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A Predicted Land Recession Hazard at El-Shorouk New City, Cairo, Egypt: Mineralogical and Geotechnical Studies

H. M. Ibrahim and H. A. Wanas

Geology Department, Faculty of Science, Menufiya University, Shebin El-Kom, Egypt

ABSTRACT

El-Shorouk New City is located about 26 Km, east of Cairo. It lies between Cairo-Suez highway at its southern boundary and Cairo-Ismalia highway at its northern boundary. The general slope of the city foundations is from its southern suburb where topographic high to northern suburb where topographic low. The topographic high comprises the Miocene Hommath Formation that consists mainly of carbonate rocks intercalated with some shale beds. The topographic low represents by gravely to silty sand deposits of the Miocene Hagul Formation.

To evaluate the above prediction, effective porosity, compressive strength and petrographical investigations have been carried out on the Hommath carbonates. In addition, the XRD and mechanical analyses were done on the Hommath shales and Hagul sands, respectively. The carbonate rocks characterise by low density, low geotechnical quality and high porosity (ranges from 22% to 28%). Petrographically, these carbonate rocks are represented by algal dolomitic mudstones, algal dolostone and dedolostones. Clay minerals constituting the shales are kaolinite as a predominant constitutent followed by montmorillonite. In some cases, montmorillonite occurs with the highest proportion. The grain-size analysis data of the Hagul clastic deposits are of the fine to very fine-grained sands and silts with a little granules.

A predicted land recession on the city. foundations may happen due to domestic seepage water from over-irrigation of the high-land villas big gardens as well as from leakage of their swimming pools. These domestic waters may be infiltrate towards two directions; firstly, underneath the villas itself; secondly, towards the low-land foundations which restricted to construction of multy-story buildings for low-income citizens. To avoid such predicted land recession hazard, domestic water seepage control measurements should be taken into consideration by the responsible authorities.

INTRODUCTION

El-Shorouk New City has been built in the area located about 26 Km, east of Cairo. This area lies between latitudes 31O 35/ & 31O 40/ E and longitudes 30O 05/ & 30O 10/ N (Fig. 1). It is marked between Cairo-Suez high way at its southern boundary and Cairo-Ismailia high way at its northern boundary. The area of study is a part of a plain sloping gradually from its southern portion where topographic high to its northern portion where topographic low (Fig. 1).

The geology of the studied area has been illustrated by many workers (e. g., Said, 1962 and Attia, 1996). Accordingly, the foundation rocks of the studied area are belonged to the Hommath and Hagul formations of Miocene age. The Hagul Formation overlies the Hommath Formation and is represented by silts, sands and gravels that forming the lithologies of northern suburb of the city where the topographic low (Fig. 1). The Hommath Formation is made up of carbonates and shale interbeds. It represents the foundation beds of the southern portion of the city where the topographic high (Fig.1).

In recent years, the assessment of landslide hazard and risk has became a topic of major interest of both geoscientists and engineering professionals as well as the communities in many parts of the world (see review of Aleotti and Chowdhury, 1999). This international interest in landslides is due to twofold: firstly, an increasing awareness of the socio-economic signature of landslides (Mora, 1995 and Fell, 1994)., secondly the increased pressure of development and urbanization on the environment (Granger, 1998). Therefore, the present study is focused to evaluate if the foundation rocks of the studied area are valid land to carry buildings on it, and if not what the solutions to avoid the problems. To achieve this work, five stratigraphic sections were measured and lithologically sampled along the studied area at El-Bavarly, El-Nakheel, Mayfair village, the second district and the first district (Figs. 1&2). The collected samples were subjected to petrographical, XRD and geotechnical investigations.

FIELD SURVEY

Five litho-stratigraphic sections representing the foundation beds along El-Shorouk City were measured (Fig. 2). The foundation bedrocks at El-Shorouk City consist of alternations of limestone and shale beds at its southern suburb (Fig. 2), and

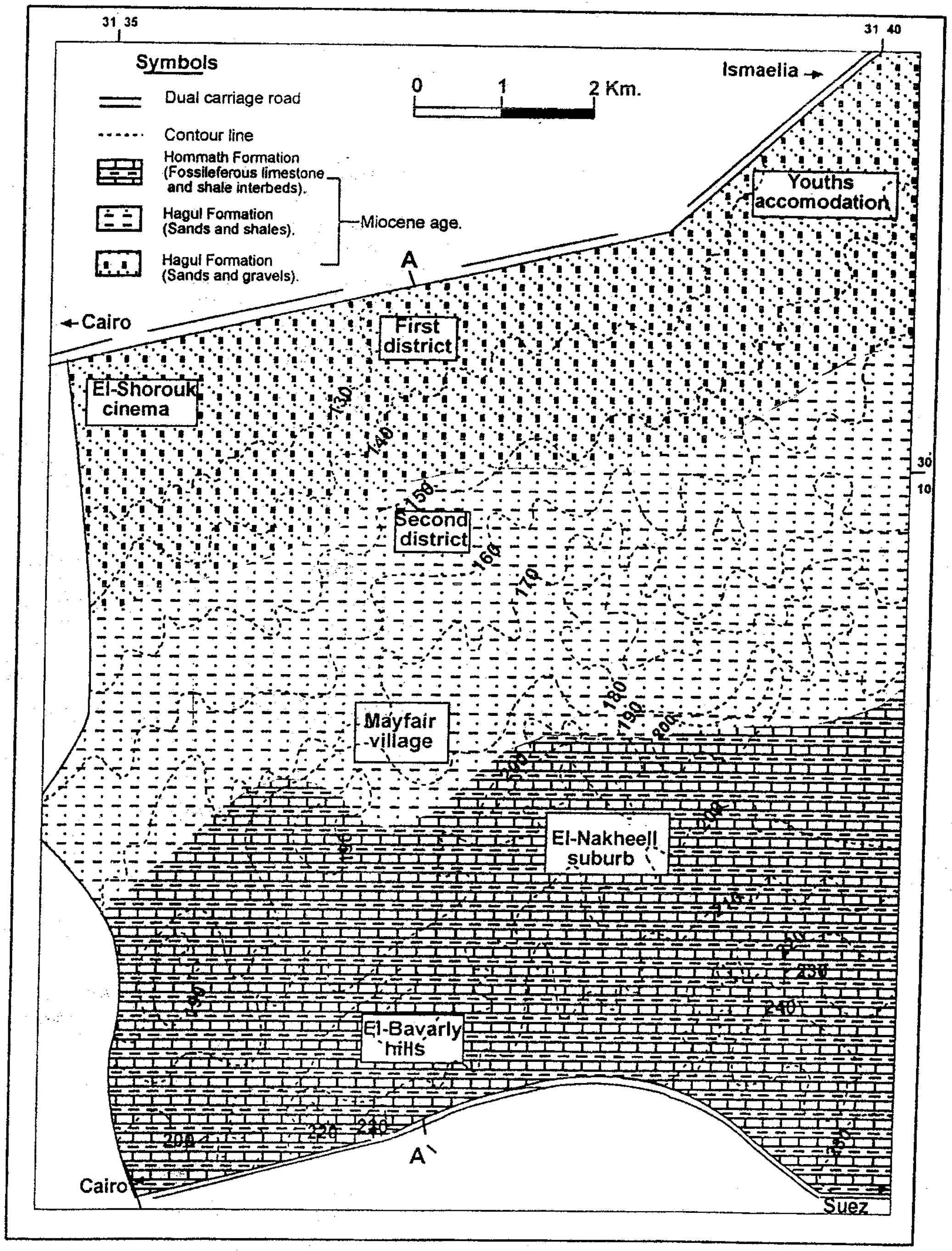

Fig. 1 Lithofacies and topographic contour map of El-Shorouk City, NE Cairo, Egypt.

loose to partly cemented sands and conglomerate bedrocks succession at its northern suburb (Fig. 2).

At El-Bavarly hills and El-Nakheel districts at the southern parts, the foundation beds are carbonate beds (Fig. 3A). These carbonates occur in an alternation with shale (Fig. 3B). They are yellowish white in colour, fossiliferous and highly fractured (Fig. 3C). The shale beds are grey in colour and fissile (Fig.3D). In the carbonate beds, the separating distance between their fractures ranging from 0.6 m to 2 m (Fig. 3C), which considered as medium discontinuity space (according to the classification of engineering geological society group working party U. K. 1977). The discontinuities are nearly vertical. The openings of discontinuities are moderately wide 6-20 cm., which filled with fine detritals. The significance of the fractures lies in the increased secondary permeability imparted to a rock mass as width increases and in the decrease instability with increasing width. The excavation of these limestones is more or less difficult, while its stability and strength ranges from fair to good. The jointed cap limestone bed is around 3 m thick followed by grey shale bed.

On the other hand, at the northern areas of El-Shorouk City where there are the first and second sector , City Council, El-Shorouk Cinema and youth accommodation, the foundation bedrock consists mainly from loose to partly cemented very fine-grained, greyish white to yellow sandstones (Fig. 3E) and red impregnated-conglomerate succession (Fig. 3F). On these foundation bedrocks, the excavation is easily (Fig. 3F) while its stability is poor and its strength is fair.

PETROGRAPHICAL INVESTIGATIONS

The petrographical investigations have been carried out to emphasize and demonstrate the different types of carbonate lithofacies. To achieve this petrographical investigation, the carbonate rocks were thin sectioned and examined under a polarizing microscope. The limestones have been classified according to Dunham's terminology (1962). However, terminology proposed by Friedman *et al.* (1992) is used to describe the dolostones. The resulted carbonate lithofacies can be illustrated as the following:-

(A)- Algal dolomitic mudstone lithofacies.

This lithofacies is recorded in the southern suburb of the studied area, and

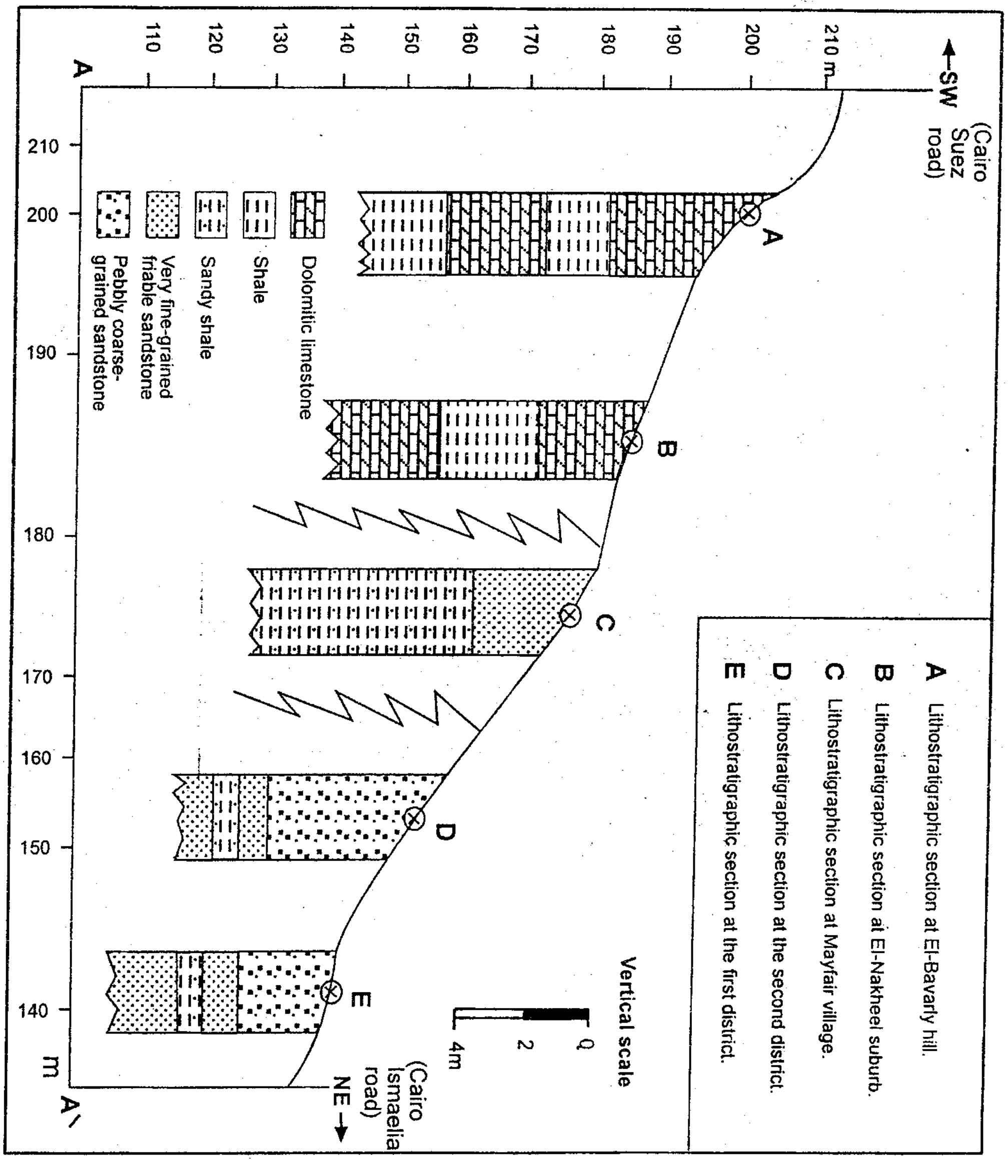

Fig. 2. Cross-section from southwest to northeast of El-Shrouk city along A –À.

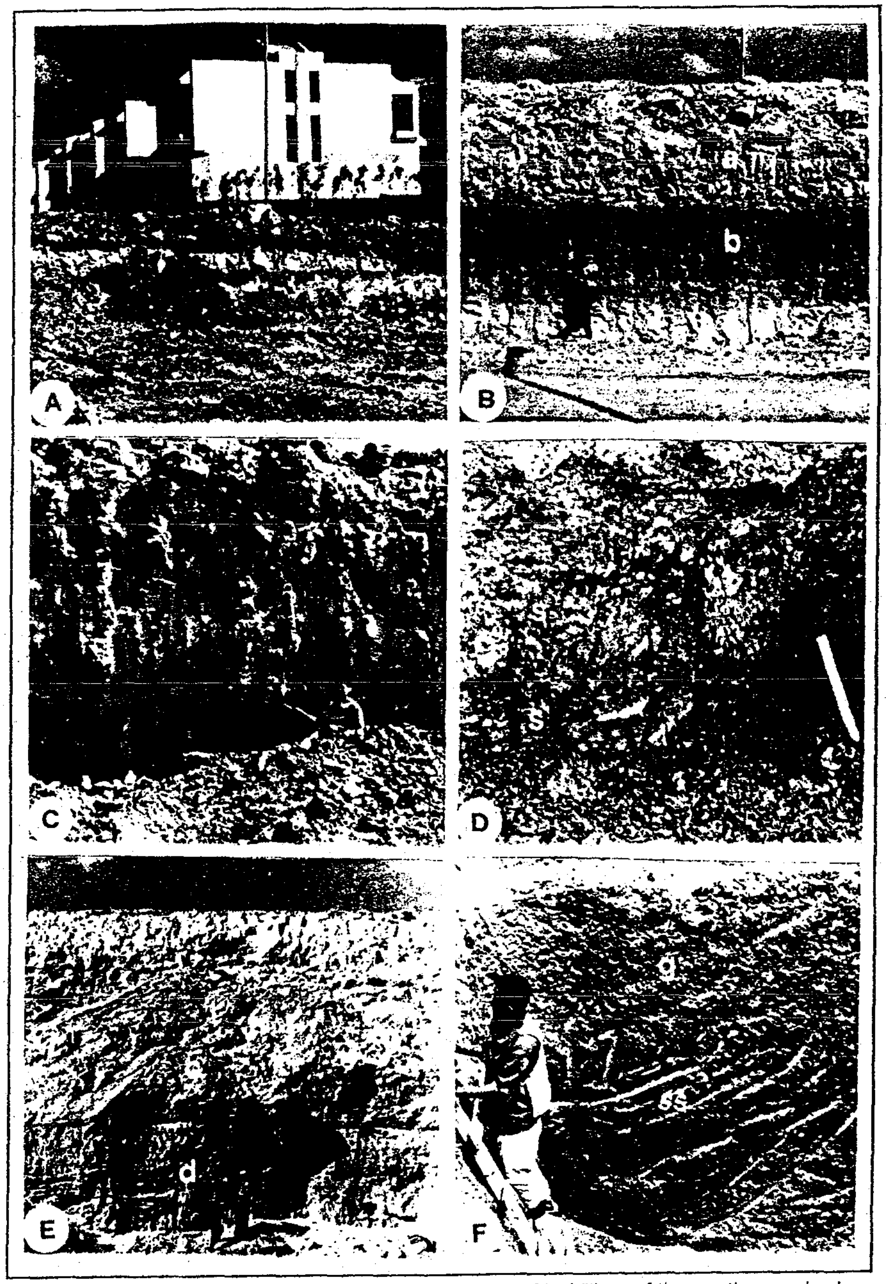

Fig. 3 : Field Photographs at El-Shorouk City showing A)- Villas of the southern suburb and their limestone foundation bed. B)- the alternating limestone (a) and shale (b) that constitute the foundation beds of the southern suburb. C)- the highly fractured limestone foundation bed at the southern suburb. D)- the occurrence of thin bands of fissile shale (s) within limestone at the sourthensuburb. E)- the foundation beds of the northern suburb that consist of friable yellow (c) and greyish white fine-grained sandstones. F)- ferrigenous pebbly sandstone (ss) and granulestone (g) that form the foundation beds of the northern suburb

occurs in an alternation with shale. It consists of micrite (70-80%) enclosing scattered dolomite rhombs (5-10%) and little amount of micritized calcareous algal fragments (<5%), (Fig. 4A). In some parts, the micrite is subjected to aggrading neomorphism forming clear patches of sparry calcite. These calcite patches show a partial dissolution leaving irregular pores (Fig. 4A). These pores contribute in the increase of porosity of the rock.

(B)- Algal dolostone lithofacies.

This lithofacies is recorded in the southern suburb of the studied area, and occurs in an alternation with shale beds. It is mainly composed of yellowish brown micro-crystalline dolomite rhombs (70-80%) and micritized algal fragments (10-15%), (Fig. 4B). The algal fragments were leached in some parts leaving pores (Fig. 4B).

(C) Dedolostone lithofacies.

It forms the carbonate beds which constitute the tops of the measured stratigraphic sections at the southern suburb of the study area (Fig. 2). It is essentially made up of 50-60% dolomite rhombs and 40-50% calcite crystals (Fig. 4C&D). Most of the dolomite rhombs are of fine to medium size (120-160 um) and have hypidotopic fabric and equigranular texture. The calcite crystals are sparry to blocky (Fig. 4C &D, respectively) enclosing relics of the host dolomite rhombs. Such occurrence of dolomite remnants within the calcite crystals is a good criterion to the prevailing of dedolomitization process (Evamy, 1967). Calcite crystals were subsequently dissolved, creating intercrystalline secondary porosity between dolomite rhombs (Fig. 4C &D).

CLAY MINERALS ANALYSIS

Selected samples of shales representing the whole area of study have been examined by using a Philips X-ray diffractometer with Cu-Kα radiation. The oriented clay fractions were prepared for XRD following the methods of Shaw (1972). XRD analyses data of the oriented clay fractions were identified according to Brindley and Brown (1980). The XRD analyses have been done in the laboratory of Dipartimento di Scienza della Terra, Universita degli Studi di Roma "La Sapienza" in Italy.

The XRD analysis data show that the clay minerals of all investigated samples are nearly the same. They are represented by kaolinite followed by smectite

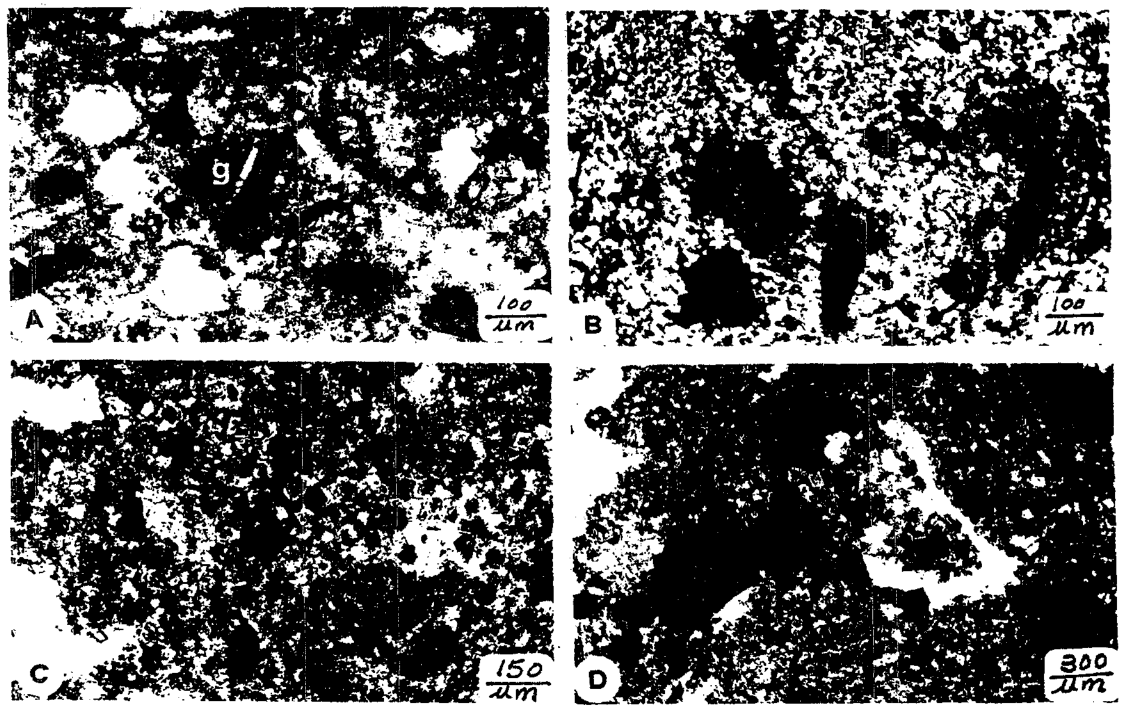

Fig. 4: Photomicrograph showing **A)**- algal dolomitic mudstone lithofacies. This lithofacies consists of micrite with clear patches of sparry calcite (white) and scattered dolomite rhombs and algal fragments (g). Notice, the sparry calcite was dissolved in some places constituting few voids (black). **B)**- algal dolostone lithofacies that is made up of dolomite rhombs and micritized algal fragments.Notice, the algal fragments exhibit a partial dissolution forming voids (black) **C)**- dedolostone lithofacies. This lithofacies composed essentially of sparry calcite (white) enclosing remanats of pre-existing dolomite rhombs. Notice, the sparry calcite was dissolved leaving intercrystalline rhombohedral pores (black). **D)**- dedolostone lithofacies consisting of blocky calcite enclosing dolomite relics. Notice, the occurrence of large voids (black) as a result of calcite dissolution.

(montmorillonite). The distribution of clay minerals in the studied samples is shown in figure (5).

GRAIN SIZE ANALYSIS

Grain-size analysis was carried out on seven samples of the loose sands that form the foundation beds representing the northern suburb of the study area (Fig. 1). This analysis has been performed using sieving technique in the laboratory of the geology department, faculty of science, Menoufia university, Egypt. This analysis has been done to know the characteristic medium diameter and sorting of the present sands. The obtained data of such analysis are listed in table (1). The resultant values indicate that the studied samples are of moderately to poorly sorted and have grain size fall within the range of fine to very fine-grained sands.

GEOTECNICAL PROPERTIES OF LIMESTONE FOUNDATIONS

To understand the behaviour of limestone foundations in El-Shorouk New City, laboratory analysis was done to investigate its capability of rationing water, its porosity, and if there is any change in its strength when wetted. Specimen preparation and testing were performed at the Rock Mechanics Laboratory of Menoufia University in Egypt. Unconfined compressive strength was determined for twelve samples (as cubes 4 cm side length) using ASTM-D-3148, 1980. Compressive strength is the load per unit area under which a block fails by shear or splitting. The compressive strength is a very important parameter in rock mechanics and it is related to porosity, mean grain size and elastic modulus of the rocks (Hatzor and Palchik, 1997; Palchik, 1999 and Palchik and Hatzor, 2000). Rock strength is unconfined near the earth surface, also on buildings.

To see if there is any change of limestone strength when wet, dry and wet test was carried out. Two cubes from the same sample, one of them was dried at 105° C for 24 hours and subjected to loads till failure (dry test). On the other hand, the second cube subjected to loads till failure after immersion in distilled water in 20° C for 48 hours (wet test). The unconfined compressive strength for the samples under investigation as dry test ranges from 85 to 180 Kg/cm^2 , while it ranges from 60-136 Kg/cm^2 in wet test (Table 2). From these results, it may be concluded that limestones

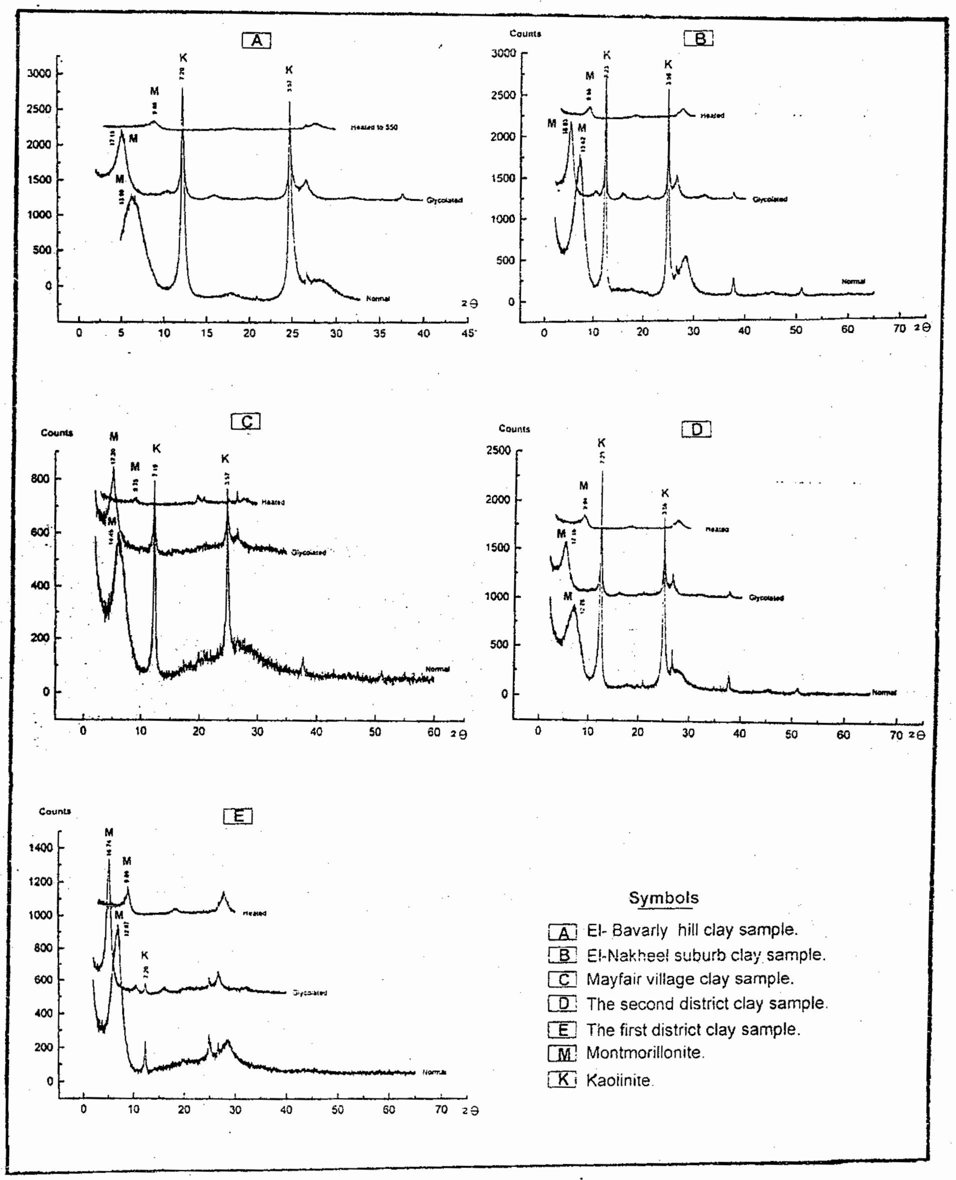

Fig.5. X-ray diffraction patterns of oriented clay-sized fractions of representative claystone samples from the studied rocks along El-Shorouk city.

Table (1): Grain size analysis data of sand samples of El-Shorouq Foundation beds.

Clast Name	Clasts Diameter (mm)	C_1 (Wt%)	C_2 (Wt%)	C_3 (Wt%)	D_1 (Wt%)	D_2 (Wt%)	E_1 (Wt%)	E_2 (Wt%)
granules	4 – 2	0.000	0.351	1.023	1.782	1.789	1.196	17.298
Very coarse sands	2 – 1	2.056	5.507	4.422	18.609	19.732	5.635	14.765
Coarse sands	1 – 0 .5	5.055	0.463	2.594	30.612	19.133	20.940	17.332
Medium sands	0.5 – 0.25	8.400	1.312	14.361	26.099	31.293	31.310	25.374
Fine sands	0.25 – 0.125	16.060	43:144	21.702	10.873	18.106	33.074	15.214
Very fine sands	0.125 – 0.625	67.760	49.003	55.019	1.696	8.052	6.687	6.490
silt and clay	< 0.625	1.345	0.219	0.892	0.334	1.933	1.148	3.535

C_1, C_2 and C_3 = Samples of the foundation beds of Mayfair village.

D_1 and D_2 = Samples of the foundation beds of the second district.

E_1 and E_2 = Samples of the foundation beds of the first district.

Table (2). Unconfined compressive strength of limestone samples collected from El-Shorouk foundation beds at dry test and after soaking in tap and sewage water for 48 hours.

Sample No.	Dry test, (Kg/cm^2)	Tap water, (Kg/cm2)	Sewage water, (Kg/cm2)
1	85	50	37
2	156	90	83
3	91	54	43
4	180	87	85
5	93	56	47
6	136	79	62

strength remarkably changes when wet. According to Hawakes and Melbr (1970), there limestones can be considered as weak ones.

Effective porosity was determined for the same twelve samples using Amyx, 1960 and Dakhnova, 1982 methods. Effective porosity for the investigated samples ranges from 13 to 28 % (Table 3).

Water absorption capacity was carried out for the same twelve samples using ASTM, 1958 method. It defined as rock water saturation after soaking in distilled water at 20° C for 48 hours expressed in percentage. The water absorption capacity for the samples under investigation ranges for 7.5 to 13.5 % (Table 3). According to Winkler (1973), the limestones can be considered as low density ones.

HYDROCHEMICAL ANALYSIS

Laboratory analysis was carried out to detect if there are any depositional soluble salts content at El-Shorouk foundation bedrock. Extracted solutions of eleven rock samples collected from limestone and shale foundation (using Rhoades method, 1982) as well as tap and sewage waters have been hydrochemically analysed. Depositional soluble salts could mobilized, especially sodium chloride, if subjected to moisture (Pigot and Helal, 1988). The mobilization of depositional soluble salts content lead to increasing rock porosity and accordingly decreasing its strength. They also create salt weathering processes as act as corrosive solutions. The results of the hydrochemical analysis are listed in table (4).

From table (4), it can be noticed that the depositional soluble salts are present in the foundation bedrock in considerable quantities. The electrical conductivity (E.C.) of extracted solutions of rock samples ranges from 0.9 to 2.3 mmoh/cm^{-3} while the total dissolved salts (T.D.S.) range from 1077 to 2129ppm. The dominant cation is sodium while the dominant anion are chlorides and sulphates. On the other hand, the electrical conductivity of tap water is 0.6 mmhos/cm and its T.D.S. are 1003 ppm. The dominant cation is sodium while the dominant anion is sulphate. The E.C. of sewage water is 38 mmhos/cm while its T.D.S. reaches up to 33255. The dominant cation is sodium while the dominant anion is sulphate.

Table (3). **Effective porosity, water absorption capacity and wet and dry test for limestone rock samples collected from El-Shorouk New City.**

Sample No.	Effective porosity Qe %	Water absorption Wa %	Uncompressive strength Dry test	Uncompressive strength Wet rest
1	26	11.5	85	67
2	16	10.1	156	126
3	28	13.2	91	60
4	13	7.9	180	136
5	23	12.9	93	69
6	17	7.5	136	109

Table (4). Hydrochemical analysis of extracted solutions of the rock samples collected from El-Shorouk foundation beds as well as tap and sewage water.

Sample No.	Sample type	E. C.	T.D.S.	Na	K	Ca	Mg	Cl	SO4	HCO3
1	Limestone	2.20	1786	320	43	56	43	654	538	132
2	Limestone	1.30	1108	230	16	40	26	380	290	126
3	Limestone	1.50	1217	260	35	42	55	410	320	95
4	Limestone	0.90	1077	216	12	35	10	435	326	43
5	Limestone	1.60	1567	311	45	61	42	560	490	58
6	Limestone	1.70	1513	302	51	69	40	570	420	61
7	Shale	2.10	2031	370	75	85	22	730	550	19
8	Shale	2.30	2129	384	82	94	50	823	671	25
9	Shale	1.90	1725	329	72	59	33	691	519	22
10	Shale	2.00	1706	296	72	63	52	670	530	23
11	Tap water	0.60	1003	164	31	93	13	184	502	17
12	Sewage	38.00	33255	5361	417	1576	354	3243	19532	11961

E. C. = **Electrical conductivity.**
T.D.S. = **Total dissolved salts.**

EXPERIMENTAL STUDY OF DOMESTIC WATER EFFECTS ON BEDROCK FOUNDATIONS.

To investigate the probability of recession to occur in the El-Shorouk proposed site due to the influence of domestic water; experimental test was designed. To detect if there is any change of the geotechnical properties of the limestones especially its compressive strength; limestone cube samples (4 cm length side) were subjected to different types of natural waters (tap and sewage waters), and determine their strength after soaking for 48 hours. The results are shown in table (2). From these results, it is noticed that there is a remarkably decrease of limestone strength after immersion on natural water. Limestones lose about 40% of their strength after soaking in tap water from 48 hours, while they lose more than half of their strength after immersion in sewage water for the same period.

SUBSURFACE WATER IN ROCK AND SOIL

Background: According to Beavis (1985); in any rock or soil mass, however, the water is in a dynamic condition of movement. Subsurface water has to be studied in terms of civil engineering works e. g., the leakage of domestic water in rock and soil masses its seepage in slopes. The dominant geological factor controlling the permeability of both soil and rocks is the fabric, both in the microscopic and macroscopic scales. At the simplest level, this can be demonstrated for a soil by comparing the permeability of an undisturbed sample, and a remoulded sample of the same soil. Remoulding alters the fabric, and effectively varies the permeability, in most soils, a reduction in permeability occurs with remoulding. For both rocks and soils, while porosity is essential for flow of water, it is the pore fabric rather than the absolute volume of pore space which will determine permeability. It is necessary for the pores to be of sufficient size and to be interconnected for flow to occur. Thus silty sand is more permeable than clay. Fissured clays with a similar porosity to homogeneous clays, have a coefficient of permeability 1000 times greater. In rocks, it has been established for sandstones and limestones that a linear relationship exists between porosity and permeability. In rocks, permeability parallel to bedding was almost invariably greater than that normal to the bedding, sometimes by a factor of over 20.

The effect of urbanization in building foundations: Urbanization leads to leakage of domestic water (Tap, sewage and garden over-irregation waters) which infiltrate through building foundations. Leakage water is considered as a problem or nuisance. The introduction of this new artificial hydrological factor resulted in a severe disturbance of the morphological balance in the desert landscape. Any permeable rock or soil will be subjected to flow of seepage water. These add to the difficulties of construction. Seepage water could cause structural damage to building foundations, and also contributes to the instability of slopes. The instability of slopes occurs due to the development of high pore-water pressure, the shearing resistance of the soil constituting a slope may be reduced to a level below the shear stresses, acting on the soil. In such a case, failure occur.

The leakage water could convert the limestone foundation through karstification processes to a rock sieve or better to a stone sponge.

MECHANISM OF PREDICTED RECESSION.

There are several criteria and observations point out of predicted recession in the new desert town El-Shorouk. The climate is almost arid nearly all the year. As we see before in the 15^{th} of May new city and El-Tob El-Ramly district, there is a severe response of a desert landscape to a relatively weak artificial hydrological change. El-Shorouk desert town can be considered as a an acute case. A predicted excessive amount of domestic water will be leaked from the swimming pools and over-irrigation big gardens as well as from unavoidable leakage from both top and sewage networks.

From field observations point of view, firstly, the special geomorphological nature of the desert town; steep slopes hilly, locally rolling high topography southern suburb and low lying flat areas northern suburb with difference of elevations between them reaches up to 100 m (Fig.1). Secondly, the high topography steep slope hilly southern suburb will occupied by Villas with accelerate the predicted recession. The introduction of this new artificial hydrological factor will result in a severe disturbance of the geomorphological balance in the desert landscape. Thirdly, the alterations of limestone and shale strata at the southern suburb, well-fractured, closely-jointed limestone will allow infiltration of domestic water to the underneath shale which will

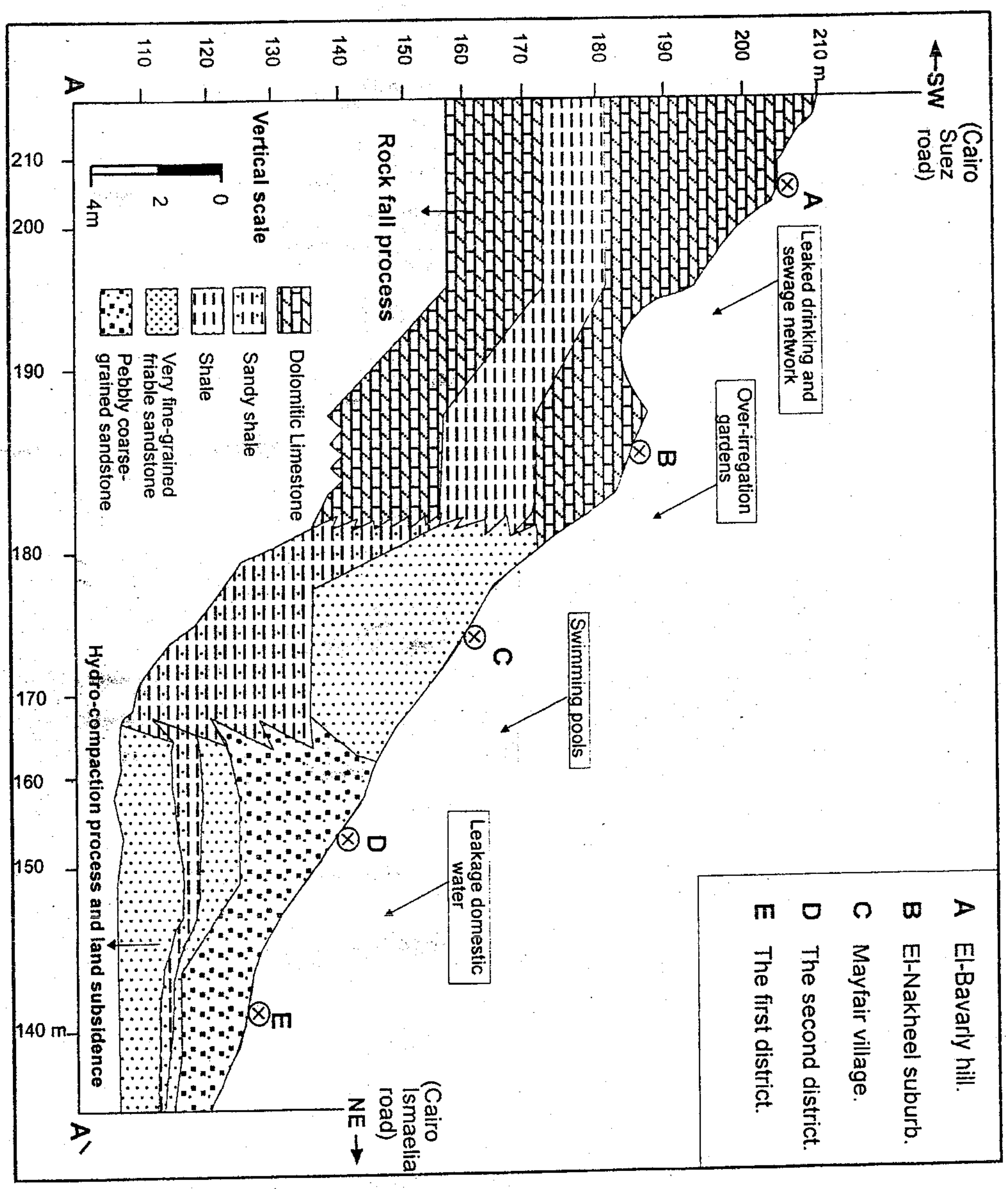

Fig. 6. Sketch diagram illustrating the predicted recession in El-Shorouk city.

swell when wet and act as a lubricating oil. As a result, slides will generate. Fourthly, the friable, unstratified and poorly cemented, fine-grained sands may be hydrocompacted when wet by domestic water infiltrate underneath from overlying buildings as well from highly topographic southern suburb. The criteria raised from lab. analysis are: Firstly, the limestone foundations at the southern suburb are highly fractured, porous, with high capacity of retaining water, low density, weak ones. Furthermore, the dolostone foundation beds were subjected to dedolomitization process forming sparry to blocky calcite which ,in turn, are easily to dissolve leaving pores. These behaviours of the limestones and dolostones will act as passages for infiltration of domestic water to underneath, substrata. Furthermore, their strength remarkably decrease when soaked in different types of domestic water. Secondly, the mineralogical investigation of shales substrata which dominant in southern suburb shows that it contain smectite (montmorillonite) mineral that highly potential of swelling when wet (Slade *et al.*, 1991). Moreover, the smectite dehydration by the overburden weight leads to land subsidence (Liu *et al.*, 2001). Accordingly, the shales will act as sliding faces for the overlying strata. Thirdly, the depositional soluble salts represented in the substrata of the desert town in considerable amounts which when re-dissolve will act on two severe folds; create more spaces which will further weaken the substrata; and will act as corrosive solutions which will attack structure foundations. Fourthly, from grain size analysis of loose, friable sands which form the low-lying northern suburb areas, it can be concluded that the fine-grained sands have high sussestibility of subsidence when wet.

The sinareo of predicted recession (Fig. 6) could begin if leakage of excessive domestic water at the steep slope hilly southern suburb into the well-fractured, highly porous limestones substrata. The relatively sudden increases in pore water and rapid reduction in cohesion will reduce friction along fractures of limestones and change the consolidation characteristics (create swelling) of the underlined shale. As a result slides may be generated. Continued introduction of domestic water caused fluctuation in the pore water pressure which enhancing progressive sliding. The rocks can not be remain stable under conditions of high water content. The swelling of underlain shales results in the development of tension fractures in the overlying limestones. These fractures are widened further till landslides occur. On the other hand, the loose fine-grained sands substrata at the northern suburb may subside when wet. The sources of domestic water may come from the overlying structures and/or from northern suburb.

SUMMARY AND CONCLUTIONS

The present work is directed to predict whether there is land recession in the foundation beds of El-Shorouk New City, NE Cairo, Egypt. These foundation beds are made up of carbonate, shale and siliciclastic rocks. The carbonate and shale beds form the foundation beds of the southern suburb of the city, whereas the siliciclastic rocks constitute the foundation beds of the northern suburb.

To evaluate this prediction, different analyses have been done on the representative rock samples. These are : effective porosity, compressive strength, petrographical, grain size and X-ray diffraction analyses. From these analyses, it was found that there are many rock characteristics which will act as factors to facilitate land recession of the site. These characters represent by the occurrence of 1) fractured, porous and low density carbonate rocks. 2)- loose fine-grained sandstone 3)- smectitic composition of shales.

A predicted land recession hazard at El-Shorouk city foundation beds may happen due to domestic seepage water from over-irrigation of the high-land villas big gardens as well as from leakage of their swimming pools. To avoid such predicted land recession, domestic water seepage control measurements should be taken into consideration by the responsible authorities.

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