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Study of Dynamic Mechanical Properties for Urban Purposes: Alamein Area in Western Desert (Egypt)

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Abstract. The Northwestern part of Egypt is considered as a promising area for several national urban projects like the New El-Alamein City and El-Dabaa nuclear project. The main issue for any urban project is to measure and evaluate the degree of stability of the bedrock for these buildings. El-Alamein area lies in the Northern portion of the Western Desert; about 100 km west of Alexandria city. The New El-Alamein city is considered as an important new urban extension of the Northwestern part of Egypt. In the present work, thirty-two rock samples were collected from some shallow boreholes, representing a great part of the Marmarica Formation (Miocene). These samples were subjected to numerous laboratory measurements such as porosity, permeability, electrical resistivity, sonic wave velocity and dynamic mechanical properties. These laboratory measurements were conducted at Ain Shams University's petrophysical lab. (PRU), the Egyptian Petroleum Research Institute (EPRI), and the British University in Egypt (BUE). The measured petrophysical parameters for the Miocene (Limestone) rocks, presented by the Marmarica Formation in New El-Alamein City show many fundamental rock properties. The sedimentological features of the Miocene limestone rocks were investigated using several thin sections to detect petrographical features and diagenesis. Some relationships between different elastic moduli and petrophysical properties were constructed to detect the different rock types based on material competence scales and material bearing Capacity. The material competence scales of the studied Middle Miocene limestone rocks show a very good relationship with Poisson's ratio and velocity ratio. It ranges from weak to moderately competent. Depending on the ultimate bearing capacity the Middle Miocene limestone rocks are considered medium-weak to medium-hard rocks.

Keywords: Mechanical properties, Middle Miocene, Western Desert, Egypt

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INTRODUCTION

The study area lies in the Northern part of the Western Desert between Latitudes 30°44' and 30°38' North and Longitudes 28°51' and 28°48' East. It is characterized by an arid to hyper-arid climate and contains many typical desert morphologies [1]. It is covered by sedimentary rocks having been formed during Tertiary and Quarterly geologic ages [2]. According to [3], these Quaternary deposits are unconformably overlying Middle Miocene deposits (Marmarica Formation) that were underlain by the Moghra Formation of the Lower Miocene. The study

area is located on an unstable-shelf, where the structure is primarily controlled by Northwest-oriented faults and East-West faults and folds associated with the Syrian Arc system in Northern Egypt [4].

The stratigraphic sequence (Figure 1) occurring in the study area ranges from the early Miocene to the Pleistocene. The Southern sector bordering El Qattara Depression is characterized by a clastic sequence of early Miocene age, alternating sandstones, marlstones, and limestone rocks [5].

It is important to examine the physical properties of the bedrock in the study area for Urban purposes due to its significance being a great touristic interest. The present work aims to investigate the relationships between different elastic moduli and petrophysical properties such as density, porosity and permutability to detect the different rock types. Different rock types are discriminated by using additional various techniques such as the hydraulic flow unit (HFU) and the Electrical flow unit (EFU). On the other hand, both Material Competence and Material Bearing Capacity were calculated for Urban purposes.

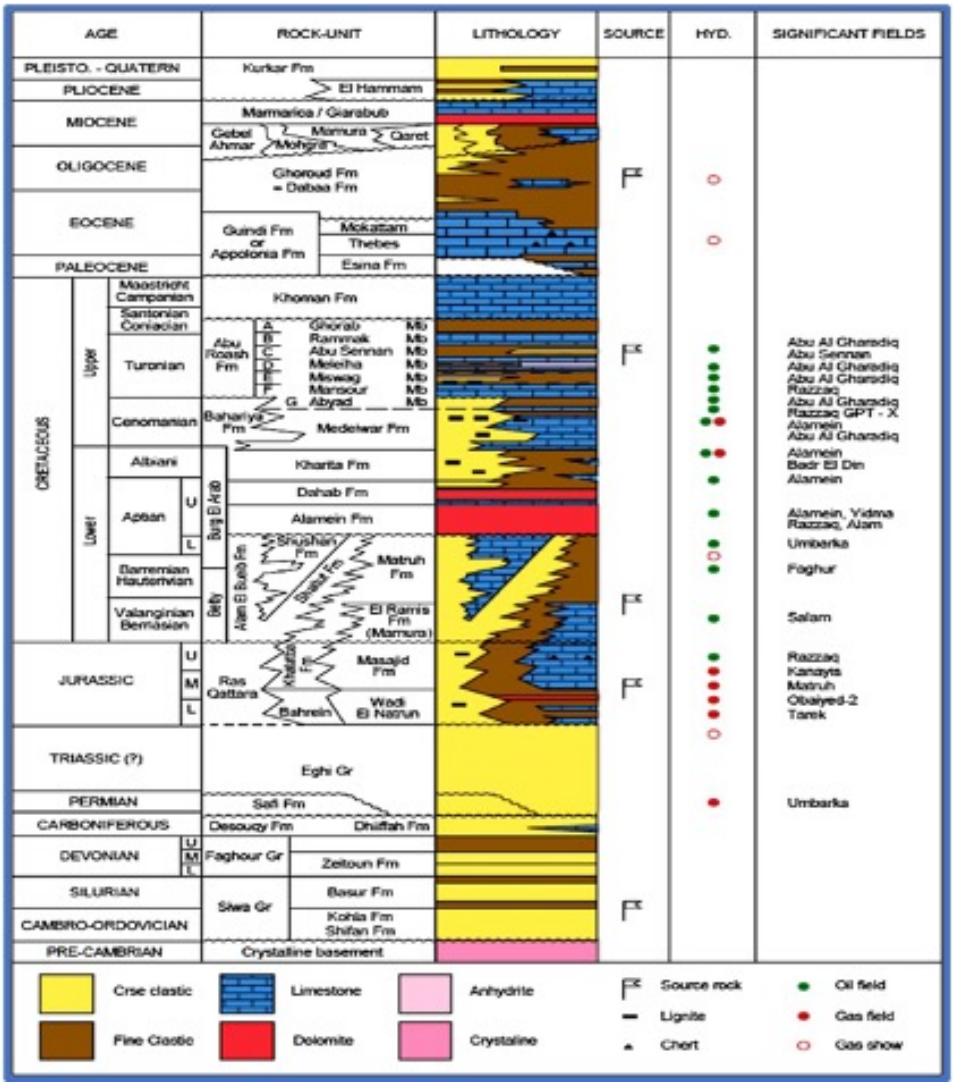

FIGURE 1. Generalized stratigraphic column of the North-Western Desert, [6]

PETROGRAPFY

Detailed petrographic investigations had been undertaken on ten of the Middle Miocene carbonate samples. These rock samples represent a great part of the Marmarica Formation. Thin sections were prepared and investigated

under the polarizing microscope '**Plate 1 and 2**' (Figure 2). They revealed some diagenetic features such as dissolution, recrystallization, micritization, and formation of gypsum veinlets. These diagenetic processes affect porosity and permeability. Some samples have low porosity and permeability due to pore filling, lining and cementation '**Plate 1a**', but many samples have high porosity and permeability because of the dissolution and crystallization processes '**Plate 1b**'. Density, porosity, permeability, and acoustic properties (velocity and dynamic mechanical properties) have been measured [7].

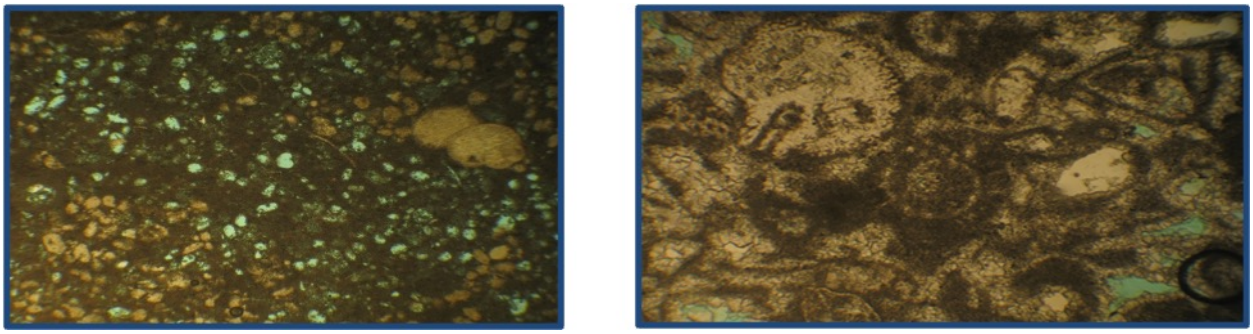

Plate 1 **Plate 2**

FIGURE 2. Plate 1-Biomicrite microfacies (scale 1cm=200µm, **Plate 2-**Pelbiomicro-sparaite microfacies (scale 1cm =200µm)

RESULTS AND DISCUSSIONS

Storage and Fluid flow capacity

Thirty-two core samples were prepared (cutting, cleaning, and drying- according to API, Specifications, 1952) and they were subjected to numerous laboratory measurements such as density, porosity, and permeability using methods adopted by [8].

Relation between bulk density and porosity

The relationship between bulk density and porosity for the study samples in Figure 3 shows a close reverse relationship with a high coefficient of correlation ($R^2 = 0.8462$) so porosity can be predicted from bulk density using the regression equation on the graph.

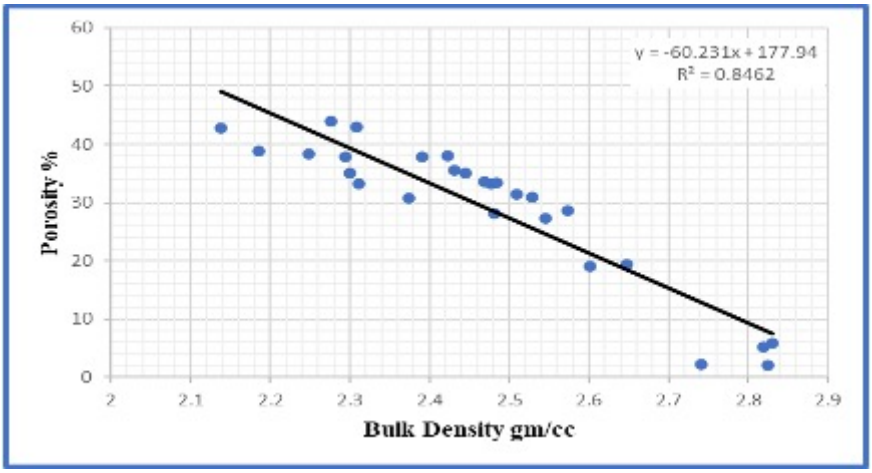

FIGURE 3. Porosity, % Versus bulk density, gm/cc.

Permeability versus Porosity

The high values of rocks' porosity do not exactly mean an existence of significant permeability and vice versa, too. The relationship between permeability and porosity of studied samples can be seen in Figure 4 and the relation shows two rock populations each of which has an average permeability; the wake stone-mudstone has K av. = 0.025 mD, and moldic grain-stone of K av. = 592 mD.

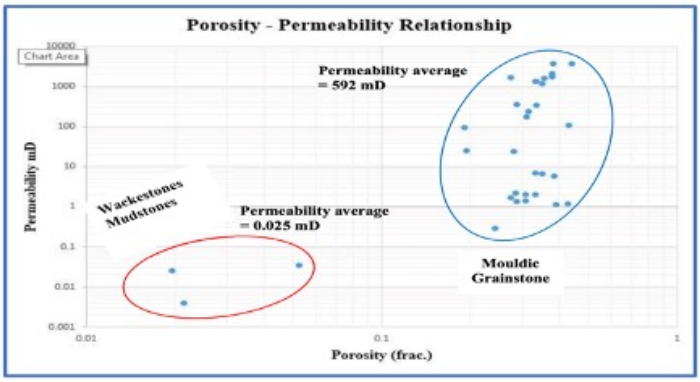

FIGURE 4. The relationship between Porosity and permeability

Pore radius (R35 and R36)

It is a fact that rock types with the highest value of pore throat size have high rock quality to flow fluids. Figure 5 shows the porosity and permeability relationship with the Z-axis Winland R35. Hydraulic flow units (HFUs) based on R35 and FZI values were classified in this study. The three hydraulic flow units (HFU1, HFU2, HFU3) have been distinguished by comparable average values of R35 and the FZI values.

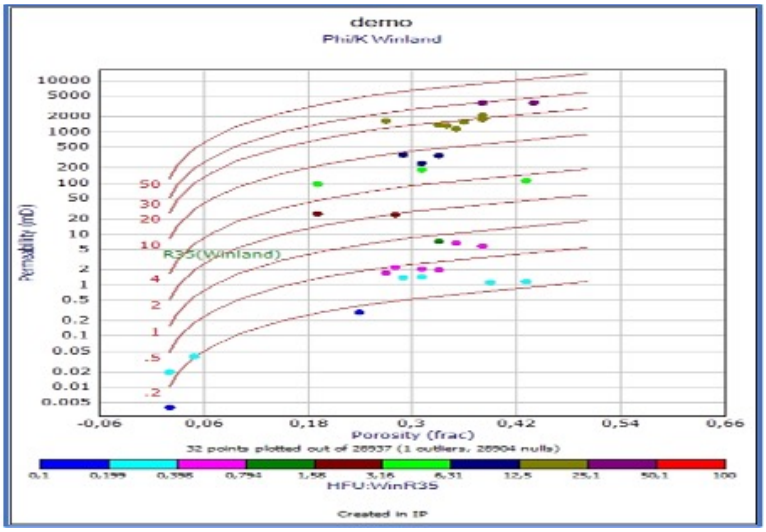

FIGURE 5. Relationship between porosity and permeability of all the studied samples with R35 (Winland) lines.

The mega porous unit represents the HFU 5 (about 12 samples of study samples), with high porosity and permeability values and with an average value of R35 = 31.8. The microporous unit represents the HFU 4 (about 25 samples) and with an average value of R35 = 15.3. The HFU3 is represented by mesoporous flow units (about 7

samples) and with an average value of R35 = 3.2. The HFU 2 is represented by mesoporous to microporous flow units (about 4 samples).

R36 [9] measurements of the studied samples showed that the pore aperture size (r36) of the Middle Miocene rocks of the Marmarica Formation varied from 0.001 to 19.6 micrometers, with a Mean value of 4.4 micrometers and Standard Deviation of 5.5 micrometers, Variance value of 30.5 micrometers, and Median value of 1.3 micrometers.

Acoustic Properties of the Samples

Relationship between acoustic wave velocities (Vp and Vs) and bulk density (ρb)

The acoustic wave velocities (Vp and Vs) and bulk density (gm/cc) relation for the studied samples are shown in Figure 6. Vp and Vs show a direct relationship with the bulk density where it converges with decreasing bulk density, as indicated by correlation coefficients of 0.99 for Vp and 0.92 for Vs.

Relationship between acoustic wave velocities (Vp and Vs) and porosity (Ø)

Acoustic velocities Vp & Vs -porosity relation for the studied samples is shown in Figure 7. Vp and Vs show a reverse relationship with the porosity, as indicated by coefficients of correlation $r^2 = 0.72$ for Vp and 0.62 for Vs.

Relationship between Young's modulus (E) and both (Vp) and (Vs) velocities

The calculated coefficients of correlations for both Vp & Vs versus Young's Modulus (E) were 0.96 and 0.9 respectively (Figure 8).

Material Competence and Material Bearing Capacity

The material index (v)

Several methods are used to evaluate the surface materials competence according to Poisson's ratio, rigidity modulus, N-value, material index, concentration index, stress ratio and density gradient,. The rocks appear to be incompetent to moderately competent as the scale of soil or rock classification [10]. The relationship between Poisson's ratio and material index (Figure 9) indicates that most studied samples are mainly of negative values as fairly to moderately competent materials ($0.35 > \sigma > 0.27$).

The material competence scales of the middle Miocene limestone rocks show a very good relationship with the Poisson's ratio, it ranged from weak incompetent to moderately competent [10].

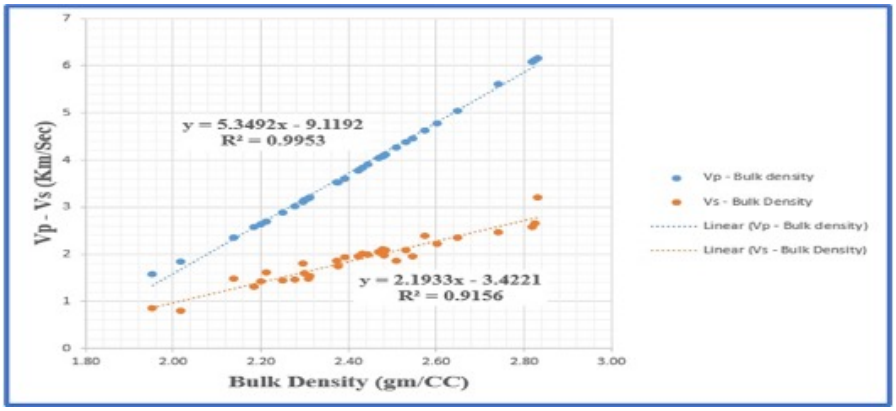

FIGURE 6. Bulk density and Vp -Vs relationships.

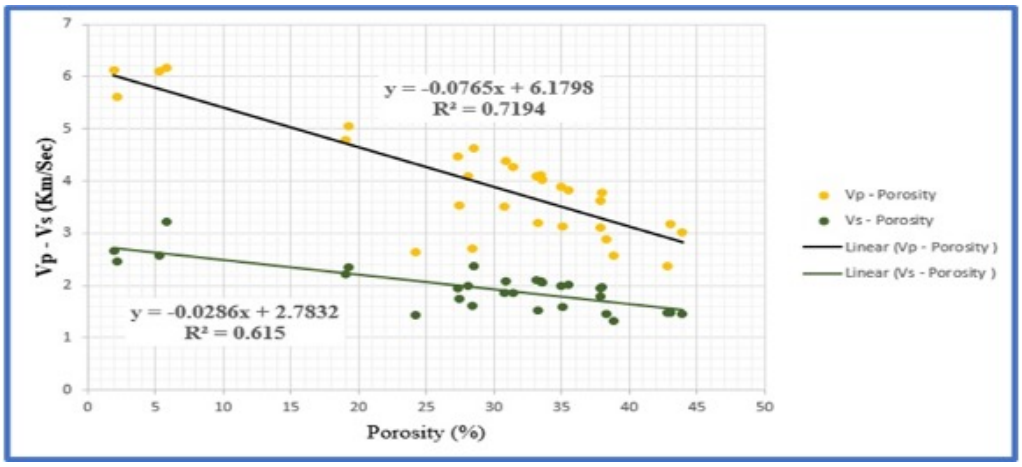

FIGURE 7. The relationship between porosity and Vp - Vs.

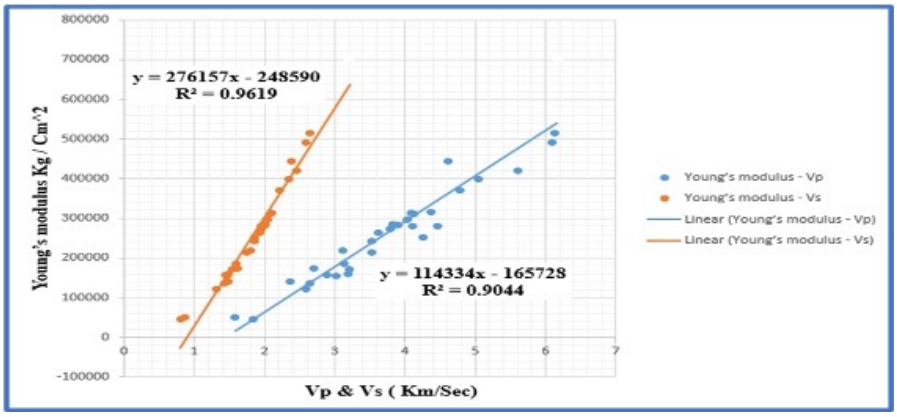

FIGURE 8. Young's Modulus Versus Vp & Vs.

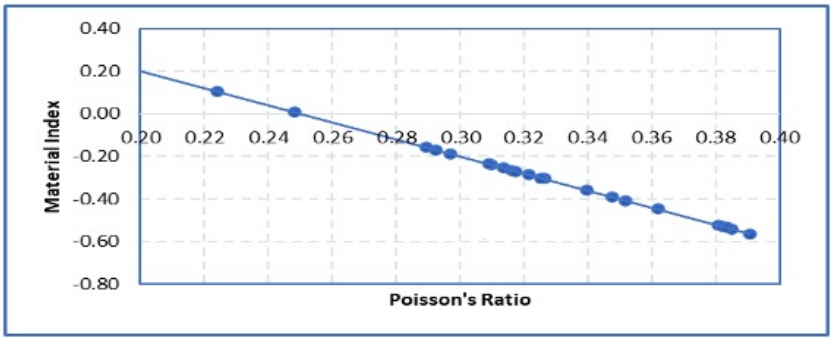

FIGURE 9. Material index Vs. Poisson's ratio.

Concentration index (CI)

For Urban purposes such as foundations and other civil engineering applications, the rock or soil compassion status is viewed as a major determinant of competence. The elastic modulus of the rock or soil, as well as the pressure distribution at their depth, are both important. The relation between the concentration index and Poisson's ratio is depicted in Figure 10. Most of the studied samples have a concentration index of less than (CI) =4.0 and Poisson's ratio (ϭ) >0.25. It indicates that 91% of studied samples are fairly compacted up to compacted.

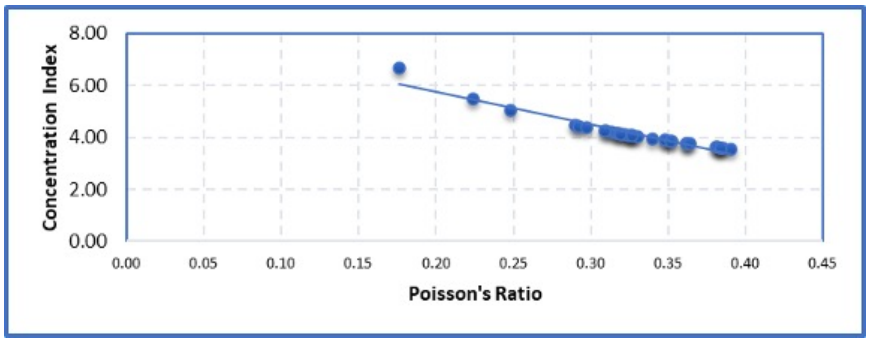

FIGURE 10. Concentration index Vs. Poisson's ratio.

Stress ratio (SI)

The stress ratio is used to create a material competence scale [11]. Figure 11 shows the relationship between the stress ratio and Poisson's ratio. This relation indicates that Most of the studied samples have a stress ratio less than (SI) = 0.57 and Poisson's ratio (ϭ) >0.25. It confirms that 91% of studied samples are fairly compacted up to compacted.

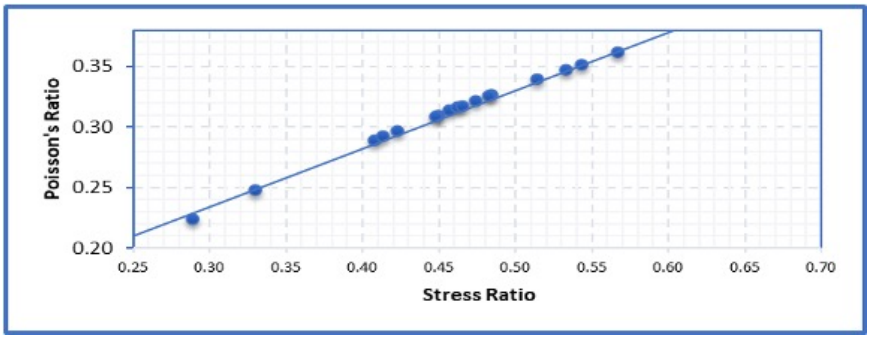

FIGURE 11. Stress ratio and Poisson's ratio.

Bearing Capacity of Foundation Material

The bearing capacity of the foundation material must be evaluated due to the possibility of liquefaction and/or shear failure. The ultimate bearing capacity of the foundation material is the highest possible. For shear failure or sand liquefaction, the load must be high enough to cause shear failure. The shear force is the soil's ultimate bearing capacity [12]. The calculated bearing and allowable pressure for the Miocene studied samples range from 77.35 up to 1070Kg/cm^2 and 4.6 up to 526 kg/cm^2 respectively. According to [13] of Soil mechanics and foundation design classification, the most studied (91%) Middle Miocene carbonate rocks are considered as medium- weak to medium-hard rocks [14].

CONCLUSION

Some samples have low porosity and permeability due to the filling of pore spaces by algae and gypsum, but most samples have high porosity and permeability because of the dissolution process. The middle Miocene limestone rock samples reflect fair-good storage and flow capacity properties. The compressional and shear waves have a direct relationship with the bulk density of rocks, which is based on porosity and diagenesis. The material competence scales of the middle Miocene limestone rocks show weak incompetent to moderately competent. The ultimate bearing capacity confirms that middle Miocene limestone rocks are considered as medium-weak to medium-hard rocks.

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