Assessing subsurface strata using geophysical and geotechnical methods for designing structures near ground cracks.

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I- Abstract

This research presents a combined approach using both geophysical and geotechnical techniques to study and evaluate the subsurface strata near ground for sites suffering from faults and cracks. It demonstrates how both techniques can be utilized to gather useful information for design geotechnical engineers. The safe distance for construction close to a ground crack is mainly dependant on the subsurface stratification and the engineering properties of underlying soils or rocks. Other factors include the area geology and concepts of safety margins. This study is carried out for a site in Al-Qassim region, Saudi Arabia. This type of faults and cracks can normally occur due to a geological or physical event or due to the nature and properties of the subsurface material. The geotechnical works included advancing rotary boreholes to depths of 25m to 31m with sampling and testing. The geophysical method used included performing 2D electrical resistivity profiles. The results of geophysical and geotechnical works showed good and close agreement. The use of 2D electrical resistivity was found useful to establish the layer thicknesses of shale and highly plastic clay. This cannot be determined without deep and expensive direct boring investigation. The results showed that a thick layer of expansive soil, which is considered a high-risk soil type containing large percentage of highly plastic clay materials, underlies the site. The volume changes due to humidity variations can result in either swelling or shrinking. These changes can have significant impact on engineering structures such as light buildings and roads. The logic of placing structures in close vicinity of the cracks is based on lateral stresses exerted on the crack face. The layer thickness is a detrimental factor to establish a safe design distance. Stress distribution analysis procedure is explained.

II- Study Location

The study area is located in the modern sediments of the Quaternary Formation above the Sudair formation, estimated age of early Triassic age. The Sudair formation consists of shale, silt, clay and variable sized stone, colored red to green with peppers and layers of siltstone and sometimes dolomite. The bottom of this shale is a limestone layer, which unfolds western region. Also the region contains active sand deposits brushes, and other deposits of gravel which are not active.

Satellite image showing the location of the study area and the agricultural activity surrounding the region.

Satellite image showing the location of the 2D electrical resistivity profiles and test drilling points at the study area.

III- Introduction

Faults and cracks are located in a residential and occupied areas of a relatively low topography compared to the surrounding region. Cracks phenomenon appeared as parallel, sequential and zigzagging taking an east-west direction. It was noticed that most of the faults and cracks appeared in the upper clay layer with varying thicknesses. The faults width measured in an order of more than 60 cm and narrow and fade in some places, while a main fault noticed continuing along more than 45 m length and visible down to 1 m depth. The effects of these cracks on buildings appeared in the form of ground and wall cracks, vertical and horizontal distortion and shape tilt. The most affected structures, mostly located along the cracks zone included residential houses and a girls high school. It was observed that these cracks were limited to the walls and did not show any cracks within the concrete structural elements.

This part provides general information about the phenomenon of faults which lead to the cracks in the surface of the earth's crust. The cause of these phenomena can be divided into two types: (1) **human interference** (man-made) and has a direct impact on the formation of terrestrial. (2) **Natural** .

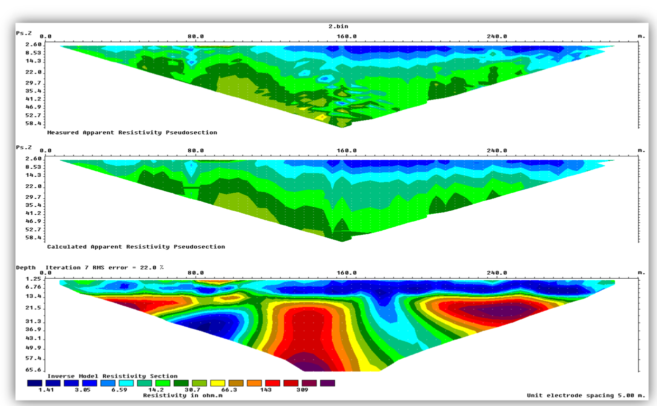
Man-made activities could cause ground cracks, for example removal of large block of the earth, excavation and blasting activities, withdrawal or pumping ground water and oil.

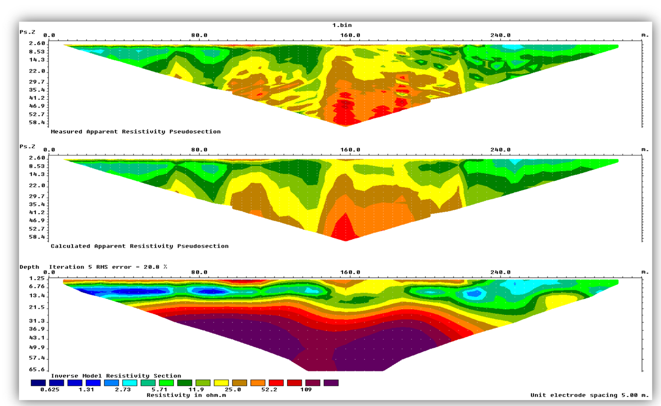
Cracks resulting from the impact of nature can take two forms: the first is directly linked to tectonic activity and the second is linked to melting and decomposition of soil chemically or physically when exposed to water.

IV- Methods of analysis:

1- 2D Electrical Resistivity Imaging

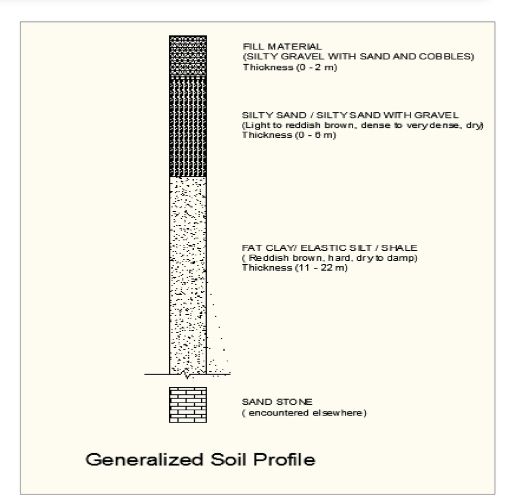
The 2D electrical resistivity data has been acquired along different profiles in the most probable cracks affected areas inside the site, using multi-electrode system of SYSCAL pro. Wenner-Schlumberger array has been utilized and the unite electrode spacing was 3 meters along all the acquired profiles. The use of 2D electrical resistivity was found useful to establish the layer thicknesses of shale and highly plastic clay. This cannot be determined without deep and expensive direct boring investigation. The results showed that a thick layer of expansive soil, which is considered a high-risk soil type containing large percentage of highly plastic clay materials, underlies the site.





2- Geotechnical Methods :

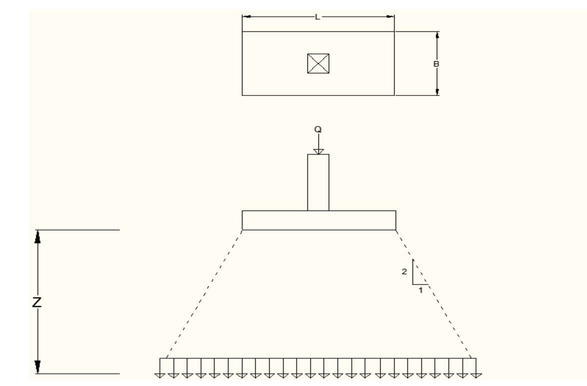
The geotechnical field works advanced four boreholes located within the cracks affected areas.The Mobile B-53 drilling was used. The depth of these boreholes ranges from 25 meters to 31.5 meters below the natural ground level, Four open test pits were also excavated. have been done on the site.



A model shows a profile of the soil layers in the study area.

V- Results and Guides

The results showed that a thick layer of expansive soil, which is considered a high-risk soil type containing large percentage of highly plastic clay materials, underlies the site. The volume changes due to humidity variations can result in either swelling or shrinking. These changes can have significant impact on engineering structures such as light buildings and roads. The logic of placing structures in close vicinity of the cracks is based on lateral stresses exerted on the crack face. The layer thickness is a detrimental factor to establish a safe design distance. Stress distribution analysis procedure is explained.



Conventional method to determine the stress distribution beneath the footing

Alternatively Boussinesq's equation (1883) can be used. This considers a point load on a semi-infinite, homogenous, isotropic, weightless, elastic half-space to obtain the increase of the stresses.

$$q_v = \frac{3Q}{2\pi z^2} * \frac{1}{\left[1+(r/z)^2\right]^{5/2}}$$

VI- Conclusions and Recommendations

- Based on the results of this study and the nature of the risks associated with this site which include:

1- The behavior of the soil and the high volume change can uplift the light single-storey buildings or any structure exerting stresses less than the swelling pressure of the soil.
2- Founding near or on fractures zones.

- The choice of the foundation type is a crucial factor in the design of any facility in this region. The deep foundations can be of better performance compared to shallow foundations.
- Depth of deep piles is suggested as a minimum of 30m based on the geophysical and geotechnical studies.
- The safe horizontal distance away from the crack face is recommended at 50m depth. This is based on the shale layer thickness forecasted by the electrical resistivity .

-Existing buildings:

The existing buildings showing cracks need to be monitored and observed periodically. If found stable they can be maintained and used.

- New building:

The new buildings need to be constructed away from the existing crack zone. A minimum distance of 50m both sides is suggested. Recommendations of foundation level and allowable bearing capacity as provided by the geotechnical engineer shall be followed.

VII- ACKNOWLEDGMENTS

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