Military Technical College

Kobry El-Kobbah,

Cairo, Egypt

12th International Conference on Civil and Architecture Engineering

ICCAE-12-2018

Using the Electromagnetic Fields to observe and monitor Rock Foundation Stability at Quarter 27th City of 15th of May, Cairo, Egypt

M.A. Atya[1], O.H. Hachay[2], O.Y. Hachay[3], El-Said A. A. Ragab[1]

[1] National Research Inst. of Astronomy & Geophysics, Helwan, Egypt.
[2] Geophysical Institute, Ural Branch, Ekaterinburg, Russia.
[3] Ural State University, Ekaterinburg, Russia.

Abstract

The site of investigation belongs to the new societies that been established on the outer extensions of the city of greater Cairo, and namely the city of 15th May City. It had been built on Eocene limestone intercalated with thin beds of clay and very thin beds of salt (Morsi at al., 2003). Generally, the Eocene limestone sediments in Egypt are characterized with karstification resulting in fractures, cracks, cavities, and land subsidence. Consequently, short after the city get in use; the city started to suffer deformations that could be evidenced on the paved roads, the successive landfalls of the foundation grounds, the water accumulation through the fissures to form swamps, and the divergence of the dwelling's blocks. Therefore; an extensive study had been conducted in cooperation of the IGF UB RAS (Geophysical Institute Federal, Ural Branch of Russian Academy of Science) and NRIAG (National Research Institute of Astronomy and Geophysics) to investigate and monitor the state stability of the foundation in a pilot area "Quarter 27", five cycles of field observations (2008, 2010, 2011, 2012, and 2013) had been acquired along profiles crossing and intersecting the Quarter dwellings.

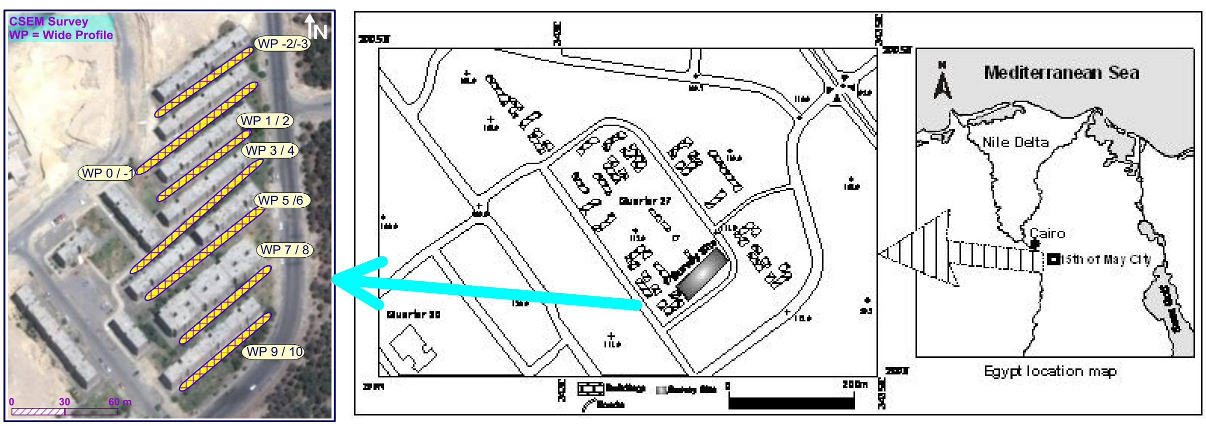
The analytical screening and mapping of the rock massive structure approaches to critical trends with meaningful impacts to the factor "safe" in the engineering geophysics and mining. The present work proposed the rock massive at its optimum state at the top of a ranged hierarchic structure model; and the rock massive at its present state represents a rank of disintegration or level of deformation of second grade that can be observed by electromagnetic techniques (Panin et al 1985, Sadovskiy et al 1987, Goldin 2002).

In 2003, a new technique had been approached to reveal the disintegration zones in rocks of different content (Hachay et al, 2003), it involves the application of Control Source of Electromagnetic "CSEM" to image the ranked deformation levels in the massive structure. It had been devoted on monitoring a complicated engineering case at the city of 15th May, Helwan. The monitoring data had been acquired over 4 measuring cycles 2008, 2010, 2011, and 2012. The processing developed passed through several phases and conceptual proposal related to the site

nature and the system of observation. The analytical treatments of the data cycles provided information about the rock massive structure and its rank of disintegration, the lateral distribution of the geotechnical heterogeneity, and finally a conclusive outcome about the foundation stability.

Introduction

The site of investigation belong to the new societies that had been established on the outer extensions of the city of greater Cairo, and namely on the city of 15th May City (Fig. 1). It had been built on Eocene limestone intercalated with thin beds of clay and very thin beds of salt (Morsi at al., 2003). Generally, the Eocene limestone sediments in Egypt are characterized with karstification resulting in fractures, cracks, cavities, and land subsidence. Consequently, short after the city get in use; the city started to suffer deformations that could be evidenced on the paved roads, the successive landfalls of the foundation grounds, the water accumulation through the fissures to form swamps, and the divergence of the dwelling's blocks (Fig. 2). Therefore; an extensive study had been conducted in cooperation of the IGF UB RAS (Geophysical Institute Federal, Ural Branch of Russian Academy of Science) and NRIAG (National Research Institute of Astronomy and Geophysics) to investigate and monitor the state stability of the foundation in a pilot area "Quarter 27", five cycles of field observations (2008, 2010, 2011, 2012, and 2013) had been acquired along profiles crossing and intersecting the Quarter dwellings.



1

Fig. 1: Location map showing the City of 15th of May and Quarter 27 "pilot area".

The analytical screening and mapping of the rock massive structure approaches to critical trends with meaningful impacts to the factor "safe" in the engineering geophysics and mining. The present work proposed the rock massive at its optimum state at the top of a ranged hierarchic structure model; and the rock massive at its present state represents a rank of disintegration or level of deformation of second grade that can be observed by electromagnetic techniques (Panin et al 1985, Sadovskiy et al 1987, Godin 2002).

Fig. 2: Photograph for some deformation appearances as a result of foundation instability.

In 2003, a new technique had been approached to reveal the disintegration zones in rocks of different content (Hachay et al, 2003), it involves the application of Control Source of Electromagnetic "CSEM" to image the ranked deformation levels in the massive structure. It had been devoted on monitoring a complicated engineering case at the city of 15th May, Helwan. The monitoring data had been acquired over 4 measuring cycles 2008, 2010, 2011, and 2012. The processing developed passed through several phases and conceptual proposal related to the site nature and the system of observation. The analytical treatments of the data cycles provided information about the rock massive structure and its rank of disintegration, the lateral distribution of the geotechnical heterogeneity, and finally a conclusive outcome about the foundation stability.

Conceptual Models and Theory

The present approach proposes the rock massive structure at its optimum state as the tiptop of a conceptual ranged hierarchic structure model, this forms the key point to investigate the inner state dynamics and the self organized system associated to the massive structure which could be observed considering the geophysical methods by Hachay (2005) and the modern conceptual geological medium model introduced by Panin 1985, Sadovskiy 1987, Nikolis 1989, and Goldin 2002. The block-hierarchic structure is the result of the destruction processes. Applying an external mechanical stress will influence the initial inner structure forming the hierarchic structural deformation levels, which can be indicated by geophysical fields. The embedded heterogeneities of the smaller rank and the block dimensions in the discrete piece-heterogeneous block medium model are named as heterogeneities of the second rank (heterogeneities can be named as heterogeneities of the next rank depending upon research scale). Applying external induction electromagnetic field with many frequencies and arrays using control source and the elaborated processing and interpretation technologies (Hachay 2003) allows revealing the disintegration zones, which indicate the rock stability. The objects of electromagnetic monitoring of geological medium state are heterogeneities of the second rank, which appear and change during the variations of external influence. In the Institute of geophysics UB RAS a new method was established to monitor the massive state, which allows classifying the rock massive by its degree of stability so that high energetic artificial influences can be estimated. In the frame of natural research, we can identify the geo-electrical heterogeneities of the second rank and achieve the objective of monitoring. They are defined by interpretation of the ratio of two horizontal components of the measured module of the magnetic field on fixed frequencies on different space points, i.e..

$$\delta = \frac{|H_\varphi|}{|H_\gamma|} * 100\% \qquad (1)$$

Applying the approaches interpreting the space-frequency distribution of the average parameter (1) (Hachay 2004, 2005) provides two elaborated integral parameters; the interval distribution of the intensity of the disintegration zones ($S_{Interval}$), and integral distribution of the intensity of the disintegration zones ($S_{Integral}$). The first provides information about the crack's activity which in turn indicates qualitatively the stability level of the rock massive, and the second helps to classify the massive stability in terms of numerical criterions using the synergetic theory approaches (Hachay 2004). The following equation is used to estimate the parameters:

$$S_{Interval}\ (N,T,\omega) = \sum_{i\ (N)} \widetilde{M}_0^i\ (\omega,T) \qquad (2)$$

$$S_{Integral}\ (L,T,\omega) = \sum_{1}^{L} S_l\ interval\ (N,T,\omega) \qquad (3)$$

Where $\tilde{M}$ the intensity of the disintegration zone, N is is the number of disintegration zones inside one interval, L total number of intervals, and ω is circle frequency of observation, T is time in years of a cycle of monitoring, $\boldsymbol{S_{integral}}$ in conventional units. This technique had been provided in the deep mines of bauxite and magnetite (up to 800 m depth); in which, the prediction and defining of the instable localities inside the mines and the forecasting of the energetic dynamic events were definitely right and approved. Furthermore; this procedure had been applied to estimate the geoelectrical and geomechanical state at habitant region in Cairo with multilevel appearances of instable features. The system of observation, method of processing and interpretation had been detailed in Atya et al. (2010).

System of Observations

The CSEM data collection is a measure of the geoelectrical parameters of a medium, through which the electromagnetic waves are to be injected into the ground via control source EM field generator and the three components of the magnetic field are to be recorded; details about the concept of data acquiring is given in Atya 2010. The Wide Profile System of Observation (Fig. 4) had been used to acquire the data at the area along the lines on the map (Fig. 1). It is a procedure employed to measure the electromagnetic response over a volume "block", therefore, it may be called volume CSEM.

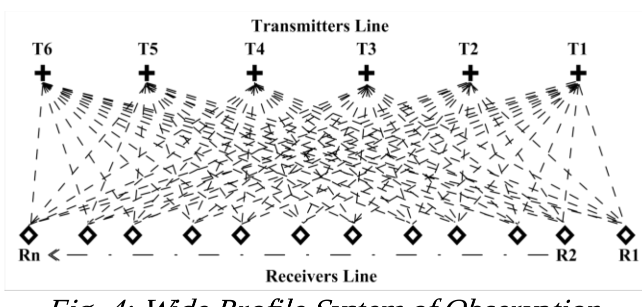


Fig. 4: Wide Profile System of Observation.

Discussions and Conclusions

The monitoring data has been analyzed after each survey cycle. For each profile, two values have been calculated; the first is the lateral heterogeneity's distribution of the average geoelectrical parameters, and the second is the distribution of resistivity along the geoelectrical cross section. They give indications for the conductivity's 2D distributions and for crack's existence, depths and densities (Atya et al., 2010). In the next step of the interpretation, we estimated the geoelectrical parameters for all depth intervals in the whole block layered half space of the massive for all profiles over the monitoring cycles and the distributions of the geomechanical and the geotechnical parameters ($S_{Integral}$ and $S_{Interval}$) driven from equations (2) and (3). Figure 5 shows the distribution of integral intensity of the cracks in the block layered half space for the area. Figure 6 shows the distribution of integral intensity of cracks of the block layered half space for the WP 5/6 (as a example).

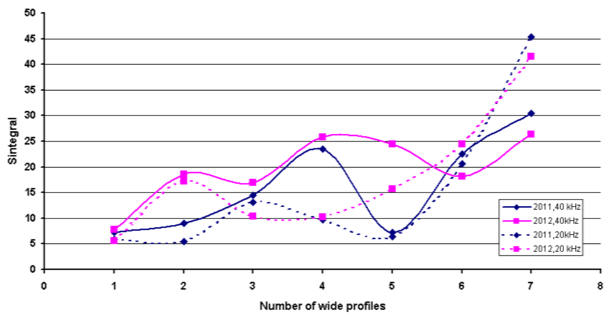


Fig. 5: Distribution of integral intensity of cracks of the block layered half space for sub parallel wide profiles, CSEM monitoring data.

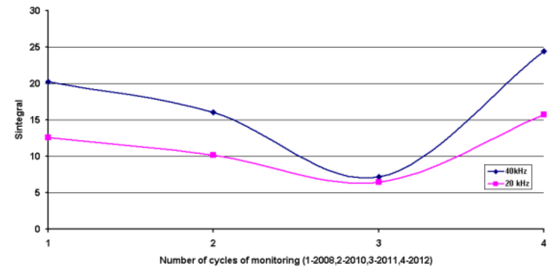


Fig. 6: Distribution of integral intensity of cracks of the block layered half space for the WP 5/6.

.

It could be concluded that the general dynamic state at the area is getting worse over the time, this is reflected in the crack's intensities and positions, also on the changes in the lateral distribution of the geoelectrical heterogeneity as indicator for water saturation. Analyzing the geomechanical and geotechnical parameters could clearly evince that, the profiles WP 3/4 and WP 5/5 (which correspond to the pass of two major faults in the site), represent a case of high change in the geotechnical parameters; this in turn could be interpreted as the fault's passage points to a general deformation case of instability close to destruction level as the northern flank at profiles WP 0/-1 and WP -2/-3 and the southern flank at WP 9/10 show relative stability. So that it is recommended to continue monitoring the massive structure beneath it.

Acknowledgements

The work had been done in the frame of the Twin Agreement between the National Research Institute of Astronomy and Geophysics (NRIAG) of Egypt and the Federal Institute of Geophysics (IGF), UB RAS together with the Ural Federal University. The institutions supported the work with researchers and equipments. The last two cycles of monitoring had been done under the research project ID: 2989 financed by the Science and Technology Development Fund (STDF).

References

[1] Goldin S.V., 2002: Destruction of lithosphere and physical mesomechanics. Physical mesomechanics V.5,N5 (in Russian).
[2] Hachay O.A., Novgorodova E.N., Hachay O.Yu., 2003: A new method for revealing disintegration zones in rocks of different content. Rock information and analytical bulletin, 11; 26-29 (in Russian).

[3] Hachay. O.A., 2004: The events of selforganization in the rock massiv under man-caused influence. // Physical mesomechanics 7, Spec.issue, P.2., 2004, p.292–295(in Russian).

[4] Hachay O.A., 2005: Research of self organization in hierarchic structures using data of space time monitoring rock shock massive. Russian geophysical Journal, 37-38: 24-28 (in Russian)..

[5] Magdy A. Atya Olga A. Khachay, Mamdouh M. Soliman, Oleg Y. Khachay, Ahmed B. Khalill, Mahmoud Gaballah, Fathy F.Shaaban, Ibrahim A.El. Hemali., 2010: CSEM imaging of the near surface dynamics and its impact for foundation stability at quarter 27,15-th of May City, Helwan, Egypt. // Earth sciences research journal, Vol.14, N1, p.76-87.

[6] Morsi, A.M., Speijer, R.P. (2003): High-resolution ostracode records of the Paleocene-/Eocene transition in the South Eastern Desert of Egypt - taxonomy, biostratigraphy, paleoecology and paleobiogeography. Senckenbergiana lethaea, 83, 61-93 (in Russian)..

[7] Nikolis D., 1989: Dynamics of hierarchic systems. The evolutional conception . Moscow MIR (in Russian.

[8] Panin V.E., Lichatchev V.A., Grinjaev Yu.V., 1985: Structure deformation levels of elastic bodies. Novosibirsk SB AN USSR Nauka (in Russian).

[9] Sadovskiy M.A., Bolchovitinov L.G., Pisarenko V.F., 1987: Deformation of geophysical medium and seismic process. Nauka, Moscow. In Russian.