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Compatibility of Electromagnetic (EM) Method and Geospatial Analysis for Identifying the Vulnerable Building Zonation in Coastline Area of Ado-Odo Ota, Ogun State, Nigeria

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Abstract: Collapsing of building incidents have been reported all over the world and seems to be commonespecially in sedimentary terrain of the coastal plain sand of Ado-Odo Ota which has the same subsurface features as the Lagos that experience regular building collapse. This building collapse is attributed to several causes. The reasons that have been identified, have added little or no impact on reducing this environmental disaster. This study presents the strength of emerging and existing geophysical tools for near-surface structural studies. The aim is to reveal the recent technical development on improving field surveys to minimize building collapse. Data acquisition using electromagnetic (EM) methods which are known for fast mapping of near-surface spatial variation as well as obtaining the subsurface vertical variation in electrical conductivity was adopted. The acquired spatial and attribute data was introduced in a GIS environment with different thematic vectors/layers created by digitizing the satellite image of the study area. The GIS digitizing was to geographically trace the acquired data with accurate coordinates from the obtained EM field data with the thematic layer representing the features such as weak zone and competence zones that can hold buildings. A transverse was taken in a strategic positions considering the regional features with 10 m spacing to cover the marked stations. It revealed the layer depths range from 0.37 to 1.64 m with the much competence layer found to be about 1.64 mbeyond which may be the thick clay Ilaro formation that underlies the recent formation. The weathered shear zone at the depth of 0.37 m may be the recent lithoral deposits which is geotechnically and geologicallyunstable and proximity to active faults of ruptured geomorphology of the building zonation.

Keywords: Building Collapse, GIS, Electromagnetic Method, Ado-Odo Ota

1. Introduction

Several types of soil pose varying problems for built foundations and the structural integrity of an entire building. McCarthy [1] identified that there is therefore urgent call to carry out soil surveys to obtain the compressibility or consolidation potentials as well as the bearing strength of the soil of a particular site

Building failures or collapses are caused by several phenomena such as design faults, construction site faults and the product failure [2]. Some other causes are environmental changes, natural or man-made hazards [3]. Engineering properties of the soil materials can be investigated by carrying out geophysical surveys [4, 5]. Properties which can be derived from geotechnical investigations include the soil arrangement in the subsurface or the borelog, in situ bulk properties (bearing capacity of the soil, the atterbergs limit). These investigations are carried out with methods such as CPT, SPT, percussion drillings, and borings. The integration of these geotechnical techniques with geophysical techniques can enhance building quality.Electromagnetic (EM) methods for near-surface applications often include active and passive source methods which are very ideal for fast mapping of electrical conductivity, magnetic susceptibility or variations in magnetic permeability, whether it's in handheld, on the ground or in airborne mode [6].

The cause of those possible failures should be the subject of investigation not to attribute all the structurally significant components such as blocks, lintel as claimed by Usman, [7].

In Nigeria, building collapse can be associated with negligence by foundation designers and structural engineers to subsurface investigations which delineate subsurface features such as cavities, sinkholes, and faults prior to infrastructure development [8, 9].Adegoroye[10] reports that on Saturday March 25, the Nigerian Industrial Development Bank's building collapsed killing two persons and injuring 23 others.Badejo[11] suggested that Engineers should adopt the multi-disciplinary approach to curb the building collapse in Nigeria. Building collapse in Nigeria has been on the increase and this is becoming an epidemic problem which requires an innovative approach. This study is aimed at providing the compatibility of EM and GIS spatial analysis to detect the shear weak zones that could hazardously put building structures at risk of collapsing in the coastal sand which indicate the loose, ill-sorted sands within the Dahomey basin of Ado-Odo Ota.

2.0 Geology of the Study Area

Ogun State with other south-western Nigerian states including Oyo and Lagos States lies in the eastern Dahomey Basin. Its geology is composed of sedimentary and basement complex rocks that are Late Cretaceous to Early Tertiary [12](Omashola et al, 1981). Stratigraphically, the sedimentary rock of Ogun State consists of the Abeokuta group, Imo group, Ewekoro, Oshosun, Ilaro and Benin formations [12] (Omashola et al, 1981). The Geology of the study area is shown in Figure 1 and the Google Earth map indicating the location is shown in Figure 2.

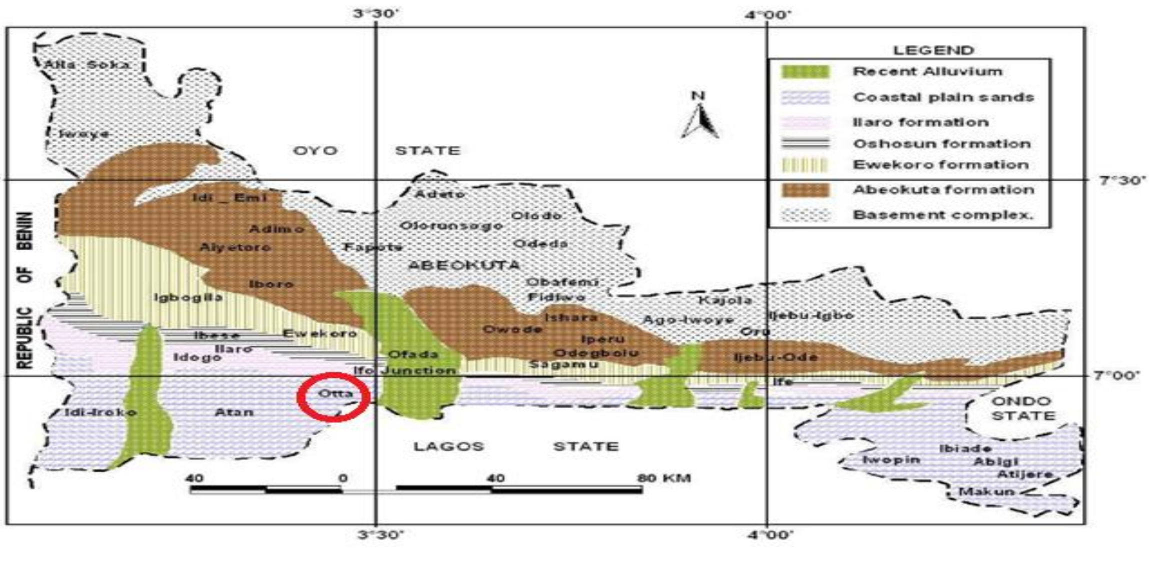

Figure 1: Geological Map of Ogun State Showing the Study Area in a Pink Circle [12]

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Figure 2: Google Earth Map the Study Showing the Boundary of the Measured Data

3.0 Materials and Method

3.1 Sample and Sampling Location

The base map indicates the areas and stations where the measurements were taken as presented in Figure 3. It can be observed that the first transvers line consists of stations from 6 (CAC6) to 13 (CAC13) with different codes. In transverse 2, it ranges from 14 (CAC14) to 25 (CAC25) and finally the last transverse ranges from 40 (CAC40) to 47 (CAC47), respectively.

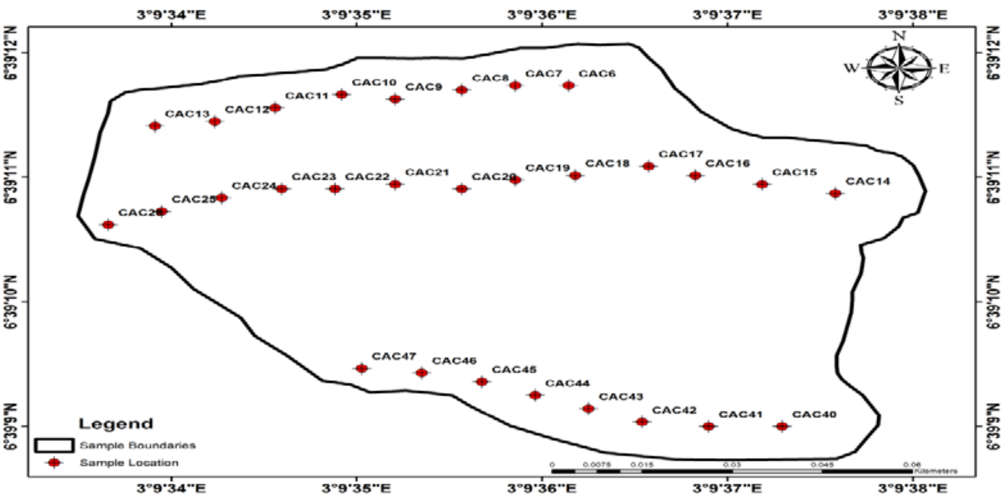

Figure 3: Base Map of the Study Area Showing the Transverse Lines of Data Acquisition

3.2 Instrument and Data Acquisition

TC-300 Series is a Hunan Puqi Geologic Exploration Equipment (Model No: PQWT-TC300) is an electromagnetic method used to study the subsurface geological features geological ore / mass bodies, groundwater and its abnormalities. These variations are useful in interpreting and solving the subsurface characteristics of the geological, geoengineering, environmental and disaster problems. The basic principle of the instrument is measuring the existing natural electric field of subsurface water / minerals /geological structures / ore bodies. The natural electric field geophysical instrument is one of the geophysical instruments, working with the source of natural electric field, measuring the subsurface rock / ore / groundwater, natural electric fields and variations at different frequencies and different depths. It detects the abnormality changes in the subsurface with a coupled 3 methods integrated and developed, consisting more and more data filters for analyzing data and filtering errors etc. It is easy operation, high quality touch screen and highly standard. The instrument profile map gives accurate mean depth, quantity, quality, shape of subsurface features and the geological structure. The instrument gives 100% results subsurface investigation and detection of bed rocks etc. The measurement is done by using tape to measure 10 meters distance and mark the starting point to be 0 meter. The configuration of M N two electrode bar equidistance is 10 meters, and subsequently both M N moved 1meter after measuring the first point placed at the position of 1.

3.3 Integration of EM Data and GIS for the Generation of Thematic Layers

The measured EM data were introduced in GIS environment as the spatial and attribute data with different thematic vectors/layers created by digitizing the satellite image. The GIS digitizing was to geographically trace the acquired data with accurate coordinates points measured with GPS. The EM field spatial data with the thematic layers represents the features such as weak shear zones, near-competence zones and competence zone, respectively. These thematic vectors/layers include the weak shear zones, near-competence and competence zones were adopted to develop and infer the building zonation of the hazardous/vulnerable layer. These steps assisted in what is important, consistent and logical to identify the individual zones of interest.

4.0 Results and Discussion

4.1 Analysis of Electromagnetic (EM) Frequency Curves Obtained in along the Transverse

The frequency of the electromagnetic (EM) data points were plotted against different stations within different stations along the transverse line. This frequency depicts the level of reliability and as well vulnerability of strong and weak zones of different layers in the subsurface. It identifies the weak share zones as well the unconformity zones which could possibly be termed as anomaly in the study area. Figure 4 presents the subsurface reliability information of competence layer that could hold foundation of building in the study area. It can be observed that between stations 6 to 12 and stations 18 to 22 at frequency ranges of 0.8 to 1.5 may not be reliable enough to hold building foundations. This may be attributed to the poor geomorphological setting of the area, as such could be vulnerable to degrade or damage building structure.

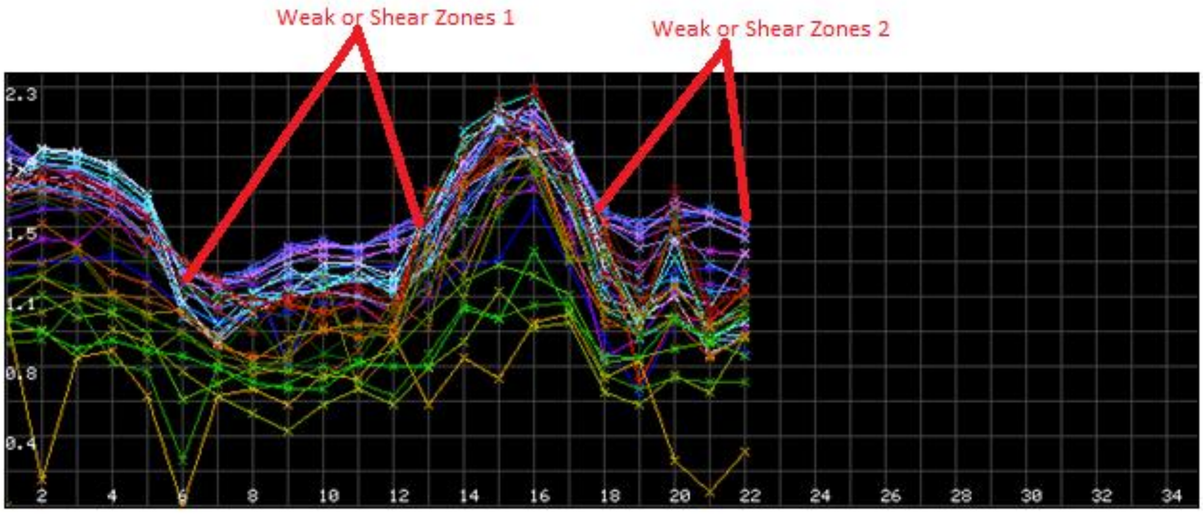

Figure 4: EM Frequency Curve against the Sampling Stations

4.2 Analysis of Electromagnetic (EM) Iso-Resistivity Map Obtained in along the Transverse

To validate the subsurface information obtained from the Figure 5, a contour map of the transverse that was automatically generated from the EM instrument. It can be observed that the competence zones are inferred to range from stations 1 to 5 and stations 14 to 17, respectively. This non-vulnerable area within the first transverse may be the class of the pre-existing rocks with high grade of compaction and cementation. The depth of observed foundation level to competence layer from Figure 5 ranges from 1.17 m to 1.36 m respectively. The near competence layer that could be found as weak to slightly strong near-surface zones ranges from 0.31 m to 0.45 m respectively along transverse.

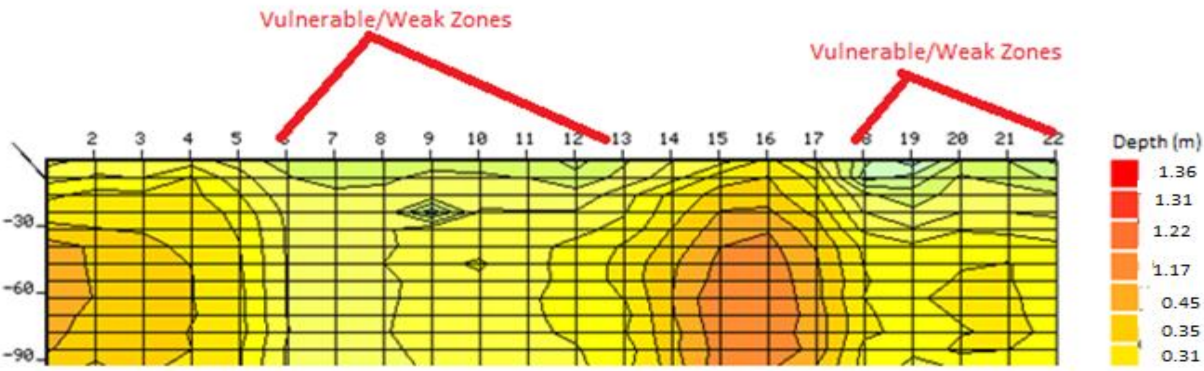

Figure 5: Identification of the Vulnerable and Competence Zones from the Contour Map along the Sampling Stations

4.3 The Interpretation of GIS Spatial Analysis of the Study Area

All the transverses were combined in ArcGIS 10.0 version to identify the vulnerable/weak zones that could unstably damage or collapse buildings in the study area using the steps discussed in methodology. This is shown in Figure 4. The major area that is vulnerably affected from the geospatial map is along the transverse 1. It can be observed that from stations 6 to 9 may be termed as geo-technically unstable zones and could be a proximity to active faults or subsurface rupture directivity phenomena and vulnerable to raising of buildings in the area. It can be noted that the source of such weak shear zones is trending from the Northern part of the study area which spread downwards to the Southern parts closer to the second transverse. Such deep core zones may be the effect of water basin with turbidity currents, rivers channels, deltas, and shallow marine areas with storm impacted conditions. On the other hand, the competence layer seems to be sandy clay underlies the lateritic topsoil which is inferred as the competence layer and may be proposed as the firm zone for foundation purposes. This firm layer that interbedds with sand and clay geologically may be the uniqueness of crystal structure of clay materials special properties. Clay's cataion exchange capability, plastic behaviou when wet may be attributed to the competency of the formation found to be the foundation zone.

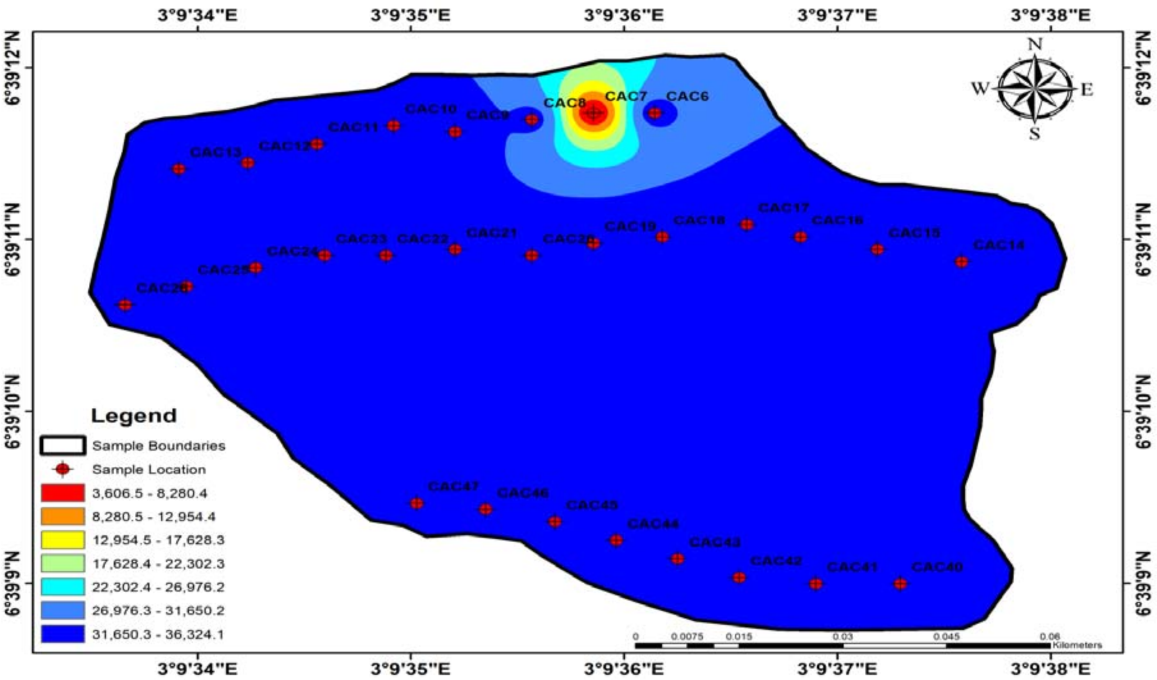

Figure 6: The Spatial Analysis Map of the Study Area showing Different Structural Layer Zones

5.0 Conclusion

The integration of electromagnetic (EM) methods and GIS spatial analysis tools in this study succeeded in identifying the hazardous building zonation areas. It has proven to be an easy approach in identifying the prone and vulnerable terrain for sitting building structures. The areas measured were able to laterally show the extent of the competence and unstable zones that could pose risks on inhabitants of buildings. It also revealed from the geospatial feature map that the lateritic topsoil overlies the sandy-clay that is presumed to have the capability of cationic exchange that could geochemically strengthen the layer to be the competence zone. This study suggest more geotechnical analysis to support the findings.

References

[1] McCarthy, D.F. (1999). Essentials of Soil Mechanics and Foundations. Cited in Criteriurn McCarthy Engineers.Odulami, A.A. (2002) Building Material Specification and Enforcement on Site in D.R. Ogunsemi (Ed) Building Collapse: Causes, Prevention and Remedies. Nigeria Building Institute, Ondo State pp22-27

[2] Oyeande, B. (1992): A research for quality in the construction industry. Builder's Magazine, June/JulyEd., Lagos

[3] Akinpelu, J.A. (2002): The need for code of conduct,building regulations and by-laws for the buildingindustry in Nigeria. The Professional Builder, NigeriaInstitute of Building, pp 11-14 *(10) (PDF) Assessment of building failures in Nigeria: Lagos and Ibadan case study*. Available from: https://www.researchgate.net/publication/237374553_Assessment_of_building_failures_in_Nigeria_Lagos_and_Ibadan_case_study [accessed May 03 2020].

[4] HoltzR D.,KovacsW D.,1981*An Introduction to Geotechnical Engineering* Englewood Cliffs, NJ Prentice Hall

[5] Fatoba J O,Alo J O, Fakeye A A., (2010) Geoelectric imaging for foundation failure investigation at OlabisiOnabanjo University minicampus, Ago-Iwoye, Southwestern Nigeria, *J. Appl. Sci. Res.*, vol. 6 (pg. 2192-2198)

[6] Tezkan, B.: A review of environmental applications of quasi-stationary electromagnetic techniques, Surveys in Geophysics, 1999, 20, 27930888.

[7] Usman, N.D.; Chen, J.A.; Lodson, J.T.: Environmental sciences and the challenges of collapse buildings
in Nigeria. J. Environ. Issues Agric. Dev. Ctries. 2(2&3), 194–198 (2010)

[8] Parolai .S, Borman .,P, Milkreit .,C., (2002) New relationships between *Vs*, thickness of sediments and resonance frequency calculated by *H*/*V* ratio of seismic noise for the Cologne area (Germany) *Bull. Seismol. Soc. Am.,* vol. 92 (pg.2521-2527)10.1785/0120010248

[9] Delgado J, Alfaro P, Galindo-Zaldivar J, JabaloyA.,LopezGarrido A C.,Sanz De Galdeano C.(2002), Structure of the Padul-Niguelas Basin (S Spain) from H/V ratios of ambient noise: application of the method to study peat and coarse sediments, *Pure Appl. Geophys.*, vol. 159 (pg.2733-2749) 10.1007/s00024-002-8756-1

[10] Adegoroye, B. (2010).“Disaster Everywhere”. Daily Sun Newspapers, Retrieved from http://www.dailysun newspaperonline.com/webpages/news/national/2006/mar/25/national-25-03-2006-006.htm

[11] Badejo, E. (2009, July 13). “Engineers, Others Urge Multi-disciplinary Approach to Curb Building Collapse”. The Guardian Newspapers, Retrieved from http://www.naijaproperties.com/news_95php

[12] Omatsola, M.E. and Adegoke, O.S. (1981): Tectonic evolution and Cretaceous stratigraphy of theDahomey basin, Nigeria Geology, 18 (51): 130-137.