Journal of Structural Engineering & Applied Mechanics (2024) 7(1):51-57
DOI 10.31462/jseam.2024.01051057

RESEARCH ARTICLE

Usability of Trabzon stone as a natural building stone and aggregate

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Article History

Received 18 March 2024
Accepted 25 March 2024

Keywords

Aggregate
Crushed stone
Ballast
Geomechanics
Marble

Abstract

This study investigated the suitability of Trabzon stone, which is used as a building stone in many areas in and around Trabzon province, as an aggregate. It was found that the uniaxial compressive strength values of the samples taken from the quarry were 87-130 MPa, P-wave velocities were 5048-5642 m/s, density value was 2.58 g/cm^3, apparent porosity values were 2.77-4.54%, water absorption values by weight were 1.04-1.78% and water absorption value by mass was 2.0%. Weight loss in the freeze-thaw test was 0.36%, weight loss in the wet-dry test was 0.22%, loss in the magnesium sulfate test was 13%, Los Angeles fragmentation resistance in coarse aggregate was 22%, abrasion resistance value was 18% and methylene blue value was 0.9%. When the results were analyzed, it was found that the mass water absorption rate and the magnesium sulfate test results were above the values required by the standards. Although these rocks are used as marble, it has been determined that the waste material is not suitable for use as ballast, crushed stone, stone fill, pere, and masonry for road and concrete construction. Despite this result, it is necessary to investigate the usability of materials from other marble quarries in the region as aggregates.

1. Introduction

Almost every region of our country, which is very rich in natural stone reserves, has natural stones that can compete in the international market [1]. Similarly, the Eastern Black Sea region has a significant amount of natural stone reserves, mostly igneous rocks [2-3]. Although the unfavorable landforms in the region make it difficult to exploit these reserves economically, there are many quarries in operation [4]. The productivity of natural stone quarries in our country is less than 50%. This leads to the problem of storing millions of cubic meters of unusable material, which in the long run leads to environmental pollution. The use of the resulting rust as gravel, aggregate, or natural gravel in various industrial sectors provides significant economic and environmental benefits. It is therefore important to investigate the use of quarried natural stone in materials such as concrete and asphalt. Trabzon Stone, the subject of this study, is located approximately 10 km south of Trabzon city center. Due to its proximity to the city center and its high attractiveness, it has been used as a paving stone for pavements and roads in Trabzon [4]. In this study, the usability of the rust left over from the use of Trabzon stone as a concrete, asphalt, and fortification material was investigated.

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eISSN 2630-5763

2. Study area

Saraftepe quarry is located within the borders of Trabzon province (Fig. 1). The rock, which varies in thickness between 25 and 30 meters and outcrop for approximately 750 meters, is located in the form of a sill between limestone, marl, sandstone, and tuff layers with an N70E/25KB direction. This rock was defined as tephritis in the study conducted in [4].

The volcanic rocks found in the quarry located on the Trabzon-Erzurum highway and approximately 10 km south of Trabzon (NE, Turkey) have been used as road paving stones in many areas around the city from the past to the present.

There are significant natural stone reserves, especially granite, in the Eastern Black Sea Region. Most of the natural stone deposits in the region where Turkey's largest granite batholith is located consist of magmatic rocks. However, due to the reflection of the problem in the natural stone sector to the region, operating activities in 10 magmatic origin natural stone quarries operated in the region in the last 10 years have ended. Today, 80% of the natural stone deposits in the region are carbonate rocks and 20% are basic tuffs. There are still a few natural stone quarries in operation in the region.

3. Physical and mechanical properties of Trabzon stone

In this study, the usability of rust left from the operation of Trabzon Stone, which is used as paving and facing stone in Trabzon and neighboring provinces, as fortification, concrete, asphalt material, and also as building stone was investigated.

Index property determination, uniaxial compression, and longitudinal wave velocity tests were carried out to determine the usability of the investigated samples as building stones.

The Los Angeles fragmentation resistance, freeze-thaw (magnesium sulfate) test, abrasion (micro-deval) test, methylene blue test, apparent density, unit volume weight, and water absorption by mass were determined to investigate the usability of Trabzon Stone as concrete, asphalt, and fortification material.

3.1. Index properties

Block samples collected from the field were cut into cubes and their volumes were determined. Water content, water absorption by weight, apparent porosity, and unit volume weight tests were performed on the cube samples according to ISRM [5] standards. The test was carried out on 30 samples and the results are presented in Table 1.

Fig. 1. The general appearance of the used stone

Table 1. Index properties and longitudinal wave velocities of cubic samples [4]

	Water absorption rate by weight (%)	Apparent porosity (%)	Unit weight (kN/m^3)
Min.	0.62	1.93	27.90
Max.	2.33	6.80	30.90
Mean	1.23	3.68	29..66
SD.	0.47	1.34	0.80

Min: minimum value; Max: maximum value; Mean: average; SD: standard deviation

Table 2. Uniaxial compressive strength and longitudinal wave velocities of the samples [4]

	Uniaxial compressive strength (MPa)	P-wave velocity (Dry) (m/s)	P-wave velocity (Saturated) (m/s)
Min.	53	4065	4717
Max.	70	5435	5435
Mean	59.1	4850.6	5038.4
SD.	5.97	386.96	213.02

Min: minimum value; Max: maximum value; Mean: average; SD: standard deviation

Table 3. Los Angeles fragmentation test results of Trabzon Stone aggregates

Initial weight (g)	Final weight (g)	Loss (g)	Loss, LA35 (%)	Test standard	Initial weight (g)
5000.4	3903.8	1096.6	22	TS EN 1097-2	5000.4

Table 4. Abrasion resistance values of Trabzon Stone aggregates

Sample no	Amount of test sample (g)	Mass of fraction retained on 1.6 mm sieve (g)	Abrasion resistance value (wet test, %)	Test standard
1	500.3	409.1	18.2	
2	500.2	411.2	17.7	TS EN 1097-2
Mean	500.5	410.15	17.95	

3.2. Longitudinal wave velocity and uniaxial compressive strength

Longitudinal wave velocity experiments were measured on 10 standard core samples using a pulse transmission (direct measurement) technique [6]. The uniaxial compressive strength test was performed on cubic specimens. Both tests were performed according to ISRM [5] standards (Table 2).

3.3. Los Angeles fragmentation test

Aggregates to be used in highly stressed materials must have a high resistance to fragmentation. According to the TS EN 1097-2 standard [7], the Los Angeles Coefficient of Fragmentation (LA35) of the aggregate at 500 cycles should be 35% or less. Table 3 shows the results of the Los Angeles test carried out on samples of Trabzon stone.

3.4. Abrasion resistance test (Micro Deval)

The abrasion resistance test was performed on the coarse aggregates obtained from the samples in accordance with the TS EN 1097-2 standard [7]. According to the standard, the coefficient value of the aggregates to be used should be 25% or less. The results of the test are presented in Table 4.

Table 5. Magnesium sulfate (freeze-thaw) test results

Sample no	Initial weight (g)	Final weight (g)	Loss (g)	Loss (%)	Test standard
1	430.8	370.4	60.4	16	
2	420.5	380.1	40.4	10	TS EN 1367-2
Mean	425.65	375.25	50.4	13	

Table 6. Methylene blue value of Trabzon stone aggregates

Dry mass of test sample (g)	Total volume of added dye solution (mL)	Methylene blue value	Test standard
210	20	0.9	TS EN 933-9

Table 7. Grain density and water absorption by mass of the analyzed samples

Water absorption by mass (%)		Grain density (g/cm^3)			Test standard
Aggregate (Fortification)	Crushed stone (concrete)	Sample No.			
		1	2	3	TS EN 1097-6[10]
20	0.9	2.54	2.60	2.61	
		Mean: 2.58			

3.5. Magnesium sulfate test

The magnesium sulfate test was performed to determine the freeze-thaw resistance of aggregates taken from the rocks under study. The test is based on the principle of determining the behavior of the material after repeated immersion of the aggregates in magnesium sulfate and drying. The results of the test, conducted in accordance with the TS EN 1367-2 standard [8], are shown in Table 5.

3.6. Methylene blue test

It is a test to determine the amount of fine-grained material in aggregates. It was carried out in accordance with the TS EN 933-9 standard [9] to determine the usability of the material taken from Trabzon Stone as a concrete aggregate. The results of the test are shown in Table 6.

3.7. Grain density and water absorption test

Grain density and water absorption tests were carried out to investigate the usability of the Trabzon Stone samples as fortification material (Table 7).

4. Evaluation of laboratory test results

The results of the tests carried out on the samples taken from Trabzon Stone were compared with the values specified in the Highways Technical Specifications and the usability of the samples as asphalt, concrete, and reinforcement material was investigated (Tables 8-10).

It can be seen that the percent fragmentation, percent MgSO4, and percent abrasion resistance values of the analyzed samples comply with the Highways Technical Specifications [11], while the percent water absorption value is not in compliance with the specifications. The Los Angeles fragmentation percentage, MgSO4 mass loss percentage, abrasion resistance mass loss percentage, and saturated surface grain density values of the samples taken from Trabzon Stone comply with the specifications, while the water absorption percentage by weight value does not comply with the specifications. To determine the usability of the investigated samples as paving and building stone, the values of uniaxial compression, unit weight, water absorption by mass, and freeze loss were evaluated according to the TS 10835 [12] standard.

Table 8. Usability of samples as asphalt material [11]

Bituminous surfacing specifications test result		
Test name	Specification	Test result
Los Angeles Fragmentation, %	≤30	22%
$MgSO_4$ Freeze Test, %	≤18	13%
Abrasion Resistance (Micro Deval), loss %	≤25	18%
Water Absorption, %	≤2.5	3.4%

Table 9. Usability of samples as concrete material [11]

Physical and mechanical properties of coarse aggregate		
Test name	Specification	Test result
Los Angeles Fragmentation, %	≤35	22
$MgSO_4$ Freeze Test, %	≤18	13
Abrasion Resistance (Micro Deval), loss %	≤25	18
Water Absorption, %	≤3.0	3.4
Saturated Surface Grain Density (g/cm^3)	≥2.55	2.58

Table 10. Usability of samples as fortification material [11]

Test name	Stone backfill	Stone fortification	Pere	Masonry construction	Test result
Los Angeles Fragmentation, %	≤35	≤30	≤30	≤30	22
$MgSO_4$ Freeze Test, %	≤10	≤8	≤8	≤8	13
Abrasion Resistance (Micro Deval), loss %	-	≤20	≤20	-	18
Water Absorption, %	≤2	≤1.8	≤1.8	≤1.8	2.0
Saturated Surface Grain Density (g/cm^3)	≥2.2	≥2.4	≥2.3	≥2.3	2.58

According to the Highways Technical Specifications [11], the tested samples are not suitable for use as stone fill, stone fortification, pere, and masonry construction material. The samples are also not suitable for use as paving or building stone according to TS 10835 [12].

5. Conclusions and recommendations

The number of quarries has increased considerably in recent years to take advantage of this feature of our country, which has a very high natural potential for building stone. Although this situation is also valid in the Eastern Black Sea region, the unique physical characteristics of the region cause the efficiency of the quarries to be very low. To prevent visual and environmental pollution caused by the resulting rust, and at the same time to increase economic efficiency, it is important to investigate the use of unusable materials such as building stone, fortification, concrete, or asphalt material. In this context, index property determination, Los Angeles fragmentation, micro deval (abrasion), methylene blue, freeze-thaw (MgSO4), grain density, and water absorption tests were performed on the samples taken from the quarry located about 10 km south of Trabzon city center in accordance with the required standards specified in the technical specifications published by the General Directorate of Highways in 2013. In addition, uniaxial compression

and longitudinal wave velocity tests were performed to investigate the usability of the samples as paving and construction stone, and the results obtained were compared with the TS 10835 [12] standard.

While the fragmentation and abrasion percentages, freeze-thaw weight loss, fines content, and grain density of the samples collected from the study area were suitable for use as asphalt, concrete, and fortification materials, the water absorption values did not meet the specification conditions. According to the TS 10835 standard [12], the values other than unit volume weights of the samples show that they are not suitable for use as building or paving stones.

Conflict of interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

This research received no external funding.

Data availability statement

Data generated during the current study are available from the corresponding author upon reasonable request.

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