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A Geotechnical Evaluation of Minia-Maghagha Area, Upper Egypt

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ABSTRACT. A geotechnical investigation was carried out on the foundation bedrocks of El Minia-Maghagha area, eastern side of the Nile River with objective of preparing an effective landuse map. This area represents the future urban extension of the crowded population sites on the western side of the Nile River. The New Minia City is the first new settlement planned and constructed on the southern part of the Minia-Maghagha area.

A surface geological map at a scale of 1:250,000 was constructed for this area. The physical and geotechnical properties of each foundation bedrock were measured and studied in detail. These measurements include bulk density, insoluble residue, total dissolved salts, effective porosity, *in situ* strength, unconfined compressive strength and Young's modulus.

The geotechnical studies indicate that the Samalut Formation (carbonate foundation bedrock), which covers 80% of the studied area, is unsuitable for foundation and construction purposes, whereas the carbonate rocks of El Minia, Maghagha, and Qarara Formations are suitable for foundation and construction and as well as building stone blocks. The unsuitability of the limestones of the Samalut Formation is related to their very low strength properties and the presence of cavities, caves and sinkholes. Samalut Formation is suitable for white cement and chemical industries.

Introduction

El Minia-Maghagha area has a rectangular shape and lies on the eastern side of the Nile River. It is located between latitude 28° and 28°40'N and longitudes 30°50' and

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31°30'E (Fig. 1). The area represents a high stable land made up of Middle Eocene limestones. This table land has an average elevation of about 130 m above sea level and is dissected by NW-trending normal faults forming several major grabens. A system of EW and NW drainage pattern is inherited in this plateau.

Serious damages to and collapse of structures are anticipated in several parts covered by the carbonates of the Samalut Formation. An early phase of geological, geotechnical, and environmental studies would help in selecting the suitable sites of new settlements and cultivated land in this area.

Detailed field measurements and laboratory testing were carried out for determining the geological and geotechnical properties of the foundation bedrocks in the area of study.

Based on the results of the present study, some recommendations are made in order to help in the selection of suitable sites for urban development and for cultivation in EL Minia-Maghagha area.

Geological Setting

The exposed rocks of El Minia-Maghagha area were studied by several workers; *e.g.* Bishay (1961), Said (1962), Omara *et al.* (1973 and 1977), Boukhary and Abdel Malik (1983), Strougo (1986), and Strougo *et al.* (1990).

According to the work of Omara *et al.* (1977), the study area includes five mapable rock units of Middle Eocene age. These units are composed mainly of limestone (Fig. 1). The oldest exposed unit is El Minia Formation which is composed of white, hard, cavernous and fossiliferous limestone (Fig. 2a). This unit is conformably overlain by snow white, soft, highly cavernous, fossiliferous limestone of the Samalut Formation (Fig. 2b). The Samalut Formation is, in turn, overlain by creamy white, mictritic, marly limestone of the Maghagha Formation. The topmost part of the Maghagha Formation consists of reddish green claystone (Fig 3a). This unit is conformably overlain by brownish yellow, sandy, fossiliferous limestone of Qarara Formation. The topmost part of the Qarara Formation includes a nodular, chalky, limestone ledge of El Fashn Formation (Fig. 3b).

The exposed rock units have a gentle northward regional dip. Local increase in the dip is related to drag on the major normal faults in the area. About 24 major normal faults were observed and mapped in the study area. These faults have NW-SE trend and form several large grabens (Fig. 1). The drainage system is mainly controlled by the system of faults. Many caves and sinkholes are observed in the limestones of the Samalut Formation and are controlled by the major faults and their related joints.

Geotechnical Properties of the Rock Units

1. Rock Mass Properties

Rock mass properties deal with the factors controlling the stability of foundation bedrocks in the area. These factors include quantitative analysis of the major struc-

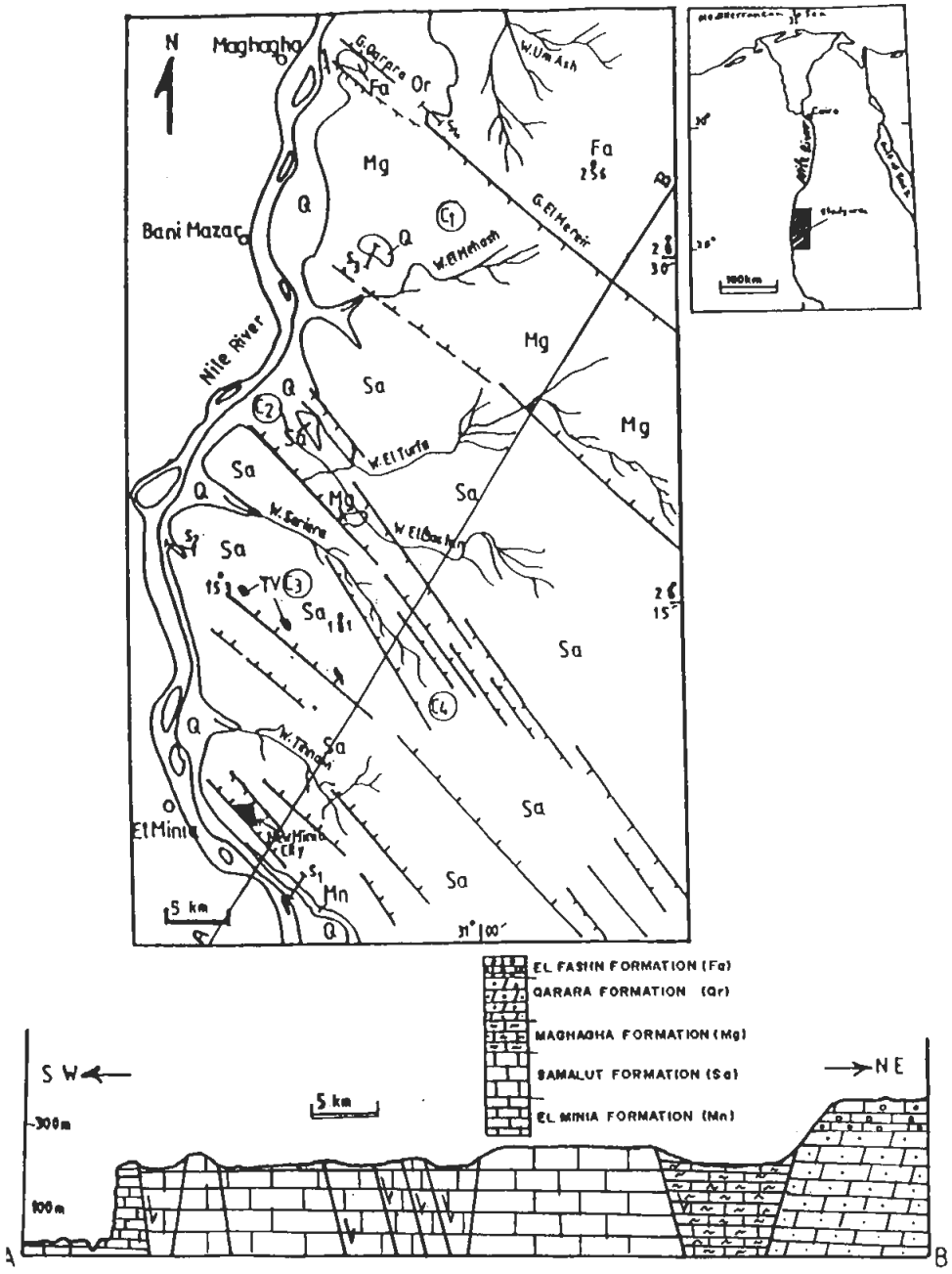
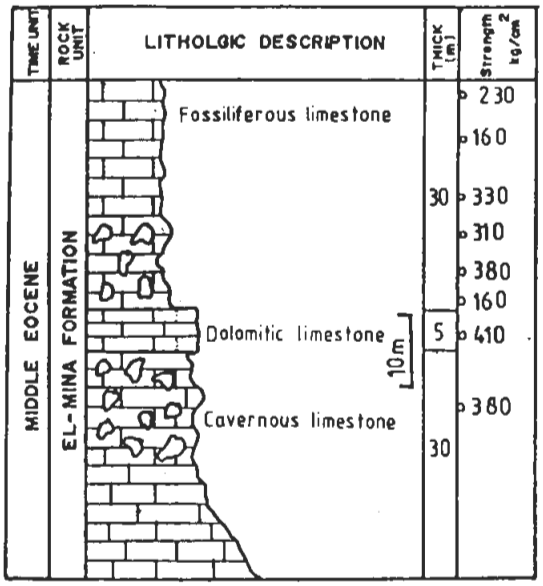
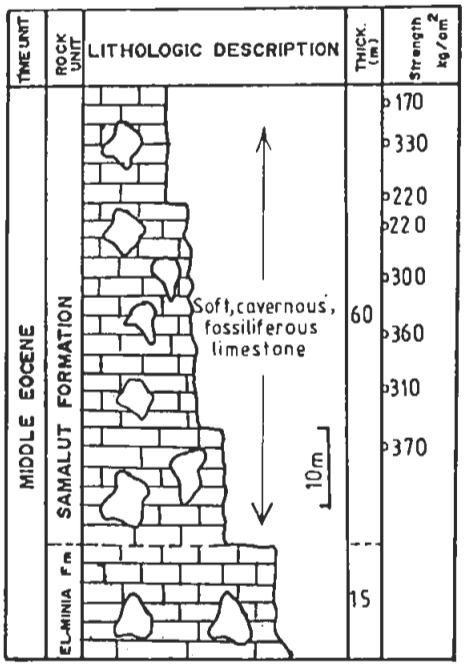


FIG. 1. Geological map and cross section of El Minia-Maghagha area (TV oligocene volcanics).



[a]



[b]

FIG. 2. Lithostratigraphic sections of El Minia Formation (a) and Samalut Formation (b). *In situ* strength measurements by Schmidt hammer are indicated on each section.

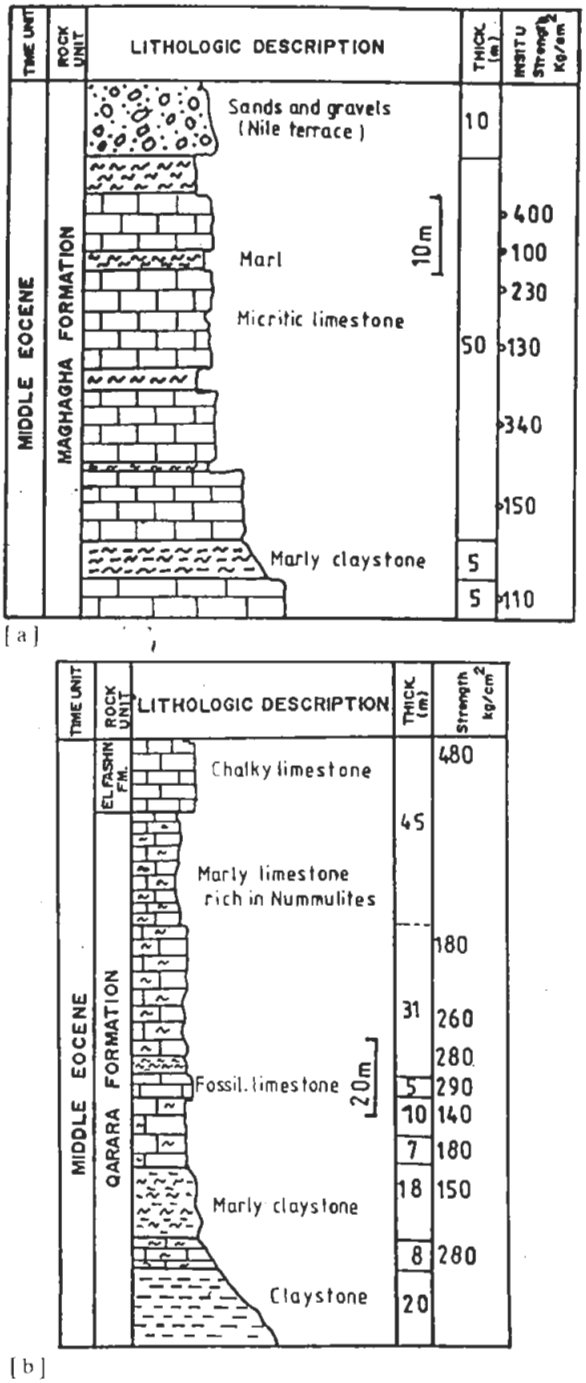


FIG. 3. Lithostratigraphic section of Maghagha Formation (a) and Qarara and El Fashn Formations (b). *In situ* strength measurements by Schmidt hammer are indicated on each section.

tural elements and discontinuities, nature of the caves and sinkholes, the effect of groundwater level, and the *in situ* rebound strength.

1.1 Major Structures and Discontinuities

A surface geologic map to a scale of 1:250,000 is drawn for El Minia-Maghagha area (Fig. 1). Base maps used for preparing this map are the Landsat Image (MSS) and topographic maps to a scale of 1:250,000. The major structural elements and the main rock units were field checked.

The mapped faults have NW-SE orientation. These faults form large grabens which indicate that the area was affected by a tensile stress regime during the post-Eocene time. Some fault zones in the area are quarried for Egyptian Alabaster ($CaCO_3$). Most of the main wadies dissecting the study area are structurally controlled.

About 565 joints were measured in the field in different rock units. The majority of these joints are vertical, smooth, planner, open, and moderately spaced. The measured joints show a predominant direction in El Minia formation (Fig. 4a), the Samalut Formation (Fig. 4b), and the Qarara Formation (Fig. 5a). Two sets of joints affect the Maghagha Formation and are oriented NE and NW (Fig. 5b).

1.2 Caves and Sinkholes

Several caves and sinkholes were observed in the soft limestones of the Samalut Formation. These caves are tabular and their diameter ranges from 0.5 m to 1 m, and the depth ranges from 5 to 20 m. These caves are characterized by smooth walls and include loose fine materials (fine sands, marl, and clays) on their floors. The trend of these holes coincides with that of the major faults and master joints. The NW-trend is the most frequent trend of these caves and sinkholes. Most of these caves are quarried for Egyptian alabaster. The topmost part of the Salamut Formation is highly affected by these caves and sinkholes. The New Minia city was built on these cavernous rocks (Abdel Tawab and Ibrahim 1991).

1.3 Rise of the Groundwater Level

Most of the new desert settlements of Egypt are suffering from the rise of water table. This rise is attributed to the water seeping through the ineffective sewage system and excess from garden irrigation. This water causes severe change in the strength of the carbonate rocks and to the swelling of clays of the Samalut and Maghagha Formations.

1.4 In Situ Rock Strength Measurements

The rebound strength of the exposed units in the Minia-Maghagha area was measured by using the Schmidt hammer. About 576 readings were carried out in the five exposed lithostratigraphic units. The strength of each unit was measured by taking the mean value of the 18 Schmidt hammer readings. Four lithostratigraphic sections were field-measured and described (Fig. 1; S1 to S4). *In situ* strength values measured in these four rock units are shown in Fig. 2 and 3.

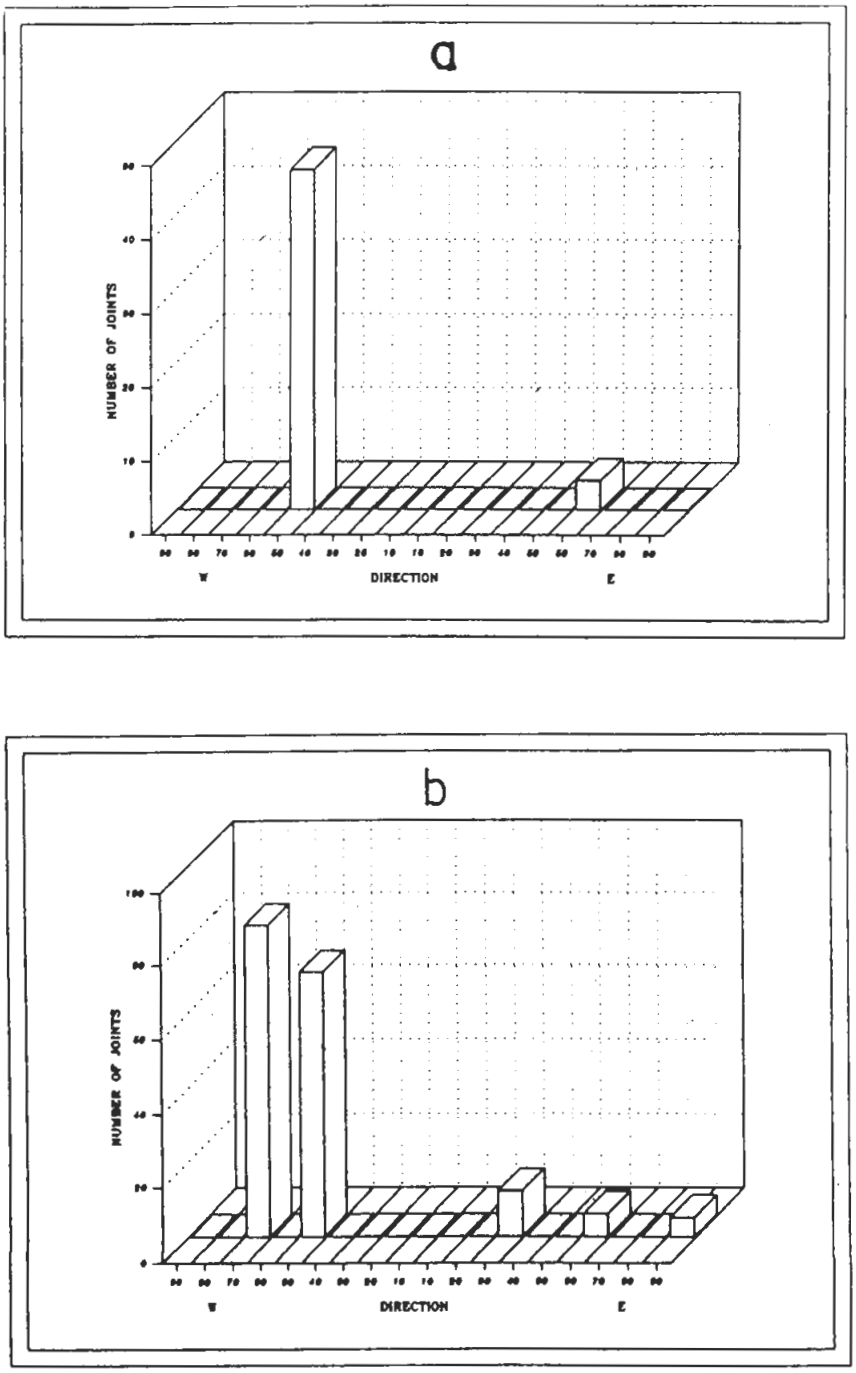


FIG. 4. Histograms of the joint systems affecting El Minia Formation (a) and Samalut Formation (b).

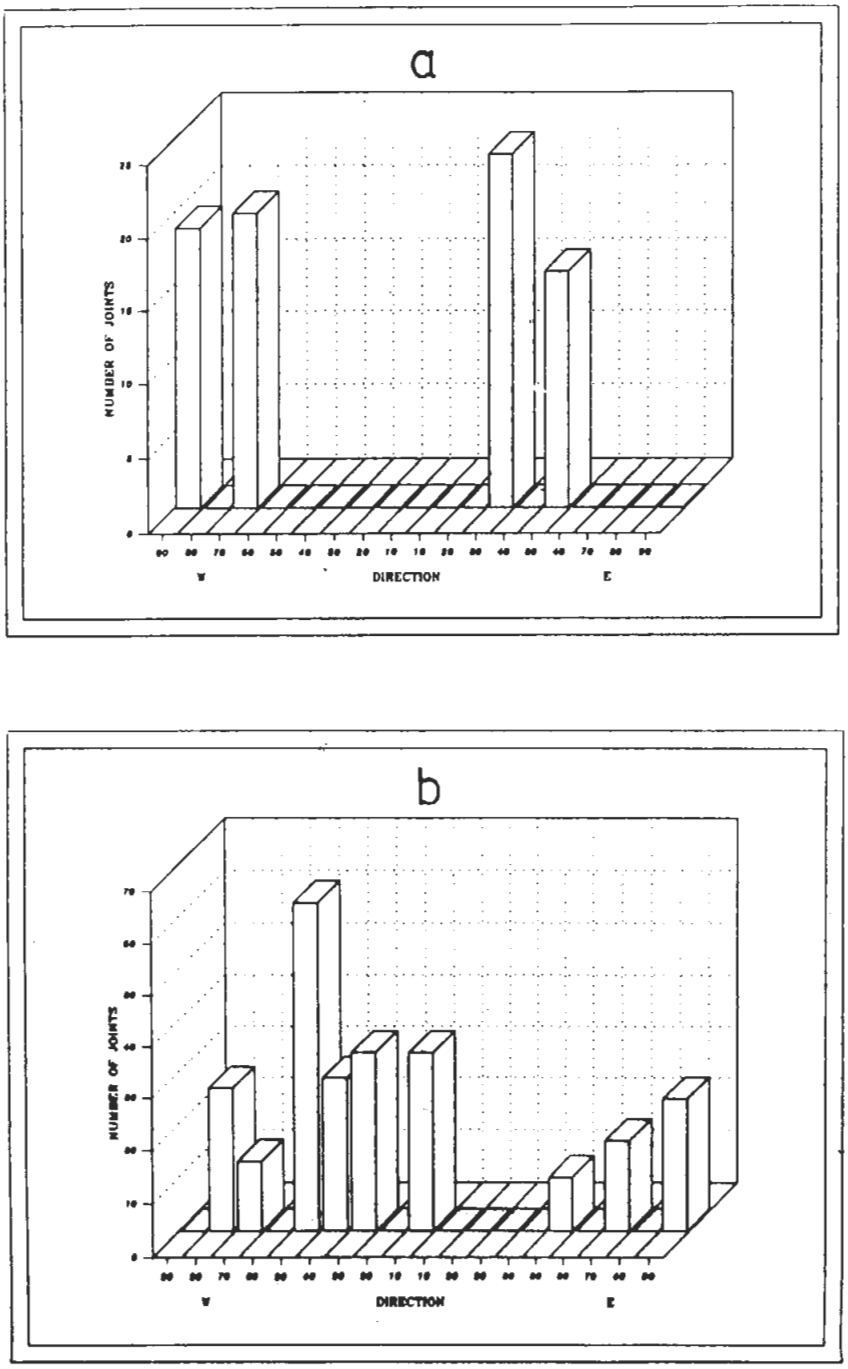


FIG. 5. Histograms of the joint systems affecting Maghagha Formation (a) and Qarara Formation (b).

2. Rock Material Properties

2.1 Sampling

The rock material properties are concerned with studying the physical and the mechanical properties of the foundation bedrocks. Several representative samples of these foundation bedrocks were collected. These samples were prepared according to the specifications of each laboratory test.

Relatively large block samples were collected from the topmost parts of the exposed foundation bedrocks of El Minia, Samalut, Maghagha, and Qarara Formations. 55 intact core specimens were prapared from the collected samples for testing their physical and mechanical properties according to the American Society for Testing and Materials (ASTM, D-3148, 1980).

2.2 Physical Properties

The physical properties were measured on both grab and core samples. These properties include the Total Dissolved Salts (TDS), Insoluble Residue (IR), bulk density, and effective porosity (Table 1). The physical properties of the collected samples indicate that EL Minia Formation has a moderate amount of dissolved salts and very low effective porosity, whereas the Samalut Formation has a very low amount of dissolved salts, very high content of carbonates, and high effective porosity. The Maghagha and Qarara Formations have high amounts of insoluble residue, high amount of dissolved salts, and moderate value of effective porosity (Table 1).

TABLE 1. Mean values of the physical and mechanical properties of the carbonates foundation bedrock of El Minia-Maghagha area.

Rock unit	Lithology	Density	TDS M/L	I.R. %	Porosity %	Strength kg/cm^2	Young's modulus MPa
El Minia Formation	Fossiliferous limestone	2.6	23	2	3	390	32000
Samalut Formation	Fossiliferous limestone	1.85	8	1	34	30	25000
Maghagha Formation	Fossiliferous limestone	1.8	1460	20	13	60	35000
Qarara Formation	Fossiliferous sandy limestone	2.5	754	25	9	200	12000

2.3 Mechanical Properties

2.3.1 Uniaxial Unconfined Compression Tests. The uniaxial unconfined compressive strength of the intact core samples was measured according to ASTM, D-3148 (1980). The test samples were axially fixed between the loading platens steel jackets with the same diameter as that of specimen were used between the core specimen and loading platens to minimize the end effect of the specimen. The load was

applied axially, uniformly distributed, and with constant rate over the based section of the core sample. The load was measured by dial gauge connected with 10 ton proving ring and the axial deformation is measured from the constant deformation rate with respect to time. The intact core samples were tested under dry and water saturation (10 days) conditions.

2.3.2 Stress-Strain Diagrams. The stress-strain diagrams for each foundation bedrock unit are illustrated in Fig. 6, 7, 8 and 9. The mean values of the ultimate compressive strength and the tangent Young's modulus are shown in Table 1. The shape of stress-strain curves for the Samalut and Qarara Formations show plastic-elastic deformation before failure. Most of the water saturated samples have low strength properties compared to the dry samples.

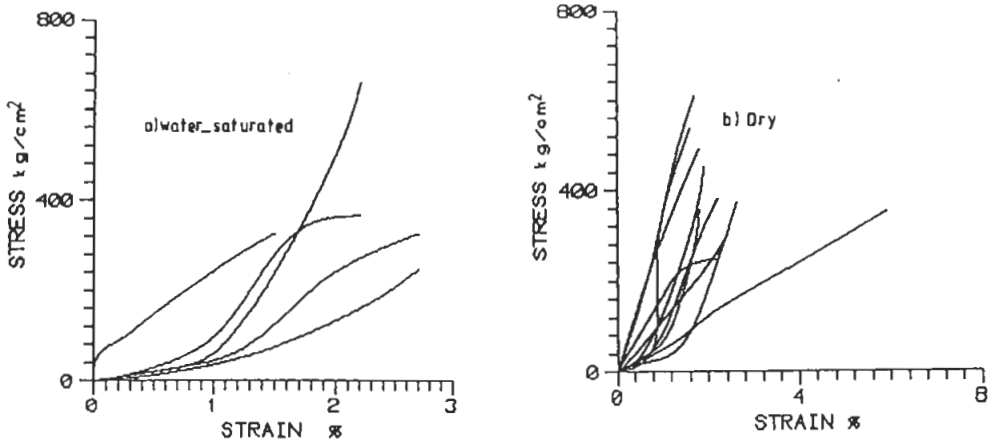


FIG. 6. Stress-strain diagrams of El Minia Formation (a) water saturated samples (10 days), (b) dry samples.

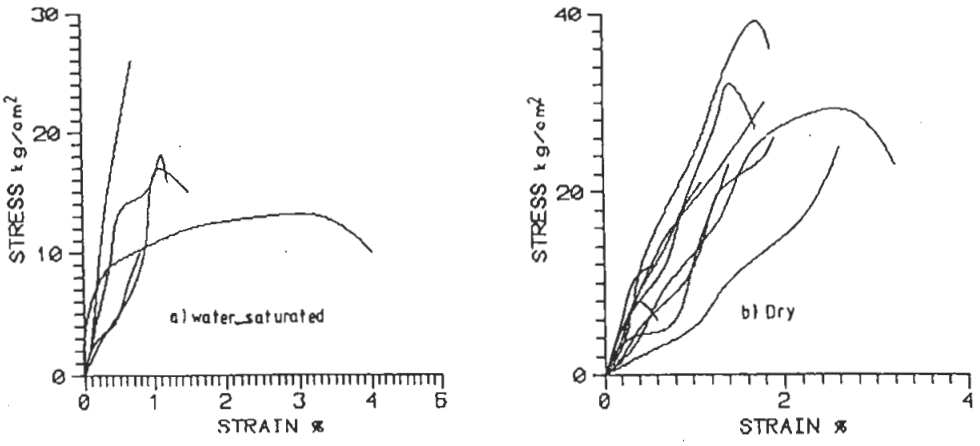


FIG. 7. Stress-strain diagrams of Samalut Formation (a) water saturated samples (10 days), (b) dry samples.

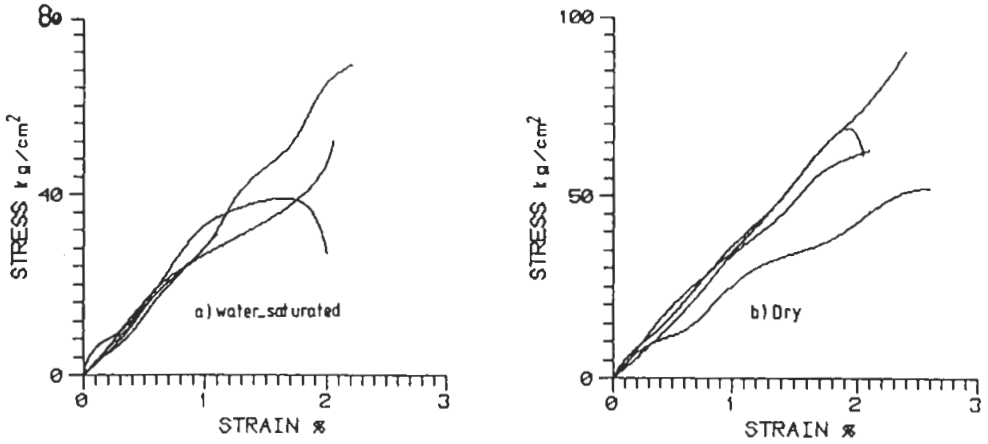


FIG. 8. Stress-strain diagrams of Maghagha Formation (a) water saturated samples (10 days), (b) dry samples.

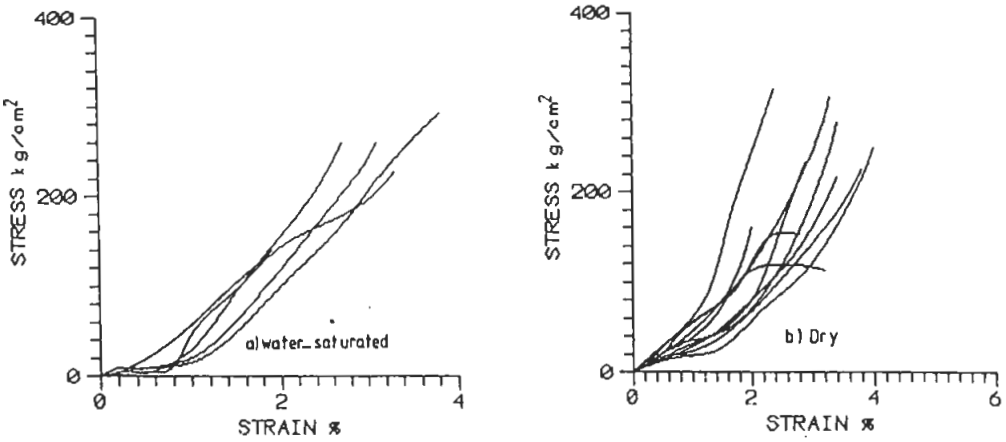


FIG. 9. Stress-strain diagrams of Qarara Formation (a) water saturated samples (10 days), (b) dry samples.

2.3.3 Engineering Classification of the Rock Units. The engineering classification (Deere 1968) is based on the ultimate compressive strength and the Young's modulus. The classification of the foundation bedrock of the study area (Fig. 10) indicates that El Minia Formation has a low modulus ratio and very high strength, whereas the Samalut Formation has a low modulus ratio and very low strength. The Maghagha and Qarara Formations have low modulus ratio and medium to high strength, respectively.

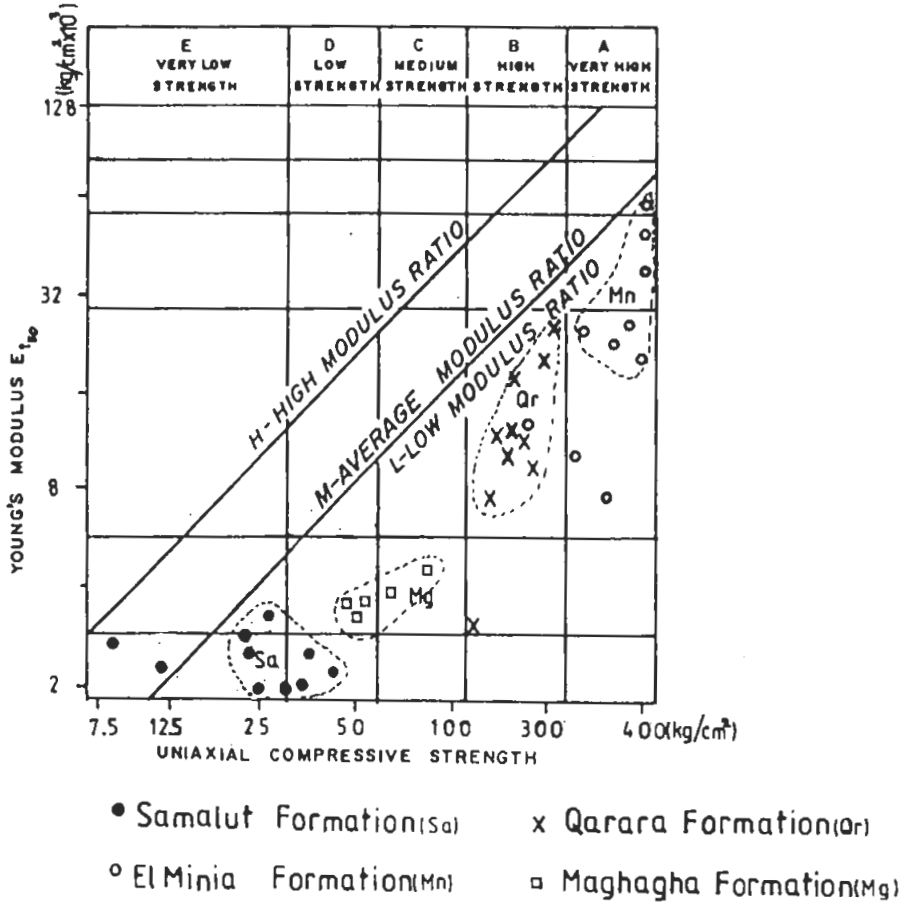


FIG. 10. Engineering classification of the carbonate rocks of El Minia, Samalut, Maghagha and Qarara Formations (According to Deere 1968).

3. *Suitability of the Foundation Bedrocks of the Area*

3.1 Suitability of Foundation

Based on the geological and geotechnical studies the suitability for foundation on the exposed rock units covering the study area can be summarized as follows :

a. El Minia Formation. This formation is characterized by high strength, low amount of dissolved salts and little affected by the caves and sinkholes. These properties make it suitable for foundation and construction building stone blocks.

b. Samalut Formation. The Samalut Formation is characterized by very low strength properties and highly affected by cavities, caves and sinkholes. The discontinuities systems dissected this Formation have carstified and dissolution criteria. These conditions make this unit unsuitable for foundation and construction building stones. The Samalut Formation is characterized by high content of $CaCO_3$ with a

very low amount of impurities which is suitable for white cement and chemical industries. A large amount of this unit is being quarried for building blocks purposes.

c. Maghagha Formation. This unit has medium strength value and is moderately affected by the joints and fractures. These properties are suitable for foundation and construction building stone blocks.

d. Qarara Formation. The Qarara Formation has medium to high strength values which is suitable for foundation and construction building stone blocks.

4. Suitable Sites for Urbanization and Cultivation

According to the geological, geotechnical and environmental conditions the study area can be classified as the following :

4.1 Urbanization Sites

The suitable sites or planning and constructing the new settlement are located to the north part of Wadi El Mehash and the southern boundary of the study area, whereas the Samalut Formation is replaced by another suitable foundation bedrock unit.

4.2 Cultivation Sites

The study area is dissected by six wadies started by Wadi Um Ash at the north to Wadi Tihnawi at the south (Fig. 1). These Wadies are drained in topographically low and flat areas of the major NW-SE grabens. The thickness of the soil in these topographically low lands ranges between 5 m and 10 m. The most suitable site for cultivation are located in the areas of C1, C2, C3 and C4 as shown in the geological map (Fig. 1).

Conclusion

Field and laboratory studies of the geological and geotechnical properties of the Middle Eocene carbonate rocks of El Minia-Maghagha area show that the limestone of El Minia, Maghagha and Qarara Formations are suitable for foundations and construction building stone blocks. The limestone of the Samalut Formation is unsuitable for foundation and construction building stone blocks, whereas suitable for white cement and chemical industries. The suitable sites for urbanization are located to the northern part of Wadi El Mehash and the southern part of the study area where the Samalut Formation is replaced by other suitable rock units. The suitable sites for cultivation are located in the area of C1, C2, C3, and C4 as shown in the geological map of the study area.

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التقيـــيم الجيـــوتـقني لمنطقـــة المنيـــا – مغاغـــة – صعيـــد مصـــر

سمير عبد التواب

قسم الجيولوجيا ، كلية العلوم ، جامعة عين شمس ، القاهـــرة – جمهورية مصر العربية

المستخلص . تم عمل دراسات جيوتقنية لطبقات صخور الأساس المتواجدة في منطقة المنيا – مغاغة على الجانب الشرقي لنهر النيل . تمثل هذه المنطقة الامتداد الطبيعي المستقبلي للتجمعات السكانية شديدة الازدحام على الجانب الغربي لنهر النيل . تعتبر مدينة المنيا الجـديدة أول تجمـع سكاني تم بناؤه في الجزء الجنوبي الغربي لمنطقة الدراسة . اشتملت الدراسة على عمل خريطة جيولوجية سطحية بمقياس ١ : ٢٥٠,٠٠٠ . الخواص الفيزيقية والجيوتقنية لكل نوع من طبقات صخور الأساس تم قياسها ودراستها تفصيليًا .

دلت نتائج هذه الدراسات على أن الحجر الجيري لتكوين سملّوط والذي يغطي ٨٠٪ من منطقة الدراسة غير مناسب للتأسيس وللاستخدام كحجر للبناء في حين أن الصخور الجيرية لتكاوين المنيا ومغاغة وقرارة مناسبة للتأسيس وللاستخدام كأحجار للبناء . ويرجع عدم ملاءمـة تكـوين سملوط إلى ضعف تحمله ووجـود فجوات وكهوف سطحية وتحت سطحية ويعتـبر الحجـر الجـيري لتكـوين سملوط منـاسبًا لصنـاعـة الأسمنت الأبيض والصناعات الكيميائية .