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THERMAL AND MECHANICAL PROPERTIES OF BUILDING STONES IN AFYON AND KARAMAN REGION

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Abstract

In this study, some of the physical properties of the Seydiler and Sorkun stones from Afyon and Kızılören and Kazım Karabekir stones from Karaman which have been used extensively as a building material in cities and even in neighbor cities were investigated. Used as construction components, these stones are highly praised by the people living in those areas due to their ease of handling and convenient thermal characteristics. The aim is to determine the thermal and mechanical properties of these stones. Samples were taken from two different quarries for each stone and after chemical analysis, they were subjected to thermal conductivity, specific heat capacity, water absorption, inhalation ability and mechanical strength tests. The results were compared with other building materials, especially in terms of energy saving, strength and comfort aspects.

Key Words: Seydiler stone, Sorkun stone, Kızılören stone, Kazım Karabekir stone, building material.

1. Introduction

Carbon prices, price inflation of construction materials, along with demand development for accommodation, hold the ability to make the national stones a current problem as building material. Most of the stones are used as carriers, but rarely as filling material, for which Diyarbakir's Karacadag stone, Sanliurfa’s Kargasabunu stone and Bitlis's Ahlat stone may be used as examples for these Stones (Bicer, 2019a, 2019b, 2019c). Based on the economic implications, this study can be concluded because using stones within a certain distance from a quarry would be more effective relative to imported building materials like block brick, hollow brick, briquette and coating material.

Stones, as under examination as to whether they have the ability to be used as construction material, can be sliced quickly with a saw much like a wood until they are extracted from the quarry, at which time they maintain the moisture, along with being able to dig with a hammer, wrapped in rough objects and nailed (Pivko, 2003**),** (Kazancı & Gürbüz, 2014) and (Devecioglu, 2001). These features of the stones made them more common as building materials in buildings that are constructed throughout the area.

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.

Celik investigated on types and usage areas of the decorative natural building stones (Celik, 2003). 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 (Devecioglu et al., 2001). Adin (2007), carried out studies on certain physical characteristics of Mardin and Midyat Stones. Kaya et al. (2008),wrote up a master’s thesis on The usage of Midyat Stone as a covering and building material researching.

This research explores the thermal and mechanical properties of the stones Sorkun, Seydiler, Kazım Karabekir and Kızıloren. The stones have been used in the area for many years as a carried building element, and are hence known by citizens as a building element. If the use of these stones is common because of its being a durable material is not known, or it is simple to obtain. This research is intended to provide an insight into this matter.

2. Materials and Methods

2.1. Materials

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Sorkun Stone: The town of Sorkun in Afyon-Sandikli possesses large reserves in Çandır location. Access to the quarries is quite easy. It is used as a building material in construction in Sandıklı district and various villages. It is very easy to remove from the furnace, it has high humidity, low mechanical strength and easy to process. However, after the moisture is removed from the body, the mechanical strength values increase.

Seydiler Stone: It has large reserves in the vicinity of Seydiler village in Iscehisar district of Afyon province. It has the characteristics of Sorkun stone as it is extracted from the quarry and it is easy to extract from the quarry and shape the stone.

Kızıloren Stone: It is mined from the quarries located in the town of Kızıloren, 45 km from Konya, on the Beyşehir Highway in Konya. It is defined as heat insulated stone in the region. It is easy to remove and process the stone from the hearth. The quarries are very rich and the extracted stones are widely used in the construction of the region as well as in the facade cladding and the restoration of historical monuments. Kızıloren stone is widely used in Konya, Antalya, Alanya and its region, outside of Karaman provinces and districts.

Kazım Karabekir Stone: The quarries in the twenty-third kilometer of Karaman-Konya Highway have large reserves and it is accessed by scraping the soil on the field. Soil thickness is around 1 to 1.5 meters. The stones come out as 2 cm thick at the top of the quarry, 4 cm thick at the bottom, then 6 cm thick, and 10 cm thick at the bottom. Access to the quarries is very easy. This stone is used extensively in the building construction in the region and also has a beautiful appearance. During extraction from the quarry, the humidity is high and at the same time, the resistance values are low and it is easy to process. However, the values increase after the moisture is removed from the body.

The hardness of the stones examined is 3-4 mohs in hardness and it can be easily shaped and processed as long as it does not lose its moisture after being extracted from the quarry and is not exposed to the chemical effects of the external environment for a long time. In this case, the stones can be sawed like wood, drilled with a drill, carved with hard cutters and even nailed. These properties of the stones, are among the reasons that ensure their reputation as building materials in the buildings built in their region. Table 1 shows the results of the chemical analysis of the materials.

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

Material \ component	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loss of ignition	Undefined
Sorkun stone	1.19	-	-	51.15	2.94	43.25	1.47
Seydiler stone	0.75	0.15	0.15	49.79	4.91	43.47	0.87
Kızılören stone	69.90	14.02	1.00	9.38	-	5.27	0.43
Kazım K. stone	2.05	0.42	0.10	54.67	-	42.37	0.39

Samples of 150x60x20 mm in size for thermal tests and 100x100x100 mm for Compressive strength and abrasion tests were prepared from the stones taken from the quarries (Fig. 1).

Fig. 1. View of the stones and its using as coating material

2.2. Methods

2.2.1. Thermal Conductivity, Specific Heat Capacity and Thermal Diffusivity Tests

The calculation procedures were performed using the "*Isomet 2104 unit"* which was calibrated under a provisional system and worked using a hot-wire device (Fig. 2). Measuring as per DIN 510406, this tool was used to conduct measurements from 3 separate points on each sample at room temperatures of 22-25 °C and to determine the geometric mean of these 3 values. The thermal conductivity coefficient of the unit has a tolerance range of 5 percent between 0.02 and 6 W/mK. Volumetric specific heat capacity is calculated with a tolerance ratio of 15% between $4.0x10^4$ and $4.0x10^6$ J/m^3 K (Vysnıauskas & Zıkas, 1988). Measurement findings as displayed in Table 2.

Fig. 2. Isomet 2104 unit

2.2.2. Compressive Strength, Tensile Strength and Abrasion Tests

Endurance tests were carried out on the samples in accordance with TS 699 standard (TS 699, 1978). Compressive strength tests for the samples were carried out with Ele International branded device, bearing the following features: 3000 kN loading capacity; digital control panel; adjustable loading rate; applying uniaxial force. Compressive strength test results were translated into tensile strength with Eq. (1) according to TS (TS 500, 2000), (Ytong, 1985).

$$f_{ctk} = 0{,}35.\sqrt{fck} \quad (1)$$

Where, f_{ck}: compressive strength (N/mm^2) and f_{ctk}: tensile strength (N/mm^2).

Volume abrasion lost results for 88 rpm within the scope of frictional abrasion tests can be seen in Table 3.

2.2.3. Water Absorption and Drying Ratio Tests

The purpose of this test is to determine the location of a dry volume where the ice crystals inside will grow as the building materials freeze (Bicer, 2019a, 2019b, 2019c) in direct contact with water. This function guarantees protection against freezing of the content. Each sample was determined to have the dry weight (Wk). Then the water level within the water tank is slowly lifted, where the samples are placed, bringing water into the tank in a manner that allows the samples to be submerged. The time-based weight shift for the samples can be seen in Figure 3. Following 48 hours of holding the samples in the tub, they were withdrawn from the bath and cleaned, determining the tub-absorbed weight (Wd), while at the same time measuring the bath-absorption ratio with the Eq. 2.

$$\text{Percentage of water absorption} =\{[W_d - W_k]/ W_k \}x100 \quad (2)$$

2.2.4. Drying Ratio

The drying ratio test aims to evaluate the samples 'breathing ability (Bicer, 2019a, 2019b, 2019c). Keeped 48 hours in the water tank, the samples are drained from the bath and cleaned with a wet rag. Then, they are left at room temperature around 22^{o}C for natural drying. The drying ratios were determined in 48 hours using the Eq. 3. Since the drying process occurred through vaporization via the material surface, the flow of water from the bottom of the material to the surface was seen via capillary channels. In other words, drying is achieved by extracting the moisture from the inside by means of resistance to vapor permeability (Fig. 4).

$$\text{Drying ratio}=\{[W_d - W_k]/ W_d \}x100 \quad (3)$$

2.2.5. Density Test

Dry weights of the samples were taken with the weighing machine having a tolerance of 1%, while the density levels were calculated by identifying the sample volumes.

3. Results and Discussion

The results obtained from the experiments were compared with the table values of other building materials from various aspects. Considering the heat transfer in both continuous and time-dependent regime, Seydiler stone looks better than granite, marble and sand stone with its thermal conductivity coefficient of 0.52 W/mK and diffusion coefficient values 2.69x10^{-7} m^2/s (Table 4). Additionally, considering the pressure of 13.4 N/mm^2 and tensile strength of 2.1 N/mm^2, it has approximately equivalent strength with artificial materials such as briquettes, bricks, aerated concrete, although it is low compared to high-strength natural building blocks. It shows that 0.472 % abrasion loss can also be used as a structural element exposed to excessive wear such as stairs and parquet.

Sorkun stone is stronger than granite, sandstone, marble and calcareous with a thermal conductivity of 0.84 W/mK and comparable to concrete values, though its diffusion coefficient is lower than those of these materials. For compressive and tensile strength and wear values it displays exactly the same values as Seydiler stone. The fact that the water absorption rate is less than 30% indicates that the stones can be used in humid environments and if the drying speeds are examined, the stones have little breathing ability.

Kizilören stone looks better than granite, marble and sand stone with a thermal conductivity of 0.47 W/mK and a coefficient of distribution of 2.41x10^{-7} m^2/s. In addition to these, given the pressure of 10.82 N/mm^2 and the tensile strength of 1.15 N/mm^2, it is similar to artificial materials such as concrete, briquette, brick, aerated concrete, although it is low compared to high-strength building blocks. The 0.8 per cent loss of wear indicates that it can also be used as a structural element exposed to excessive wear, such as stairs and parquet flooring.

Although Kazım Karabekir stone is better than granite, sandstone, marble limestone with a thermal conductivity of 0.63 W/mK and close to concrete values, it is smaller than the values of these materials as its coefficient of diffusion. Compressive and tensile strength and volume abrasion values appear to be more durable than Kızılören stones. The fact that the water absorption rate is less than 30% suggests that the stones should be used in humid areas and that, if the drying speed is tested, the stones have no breathability**.**

Table 2. Thermal properties of materials

Materials	**Density (kg/m^3)**	**Thermal conductivity (W/mK)**	**Specific heat capacity Cp(J/kgK)**	**Thermal diffusivity a.10^{-7}(m^2/s)**
Sorkun stone	2550	0.84	1045	3.15
Seydiler stone	1920	0.52	1015	2.69
Kızılören stone	1340	0.47	1030	3.41
Kazım K. stone	2260	0.63	940	2.97

Table 3. Mechanical properties of materials

Materials	**Compressive strength (N/mm^2)**	**Tensile strength (N/mm^2)**	**Water absorption (%)**	**Volume abrasion (%)**
Sorkun stone	13.49	2.1	13.5	0.364
Seydiler stone	14.88	2.3	15.6	0.472
Kızılören stone	10.82	1.15	17.5	0.8
Kazım K. stone	31.4	4.15	14.8	0.2

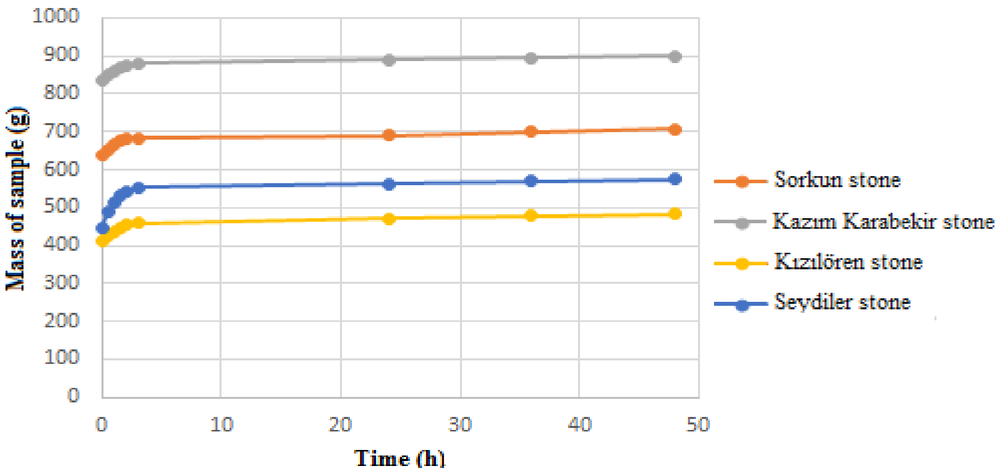

Fig. 3. Mass change of stones according to time in water absorption test

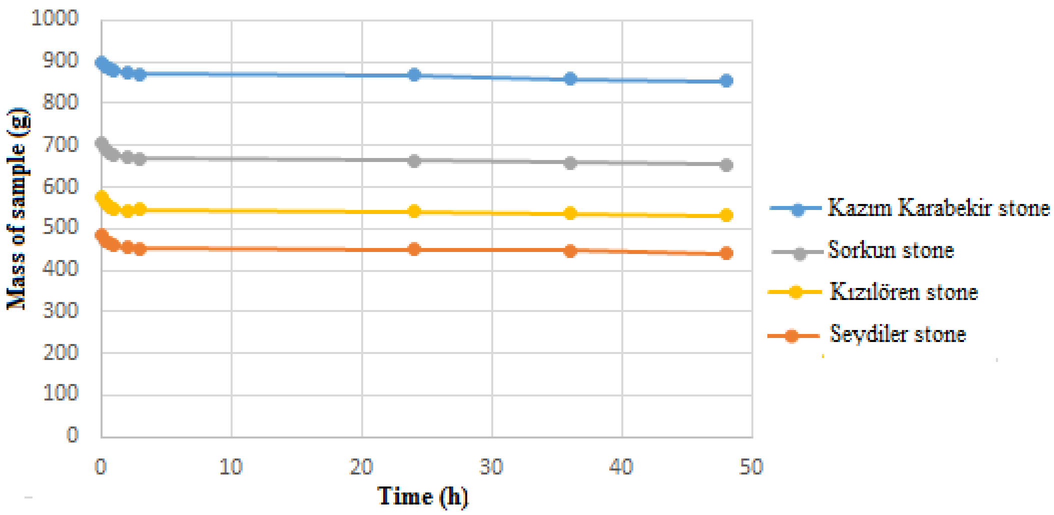

Fig. 4. Mass change of stones according to time in drying test

Table 4. The physical properties of some building materials (Toksoy 1988).

Materials	**Density (kg/m^3)**	**Thermal conductivity (W/mK)**	**Specific heat capacity Cp(J/kgK)**	**Thermal diffusivity $a.10^7(m^2/s)$**
Concrete	1906	0.814	879	4.91
Granite	2643	1.73	816	13.15
Limestone	2483	1.16	906	5.68
Sandstone	2235	1.85	712	11.65
Marble	2603	2.77	808	3.94
Common brick	1602	0.692	837	5.16

4. Conclusions

The thermal and mechanical properties of local stones used in the central and districts of the cities of Afyon and Karaman have been experimentally studied. The findings of these independent analyses are also listed in the tables.

✓ It is a reason for preference with regards to these stones to be used instead of brick or briquette 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.

✓ Seydiler and Kızıloren stones have low coefficients of heat transfer (0.52 W/mK and 0.47 W/mK), it is important to use bricks on the exterior walls of the building in terms of energy savings. In addition to these stone characteristics, it is a great benefit in terms of durability that it can be quickly handled relative to other building components, can be drilled, cut in order to open electrical and water construction channels to allow nails to screws to be used. These stones in order for using these stones in the aforementioned regions.

✓ All stones are used for thermal comfort, while Seydiler and Sorkun stones are being used as load bearing, and also Kazım Karabekir stone is used as coating material in the local buildings thanks to the thermal and mechanical properties of the stones.

✓ Having a water absorption ratio lower than 30%, which indicates that the stones can be used in humid environments, leastwise having the ability to breathe based on the review of drying rates.
The explanation for the choice is that the quarries have rich deposits and the expense is low due to the ease at which they are made available.

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