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Geophysical Investigation of Bulding Distress in Gashua, Nigeria

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ABSTRACT

Gashua is the Headquarter of Bade local government in Yobe State, it has a population of about 125, 000 according to the 2006 population census. It is a densely populated town located in a flood plain within the Chad Basin. In an attempt to proffer solutions to the prevailing building distress in Gashua and its environs, this study was carried out to accurately characterize the subsurface geology of the area, thereby reducing the incidence of building failure in the area to minimum. In this study, electrical resistivity method was used to determine the causes of building distress and failure in Gashua and its environs. Vertical Electrical Sounding (VES) using Schlumberger array and Electrical Resistivity Tomography (ERT) were adopted for the study. The results of the VES survey showed that the area is composed of five geologic layers which are; the topsoil, clay, sand, sandy-clay, and sand. The ERT results showed that most of the building foundations in the study area were laid within the second layer which is a clay formation. The findings of this study showed that the building distress and failure which are common in the study area were caused by the volumetric changes of the clay formation due to hydrological dynamics. The clay formation absorbs water during the raining season and swells up, and during the dry season it shrinks, this changes in the volume of the clay formation underlying the building foundation in the study area induces a significant mechanical stress on the buildings leading to the formation of cracks, voids, fissures and fracturing of the buildings, which eventually culminate into collapse. In this study, electrical resistivity method of geophysical investigation has demonstrated to be a veritable tool for geotechnical soil evaluation. Based on the findings of this study, geophysical investigation of a proposed site for any civil engineering structural development in Gashua and its environs is very important in order to choose the appropriate foundation that will compensate for the deficiency of the soil's load bearing capacity. The use of appropriate foundation type for building projects in the study area will help to avert building distresses and failures.

Keywords:
Building,
Distress,
Failure,
Electrical,
Resistivity,
Clay.

INTRODUCTION

Many building distresses such as cracks, foundation failure, building collapse and building tilting are caused by earth subsurface conditions. The inability of many house owners to investigate the subsurface conditions of where their houses are built has led to building failures in both rural and urban areas around the world. The durability and stability of civil engineering structures is a function of the stability of the soil upon which their foundations are laid. Feld (2005) observed that there is a need for geotechnical investigation of any civil engineering site allocated for structural development which includes; Dams, Bridges and Houses. Unfortunately, many houses and other civil engineering projects are executed sometimes with little or no soil evaluation and thereby leading to building failure. Building failure is a great economic loss which in most cases leads to loss of lives and properties. Geotechnical investigations are in most cases focused at reducing and preventing building collapse and other civil engineering structural failures.

Folabi (2009), identified some of the factors responsible for building failures as inadequate education, poor public awareness, poor understanding and enforcement of building codes, the use of substandard building materials, inadequate funding, lack of skills and neglect for established rules and regulations. In Nigeria there are rising cases of building collapse which has led to loss of many lives. According to Omenihu *et al*. (2016), a building is said to have failed when it no longer function proficiently and it eventually collapsed. Gashua is a local government headquarter in Yobe State of Nigeria. It is a densely populated town with high commercial activities. Gashua is located in a flood plain and it is mostly affected by flood annually. In Gashua and its environs, many buildings and other civil engineering structures are mostly cited based on surface assessment of the sites without any subsurface investigation to determine the soil integrity. This is a common practice in many urban and rural areas in Nigeria and this practice has contributed to building failures across Nigeria. Figure 1 shows typical building distresses observed in the study area.

Figure 1: Common building distress leading to building failure in the study area

The increase in building collapse in Nigeria has claimed many lives and properties. The situation calls for urgent attention. It is an incident which can occur at any time depending on the amount of distress on a building (Figure 1). In Nigeria, Lagos State has the highest cases of building collapse, although the problem of building collapse occur all over Nigeria but the scale of its occurrence varies from one geographical location to another.

Ozegin *et al.* (2011) reported that preliminary studies of a designated construction site will help to prevent problems associated with soil expansivity and the effects of naturally occurring geologic structures such as faults, voids and cavities on buildings. Therefore, geophysical investigation of any designated site for building construction is significant and helpful to secure the building from failure. Proper understanding of the subsurface lithology of any designated area for construction will help to inform the load bearing capacity of the area or soil competency and the type of foundation to be adopted.

Electrical resistivity method has been proven to be very efficient and cost effective for the investigation of building structural failure. Its role in civil engineering construction is highly appreciated by several authors (Adepelumi and Olorunfemi, 2000; Adepelumi *et al.*, 2009; Akintorinwa *et al*., 2011, and Salami *et al.*, 2012; Fatoba et al., (2013); Ibitoye, 2013; Aderoju and Adebayo, 2017). Adebowale *et al*. (2016) reported that the increase in the number of building collapse in Nigeria are due to several factors which includes derailment from the approved plan to minimize cost, lack of monitoring from approving authorities, and the execution of building projects by un-professionals. Considering the rising cases of building distress in Gashua and its environs and its corresponding implications, this study investigates the cause of building failure in Gashua and its environs using electrical resistivity methods. The objectives of this study involves the delineation of the lithology of the study area, determination of the thickness of the various subsurface layers and the evaluation of the subsurface layers characteristics in order to establish their impact on buildings in the study area.

MATERIALS AND METHODS

The Study Area

Gashua is a town in Yobe State northeast Nigeria, it is located between latitudes 12°52'05''N and longitudes 11°2'47'' E (Figure 2). The study area has a semi-arid climate characterized with relative short rainfall (June to September) and prolonged dry season (October to May). The annual rainfall ranged from 500mm–1000mm (Agada *et al*., 2011). Gashua has a mean annual temperature of about 39 ºC. Gashua has a population of about 125,000 according to 2006 population census results. It has an average elevation of 299m. The study area is located within the Chad Basin. The Chad basin extends to Central Africa Republic, Cameroon, Chad Republic, Nigeria, and Niger.

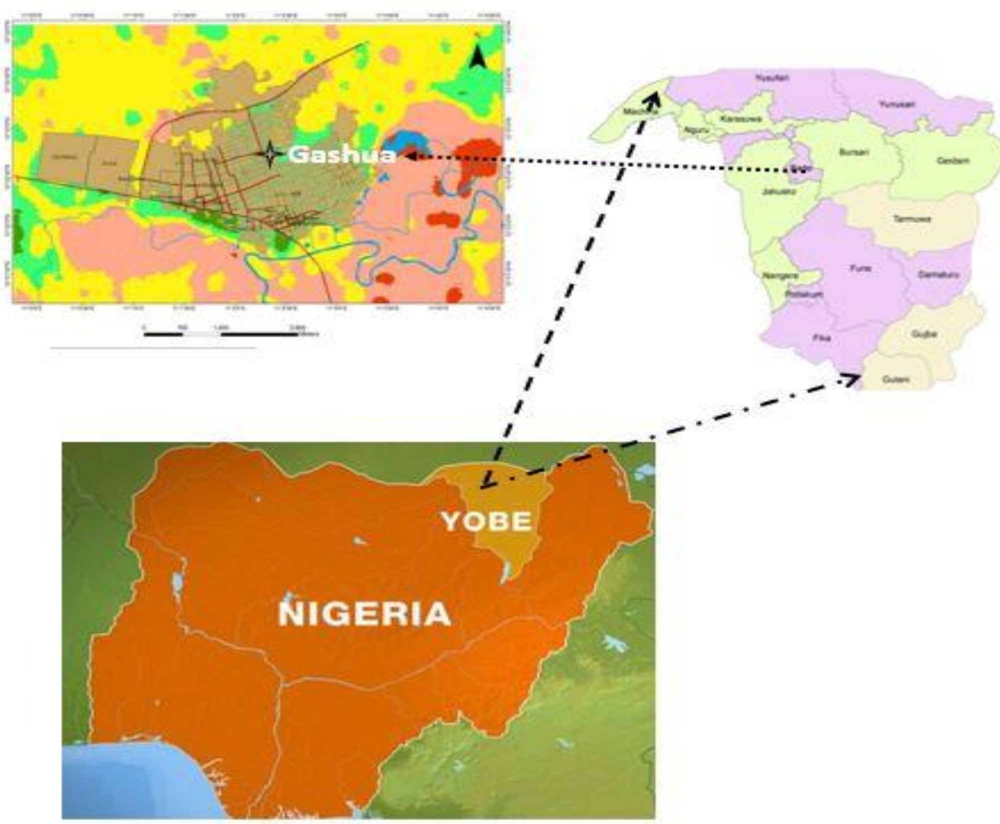


Figure 2: Map of Nigeria Showing Gashua the study area

The basin lies between latitudes 11^0 N and 14^0 N and Longitudes 9^0 E and 14^0 E covering parts of Borno State, Yobe and Jigawa State in Nigeria. About ten percent of the Chad basin lies in the north-eastern part of Nigeria. The Chad basin resulted from plate divergence along the West Africa continental margin (Oteze and Fayose, 1988). The Chad Basin contains three water bearing horizons i.e. the upper, middle, and the lower zones

(Matheis, 1976). Lithologically, the upper zone is composed of layers of clayed grits and sands or sand stones of varying thickness (Makinde *et al*., 2010).

Materials

In this study, instruments such as ABEM SAS1000 Terrameter, Reels of cables, Electrodes, Metre tape, Global Positioning System device, Hammers, Base maps, 12V Car Battery and Laptop computer were used to obtain the field data.

Methods

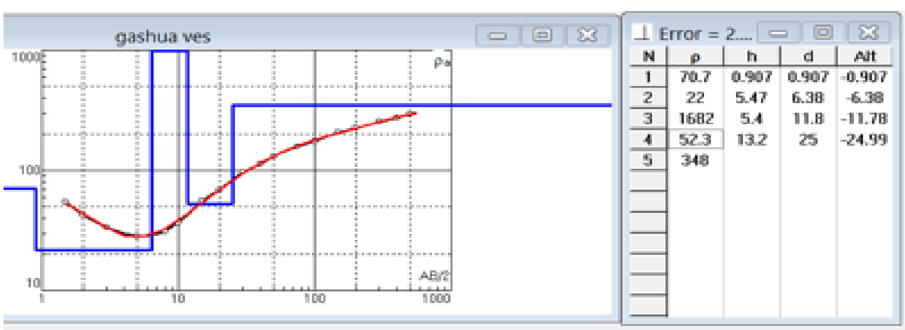
Electrical resistivity survey

In this study electrical resistivity method which involved the Vertical Electrical Sounding (VES) and 2 D Electrical Resistivity Tomography (ERT) were used for the data acquisition. Twelve (12) Vertical Electrical Soundings (VES) were carried out in a carefully selected areas of the study. A Schlumberger electrode configuraton was adopted for the VES to determine the subsurface lithology of the area and a wenner-schlumberger electrode configuration with inter-electrode spacing of 2 metres was used for ERT data acquisition. The electrical resistivty field data was interpreted using IPi2win Software and ERT data was interpreted using an inversion software (RES2DINV).

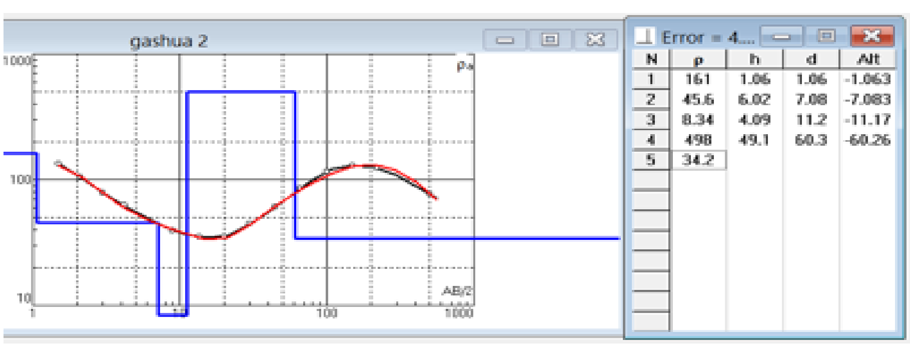
RESULTS AND DISCUSSION

The results of this study were presented in the form of curves (Figure 3), tables (Table 1), geoelectric section (Figure 4) and inverted resistivity models (Figures 5a and 5b). The topsoil has a thickness which ranged from 0.6 to 0.9 m and its resistivity value ranged from 70.7 to 242.4 Ωm (Table 1). The topsoil is a mixture of sand, clay and remains of plant materials. It is thin and has a varying thickness across the study area with an average thickness of 0.8 m (Figure 4). The second layer thickness ranged from 0.8 to 14.6 m and it has an average thickness of 8.7 m. The resistivity of the second layer ranged from 17.6 to 86.0 Ωm (Table 1). It has an average resistivity value of 49.7 Ωm (Tabble 1). The resistivity characteristics of the second layer clearly showed that it is a clay formation.

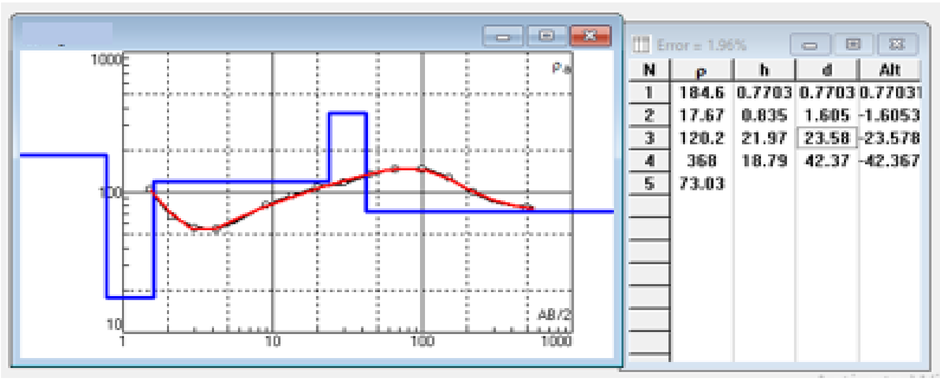
Clay soil are characterized with low resistivity values due to its conductivity. The third layer has resistivity values which ranged from 8.3 to 1682 Ωm. It has an average resistivity value of 362.9 Ωm. It is mainly a sandy formation intercalated by clay in the vicinity of VES 2 and 3 (Figure 3). The fourth layer has resistivity values which ranged from 52.3 to 498.0 Ωm. It has an average resistivity of 160 Ωm. It is mainly a sandy clay formation with the exception of VES 2 and 3 areas that were intercalated by sand (Figure 4a). It has an average thickness of 100 m. The fifth layer has an average resistivity of 262.5 Ωm. It is a sandy formation intercalated by clay at VES 2 area. In this study emphasis was on the lithology of the study area and how it impacts the buildings in Gashua and its environs.



VES 1



VES 2



VES 3

Figure 3: Typical geoelectirc curves obtained from the study area

Table 1: Results of the Vertical Electrical Sounding (VES) Survey

VES	Layer Resistivity (Nm)					Layer Thickness (m)				Depth (m)			
	p1	**p2**	**p3**	**p4**	**p5**	**h1**	**h2**	**h3**	**h4**	**d1**	**d2**	**d3**	**d4**
1	70.7	22.0	1682.0	52.3	348.0	0.9	5.5	5.4	13.2	0.9	6.4	11.8	25.0
2	161.0	45.6	8.3	498.0	34.2	1.1	6.0	4.1	49.1	1.1	7.1	11.2	60.3
3	184.6	17.7	120.2	360.0	73.0	0.8	0.8	22.0	18.8	0.8	0.8	22.0	42.4
4	119.0	55.4	175.5	130.2	330.4	0.7	6.0	45.5	42.8	0.7	6.7	52.2	95.0
5	190.0	55.3	329.0	110.6	273.3	0.6	10.7	43.0	64.5	0.6	11.3	54.3	118.8
6	206.3	39.3	261.7	122.1	359.6	0.9	11.1	41.4	46.3	0.9	12.0	53.4	99.7
7	154.1	65.2	243.4	136.2	220.3	1.1	13.5	30.0	66.6	1.1	14.6	44.6	111.2
8	145.0	86.0	210.3	129.7	311.7	0.8	11.0	51.2	52.0	0.8	11.8	63.0	115.0
9	127.3	74.0	258.0	112.5	237.2	0.7	14.6	66.7	78.4	0.7	15.3	82.0	160.4
10	242.4	39.9	470.0	119.0	390.1	0.7	8.4	30.2	74.0	0.7	9.1	39.3	113.3
11	186.0	60.6	340.0	137.1	279.6	1.0	7.5	62.0	58.3	1.0	8.5	70.5	128.8
12	124.0	35.4	256.0	121.5	292.4	0.9	9.8	57.3	65.2	0.9	10.7	68.0	133.2
Average	159	49.7	362.9	159.7	262.5	0.8	8.7	38.2	52.2	0.8	9.5	43.2	100.2
Maximum	242.4	86.0	1682.0	498.0	390.1	1.1	14.6	66.7	78.4	0.9	15.3	82.0	160.4
Minimum	70.7	17.7	8.3	52.3	34.2	0.6	0.8	4.1	13.2	0.6	0.8	11.2	25.0

The results of the Vertical Electrical Sounding (VES) revealed that the thickness of the first layer was thin and it was underlain by a layer of clay formation.

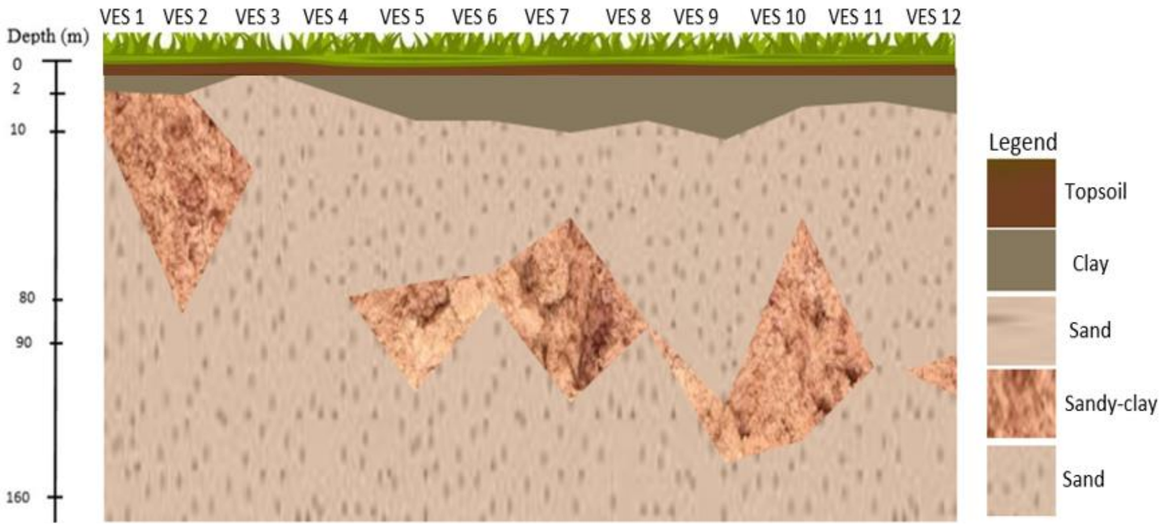


Figure 4: Geoelectric section of the study area

The results of the 2D electrical resistivity tomography (Figures 5a) showed that in some parts of the study area, the clay soil extends to the surface, while in the greater parts of the study area the topsoil is underlain by clay soil (Figure 5a). The 2D-ERT results correlated well with the Vertical Electric Sounding results. Some of the foundations of the buildings in the study area were situated within the clay layer due the proximity of the clay layer to the surface of the Earth. The response of the clay formation to periodical hydrological conditions of the study area affects the buildings in the area. The contraction and expansion characteristics of clay formation which occur during dry and wet seasons often induce significant mechanical stress on buildings whose foundation are laid within the clay horizons.

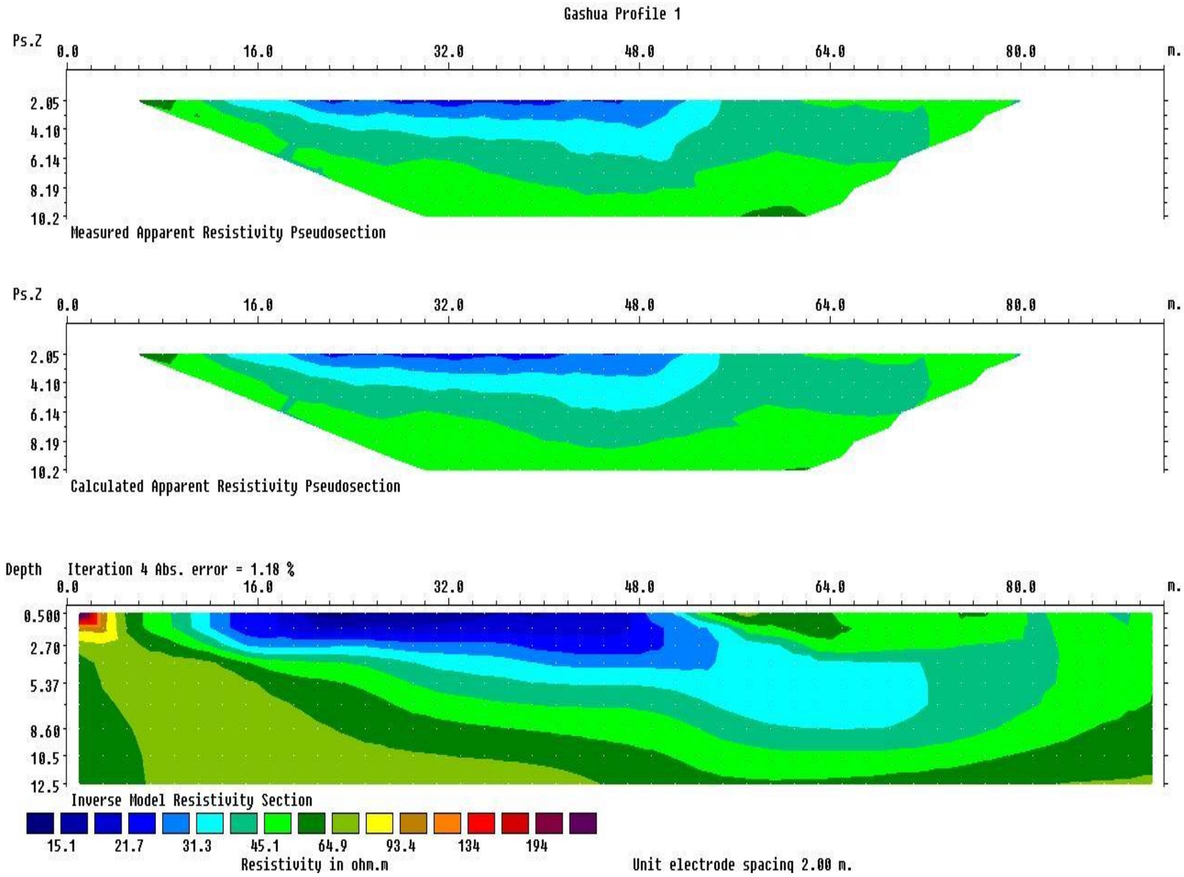


Figure 5a: Inverted resistivity model of profile 1 in the study area showing the proximity of the clay layer to the Earth surface. The clay materials are indicated in blue color and they are characterized with low resistivity values which ranged from 10 - 35 Ωm

Buildings cited on incompetent materials are liable to collapse due to poor load bearing capacity of the area. Geophysical investigation of a proposed site for civil engineering construction is very important as it reveals the nature of the subsurface underlying the site. Therefore, the role of geophysical survey in building development cannot be neglected. Many of the buildings cited in the study area were built without regards to the subsurface underlying materials and this observation is in consonance with the report of Feld (2005). The inadequate exposure of the inhabitants of the study area to the role of geophysical investigation in building projects also contributed to the increasing rate of building failure, this observation in agreement with the observations of Folabi (2009) concerning the education of the populace on the factors causing building failures and how it can be controlled.

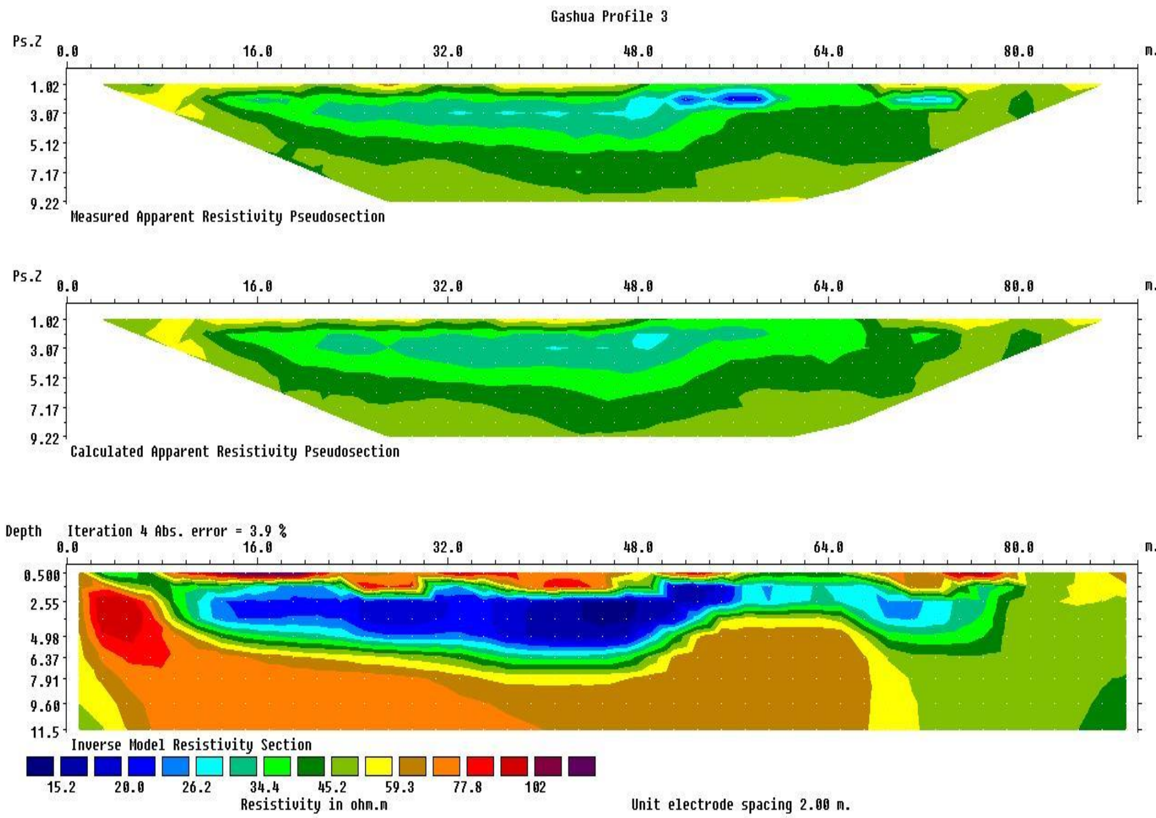


Figure 5b: Inverted resistivity model of Profile 2 showing the distribution of clay and other incompetent materials in blue color in the subsurface of the study area. These materials area responsible for building distress and failure in the study area

The nature of the foundation to be adopted for any civil engineering structure should be a function of the nature of the subsurface materials underlying the site and the type of structure to be built. Areas underlain by less competent materials requires special foundation to compensate for the load bearing capacity of the soil. The results of this study showed that the study area has a thin topsoil which is relatively lower than 1.2 m. This topsoil is underlain by a clay formation which undergoes volumetric changes due the variation in its moisture content. The volumetric changes in the size of the clay formation distorts the stability of the buildings in the study area. The results of this study showed that areas underlain by thin clay layer requires the excavation of the clay materials before laying the foundation (Figure 5a), while areas with thick clay layer and other incompetent materials need specific reinforcement and special foundation to support the buildings (Figure 5b).

CONCLUSION

In this study, the causes of building distress were investigated in Gashua Nigeria, using electrical resistivity methods. Both Vertical Electrical Sounding (VES) and 2D-ERT methods were adopted for the study. The results of the study showed that some of the building foundations in the study area were cited on clay layer and less competent materials. The behavior of the clay and other incompetent materials underlying the foundation of the buildings in the study area induce mechanical stress on the buildings leading to their failure. The study demonstrated the importance of geophysical survey in civil engineering projects. It was observed that some of the buildings in the study area lack the appropriate foundation type that will compensate for the deficiency in the soil load bearing capacity. However, the choice of appropriate foundation technique will help in reducing the incidences of building distress and failure in the study area. Based on the finding of this study, we recommend geophysical investigation for building projects in the study area and its environs, as it will help to unravel the soil integrity and in the determination of the appropriate foundation to be adopted for building development.

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