

Research Article

Determination of Mechanical Properties of Mountain Rocks in Piedmont Areas of Namangan Region

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Abstract

The article presents a detailed study of the physical and mechanical properties of natural mountain rocks that are commonly used by the local population as construction materials in the mountainous areas of Chartak District, located in the Namangan Region. The research was conducted to determine the suitability of these rock types for various construction and infrastructure purposes, especially in regions where natural resources are directly used from the surrounding environment. As part of the study, several critical parameters were analyzed through laboratory testing. The compressive strength of the examined rock samples was found to range between 66 and 78 MPa, which indicates a relatively high ability to withstand axial loads. This makes the rocks well-suited for use in load-bearing walls and foundations. In addition to compressive strength, the flexural strength of the rocks was assessed. The values ranged from 5.63 to 13.07 MPa, reflecting the materials' capacity to resist bending forces, which is crucial in structural components subject to stress and vibration. These values suggest that the rocks exhibit sufficient resistance to flexural deformation, which further supports their application in various building elements. Another significant aspect evaluated was the abrasion resistance, represented by the index I_1 , which ranged from 11.6% to 11.8%. This relatively low abrasion loss indicates that the rocks possess good wear resistance, making them particularly effective for use in areas exposed to friction and mechanical wear, such as pavements and road surfaces. Furthermore, when the obtained values were compared to relevant construction and materials standards, it was determined that these rocks meet the necessary requirements for use in the construction of highways, pedestrian walkways, and structures subjected to high loads. Their strength, durability, and resistance to external influences make them a viable option for sustainable and long-term use in civil engineering projects. Overall, the findings of this research provide valuable insight into the engineering characteristics of locally available rock materials and support their broader application in infrastructure development, especially in rural and mountainous regions where access to industrial materials may be limited.

Keywords

Mountain Rock, Flexural Strength, Compressive Strength, Abrasion, Construction, Abrasive Wear, Fraction, Crushed Stone

1. Introduction

Mountain rocks have been widely used as construction materials since ancient times. Due to their high strength, durability, and long service life, they remain significant in

modern infrastructure projects. However, the physical-mechanical properties of rocks can vary considerably depending on their mineralogical composition, structure, and

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formation conditions. Therefore, it is essential to accurately evaluate their compressive strength, flexural strength, and abrasion resistance before using them as construction materials.

In recent years, numerous scientific studies have been conducted on the mechanical properties of rocks. Fjaer et al. (2021), in their comprehensive work "Petroleum Related Rock Mechanics", examined various aspects of rock behavior under stress, including compressive and tensile strength, elastic deformation, and failure mechanisms. Their research provided valuable insights into how different rock types respond to mechanical loads in subsurface environments. [1]. According to his research, the average compressive strength of granite ranges between 150-300 MPa, while that of limestone is 30-100 MPa. Zhang and Liu investigated rock compressive resistance using electron microscopy, revealing that when rock porosity exceeds 5%, strength sharply decreases [2].

Gonzalez studied the flexural strength of metamorphic rocks such as marble and quartzite in accordance with GOST 8264-85, finding their flexural strength to be 10-20 MPa, which is lower than that of igneous rocks. Prikrýl's research examined the effect of moisture on rock flexural properties, confirming that under 95% relative humidity, flexural resistance decreases by 15-20% [3].

Kazi and Al-Mansour's studies demonstrated that rocks like basalt and diabase exhibit the highest abrasion resistance, with wear rates below 2%, while limestone is the weakest, with wear rates exceeding 10%. Aydin and Basu used the Micro-Deval method to analyze the influence of intergranular bonding strength on abrasion resistance. [4]

In recent years, the use of rocks as construction materials has expanded significantly. Their unique strength, decorative properties, cost-effectiveness, and environmental benefits have secured them a key role in modern construction. In the foothills of Namangan Region, local communities widely use mountain rocks for building foundations, pavement slabs, and decorative elements [5]. However, a comprehensive evaluation of material properties—including compressive strength, flexural strength, and abrasion resistance—remains a pressing issue in construction practice.

The primary objective of this study is to investigate three key indicators—compressive strength, flexural strength, and abrasion resistance—of mountain rocks extracted from the Chartak District of Namangan Region (an area where local populations actively quarry these rocks). Based on the findings, the study aims to determine their optimal applications in construction.

2. Experimental Procedures

Compressive strength,

$$\sigma_c = \frac{F}{A}; \quad (1)$$

Here, F - maximum load at failure (N), A - is the surface area of the sample ($a \times b, mm^2$).

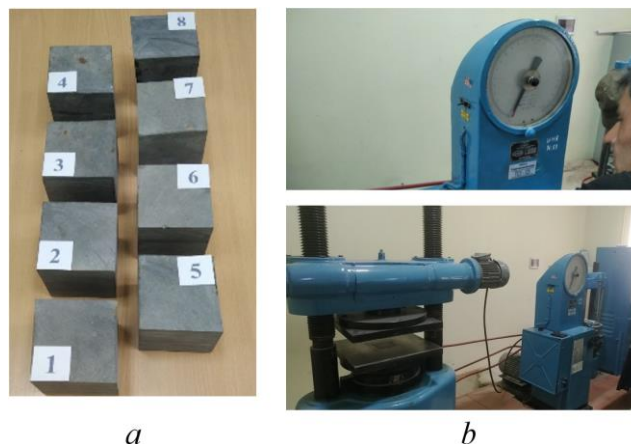


Figure 1. Samples (a) and compression testing process (b).

When determining the compressive strength of natural stones, their operational efficiency in various conditions and environments is studied. Primarily, the advantages of using stones for walls and foundation parts in residential construction are established. Therefore, this research was conducted extensively under laboratory conditions. Figure 2 Samples taken from Quarry 1 and Quarry 2 to determine the bending strength of natural stones.

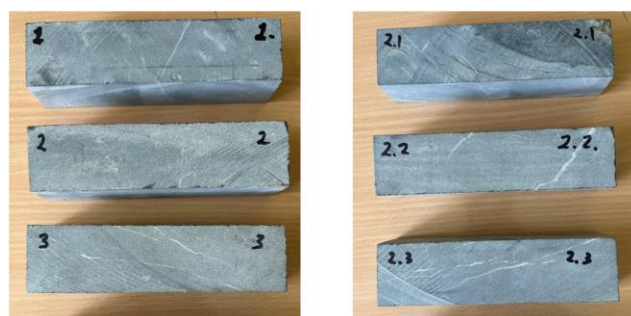


Figure 2. Test specimens for bending.

The flexural strength of the investigated rock samples was determined in accordance with GOST 8462-85 and GOST 32730-2014 standards. The flexural test was carried out using the three-point bending method. A total of six rectangular prism-shaped samples with dimensions of $40 \times 40 \times 160$ mm ($a \times b \times h$) were prepared in accordance with GOST 8269.0 The flexural strength was calculated using the following formula:

$$\sigma_{eg} = \frac{3F_{max}l}{2bh^2} \quad (2)$$

here, F_{max} is the maximum bending force at the moment of fracture (in N), l is the span between supports (in mm), b is

the width of the specimen (in mm), h is the thickness of the specimen (in mm).

The abrasion resistance test was conducted according to GOST 8269.097 (section 4.4.10). Although structurally similar to the Los Angeles test, this method determines the crushing outcome of stones through a 1.25 mm sieve. The proportion (%) of crushed fraction passing the sieve is evaluated as the abrasion coefficient. Basalt and granite samples from Chortoq district, Namangan region, showed abrasion coefficients below 25%, qualifying them as high-quality materials suitable for road construction. This methodology aligns with the construction standards of the Republic of Uzbekistan and is consistent with international practice.



Figure 3. Determination of abrasion resistance (wear coefficient) of rock samples.

The abrasion coefficient was calculated using the following formula:

$$H_{1,2,3} = \frac{m_1}{m_0} \times 100\%, \quad (3)$$

3. Materials and Methods

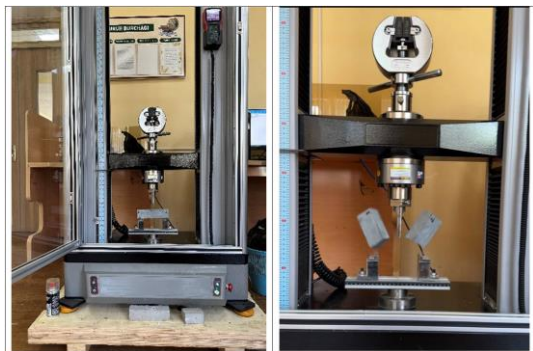


Figure 4. Bending test process.

The flexural strength of the investigated rock samples was determined in accordance with GOST 8462-85 and GOST 32730-2014 standards. The flexural test was carried out using the three-point bending method. A total of six rectangular prism-shaped samples with dimensions of 40×40×160 mm ($a \times b \times h$) were prepared in accordance with GOST 8269.0 (see Figure 2). The samples were collected from quarries located at a distance of 500 meters from each other. The span between the supports was set to $l = 2.5a$, which corresponds to $l = 100$ mm. A bending load was applied gradually to the center of the sample (Figure 2). When the applied bending force reached its maximum value, denoted as F_{max} , the rock sample fractured. [2].

Resistance to Abrasion Wear. The testing procedure involved 5000 grams of crushed stone within the 10-20 mm fraction, placed together with 11 steel balls weighing 400-500 grams in total, inside a rotating drum operating at 30-33 rotations per minute. The drum was rotated 500 times. After rotation, the sample was sieved through a 1.25 mm mesh, and the mass of fine particles passing through the sieve was weighed. [3, 4].

4. Results

Figure 1. To determine the compressive strength of natural rock samples, uniaxial compression tests were conducted on eight specimens extracted from varying depths. For each specimen, the following physical and mechanical parameters were recorded: sample dimensions (a, b, c), loading area (A), failure load (F), and compressive strength.

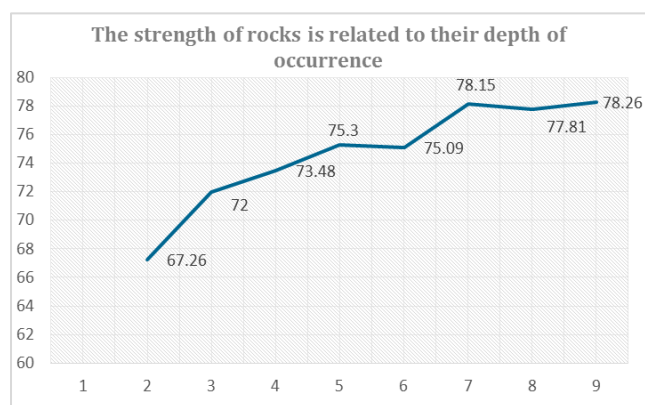


Figure 5. Dependence of rock compressive strength on sampling depth.

Figure 5. The results indicate a general increase in compressive strength with increasing extraction depth. Specifically, the compressive strength of the first sample taken from a depth of 2 meters was 67.26 MPa, while the eighth sample, extracted from 16 meters, exhibited a compressive strength of 78.26 MPa. This represents an increase of approximately 16.35% in strength with depth. The compressive strength

values for each sample are as follows [15]:

Table 1. These results clearly show that the compressive strength of the rock tends to increase with depth. This trend

may be attributed to higher rock density and improved crystalline structure in the deeper strata of the formation.

Table 1. Variation of Rock Compressive Strength with Depth.

Sample Number	Extraction Depth, h, m	Sample Dimensions			Loading Area, $A, (mm^2)$	Failure Load, F, N	Compressive Strength, $\sigma_c MPa$
		a, mm	b, mm	c, mm			
1	2	100,3	99,8	99,5	10109,74	680000	67,26
2	4	99,8	100,2	100,2	9999,96	720000	72,0
3	6	100,5	100,2	99,4	10070,1	740000	73,48
4	8	99,8	99,8	100,2	9960,04	750000	75,3
5	10	100,6	100,2	99,4	10080,12	757000	75,09
6	12	100	99,8	100,4	9980	780000	78,15
7	14	100,4	99,6	100,8	10049,64	782000	77,81
8	16	99,8	100,5	100,3	10029,9	785000	78,26

Figure 5. Overall, the data demonstrate the mechanical stability of the rock samples under uniaxial compressive loads and highlight the influence of depth on strength parameters. These findings provide important insights for evaluating the load-bearing capacity of geological formations and have significant implications for geotechnical and structural applications [13, 14].

Figure 6. Figure 7. Table 2. The test results indicate a clear decreasing trend in flexural strength with increasing depth. The highest bending strength, 13.07 MPa, was observed in Sample 1 taken from 5 meters depth at Site 1. In contrast, the lowest value, 5.63 MPa, was recorded for Sample 6 extracted from 15 meters at Site 3. This represents a reduction in strength by a factor of approximately 2.3.

The bending strength values for the samples are as follows:

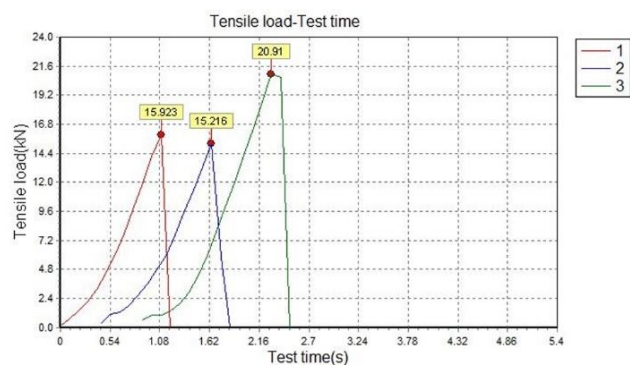


Figure 6. Bending strength result, quarry 1.

To assess the flexural strength of natural rock samples, a three-point bending test was conducted on six specimens extracted from various locations and depths. For each sample, the maximum applied force (F_{max}) and bending strength [5, 6]. (1)

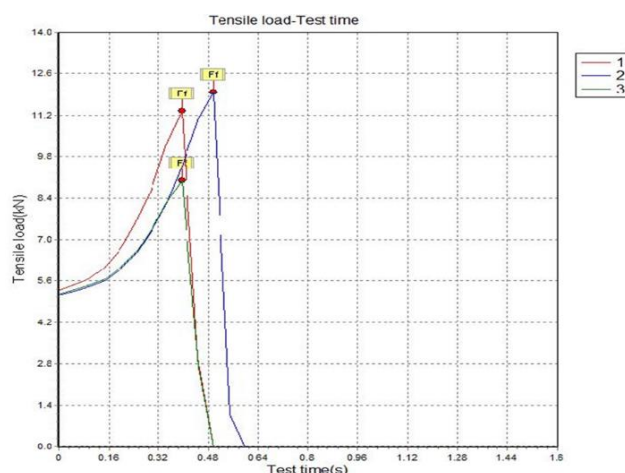


Figure 7. Bending strength result, quarry 2.

Table 2. The bending strength values.

Sample Number	Excavation site/Depth (m)	Max Force, F_{max} (N)	Bending Strength, σ_{eg} (MPa)
1	1/5	20910,0	13,07
2	1/10	15216	9.95
3	1/15	15923	9.51
4	2/5	11970	7.48
5	2/10	11358	7.10
6	3/15	9001	5.63

These results suggest that although rock hardness generally increases with depth, its resistance to bending tends to decline. This trend may be attributed to increased internal microcracking, structural discontinuities, or changes in mineral composition at greater depths. [7, 8]

Such findings are essential for evaluating the flexural behavior, fracture susceptibility, and structural integrity of rock

formations in geotechnical and engineering applications.

To evaluate the abrasion resistance of natural rock samples, laboratory tests were conducted to determine the wear index (I) under frictional forces [9, 10]. Based on the standard classification, abrasion quality is categorized as follows. Table 3.

According to the results:

Table 3. abrasion quality.

Experience sample	High quality	Average quality I1 ≤ 25%	Past quality I2=25-35%	Low quality I3 > 35%
1		11,6	-	-
2		11.4	-	-

As both samples fall below the 25% threshold, they are classified as high-quality rocks with excellent resistance to abrasion.

These results indicate that the tested rock materials possess high durability, low susceptibility to wear, and long-term performance potential. Such characteristics make them highly suitable for use in construction applications exposed to constant frictional forces, including pavements, road surfaces, and structural stonework. [11, 12]

5. Conclusions

Based on the conducted research, it can be concluded that the compressive strength of rock increases with greater depth. At a depth of 2 m, the destructive stress was 67.26 MPa, while at 16 m, it reached 78.26 MPa. Additionally, the difference in rock strength was 4.74 MPa in the 2-4 m depth range but only 0.45 MPa in the 14-16 m range, indicating a decrease in the variability of compressive resistance with depth.

The study results also revealed that flexural strength decreases with increasing excavation depth. Samples from

upper layers (1/5 - σ_{bend} = 13.07 MPa) exhibited higher flexural strength compared to those from deeper layers (2/15 - σ_{bend} = 5.63 MPa). This confirms that the physico-mechanical properties of rocks vary with depth, and near-surface layers are mechanically more stable.

Furthermore, the average weathering resistance index (I1) of the studied rock samples was 11.5%, demonstrating high weathering resistance in the region's rocks.

Abbreviations

F_{max}	The Maximum Bending Force at the Moment of Fracture (in N)
L	The Span Between Supports (in mm)
B	The Width of the Specimen (in mm)
H	The Thickness of the Specimen (in mm)

Author Contributions

Mamahonov Azam: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Methodology, Project

administration, Software, Validation, Visualization

Sultanov Davronbek: Investigation, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography



Mamahonov Azam is a distinguished Doctor of Technical Sciences and a renowned scholar specializing in machine components. His numerous scientific articles and textbooks are considered fundamental references in the field. The professor's profound knowledge and expertise have earned him recognition both nationally and internationally. Currently serving as a professor at Namangan State Technical University, he dedicates himself to sharing his valuable knowledge and experience with future engineers. Throughout his illustrious career, Professor Mamahonov has mentored many students, contributing significantly to their professional success. His unwavering commitment to scientific research, education, and the advancement of mechanical engineering has established him as a leading expert, leaving a lasting impact on both academia and industry..



Sultanov Davronbek is a PhD candidate currently conducting doctoral research. He completed his Bachelor's degree at Namangan Engineering-Construction Institute in 2021 and earned his Master's degree in "Ground Vehicles and Systems" (by mode of transport) from the same institution in 2023. In recent years, he has actively participated in several international research collaboration projects.

Research Field

Mamahonov Azam: His research interests include the Theory of Machines and Mechanisms, Mechanical Engineering, the application of elastic elements in gear transmissions, dynamics and kinematics of technological machines, vibration analysis in gear systems, and improving the reliability and efficiency of machine components.

Sultanov Davronbek: His research focuses on the physico-mechanical properties of natural rock materials, determination of their strength and priority indicators, rock mechanics and geological analysis, the spatial distribution of rock formations, as well as their role and significance in construction, and comprehensive study of their physico-mechanical characteristics.