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Geodetic Monitoring and Analysis of Ikemba Odumegwu Ojukwu and Major-General Aguiyi Ironsi's Tunnels in Owerri Capital Territory, Imo State, Nigeria

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ABSTRACT: *Ikemba Odumegwu Ojukwu and Major-General Aguiyi Ironsi's tunnels situated along Port-Harcourt road in Owerri Imo state were constructed for the purpose of road transportation. These two tunnels developed drainage problems and this made some road users to desist from using them. A speculation arose that the drainage problem could be as a result of bad construction works which could lead to deterioration the tunnels and as such, poses danger to lives and properties. Deformation monitoring analysis was carried out on these two tunnels by establishing control, reference and monitoring points around them using geodetic techniques.*

Four control points covering the two tunnels were established, after which another set of four control points were established around each of the tunnels. A monitoring network consisting of six reference points and twenty four monitoring points were also established on the tunnels. These observations were made using a dual frequency Global Positioning System (GPS) receiver on RTK (Real Time Kinematics) mode and the observations were carried out on two different epochs: June and December 2019. Levelling observations were also carried out on the twenty four monitoring points using NIKON Automatic Level (KTS 445). A Statistical analysis (correlation analysis) was carried out using the GPS data for the two different epochs and the results showed that Ikemba Odumegwu Ojukwu and Major-General Aguiyi Ironsi's tunnels yielded the following correlation coefficients ($r_{1=-0.752}$, $r_{2=-0.752)}$ and ($r_{1=-0.472}$,$r_{2=-0.471}$) respectively. These results, according to Bivariate correlation model, showed that the two tunnels were not undergoing any deformation as at the time of the observations but monitoring is still continuing.

Key words: *Tunnels, Geodetic monitoring, Correlation Analysis, Epochs.*

I. INTRODUCTION

Deformation in engineering refers to changes in size, shape and position of an object as a result of changes in temperature or due to an applied force. These changes are experienced on engineering and surface structures. The changes can be natural or man-made and in extreme cases leads to the collapse of the structure, hence a need to carry out deformation monitoring regularly on such structures arises (Uren, 1994).

Deformation survey/monitoring is an essential component of any engineering structure and which should be carried out during and after a construction work to enable the timely detection of any behavioural changes that could lead to deterioration or a collapse. Considering the cost, time and labour invested in such projects, care must be taken to ensure that the entire process is not a waste of time and resources (Ibid).

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Deformation monitoring can be carried out in high-rise buildings, dams, bridges, tunnels, rail tracks, retaining walls, landslides viaducts etc (Ibid).

IKEMBA ODUMEGWU OJUKWU AND MAJOR-GENERAL AGUIYI IRONSI'S TUNNELS

Tunnels are underground passageway dug through earth / rock/soil and enclosed except for entrance and exit. Tunnels can be natural (by nature's action as a result of the dissolution of a soluble rock such as limestone) or man-made. Tunnels are horizontal passageways while shafts are vertical openings. Tunnels are constructed for many purposes such as transportation (cars, trains etc), subways, canals, vehicle parking, water/oil storage, hydro-electric power plants, mining and so many other purposes (Erol *et al.*, 2005).

Ikemba Odumegwu Ojukwu and Major-General Aguiyi Ironsi's tunnels were constructed for the purpose of road transportation in Owerri capital city. The aim of this research work was to carry out a geodetic monitoring on these two tunnels and to establish controls and bases for future monitoring.

II. STUDY AREAS

The study areas are Ikemba Odumegwu Ojukwu's tunnel (Latitude 05° 28' 42.87" N and 05° 28' 38.82"N, Longitude 007° 00' 41.73"E and 007° 00' 44.55"E) and Major-General Aguiyi Ironsi's tunnel (Latitude 005° 29' 49" N and 005° 28' 59.28"N, Longitude 007° 00' 57.55"E and 007° 1' 0.88"E)both located along Port Harcourt road, in Owerri Municipal Council of Imo state, Nigeria.

FIGURE 1: PHOTOGRAPHIC IMAGE OF IKEMBA ODUMEGWU OJUKWU'S TUNNEL.

FIGURE 2: PHOTOGRAPHIC IMAGE OF AGUYI IRONSI'S TUNNEL.

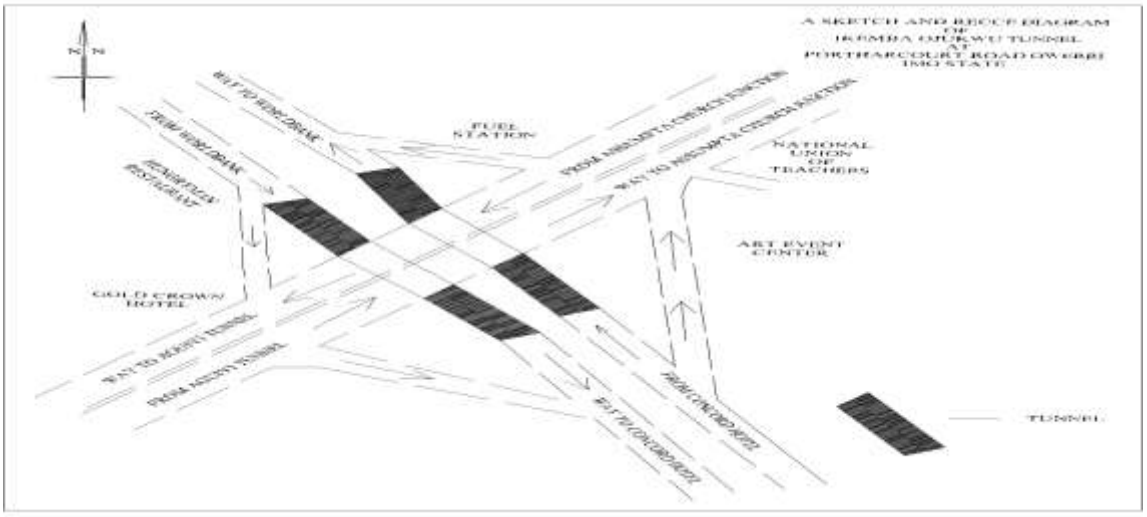

FIGURE 3: A SKETCH OF ODUMEGWU OJUKWU'S TUNNEL ALONG PORT-HARCOURT ROAD, OWERRI IMO STATE.

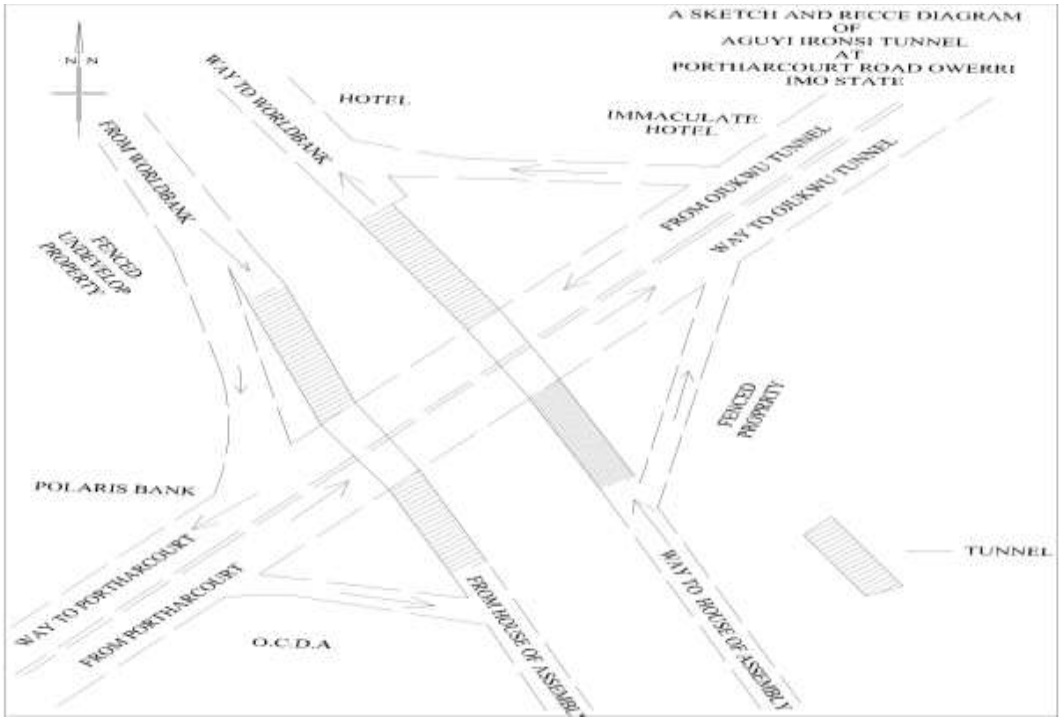

FIGURE4: A SKETCH OF AGUIYI IRONSI'S TUNNEL ALONG PORT-HARCOURT ROAD, OWERRI IMO STATE.

III. LITERATURE REVIEWS

1. DEFORMATION MONITORING OF ATATÜRK DAM IN TURKEY.

Ataturk dam in Turkey was constructed between 1983 -1992 for both hydro-electric power generation and irrigation purposes. The dam has a volume of 84,500 cubic meters and a height of 169 meters from the river bed. Both geodetic and non-geodetic techniques of monitoring were employed in the deformation monitoring. The deformation monitoring started from the period of construction in 1990 to 2008. The non-geodetic measurements carried out were slope measurements with inclinometer, displacement measurement using settlement column, pore-water measurement with Piezometer, grouting measurements with joint meter and crack measurement with crack meter. The Geodetic measurements that were carried out are precise

trigonometric levelling, precise geometric levelling and GNSS survey using GPS, GLONASS and GALILEO receivers (Kalkan et al., 2009).

2. DEFORMATION MONITORING OF THE NEW ADMINISTRATIVE BUILDING OF THE FEDERAL SCHOOL OF SURVEY, OYO, NIGERIA.

The new administrative block of Federal school of surveying Oyo was carried out using geodetic technique of monitoring. Control points were established using GPS surveying for both new and existing pillars within the building. Precise levelling was carried out to determine height differences of the monitoring points. These observations were carried out on three different epochs (January, March and April 2012). The levelling data was analysed using an approach of height differences on the two sets of data. The GPS data was also analysed and the results shows that the building was in good working condition as at the time of survey (Abdullahi *et al.*,2016).

3. CRUSTAL DEFORMATION STUDIES IN THE NOTHERN PART OF ASWAN LAKE USING GPS TECHNIQUE.

Aswan region is located within the stable platform of Arabio-Nubian Massif in Egypt. The main objective of carrying out this deformation study was to monitor the surface crustal deformation around the reservoir, and for understanding the geodynamics of the region.

Also, an attempt was made to investigate the recent crustal movements of the area using precise geodetic and seismic techniques and by two solutions.

Comparing the geodetic results with the seismic activity in the area (a relationship between the accumulated energy releases associated with the earthquake occurrences) shows that there are deformations. The seismic activity reflects the release of energy accumulated as a result of the pressure accumulated in the area. The strain rate tensors estimated in this study area showed compression and extension components directed in NW-SE and NN-SW axis and this is consistent with the T-axes and P-axes derived data from earthquake fault plane solutions respectively. The simple blocks model suggests that Aswan region is characterized by Compressional and extensional deformation which is consistent with the earthquake focal mechanisms and in agreement with the previous kinematics models of this area (Hamed et al,. 2010).

4. DEFORMATION MONITORING OF TYMFRISTOS TUNNEL KARPENISI CENTRAL GREECE.

Tymfristos Tunnel in Greece which is 1,365m long with 11m sectional diameter was constructed for transportation purposes. The tunnel was constructed in two phases using both geodetic and geotechnical techniques. The mining of the tunnel was done from 1992 and was completed in 1998 while the construction work started from 1992 and ended in 1995 in two phases. The excavation of the tunnel in the first phase proved (at least for a 501m long section (Ch.0+810m to Ch. 1+311m)) unsuccessful, leading to high deformation of the tunnel sections, failure of the support shell, breaching of the contract, and partial re-excavation of the tunnel following a new geotechnical study under a new contract (Kontogianni and Stiros, 2004).

Deformation monitoring of the tunnel started during the second phase of the construction work and was based on both geodetic and geotechnical technique (Ibid).

DEFORMATION MONITORING OF IKEMBA ODUMEGWU OJUKWU AND MAJOR-GENERAL AGUIYI IRONSI'S TUNNELS USING GPS TECHNIQUE.

GPS (Global Positioning System) technique is one of the geodetic methods of studying deformation and other geophysical phenomena on structures.

In this research work, deformation monitoring and analysis were carried out on these two tunnels by establishing four control points around the two tunnels after which another set of four control points were established around each of the tunnels. The coordinates of these points were obtained after observations using a dual frequency Global Positioning System (GPS) receiver on RTK (Real Time Kinematics) mode and they served as a control for the entire monitoring process. Observations were carried on the monitoring points at

two different epochs of six months interval: June and December 2019. These data were analysed and statistically tested to determine the extent of deformation.

IV. METHODOLOGY

The acquisition of data involved the preliminary planning in the office, field operations, data collection and processing as shown in Figure 5 below.

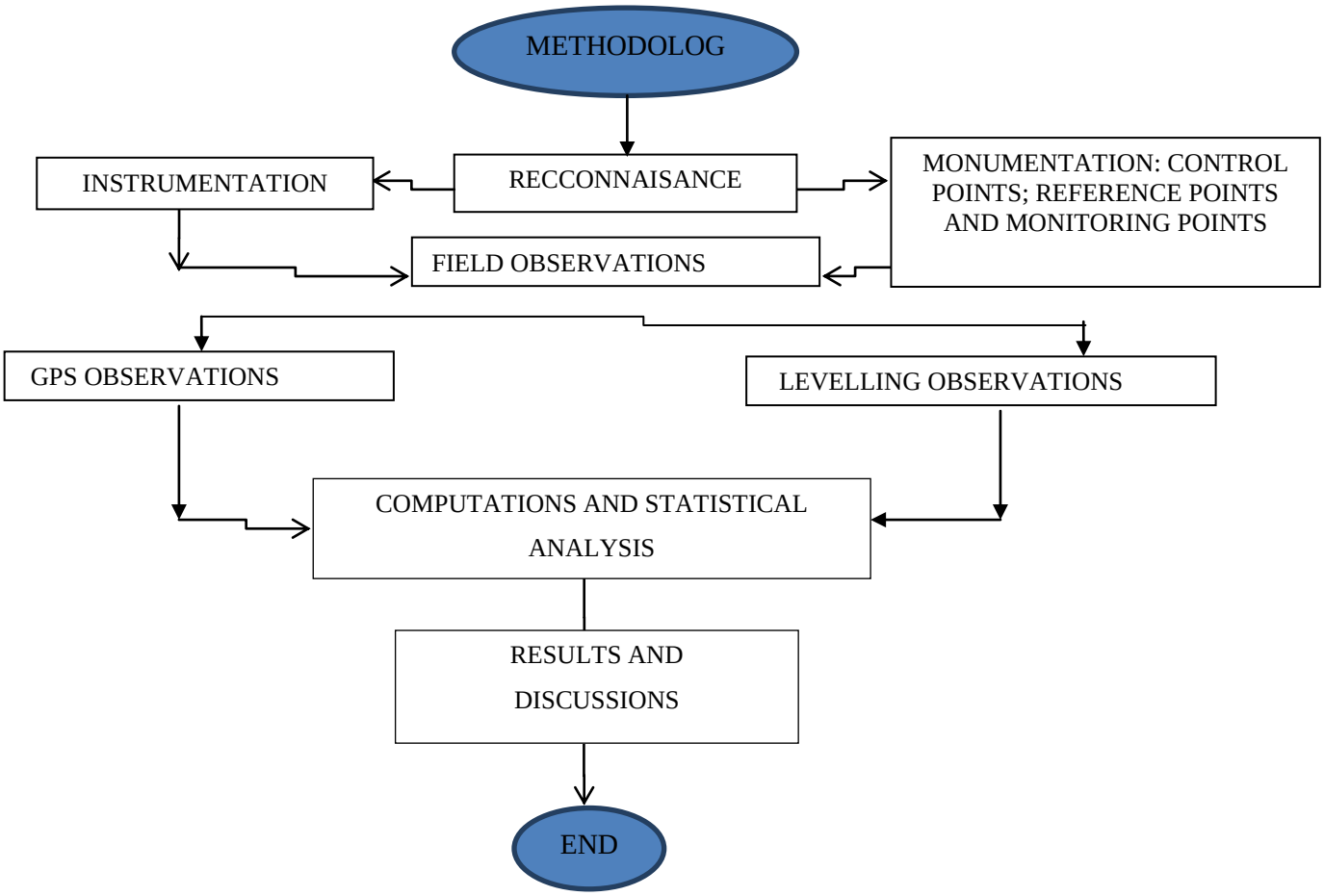

FIGURE 5: METHODOLOGY FLOWCHART

DATA ACQUISITION TECHNIQUE

Global Positioning System (GPS) technique was used to carry out observations of the control, reference and monitoring points. The observations were carried out on RTK (Real Time Kinematics) mode using KQ GEO DGPS (Dual Frequency Global Positioning System) receiver. For the control and reference points on the ground, solid and stable monuments were erected to mark them on the ground, but for the monitoring points, round knobs and nails were used to establish them on the tunnels. Series of levelling operations were carried out using Nikon Automatic level (KTS 445) through the tunnels, in which the reference points served as the benchmarks. Invert levelling and cross-sectional levelling were carried out at 6m interval; the data were reduced to obtain the height data for the tunnels. A monitoring network consisting of six reference points and twenty four monitoring points were established by levelling observations using NIKON Automatic Level (KTS 445) instrument.

DATA SOURCES AND ANALYSIS

Basically, there are two sources of data for this research work, primary and secondary data sources. The primary sources of data are the data sets obtained directly by field observations. They are coordinates of the newly established four control points covering the two tunnels, the eight reference points (four on each tunnel) and the twenty four monitoring points. The secondary source of data is the coordinates of station Z001obtained from the Owerri zonal survey office. All these data were reduced and adjusted using least squares adjustment method to obtain the final data which were used for analysis.

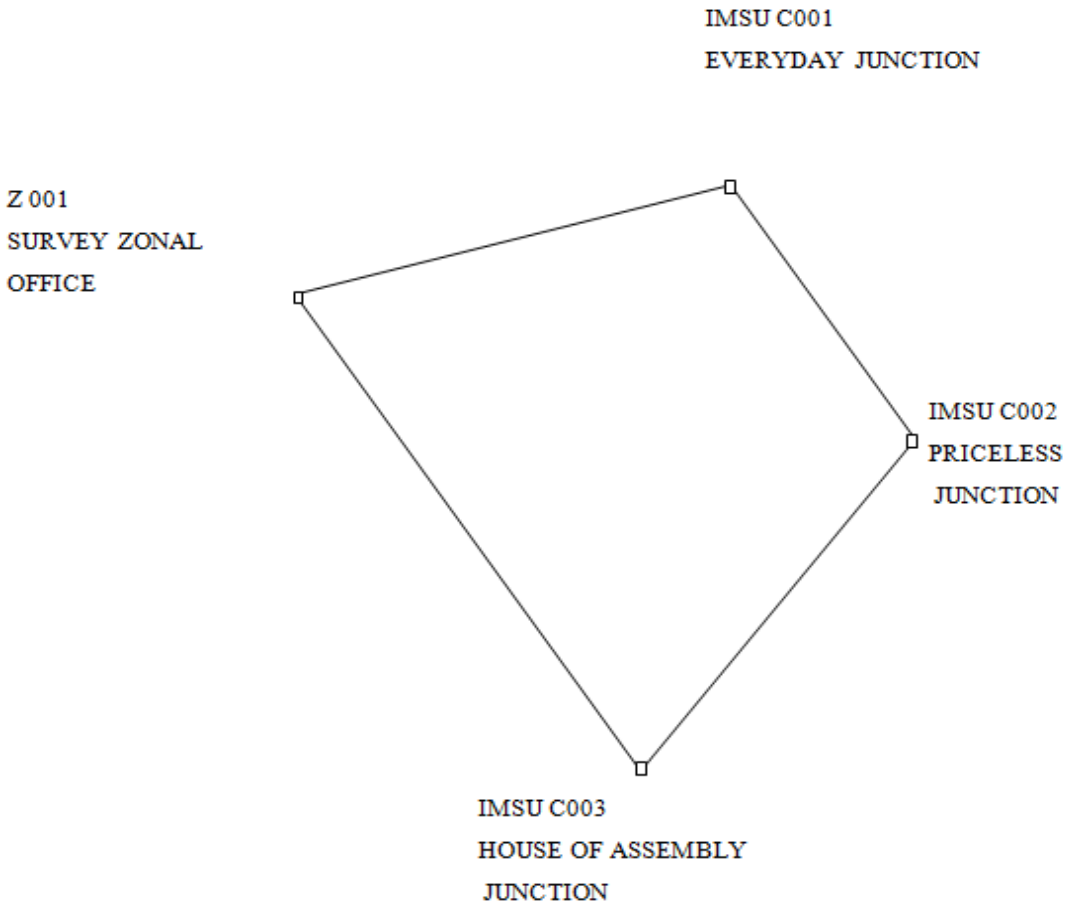

Figure 6: A Network of Four Points Covering The Two Tunnels

Table 1: Coordinates Of The Four Control Points Covering The Two Tunnels.

S/N	POINT ID	EASTHINGS (m)	NORTHINGS (m)	HEIGHT (m)	LOCATION
1	Z001	507918.608	164873.157	100.032	SURVEY ZONAL OFFICE
2	IMSU C001	506099.875	164514.984	105.539	EVERYDAY JUNCTION
3	IMSU C002	506379.917	163877.934	105.824	PRICELESS JUNCTION
4	IMSU C003	506003.151	162959.553	105.921	NATIONAL ASSEMBLY JUNCTION

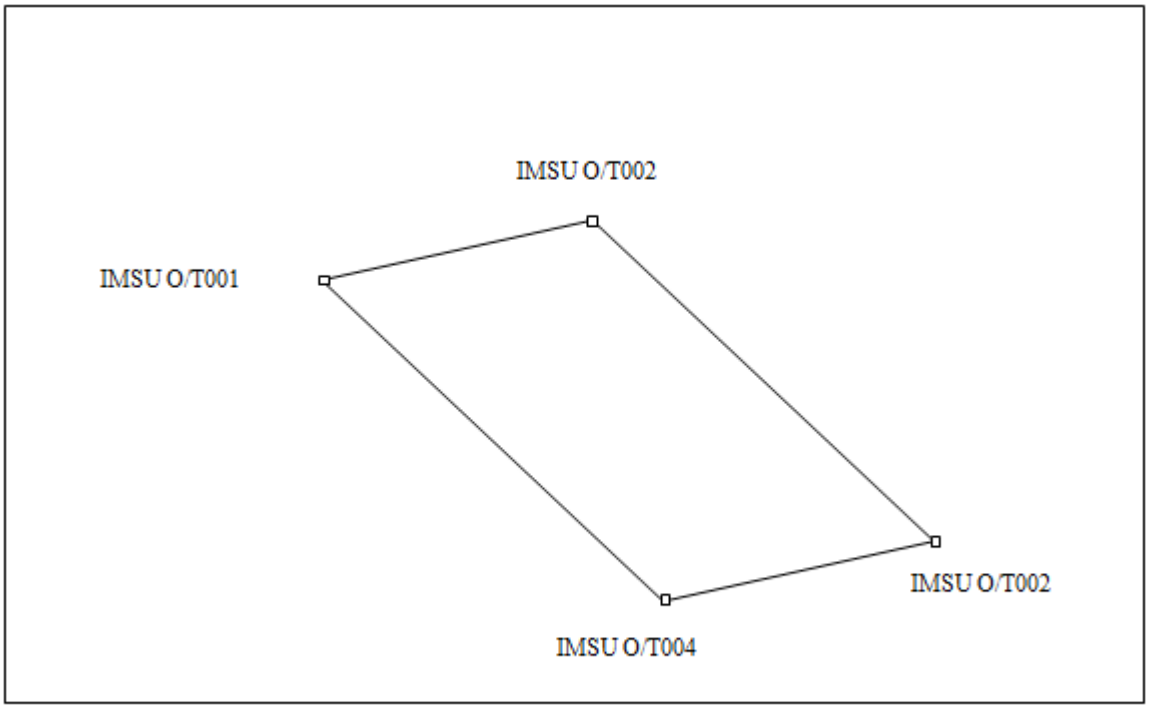

Figure 7: A Network of Points Covering Ikemba Odumegwu Ojukwu's Tunnel

Table 2: Coordinates Of the Four Control Points at Ikemba Odumegwu Ojukwu's Tunnel

POINT ID	EASTHINGS (m)	NORTHINGS (m)	HEIGHT (m)
IMSU O/T001	506215.416	164192.517	105.757
IMSU O/T002	506240.086	164228.765	105.655
IMSU O/T003	506253.921	164123.626	105.467
IMSU O/T004	506283.766	164138.043	105.344

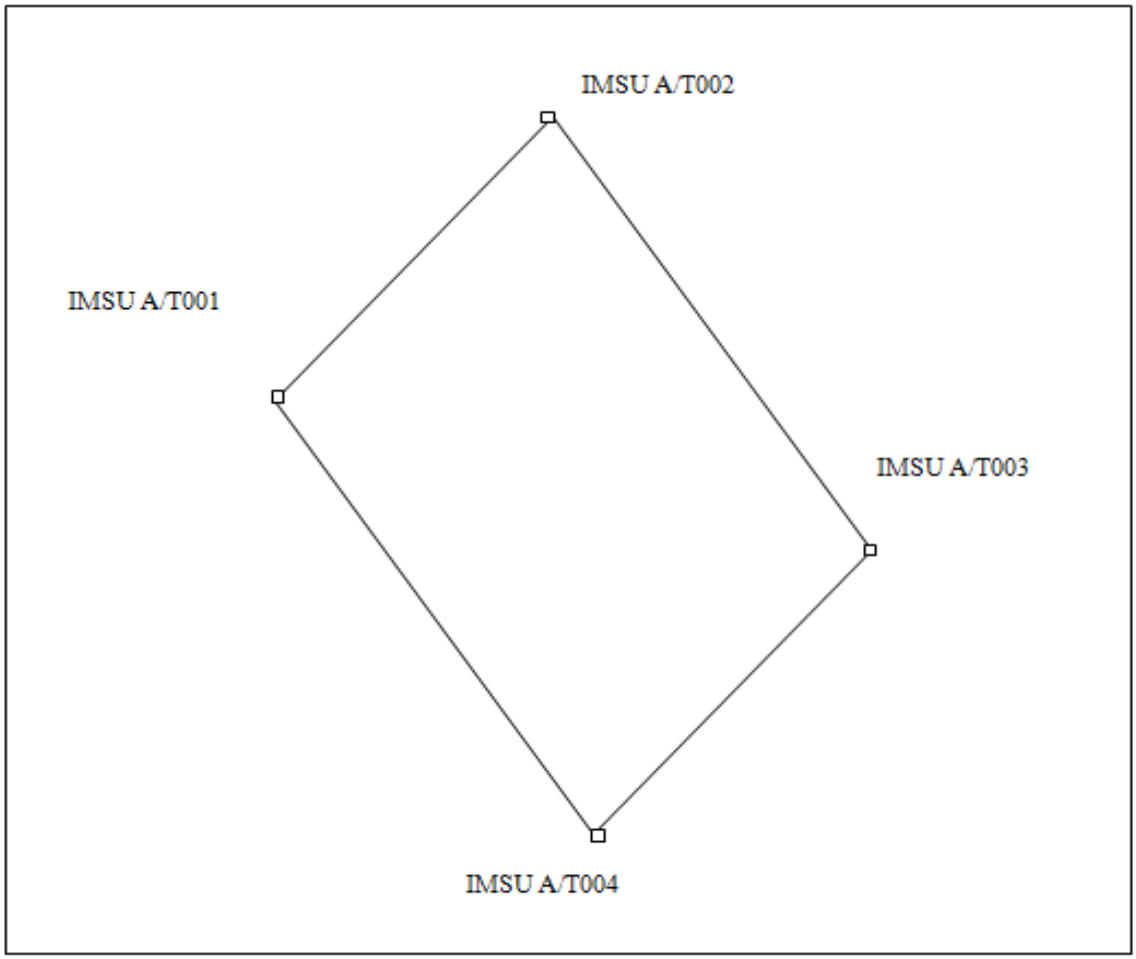

Figure 8: A Network of Points Covering Aguiyi Ironsi's Tunnel

Table 3: Coordinates of the Control Points at Aguiyi Ironsi's Tunnel

POINT ID	EASTHINGS (m)	NORTHINGS (m)	HEIGHT (m)
IMSU A/T001	505722.529	163565.340	106.479
IMSU A/T002	505768.577	163589.532	107.209
IMSU A/T003	505767.037	163445.448	106.260
IMSU A/T004	505805.989	163485.489	106.275

ANALYSIS OF RESULT

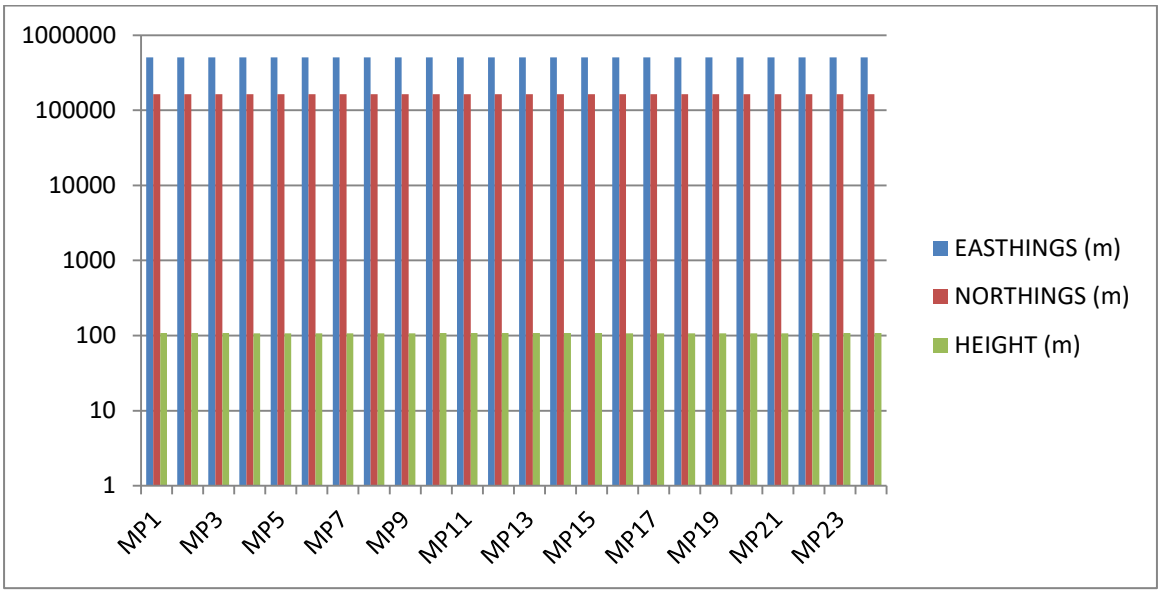

Figure 9: A Bar Graph Showing the Monitoring Points on Ikemba Odumegwu Ojukwu's Tunnel (Epoch) 1)

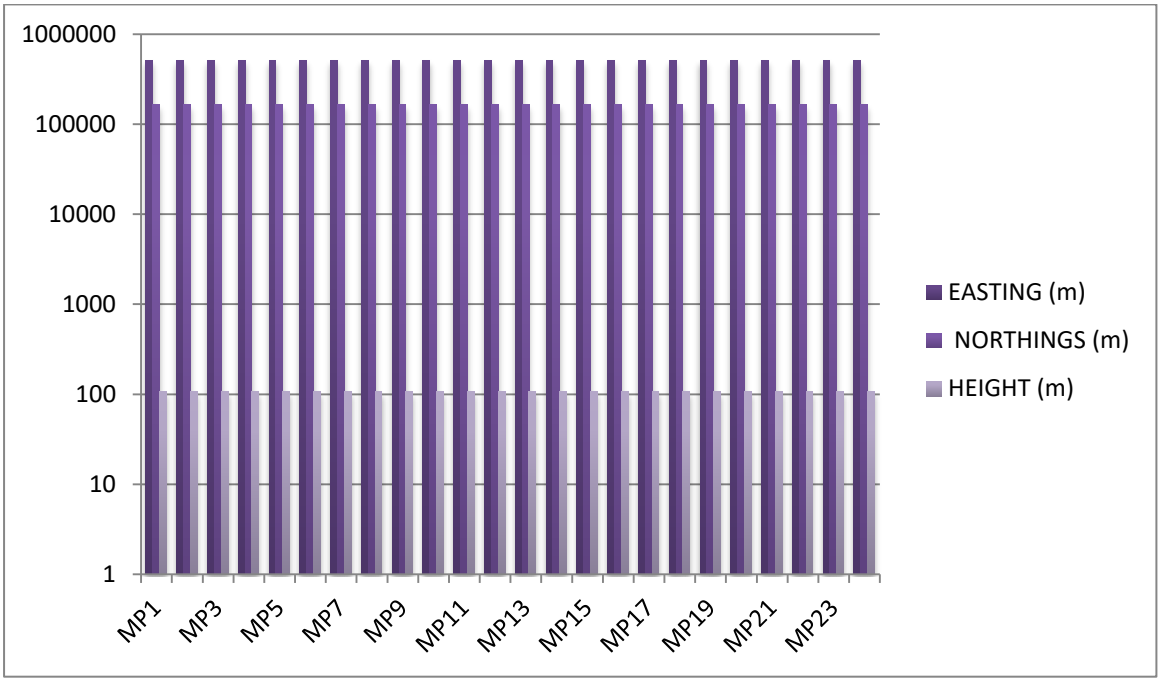

Figure 10: A Bar Graph Showing the Monitoring Points on Ikemba Odumegwu Ojukwu's Tunnel (Epoch 2)

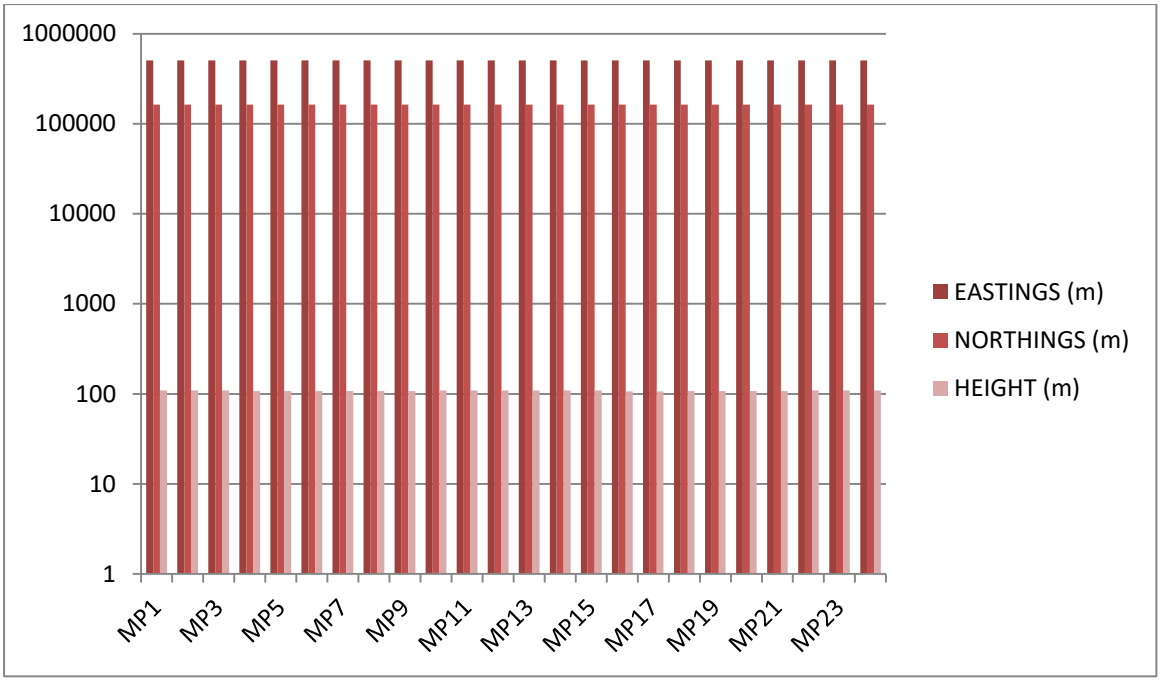

Figure 11: A Bar Graph Showing the Monitoring Points on Major-General Aguiyi Ironsi's Tunnel (Epoch 1)

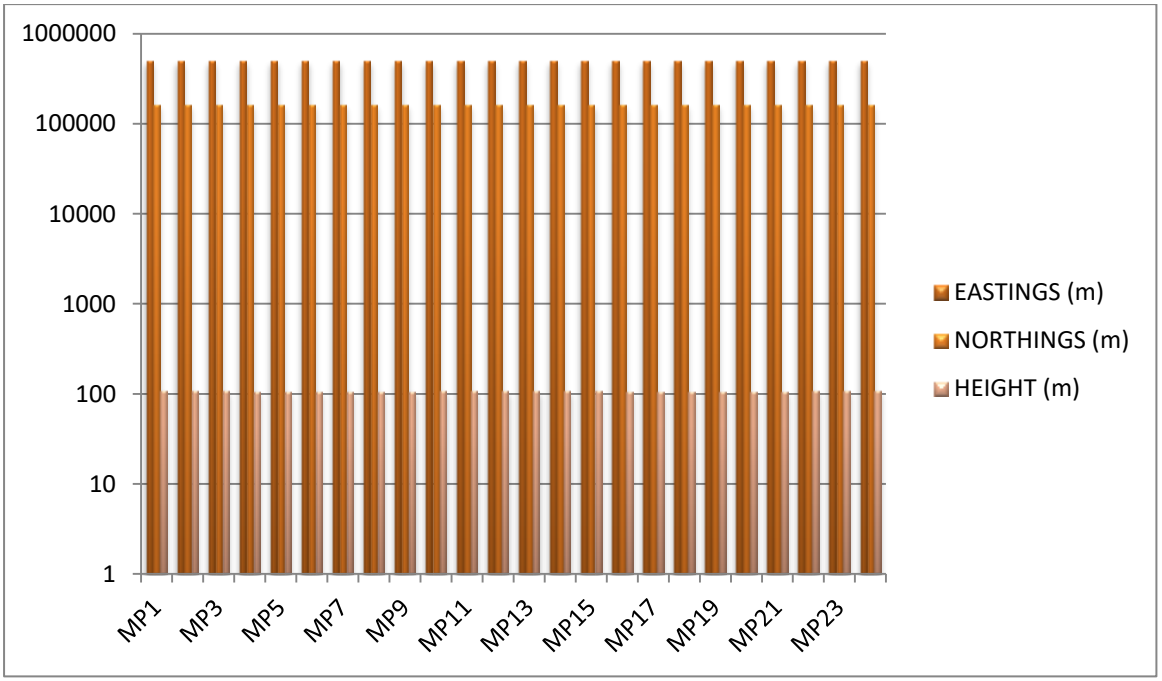

Figure 12: A Bar Graph Showing the Monitoring Points on Major-General Aguiyi Ironsi's Tunnel (Epoch 2)

The bar graphs above are plots of the monitoring points on both tunnels (Ikemba Odumegwu Ojukwu and Major-General Aguiyi Ironsi's tunnels). The bar graphs showed no significant changes in the coordinates of the Tunnels for the two epochs. The little changes that were noticed in the bar graph were only at centimetre levels which are quite insignificant, and this implies that the tunnels were not undergoing any deformation as at the time of observations, nevertheless monitoring should continue.

STATISTICAL ANALYSIS

The Data acquired for two different epochs (June and December 2019) on the 24 monitoring points were analysed statistically (correlation analysis) using Bivariate correlation model equation (1) as shown bellow.

Bivariate correlation model is given as: $$r = \frac{\sum((x-\bar{x})(y-\bar{y}))}{\sqrt{(x-\bar{x})^2} + \sqrt{(y-\bar{y})^2}} \quad \ldots\ldots\ldots\ldots \quad (1)$$

Where:

r = The value of the correlation (correlation coefficient)

x, y = Eastings and Northings respectively

$\bar{x}, \bar{y}$ = The mean values of Eastings and Northings respectively

Analysis on Ikemba Odumegwu Ojukwu's Tunnel for the two epochs

Epoch 1

$$r = \frac{\sum(x-\bar{x}(y-\bar{y}))}{\sqrt{(x-\bar{x})^2}*\sqrt{(y-\bar{y})^2}} = \frac{-4666.581}{\sqrt{4194.179}*\sqrt{9187.079}}$$

$$= r = \frac{-4666.581}{64.762*95.849} = \frac{-4666.581}{6207.373} = -0.752$$

Epoch 2

$$r = \frac{\sum(x-\bar{x}(y-\bar{y}))}{\sqrt{(x-\bar{x})^2}*\sqrt{(y-\bar{y})^2}} = \frac{-4665.611}{\sqrt{4193.611}*\sqrt{9185.093}}$$

$$= r = \frac{-4665.611}{95.849 * 95.839} = \frac{-4665.610}{6206.342} = -0.752$$

Analysis on Major-General Aguiyi Ironsi's Tunnel for the two epochs

Epoch 1

$$r = \frac{\sum(x-\bar{x}(y-\bar{y}))}{\sqrt{(x-\bar{x})^2}*\sqrt{(y-\bar{y})^2}} = \frac{-6460.298}{\sqrt{7089.509}*\sqrt{26470.066}}$$

$$= r = \frac{-6460.298}{84.199 * 162.696} = \frac{-6460.298}{13698.841} = -0.472$$

Epoch 2

$$r = \frac{\sum(x-\bar{x}(y-\bar{y}))}{\sqrt{(x-\bar{x})^2}*\sqrt{(y-\bar{y})^2}} = \frac{-6452.920}{\sqrt{7077.520}*\sqrt{26465.457}}$$

$$= r = \frac{-6452.920}{84.128 * 162.682} = \frac{-6452.920}{13686.111} = -0.471$$

V. DISCUSSIONS

In conclusion, the aim and objectives of this project were achieved. In correlation analysis, the stronger the relationship, the closer the correlation coefficient is to 1. According to Bivariate correlation model, the direction of the relationship can be positive (direct) or negative (inverse or contrary). Correlation values ranges from 1 to -1. A correlation value of 1 is a perfect positive correlation, a correlation value of -1 is a perfect negative correlation while a correlation value of zero shows no correlation at all (i.e. the values do not seem to link at all) (Zaid, 2015).

The results obtained in this research work showed that Ikemba Odumegwu Ojukwu's tunnel yielded a strong negative correlation value while Aguiyi Ironsi's tunnel yielded an average correlation value for the two epochs. These results showed that the two tunnels were not undergoing any deformation as at the time of the observations but monitoring are still on-going for further analysis.

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