Physical and mechanical properties of the south Mashhad's granites, Robat Torogh's area (North East of Iran)

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***Abstract*— Recognition of intact rock's engineering characteristics in construction projects that are dealing with the foundation rock, is quite important and in the primary stages of implementing engineering structures will be seriously considered. In this research, to study the engineering properties of granitic rocks in south of Mashhad City (North East of Iran), three boreholes were drilled to a depth of 10 m in the rock mass and the rock samples were transported to the laboratory. To determine the physical and mechanical properties of these rocks experimental tests such as uniaxial compressive test, triaxial, direct shear, dry and saturated density, porosity and water absorption were performed on the core specimens. Also, joint's roughness coefficient was estimated by the method of Barton. The results can be used for calculation of bearing capacity of rock mass and also in optimal designing of the construction of high-rise structures.**

***Index Terms*— Granite, physical and mechanical properties, Mashhad, engineering structure**

I. INTRODUCTION

Identification and assessment of rock mass engineering properties is significantly important in civil projects [1]-[4]. According to the extension and abundance of granitic masses in Iran country, variations in their geotechnical features and the connection between this sort of rock and many great civil projects, study about engineering properties of granites can play an important role for designing of the optimizers. Recently many studies have been performed about engineering properties of rocks which lead to offering different equations about physical and mechanical characteristics of rock masses in different geological formations[5], [6].

Due to the daily increment of constructing of high-rise structures in south regions of Mashhad city and also the necessity of having the knowledge of geotechnical properties of granitic outcrop of that region in order to designing stable foundations, this research was performed. In this research, 3 boreholes with final depth of 10 m which was near historical city of Robat Toroq were drilled. Some tests such as uniaxial and triaxial compressive strength, direct shear, dry and saturated density, porosity and water absorption were performed on the core specimens. Also, roughness coefficient of the joints by Barton [7] method was determined.

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II. GEOGRAPHICAL LOCATION OF STUDIED REGION

Fig. 1 shows the geographical location of mentioned region and the location of excavated boreholes. Studied region is located on south part of Mashhad and near the historical monument of Robat Toroq

Mashhad city located in north of Khorasan Razavi. Mashhad's plain situated within longitude of $58^0, 20'$ to $60^0, 8'$ eastern and latitude of $35^0, 40'$ to $36^0, 3'$ northern in northeast of Iran. It is surrounded by Ridge of Hezar Masjed Mountains from north and Ridge of Binalood Mountains from south. Geologically, the studied region is a part of granitoid band which outcrop along the North West - South East.

The recent surveys demonstrated that the granite, pegmatite and metamorphic in south regions of Mashhad might have continental origin and they may be the outcome of the two continental crust collision [8]. Leucogranite allocate the major parts of granitic set of studied area which are disconnected by the numerous pegmatite and aplite veins. The bright color of granites of that area shows the increment of the amount of bright minerals such as quartz and feldspar

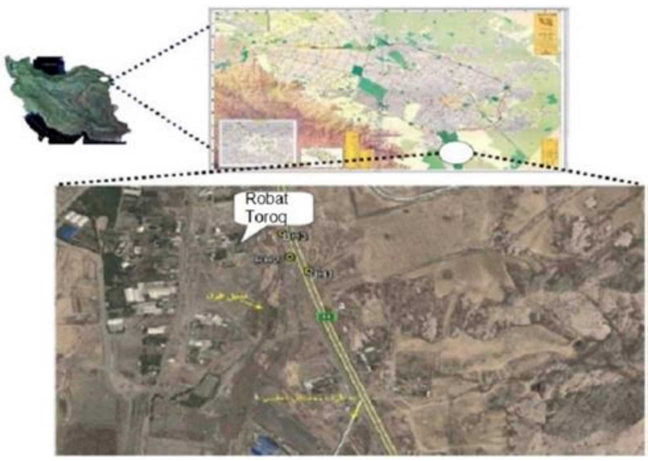

Fig.1 Geographical location of studied region and the excavation points of boreholes.

III. MATERIAL AND METHODS

In order to implement this research, after drilling three boreholes, the rotary drilling and sampling was performed. The depth of mummified rocky samples are presented in table 1. Also, general specifications of boreholes is presented in table 2.

Table 1 Depth of mummified samples

Borehole	Depth of sample		
BH1	8 – 8.52	6.47 – 6.85	3 – 3.42
BH2	8.38 – 9	6.42 – 6.9	4 – 4.63
BH3	-	6 – 6.7	4 – 4.5

Table 2 General specifications of exploratory boreholes

Borehole	UTM Coordination X	UTM Coordination Y	Depth (m)	Range of borehole level to the Toroq's stream (m)	Depth of pouring soil (m)	Depth of debris and weathered materials (m)	Depth of intact rock (m)
BH1	735960	4008037	10	+4	-	2	2
BH 2	735919	4008091	10	+4	0.72	-	0.72
BH 3	735908	4008174	10	+5	0.84	-	0.84

After transferring the samples to the laboratory, the physical experiments such as determination of dry density, saturated density, percentage of water absorption and porosity based on the ISRM standard [9] was performed on 5 selected samples. Also, the uniaxial compressive test was performed on the 5 samples, and triaxial and direct shear tests was done on 2 selected samples according to ASTM standard [10].

A. Physical properties

Physical properties of intact rock is depend on its microstructures. These microstructures contains minerals, grain boundaries and tiny failures. Tiny failures affect the rock strength and break direction [11]. The results of physical tests are shown in Table (3).

Results demonstrated that the increment of specific weight in studied samples leads to decreasing of porosity. According to [12] classification for specific weight and [13] for porosity, studied rocks consider as rocks with high specific weight and from porosity viewpoint they will place in category of rocks with very low porosity.

Table 3. Results of physical experiments

borehole	**Depth (meter)**	**Type of rock**	**Dry density gr/cm3**	**Saturation density gr/cm3**	**Water absorption %**	**Porosity%**
BH1	0 – 2	granite	2.586	2.609	0.878	2.272
BH1	5 – 6	Pegmatite with Orthoclase veins	2.596	2.608	0.472	1.225
BH2	1 – 2	Granite	2.623	2.638	0.414	1.087
BH2	7 – 8	Granite	2.619	2.631	0.462	1.209
BH3	2 – 3	Granite	2.539	2.595	2.229	5.658

B. Mechanical Properties

Determining and analyzing the mechanical properties of rocks are the most important part of each engineering Geology project [6]. The results of the uniaxial compressive test performed based on the ASTM 2938 standard [10] on 5 chosen samples from the excavated cores are shown in Table 4. As it can be seen in this table, the compressive strength amounts are variable from 24.28 to 55.94. This discrepancy may be the result of internal discontinuity, petrographic difference or structure complexity of granite. Samples condition in uniaxial compressive test-before and after the test- are shown in Fig. 2.

Table 4 Results of mechanical tests

Borehole	**Depth (meter)**	**Type of rock**	**Sample condition**	**Density (gr/cm3)**	**Compressive strength (Mpa)**	**E (Gpa)**	**υ**
BH1	3.00-3.42	Granite	Saturated	2.61	43.34	41.96	0.36
BH1	6.47-6.85	Granite	Saturated	2.61	34.68	23.66	0.4
BH2	6.42-6.9	Granite	Dry	2.61	55.94	52.28	0.37
BH2	8.38-9.00	Granite	Saturated	2.6	52.49	40.6	0.37
BH3	4-4.5	Pegmatites	Dry	2.65	24.28	23.08	0.34

Fig 2. Samples condition in uniaxial compressive: Before the test on the left and after it on the right.

Rocks are under the three axial stress in the nature and real situations. In such situations, their strength is important for calculating the allowable bearing capacity of foundation rocks, designing dams, studying the mechanism of fault and folds creation and underground excavations [14]. The results of the triaxial compressive strength test performed based on the ASTM D 2664 standards [15] on 2 selected samples from the drilling cores are shown in Table 5.

The above results can be used for determining the rock engineering parameters. Samples condition in uniaxial test- before and after the test- are shown in Fig. 3.

Table 5. The result of triaxial test.

Borehole	Depth (meter)	Type of rock	Sample condition	Dry density	Humidity (%)	C (Kg/cm2)	ϕ (Deg)
BH2	4.00-4.63	Granite	Saturated	2.6	0.27	0.4	36.4
BH3	6.00-6.70	Pegmatites with abundant orthoclase	Saturated	2.59	0.33	0.3	36.9

Fig. 3 Samples condition in Universal test: Before the test on the left and after it on the right.

In order to determine the mechanical properties of the studied granite rocks, the direct shear test on the broken surface and the natural seam of 2 sample rocks based on the ASTM D 5607 standard[16] was carried out to estimate the rock shearing strength in weak surfaces. The results of rock direct shear test on 2 selected samples of excavated cores have been shown in the Table 6.

Table 6 the results of the direct shear test.

Borehole	Depth (m)	Type of rock	Sample condition	Dry density (gr/cm3)	Water content (%)	C (kg/cm2)	ϕ (degree)	descriptions
BH1	3.0-3.42	Granite	dry	2.62	0.19	0.7	30.3	Cutting on the joints
BH2	4.50- 4.80	Weathered pegmatiteswith abundant muscovite	Saturated	2.6	0.33	0.23	27.2	Cutting on the joints

C. Joint Roughness Coefficient determining (JRC)

The JRC is a value that using it the shearing strength of a discontinued surface can be estimated in the normal stresses higher than the experimental limit. In the high normal stresses, the surfaces teeth can be broken and the shearing strength are near the intact rock strength [7]

Table 7 JRC values

Borehole	Depth (meter)	The joint length (cm)	Asperity amplitude (mm)	The JRC amount by using Barton profiles
BH1	7.2	8.2	2.5	8-10
BH1	9.43	8	3	10-12
BH2	7.2	6.2	15	12-14
BH2	8.2	8.1	2	8-10
BH3	7.75	9	10	16-18

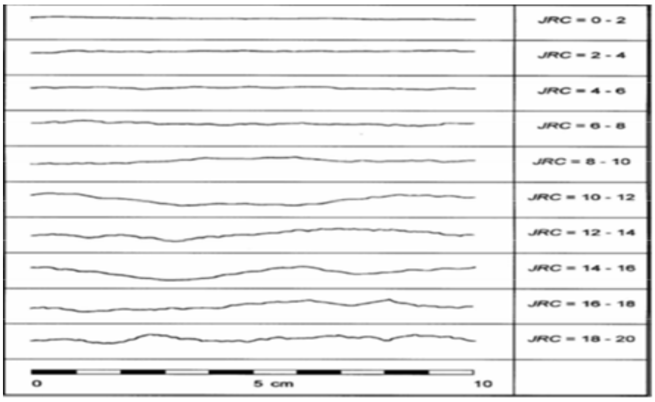

Fig. 4 Roughness profiles for estimating the JRC value [7]

The JRC is determined by comparing the discontinuity appearance with standards profiles distributed by Barton [7] and shown in the Fig. 4. The JRC for 5 samples are shown in Table 7 and the measured discontinuity surfaces fluctuations is shown in Fig. 5

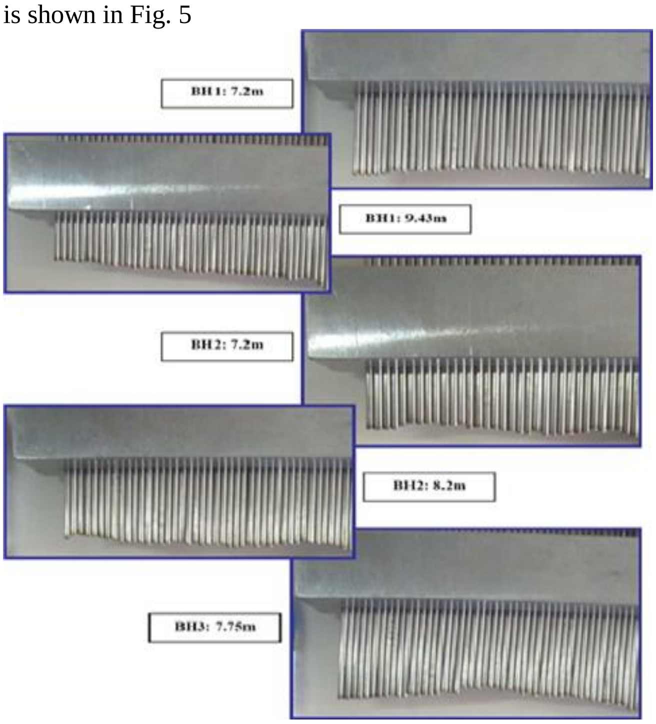

Fig. 5 The measured discontinuity surfaces fluctuations

IV. CONCLUSION

Regarding to the construction growth in southern areas of Mashhad and the existence of granite outcrops in such areas, studying the physical and mechanical properties of these rocks is essential. According to the uniaxial compressive strength and Deer and Miller [17] classifications, the studied rocks are categorized in the high strength class and high modular ratio that shows high elastic modulus and low compressibility of these rocks. According to the Anon [12] classification, the studied rocks are ranked in the category of rocks with very high specific weight and very low porosity. According to the direct shear test, the cohesion parameter deals with these rocks is 0.70 Kg/cm2 and the friction angle is 30.3 degree.

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