

Physical properties of Tabriz gray marlstone, NW of Iran

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ABSTRACT: Tabriz is one of the largest cities in Iran, with a population of more than 2 million. Marlstone is the bedrock of most areas of the city. These marls, consisting of lime and clay, are found in different colors such as yellow, olive, and gray, which mostly belong to Baghmisheh and Upper Red Formations. These marls have different amounts of organic materials and in high percentages cause the formation of lignite. The physical characteristics of the marl are different and the gray marl has a high density and strength. Another important characteristic of marls is the high rate of weathering which in excavations, changes over several months and turns into soil. Therefore, marl is considered both a weak rock and a hard soil. This study, by sampling and conducting experiments, presents the physical and mechanical characteristics of gray marls in different parts of Tabriz city. The carbonate content of the mentioned marls is between 30 and 60% and their dry unit weight is between 17.5 and 20.0 kN/m³. The clay minerals in these marls also include illite, montmorillonite, etc.

1 INTRODUCTION

Marl is a term to describe the mixture of calcium carbonate and clay, normally between 35 and 65 percent (Pettijohn, 1975). Terzaghi and Peck (1967) have defined marl as a hard to very hard marine carbonate soil in green color. Sowers and Sowers (1979) introduced marl as a sandy deposit with silt and clay containing gray or green calcite and McCarthy (1977) stated that marl is soft limestone. Mitchell (1976), considers marl a soft, carbonated, and clay-rich material, and Bell (1981), has pointed out that marl is a term with different meanings, which is used for rocks with 35-65% carbonate and a large amount of clay. Qahvash (1989) introduced limestone sediments with 55 to 80 percent carbonates as marl.

In engineering geology and geotechnical engineering, terms such as colored soils, carbonate, and marl soils are used to specify the composition of fine-grained soil with carbonate minerals. The most important studies conducted on marls are: Bell (1981) conducted a study on the physical and resistance properties (unit weight, specific gravity, porosity and Young's modulus) of marls in the Middlebrook region of England. Qahvash (1989) conducted research on plastic properties, granulation, specific gravity, porosity, etc. in the Dhahran region of Saudi Arabia. El-Amrani et al. (1998), measured the uniaxial strength, deterioration index, carbonate percentage, dispersion index, water absorption, sulfate percentage, specific gravity, etc. in the Grande region of Spain. Hooshmand et al. (2012) studied parameters such as point load index, SPT, Young's and shear modulus, plasticity properties, specific gravity, porosity, and shear strength, in some areas of Tabriz city. Amirali and Katebi (2016) tested the carbonate content, color, strength, shear wave speed, and physical properties of Tabriz marls. Asghari-Kalajahi et al. (2019), studied parameters such as mineralogy, creep, and swelling behavior of marls in the Baghmisheh area of Tabriz.

Tabriz is one of the largest cities in Iran (Figure 1), with a population of more than 2 million. Marlstone is the bedrock of most areas of the city. The old area of Tabriz was

formed on smooth topographic surfaces and alluvial deposits. Still, with the growth and development of the city in the eastern side, a large part of the city's development in areas such as Valiasr town, Baghmisheh, Roshdieh, Marzadaran, and its extension to Ahar road in rough topographic, it is mostly placed on marlstone (NGDIR, 2004). Due to the development of the city on marl layers and the desire to build high-rise buildings and the need to place foundations in deeper layers, huge excavations have taken place in these layers and the future will be more than now will be required. To design the foundations of high-rise buildings, assess the risk of heavy constructions against possible earthquakes, and landslides, as well as guardian structures in deep excavations, it is necessary to exhaustively understand these layers from a physical and mechanical point of view. For this purpose, samples were taken from different parts of Tabriz tested for identification. The performed tests generally include moisture content, Atterberg limits, unit weight, specific gravity and uniaxial strength. On a group of samples, tests were performed to determine the percentage of calcium carbonate, percentage of organic matter, and mineral identification.



Figure 1. The location of Tabriz city on the Iran map.

2 GEOLOGY OF TABRIZ REGION

Marls of Tabriz are the carbonate sediments of lakes that are exposed in the eastern, northern, and southern areas of the city. Some pictures of these marls are illustrated in the Figure 2. The geology map of Tabriz region is showed on Figure 3. They form the bedrock in most areas of the city and are located under the alluvial sediments.

Considering that marls are often formed in warm and shallow lake areas, it can be concluded that such an environment prevailed in the current location of Tabriz city and the continental sediments in this area contained Lignite, shale, and fossil. The presence of gypsum and coal veins reduces the resistance characteristics of these deposits. In many marls, thin layers of gypsum are also observed. It seems that part of the carbonate materials required for the formation of marls in Tabriz is supplied from the limestone springs caused by the presence of Lake Urmia, and the presence of minerals and fossils such as coal, diatomite, sinerite, chlorite, and ferrous iron (Hooshmand, 2012). The marl layers are horizontal in most of the different areas, but in the northern parts of the city, due to the proximity to the Tabriz North fault and tectonic activities, it is inclined. From the point of view of soil mechanics, these materials are classified as clay or silty type with high plastic properties (Babazadeh and Ghobadi, 2013).



Figure 2. Some pictures of marlstone outcrops in the around of Tabriz city.

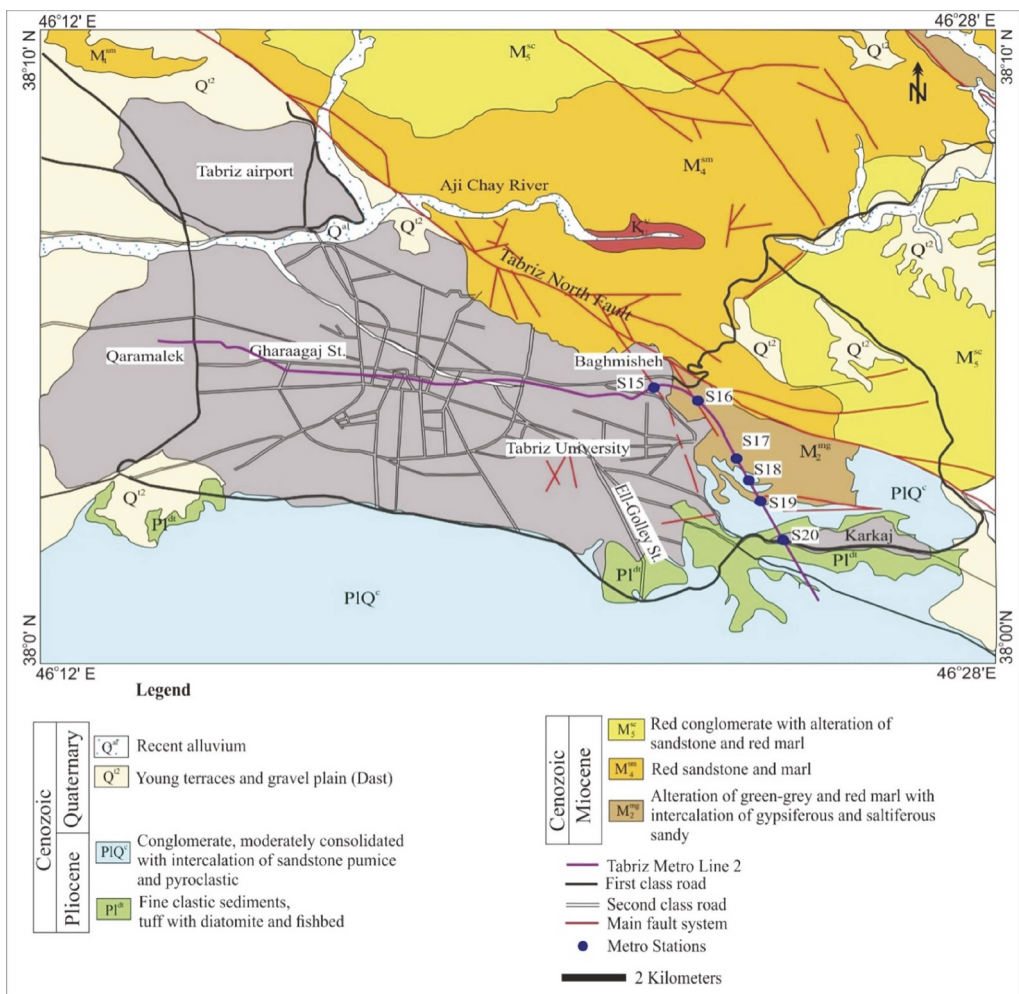


Figure 3. Geological map of Tabriz region (adapted from the geology map of GSI, 1996).

3 RESEARCH METHOD

During the visits to different areas of the city, taking pictures and taking samples in the places where geotechnical excavations were carried out, core samples were taken. Marls can be seen under the alluvial sediments in the central area of the city. In the reconnaissance excavations for the Tabriz metro project, gray marl layers have been observed at depths of 10 to 50 meters in the central areas of the city (Figure 4).



Figure 4. Outcrop of green and gray marls around Baghmisheh town.

4 TEST RESULTS AND DISCUSSION

The physical tests that have been performed on most of the samples include grading, Atterberg limits, specific gravity, and dry density. The test results are presented in Table 1. It can be seen that the soil unified classification of marls are MH, CL and CH. Atterberg limit tests performed on these marls have determined different liquid limits from 39 to 69.5% for yellow marls, 60 to 72% for olive green marls, and 40 to 80% for different types of gray marls. Their plastic index is from 17 to 46% for yellow marls, 38.5 to 42.5% for green marls, and 32 to 60% for different types of gray marls. Therefore, they have medium to high plastic properties. This is due to the change in their calcium carbonate content, the type and amount of clay minerals in them. Based on the Holtz and Kovacs diagram and comparing the results of the Atterberg limit test, it can be seen that the marl clay minerals of the studied area are illite, kaolinite and montmorillonite (Figure 5).

The different characteristics of marls in Tabriz are mostly related to the sedimentary environment and the conditions of their formation, so that layers of gray marl related to Baghmisheh Formation indicate their formation in a sweet lake environment and a large amount of

Table 1. The results of some physical tests.

Type of test	Upper limit	Lower limit	Average
Liquid limit (%)	80	39	52
Plastic limit (%)	58	15	35
Plastic index (%)	60	17	33
Dry density (kN/m^3)	19.0	15.0	15.6
Specific gravity	2.85	2.42	2.56

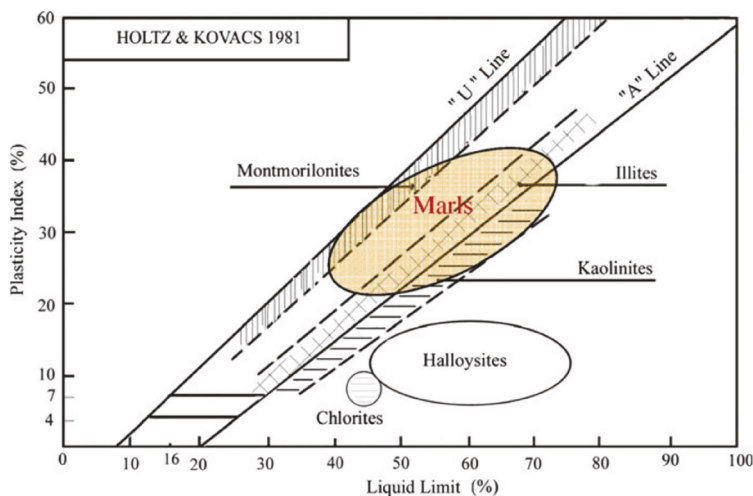


Figure 5. The relationship between the liquid limit and the plasticity index of marls on the Holtz and Kovacs) 1981) chart.

organic matter. Gray marl is an indication of reduced sedimentary environment and their formation next to joints and faults as a porous environment or reduction of iron due to changes in organic matter.

The gray marls of Tabriz contain a relatively large amount of calcium carbonate compared to the yellow and green marls, and by forming at greater depths due to the increase in confining pressure and the decrease in the porosity ratio with the depth and overburden pressure, they show the highest amount of resistance and the least deformation.

The minerals that makes Tabriz marls are not the same due to the difference in the way and time of formation, the way of deposition, the thickness of the layer, weathering conditions, as well as the conditions of the of the parent soil, and similar things. The main minerals in the X-ray diffraction test are quartz, albite, calcite, dolomite, chamosite, anorthite, and albite, and secondary minerals are illite, kaolinite, montmorillonite, hematite, and aragonite

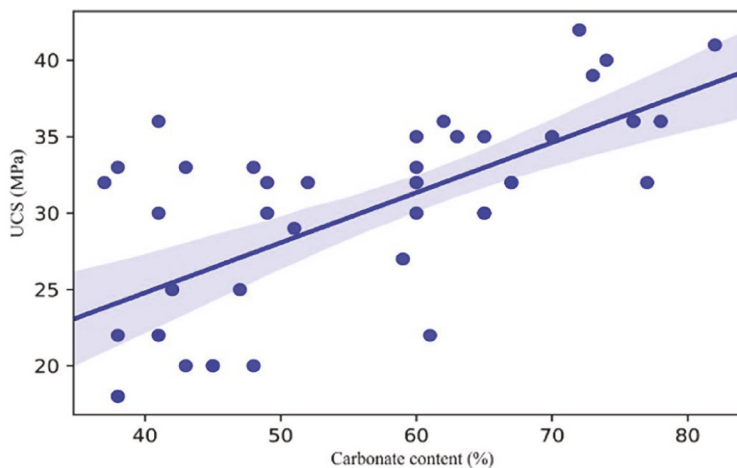


Figure 6. Relationship between calcium carbonate content and compressive strength in marlstone (Azarafza et al., 2019).

(Soleimani et al., 2019). From the geotechnical point of view, the presence of organic materials has a negative effect on soil characteristics. For example, they reduce the mechanical resistance of the soil and increase its settlement and creep. The maximum percentage of weight loss in the loss on ignition (LOI) test for organic matter is 2.6% for Tabriz gray marl, which can be concluded that the percentage of organic matter in Tabriz marl is very low and this value will not have much effect on properties (El Howayek et al., 2012). The amount of calcium carbonate can also affect the physical and mechanical characteristics of the soil. There is an inverse relationship between carbonate content and swelling behavior. Marls with high carbonate and high sulfate content as well as granular particles are easily compacted and their resistance parameters increase dramatically. Also, in these marls, the resulting compaction is irreversible (Figure 6).

Clay content appears to affect the maximum dry density in the case of the standard compaction test. This is attributed to adsorption of water by the clay minerals, whereas other clay-sized minerals such as carbonate do not have such an effect. The amount of calcium carbonate in Tabriz marl is between 10% and 30%, obtained during previous research, and this amount of carbonate does not have much effect on the behavior of marl and can be affected by the parent soil (Khamechian et al., 2000). Since the gray marl is known as the bedrock of Tabriz and continues to the thickness of 100 meters and more, the olive and yellow marl generally includes the surface layers of the soil. Practical experiments have shown that gray marl has more suitable characteristics in terms of resistance than olive marl. Regarding the resistance properties, there is a huge difference between the gray, olive, and yellow marls, and the results of the SPT and uniaxial compression tests are shown in Table 2.

Table 2. Results of SPT and uniaxial compressive strength tests.

Marl Type	SPT	UCS (MPa)	Modulus of elasticity (MPa)
Yellow Marl	7-25	0.25-1.0	<8
Green Marl	25-40	0.4-1.1	8.0-20.0
Gray Marl	28-50	0.65-1.9	10.0-30.0
Solid gray marl	>50	>1.9	>30.0

The above results and practical experiences in construction projects show that gray marl is in the very dense category in terms of SPT and at lower depths, it is like weak rock. The modulus of deformation in gray marl is higher than olive and yellow marl. This issue will cause high confidence in placing foundations of heavy structures in gray marl layers. Marlstones are among strong soil and weak rocks in engineering and behavior. This behavior depends on the amount of clay and calcium carbonate. By increasing the percentage of calcium carbonate and depth, the engineering behavior of marls is similar to weak rock, and by increasing the percentage of clay, this behavior is similar to hard soil. Marlstones are strongly affected by the conditions of their environment; for example, when they are exposed to moisture their primary structure disintegrates; in this situation, it is no longer possible to describe the stone's behavior based on its primary characteristics. The most important determining factor in the design of structures on marl is elastic, plastic, and ultimately rupture deformation. Due to rapid weathering and erosion, marls cause problems such as foundation and slope rupture, tensile cracks in streams, expansion of instabilities in natural slopes and trenches, and geotechnical projects. Dry and wet cycles has important effects on the behavior of marl soils. In a way that most ruptures occur after long rains. The strength and stability of structures in Tabriz city due to the extent of marl formations and weather conditions are associated with settlement and creep issues. So that the marl masses have caused severe landslides in the steep paths (Figure 7), Parsa et al., (2021).



Figure 7. Some pictures of the landslides that occurred in the marl layers in the east of Tabriz.

The results of mineralogical tests show the presence of very little quartz, calcite, dolomite, and feldspar minerals. Muscovite and gypsum are in the mineralogical composition of all marl samples. The color of green marls is mostly attributed to the presence of Hematite and the color of yellow marls is also attributed to the presence of yellowish brown limonite. The color of gray marls is also attributed to the presence of organic matter in them. The clay minerals of the studied marls are mostly Illite and in the next categories, montmorillonite and Kaolinite. Because the mineral type determination test provides only qualitative and descriptive results, it is not possible to obtain the percentage of minerals from its results, only the presence of minerals is mentioned. (Figure 8).

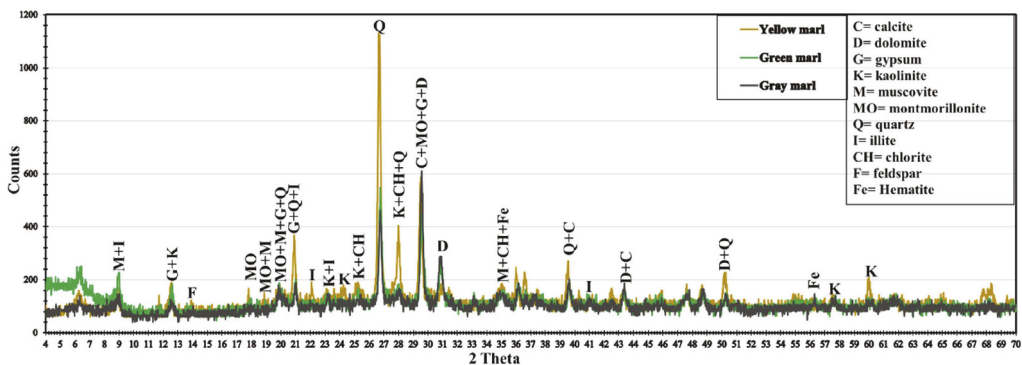


Figure 8. XRD for three types of Tabriz marls (Jalali-Milani et al., 2017).

5 CONCLUSION

Gray marlstone is the bedrock of most areas of the city. According to X-ray diffraction tests, the dominant minerals of Tabriz marls include quartz, illite, calcite, albite, and the dominant clay minerals are illite, montmorillonite, and kaolinite, but these minerals are not the same in different samples. The USCS of marly soils of Tabriz are CH, CL and MH. The percentage of organic matter in Tabriz marls is limited and generally less than 3% and is not included in the organic soil group in terms of classification.

According to the uniaxial compressive strength tests, yellow marls show the lowest strength and the most ductility due to stress and within the range 0.25-1.0 MPa, gray marls show the highest strength (0.65-1.9 MPa) and the least ductility. Green marls are intermediate between these two types and have uniaxial strength 0.4 to 1.1 MPa. The unit weight of marls increases with increasing depth, but this characteristic shows a decreasing trend with increasing moisture percentage. Dry density for the studied marls are between 15.0 and 19.0 kN/m³.

The SPT values for yellow marl are between 7 and 25, green marl 25-40 and gray marl 28-50, which shows the high strength of gray marls.

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