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INVESTIGATION OF PHYSICAL PROPERTIES OF BASALT STONES IN THE SOUTHEAST ANATOLIAN REGION OF TURKEY

ABSTRACT

In this study the physical properties of basalt stones, which were picked up from three different regions according to their spread fields in the Diyarbakır-Karacadağ, which is located in the Southeast Anatolian Region of Turkey, have been investigated. Density, water absorption and drying tests, durability of natural freezing effects, and compressive strength after freezing and freeze loss test with sodium sulfate have been carried out in order to determine the physical properties of the basalt stone specimens. As a result of this study, it has been determined that Diyarbakır Karacadağ Basalts are an important material for architecture constructions and can resist to external effects since the test results is not exceeding the limit given in TS 699.

Keywords: Basalt Stone, Physical Properties, Freeze Loss, Density Test, Water Absorption, Drying Test

TÜRKİYENİN GÜNEYDOĞU ANADOLU BÖLGESİNDEKİ BAZALT TAŞLARININ FİZİKSEL ÖZELLİKLERİNİN İNCELENMESİ

ÖZET

Bu çalışmada, Türkiye'nin Güneydoğu Anadolu Bölgesi'nde yer alan Diyarbakır Karacadağ yöresindeki, yayılım alanlarına göre farklılık gösteren üç bölgeden alınan bazalt taşlarının fiziksel özellikleri incelenmiştir. Bazalt taşı numunelerinin fiziksel özelliklerini belirlemek amacıyla yoğunluk tespiti deneyi, su emme ve kuruma deneyi, tabii don tesirlerine dayanıklılık ve don sonu basınç dayanımı deneyi ile sodyum sülfat don kaybı deneyleri yapılmıştır. Çalışmanın sonucu olarak, Diyarbakır-Karacadağ bazaltlarının mimari yapılar için önemli bir malzeme olduğu ve TS 699'da belirtilen sınırları aşmamış olması nedeniyle de dış etkilere karşı koyabilecek bir yapıya sahip olduğu belirlenmiştir.

Anahtar Kelimeler: Bazalt Taşı, Fiziksel Özellikler, Don Kaybı, Yoğunluk Deneyi, Su Emme, Kuruma Deneyi

1. INTRODUCTION (GİRİŞ)

Natural stones have been one of the most important structural materials in the humankind life since century ago. They have been preferred in the past and nowadays because of their unique properties such as their widespread and various kinds in nature, their workability by simple tools and methods, their high compressive strength etc.

Basalt is a stiff, durable, grey and black colored volcanic rock and it is commonly available in nature. Basalt rocks are commonly used as construction materials such as aggregate in concrete and asphalt, rock filling in dams and breakwaters, crushed gravel in railway ballast and airway foundation [1].

There are various studies about basalt reported in literatures. As a result of studies dealing with basalt, it has been concluded that basaltic aggregates increase the quality of concrete [2 and 3].

There are basalts in Turkey, particularly in the districts of Diyarbakır, Afyon and Thrace, with widespread and various properties.

The basalt from the volcanic Karacadağ Mountain has widely spread to three regions in the Diyarbakır. Basalts climbed down from Karacadağ volcano, forming Diyarbakır Karacadağ basalts, are widespread especially in three region of Diyarbakır. These basalt plateaus are widespread in a 120 km diameter of the wide region neighboring Diyarbakır-Şanlıurfa road in the west, Diyarbakır-Elazığ road in the north and Diyarbakır-Mardin road in the east.

There has been a limited investigation on geology, petrography, tectonic and basalt-marble properties of Diyarbakır Karacadağ basalts [4, 5, 6, 7, 8, 9, 10, 11 and 12] up to now.

2. RESEARCH SIGNIFICANCE (ÇALIŞMANIN ÖNEMİ)

In this study, physical properties of Diyarbakır Karacadag basalts are examined and it has been tried to determine its usage in the modern architectural areas.

3. MATERIAL AND METHOD (MATERYAL VE METOD)

Diyarbakır Karacadağ basalt, which is studied to determine its physical properties, is spread about 10 000 km^2 area in Diyarbakır and its surrounding area. Three different regions were selected for experimental study. These regions are given in Figure 1; the first region is west of Diyarbakır, Şanlıurfa route, the second region is north of Diyarbakır, Elazığ route, and the third region is east of Diyarbakır, Mardin route.

Basalt stones were provided as block specimen for the lab study from three different factories located in the regions which are shown in Figure 1. The cubic specimens to be used for the experimental studies are obtained from the block specimens by using a cutting machine with a diamond end. A water operated stone cutting blade with diamond has been used for preparing the cube samples. Experimental specimens were prepared according to TS 699 Standard. All specimens to be used for the experiments were kept in room conditions at 20°C±3°C and 40-60% RH for one week.

Density, water absorption and drying, durability at natural freeze-thaw effects and freeze loss test with sulphate tests have been conducted for the purpose of determining the physical properties of Diyarbakır- Karacadağ Basalts.

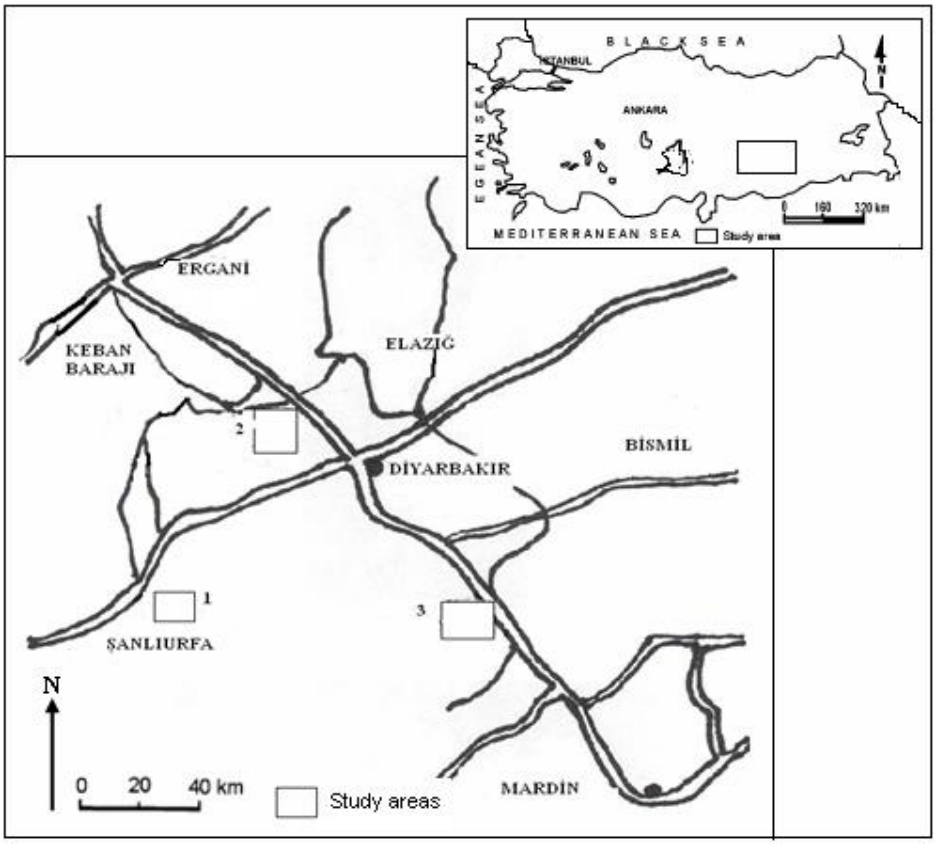

Figure 1. Location map of the three regions
(Şekil 1. Üç bölgenin yerleşim haritası)

3.1. Density Test (Yoğunluk Deneyi)

The density test was carried out in order to determine the mass density (including pores) and the unit weight of the basalt specimens. Basalt specimens were prepared in a cubic shape with 40x40x40 and 70x70x70 mm^3 dimensions and their dimensions were accurately measured by using an electronic caliper and their volumes were calculated. Then, the weight of basalt specimens was determined by using an electronic scale (± 0.01) and their density was calculated in gr/cm^3.

3.2. Water Absorption and Drying Test (Su Emme ve Kuruma Deneyi)

Water absorption and drying tests were performed for the purpose of determining the water absorption capacity and the water saturation ratio of basalt specimens according to their weights and volumes. Basalt specimens were prepared in a cubic shape with 40x40x40 mm^3 dimension which was mentioned in TS 699 Standard. Following the tests, mass water absorption ratio and volume water absorption ratio have been calculated by using equations 1 and 2, respectively.

$$S_k = \frac{G_d - G_k}{G_k} x100 \quad (1)$$

$$S_h = \frac{G_d - G_k}{G_d - G_{ds}} x100 \quad (2)$$

Where S_k is the mass water absorption ratio (m/m, %), S_h is the volume water absorption ratio (v/v, %) and G_d is the mass water absorption weight (gr), G_k is the mass dried until changeless state (gr) and G_{ds} is the saturated mass inside the water.

3.3. Freeze-Thaw Durability Test (Don Tesirlerine Dayanıklılık Deneyi)

These tests were carried out to learn the durability and the mass loss due to freeze effect of Diyarbakır Karacadağ basalt specimen. Basalt specimens were prepared in a cubic shape with 40x40x40 mm^3 dimensions and tests were done according to TS 699 Standard. The mass loss ratio occurred on the specimens following the freeze-thaw test was calculated by using the Equation 3.

$$D_k = \frac{G_0 - G_k}{G_0} x100 \quad (3)$$

Where, D_k is the percentage of freeze loss, G_0 is the sample weight before the test (gr), G_k is the of sample weight after the test (gr).

After determining the percentage of freeze loss of the specimens, uniaxial compressive strength was calculated and the strength loss was also calculated by using Equation 4.

$$\Delta f = \frac{f_b - f_{db}}{f_b} x100 \quad (4)$$

Where, Δf is the percentage of compressive strength loss (%) after the freeze-thaw test, f_b is compressive strength of the specimen which were not tested (MPa) and f_{db} is compressive strength of the specimen (MPa) after the freeze test.

3.4. Freeze Loss Test with Sodium Sulphate (Sodyum Sülfatla Don Kaybı Deneyi)

This test is accelerated method of the freeze-thaw test and made by using sodium sulphate and magnesium sulphate solutions. Crystallized sodium sulphate (Na_2SO_3) was used in this study.

The basalts were broken by using hammer or rock crusher and sieved with suitable size. Then they were separately put in a container and prepared for the test according to TS 699.

After the sodium sulphate freeze loss test, equation 5 was used for determining the freeze loss values according to TS 699.

$$K_d = \frac{G_0 - G_1}{G_0} x100 \quad (5)$$

Where, K_d is sodium sulphate freeze loss (%), G_0 is mass of the specimen before test (gr) and G_1 is mass of the test specimen that was the rest on the sieve (gr).

4. RESULTS AND DISCUSSION (SONUÇLAR VE TARTIŞMA)

4.1. Results of Density Test (Yoğunluk Tespiti Deney Sonuçları)

The test results obtained from the specimens which are approximately 70 and 40 mm cubic shaped are shown a table and in graphical form in Table 1 and Figure 2, respectively.

It was observed from Figure 2 that the specimens from Region II have the maximum density values but Region III have the minimum density values. The density values that are obtained with the study are good agreement with the literature [11].

Table 1. Density test values of the Diyarbakır-Karacadağ basalts
(Tablo 1. Diyarbakır Karacadağ bazaltlarının yoğunluk değerleri)

Regions	Specimens	Dimensions	Volume (cm^3)	Weight (gr)	Density (gr/cm^3)	Average Density (gr/cm^3)
Region I	1	71.3x72.4x70.9	365.99	1018	2.78	2.79
	2	71.0x71.1x70.3	354.88	990	2.78	
	3	70.8x70.4x70.4	350.89	985	2.80	
	4	39.1x41.4x39.7	64.26	167	2.59	2.66
	5	38.2x40.4x38.9	60.03	165	2.74	
	6	40.2x39.7x40.7	64.95	172	2.64	
Region II	1	72.3x71.7x69.2	358.72	1049	2.92	2.93
	2	72.4x71.9x68.1	354.49	1052	2.96	
	3	71.2x71.1x96.5	351.83	1025	2.91	
	4	40.5x42.3x39.1	67.15	189	2.81	2.91
	5	39.3x40.6x37.3	59.61	187	3.13	
	6	39.1x40.0x41.2	64.46	181	2.80	
Region III	1	69.4x69.1x73.8	353.91	857	2.42	2.47
	2	69.1x70.3x70.3	341.49	854	2.50	
	3	69.8x71x69.01	341.99	859	2.51	
	4	39.5x39.7x39.7	62.25	157	2.52	2.45
	5	39.4x40.0x42.6	67.18	159	2.36	
	6	40.0x39.6x41.2	65.26	162	2.48	

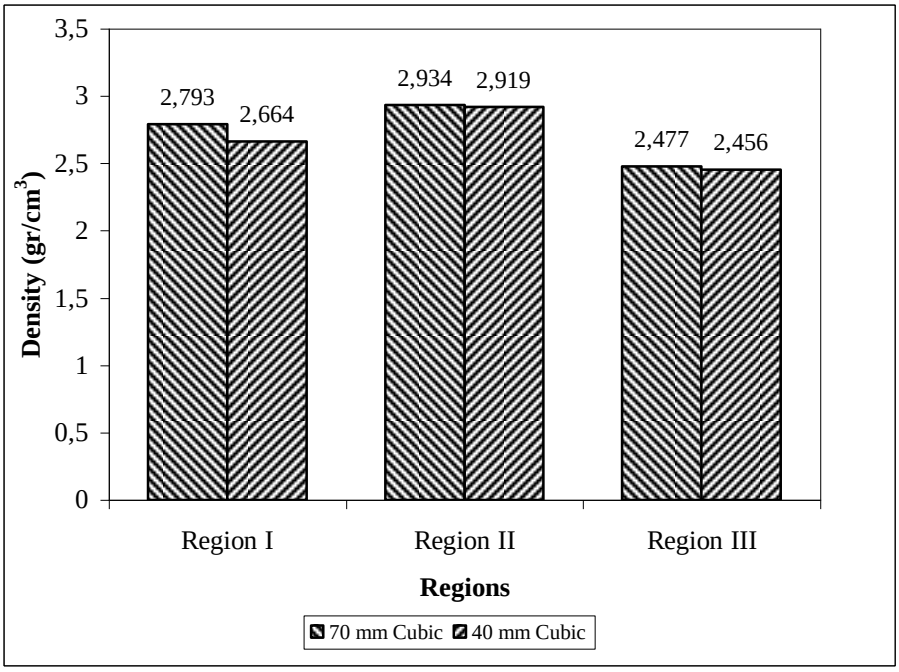

Figure 2. Density variations of the basalt stones
(Şekil 2. Basalt taşlarının yoğunluk değişimleri)

4.2. Results of Water Absorption and Drying Test (Su Emme ve Kuruma Deneyi Sonuçları)

The water absorption test of the specimens was repeated during 5 days. The water absorption ratios of the specimens obtained after the test are shown as a table and in graphical form Table 2 and Figure 3, respectively.

Table 2. Water absorption ratios of the basalt stones
(Tablo 2. Bazalt taşlarının su emme oranları)

Regions	Specimens	Saturated Weight of the Basalts (G_d), (gr)	Invariable Weight (G_k), (gr)	Saturated Weight into the Water (G_{ds}) (gr)	Water Absorption Raito, In Volume (S_h), (%)	Water Absorption Ratio, In Weight (S_k), (%)
Region I	1	170.62	169.26	106.62	2.1	0.8
	2	171.13	169.25	107.13	1.1	2.9
	3	165.86	164.53	101.86	0.8	2.0
Region II	1	195.93	195.20	131.93	0.3	1.1
	2	190.31	189.32	126.31	1.5	0.5
	3	193.02	192.09	129.02	1.4	0.4
Region III	1	163.88	161.19	99.88	4.2	1.6
	2	162.21	159.75	98.21	3.8	1.5
	3	163.52	160.05	99.52	5.4	2.1

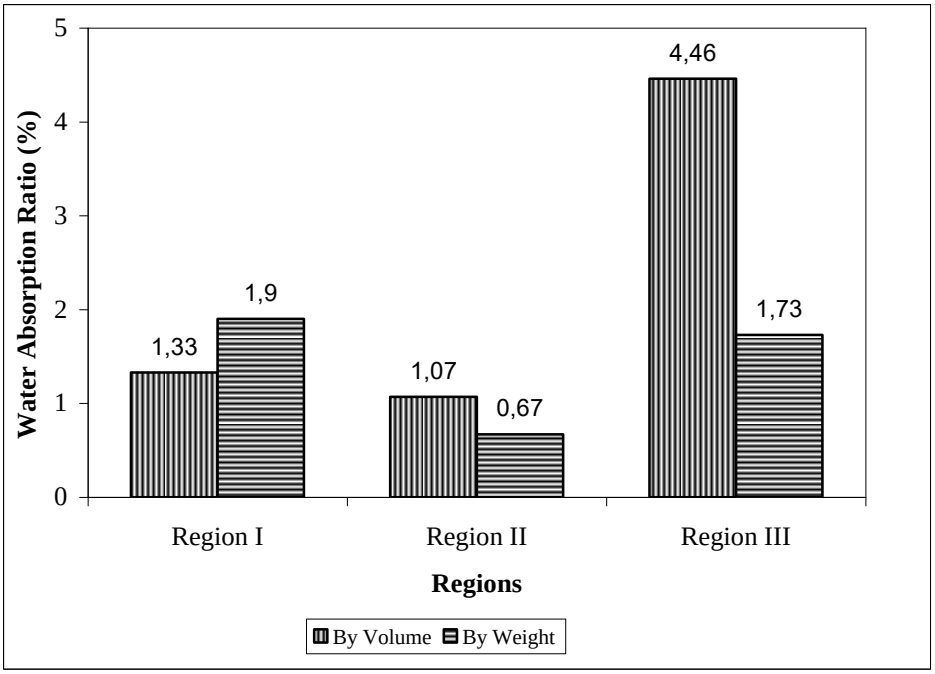

Figure 3. Water absorption ratios of the Basalt stones
(Şekil 3. Bazalt taşlarının su emme oranları)

According to the Figure 3, the maximum water absorption ratio (according to volume and weight) was obtained from Region III and the minimum water absorption ratio was obtained from Region II. These results are harmonious with the values of the density test in this study.

4.3. Result of Freeze-Thaw Durability Test
(Don Tesirlerine Dayanıklılık Deneyi Sonuçları)

After the freeze-thaw durability test, the mass loss values of 40x40x40 mm cubic shaped Diyarbakır Karacadağ Basalt which was obtained from different regions are demonstrated as a table and in graphical form in Table 3 and Figure 4, respectively.

Table 3. Mass loss values of the Basalt stones after freeze-thaw test
(Tablo 3. Don tesiri deneyi sonrası bazalt taşlarının kütle kaybı değerleri)

Regions	Specimens	Dimensions, (mm)	Dry Weight G_0 (gr)	Dry Weight after Experiment G_k, (gr)	Mass Loss (%)	Average Mass Loss (%)
Region I	1	39.1x41.4x39.7	169.26	168.63	0.372	0.325
	2	38.2x40.4x38.9	169.43	167.34	0.233	
	3	40.2x39.7x40.7	164.53	163.92	0.370	
Region II	1	39.5x39.7x39.7	195.20	194.93	0.138	0.154
	2	39.4x40.0x42.6	192.09	191.79	0.156	
	3	40.0x39.6x41.2	189.32	189.00	0.169	
Region III	1	40.5x42.3x39.1	161.19	160.00	0.738	0.798
	2	39.3x40.6x37.3	169.75	157.32	0.732	
	3	39.1x40.0x41.2	160.05	158.57	0.924	

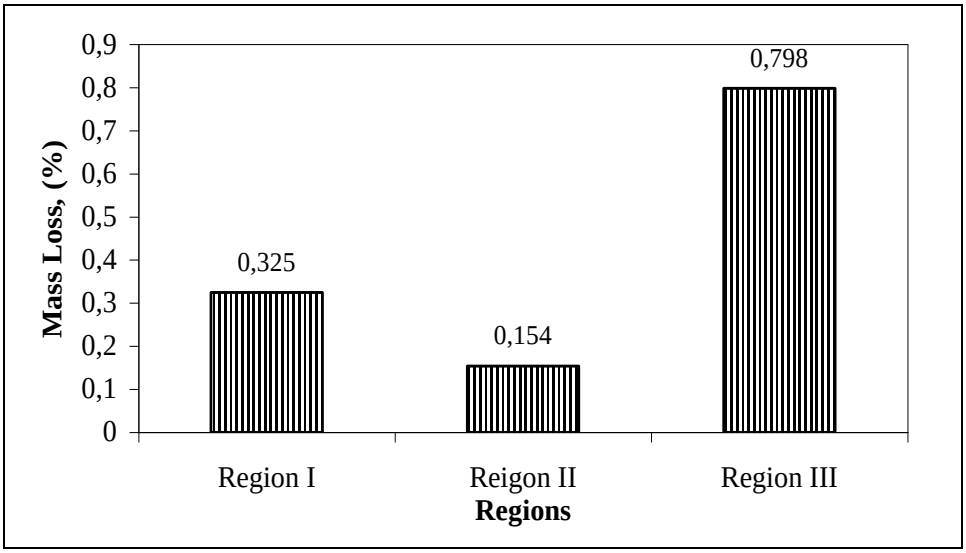

Figure 4. Mass loss variations of the specimens after freeze-thaw test
(Şekil 4. Don tesiri deneyi sonrası numunelerin kütle kaybı değişimleri)

The compressive strength loss values after this experiment are shown in Table 4 and Figure 5, respectively.

Table 4. Compressive strength loss values of the specimens after freeze thaw test
(Tablo 4. Don deneyi sonrası numunelerin basınç dayanımı kaybı değerleri)

Regions	Specimen	Dimensions, (mm)	Compressive Strength before Test f_b, (MPa)	Comp. Strength after Test f_{db} (MPa)	Comp. Strength Loss (%)	Average Comp. Strength Loss (%)
Region I	1	39.1x41.4x39.7	185.94	125.28	32.62	45.63
	2	38.2x40.4x38.9	204.75	98.70	51.80	
	3	40.2x39.7x40.7	203.01	96.49	52.47	
Region II	1	39.5x39.7x39.7	264.95	169.24	36.12	39.61
	2	39.4x40.0x42.6	324.64	206.15	46.24	
	3	40.0x39.6x41.2	287.14	154.35	33.39	
Region III	1	40.5x42.3x39.1	152.40	101.50	33.39	24.86
	2	39.3x40.6x37.3	109.32	104.41	4.49	
	3	39.1x40.0x41.2	171.96	108.85	36.70	

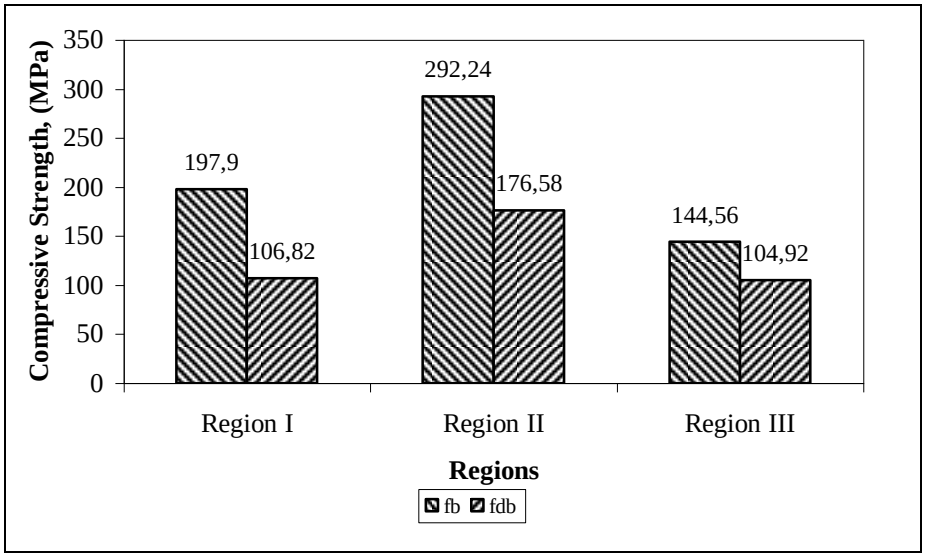

Figure 5. Compressive strength loss variations of the specimens after freeze-thaw test
(Şekil 5. Don deneyi sonrası numunelerin basınç dayanımı kaybı değişimleri)

After the freeze-thaw durability test, pores of the basalt samples were increased and became rusty due to the Fe_2O in the basalt. According to Figure 4, the minimum weight loss after the test appeared in the specimens of Region II and the maximum weight loss appeared in the specimens of Region III.

It was observed that the specimens were influenced from result of the freeze-thaw effect test. Although the weight loss values of the samples were low, the compressive strength of the specimens was significantly reduced after the test. According to the Figure 5, the maximum compressive strength values were obtained from Region II both before and after the freeze-thaw test. However the maximum compressive strength loss was obtained from the same region. Besides, the minimum compressive strength values belonged to Region III both before and after the test.

4.4. Results of Freeze Loss Test with Sodium Sulphate (Sodyum Sülfatla Don Kaybı Deneyi Sonuçları)

The sodium sulphate soundness test results of Diyarbakır-Karacadağ Basalts are shown in Table 5 and Figure 6, respectively.

Table 5. Freeze loss values of the specimens after sodium sulphate soundness test
(Tablo 5. Sodyum Sülfat dayanım deneyi sonrası numunelerin don kaybı değeleri)

Regions	Sieve Aperture Size	First Weight, (gr)	Last Weight, (gr)	Freeze Loss, (%)	Average Freeze Loss, (%)
Region I	3/4"-1/2"	500	460.89	7.8	10.3
	1/2"-3/8"	120	100.76	16	
	3/8"-4"	350	324.5	7.2	
Region II	3/4"-1/2"	600	564.81	5.87	9.61
	1/2"-3/8"	370	354.89	6.79	
	3/8"-4"	250	239.54	16.18	
Region III	3/4"-1/2"	440	434.6	1.2	13.45
	1/2"-3/8"	90	55.18	38.68	
	3/8"-4"	310	308.49	0.48	

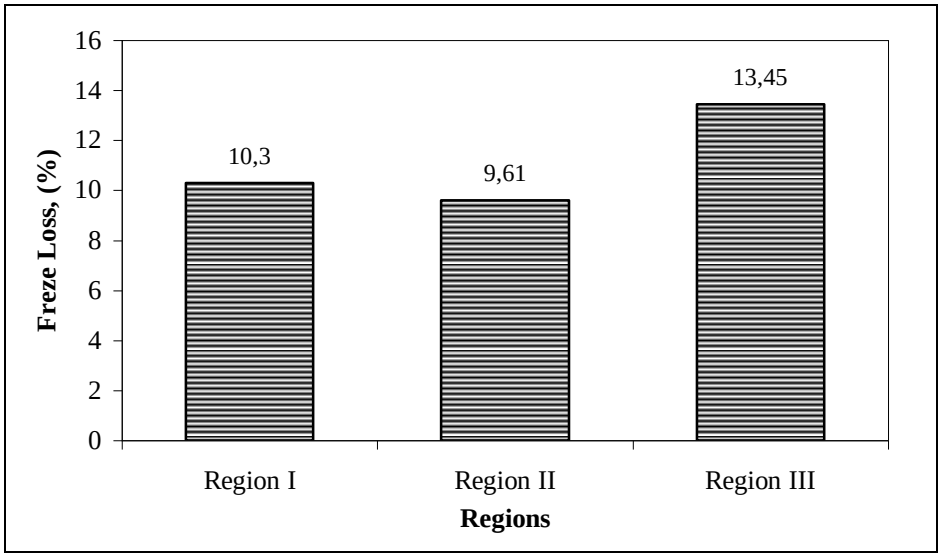

Figure 6. Freeze loss with sodium sulphate variations of the specimens
(Şekil 6. Numunelerin sodyum sülfat don kaybı değişimleri)

According to Figure 6, the maximum freeze loss was obtained from Region III and the minimum strength loss was obtained from Region II. Freeze loss values are in nature supporting the other tests values.

5. CONCLUSIONS (SONUÇLAR)

On the basis of experimental study that has been carried out and presented in this article, the following conclusions can be drawn.

- As the result of this investigation, it was observed that the density values of basalt specimens taken from three different regions varied between 2.45 and 2.93 gr/cm^3. The maximum density value was obtained from Region II and the minimum value was obtained from Region III.

- According to the water absorption and drying test results, the minimum water absorption capacity was obtained from Region II. This is related with density of specimens of Region II.
- The results of natural freezing effect tests indicated that the minimum weight loss occurred at the specimen taken from Region II while maximum weight loss occurred at the specimens taken from Region III. Besides, the maximum compressive strength values were obtained from specimens of Region II and the minimum compressive strength values were obtained from specimens of Region III. Both weight loss and compressive strength values of Diyarbakır Karacadağ Basalt stone were identical.
- Results of both freeze loss test with Na_2SO_3 and natural freeze effect test indicated that basalt specimens selected from Region II were minimally affected, but the specimens selected from III were highly affected. Freeze loss with sodium sulphate test results are under 15% which is the limit value for Southeast Anatolian Region.
- Test results of the freeze-thaw durability and Sodium sulphate freeze loss tests shown that basalt can be used in the constructions in which corruption associated with climatic conditions is avoided.
- All the experimental results obtained from three different regions of Diyarbakır Karacadağ Volcano presented similar features. After this experimental study, it was determined that physical properties of basalt specimens used in this study are closely identical. However, it was found that physical properties of the basalt specimens of Region II are more preeminent than the specimens from the other two regions.
- The results of the study indicated that Diyarbakır Karacadağ Basalt stone which is used in both traditional and modern architecture constructions of Diyarbakır Region can upgrade service life and quality of these constructions. Therefore, the studies can perform for purpose of generalizing of their application area with suitable technology. Thus, basalt stone will be used instead of most material in the future.

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