rarely being used as filling materials. This study examines the physical properties of Karacadag (Diyarbakır) stone, Sanlıurfa stone, Mardin stone, Midyat stone and Hasankeyf (Batman) stone, as five sub regions in Southeast Anatolia Region. These Stones have been used as carrier construction element and filling materials in numerous buildings for many years within the regions, thus being recognized as respected construction material by the public. However, it is not certain whether the reason why this stone is respected, is due to being factually a solid material, or being easy-to-access.

The examined stones, except for Karacadag stone, are classified as organic sediment stone. Once the stones are taken out of the quarries, it is quite easy to cut, dress and process the stone due to the moisture in it. Additionally, its wood-like structure makes it easy to be cut with a saw, as well as for drilling with a driller, being dressed with hard objects, even being driven a nail. The moisture is disposed of the body in time, which leads the stones to become harder and gives resistance to the stones. Therefore, the stones were widely accepted as a construction material in the builds within the region thanks to these properties.

The number of studies on regional stones, carried out within the national borders, is quite limited. Some of these studies can be summarized as follows.

Devecioglu wrote up a master's thesis on heat transfer in porous stones (Devecioglu, 2001). Devecioglu et al carried out studies on certain physical characteristics of Diyarbakir Karacadag stone (Devicioglu, Bicer & Kavak, 2001). Bicer et al carried out researches on the physical characteristics of Mardin stone (Bicer, Yildiz & Pehlivan, 1996). Bicer et al also carried out researches on certain characteristics of the building Stones in Fırat Basin (Bicer, Tanyildizi, Pehlivan & Yildirim, 1993). In another study, Bicer et al carried out theoretical and practical studies on heat transfer in porous Stones (Biçer, Devecioglu A.G & Akpinar E.K. 2004).

In this work, Karacadag, Sanliurfa, Midyat, Mardin and Hasankeyf stones were studied to constitute a step to an analysis which could be extended to the construction elements of all the regions. These stones have whitish

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color in appearance, have been used for a long time as a main supporting construction element and have a great reputation among the people due to durability and ease of handling.

2. Materyal ve Metot

2.1. Materyal

Karacadag Stone: Classified as igneous extrusive rocks, this stone is basalt-type and black-colored. It has been used for buildings in the center and districts of the province Diyarbakır, and for construction of fortifications in the province. It is very challenging for this stone to be processed, having a hardness degree of 6-7 mohs

Sanlıurfa Stone: Classified as organic sediment stone, this is a light yellowish and whitish stone. It has been used for construction of masonries in particular within the region for many years. Having large amounts of reserves, these stones have a hardness degree of 3-4 mohs, thus being easily processed. After being taken out of the query, it can be easily formed and processed compared to other stone structures, unless the moisture in it is lost and it is not exposed to the chemical effects of the external environment. Thanks to this characteristic, stones can be cut with a saw like wood, as well as being drilled with a driller, dressed with hard-cutters and even pounded with nails. This appealing characteristic is the reason why this stone type is widely recognized as construction materials for Keferhuvvar villages and buildings built in these regions.

Midyat Stone: Great deal of Stones are present in the rich seams near Keferhuvvar village of Estel region in Midyat town of Mardin. The seams are 10 km far from Midyat and 6 km from Estel. Travvelling between region in Midyat and Estel is very easy. But the road between Estel and the seam is not surfaced. The stones are being used in the region extensively as building material. Their withdrawing are easy and water contentshigh.

Mardin Stone: The stone is drawn out Kabala region in Mardin. The seam is 2 km far from city center and near the road. It can be shaped easily without damage.Taşlar beyaz bazan sarımtırak renkte olup sertlik derecesı 3-4 in Mohs scale dır.

Hasankeyf Stone: The seam from which the stones were drawn is in the border of Kesmekopru.Hasankeyf town which is 35 km from Batman city and to the northwest 15 km far from this willage. It is named also as Kesmeköprü stone. It is composed mainly of sedimentary rocks and assumed rock from by deposition in their locations due to abrasion and entrainement. Cracks and brokes may present in it’s structure. It may deform with physical forces. Its hardness is about 3-4 in Mohs scale. The porosities may show slight changes depending on the seam and is about 5%.

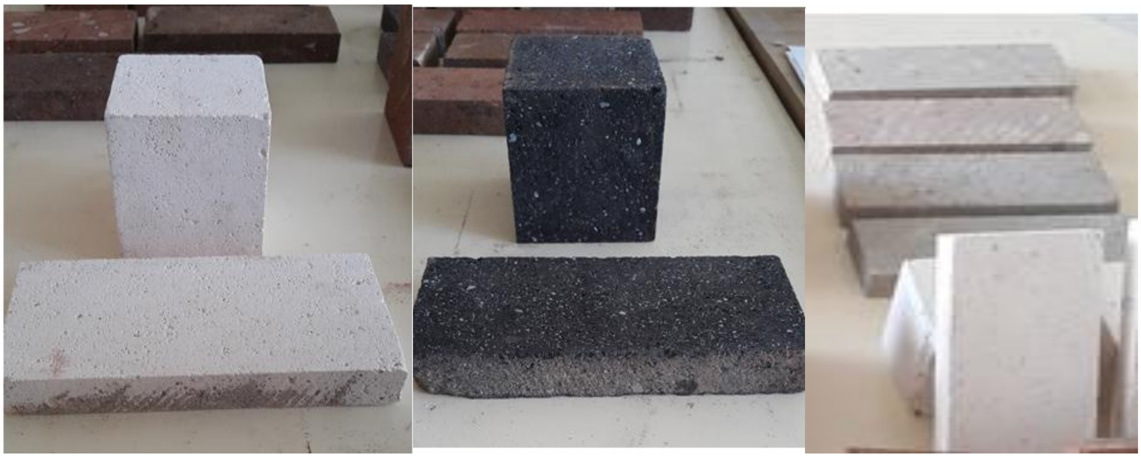
Last four stones are whitish yellow colored limestones. They can be easşly shaped with handtools and this is the main reason for their preference. The chemical compositions of these stones are given in Table 1.

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

Component Material	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss of ignition	Undefined
Karacadag stone	47.24	15.30	4.70	13.04	3.74	13.58	2.40
Sanlıurfa stone	1.00	0.15	0.10	53.48	1.02	43.63	1.52
Midyat stone	0.30	-	-	34.10	18.65	46.63	0.32
Mardin stone	0.18	-	-	30.00	22.58	47.09	0.15
Hasankeyf stone	73.99	13.40	1.50	-	3.75	5.21	2.15

2.2. Testing Metot

The samples of Stones were taken from the seams and a number of rectangular blocks (150x60x20 mm) for each sample were prepared to be used in the density, thermal conductivity, specific heat capacity and water absorption measurements. In addition, cubical blocks (71x71x71 mm) were also cut for mechanical strength and abrasion tests.



a) b) c)

Fig 2.1**.** Samples of stones a) Sanlıurfa, b) Karacadag c) Mardin and Midyat

The thermal conductivities and specific heats of specimens were detected by *Isomet 2104* portable heat transfer analyzer, which makes measurements by using the hot wire method according to Norm (DIN) 51046 (Fig 2). Measurements were made on different parts of the specimens five times and the averages of these measurements were used in the study. Measuring device detected thermal conductivity coefficient in the range between 0.04 W/mK and 6 W/mK with 5% precision and volumetric heat capacity in the range of 4.0×10^4 $J/m^3 K$ and 4.0×10^6 $J/m^3 K$ with 15% precision. The temperature was between 22°C and 25°C during measurement. Thermal diffusivity of specimens whose thermal conductivities, specific heats and densities were known was determined by calculating with the Eq. (1)

$$a = \frac{k}{\rho.C} \tag{1}$$

Fig 2.2. Isomet 2104 portable heat transfer analyzer

Compressive strength and tensile strength were applied on each sample block. Average values of at least three measurements were taken. Tensile strength values calculated according to the TS 500 standard by Eq. (2), (TS 500 and TS 699, 2000)

$$f_{ctk} = 0,35.\sqrt{fck} \tag{2}$$

The aim of water absorption test is to investigate the maximum amount of of observed water ratio in the samples. This property is important in determining the suitability of the material against freezing hazards. The critical amount of moisture is 30% of the total dry volume, below which the material does not deform on freezing (Bicer and Kar, 2017, 2017, and 2016). The experiments were performed according to the *BS 812. Part 2* standard by keeping the specimens in water for 24 hours. Water absorption values calculated by Eq. (3)

$$\text{Water absorption percent} = \frac{Wd - Wk}{Wk} \,.\, 100 \quad (3)$$

The purpose of drying ratio test is to search the respiration abilities of the samples. After being left in water contained for 48 hours the samples were taken from the water, wiped with a wet piece of cloth and left to natural drying at 22^{o}C room temperature. The drying ratio values are calculated by Eq. (4). Drying occurs through evaporation from the surface of the material; here it is about the movement of water from the depth of the material through capillary canals, meaning that moisture is expelled from the body through steam permeability resistance and drying occurs.

$$\text{Drying ratio} = \frac{Wd - Wk}{Wd} \,.\, 100 \quad (4)$$

3. Results and Discussions

The following results were obtained in this study, carried out for examining the physical properties of the stones which have been used for many years in Karacadag (Diyarbakır), Sanlıurfa, Mardin, Midyat, Hasankeyf that are located in Southeast Anatolia Region.

Thermal conductivity coefficients and thermal diffusivity values of Mardin Stone (0.58 W/mK and 4.05x 10^{-7} m^2/s) and Midyat stone (0.60 W/mK and 4.44x10^{-7} m^2/s) are lower than all the construction materials stated in Table 2. Midyat stone seems as a better materials with respect to the thermal diffusion coefficient than granite, marble and sand stone. The thermal diffusion coefficient of Mardin stone is similar to most of these materials except granite and sand stone. Wide-use of these stones instead of brick or briquettes in structures as separators will ensure energy saving and lower building costs. No significant characteristic was detected in Sanlıurfa stone, Karacadag stone and Hasankeyf stones compared to similar construction materials in terms of power saving.

The water absorption ratio of the samples is found to be lower than 30% which is the critical value. Hence, none of the stones pose a risk for being frozen under 0^{o}C, indicating that these stones can be used in humid environments. The time-based weight changes of the samples can be seen in Figure 4, which were obtained from the water absorption tests. On the other hand, it can be seen based on the results of drying test that the stones, except for Karacadag stone, bear the breathing-ability, even if just a hint (Fig 5).

Compressive strength (105 N/mm^2), tensile strength (9.0 N/mm^2) and abrasion loss (1.8%) of Karacadag stone were found to be higher than similar construction materials in this respect (Table 3). Despite having relatively lower values compared to high-strength natural building stones, the strength level of the stones that are examined in this study are equivalent to such construction materials like briquette and brick in this respect. However, they do not possess the required strength capacity in terms of abrasion strength. Therefore, the stones, except for Karacadag stone, should not be used as construction materials for parquet stairs, which are exposed to high-abrasion.

Density is the one of important factor affecting the thermal conductivity coefficients of the samples. Drying occurs through evaporation from the surface of the material; here it is about the movement of moisture from the depth of the material through capillary canals. For this reason micro-pores are formed in the structure of the stones during the drying process of the samples and the heat transfer coefficients values are reduced as the density values of samples are reduced.

Table 2. The physical properties of some building materials and natural stones (bicer 2004, Toksoy 1998].

Material	**Density (g/cm^3)**	**Thermal conductivity (W/mK)**	**Specific heat capacity C_p(J/kg°C)**	**Thermal diffusivity $a.10^{-7}(m^2/s)$**
Concrete	1906	0.814	879	4.91
Granite	2643	1.73-3.98	816	13.15
Limestone	2483	1.16	906	5.68
Common brick	837	0.692	837	5.16
Sandstone	2235	1.855	712	11.65
Marble	2603	277	808	3.94
Karacadag stone	**2890**	**1.610**	**1128**	**4.99**
Sanlıurfa stone	**2190**	**1.38**	**927**	**7.16**
Midyat stone	**1460**	**0.60**	**1013**	**4.05**
Mardin stone	**1350**	**0.58**	**968**	**4.44**
Hasankeyf stone	**2559**	**2.1**	**850**	**10.03**

It poses a massive advantage for all the stones, except for Karacadag stone, to be processed easily compared to a number of construction materials, as well as being drilled, cut, dressed, and used for electricity and water service channels, even allowing the use of nails and screws.

Table 3. Mechanical properties of stones

Material	**Compressive strength (N/mm^2)**	**Tensile strength (N/mm^2)**	**Water absorption (%)**	**Volume abrasion (%)**
Karacadag stone	105	9.00	0.31	1.80
Sanliurfa stone	24	3.10	12.50	120
Midyat stone	6.13	1.03	13.70	0.65
Mardin stone	4.91	0.77	18.64	0.64
Hasankeyf stone	42.47	6.20	1.86	0.24

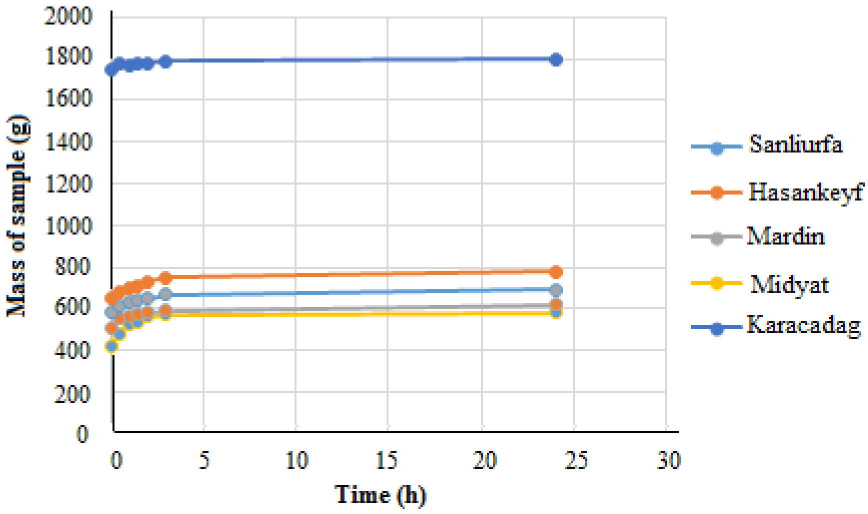


Fig 3.1. Mass change of samples in water the abrasion tests

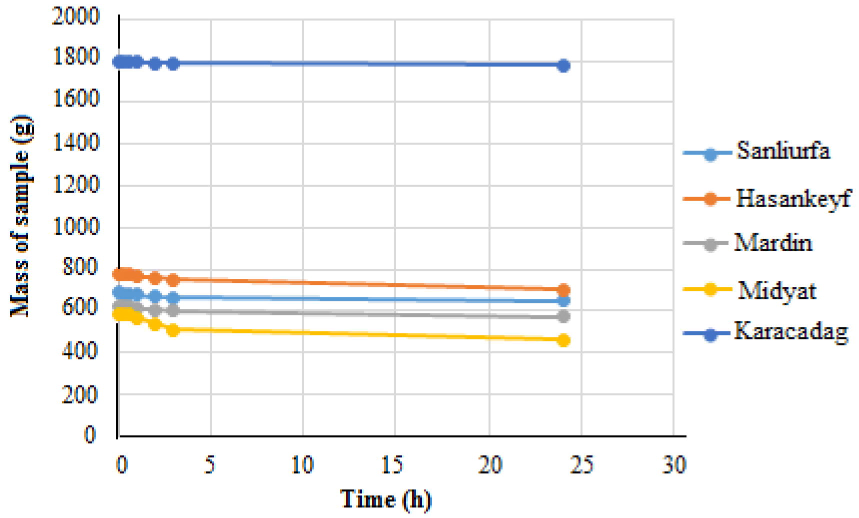


Fig 3.2. Mass change of samples in the drying test

Based on the stones in this study, Table 4 was drawn up for comparing the studies within the literature. There are two critical parameters in the table: thermal conductivity and compressive strength. It can be seen that these two parameters in this study are similar compared to those from other studies. The differences arise out of the location, where the stones are procured from, along with the measuring instrument and measurement errors.

Table 4. Physical properties of similar study

Materials	Thermal conductivity (W/mK)	Compressive strength (N/mm^2)	Literature
	1.77	120	(Devicioglu et al 2001)
Karacadag stone	1.63	110	(Bicer et al 1993)
	1.61	105	present
	1.4	26	(Bicer et al 1993)
Sanlıurfa stone	1.51	28	(Bicer et al 2004)
	1.38	24	present
	0.68	4.93	(Bicer et al 1996)
Mardin stone	0.80	4.99	(Bicer et al 2004)
	0.58	4.91	present

4. Conclusions

Based on the results of the researches and tests carried out on the stones that are recognized as respected construction materials and widely used by the locals in the region;

✓ It is a reason for preference with regards to these stones to be used instead of brick or briquette as load bearing elements in structures (i.e. buildings) due to having reserves in large amounts, being suitable to be used for many years, as well as being easy to procure, ensuring energy saving and lowering the costs.

✓ Mardin and Midyat stones are used as load bearing for thermal comfort, while Sanliurfa and Hasankeyf stones are being used as load bearing, and Karacadag stone is used as load bearing, and floor covering in the local buildings thanks to the thermal and mechanical properties of the stones.

✓ Water absorption ratios of the samples were under the critical value (30%). Such materials can be used without freezing risk at places having direct contact with water such as sidings.

✓ For having a characteristic to be processed easily, Mardin, Midyat and Hasankeyf stones can also be used for decorative purposes, as well.

Nomenclature
a : Thermal diffusivity, (m2/s)
r : Density, (g/cm3)
k : Thermal conductivity coefficient, (W/mK)
fck : Compressive strength, (MPa)
fctk : Tensile strength, (MPa)
Wk : Dry weight of sample, (g)
Wd : Wet weight of sample, (g)

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